TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

ATTITUDE CONTROL AND STABILIZATION TECHNOLOGY DISCIPLINE

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TECHNOLOGY FOR SPACE STATION EVOLUTION -A WORKSHOP

TECHNOLOGY DISCIPLINE SUMMARY FOR ATTITUDE CONTROL & STABILIZATION

<u>ADVANCED CONTROLS TECHNOLOGIES REQUIRED FOR SPACE STATION EVOLUTION</u>

<u>TECHNOLOGY DRIVERS</u>

- LARGE MASS PROPERTIES AND CONFIGURATION CHANGES
- CONCURRENT USERS
- LARGE MULTIPLE FLEXIBLE STRUCTURES
- EXPANDED INTER-ORBIT TRAFFIC

<u>TECHNOLOGY DEVELOPMENT AREAS</u>

- ATTITUDE CONTROL TECHNOLOGIES FOR MULTI-USER ACCOMMODATION
- FLEXIBLE DYNAMICS AND CONTROL
- COMPUTATIONAL CONTROL TECHNIQUES
- AUTONOMOUS RENDEZVOUS AND PROXIMITY OPERATIONS

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ATTITUDE CONTROL & STABILIZATION

ATTITUDE CONTROL TECHNOLOGIES FOR MULTI-USER ACCOMMODATION

BACKGROUND

SCOPE - Advanced control system strategies able to cope with uncertainties in the orbital environment, dynamically changing spacecraft configurations via docking and buildup, and potential hardware failures

OBJECTIVES - To define, develop, and evaluate control system technologies for the evolving Space Station which maintain good performance in spite of disturbances caused by crew motion, mission activity, aerodynamic uncertainty, vehicle mismodeling, and changing configurations.

RATIONALE - Present control system technology does not meet the more demanding operational requirements of the evolutionary Space Station. Due to crew and aerodynamic disturbances, changes in vehicle parameters, dynamic interaction with the control system, and concurrent operations of multiple controllers/users, issues that have not been of concern in the past will become drivers in the design and development of an attitude control and stabilizaiton system for the advanced Space Station.

ATTITUDE CONTROL & STABILIZATION

ATTITUDE CONTROL TECHNOLOGIES FOR MULTI-USER ACCOMMODATION

PROGRAM PLAN

APPROACH :

1. Investigate advanced momentum effectors. These include larger, more efficient shell rotor designs, electro-magnetically suspended rotors, and fluid moment loops replacing spinning rotor designs.

2. Develop mass properties management system. This system might consist of a series of ballast tanks containing consumables (water, propellant) that can be pumped around the Station for the purpose of managing mass properties.

3. Develop an on-board system identification capability. This will produce on-board characterization of the Space Station mass properties and identification of disturbances.

4. Develop an on-line adaptive control system. The adaptive controller develops an updated state feedback controller for the identified updated Station model.

5. Develop scheduling algorithms for Space Station momentum management. This approach schedules the activities of the Station in an optimal manner to insure that sufficient control authority from the CMGs is always available.

DELIVERABLES :

