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SPACE APPLICATIONS OF AUTOMATION, ROBOTICS AND MACHINE INTELLIGENCE SYSTEMS (ARAMIS) VOLUME 4: SUPPLEMENT, APPENDIX 4.3: CANDIDATE ARAMIS CAPABILITIES

By Rene H. Miller, Marvin L. Minsky, and David B. S. Smith
Massachusetts Institute of Technology
Space Systems Laboratory
Artificial Intelligence Laboratory
77 Massachusetts Avenue
Cambridge, Massachusetts 02139

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Rene H. Miller, Marvin L. Minsky, and David B. S. Smith

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16. ABSTRACT

This study explores potential applications of automation, robotics, and machine intelligence systems (ARAMIS) to space activities, and to their related ground support functions, in the years 1985-2000, so that NASA may make informed decisions on which aspects of ARAMIS to develop. The study first identifies the specific tasks which will be required by future space projects. It then defines ARAMIS options which are candidates for those space project tasks, and evaluates the relative merits of these options. Finally, the study identifies promising applications of ARAMIS, and recommends specific areas for further research.

The ARAMIS options defined and researched by the study group span the range from fully human to fully machine, including a number of intermediate options (e.g., humas assisted by computers, and various levels of teleoperation). By including this spectrum, the study searches for the optimum mix of humans and machines for space project tasks.

This document consists of the appendix to Volume IV, and is entitled: APPENDIX 4.E: CANDIDATE ARAMIS CAPABILITIES: COMPARISON CHARTS AND APPLICATION FORMS.

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NOTE

This binding is the Supplement to Volume 4: Application of ARAMIS Capabilities to Space Project Functional Elements, of the Main Study Final Report of the study "Space Applications of Automation, Robotics and Machine Intelligence Systems (ARAMIS)", Phase I (NASA contract no. NAS8-34381). The NASA Marshall Space Flight Center Contracting Officer's Representative is Georg F. von Tiesenhausen (205-453-2789). The study was performed by the Space Systems Laboratory and the Artificial Intelligence Laboratory of the Massachusetts Institute of Technology, under Professors René H. Miller (617-253-2263) and Marvin L. Minsky (617-253-5864). The MIT Study Manager was David B.S. Smith (617-253-2298).

This Supplement presents Appendix 4.E: Candidate ARAMIS Capabilities: Comparison Charts and Application Forms. Since this Appendix includes 465 Application Forms, it was separated from the rest of Volume 4, to keep the size of that binding manageable. This separation is also for the convenience of the reader, as it allows Appendix 4.E to be consulted simultaneously with other appendices in Volume 4.

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4.E.1 Notes on this Appendix

This appendix presents the study group's evaluation of the relative merits of candidate ARAMIS capabilities. For each of the 69 GFE's under detailed study, one Decision Criteria Comparison Chart and several ARAMIS Capability Application Forms are presented. The GFE's are grouped by types of GFE's.

The Decision Criteria Comparison Chart (introduced and discussed in Section 4.6.2) lists the GFE name and type, and repeats the GFE's definition (presented in Appendix 4.C). The chart then lists the candidate capabilities for that GFE (first listed in Appendix 4.D). For each of the candidate capabilities, the chart presents the values estimated by the study group for the seven decision criteria (defined and discussed in Section 4.6.1). Each criterion is evaluated on a 1-to-5 scale, with 1 being favorable performance and 5 unfavorable. The chart also identifies the capability selected as "current technology" (C.T.). which receives set values for its criteria: "3" for time, maintenance, recurring cost, failure-proneness, and useful life; "2" for nonrecurring cost; and "1" for developmental risk. The other capabilities' criteria values were estimated relative to the current technology capability.

Each GFE's Comparison Chart is followed by several ARAMIS

Capability Application Forms (introduced and discussed in Section 4.6.2). For each of the GFE's candidate capabilities, an Application Form repeats the decision criteria values in the Comparison Chart, adding commentary on why any particular criterion value was selected. The form also includes remarks on special aspects of the capability's application to the GFE. This special aspects section includes identification of which of the candidate capabilities is considered the current technology option for this GFE.

In some cases, the Application Forms in this study refer to data sources by last name only; the full names can be found in the General Information Forms in Appendix 3.C. In general, it is suggested that, while looking at the Application Forms, the user should also look up the relevant General Information Forms, since they contain definitions of the capabilities.

Thus the appendix presents the information GFE by GFE. For each GFE, the Comparison Chart presents the GFE's candidate capabilities and their relative decision criteria values; the Application Forms immediately following present rationale for, and commentary on, the criteria values. This grouping makes it easy for the study recipient to consider the study group's remarks together with the estimated values; as mentioned in Section 4.6.3, in most cases this commentary is more instructive than the numbers themselves.

Each Application Form deals with the application of an ARAMIS capability to one particular GFE. Therefore capabilities which are candidates for several GFE's have several Application Forms appearing in this appendix, filed under the appropriate GFE's (there are 465 Application Forms altogether). For general descriptions of capabilities, the study user is referred to the ARAMIS Capability General Information Forms in Appendix 3.C (Volume 3), which describe each of the 78 capabilities defined by this study.

For the study recipient who is interested in particular capabilities and their various applications to GFE's, Appendix 4.G presents the transpose matrix: for each capability, each GFE to which it applies is listed, followed by the decision criteria values for that application.

As a final comment, the study group urges the study user to consider the limitations to this evaluation method, discussed in Section 4.6.3, while examining this Appendix. The listing of Decision Criteria Comparison Charts and ARAMIS Capability Application Forms follows.

DECISION CRITERIA COMPARISON CHART

GFE: g1 VERIFY POWER SYSTEM FUNCTION

GFE TYPE: A. Power Handling

Verification of the proper function of spacecraft power subsystems, during payload assembly and integration at KSC (usually done by the spacecraft contractor). This GFE includes verification of subsystems, prior to launch, in general.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.6 MANUAL TESTING ON GROUND	4	1	1	2	4	4	1	
16.1 COMPUTER MODELING AND SIMULATION	2	3	4	2	2	1	2	
27.1 EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	1	3	4	3	2	1	2	
27.2 EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	3	2	2	2	3	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g1 Verify Power System Function

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Manual Testing On Ground
CODE NUMBER: 14.6 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g1 Verify Power System Function

DECISION CRITERIA (1 TO 5 SCALES: CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This process is slower than the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: The equipment used is less complex than that of the alternatives.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Very little development must be done.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The main recurring cost is that of the personnel and facilities involved.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This procedure cannot test as many conditions as the more automated alternatives; hence it is less thorough.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This capability can only handle simple tasks at present. As complexity of power systems increases, this will be harder to implement, and will become obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Modeling And Simulation
CODE NUMBER: 16.1 DATE: 3/19/82 NAME(S): Spofford/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g1 Verify Power System Function

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is faster than current technology (Human on Ground with Computer Assistance) because more of the operation is automated.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes computer hardware and software maintenance and is comparable to current technology. A high-reliability computer system is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This includes the development of a comprehensive system model and generation of the computer database. The cost of writing the software to manipulate the database is also included in the nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This includes the operator's salary, hardware and software maintenance, and the cost of updating the database as the spacecraft changes. This is less than current technology because less operator time is needed.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: With Computer Modeling And Simulation it is possible to model things that are not directly testable. As long as the computer model of the system is accurate, this capability is not likely to fail. It is more reliable than the current technology option because the computer can manipulate more information in its database than a human can.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This capability has a long useful life because the database may be updated as the spacecraft changes. The system model can be upgraded to include repairs, failures, component degradation, and design changes as necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development and validation of a sufficiently accurate database is a major risk of this option.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/26/81 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g1 Verify Power System Function

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Function test will execute faster than a simulation, which is faster than current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance for the computer necessary for this capability will be on par with current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Nonrecurring cost includes the development of the necessary software and the function test itself.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost is given a rating comparable to current technology because of higher and lower costs related to this system. On the lower side, there is no need for the costs related to maintaning a human. However, the computer necessary is more sophisticated and therefore more costly than the computer required for current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The function test will gather more data than current technology, it will therefore be more reliable. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The higher reliability and the absence of need for human assistance give this system a good useful life rating.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the software for this system.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test Via Onsite Human
CODE NUMBER: 27.2 DATE: 6/25/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g1 Verify Power System Function

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Time to complete will be comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The microcomputer will require less maintenance than the large computers used by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The cost for developing the dedicated microcomputer will be comparable to the cost for developing the software for current technology. The function test for this functional element is very simple and will not raise nonrecurring cost for its development.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Cost for maintaining the microcomputer will be less than current technology. The cost for human upkeep is the same as human upkeep in current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The amount of information gathered is about the same as current technology, so the reliability will be about the same. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The lower cost and sophistication of the microcomputer give this system a more favorable useful life rating.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes the development of the dedicated microcomputer, the associated software, and the development of the function test.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human on Ground with Computer Assistance. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer). This functional element takes place on the ground.

DECISION CRITERIA COMPARISON CHART

GFE: g23 POWER SUBSYSTEM CHECKOUT

GFE TYPE: A. Power Handling

On-orbit checkout of spacecraft power subsystems, either after launch or after maintenance and repair. This study focuses on methods of controlling the checkout process and evaluating subsystem performance, rather than specific sensors. As spacecraft state-of-the-art moves toward fully integrated power management systems, this task may include g48 Thermal Subsystem Checkout (in B. Checkout).

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.3 HUMAN IN EVA WITH TOOLS	4	5	3	5	3	4	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	3	5	3	4	2	3	2	
27.1 EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	2	3	3	2	3	1	2	
27.2 EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	3	4	3	4	2	3	2	
27.3 EQUIPMENT FUNCTION TEST VIA TELEMETRY	3	3	2	3	3	3	1	C.T.
27.4 EQUIPMENT DATA CHECKS BY ONBOARD COMPUTER	1	3	2	2	4	1	2	
27.5 EQUIPMENT DATA CHECKS BY ONSITE HUMAN	3	4	2	4	3	3	2	
27.6 EQUIPMENT DATA CHECKS VIA TELEMETRY	2	3	1	3	4	3	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g23 Power Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This operation requires EVA activity, taking more time than the alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes astronaut training and the development cost of specialized tools.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than the other alternatives, which are performed remotely.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The human in EVA has no inherent reliability advantage over remote operations for checking out an electrical system. With the proper tools, the reliability can be as good as the current technology (Equipment Function Test Via Telemetry).

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: There is no real need for a human to go EVA to perform this task when automatic methods are available.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g23 Power Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The thoroughness of the power subsystem checkout is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will often be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/28/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g23 Power Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete will be less than current technology because of the lack of transmission delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: An onboard computer would require costly maintenance if something should go wrong, but it does not requite maintenance of the communications links.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.= 2): 3
REMARKS AND DATA SOURCES: Cost of developing the necessary software and adapting the computer to the specific spacecraft. The nonrecurring cost could be reduced somewhat by designing modular computers that could be easily modified for various spacecraft.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because of the absence of human supervison; nobody has to monitor the telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The same amount of information is gathered by this capability as current technology, so the failure-proneness will be comparable to current technology. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The speed and fully autonomous nature of this system make it unlikely to become obsolete in the near future.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The ability of the software to conform to the spacecraft computer safety codes is the primary source of risk.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/25/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g23 Power Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Time should be comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance includes the human upkeep.

NONRECURRING COST (1 LOW, HIGH 5; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost includes the cost to develop the dedicated microcomputer and the function test.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The onsite human will be capable of detecting problems which could not be found by current technology. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The higher reliability offsets the cost.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the dedicated microcomputer and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3   DATE: 7/1/82   NAME(S): Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g23 Power Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time to complete includes the time delay associated with communicating between earth orbit and the ground. Until TDRSS, this capability may not be available at all times, because of the loss of transmission.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The communications network must be maintained.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The nonrecurring cost includes outfitting the spacecraft with the necessary equipment as well as designing the equipment function test itself.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost includes the maintenance cost of the communications links and the operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The reliability of this capability is dependent on the sophistication of the function test, and on how much information it sends back. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The need for human interaction will make this capability give way to automatic systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risk includes the designing of the necessary equipment into the spacecraft and developing a function test.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/15/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g23 Power Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is the fastest method to verify proper operation of the subsystem because it will immediately measure the system's currents and voltages and check them against predetermined tolerances.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Onboard computers will be reliable and probably self maintaining for the life of a mission. Their maintenance will be comparable to the telemetry link and ground computer required by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Data checks (as opposed to function tests) do not require safety reviews of commands to the spacecraft. The development cost is essentially the cost of simple software to implement the data checks now performed on the ground via telemetry.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The sensors and computer software to perform this functional element are less expensive than use of telemetry links and human analysis.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability can only test the current operational mode of the power subsystem because it only monitors data. It cannot command a new power subsystem operational mode. Thus it can overlook problems and failures in the untested operation modes.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: As computers become more and more common on spacecraft this method of power subsytem checkout will become standard procedure.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Spacecraft computers are under development and they will be incorporated in new spacecraft designs. The algorithm and software development will require no new technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is only capable of verifying that the present mode of the power subsystem is operating properly. This capability is passive and con not command changes in the power subsystem state which are necessary for a complete checkout. Current technology for performing this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onsite Human
CODE NUMBER: 27.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g23 Power Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time is essentially limited by the human's recognition time.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Some astronaut training is required; he or she must be able to recognize the correct data and identify possible failures. Also, a space-rated dedicated microprocessor must be developed.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The experience and flexibility of the human makes accurate diagnosis of problems more likely than with the other, automated, data checks.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard computer-run checks will probably become more thorough and less expensive than alternatives involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Interfaces and specific test equipment would need to be developed for a given power system application.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computers). Current technology for this GFE is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks via Telemetry
CODE NUMBER: 27.6 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g23 Power Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Capability takes less time to perform than the current technology option Equipment Function Test via Telemetry because it does not call for any configuration changes. However, relative to Equipment Function Test by Onboard Computer, its rating is the same because the time delays associated with the telemetry aspect are offset by the longer function test.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance required will be comparable with that required by the current technology option, Equipment Function Test via Telemetry.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This capability has the lowest nonrecurring costs because it is already available and requires no additional hardware or software.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The costs associated with the telemetry prevent this from having as low a rating as its onboard counterpart, Equipment Data Checks by Onboard Computer.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability is able to locate the source of a failure only by deduction from normally available data.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This capability will be made obsolete by its onboard counterpart, Equipment Data Checks by Onboard Computer.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: The disadvantage of this capability is that it only asserts whether or not a failure exists and gives little indication, other than on a subsystem level, as to its location or severity. The advantage is that it is routine and requires no changes in configuration. The current technology capability for performing this functional element is an Equipment Function Test via Telemetry.

DECISION CRITERIA COMPARISON CHART

GFE: g87 ADJUST CURRENTS AND VOLTAGES

GFE TYPE: A. Power Handling

The control of spacecraft power systems, including evaluation of operational and state-of-health data, power allocation and network configuration, switching and power level control, mechanical actuation (e.g. solar array pointing), and contingency management. This study concentrates on the evaluation and control functions, rather than specific switching or measurement equipment. As spacecraft state-of-the-art moves toward fully integrated power management systems, this task may include g83 Adjust Cooling/Heating Systems (in E. Monitoring and Control).

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
1.6 AUTOMATIC SWITCHING SYSTEMS	1	3	2	1	3	3	1	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.4 HUMAN WITH CHECKLIST	4	2	2	4	4	5	1	
21.1 ONBOARD SEQUENCER	1	2	2	1	5	4	1	
21.2 OPERATIONS OPTIMIZATION PROGRAM	3	3	3	2	1	2	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	2	4	5	2	1	1	4	
25.1 ONBOARD DEDICATED MICROPROCESSOR	2	4	3	2	2	2	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	2	3	4	2	1	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	4	3	2	2	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	3	3	2	2	2	3	1	
25.5 ONBOARD ADAPTIVE CONTROL SYSTEM	2	2	4	2	1	1	3	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Automatic Switching Systems
CODE NUMBER: 1.6 DATE: 6/15/82 NAME(S):Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents and Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This system, because it reacts immediately to preset criteria, is much faster than systems with human interaction. It is also faster than systems which act based upon computation. How much faster is a function of the complexity of the computation.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although they require virtually no maintenance, automatic switching sytems are slightly more likely to need servicing than the self-maintaining computers and control systems of future spacecraft.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and are a mature technology.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: This application (adjust currents and voltages) is not a simple spacecraft power bus voltage maintenance operation. It is a power allocation and distribution as well as maintenance problem. The automatic switching system can only perform this function to a very limited degree, but what it is capable of doing it does for less cost than any other option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The more advanced, flexible systems, such as the adaptable control system, are less likely to make an error than the automatic switching system because they can react to unanticipated conditions. The automatic switching system can only respond to foreseen conditions.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: As the complexity of modern spacecraft increases, the ability of automatic switching systems to handle the more complex power supply requirements will decrease, and more sophisticated systems will be necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability is currently used on spacecraft.

OTHER REMARKS AND SPECIAL ASPECTS: If this functional element involves the management of a complex spacecraft power supply system, it is questionable this capability would be practical. Automatic Switching Systems are limited to simple power systems. The current technology capability for this GFE is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents And Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents And Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Personnel costs are included here, and the human with checklist may take much longer to perform this task than a human aided by a computer. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Sequencer
CODE NUMBER: 21.1 DATE:6/9/82 NAME(S):Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents And Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The Onboard Sequencer is activated by a clock or by an external trigger. It is very fast because it responds immediately to the clock or trigger.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The Onboard Sequencer is not self maintaining, but its simplicity makes it as reliable as spacecraft computers.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Onboard Sequencers have been used for several years and are a mature technology.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Due to their simplicity both in hardware and software Onboard Sequencers are relatively inexpensive. They must be reprogrammed often, but this is a simple procedure.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The system's extremely limited ability to respond to changing spacecraft conditions make it likely to fail.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Onboard computers will probably replace Onboard Sequencers in the near future.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is a fully developed technology that has been used for years.

OTHER REMARKS AND SPECIAL ASPECTS: To apply this capability to Adjust Currents and Voltages assumes that adjustments can be made based upon a clock or some simple condition that can be used to activate the sequencer. The current technology for performing this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Operations Optimization Program
CODE NUMBER: 21.2 DATE: 6/20/82 NAME(S): Thiel/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents And Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: In most cases this program will be about as fast as other computer control approaches, but in some cases the optimization will not be a quick process: the problem could be very complex and cause combinatorial expansion problems.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance requirements should be similar to other large software packages such as the Deterministic Computer Program on Ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The basic technology is developed, but it must be applied to this specific problem.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The cost is basically just computer time, which is comparable to the other software packages applied to this functional element. It should be less expensive than the current technology of Human On Ground With Computer Assistance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: As long as the input data to the program is valid it should be error free.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The basic algorithms should remain useful for optimization functions for many years to come.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The fundamental technology has been perfected, but it must be applied to this specific task.

OTHER REMARKS AND SPECIAL ASPECTS: Assumes that the voltage adjustments can be delayed if the program takes significant computation time. The current technology for performing this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 7/3/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents and Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Once the learning expert system is operational it will be capable of adjusting system currents and voltages. Most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents And Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The onboard dedicated microprocessor is faster than current technology (Human on Ground with Computer Assistance) because there are no transmission delays or human decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is more than current technology because it is harder to maintain the hardware and software on-orbit than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is more than current technology because the on-orbit software must be developed.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The microprocessor is cheap compared to current technology because there is no operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This is more reliable than current technology because the onboard microprocessor can react faster, and is not vulnerable to communications failures.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Better than current technology because the microprocessor is onboard.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development of software and implementation of microprocessor on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. If the spacecraft power system is complex, the simpler options (e.g. Automatic Switching Systems, Onboard Sequencer, humans on the ground, and this capability) will not be adequate to the task. Current technology for this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents and Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options (except for the Automatic Switching Systems and the Onboard Sequencer). It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this

functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents and Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay. However, the needed computation time makes this slower than open-loop sequencers or automatic switches.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The rapid reaction time makes this less failure prone than the current technology human via telemetry.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents and Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Although slightly faster than current tehcnology, this option is slower than the onboard options (which have no telemetry delays), or than the more sophisticated software systems (which can anticipate trouble).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to the software development and operator training costs of current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: More thorough than current technology, this option is comparable to other deterministic systems. Predictive or adaptive systems are more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Both this option and current technology will be outdated by onboard or more sophisticated software options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: For most spacecraft power systems, control by a deterministic program is not complicated. However, it is not optimal, and does not respond to component changes. For optimal control of complex power systems, more sophisticated options will be required.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Adaptive Control System
CODE NUMBER: 25.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g87 Adjust Currents And Voltages

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The onboard electronic systems are faster than current technology (Human On Ground With Computer Assistance).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The control system can adapt itself to changes in the system parameters, so it does not need to be updated. It can also compensate for its own components degrading.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Development of a suitable model for the problem is important, and this contributes to nonrecurring cost. Development of the proper hardware to implement the system is also included.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hardware required is more complex than automatic switching systems, but equivalent to onboard microprocessors.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The control system has a built-in capability to adapt to changes in the environment, including component failures, etc.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The sophistication of the model used can be improved as needed, and the hardware used to implement it can be upgraded, so there is little chance of obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developmental risk is basically that associated with the hardware used, and with the self-adjusting character of the software. In this case the hardware is likely to be an onboard microprocessor hierarchy.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g88 ADJUST BATTERY CHARGING CYCLE

GFE TYPE: A. Power Handling

The monitoring, evaluation, and adjustment of the charging cycle for spacecraft batteries. This includes switching to reconditioning cycles as needed.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2	HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
25.1	ONBOARD DEDICATED MICROPROCESSOR	1	4	3	1	2	2	2	
25.2	ONBOARD MICROPROCESSOR HIERARCHY	1	3	4	1	1	1	3	
25.3	ONBOARD DETERMINISTIC COMPUTER PROGRAM	1	4	3	1	2	2	2	
25.4	DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	2	1	2	3	1	
25.5	ONBOARD ADAPTIVE CONTROL SYSTEM	1	2	4	2	1	1	3	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g88 Adjust Battery Charging Cycle

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g88 Adjust Battery Charging Cycle

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The onboard dedicated microprocessor is faster than current technology (Human on Ground with Computer Assistance) because there are no transmission delays or human decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is more than current technology because it is harder to maintain the hardware and software on-orbit than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is more than current technology because the on-orbit software must be developed.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The microprocessor is cheap compared to current technology because there is no operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This is more reliable than current technology because the onboard microprocessor can react faster.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Better than current technology because the microprocessor is onboard.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development of software and implementation of microprocessor on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g88 Adjust Battery Charging Cycle

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g88 Adjust Battery Charging Cycle

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay. However, dedicated microprocessor systems will be slightly faster.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The rapid reaction time makes this less failure prone than the current technology human via telemetry.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g88 Adjust Battery Charging Cycle

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to the software development and operator training costs of current technology.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: For this simple task, updates should be almost never needed. Current technology, on the other hand, includes operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The probability of software failure (once debugged) is small for this straightforward task.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Both this option and current technology will be outdated by onboard or more sophisticated software options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The technological risks are minimal, given that this is a well tested technology. The program is not complicated.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Adaptive Control System
CODE NUMBER: 25.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g88 Adjust Battery Charging Cycle

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The onboard electronic systems are faster than current technology (Human On Ground With Computer Assistance).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The control system can adapt itself to changes in the system parameters, so it does not need to be updated. It can also compensate for its own components degrading.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Development of a suitable model for the problem is important, and this contributes to nonrecurring cost. Development of the proper hardware to implement the system is also included.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hardware required is more complex than automatic switching systems, but equivalent to an onboard microprocessor hierarchy.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The control system has a built-in capability to adapt to changes in the environment, including component failures, etc.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The sophistication of the model used can be improved as needed, and the hardware used to implement it can be upgraded, so there is little chance of obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developmental risk is basically that associated with the hardware used, and the self-adjusting nature of the software. In this case the hardware is likely to be an onboard microprocessor hierarchy. This task is relatively simple for adaptive control; the system would probably handle more complex functions also.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g240 MAINTAIN SAFE BATTERY CHARGE LEVELS **GFE TYPE:** A. Power Handling

The evaluation of the state of charge of spacecraft batteries, and the avoidance of discharge or overcharge conditions which may damage the batteries. This can range from a local protection circuit dedicated to one battery to a spacecraft power control system that trades off battery state-of-health with other mission objectives.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
1.6 AUTOMATIC SWITCHING SYSTEMS	3	3	2	3	3	3	1	C.T.
25.1 ONBOARD DEDICATED MICROPROCESSOR	2	3	3	3	3	1	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	2	2	4	3	2	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	3	2	3	3	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	4	2	2	3	3	4	1	
25.5 ONBOARD ADAPTIVE CONTROL SYSTEM	2	1	4	3	2	1	3	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Automatic Switching Systems
CODE NUMBER: 1.6 DATE: 6/15/82 NAME(S): Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g240 Maintain Safe Battery Charge Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Automatic switching systems respond directly to the battery charge levels and therefore have rapid response to sudden changes. However, computational options can anticipate and prevent trouble. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although they require virtually no maintenance, automatic switching sytems are slightly more likely to need servicing than the self-maintaining computers and control systems of future spacecraft. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and are a mature technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The computers or computers plus telemetry links are slightly more expensive than automatic switching systems for a continuous monitoring operation because of their greater complexity and operations costs. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The more advanced, flexible systems, such as the adaptable control system, are less likely to make an error than the automatic switching system because they can react to unanticipated problems. The automatic switching system and the deterministic computer program can only handle foreseen problems. The deterministic program can be programmed to respond to many more problems than the hardwired automatic switching system.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Although the other options may be more expensive, they also have the capacity to recondition the batteries and predict lifetimes by trend analysis, etc. These additional capabilities will cause the more advanced systems to be selected instead of automatic switching systems. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Automatic Switching Systems have been used on virtually all spacecraft and is a mature technology.

OTHER REMARKS AND SPECIAL ASPECTS: Automatic Switching Systems are the current technology for maintaining battery charge levels.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g240 Maintain Safe Battery Charge Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The microprocessor is faster than the current technology switching system because it can perform a trend analysis and adjust the system before the hardwired switching system's limit would trip.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The microprocessor's software is slightly easier to maintain than the hardwired automatic switching system.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The major cost for the microprocessor is the software development; higher than for the established current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: Much better useful life because the microprocessor can spot trends in battery charge/discharge cycles and adjust the charging rate for maximum battery life. The switching system does not have this flexibility.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Automatic Switching Systems are a standard item. The microprocessor must be integrated into the system and software developed.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is an Automatic Switching System.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g240 Maintain Safe Battery Charge Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be slightly faster than the other autonomous options. It is a real-time system which can perform trend analysis to avoid potential problems.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged below an Automatic Switching System, the current technology option, which is costly to repair if it malfunctions, while the hierarchy is relatively easy to repair and has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel). It is equal in recurring costs to the dedicated Automatic Switching System, because while the hierarchy is more complex, it requires less maintenance and shares its costs between many spacecraft functions.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is Automatic Switching Systems.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g240 Maintain Safe Battery Charge Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The onboard computational options can anticipate problems from battery histories and trends, thus avoiding trouble.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The software updates and occasional hardware maintenance are comparable to the current technology's more frequent hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: All of the options have comparable recurring costs. Variations will depend on the actual application.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology. This is a simple task.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: More versatile than current technology, less than more advanced computational options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Automatic Switching Systems.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g240 Maintain Safe Battery Charge Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Slightly slower than current technology, due to telemetry delays and computation time.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: For this simple task, system maintenance is less than the occasional in-space maintenance of current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: For this simple task, comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The system maintenance and occasional human supervision for this capability are comparable to the occasional in-space maintenance costs of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Though slower in response to crisis than current technology, this option can anticipate and avoid some problems.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Because of the simplicity of the task and the large amount of data handling involved, onboard automation will be preferred for this task.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The required software is simple.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is an Automatic Switching System.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Adaptive Control System
CODE NUMBER: 25.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g240 Maintain Safe Battery Charge Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The onboard processor systems can all anticipate problems, from component histories and trends, and can act to prevent trouble.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: The control system can adapt itself to changes in the system parameters, so it does not need to be updated. It can also compensate for its own components degrading.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Development of a suitable model for the problem is important, and this contributes to nonrecurring cost. Development of the proper hardware to implement the system is also included.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The hardware required, equivalent to an onboard microprocessor, is more complex than automatic switching systems, but requires less maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The control system has a built-in capability to adapt to changes in the environment, including component failures, etc.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The sophistication of the model used can be improved as needed, and the hardware used to implement it can be upgraded, so there is little chance of obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developmental risk is basically that associated with the hardware used, and the self-adjusting character of the software. In this case the hardware is likely to be an onboard microprocessor hierarchy. This task is relatively simple for adaptive control; the system would probably handle more complex functions also.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is an Automatic Switching Systems.

DECISION CRITERIA COMPARISON CHART

GFE: g5 MISSION SEQUENCE SIMULATION

GFE TYPE: B. Checkout

The simulation of spacecraft mission tasks, during payload integration and checkout, prior to launch. Intended to verify the proper function and interaction of spacecraft subsystems, this task can be performed either with the spacecraft hardware, or with computer simulation, or with a mixture of both.

CANDIDATE ARAMIS CAPABILITIES:

		DECISION CRITERIA							
		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2	HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.6	MANUAL TESTING ON GROUND	5	2	1	2	4	4	1	
16.1	COMPUTER MODELING AND SIMULATION	1	3	3	1	2	2	2	
23.2	LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	3	5	1	1	1	5	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g5 Mission Sequence Simulation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Manual Testing On Ground
CODE NUMBER: 14.6 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g5 Mission Sequence Simulation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This process is slower than the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The maintenance costs are less than for a computer system which requires test software to be updated for new mission sequences, but more than for the expert system which adapts its own test sequences.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Very little development must be done.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The main recurring cost is that of the personnel and facilities involved.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This procedure cannot test as many conditions as the more automated alternatives; hence it is less thorough.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: At present this capability can only handle limited simulations of simple sequences. As mission sequence complexity increases, this will be harder to implement and will become obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Modeling And Simulation
CODE NUMBER: 16.1 DATE: 3/19/82 NAME(S): Spofford/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g5 Mission Sequence Simulation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is faster than current technology (Human on Ground with Computer Assistance) because more of the operation is automated.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes computer hardware and software maintenance and is comparable to current technology. A high-reliability computer system is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes the development of a comprehensive system model and generation of the computer database. The cost of writing the software to manipulate the database is also included in the nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: This includes the operator's salary, hardware and software maintenance, and the cost of updating the database as the spacecraft changes. This is less than current technology because less operator time is needed.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: With Computer Modeling And Simulation it is possible to model things that are not directly testable. As long as the computer model of the system is accurate, this capability is not likely to fail. It is more reliable than the current technology option because the computer can manipulate more information in its database than a human can.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability has a long useful life because the database may be updated as the spacecraft changes. The system model can be upgraded to include repairs, failures, component degradation, and design changes as necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development and validation of a sufficiently accurate database is a major risk of this option.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g5 Mission Sequence Simulation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES:
A Learning Expert System is a more than reasonable choice for simulating a mission sequence as well as generating general mission sequence scenarios. Once the system is fully operational, most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g10 CHECK ELECTRICAL INTERFACES

GFE TYPE: B. Checkout

Checks of the integrity and proper function of electrical interfaces, after payload integration, but before launch. This includes interfaces within a spacecraft, between a spacecraft and a booster stage, and between a spacecraft and the Shuttle Orbiter.

CANDIDATE ARAMIS CAPABILITIES:

		DECISION CRITERIA							
		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2	HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.6	MANUAL TESTING ON GROUND	5	2	1	4	4	4	1	
25.4	DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	2	2	2	2	2	
27.1	EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	2	3	3	2	1	1	3	
27.2	EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	3	3	3	3	3	3	2	
27.4	EQUIPMENT DATA CHECKS BY ONBOARD COMPUTER	2	2	2	2	2	1	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g10 Check Electrical Interfaces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Manual Testing On Ground
CODE NUMBER: 14.6 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g10 Check Electrical Interfaces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This process is slower than the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The equipment used is less complex than that of the alternatives.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Very little development must be done.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The main recurring cost is that of the personnel involved. In this case this is quite expensive, due to the typically large number of interfaces.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This procedure cannot test as many conditions as the more automated alternatives; hence it is less thorough.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: As complexity of electrical systems increases, this will be harder to implement, and eventually become obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g10 Check Electrical Interfaces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to the software development and operator training costs of current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The probability of software failure (once debugged) is small for this straightforward task.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Such automated checking routines will outdate the more expensive checks involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risks are minimal, but higher than the established current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance. This task is performed on the ground, prior to launch.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/26/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g10 Check Electrical Interfaces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Entirely computer-controlled equipment will be faster than systems with active human elements. The fact that this system is onboard and current technology is on the ground with its associated time elay is another factor taken into consideration.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance will be comparable to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Cost of developing the necessary software and adapting the computer to the specific spacecraft. The nonrecurring cost could be reduced somewhat by designing modular computers that could be easily modified for various spacecraft.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring cost is less than current technology because of the lower maintenance costs.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: All tests which are necessary to check the interface can be accomplished by the computer. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The speed and fully autonomous nature of this system make it unlikely to become obsolete in the near future.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The development of the function test and the ability to conform to the safety codes required for the spacecraft computer are the primary problems to be overcome.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human on Ground with Computer Assistance. This functional element takes place on the ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE:6/25/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g10 Check Electrical Interfaces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Time should be comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance may be slightly less than current technology, because the dedicated microcomputer is simpler than the current technology computer.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Cost for developing the microcomputer and function test.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring cost includes human salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Failure-proneness is comparable to current technology. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Useful life is the same as current technology, in that both will eventually be replaced by more automated options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes development of the dedicated microcomputer and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human on Ground with Computer Assistance. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer). This functional element takes place on the ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/23/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g10 Check Electrical Interfaces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: To verify the integrity of the interface connection the computer compares sampled data, voltages, etc., to expected values. This process is very fast.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The computer, sensors and data monitoring equipment require little if any maintenance for this application; this task is done on the ground, prior to launch.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Since this operation is relatively simple, it can be programmed into projected spacecraft computer systems with little development cost.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The computer can carry out this functional element quickly and accurately in less time and cost than a system with direct human involvement.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The computer monitors data streams and verifies that they are within expected parameters. It is unlikely that the data (in this application) would be misintepreted. This method is slightly more failure prone than equipment function tests because the computer is restricted to passive tests only.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: Since onboard computers will become common on most spacecraft this method of electrical interface checkout will be routine and probably common for all spacecraft.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The only significant development needed is for computers to become more common for general spacecraft operations. Ground based algorithms and software need to be adapted for onboard computer use.

OTHER REMARKS AND SPECIAL ASPECTS: This task is done on the ground, prior to launch. If the spacecraft computer itself does this check, then the procedure could be repeated in space if necessary (e.g. on the interfaces between the spacecraft and a booster stage). The current technology for this functional element is Human On Ground With Computer Assistance.

4-3

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DECISION CRITERIA COMPARISON CHART

GFE: g33 VERIFY DEPLOYMENT SEQUENCES

GFE TYPE: B. Checkout

On-orbit check that the deployed components (e.g. solar arrays, radiators, instrument booms) have properly deployed and latched into position. Although usually done shortly after launch, deployment and this verification may need to be repeated later in the spacecraft life; for such repetitions, it may be more difficult to provide onsite humans (e.g. in GEO).

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CANDIDATE ARAMIS CAPABILITIES:

		DECISION CRITERIA							
		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
6.1	OPTICAL SCANNER (PASSIVE COOPERATIVE TARGET)	2	3	3	2	3	2	2	
11.1	IMAGING (STEREO) WITH MACHINE PROCESSING	5	4	5	3	3	2	4	
11.2	IMAGING (NON-STEREO) WITH MACHINE PROCESSING	5	4	5	3	3	2	4	
13.1	HUMAN EYESIGHT VIA VIDEO	4	4	1	4	4	3	1	
14.1	DIRECT HUMAN EYESIGHT	5	4	1	4	3	2	1	
14.7	ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	5	3	3	3	2	2	
27.1	EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	2	3	4	2	2	1	2	
27.2	EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	4	5	4	4	1	2	2	
27.3	EQUIPMENT FUNCTION TEST VIA TELEMETRY	3	3	3	3	2	2	1	
27.4	EQUIPMENT DATA CHECKS BY ONBOARD COMPUTER	2	3	3	2	3	2	2	
27.5	EQUIPMENT DATA CHECKS BY ONSITE HUMAN	3	5	3	4	2	3	2	
27.6	EQUIPMENT DATA CHECKS VIA TELEMETRY	3	3	2	3	3	3	1	C.T.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Optical Scanner (Passive Cooperative Target)
CODE NUMBER: 6.1 DATE: 7/5/82 NAME(S): Thiel/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Although it cannot verify latch closures, etc., this is the fastest method for determining if a deployed assembly is in the proper position. The laser scanner can measure range (accuracy in microns) and vibrations (up to kilohertz) frequencies in a few milliseconds (JPL/Lockheed).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The system has few moving parts and can be made redundant. It certainly does not require more maintenance than the current technology of Equipment Data Checks Via Telemetry.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The system is very near present technology, but some R&D is necessary to bring it online. Also, the device must be space rated.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The Optical Scanner is comparable to radar in complexity and is simpler than active target systems. Individual units are expensive, but have long lifetimes and can perform many tasks, so the cost per task is low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Although the scanner has outstanding measurement capabilities cannot verify switch and latch positions which are important for determining if a piece of hardware is properly deployed and locked.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The simplicity (compared to imaging systems) and the speed of the scanner insures a long useful life. It can be used in parallel with other sensing devices (imaging and non-imaging).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development is nearly complete and breadboard test models perform very well. Lockheed expects space rating will be fairly easy.

OTHER REMARKS AND SPECIAL ASPECTS: The laser could be dangerous when operating at long range scan power levels. The current technology for performing this functional element is Equipment Data Checks By Onboard Computer.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Stereo) With Machine Processing
CODE NUMBER: 11.1 DATE: 6/23/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff). An imaging system is slower than the current technology option as it requires transportation to the payload.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability does not necessitate the support of a human and is relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). Stereo can handle more uncertainty than non-stereo. Optical techniques would not be capable of verifying some of the things which a data check or a function test could, such as the locking of a latch on a deployed structure.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use space-to-ground communications and use human-on-ground time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides verifying deployment sequences. The current technology capability is Equipment Data Checks Via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

* CAPABILITY NAME: Imaging (Non-Stereo) With Machine Processing
CODE NUMBER: 11.2 DATE: 6/23/82 NAMES: Kurtzman/Caley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff). An imaging system is slower than the current technology option as it requires transportation to the payload.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability does not necessitate the support of a human and is relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). A non-stereo system is, in some applications, more error-prone than one with a stereo capability. Optical techniques would not be capable of verifying some of the things which a data check or a function test could, such as the locking of a latch on a deployed structure.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use space-to-ground communications and use human-on-ground time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides verifying deployment sequences. The current technology capability is Equipment Data Checks Via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Video
CODE NUMBER: 13.1 DATE: 5/26/82 NAME(S): Glass/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Visual verification takes longer than telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Solid-state video cameras are more reliable than vidicon tube cameras, but require more maintenance than current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Video cameras have already been developed for use in space.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability requires a human to observe the deployment sequence, therefore incurring salary costs.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Hardware failures are possible. This capability is also limited by the camera/monitor resolution and a restricted field of view. In the case of deployment failures, however, this may be a very useful diagnostic aid.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The useful life of this capability will depend on how it is applied. For this GFE, more thorough or more automated options will evetually be preferable. However, the same video camera can be used to observe many events sequentially.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability has already been demonstrated on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Equipment Data Checks Via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Human Eyesight
CODE NUMBER: 14 1 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Human recognition time is short, but electronic data checks are faster, if delay time for ground transmission is not a factor. With the delay, time is comparable. This may also require suiting up for EVA, however; a lengthy process.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: A relatively small amount of training is required to perform this task. The astronaut needs only to be able to recognize the correct configuration, and identify possible failures.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This depends on range to target and surrounding environment. Human cannot detect small alignment errors unaided, but can diagnose a wide range of deployment failures, which may be indistinguishable from telemetry data alone. In the event of a failure, human visual data would be very valuable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The important factor is technical obsolescence. Automatic methods will be developed to do the job cheaply, but direct vision will often be a convenient check.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: If a human is available, this task will be little additional effort, and provide useful information, particularly if something unforeseen occurs. Current technology is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The thoroughness of the deployment sequence checkout is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1   DATE: 6/28/82   NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete will be less than current technology because of the lack of transmission delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: An onboard computer would require costly maintenance if something should go wrong, but it does not requite maintenance of the comunnications links.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The cost for developing the function test, as well as the cost of developing the necessary software and adapting the computer to the specific spacecraft, are the main nonrecurring costs. The nonrecurring cost could be reduced somewhat by designing modular computers that could be easily modified for various spacecraft.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because of the absence of human supervison; nobody has to monitor the telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Function tests will gather more information than data checks, and will therefore be better able to verify if the deployment was successful. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The speed and fully autonomous nature of this system make it unlikely to become obsolete in the near future. The onboard computer can also perform other tasks as well.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The development of the function test, which must adhere to the spacecraft saftey codes, is the principal risk.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Function tests take longer to initiate than data checks. The human is also slower than automatic methods.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The human needs more maintenance than current technology. The maintenance needed for the test equipment makes the maintenance rating higher than Direct Human Eyesight.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Cost for development of the dedicated microcomputer and the function tests.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Failure-proneness is much lower because the function test gathers more data than the data checks and the human in the loop can diagnose problems more reliably than automatic methods. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Useful life is longer then current technology because function tests are more reliable than data checks.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes development of the dedicated microcomputer, the associated software, and the equipment function test.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Data Checks via Telemetry. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The Function Test via Telemetry will take slightly longer than Equipment Data Checks via Telemetry. However it will be faster than the Equipment Function Test by Onsite Human. This includes the time associated with the transmission lag that accompanies communicating between the spacecraft and the ground.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Basically the same equipment is used for the Equipment Function Test via Telemetry and the Equipment Data Check via Telemetry. Therefore the amount of maintenance needed will be about the same as that needed for current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The nonrecurring cost is higher because of the development cost of the equipment function test. This includes the cost of outfitting the spacecraft with the necessary equipment, a cost that current technology also has.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring cost includes maintenance of the communications links.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Equipment function tests gather more information than data checks, and will be able to verify deployment sequences more reliably than data checks.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The lower failure-proneness at comparable cost gives this system a better useful life rating.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risk includes designing the necessary equipment into the spacecraft and developing the function test. However this capability is already in use so it receives a low developmental risk rating.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipmert Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/14/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This option is faster than transmitting data to a remote location (telemetry) because of delays due to ground station availability. The onboard computer can analyze the data and reach a conclusion before a human can read a display screen or printout.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Onboard computers will be reliable and probably self maintaining for the life of a mission. Their maintenance will be comparable to the telemetry link and ground equipmnet required by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This test is identical to tests performed on telemetered data so ground software and analysis techniques must be transferred to space rated computers. This initial cost should not be very large.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The sensors and computer software to perform this functional element are less expensive than use of telemetry links and human analysis.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Human analysis is adaptable to unanticipated conditions whereas the equipment data checking programs are not. Also, this system only looks at data; it cannot test system functions as equipment function test programs can.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Since onboard computers will become common on most spacecraft this method of deployment checkout will be routine and probably common for many spacecraft.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The only significant development needed is for computers to become more common for general spacecraft operations. Ground based algorithms and software need to be adapted for onboard computer use.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onsite Human
CODE NUMBER: 27.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time is essentially limited by the human's recognition time, and is comparable to the current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Some astronaut training is required; he or she must be able to recognize the correct data and identify possible failures. Also, a space-rated dedicated microprocessor must be developed.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The experience and flexibility of the human makes accurate diagnosis of problems more likely than with the other, automated, data checks.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard computer-run checks will probably become more thorough and less expensive than alternatives involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Interfaces and specific test equipment would need to be developed for a given deployment configuration.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computers). Current technology for this GFE is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks via Telemetry
CODE NUMBER: 27.6 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g33 Verify Deployment Sequences

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This option is the current technology and can be accomplished simply and quickly. However, onboard options not involving humans will be faster.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This option is current technology. Since this GFE is not accomplished continuously, down time is not significant. Maintenance costs are low, since they only involve software checks and updates.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This option is currently available.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The most expensive aspect is that of the telemetry, therefore it will be more expensive to operate than its onboard counterpart, Equipment Data Checks by Onboard Computer.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This option is the current technology. An Equipment Function Test by Onsite Human will give the most definitive determination.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This option will be made technically obsolete by Equipment Function Test by Onboard Computer.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This option is currently in use.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology option.

DECISION CRITERIA COMPARISON CHART

GFE: g48 THERMAL SUBSYSTEM CHECKOUT

GFE TYPE: B. Checkout

On-orbit check that thermal components (e.g. heaters, pumps, radiators) are functioning properly. Usually done shortly after launch, this checkout may have to be repeated later in the spacecraft life (e.g. after modifications or repairs). As the spacecraft state-of-the-art moves toward fully integrated power management systems, this task may be incorporated with g23 Power Subsystem Checkout (in A. Power Handling).

