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Hypersonic Research Facilities Study

Volume IV Part 3

Phase III Final Studies

Research Requirements Analysis and Facility Potential

Prepared Under Contract No. NAS2-5458
by
Advanced Engineering
MCDONNELL AIRCRAFT COMPANY
for
OART - ADVANCED CONCEPTS AND MISSIONS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Moffett Field, California 94035

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FOREWORD

This report summarizes the results of the Hypersonic Research Facilities Study Phase III effort performed during the period from 2 January 1970 through 26 June 1970 under National Aeronautics and Space Administration Contract NAS2-5458 by McDonnell Aircraft Company, (MCAIR), St. Louis, Missouri, a division of McDonnell Douglas Corporation.

The study was sponsored by the Office of Advanced Research and Technology with Mr. Richard H. Petersen as Study Monitor and Mr. Hubert Drake as alternate Study Monitor.

Mr. Charles J. Pirrello was Manager of the HYFAC project and Mr. Paul A. Czysz was Deputy Manager. The study was conducted within MCAIR Advanced Engineering, which is directed by Mr. R. H. Belt, Vice President, Aircraft Engineering. The HYFAC study team was an element of the Advanced Systems Concepts project managed by Mr. Harold D. Altis.

The Phase III analysis of Research Requirements and Facility Potential primarily involved quantification of the value of the candidate research facilities at the Research Task level, and consolidation of the research requirements defined in the earlier phases of the study.

This is Volume IV, Part 3 of the overall HYFAC report, which is organized as follows:

		NASA CONTRACTOR REPORT NUMBER
Volume I	Summary	CR 114322
Volume II	Phase I Preliminary Studies	
	Part 1 - Research Requirements and Ground Facility Synthesis	CR 114323
	Part 2 - Flight Vehicle Synthesis	CR 114324
Volume III	Phase II Parametric Studies	
	Part 1 - Research Requirements and Ground Facility Synthesis	CR 114325
	Part 2 - Flight Vehicle Synthesis	CR 114326
Volume IV	Phase III Final Studies	
	Part 1 - Flight Research Facilities	CR 114327
	Part 2 - Ground Research Facilities	CR 114328
	Part 3 - Research Requirements Analysis and Facility Potential	CR 114329
Volume V	Limited Rights Data	CR 114330
Volume VI	Operational System Characteristics	CR 114331

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This work was performed by an Aircraft Advanced Engineering study team with Charles J. Pirrello as Study Manager.

The following contributed significantly to the contents of this volume:

R. D. Dighton	Systems Analysis
R. E. Bay	Flight Test Methods
R. D. Hardin	Ground Test Methods and Ground Facility Capability
J. L. Schudel	Research Requirements and Facility Research Value Evaluation
J. M. Sinnett	Research Facility Capability

SUMMARY

The primary objective of the Hypersonic Research Facilities Study is to assess the research requirements for hypersonic aircraft and define several desirable hypersonic research facilities based on these requirements. Assessment of hypersonic research requirements and evaluation of the potential of several attractive facilities to satisfy these requirements is summarized in this volume.

HYFAC study results include definition of the major Research Tasks applicable to operational hypersonic systems, design of two attractive flight research vehicles and five conceptual ground research facilities and quantitative evaluation of individual facility capability to accomplish the identified Research Tasks.

Hypersonic research requirements were established through unique decision-theory techniques applied to a systematic survey involving 66 NASA, USAF, and MCAIR technical specialists. This survey formed the basis for the establishment of the intrinsic value, or relative importance, of each Research Task.

Facility capability assessment is based on the degree of simulation provided by the candidate research facilities, relative to the simulation requirements judged to satisfy the intent of the Research Tasks. Facility capability is, therefore, primarily dependent on the characteristics of the candidate research facilities developed in this study. Two extremely attractive flight research vehicles are outputs of the year-long design iteration and refinement.

- a Mach 6 turboramjet-powered, conventional wing-body aircraft
- a Mach 12 rocket-powered, air launched, all-body vehicle

Both of these vehicles are designed with provisions for installation of options to accomplish focused investigation of particular areas of research. Candidate ground facilities developed during the study include:

- a polysonic gas dynamic facility (Mach .5 to 8.5)
- a hypersonic impulse gas dynamic tunnel (Mach 8 to 13)
- a compound turbomachinery engine facility with clean air capability to Mach 5.5
- a dual-mode ramjet engine facility with equivalent energy simulation to Mach 11
- an integrated structural/fluid systems research facility incorporating thermal, mechanical, acoustic, altitude simulation, and cryogenic flow capabilities.

The conceptual ground research facilities have a complementary capability, as contrasted to the flight research vehicles which are shown to provide uniquely different as well as overlapping research capabilities.

The measure of candidate facility research potential is expressed as Facility Research Value, the product of task intrinsic values and facility capabilities. In general, the Facility Research Values of the candidate flight research vehicles are about 2.0 to 2.5 times the research value of combined existing ground facilities. Although the ground facilities can contribute to research potential only in specific technological areas, they are capable of an improvement of about fifty percent over the combined capability of similar existing facilities.

All of the candidate research facilities are capable of contributing to in-depth research into specific technological areas. The flight research vehicles, however, provide a breadth of research potential which cuts across technological area boundaries and allows examination of vehicle configuration interactions.

A typical high-priority research program, involving scramjet development and integration, was evaluated using the Research Objectives and test methods defined in the study. This typical research program can be conducted, using the candidate research facilities, for less than 100 million dollars.

A dominant observation of the study is that research facility development lead time has a major impact on the successful accomplishment of Research Objectives. Much of the required research is of sufficient complexity, and possesses uniform applicability to all potential operational hypersonic systems, that a research program must be started soon to satisfy projected requirements in the 1980's. For instance, considering a flight research program to establish the confidence to proceed with development of an operational system, a minimum of fifteen years would elapse between research vehicle go-ahead and introduction of an operational system capability.

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1. INTRODUCTION

Hypersonic aircraft are expected to become operational in the post-1980 time period to satisfy military and/or commercial requirements. An extensive research and development program will be required prior to production of any hypersonic aircraft system. The overall objective of the Hypersonic Research Facilities Study is to assess the research requirements for hypersonic aircraft and define several desirable hypersonic research facilities to satisfy these requirements.

The approach followed to fulfill this study objective involved:

(a) Definition of a spectrum of Research Objectives and subsets of Research Tasks necessary for development of representative operational systems

(b) Disciplined quantification of the relative importance of these objectives and tasks as they relate to each operational system

(c) Definition of new conceptual flight research vehicles and ground test facilities to accomplish the identified research tasks

(d) Quantification of the relative capability of existing and new ground facilities and new flight research vehicles to accomplish this research

(e) Estimation of the cost to build and operate these new research facilities.

This volume of the Hypersonic Research Facilities Study report briefly reviews the research requirements analysis performed during the first two phases of the study and presents the results of the facility research potential evaluation completed during Phase III. An important study element involved an assessment of the value of hypersonic research facilities, both flight vehicles and ground installations, in terms of their contribution to achieving the confidence to proceed with operational hypersonic aircraft. It is well recognized that development of critical technologies, properly phased with advanced systems requirements, is the key to this nation's leadership in aerospace. The intent of the research requirements analysis conducted during this study is to identify the relative contribution of Research Tasks to a credible hypersonic research plan. The importance or value of specific Research Tasks is related to the capability of the candidate research facilities to perform these tasks to yield the overall research potential of each conceptual research facility.

Two attractive flight research vehicles were selected for Phase III refinement. These vehicles, described in detail in Part 1 of Volume IV, can be briefly characterized as follows:

- Mach 6 Research Vehicle (C210) - A manned turboramjet-powered vehicle designed for c[illegible]entional takeoff and landing operation.

- Mach 12 Research Vehic[illegible]3) - A manned rocket-propelled vehicle designed for ai[illegible]-la[illegible]tion.

Configuration options were developed for each of these basic vehicles to perform specialized research tasks while minimizing cost and weight penalties in the basic vehicle. The principal options include:

- Mach 6 Research Vehicle

  Thermal Protection System
  Armament

- Mach 12 Research Vehicle

  Scramjet
  Convertible Scramjet
  Thermal Protection System
  Armament
  Horizontal Takeoff/Vertical Takeoff
  Staging
  Subsonic Turbojet

A comprehensive spectrum of ground research facilities was developed during the HYFAC Study, and the list of five facilities selected for Phase III refinement includes:

- GD7 - Hypersonic impulse gasdynamic research facility

- GD20 - Polysonic gasdynamic research facility

- E9 - Dual-mode ramjet engine research facility

- E20 - Integrated turbomachinery/ramjet engine research facility

- S20 - Integrated structures/fluid systems research facility.

The capability of each of the flight research vehicles and ground research facilities to accomplish each identified Research Task has been evaluated. This evaluation was performed by MCAIR specialists in flight and ground testing and forms the basis for measuring the effectiveness of each facility.

Effectiveness of candidate research facilities is defined in this study as research potential, measured in terms of Facility Research Value. Two basic measures of Facility Research Value are presented. One measure is based on the facility's "characteristic" capability; that is, a measure of the facility's ability to accomplish a spectrum of research, not only in the predominant technology area for which it is designed but in other ancillary areas in which it provides a capability. This value provides a measure of the facility's broad versatility. A second, more specific measure evaluates the "focused" Facility Research Value. This is a value representative of the facility's capability to conduct research in the technology area for which it is primarily designed.

Facility Research Values are developed, discussed and interpreted in the following sections for each of the facilities selected for Phase III refinement.

In addition, a typical high-priority research program, development of a scramjet propulsion system, is discussed to illustrate the cost and time involved in accomplishing a typical focused research program. This example provides the arena in which applicability of particular research facilities, costs of performing tasks, and scheduling of tests can be discussed.

2. APPROACH

Analysis of research requirements and evaluation of the capability of candidate hypersonic research facilities to perform the identified research is a key element of the Hypersonic Research Facilities Study. The approach to this study element is briefly described in this section, with a more detailed explanation of the procedure presented in Section 5.

The end result of the research requirements and facility potential analysis is expressed in terms of Facility Research Value. This figure of merit integrates the intrinsic value of each Research Task with the capability of ground and flight research facilities to accomplish the task, as illustrated in Figure 2-1. Summation of the products of intrinsic values and facility capabilities across the spectrum of applicable Research Tasks allows a quantification of the relative research potential of candidate facilities. This research requirements and facility capability analysis has been used, in a broader form, in Phases I and II to select the most effective facilities for further refinement. During Phase III, this analysis has been utilized, not to select or reject facilities, but rather to establish the research potential of the Phase III research facilities. Two major refinements were incorporated in the Phase III analysis.