1. Demonstrations of effector hardware.

2. Software demonstrations on appropriate Space Station test beds.

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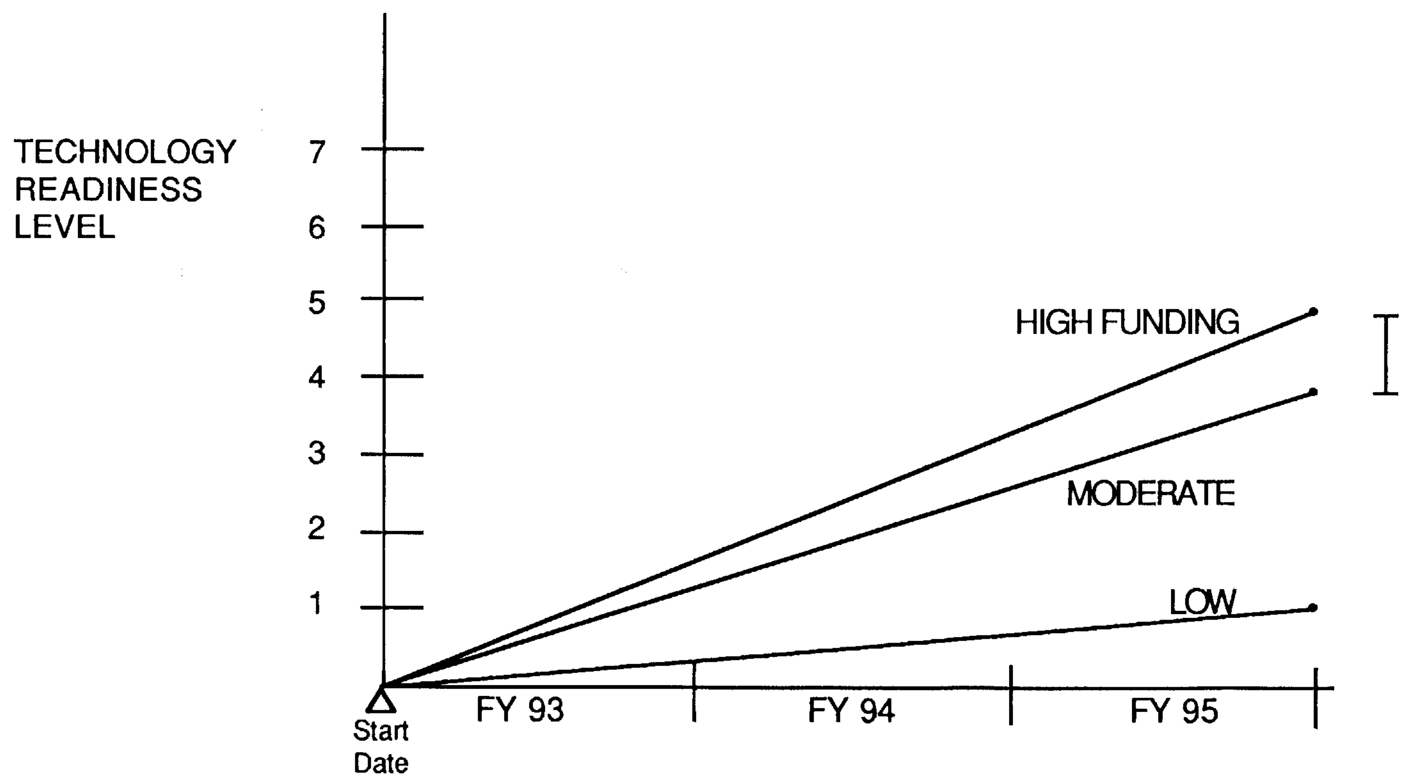
ATTITUDE CONTROL TECHNOLOGIES FOR MULTI-USER ACCOMMODATION

<ins>TECHNOLOGY ASSESSMENT</ins>



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ATTITUDE CONTROL & STABILIZATION

FLEXIBLE DYNAMICS AND CONTROL

BACKGROUND

SCOPE - Development of modeling and control methodologies and sensor hardware for flexible dynamics characterization, on-board sensing and vibration control.

OBJECTIVES - To develop the methods, algorithms, and architectures for on-board identification of space station dynamics; math models to describe the characteristics of the system and payloads; techniques for the optimal placement of actuators and sensors; and active/passive methods to control dynamic responses and the propagation of disturbances.

RATIONALE - Due to the limitations of ground testing and to the evolving nature of operations and configuration, an on-board capability is required to characterize the system as it evolves in time. The dynamic interactions and disturbances resulting from the planned concurrent use of the station by multiple users for assembly of Lunar/Mars vehicles, Earth/space/microgravity payloads, etc., will limit the utility and operational performance of the evolving station.

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FLEXIBLE DYNAMICS AND CONTROL

PROGRAM PLAN

APPROACH -

1. Develop an on-orbit flexible body and disturbance identification subsystem. This includes an automated system of methods, signal processing algorithm designs and data acquisition, interfacing architecture, and excitation/sensing specifications.

2. Develop a passive and active control technology. This includes control of dynamic response levels and propagation of disturbances. Conduct performance analysis and experimental verifications.

3. Develop an optical system identification and alignment sensor. This will allow real time system identification and control of the system and attached payloads.

4. Develop modal selection and model reduction methods. Both methods will be designed implementing a multi-objective design technique.

5. Develop a distributed fiber optics sensing system. This includes fiber optic rotation, acceleration, stress, and temperature sensors.