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
10.1 THERMAL IMAGING SENSOR WITH HUMAN PROCESSING	4	3	4	4	2	3	2	
11.3 THERMAL IMAGING SENSOR WITH MACHINE PROCESSING	2	3	5	3	2	2	3	
14.3 HUMAN IN EVA WITH TOOLS	5	5	2	5	4	4	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	4	4	4	2	2	2	
27.1 EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	3	3	4	2	2	1	2	
27.2 EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	4	4	4	4	1	2	2	
27.3 EQUIPMENT FUNCTION TEST VIA TELEMETRY	4	3	3	3	2	2	1	
27.4 EQUIPMENT DATA CHECKS BY ONBOARD COMPUTER	2	3	3	2	3	1	2	
27.5 EQUIPMENT DATA CHECKS BY ONSITE HUMAN	3	4	3	4	2	3	2	
27.6 EQUIPMENT DATA CHECKS VIA TELEMETRY	3	3	2	3	3	3	1	C.T

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Thermal Imaging Sensor with Human Processing
CODE NUMBER: 10.1 DATE: 7/5/82 NAME(S): Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The presence of a human in evaluating the images makes this capability slower than one with machine processing.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes in-space maintenance of the thermographic equipment (the human who is doing the processing is located on the ground). If the human is located in space, instead of on the ground, this criteria value would then become a 4.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The investment required to develop and space-rate thermographic equipment is large compared to the other options.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This includes the costs of procuring the equipment as well as salary for the human. A space-qualified Thermal Imaging System with Human Control would probably cost an estimated $100,000 - 200,000, which is extrapolated from the cost of the aircraft-based Flir Thermal Imaging System (see the General Information Form for this capability), currently quoted at $53,075.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability will allow monitoring of hot-spots over the entire exterior of the spacecraft. It cannot, however, perform a function test.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The necessity of having a human available makes this option less desirable than the autonomous options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The risk in adapting a thermal imaging sensor to the space environment is small.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is an Equipment Data Check via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Thermal Imaging Sensor with Machine Processing
CODE NUMBER: 11.3 DATE: 7/5/82 NAME(S): Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: No human is required for this capability as it operates autonomously on a computer and hence implementation is very rapid.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes the maintenance of the imaging system and the computer in space.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The costs of space-rating thermographic equipment and developing the necessary software to perform the analysis make this the costliest option to develop.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This includes the costs of procuring the computer and thermographic equipment and is equivalent to the salary costs in the current technology capability. A space-qualified Thermal Imaging System (without the computer control) would probably cost an estimated $100,000 - 200,000, which is extrapolated from the cost of the aircraft-based Flir Thermal Imaging System (see the General Information Form for this capability), currently quoted at $53,075.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability will allow monitoring of hot-spots over the entire exterior of the spacecraft. It cannot, however, perform a function test.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The information derived from a thermal sensor is very valuable when evaluating the thermal subsystem. It is likely that this capability will eventually be augmented with an Equipment Function Test by Onboard Computer for maximum performance.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The risk associated with this capability is primarily that associated with developing machine processing capable of adequately evaluating the data from the thermal imaging sensors.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is an Equipment Data Check via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This operation requires EVA activity, taking more time than the alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes astronaut training and the development cost of specialized tools.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than the other alternatives, which are performed remotely.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human in EVA has no inherent reliability advantage over remote operations for checking out a thermal system.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: There is no real need for a human to go EVA to perform this task when automatic methods are available.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): H. Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The thoroughness of the thermal subsystem checkout is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/28/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The thermal subsystem takes time to react to an equipment function test while the data checks have no such time lag. However the inherent speed of the computer makes its rating comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: An onboard computer would require costly maintenance if something should go wrong, but it does not requite maintenance of the comunnications links.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The cost for developing the function test, as well as the cost of developing the necessary software and adapting the computer to the specific spacecraft, are the main nonrecurring costs. The nonrecurring cost could be reduced somewhat by designing modular computers that could be easily modified for various spacecraft.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because of the absence of human supervison; nobody has to monitor the telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Function tests will gather more information than data checks, and will therefore be better able to verify if the deployment was successful. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The speed and fully autonomous nature of this system make it unlikely to become obsolete in the near future. The onboard computer can also perform other tasks as well.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The development of the function test, which must adhere to spacecraft saftey codes is the principal risk.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The thermal subsystem takes time to react to an equipment function test while the data checks have no such time lag.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The human in space requires more maintenance than ground based equipment.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Nonrecurring cost includes the cost for developing the dedicated microcomputer as well as the development cost of the function test.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Failure-proneness is much lower because the function test gathers more data than the data checks and the human in the loop can diagnose problems more reliably than automatic methods. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Useful life is longer than current technology because of the higher reliability.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes the development of the dedicated microcomputer the associated software, and the development of the function test.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Data Checks via Telemetry. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsytem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The time to complete includes the time delay associated with communicating between earth orbit and the ground. Until TDRSS, this capability may not be available at all times, because of the loss of transmission. The thermal subsytem also takes time to react to a function test, while with data checks the data is available immediately.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The Equipment Function Test via Telemetry uses basically the same equipment as the Data Check via Telemetry, so the maintenance should be about the same.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The nonrecurring cost includes the cost for equipping the satellite with the equipment necessary to carry out the function test, this is basically the same as the equipment necessary for current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Should be comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The equipment function test gathers more data than a data check; it will therefore be more reliable. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life should be slightly longer than current technology because of the higher reliability.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This system has already been used The only risk will be to design the system to the particular spacecraft.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/14/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Data monitoring is one of the fastest methods to verify thermal subsystem operation. A simple check of temperature sensors indicates if the thermal subsystem is keeping temperatures within tolerance limits.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Onboard computers will be reliable and probably self maintaining for the life of a mission. Their maintenance will be comparable to the telemetry link and ground computer required by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Essentially this operation is presently done by telemetry and computers or by onboard computers on some advanced spacecraft (Voyager). The nonrecurring cost involves adapting the software to the specific application.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The sensors and computer software to perform this functional element are less expensive than use of telemetry links and ground analysis.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Ground analysis is adaptable to unanticipated conditions whereas the equipment data checking programs are not. Also, this system only looks at data; it cannot test system functions as equipment function test programs can.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: Since onboard computers will become common on most spacecraft this method of thermal checkout will be routine and probably common for many spacecraft.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The only significant development needed is for computers to become more common for general spacecraft operations. Ground based algorithms and software need to be adapted for onboard computer use.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onsite Human
CODE NUMBER: 27.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time is essentially limited by the human's recognition time.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Some astronaut training is required; he or she must be able to recognize the correct data and identify possible failures. Also, a space-rated dedicated microprocessor must be developed.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The experience and flexibility of the human makes accurate diagnosis of problems more likely than with the other, automated, data checks.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard computer-run checks will probably become more thorough and less expensive than alternatives involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Interfaces and specific test equipment would need to be developed for a given thermal system application.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance which uses the Shuttle orbiter computers). Current technology for this GFE is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks via Telemetry
CODE NUMBER: 27.6 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g48 Thermal Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The only option which will be faster is its onboard counterpart Equipment Data Checks by Onboard Computer.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This option is current technology. Since this GFE is not accomplished continuously, down time is not significant. Maintenance costs are low, since they only involve software checks and updates.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This option is currently available.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The most expensive aspect is that of the telemetry. Therefore it will be more expensive to operate than its onboard counterpart, Equipment Data Checks by Onboard Computer.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This option is the current technology. For this GFE, Equipment Function Test by Onsite Human will give the most definitive determination.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This option will be made technically obsolete by Equipment Function Test by Onboard Computer and Equipment Data Checks by Onboard Computer.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This option is currently in use.

OTHER REMARKS AND SPECIAL ASPECTS: This option is the current technology option.

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DECISION CRITERIA COMPARISON CHART

GFE: 949 STRUCTURE SUBSYSTEM CHECKOUT

GFE TYPE: B. Checkout

On-orbit check of the mechanical integrity of spacecraft components. Usually done shortly after launch, this may need to be repeated later in the spacecraft life (e.g. after modifications or repairs). The study concentrates more on the data handling and evaluation aspects of this task than on the actual sensors (e.g. strain gauges).

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
6.1	OPTICAL SCANNER (PASSIVE COOPERATIVE TARGET)	2	3	3	2	5	5	2	
11.1	IMAGING (STEREO) WITH MACHINE PROCESSING	5	4	5	3	4	3	4	
11.2	IMAGING (NON-STEREO) WITH MACHINE PROCESSING	5	4	5	3	4	3	4	
13.1	HUMAN EYESIGHT VIA VIDEO	4	4	1	4	4	3	1	
14.1	DIRECT HUMAN EYESIGHT	3	4	1	4	4	4	1	
14.7	ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	5	3	3	3	3	2	
27.1	EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	2	3	3	2	3	2	2	
27.2	EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	4	5	3	4	2	3	2	
27.3	EQUIPMENT FUNCTION TEST VIA TELEMETRY	3	3	2	3	3	3	1	C.T
27.4	EQUIPMENT DATA CHECKS BY ONBOARD COMPUTER	2	3	2	2	4	3	2	
27.5	EQUIPMENT DATA CHECKS BY ONSITE HUMAN	4	5	2	4	3	3	2	
27.6	EQUIPMENT DATA CHECKS VIA TELEMETRY	3	3	1	3	4	4	1	
27.7	INTERNAL ACOUSTIC SCANNING	2	3	3	2	2	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Optical Scanner (Passive Cooperative Target)
CODE NUMBER: 6.1 DATE: 7/5/82 NAME(S): Thiel/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Although it cannot verify latch closures, etc., this is the fastest method for determining if a deployed assembly is in the proper position. The laser scanner can measure range (accuracy in microns) and vibrations (up to kilohertz) frequencies in a few milliseconds (JPL/Lockheed), but it is unable to locate or identify cracks in s structure.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The system has few moving parts and can be made redundant. It certainly does not require more maintenance than the current technology of Equipment Function Tests Via Telemetry.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The system is very near present technology, but some R&D is necessary to bring it online. Also, the device must be space rated.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The Optical Scanner is comparable to radar in complexity and is simpler than active target systems. Individual units are expensive, but have long lifetimes and can perform many tasks as the cost per task is low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The Optical Scanner is unable to identify or locate cracks and can not measure strains or stresses. This means that while it can verify that a structure is in its proper position, the laser scanner cannot be used to check for damage, overstresses, or to determine if latching mechanisms are in the proper configuration. Therefore laser scanners have a high failure-proneness for Structure Subsystem Checkout.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Since the failure-proneness is so high this capability would be used as little as possible, thus giving it a short useful life.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development is nearly complete and breadboard test models perform very well. Lockheed expects space rating will be fairly easy.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Equipment Function Test Via Telemetry.

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Stereo) With Machine Processing
CODE NUMBER: 11.1 DATE: 6/23/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff). An imaging system is slower than the current technology option as it requires transportation to the payload.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability does not necessitate the support of a human and is relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). Stereo can handle more uncertainty than non-stereo. Optical techniques would not be capable of performing all of the structural tests which an equipment function test could.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides performing structure subsystem tests. The current technology capablility is Equipment Function Tests Via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Non-Stereo) With Machine Processing
CODE NUMBER: 11.2 DATE: 6/23/82 NAMES: Kurtzman/Caley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff). An imaging system is slower than the current technology option as it requires transportation to the payload.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability does not necessitate the support of a human and is relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). A non-stereo system is, in some applications, more error-prone than one with a stereo capability. Optical techniques would not be capable of performing all of the structural tests which an equipment function test could.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides performing structure subsystem tests. The current technology capablility is Equipment Function Tests Via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Video
CODE NUMBER: 13.1 DATE: 5/26/82 NAME(S): Glass/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Visual checkout takes longer than telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Solid-state video cameras are more reliable than vidicon tube cameras, but require more maintenance than current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Video cameras have already been developed for use in space.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability requires a human to observe the structure, therefore incurring salary costs.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Hardware failures are possible. This capability is also limited by the camera/monitor resolution and a restricted field of view. In the case of structural failures, however, this may be a very useful diagnostic aid.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The useful life of this capability will depend on how it is applied. For this GFE, more thorough or more automated options will evetually be preferable. However, the same video camera can be used to observe many events sequentially.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability has already been demonstrated on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Equipment Function Test Via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Human Eyesight
CODE NUMBER: 14.1 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Human recognition time is short, but electronic data checks are faster, if delay time for ground transmission is not a factor. With the delay, time is comparable.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays). This task may require suiting up for a closer look.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: A relatively small amount of training is required to perform this task. The astronaut needs only to be able to recognize the correct configuration, and identify possible failures.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This depends on range to target and surrounding environment. However, humans cannot detect small cracks or alignment errors unaided, which could be very important here. In the event of a structural failure, human visual data would be very valuable.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The only factor here is technical obsolescence. Automatic devices are capable of performing the task, and will get better and cheaper as they are developed.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability would not be good for a thorough checkout, but could be very useful in diagnosing a problem that has been detected by some other means. Current technology is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The thoroughness of the structure subsystem checkout is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/28/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete will be less than current technology because of the lack of transmission delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although this system will not require maintenance as often as current technology, when this system does require it, the maintenance needed will tend to be more expensive than the maintenance required by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Cost of developing the necessary software and adapting the computer to the specific spacecraft. The nonrecurring cost could be reduced somewhat by designing modular computers that could be easily modified for various spacecraft.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because there is no need for human interaction; nobody has to monitor the telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The onboard computer receives as much information as current technology, therefore the failure-proneness will be about the same. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The fully autonomous nature of this system gives it a more favorable useful life rating than current technology. However, for this application function tests may not be the most effective method that can be used. Undesirable damage can occur to the structure without affecting the function test equipment; Internal Acoustic Scanning may be more reliable in some cases.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes the development of the necessary software and adhering to the software and hardware safety codes.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The human will take a little longer than telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: A human in space requires considerable maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The nonrecurring cost includes the cost of developing the dedicated microcomputer.

RECURRING COST (1 LOW, 5 HIGH):4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: For the structure subsystem, function tests will not give all necessary information, however, the human will be able to find problems that telemetry and computers cannot. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: For this application, this capability will be replace by the more automated options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The risk is for the development of the dedicated microcomputer, and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time to complete includes the time delay associated with communicating between earth orbit and the ground. Until TDRSS, this capability may not be available at all times, because of the loss of transmission.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The communications network must be maintained.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The nonrecurring cost includes outfitting the spacecraft with the necessary equipment as well as designing the equipment function test itself.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost includes the maintenace cost of the communications links.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The reliability of this capability is dependant upon the sophistication of the function test, and how much information it sends back. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The need for human interaction will make this capability give way to automatic systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risk includes the designing of the necessary equipment into the spacecraft and developing a function test.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/22/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This option is faster than transmitting data to a remote location (telemetry) because of delays due to ground station availability. The onboard computer can analyze the data and reach a conclusion before a human can read a display screen or printout.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Onboard computers will be reliable and probably self maintaining for the life of a mission. Their maintenance will be comparable to the telemetry link and ground computer required by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This test is identical to tests performed on telemetered data. Existing ground software and analysis techniques must be transferred to space rated computers, but the current technology function tests are more complex than data checks; therefore their costs are comparable.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The computer can carry out this functional element at less cost than the telemetry and ground review required by current technology .

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The computer is attempting to infer from data analysis of spacecraft equipment the state of the spacecraft structure. It is probable that an occaisional error would be made due to misinterpretation of data. The current technology function test is more thorough.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: More sophisticated indirect tests (equipment function tests) nd direct testing methods (Internal Acoustic Scanning) will render this method obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Spacecraft computers are under development and they will be incorporated in new spacecraft designs. The algorithm and software development will require no new technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onsite Human
CODE NUMBER: 27.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The time is essentially limited by the human's recognition time.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costl compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Some astronaut training is required; he or she must be able to recognize the correct data and identify possible failures. Also, a space-rated dedicated microprocessor must be developed.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The experience and flexibility of the human makes accurate diagnosis of problems more likely than with the other, automated, data checks.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard computer-run checks will probably become more thorough and less expensive than alternatives involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Interfaces and specific test equipment would need to be developed for a given structural configuration.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computers). Current technology for this GFE is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks via Telemetry
CODE NUMBER: 27.6 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This option takes more time to complete than its onboard counterpart, Equipment Data Checks by Onboard Computer, because of the delay introduced by telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance required will be comparable with that required by the current technology option, Equipment Function Test via Telemetry.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This capability has one of the lowest nonrecurring costs because it is already available and requires no additional hardware or software.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The costs associated with the telemetry prevent this from having as low a rating as its onboard counterpart, Equipment Function Test by Onboard Computer.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability may not be able to locate the specific source of a failure.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This capability will be made obsolete by either Equipment Function Test by Onboard Computer or Internal Acoustic Scanning.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This disadvantage of this capability is that it only asserts whether or not a failure exists and gives little indication, other than on a subsystem level, as to its location or severity. The advantage is that it is routine and requires no changes in configuration. The current technology capability is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Internal Acoustic Scanning
CODE NUMBER: 27.7 DATE: 7/2/82 NAME(S): Marra/Jones-Oliviera
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g49 Structure Subsytem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The time needed to generate an acoustic signature and compare it to the library of acoustic signatures should be faster than activating function test equipment.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The equipment needed to perform this capability should need as much maintenance as current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The cost of equipping the spacecraft with the necessary equipment as well as the development costs.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The operational cost will be lower than current technology because of the lack of a human component.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability should be very reliable. It will be able to find faults in the structure which might not immediately affect the function test equipment.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This system is designed specifically for this function, while current technology is not. The higher reliability of properly diagnosing the status of the structure subsystem makes the useful life of this system longer than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The equipment necessary for this capability should comparable to the equipment needed for the Optical Scanner.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry.

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DECISION CRITERIA COMPARISON CHART

GFE: g51 ATTITUDE CONTROL SUBSYSTEM CHECKOUT **GFE TYPE:** B. Checkout

On-orbit check of the proper function of the attitude control subsystem of the spacecraft. Usually done in the vicinity of the Shuttle after launch and deployment, this task may be repeated later in the spacecraft life, especially after modifications to the spacecraft which modify its dynamic properties.

CANDIDATE ARAMIS CAPABILITIES:

		DECISION CRITERIA							
		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.7	ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	5	3	4	3	4	2	
27.1	EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	2	3	3	2	3	2	2	
27.2	EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	4	4	3	4	2	3	2	
27.3	EQUIPMENT FUNCTION TEST VIA TELEMETRY	3	3	2	2	3	3	1	C.T.

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g51 Attitude Control Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The thoroughness of the attitude control subsystem checkout is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/28/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g51 Attitude Control Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete will be less than current technology because of the lack of transmission delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although this system will not require maintenance as often as current technology, when this system does require it, the maintenance needed will tend to be more expensive than the maintenance required by current technology, so the overall maintenance rating is comparable to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Cost of developing the necessary software and adapting the computer to the specific spacecraft. The nonrecurring cost could be reduced somewhat by designing modular computers that could be easily modified for various spacecraft.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because there is no need for human interaction; nobody has to monitor the telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The onboard computer receives as much information as current technology, therefore the failure-proneness will be about the same. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The fully autonomous nature of this system gives it a more favorable useful life rating than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes developing the necessary software in adherance to the spacecraft safety codes.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g51 Attitude Control Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The human takes longer than current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: A human in space requires considerable maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Cost of developing the dedicated microcomputer.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The onsite human will be better at finding problems than current technology. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The risk includes the development of the dedicated microcomputer and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer).

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g51 Attitude Control Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time to complete includes the time delay associated with communicating between earth orbit and the ground. Until TDRSS, this capability may not be available at all times, because of the loss of transmission.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The communications network must be maintained.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The nonrecurring cost includes outfitting the spacecraft with the necessary equipment as well as designing the equipment function test itself.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost includes the maintenace cost of the communications links.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The reliability of this capability is dependent on the sophistication of the function test, and on how much information it sends back. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The need for human interaction will make this capability give way to automatic systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risk includes the designing of the necessary equipment into the spacecraft and developing a function test.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology.

DECISION CRITERIA COMPARISON CHART

GFE: g52 PROPULSION SUBSYSTEM CHECKOUT

GFE TYPE: B. Checkout

On-orbit check of the components of a spacecraft propulsion system. Currently done by successive tests of individual components, without actually firing the system. This procedure is not expected to change; the study focuses on commanding the tests and evaluating the return data.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.7	ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	5	3	4	3	4	2	
27.1	EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	2	3	3	2	3	2	2	
27.2	EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	4	4	3	4	3	3	2	
27.3	EQUIPMENT FUNCTION TEST VIA TELEMETRY	3	3	2	3	3	3	1	C.T

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g52 Propulsion Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The thoroughness of the propulsion subsystem checkout is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/28/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g52 Propulsion Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete will be less than current technology because of the lack of transmission delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although this system will not require maintenance as often as current technology, when this system does require it, the maintenance needed will tend to be more expensive than the maintenance required by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Cost of developing the necessary software and adapting the computer to the specific spacecraft. The nonrecurring cost could be reduced somewhat by designing modular computers that could be easily modified for various spacecraft.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because there is no need for human interaction; nobody has to monitor the telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The onboard computer receives as much information as current technology, therefore the failure-proneness will be about the same. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The fully autonomous nature of this system gives it a more favorable useful life rating than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risks include the development of the software in adherance to spacecraft safety codes.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry. Due to the nature of the propulsion subsystem, actual operation of the system is rarely practical, i.e. actually firing the boosters. In this functional element, a function test is merely going through the entire system, opening and closing valves checking pressures and similar tests.

ARAMIS C PABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g52 Propulsion Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The human takes longer than current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: A human in space requires considerable maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost includes the development cost of the dedicated microcomputer.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: For the propulsion subsystem all of the function tests will be equally reliable. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the dedicated microcomputer and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry. Due to the nature of the propulsion subsystem, actual operation of the system is rarely practical, i.e. actually firing the boosters. In this functional element, a function test is merely going through the entire system, opening and closing valves, checking pressures, etc.. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g52 Propulsion Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time to complete includes the time delay associated with communicating between earth orbit and the ground. Until TDRSS, this capability may not be available at all times, because of the loss of transmission.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The communications network must be maintained.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The nonrecurring cost includes outfitting the spacecraft with the necessary equipment as well as designing the equipment function test itself.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost includes the maintenace cost of the communications links.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The reliability of this capability is dependent on the sophistication of the function test, and on how much information it sends back. Under certain condtions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The need for human interaction will make this capability give way to automatic systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risk includes the designing of the necessary equipment into the spacecraft and developing a function test.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology.

DECISION CRITERIA COMPARISON CHART

GFE: g54 CONSUMABLES LEVELS CHECKOUT

GFE TYPE: B. Checkout

On-orbit check of fluid levels in consumables tanks (e.g. propellant, cooling fluids, gas supplies, life-support fluids). The study concentrates on data evaluation rather than specific sensors.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	3	5	4	4	2	4	2	
27.4 EQUIPMENT DATA CHECKS BY ONBOARD COMPUTER	2	3	3	2	3	2	2	
27.5 EQUIPMENT DATA CHECKS BY ONSITE HUMAN	3	5	3	4	2	3	2	
27.6 EQUIPMENT DATA CHECKS VIA TELEMETRY	3	3	2	3	3	3	1	C.T.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g54 Consumables Levels Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The onsite human's judgement makes this slightly more reliable than current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/22/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g54 Consumables Levels Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This option is faster than transmitting data to a remote location (telemetry) because of delays due to ground station availability. The onboard computer can analyze the data and reach a conclusion before a human can read a display screen or printout.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Onboard computers will be reliable and probably self maintaining for the life of a mission. Their redundancy will make them as reliable as the spacecraft side of a telemetry link.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Since this operation is relatively simple, it can be programmed into projected spacecraft computer systems with little development cost.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The onboard computer uses no expensive telemetry links and would cost much less to accomplish this task than would a human.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: It is unlikely that any of the proposed methods of accomplishing this task would make significant errors. The onsite human options will be slightly more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: As computers become more and more common on spacecraft this method of consumables checkout will become standard procedure.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Spacecraft computers are under development and they will be incorporated in new spacecraft designs. The algorithm and software development will require no new technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this functional element is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onsite Human
CODE NUMBER: 27.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g54 Consumables Levels Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time is essentially limited by the human's recognition time.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Some astronaut training is required; he or she must be able to recognize the correct data and identify possible failures. Also, a space-rated dedicated microprocessor must be developed.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly \$100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The experience and flexibility of the human makes accurate diagnosis of problems more likely than with the other, automated, data checks.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard computer-run checks will probably become more thorough and less expensive than alternatives involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Interfaces and specific test equipment would need to be developed for a given application.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computers). Current technology for this GFE is Equipment Data Checks via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks via Telemetry
CODE NUMBER: 27.6 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g54 Consumables Levels Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The only option which will be faster is its onboard counterpart, Equipment Data Checks by Onboard Computer.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This option is current technology. Since this GFE is not accomplished continuously, down time is not significant. Maintenance costs are low, since they only involve software checks and updates.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This option is currently available.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The most expensive aspect is that of the telemetry. Therefore it will be more expensive to operate than its onboard counterpart, Equipment Data Checks by Onboard Computer.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This option is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This option will be made obsolete by its onboard counterpart, Equipment Data Checks by Onboard Computer.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This option is currently in use.

OTHER REMARKS AND SPECIAL ASPECTS: This option is the current technology option.

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DECISION CRITERIA COMPARISON CHART

GFE: g260 SP/PAYLOAD INTERFACE CHECKOUT

GFE TYPE: B. Checkout

On-orbit check of the electrical power, cooling, computer, and communications interfaces between a newly installed payload and the Space Platform. More generally, this task includes checking the interface between a retrieved payload and the Shuttle Orbiter, and the interface between an experimental package and an SP pallet.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.3 HUMAN IN EVA WITH TOOLS	4	4	1	4	2	2	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
25.1 ONBOARD DEDICATED MICROPROCESSOR	1	2	3	1	2	1	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	1	1	3	1	2	1	3	
27.1 EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	1	2	4	2	2	1	3	
27.2 EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	3	3	3	3	2	3	2	
27.3 EQUIPMENT FUNCTION TEST VIA TELEMETRY	2	2	2	2	3	3	2	

AF^MIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g260 SP/Payload Interface Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This operation requires EVA activity, taking more time than the alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Training of astronaut is required for this as well as for the current technology (Onsite Human With Computer Assistance), but no sofware development is needed here.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than the other alternatives, which are performed remotely.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The human in EVA can directly examine the interface. When he is provided with suitable tools, this process is less likely to miss a fault than the current technology (Onsite Human With Computer Assistance).

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability will always be useful, if only as a backup to automated methods.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is an Onsite Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g260 SP/Payload Interface Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions). This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The procedure consists of comparing observed test responses to calculated ones, which can be reliably performed by a computer under human direction. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used. An onsite fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g260 SP/Payload Interface Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: All the electronic systems are faster than the human (current technology) at this task.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This capability does not involve life-support or down-time for an astronaut as does current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This task is sufficiently complex that the required software would be more costly than the training and software development for the Onsite Human with Computer Assistance. This higher cost contributes to the low failure-proneness of the microprocessor.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Current technology requires a considerable amount of crew attention. Sensors are cheaper than human time here.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This procedure consists of comparing observed test responses to calculated ones. This will be more reliable when automated.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: Doesn't require direct human attention or orbiter computers.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Space-rating of microprocessor and development software.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is Onsite Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g260 SP/Payload Interface Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged below current technology as the expense of maintaining a human with a computer in space is greater than the costs associated with maintaining a number of microprocessors. Also, the hierarchy's programming includes the ability to compensate for many malfunctions, thereby making unnecessary otherwise expensive maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel). This capability does not require the costs associated with a human in space, as the current technology capability does.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is an Onsite Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/28/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g260 SP/Payload Interface Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Entirely computer-controlled equipment will be faster than systems with active human elements. This capability is onboard, and therefore faster than a function test via telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Maintenance will be less than current technology because there will be no need for the maintenance of the operator.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Nonrecurring cost is high because of the development costs for the Space Platform computers as well as the necessary software.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The absence of a human operator and his maintenance and upkeep costs are why this system receives a low recurring cost rating.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: All tests which are necessary to check the interface can be accomplished by the computer. However, under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The speed in which this capability accomplishes this functional element along with the low recurring cost and the high reliability of this system give it a long useful life.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developmental risks include the development of the software along with the development of the Space Platform computer.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onsite Human with Computer Assistance. The computer used in this application of Equipment Function Test by Onboard Computer is assumed to be the Space Platform computer.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g260 SP/Payload Interface Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Time to complete will be comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance requirement of the human dominates. However maintenance may be slightly less than current technology due to the comparatively lower maintenance requirements of the dedicated microprocessor.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost includes the development cost of the dedicated microcomputer.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology. Recurring costs include the life support of the operator. It costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The function test by the dedicated microprocessor gathers more precise information than current technology, and will be able to check the interface more reliably.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Useful life is comparable to current technology. They will both be made obsolete by Equipment Function Test by Onsite computer.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes the development of the dedicated microcomputer, the associated software as well as the development of the equipment function test.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human. Current technology is Onsite Human with Computer Assist, which uses the Shuttle orbiter computer.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g260 SP/Payload Interface Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete will be faster than current technology, because the current technology human may have to suit up.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: It is easier to maintain equipment on the ground than equipment in space. Communications links must also be maintained.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Non-recurring cost is lower than current technology, because of the lack of need for space-rating a computer.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring cost is lower because most of the equipment is on the ground and less expensive to operate, and no in-space operato need be maintained.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Failure-proneness will be comparable to current technology. The function test will be able to gather more information, but the onsite human will be in a better position to inspect the interface.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Useful life will be comparable to current technology. It is less expensive than current technology but not as reliable. More sophisticated systems will outdate both capabilities.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The development of the function test is the primary risk.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onsite Human with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g27 DEPLOY ANTENNA RECEIVER ARRAYS

GFE TYPE: C. Mechanical Actuation

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The on-orbit deployment of the GSP antenna receiver arrays and, more generally, of any spacecraft components which are not extremely fragile (fragile components are deployed under g31 Deploy Solar Arrays). Most of these deployments happen once, at the beginning of spacecraft on-orbit life; some components are later retracted and redeployed, usually as part of servicing and repair sequences.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
1.1 STORED ENERGY DEPLOYMENT DEVICE	3	3	2	2	3	5	1	
1.2 SHAPE MEMORY ALLOYS	3	3	4	4	3	5	4	
1.3 INFLATABLE STRUCTURE	3	5	4	4	4	4	2	
2.1 ONBOARD DEPLOYMENT/RETRACTION ACTUATOR	3	3	2	3	3	3	1	C.T.
2.2 DEDICATED MANIPULATOR UNDER COMPUTER CONTROL	4	4	3	4	4	2	2	
4.1 COMPUTER-CONTROLLED SPECIALIZED COMPLIANT MANIPULATOR	4	4	4	4	4	2	3	
4.2 COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH FORCE FEEDBACK	4	4	4	4	4	2	4	
4.3 COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH VISION AND FORCE FEEDBACK	4	4	5	4	2	1	5	
14.3 HUMAN IN EVA WITH TOOLS	5	5	2	5	1	1	1	
15.1 SPECIALIZED MANIPULATOR UNDER HUMAN CONTROL	5	5	4	4	2	2	2	
15.2 DEXTROUS MANIPULATOR UNDER HUMAN CONTROL	5	5	3	4	2	2	2	
15.3 TELEOPERATOR MANEUVERING SYSTEM WITH MANIPULATOR KIT	5	5	4	5	3	1	2	

RAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Stored Energy Deployment Device
CODE NUMBER: 1.1 DATE: 6/4/82 NAME(S): Thiel/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is the least complex method of deploying receiver arrays, etc. The nature of stored energy devices will, in most cases, require a quick deployment sequence.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: These devices are only used once, but they must be carefully checked out before use (prior to launch). They are thus comparable to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Stored energy devices have been used on a variety of spacecraft and are a fully developed technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Although some stored energy devices are quite complicated and are only used once, they are less expensive per use than motorized devices (actuators and manipulators).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: These devices are very reliable, but almost any failure is severe because it will prevent the deployment.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Although such a system does not degrade significantly with time, it can only be used once and is becomming obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Stored energy devices have been in use for years and are a mature technology.

OTHER REMARKS AND SPECIAL ASPECTS: This technology is necessitated by shuttle payload bay restrictions. Stored energy deployment devices are limited to reasonably small objects and arrays because of the loads induced by activating the stored energy device. Also, the mechanical complexity becomes too great when attempting to deploy large arrays. The current technology for this functional element is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Shape Memory Alloys
CODE NUMBER: 1.2 DATE: 6/21/82 NAMES: Kurtzman/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Deployment is more rapid than with any of the capabilities requiring human assistance.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: As with the current technology capability, no maintenance is required.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Much research still needs to be done to develop this technology to a usable level. The problems to be solved are engineering ones, not metallurgical.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The increase in cost of making an antenna out of a shape memory material is probably greater than the cost of an Onboard Deployment/Retraction Actuator.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Failure-proneness of this capability should be comparable to that of current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: The shape memory alloy antenna can only be deployed once, and for this functional element the versatility and potential number of uses for each capability, rather than obsolescence, was the criterion for evaluating useful life.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The design of antennas from shape memory alloys is a complicated design problem, and much engineering needs to be performed before this technology can be applied.

OTHER REMARKS AND SPECIAL ASPECTS: Due to the manner in which the device is stored and deployed, shape memory alloy antennas are only a usable alternative for special antennas which will allow slight imprecision in their deployed configuration. For more information about shape memory alloys, see L. McDonald Schetky, "Shape-Memory Alloys," Scientific American, Volume 241, Number 5, November 1979. The current technology capability for performing this functional element is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Inflatable Structure
CODE NUMBER: 1.3 DATE: 6/28/82 NAME(S): Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time this capability takes to deploy an antenna should be comparable to current technology, maybe slightly slower.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Inflatable structures will require constant maintenance due to their nature. If leaks are not repaired, the structure will lose its shape.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The nonrecurring cost includes the development of spaced-rated polymers and sealants.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The recurring cost will be higher than current technology, because the current technology has virtually no operations cost while Inflatable Structures are expected to require maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Inflatable structures cannot be very precise in their deployment (Vought Corporation Systems Div. Report). If something goes wrong it could cause a major failure.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The high failure-proneness is somewhat compensated for by the fact that Inflatable Structures can both deploy and retract.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Not much needs to be done in order to bring this capability on line. Some more work on space-rated sealants and polymers is needed.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deployment/Retraction Actuator
CODE NUMBER: 2.1 DATE: 6/21/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Array

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Deployment/Retraction Actuators require no maintenance (discussion with William B. Palmer, TRW).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are up to 100% effective, depending of specifics. (discussion with Charles R. Griffin, Goddard Space Flight Center)

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology. Actuators may be simultaneously used for Attitude Control. Only one antenna can be deployed by one actuator, and in some cases more than one actuator is necessary.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dedicated Manipulator under Computer Control
CODE NUMBER: 2.2 DATE: 7/12/82 NAME(S): Marra/Dalley/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: A Dedicated Manipulator under Computer Control will take longer than current technology because of the time necessary to position the manipulator. This capability will be faster than the human controlled capabilities because of the inherent speed advantage computers have over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be on par with most space equipment (discussion with Carl Ruoff, JPL). Current technology, however, requires none.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The nonrecurring cost includes the cost of developing the necessary software, as well as the manipulator itself.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The cost of maintenance is the primary recurring cost. Since current technology has no maintenance costs, the Dedicated Manipulator under Computer Control receives a higher recurring cost rating.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability should be reliable. However, the severity of failure, the inability to complete the deployment if a failure should occur or actual damage to the arrays themselves, gives this capability a slightly higher failure-proneness rating.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The ability of this capability to deploy more than one array gives it a slightly better useful life rating.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the necessary software. Less risk is incurred than with the Computer-Controlled Specialized Compliant Manipulator.

OTHER REMARKS AND SPECIAL ASPECTS: The Dedicated Manipulator under Computer Control can be designed to deploy more than one antenna array, while an Onboard Deployment/Retraction Actuator can only deploy a single array. Current technology for this GFE is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Specialized Compliant Manipulator
CODE NUMBER: 4.1 DATE: 6/22/82 NAME(S): Marra/Ferreira/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Computer-Controlled Specialized Compliant Manipulators will take longer than current technology because of the time necessary to position the manipulator. This system will be faster than the human controlled systems because of the inherent speed advantage computers have over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be on par with most space equipment (discussion with Carl Ruoff, JPL). Current technology, however, requires no maintenance. This system will require less maintenance than the Computer-Controlled Manipulator with Force Feedback and the Computer-Controlled Manipulator with Vison and Force Feedback and more maintenance than the Dedicated Manipulator under Computer Control.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Primary nonrecurring costs include production of end effectors and development of software. This is lower than both the Computer-Controlled Manipulator with Force Feedback and the Computer-Controlled Manipulator with Vision and Force Feedback.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The cost of maintenance is the primary recurring cost. The recurring cost will be less than the recurring cost of the Specialized Manipulator under Human Control and Dextrous Manipulator under Human Control; slightly more than the recurring cost for Shape Memory Alloys.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This system will be fairly reliable. However, the severity of failure gives this a higher failure-proneness rating. In this application the compliance gives no great advantage.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The ability to deploy more than one antenna gives this system a longer useful life than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The Computer-Controlled Specialized Compliant Manipulator has a slightly higher developmental risk than the Computer-Controlled Dedicated Manipulator. This includes the development of the specialized end effector and the necessary software.

OTHER REMARKS AND SPECIAL ASPECTS: The Computer-Controlled Specialized Compliant Manipulator is capable of deploying all the antenna arrays inside of the manipulator's working envelope. It is also capable of entirely different functions, such as assembly. Current technology is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Dextrous Manipulator With Force Feedback
CODE NUMBER: 4.2 DATE: 6/21/82 NAMES: Kurtzman/Paige/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The dextrous manipulator requires more time than an Onboard Deployment/Retraction Actuator as the actuator does not need to be transported to the payload as a manipulator would.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software and sensors would be very reliable (Minsky). The current technology capability, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability was judged greater than current technology in recurring costs as the Onboard Deployment/Retraction Actuator costs very little to procure and operate. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is higher than that of a human (who can correct problems after they occur) since the programming is neither adaptive or intelligent. The dedicated Onboard Deployment/Retraction Actuator is less likely to fail, although it is also more failure-prone than a human.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator. Eventually it should be replaced by manipulators with vision. Its useful life is judged longer than the single use current technology as it is capable of performing many tasks. For this functional element, the number of potential uses of the capability rather than when obsolescence will occur was the primary criterion for evaluating useful life.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and to advance to computer control would also be a large step.

OTHER REMARKS AND SPECIAL ASPECTS: This manipulator has the advantage of being adaptable to a number of tasks. The system could probably be built with a modular design, so that a vision capability could easily be added as it comes online. The current technology capability for performing this functional element is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Dextrous Manipulator With Vision and Force Feedback
CODE NUMBER: 4.3 DATE: 6/21/82 NAMES: Kurtzman/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The dextrous manipulator requires more time than an Onboard Deployment/Retraction Actuator as the actuator does not need to be transported to the payload as a manipulator would. However, implementation of vision greatly increases the speed, if the system is under computer control (Minsky).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software, vision, and sensors would be very reliable (Minsky). The current technology capability, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator, and extensive research and development is required to achieve a vision capability. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability was judged greater than current technology in recurring costs as the Onboard Deployment/Retraction Actuator costs very little to procure and operate. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance. Recurring costs will also depend on the production rate of multiple units. Costs would decrease if mass production were implemented (Minsky).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This manipulator would have lower failure-proneness than other computer-controlled options (Minsky). It has the ability to redo the task if improperly done.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator, and the hardware components could be modularly replaced as improvements are made. The software would require little updating (Minsky). Its useful life is judged longer than the single use current technology as it is capable of performing many tasks. For this functional element, the number of potential uses of the capability over its lifetime rather than how soon obsolescence will occur was the primary criterion for evaluating useful life.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and an advance to computer control is a large step. The development of a vision system is also complicated and research has shown that artificial intelligence problems often tend to be much more

difficult than originally anticipated (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A multipurpose dextrous manipulator can replace many special purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology capability is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This operation requires EVA activity, which takes more time than the automatic alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes astronaut training and the development cost of specialized tools.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than most of the automated alternatives.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The human in EVA has a great deal of flexibility in options for diagnosing and repairing unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The number is based on number of reuses possible, not technical obsolescence. The human is so versatile that technical obsolescence is unlikely.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Specialized Manipulator under Human Control
CODE NUMBER: 15.1 DATE: 6/23/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Reciever Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Time to complete will be longer than current technology because of the time necessary to position the manipulator. This system will not be as fast as the computer-controlled systems because of the computers' speed advantage over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: This system will require more maintenance than current technology, which requires none. This includes the maintenance of the operator if the operator is located in space.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Nonrecurring cost includes the development of specialized end effectors.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC). The cost per unit is also much higher than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The human in the command loop can recover from mistakes better than current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life is longer than current technology because it can be applied to entirely different tasks.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Only refinements of currently available technology are necessary to develop this system.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onboard Deployment/Retraction Actuator. The Specialized Manipulator under Human Control can deploy all of the arrays inside the manipulator's working envelope. It can also perform entirely different tasks, such as assembly.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dextrous Manipulator Under Human Control
CODE NUMBER: 15.2 DATE: 6/30/82 NAME(S): Spofford/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Because this manipulator is operated by a human, it take a much longer time to complete this task than a Onboard Deployment/Retraction Actuator does. In addition it must be transported to the deployment site.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be about the same as most space equipment (Carl Ruoff, JPL). Current technology requires no maintenance, however.

NONRECURRING COST (1 LOW 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes the cost of end-effector development.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This manipulator will cost more to buy and operate than the Onboard Deployment/Retraction Actuator. Recurring costs include operator life support and salary. The current cost is $100K per human per day in space (Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: One benefit of having a human-operated manipulator is the reduced chance of failure. The operator can adapt to situations that automated systems are not programmed to handle. This capability is more reliable than the current technology, which is unable to recover from a failure.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability can be applied to other functional elements in addition to this deployment element. Therefore it was considered to have a longer useful life than any dedicated device.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: This manipulator may be used for many different operations. Because it has a human operator, it adapts to new applications quickly. A multi-purpose dextrous manipulator can replace many special-purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology for this functional element is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Teleoperator Maneuvering System With Manipulator Kit
CODE NUMBER: 15.3 DATE: 6/30/82 NAME(S): Spofford/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g27 Deploy Antenna Receiver Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Because this manipulator is operated by a human, it take a much longer time to complete this task than a Onboard Deployment/Retraction Actuator does. In addition it must transport itself to the deployment site.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Compared to current technology, this capability will require a lot of maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The TMS cost is not included here; it is assumed that this device is already developed and ready for use. Only the TMS manipulator kit is covered in this cost.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The recurring cost of this capability includes the operating cost of the TMS and the operator's salary. Recurring costs include operator life support.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The possibility of collision is a factor in the failure-proneness of the TMS with manipulator kit. With a human-operated manipulator the chance of failure is reduced because the operator can adjust to situations that automated systems are not programmed to handle.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This capability has a long useful life as applied to this functional element. With its integral free-flight capability the TMS with manipulator kit can handle large-scale manipulation tasks. As antenna sizes grow, other actuation systems will become awkward and impractical.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Since the TMS is assumed to be already available, the only development risk is that of the manipulator kit itself. There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: The TMS with manipulator kit is very versatile at deployment compared to other capabilities, due to its free-flight and self-transport capabilities. It may be used with any size array, including extremely large arrays. The current technology for this functional element is an Onboard Deployment/Retraction Actuator.

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DECISION CRITERIA COMPARISON CHART

GFE: g31 DEPLOY SOLAR ARRAYS

GFE TYPE: C. Mechanical Actuation

The on-orbit deployment of solar arrays and, more generally, of spacecraft components. This includes fragile components (e.g. solar panels, radiators) that require safe geometries and minimal stresses during deployment. Most of these components require retractions and redeployment during spacecraft life.

4E.135

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
1.1	STORED ENERGY DEPLOYMENT DEVICE	3	3	2	3	4	5	1	
2.1	ONBOARD DEPLOYMENT/RETRACTION ACTUATOR	3	3	2	3	3	3	1	C.T.
2.2	DEDICATED MANIPULATOR UNDER COMPUTER CONTROL	4	4	3	4	4	2	2	
4.1	COMPUTER-CONTROLLED SPECIALIZED COMPLIANT MANIPULATOR	4	4	4	4	4	2	3	
4.2	COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH FORCE FEEDBACK	4	4	4	4	4	2	4	
4.3	COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH VISION AND FORCE FEEDBACK	4	4	5	4	2	1	5	
14.3	HUMAN IN EVA WITH TOOLS	5	5	2	5	1	1	1	
15.1	SPECIALIZED MANIPULATOR UNDER HUMAN CONTROL	5	5	4	4	2	2	2	
15.2	DEXTROUS MANIPULATOR UNDER HUMAN CONTROL	5	5	3	4	2	2	2	
15.3	TELEOPERATOR MANEUVERING SYSTEM WITH MANIPULATOR KIT	5	5	4	4	3	1	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Stored Energy Deployment Device
CODE NUMBER: 1.1 DATE: 6/4/82 NAME(S): Thiel/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is the least complex method of deploying solar arrays. The nature of stored energy devices will, in most cases, require a quick deployment sequence.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: These devices are only used once, but they must be carefully checked out before use (prior to launch). They are thus comparable to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Stored energy devices have been used on a variety of spacecraft and are a fully developed technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost of the stored energy deployment devices is higher for solar arrays than for antennas because of the increased mass of the solar arrays. More mass means more stored energy and more dampers. (William B. Palmer, TRW Defense and Space Systems Group).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Due to the size of the solar arrays the stored energy devices must be larger than those used for antenna deployment. This means more hardware and more failure points. Also, the additional stored energy increases the chances of damage to the spacecraft if a malfunction occurs.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Although such a system does not degrade significantly with time, it can only be used once and is becomming obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Stored energy devices have been in use for years and are a mature technology.