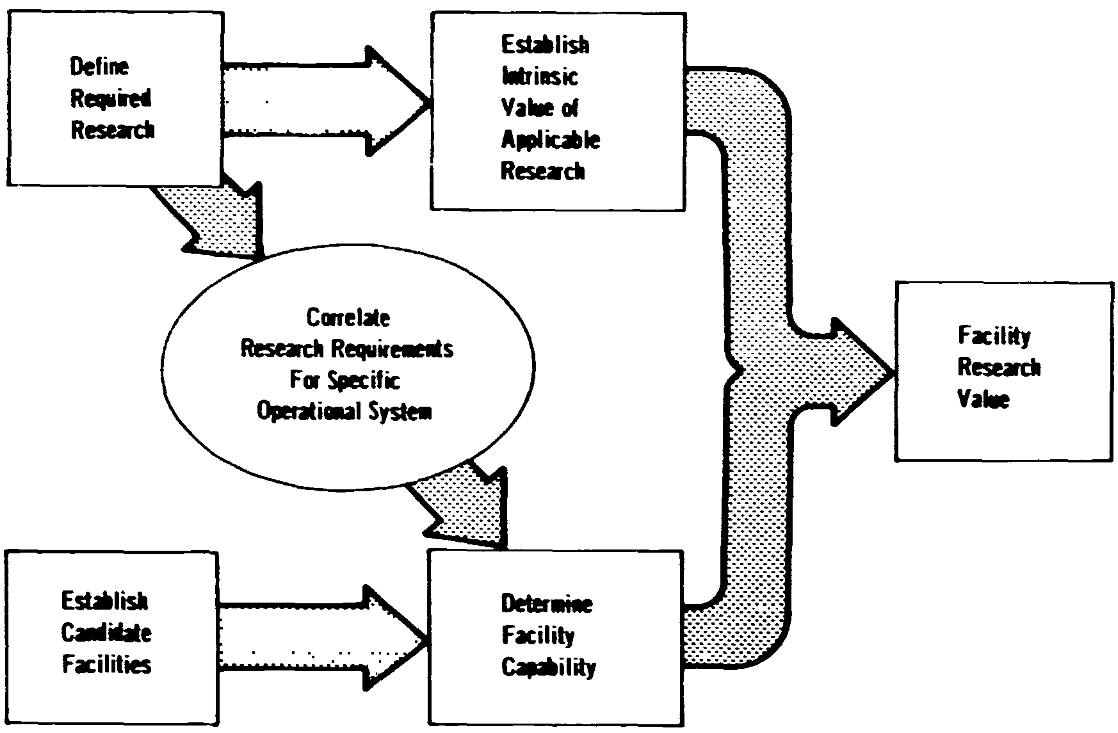
1) The Research Tasks were modified to provide a more precise statement of the research requirements.

2) The evaluation of research facility capability was improved to better reflect the differences between research for which a facility has general capability (identified as "characteristic" research) and research for which the facility would be specifically designed (labeled "focused" research).

Recognizing that specific hypersonic research requirements could not be defined without reference to operational systems, nine hypersonic systems were defined at the initiation of the study. This spectrum of hypersonic aircraft includes four reusable launch systems in the Mach 5 to Mach 12 range, two hypersonic transports cruising at Mach 6 and Mach 10, and three hypersonic weapon systems covering the Mach 4.5 to Mach 12 speed range. Four representative operational systems selected from this comprehensive spectrum have been used throughout Phase III. Their principal characteristics are summarized as follows:

CODE	SYSTEM TYPE	MACH NO.	PROPULSION
L2	Reusable Launch	8-10	Turbojet + Convertible Scramjet
C1	Hypersonic Transport	6	Turboramjet
M1	Advanced Manned Interceptor	4.5	Turboramjet
M2	Strategic Strike	12	Rocket + Scramjet

FIGURE 2-1
FACILITY RESEARCH VALUE DEVELOPMENT



A comprehensive list of 78 Research Objectives was defined during the study to encompass the research needed to provide an adequate level of confidence to proceed with development of a hypersonic system. The relative importance, or intrinsic value, of each Research Objective was determined with the aid of a unique application of decision theory techniques. These techniques, applied to basic inputs from 66 NASA, USAF, and industry technical specialists, provided a disciplined and objecttive analysis of hypersonic aircraft research requirements. Widespread scientific-community participation to this extent in such a disciplined approach is believed to be unprecedented for identifying and evaluating research requirements for future aerospace programs.

The resulting list of objectives was later subdivided into 237 Research Tasks to allow a more detailed analysis to be performed during Phases II and III. Evaluation of the research potential of the five conceptual ground facilities and the two candidate flight research vehicles to perform these Research Tasks was a primary Phase III effort. The capability of each candidate new research facility is determined in terms of the percentage of each Research Task potentially accomplished in the facility. Research potential for each applicable task is the product of the task intrinsic value and the facility capability value. Adding these products over the tasks applying to a particular operational system yields the Facility Research Value. Facility Research Values are presented in this report on both a characteristic and a focused basis.

The unique nature of the research requirements and facility capability analysis has resulted in the coining of many new terms with specific meanings. In order to assist in the understanding of this analysis, a glossary of the principal terms is presented.

Operational System	A specific aircraft configuration identified within the spectrum of hypersonic vehicles potentially operable in the post-1980 time period.
Research Objective	Major research in a specific area which must be accomplished prior to initiation of the development cycle of an operational system.
Research Task	A specific research item identified as an element of one of the defined Research Objectives and involving particular types of tests or analyses.
Intrinsic Values	A measure of the importance of the Research Objectives and Tasks as they relate to one another with respect to a particular operational system.
Facility Capability	A measure of the ability of a facility to perform the research defined by a particular Research Task.
Facility Research Value	A quantitative measure of a facility's effectiveness in accomplishing research, considering both intrinsic values and facility capabilities.
Characteristic Facility Research Value	A measure of a facility's ability to accomplish a broad spectrum of research.
Focused Facility Research Value	A value representative of a facility's capability to accomplish research for which it is primarily designed.
Acquisition Cost	The Research and Development cost plus the Investment Cost for a ground facility or flight research vehicle (Operating costs are excluded).

3. RESEARCH TASKS

A preliminary list of Research Tasks was established during Phase II and is presented in Volume III, Part 1. One of the major efforts during the early stages of Phase III involved the refinement and condensation of this list into a final set of tasks for use in the Phase III research requirements analysis. The resulting final Research Tasks list, presented in the following pages, contains a total of 237 Research Tasks, each designated by the abbreviation "RT". The Research Objectives to which these tasks relate are indicated by the abbreviation "RO". Since the initial list of Research Objectives defined in Phase I totaled 102, the code numbers of the Research Objectives and Tasks accumulate to this number. However, 24 of these original objectives were combined with other objectives during Phase II. The Phase III analysis includes only the remaining 78 objectives and their corresponding tasks.

The tasks are classified according to the technology area to which they can be most closely identified, as were the Research Objectives. The number of Research Tasks in each technological area is as follows:

Category	No. of Tasks
Aerodynamics	51
Thermodynamics	23
Structures and Materials	44
Propulsion	53
Subsystems	45
Operation	21
	237

PHASE III RESEARCH TASKS

AERODYNAMICS

RO 1 - Determine low speed (takeoff and landing) aerodynamic characteristics of hypersonic aircraft.

RT 1.1 - Investigate low speed, takeoff and landing, high lift, longitudinal, lateral, and directional stability and control and aerodynamic loads of most promising hypersonic aircraft configurations.

RT 1.2 - Investigate methods of providing takeoff and landing performance employing aerodynamic surfaces, propulsive systems and/or combined aero-propulsive systems.

RT 1.3 - Evaluate integrated high lift configuration performance and maximum useable angle of attack as limited by power effects, ground effects, buffet, wing drop, ground clearance and pilot visibility.

RT 1.4 - Investigate handling characteristics and evaluate trim capability, effects of adverse C.G. location on trim and basic flight characteristics and on the control power available from the trimmed condition.

RO 2 - Determine subsonic and transonic aerodynamic characteristics of hypersonic aircraft.

RT 2.1 - Investigate subsonic/transonic longitudinal and lateral-directional stability and control and aerodynamic loads of most promising hypersonic aircraft configurations.

RT 2.2 - Investigate methods of providing high subsonic/transonic performance considering such factors as shape, trim requirements, inlet position, jet effects, and effects of shock wave/boundary layer interaction.

RT 2.3 - Investigate subsonic/transonic configuration performance and maximum useable angle of attack as limited by buffet onset, thrust margin, maximum lift, and longitudinal control power.

RT 2.4 - Investigate handling characteristics and evaluate trim capability, effects of adverse C.G. location on trim and basic flight characteristics and on the control power available from the trimmed condition.

RO 3 - Determine supersonic and hypersonic aerodynamic characteristics of hypersonic aircraft.

RT 3.1 - Investigate methods of providing high supersonic/hypersonic performance considering such factors as shaping to achieve maximum lift-to-drag ratio, neutral point control, and low trim drag requirements.

RT 3.2 - Investigate supersonic/hypersonic longitudinal and lateral-directional stability and control and aerodynamics loads of the most promising hypersonic aircraft configurations.

RT 3.3 - Investigate the effects of boundary layer transition, separation, and interaction with shock waves on lift/drag, performance, stability and control.

RT 3.4 - Investigate the effect of engine exhaust plumes on lift, drag and longitudinal stability.

RO 4 - Provide new or update present testing techniques for aerodynamic research facilities so Reynolds number, shock wave, and boundary layer dependent phenomena can be correctly simulated using subscale models.

RT 4.1 - Investigate techniques to better approximate the free flight recovery temperature to skin temperature ratios in ground tests.

RT 4.2 - Develop techniques to allow determination of more representative free flight aerodynamic data from conventional wind tunnels. Minimize extrapolation range and improve soundness of technical base.

RT 4.3 - Investigate relationship between boundary layer thickness and shock location on the local flow structure.

RO 5 - Define the design criteria and systems requirements for acceptable handling qualities for hypersonic aircraft.

RT 5.1 - Define fundamental parameters and levels of acceptance of flying qualities in longitudinal and lateral directional mode.

RT 5.2 - Investigate control systems response characteristics required to provide acceptable flying qualities for a hypersonic aircraft.

RT 5.3 - Investigate the interaction between control capability, structural flexibility, controls system dynamics, and pilot response as related to pilot induced oscillations.

RO 6 - Evaluate design techniques for obtaining favorable aerodynamic interference effects through surface or inlet positioning.

RT 6.1 - Investigate interference flow field characteristics relative to aerodynamic surfaces and evaluate the effects of surface positioning on performance stability and control.

RT 6.2 - Investigate interference flow field characteristics relative to engine inlets and evaluate the effects of inlet positioning on performance, stability and control.

RT 6.3 - Investigate interference flow field of integrated configurations and evaluate the performance, stability and control characteristics with most promising surface and inlet arrangement.

RO 7 - Evaluate design techniques of using the aircraft body for engine exhaust expansion, thereby providing lift. Determine the effect of propulsive gas flow interactions.

RT 7.1 - Determine simulation requirements (flow field and exhaust flow) for meaningful data return from ground tests of subscale models.

RT 7.2 - Investigate nozzle design factors such as exhaust vector, local heating, pressure distributions and noise.

RT 7.3 - Investigate effects of afterbody contours (with engine operation) on aerodynamic characteristics over the flight Mach number range.

RO 9 - Investigate the effects of variable inlet and nozzle geometry, bypass airflow, propulsion mode changes, and aerothermoelastic effects on hypersonic aircraft stability and aerodynamic forces.

RT 9.1 - Investigate the effects of engine inlet and exhaust flow on aircraft, performance, stability and control.

RT 9.2 - Investigate the effects of engine on-off operation and inlet unstarts on stability and control.

RT 9.3 - Investigate the effects of variable bypass and propulsion mode changes on performance, stability and control.

RT 9.4 - Investigate aerothermoelastic effects on hypersonic aircraft performance, stability and control.

RO 10 - Develop design principles for stage integration which provide reduced drag characteristics and other aerodynamic improvements throughout the speed range for two-stage hypersonic launch vehicles.

RT 10.1 - Evaluate launch mode stage integration concepts including configuration, performance and structural design requirements.

RT 10.2 - Investigate the aerothermodynamic effects and the impact of the design concepts on flight vehicle performance, stability and control.

RO 11 - Determine separation techniques for two-staged hypersonic vehicles which will provide positive separation and individual staged control.

RT 11.1 - Identify attractive separation concepts.

RT 11.2 - Investigate individual vehicle flying qualities and the effects of local flow field during stage separation. This task includes evaluation of the effects of the separation pressure fields on structural dynamic characteristics of both stages. Investigations also include evaluation of the effects of size, shape, relative positioning, proximity and exhaust plumes as well as methods of measurement and analysis.