DELIVERABLES -

1. An integrated identification subsystem proof-of-concept design.

2. Experimental demonstration of passive and active control technology.

3. Model-based modal selection/model reduction algorithms and software.

4. Optical system identifier and alignment sensor.

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FLEXIBLE DYNAMICS AND CONTROL

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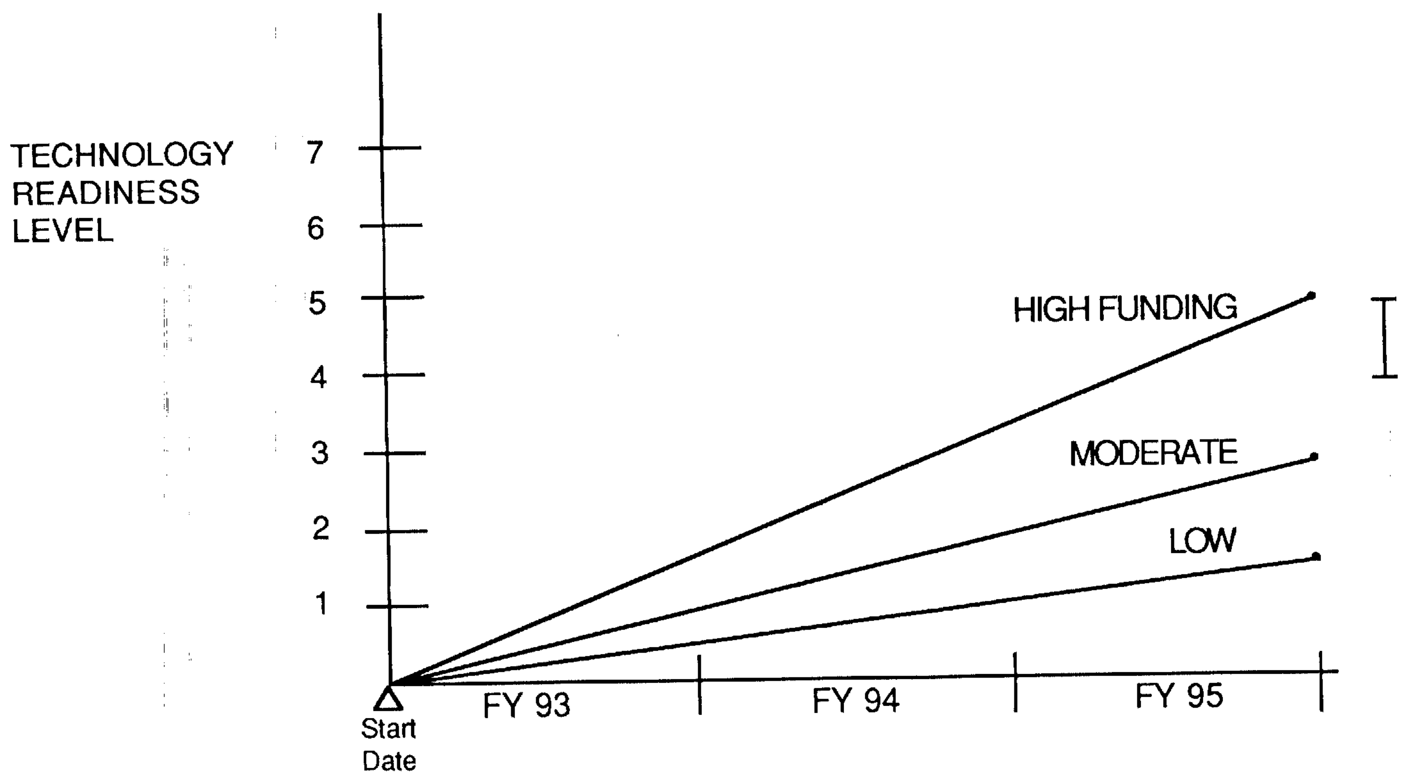

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ATTITUDE CONTROL &
STABILIZATION SYSTEM

COMPUTATIONAL CONTROL TECHNIQUES

BACKGROUND

SCOPE - A set of computer-aided control systems modeling, design and simulation tools for control system design and real-time hardware-in-the-loop subsystem testing.