OTHER REMARKS AND SPECIAL ASPECTS: This technology is necessitated by shuttle payload bay restrictions. Stored energy deployment devices are limited to reasonably small objects and arrays because of the loads induced by activating the stored energy device. Also, the mechanical complexity becomes to great when attempting to deploy large arrays. The current technology for this functional element is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deployment/Retraction Actuator
CODE NUMBER: 2.1 DATE: 6/21/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators will require no maintenance (Discussion with William B. Palmer).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are up to 100% effective, depending on specifics. (discussion with Charles R. Griffin, Goddard Space Flight Center)

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology. Actuators may be simultaneously used for attitude control. Only one solar array can be deployed with one actuator, in some cases more than one actuator will be necessary to deploy one array.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dedicated Manipulator under Computer Control
CODE NUMBER: 2.2 DATE: 7/12/82 NAME(S): Marra/Dalley/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: A Dedicated Manipulator under Computer Control will take longer than current technology because of the time necessary to position the manipulator. This capability will be faster than the human controlled capabilities because of the inherent speed advantage computers have over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be on par with most space equipment (discussion with Carl Ruoff JPL). Current technology, however, requires none.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The nonrecurring cost includes the cost of developing the necessary software, as well as the manipulator itself.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The cost of maintenance is the primary recurring cost. Since current technology has no maintenance costs, the Dedicated Manipulator under Computer Control receives a higher recurring cost rating.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability should be reliable. However, the severity of failure, the inability to complete the deployment if a failure should occur or actual damage to the arrays themselves, gives this capability a slightly higher failure-proneness rating.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The ability of this capability to deploy more than one array gives it a slightly better useful life rating.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the necessary software. Less risk is incurred than with the Computer-Controlled Specialized Compliant Manipulator.

OTHER REMARKS AND SPECIAL ASPECTS: The Dedicated Manipulator under Computer Control can be designed to deploy more than one antenna array, while an Onboard Deployment/Retraction Actuator can only deploy a single array. Current technology for this GFE is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Specialized Compliant Manipulator
CODE NUMBER: 4.1 DATE: 6/22/82 NAME(S): Marra/Ferreira/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Computer-Controlled Specialized Compliant Manipulators will take longer than current technology because of the time necessary to position the manipulator. This system will be faster than the human controlled systems because of the inherent speed advantage computers have over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be on par with most space equipment (discussion with Carl Ruoff, JPL). Current technology, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Primary nonrecurring costs include production of end effectors and development of software. This is lower than both the Computer-Controlled Manipulator with Force Feedback and the Computer-Controlled Manipulator with Vision and Force Feedback.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The cost of maintenance is the primary recurring cost. Cost per unit and operating cost is higher than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This system will be fairly reliable. However, the severity of failure gives this a slightly higher failure-proneness rating. In this application the compliance gives no great advantage.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The ability to deploy more than one antenna gives this system a longer useful life than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The Computer-Controlled Specialized Compliant Manipulator has a slightly higher developmental risk than the Computer-Controlled Dedicated Manipulator. This includes the development of the specialized end effector and the necessary software.

OTHER REMARKS AND SPECIAL ASPECTS: The Computer-Controlled Specialized Compliant Manipulator is capable of deploying all the solar arrays inside of the manipulator's working envelope. It is also capable of entirely different functions, such as assembly. Current technology is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Dextrous Manipulator With Force Feedback
CODE NUMBER: 4.2 DATE: 6/21/82 NAMES: Kurtzman/Paige/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The dextrous manipulator requires more time than an Onboard Deployment/Retraction Actuator as the actuator does not need to be transported to the payload as a manipulator would.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software and sensors would be very reliable. The current technology capability, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability was judged greater than current technology in recurring costs as the Onboard Deployment/Retraction Actuator costs very little to procure and operate. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is higher than that of a human (who can correct problems after they occur) since the programming is neither adaptive or intelligent. Similarly, the dedicated Onboard Deployment/Retraction Actuator is also less likely to fail, although it is still more failure-prone than a human.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator. Eventually it should be replaced by manipulators with vision. Its useful life is judged longer than the single use current technology as it is capable of performing many tasks. For this functional element, the number of potential uses of the capability over its lifetime rather than how soon obsolescence will occur was the primary criterion for evaluating useful life.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and to advance to computer control would also be a large step.

OTHER REMARKS AND SPECIAL ASPECTS: This manipulator has the advantage of being adaptable to a number of tasks. The current technology capability is an Onboard Deployment/Retraction Actuator. The system could probably be built with a modular design, so that a vision capability could easily be added as it comes online.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Dextrous Manipulator With Vision and Force Feedback
CODE NUMBER: 4.3 DATE: 6/21/82 NAMES: Kurtzman/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The dextrous manipulator requires more time than an Onboard Deployment/Retraction Actuator as the actuator does not need to be transported to the payload as a manipulator would.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software, vision, and sensors would be very reliable (Minsky). The current technology capability, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator, and extensive research and development is required to achieve a vision capability. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability was judged greater than current technology in recurring costs as the Onboard Deployment/Retraction Actuator costs very little to procure and operate. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance. Recurring costs will also depend on the production rate of multiple units. Costs would decrease if mass production were implemented (Minsky).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This manipulator would have lower failure-proneness than other computer-controlled options (Minsky). It has the ability to redo the task if improperly done.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator, and the hardware components could be modularly replaced as improvements are made. The software would require little updating (Minsky). Its useful life is judged longer than the single use current technology as it is capable of performing many tasks. For this functional element, the number of potential uses of the capability rather than when obsolescence will occur was the primary criterion for evaluating useful life.

DEVELOPMENTAL R.S. (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and an advance to computer control is a large step. The development of a vision system is also complicated and research has shown that artificial intelligence problems often tend to be much more difficult than originally anticipated (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A multipurpose dextrous manipulator can replace many special purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology capability is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This operation involves EVA activity, which takes more time than the automatic alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes astronaut training and the development cost of specialized tools.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than most of the automated alternatives.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The human in EVA has a great deal of flexibility in options for diagnosing and repairing unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The number is based on number of reuses possible, not technical obsolescence. The human is so versatile that technical obsolescence is unlikely.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Specialized Manipulator under Human Control
CODE NUMBER: 15.1 DATE: 6/23/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solay Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Time to complete will be longer than current technology because of the time necessary to position the manipulator. This system will not be as fast as the computer-controlled systems because of the computers' speed advantage over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: This system will require more maintenance than current technology, which requires no maintenance. this includes the maintenance of the operator.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Nonrecurring cost includes the development of specialized end effectors.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC). The cost per unit is also much higher than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The human in the command loop can recover from mistakes better than current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life is longer than current technology because it can be applied to entirely different tasks.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Only refinements of current technology are necessary to develop this system.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onboard Deployment/Retraction Actuator. The Specialized Manipulator under Human Control can deploy all of the arrays inside the manipulator's working envelope. It can also perform entirely different tasks, such as assembly.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dextrous Manipulator Under Human Control
CODE NUMBER: 15.2 DATE: 6/30/82 NAME(S): Spofford/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Because this manipulator is operated by a human, it takes a much longer time to complete this task than a Onboard Deployment/Retraction Actuator does. In addition it must be transported to the deployment site.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be about the same as most space equipment (Carl Ruoff, JPL). Compared to current technology, however, this option will require more.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes the cost of end-effector development.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include operator life support and salary. The current cost is $100K per human per day in space (Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: One benefit of having a human-operated manipulator is the reduced chance of failure. The operator can adapt to situations that automated systems are not programmed to handle. This capability is more reliable than the current technology, which is unable to recover from a failure.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability can be applied to other functional elements in addition to this deployment element. Therefore it was considered to have a longer useful life than any dedicated device.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: A multi-purpose dextrous manipulator can replace many special-purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology for this functional element is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Teleoperator Maneuvering System With Manipulator Kit
CODE NUMBER: 15.3 DATE: 6/30/82 NAME(S): Spofford/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g31 Deploy Solar Arrays

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Because this manipulator is operated by a human, it take a much longer time to complete this task than a Onboard Deployment/Retraction Actuator does. In addition it must transport itself to the deployment site.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Compared to current technology, this capability will require a lot of maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The TMS cost is not included here; it is assumed that this device is already developed and ready for use. Only the TMS manipulator kit is covered in this cost.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The recurring cost of this capability includes the operating cost of the TMS and the operator's salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The possibility of collision is a factor in the failure-proneness of the TMS with manipulator kit. With a human-operated manipulator the chance of failure is reduced because the operator can adjust to situations that automated systems are not programmed to handle.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This capability has a long useful life as applied to this functional element. With its integral free-flight capability the TMS with manipulator kit can handle large-scale manipulation tasks. As solar array sizes grow, other actuation systems will become awkward and impractical.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Since the TMS is assumed to be already available, the only development risk is that of the manipulator kit itself. There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this functional element is an Onboard Deployment/Retraction Actuator. The TMS with manipulator kit is very versatile at deployment compared to other capabilities, due to its free-flight and self-transport capabilities. It may be used with any size array, including extremely large arrays.

DECISION CRITERIA COMPARISON CHART

GFE: g67 TRANSFER REPAIR EQUIPMENT TO REPAIR SITE

GFE TYPE: C. Mechanical Actuation

The movement of necessary repair tools and replacement parts to the specific location requiring repair. This can include: the swiveling into place of dedicated repair equipment flown on the spacecraft; the movement of a repair platform or unit to the site; the movement of repair-qualified end-effectors on long manipulators; or the use of free-flying repair devices.

4E.147

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
2.1 ONBOARD DEPLOYMENT/RETRACTION ACTUATOR	1	2	3	1	4	4	1	
2.2 DEDICATED MANIPULATOR UNDER COMPUTER CONTROL	3	2	3	2	4	2	2	
4.2 COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH FORCE FEEDBACK	3	2	4	2	4	2	3	
4.3 COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH VISION AND FORCE FEEDBACK	3	2	5	2	3	1	4	
14.3 HUMAN IN EVA WITH TOOLS	3	3	2	3	3	3	1	C.T.
15.1 SPECIALIZED MANIPULATOR UNDER HUMAN CONTROL	3	2	3	3	3	2	1	
15.2 DEXTROUS MANIPULATOR UNDER HUMAN CONTROL	3	2	3	3	3	2	2	
15.3 TELEOPERATOR MANEUVERING SYSTEM WITH MANIPULATOR KIT	2	3	3	3	3	1	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deployment/Retraction Actuator
CODE NUMBER: 2.1 DATE: 6/21/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g67 Transfer Repair Equipment to Repair Site

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The Onboard Deployment/Retraction Actuator is built into the system so no time is needed to move to the repair site as with other systems.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: As compared to current technology, little maintenance will be necessary. The maintenace of a space suit is much more involved than the maintenance of an actuator.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The entire system must be specifically designed to incorporate this system.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators have almost no operational costs. Cost per unit is very low as compared to current tehnology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Although very reliable, if a failure should occur repairs would have to be made on a system not designed to accomodate outside repairs.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: These systems are hampered by the fact that one actuator can serve only one system. Although this capability will be useful in fully automated situations, more versatile systems will probably outdate them.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: These have been used already.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human in EVA with Tools. In this application, the Actuator, either is similar to a "lazy Susan" (i.e., the machinery is built in a modular; when a failure occurs, a new component is rotated into place by the actuator) or involves the swiveling of a dedicated repair unit into the appropriate location. If this system is to be used, an actuator must be built into every location where repairs are desired.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dedicated Manipulator under Computer Control
CODE NUMBER: 2.2 DATE: 7/12/82 NAME(S): Marra/Dalley/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g67 Transfer Repair Equipment to Repair Site

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The maintenance rating for this capability is lower than that of current technology because of the lack of a space suit to maintain.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The cost to develop the dedicated hardware and software should be more than current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are lower than the recurring costs for current technology, because there is less maintenance and no astronaut salary required.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is higher than current technology because of the severity of failure. The manipulator cannot react properly to unexpected situations, such as collisions.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The autonomous nature of this capability gives it a longer useful life than current technology, for those tasks suitable for a dedicated manipulator.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the dedicated hardware and software.

OTHER REMARKS AND SPECIAL ASPECTS: The Dedicated Manipulator under Computer Control can only move repair equipment in a predetermined sequence. This may not be useful if the repair equipment must be moved to an unforeseen area. Current technology for this GFE is Human in EVA with Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Controlled Dextrous Manipulator With Force Feedback
CODE NUMBER: 4.2 DATE: 6/15/82 NAMES: Paige/Ferreira/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g67 Transfer Repair Equipment To Repair Site

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The dextrous manipulator requires approximately the same time as a Human in EVA with Tools if the worksite is remote. The manipulator does not require suiting time and can optimize motions to the mechanical limit of the hardware.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software and sensors would be very reliable.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is higher than that of a human (who can correct problems after they occur) since the programming is neither adaptive or intelligent.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator. Eventually it should be replaced by manipulators with vision. Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and to advance to computer control would also be a large step.

OTHER REMARKS AND SPECIAL ASPECTS: This manipulator has the advantage of being adaptable to a number of tasks. The system could probably be built with a modular design, so that a vision capability could easily be added as it comes online. The current technology capability is Human in EVA with Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Controlled Dextrous Manipulator With Vision and Force Feedback
CODE NUMBER: 4.3 DATE: 6/15/82 NAMES: Paige/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g67 Transfer Repair Equipment To Repair Site

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The dextrous manipulator requires approximately the same time as a Human in EVA with Tools if the worksite is remote. The manipulator does not require suiting time and can optimize motions to the mechanical limit of the hardware. Implementation of vision increases the speed, if the system is under computer control (Minsky).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software, vision, and sensors would be very reliable (Minsky).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator, and extensive research and development is required to achieve a vision capability. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance. Recurring costs will also depend on the production rate of multiple units. Costs would decrease if mass production were implemented (Minsky).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This manipulator would have a lower failure-proneness than the other computer-controlled options (Minsky). It has the ability to redo the task if improperly done.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator, and the hardware components could be modularly replaced as improvements are made. The software would require little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and an advance to computer control is a large step. The development of a vision system is also complicated and research has shown that artificial intelligence problems often tend to be much more difficult than originally anticipated (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A multipurpose dextrous manipulator can replace many special purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology capability is a

Human in EVA with Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g67 Transfer Repair Equipment To Repair Site

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This operation requires EVA activity. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance costs of humans in EVA, i.e., consumables and maintenance of EVA equipment. Also, the down-time is that of the human (8-hour workdays minus current EVA restrictions). This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Includes design of tools and training of astronauts. Mission-specific training for EVA costs roughly $200k/person. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes cost of dedicated astronaut time at roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC). This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability is both highly reliable in a situation which has been planned for, and highly flexible in unplanned circumstances. However, in some applications the human may be rough on very delicate hardware. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Not particularly applicable. The human is so versatile that technical obsolescence is not likely. Individual astronauts can expect 20 years of occasional on-orbit work. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: A human in EVA with tools can perform many other functions in the same EVA. This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Specialized Manipulator under Human Control
CODE NUMBER: 15.1 DATE: 6/23/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g67 Transfer Repair Equipment to Repair Site

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Should be slightly faster than current technology, but not much. This system will not be as fast as the computer-controlled systems because of the computer's speed advantage over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Maintenance for the specialized manipulator should be less than that for space suits.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The cost of developing end effectors should be more than the cost of current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Space quality hardware should require little maintenance. Recurring costs include the life support of the operator. It costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Useful life will be longer than current technology; more sophisticated manipulators will make it obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Only refinements in current systems are necessary.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human in EVA with Tools. The manipulator can only move the repair equipment inside the working envelope of the manipulator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dextrous Manipulator Under Human Control
CODE NUMBER: 15.2 DATE: 6/30/82 NAME(S): Spofford/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g67 Transfer Repair Equipment To Repair Site

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This option is comparable to current technology although the manipulator is fixed in place. This option will not be effective if the equipment must be transfered more than a short distance.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be about the same as most space equipment (Carl Ruoff, JPL). This will be less than the maintenance required for a human in EVA.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes the cost of end-effector development.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring costs include operator life support and salary. The current cost is $100K per human per day in space (Stephen B. Hall of NASA MSFC). This cost, which includes maintenance on the manipulator, is comparable to the cost of EVA.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: One benefit of having a human-operated manipulator is the reduced chance of failure. The operator can adapt to situations that automated systems are not programmed to handle. This option does not have the combination of mobility and dexterity that a human in EVA does.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability can be applied to other functional elements in addition to this deployment element. Therefore it was considered to have a longer useful life than any dedicated device. However, it is limited to short-range transfers because it does not have the free-flight ability of the TMS.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: A multi-purpose dextrous manipulator can replace many special-purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology for this functional element is a Human In EVA With Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Teleoperator Maneuvering System With Manipulator Kit
CODE NUMBER: 15.3 DATE: 6/30/82 NAME(S): Spofford/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g67 Transfer Repair Equipment To Repair Site

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The TMS With Manipulator Kit will be the fastest capability if the repair equipment must be transfered a medium to long distance (over 100 m).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance on the TMS and manipulator kit will be about the same as for a human in EVA.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The TMS cost is not included here; it is assumed that this device is already developed and ready for use. Only the TMS manipulator kit is covered in this cost.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost of this capability includes the operating cost of the TMS and the operator's salary, comparable to the costs of EVA.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The possibility of collision is a factor in the failure-proneness of the TMS with manipulator kit, comparably to a human in EVA. With a human-operated manipulator the chance of failure is reduced because the operator can adjust to situations that automated systems are not programmed to handle.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This capability has a long useful life as applied to this functional element. With its integral free-flight capability the TMS with manipulator kit can handle large-scale, very remote repair tasks; to limit communications delays, however, the operators may eventually be in space also.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Since the TMS is assumed to be already available, the only development risk is that of the manipulator kit itself. There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this functional element is a Human In EVA With Tools. The TMS with manipulator kit is very useful for equipment transfer compared to other capabilities, due to its free-flight and self-transport capabilities. The TMS is the only effective option for transfer of equipment over long distances (outside the operating range of the human in EVA).

DECISION CRITERIA COMPARISON CHART

GFE: g73 POSITION AND CONNECT NEW COMPONENT

GFE TYPE: C. Mechanical Actuation

The movement, alignment, insertion, and fastening of a component to (or into) a spacecraft. This includes the fastening of mechanical, electrical, and fluid interfaces. The inverse of this task covers the disconnection and removal of components from a spacecraft. Since the task includes alignment of the component, it requires either a close-tolerance actuator in a close-tolerance worksite geometry, or compliance in actuator or worksite, or feedback to the actuator control.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
2.2	DEDICATED MANIPULATOR UNDER COMPUTER CONTROL	1	1	3	2	5	4	2	
4.1	COMPUTER-CONTROLLED SPECIALIZED COMPLIANT MANIPULATOR	2	2	4	2	3	3	3	
4.2	COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH FORCE FEEDBACK	2	2	4	2	4	2	4	
4.3	COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH VISION AND FORCE FEEDBACK	1	2	5	2	3	1	5	
14.3	HUMAN IN EVA WITH TOOLS	3	3	2	[illegible]	3	3	1	C.
15.1	SPECIALIZED MANIPULATOR UNDER HUMAN CONTROL	3	2	3	3	4	2	2	
15.2	DEXTROUS MANIPULATOR UNDER HUMAN CONTROL	3	2	4	3	3	2	3	
15.3	TELEOPERATOR MANEUVERING SYSTEM WITH MANIPULATOR KIT	3	3	3	3	4	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dedicated Manipulator under Computer Control
CODE NUMBER: 2.2 DATE: 7/12/82 NAME(S): Marra/Dalley/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g73 Position and Connect New Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This capability will complete its task very quickly as it designed for only one task and will therefore perform it efficiently.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: This capability should require less maintenance than a space suit. Because the Dedicated Manipulator is designed for only one specific task, it will require less maintenance than other manipulators as points of stress can be strengthened with little loss in versatility.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The cost to develop the dedicated hardware and software should be more than current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are lower than the recurring costs for current technology, because there is less maintenance and no astronaut salary required..

FAILURE-PRONENESS (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The failure-proneness is higher than current technology because of the severity of failure. The dedicated manipulator has no capacity for recovering from unforseen events.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The fact that the Dedicated Manipulator under Computer Control is designed for only one task, gives it a less favorable useful life rating than current technology. There are situations, however, where the lack of versatility is no problem (in construction, where there are many of the same fixtures to be connected, for example).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the dedicated hardware and software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this GFE is Human in EVA with Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Specialized Compliant Manipulator
CODE NUMBER: 4.1 DATE: 6/22/82 NAME(S): Marra/Ferreira/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g73 Position and Connect New Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The Computer-Controlled Specialized Compliant Manipulator is not as fast as a Computer-Controlled Dedicated Manipulator. However, it will be faster than the Computer-Controlled Dextrous Manipulator with Force-Feedback. It will be faster than all the human controlled systems because computers are inherently faster than humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This system should require as much maintenance as current space hardware; this is much less than a space suit.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Primary nonrecurring costs include production of end effectors and development of software. This is lower than the Computer-Controlled Manipulator with Force Feedback.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost will be less than current technology, because of the lower maintenance cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This system will be fairly reliable. However, the severity of failure gives this a slightly higher failure-proneness rating.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This is the primary function that this system was designed for. It will have a useful life comparable to current technology, because the more advanced computer-controlled systems will render it obsolete for some functions but for repetitious functions it will be more cost effective.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The risk is in developing the specialized end-effectors and software for use in space.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human in EVA with Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Controlled Dextrous Manipulator With Force Feedback
CODE NUMBER: 4.2 DATE: 6/15/82 NAMES: Paige/Ferreira/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g73 Position and Connect New Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The dextrous manipulator requires less time than a Human in EVA with Tools since it doesn't involve human safety, does not require suiting time, and can optimize motions to the mechanical limit of the hardware.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software and sensors would be very reliable (Minsky).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is higher than that of a human (who can correct problems after they occur) since the programming is neither adaptive or intelligent.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator. Eventually it should be replaced by manipulators with vision. Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and to advance to computer control would also be a large step.

OTHER REMARKS AND SPECIAL ASPECTS: This manipulator has the advantage of being adaptable to a number of tasks. The system could probably be built with a modular design, so that a vision capability could easily be added as it comes online. The current technology capability is Human in EVA with Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Controlled Dextrous Manipulator With Vision and Force Feedback
CODE NUMBER: 4.3 DATE: 6/15/82 NAMES: Paige/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g73 Position and Connect New Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The dextrous manipulator requires less time than a Human in EVA with Tools since it doesn't involve human safety, does not require suiting time, and can optimize motions to the mechanical limit of the hardware. Implementation of vision greatly increases the speed, if the system is under computer control (Minsky).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software, vision, and sensors would be very reliable (Minsky).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator, and extensive research and development is required to achieve a vision capability. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance. Recurring costs will also depend on the production rate of multiple units. Costs would decrease if mass production were implemented (Minsky).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This manipulator would have lower failure-proneness than the other computer-controlled options (Minsky). It has the ability to redo the task if improperly done.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator, and the hardware components could be modularly replaced as improvements are made. The software would require little updating (Minsky). Its useful life is longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and an advance to computer control is a large step. The development of a vision system is also complicated and research has shown that artificial intelligence problems often tend to be much more difficult than originally anticipated (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A multipurpose dextrous manipulator can replace many special purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology capability is Human in

EVA with Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g73 Position And Connect New Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This operation requires EVA activity, taking more time than the alternatives. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance costs of humans in EVA, i.e., consumables and maintenance of EVA equipment. Also, the down-time is that of the human (8-hour workdays minus current EVA restrictions). This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Includes design of tools and training of astronauts. Mission-specific training for EVA costs roughly $200k/person. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes cost of dedicated astronaut time at roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC). This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability is both highly reliable in a situation which has been planned for, and highly flexible in unplanned circumstances. However, in some applications the human may be rough on very delicate hardware. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Not particularly applicable. The human is so versatile that technical obsolescence is not likely. Individual astronauts can expect 20 years of occasional on-orbit work. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: A human in EVA with tools can perform many other functions in the same EVA. This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Specialized Manipulator under Human Control
CODE NUMBER: 15.1 DATE: 6/24/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g73 Position and Connect New Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This system may be slightly faster than current technology, but not much. This system will not be as fast as the computer-controlled systems because of the computer's speed advantage over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This capability does not require the maintenance of a space suit which current technology does.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The nonrecurring cost includes the development of the specialized end effectors and will therefore be more than current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring cost will be slightly less than current technology. Space quality hardware should require little maintenance. Recurring costs include the life support of the operator. It costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The Specialized Manipulator under Human Control will make as many mistakes as current technology, but it will not be able to recover as well.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life will be longer than current technology, because of the cost advantage.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Only refinements of existing technolog, are necessary. Development of specialized end effectors is also included.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human in EVA with Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dextrous Manipulator Under Human Control
CODE NUMBER: 15.2 DATE: 6/30/82 NAME(S): Spofford/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g73 Position And Connect New Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time required to position and connect components will be about the same for a dextrous manipulator as for a human in a pressure suit. The dextrous manipulator doesn't involve human safety or require suiting time.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be about the same as most space equipment (Carl Ruoff, JPL). This will be less than the maintenance required for a human in EVA.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This includes the cost of end-effector development.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring costs include operator life support and salary. The current cost is $100K per human per day in space (Stephen B. Hall of NASA MSFC). This is comparable to the cost of EVA.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: One benefit of having a human-operated manipulator is the reduced chance of failure. The operator can adapt to situations that automated systems are not programmed to handle. This option does not have the combination of mobility and dexterity that a human in EVA does.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability can be applied to other functional elements in addition to this deployment element. Therefore it was considered to have a longer useful life than any dedicated device.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: A multi-purpose dextrous manipulator can replace many special-purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology for this functional element is a Human In EVA With Tools.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Teleoperator Maneuvering System With Manipulator Kit
CODE NUMBER: 15.3 DATE: 6/30/82 NAME(S): Spofford/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g73 Position And Connect New Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time required to position and connect components will be about the same for a dextrous manipulator as for a human in a pressure suit. The dextrous manipulator doesn't involve human safety or require suiting time, but the TMS must be activated and deployed.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance on the TMS and manipulator kit will be about the same as for a human in EVA.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The TMS cost is not included here; it is assumed that this device is already developed and ready for use. Only the TMS manipulator kit is covered in this cost.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost of this capability includes the operating cost of the TMS and the operator's salary, comparable to the cost of EVA.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The possibility of collision is a factor in the failure-proneness of the TMS with manipulator kit. With a human-operated manipulator the chance of failure is reduced because the operator can adjust to situations that automated systems are not programmed to handle. However, the dexterity and onsite ingenuity of the human in EVA make that option more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability has a long useful life as applied to this functional element. With its integral free-flight capability the TMS with manipulator kit can handle large-scale manipulation tasks, at very remote worksites; to limit communications delays, however, the operators may eventually be in space also.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Since the TMS is assumed to be already available, the only development risk is that of the manipulator kit itself. There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this functional element is a Human In EVA With Tools. The TMS With Manipulator Kit is very versatile due to its free-flight and self-transport ability. In particular, it can handle tasks in remote or dangerous locations. For delicate operations, such as this GFE, the difficulties from communications delays suggest putting the operators in space (e.g. a radiation-protected shirtsleeves environment in geostationary orbit, from which operators control TMS's at a nearby worksite).

DECISION CRITERIA COMPARISON CHART

GFE: g134 GRASP FIXTURE

GFE TYPE: C. Mechanical Actuation

The grasping of the Shuttle RMS grapple fixture on a spacecraft or payload. More generally, the grasping of any dedicated grappling fixture on a free-floating or attached payload or spacecraft.

4F.167

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
2.2 DEDICATED MANIPULATOR UNDER COMPUTER CONTROL	1	1	3	2	3	4	2	
4.1 COMPUTER-CONTROLLED SPECIALIZED COMPLIANT MANIPULATOR	2	2	4	2	3	3	3	
4.2 COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH FORCE FEEDBACK	2	3	4	2	3	2	3	
4.3 COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH VISION AND FORCE FEEDBACK	1	4	5	2	2	1	4	
14.3 HUMAN IN EVA WITH TOOLS	4	5	2	4	2	3	1	
15.1 SPECIALIZED MANIPULATOR UNDER HUMAN CONTROL	3	3	2	3	3	3	1	C.T.
15.2 DEXTROUS MANIPULATOR UNDER HUMAN CONTROL	3	2	4	3	3	2	3	
15.3 TELEOPERATOR MANEUVERING SYSTEM WITH MANIPULATOR KIT	3	3	2	3	3	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dedicated Manipulator under Computer Control
CODE NUMBER: 2.2 DATE: 7/12/82 NAME(S): Marra/Dalley/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g134 Grasp Fixture

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The computer's inherent speed advantage over humans, coupled with the speed gained by the dedicated nature of the manipulator, gives this capability a short time rating.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Because the Dedicated Manipulator is designed for only one specific task, it will require less maintenance than other manipulators as points of stress can be strengthened with little loss in versatility.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The cost to develop the dedicated hardware and software should be more than the nonrecurring cost of current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The lower maintenance costs along with the lack of a human component gives this capability a lower recurring cost rating.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Should be comparable to current techonology.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The lack of versatility gives this capability a less favorable useful life rating than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the dedicated hardware and software.

OTHER REMARKS AND SPECIAL ASPECTS: This capability will only be able to grasp one kind of fixture. Current technology for this GFE is Specialized Manipulator under Human Control.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Specialized Compliant Manipulator
CODE NUMBER: 4.1 DATE: 6/22/82 NAME(S): Marra/Ferreira/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g134 Grasp Fixture

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This system will be a little faster than current technology due to the fact that computers are inherently faster than humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This system will require less manintenance than current technology, because there is no in space human to maintain.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Primary nonrecurring costs include production of end effectors and development of software. This is lower than the Computer-Controlled Manipulator with Force Feedback.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring cost will be less than current technology, because of the difference in the maintenance costs.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The compliance of the wrist makes this system unlikely to fail; however, if a failure occurs, it probably could not recover.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Useful life will be comparable to current technology. This system is better suited to repetitious tasks, while current technology is better for tasks with constantly changing conditions.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The risks include the manipulator's software and the dedicated end effector. The Computer-Controlled Specialized Compliant Manipulator has a slightly higher developmental risk than the Computer-Controlled Dedicated Manipulator.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Specialized Manipulator under Human Control.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Controlled Dextrous Manipulator With Force Feedback
CODE NUMBER: 4.2 DATE: 6/15/82 NAMES: Paige/Ferreira/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g134 Grasp Fixture

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The dextrous manipulator requires less time than a Specialized Manipulator Under Human Control as a computer controlled unit should operate faster than a teleoperated one.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software and sensors would be very reliable.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A computer controlled manipulator will make less mistakes than one under human control, but it will not be able to compensate for them as well as a human could.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator. Eventually it should be replaced by manipulators with vision. Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and to advance to computer control would also be a large step.

OTHER REMARKS AND SPECIAL ASPECTS: This manipulator has the advantage of being adaptable to a number of tasks. The system could probably be built with a modular design, so that a vision capability could easily be added as it comes online. The current technology capability is a Specialized Manipulator Under Human Control.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Controlled Dextrous Manipulator With Vision and Force Feedback
CODE NUMBER: 4.3 DATE: 6/15/82 NAMES: Paige/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g134 Grasp Fixture

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The dextrous manipulator requires less time than a Specialized Manipulator under Human Control as a computer controlled unit should operate faster than a teleoperated one. Implementation of vision greatly increases the speed, if the system is under computer control (Minsky).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software, vision, and sensors would be very reliable (Minsky).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator, and extensive research and development is required to achieve a vision capability. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance. Recurring costs will also depend on the production rate of multiple units. Costs would decrease if mass production were implemented (Minsky).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This manipulator would have lower failure-proneness than other computer-controlled options (Minsky). It has the ability to redo the task if improperly done.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator, and the hardware components could be modularly replaced as improvements are made. The software would require little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and an advance to computer control is a large step. The development of a vision system is also complicated and research has shown that artificial intelligence problems often tend to be much more difficult than originally anticipated (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A multipurpose dextrous manipulator can replace many special purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology capability is a Specialized Manipulator Under Human Control.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g134 Grasp Fixture

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This operation requires EVA activity, taking more time than the alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes astronaut training, which is also needed for the current technology.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than the other alternatives, which are performed remotely.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human in EVA has a wider range of possible actions than a specialized manipulator, hence is more likely to be able to successfully perform this task.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The human is so versatile that technical obsolescence is unlikely. However, for specific standardized applications, automated techniques will be superior and cheaper.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Specialized Manipulator under Human Control (e.g. the Shuttle RMS).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Specialized Manipulator under Human Control
CODE NUMBER: 15.1 DATE: 6/24/82 NAME(S): Mar a/Paig
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g134 Grasp Fixture

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The Specialized Manipulator under Human Control is current technology. This system will not be as fast as the computer-controlled systems because of the computer's speed advantage over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Space quality hardware should require little maintenance (discussion with Carl Ruoff, JPL).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The Specialized Manipulator under Human Control is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. It costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The Specialized Manipulator under Human Control is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The Specialized Manipulator under Human Control is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Risk to develop the end effectors

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dextrous Manipulator Under Human Control
CODE NUMBER: 15.2 DATE: 6/30/82 NAME(S): Spofford/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g134 Grasp Fixture

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The dextrous manipulator is about as fast at this task as the Specialized Manipulator Under Human Control is, once positioned within reach of the fixture.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be about the same as most space equipment (Carl Ruoff, JPL).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The cost to develop a dextrous manipulator will be more than the current technology option, a specialized manipulator.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring costs include operator life support and salary. The current cost is $100K per human per day in space (Stephen B. Hall of NASA MSFC). This is comparable to the similar costs in the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: One benefit of having a human-operated manipulator is the reduced chance of failure. The operator can adapt to situations that automated systems are not programmed to handle. The dextrous manipulator will be about as likely to fail as the current technology option.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability can be applied to other functional elements in addition to this deployment element. Therefore it was considered to have a longer useful life than any specialized manipulator.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES. There is currently no manipulator that can be called dextrous, but dexterity is not essential to this task (grasping a standardized fixture).

OTHER REMARK AND SPECIAL ASPECTS: A multi-purpose dextrous manipulator can replace many special-purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology for this functional element is a Specialized Manipulator Under Human Control. The Dextrous Manipulator may use a dedicated end-effector for this task, since the fixture is standardized.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Teleoperator Maneuvering System With Manipulator Kit
CODE NUMBER: 15.3 DATE: 6/30/82 NAME(S): Spofford/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g134 Grasp Fixture

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The dextrous manipulator carried by the TMS is about as fast at this task as the Specialized Manipulator Under Human Control, once either option has been positioned within reach of the fixture.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance for the TMS and manipulator kit will be comparable to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The TMS cost is not included here; it is assumed that this device is already developed and ready for use. Only the TMS manipulator kit is covered in this cost, which is expected to be comparable to the development of the specialized manipulator and its end-effectors.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost of this capability includes the operating cost of the TMS and the operator's salary, comparable to the similar costs in the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The possibility of collision is a factor in the failure-proneness of the TMS with manipulator kit, similarly to the current technology option. With a human-operated manipulator the chance of failure is reduced because the operator can adjust to situations that automated systems are not programmed to handle.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability has a long useful life as applied to this functional element. With its integral free-flight capability the TMS with manipulator kit can handle large-scale manipulation tasks.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Since the TMS is assumed to be already available, the only development risk is that of the manipulator kit itself. There is currently no manipulator that can be called dextrous, but dexterity is not essential to this task (grasping a standardized fixture).

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this functional element is a Specialized Manipulator Under Human Control. The TMS With Manipulator Kit is very versatile due to its free-flight and self-transport ability. Therefore it can perform this task in remote locations. Since the fixture to be grasped is standardized for this task, the TMS's manipulator kit needs only dedicated end-effectors.

DECISION CRITERIA COMPARISON CHART

GFE: 9146 FASTEN DOCKING LATCH

GFE TYPE: C. Mechanical Actuation

The process of hard-docking two spacecraft together. Includes the final approach of the docking spacecraft (i.e. the location of the docking target and the control of the closing motion) and the operation of mechanical docking hardware. The inverse of this task covers un-docking of spacecraft.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
3.1 AUTOMATED DOCKING MECHANISM	2	1	3	1	4	2	2	
13.3 DOCKING UNDER ONSITE HUMAN CONTROL	3	3	2	3	3	3	1	C.T
14.3 HUMAN IN EVA WITH TOOLS	5	4	1	4	2	4	1	
15.4 TELEOPERATED DOCKING MECHANISM	4	2	2	2	4	3	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Automated Docking Mechanism
CODE NUMBER: 3.1 DATE: 5/28/82 NAME(S): Glass/Ferreira/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g146 Fasten Docking Latch

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: No decision-making; the system operates automaticaly.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: No human operator to be maintained in space.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Components must be integrated and space-rated.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: No operator salary. Hardware maintenance costs are comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The system has little fault-tolerance. The current technology option benefits from direct visual feedback and the human's self-correction ability.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Doesn't require human operator, so its lesser cost will make this option preferable.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The hardware is essentially developed. The system has not been tested on-orbit (except in the Soviet Salyut program).

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Docking Under Onsite Human Control.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Docking Under Onsite Human Control
CODE NUMBER: 13.3 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g146 Fasten Docking Latch

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The onsite human is slower than a fully automated system, but faster than teleoperator control. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance cost also includes astronaut life support. which is costly compared to equipment maintenance. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Astronaut training and docking adapter development are the main contributions to nonrecurring cost. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (source: Stephen B. Hall at NASA MSFC). This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The flexibility of humans makes this a reliable system. The human onsite can take a variety of actions in response to a problem. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This capability could eventually be replaced entirely by automation. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g146 Fasten Docking Latch

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This operation involves EVA activity, which takes more time than the automatic alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: A relatively small amount of training is required to perform this task.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than most of the automated alternatives.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The human in EVA has a great deal of flexibility in options for diagnosing and repairing unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: There is no real need for a human to go EVA to perform this task when automatic methods are available.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Docking under Onsite Human Control.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Teleoperated Docking Mechanism
CODE NUMBER: 15.4 DATE: 5/27/82 NAME(S): Glass/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g146 Fasten Docking Latch

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than current technology (onsite human control), because of transmission time lags.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This capability requires less maintenance than current technology because of the reduced amount of hardware required on-orbit.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The development cost for this will not be significant because all the subsystems required have already been used in space. This system is currently used by the Soviet Union.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Less than current technology because a human is not needed on-orbit.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Higher than a directly-operated docking system because of the restricted field-of-view through video cameras.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: About the same as current technology because both require a human operator.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Although a teleoperated docking system has not been proven on-orbit yet, all required components have been demonstrated (ie. docking mechanisms, orbit-to-earth visual links, and teleoperation).

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Docking Under Onsite Human Control.

DECISION CRITERIA COMPARISON CHART

GFE: g148 EXTEND AND ATTACH UMBILICAL

GFE TYPE: C. Mechanical Actuation

The extension and fastening of a propellant-refueling umbilical between two spacecraft, after the spacecraft have hard-docked. More generally, the extension and attachment of any type of umbilical between hard-docked spacecraft or between components of a spacecraft.

CANDIDATE ARAMIS CAPABILITIES:

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
2.1 ONBOARD DEPLOYMENT/RETRACTION ACTUATOR	3	3	2	3	3	3	1	C.T.
2.2 DEDICATED MANIPULATOR UNDER COMPUTER CONTROL	3	4	3	3	4	3	2	
4.1 COMPUTER-CONTROLLED SPECIALIZED COMPLIANT MANIPULATOR	4	4	3	4	4	2	3	
4.2 COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH FORCE FEEDBACK	4	4	4	4	4	2	4	
4.3 COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH VISION AND FORCE FEEDBACK	4	4	5	4	2	1	5	
14.3 HUMAN IN EVA WITH TOOLS	5	5	2	5	1	2	1	
15.1 SPECIALIZED MANIPULATOR UNDER HUMAN CONTROL	4	4	3	4	2	2	2	
15.2 DEXTROUS MANIPULATOR UNDER HUMAN CONTROL	4	4	4	4	2	2	3	
15.3 TELEOPERATOR MANEUVERING SYSTEM WITH MANIPULATOR KIT	3	4	2	4	3	2	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deployment/Retraction Actuator
CODE NUMBER: 2.1 DATE: 6/22/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g148 Extend and Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Actuators require no maintenace (discussion with William B. Palmer, TRW)

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology. A failure during operation can cause serious problems.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The Soviets currently use such a system.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dedicated Manipulator under Computer Control
CODE NUMBER: 2.2 DATE: 7/12/82 NAME(S): Marra/Dalley/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g148 Extend and Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Time to complete should be comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This capability should not require much maintenance. Current technology, however, requires none.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The cost to develop the dedicated hardware and software should be more than the nonrecurring cost of current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Should be comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is a little higher than current technology because of the severity of failure. If a failure should occur, the manipulator may cause damage to the umbilical.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the dedicated hardware and software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this GFE is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Specialized Compliant Manipulator
CODE NUMBER: 4.1 DATE: 6/22/82 NAME(S): Marra/Ferreira/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g148 Extend and Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Computer-Controlled Specialized Compliant Manipulators will take longer than current technology because of the time necessary to position the manipulator. This system will be faster than the human controlled systems because of the inherent speed advantage computers have over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be on par with most space equipment (discussion with Carl Ruoff, JPL). Current technology, however, requires no maintenance. The Computer-Controlled Manipulator with Force Feedback and the Computer-Controlled Manipulator with Vision and Force Feedback will require more maintenance, while the Dedicated Manipulator under Computer Control will require less.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Primary nonrecurring costs include production of end effectors and development of software. This is lower than both the Computer-Controlled Manipulator with Force Feedback and the Computer-Controlled Manipulator with Vision and Force Feedback.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The primary recurring cost is the cost of maintenance. The recurring cost is comparable to the other computer-controlled options, and is slightly less than the Specialized Manipulator under Human Control and Dextrous Manipulator under Human Control.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This system will be fairly reliable. The systems compliance can be an advantage in the attachment of the umbilical. However, the severity of failure gives this a slightly higher failure-proneness rating.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The fact that this system can be used for more than one task is why it recieves a better useful life rating. The useful life of the Computer-Controlled Specialized Compliant Manipulator is slightly better than the useful life of the Specialized Manipulator under Human Control, and slightly shorter than the Computer-Controlled Dextrous Manipulator with Force Feedback.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The risk is a result of the software development and the specialized end effectors. The Computer-Controlled Specialized Compliant Manipulator has a slightly higher developmental risk than the Computer-Controlled Dedicated Manipulator.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onboard Deployment/Retraction Actuator. The Computer-Controlled Specialized Compliant Manipulator is capable of other tasks, such as assembly, while current technology is generally restricted to only one application per unit.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Dextrous Manipulator With Force Feedback
CODE NUMBER: 4.2 DATE: 6/21/82 NAMES: Kurtzman/Paige/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g148 Extend and Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The dextrous manipulator requires more time than an Onboard Deployment/Retraction Actuator as the actuator does not need to be transported to the payload as a manipulator would.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software and sensors would be very reliable. The current technology capability, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability was judged greater than current technology in recurring costs as the Onboard Deployment/Retraction Actuator costs very little to procure and operate. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is higher than that of a human (who can correct problems after they occur) since the programming is neither adaptive or intelligent. Similarly, the dedicated Onboard Deployment/Retraction Actuator is also less likely to fail, although it is still more failure-prone than a human.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator. Eventually it should be replaced by manipulators with vision.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and to advance to computer control would also be a large step.

OTHER REMARKS AND SPECIAL ASPECTS: This manipulator has the advantage of being adaptable to a number of tasks. The system could probably be built with a modular design, so that a vision capability could easily be added as it comes online. The current technology capability is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Dextrous Manipulator With Vision and Force Feedback
CODE NUMBER: 4.3 DATE: 6/21/82 NAMES: Kurtzman/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g148 Extend and Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The dextrous manipulator requires more time than an Onboard Deployment/Retraction Actuator as the actuator does not need to be transported to the payload as a manipulator would. However, implementation of vision greatly increases the speed, if the system is under computer control (Minsky).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software, vision, and sensors would be very reliable (Minsky). The current technology capability, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator, and extensive research and development is required to achieve a vision capability. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability was judged greater than current technology in recurring costs as the Onboard Deployment/Retraction Actuator costs very little to procure and operate. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance. Recurring costs will also depend on the production rate of multiple units. Costs would decrease if mass production were implemented (Minsky).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This manipulator would have a lower failure-proneness than the other computer-controlled options (Minsky). It has the ability to redo the task if improperly done.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator, and the hardware components could be modularly replaced as improvements are made. The software would require little updating (Minsky).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and an advance to computer control is a large step. The development of a vision system is also complicated and research has shown that artificial intelligence problems often tend to be much more difficult than originally anticipated (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A multipurpose dextrous manipulator can replace many special purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology capability is an Onboard Deployment/Retraction Actuator.