RT 11.3 - Evaluate active, augmented, or passive control of the second stage during separation to identify the concept providing the greatest reliability and responsive performance.

RO 12 - Improve fundamental knowledge of hypersonic boundary layer behavior in the presence of adverse pressure gradients and shock interactions.

RT 12.1 - Determine effect of recovery temperature to surface temperature ratio on shock-induced flow separation tolerance at hypersonic Mach numbers.

RT 12.2 - Investigate Reynolds number and pressure gradient effects on shock strength and shock induced separations on inclined or discontinuous surfaces and inlet ramps.

RT 12.3 - Investigate boundary layer growth and methods of control on inclined surfaces and inlet ramps.

RO 14 - Develop correlation techniques for the prediction of buffet onset for low aspect ratio configurations, involving longitudinal (body) bending motions as well as wing bending responses.

RT 14.1 - Investigate methods of correlating and applying buffet onset and intensity evaluations to full scale hypersonic aircraft considering variations in geometric parameters such as aspect ratio, leading edge sweepback and slenderness ratio of hypersonic aircraft.

RT 14.2 - Evaluate the effect of a non-steady flow field condition on buffet onset.

RT 14.3 - Correlate wind tunnel-obtained buffet onset and intensity with a flight vehicle representative of an operational hypersonic vehicle.

RO 15 - Evaluate configuration shaping techniques and flight path variation for alleviating sonic boom intensity, and study near and far field noise levels.

RT 15.1 - Investigate sonic boom signature characteristics and near and far field noise frequency/intensity spectrum which constitute an irritation.

RT 15.2 - Investigate the feasibility of configuration shaping to materially affect the perceived sonic boom intensity.

RT 15.3 - Evaluate changes in perceived sonic boom intensity and noise levels as produced by variation in flight path.

THERMODYNAMICS

RO 20 - Determine the overall vehicle thermodynamic characteristics in hypersonic flight.

RT 20.1 - Investigate the hypersonic heat transfer distributions on representative operational configurations as a function of attitude and Reynolds number.

RT 20.2 - Investigate the hypersonic heat transfer distributions on aerodynamic surfaces in the vicinity of reaction control jets.

RT 20.3 - Investigate the effects of staging and separation on hypersonic heat transfer distributions.

RT 20.4 - Study and substantiate the analytical modeling of generalized and localized flow fields to provide full scale prediction techniques.

RO 22 - Investigate shaping of aerodynamic surfaces to reduce skin temperatures, and the effects of protuberances and surface irregularities on hypersonic aircraft drag and aerodynamic heating.

RT 22.1 - Investigate the effects of surface shaping on skin temperature distributions.

RT 22.2 - Investigate the effects of protuberance shaping on local skin temperatures.

RT 22.3 - Investigate the effects of surface irregularities on aerothermodynamic design and performance.

RO 23 - Determine the effects of transpirative or ablative processes on skin friction and heat transfer.

RT 23.1 - Investigate and describe the mechanisms of mass transfer peculiar to each process (ablation, transpiration) and the effects of these mechanisms on skin friction and heat transfer.

RT 23.2 - Develop an analytical model which characterizes the surface phenomena for each process. Refine the model to reflect the impact of ablation and transpiration on skin friction and heat transfers and experimentally substantiate the validity of the model.

RT 23.3 - Investigate the application of these techniques to time variant conditions corresponding to the flight profile, evaluating the impact of ablation and transpiration on overall vehicle performance.

RO 24 - Determine the effects of embedded shock, vortices, separation, and reattachment on skin friction and heat transfer for leeside flows.

RT 24.1 - Investigate leeside flow conditions of hypersonic aircraft configurations and the effects of such factors as separation, vortex formations, and shock waves on the flow field description.

RT 24.2 - Investigate mechanisms of mixed boundary layer leeside flows characterized by such phenomena as cross flows, vortices, embedded shock waves, separations, reattachments and interferences.

RT 24.3 - Experimentally obtain and correlate skin friction and heat transfer data for leeside flows including the effects of such flow phenomena as vorticity, separation, reattachment, and embedded shocks.

RO 25 - Determine the aerodynamic heating effects produced by flow through gaps resulting from adjacent aircraft surfaces, and rapid changes in operational altitude.

RT 25.1 - Investigate the effects of gap flow on aerodynamic heating of structures such as leading edges and shingles.

RT 25.2 - Investigate the effects of gap flow on aerodynamic heating of moveable control surfaces.

RT 25.3 - Investigate the effect of gap flow and resulting heating of control surfaces on control effectiveness.

RT 25.4 - Study interaction of structural breathing during climb and descent with local pressure and heat transfer conditions.

RO 26 - Determine changes in heat transfer due to reduced radiation cooling efficiency resulting from vehicle geometric interactions (view factors).

RT 26.1 - Investigate methods of evaluating two-and-three-dimensional view factors for complex structural elements.

RT 26.2 - Experimentally develop and substantiate analytical modeling for predicting view factors for adjacent and intersecting external surfaces as well as for internal structural arrangements.

RT 26.3 - Investigate the effects of internal and external view factors on equilibrium surface temperatures.

Develop methods for predicting heat transfer due to radiation or gas impingement from engine exhaust.

RT 27.1 - Evaluate the severity of increases in heat transfer due to exhaust gas interaction. This task includes adequate definition of exhaust flow field and gaseous radiation, as well as, application of view factor and hypersonic boundary layer data.

RT 27.2 - Determine simulation requirements (exhaust flow and heat transfer to external surface) for meaningful data return from ground tests of subscale models.

RT 27.3 - Experimentally develop methods for predicting heat transfer in the engine exhaust area and establish scaling laws.

STRUCTURES AND MATERIALS

RO 28 - Develop efficient reusable thermal protection systems for cryogenic fuel and oxidizer tankage.

RT 28.1 - Evaluate potential of candidate materials (tank structure, insulation and vapor barrier) in their operating thermal environment. This task will include consideration of physical properties, chemical compatibility, operating lifetime and duty cycles.

RT 28.2 - Evaluate fabrication techniques for incorporating attractive materials into thermal protection concepts for cryogenic tankage. The accomplishment of this task will require the consideration of bonding and joining techniques, tank penetrations, subsystem supports, thermal cycling, and equivalent panel thermal conductivity.

RT 28.3 - Investigate and demonstrate non-destructive evaluation (NDE), fabrication, inspection, and repair techniques.

RT 28.4 - Demonstrate and verify the structural and thermal protection concepts by subjecting representative tank structures to flight simulated thermal and altitude environments, mechanical loads, and fuel-flow conditions.

RO 30 - Evolve more efficient concepts for fuselage and tank structures for both circular and non-circular applications.

RT 30.1 - Investigate methods of tankage integration into promising aerothermodynamic shapes and develop analytical models to allow determination of efficient and practical tank structural concepts.

RT 30.2 - Investigate fabrication, installation and repair methods and construct demonstration models of most promising tankage concepts.

RT 30.3 - Experimentally verify the adequacy of analytical models used to define tank and fuselage structures and to develop promising tankage concepts.

RO 32 - Develop efficient reusable leading edge concepts and identify promising concepts for specific materials in relation to the flight regime.

RT 32.1 - Perform basic high temperature materials research for possible material candidates for use in oxidizing environments. The strength at temperature, creep resistance/time to rupture, oxidation resistance, duty cycle/operating lifetime, and the tenacity of oxide film must be considered in accomplishing this task.

RT 32.2 - Investigate and demonstrate the applicability of protective coating concepts to maintain basic materials limits in a reusable application. The coating concepts to be considered in this task include oxidation protection coatings and insulative protection coatings that permit higher surface temperature operation, and emissivity control coatings.

RT 32.3 - Evaluate various leading edge concepts considering fabrication techniques, material compatibility, coating, and major structural build-up.

RO 33 - Develop control surface technology and demonstrate the design concept fabrication techniques, and operation under flight-like conditions of temperature and loads.

RT 33.1 - Integrate available research results and define control surface physical and environmental boundaries.

RT 33.2 - Investigate the requirements and develop thermal protection system concepts, methods of attachment, aerodynamic sealing, and methods of actuation.

RT 33.3 - Demonstrate the satisfactory performance and operational duty cycles of the control surfaces and associated hardware in a duplicated flight thermal and mechanical load environment.

RO 34 - Develop long life regeneratively cooled structural concepts for application in high heat flux areas such as leading edges and propulsion systems.

RT 34.1 - Investigate the applicability of multiple/single fluid cooling concepts for operation in the proposed flight environment and specify the required thermophysical properties of candidate heat exchanger materials. The selection of candidate materials will include the development of fabrication techniques by manufacturing prototype panels, developing inspection techniques, and integrating the prototype panels into the primary structure.

RT 34.2 - Determine physical and chemical compatibility of candidate heat exchanger materials with heat exchange fluids in the operating temperature/pressure regime.

RT 34.3 - Analytically determine flow passage orientation and shape. The accomplishement of this task will include the consideration of heat transfer, flow velocity, operating pressure level, temperature distribution (panel ΔT and maximum wall temperature), and panel strength to weight ratio.

RT 34.4 - Demonstrate the integrity and operation of the heat exchanger panel under flight heat transfer rates and flow conditions.

RO 35 - Provide a structure which maintains aerodynamic smoothness under actual operational conditions and use.

RT 35.1 - Analytically and empirically establish allowable limits of surface irregularities and smoothness to maintain vehicle heating and performance within design limits.

RT 35.2 - Investigate structural concepts under mechanical loads, thermal, and thermal/mechanical load testing to verify structural smoothness and surface irregularities are within the established limits.

RO 36 - Define the effects of combined mechanical loading and thermal stress cycling under actual environmental conditions on the life of the structural components.

RT 36.1 - Define environmental and design parameters that will affect materials research, and candidate materials selection.

RT 36.2 - Conduct extensive coupon testing to select candidate materials by determining their physical and thermal properties, physical and chemical compatibility, and high temperature oxidation resistance. Determine the effect of repeated duty cycles under flight environmental conditions on the materials properties and characteristics.

RT 36.3 - Construct full-scale structural components and test under combined thermal, load, and other environmental conditions to verify coupon data and to establish a realistic measure of operating life.

RO 38 - Determine the effects of fuel slosh on the dynamics and inertia loads of low aspect ratio hypersonic aircraft with large volume fuel tankage.

RT 38.1 - Study slosh modes and intensities to determine the influence of the fluid dynamics on structural loading and tank design.

RT 38.2 - Investigate inertial forces and center of gravity perturbations produced by fuel slosh and translate this into effects on the stability and control of hypersonic aircraft throughout its flight regime. Identify those regions where this effect is significant.

RT 38.3 - Investigate methods to minimize fuel motion effects and verify the effectiveness of slosh suppression devices. Determine impact on the overall vehicle flight characteristics.

RO 39 - Determine the parameters of correlation for the analysis of the effects of near field noise on minimum gauge structures, composite structures, and non-metallics.

RT 39.1 - Examine the potential hypersonic vehicles to determine those locations where the structure consists of thin-gauge, composite, or non-metallic materials, and identify the temperature/time and acoustic power spectral density/time characteristics at these locations in order to identify the corresponding thermal-acoustical environment.

RT 39.2 - Experimentally identify failure mechanisms of a structural element in an actual thermal-acoustic environment and develop an analytical model to describe the structural failure mode.

RO 40 - Develop non-destructive evaluation (NDE) and inspection methods for sandwich structure, composite materials, diffusion bonded materials, and coatings.

RT 40.1 - Investigate non-destructive evaluation methods which can detect and identify potential structural failures.

RT 40.2 - Evaluate the effectiveness of NDE techniques through the use of "calibrated failure" specimens (calibrating output of NDE systems vs degree of failure).