OBJECTIVE - To develop fast and cost effective articulated multibody modeling, control design and simulation methods, and prototype software tools. The first specific objective is development of modeling tools for the representation of the plant and control system. The second specific objective is development of high-speed simulation tools with super-real-time hardware-in-the-loop capability. The third specific objective is building an efficient computer-aided control design and analysis capability. The last, but not least, important objective is to produce a computational environment that integrates the above tools into a system that allows high user productivity. These capailities should handle 400 states and 800 states systems by the third and fifth year of the program, respectively.

RATIONALE - The current control design and simulation tools are a limiting factor in today's control design and testing and are inadequate for future needs. The areas of concern are: a) control design tools break down for high order systems; b) spacecraft simulation tools are too slow to be used effectively for design and testing; and c) an integrated computer-aided control design environment is needed to improve productivity.

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COMPUTATIONAL CONTROL TECHNIQUES

PROGRAM PLAN

APPROACH -

Develop effective multibody component model representaion techniques and software tools to capture capture the relevant sytem model using projection and component mode synthesis methods. Then numerically efficient algorithms, based on spatially recursive formulation, will be developed and tuned for serial supercomputers and massively parallel computers for super-real-time simulation. The capability to handle larger problems will be accomplished through a larger hardware system and evolutionary numerical algorithms. Natural problem condensation, scaling and high-order system solution techniquesand algorithms will be developed for control design and analysis tools. Lastly, menu-driven graphics anda data base will be used to integrate the tools into a user-oriented system.

DELIVERABLES -

1. Component model reduction software

2. Super-real-time hardware-in-the-loop simulation system.

3. High-order control design and analysis software.

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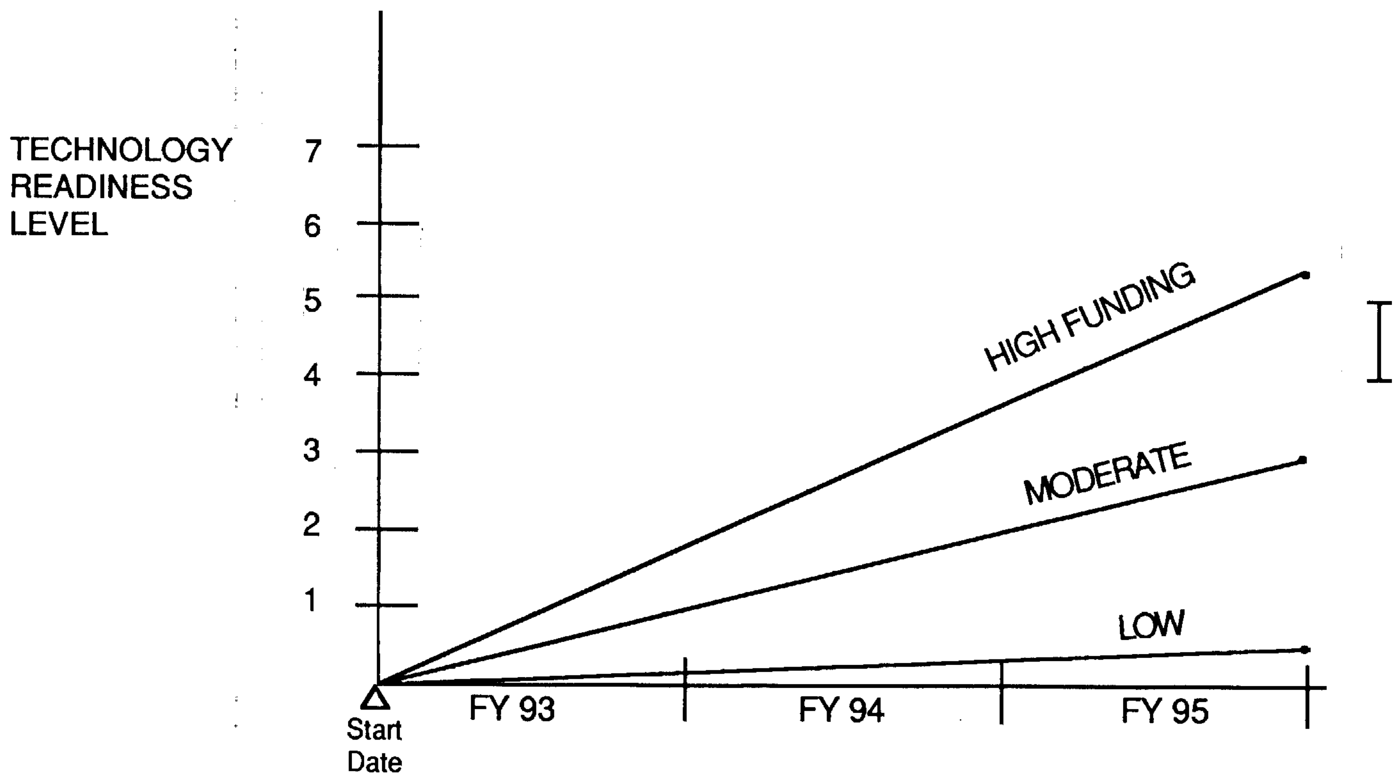