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g148 Extend And Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This operation involves EVA activity, which takes more time than the automatic alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes astronaut training and the development cost of specialized tools.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than most of the automated alternatives.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The human in EVA has a great deal of flexibility in options for diagnosing and repairing unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The human is so versatile that technical obsolescence is unlikely. However, for specific standardized applications, automated techniques will be superior and cheaper.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Specialized Manipulator under Human Control
CODE NUMBER: 15.1   DATE: 6/24/82   NAMF(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g148 Extend and Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Time to complete will be longer than current technology because of the time necessary to position the manipulator. This system will slightly slower than the computer-controlled systems because of the computer's speed advantage over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Will require more maintenance than current technology, which require none. This includes maintenance of the operator.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.= 2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost includes development of specialized end effectors.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. It costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The human in the command loop will be able to recover for failures, where as current technology cannot.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Useful life is longer than current technology because this system can be applied to other tasks.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risks include development of specialized end effectors.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dextrous Manipulator Under Human Control
CODE NUMBER: 15.2 DATE: 6/30/82 NAME(S): Spofford/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g148 Extend And Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This option takes longer than current technology to complete this task because it must first grasp the umbilical before positioning it. Additionally, the current technology actuator is automatic, while the dextrous manipulator is human-controled.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be about the same as most space equipment (Carl Ruoff, JPL). However, the current technology option requires almost no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This includes the cost of end-effector development. A dextrous manipulator will cost more to develop than a current technology dedicated actuator.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include operator life support and salary. The current cost is $100K per human per day in space (Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: One benefit of having a human-operated manipulator is the reduced chance of failure. The operator can adapt to situations that automated systems are not programmed to handle. This capability is more reliable than the current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability can be applied to other functional elements in addition to this deployment element. Therefore it was considered to have a longer useful life than any dedicated device. It can handle a variety of umbilical-attachment tasks.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: A multi-purpose dextrous manipulator can replace many special-purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology for this functional element is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Teleoperator Maneuvering System With Manipulator Kit
CODE NUMBER: 15.3 DATE: 6/30/82 NAME(S): Spofford/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: 148 Extend And Attach Umbilical

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: As applied to this functional element, the TMS is carrying a kit which includes a dedicated umbilical of the Onboard Deployment/Retraction Actuator type (which is current technology).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance of the TMS.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The TMS cost is not included here; it is assumed that this device is already developed and ready for use. Only the TMS manipulator kit is covered in this cost. In this application the kit is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The recurring cost of this capability includes the operating cost of the TMS and the operator's salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The possibility of collision is a factor in the failure-proneness of the TMS with manipulator kit. With a human-operated manipulator the chance of failure is reduced because the operator can adjust to situations that automated systems are not programmed to handle.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability has a long useful life as applied to this functional element. With its integral free-flight capability the TMS with manipulator kit can handle a variety of refueling and umbilical-attachment tasks.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Since the TMS is assumed to be already available, the only development risk is that of the manipulator kit itself. In this application the kit is comparable to current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this functional element is an Onboard Deployment/Retraction Actuator. The TMS With Manipulator Kit is very versatile due to its free-flight and self-transport ability. As applied to this functional element, the TMS is carrying a dedicated umbilical of the Onboard Deployment/Retraction Actuator type (which is current technology).

DECISION CRITERIA COMPARISON CHART

GFE: g177 RELEASE SOLAR ARRAY RESTRAINTS

GFE TYPE: C. Mechanical Actuation

ORIGINAL PAGE IS OF POOR QUALITY

The unlatching of restraints on the AXAF solar arrays. More generally, the release of component or payload restraints on or between spacecraft. The restraints are assumed to be standardized, so that any capability developed for one set of restraints could apply to many others. The inverse of this task is the fastening of component or payload restraints.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
2.1	ONBOARD DEPLOYMENT/RETRACTION ACTUATOR	3	3	2	3	3	3	1	C.T.
2.2	DEDICATED MANIPULATOR UNDER COMPUTER CONTROL	3	4	3	3	4	4	2	
4.1	COMPUTER-CONTROLLED SPECIALIZED COMPLIANT MANIPULATOR	4	4	3	4	4	3	3	
4.2	COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH FORCE FEEDBACK	4	4	4	4	4	3	4	
4.3	COMPUTER-CONTROLLED DEXTROUS MANIPULATOR WITH VISION AND FORCE FEEDBACK	4	4	5	4	2	3	5	
14.3	HUMAN IN EVA WITH TOOLS	5	5	2	5	3	3	1	
15.1	SPECIALIZED MANIPULATOR UNDER HUMAN CONTROL	4	4	3	4	4	3	2	
15.2	DEXTROUS MANIPULATOR UNDER HUMAN CONTROL	4	4	4	4	4	3	3	
15.3	TELEOPERATOR MANEUVERING SYSTEM WITH MANIPULATOR KIT	4	4	4	4	4	3	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deployment/Retraction Actuator
CODE NUMBER: 2.1 DATE: 6/22/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: No maintenance is required (discussion with William B. Palmer, TRW).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology. A failure during operation can cause serious problems.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Onboard Deployment/Retraction Actuators are current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this GFE. One actuator must be used for each retraint mechanism.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dedicated Manipulator under Computer Control
CODE NUMBER: 2.2 DATE: 7/12/82 NAME(S): Marra/Dalley/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Time to complete should be comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This capability should not require much maintenance. Current technology, however, requires none.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The cost to develop the dedicated hardware and software should be more than the nonrecurring cost of current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Should be comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is a little higher than current technology because of the severity of failure. If a failure should occur, the manipulator may cause damage to the arrays.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The extra expense for this system is not justified by the abilities of this capability. Current technology does the same as this computer-controlled device.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the development of the dedicated hardware and software.

OTHER REMARKS AND SPECIAL ASPECTS: More than one solar array restraint may be released by this capability. Current technology for this GFE is Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Specialized Compliant Manipulator
CODE NUMBER: 4.1 DATE: 6/22/82 NAME(S): Marra/Ferreira/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Computer-Controlled Specialized Compliant Manipulators will take longer than current technology because of the time necessary to position the manipulator. This system will be faster than the human controlled systems because of the inherent speed advantage computers have over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be on par with most space equipment (discussion with Carl Ruoff, JPL). Current technology, however, requires none. This system will require less maintenance than the Computer-Controlled Manipulator with Force Feedback and the Computer-Controlled Manipulator with Vison and Force Feedback. This system will require more than the Dedicated Manipulator under Computer Control.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost includes software development as well as design of the specialized end effectors. The nonrecurring cost for this system is more than the nonrecurring cost for the Dedicated Manipulator under Computer Control.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The cost of maintenance is the primary recurring cost. The cost per unit is also much higher than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This system will be fairly reliable. This capability will be less failure-prone than the Dedicated Manipulator under Computer Control. However, the severity of failure gives this a slightly higher failure-proneness rating.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The complexity of this system makes up for the fact that more than one restraint can be released by this system.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes the software development and the specialized end effector. The Computer-Controlled Specialized Compliant Manipulator has a slightly higher developmental risk than the Computer-Controlled Dedicated Manipulator.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onboard Deployment/Retraction Actuator. The Computer-Controlled Specialized Compliant Manipulator is capable of releasing all of the array restraints inside of the manipulator's working envelope. It is also capable of performing completely different tasks, such as assembly.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Dextrous Manipulator With Force Feedback
CODE NUMBER: 4.2 DATE: 6/21/82 NAMES: Kurtzman/Paige/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The dextrous manipulator requires more time than an Onboard Deployment/Retraction Actuator as the actuator does not need to be transported to the payload as a manipulator would.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software and sensors would be very reliable. The current technology capability, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability was judged greater than current technology in recurring costs as the Onboard Deployment/Retraction Actuator costs very little to procure and operate. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The failure-proneness is higher than that of a human (who can correct problems after they occur) since the programming is neither adaptive or intelligent. The dedicated Onboard Deployment/Retraction Actuator is less likely to fail, although it is still more failure-prone than a human.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator. All the capabilities except for the dedicated manipulator were judged equal in useful life as applied to this functional element.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and to advance to computer control would also be a large step.

OTHER REMARKS AND SPECIAL ASPECTS: This manipulator has the advantage of being adaptable to a number of tasks. The system could probably be built with a modular design, so that a vision capability could easily be added as it comes online. The current technology capability is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Controlled Dextrous Manipulator With Vision and Force Feedback
CODE NUMBER: 4.3 DATE: 6/21/82 NAMES: Kurtzman/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The dextrous manipulator requires more time than an Onboard Deployment/Retraction Actuator as the actuator does not need to be transported to the payload as a manipulator would. However, implementation of vision increases the speed, if the system in under computer control (Minsky).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance would be low since the only parts likely to need service are the mechanical parts. The software, vision, and sensors would be very reliable (Minsky). The current technology capability, however, requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: This cost is high since no system has yet been developed which incorporates the abilities of this manipulator, and extensive research and development is required to achieve a vision capability. Some of the R&D will probably be done commercially.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability was judged greater than current technology in recurring costs as the Onboard Deployment/Retraction Actuator costs very little to procure and operate. This capability may cost slightly more than a dedicated manipulator since the end-effector would require more maintenance. Recurring costs will also depend on the production rate of multiple units. Costs would decrease if mass production were implemented (Minsky).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This manipulator would have a lower failure-proneness than the other computer-controlled options (Minsky). It has the ability to redo the task if improperly done.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The dextrous manipulator has a useful life which is longer than the more obsolescent dedicated manipulator, and the hardware components could be modularly replaced as improvements are made. The software would require little updating (Minsky). All the capabilities except for the dedicated manipulator were judged equal in useful life as applied to this functional element.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: This is high since there is currently no manipulator that can be called dextrous, and an advance to computer control is a large step. The development of a vision system is also complicated and research has shown that artificial intelligence problems often tend to be much more difficult than originally anticipated (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A multipurpose dextrous manipulator can replace many special purpose manipulators and perform many other tasks requiring versatility (Minsky). The current technology capability is an

Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human In EVA With Tools
CODE NUMBER: 14.3 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This operation involves EVA activity, which takes more time than the automatic alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The equipment involved in EVA incurs a substantial maintenance cost. The maintenance also includes astronaut life support.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes astronaut training and the development cost of specialized tools.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The logistics involved with EVA operations are more complicated than most of the automated alternatives.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The human in EVA has a great deal of flexibility, but due to the simplicity of this task, the current technology (Onboard Deployment/Retraction Actuator) is no more failure-prone.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The human is so versatile that technical obsolescence is unlikely. However, for specific standardized applications, automated techniques will be superior and cheaper.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Specialized Manipulator under Human Control
CODE NUMBER: 15.1 DATE: 6/24/82 NAME(S): Marra/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Time to complete will be longer than current technology because of the time necessary to position the manipulator. This system will not be as fast as the computer-controlled systems because of the computer's speed advantage over humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Will require more maintenance than current technology, which requires none. This includes maintenance of the operator in space.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost includes development of specialized end effectors.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This system will be fairly reliable. This capability will be less failure-prone than the Dedicated Manipulator under Computer Control. However, the severity of failure gives this a slightly higher failure-proneness rating.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Useful life is the same as current technology because of the high reliability of current technology. More sophisticated systems will not accomplish the task any better.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risks include the development of the specialized end effector.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Onboard Deployment/Retraction Actuator. The Specialized Manipulator under Human Control is capable of releasing all of the restraints inside the manipulator's working envelope. A specialized manipulator is also capable of completing different tasks, such as assembly.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dextrous Manipulator Under Human Control
CODE NUMBER: 15.2 DATE: 6/30/82 NAME(S): Spofford/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Because this manipulator is operated by a human, it take a longer time to complete this task than a Onboard Deployment/Retraction Actuator does. In addition it must be transported to the deployment site.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Little maintenance should be required. Should be about the same as most space equipment (Carl Ruoff, JPL). Compared to current technology, however, this capability will require more maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This includes the cost of end-effector development. A dextrous manipulator will cost more to develop than the current technology actuator.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include operator life support and salary. The current cost is $100K per human per day in space (Stephen B. Hall of NASA MSFC). Current technology is cheaper because it does not require as much operator time as the manipulator option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: One benefit of having a human-operated manipulator is the reduced chance of failure. The operator can adapt to situations that automated systems are not programmed to handle. For this simple task, however, current technology is more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This capability can be applied to other functional elements in addition to this deployment element. However, for this simple task almost all the options have comparable useful lives.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: A multi-purpose dextrous manipulator can replace many special-purpose manipulators and perform many other tasks requiring versatility (Minsky). The dexterity of this option is probably not as useful for this task as for others. The current technology for this functional element is an Onboard Deployment/Retraction Actuator.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Teleoperator Maneuvering System With Manipulator Kit
CODE NUMBER: 15.3 DATE: 6/30/82 NAME(S): Spofford/Paige
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g177 Release Solar Array Restraints

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Because this manipulator is operated by a human, it take a longer time to complete this task than a Onboard Deployment/Retraction Actuator does. In addition it must transport itself to the deployment site.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Compared to current technology, TMS needs more.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The TMS cost is not included here; it is assumed that this device is already developed and ready for use. Only the TMS manipulator kit is covered in this cost.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The recurring cost of this capability includes the operating cost of the TMS and the operator's salary. Current technology is cheaper in this case.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The possibility of collision is a factor in the failure-proneness of the TMS with manipulator kit. With a human-operated manipulator the chance of failure is reduced because the operator can adjust to situations that automated systems are not programmed to handle. For this very simple task, however, current technology is more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Almost all the options have comparable useful lives for this simple task. The flexibility of a TMS isn't really needed here; however its free-flight ability may prove useful if an Onboard Deployment/Retraction Actuator fails.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Since the TMS is assumed to be already available, the only development risk is that of the manipulator kit itself. There is currently no manipulator that can be called dextrous.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this functional element is an Onboard Deployment/Retraction Actuator. The TMS With Manipulator Kit is very versatile due to its free-flight and self-transport ability, but this flexibility is probably less useful in this application than in others.

DECISION CRITERIA COMPARISON CHART

GFE: g50 COMMUNICATIONS SUBSYSTEM CHECKOUT

GFE TYPE: D. Data Handling and Communication

On-orbit check of the proper function of spacecraft communications equipment. Usually done shortly after launch, this task may be repeated later, after spacecraft repairs or modifications. It can include communication with the Orbiter or with the ground. This task also covers the verification of the communications system at KSC, prior to launch, since this usually includes an all-up simulated test.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	5	4	4	2	3	2	
27.1 EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	2	3	3	2	3	1	2	
27.2 EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	4	4	3	4	2	2	2	
27.3 EQUIPMENT FUNCTION TEST VIA TELEMETRY	3	3	2	3	3	3	1	C.T

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g50 Communications Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The thoroughness of the communications subsystem checkout is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/28/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g50 Communications Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete will be less than current technology because of the lack of transmission delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although this system will not require maintenance as often as current technology, when this system does require it, the maintenance needed will tend to be more expensive than the maintenance required by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Cost of developing the necessary software and adapting the computer to the specific spacecraft. The nonrecurring cost could be reduced somewhat by designing modular computers that could be easily modified for various spacecraft.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because there is no need for human interaction nobody has to monitor the telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The onboard computer receives as much information as current technology, therefore the failure-proneness will be about the same. Under certain conditions, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The fully autonomous nature of this system gives it a more favorable useful life rating than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risks include the development of the software in adherance to the spacecraft safety codes.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g50 Communications Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The human will take a little longer than telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: A human in space requires considerable maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The human in the loop will be able to find problems more reliably than current technology. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The higher reliability is why this system has a longer useful life than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The risk includes the development of the dedicated microcomputer and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Equipment Function Test via Telemetry. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g50 Communications Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time to complete includes the time delay associated with communicating between earth orbit and the ground. Until TDRSS, this capability may not be available at all times, because of the loss of transmission.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The communications net must be maintained.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The nonrecurring cost includes outfitting the spacecraft with the necessary equipment as well as designing the equipment function test itself.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring cost includes the maintenance cost of the communications links and the operator upkeep.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The reliability of this capability is dependent on the sophistication of the function test, and on how much information it sends back. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The need for human interaction will make this capability give way to automatic systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risk includes the designing of the necessary equipment into the spacecraft and developing a function test.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology.

DECISION CRITERIA COMPARISON CHART

GFE: g78 DATA/COMMAND ENCODING

GFE TYPE: D. Data Handling and Communication

The conversion of data or commands from raw form to a digital bit stream suitable for transmission to or from the spacecraft. This task may involve different equipment for transmission from ground to spacecraft than vice-versa.

4E.207

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
19.1 ANALOG/DIGITAL CONVERTER	3	3	2	3	3	3	1	C.T.
25.1 ONBOARD DEDICATED MICROPROCESSOR	4	3	2	3	2	1	2	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	4	3	3	3	2	1	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	5	2	2	3	2	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Analog/Digital Converter
CODE NUMBER: 19.1 DATE: 6/3/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g78 Data/Command Encoding

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Solid-state electronics does not require much maintenance. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This has already been developed and is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This will always be used to convert analog data to digital form. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g78 Data/Command Encoding

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Slower than current technology because the microprocessor manipulates the data.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Comparable to current technology because both are integrated circuits.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to current technology. Analog/Digital converters are specialized to their application; the microprocessor is a general-purpose device.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: More reliable than current technology. May incorporate error checking and redundant codes.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The microprocessor can encode data and commands in many formats, and may be reprogrammed as needed.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Space-rated software development.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is an Analog/Digital Converter.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g78 Data/Command Encoding

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slow relative to high speeds of A/D converters.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The occasional software and hardware maintenance of such systems is minimal, comparable to the hardware maintenance of A/D converters.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Comparable to the cost of space-rating an A/D converter.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring costs should be low, essentially the cost of maintaining the hardware and software of the system, comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The probability of system failure once it is fully operational is very small, and the software can recover from some failures.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This is an inherently versatile method, which can be implemented on any spacecraft with a computer.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is an A/D converter.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g78 Data/Command Encoding

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This computational function is slower than the hardwired A/D converter.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Once debugged, the software is less likely to need repair than the A/D converter; it is also easier to upgrade software.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a simple program, comparable in R&D cost to the current technology option.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The low maintenance and occasional human supervision of this option should have costs comparable to the occasional repair and upgrading of A/D converters.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The software is slightly more reliable, in that it can check the bit-stream as it produces it.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The higher reliability and easier upgrading of this option make it ultimately preferable to the dedicated current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Slightly more complex to develop than the established current technology, if the program checks its bit-stream output.

OTHER REMARKS AND SPECIAL ASPECTS: This capability only applies to the uplink part of this GFE, i.e. the encoding of data and commands being transmitted from ground to spacecraft. The current technology for this GFE is an Analog/Digital Converter.

DECISION CRITERIA COMPARISON CHART

GFE: g79 DATA/COMMAND TRANSMISSION

GFE TYPE: D. Data Handling and Communication

The process of transmitting a bit stream to or from the spacecraft. The study focuses on the alternative transmission links, rather than the specific transmission hardware.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
17.1 TRACKING AND DATA RELAY SATELLITE SYSTEM	3	2	3	1	2	1	2	
17.2 DIRECT TRANSMISSION TO/FROM GROUND	3	3	2	3	3	3	1	C.T.
17.3 DIRECT TRANSMISSION TO/FROM ORBITER	2	3	2	3	3	3	1	
17.4 DIRECT COMMUNICATION TO/FROM ORBITER VIA CABLE	2	3	1	2	1	4	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Tracking and Data Relay Satellite System
CODE NUMBER: 17.1 DATE: 6/15/82 NAME(S): Jones-Oliveira/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g79 Data/Command Transmission

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Relative to the other capabilities for this GFE, the time delays imposed by the increased transmission distances rate TDRSS on par with current technology, Direct Transmission To/From Ground.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: TDRSS is at an advantage in that it necessitates fewer ground stations.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: TDRSS is nearing the completion of the R&D phase, and a January 1983 first launch is planned.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Once operational, TDRSS will require little in the form of recurring costs.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Of the microwave options, TDRSS is the least failure-prone.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: Because of its systems characteristics described in the description of the capability, TDRSS will be applicable to many operations for years to come. Should there be an increase in demand beyond the capabilities of the three proposed satellites, the demand may be met with the inclusion of additional satellites into the system.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: As the system is not yet at Level 7, it was rated a 2, relative to the other options which are operational.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Direct Transmission To/From Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Transmission To/From Ground
CODE NUMBER: 17.2 DATE: 6/30/82 NAME(S): Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g79 Data/Command Transmission

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is the communication mode in use today. It is slower than communicating directly with the orbiter due to ground station viewing requirements. (This assumes that the orbiter is in an orbit similar to that of the spacecraft it wishes to communicate with so the orbiter is in constant view of the spacecraft).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This method is reliable when the spacecraft is in view of a ground station. It requires less maintenance than TDRSS because TDRSS has fewer ground stations. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This system is in use today and requires no new technology or communications system design. TDRSS uses advanced data transmission modes which require more advanced onboard communications systems. These communications systems are still being designed and upgraded to take advantage of TDRSS, so they have higher nonrecurring costs than direct transmission to the ground.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring costs of this method are higher than the highly automated TDRSS because of the high cost of operating multiple ground stations. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Due to ground station availability this system is unavailable at certain times, giving it a higher failure-proneness than TDRSS. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: TDRS will make this current technology obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: No development necessary, this is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This is current technology for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Transmission To/From Orbiter
CODE NUMBER: 17.3 DATE: 7/3/82 NAME(S): Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g79 Data/Command Transmission

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Communicating directly with the orbiter is the fastest way to transfer information from a spacecraft to a manned control station (either in orbit or on the ground). This is because of the inherent delays in TDRSS and because transmission to the ground is dependent on ground station availability.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The direct transmission to the orbiter will usually require significant human involvement. Human support in space requires substantial maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This technology, using either radio or the Ku band communication/radar link, requires little development. The cost of the first unit will be much less than the cost of the first TDRSS unit.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Since humans will usually be directly involved in the link the recurring cost of this capability is comparable to that of Direct Transmission To/From Ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A system designed to communicate only with the orbiter is dependent on the orbiter for communications. If it has tracking difficulties or the orbiter communication system fails the spacecraft could be left without communications.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Most spacecraft operations will be switched over to TDRSS or other systems, or the spacecraft will be autonomous and not need to receive data/commands from the orbiter or ground. Although the orbiter will always have such a system for docking, EVA, etc., it will not be a primary option for satellite test or control.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The ability of spacecraft to communicate with each other is already proven. The orbiter has the necessary hardware available for this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Direct Transmission To/From Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Communication To/From Orbiter Via Cable
CODE NUMBER: 17.4 DATE: 6/24/82 NAME(S): Marra/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g79 Data/Command Transmission

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete is short due to the close proximity necessary for this system to be practical. This does not include the time necessary to connect the cable.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This should be comparable to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This is a very simple system and should have a low nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Although this system requires maintenance, the maintenance required is very simple.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: This is a very reliable system.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This system has limited usefulness due to the constraints on distance it imposes.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Communications cables have been used in space before.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Direct Communication To/From Ground.

DECISION CRITERIA COMPARISON CHART

GFE: g89 SHORT-TERM MEMORY STORAGE

GFE TYPE: D. Data Handling and Communication

Storage of data or commands on board the spacecraft, prior to data manipulation, command execution, or transmission from the spacecraft. This storage is expected to be repeatedly erased and refilled with other data during nominal spacecraft operations.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
18.2 RANDOM ACCESS MEMORY	3	3	2	3	3	3	1	C.T.
18.3 MAGNETIC TAPE	5	5	2	4	5	5	1	
18.4 MAGNETIC BUBBLE MEMORY	4	3	3	2	4	3	2	
18.5 MAGNETIC DISC MEMORY	4	4	4	2	4	4	3	
18.7 ERASABLE OPTICAL DISC	4	4	5	1	3	4	4	
18.8 HOLOGRAPHIC STORAGE	4	4	5	1	2	4	5	
18.11 CRYOELECTRONIC MEMORY	1	4	5	2	4	1	5	
18.12 ELECTRON BEAM MEMORY	3	4	5	4	4	5	4	
18.13 CHARGE-COUPLED DEVICE MEMORY	4	3	3	2	3	3	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Random Access Memory
CODE NUMBER: 18.2 DATE: 6/12/82 NAME(S): Spofford/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This characterizes the access time required to read from or write to the memory device. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The newer, high-density memory devices have not been space-rated yet. These will require more effort to radiation-harden because the size of features (such as connections or transistors) on the integrated circuit are much smaller than on older chips. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is defined as the cost per bit of data stored. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Improved radiation-hardening and/or shielding will reduce the failure-proneness of integrated circuits used on-orbit. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Random Access Memory will have a long useful life for this functional element, due to its versatility. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risk to space-rate the newer random access memory devices will be higher than for the current technology random access memories.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Magnetic Tape
CODE NUMBER: 18.3 DATE: 6/4/82 NAME(S): Thiel/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Tape drives are slow and are serial access only.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Although space rated units are common they are inherently less reliable than modern solid state systems.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The nonrecurring costs are due to new or modified design costs necessary to meet a specific mission need, comparable to the costs of space-rated random-access memory.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Tape units are comparatively expensive to procure, and expensive to use for short-term memory because of their long access time and high power consumption during operation.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The mechanical parts, including the tape, are reliable when used for long term storage, but the nearly continuous operation required for short term storage will induce high failure rates.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Tape units, except for long term high density storage, are virtually obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Magnetic tape is a fully developed technology and has been used on spacecraft for several years.

OTHER REMARKS AND SPECIAL ASPECTS: In general tape units are poor choices for short term memory due to their long access time. The current technology for performing this functional element is Random Access Memory.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Magnetic Bubble Memory
CODE NUMBER: 18.4 DATE: 6/4/82 NAME(S): Spofford/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: These memory devices store data in serial loops. While the data transfer rate is fairly fast (about 1 Mhz), it is not as fast as the current technology option, Random Access Memory. In addition a bubble memory must locate a given piece of data within the loop.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is a solid-state device and has no moving parts, the same as current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: More development is needed to space-rate these than current technology random access memories.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This is defined as the cost per bit of data stored, relative to current technology. Bubble memory requires less power per bit than random access memory.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: These may be harder to protect against radiation than random access memories using transistors.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: While this memory is organized in serial loops, it does not require power to retain its contents. Overall, it is judged comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: These devices must be space-rated.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Random Access Memory.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Magnetic Disk Memory
CODE NUMBER: 18.5 DATE: 6/4/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This capability is slow because of the read/write head access time and the time for the disk platter to rotate into position. This capability is not useful where data must be written and read non-sequentially and fast.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: If the disk mechanism fails the device will be unusable and data recovery may be impossible. Current technology has no moving parts and is therefore more reliable.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: These have been developed commercially, but not for space use. Compared to random access memories, much development is necessary.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This is defined as the cost per bit of data stored, relative to current technology. Electromechanical component cost will be large when compared to solid state memory units.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Because these memory units have rotating parts, they are more likely to fail than current technology solid-state devices.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Since it is not possible to read and write randomly with magnetic disks, without access delays, they do not have as long a useful life as random access memories for this GFE.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: These have been developed commercially, but not for space use.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Random Access Memory.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Erasable Optical Disc
CODE NUMBER: 18.7 DATE: 6/28/82 NAME(S): Marra/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Erasable optical discs will operate on the same order of magnitude as magnetic discs, however not as fast as current technology. For this functional element, time to complete is the access time.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Erasable Optical Discs will require a little more maintenance than current technology, which requires none.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Research still needs to be done on storage mediums for the erasable optical disc, along with development of laser systems.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The recurring cost is cost per byte. The erasable optical disc should be capable of holding 10-50 gigabytes of information, thus making the cost per byte very low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The optical disc will be at least as reliable as the magnetic disc. The large capacity makes redundant memory storage possible.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This is a very promising system. However, current technology will probably remain useful for quite some time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The erasability of the optical disc still needs a considerable amount of research.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Random Access Memory.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Holographic Storage
CODE NUMBER: 18.8 DATE: Jul 1982 NAME(S): Howard/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: For the hypothesized fiche-based system, random-access time is shorter than for magnetic tape, but longer than the solid-state memories.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: There are some moving parts which may require maintenance, and power consumption is much higher than the solid-state alternatives when reading or writing (idle power is zero).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Significant research must be done to find a suitable storage medium, which can be write-read-erase cycled reliably a large number of times. This is important for short-term storage.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: On a cost-per-bit-stored basis, the holographic storage method is inexpensive for a large memory.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Optical memories are not as vulnerable to damage from the radiation environment in space as semiconductor devices.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Advances in semiconductor memory will probably surpass the holographic system in performance and cost. Optical systems may still be less vulnerable to radiation, however.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: A suitable storage medium must be found, which can be write-read-erase cycled reliably a large number of times. This is most important for short-term storage.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Random-Access Memory.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Cryoelectronic Memory
CODE NUMBER: 18.11   DATE: 6/24/82   NAME(S): Kurtzman/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Information can be stored or retrieved faster than any other computer memory system yet built.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Mechanical designs will allow for the replacement of the machine to facilitate engineering changes or to repair faulty parts.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.= 2): 5
REMARKS AND DATA SOURCES: The cost to develop this capability is estimated to be higher than the nonrecurring cost for any of the other option which fulfill this functional element.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring cost represents cost per bit. Due to the large bit density achievable the recurring cost is lower than current technology. Included in the cost per bit is the operational costs. The cost of the helium refrigeration is comparable to the cost of the much larger power supply and cooling system that are required by a semiconductor computer.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The computer is not liable to make errors in normal operation, but a disruption of cooling would cause large thermal stresses which could result in extensive damage.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The low temperatures at which this system operates virtually stop corrosion. Josephson computers could potentially replace semiconductor computers in most applications due to their speed.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: All the technologies necessary for the development of the Josephson computer are available. However, it is still not clear how to assemble these technologies and whether or not the system will actually work (disscussion with Dennis Herrel, IBM).

OTHER REMARKS AND SPECIAL ASPECTS: There are many computational tasks in which speed of present computers is a limiting factor, such as long-range weather prediction. Development of a high speed Josephson computer could make more practial the performance of tasks which stretch the limits of today's computers, as well as make conventional computations less expensive. The Josephson computer has a very small power dissipation which results in higher efficiency. (IBM Journal of Research and Development, Vol 24, Num 2, March 1980; Scientific American, "The Super-Conducting Computer", Juri Matisoo, May 1980). The current technology for this task is Random Access Memory.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Electron Beam Memory
CODE NUMBER: 18.12 DATE: 6/15/82 NAME(S): Jones-Oliveira/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This capability has a read/write rate of 4 megahertz which is analogous to current technology, Random Access Memory (RAM).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Although the system is fault tolerant, 95% duty cycle is not adequate for these types of applications.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: There are significant advancements which must be made prior to space rating.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The recurring costs are relatively high because the relacement cost is high and large quantities of power are necessary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Even with the fault tolerant capability, this capablility is more failure-prone than RAM (current technology).

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: This capability will most likely be technically obsolete before it becomes space rated.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: Although this capability has been shelved, because 500 people-years of work have already been invested, it rates a lower developmental risk than the more advanced Holographic Storage and Cryoelectronic Memory.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Random Access Memory.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Charge-Coupled Device Memory
CODE NUMBER: 18.13 DATE: 7/9/82 NAME(S): Kurtzman/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g89 Short-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Charge-Coupled Device (CCD) Memory will operate with an average access time of on the order of .1 milliseconds compared to Random Access Memory (RAM) with an access time of the order of .1 microseconds (see David A. Hodges, "Microelectronic Memories," Scientific American, Volume 233, Number 9, September 1977).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Solid-state charge-coupled arrays eliminate all mechanical motion and parts. Like RAM but unlike a Magnetic Bubble Memory, CCD Memories must be continuously regenerated, and information is therefore lost if power is disrupted (ibid.). Power necessary to sustain a charge-coupled memory device is very low since the storage element is not active. A one-megahertz (rate at which bits are shifted from one storage site to the next), one megabit CCD Memory would require a power of somewhere between a milliwatt and a watt to sustain it, excluding logic and other functions. The volume required for such a memory is less that that of a pack of cigarettes (see Gilbert F. Amelio, "Charge-Coupled Devices," Scientific American, Volume 230, Number 2, February 1974).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: CCD memories must be adapted for space use.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: CCD Memories can be designed to have a smaller total area per bit than RAM, and the total silicon area per bit for complete memory components is about a factor of two to three smaller for a CCD Memory than it is for a RAM. This results in lower memory costs (at a penalty of a longer access time). Cost for a CCD Memory was estimated at approximately .01 cents/bit in 1977 and it is estimated that costs will drop to around .001 cents/bit by 1987. Costs for the more expensive RAM were estimated at .1 cents per bit in 1977 with a similar improvement in cost expected (see David A. Hodges, "Microelectronic Memories").

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Radiation damage-proneness should be comparable to the current technology RAM.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: CCD Memories must be space-rated. In other applications, such as imaging sensors, CCDs have already been used in space.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability is Random Access Memory.

DECISION CRITERIA COMPARISON CHART

GFE: g90 LONG-TERM MEMORY STORAGE

GFE TYPE: D. Data Handling and Communication

The storage of data or canned command procedures, on the spacecraft, or, in some cases, on the ground. This storage is expected to be either never altered, or altered by hardware exchange (e.g. module replacement during spacecraft modification), or altered through an occasional procedure involving release of protection systems.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
18.3 MAGNETIC TAPE	3	3	2	3	3	3	1	C.T.
18.4 MAGNETIC BUBBLE MEMORY	1	1	4	1	3	2	3	
18.5 MAGNETIC DISC MEMORY	2	2	3	2	2	3	[illegible]	
18.6 OPTICAL DISC	2	2	3	1	2	2	3	
18.7 ERASABLE OPTICAL DISC	2	2	4	1	2	2	4	
18.8 HOLOGRAPHIC STORAGE	2	2	4	1	2	1	3	
18.9 MICROFORM ON GROUND	5	1	1	2	1	2	1	
18.10 ELECTRICALLY ALTERABLE READ ONLY MEMORY	1	1	2	2	2	4	2	
18.12 ELECTRON BEAM MEMORY	1	2	5	4	3	5	4	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Magnetic Tape
CODE NUMBER: 18.3 DATE: 6/3/82 NAME(S): Thiel/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Many other types of memory technology are faster, but speed may not be essential for this application. Also, tape memories are slow at locating specific pieces of information, but are fast at reading or writing large amount of serial data. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Tape units require significant amounts of maintenance during operation, but require none when data is not being stored or retrieved. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Since tape units are the current technology for long term storage, R&D costs are virtually nonexistant. The nonrecurring costs are due to new or modified design costs necessary to meet a specific mission need.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Tape drives and tape are expensive and consume large quantities of power during read/write operations, but storage costs are relatively inexpensive. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The mechanical parts, including the tape, are reliable when used for long term storage. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Tape will continue to be used until disk recorders and optical methods are ready to replace it.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is already developed.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology. When not performing read/write operations tape units require no power or maintenance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Magnetic Bubble Memory
CODE NUMBER: 18.4 DATE: 6/4/82 NAME(S): Spofford/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: These memory devices store data in serial loops. The data transfer rate is about as fast as the current technology option (Magnetic Tape), but the bubble memory can locate a given piece of data much faster.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: This is a solid-state device and has no moving parts. Current technology has many electromechanical components and requires much more maintenance than bubble memories.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Current technology tape recorders are already space-rated and do not require as much development as bubble memories.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: This is defined as the cost per bit of data stored, relative to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The probability of bubble memory failure due to cosmic rays was judged comparable to the failure probability of current tape recorders, when compared to the other options.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: These solid-state memories will last longer than memory units with moving parts, especially when the memory is used frequently.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: These devices must be space-rated.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Magnetic Tape.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Magnetic Disk Memory
CODE NUMBER: 18.5 DATE: 6/4/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Magnetic disks transfer data at rates comparable to current technology magnetic tapes. They are faster at accessing a given piece of data because they acess data in blocks, rather than serially.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: If the disk mechanism fails the device will be unusable and data recovery may be impossible. This is still expected to be more reliable than current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: These have been developed commercially, but not for space use.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This is defined as the cost per bit of data stored, relative to current technology. These devices can store as much as current technology tape drives, and require less maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Magnetic disks are expected to be more reliable than current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This is comparable to current technology because both rely on mechanical systems to access data.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: These have been developed commercially, but not for space use.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Magnetic Tape.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Optical Disc
CODE NUMBER: 18.6 DATE: 6/28/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Time to complete this functional element is access time. The access time for optical discs should be on the order of 22-100 ms, which is slower than electronic storage methods, but better than the mechanical storage methods.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Optical discs will need less maintenance than current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The system still needs to be perfected so the nonrecurring cost includes the research left to be done.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: For this functional element, recurring cost is cost per byte. Optical discs will be able to hold 10 to 50 gigabytes, making it very cost effective per byte.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Optical discs will be at least as reliable as magnetic discs, probably slightly better.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The incredibly large storage capacity along with its fast access time gives this system a very long useful life. Optical discs are predicted to make magnetic discs and magnetic tape obsolete (discussion with Martin Marshall, former editor of Computers and Instruments of "Electronics" magazine).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: Research still needs to be done on improving the access time. Developments in laser technology are also needed.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Magnetic Tape.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Erasable Optical Disc
CODE NUMBER: 18.7 DATE: 6/28/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Erasable optical discs will operate on the same order of magnitude as magnetic discs. For this functional element, time to complete is the access time.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Optical discs will need less maintenance than current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Research still needs to be done on storage media for the erasable optical disc, along with development of laser systems.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The recurring cost is cost per byte. The erasable optical disc should be capable of holding 10-50 gigabytes of information, thus making the cost per byte very low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The optical disc will be at least as reliable as the magnetic disc. The large capacity makes redundant memory storage possible.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The incredibly large storage capacity along with its fast access time gives this system a very long useful life. Optical discs are predicted to make magnetic discs and magnetic tape obsolete (discussion with Martin Marshall, former editor of Computers and Instruments of "Electronics" magazine).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The erasablility of the optical disc still needs to be worked on.

OTHER REMARKS AND SPECIAL ASPECTS: Erasability may not be a necessity for this GFE. Current Technology is Magnetic Tape.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Holographic Storage
CODE NUMBER: 18.8 DATE: June 1982 NAME(S): Howard/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: For the hypothesized fiche-based system, random-access time is shorter than for magnetic tape, but longer than the solid-state memories.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: There are fewer moving parts than magnetic tape units, and lower power consumption.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Significant research must be done to find a suitable storage medium which can be reliably recycled.

RECURRING COST (1 LOW, 5 HIGH):
REMARKS AND DATA SOURCES: On a cost-per-bit-stored basis, the holographic storage method is inexpensive for a large memory.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Optical memories are not as vulnerable to damage from the radiation environment in space as semiconductor devices.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: For long-term storage, this system is relatively good. Data is maintained with no power consumption and very little degradation for long periods of time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developments needed are in the areas of lasers and storage media. The requirements on the storage medium are less critical for long-term storage than for short-term (less recycling needed).

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Magnetic Tape.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Microform on Ground
CODE NUMBER: 18.9 DATE: 6/22/82 NAME(S): Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Time to complete represents the time it takes to access the data. For Microform on Ground it is a matter of minutes, while for current technology it is a matter of seconds.

MAINTENANCE (1 LITTLE 5 'OTS): 1
REMARKS AND DATA SOURCES: Aside from moderate climate control, microform requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Microform has already been developed, therefore the nonrecurring cost will be low.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring cost represents cost per byte. Microform is very inexpensive to maintain.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Once properly recorded, there is little chance of losing the data, save by fire or similar catastrophe.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Due to Microform's durability, it will last longer than current technology. However, the more advanced electronic storage methods will make microform obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Currently used.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Magnetic Tape.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Electrically Alterable Read Only Memory
CODE NUMBER: 18.10 DATE: 6/7/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This capability is comparable to current technology in its data read rate, but is capable of random access. Writing takes longer than reading. This was given a low number because of its fast random access ability.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: This solid-state memory unit requires much less maintenance than current technology (Magnetic Tape).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Compared to the other capabilities for this GFE, this option has essentially the same development cost as current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This is defined as the cost per bit of data stored, relative to current technology. This is less than current technology because very little maintenance is required.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The probability of failure from radiation is less than the failure-proneness of current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: These memories are not useful where large quantities of data must be stored and updated. They are better suited to applications on the order of kilobytes where the data is rewritten infrequently.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: These memories have not been space-rated yet. This is not expected to be any more dificult than other integrated circuit memories.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Magnetic Tape.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Electron Beam Memory
CODE NUMBER: 18.12 DATE: 6/15/82 NAME(S): Jones-Oliveira/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g90 Long-Term Memory Storage

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This capability has a read/write rate of 4 megahertz which is significantly faster than current technology, Magnetic Tape.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Relative to current technology, its fault tolerant capability lowers maintenance, even with a 95% duty cycle.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: There are significant advancements which must be made prior to space rating.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The recurring costs are relatively high because the replacement cost is high and large quantities of power are necessary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability has a failure-proneness analogous to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: This capability will most likely be technically obsolete before it becomes space rated.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: Although this capability has been shelved, because 500 people-years of work have already been invested, it is on par with Erasable Optical Disc.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Magnetic Tape.

DECISION CRITERIA COMPARISON CHART

GFE: g109 DATA/COMMAND DISPLAY

GFE TYPE: D. Data Handling and Communication

The display of data or commands to humans, either in space or on the ground. This might include state-of-health data on components, task scheduling commands and status information, scientific and operational data, output from computer calculations and evaluations.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
13.2 HUMAN EYESIGHT VIA GRAPHIC DISPLAY	3	3	2	3	3	3	1	C.T.
13.4 COMPUTER PRINTOUT	4	3	2	3	3	5	1	
13.5 COMPUTER-GENERATED AUDIO	4	2	2	1	4	2	1	
13.6 STEREOPTIC VIDEO	2	4	3	4	3	3	2	
13.7 3-D DISPLAY	2	5	5	4	4	2	3	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Graphics Display
CODE NUMBER: 13.2 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g109 Data/Command Display

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The limiting factor is human recognition time of the important information. In this format the information can be presented more conveniently than in a printout, for instance. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance cost is related only to equipment complexity in this case. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes the cost of developing the display software. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The cost here is that of the display equipment. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: There is the possibility of false interpretation of ambiguous data. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: With more efficient display algorithms and useful display formats, the useful life should be long. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Printout
CODE NUMBER: 13.4 DATE: 6/24/82 NAMES: Kurtzman/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g109 Data/Command Display

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: It is usually slower to read data as it comes from a printer than from a graphic display.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance includes the upkeep of the computer printer as well as maintaining a paper supply.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The computer printout, like the graphic display, is a currently available option for performing this functional element, and requires no research and development.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This includes the cost of the paper and the computer printer. The cost of printers and graphic displays are comparable. If the printer is in space, instead of on the ground, the costs of paper supply and transportation will be much larger, and this capability will then receive a 5 in recurring costs.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This includes the possibility of printer breakdowns and typographical errors, as well as the possibility of the printer being unable to properly convey information to the user due to limitations inherent in printed output.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: The problems of paper supply, storage, and disposal in space (and to a lesser degree on the ground) make a computer printout an unattractive option for most uses, and hence it will only be used in circumstances where hard copies are a necessity.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is a currently used method of performing this functional element.

OTHER REMARKS AND SPECIAL ASPECTS: It is not possible to use this capability in EVA as can be done with a graphic (heads up) display or computer-generated audio. The current technology capability for this functional element is Human Eyesight Via Graphic Display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer-Generated Audio
CODE NUMBER: 13.5 DATE: June 1982 NAME(S): Howard/Kurtzman
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g109 Data/Command Display

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The human rate of assimilating audio data is less than that of visual data. In some instances, however, the human's eyesight may be otherwise occupied.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The equipment involved is simpler than that of visual systems.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Equipment currently exists which is capable of performing this task.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Implementation of this capability would be inexpensive compared to the visual display systems.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Failure-proneness here is mostly due to the narrow range of applications this type of display is suited for. In the proper environment, however, it is quite reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Some applications may always exist, and in most cases this method is cheaper to implement than the alternatives. The more advanced versions with speech synthesis will be very useful indefinitely for transferring information without requiring a specific action (such as looking at a visual display).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The technology for this capability is in existence.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human Eyesight via Graphics Display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Stereoptic Video
CODE NUMBER: 13.6 DATE: 4/13/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g109 Data/Command Display

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Information which can be presented as spatial relationships can be assimilated rapidly from a stereo display.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The equipment involved is more complex than a conventional graphic display.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The development of software and hardware to generate stereoptic displays is more complex than for the current two dimensional displays.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: More costly due to increased equipment complexity and maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The failure-proneness of this system is no worse than current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This particular system for generating the three-dimensional effect will be superseded in time by systems with fewer limitations. For some applications three-dimensional displays will perform better than two-dimensional displays.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The application to a given task must be developed, and the physical constraints of a particular problem may make this technology unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Human Eyesight Via Graphic Display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: 3-D Display
CODE NUMBER: 13.7 DATE: 6/30/82 NAME(S): Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g109 Data/Command Display

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This technology can display the same information at the same speed as 2-D displays, but more advanced information (3-D) is displayed in a manner superior to 2-D displays and can be understood faster by a human operator.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: High speed rotating parts with large bandwidth transmission across rotating interfaces reduces reliability.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.= 2): 5
REMARKS AND DATA SOURCES: The units still require extensive software and LED planar array development.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Each unit has high speed rotating parts and data interfaces plus significant computation tasks which require sophisticated hardware.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Graphical and pictorial display are superior to conventional systems and are more likely to be interpreted properly, but the hardware is less reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life should be fairly long. Alternative approaches are either significantly different (stereo-optic video) or many years away (holographic projection).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: An operational prototype exists at the MIT Innovation Center.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Human Eyesight via Graphic Display.

DECISION CRITERIA COMPARISON CHART

GFE: g218 TAKE DATA FROM DETECTOR

GFE TYPE: D. Data Handling and Communication

The acceptance of data from an AXAF detector by the spacecraft, prior to any data processing or transmission from the spacecraft. More generally, the taking of data from any scientific instrument. This data can be either recorded as generated, or coded in a more useful format. [For low-level data processing, see g224 Process Image Data; for data transmission, see g79 Data/Command Transmission; for data storage, see g89 Short-Term Memory Storage or g90 Long-Term Memory Storage; for high-level data processing, see g92 Numerical Computation or g93 Logic Operations (both in F. Computation).]