RT 40.3 - Experimentally determine the effects of partial damage or minor defects and correlate degree of failure with remaining operational life.

RO 41 - Develop a capability to accurately estimate component and structural mass fractions for all types of hypersonic aircraft designs.

RT 41.1 - Develop a matrix of weight accounting systems for each major component concept, reflecting parametric variations within the concept and specifying its applicability within discrete portions of the flight envelopes.

RT 41.2 - Develop an analytical discriminatory accumulation/recall technique for selecting and incorporating applicable portions of the matrix to arrive at integrated mass fraction estimates for major vehicle elements. Provisions should be made for continual update of each matrix element of design concept information and actual weight verification as information becomes available.

RO 42 - Verify and demonstrate the integrity of the structural and thermal-structural concepts by testing full-scale structural sections.

RT 42.1 - Demonstrate the structural and thermal adequacy of a fully integrated structure (a major section of an operational system) and verify the performance of individual systems and components contained in the major section when subjected to flight-simulated operating environments. Testing major-section sized test articles will verify component assembly, structural and thermal interactions, structural dynamic damping and transmissibility, thermal protection system performance, and demonstration of maintenance and repair techniques.

RO 43 - Develop efficient reusable thermal protection systems for the primary structure.

RT 43.1 - Evaluate potential candidate materials (active and passive system concepts) in their operating thermal and altitude environments. This task will include consideration of physical and thermal properties, chemical compatibility, bonding techniques, and operating lifetime and duty cycles.

RT 43.2 - Establish the reusability capability of candidate thermal protection systems and materials and determine the mean time between failure, minimum time before maintenance, lifetime/duty cycles, and extent of maintenance and repair required.

RT 43.3 - Investigate and demonstrate non-destructive evaluation (NDE), fabrication, inspection, and repair techniques.

RT 43.4 - Correlate experimental data with original analyses to determine adequacy of the analytical base and potential improvements through the use of experimental results.

RO 44 - Define the mechanical and physical properties of advanced materials that have potential application in hypersonic aircraft.

RT 44.1 - Identify potential materials that can significantly improve the aircraft. The principal types of materials to be considered include metal matrix composites, high temperature titaniums, super alloys, refractory metals, and insulative materials.

RT 44.2 - Experimentally establish physical, chemical, and thermal properties, formability, weldability, and fabrication characteristics, and lifetime/duty cycle limits of candidate materials.

RO 45 - Improve fabrication techniques for advanced materials and complex structure.

RT 45.1 - Investigate suitability of fabrication techniques for metallic, non-metallic and composite sandwich structural concepts which have the potential of improving overall aircraft performance.

RT 45.2 - Investigate the effects of various fabrication processes such as welding, brazing, bonding and forming elements of structural assemblies as well as the effects of reuseable coatings of refractory metals on the integrity of various structural concepts.

RT 45.3 - Experimentally demonstrate the capability of various fabrication techniques by subjecting coupons and/or structural elements or assemblies to representative operating or flight conditions.

RO 46 - Develop high temperature bearings, lubricants, closure seals, tires, windshields, and radomes.

RT 46.1 - Investigate and define operating environments of system components and establish existing material performance limits as applicable to each design in a component class.

RT 46.2 - Identify required improvements in each system component and investigate potential gains in performance, service life, and reliability of modified component designs and alternate materials.

PROPULSION

RO 48 - <u>Develop inlet configurations for the desired flight conditions and engine operating modes to enable the propulsion system to achieve the desired performance</u>.

RT 48.1 - Investigate vehicle forebody configurations upstream of the inlet, to establish the local flow field conditions at potential inlet locations over the operational range of α and β.

RT 48.2 - Experimentally study different inlet classes to determine the airflow characteristics delivered to the propulsion system for each inlet class as a function of operational variables such as attitude (α, β), Mach number, and Reynolds number.

RT 48.3 - Investigate scaling laws to allow determination of minimum inlet model size for meaningful data and to provide extrapolation rules from model size to full-scale.

RT 48.4 - Investigate inlet design and forebody shapes to determine overall aerodynamic and engine airflow characteristics. This task includes considerations of additive drag, bypass and bleed drag, configuration L/D, aerodynamic stability, steady-state and time variant distortion, pressure recovery, and off-design operation.

RT 48.5 - Investigate the inlet problems associated with use of a common inlet for combination engine concepts.

RO 52 - <u>Develop engine design concepts amenable to cooling by various techniques (regeneration, ablation, radiation, transpiration)</u>.

RT 52.1 - Investigate existing engine concepts throughout their applicable Mach number range to determine what conceptual alterations would result from considering active cooling of rotating machinery, combustors, and nozzle throat at inception of the concept.

RT 52.2 - Define component technology levels and their design/performance requirements for ablation and transpiration cooling system.

RT 52.3 - Define component technology levels and their design/performance requirements for regenerative and radiative cooling concepts.

RT 52.4 - Experimentally evaluate individual component performance, using this data as a baseline to assess overall cooled-engine concept feasibility and available performance increment.

RO 55 - <u>Investigate methods for reducing engine noise during takeoff and landing</u>.

RT 55.1 - Investigate noise abatement systems for airbreathing engine inlets.

RT 55.2 - Investigate noise abatement systems for airbreathing engine nozzles.

RT 55.3 - Investigate noise abatement systems for rocket engine nozzles.

RO 57 - Develop and integrate engine components into a complete large-scale turboramjet system. Demonstrate compatibility and overall performance throughout an applicable flight envelope.

RT 57.1 - Perform cycle analysis for each engine concept in all operating modes to determine the necessary levels of performance for individual components.

RT 57.2 - Formulate potential design concepts for each turboramjet component. This task includes considerations of materials selection, thrust/weight, operating stress levels, case temperatures and pressures, and concept reliability.

RT 57.3 - Investigate engine qualification techniques (considering facility capability) and establish a qualification and acceptance program for turboramjet engines.

RT 57.4 - Verify technology of component design and operation through experiment at operating conditions.

RT 57.5 - Integrate proven components into a demonstrator engine system and demonstrate its performance.

RT 57.6 - Demonstrate integrated inlet/engine/nozzle concept propulsion systems performance over the range of Mach number, altitude, and attitude.

RO 58 - Perform sufficient cycle analysis and mission analysis to select the best multi-mode cycle and size engine for application to a specific hypersonic mission aircraft.

RT 58.1 - Define representative mission profiles in order to identify the dominant characteristics which drive installed engine performance levels.

RT 58.2 - Perform cycle analyses and select candidate engine concepts consistent with mission requirements. This task includes studies of single mode, combination single mode, composite cycle, and dual mode engines.

RT 58.3 - Perform mission performance studies, identifying the most attractive integrated propulsion system concept satisfying the performance objectives. This task includes considerations of aerodynamic performance, installed engine performance, and aircraft configuration.

RO 59 - Develop and integrate engine components into a complete, large-scale ramjet system. Demonstrate compatibility and overall performance throughout an applicable flight envelope.

RT 59.1 - Perform cycle analysis for ramjet engine concepts to establish necessary levels of performance, operating environment, and limiting conditions for engine starting.

RT 59.2 - Formulate potential design concepts for each ramjet component. This task includes considerations of materials selection, thrust/weight, operating stress levels, case temperatures and pressures, and concept reliability.

RT 59.3 - Investigate engine qualification technique (considering facility capability) and establish a qualification and acceptance program for man-rated ramjet engines.

RT 59.4 - Verify technology of component design and operation through experiment at operating conditions.

RT 59.5 - Integrate proven components into a demonstrator engine system and demonstrate its performance.

RT 59.6 - Demonstrate integrated (inlet/engine/nozzle) propulsion systems' performance over the range of Mach number, altitude, and attitude.

RO 60 - Develop and integrate engine components into a complete significantly sized convertible scramjet module. Demonstrate compatibility and overall performance throughout an applicable flight envelope.

RT 60.1 - Perform cycle analysis for dual mode ramjet (convertible scramjet) modules to establish necessary levels of performance, operating environment, and Mach number limits for engine starting, for both the subsonic and supersonic combustion modes.

RT 60.2 - Formulate potential design concepts for each convertible scramjet component. This task includes considerations of materials selection, thrust/weight, operating stress levels, surface temperatures and pressures, and concept reliability.

RT 60.3 - Investigate engine qualification technique (considering facility capability) and establish a qualification and acceptance program for man-rated convertible scramjet engines.

RT 60.4 - Verify technology of component design and operation through experiment at operating conditions.

RT 60.5 - Integrate proven components into a demonstration engine module to serve as an operable base line for demonstration and determine its performance characteristics.

RT 60.6 - Demonstrate integrated (inlet/engine/nozzle) propulsion systems performance over the range of Mach number, altitude and attitude.

RO 61 - <u>Develop and integrate engine components into a complete, significantly sized scramjet module. Demonstrate compatibility and overall performance throughout an applicable flight envelope.</u>

RT 61.1 - Perform cycle analysis for scramjet module concepts to establish necessary levels of performance, operating environment, and Mach number limits for engine starting.

RT 61.2 - Formulate potential design concepts for each scramjet module component. This task includes considerations of materials selection, thrust/weight, operating stress levels, surface temperatures and pressures, and concept reliability.

RT 61.3 - Investigate engine qualification technique (considering facility capability) and establish a qualification and acceptance program for man-rated scramjet engines.

RT 61.4 - Verify technology of component design and operation through experiment at operating conditions.

RT 61.5 - Integrate proven components into a significantly sized engine module and demonstrate its performance.

RT 61.6 - Demonstrate integrated (inlet/engine/nozzle) propulsion systems performance over the range of Mach number, altitude, and attitude.

RO 62 - <u>Integrate a rocket engine into a horizontal take-off aircraft configuration and demonstrate system performance throughout an applicable flight envelope.</u>

RT 62.1 - Investigate potential aircraft configurations and rocket engine systems (including fuel tankage concepts) and select the most promising combination for demonstration purposes.

RT 62.2 - Integrate engine and airframe into a demonstration vehicle. This task covers design, development, fabrication and assembly of a significantly sized system.

RT 62.3 - Demonstrate operation of the engine and airframe system from launch throughout an extensive maneuvering flight envelope of Mach number, altitudes, and attitudes.

RO 63 - <u>Develop inlet controls for hypersonic aircraft which are simple, reliable, accurate, and have rapid response.</u>

RT 63.1 - Define the aerothermodynamic environment of inlet control surfaces.

RT 63.2 - Investigate techniques of sensor control to achieve desired levels of performance.

RT 63.3 - Define and demonstrate control and actuator system designs for precision control positioning in flight environments.

RO 64 - Evaluate suitability of auxiliary turbojets for landing of hypersonic vehicles.

RT 64.1 - Investigate the operational aspects of a turbojet assisted landing mode for hypersonic configurations to delineate advantages of power assisted descent and landing, deployment point in terminal trajectory, and thrust vector orientation.

RT 64.2 - Determine low speed stability and handling qualities with turbojet assist and compare with baseline landing mode data for hypersonic configurations.

RO 65 - Determine nozzle configurations to produce high net thrust while maintaining efficient integration with the airframe.

RT 65.1 - Investigate the engine exhaust nozzle requirements for turboramjets, ramjets, convertible scramjets, and scramjets.

RT 65.2 - Define performance requirements and possible nozzle configurations such as convergent - divergent, laval, expansion - deflection, plug nozzles which provide compatibility in engine - airframe integration.

RT 65.3 - Evaluate integrated engine - airframe net thrust, afterbody, and boat tail drag over a representative flight regine, identifying the features which contribute favorably to hypersonic aircraft performance.

RO 67 - Determine inlet/engine compatibility criteria (both steady-state and time-varying) for high-total-pressure-recovery, wide Mach range inlets.