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ATTITUDE CONTROL & STABILIZATION

AUTOMATIC PROXIMITY OPERATIONS

BACKGROUND

SCOPE - Automatic proximity operations to provide safe, cost-effective, reliable, and readily available interactive operations of co-orbiting vehicles/facilities to support transportation nodes and interplanetary exploration missions.

OBJECTIVES - To develop the trajectory control techniques, relative navigation sensors, guidance and navigation algorithms; cooperative, multi-vehicle control algorithms, optimum orbital placements, station-keeping techniques, on-board flight planning, and collision avoidance strategy for integrated, automatic proximity operations capabilities, without requiring flight crew or remote piloting support. The study will focus on accelerating the development of these elements and integrating available and emerging technologies into systems which match mission and user requirements.

RATIONALE - Future on-orbit operations for the Space Station Program, the Human Exploration Initiative, and satellite servicing will result in significantly increased traffic of co-orbiting, interactive manned and unmanned vehicles in Earth, lunar, and planetary orbits. Automatic proximity operations will enhance Earth-orbit operations by reducing flight or ground crew participation and reducing the operational constraints associated with manual or remote piloting. Automatic proximity operations are enabling technologies for the interplanetary exploration missions, where transport lags preclude remote piloting and long transfer times reduce the proficiency of flight crews for complex piloting tasks. A systematic development of these technologies can be facilitated by using current and emerging flight systems such as the NSTS, Space Station Freedom Program, and Orbital Maneuvering Vehicle (OMV) as test beds.

Maximum synergism would be effected with the Autonomous Rendezvous and Docking Project under Project Pathfinder. However, the Pathfinder AR&D funding of approximately $350K is inadequate to support the Space Station evolution needs by itself. There are unique Space Station challenges including station-keeping, sensor obscuration, and berthing/docking approaches around large appendages.

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ATTITUDE CONTROL& STABILIZATION

AUTOMATIC PROXIMITY OPERATIONS

PROGRAM PLAN

APPROACH -

1. Determine requirements for relative navigation sensors required for automatic rendezvous, proximity operations, and docking/berthing approaches and support their development and integration into automatic proximity operations capabilities, including trajectory control techniques, GN&C algorithms, and collision-avoidance techniques.

2. Develop optimum orbital placements of co-orbiting systems, on-board flight planning techniques, and orbital transfer techniques, which reduce transfer propellant and time with safety and low interference among multi-vehicle traffic operations.

3. Demonstrate these integrated capabilities via a series of ground and flight demonstrations. Ground demonstrations will involve math model simulations and hardware/software demonstrations. Flight demonstrations will begin with open-loop sensor demonstrations, progressing to closed-loop flight demonstrations using current and emerging flight systems.

DELIVERABLES -

1. Prototype relative navigation sensors integrated with GN&C algorithms, trajectory control and collision avoidance techniques, on-board flight planning, and orbital placement and transfer techniques.

2. Ground demonstrations of these integrated capabilities using graphics simulations and hardware/software test beds.

3. Progressive series of flight demonstrations of automatic proximity operations capabilities, commencing with open-loop sensor tests and culminating in full, closed-loop flight performance.