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
18.1 ONBOARD DATA RECORDER	3	3	2	3	3	3	1	C.T.
25.1 ONBOARD DEDICATED MICROPROCESSOR	2	2	2	2	2	2	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	2	1	3	3	1	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	2	3	2	2	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Data Recorder
CODE NUMBER: 18.1 DATE: 6/3/82 NAME(S): Thiel/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g218 Take Data From Detector

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Although tape units do not have random access capability and are therefore very slow for most memory uses, they do have a fast read/write capability for serial data. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Tape units require significant amounts of maintenance during operation, but require none when data is not being stored or retrieved. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Since tape units are the current technology for long term storage, R&D costs are virtually nonexistant. The nonrecurring costs are due to new or modified design costs necessary to meet a specific mission need. Most uses for data recorders on a spacecraft will be be to record serial data and play it back at a later time. Although the time interval may be short this is equivalent to long-term storage. It should be noted that, for space use, higher information density, lighter weight tape units are desirable. Efforts to develope such units will contribute to the nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Tape drives and tape are expensive and consume large quantities of power during read/write operations, but storage costs are relatively inexpensive. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The mechanical parts, including the tape, are reliable when used for long term storage, but the nearly continuous operation required for short term storage will induce high failure rates. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Tape will continue to be used until disk recorders and optical methods are ready to replace it.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is already developed.

OTHER REMARKS AND SPECIAL ASPECTS: This option is current technology for this GFE. Data Recorder is defined to be a magnetic tape recorder. For other future options for onboard data storage, the reader is referred to GFE's g89 Short-Term Memory Storage and g90 Long-Term Memory Storage (in D. Data Handling and Communication).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g218 Take Data From Detector

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: A dedicated microprocessor can accept data from a detector very fast.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Microprocessors require less hardware maintenance than a data recorder.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Very close to current technology; all that is needed is software development.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Onboard data recorders are expensive to purchase and maintain. The cost of microprocessors will be comparatively low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Microprocessors are more reliable than current technology data recorders as they are solid-state devices and have no moving parts. This rating assumes that the data quantity and rate are within the abilities of the microprocessor.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of dedicated microprocessors are longer than data recorders because they use less power and do not cause vibration. Eventually they will be replaced by microprocessor hierarchies.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Current technology has no software development.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functio element is an Onboard Data Recorder.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g218 Take Data From Detector

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged below current technology as the hierarchy's programming includes the ability to compensate for many malfunctions, thereby making unnecessary otherwise expensive maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979). For this functional element, the taking of data from a detector is the type of function which a microprocessor can easily perform, and hence this capability is only rated one level above the current technology option.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this

functional element is an Onboard Data Recorder.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g218 Take Data from Detector

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The options other than the current technology recorder can evaluate data and act on it in real time, which can be an advantage in some cases.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Maintenance is expected less often than for mechanical tape drives.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The R&D costs are higher than for existing technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs, once the system application is debugged, are minimal. The maintenance costs of this capability are less than those for the Onboard Data Recorder.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The probability of system failure is small, once the system is debugged. Data recorders are notoriously unreliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of this capability is better than the near-obsolete current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Onboard Data Recorder.

DECISION CRITERIA COMPARISON CHART

GFE: g224 PROCESS IMAGE DATA

GFE TYPE: D. Data Handling and Communication

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A low-level processing function, part of the AXAF observation sequence: the position of the Xray target is found on sensor arrays, so that the target acquisition can be confirmed and a final alignment correction to center the target in the telescope can be calculated. By extension, this includes data processing to find a known and expected pattern (without doing any pattern interpretation) in a simple image.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
13.2	HUMAN EYESIGHT VIA GRAPHIC DISPLAY	3	3	2	3	3	3	1	C.T
25.1	ONBOARD DEDICATED MICROPROCESSOR	1	5	3	2	2	1	2	
25.2	ONBOARD MICROPROCESSOR HIERARCHY	1	4	4	2	1	1	3	
25.3	ONBOARD DETERMINISTIC COMPUTER PROGRAM	1	5	3	2	2	1	2	
25.4	DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	4	2	1	2	2	1	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Graphics Display
CODE NUMBER: 13.2 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g224 Process Image Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The limiting factor is human recognition time of the important information. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance cost is related only to equipment complexity in this case. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes the cost of developing the display software (which is minimal for this task). This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The cost here is that of the display equipment. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The accuracy of a human in determining the coordinates of a signal peak visually is not as high as that obtainable with the automated alternatives. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The task is simple enough that an automated system will eventually make human involvement unnecessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g224 Process Image Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: For this simple processing task, this capability is faster than a human and does not involve a telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: This in-space capability has more expensive maintenance than current technology (on the ground), which requires little. It is also more expensive than the microprocessor hierarchy which can reconfigure itself around failures.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is comparable to the Onboard Deterministic Computer Program, and cheaper than the microprocessor hierarchy.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: There is no salary cost as with current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Machine processing is less failure-prone than a human at picking out features in an image. The microprocessor hierarchy hardware is more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The useful life of the onboard options is better than the ground options (especially current technology).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development of software and space-rating the microprocessor. This low-level processing of a simple image is within the ability of a microprocessor.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is Human Eyesight Via Graphic Display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g224 Process Image Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This will usually be much faster than the human options and slightly faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged higher than current technology as maintaining the microprocessors in space is much more difficult and costly than servicing a graphic display on the ground. However, the hierarchy has the ability to compensate for malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system, but should be more than for a graphic display.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive systems (ibid.). The current technology option for performing this functional element is Human Eyesight Via Graphic Display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g224 Process Image Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: For this simple processing task, this capability is faster than a human, and also does not involve a telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: This in-space capability has more expensive maintenance than current technology (on ground). It is also more expensive than the microprocessor hierarchy, which can reconfigure itself around failures.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Comparable to onboard microprocessors, cheaper than an onboard microprocessor hierarchy.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This does not involve the salary of the current technology human. Its in-space maintenance, however, is more expensive than that of Deterministic Computer Program on Ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Machine processing is less failure-prone than a human in picking out subtle distinctions in a simple image. However, the Onboard Microprocessor Hierarchy will be better.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The useful life of all the onboard options is better than that of the ground options (especially of current technology).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Human Eyesight with Graphic Display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g224 Process Image Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Software updates and system maintenance are expected to be slightly more complex than the maintenance of the graphic display.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to current technology. Onboard options are more expensive.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: This option does not include the salary cost of the current technology human.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The computer can make more subtle discriminations in the image data, and generates numerical information directly.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Cheaper than the human, therefore preferred. However, increasing amounts of data to be handled will eventually favor onboard processing.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Since the image to be processed is simple, this option is not overly difficult to develop, comparable to a graphic display.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for this GFE is Human Eyesight via Graphic Display.

DECISION CRITERIA COMPARISON CHART

GFE: g241 MAINTAIN COMMUNICATIONS LINKS

GFE TYPE: D. Data Handling and Communication

The process of keeping spacecraft communications links active, either to the ground or to other spacecraft. This includes ensuring adequate antenna pointing (if directional antennas are used) and sufficient communications component functions to receive incoming signals and (usually) to transmit responses. This study focuses on the evaluation of problems and the definition and command of corrective actions, rather than on the specific sensors or actuators involved.

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CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
1.6	AUTOMATIC SWITCHING SYSTEMS	3	3	2	3	3	3	1	C.T.
25.1	ONBOARD DEDICATED MICROPROCESSOR	2	3	3	2	2	2	2	
25.2	ONBOARD MICROPROCESSOR HIERARCHY	2	2	4	2	2	1	3	
25.3	ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	3	3	2	2	2	2	
26.1	FAULT TOLERANT SOFTWARE	2	1	4	2	1	1	3	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Automatic Switching Systems
CODE NUMBER: 1.6 DATE: 6/15/82 NAME(S): Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g241 Maintain Communication Links

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The automatic switching system does not identify the communications link problem and solve it as would a more sophisticated system. Instead, it cycles through a number of options until communications are restored. This process can be time consuming. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although they require virtually no maintenance, automatic switching sytems are slightly more likely to need servicing than the self-maintaining computers and control systems of future spacecraft. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and is a mature technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Other than spacecraft and antenna pointing (which is usually done by the attitude control system), maintaining communications links is a task which consists of responding to hardware failures. After a failure has occurred a programmable system can be modified to work around a failure, particularly an unanticipated failure; an automatic switching system cannot. For an intermittent operation the automatic switching system is more expensive than computer control because the automatic switching system is dedicated to this task while the computer can be assigned to other work. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The more advanced, flexible systems, such as the fault tolerant software, are less likely to make an error than the automatic switching system because they can react to unanticipated problems. The automatic switching system and the deterministic computer program can only handle foreseen problems. The deterministic program can be programmed to respond to many more problems than the hardwired automatic switching system. This is current technology

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: As spacecraft computers become more common it will be more cost effective to devote a small portion of their time to maintaining communication links than to have a dedicated hardwired system do it. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and is a mature technology.

OTHER REMARKS AND SPECIAL ASPECTS: The capability is current technology for maintaining communications links.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g241 Maintain Communication Links

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The microprocessor is faster than the current technology switching system because it can perform a trend analysis and adjust the system before the hardwired switching system's limit would trip.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The microprocessor's software is slightly easier to maintain than the hardwired automatic switching system.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The major cost for the microprocessor is the software development; higher than for the established current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Less than current technology because the microprocessor can track the communications links more smoothly, using less power, and because it is cheaper to upgrade (by reprogramming).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The microprocessor is less likely to fail because it can adjust the system based on trends, rather than set limits.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Because it is less failure-prone and more flexible, the microprocessor has a longer useful life than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Automatic Switching Systems are a standard item. The microprocessor must be integrated into the system and software developed.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is an Automatic Switching System.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g241 Maintain Communications Links

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be slightly faster than the other autonomous options. It is faster than the current technology option which tries to restore communications by trial and error methods.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged below an Automatic Switching System, the current technology option, which is costly to repair if it malfunctions. The hierarchy is relatively easy to repair and has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel). It is lower in recurring costs than the dedicated Automatic Switching System, because the hierarchy requires less maintenance and shares its costs between many spacecraft functions.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is Automatic Switching Systems.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g241 Maintain Communication Links

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The computational options can anticipate problems, from orbital and attitude parameters and component trends, and can act to prevent trouble.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The software updates and occasional hardware maintenance are comparable to the current technology's more frequent hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is a critical spacecraft function, and this software will need thorough checking, more expensive than the more mature current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is a function of general maintenance costs, but updates of software options are less expensive.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Once the systems are operational, the probability of failure is lower than current technology, as the software can more intelligently recover from problems, and can anticipate trouble.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: More versatile than current technology, less than more advanced computational options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Automatic Switching Systems.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME· Fault Tolerant Software
CODE NUMBER: 26.1 DATE: 6/30/82 NAME(S): Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g 241 Maintain Communication Links

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: May take longer to make a decision than the automatic switching system, but it will probably solve the overall problem in less time, since it does not use trial-and-error methods.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: This software system should be self-updating and self-checking, and can recover from failures.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Although present applications exist (military aircraft computers), space rated software of the type envisioned here will require significant developmental effort.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The lower maintenance requirement leads to a lower recurring cost than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Since it is self-checking and is designed specifically for failure protection and recovery the probability of a failure should be low.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This is an evolving technology which will eventually be found on most computer systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: Some limited applications exist (aircraft computers) and military development by industry and research centers (Draper Laboratories) is continuing.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Automatic Switching Systems.

DECISION CRITERIA COMPARISON CHART

GFE: g35 INITIALIZE GUIDANCE SYSTEM

GFE TYPE: E. Monitoring and Control

The initial and occasional calibration of the spacecraft guidance system, using either onboard navigation equipment (e.g. star trackers), data from other satellites (e.g. the Global Positioning System), or information from the ground. This study focuses on the data processing and evaluation, and on the calibration command generation, rather than on the specific navigation or guidance hardware.

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CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	4	3	4	3	3	1	
25.1 ONBOARD DEDICATED MICROPROCESSOR	3	3	2	3	3	3	2	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	3	3	2	3	3	3	1	C.T
25.4 DETERMINISTIC COMPUTER PROGRAM ON GR[illegible]ND	4	2	2	3	4	4	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g35 Initialize Guidance System

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The failure-proneness is equivalent to that of current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is an Onboard Deterministic Computer Program.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g35 Initialize Guidance System

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is comparable to current technology, which is also an onboard computer option.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes both hardware and software maintenance and is comparable to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is comparable to current technology, which is mostly software development. Microprocessors have already been space-rated.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is similar to current technology and includes the cost of software revisions as well as the microprocessor hardware.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Similar to current technology because onboard options are preferable to ground-based options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Software development and space-qualification of the microprocessor chip.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is the Onboard Deterministic Computer Program.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g35 Initialize Gui ance System

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Once the software is debugged the maintenance is low, involving occasional updates of software, and any needed hardware maintenance. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The initial costs include software development and reviewing it for onboard computer safety. This is current technology.

RECURRING COST (1 LOW 5 HIGH): 3
REMARKS AND DATA SOURCES: The cost of software updating and hardware maintenance constitute the recurring costs. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Once debugged, quality software is largely failure free; failure will more likely stem from hardware problems. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Long life is expected for high quality software. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g35 Initialize Guidance System

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This capability requires telemetry; the current technology option does not.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Compared to the other onsite options, this program requires less expensive maintenance, particularly when compared to the onsite human.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This technology has been used before.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The costs for system maintenance, telemetry, and occasional human supervision are comparable to the very occasional in-space maintenance of the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Compared to current technology, this option is vulnerable to communications failures.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The other onsite options, including current technology, are more reliable. Therefore they will be preferable to this option.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology has been used before.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is an Onboard Deterministic Computer Program. In general, this task is important but straightforward, and is likely to become a routine automated function.

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DECISION CRITERIA COMPARISON CHART

GFE: g47 ACTIVATE SUBSYSTEMS

GFE TYPE: E. Monitoring and Control

The timely activation of components within spacecraft subsystems, to bring equipment to the operational state. This task requires that a sequence of components be activated in the proper order, possibly with verification of spacecraft status between certain steps, to ensure the safety of hardware and software. Such components might include electronic and power systems, mechanical actuators, optical equipment, thermal components, and fluid pumps and valves. This task may become critical in contingency management during failures. Its inverse covers subsystem shutdown.

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CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	C.T.
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	
14.4 HUMAN WITH CHECKLIST	4	2	1	2	3	2	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	3	5	3	4	3	3	1	
21.1 ONBOARD SEQUENCER	1	3	1	1	4	5	1	
25.1 ONBOARD DEDICATED MICROPROCESSOR	1	4	3	2	3	2	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	1	3	4	2	2	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	1	4	3	2	3	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	3	2	3	2	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g47 Activate Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g47 Activate Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This consists mainly of personnel costs, which are low for this task. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The simplicity of the task is such that a computer will not necessarily improve failure-proneness.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This task is a simple sequence of operations which may not be repeated more than once, so a human with checklist will always be an inexpensive alternative.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g47 Activate Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The failure-proneness is equivalent to that of current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Sequencer
CODE NUMBER: 21.1 DATE: 6/9/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g47 Activate Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The Onboard Sequencer is activated by a clock or by an external trigger. It is very fast because it responds immediately to the clock or trigger.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The Onboard Sequencer is not self maintaining, but its simplicity makes it as reliable as spacecraft computers.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Onboard Sequencers have been used for several years and are a mature technology.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Due to their simplicity both in hardware and software Onboard Sequencers are relatively inexpensive. They must be reprogrammed often, but this is a simple procedure.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The system's extremely limited ability to respond to changing spacecraft conditions make it likely to fail.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Onboard computers will probably replace Onboard Sequencers in the near future.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is a fully developed technology that has been used for years.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g47 Activate Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The onboard dedicated microprocessor is faster than current technology (Human on Ground with Computer Assistance) because there are no transmission delays or human decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is more than current technology because it is harder to maintain the hardware and software on-orbit than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is more than current technology because the on-orbit software and hardware must be developed.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The microprocessor is cheap compared to current technology because there is no operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Better than current technology because the microprocessor is onboard.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development of software and implementation of microprocessor on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g47 Activate Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options (except for the automatically operating Onboard Sequencer). It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=) 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this

functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g47 Activate Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g47 Activate Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Although not complicated, this program requires careful review to guarantee spacecraft safety during operation.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Most options for this task are comparable to current technology in failure-proneness.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Such automated control programs will outdate the more expensive options involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risks are minimal, given that this is a well tested technology. This program is not complicated.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g83 ADJUST COOLING/HEATING SYSTEMS

GFE TYPE: E. Monitoring and Control

The control of spacecraft or instrument heating and cooling systems, including evaluation of operational and state-of-health data, capacity allocation and network configuration, fluid system switching and level control, mechanical actuator command (e.g. louvers, radiator pointing), and contingency management. This study concentrates on the evaluation and control functions, rather than specific thermal equipment. As spacecraft state-of-the art moves toward fully integrated power management systems, this task may be incorporated with g87 Adjust Currents and Voltages (in A. Power Handling).

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
1.6	AUTOMATIC SWITCHING SYSTEMS	3	3	2	3	3	3	1	C.T.
14.2	HUMAN ON GROUND WITH COMPUTER ASSISTANCE	4	2	2	5	2	4	1	
14.4	HUMAN WITH CHECKLIST	5	1	1	5	3	5	1	
21.1	ONBOARD SEQUENCER	3	3	2	3	4	5	1	
21.2	OPERATIONS OPTIMIZATION PROGRAM	3	2	3	3	1	1	2	
25.1	ONBOARD DEDICATED MICROPROCESSOR	3	2	3	3	2	3	2	
25.2	ONBOARD MICROPROCESSOR HIERARCHY	3	2	4	3	1	2	3	
25.3	ONBOARD DETERMINISTIC COMPUTER PROGRAM	3	2	3	3	2	2	2	
25.4	DETERMINISTIC COMPUTER PROGRAM ON GROUND	3	2	3	3	2	2	1	
25.5	ONBOARD ADAPTIVE CONTROL SYSTEM	3	1	4	3	1	1	3	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Automatic Switching Systems
CODE NUMBER: 1.6 DATE: 6/15/82 NAME(S): Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The automatic switching system responds immediately according to preset criteria. More advanced systems may take time to perform computations before adjusting a heating or cooling system, but they can also anticipate problems, which this capability cannot.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although they require virtually no maintenance, automatic switching sytems are slightly more likely to need servicing than the self-maintaining computers and control systems of future spacecraft.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and are a mature current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is a task which consists of responding to changing environmental conditions. Since this task must be done continuously an automatic switching system, such as a thermostat, is one of the least expensive ways to perform the task. More complex environmental conditions and control requirements will necessitate computer control. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The more advanced, flexible systems, such as the adaptable control system, are less likely to make an error than the automatic switching system because they can react to unanticipated problems. The automatic switching system can only handle foreseen problems. The deterministic program can be programmed to respond to many more problems than the hardwired automatic switching system. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: As spacecraft computers become less expensive and spacecraft environmental requirements become more complex, it will be more cost effective to use computer control. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology. The automatic switching system cannot be easily modified to accomodate spacecraft changes such as the addition and removal of components.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than current technology due to transmisson delay and human decision-making time.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed. The occasional in-space maintenance of the current technology is more expensive.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. Comparable to the space hardware development of current technology.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. The human decision makes this more reliable than the Automatic Switching Systems.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. However, the high cost of this this option will make it obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Automatic Switching Systems is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: Personnel costs are included here, and the human with checklist may take much longer to perform this task than the automated alternatives. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: This task is relatively easy to automate and costly to perform with a human, so a human with checklist will rapidly become obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Automatic Switching System.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Sequencer
CODE NUMBER: 21.1 DATE: 6/9/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The Onboard Sequencer is activated by a clock or by an external trigger. It is as fast as the current technology of Automatic Switching Systems because it responds immediately to the clock or trigger.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The Onboard Sequencer is as reliable as spacecraft computers, but will often need to be updated to keep up with spacecraft heating/cooling needs.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Onboard Sequencers have been used for several years and are a mature technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Onboard Sequencers are relatively inexpensive, but they need to be updated often to reflect changing spacecraft conditions, so they are slightly more expensive than Automatic Switching Systems.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The system's extremely limited ability to respond to changing spacecraft conditions make it likely to fail.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Onboard computers will probably replace Onboard Sequencers in the near future.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is a fully developed technology that has been used for years.

OTHER REMARKS AND SPECIAL ASPECTS: It is more likely that Adjustment of a Heating/Cooling System would be done by Automatic Switching Sytems or by an onboard computer of some type than the Onboard Sequencer. The current technology for performing this functional element is Automatic Switching System.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Operations Optimization Program
CODE NUMBER: 21.2 DATE: 6/20/82 NAME(S): Thiel/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: In most cases this program will be about as fast as other computer control approaches, but in some cases the optimization will not be a quick process: the problem could be very complex and cause combinatorial expansion problems.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The maintenance requirements should be similar to other large software packages such as the deterministic computer programs.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The basic technology is developed, but it must be applied to this specific problem.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Computer time costs are similar to other large software packages, but an optimal allocation of heating/cooling resources should reduce costs in other areas (energy, etc.) making this option slightly less expensive.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: As long as the input data to the program is valid it should be error free.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The basic algorithms should remain useful for optimization functions for many years to come.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The fundamental technology has been perfected, but it must be applied to this specific task.

OTHER REMARKS AND SPECIAL ASPECTS: The program can be instructed to optimize with respect to energy cost or total cycles of the heating system, etc. The current technology for performing this functional element is Automatic Switching System.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Less than current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: A new switching system must be developed for each spacecraft. The major cost for the microprocessor is the software development.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: More reliable than current technology. The microprocessor can extrapolate trends and adjust the systems accordingly.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: For this task, the microprocessor is comparable to current technology, when compared to other optons (e.g. Onboard Microprocessor Hierarchy).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Automatic Switching Systems are a standard item. The microprocessor must be integrated into the system and software must be developed.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is an Automatic Switching System.

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options (except for the Automatic Switching Systems and the Onboard Sequencer). It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged below an Automatic Switching System, the current technology option, which is costly to repair if it malfunctions while the hierarchy is relatively easy to repair and has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel). It is equal in recurring costs to the dedicated Automatic Switching System, because while the hierarchy is more complex, it requires less maintenance and shares its costs between many spacecraft functions.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is Automatic Switching Systems.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Comparable to other onboard options, including current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The software updates and occasional hardware maintenance are less than the hardware updates and repairs for current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Comparable to onboard microprocessors, cheaper than microprocessor hierarchies and adaptive systems.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance and system adaptations, comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The ability to consider many variables and to calculate trends makes this capability less failure-prone than current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This system will make current technology obsolete, but will be replaced by more advanced software.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Automatic Switching Systems.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g8: Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: All of the automated options for this task, including current technology, are comparable in speed.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The on-ground software and communication links maintenance for this option are less expensive than the occasional on-orbit maintenance and upgrading of current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: More expensive to develop than established current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The system maintenance and occasional human supervision for this capability are comparable to the occasional in-space maintenance costs of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The more versatile computer program can deal with a wider range of situations (or can be reprogrammed), compared to the dedicated current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This option is versatile enough to replace current technology, but it will be replaced in turn by onboard or more sophisticated systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: As long as the task is kept simple, the program is not complicated. For optimal control of spacecraft energy management, the more advanced options are required.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is an Automatic Switching System.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Adaptive Control System
CODE NUMBER: 25.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g83 Adjust Cooling/Heating Systems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The electronic systems all operate with essentially the same speed as current technology (Automatic Switching Systems).

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: The control system can adapt itself to changes in the system parameters, so it does not need to be updated. It can also compensate for its own components degrading.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Development of a suitable model for the problem is important, and this contributes to nonrecurring cost. Development of the proper hardware to implement the system is also included.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The hardware required, equivalent to an onboard microprocessor hierarchy, is more complex than automatic switching systems. But the adaptive control system requires less maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The control system has a built-in capability to adapt to changes in the environment, including valve actuator failures, etc.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The sophistication of the model used can be improved as needed, and the hardware used to implement it can be upgraded, so there is little chance of obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developmental risk is basically that associated with the hardware used, and with the self-adjusting character of the software. In this case the hardware is likely to be an onboard microprocessor hierarchy.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is an Automatic Switching Systems.

DECISION CRITERIA COMPARISON CHART

GFE: g150 MONITOR FLUID TRANSFER

GFE TYPE: E. Monitoring and Control

The real-time check of the proper function of fluid transfer between two spacecraft (via umbilical) or between two components of a spacecraft. Includes checks of valve operations in the proper order, measurement of fluid quantity transferred, and checks for leaks or overpressures. [See also g239 Avoid Tank Overpressures.]

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CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

Capability	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
1.6 AUTOMATIC SWITCHING SYSTEMS	2	1	2	2	4	3	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
25.1 ONBOARD DEDICATED MICROPROCESSOR	2	1	2	2	4	2	2	
27.4 EQUIPMENT DATA CHECKS BY ONBOARD COMPUTER	2	2	3	2	4	2	2	
27.5 EQUIPMENT DATA CHECKS BY ONSITE HUMAN	3	3	2	3	3	3	1	
27.6 EQUIPMENT DATA CHECKS VIA TELEMETRY	3	2	2	2	4	4	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Automatic Switching Systems
CODE NUMBER: 1.6 DATE: 6/15/82 NAME(S):Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g150 Monitor Fluid Transfer

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Automatic switching systems do not perform computations for decision making; instead they respond directly to the fluid transfer conditions and are the fastest system to perform this function. However, the speed difference between this and other automatic controllers (computers) is marginal.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Automatic switching systems require much less maintenance than an onsite human.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and are a mature technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The automatic switching system can repeatedly monitor fluid transfers and spread its purchase cost over many uses. It has virtually no operations cost, so it is significantly less expensive than an onsite human.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: If an unforeseen anomaly occurs in the transfer, the automatic switching system may not be capable of changing its behavior to accommodate the problem.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: As onboard computers become routine on spacecraft they will naturally take over this function.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and are a mature technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology (US space program) for this functional element is Onsite Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g150 Monitor Fluid Transfer

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions). This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The human is most effective in a supervisory role, as in a task like this. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in some cases a fully automatic system will ultimately be preferred. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). This is listed as current technology because this is the way the task would be performed today, although it has not yet been done in space.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g150 Monitor Fluid Transfer

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: All the electronic systems are faster than the human (current technology) at this task.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: This capability does not involve life-support or down-time for an astronaut as does current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to current technology. Requires no astronaut training or orbiter computer software validation, but needs space-rated software and hardware.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Current technology requires a considerable amount of crew attention. Sensors are cheaper than human time here.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The potential for damage and contamination from a fuel or cryogen spill during transfer makes a human controlled/monitored system more reliable than an electronic system. The human will be able to recognize potential danger in unanticipated situations.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Doesn't require direct human attention or orbiter computers. Eventually, automated refueling systems will be reliable and necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Space-rate microprocessor and development software. Procedures for this type of operation exist in the Shuttle and Salyut programs. These procedures must be automated.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is Onsite Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/20/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g150 Monitor Fluid Transfer

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: For this particular application any electronic system has about the same speed as any other. All electronic systems (in this case) are faster than systems with human involvement.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Onboard computers will be reliable and probably self maintaining for the life of a mission. Their maintenance cost is less than that of an onsite human.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The development cost for this option (although small) is greater than for systems in which humans are involved. Automatic switching systems are also less expensive, but are less flexible.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The sensors and computer software to perform this functional element are less expensive than human analysis.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4⁻
REMARKS AND DATA SOURCES: The potential for significant damage and contamination from a fuel or cryogen spill during transfer makes a human controlled/monitored system more reliable than an electronic system because the human will be able to recognize potential danger in unanticipated situations.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: As computers become more common on spacecraft and more intelligent they will monitor and control complicated and dangerous tasks as a matter of routine.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The procedures for this type of operation exist in the Shuttle program and the Soviet Salyut program. They must be adapted for automated use.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Onsite Human With Computer Assistance (using the Shuttle orbiter computer).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onsite Human
CODE NUMBER: 27.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g150 Monitor Fluid Transfer

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time is essentially limited by the human's recognition time.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Some astronaut training is required; he or she must be able to recognize the correct data and identify possible failures. Also, a space-rated dedicated microprocessor must be developed.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The experience and flexibility of the human makes accurate diagnosis of problems more likely than with the other, automated, data checks.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard computer-run checks will probably become more thorough and less expensive than alternatives involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Interfaces and specific test equipment would need to be developed for a given fluid transfer system. But this would need to be developed for the "current technology" system also, since it has not yet been done.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computers). Current technology is an Onsite Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks via Telemetry
CODE NUMBER: 27.6 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g150 Monitor Fluid Transfer

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This assumes that there is a human on the ground in the loop. If this is being monitored by a computer, the evaluation should be rated a 2.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The maintenance is very low relative to costs of life-support for onsite humans.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This capability is currently available.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability does not require maintenance of an onsite human, and therefore the recurring costs are low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This capability does not have the advantage of the judgement of an onsite human.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This capability will be made obsolete by its onboard counterpart, Equipment Data Checks by Onboard Computer, or by an Onboard Dedicated Microprocessor.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Although this capability is currently available, there is some question as to its safety as it is not monitored by an onsite human and problems can result from time delays due to the transmission.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is an Onsite Human with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g184 MONITOR TELEMETRY

GFE TYPE: E. Monitoring and Control

The monitoring of ground telemetry during the AXAF checkout and observation sequences. More generally, the monitoring of spacecraft telemetry on the ground, to obtain status data, to review instrument output, and to confirm completion of tasks. See also g56 Determine anomalous Data (in H. Fault Diagnosis and Handling).

4E.296

CANDIDATE ARAMIS CAPABILITIES:

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.4 HUMAN WITH CHECKLIST	4	2	1	4	4	4	1	
14.5 HUMAN JUDGMENT ON GROUND	4	1	1	4	4	4	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	2	4	4	3	2	2	3	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	3	5	1	1	1	4	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	3	2	4	2	2	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g184 Monitor Telemetry

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g184 Monitor Telemetry

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Personnel costs are included here, and the human with checklist may take much longer to perform this task than a human aided by a computer. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance. A human's time while monitoring telemetry is probably fully dedicated to that task. A human cannot store or process the data, and hence is unsuited to monitoring many types of telemetry.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g184 Monitor Telemetry

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The absence of any computer assistance will make this capability slower than current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: This capability has no hardware or software to maintain.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This capability requires no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The recurring costs for human judgment does not include any computer costs, as it does for the current technology capability. There will be additional salary costs, however, as it takes a human without a computer considerably longer to perform the functional element if there are large amounts of telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human without a computer is more likely to err than a person with access to computational aids. A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist. Conversely, however, it is conceivable that a checklist user would not be as familiar with the system as someone who would be relied upon to make judgmental decisions.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: A human's time while monitoring telemetry is probably fully dedicated to that task. A human cannot store or process the data, and hence is unsuited for monitoring many types of telemetry. The current technology option for performing this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g184 Monitor Telemetry

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: An Expert System will significantly outperform the human with computer assistance. The Expert System is faster than current technology (Human on Ground with Computer Assistance) because in this case the expert system is aware of the relationships between spacecraft status and the various streams of telemetry, and can spot anomalies.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. For this application, the expert system is located on the ground. In any case, the data base needs checks and updates by qualified operators.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring costs will be a function of computer time, necessary system maintenance, and updates of the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain. This evaluation is not quite as low as the Learning Expert System with Internal Simulation because of the adaptive aspect of the Learning Expert System.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The technological risks associated with the developmental applications of an Expert System to monitoring telemetry are minimal, given that there already exists a signal code processing Expert System by the name of SU/X (see Hayes-Roth "Tutorial on Expert Systems: Putting Knowledge to Work," IJCAI-81).

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on the Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g184 Monitor Telemetry

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the system is fully operational, most tasks will be accomplished within seconds. This task is a straightforward comparison of spacecraft data to the expert system's internal simulation of the spacecraft.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g184 Monitor Telemetry

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Since this program must evaluate data by statistical analysis or other methods, it is more sophisticated than current technology, which relies on human judgement.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Although this capability can apply thorough computational checks, the human judgement in the current technology option is more reliable in evaluating instrument data and component status.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Such automated checking routines will outdate ethe more expensive checks involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The complexities of evaluating instrument and spacecraft status data make the development of this option more difficult than that of current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g239 AVOID TANK OVERPRESSURES

GFE TYPE: E. Monitoring and Control

The process of ensuring that hazardous overpressures do no occur in spacecraft tankage, either by controlling tank feeds and outputs to avoid creating the hazard, by venting the tank as needed, or both. The study concentrates more on the methods to determine the hazardous condition and to command corrective action than on specific tank hardware.

4E.303

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
1.6	AUTOMATIC SWITCHING SYSTEMS	3	3	2	3	3	3	1	C.T.
25.1	ONBOARD DEDICATED MICROPROCESSOR	2	3	3	3	4	3	2	
25.3	ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	3	3	3	4	3	2	
25.4	DETERMINISTIC COMPUTER PROGRAM ON GROUND	3	2	3	3	4	4	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Automatic Switching Systems
CODE NUMBER: 1.6 DATE: 6/15/82 NAME(S): Thiel/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g239 Avoid Tank Overpressures

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Once a tank overpressure has occurred this system is the fastest means to alleviate the problem, but more advanced systems can anticipate conditions that lead to overpressures and prevent them. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Although they require virtually no maintenance, automatic switching sytems are slightly more likely to need servicing than the self-maintaining computers and control systems of future spacecraft. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and are a mature current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The computers or computers plus telemetry links are slightly more expensive than automatic switching systems for a continuous monitoring operation because of their greater complexity and operations costs. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Due to the extreme simplicity of some automatic switching systems (a safety release valve for example) they are less likely to fail than some of more complex alternative systems for performing this functional element. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Because of the potential simplicity of this system for this application, its useful life is comparable to the other onboard options. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Automatic switching systems have been used on virtually all spacecraft and is a mature technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is the current technology for performing this functional element. This system (for this particular application) can be as simple as a safety release valve.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g239 Avoid Tank Overpressures

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The microprocessor is faster than the current technology switching system because it can perform a trend analysis and adjust the system before the switching system's limit would trip.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The microprocessor's software is slightly easier to maintain than the dedicated automatic switching system.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The cost of developing the space-rated software and microprocessor is higher than that of the simple current technology (e.g. a pressure release valve).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: More failure-prone because current technology is very reliable. A failure in this task can be critical.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Comparable to current technology, trading this option's ability to anticipate trouble wiht current technology's greater reliablity.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Automatic Switching Systems are a standard item. The microprocessor must be integrated into the system and software developed.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is an Automatic Switching System.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g239 Avoid Tank Overpressures

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The onboard computational options can anticipate overpressures, from pressure histories and trends, and thus avoid problems.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Comparable to current technology (which is a very reliable pressure valve in this case).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Comparable to the other options, but more expensive than the existing current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance and adaptations, comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The higher system complexity, compared to the very simple current technology, makes this capability more failure-prone.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: All the options are considered similar in useful life, except the more obsolescent Deterministic Computer Program on Ground.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Automatic Switching Systems.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g239 Avoid Tank Overpressures

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This option can anticipate and prevent problems to some extent, while the current technology can only react to trouble. However, this option requires telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: For this simple task, system maintenance is less than the occasional in-space maintenance of all onboard options.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: More expensive to develop than current technology (e.g. a simple pressure release valve).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The system maintenance and occasional human supervision for this capability are comparable to the occasional in-space maintenance costs of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: All the options are expected to be reliable; however the current technology option has slightly faster reflexes in a crisis.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This task is simple enough to automate onboard easily, so this option will soon be obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risks are minimal, but higher than the established current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Automatic Switching Systems.

DECISION CRITERIA COMPARISON CHART

GFE: g264 MONITOR MICRO-GRAVITY LEVELS

GFE TYPE: E. Monitoring and Control

The measurement, recording, and (possibly) evaluation of microgravity levels during zero-g materials processing. More generally, the monitoring of environmental factors during sensitive activities. This can range from recording of the parameters for later review of test results, to real-time data processing and evaluation to determine corrective action.

4E.308

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	C.T.
18.1 ONBOARD DATA RECORDER	3	3	2	3	3	3	1	
25.1 ONBOARD DEDICATED MICROPROCESSOR	3	1	3	1	2	2	2	
27.4 EQUIPMENT DATA CHECKS BY ONBOARD COMPUTER	3	1	3	1	2	2	2	
27.6 EQUIPMENT DATA CHECKS VIA TELEMETRY	4	2	2	2	2	4	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Data Recorder
CODE NUMBER: 18.1 DATE: 6/10/82 NAME(S): Thiel/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g264 Monitor Micro-Gravity Levels

DECISION CRITERIA (1 TO 5 SCALES: CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Although tape units do not have random access capability and are therefore very slow for most memory uses, they do have a fast read/write capability for serial data. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Tape units require significant amounts of maintenance during operation, but require none when data is not being stored or retrieved. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Since tape units are the current technology for long term storage, R&D costs are virtually nonexistant. The nonrecurring costs are due to new or modified design costs necessary to meet a specific mission need. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Tape drives and tape are expensive and consume large quantities of power during read/write operations, but storage costs are relatively inexpensive. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The mechanical parts, including the tape, are reliable when used for long term storage, but the nearly continuous operation required for short term storage will induce high failure rates. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Tape will continue to be used until disk recorders and optical methods are ready to replace it.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Onboard Data Recorders are current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This option is current technology for this GFE. Data Recorder is defined to be a magnetic tape recorder. For other future options for onboard data storage, the reader is referred to GFE's g89 Short-Term Memory Storage and g90 Long-Term Memory Storage (in D. Data Handling and Communication).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g264 Monitor Micro-Gravity Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Microprocessors require less hardware maintenance than a data recorder.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Very close to current technology; all that is needed is software development.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Onboard data recorders are expensive to purchase and maintain. The cost of microprocessors will be comparatively low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Microprocessors are more reliable than current technology data recorders as they are solid-state devices and have no moving parts.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of dedicated microprocessors are longer than data recorders because they use less power and do not cause vibration. Eventually they will be replaced by microprocessor hierarchies.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Current technology has no software development.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is an Onboard Data Recorder.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/20/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g264 Monitor Micro-Gravity Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: For this application speed is not essential. As long as data can be taken quickly enough to record transient microgravity fluctuations (vibrations) the top speed of the system is not critical.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Onboard computers will be reliable and probably self maintaining for the life of a mission. Their maintenance is expected to be less than the notoriously unreliable magnetic tape recorders.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Since this operation is relatively simple, it can be programmed into projected spacecraft computer systems with little development cost.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The cost of telemetry links and the personel to operate them makes the onboard computer a significantly less expensive option for recording microgravity levels. It is also less expensive than the onboard data (tape) recorder, because of its maintenance cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The onboard computers should be as reliable as a telemetry link. The computer has multiple backup modes and has no moving parts so it is more reliable than an onboard data (tape) recorder.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Most spacecraft needing to monitor microgravity levels will also require onboard computers so this option will have a long useful life.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.= 1): 2
REMARKS AND DATA SOURCES: Spacecraft computers are under development and they will be incorporated in new spacecraft designs. The algorithm and software development will require no new technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Onboard Data Recorder. It should be noted that the recorded data must be transmitted and analyzed. The current technology option transmits all the data, adding to its recurring cost. Some of the other options can process the data onboard and transmit only relevant information.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks via Telemetry
CODE NUMBER: 27.6 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g264 Monitor Micro-Gravity Levels

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: There will be delays due to the telemetry time lag. Although small, these delays make real-time corrective action from the ground difficult.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Maintenance costs will be mostly for telemetry equipment on the ground, and therefore lower than the Onboard Data Recorder. The costs of the telemetry, however, dicate a higher rating than comparable capabilities onboard.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to current technology; very little R&D required.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring costs, relative to the current technology option, are low; the Onboard Data Recorder requires in-space maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Problems will be detected more quickly than with the Onboard Data Recorder. Also, the Onboard Data Recorder may fail without warning to the ground.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This capability will be replaced by onboard real-time systems, which can react usefully to the measurements.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability uses comparable technology to the Onboard Data Recorder.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Onboard Data Recorder.

DECISION CRITERIA COMPARISON CHART

GFE: g318 ADJUST HABITAT-MAINTENANCE SUBSYSTEMS

GFE TYPE: E. Monitoring and Control

The measurement of habitat life-support parameters (e.g. atmospheric pressure, composition, temperature), the comparison of these parameters to acceptable limits and ranges, the choice and computation of any corrective action, and the control of appropriate life-support devices. More generally, the monitoring and control of atmospheric and other environmental parameters in sensitive instrumentation (e.g. furnaces).

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	4	2	3	4	4	5	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	4	3	4	3	4	1	
25.1 ONBOARD DEDICATED MICROPROCESSOR	3	3	2	2	2	2	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	3	2	4	3	1	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	3	3	2	3	3	3	1	C.T.
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	3	2	2	3	3	4	1	
25.5 ONBOARD ADAPTIVE CONTROL SYSTEM	3	2	4	2	1	1	3	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g318 Adjust Habitat-Maintenance Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: With this capability, the operator makes the decisions. The current technology capability is faster because the computer makes the decisions and there are no transmisson delays.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed. The ground software is cheaper to update than the space equivalent, which must be more carefully safety-reviewed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes software development and operator training costs, higher than the costs of the established current technology.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. The salary makes this more costly than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This is a complex and critical problem. This capability suffers from limited computational ability (compared to current technology) and the dangers of communications failures. More sophisticated onboard options are safer.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. However, the safer, more computational onboard options will make this obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Onboard Deterministic Computer Program is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g318 Adjust Habitat-Maintenance Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the station computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The station computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The failure-proneness should be comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This capability will be outdated by fully automatic systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: In this case, this capability uses the station computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is an Onboard Deterministic Computer Program.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g318 Adjust Habitat-Maintenance Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is comparable to current technology, which is also an onboard computer option.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes both hardware and software maintenance and is comparable to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is comparable to current technology, which is mostly software development. Microprocessors have already been space-rated.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This is close to current technology, including the cost of software revisions as well as the microprocessor hardware. Rated lower because this option uses dedicated hardware, and is therefore expected to need less supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This is more reliable than current technology, because it is dedicated to this critical task.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Expected to be a little better than current technology. Onboard options are preferable to ground-based options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Software development and space-qualification of the microprocessor chip.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. If this task is large and complex (e.g. the control of a sizable multi-module station), a single microprocessor may not be sufficient, suggesting more sophisticated alternatives. Current technology for this functional element is the Onboard Deterministic Computer Program.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: 9318 Adjust Habitat-Maintenance Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options (except for the Onboard Adaptive Control System). It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged below current technology as the hierarchy's programming includes the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this

functional element is an Onboard Deterministic Computer Program.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g318 Adjust Habitat-Maintenance Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Once the software is debugged the maintenance is low, involving occasional updates of software, and any needed hardware maintenance. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The initial costs include software development and reviewing it for onboard computer safety. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The cost of software updating and hardware maintenance constitute the recurring costs. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Once debugged, quality software is largely failure free; failure will more likely stem from hardware problems. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Long life is expected for high quality software. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g318 Adjust Habitat-Maintenance Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: All of the computerized options for this task require comparable time; the options involving humans are slower.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Compared to the other onsite options, this capability requires less expensive maintenance (except for the Onboard Adaptive Control System, which should hardly ever need upgrading or modification).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This technology is comparable in R&D to its current technology onboard counterpart.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The system costs for maintenance, telemetry, and occasional human supervision are comparable to the very occasional in-space maintenance of the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology. Automated onboard systems are less failure-prone.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Failure-proneness and cost contribute to obsolescence. Therefore the automated onboard systems will eventually be preferable.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Comparable to current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for this GFE is Onboard Deterministic Computer Program. Because of the continuous aspect of this task, and the considerable amount fo data handling required, this is a likely function to be automated onboard.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Adaptive Control System
CODE NUMBER: 25.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g318 Adjust Habitat-Maintenance Subsystems

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The electronic systems all operate with essentially the same speed as current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The control system can adapt itself to changes in the system parameters, so it does not need to be updated. It can also compensate for its own components degrading.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Development of a suitable model for the problem is important, and this contributes to nonrecurring cost. Development of the proper hardware to implement the system is also included.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hardware required is more complex than automatic switching systems, but equivalent to onboard microprocessors. Some updates of the software may be required after major habitat modifications.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The control system has a built-in capability to adapt to changes in the environment, including component failures, etc.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The sophistication of the model used can be improved as needed, and the hardware used to implement it can be upgraded, so there is little chance of obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developmental risk is basically that associated with the hardware used, and the self-adjusting character of the software. In this case the hardware is likely to be an onboard microprocessor hierarchy.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is an Onboard Deterministic Computer Program.

DECISION CRITERIA COMPARISON CHART

GFE: g325 MONITOR VITAL SIGNS OF CREW MEMBERS

GFE TYPE: E. Monitoring and Control

ORIGINAL PAGE IS OF POOR QUALITY

The measurement, recording, and evaluation of medical data on spacecraft crew members, including real-time parameters (e.g. heart rate and body temperature during EVA) and long-term effects (e.g. rest patterns, nutrition, cardiovascular and skeletal adaptation to zero-g), and the formulation of corrective action as needed. The study focuses on methods of evaluation and decision, rather than on specific sensor equipment.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	3	5	3	4	2	1	1	
14.8 ONSITE HUMAN JUDGMENT	3	5	2	4	2	1	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	1	5	3	3	2	1	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	2	2	1	5	
25.1 ONBOARD DEDICATED MICROPROCESSOR	1	4	3	2	4	2	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	1	3	4	2	3	2	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	1	4	3	2	3	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	2	2	3	3	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs Of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs Of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the station computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The station computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2⁻
REMARKS AND DATA SOURCES: The human/computer combination may not be available at all times for the performance of this task, but should do so reliably when available.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: For medical review and diagnosis, the human/computer combination is likely to be preferred for many years to come.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: In this case, this capability uses the station computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human Judgment
CODE NUMBER: 14.8 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: None of the human options (except the expert system) differ significantly in speed when applied to this functional element.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: More maintenance is required to support a human in space than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs (beyond normal medical training).