RT 67.1 - Study the engine simulation technique currently used for wind tunnel tests. Develop techniques representative of the pneumatic/acoustic impedences and operational characteristics of hypersonic aircraft engine concepts.

RT 67.2 - Investigate techniques for duplicating the flow disturbances and their effect on the time variant engine face pressure distributions, permitting evaluation of actual engine operations in the presence of these distrubances.

RT 67.3 - Study and correlate research results, using improved techniques, to derive parameters indicative of engine tolerance to steady state and time variant flow non-uniformities. This task also includes formulation of integration criteria and engine/inlet design guidelines.

SUBSYSTEMS

RO 68 - Develop operational systems and procedures for the thermal conditioning, storage, safe handling, and logistics of cyrogenic propellants which are compatible with typical airfield requirements.

RT 68.1 - Conduct basic research into subcooling methods and analyze attractiveness in terms of capital investment, operational cost, and complexity required to significantly improve performance. This includes study of such methods as low pressure boiloff (vacuum pumping), helium refrigeration, and isentropic expansion.

RT 68.2 - Provide a "pilot plant" subcooling system to permit experimental research into potential development problems, operational requirements, and verification of the subcooling technique as applied to large-scale continuous production.

RT 68.3 - Investigate attractive methods to provide techniques for safe, efficient storage and transport of normal boiling point and subcooled cyrogenic propellants. Consideration is given to global support and minimum base/facility requirements.

RO 69 - Develop analytical correlation techniques through empirical evaluation to permit the determination of the fluid dynamic and thermodynamic characteristics of cyrogenic propellants in large horizontal tankage in a vibrating, sloshing, pressurized environment.

RT 69.1 - Investigate contemporary vertical tank correlation techniques and research their capability to account for transverse geometric and acceleration characteristics. Study the parametric variations in slosh, tank outflow, and heat flux to determine the effects upon overall heat and mass transfer within the tank, propellant gas quantities, and tank pressure recovery/response rates.

RT 69.2 - Design, develop, and test subscale tankage to either substantiate available correlations or to permit developing new correlations. Research must include simulation of dynamic, pressurized, thermal aircraft environment.

RT 69.3 - Evaluate the effects of slosh suppression techniques and subcooled vs NBP operation on pressurant collapse potential, tank pressure recovery, and minimum ullage capability.

RO 70 - Develop regenerative cryogenic heat exchangers, thermodynamic correlations, and control systems for structural and engine cooling which are compatible with representative heat loads and material temperature limits.

RT 70.1 - Investigate regenerative cryogenic heat exchanger requirements and define expected heat loads throughout the operating environment.

RT 70.2 - Experimentally establish fluid correlations for film coefficient, pressure drop, and pressure oscillations in the range of fluid properties near critical temperature or pressure of the fluid.

RT 70.3 - Experimentally investigate characteristics of material properties and fabrication techniques for use in high temperature hydrogen heat exchanger environments.

RT 70.4 - Investigate designs of heat exchanger components such as heat exchanger panels, high heat flux heaters, and high temperature control hardware in a simulated operating environment.

RT 70.5 - Investigate integrated heat exchanger systems in a simulated operating environment and demonstrate ultimate heat flux capabilities, life/duty cycles and control adequacy.

RO 71 - <u>Improve the performance of new or existing hydrocarbon fuels by increasing the heat sink potential and heat of combustion.</u>

RT 71.1 - Experimentally determine the performance capability of improved JP fuels and establish fuel performance criteria for generic engine and cooling concepts.

RT 71.2 - Develop catalyst systems with reaction rate/system weight and cooling flexibility characteristics consonant with high temperature/high speed aircraft operation with catalytic endothermic fuels.

RT 71.3 - Evaluate various high density, high energy advanced fuels and additives and their effects on fundamental combustion properties, vehicle and fuel logistics requirements.

RO 72 - <u>Determine fuel system design requirements imposed by the use of thermally stable and endothermic fuels in high temperature aircraft environments.</u>

RT 72.1 - Investigate contamination limits for the candidate fuels and evaluate susceptibility of fuel system materials to degradation caused by dissolved substances which might either precipitate or inhibit catalytic reactions.

RT 72.2 - Investigate inert pressurization techniques and investigate the feasibility of airborne systems to ensure preservation of fuel thermal/oxidative stability. This task includes considerations of GN_2 (inert gas by direct addition), catalytic combustion (inert gas product), and fuel fog (above fuel rich limit).

RT 72.3 - Identify unique ground support and logistics requirements to effectively handle (without potential chemical reaction) and maintain fuel purity.

RO 73 - Advance the technology of cryogenic fuel system components in the areas of reduced weight and increased reliability. Particular emphasis should be applied to liquid hydrogen static and dynamic sealing and rotating machinery operating in a cryogenic environment.

RT 73.1 - Investigate materials and their capability to withstand the elements of their environment including thermal shock, loads, wear and embrittlement.

RT 73.2 - Investigate fuel system component design concepts and evaluate potential weight savings and increases in reliability and performance.

RT 73.3 - Experimentally investigate the performance and reliability of promising fuel system component design concepts in an equivalent operational environment.

RO 74 - Determine rapid cryogenic servicing techniques necessary to achieve required reaction and turnaround times for military and commercial vehicles.

RT 74.1 - Investigate aircraft operational criteria to determine fuel loading rates consistent with aircraft ground turnaround requirements.

RT 74.2 - Assess limiting geometric and operational scaling parameters within which meaningful data may be acquired on reduced scale tankage systems.

RT 74.3 - Perform a parametric evaluation using scale tankage and fueling systems to fully characterize those factors having a major impact on vehicle turnaround/loading rates. This task includes considerations of chilldown rate, vent sizing, flow velocity, hazards, and subcooled fuel.

RO 75 - Develop aircraft fuel tankage concepts, system operation and control techniques for cryogenically fueled aircraft.

RT 75.1 - Evaluate various tankage/insulation concepts to determine the advantages of each configuration. Potential concepts include integral/non-integral tankage and internal/external insulation systems; which can be evaluated on the basis of installed weight, thermal efficiency, development risk, and overall system cost.

RT 75.2 - Develop subscale fuselage/tankage sections to permit experimental determination of potential performance and to identify suitable scaling factors, the relative importance of geometric scale, and the effects of fuel flow rates, thermal environment, pressure loads, mechanical loads, and dynamic motion.

RT 75.3 - Determine control techniques for propellant utilization and management, and determine pressurization requirements during both static and dynamic environments.

RO 77 - Determine flush or recessed antenna design techniques necessary to allow operation in the elevated hypersonic temperature environment.

RT 77.1 - Investigate size, shape, and construction requirements of antenna systems and study the vehicle structure to determine feasible locations for flush-mounted antenna systems. This task includes consideration of antenna applications such as communication, navigation, identification, reconnaissance and electronic warfare, as well as considerations of vehicle structural integrity, thermal protection and adequate antenna look angles.

RT 77.2 - Develop analytical models for predicting antenna performance in an operating environment characterized by temperature, shock and vibration throughout the flight envelope. This task includes a survey of materials technology for products that will provide the electrical characteristics required for an acceptable antenna system. Also included are the design, fabrication, test, and demonstration of antenna hardware to investigate structural integrity, transmission patterns and frequency stability in an operating environment.

RO 78 - Investigate stability augmentation systems capable of control in the hypersonic region, and recovery from pilot-induced oscillations.

RT 78.1 - Analyze the vehicle dynamics over the flight profile to determine stability augmentation requirements for potential operational hypersonic vehicles.

RT 78.2 - Investigate stability augmentation system requirements relative to flying an unstable aircraft.

RT 78.3 - Investigate and demonstrate methods to ensure qualification of desired levels of performance, prior to aircraft development.

RO 79 - Determine air data measurement techniques applicable to the hypersonic environment.

RT 79.1 - Perform a study to determine those parameters, sensors, and calibration techniques required to define the airplane environment for control and data analysis.

RT 79.2 - Demonstrate proper operation of the sensors and air data system in flight environments over the Mach number, altitude, and attitude range consistent with the operational vehicle concept under consideration.

RO 80 - Develop actuation techniques and hardware to provide necessary surface motion.

RT 80.1 - Investigate surface travel, response requirements and drive system operational environment consonant with operational system flight envelope. Review existing materials properties, determine limiting operating temperatures, their impact on vehicle design, and initiate studies directed toward providing higher temperature fluids and seals where necessary.

RT 80.2 - Investigate the relative merits of alternative control drive systems; and, perform research on basic actuation techniques and drive systems to demonstrate performance, reliability, and operational limits in an operational environment.

RO 82 - <u>Develop auxiliary power units for rocket, scram, and ramjet powered aircraft, including necessary emergency power equipment in case of primary unit failure.</u>

RT 82.1 - Evaluate various methods/energy sources for obtaining auxiliary power for rocket, scram, and ramjet powered aircraft. Study integration of the most promising concepts with vehicle and propulsion system to determine operational and load requirements/constraints. Potential sources of available energy which should be considered include bleed air, ram air, aerodynamic heating, and fuel combustion. Studies will include evaluation of energy conversion techniques and the use of regenerative gas supply, fluid pumps, electric generator/motors, and auxiliary turbine engines.

RT 82.2 - Experimentally develop basic APU components, evaluating performance, reliability, and operational constraints when subjected to the anticipated thermal/dynamic environment.

RT 82.3 - Assemble components into prototype operational systems and perform developmental testing including simulation of temperature, loads, and potential component failure modes.

RO 83 - <u>Develop environmental control systems utilizing liquid cryogens as the heat sink, based on allowable internal wall temperatures for crew and passenger comfort and effectiveness.</u>

RT 83.1 - Investigate the usefulness of liquid cryogens as a reliable heat sink for environmental cooling. This task includes considerations of flight heat loads, cabin and compartment cooling, and accessory heat loads.

RT 83.2 - Provide a functional prototype of an ECS system and demonstrate obtainable levels of reliability and performance under simulated operational conditions.

RO 84 - <u>Develop environmental control systems for Mach 4 to 6 hydrocarbon fueled vehicles, based on allowable internal wall temperatures for crew and passenger comfort and effectiveness.</u>

RT 84.1 - Investigate the suitability of current ECS concepts, as applied to this class of vehicle, and determine alternatives and combinations for achieving desired performance levels.

RT 84.2 - Provide a functional prototype of an ECS system and demonstrate obtainable levels of reliability and performance under simulated operational conditions.

RO 85 - Develop launch techniques for AAM and ASM weapons in hypersonic flight.

RT 85.1 - Investigate the potential threat/target spectrum relative to operational vehicle track to enable evaluation of candidate missile systems.

RT 85.2 - Study methods for integration of the candidate weapons system based on experimental data.

RT 85.3 - Experimentally establish design guidelines for combinations of operational systems concepts, threat/target spectrum, missile systems, and launch techniques applicable to development of the operational aircraft system.

OPERATION

RO 87 - Evaluate various methods of terminal approach, landing, ground operations, and takeoff for hypersonic aircraft.

RT 87.1 - Study and compare operational procedures for the potential operational hypersonic aircraft with those existing for current operational aircraft. Identify where and to what extent differences exist.

RT 87.2 - Investigate the adequacy of existing facilities to accommodate hypersonic aircraft operational requirements. Define programs for improving existing capability where appropriate. Investigate minimum modification approaches to existing facilities and determine impact on potential operational vehicle concepts, including the feasibility of the vehicle itself.

RT 87.3 - Experimentally demonstrate ground system capability to accommodate hypersonic aircraft.

RO 89 - Investigate man-machine compatibility as related to the decision/time aspects of course alteration of a hypersonic vehicle at both high and low Mach numbers.

RT 89.1 - Study various classes of potential operational vehicles and determine navigational requirements, degree of manual control, and pilot display concepts.