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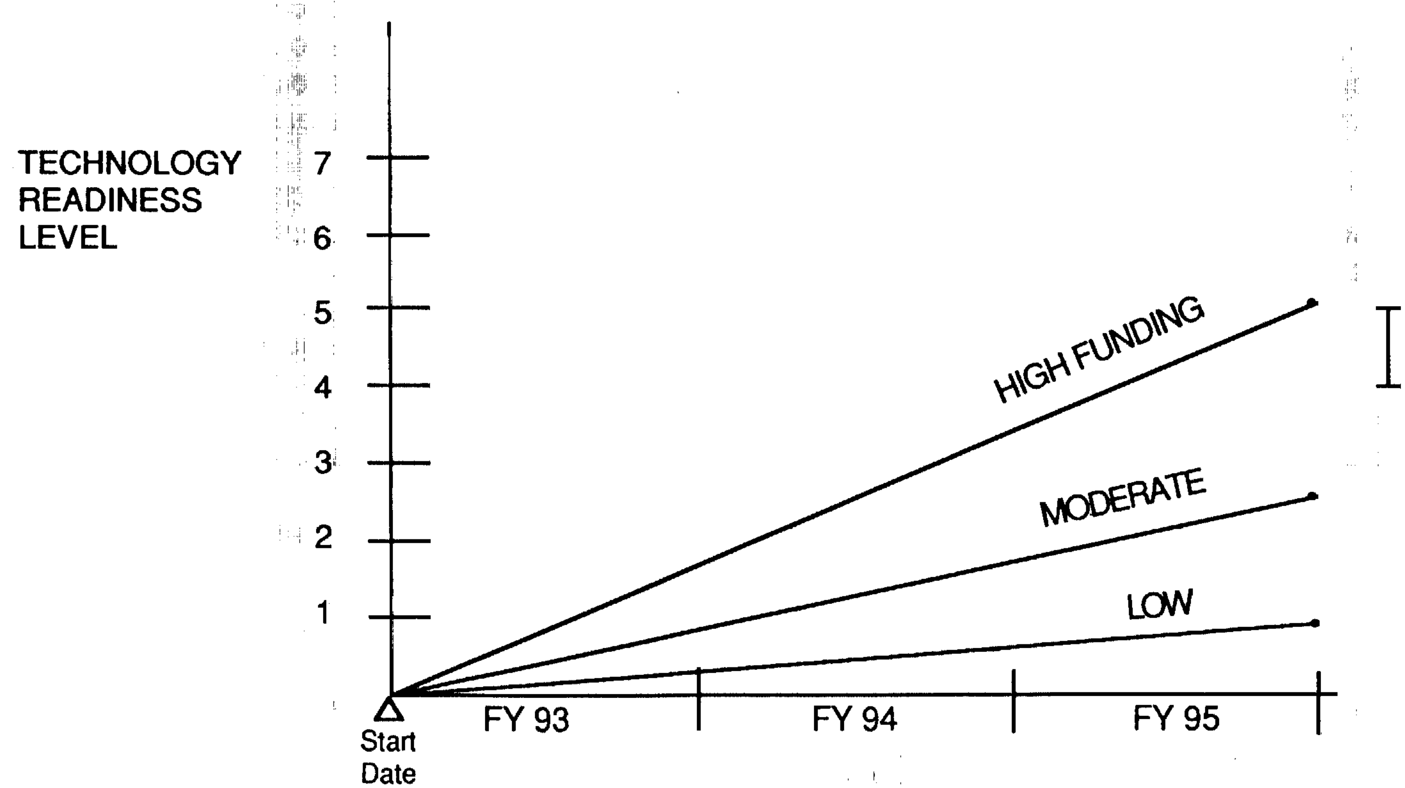

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RECOMMENDATIONS/ISSUES FOR ATTITUDE CONTROL & STABILIZATION

ADVANCED CONTROLS TECHNOLOGIES REQUIRED FOR SPACE STATION EVOLUTION

RECOMMENDATION

A PROGRAM FUNDED AT $13 M/YR IS STRONGLY RECOMMENDED DUE TO THE ENABLING NATURE OF THE TECHNOLOGIES NEEDED FOR AN EVOLUTIONARY SPACE STATION SUCH AS:

- MOMENTUM MANAGEMENT IN A MULTI-USER ENVIRONMENT.
- MULTI-VEHICLE TRAFFIC MANAGEMENT AND PROXIMITY OPERATIONS.
- CONTROL SYSTEM STABILITY FOR MULTIPLE FLEXIBLE STRUCTURES.
- ROBUST PERFORMANCE FOR VASTLY CHANGING CONFIGURATIONS.

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