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human in space is much more expensive to support than a human on the ground. Astronauts' dedicated time is valuable, roughly $100k/person-day (Stephen B. Hall, NASA MSFC), but this capability has none of the costs associated with buying and operating a computer, as does the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human in space, with first hand access to the situation, can more accurately monitor the vital signs of crew members than can a person on the ground; however, there are a large number of people available on ground some of which probably have expertise beyond that of any onsite human, and hence could potentially make more accurate diagnoses from the vital signs. A person without access to computer facilities would be more likely to err than a person with that capability.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: Human judgment will never be obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: An Expert System will significantly outperform the human with computer assistance. The Expert System is faster than current technology (Human on Ground with Computer Assistance) because in this case the computer generates the options for human decision, and computes the associated probabilities. Particular attention should be given to the applications of the medical diagnosis expert systems MYCIN and EMYCIN (at Stanford AI) and how they may be modified for the purpose of monitoring the vital signs of crew members.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. As the expert system is in space, it requires expensive in space human and computer maintenance. If the operator is on the ground, this criteria value should be a 4.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring costs will be a function of computer time, necessary system maintenance, and updates of the data base (e.g., regular inputs form the crew members).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain. However, medical diagnosis of humans will always carry a risk of failure.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The technological risks involved with this application of an Expert System is very low, given that EMYCIN had approximately the equivalent diagnostic ability of a first year intern six years ago. Also, the final decisions are made by humans.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the system is fully operational, most tasks will be accomplished within seconds. This is straightforward data acquisition and comparison to model.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH, CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country (e.g., the medical diagnosis systems MYCIN and EMYCIN at Stanford AI). Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself. For this task, some human review of the diagnoses will be likely, if only for psychological reasons.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence. In the process, it will develop an increasingly sophisticated model of human adaption to zero-g.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs Of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The onboard dedicated microprocessor is faster than current technology (Human on Ground with Computer Assistance) because there are no transmission delays or human decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is more than current technology because it is harder to maintain the hardware and software on-orbit than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is more than current technology because the on-orbit software must be developed.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The microprocessor is cheap compared to current technology because there is no operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: This is less reliable than current technology. Human supervision of the crew is more likely to notice problems that are too subtle for the database of a microprocessor. Microprocessors are adequate to monitor some low-level parameters such as pulse, respiration, nutrition, rest, and blood pressure.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Better than current technology because the microprocessor is onboard.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development of software and implementation of microprocessor on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in-space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.). With a functional element as complicated as the monitoring of vital signs, it is unlikely that an autonomous system will be more reliable than a Human with Computer Assistance, except for the Learning Expert System.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). However, due to the complexity of this GFE as well as for psychological reasons, the performance of this task is unlikely to be without some degree of human supervision. The current technology option for performing this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g325 Monitor Vital Signs of Crew Members

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: To collect medical data, do statisical checks and trend analysis, and to compare information to a simple model, a relatively simple program is adequate. More complex diagnoses, however, require one of the more sophisticated human or computer options.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology, as long as the task involves only data collection and model comparisons. Diagnosis requires more sophisticated options.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Both this option and current technology will be outdated by onboard or more sophisticated software options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: As long as this program is only required for data collection and comparison to a model, its complexity is slightly higher than current technology. More difficult options are also more capable.

OTHER REMARKS AND SPECIAL ASPECTS: This option can only evaluate data in very simple terms; accurate medical diagnosis of crew members is beyond it. The current technology option for this GFE is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g24 INFORMATION PROCESSING SUBSYSTEM CHECKOUT

GFE TYPE: F. Computation

On-orbit checks of the proper function of spacecraft computer hardware and software (including verification of memory). These checks occur shortly after launch, and occasionally during spacecraft life, particularly after spacecraft hardware modifications or repair and after reprogramming of spacecraft or ground support software.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	4	3	2	4	2	3	1	
14.4 HUMAN WITH CHECKLIST	5	1	1	4	3	4	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	5	3	5	2	3	2	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	3	5	3	2	2	2	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	2	4	5	1	1	1	4	
25.1 ONBOARD DEDICATED MICROPROCESSOR	2	4	3	1	3	3	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	2	3	4	2	2	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	4	3	3	2	3	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	3	3	2	3	3	3	1	C.T.
27.2 EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	3	4	2	5	3	4	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: With this capability, the operator makes the decisions. The current technology capability is faster because the computer makes the decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software, comparable to current technology. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs, comparable to the more complex software development of current technology.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. The salary cost makes this higher than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. Both this and the current technology options will be outdated by more advanced software or onboard options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: The Deterministic Computer Program On Ground is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Personnel costs are included here, and the human with checklist may take much longer to perform this task than a human aided by a computer. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Deterministic Computer Program on Ground.

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The thoroughness of the information processing subsystem checkout is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will often be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24: Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: Expert system will significantly outperform a human with computer assistance. The time necessary for the human with computer assistance to arrive at a decision is larger than the time required by an expert system to arrive at a decision given the same problem.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an expert system is functionally dependent upon the longevity of the supporting system hardware. If the Expert System is located in space, it requires expensive in space human and computer maintenance. If the operator is on the ground, then this criteria value should be a 4. In any case, the data base needs checks and updates by qualified operators.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: It is not unreasonable to expect that a 5 to 6 man-year investment be made here. This is the time necessary to go from being developmental to a fully operational state of this application.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: Recurring costs will be a function of computer time and necessary maintenance of system hardware/software updating (modification).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The expert systems tested to date have high success ratings for a given problem domain.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Feigenbaum: The useful life of an expert system is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the expert system will never be obsolete, merely updated and refined from generation to generation.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Considering the state of the art in Expert Systems development the technological risks are quite low.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE application is a Deterministic Computer Program on Ground

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: A Learning Expert System is a very reasonable choice for an application to information processing subsystem checkout. Once the system is fully operational, most tasks will be accomplished with seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The test of checking out an information processing subsystem is a problem to which a learning expert system is suited. The current technology capability for performing this functional element is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Faster than current technology, which requires telemetry of data.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance of software and hardware is more difficult because the microprocessor is on-orbit. Current technology is on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: No operator training as with current technology, but software development will be higher.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Cheaper than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Judged comparable to current technology; includes hardware failures and data misinterpretation.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Space-rated software and hardware development.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this

functional element is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is the sort of task for which quality software is designed. This is faster than current technology because it does not require telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Long life is expected once the software is debugged. However, when changes must be made, the safety reviews for onboard software are more stringent than for software on the ground. Also, onboard computer maintenance is more expensive.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: In general, software updating and rewriting will constitute recurring costs, similarly to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Failure will be a function of the supporting hardware once the software is operational and tested. This is rated better than current technology because it is not prone to communications failures.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Long life is expected for quality software, comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The technological risks are low, involving only the onboard safety-rating of current ground software.

OTHER REMARKS AND SPECIAL ASPECTS: For simple applications, such software has already been used in space. The current technology for this GFE is Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This system requires telemetry of data. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance on the ground. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: System maintenance and the salary costs of occasional human supervision. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is a function of software failures (unlikely after debugging), ground hardware or communications link trouble, or misinterpretation of data. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This refers to technical obsolescence of capabilities. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g24 Information Processing Subsystem Checkout

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Time to complete will be comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The maintenance includes the maintenance of the microcomputer as well as the in space maintenance of the human.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The cost for the dedicated microcomputer is comparable to the development cost for the software.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. Today it costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Failure-proneness will be about the same as current technology, maybe slightly less. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Useful life is shorter than current technoogy because of the cost of the onsite human; other more automated options will replace both.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk includes development of the dedicated microcomputer and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Deterministic Computer Program on Ground. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer).

DECISION CRITERIA COMPARISON CHART

GFE: g92 NUMERICAL COMPUTATION

GFE TYPE: F. Computation

The numerical processing of spacecraft status data (e.g. structural or thermal data from many points on the spacecraft) or instrument output (e.g. telescope images, time histories of furnace parameters), for the purpose of real-time evaluation and response, data compression and display, or calculation of control profiles.

4E.345

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	4	3	2	4	2	2	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	5	3	4	2	3	1	
25.1 ONBOARD DEDICATED MICROPROCESSOR	2	4	3	1	3	3	1	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	2	3	4	2	2	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	4	3	3	3	3	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	3	3	2	3	3	3	1	C.T.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assis ance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g92 Numerical Computation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: With this capability, the operator makes the decisions. The current technology capability is faster because the computer makes the decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software, comparable to current technology. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs, comparable to the more complex software development of current technology.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. The salary cost makes this higher than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. The human operator can rapidly set up simple computations, an improvement over current technology. Eventually lower-cost onboard systems will be preferable.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Deterministic Computer Program On Ground is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g92 Numerical Computation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Up to the maximum level of complexity that can be handled by the Shuttle computers, this is as reliable as any other method.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g92 Numerical Computation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Faster than current technology, which requires telemetry of data.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance of software and hardware is more difficult because the microprocessor is on-orbit. Current technology is on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: No operator training as with current technology, but software development will be higher.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Cheaper than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Judged comparable to current technology; includes hardware failures and data misinterpertation.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. However, if the computational task is complex or sizable, this capability may not be adequate, pushing the choice to more sophisticated options. Current technology for this functional element is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g92 Numerical Computation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g92 Numerical Computation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is the sort of task for which quality software is designed. This is faster than current technology because it does not require telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Long life is expected once the software is debugged. However, when changes must be made, the safety reviews for onboard software are more stringent than for software on the ground. Also, onboard computer maintenance is more expensive.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: In general, software updating and rewriting will constitute recurring costs, similarly to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Failure will be a function of the supporting hardware once the software is operational and tested. This is rated better than current technology because it is not prone to communications failures.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Long life is expected for quality software, comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The technological risks are low, involving only the onboard safety-rating of current ground software.

OTHER REMARKS AND SPECIAL ASPECTS: For simple applications, such software has already been used in space. The current technology for this GFE is Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g92 Numerical Computation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This system requires telemetry of data. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance on the ground. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: System maintenance and the salary costs of occasional human supervision. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is a function of software failures (unlikely after debugging), ground hardware or communications link trouble. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This refers to technical obsolescence of capabilities. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE. This task involves receiving and processing data from the spacecraft; the results may be used on the ground, or returned to the spacecraft.

DECISION CRITERIA COMPARISON CHART

GFE: g93 LOGIC OPERATIONS

GFE TYPE: F. Computation

Evaluation and decision processes applied to spacecraft data, either on the spacecraft or on the ground. Such processes include: comparison of spacecraft component data to set-points or functional models; maintenance of checklists covering task scheduling, safety interlocks, equipment inventory; avoidance of potentially hazardous conditions and procedures; confirmation of proper communication (between spacecraft, to the ground, or between components on a spacecraft); choice of appropriate next actions, or of new set-points and limits, based on spacecraft status data and mission objectives. The actual logic operations consist primarily of comparisons of data to models, leading to if-then decisions. In their simplest form, they merely involve commanding spacecraft functions in a preset manner; in their most complex form, they involve evaluation and response to a wide array of spacecraft data, including simulation of possible future actions to determine optimal courses of action. The logic operations result in commands to spacecraft components and (possibly) status messages and information requests to spacecraft controllers.

4E.352

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T
14.4 HUMAN WITH CHECKLIST	4	1	1	4	4	5	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	2	4	3	2	2	1	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	1	1	1	4	
25.1 ONBOARD DEDICATED MICROPROCESSOR	1	4	3	1	3	2	2	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	1	3	4	1	2	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	1	4	3	1	3	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	3	1	3	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g93 Logic Operations

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g93 Logic Operations

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Personnel costs are included here, and the human with checklist may take much longer to perform this task than a human aided by a computer. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g93 Logic Operations

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: An Expert System will significantly outperform the human with computer assistance. The Expert System is faster than the Human with Computer Assistance in making multi-variable and logic-tree decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. The data base will need checks and updates whenever spacecraft procedures or hardware change.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonale to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain in which specific logical operations are to be accomplished.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring costs will be a function of computer time, necessary system maintenance, and updates of the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain (e.g. logical operations).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The resolution of logical operations as a result is one of the principal design objectives of any Expert System.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 7/3/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g93 Logic Operations

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the learning expert system is operational it will find the task of logic operations to be simple. Most tasks will be performed within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Updates and expansions of the data base will be needed as spacecraft procedures and components evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g93 Logic Operations

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The onboard dedicated microprocessor is faster than current technology (Human on Ground with Computer Assistance) because there are no transmission delays or human decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is more than current technology because it is harder to maintain the hardware and software on-orbit than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is more than current technology because the on-orbit software must be developed.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The microprocessor is cheap compared to current technology because there is no operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Better than current technology because the microprocessor is onboard.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development of software and implementation of microprocessor on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. However, some logic tasks require keeping large blocks of data in memory (e.g. models for comparison, historical data from components). In some cases, the memory capacity of this option may be inadequate. Current technology for this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g93 Logic Operations

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g93 Logic Operations

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision. It will therefore also be cheaper than Expert System with Human Supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g93 Logic Operations

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This depends on the complexity of the logic operations. For simple data comparisons to models, this option would receive a value of 2. However, for more complex sequencing of operations, including safety checks of components and use of internal checklists, this option rates a 3.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: This option is comparable to other computational capabilities, less expensive than options involving humans salaries.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology. Onboard or more sophisticated software options are more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Such automated logic software will outdate the more expensive options involving humans. But the more versatile computer options will be even better.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The complexity of some logic operations makes this program more difficult to develop than current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g94 COMPUTER LOAD SCHEDULING

GFE TYPE: F. Computation

The process of setting priorities and allocating computer hardware use to the various software functions on a spacecraft. This process attempts to optimize the use of core capacity, memory, and input/output functions to run the software as rapidly as possible, subject to operational constraints (e.g. a particular software function must be run every five minutes, or certain types of memory should not be run during certain other spacecraft functions).

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CANDIDATE ARAMIS CAPABILITIES:

	DECISION CRITERIA							
	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	4	3	2	4	2	3	1	
14.4 HUMAN WITH CHECKLIST	4	1	1	4	4	3	1	
21.2 OPERATIONS OPTIMIZATION PROGRAM	2	4	3	2	2	2	2	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	3	4	3	2	2	2	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	2	4	5	1	1	1	4	
25.2 ONBOARD MICROPROCESSOR HIERARCHY	2	3	4	2	2	1	3	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	4	3	3	3	3	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	3	3	2	3	3	3	1	C.T.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g94 Computer Load Scheduling

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: With this capability, the operator makes the decisions. The current technology capability is faster because the computer makes the decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software, comparable to current technology. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs, comparable to the more complex software development of current technology.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. The salary cost makes this higher than current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. Both this and the current technology options will be outdated by more advanced software or onboard options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Deterministic Computer Program On Ground is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g94 Computer Load Scheduling

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Personnel costs are included here, and the human with checklist may take much longer to perform this task than a human aided by a computer. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Operations Optimization Program
CODE NUMBER: 21.2 DATE: 6/20/82 NAME(S): Thiel/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g94 Computer Load Scheduling

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: In almost all cases the operations optimization program will be faster than any method with human involvement, unless the problem cannot be optimized.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The maintenance requirements should be similar to other large software packages such as the Onboard Deterministic Computer Program.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The basic technology is developed, but it must be applied to this specific problem.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The cost is basically just computer time, which is comparable to the other software packages applied to this functional element.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The Operations Optimization Program is not likely to err in Computer Load Scheduling because the input data should be very accurate. Although a failure will cause problems, it would probably not be severe (i.e. mission threatening).

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The basic algorithms should remain useful for optimization functions for many years to come.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The fundamental technology has been perfected, but it must be applied to this specific task.

OTHER REMARKS AND SPECIAL ASPECTS: Occasionally this system may not be able to perform optimizations fast enough to keep up with demand. The current technology for performing this functional element is Deterministic Computer Program On Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g94 Computer Load Scheduling

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time for the expert system to perform load scheduling should be comparable to the current technology option, a Deterministic Computer Program on Ground.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. If this expert system is in space, it requires expensive in space human and computer maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain in which a computer load schedule is to be accomplished.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs will be a function of computer time, necessary system maintenance, and updates of the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The task of computer load scheduling is the sort of task for which Expert Systems are designed.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for this GFE is a Deterministic Computer Program on the Ground. In comparison, the Expert System is much more than sufficient; if an expert system is used for other functions, then it can easily handle this task as well.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System With Internal Simulation
CODE NUMBER: 23.2 DATE: 7/3/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g94 Computer Load Scheduling

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Once the learning expert system is operational it will find the task of computer load scheduling to be simple. Most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve, but the system does not need onsite human supervision.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. The current technology for this CFE is a Deterministic Computer Program on Ground. In comparison, the Expert System with Human Supervision is much more than sufficient; if an expert system is used for other functions, then it can easily handle this task as well.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g94 Computer Load Scheduling

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is a Deterministic Computer Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g94 Computer Load Scheduling

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is the sort of task for which quality software is designed. This is faster than current technology because it does not require telemetry.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Long life is expected once the software is debugged. However, when changes must be made, the safety reviews for onboard software are more stringent than for software on the ground. Also, onboard computer maintenance is more expensive.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: In general, software updating and rewriting will constitute recurring costs, similarly to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology, which relies on ground computers and communications links.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Long life is expected for quality software, comparable to current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The technological risks are low, involving only the onboard safety-rating of current ground software.

OTHER REMARKS AND SPECIAL ASPECTS: For simple applications, such software has already been used in space. The current technology for this GFE is Deterministic Program on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g94 Computer Load Scheduling

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This system requires telemetry of data. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance on the ground. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: System maintenance and the salary costs of occasional human supervision. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is a function of software failures (unlikely after debugging), ground hardware or communications link trouble. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This refers to technical obsolescence of capabilities. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE. This task involves sending commands to the spacecraft computer, possibly after receiving data form the spacecraft.

DECISION CRITERIA COMPARISON CHART

GFE: g103 APPLY COMPENSATING FORCES **GFE TYPE:** F. Computation

The computation of stress and vibration parameters for spacecraft structures, their comparison to acceptable ranges or limits, the computation of appropriate responses to the conditions, and the formulation of corrective control commands to active force, torque, and damping actuators. The study focuses on data evaluation and formulation of corrective action, rather than on specific sensors or actuators. [See also g92 Numerical Computation and g93 Logic Operations.]

4E.370

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2	HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
25.1	ONBOARD DEDICATED MICROPROCESSOR	2	4	3	2	3	2	2	
25.2	ONBOARD MICROPROCESSOR HIERARCHY	2	3	4	2	2	1	3	
25.3	ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	4	3	2	3	2	2	
25.5	ONBOARD ADAPTIVE CONTROL SYSTEM	2	2	4	2	1	1	3	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g103 Apply Compensating Forces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g103 Apply Compensating Forces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The onboard dedicated microprocessor is faster than current technology (Human on Ground with Computer Assistance) because there are no transmission delays or human decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is more than current technology because it is harder to maintain the hardware and software on-orbit than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is more than current technology because the on-orbit software must be developed.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The microprocessor is cheap compared to current technology because there is no operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Better than current technology because the microprocessor is onboard.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development of software and implementation of microprocessor on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. For current spacecraft, this capability is sufficient to the task. Some later spacecraft,however, may require the reading of numerous sensors and the control of many actuators, under tight time and tolerance constraints (e.g. large antennas). This option may not be adequate for that large a computation task, suggesting more sophisticated capabilities. Current technology for this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Microprocessor Hierarchy
CODE NUMBER: 25.2 DATE: 6/28/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g103 Apply Compensating Forces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is very dependent on the task, but it will usually be much faster than the human options and slightly faster than the other autonomous options. It is a real-time system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: New capabilities can be added or deleted with a minimum of impact on the rest of the system (J. Albus, A. Barbera, R. Nagel). It is judged equal to current technology as maintaining the microprocessors in space is more difficult and costly than servicing a computer on the ground. The hierarchy, however, has the ability to compensate for many malfunctions, thus eliminating otherwise expensive servicing.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is very dependent on the necessary complexity of the system. The theory available for the design of complex facilities has not progressed to the point where it can be applied to achieve optimum control, and there will always be a cost for designing a system for any particular application (S. Kahne, I. Lefkowitz and C. Rose, in "Automatic Control by Distributed Intelligence," Scientific American, June 1979).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hierarchy in a network of microprocessors is one of the best ways to achieve low cost and upward compatibility (J. Albus, A. Barbera, R. Nagel).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: If one part fails, programming will include the ability to compensate. Large perturbations in the environment may overwhelm the lower level feedback loops and require strategy changes at higher levels in order to maintain the system within the region of successful performance. If the environment is so perverse that the system is overwhelmed, then the trajectories diverge from the region of successful performance and failure occurs. (Ibid.).

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: A hierarchical control structure is a concept that will not become obsolete in the near future. It is a real-time sensory interactive hierarchical control system with sufficient modularity that complexity of any module can be kept within tolerable limits regardless of the complexity of the overall system. The software is also modular. (Ibid.).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: A great deal of additional work needs to be done to specify the data bases, the control software, and the computing architecture (ibid.).

OTHER REMARKS AND SPECIAL ASPECTS: A hierarchical microprocessor control system is essential to the development of sophisticated sensory-interactive control systems (ibid.). The current technology option for performing this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g103 Apply Compensating Forces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Adaptive Control System
CODE NUMBER: 25.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g103 Apply Compensating Forces

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The onboard electronic systems are faster than current technology (Human On Ground With Computer Assistance).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The control system can adapt itself to changes in the system parameters, so it does not need to be updated. It can also compensate for its own components degrading.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Development of a suitable model for the problem is important, and this contributes to nonrecurring cost. Development of the proper hardware to implement the system is also included.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The hardware required is equivalent to an onboard microprocessor hierarchy.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The control system has a built-in capability to adapt to changes in the environment, including component failures, etc.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The sophistication of the model used can be improved as needed, and the hardware used to implement it can be upgraded, so there is little chance of obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developmental risk is basically that associated with the hardware used and with the self-adjusting character of the software. In this case the hardware is likely to be an onboard microprocessor hierarchy.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g221 DETERMINE IF TARGET IS WITHIN DETECTOR FIELD OF VIEW

GFE TYPE: F. Computation

A low-level data processing function on the AXAF detector image (or AXAF aspect sensor image) to determine if the desired X-ray target is within the detector field of view. [See also g224 Process Image Data, in D. Data Handling and Communication, and g223 Select New Telescope Attitude if Necessary, in G. Decision and Planning.]

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DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
13.2 HUMAN EYESIGHT VIA GRAPHIC DISPLAY	3	2	2	3	3	4	1	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
25.1 ONBOARD DEDICATED MICROPROCESSOR	1	4	3	2	3	2	2	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	1	4	3	2	3	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	3	1	3	3	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Graphics Display
CODE NUMBER: 13.2 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g221 Determine If Target Is Within Detector FOV

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time-determining factor here is the human involvement, similar to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Similar equipment to that of current technology is involved.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The software to perform this task is simple, so the cost is basically the same as the current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The logistics, maintenance, and operations costs are the same as those for current technology, due to the similarity of equipment.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The task is simple; the possibility of failure is minor, consisting only of the chance of electronic equipment failure.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The task is simple enough that an automated system will make human involvement unnecessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is already available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g221 Determine If Target Is Within Detector FOV

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Dedicated Microprocessor
CODE NUMBER: 25.1 DATE: 6/17/82 NAME(S): Spofford/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g221 Determine If Target Is Within Detector FOV

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The onboard dedicated microprocessor is faster than current technology (Human on Ground with Computer Assistance) because there are no transmission delays or human decisions.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is more than current technology because it is harder to maintain the hardware and software on-orbit than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is more than current technology because the on-orbit software must be developed.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The microprocessor is cheap compared to current technology because there is no operator salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Better than current technology because the microprocessor is onboard.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development of software and implementation of microprocessor on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: The same type of general-purpose microprocessor may be used in many applications. Current technology for this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g221 Determine if Target is Within Detector FOV

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmenta' risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE JMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g221 Determine if Target is Within Detector Field of View

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This low-level image processing program is slightly more expensive to develop than the current technology, which relies on human judgment to evaluate the data.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: This simple program is not likely to need updating, and does not incur the near-continuous salary costs of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: All of the options for this task have comparable reliabilities.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Although ground computer options such as this are more precise than humans, they will be replaced by less expensive onboard options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risks are minimal, but higher than the more established current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g37 DETERMINE DESIRED ORBITAL PARAMETERS

GFE TYPE: G. Decision and Planning

The determination of the desired orbital parameters of a spacecraft from knowledge of its current parameters and of mission objectives. If the spacecraft is expected to rendezvous with another, this task includes the computation of the expected position of the target. By extension, this task also covers the determination of desired spacecraft attitude.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.4 HUMAN WITH CHECKLIST	4	2	2	2	4	4	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	1	3	3	3	3	1	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	2	2	1	5	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	1	4	3	2	3	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	2	2	3	3	2	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g37 Determine Desired Orbital Parameters

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g37 Determine Desired Orbital Parameters

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This consists mainly of personnel costs, which are low for this task. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: If calculations are required, the human would do better with computer assistance.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g37 Determine Desired Orbital Parameters

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: An Expert System will significantly outperform the human with computer assistance. The Expert System is faster than the human with computer assistance in the time domain (time required for hypothesis formulation).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. In this application, the expert system is located on the ground. In any case, the data base needs checks and updates by qualified operators.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain in which the determination of orbital parameters is to be accomplished.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: Recurring costs will be a function of computer time and necessary maintenance of the system's hardware.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The determination of orbital parameters is the sort of problem for which an Expert System is constructed.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is "Human on Ground with Computer Assistance" for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g37 Determine Desired Orbital Parameters

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: A Learning Expert System is a very reasonable choice for implementation in accomplishing the task of determining desirable orbital parameters. Once the system is fully operational, most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology capability for performing this functional element is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g37 Determine Desired Orbital Parameters

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g37 Determine Desired Orbital Parameters

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Comparable to the software development and operator training costs of current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Most options for this task are comparable to current technology in failure-proneness.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Both this option and current technology will be outdated by onboard or more sophisticated software options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risks are minimal, but higher than the established current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance. The extent to which an automated capability can be applied to this task depends on whether high-level decisions about mission objectives are involved. For station-keeping corrections, deterministic programs are adequate; for decisions about major orbital changes, they may not be.

DECISION CRITERIA COMPARISON CHART

GFE: g38 CHOOSE OPTIMAL TRAJECTORY

GFE TYPE: G. Decision and Planning

The choice of a precomputed trajectory (or the computation of one) to achieve the spacecraft's desired orbital parameters in an optimal manner. Optimality is defined according to the mission objectives (e.g. minimum time, minimum propellant use) and available hardware.

4E.389

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T
14.4 HUMAN WITH CHECKLIST	4	2	2	2	4	4	1	
21.2 OPERATIONS OPTIMIZATION PROGRAM	2	4	3	1	2	1	2	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	4	3	2	3	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	3	2	3	3	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g38 Choose Optimal Trajectory

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g38 Choose Optimal Trajectory

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This consists mainly of personnel costs, which are low for this task. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: If calculations are required, the human would do better with computer assistance.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Operations Optimization Program
CODE NUMBER: 21.2 DATE: 6/20/82 NAME(S): Thiel/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g38 Choose Optimal Trajectory

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: In almost all cases the operations optimization program will be faster than any method with human involvement, unless the problem cannot be optimized.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The maintenance requirements should be similar to other large software packages such as the Onboard Deterministic Computer Program.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The basic technology is developed, but it must be applied to this specific problem.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The cost is basically just computer time, which is comparable to the other software packages applied to this functional element It should be less expensive than the current technology of Human On Ground With Computer Assistance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: As long as the input data to the program is valid it should be error free.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The basic algorithms should remain useful for optimization functions for many years to come.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The fundamental technology has been perfected, but it must be applied to this specific task.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g38 Choose Optimal Trajectory

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Dr. Richard Battin (Draper Labs): The determination of an optimal trajectory by quality software is within our current technology capabilities. The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAM : Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g38 Choose Optimal Trajectory

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Since this task involves choice or computation of optimal parameters, a sophisticated program is required.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Most options for this task are comparable to current technology in failure-proneness.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Both this option and current technology will be outdated by onboard or more sophisticated software options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: This sophisticated program requires more development than current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance. This task assumes that the desired orbital parameters are known, and considers only the trajectory to achieve those parameters.

DECISION CRITERIA COMPARISON CHART

GFE: g64 UPDATE SPACECRAFT MODEL

GFE TYPE: G. Decision and Planning

The updating of the functional representation of a spacecraft used by the decision and planning agency. This update uses status data from the spacecraft. The model itself can be as simple as an identification of the present modes of operation of spacecraft components, or as complex as a full-spacecraft computer simulation including cause-and-effect relationships between components and procedures. This includes updates showing degradation or failure of components, or modifications to the spacecraft.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T
14.4 HUMAN WITH CHECKLIST	4	2	2	3	4	4	1	
16.1 COMPUTER MODELING AND SIMULATION	2	3	4	2	2	2	3	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	1	1	1	5	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g64 Update Spacecraft Model

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g64 Update Spacecraft Model

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This consists mainly of personnel costs, which are low for this task. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Modeling And Simulation
CODE NUMBER: 16.1 DATE: 3/19/82 NAME(S): Spofford/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g64 Update Spacecraft Model

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is faster than current technology (Human on Ground with Computer Assistance) because more of the operation is automated.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes computer hardware and software maintenance and is comparable to current technology. A high-reliability computer system is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This includes the development of a comprehensive system model and generation of the computer database. The cost of writing the software to manipulate the database is also included in the nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This includes the operator's salary, hardware and software maintenance, and the cost of updating the database as the spacecraft changes. This is less than current technology because less operator time is needed.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: With Computer Modeling And Simulation it is possible to model things that are not directly testable. As long as the computer model of the system is accurate, this capability is not likely to fail. It is more reliable than the current technology option because the computer can manipulate more information in its database than a human can.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability has a long useful life because the database may be updated as the spacecraft changes. The system model can be upgraded to include repairs, failures, component degradation, and design changes as necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: Development and validation of a sufficiently accurate database is a major risk of this option.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 7/3/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g64 Update Spacecraft Model

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the learning expert system is operational the task of updating the spacecraft model will reside within the scope of the system's processing capability. Most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: The interested reader may be refered to Dr. Hayes-Roths' report "Tutorial on Expert Systems: Putting Knowledge to Work," IJCAI-81. See the details on MOLGEN and OP-PLANNER. If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: 97 PROJECT CONSUMABLES REQUIREMENTS FROM MISSION PROFILE

GFE TYPE: G. Decision and Planning

The identification and estimation of quantities of consumables required by mission objectives. This includes estimation of propellant and other fluid requirements for nominal operations, losses from fluid leakage, degradation of replaceable hardware (e.g. solar cells, batteries), and safety margins for contingencies.

4E.400

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2	HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.4	HUMAN WITH CHECKLIST	4	1	2	4	4	4	1	
16.1	COMPUTER MODELING AND SIMULATION	1	3	4	2	2	1	3	
23.1	EXPERT SYSTEM WITH HUMAN SUPERVISION	2	4	4	3	2	2	3	
23.2	LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	1	1	1	4	
25.3	ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	4	3	2	3	2	2	
25.4	DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	3	2	3	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g97 Project Consumables Requirements From Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g97 Project Consumables Requirements From Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Personnel costs are included here, and the human with checklist may take much longer to perform this task than a human aided by a computer. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Modeling And Simulation
CODE NUMBER: 16.1 DATE: 3/19/82 NAME(S): Spofford/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g97 Project Consumables Requirements From Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This is faster than current technology (Human on Ground with Computer Assistance) because more of the operation is automated.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes computer hardware and software maintenance and is comparable to current technology. A high-reliability computer system is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This includes the development of a comprehensive system model and generation of the computer database. The cost of writing the software to manipulate the database is also included in the nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This includes the operator's salary, hardware and software maintenance, and the cost of updating the database as the mission profile changes. This is less than current technology because less operator time is needed.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: As long as the computer model of the system is accurate, this capability is not likely to fail. It is more reliable than the current technology option because the computer can manipulate more information in its database than a human can.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This capability has a long useful life because the database may be updated as the mission profile changes. The system model can be upgraded to include repairs, failures, component degradation, and design changes as necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: Development and validation of a sufficiently accurate database is a major risk of this option.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g97 Project Consumables Requirements from Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is faster than current technology (Human on Ground with Computer Assistance) because in this case the expert system produces the options for human decision, and computes the associated probabilities.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. In this application, the Expert System is located on the ground. In any event, the data base must be updated by operators.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain in which to project consumables requirements from mission profiles.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring costs will be a function of computer time, necessary system maintenance and updates of the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The projection of consumables requirements from a given mission profile is the sort of task that Expert Systems were designed for.

OTHER REMARKS AND SPECIAL ASPECTS: The current technological option for this GFE is Human on the Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g97 Project Consumables from Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once operational the projection of consumables requirements from a given mission profile will be simple. Most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is a Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g97 Project Consumables Requirements from Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay. However it will be limited in sophistication, and will therefore be slower than more advanced modeling systems.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The software development cost is comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g97 Project Consumables Requirements from Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This requires a computer model of the consumables requirements of the various mission activities, including interaction between activities.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology. The more advanced simulation and prediction options will be more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This will outdate the more expensive current technology. Options involving advanced simulations will ultimately be preferable.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The development of the needed computer model (including interactions between activities) makes this more difficult than current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance. The various computational options for this task evolve from one to the other (e.g. a sophisticated Deterministic Computer Program is close to Computer Modeling and Simulation, etc).

DECISION CRITERIA COMPARISON CHART

GFE: 998 COMPUTE OPTIMAL CONSUMABLES ALLOCATION

GFE TYPE: G. Decision and Planning

The determination of the optimal sequencing of tasks, and the optimal mode of performance of each task, to minimize consumables usage while meeting mission objectives. This determination is based on knowledge of the mission requirements, of the spacecraft hardware characteristics, and of the available procedural options. This task can run into combinatorial difficulties for complex spacecraft, when the number of procedural options is large.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
21.2 OPERATIONS OPTIMIZATION PROGRAM	2	3	3	1	2	1	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	1	1	1	4	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: 598 Compute Optimal Consumables Allocation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Operations Optimization Program
CODE NUMBER: 21.2 DATE: 6/20/82 NAME(S): Thiel/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g98 Compute Optimal Consumables Allocation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: One hour of computation time could optimize several months of operation. Depending on the particular application such a program might also be run as a real time monitor.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The reliability is approximately that of large software packages in general.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The fundamentals of the technology exist, but it needs further work before it is ready for space use.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The primary cost is the computer time used by the program. It is likely that it would be significantly less than the current technology of a Human On Ground With Computer Assistance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The program cannot distinguish bad data from good, so if it is fed poor information it will fail. Otherwise, it should be virtually error free.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The basic algorithms should remain useful for optimization functions for many years to come.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The fundamental technology has been perfected, but it must be applied to this specific task.

OTHER REMARKS AND SPECIAL ASPECTS: The system is fast enough to run multiple cases with different consumable constraints. The current technology capability for this GFE is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 3/17/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g98 Compute Optimal Consumables Allocation

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the system is fully operational, most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology capability for performing this functional element is a Deterministic Computer Program on Ground.

DECISION CRITERIA COMPARISON CHART

GFE: g105 PROJECT DESIRED FUNCTIONS FROM MISSION PROFILE

GFE TYPE: G. Decision and Planning

The definition of the spacecraft or ground support activities required or desired to meet the mission objectives. [The space project breakdowns used in this study are one method to do this task.] Originally done during the mission design process, this task may need repetition if the mission profiles are modified during the life of the spacecraft.

4E.412

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.4 HUMAN WITH CHECKLIST	3	3	2	3	3	3	1	C.T.
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	2	5	4	2	2	2	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	1	1	1	4	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILI Y NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g105 Project Desired Functions From Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This consists mainly of personnel costs. This is current technology. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This is an abstract task, and therefore only very sophisticated automation will be competitive with human judgement. This is the current tehcnology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g105 Project Desired Functions from Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is faster than current technology (Human with Checklist) because in this case the computer produces the options for human decision, and computes the associated probabilities.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. If the expert system is in space, it requires expensive in-space human and computer maintenance. If the expert system is on the ground, this criteria value should be a 4.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain in which to project desired functions from a mission profile.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs will be a function of computer time and necessary system maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain. In this case the final decisions are made by humans, with the expert system suggesting and checking options.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The projection of desired functions from a mission profile is the sort of task that an Expert System was designed for.

OTHER REMARKS AND SPECIAL ASPECTS: Reference: Dr. Hayes-Roth, "Tutorial on Expert Systems: Putting Knowledge to Work," IJCAI, 1981. The current technology option for this GFE is the Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g105 Project Desired Functions from Mission Profile

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once operational, the system will incorporate a model of the relationships between spacecraft functions and mission objectives. From this, a projection of desired functions can be quickly generated.

MAINTENANCE (1 LITTLE, 5 LOTS):
REMARKS AND DATA SOURCES: Once the system is fully operational, most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology option for this is a Human with Checklist.

DECISION CRITERIA COMPARISON CHART

FE: g107 DETERMINE CONSTRAINTS AND FIGURES OF MERIT

GFE TYPE: G. Decision and Planning

The definition of procedural constraints and acceptable ranges of operation for spacecraft components (e.g. voltage limits, mechanical motion envelopes, safe sequences of valve actuations). Also, the definition of optimality criteria for the expected spacecraft functions (e.g. minimum propellant use, maximum data return, minimum wear). This determination is based on the estimation of risks to the spacecraft and to the mission objectives from the projected spacecraft activities.

4E.416

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.5 HUMAN JUDGMENT ON GROUND	4	1	1	3	4	4	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	2	4	4	2	2	2	3	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	2	4	5	1	1	1	5	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g107 Determine Constraints And Figures Of Merit

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g107 Determine Constraints and Figures of Merit

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The absence of any computer assistance will make this capability slower than current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: This capability has no hardware or software to maintain.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This capability requires no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring costs for human judgment does not include any computer costs, as it does for the current technology capability. There will be additional salary costs, however, as it takes a human without a computer longer to perform the functional element.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human without a computer is more likely to err than a person with access to computational aids.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for performing this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g107 Determine Constraints and Figures of Merit

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is faster than current technology (Human on Ground with Computer Assistance) because in this case the computer produces the options for human decision, and computes the associated probabilities.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. For this application, the Expert System is located on the ground. In any event, the data base need checks and updates by qualified operators.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to speifically meet the needs of a particular knowledge domain. Errand planners (e.g., OP-PLANNER at Rand) and experiment planners (e.g. MOLGEN at Stanford AI) are moving in this direction.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs will be a function of computer time, necessary system maintenance, and updates to the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain. In this case the final decisions are done by humans, and checked out on the expert system.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the expert system will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The developmental risk involved here is minimal, since the decision-making agency is human.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Human on the Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g107 Determine Constraints and Figures of Merit

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Once the system is fully operational, the system will incorporate a model of the relationships between spacecraft and mission objectives. Using this model, internal simulations can determine acceptable ranges of operation and optimum settings.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is a Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GPE: g110 DETERMINE NEW CONFIGURATION FOR SPACECRAFT COMPONENTS

GPE TYPE: G. Decision and Planning

The modeling of the overall attitude and geometric configuration of spacecraft components, including solar arrays, radiators, communications antennas, sensors and instruments. This modeling can serve three purposes: to determine what a new configuration should be, to fullfill the next mission objective (e.g. to reorient the AXAF while keeping solar arrays and communication antennas properly pointed); before a new configuration is assumed, to verify the safety of that configuration (e.g. to avoid collisions between spacecraft components); while the configuration is in effect, to support the structural dynamic analysis of the spacecraft.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.4 HUMAN WITH CHECKLIST	4	2	2	3	4	4	1	
16.1 COMPUTER MODELING AND SIMULATION	2	3	4	2	2	2	3	
22.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	2	4	5	2	1	1	4	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	4	4	2	3	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	3	3	2	3	3	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g110 Determine New Configuration For Spacecraft Components

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardwarr is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g110 Determine New Configuration For Spacecraft Components

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: In comparison to the cheaper automated options, this capability is comparable to current technology. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Modeling And Simulation
CODE NUMBER: 16.1 DATE: 3/19/82 NAME(S): Spofford/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g110 Determine New Configuration For Spacecraft Components

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is faster than current technology (Human on Ground with Computer Assistance) because more of the operation is automated.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes computer hardware and software maintenance and is comparable to current technology. A high-reliability computer system is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This includes the development of a comprehensive system model and generation of the computer database. The cost of writing the software to manipulate the database is also included in the nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This includes the operator's salary, hardware and software maintenance, and the cost of updating the database as the spacecraft changes. This is less than current technology because less operator time is needed.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: With Computer Modeling And Simulation it is possible to model things that are not directly testable. As long as the computer model of the system is accurate, this capability is not likely to fail. It is more reliable than the current technology option because the computer can manipulate more information in its database than a human can.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability has a long useful life because the database may be updated as the spacecraft changes. The system model can be upgraded to include repairs, failures, component degradation, and design changes as necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: Development and validation of a sufficiently accurate database is a major risk of this option.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Human On Ground With Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g110 Determine New Configuration for Spacecraft Components

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This task is a relatively simple use of the geometric model of the spacecraft in the expert system. This simulation should be rapid.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g110 Determine New Configuration for Spacecraft Components

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is an automated program, thus faster than a human. It also has no telemetry delay.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Occasional updates of software are required, and they require safety review. There is also some hardware maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This requires equipping the spacecraft with a computer large enough to do the geometric modeling of spacecraft components. Therefore this is higher than current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for software updates and hardware maintenance are similar to current technology; however this capability does not require human supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of quality software is long once operational. This onboard system will outdate telemetry.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g110 Determine New Configuration for Spacecraft Components

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This requires a computer model of the spacecraft geometry, capable of identifying orientations of solar arrays, radiators, antennas, and potential collisions.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology. The more advanced simulation and prediction options will be more reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Both this option and current technology will be outdated by onboard or more sophisticated software options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The development of the needed geometric model makes this more difficult than current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance. The various computational options for this task evolve from one to the other (e.g. a sophisticated Deterministic Computer Program is close to Computer Modeling and Simulation, etc).

DECISION CRITERIA COMPARISON CHART

GFE: g185 EVALUATE SYSTEM PERFORMANCE

GFE TYPE: G. Decision and Planning

The evaluation of spacecraft and ground support performance in achieving mission objectives. This includes evaluation of spacecraft state-of-health and suitability for further activities. This may also include definition of desirable improvements in hardware or procedures.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.4 HUMAN WITH CHECKLIST	4	2	2	4	4	4	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	2	5	3	4	2	2	1	
14.8 ONSITE HUMAN JUDGMENT	2	4	2	4	3	2	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	2	4	4	3	2	2	3	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	2	1	1	5	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g185 Evaluate System Performance

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g185 Evaluate System Performance

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Personnel costs are included here, and the human with checklist may take much longer to perform this task than a human aided by a computer. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This task can be highly abstract for a complex system. Therefore only very sophisticated automation can compete with human judgement for such complex instances. However, the Human with Checklist only exercises jugement in the formulation of the checklist. Current technology is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g185 Evaluate System Performance

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The thoroughness of the performance evaluation is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems. Onsite judgement is inherently more reliable than judgement from the ground.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used. Only sophisticated automation can compete with human judgement in the evaluation of complex systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human Judgment
CODE NUMBER: 14.8 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g185 Evaluate System Performance

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: A human onsite would probably be faster at performing this functional element than one on the ground.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: More maintenance is required to support a human in space than on the ground.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human in space is much more expensive to support than a human on the ground. Astronauts' dedicated time is valuable, roughly $100k/person-day (Stephen B. Hall, NASA MSFC). However, this capability has none of the costs associated with buying and operating a computer, as does the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A person without access to computer facilities would certainly be more likely to err than a person with that support. A human in space can more accurately gauge the system performance than can a person on the ground as he has first hand access to the situation. It should be noted, however, that there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially evaluate the system performance better. A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist. Conversely, however, it is conceivable that a checklist user would not be as familiar with the system as someone who would be relied upon to make judgmental decisions.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Human judgment will never be obsolete, especially when evaluating the perfomance of other humans, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g185 Evaluate System Performance

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: An Expert System will significantly outperform the human with computer assistance. The Expert System is faster than current technology (Human on Ground with Computer Assistance) because in this case the computer displays status information and relationships, identifies possible outcomes, and computes probabilities of success or failure.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. For this application, the Expert System is located on the ground. The data base needs checks and updates by qualified operators.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain. In this case, the final evaluation is made by humans.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The recurring costs will be a function of computer time, necessary system maintenance, and updates of the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain. The final decisions are made by humans in this case, improving the computer's reliability.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: The technological risks in developing this application of an expert system is minimal. Most of the task complexity is left to humans.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g185 Evaluate System Performance

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the system is fully operational, most tasks will be accomplished within seconds. If the evaluation involves verification of acceptable behavior of the spacecraft, it is a rapid comparison of spacecraft data to the expert system's internal simulation. If the system is used to suggest improvements in the system, then alternative simulations will be run to evaluate future results; the time would then rate a 2.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g220 PICK X-RAY SOURCE WITH KNOWN OPTICAL COUNTERPART

GFE TYPE: G. Decision and Planning

The choice of the next target for the AXAF. Issues in the choice are minimization of telescope movement and avoidance of occultation of the target by sun, moon, or planet during the observation sequence (even a near-occultation can damage AXAF sensors).