RT 89.2 - Investigate the capability of existing flight, ground, celestial, and satellite navigational systems in terms of the navigational requirements and evaluate potential improvements to provide the needed capability.

RT 89.3 - Investigate the navigational and information display systems to determine which combinations best satisfy the mission/vehicle requirements. This task considers fuel reserves/loiter time, diversion to alternate bases, and vehicle range/speed envelope.

RO 93 - Investigate effects of vehicle dynamics on crew performance capability and passenger comfort in hypersonic flight.

RT 93.1 - Relate human tolerances and comfort indices to the operational system. Evaluate resulting vehicle limits in terms of impact on flight/mission profile, structural design, subsystems, stability and control and performance.

RT 93.2 - Investigate the feasibility of techniques to supplement human tolerances and responses to allow maximum attainment of aircraft performance. Establish design criteria for modifying the transmission of abrupt forces and motions to insure satisfactory ride quality.

RO 94 - Develop abort and crew escape systems and procedures for hypersonic aircraft.

RT 94.1 - Analyze the missions of different classes of hypersonic aircraft including military systems, launch vehicles, and commercial vehicles. Investigate and establish the abort and crew escape criteria for different points on the flight trajectory from departure through landing. This task includes considerations of airborne crew escape, ground crew/passenger escape, crashes/egress over hot structure, and fuel storage/disposal.

RT 94.2 - Investigate methods to provide the necessary procedures, vehicle concepts, and devices to attain a level of safety consistent with vehicle mission and flight condition. Evaluate the procedures developed as they impact the hypersonic aircraft concept. This task includes considerations of concept feasibility, aircraft design, vehicle manufacture, and systems operation.

RT 94.3 - Investigate methods to adequately demonstrate the desired abort/crew escape procedures and systems. Perform the experimental research necessary to qualify the abort procedures and escape methods.

RO 96 - Define and demonstrate the capability to stay within specified operational margins and not exceed aircraft placards (i.e., duct pressure, temperature, stability, dynamic pressure, and load factor limits).

RT 96.1 - Define the limits on operational parameters throughout the flight path and maneuvering envelope for different hypersonic aircraft concepts.

RT 96.2 - Investigate suitable crew warning techniques which may also provide automatic corrective action where necessary. Experimentally investigate attractive concepts, such as adaptive control, audio warning, visual presentation/display, and control limiting devices.

RO 97 - Develop leak detection methods for cryogenic propellant tanks.

RT 97.1 - Investigate the principles of fuel leak detection for flight vehicle cryogenic tankage and fuel systems and current methods for determination of external leakage. Postulate and evaluate potential new concepts where appropriate.

RT 97.2 - Experimentally determine the effectiveness of a network of sensing systems. Investigate operation of most promising systems under simulated thermal and mechanical environment, and scale the system to representative flight weight size.

RO 16 - Develop correlation methods for the prediction of heat transfer and friction drag for turbulent boundary layers with pressure gradients and three-dimensional windward flows.

RT 16.1 - Investigate methods of correlating and predicting heat transfer and friction drag of three-dimensional windward surfaces in turbulent flows.

RT 16.2 - Investigate the impact of laminar sublayer extent and Reynolds analogy on heat transfer and friction drag predictions.

RT 16.3 - Evaluate the accuracy of prediction methods through tests at flight conditions.

RO 17 - Determine correlations for the prediction of hypersonic boundary layer transition.

RT 17.1 - Investigate the mechanics of boundary layer transition as influenced by reynolds number, Mach number, flow gradients, and noise.

RT 17.2 - Investigate the mechanisms of boundary layer transition which are affected by surface inclination, surface roughness, and angle of attack.

RO 18 - Investigate the use of strategically located reaction control jets on hypersonic aircraft to reduce the aerodynamic control surface deflection and surface heating.

RT 18.1 - Investigate and evaluate the effects of deflection angle on local control surface temperatures as a function of reaction jet thrust/time history and jet location for equivalent control effectiveness.

RT 18.2 - Evaluate the relative payoff of reaction control weight as compared to reductions in control surface weight.

RO 19 - Determine the effectiveness of various types of control surfaces and their locations for providing sufficient control throughout the entire flight spectrum, and improve methods of predicting aerodynamic heating for deflected control surfaces.

RT 19.1 - Investigate effectiveness of various control concepts such as wing tip devices, trailing edge devices, all movable surfaces, canards throughout the flight regime.

RT 19.2 - Investigate local control surface temperature as a function of deflection angle.

RO 99 - Investigate techniques to shorten takeoff runs by using forced rotation including gimballed rocket and canard techniques.

RT 99.1 - Investigate effect of techniques applicable to forced rotation on the overall aerodynamic characteristics such as canards, auxiliary rockets, and gimballed main rockets. Analyze the feasibility of the technique relative to such considerations as control system requirements, thrust required and control, pilot orientation, airframe integrity, and runways.

RT 99.2 - Evaluate techniques consistent with providing technology level required for the potential operational hypersonic aircraft under consideration.

RO 100 - Develop practical ground hold methods for cryogenic systems leading to quick response times and high operational readiness.

RT 100.1 - Investigate system limitations attributed to ground cooldown/thermal maintenance systems size, complexity and cost. Experimentally, identify major factors limiting fuel flow rates for rapid chill/fill techniques, including identification of benefits attributable to prechilling or subcooling the fuel, and the influence of residual fuel in the tanks after flight.

RT 100.2 - Investigate the impact of candidate ground systems on design and operation of the flight vehicle. Demonstrate combinations of rapid filling ground hold techniques to identify most promising system for shortest reaction/turn around times.

RO 102 - Develop inspection and repair techniques for hypersonic vehicle structures.

RT 102.1 - Compile testing, inspection, and repair techniques so that a comprehensive view may be provided for operational hypersonic vehicles.

RT 102.2 - Investigate methods to incorporate these procedures into a useful, workable program for an operational system. In a simulated operational situation, develop the candidate techniques and provide the required training to achieve an operational level of competence.

4. METHODS OF ACCOMPLISHING RESEARCH TASKS

A major Phase III work element involved the identification of methods to accomplish the Research Tasks listed in Section 3, utilizing the new conceptual flight vehicles and ground facilities developed in this study. To accomplish a particular Research Task may require use of one or more of these ground and flight test facilities. Detailed procedures of testing vary widely depending on the test objectives of the particular experimental program. The data presented in this section is intended to provide an overview of the test methods employed in utilizing new ground and flight facilities, as well as some insight into the cost of performing these tests.

4.1 FLIGHT RESEARCH VEHICLES TEST METHODS

The new flight research vehicles developed in this study have been examined to determine the manner in which they can be employed to accomplish the defined Research Tasks. This section describes the test methods applicable to the individual flight Research Tasks. The test methods presented herein are not unique and are considered to be standard practice in R&D flight test programs. These methods, simply stated, involve the collection of qualitative and quantitative information by operating the research vehicle, equipped with a reliable data acquisition system, throughout its envelope. The flight test plans for the Mach 6 and Mach 12 research vehicles were derived by estimating the flight test requirements for each Research Task individually and thus do not represent an integrated program flight test plan. The magnitude of effort required to accomplish each Research Task varies widely, and is dependent on the following criteria:

(a) Research Task requirements including:

- o Type of research involved (aerodynamics, structures, etc)
- o Expanse of the flight vehicle operating envelope required
- o Type of testing required (maneuvering flight, cruise, etc)

(b) Research vehicle capability as a function of:

- o Vehicle configuration
- o Vehicle performance

4.1.1 FLIGHT TEST PLANS - The flight test plans for the Mach 12 research vehicle, presented in Figure 4-1, and the Mach 6 research vehicle, shown in Figure 4-2, are based on the following ground rules:

1. FLIGHT RESEARCH VEHICLE UTILIZATION - The estimated number of flights to accomplish a Research Task are subdivided into two categories in order to show research vehicle utilization.

FIGURE 4-1
FLIGHT TEST PLANS FOR RESEARCH TASK ACCOMPLISHMENT
MACH 12 RESEARCH VEHICLE
Basic Vehicle

Research Task No.	No. of Flights and Utilization			Est. Time Span A C No.	Test Basis	Test Phase (1)			Test Method		
	Build-Up	Test	Total			P	E	R	Type of Flight Tests	Instrumentation Parameters: No. Req'd.	Instrumentation Parameters: Type
1 1		10	10	9	Concurrent	*	*		Lnd, Stab.	100	Basic
1 2		5	5	4 5		*	*			100	
1 3		5	5	4 5		*	*		Lnd, Stab., Man.	100	
1 4		5	5	4 5		*	*			100	
2 1		5	5	4 5	Concurrent	*	*		Stab.	100	Basic
2 2		5	5	4 5		*	*		Perf.	100	
2 3		5	5	4 5		*	*		Stab., Man., Perf.	100	
2 4		5	5	4 5		*	*		Stab., Man.	100	
3 1	70	3	73	65	B U Conc Test Pri	*	*	*	Stab.	300	Basic, Airf.
3 2	70	3	73	65		*	*	*	Stab., Man.	200	
3 3	70	3	73	65		*	*	*		300	
3 4	70	1	71	65		*	*	*	Perf.	150	
4 1	70	5	75	67	B U Conc Test Pri	*	*	*	Man., Perf.	300	Basic, Airf.
4 2	70	5	75	67		*	*	*		300	
4 3	70	[illegible]	[illegible]	67		*	*	*		300	
5 1	70	2	72	65	B U Conc Test Pri	*	*	*	Stab., Man., Perf.	200	Basic
5 2	70	2	72	65		*	*	*		250	Basic, Subs.
5 3	70	2	72	65		*	*	*		400	Basic, Airf, Subs.
6 1	70	5	75	67	Concurrent	*	*	*	Stab., Man.	250	Basic, Airf.
6 2	70	5	75	67		*	*	*	Stab., Man., Perf.	250	
6 3	70	5	75	67		*	*	*	Stab.	250	
7 2	70	2	72	65	Concurrent	*	*	*	Man., Perf.	300	Basic, Airf, Rkt Prop.
7 3	70	2	72	65		*	*	*		300	
10 1	70	2	72	65	B U Conc Test Pri	*	*	*	Stab., Perf, Hi Alt.	400	Basic, Airf.
10 2	70	2	72	65		*	*	*			
11 2	70	2	72	65	B U Conc Test Pri	*	*	*	Stab., Perf. Hi Alt.	400	Basic, Airf.
12 1	70	5	75	67	Concurrent	*	*	*	Man., Perf.	500	Basic, Airf.
12 2	70	5	75	67		*	*	*		300	
12 3	70	5	75	67		*	*	*		300	
14.1	70		70	63	Concurrent	*	*	*	Man.	300	Basic, Airf.
14.2	70		70	63		*	*	*		300	
14.3	70		70	63		*	*	*		300	
15.1	70		70	63	Concurrent	*	*		Man., Perf.	150	Basic, Airf.
15.2	70		70	63		*	*			150	
15.3	70		70	63		*	*			150	
16.1	70	10	80	72	Concurrent	*	*	*	Perf.	500	Basic, Airf.
16.2	70	10	80	72		*	*	*		500	
16.3	70	10	80	72		*	*	*		500	
17.1	70	6	76	68.5	Concurrent	*	*	*	Man., Perf.	300	Basic, Airf, Subs.
17.2	70	6	76	68.5		*	*	*		300	
18.1	70	2	72	65	B U Conc Test Pri	*	*	*	Stab., Man., Perf, Hi Alt.	400	Basic, Airf, Subs.
18.2	70	2	72	65		*	*	*		400	
19.1	70	10	80	72	Concurrent	*	*	*	Stab., Perf.	300	Basic, Airf.
19.2	70	10	80	72		*	*	*		400	

Note (1): P – Predelivery E – Envelope Expansion R – Research

FIGURE 4-1 (CONTINUED)
Basic Vehicle (Continued)

Research Task No.	No. of Flights and Utilization			Est. Time Span A/C No.	Test Basis	Test Phase (1)			Test Method		
	Build-Up	Test	Total			P	E	R	Type of Flight Tests	Instrumentation Parameters	
										No. Req'd.	Type
20.1	70	18	88	79	B/U Conc Test Pri	•	*	*	Man., Perf.	900	Basic, Airf.
20.2	70	5	75	67		*	*	*	Stab. Man., Perf,	200	
20.3	70	2	72	65		*	*	*	Hi Alt.	400	
20.4	70	18	88	79		*	*	*	Man., Perf.	700	
22.1	70	18	88	79	Concurrent	•	*	*	Man., Perf.	300	Basic, Airf.
22.2	70	18	88	79		*	*	*		300	
22.3	70	18	88	79		*	*	*		300	
23.1	70	18	88	79	B/U Conc Test Pri	*	*	*	Man., Perf.	900	Basic, Airf.
23.2	70	18	88	79		*	•	*		900	
23.3	70	18	88	79		*	*	*		900	
24.1	70	18	88	79	B/U Conc Test Pri	*	*	*	Man., Perf.	900	Basic, Airf.
24.2	70	18	88	79		•	*	*		900	
24.3	70	18	88	79						900	
25.1	70	18	88	79	B/U Conc Test Pri	*	*	*	Man., Perf.	400	Basic, Airf.
25.2	70	18	88	79		*	*	*		400	
25.3	70	18	88	79		*	*	*	Stab., Man., Perf.	400	
25.4	70	18	88	79		*	*	*	Perf, Hi Alt.	400	
26.1	70	18	88	79	B/U Conc Test Pri	*	*	*	Man., Perf.	700	Basic, Airf.
26.2	70	18	88	79		*	*	*		700	
26.3	70	18	88	79		*	*	*		700	
27.1	70	6	76	68.5	B/U Conc Test Pri	*	*	*	Man., Perf.	300	Basic, Airf.
27.2	70	6	76	68.5		*	*	*		300	
27.3	70	6	76	68.5		*	*	*		300	
28.2	70	12	82	74	B/U Conc Test Pri	*	*	*	Man., Perf.	500	Basic, Airf.
28.4	70	12	82	74		*	*	*		500	
30.3	70	12	82	74	B/U Conc Test Pri	*	*	*	Man., Perf.	200	Basic, Airf.
32.3	70	12	82	74	B/U Conc Test Pri	*	*	*	Man., Perf.	200	Basic, Airf.
33.3	70	30	100	90	Concurrent	*	*	*	Man., Perf.	300	Basic, Airf.
35.1	70	12	82	74	Concurrent	*	*	*	Man., Perf.	500	Basic, Airf.
35.2	70	30	100	90		*	*	*		900	
36.3	70	12	82	74	B/U Conc Test Pri	*	*	*	Man., Perf.	900	Basic, Airf.
38.3	70	6	76	68.5	Concurrent	*	*	*	Man., Perf.	200	Basic, Airf.
39.1	70	15	85	76.5	Concurrent	.	*	*	Man., Perf.	450	Basic, Airf.
39.2	70	15	85	76.5		*	*	*		450	
40.3	70	30	100	90	Concurrent	*	*	*	Man., Perf.	250	Basic, Airf.
42.1	70	30	100	90	B/U Conc Test Pri	*	*	*	Man., Perf.	900	Basic, Airf.
43.1	70	30	100	90	[illegible]	*	*	*	Man., Perf.	700	Basic, Airf.
43.2	70	30	100	90		*	*	*		700	
44.1	70	30	100	90	[illegible]	*	*	*	Man., Perf.	500	Basic, Airf.
45.2	[illegible]	12	[illegible]	74	[illegible]	*	*	*	Man., Perf.	400	Basic, Airf.
45.3	70	12	82	74		*	*	*		400	
46.2	70	30	100	90	Concurrent	*	*	*	Man., Perf.	150	Basic, Subs.
62.3	70		70	63	Concurrent	*	*	*	Man., Perf, Prop.	160	Basic
69.3	70	5	75	67	Concurrent	*	*	*	T.O., Man., Perf.	200	Basic, Airf, Subs.
70.5	70	18	88	79	Concurrent	*	*	*	Man., Perf.	300	Basic, Airf, Subs.

FIGURE 4-1 (CONTINUED)
Basic Vehicle (Continued)

Research Task No.	No. of Flights and Utilization: Build-Up	Test	Total	Est. Time Span A C Mo.	Test Basis	Test Phase (1): P	E	R	Test Method: Type of Flight Tests	Instrumentation Parameters: No. Req'd.	Type
73.1	70	30	100	90	Concurrent	*	*	*	Man., Perf, Prop.	300	Basic, Airf, Subs.
73.2	70	30	100	90		*	*	*		300	
73.3	70	30	100	90		*	*	*		300	
75.3	70	12	82	74	Concurrent	*	*	*	Man., Perf, Prop.	150	Basic, Subs.
77.2	70	15	85	76.5	Concurrent	*	*	*	Man., Perf.	150	Basic, Subs.
78.2	70	10	80	72	Concurrent	*	*	*	Stab., Man., Perf.	200	Basic, Subs.
78.3	70	10	80	72		*	*	*		150	
79.2	70	10	80	72	Concurrent	*	*	*	T.O., Lnd, Man., Perf.	100	Basic
80.1	70	30	100	90	Concurrent	*	*	*	Basic, Lnd, Stab., Man., Perf.	200	Basic, Airf, Subs.
80.2	70	30	100	90						200	
82.3	70	30	100	90	Concurrent	*	*	*	Man., Perf.	150	Basic, Subs.
83.2	70	30	100	90	Concurrent	*	*	*	Man., Perf.	150	Basic, Subs.
84.2	25	10	35	31.5	Concurrent	*	*	*	Man., Perf.	150	Basic, Subs.
87.3		20	20	18	15 Conc 5 Pri	*	*		Lnd.	100	Basic
89.2	70		70	63	Concurrent	*	*		Stab., Man., Perf.	150	Basic, Subs.
89.3	70		70	63		*	*			150	
93.2	70		70	63	Concurrent	*	*		T.O., Lnd, Man., Perf.	100	Basic
96.1	70	30	100	90	Concurrent	*	*	*	T.O., Lnd, Stab., Man., Perf.	200	Basic, Subs.
96.2	70	30	100	90		*	*	*		200	
97.2	70	30	100	90	Concurrent	*	*	*	Man., Perf.	130	Basic, Subs.
102.1	70	30	100	90	Concurrent	*	*	*	Man., Perf.		
102.2	70	30	100	90		*	*	*			

HTO/VTO Option

1.1		7	7	6	50% Conc 50% Pri			*	T.O., Lnd, Stab.	150	Basic, Subs.
1.2		7	7	6				*		150	
1.3		7	7	6				*	T.O., Lnd, Stab., Man.	150	
1.4		7	7	6				*		150	
2.1		7	7	6	50% Conc 50% Pri			*	Stab.	150	Basic, Subs.
2.2		7	7	6				*	Perf.	150	
2.3		7	7	6				*	Stab., Man., Perf.	150	
2.4		7	7	6				*	Stab., Man.	150	
52.3		7	7	6	Primary			*	T.O., Man., Perf, Prop.	150	Basic, Subs
87.3		7	7	6	Primary			*	T.O., Lnd.	150	Basic, Subs.
99.1		7	7	6	Primary			*	T.O.	150	Basic, Subs.
99.2		7	7	6						150	

FIGURE 4-1 (CONTINUED)
Scramjet Option

Research Task No.	No. of Flights and Utilization			Est. Time Span A/C Mo.	Test Basis	Test Phase (1)			Test Method		
	Build-Up	Test	Total			P	E	R	Type of Flight Tests	Instrumentation Parameters No. Req'd.	Instrumentation Parameters Type
3.4	10	4	14	12.5	Concurrent			*	Stab., Man., Perf.	200	Basic, Airf, Airb Prop.
6.2	10	8	18	15	B/U Conc			*	Stab., Man., Perf.	400	Basic, Airf,
6.3	10	2	12	11	Test Pri			*	Stab.	400	Airb Prop.
7.3	10	6	16	14.5	B/U Conc			*	Man., Perf.	400	Basic, Airf,
7.4	10	6	16	14.5	Test Pri			*		400	Airb Prop.
9.1	10	4	14	12.5	B/U Conc			*	Stab., Man., Perf.	400	Basic, Airf,
9.2	10	4	14	12.5	Test Pri			*	Stab., Man., Perf, Prop.	150	Airb Prop.
9.3	10	6	16	14.5				*		200	
9.4	10	4	14	12.5				*	Stab., Man., Perf.	500	
12.1	10	2	12	11	Concurrent			*	Man., Perf.	600	Basic, Airf,
12.2	10	4	14	12.5				*		500	Airb Prop.
12.3	10	4	14	12.5				*		500	
27.1	10	6	16	14.5	Concurrent			*	Man., Perf.	400	Basic, Airf,
27.2	10	6	16	14.5				*		400	Airb Prop.
27.3	10	6	16	14.5				*		400	
34.1	10	6	16	14.5	Concurrent			*	Man., Perf.	400	Basic, Airf,
34.4	10	6	16	14.5				*		400	Airb Prop.
48.1	10	6	16	14.5	B/U Conc			*	Man., Perf, Prop.	500	Basic, Airf,
48.2	10	6	16	14.5	Test Pri			*		500	Airb Prop.
48.3	10	6	16	14.5				*		500	
48.4	10	6	16	14.5				*		500	
52.4	10	14	24	21.5	Concurrent			*	Man., Perf.	400	Basic, Airf, Airb Prop.
58.3	10	14	24	21.5	Concurrent			*	Man., Perf, Prop.	400	Basic, Airf, Airb Prop.
60.4	10	10	20	18	Concurrent			*	Man., Perf, Prop.	300	Basic, Airf,
60.5	10	10	20	18				*		300	Airb Prop.
60.6	10	10	20	18				*		400	
61.4	10	14	24	21.5	Primary			*	Man., Perf, Prop.	300	Basic, Airf,
61.5	10	14	24	21.5				*		300	Airb Prop.
61.6	10	14	24	21.5				*		400	
63.1	10	6	16	14.5	B/U Conc			*	Man., Perf.	250	Basic, Airf,
63.2	10	6	16	14.5	Test Pri			*		250	Airb Prop.
63.3	10	6	16	14.5				*		250	
65.2	10	6	16	14.5	Concurrent			*	Man., Perf.	250	Basic, Airf,
65.3	10	10	20	18				*	Man., Perf, Prop.	300	Airb Prop.
67.2	10	8	18	16	B/U Conc			*	Man., Perf.	400	Basic, Airf, Airb
67.3	10	8	18	16	Test Pri			*		400	Prop., Subs.
70.5	10	14	24	21.5	Concurrent			*	Man., Perf.	200	Basic, Airf, Airb Prop., Subs.
73.1	10	14	24	21.5	Concurrent			*	Stab., Man.,	400	Basic, Airf, Airb
73.2	10	14	24	21.5				*	Perf, Prop.	400	Prop., Subs.
73.3	10	14	24	21.5				*		400	
[illegible]	10	14	24	21.5	Concurrent			*	Stab., Man.,	300	Basic, Airb
96.2	10	14	24	21.5				*	Perf, Prop.	300	Prop., Subs.