4E.435

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.4 HUMAN WITH CHECKLIST	3	3	2	3	3	3	1	C.T.
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	5	3	2	3	1	1	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	4	3	2	3	2	1	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g220 Pick X-Ray Source With Known Optical Counterpart

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This consists mainly of personnel costs (low in this case). This is current technology. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The simplicity of the task is such that a computer will not necessarily improve failure-proneness. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This task is a simple sequence of operations, so a human with checklist will always be an inexpensive alternative.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g220 Pick X-Ray Source with Known Optical Counterpart

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The automated programs are faster than the current technology human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The occasional software updates and hardware maintenance are far more costly than checklist updates.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: More expensive than setting up a checklist.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs reside in occasional maintenance and system adaptations, less than the human salary in the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The failure-proneness is almost nonexistent for all options.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The low recurring cost and absence of need for telemetry make this the most desirable option in the long term.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The technological risks are low for such a simple program.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g220 Pick X-Ray Source with Known Optical Counterpart

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The software updates and communications link maintenance are more substantial than the updates of checklists.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This is a simple task, and current technology has very low R&D cost (setting up checklists). In comparision, this software development is higher.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Less than the occasional human salary required by current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: All options have comparable (very low) failure-proneness.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: less expensive, therefore ultimately preferred over current technology. Eventually, an onboard option may outdate this option.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: All options for this task are simple to develop.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human with Checklist.

DECISION CRITERIA COMPARISON CHART

GFE: g223 SELECT NEW TELESCOPE ATTITUDE IF NECESSARY

GFE TYPE: G. Decision and Planning

The selection of another telescope attitude for AXAF, if the first attempt to find a new Xray target is unsuccessful. Success is defined by acquisition of the target by both optical and X-ray sensors. If there are misalignments between sensors (e.g. due to thermal deformations in the telescope) the target may appear only to one type of sensor; or the target may be out of view entirely. The task involves trying to deduce the necessary attitude correction from partial or circumstantial data, or using a preset systematic search pattern.

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CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.5 HUMAN JUDGMENT ON GROUND	3	3	2	3	3	3	1	C.T.
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	5	4	2	2	1	4	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	5	3	2	4	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	4	3	2	4	2	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g223 Select New Telescope Attitude If Necessary

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This capability is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This capability is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This capability requires no research and development except for any necessary training costs.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is a fairly simple functional element to perform, and would require little dedicated human time.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform this functional element if possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is the current technology option for performing this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g223 Select New Telescope Attitude if Necessary

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the system is fully operational, most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. This is one of the simpler Learning Expert Systems to bring up. The current technology for this GFE is Human Judgement on the Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic Computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g223 Select New Telescope Attitude if Necessary

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is faster than current technology which includes a human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: This is considerably higher than the human on the ground, who has no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Higher than the training costs of current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are low, once the system is operational. This does not require paying a human's salary.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A deterministic program does not have a human's intuition or learning ability.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Less expensive than a human, this option will eventually be replaced by more advanced software.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Human Judgement on the Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g223 Select New Telescope Attitude if Necessary

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The current technology capability requires no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: More expensive than the training cost of the current technology human.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: All of the computational options have comparable recurring costs, less than the salary cost of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Because the deterministic programs do not benefit from intuition or learning abilities, they are less likely to succeed in this task than other options.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Cheaper than current technology, therefore preferred. If a learning Expert System is eventually used for spacecraft functions, this task would be a small part of its duties.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Slightly higher difficulty than the training of the current technology human.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for this GFE is Human Judgement on Ground.

DECISION CRITERIA COMPARISON CHART

GFE: g244 AVOID CONFLICTING OBJECTS

GFE TYPE: G. Decision and Planning

The determination that one or more objects are on collision courses with the spacecraft; the choice of avoidance procedure; the formulation of the corrective action; and the computation of the appropriate control commands to avoid contact. This includes avoidance of components potentially in the way of a target spacecraft's docking hardware, or of free-flying objects in the target's vicinity.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	4	2	1	2	4	5	1	
14.5 HUMAN JUDGMENT ON GROUND	4	1	1	1	5	5	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	3	3	2	3	3	3	1	C.T.
14.8 ONSITE HUMAN JUDGMENT	3	2	1	3	4	3	1	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	2	2	4	1	2	1	4	
25.3 ONBOARD DETERMINISTIC COMPUTER PROGRAM	2	2	2	2	4	2	2	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	4	1	1	2	5	4	2	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g244 Avoid Conflicting Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This is slower than current technology due to transmission delays.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed. Current technology requires the maintenance of an onsite human and of the orbiter computer.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This includes software development and operator training costs, less than the astronaut training and the software verification for the Shuttle orbiter computer.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software, less than the maintenance costs of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. However, the time delays are critical in this application, so onsite options are superior.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. However, the failure-proneness of this option makes it a candidate for early replacement.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Onsite Human With Computer Assistance (using the Shuttle orbiter computers) is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g244 Avoid Conflicting Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: A human on the ground would be much slower at performing this functional element than one onsite.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Less maintenance is required to support a human on ground than in space.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This capability requires no research and development except for training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: A human on ground is less expensive to support than a human in space. This capability has none of the costs associated with buying and operating a computer, as does the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: A person without access to computer facilities would certainly be more likely to err than a person with that support. A human on ground would not be able to react as quickly as one onsite, causing potential collisions with conflicting objects.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: For performing this functional element, it is very advantageous that the capability be located onsite. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Onsite Human with Computer Assistance. In general, if the capability used to track the objects involves human eyesight, the avoidance of the objects should probably use human control. This is due to difficulties in passing position and velocity data from human to machine. Machine tracking can be input to human control via graphic display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g244 Avoid Conflicting Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions). This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The limiting factor may be the speed and capacity of the orbiter computers, which restricts the complexity of the environment that can be accurately dealt with in real-time. On the other hand, the onsite human adds flexibility to the system, and can direct the computers to neglect objects which are not important. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in some cases a fully automatic system will ultimately be preferred. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.= 1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology numbers are used, but this has not yet been performed in space.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human Judgment
CODE NUMBER: 14.8 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g244 Avoid Conflicting Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: A human onsite would be much faster at performing this functional element than one on the ground.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: More maintenance is required to support a human in space than on the ground. This capability does not require the maintenance of computer hardware, software, and its associated database.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human in space is much more expensive to support than a human on the ground. Astronauts' dedicated time is valuable, roughly $100k/person-day (Stephen B. Hall, NASA MSFC), but this capability has none of the costs associated with buying and operating a computer, as does the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A person without access to computer facilities would certainly be more likely to err than a person with that support. A human in space would be able to react much quicker than one on the ground, avoiding potential collisions with conflicting objects.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: For performing this functional element, it is very desirable that the capability be located onsite. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Onsite Human with Computer Assistance. In general, if the capability used to track the objects involves human eyesight, the avoidance of the objects should probably use human control. This is due to difficulties in passing position and velocity data from human to machine. Machine tracking can be input to human control via graphic display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g244 Avoid Conflicting Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Once the system is fully operational, most tasks will be accomplished within seconds. This task requires the simulation of spacecraft and object trajectories into the future, including alternative evasive actions.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is Onsite Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Deterministic computer Program
CODE NUMBER: 25.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g244 Avoid Conflicting Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This capability is faster than the current technology which involves a human.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: This does not require maintenance of an in-space human, or of the human-machine interfaces.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This will be cheaper to develop than the human-machine interfaces required by current technology.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is a function of maintenance costs, which do not include in-space human maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: For this kind of task, a pilot's reflexes are superior to a deterministic computer program.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: Since the current technology human is expensive and possibly unavailable, autonomous techniques are ultimately preferable.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The developmental risk is in space-rating the software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is Onsite Human with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g56 Determine Anomalous Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes software development and operator training costs. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g56 Determine Anomalous Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew: this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The thoroughness of the data check is limited by the complexity of programs usable on the flight computers. On the other hand, the onsite human adds flexibility to the system, increasing its ability to deal with unforeseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Human On ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g56 Determine Anomalous Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once operational, a learning expert system is a reasonable choice for implementation in accomplishing the task of determining the existence of anomalous data, onboard or from transmission. Most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning.
The current technology application for this GFE is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g56 Determine Anomalous Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This consists of software updates and computer maintenance, similarly to current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Since this program must evaluate data by statistical analysis or other methods, it is more sophisticated than current technology, which relies on human judgement.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs are a function of system maintenance (comparable to current technology), and of occasional human supervision (less than the near-continuous human salary required by the current technology option).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Although not benefiting from human judgement, this capability can apply more thorough computational checks.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Both this option and current technology will be outdated by onboard or more sophisticated software options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Although sophisticated, the program is no more difficult to develop than current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: F~ult Tolerant Software
CODE NUMBER: 26.1 DATE: 7/3/82 NAMES): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g56 Determine Anomalous Data

DECISION CRITER'A (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The fault tolerant software should be able to find bit flips, encoding errors, etc., about as quickly as a data check program on an onboard computer. The advanced versions of this software should also be able to recognize data which "does not make sense" or contradicts other data or known facts. It will be able to do this in significantly less time than a human.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: One of the key goals of the fault tolerant software is the ability to be self checking and self maintaining. The software executes self checks and performs its own updating to reflect changes in the spacecraft's systems.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: Some versions of fault tolerant software presently exist for aircraft computers. The advanced capabilities envisioned here (up to recognizing programming errors) are in the preliminary research stage and will be expensive to develop.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A complete fault tolerant software package will probably be expensive, but it will also perform a great many functions. Determining anomalous data will be included as a standard addition to the self checking functions. As a result the cost of performing this operation will be low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Fault tolerant software is self checking and is designed specifically for failure protection and recovery. It, particularly the advanced versions, will rarely fail. Also, if a failure does occur and the system can not solve the problem it is designed to fail into a safe mode.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This is an evolving technology which will eventually be found on most computer systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: For the advanced fault tolerant software the risk of this technology being ready for use at a specific time is high.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onboard Computer
CODE NUMBER: 27.4 DATE: 6/24/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g56 Determine Anomalous Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: This option is faster than transmitting data to a remote location (telemetry) because of delays due to ground station availability. The onboard computer can analyze the data and reach a conclusion before a human can read a display screen or printout.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Onboard computers will be reliable and probably self maintaining for the life of a mission. Their maintenance will be comparable to the telemetry link and ground equipmnet required by current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This test is identical to tests performed on telemetered data so ground software and analysis techniques must be transferred to space rated computers.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The computer can carry out this functional element quickly and accurately at less cost than a system with direct human involvement.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The data checks by onboard computer are less likely to error than systems with human involvement due to the large amount of data to be processed. More advanced systems, such as fault tolerant software, are capable of handling data errors which were not explicitly anticipated. The data checking system can only handle foreseen problems.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: As computers become more and more common on spacecraft this method of determining anomalous data will be a routine procedure.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Spacecraft computers are under development and they will be incorporated in new spacecraft designs. Some software development will be necessary, but the technology for recognizing questionable data already exists.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Human On Ground With Computer Assistance. It should be noted that this technology has many levels of complexity. It can be as simple as parity checks to identify bit flips in a data stream or as complicated as signal processing to identify failed sensors, etc.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks By Onsite Human
CODE NUMBER: 27.5 DATE: June 1982 NAME(S): Howard/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g56 Determine Anomalous Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time is essentially limited by the human's recognition time.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Some astronaut training is required; he or she must be able to recognize the correct data and identify possible failures. Also, a space-rated dedicated microprocessor must be developed.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The experience and flexibility of the human helps in accurate diagnosis of problems. However, automated methods can perform more comprehensive checks.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Onboard computer-run checks will probably become more thorough and less expensive than alternatives involving humans.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Interfaces and specific test equipment would need to be developed for a given application.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computers). Current technology for this GFE is a Human on Ground with Computer Assistance.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Data Checks via Telemetry
CODE NUMBER: 27.6 DATE: 5/12/82 NAME(S): Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g56 Determine Anomalous Data

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The speed of this capability will not differ from that of current technology, Human on Ground with Computer Assistance.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Since this GFE is not accomplished continuously, down time is not significant. Maintenance costs are low, since they only involve software checks and updates.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This option is currently available.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs for this capability are less than that for the current technology option, Human on Ground with Computer Assistance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability will be comparable to its onboard counterpart, Equipment Data Checks by Onboard Computer, because this GFE excludes errors made in transmission.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This option will be made obsolete by either a Learning Expert System witn Internal Simulation or Fault Tolerant Software.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This option is currently in use.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Human on Ground with Computer Assistance.

DECISION CRITERIA COMPARISON CHART

GFE: g57 FORM HYPOTHESIS FOR PROBLEM

GFE TYPE: H. Fault Diagnosis and Handling

ORIGINAL PAGE IS OF POOR QUALITY

The formulation of a hypothesis to explain anomalous data, identifying suspected defective hardware or software.

4E.461

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	2	4	3	3	2	2	1	
14.4 HUMAN WITH CHECKLIST	3	3	2	3	3	3	1	C.T.
14.5 HUMAN JUDGMENT ON GROUND	3	2	2	3	4	3	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	2	5	3	4	2	2	1	
14.8 ONSITE HUMAN JUDGMENT	3	4	2	4	4	3	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	2	5	3	2	1	1	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	2	1	1	5	
24.1 THEOREM PROVING PROGRAM	2	4	4	2	2	1	3	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g57 Form Hypothesis For Problem

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The use of computer routines speeds up the decision-making process.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes software development and operator training costs. The software development is expected to be more expensive than the production of checklists.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. Comparable to the salary and checklist update costs of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. The greater versatility of this capability outdates checklists. Only very sophisticated automation can replace human judgement in this task.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Human With Checklist is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g57 Form Hypothesis For Problem

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This consists mainly of personnel costs. This is current technology. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: If the problem is not one that was considered in the development of the checklist, the checklist will not identify it correctly. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g57 Form Hypothesis For Problem

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Less maintenance is required to support a human on ground than in space. This capability was judged below current technology as it does not require the maintenance of a checklist.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human on ground is less expensive to support than a human in space.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist; however, it is conceivable that a checklist user would not be as familiar with the problem as someone who would be relied upon to make judgmental decisions. A human on ground receives the same criteria value as an onsite human because while the human on ground is probably less able to form an accurate hypothesis without first hand access to the problem, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially diagnose a problem more accurately.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Same as current technology. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Human With Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g57 Form Hypothesis For Problem

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: In this case, human judgment is the most important factor, with calculations performed by the computers.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used. Only very sophisticated automation can replace human judgement in this task.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment Function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human Judgment
CODE NUMBER: 14.8   DATE: 6/25/82   NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g57 Form Hypothesis For Problem

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: More maintenance is required to support a human in space than on ground. This consists primarily of astronaut life support, which is costly compared to electronic equipment maintenance. There is also down time (8-hour workday).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human in space is more expensive to support than one on the ground. Astronauts' dedicated time is valuable, roughly $100k/person-day (Stephen B. Hall, NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist; however, it is conceivable that a checklist user would not be as familiar with the problem as someone who would be relied upon to make judgmental decisions. An onsite human receives the same criteria value as a human on ground because while the human in space is probably better able to form an accurate hypothesis with first hand access to the problem, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially form a more accurate hypothesis.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Same as current technology. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Human With Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g57 Form Hypothesis for Problem

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: An Expert System will significantly outperform the human with computer assistance. The Expert System is faster than the Human with Computer Assistance in hypothesis formulation.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. If the expert system is in space, it requires expensive in space human and computer maintenance. If the expert system is on the ground, this criteria value should be a 4. In any case the data base needs checks and updates by qualified operators.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain in which hypothesis formulation is to be accomplished.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring costs will be a function of computer time, necessary maintenance of system hardware, and updates of the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning,' the Expert System never will be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The generation of a hypothesis for problem solving is principally one of the typical applications for which an expert system is constructed (such as the current medical system EMYCIN at Stanford AI).

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is "Human with Checklist" for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g57 Form Hypothesis for Problem

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the learning expert system is operational it will accomplish the task of hypothesis formulation for problem solving. Most tasks will be performed within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Theorem Proving Program
CODE NUMBER: 24.1 DATE: 7/5/82 NAME(S): Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g57 Form Hypothesis For Problem

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Having a human suggest alternatives for the program to consider will slow down the system slightly, but it will still be faster than a Human with Checklist.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The programming is not adaptive so new problem configurations require new programming. The hardware also requires maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The investment required to refine and adapt current prototype theorem proving programs to specific applications is fairly substantial.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring costs should be very similar to those for an Expert System Under Human Supervision.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Theorem proving programs should have a high success rate in a given problem area, provided that the problem can be stated as if-then relationships. Since the system has no creativity, a human must suggest hypotheses for the problem, and the system checks on their likelihood of success.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The theorem proving ability will never become obsolete. In fact, it is desirable that a Theorem Proving program be incorporated into a Learning Expert System with Internal Simulation.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: It will take a considerable effort to develop the data base and programming necessary to formulate hypotheses accurately.

OTHER REMARKS AND SPECIAL ASPECTS: In order for a theorem proving program to form a hypothesis for a problem, it will be necessary that a human suggest alternatives that the computer will attempt to evaluate. The current technology capability for performing this functional element is a Human with Checklist. Expert systems (capabilities 23.1 and 23.2) can also perform this task, but they behave as Theorem Proving Programs in doing so.

DECISION CRITERIA COMPARISON CHART

GFE: 958 DEVISE TEST FOR FAILURE HYPOTHESIS

GFE TYPE: H. Fault Diagnosis and Handling

The definition of a test to validate or disprove a hypothesis on a spacecraft failure. The output of this task is a set of commands to be sent to the spacecraft, and a description of the expected responses which would confirm the suspected failure. The output of the task could also be a sequence of procedures (e.g. disassembly and examination of components) to be carried out onsite.

CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	2	4	3	3	2	2	1	
14.4 HUMAN WITH CHECKLIST	3	3	2	3	3	3	1	C.T.
14.5 HUMAN JUDGMENT ON GROUND	3	2	2	3	4	3	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	2	5	3	4	2	2	1	
14.8 ONSITE HUMAN JUDGMENT	3	4	2	4	4	3	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	2	5	3	2	1	1	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	2	1	1	5	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g58 Devise Test For Failure Hypothesis

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The use of computer routines speeds up the decision-making process.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes software development and operator training costs. The software development is expected to be more expensive than the production of checklists.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. Comparable to the salary and checklist update costs of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. The greater versatility of this capability outdates checklists. Only very sophisticated automation can replace human judgement in this task.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Human With Checklist is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g58 Devise Test For Failure Hypothesis

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This consists mainly of personnel costs. This is current technoiogy. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: There is always the possibility that the checklist does not deal with the problem at hand, so the computer-aided systems are more likely to succeed. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g58 Devise Test For Failure Hypothesis

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Less maintenance is required to support a human on ground than in space. This capability was judged below current technology as it does not require the maintenance of a checklist.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human on ground is less expensive to support than a human in space.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist; however, it is conceivable that a checklist user would not be as familiar with the problem as someone who would be relied upon to make judgmental decisions. A human on ground receives the same criteria value as an onsite human because while the human on ground is probably less able to devise an accurate test without first hand access to the problem, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially devise a better test.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Same as current technology. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Human With Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g58 Devise Test For Failure Hypothesis

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: In this case human judgment is the most important factor, with calculations performed by the computers.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used. Only very sophisticated automation can replace human judgement in this task.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human Judgment
CODE NUMBER: 14.8 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g58 Devise Test For Failure Hypothesis

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: More maintenance is required to support a human in space than on ground. This consists primarily of astronaut life support, which is costly compared to electronic equipment maintenance. There is also down time (8-hour workday).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human in space is more expensive to support than one on the ground. Astronauts' dedicated time is valuable, roughly \$100k/person-day (Stephen B. Hall, NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist; however, it is conceivable that a checklist user would not be as familiar with the problem as someone who would be relied upon to make judgmental decisions. An onsite human receives the same criteria value as a human on ground because while the human in space is probably better able to devise a good test with first hand access to the problem, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially devise a better test.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Same as current technology. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Human With Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g58 Devise Test for Failure Hypothesis

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: An Expert System will significantly outperform the human with computer assistance. The Expert System is faster than the Human with Computer Assistance in formulating a proof test for a hypothesis.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. As the expert system is in space, it requires expensive in space human and computer maintenance. If the expert system is on the ground this criteria value should be a 4. In any case, the data base requires checks and updates by qualified operators.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain in which the test of a failure hypothesis is to be defined.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring costs will be a function of computer time and necessary maintenance of system hardware, and updates of the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never by obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The determination of a test for a failure hypothesis is one of the expected functions of an Expert System (e.g., EMYCIN at Stanford AI).

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option for this GFE is "Human with Checklist".

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g58 Devise Test for Failure Hypothesis

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: A Learning Expert System, once operational, will accomplish the task generating tests to determine the failure of a hypothesis. Moreover, this function is an integral aspect of an Expert System, and as such, an integral aspect of a Learning Expert System. Most tasks will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is Human with Checklist.

DECISION CRITERIA COMPARISON CHART

GFE: g60 IDENTIFY FAULTY COMPONENT

GFE TYPE: H. Fault Diagnosis and Handling

The confirmed identification of a specific piece of defective spacecraft hardware. This task includes the application of methods to trace the cause of the failure.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	2	4	3	3	2	3	1	
14.4 HUMAN WITH CHECKLIST	3	3	2	3	3	3	1	C.T.
14.5 HUMAN JUDGMENT ON GROUND	3	2	2	3	4	3	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	2	5	4	4	2	2	2	
14.8 ONSITE HUMAN JUDGMENT	3	4	2	4	4	3	1	
23.1 EXPERT SYSTEM WITH HUMAN SUPERVISION	1	5	3	2	2	2	2	
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	1	4	5	1	1	1	5	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	2	4	3	1	2	2	1	
27.1 EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	1	4	3	1	2	1	2	
27.2 EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	3	5	3	4	1	2	2	
27.3 EQUIPMENT FUNCTION TEST VIA TELEMETRY	3	4	3	3	2	2	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The use of computer routines speeds up the decision-making process.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes software development and operator training costs. The software development is expected to be more expensive than the production of checklists.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software. Comparable to the salary and checklist update costs of current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. Both this and current technology will be replaced by more thorough or onboard options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Human With Checklist is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives. This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost. This is current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This consists mainly of personnel costs. This is current technology. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: If the problem is not one that was considered in the development of the checklist, the checklist will not identify it correctly. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element.

MAINTENANCE (1 LITTLE, 5 LOT): 2
REMARKS AND DATA SOURCES: Less maintenance is required to support a human on ground than in space. This capability was judged below current technology as it does not require the maintenance of a checklist.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human on ground is less expensive to support than a human in space.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist; however, it is conceivable that a checklist user would not be as familiar with the problem as someone who would be relied upon to make judgmental decisions. A human on ground receives the same criteria value as an onsite human because while the human on ground is probably less able to identify the faulty component without first hand access to the problem, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially identify the faulty component more accurately.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Same as current technology. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Humar With Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This procedure consists of comparing observed test responses to calculated ones, which can be reliably performed by a computer under human direction.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is a Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human Judgment
CODE NUMBER: 14.8 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: More maintenance is required to support a human in space than on ground. This consists primarily of astronaut life support, which is costly compared to electronic equipment maintenance. There is also down time (8-hour workday).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human in space is more expensive to support than one on the ground. Astronauts' dedicated time is valuable, roughly \$100k/person-day (Stephen B. Hall, NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist; however, it is conceivable that a checklist user would not be as familiar with the problem as someone who would be relied upon to make judgmental decisions. An onsite human receives the same criteria value as a human on ground because while the human in space is probably better able to identify a faulty component with first hand access to the problem, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially identify a faulty component more accurately.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Same as current technology. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Human With Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Expert System with Human Supervision
CODE NUMBER: 23.1 DATE: 5/12/82 NAME(S): Jones-Oliveira/Glass/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: An Expert System will significantly outperform the human with computer assistance. The Expert System is faster than the Human with Computer Assistance in the determination of a conclusion from data.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Based on Hayes-Roth's research: The reliability of this application of an Expert System is functionally dependent upon the longevity of the supporting system hardware. If the expert system is in space, it requires expensive in space human and computer maintenance. In any case, the data base requires checks and updates by qualified operators. If the expert system is on the ground, this criteria value should be a 4.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Based on Hayes-Roth and Feigenbaum's research: It is not unreasonable to expect a 2 to 3 man-year period to refine already existing Expert Systems to specifically meet the needs of a particular knowledge domain in which faulty component detection is to be accomplished.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring costs will be a function of computer time, necessary maintenance of the system's hardware and updates of the data base.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Expert Systems tested to date have high success ratings for a given problem domain.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The useful life of an Expert System is long; given that representations of knowledge will evolve along with optimization techniques for system "reasoning," the Expert System will never be obsolete, merely updated and refined as an evolutionary process.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The identification of a faulty component is a task essentially similar to current diagnostic uses of expert systems (e.g., EMYCIN at Stanford AI).

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is "Human with Checklist" for this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 7/3/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Once the learning expert system is operational the task of faulty component identification will be a simple exercise and will be accomplished within seconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accommodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its develoment for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. The current technology for this GFE is a Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This automated program is faster than options including humans.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The software updates and communications link maintenance are more substantial than the updates of checklists.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This task involves complex decisions from partial data. Therefore the software development is more expensive than the production of checklists.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Much less than the human salary required by the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Comparable to several other automated options, this capability is superior to unassisted human judgement, but surpassed by Equipment Function Test by Onsite Human and Learning Expert System.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: More reliable than current technology, therefore preferred. Onboard or more sophisticated software will replace it.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Compared to the onboard computational systems, this option is comparable to current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for this GFE is a Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/28/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The inherent speed advantage that computers have over humans is the primary reason for the low time rating. Close proximity of the computer gives it a speed advantage over systems which are on the ground.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This capability recieves a less favorable maintenace rating than current technology, because of the extra expense of maintaining space-based equipment.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The costs to develop the software should be comparable to current technology.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because there is no need for human interaction; nobody has to monitor the telemetry.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The computer is not likely to overlook items or make careless mistakes which humans occasionally do. Therefore this system receives a lower failure-proneness rating. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The fully autonomous nature of this system gives it a more favorable useful life rating than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The risks include the development of the software in adherance to the spacecraft safety codes.

OTHER REMARKS AND SPECIAL ASPECTS: There are some instances, however, where a function test will not be desirable for safety reasons. Testing the firing mechanism of a solid rocket booster is one such example.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Time to complete will be comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: A human in space requires considerable maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost includes the cost of development of the dedicated microcomputer as well as the development cost of the function test.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. It costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: A function test will be very good at finding the source of a problem. The human in the loop also improves its reliability. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The high reliablity of this system gives this capability a longer useful life.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes the development of the dedicated microcomputer and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: There are some instances where a function test will not be desirable for safety reasons. Testing the firing mechanism of a solid rocket booster is one such example. This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer). Current technology is Human with Checklist.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Jones-Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g60 Identify Faulty Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time necessary for the function test to find the faulty component is comparable to the time for current technology. This includes the time lag associated with communication between earth orbit and the ground.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The maintenance necessary for this capability includes the maintenance of the communications link. The equipment necessary for this capability is more complicated than the equipment used in current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes the cost of equipping the spacecraft with the necessary equipment.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring cost will be comparable to current technology. This capability uses about the same amount of dedicated human time as current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The failure-proneness will be lower than current technology because the exact nature of the failure will be found, leading to a more reliable diagnosis of the problem.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The higher reliability and comparable cost gives this capability a longer useful life than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This system is already developed.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human with Checklist.

DECISION CRITERIA COMPARISON CHART

GFE: g65 DEFINE ACCESS SEQUENCE

GFE TYPE: H. Fault Diagnosis and Handling

The formulation of a sequence of commands and procedures to yield physical access to a particular spacecraft component, usually for the purpose of repair. Besides the definition of the proper sequence of disassembly and removal of any surrounding hardware (e.g. thermal blankets, micrometeorite shields), this task also includes the formulation of an acceptably safe sequence of equipment shutdowns and disconnections, to avoid causing damage to other spacecraft components. Also involved is the safety of the human or device which will access the component of interest. This task may involve choices between alternative methods of access.

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CANDIDATE ARAMIS CAPABILITIES:

DECISION CRITERIA

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.2 HUMAN ON GROUND WITH COMPUTER ASSISTANCE	2	4	3	3	2	3	1	
14.5 HUMAN JUDGMENT ON GROUND	3	3	2	3	3	3	1	C.T
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	2	5	4	4	2	2	1	
14.8 ONSITE HUMAN JUDGMENT	3	4	2	4	3	3	1	
24.1 THEOREM PROVING PROGRAM	1	4	5	2	2	1	4	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human On Ground With Computer Assistance
CODE NUMBER: 14.2 DATE: 3/19/82 NAME(S): Spofford/Howard
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g65 Define Access Sequence

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The use of computer routines speeds up the decision-making process.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This is mostly maintenance of the computer hardware and software. A high-reliability computer system (such as the Tandem Non-Stop) is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes software development and operator training costs, more expensive than the more complex training for current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Includes operator salary and maintenance of computer hardware and software, comparable to the higher salary for current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human with a computer may not be able to explore all possibilities to find the optimum result, but the operator can compare results with expectations and intelligently direct the search. The computer hardware is expected to be very reliable.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The ground-based software may be upgraded and the operator retrained to improve the capability. The onsite human option and the Theorem Proving Program are better in the long run.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is in use today.

OTHER REMARKS AND SPECIAL ASPECTS: Human Judgement On Ground is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g65 Define Access Sequence

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This capability is current technology. The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This capability is current technology. Less maintenance is required to support a human on ground than in space.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This capability is current technology and requires no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability is current technology. A human on ground is less expensive to support than a human in space.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability is current technology. A human on ground receives the same criteria value as an onsite human because while the human on ground is probably less able to define an access sequence without first hand observation to the situation, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially define the access sequence more accurately.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This capability is current technology. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability is current technology and there is no developmental risk associated with it.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY 'AME: Onsite Human With Computer Assistance
CODE NUMBE..: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g65 Define Access Sequence

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: In this case human judgment is the most important factor, with calculations and bookkeeping performed by the computers.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used. This may be an advantage during repair functions, if unexpected problems occur. Only sophisticated automation can replace human judgment if the access sequence is complex.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Human Judgment on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human Judgment
CODE NUMBER: 14.8 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g65 Define Access Sequence

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: More maintenance is required to support a human in space than on ground. This consists primarily of astronaut life support, which is costly compared to electronic equipment maintenance. There is also down time (8-hour workday).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human in space is more expensive to support than one on the ground. Astronauts' dedicated time is valuable, roughly \$100k/person-day (Stephen B. Hall, NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: An onsite human receives the same criteria value as a human on ground because while the human in space is probably better able to accurately define an access sequence with first hand observation of the situation, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially devise a better access sequence.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Same as current technology. Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this GFE is Human Judgment on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Theorem Prc ing Program
CODE NUMBER: 24.1 DAT_: 7/5/82 NAME(S): Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g65 Define Access Sequence

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: No human is required for this capability as it operates autonomously on a computer, and hence implementation is very rapid.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The programming is not adaptive so new spacecraft configurations require new programming. The hardware also requires maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The investment required to refine and adapt current prototype theorem proving programs to specific applications is fairly substantial.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The system operates autonomously, requiring no salary (as would be necessary for a human).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Theorem proving programs should have a high success rate in a given problem area, provided the problem can be stated as if-then relationships.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The theorem proving ability will never become obsolete. In fact, it is desirable that a Theorem Proving Program be incorporated into a Learning Expert System with Internal Simulation.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: It will take a considerable effort to develop the data base and programming necessary for a theorem proving program to become proficient at defining an access sequence.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Human Judgement on Ground. Expert systems (capabilities 23.1 and 23.2) can also perform this task, but they behave as Theorem Proving Programs in doing so.

DECISION CRITERIA COMPARISON CHART

GFE: g77 DETERMINE CORRECTION ALGORITHM

GFE TYPE: H. Fault Diagnosis and Handling

The definition of a piece of spacecraft or ground support software, to replace or patch defective software, thus restoring the system's nominal operation. This may involve trying potential correction algorithms on a simulation of the overall system. In some cases, an alternative computer procedure (e.g. reloading the system) may be sufficient to solve the problem.

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.5 HUMAN JUDGMENT ON GROUND	3	3	2	3	3	3	1	c.r.
16.1 COMPUTER MODELING AND SIMULATION	2	4	3	2	2	2	2	
22.1 AUTOMATIC PROGRAMMER AND PROGRAM TESTER	2	4	3	1	2	2	3	
24.1 THEOREM PROVING PROGRAM	2	4	4	2	1	1	4	
26.1 FAULT TOLERANT SOFTWARE	1	3	5	1	2	1	5	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g77 Determine Correction Algorithm

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This capability is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This capability has no hardware or software to maintain.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This capability requires no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This includes salary, but it does not include any computer costs (as are associated with the other options for performing this capability).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: This is the current technology capability for performing this GFE.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Modeling And Simulation
CODE NUMBER: 16.1 DATE: 3/19/82 NAME(S): Spofford/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g77 Determine Correction Algorithm

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This is faster than current technology (Human Judgement on Ground) because more of the operation is automated.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This includes computer hardware and software maintenance and is comparable to current technology. A high-reliability computer system is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This includes the development of a comprehensive system model and generation of the computer database. The cost of writing the software to manipulate the database is also included in the nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This includes the operator's salary, hardware and software maintenance, and the cost of updating the database as the spacecraft changes. This is less than current technology because less operator time is needed.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: As long as the computer model of the system is accurate, this capability is not likely to fail. It is more reliable than the current technology option because the computer can manipulate more information in its database than a human can.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: This capability has a long useful life because the database may be updated as the spacecraft software changes. The system model can be upgraded to include failures and design changes as necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development and validation of a sufficiently accurate database is a major risk of this option.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Human Judgment On Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Automatic Programmer And Program Tester
CODE NUMBER: 22.1 DATE: 5/27/82 NAME(S): Thiel/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g77 Determine Correction Algorithm

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This capability, when provided with a suggested general method of solving a problem, can quickly generate detailed software to implement the proposed solution. This solution can be suggested by a human operator or by another computer program.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Since humans will probably be involved with the system it will require more maintenance than humans alone. Also, this system must be kept updated as to spacecraft state so that its software will be able to properly model the spacecraft's.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The initial software cost of an Automatic Programmer is high due to technology development and because it must be programmed with specific information about the system for which it is writing software. This cost depends on the complexity of the software to which this capability is applied. The given rating assumes that relatively simple software needs patching.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The cost of operation is low, because this system combines human judgement with the speed of the computer. It quickly generates software that is accurate, based upon a spacecraft controller's expert opinion of the best way to solve a problem.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The system is less likely to make a programming error than Human Judgement of Ground.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The Automatic Programmer is able to perform many programming functions and will become more important as software complexity increases.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: Prototypes have been developed for some ground based applications. The current technology for performing this functional element is Human Judgement on Ground.

OTHER REMARKS AND SPECIAL ASPECTS: Requires input to determine program goals. Useful for general software development, such as upgrades of spacecraft software. The current technology capability for this GFE is Human Judgment on Ground.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Theorem Proving Program
CODE NUMBER: 24.1 DATE: 7/5/82 NAME(S): Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g77 Determine Correction Algorithm

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Having a human suggest alternatives for the program to consider will slow down the system slightly, but it will still be faster than Human Judgment on Ground.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The programming is not adaptive so new problem configurations require new programming. The hardware also requires maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The investment required to refine and adapt current prototype theorem proving programs to specific applications is fairly substantial.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Recurring costs should be very similar to those for computer modeling and simulation.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Theorem proving programs should have a high success rate in a given problem area, provided that the problem can be stated as if-then relationships. Since the system has no creativity, a human must suggest correction algorithms, and the system checks on their likelihood of success.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The theorem proving ability will never become obsolete. In fact, it is desirable that a Theorem Proving Program be incorporated into a Learning Expert System with Internal Simulation.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: It will take a considerable effort to develop the data base and programming necessary to adequately determine the validity of a correction algorithim.

OTHER REMARKS AND SPECIAL ASPECTS: In order for a theorem proving program to determine correction algorithms, it will be necessary that a human suggest alternatives that the computer will attempt to evaluate. The current technology capability for performing this functional element is Human Judgment on Ground. Expert systems (capabilities 23.1 and 23.2) can also perform this task, but they behave as Theorem Proving Programs in doing so.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Fault Tolerant Software
CODE NUMBER: 26.1 DATE: 6/28/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g77 Determine Correction Algorithm

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The fault tolerant software will be slightly faster than the automatic programmer or theorem proving program because it is an integrated system designed specifically to determine fault recovery options. It should be very much faster than a human for simple correction procedures. For complex problems it should also be faster than a human, but this assumes a very sophisticated system.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: One of the key goals of the fault tolerant software is the ability to be self checking and self maintaining. The software executes self checks and performs its own updating to reflect changes in the spacecraft's systems. In this case it is ranked equal to humans because ground based humans require no maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Some versions of fault tolerant software presently exist for aircraft computers. The advanced capabilities envisioned here are in the preliminary research stage and will be expensive to develop.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Spacecraft downtime is expensive so the faster the recovery from a fault, the lower the cost. Since the fault tolerant software mormally controls the spacecraft it has an advantage over other options because it can perform high speed tests by commanding spacecraft functions and observing the results. This will often be necessary because sensors do not always provide enough reliable data for an immediate conclusion.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Due to the potential complexity of the logic operations involved and the uncertainty of reliable data being available, it is likely that some errors will be made. The theorem proving program may be slightly less likely to err because of its rigid logic requirements, but its advantage could be eliminated by its inability to operate on probabilities (sensors assigned a probability of being correct, for example) thus rendering it unable to reach a conclusion.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This application of fault tolerant software is one which will become necessary as spacecraft systems reach greater levels of complexity.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: This is a very advanced technology which will require significant advances in computer science before it is available.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Human Judgment on Ground.

DECISION CRITERIA COMPARISON CHART

GFE: g194 IDENTIFY FAULTY SOFTWARE

GFE TYPE: H. Fault Diagnosis and Handling

The confirmed identification of a specific piece of defective spacecraft or ground support software, or of a specific computer procedure causing anomalous responses. This task includes the application of methods to trace the problem (e.g. test subroutines on simulations).

4E.502

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
14.4 HUMAN WITH CHECKLIST	5	2	1	2	4	5	1	
14.5 HUMAN JUDGMENT ON GROUND	5	1	1	2	4	4	1	
14.7 ONSITE HUMAN WITH COMPUTER ASSISTANCE	4	5	3	4	3	4	2	
14.8 ONSITE HUMAN JUDGMENT	5	4	2	4	4	4	1	
16.1 COMPUTER MODELING AND SIMULATION	3	3	2	3	3	3	1	C.T.
23.2 LEARNING EXPERT SYSTEM WITH INTERNAL SIMULATION	2	4	5	1	1	1	5	
24.1 THEOREM PROVING PROGRAM	3	3	4	3	2	2	4	
25.4 DETERMINISTIC COMPUTER PROGRAM ON GROUND	3	3	2	3	3	3	1	
26.1 FAULT TOLERANT SOFTWARE	2	1	3	2	2	1	3	
27.1 EQUIPMENT FUNCTION TEST BY ONBOARD COMPUTER	2	4	2	2	3	3	2	
27.2 EQUIPMENT FUNCTION TEST BY ONSITE HUMAN	4	5	3	4	3	3	2	
27.3 EQUIPMENT FUNCTION TEST VIA TELEMETRY	3	3	2	3	4	4	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human With Checklist
CODE NUMBER: 14.4 DATE: June 1982 NAME(S): Howard/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: This is slower than any of the more automated alternatives.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: No maintenance is required for a human on the ground, but updating a checklist to account for changes in mission goals or spacecraft parameters will incur some maintenance cost.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: Less development is needed than for the other alternatives.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This consists mainly of personnel costs, which are low for this task. The human is on the ground.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The human with checklist is less capable than a human with computer assistance, for example, since the computer could at least keep track of the checklist, and potentially aid in other ways. The extra capabilities of a computer would increase reliability, particularly for complex tasks. However, there is also some chance that the computer hardware would break down, and the checklist would not.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Eventually many systems will become too complex for this method to be feasible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Computer Modeling and Simulation.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Judgment On Ground
CODE NUMBER: 14.5 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element. It would probably take a human without any form of computer assistance considerably longer than one able to perform computer modeling and simulation.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Less maintenance is required to support a human on ground than in space. This capability was judged below current technology as it does not require the maintenance of computer hardware, software, and its associated database.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 1
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human on ground is less expensive to support than a human in space. This capability has none of the costs associated with buying and operating a computer, as does the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A person without access to computer facilities would certainly be more likely to err than a person with that support. A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist; however, it is conceivable that a checklist user would not be as familiar with the problem as someone who would be relied upon to make judgmental decisions. A human on ground receives the same criteria value as an onsite human because while the human on ground is probably less able to identify the faulty software without first hand access to the problem, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially identify the faulty software more accurately.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Computer Modeling and Simulation.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human With Computer Assistance
CODE NUMBER: 14.7 DATE: June 1982 NAME(S): Howard/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: This takes longer than the fully automated onsite alternatives, but is faster than an unassisted human.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: The maintenance includes life support for the astronaut and down-time for both the astronaut (8-hour workdays) and the computers (which may be pre-empted for flight-critical functions).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The only hardware developments required are task-specific interfaces. Development of appropriate software, and its validation on the orbiter computers, are also required. Training of the astronaut is included here, also.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The flight computer system requires considerable attention by the crew; this contributes to recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The procedure consists of comparing observed test responses to calculated ones, which can be reliably performed by a computer under human direction.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The hardware and human will be available when the shuttle is used, but in many cases a fully automatic system will ultimately be preferred.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software would need to be developed, and there is some chance that the (fixed) hardware configuration would be unsuitable.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses the Shuttle orbiter computers to support the onsite human (not to be confused with Equipment function Test or Equipment Data Checks by Onsite Human, which use dedicated microprocessors). Current technology for this GFE is Computer Modeling and Simulation.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onsite Human Judgement
CODE NUMBER: 14.8 DATE: 6/25/82 NAMES: Kurtzman/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: The location of the human (onsite vs. ground) would probably not affect the time to complete this functional element. A human without any form of computer assistance would take considerably longer than one able to perform computer modeling and simulation in most situations.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: More maintenance is required to support a human in space than on ground. This consists primarily of astronaut life support, which is costly compared to electronic equipment maintenance. There is also down time (8-hour workday). This capability does not require the maintenance of computer hardware, software, and its associated database.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is a currently employed capability requiring no research and development except for any necessary training and simulation costs.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A human in space is more much expensive to support than one on the ground. Astronauts' dedicated time is valuable, roughly $100k/person-day (Stephen B. Hall, NASA MSFC). This capability has none of the costs associated with buying and operating a computer, as does the current technology option.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A person without access to computer facilities would certainly be more likely to err than a person with that support. A human with judgment could conceivably make a judgmental error or not think something out as well as would be done by a preparer of a checklist; however, it is conceivable that a checklist user would not be as familiar with the problem as someone who would be relied upon to make judgmental decisions. An onsite human receives the same criteria value as a human on ground because while the human in space is probably better able to identify the faulty software with first hand access to the problem, there are a large number of people available on ground, some of which probably have expertise beyond that of any onsite human, and hence could potentially identify the faulty software more accurately.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: Human judgment will never be obsolete, but eventually it is desirable that autonomous systems perform as much of this functional element as possible.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: There is no developmental risk associated with this capability.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Computer Modeling and Simulation.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Computer Modeling And Simulation
CODE NUMBER: 16.1 DATE: 3/19/82 NAME(S): Spofford/Akin
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This includes computer hardware and software maintenance. This is current technology. A high-reliability computer system is assumed.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This includes the development of a comprehensive system model and generation of the computer database. The cost of writing the software to manipulate the database is also included in the nonrecurring cost. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This includes the operator's salary, hardware and software maintenance, and the cost of updating the database as the spacecraft changes. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: With Computer Modeling And Simulation it is possible to model things that are not directly testable. As long as the computer model of the system is accurate, this capability is not likely to fail. It is more reliable than human judgement options because the computer can manipulate more information in its database than a human can. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This capability has a long useful life because the database may be updated as the spacecraft software changes. The system model can be upgraded to include failures and design changes as necessary. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Learning Expert System with Internal Simulation
CODE NUMBER: 23.2 DATE: 5/12/82 NAME(S): Jones-Oliveira/Dalley/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Once the system is fully operational, most tasks will be accomplished within seconds. Since the behavior of healthy software can be exactly predicted, this is a straightforward verification task.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: System is available continuously and down-time will result primarily from software aspects in early use. Some update and expansion of the data base will be needed as requirements evolve.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: The necessary technology is being pursued simultaneously by several groups across the country. Much could be gained from a synthesis of these parallel efforts.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Computing time will dominate the operating budget (cheap after debugging). At first, the system will require a quality software engineering team until the system "learns enough" to monitor itself.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: An inherent aspect to learning is failure as well as success; therefore, human monitoring will be necessary in the system's early development. This supervision will be inversely proportional to the learning accomplished.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The system will improve itself with experience and is therefore able to adapt to accomodate new situations, thus avoiding technical obsolescence.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: The expert system is current technology. The learning aspect requires further development, and may be a complex problem depending on the actual situation the system is applied to.

OTHER REMARKS AND SPECIAL ASPECTS: If successfully developed, this system will be an adaptable tool with multiple applications. It has the potential to make rapid multi-variable decisions, and therefore may enable certain space activities otherwise considered too risky. It may, however, be difficult to justify its development for a single application. Its advantage is its ability to adapt and apply the knowledge learned from one situation to another. Therefore, its justification is as cumulative as its learning. Large data base cuts down on choices, therefore combinatories. on which theorem proving must be computed. The current technology for this GFE is Computer Modeling and Simulation.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Theorem Proving Program
CODE NUMBER: 24.1 DATE: 7/5/82 NAME(S): Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: No human is required for this capability as it operates autonomously on a computer, and hence implementation is very rapid.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The programming is not adaptive so new problem configurations require new programming. The hardware also requires maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: The investment required to refine and adapt current prototype theorem proving programs to specific applications is fairly substantial.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The system operates autonomously, requiring no salary (as would be necessary for a human).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Theorem proving programs should have a high success rate in a given problem area, provided that the problem can be stated as if-then relationships.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The theorem proving ability will never become obsolete. In fact, it is desirable that a Theorem Proving Program be incorporated into the more advanced Learning Expert System with Internal Simulation.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: It will take a considerable effort to develop the data base and programming necessary to identify faulty software.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for performing this functional element is Computer Modeling and Simulation. The expert systems (capabilities 23.1 and 23.2) could also do this task, but they would behave as Theorem Proving Programs in doing so.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Deterministic Computer Program on Ground
CODE NUMBER: 25.4 DATE: 7/8/82 NAME(S): Jones-Oliveira/Glass/Oliveira/Smith
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The software updates and communications links maintenance are comparable to the computer model updates of current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The computational options for this task are roughly comparable, except for very advanced software.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The maintenance costs and human salary costs for this capability are comparable to those for Computer modeling and Simulation.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Comparable to current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Comparable to other computational options, but likely to be replaced by advanced software systems.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The complexity of this capability is similar to that of the current technology option.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology capability for this GFE is Computer Modeling and Simulation. Since the Deterministic Computer Program on Ground resembles this current technology option in the performance of this task, it is not surprising that it received equivalent criteria values.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Fault Tolerant Software
CODE NUMBER: 26.1 DATE: 7/3/82 NAME(S): Thiel/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG):2
REMARKS AND DATA SOURCES: The fault tolerant software uses theorem proving and software comparison techniques to verify that the software is logically self consistent. Currently this can only be done for simple programs because larger programs cause combinatorial expansion problems when theorem proving techniques are applied. Fault tolerant software might be significantly faster than pure theorem proving techniques because the fault tolerant software can use other analysis methods to reduce the size of the problem and thus reduce the combinatorial difficulties.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: One of the key goals of the fault tolerant software is the ability to be self checking and self maintaining. The software executes self checks and performs its own updating to reflect changes in the spacecraft's systems.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Compared with current technology (simulation and test) fault tolerant software is expensive, but it is far less so than an advanced learning expert system.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Fault tolerant software is less expensive than options with human involovement because it is much faster than humans and requires less maintenance. It is more expensive than the learning expert system because the expert system may be able to recognize faulty software without resorting to theorem proving techniques which consume large amounts of computer time.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The fault tolerant software is not likely to make an incorrect decision, but it may be unable to reach a decision. The expert system has the same information and techniques available to it as does the fault tolerant software, but it also has a large data base of "experience" to use in its analysis. Consequently the expert system is slightly less failure-prone than the fault tolerant software.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: This application of fault tolerant software is one which will become necessary as spacecraft software reaches greater levels of complexity.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: This is a very advanced technology which will require significant advances in computer science before it is available.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology for performing this functional element is Computer Modeling and Simulation.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onboard Computer
CODE NUMBER: 27.1 DATE: 6/26/82 NAME(S): Marra/Dalley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The function test is faster than current technology, as it can pinpoint the source of a malfunction quickly. Computer simulations, on the other hand, to go through the different possibilities in order to find the faulty subroutine.

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: This capability recieves a less favorable maintenace rating than current technology, because of the extra expense of maintaining space-based equipment.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The nonrecurring cost, to develop the appropriate function test should be about the same as for the current technology simulation software.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The recurring cost is lower than current technology because there is no human component in the loop. Eventually a human evaluates the results of the Computer Modeling and Simulation, while in this case the onboard computer handles the entire process.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Failure-proneness is comparable to current technology, maybe slightly lower. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The useful life of this system is about the same as current technology. it will eventually be replaced by the more sophisticated Theorem Proving Program.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The development of the necessary software in adherance with the spacecraft computer safety codes is the primary risk involved.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Computer Modeling and Simulation. A function test will not always be desirable for saftey reasons. Using an equipment function test on defective software can make the problems worse.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test by Onsite Human
CODE NUMBER: 27.2 DATE: 6/26/82 NAME(S): Marra/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The human in the loop makes this system slower than current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: A human in space requires considerable maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Nonrecurring cost includes the developmental cost of the dedicated microcomputer and cost of the function test.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Recurring costs include the life support of the operator. It costs $100,000 a day to keep one human in space (discussion with Stephen B. Hall of NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This system will be no better or worse at finding software problems than current technology. Under certain conditions, however, a function test may actually cause damage if a malfunctioning system is being tested.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Useful life is about the same as current technology, somewhat shorter than the more advanced Theorem Provirg Program.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Developmental risk includes the development of the dedicated microcomputer and the associated software.

OTHER REMARKS AND SPECIAL ASPECTS: This capability uses a dedicated microprocessor to support the onsite human (not to be confused with Onsite Human with Computer Assistance, which uses the Shuttle orbiter computer). Current technology is Computer Modeling and Simulation.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Equipment Function Test via Telemetry
CODE NUMBER: 27.3 DATE: 7/2/82 NAME(S): Marra/Oliveira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g194 Identify Faulty Software

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This system will be about as fast as current technology. The function test will find the cause of difficulty faster than current technology, but the human in the loop slows it down. The time delay associated with communicating between the ground and earth orbit is another factor.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The need for maintaining the communications links will be about the same as current technology.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The cost to develop the appropriate function test will be about the same as developing the simulation software.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Recurring cost is comparable to current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Because of the distance involved in this capability, it will not always be possible to determine if the malfunction resides in the hardware or the software. Under certain conditions, the function test can make the problems worse

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The lower reliability gives this capability a less favorable useful life rating than current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: The developmental risk includes designing the function test in adherance with spacecraft saftey codes.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Computer Modeling and Simulation.

DECISION CRITERIA COMPARISON CHART

GFE: g69 OBSERVE/LOCATE DEFECTIVE COMPONENT

GFE TYPE: I. Sensing

The determination of the position of a defective spacecraft component, with sufficient accuracy to allow close scanning (e.g. with diagnostic sensors) or repair and adjustment (e.g. with a manipulator). It is assumed that the system already knows which component is defective; but it must recognize the correct component amid other spacecraft components. More generally, this task includes the recognition and location of any spacecraft component, assuming that the approximate shape and location of the component are known (so that template-matching pattern recognition can be used, rather than total scene interpretation).

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
6.1 OPTICAL SCANNER (PASSIVE COOPERATIVE TARGET)	1	1	3	1	2	2	2	
6.2 PROXIMITY SENSORS	5	1	3	1	4	5	1	
7.1 DEAD RECKONING FROM STORED MODEL	1	2	2	1	5	5	2	
8.1 TACTILE SENSORS	4	1	3	1	4	4	2	
11.1 IMAGING (STEREO) WITH MACHINE PROCESSING	3	2	5	2	3	2	5	
11.2 IMAGING (NON-STEREO) WITH MACHINE PROCESSING	3	2	5	2	3	2	5	
13.1 HUMAN EYESIGHT VIA VIDEO	3	3	2	3	3	3	1	C.T.
13.2 HUMAN EYESIGHT VIA GRAPHIC DISPLAY	3	3	3	3	2	2	3	
14.1 DIRECT HUMAN EYESIGHT	3	4	2	4	2	4	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Optical Scanner (Passive Cooperative Target)
CODE NUMBER: 6.1 DATE: 7/5/82 NAME(S): Thiel/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The system locates laser reflection patterns on the target. Knowing their position relative to the component the system calculates the component location. Is should take only a few milliseconds for the whole process.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Similar sensors are being developed for military use and can be made very rugged. The laser system requires less maintenance than an imaging system and can look at the sun or another laser without damage.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2):3
REMARKS AND DATA SOURCES: The system is very near present technology, but some R&D is necessary to bring it online. Also, the device must be space rated.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The Optical Scanner is comparable to radar in complexity and is simpler than active target systems. Individual units are expensive, but have long lifetimes and can perform many tasks, or the cost per task is low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The scanner is reliable, easily made redundant (additional scanners and reflectors can be used), and it scans very rapidly (100 measurements per second) so it can correct its own errors.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The simplicity (compared to imaging systems) and the speed of the scanner insures a long useful life. It can be used in parallel with other sensing devices (imaging and non-imaging).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development is nearly complete and breadboard test models perform very well. Lockheed expects space rating will be fairly easy.

OTHER REMARKS AND SPECIAL ASPECTS: The laser beam could be potentially dangerous during long range measurements. The current technology for performing this functional element is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Proximity Sensor
CODE NUMBER: 6.2 DATE: 6/22/82 NAMES: Kurtzman/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: The Proximity Sensor, although fast for orienting repair mechanisms, will be very slow for locating objects.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: The Proximity Sensor is an electro-optical system witn maintenance requirement similar to the Optical Scanner.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: This capability is essentially state-of-the-art technology that needs to be refined and space rated.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Operating and procurement costs on a per use basis should be very small.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The Proximity Sensor is prone to measure the proximity to the wrong object because of a lack of object recognition capability.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: For performing this functional element alone, this capability is already obsolete, being supplanted by scanners and imaging sensors with object identification capability. It is quite possible, however, that a proximity sensor would be incorporated into an overall system for performing this functional element.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability is a relatively simple and straight forward system.

OTHER REMARKS AND SPECIAL ASPECTS: The present NBS system is suitable for teleoperation and could be adapted for automation (See J. Albus, "Proximity-Vision System For Protoflight Manipulator Arm," National Bureau of Standards, 1979). The current technology capability for performing this functional element is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Dead Reckoning From Stored Model
CODE NUMBER: 7.1 DATE: 6/21/82 NAME(S): Glass/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: Dead Reckoning ignores all except what it is trying to find, therefore it will operate much faster than current technology; it will be slightly faster than the Optical Scanner.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Dead Reckoning does not require life support, however, it does require occasional updating of the worksite model

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: The primary nonrecurring cost is in storing the model. This cost should be on par with current technology's nonrecurring cost.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The cost of updating model is minimal; Dead Reckoning should have no other recurring cost.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: Failure-proneness will be high as the system has no contact with the environment it is working with. If there is significant structural damage, dead reckoning may not be able to locate what it is looking for.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Useful life is short as any modification to the spacecraft requires an update of the model.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Will vary with the complexity of the model; many industrial robots use elementary systems of this type.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this GFE is Human Eyesight via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Tactile Sensors
CODE NUMBER: 8.1 DATE: 6/24/82 NAME(S): Ferreira/Paige/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: Non-contact vision is faster since the tactile sensor must be mechanically positioned.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: The sensor is essentially a solid block of silicone rubber and has no moving parts. If a sensor cell fails, the device can still operate with degraded performance. Video cameras are more failure-prone.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Needs to be space-rated. Prototypes of such sensors exist, which communicate their data to computers. Sensor-to-human interfaces will need more work.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: Inexpensive to use, due to the low maintenance.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The hardware itself is expected to be very reliable. However the sense of touch may not be a sufficiently accurate means of component observation.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: This will not be as good as vision, except for some special applications.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The technology is fairly well understood.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Stereo) With Machine Processing
CODE NUMBER: 11.1 DATE: 6/23/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human and, while the procurement of the individual units is potentially expensive, they will be relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human is less failure-prone in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). Stereo can handle more uncertainty than non-stereo. This capability was judged to have a somewhat higher failure-proneness than current technology as the operating environment to observe/locate a defective component is not very predictable. It receives a decision criteria value of 3, however, as it is clearly a level less failure-prone than those capabilities which received a 4.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time. The vision system is not given a decision criteria value of one, however, because this functional element is a difficult one for a vision system to perform and it is anticipated that in certain cases human abilities will always be necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: Performing this functional element would be a difficult task for a vision system due to the many types of component defects and the variability in the different types of components. The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally

expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides observing and locating a defective component. The current technology capablility is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Non-Stereo) With Machine Processing
CODE NUMBER: 11.2 DATE: 6/23/82 NAMES: Kurtzman/Caley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human and, while the procurement of the individual units is potentially expensive, they will be relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human is less failure-prone in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). A non-stereo system is, in some applications, more error-prone than one with a stereo capability. This capability was judged to have a somewhat higher failure-proneness than current technology as the operating environment to observe/locate a defective component is not very predictable. It receives a decision criteria value of 3, however, as it is clearly a level less failure-prone than those capabilities which received a 4.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time. The vision system is not given a decision criteria value of one, however, because this functional element is a difficult one for a vision system to perform and it is anticipated that in certain cases human abilities will always be necessary.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 5
REMARKS AND DATA SOURCES: Performing this functional element would be a difficult task for a vision system due to the many types of component defects and the variability in the different types of components. The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally

expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides observing and locating a defective component. The current technology capablility is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Video
CODE NUMBER: 13.1 DATE: 5/26/82 NAME(S): Glass/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Solid-state video cameras are more reliable than vidicon tube cameras.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Video cameras have already been developed for use in space. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability requires a human to locate and observe the component. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Hardware failures are possible. This capability is also limited by the camera/monitor resolution and a restricted field of view. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The useful life of this capability will depend on how it is applied. The same video camera can be used to observe many events sequentially. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability has already been demonstrated on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Graphics Display
CODE NUMBER: 13.2 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time-determining factor is the human involvement, which is the same as for the current technology (Human Eyesight Via Video).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Similar equipment to that of the current technology is involved.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The development of the necessary software for a given application increases the cost over that of the current technology (Human Eyesight Via Video).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: If used to reduce the transmission data rate, the cost of communications is less (compared to the current technology), but this is offset by the cost of additional equipment (processors, etc.).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A well-designed graphic display, working in the environment it was designed for, presents clearer and more usable information to the operator than an unprocessed video image.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: With more efficient pattern recognition and image-processing techniques, the useful life should be long.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: Data acquisition, display techniques, and hardware must be developed. In this case, these would include either efficient algorithms to recognize the component (e.g. template matching) or onsite feature extraction to compress the transmitted picture.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human Eyesight via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Human Eyesight
CODE NUMBER: 14.1 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g69 Observe/Locate Defective Component

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Human recognition time is short, but data transmission may take time, depending on what is to be done with the information. Typically the human will act using the information (obviating the need for transmission).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support. In some cases this function would involve EVA, while the current technology capability (Human Eyesight via Video) would not, so the maintenance cost here is higher.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: About the same amount of training would be required for this as for the current technology capability (Human Eyesight via Video), and that is the main nonrecurring cost. Mission-specific training costs roughly $200k/person (Source: Stephen B. Hall at NASA MSFC).

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's time costs the same as for the current technology capability (Human Eyesight via Video), but obtaining Direct Eyesight may need EVA, increasing the cost of logistics and operations.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Depends on range to target and surrounding environment. Assumption: target is in standard situation, for which astronaut has been trained. If the task is within physiological limits, humans can resolve ambiguities well and are self-correcting.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The only factor here is technical obsolescence. Video is ultimately more versatile, and in time other capabilities will overtake the human abilities (e.g. stereo imaging with computer processing).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: The human is not very good at numerical estimates of position, so this capability is not likely to be coupled to machines except under human control. Under favorable conditions however, system performance and reliability improve with experience. Current technology is Human Eyesight via Video.

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DECISION CRITERIA COMPARISON CHART

GFE: g132 LOCATE GRASPING FIXTURE ON TARGET

GFE TYPE: I. Sensing

The location of a dedicated fixture (e.g. the Shuttle RMS grapple fixture) on a free-floating or attached target, with sufficient accuracy that it can be grasped. [For the grasping, see g134 Grasp Fixture, in C. Mechanical Actuation.] If the target is free-floating (e.g. a spacecraft to be retrieved), this task may require determination of the velocity of the grasping fixture as well. More generally, the task covers the location of any clearly recognizable fixture (e.g. standardized restraints) on a payload.

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DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

		TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
6.1	OPTICAL SCANNER (PASSIVE COOPERATIVE TARGET)	1	1	3	1	2	2	2	
6.3	RADAR (PASSIVE TARGET)	1	1	4	2	4	5	3	
6.4	RADAR (ACTIVE TARGET)	1	2	3	3	3	3	2	
11.1	IMAGING (STEREO) WITH MACHINE PROCESSING	3	2	5	2	3	1	4	
11.2	IMAGING (NON-STEREO) WITH MACHINE PROCESSING	3	2	5	2	3	1	4	
13.1	HUMAN EYESIGHT VIA VIDEO	3	3	2	3	3	3	1	C.T.
13.2	HUMAN EYESIGHT VIA GRAPHIC DISPLAY	3	3	3	3	2	2	2	
14.1	DIRECT HUMAN EYESIGHT	2	4	2	4	2	4	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Optical Scanner (Passive Cooperative Target)
CODE NUMBER: 6.1 DATE: 7/5/82 NAME(S): Thiel/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g132 Locate Grasping Fixture On Target

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The system locates laser reflection patterns on the fixture. Knowing their position relative to the fixture, it calaculates the fixture's location. The whole process should take only a few milliseconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: The units usually have few moving parts. System reliability is dependent on the reliability of the electronic components such as laser tubes and optical sensors.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The system is very near present technology, but some R&D is necessary to bring it online. Also, the device must be space rated.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The Optical Scanner is comparable to radar in complexity and is simpler than active target systems. Individual units are expensive, but have long lifetimes and can perform many tasks so the cost per task is low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The scanner is reliable, easily made redundant (additional scanners and reflectors can be used), and it scans very rapidly (100 measurements per second) so it can correct its own errors.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The simplicity (compared to imaging systems) and the speed of the scanner insures a long useful life. It can be used in parallel with other sensing devices (imaging and non-imaging).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development is nearly complete and breadboard test models perform very well. Lockheed expects space rating will be fairly easy.

OTHER REMARKS AND SPECIAL ASPECTS: The laser beam could be potentially dangerous during long range measurements. The current technology for performing this functional element is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Radar (Passive Target)
CODE NUMBER: 6.3 DATE: 3/19/82 NAME(S): Jones-Oliveira/Katz/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g132 Locate Grasping Fixture on Target

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The incoming data is not large, and can be processed quickly with Very High Speed Integrated Circuits (VHSIC).

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Modern solid state electronics are fairly easy to test, repair, and manufacture.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This is an advanced technology requiring significant R&D funding. This capability is more difficult and expensive to develop than Radar (Active Target). However, relative to that of Imaging (Stereo) with Machine Processing and Imaging (Non-Stereo) with Machine Processing, these costs are reasonable.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Reliable system with few working parts, that does not require consumables.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Currently (1982), this would be a 5, because radar may not be accurate enough in "near field" applications. Rating of 4 assumes improved capability in 1986.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Area of rapid advance, so technological obsolescence may replace this capability with better options.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 3
REMARKS AND DATA SOURCES: In general, the use of radar for close-in, fine resolution work is difficult, and would therefore require complex enhancement techniques. Grasping fixtures are typically small objects.

OTHER REMARKS AND SPECIAL ASPECTS: Although this capability is more difficult to develop than Radar (Active Target), it has the advantage that once operational, its equipment is re-usable for many applications, both planned and currently unanticipated. It is the problem of "near field" angular resolution within a 200 meter range that limits this capability at present. The current technology option for performing this functional element is Human Eyesight via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Radar (Active Target)
CODE NUMBER: 6.4 DATE: 3/19/82 NAME(S): Jones-Oliveira/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g132 Locate Grasping Fixture on Target

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 1
REMARKS AND DATA SOURCES: The technology for locating a relatively small target in far fields is highly developed, and the added benefit of the target either emitting or amplifying the signal is under development. When these capabilities are combined and refined for near field applications, the resulting capability should be very fast.

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: Routine monitoring for component faults. Typical radar hardware needs little maintenance. However, relative to Radar (Passive Target), the presence of the active targets necessitates more maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Current research for far field applications is being expanded to near field applications with modifications. However, near field angular resolution problems may be difficult to solve.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Once in operation, costs will be nominai.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Failure-proneness will be that of current radar technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This capability, once developed, will be a relatively inexpensive option which will be viable for many applications. Developments in Imaging Systems, however, may make this option obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Radar sensing and pointing is a well developed technology. However, an application to short range (200 meters) may not prove desirable due to problems in angular resolution introduced by near field effects.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Human Eyesight via Video. The minimum range may pose problems in measuring both the elevation and azimuth angles, but range measurements pose no problems as radar range finders are an existing technology.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Stereo) With Machine Processing
CODE NUMBER: 11.1 DATE: 6/23/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g132 Locate Grasping Fixture on Target

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human and, while the procurement of the individual units is potentially expensive, they will be relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). Stereo can handle slightly more uncertainty than non-stereo.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides locating a grasping fixture. The current technology capablility is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Non-Stereo) With Machine Processing
CODE NUMBER: 11.2 DATE: 6/23/82 NAMES: Kurtzman/Caley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g132 Locate Grasping Fixture on Target

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human and, while the procurement of the individual units is potentially expensive, they will be relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). A non-stereo system is, in some applications, more error-prone than one with a stereo capability.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides locating a grasping fixture. The current technology capablility is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Video
CODE NUMBER: 13.1 DATE: 5/26/82 NAME(S): Glass/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g132 Locate Grasping Fixture On Target

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Solid-state video cameras are more reliable than vidicon tube cameras.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Video cameras have already been developed for use in space. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability requires a human to observe the grasping fixture. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Hardware failures are possible. This capability is also limited by the camera/monitor resolution and a restricted field of view. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The useful life of this capability will depend on how it is applied. The same video camera can be used to observe many events sequentially. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability has already been demonstrated on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Graphics Display
CODE NUMBER: 13.2 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g132 Locate Grasping Fixture On Target

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time-determining factor is the human involvement, which is the same as for the current technology (Human Eyesight Via Video).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Similar equipment to that of the current technology is involved.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The development of the necessary software for a given application increases the cost over that of the current technology (Human Eyesight Via Video).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: If used to reduce the transmission data rate, the cost of communications is less (compared to the current technology), but this is offset by the cost of additional equipment (processors, etc.).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A well-designed graphic display, working in the environment it was designed for, presents clearer and more usable information to the operator than an unprocessed video image.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: With more efficient pattern recognition and image-processing techniques, the useful life should be long.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Efficient algorithms for feature extraction must be developed.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human Eyesight via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Human Eyesight
CODE NUMBER: 14.1 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g132 Locate Grasping Fixture On Target

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Human recognition time is short, but data transmission may take time, depending on what is to be done with the information. Typically the human will act using the information (obviating the need for transmission).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support. In some cases this function would involve EVA, while the current technology capability (Human Eyesight via Video) would not, so the maintenance cost here is higher.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: About the same amount of training would be required for this as for the current technology capability (Human Eyesight via Video), and that is the main nonrecurring cost. Mission-specific training costs roughly $200k/person (Source: Stephen B. Hall at NASA MSFC).

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Astronaut's time costs the same as for the current technology capability (Human Eyesight via Video), but obtaining Direct Eyesight may need EVA, increasing the cost of logistics and operations.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This depends on range to target and surrounding environment. Assumption: target is in standard situation, for which astronaut has been trained. If the task is within physiological limits, humans can resolve ambiguities well and are self-correcting.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The only factor here is technical obsolescence. In time other capabilities will overtake the human abilities (e.g. stereo imaging with computer processing).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: The human is not very good at numerical estimates of position and velocity, so this capability is not likely to be coupled to machines except under human control. Under favorable conditions however, system performance and reliability improves with experience. Current technology is Human Eyesight via Video.

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DECISION CRITERIA COMPARISON CHART

GFE: g243 TRACK NEARBY OBJECTS

GFE TYPE: I. Sensing

The determination of the positions and velocities of any objects on potential collision courses with a spacecraft. Also, the location of a target object, for either close approach or docking. Also, the location of attached spacecraft components, to confirm the expected spacecraft configuration (e.g. measuring the position of solar arrays and antennas).

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
6.1 OPTICAL SCANNER (PASSIVE COOPERATIVE TARGET)	3	3	2	3	2	2	1	
6.3 RADAR (PASSIVE TARGET)	3	3	2	3	3	3	1	C.T.
6.4 RADAR (ACTIVE TARGET)	3	3	2	3	2	2	1	
6.5 ONBOARD NAVIGATION AND TELEMETRY	2	4	4	3	2	2	2	
11.1 IMAGING (STEREO) WITH MACHINE PROCESSING	4	4	5	3	3	3	4	
11.2 IMAGING (NON-STEREO) WITH MACHINE PROCESSING	4	4	5	3	4	3	4	
13.1 HUMAN EYESIGHT VIA VIDEO	5	5	2	5	5	5	1	
13.2 HUMAN EYESIGHT VIA GRAPHIC DISPLAY	4	5	3	4	3	3	2	
14.1 DIRECT HUMAN EYESIGHT	5	5	2	5	5	5	1	

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ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Optical Scanner (Passive Cooperative Target)
CODE NUMBER: 6.1 DATE: 7/5/82 NAME(S): Thiel/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: A group of scanners (to provide a full field of view) should be as fast as radar, but also able to identify individual objects by their laser reflector pattern.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: The scanner may need laser tube replacement occasionally. The maintenance should be comparable to a high reliability phased array radar unit.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Although this system has some development work left, the nonrecurring cost for a space rated unit is similar to that of a radar unit (a rather simple radar).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The Optical Scanner is comparable to radar in complexity and is simpler than active target systems. Individual units are expensive, but have long lifetimes and can perform many tasks, so the cost per task is low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The scanner is reliable, easily made redundant (additional scanners and reflectors can be used), and it scans very rapidly (100 measurements per second) so it can correct its own errors.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The simplicity (compared to imaging systems) and the speed of the scanner insures a long useful life. It can be used in parallel with other sensing devices (imaging and non-imaging).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Development is nearly complete and breadboard test models perform very well. Lockheed expects space rating will be fairly easy. Optical scanners recieved a 1 rating here because they are very close to radar in terms of risk even if they are not current technology.

OTHER REMARKS AND SPECIAL ASPECTS: The laser system functions well at close or long range. Can be used around active communications systems where radars could cause damage. The current technology for performing this functional element is Radar (Passive Target).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Radar (Passive Target)
CODE NUMBER: 6.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Katz/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology. Once developed, Onboard Navigation and Telemetry will be faster.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: This is current technology. None of the other capabilities are expected to have lower maintenance costs because modern solid state electronics are fairly easy to test and repair.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is current technology. Reliable system with few working parts, that does not require consumables.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is current technology. The problems of angular resolution associated with the "near field" effects is not as important a limiting factor as the object increases in volume.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: This is current technology, and will most likely be made obsolete by other developing capabilities.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This is current technology, provided the objects to be tracked are of sufficient size.

OTHER REMARKS AND SPECIAL ASPECTS: Tracking nearby objects, as long as the objects are of sufficient size, is currently in use. This capability is not appropriate for small objects in close proximity.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Radar (Active Target)
CODE NUMBER: 6.4 DATE: 5/12/82 NAME(S): Jones-Oliveira/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time will not differ substantially from the current technology option, Radar (Passive Target).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Maintenance costs are minimal.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: This is analogous to current technology, Radar (Passive Target).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This is analogous to current technology, Radar (Passive Target).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The active radar will have less failure-proneness than the passive radar.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The active radar will make the Radar (Passive Target) obsolete.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Radar (Passive Target). Tracking nearby objects, so long as the object is of ample size, is currently in use.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Onboard Navigation and Telemetry
CODE NUMBER: 6.5 DATE: 6/22/82 NAMES: Kurtzman/Thiel
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This capability should be able to give object position and velocity quickly. Satellites will perform orbit determination calculations in real-time with onboard computers for highly dynamic users (see Byron D. Tapley, Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin, "A Study of Autonomous Satellite Navigation Methods Using the Global Positioning Satellite System," NASA-CR-162635, April 20, 1980).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance is comparable to the imaging systems, involving upkeep of the onboard computer, antenna, receiver, and input/output interfaces (see Burton G. Glazer, "GPS Receiver Operation," in Principles and Operational Aspects of Precision Position Determination Systems, ed. C. T. Leondes, AGARD-AG-245, 1979).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 4
REMARKS AND DATA SOURCES: This includes the costs of developing the onboard receiver and the special orbit determination algorithms that are being developed to accomodate the size and speed limitations of onboard computer systems (see Byron D. Tapley, "A Study of Autonomous Satellite Navigation Methods Using the Global Positioning Satellite System").

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: The costs of procuring and operating the onboard equipment on a per use basis should be small. This includes the use of an omni-directional or hemispherical pattern antenna. Cost for a non-combat military aircraft unit is estimated at $15,000, assuming small scale production. The cost for an in space unit may be several times this estimate (see Burton G. Glazer, "GPS Receiver Operation").

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Position measurements should be accurate to 10 meters rms or better. Velocity measurements should be accurate to better than .15 meters per second. The system is tolerant to nonintentional as well as intentional interference. (See Robert J. Milliken and Curt J. Zoller, "Principles of Operation of NAVSTAR and System Characteristics," in Principles and Operational Aspects of Precision Position Determination Systems, ed. C. T. Leondes, AGARD-AG-245, 1979.)

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The system should have a long lifetime, should not become obsolete for some time, and offers world-wide military and civilian coverage.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The primary risk is in the positioning satellite network, not in developing the onboard navigation equipment.

OTHER REMARKS AND SPECIAL ASPECTS: The maintenance, nonrecurring cost and recurring cost decision criteria are only for the GPS receiver, not for the entire global positioning system. This capability is only usable if the tracking spacecraft and the object to be tracked both have onboard navigation equipment. The current technology capability for performing this functional element is Radar (Passive Target).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Stereo) With Machine Processing
CODE NUMBER: 11.1 DATE: 6/23/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The current technology option is real-time, and an imaging system may be slower. If a human can look through a window or video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability does not necessitate the support of a human and is relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Expected to be similar to current technology. A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). Stereo can handle more uncertainty than non-stereo.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: The numbers above assume that "nearby objects" are within the range of the imaging sensor (the current technology capability can also track distant objects). The development of a vision system would have many other applications besides tracking nearby objects. The current technology capablility is Radar (Passive Target).
FEEDBACK

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Non-Stereo) With Machine Processing
CODE NUMBER: 11.2 DATE: 6/23/82 NAMES: Kurtzman/Caley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: The current technology option is real-time, and an imaging system may be slower. If a human can look through a window or video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability does not necessitate the support of a human and is relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: A non-stereo system is more error-prone than a stereo system in tasks requiring precise ranging of arbitrary objects. A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff).

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: The numbers above assume that "nearby objects" are within the range of the imaging sensor (the current technology capability can also track distant objects). The development of a vision system would have many other applications besides tracking nearby objects. The current technology capablility is Radar (Passive Target).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Video
CODE NUMBER: 13.1 DATE: 5/26/82 NAME(S): Glass/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: A human observer will not be fast at detecting and tracking objects through a video link.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Solid-state video cameras are more reliable than vidicon tube cameras. The camera would require an accurate motion platform and large lenses to track objects. These would require more maintenance than the camera. The current technology radar has very little maintenance.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Video cameras have already been developed for use in space.

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: This capability requires a human to observe the objects. The lenses and motion platform could be expensive to maintain.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: Hardware failures are possible. This capability is also limited by the camera/monitor resolution and a restricted field of view. A human might not be able to keep up with a fast, nearby object, and would certainly have much difficulty tracking several objects at once.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: More accurate and automated options make this capability obsolete for this task.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: Video cameras have already been demonstrated on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology for this functional element is Radar (Passive Target).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Graphics Display
CODE NUMBER: 13.2 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 4
REMARKS AND DATA SOURCES: When human skills are involved, the task takes more time than would a purely electronic radar system. However, a good graphics system will reduce recognition time below that of unaided video.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Maintenance here includes the cost of the human involved, which is higher than a radar system. If multiple targets must tracked simultaneously, this may require multiple humans.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: Development of software is the greatest cost, making this more expensive than video or direct vision.

RECURRING COST (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: The cost of running the equipment is similar to that of human eyesight via video, but communications and training costs should be less.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: With a properly-designed graphic system, the need for great accuracy of human judgment is reduced. The human may only need to supply high-level decisions, such as which target to track.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: With more efficient pattern recognition and image-processing techniques, the useful life should be long.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Task-specific software must be developed.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Radar (Passive Target).

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Human Eyesight
CODE NUMBER: 14.1 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g243 Track Nearby Objects

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 5
REMARKS AND DATA SOURCES: Compared to a radar system, the human tracking ability is quite slow. Also, if the information needs to be encoded, it would be time-consuming. Typically the human would act directly on the information.

MAINTENANCE (1 LITTLE, 5 LOTS): 5
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support, which is costly compared to electronic equipment maintenance. There is also down-time (8-hour workdays).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Training of astronaut is required. Mission-specific training costs roughly $200k/person (Source: Stephen B. Hall at NASA MSFC).

RECURRING COST (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: Astronaut's dedicated time is valuable, roughly $100k/person-day (Source: Stephen B. Hall at NASA MSFC).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 5
REMARKS AND DATA SOURCES: Human has difficulty tracking more than one object at a time, and has a restricted range of trackable distances and velocities. Accuracy of tracking data is adequate for some applications, but radar is better.

USEFUL LIFE (1 LONG, 5 SHORT): 5
REMARKS AND DATA SOURCES: Cheaper, more accurate options are already available.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: If human abilities are adequate for a given task, and a human is available, this could be a good choice, simply to minimize equipment complexity. Current technology is Radar (Passive Target).

DECISION CRITERIA COMPARISON CHART

GFE: g245 OBSERVE TUMBLING SPACECRAFT

GFE TYPE: I. Sensing

The location and tracking of a tumbling spacecraft or object, for the purpose of capture or grasping. This includes determination of the spin axis (the line of safest approach).

4E.547

DECISION CRITERIA

CANDIDATE ARAMIS CAPABILITIES:

CANDIDATE ARAMIS CAPABILITIES	TIME	MAINTENANCE	NONRECURRING COST	RECURRING COST	FAILURE PRONENESS	USEFUL LIFE	DEVELOPMENTAL RISK	
6.1 OPTICAL SCANNER (PASSIVE COOPERATIVE TARGET)	2	1	3	1	2	2	2	
6.3 ADAR (PASSIVE TARGET)	2	1	3	2	4	3	2	
6.4 RADAR (ACTIVE TARGET)	2	1	3	2	3	2	2	
11.1 IMAGING (STEREO) WITH MACHINE PROCESSING	3	2	5	2	2	1	4	
11.2 IMAGING (NON-STEREO) WITH MACHINE PROCESSING	3	2	5	2	3	1	4	
13.1 HUMAN EYESIGHT VIA VIDEO	3	3	2	3	3	3	1	C.T.
13.2 HUMAN EYESIGHT VIA GRAPHIC DISPLAY	3	3	3	3	2	2	2	
14.1 DIRECT HUMAN EYESIGHT	3	4	2	4	2	4	1	

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Optical Scanner (Passive Cooperative Target)
CODE NUMBER: 6.1 DATE: 7/5/82 NAME(S): Thiel/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g245 Observe Tumbling Spacecraft

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: The system locates laser reflection patterns on the spacecraft. Knowing their position relative to the spacecraft, it calculates the spacecraft's location. The whole process should take only a few milliseconds.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: The units usually have few moving parts. System reliability is dependent on the reliability of the electronic components such as laser tubes and optical sensors.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The system is very near present technology, but some R&D is necessary to bring it online. Also, the device must be space rated.

RECURRING COST (1 LOW, 5 HIGH): 1
REMARKS AND DATA SOURCES: The Optical Scanner is comparable to radar in complexity and is simpler than active target systems. Individual units are expensive, but have long lifetimes and can perform many tasks so the cost per task is low.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: The scanner is reliable, easily made redundant (additional scanners and reflectors can be used), and it scans very rapidly (100 measurements per second) so it can correct its own errors.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The simplicity (compared to imaging systems) and the speed of the scanner insures a long useful life. It can be used in parallel with other sensing devices (imaging and non-imaging).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Development is nearly complete and breadboard test models perform very well. Lockheed expects space rating will be fairly easy.

OTHER REMARKS AND SPECIAL ASPECTS: The current technolgy for this functional element is Human Eyesight Via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Radar (Passive Target)
CODE NUMBER: 6.3 DATE: 5/12/82 NAME(S): Jones-Oliveira/Katz/Ferreira
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g245 Observe Tumbling Spacecraft

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: Relative to human eyesight, because of the accuracy and speed of the data, this option is faster.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Maintenance of solid state electronics is minimal.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: There are developmental advances necessary. However, these are not as significant as for those options involving imaging.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Once operational, the recurring costs are low because the equipment is versatile and relatively inexpensive; also, there are no consumables.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 4
REMARKS AND DATA SOURCES: Because angular resolution is particularly important for this task, this option is more failure prone than the Radar (Active Target).

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: Its versatility will make its useful life substantial.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: The problems with angular resolution have yet to be fully resolved.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Human Eyesight via Video. In general, if the capability used to observe the spacecraft involves human eyesight, the capture of the spacecraft should probably use human control. This is due to difficulties in passing position and spin data from human to machine. Machine-sensed data can be input to human control via graphic display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Radar (Active Target)
CODE NUMBER: 6.4 DATE: 5/12/82 NAME(S): Jones-Oliveira/Katz
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g245 Observe Tumbling Spacecraft

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 2
REMARKS AND DATA SOURCES: This option is faster than human eyesight, due to the accuracy and speed of the data.

MAINTENANCE (1 LITTLE, 5 LOTS): 1
REMARKS AND DATA SOURCES: Maintenance of solid state electronics is minimal.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: There are developmental advances necessary. These are, however, not as significant as for those options involving imaging.

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: Once operational, the costs should be nominal.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Expected to be as reliable as current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: The active radar will make the Radar (Passive Target) obsolete. However, this capability will then be made obsolete by the capabilities involving imaging.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Although not as mature as current technology, this capability has straightforward R&D.

OTHER REMARKS AND SPECIAL ASPECTS: The current technology option is Human Eyesight via Video. In general, if the capability used to observe the spacecraft involves human eyesight, the capture of the spacecraft should probably use human control. This is due to difficulties in passing position and spin data from human to machine. Machine-sensed data can be input to human control via graphic display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Stereo) With Machine Processing
CODE NUMBER: 11.1 DATE: 6/23/82 NAMES: Kurtzman/Glass
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g245 Observe Tumbling Spacecraft

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human and, while the procurement of the individual units is potentially expensive, they will be relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). Stereo can handle more uncertainty than non-stereo.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides observing a tumbling spacecraft. The current technology capability is Human Eyesight Via Video. In general, if the capability used to observe the spacecraft involves human eyesight, the capture of the spacecraft should probably use human control. This is due to difficulties in passing position and spin data from human to machine. Machine-sensed data can be input to human control via graphic display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Imaging (Non-Stereo) With Machine Processing
CODE NUMBER: 11.2 DATE: 6/23/82 NAMES: Kurtzman/Caley
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g245 Observe Tumbling Spacecraft

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: If a human can look through a window or a video screen, he may complete the functional element slightly faster, but if he must suit up (EVA) it will take him much longer (1990 technology assumed) (Ruoff).

MAINTENANCE (1 LITTLE, 5 LOTS): 2
REMARKS AND DATA SOURCES: The software and vision will be very reliable. This differs little from the other non-human options. Down time should be approximately the same as that for present avionics systems (Ruoff).

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 5
REMARKS AND DATA SOURCES: Extensive research and development is required to achieve a vision capability. Cost, though high, will be partially consumed by industry (Ruoff).

RECURRING COST (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This capability was judged below current technology in recurring costs as it does not necessitate the support of a human and, while the procurement of the individual units is potentially expensive, they will be relatively inexpensive to operate.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: A human is less failure-prone but only in short bursts. A robust vision system will be consistently good in a predictable environment (Ruoff). A non-stereo system is, in some applications, more error-prone than a stereo system.

USEFUL LIFE (1 LONG, 5 SHORT): 1
REMARKS AND DATA SOURCES: The capability will be modularly upgraded so that the entire system will never need to be replaced, thus avoiding technical obsolescence (Ruoff). The software would need little updating (Minsky). Its useful life is judged longer than current technology as it is deemed more desirable to have an autonomous system than use valuable human-in-space time.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 4
REMARKS AND DATA SOURCES: The development of a vision system is a complicated engineering problem, and artificial intelligence research has shown that problems are often harder than originally expected (Ruoff).

OTHER REMARKS AND SPECIAL ASPECTS: A development of a vision system would have many other applications besides observing a tumbling spacecraft. The current technology capablility is Human Eyesight Via Video. In general, if the capability used to observe the spacecraft involves human eyesight, the capture of the spacecraft should probably use human control. This is due to difficulties in passing position and spin data from human to machine. Machine-sensed data can be input to human control via graphic display.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Video
CODE NUMBER: 13.1 DATE: 5/26/82 NAME(S): Glass/Spofford
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g245 Observe Tumbling Spacecraft

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: This is current technology.

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Solid-state video cameras are more reliable than vidicon tube cameras.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 2
REMARKS AND DATA SOURCES: Video cameras have already been developed for use in space. This is current technology.

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: This capability requires a human to observe the spacecraft. This is current technology.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Hardware failures are possible. This capability is also limited by the camera/monitor resolution and a restricted field of view. This is current technology.

USEFUL LIFE (1 LONG, 5 SHORT): 3
REMARKS AND DATA SOURCES: The useful life of this capability will depend on how it is applied. The same video camera can be used to observe many events sequentially. This is current technology.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This capability has already been demonstrated on-orbit.

OTHER REMARKS AND SPECIAL ASPECTS: This capability is current technology for this functional element.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Human Eyesight Via Graphics Display
CODE NUMBER: 13.2 ATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g245 Observe Tumbling Spacecraft

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: The time-determining factor is the human involvement, which is the same as for the current technology (Human Eyesight Via Video).

MAINTENANCE (1 LITTLE, 5 LOTS): 3
REMARKS AND DATA SOURCES: Similar equipment to that of the current technology is involved.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.=2): 3
REMARKS AND DATA SOURCES: The development of the necessary software for a given application increases the cost over that of the current technology (Human Eyesight Via Video).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: If used to reduce the transmission data rate, the cost of communications is less (compared to the current technology), but this is offset by the cost of additional equipment (processors, etc.).

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: A well-designed graphic display, working in the environment it was designed for, presents clearer and more usable information to the operator than an unprocessed video image.

USEFUL LIFE (1 LONG, 5 SHORT): 2
REMARKS AND DATA SOURCES: With more efficient pattern recognition and image-processing techniques, the useful life should be long.

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 2
REMARKS AND DATA SOURCES: Efficient algorithms for feature extraction must be developed.

OTHER REMARKS AND SPECIAL ASPECTS: Current technology is Human Eyesight via Video.

ARAMIS CAPABILITY APPLICATION FORM

CAPABILITY NAME: Direct Human Eyesight
CODE NUMBER: 14.1 DATE: June 1982 NAME(S): Howard/Marra
GENERIC FUNCTIONAL ELEMENT NUMBER AND NAME: g245 Observe Tumbling Spacecraft

DECISION CRITERIA (1 TO 5 SCALES; CURRENT TECH.=3 UNLESS NOTED)

TIME TO COMPLETE FUNCTIONAL ELEMENT (1 SHORT, 5 LONG): 3
REMARKS AND DATA SOURCES: Recognition time is short, but data transmission may take time, depending on what is to be done with the information. Typically the human will act using the information (obviating the need for transmission).

MAINTENANCE (1 LITTLE, 5 LOTS): 4
REMARKS AND DATA SOURCES: Maintenance also includes astronaut life support. In some cases this function would involve EVA, while the current technology capability (Human Eyesight via Video) would not, so the maintenance cost here is higher.

NONRECURRING COST (1 LOW, 5 HIGH; CURRENT TECH.= 2): 2
REMARKS AND DATA SOURCES: About the same amount of training would be required for this as for the current technology capability (Human Eyesight via Video), and that is the main nonrecurring cost. Mission-specific training costs roughly $200k/person (Source: Stephen B. Hall at NASA MSFC).

RECURRING COST (1 LOW, 5 HIGH): 3
REMARKS AND DATA SOURCES: Astronaut's time costs the same as for the current technology capability (Human Eyesight via Video), but obtaining Direct Eyesight may need EVA, increasing the cost of logistics and operations.

FAILURE-PRONENESS (1 LOW, 5 HIGH): 2
REMARKS AND DATA SOURCES: This depends on range to target and surrounding environment. Assumption: target is in standard situation, for which astronaut has been trained. If the task is within physiological limits, humans can resolve ambiguities well and are self-correcting.

USEFUL LIFE (1 LONG, 5 SHORT): 4
REMARKS AND DATA SOURCES: The only factor here is technical obsolescence. In time other capabilities will overtake the human abilities (e.g. stereo imaging with computer processing).

DEVELOPMENTAL RISK (1 LOW, 5 HIGH; CURRENT TECH.=1): 1
REMARKS AND DATA SOURCES: This technology is currently available.

OTHER REMARKS AND SPECIAL ASPECTS: Humans are not very good at numerical estimates of position and velocity, so this capability is not likely to be coupled to machines except under human control. Under favorable conditions however, system performance and reliability improves with experience. Current technology is Human Eyesight via Video.