FIGURE 4-1 (CONTINUED)
Convertible Scramjet Option

Research Task No.	No. of Flights and Utilization			Est. Time Span A/C No.	Test Basis	Test Phase (1)			Test Method		
	Build-Up	Test	Total			P	E	R	Type of Flight Tests	Instrumentation Parameters No. Req'd.	Instrumentation Parameters Type
3.4	10	4	14	12.5	Concurrent			•	Stab., Man., Perf.	200	Basic, Airf, Airb Prop.
6.2	12	8	20	18	B/U Conc Test Pri			•	Stab., Man., Perf.	400	Basic, Airf, Airb Prop.
6.3	12	2	14	12.5				•	Stab.	400	
7.3	12	6	18	16	B/U Conc Test Pri			*	Man., Perf.	400	Basic, Airf, Airb Prop.
7.4	12	6	18	16				*		400	
9.1	12	4	16	14.5	B/U Conc Test Pri			*	Stab., Man., Perf.	400	Basic, Airf, Airb Prop.
9.2	12	4	16	14.5				*	Stab., Man., Perf, Prop.	150	
9.3	12	6	18	16				*		200	
9.4	12	4	16	14.5				•	Stab., Man., Perf.	500	
12.1	12	2	14	12.5	Concurrent			*	Man., Perf.	600	Basic, Airf, Airb Prop.
12.2	12	4	16	14.5				*		500	
12.3	12	4	16	14.5				*		500	
27.1	12	6	18	16	Concurrent			*	Man., Perf.	400	Basic, Airf, Airb Prop.
27.2	12	6	18	16				*		400	
27.3	12	6	18	16				*		400	
34.1	12	6	18	16	Concurrent			*	Man., Perf.	400	Basic, Airf, Airb Prop.
34.4	12	6	18	16				*		400	
48.1	12	8	20	18	B/U Conc Test Pri			*	Man., Perf, Prop.	500	Basic, Airf, Airb Prop.
48.2	12	8	20	18				*		500	
48.3	12	8	20	18				*		500	
48.4	12	8	20	18				*		500	
52.4	12	24	36	32.5	Concurrent			•	Man., Perf.	400	Basic, Airf, Airb Prop.
58.3	12	24	36	32.5	Concurrent			*	Man., Perf, Prop.	400	Basic, Airf, Airb Prop.
59.4	6	6	12	32.5	Concurrent			*	Man., Perf. Prop.	300	Basic, Airf, Airb Prop.
59.5	6	6	12	32.5				*		300	
59.6	6	6	12	32.5				*		400	
60.4	12	24	36	32.5	Primary			*	Man., Perf, Prop.	300	Basic, Airf, Airb Prop.
60.5	12	24	36	32.5				*		300	
60.6	12	24	36	32.5				*		400	
61.4	12	12	24	21.5	B/U Conc Test Pri			*	Man., Perf, Prop.	300	Basic, Airf, Airb Prop.
61.5	12	12	24	21.5				*		300	
61.6	12	12	24	21.5				*		400	
63.1	12	8	20	18	B/U Conc Test Pri			*	Man., Perf.	250	Basic, Airf, Airb Prop.
53.2	12	8	20	18				*		250	
63.3	12	8	20	18				*		250	
65.2	12	8	20	18	Concurrent			*	Man., Perf.	250	Basic, Airf, Airb Prop.
65.3	12	18	30	27				*	Man., Perf, Prop.	300	
67.1	12	10	22	20	B/U Conc. Test Pri			*	Man., Perf.	400	Basic, Airf, Airb Prop.
67.2	12	10	22	20				*		400	
70.5	12	24	36	32.5	Concurrent			•	Man., Perf.	200	Basic, Airf, Airb Prop., Subs.
73.1	12	24	36	32.5	Concurrent			*	Stab., Man., Perf, Prop.	400	Basic, Airf, Airb Prop., Subs.
73.2	12	24	36	32.5				*		400	
73.3	12	24	36	32.5				*		400	
96.1	12	24	36	32.5	Concurrent			*	Stab., Man., Perf, Prop.	300	Basic, Airb Prop., Subs.
96.2	12	24	36	32.5				*		300	

FIGURE 4-1 (CONTINUED)

Thermal Protection System Option

Research Task No.	No. of Flights and Utilization			Est. Time Span A/C No.	Test Basis	Test Phase (1)			Test Method		
	Build-Up	Test	Total			P	E	R	Type of Flight Tests	Instrumentation Parameters No. Req'd.	Instrumentation Parameters Type
23.1	4	4	8	6	B/U Conc Test Pri			*	Man., Perf.	650	Basic, Airf.
23.2	4	4	8	6				*		650	
23.3	4	4	8	6				*		650	
25.1	4	4	8	6	B/U Conc Test Pri			*	Man, Perf.	500	Basic, Airf.
25.4	4	4	8	6				*	Perf, Hi Alt.	650	
28.2	4	4	8	6	B/U Conc Test Pri			*	Man., Perf.	650	Basic, Airf.
28.4	4	4	8	6				*		650	
43.1	4	8	12	9	B/U Conc Test Pri			*	Man., Perf.	650	Basic, Airf.
43.2	4	8	12	9				*		650	
77.2	4	8	12	9	Concurrent			*	Man., Perf.	250	Basic, Subs.

Armament Option

Research Task No.	Build-Up	Test	Total	Est. Time Span A/C No.	Test Basis	P	E	R	Type of Flight Tests	No. Req'd.	Type
77.2		17	17	15	12 Conc. 5 Pri			*	Man., Perf, Wpn.	250	Basic, Subs.
85.2		12	12	11	Primary			*	Wpn.	250	Basic, Subs.
85.3		12	12	11				*		250	

Staging Option

Research Task No.	Build-Up	Test	Total	Est. Time Span A/C No.	Test Basis	P	E	R	Type of Flight Tests	No. Req'd.	Type
10.1	2	10	12	10.8	Primary			*	Stab., Perf, Hi Alt, Stg.	500	Basic, Airf.
10.2	2	10	12	10.8				*		500	
11.2	2	10	12	10.8	Primary			*	Stab., Perf, Hi Alt, Stg.	500	Basic, Airf.
11.3	2	10	12	10.8				*		500	
20.3	2	10	12	10.8	Primary			*	Stab., Perf, Hi Alt, Stg.	500	Basic, Airf.

Subsonic Turbojet Option

Research Task No.	Build-Up	Test	Total	Est. Time Span A/C No.	Test Basis	P	E	R	Type of Flight Tests	No. Req'd.	Type
1.1		5	5	1.0	Primary			*	T.O., Lnd, Stab.	150	Basic, Airb Prop.
1.2		5	5	1.0				*		150	
1.3		5	5	1.0				*	T.O., Lnd, Stab., Man.	150	
1.4		5	5	1.0				*		150	
5.1		2	2	0.5	Primary			*	Stab., Man.	150	Basic, Airb Prop.
5.2		2	2	0.5				*		150	
5.3		2	2	0.5				*		150	
55.1		5	5	1.0	Concurrent			*	T.O., Lnd.	150	Basic, Airb Prop.
55.2		5	5	1.0				*		150	
64.1		5	5	1.0	Primary			*	Lnd, Stab., Prop.	150	Basic, Airb Prop.
[illegible]		[illegible]	[illegible]	1.0				*		150	
[illegible]		[illegible]	[illegible]	4.0	10 Conc 10 Pri			*	Lnd.	150	Basic, Airb Prop.
[illegible]			[illegible]	4.0	Concurrent			*	Stab., Man., Perf.	150	Basic, Airb Prop.
[illegible]				[illegible]				*		150	

FIGURE 4-2
FLIGHT TEST PLANS FOR RESEARCH TASK ACCOMPLISHMENT
MACH 6 RESEARCH VEHICLE
Basic Vehicle

Research Task No.	No. of Flights and Utilization			Est. Time Span A/C No.	Test Basis	Test Phase (1)			Test Method		
										Instrumentation Parameters	
	Build-Up	Test	Total			P	E	R	Type of Flight Tests	No. Req'd.	Type
1.1		5	5	4.5	Concurrent	*	*		T.O., Lnd, Stab.	150	Basic
1.2		5	5	4.5		*	*			150	
1.3		5	5	4.5		*	*		T.O., Lnd, Stab., Man.	150	
1.4		5	5	4.5		*	*			150	
2.1		3	3	2.7	Concurrent	*	*		Stab.	150	Basic
2.2		3	3	2.7		*	*		Perf.	150	
2.3		3	3	2.7		*	*		Stab., Man., Perf.	150	
2.4		3	3	2.7		*	*		Stab., Man.	150	
3.1	62	3	65	58.5	B/U Conc Test Pri	*	*	*	Stab.	300	Basic, Airf.
3.2	62	3	65	58.5		*	*	*	Stab., Man.	200	
3.3	62	3	65	58.5		*	*	*		300	
3.4	62	3	65	58.5		*	*	*	Perf.	250	
4.1	62	3	65	58.5	B/U Conc Test Pri	*	*	*	Man., Perf.	300	Basic, Airf.
4.2	62	3	65	58.5		*	*	*		300	
4.3	62	3	65	58.5		*	*	*		300	
5.1	62	2	64	57.5	B/U Conc. Test Pri	*	*	*	Stab., Man., Perf.	200	Basic
5.2	62	2	64	57.5		*	*	*		250	Basic, Subs.
5.3	62	2	64	57.5		*	*	*		400	Basic, Airf, Subs.
6.1	62	5	67	60	Concurrent	*	*	*	Stab., Man.	250	Basic, Airf.
6.2	62	5	67	60		*	*	*	Stab., Man., Perf.	250	
6.3	62	5	67	60		*	*	*	Stab.	250	
7.2	62	5	67	60	Concurrent	*	*	*	Man., Perf.	300	Basic, Airf, Airb Prop.
7.3	62	5	67	60		*	*	*		300	
9.1	62	5	67	60	Concurrent	*	*	*	Stab., Man., Perf.	400	Basic, Airf, Airb Prop.
9.2	62	5	67	60		*	*	*	Stab., Man., Perf, Prop.	200	
9.3	62	5	67	60		*	*	*	Stab., Man., Perf.	250	
9.4	62	5	67	60		*	*	*		500	
10.1	62	4	66	59.5	B/U Conc Test Pri	*	*	*	Stab., Perf, Hi Alt	400	Basic, Airf.
10.2	62	4	66	59.5		*	*	*		400	
11.2	62	4	66	59.5	B/U Conc Test Pri	*	*	*	Stab., Man., Perf. Hi Alt.	400	Basic, Airf.
12.1	62	5	67	60	B/U Conc Test Pri	*	*	*	Man., Perf.	550	Basic, Airf.
12.2	62	5	67	60		*	*	*		350	
12.3	[illegible]	5	67	60		*	*	*		350	
14.1	[illegible]		62	56	Concurrent	*	*		Man.	350	Basic, Airf.
14.2	62		62	56		*	*			350	
14.3	62		62	56		*	*			350	
15.1	62		62	56	Concurrent	*	*		Man., Perf.	200	Basic, Airf.
15.2	62		62	56		*	*			200	
15.3	62		62	56		*	*			200	
16.1	62	6	68	61	Concurrent	*	*	*	Perf.	550	Basic, Airf.
16.2	62	6	63	61		*	*	*		550	
16.3	62	6	68	61		*	*	*		550	
17.1	62	4	66	59.5	Concurrent	*	*	*	Man., Perf.	350	Basic, Airf, Subs.
17.2	62	4	66	59.5		*	*	*		350	

Note (1): P – Predelivery E – Envelope Expansion R – Research

FIGURE 4-2 (CONTINUED)
Basic Vehicle (Continued)

Research Task No.	No. of Flights and Utilization: Build-Up	Test	Total	Est. Time Span A/C No.	Test Basis	Test Phase (1): P	E	R	Test Method: Type of Flight Tests	Instrumentation Parameters: No. Req'd.	Type
18.1	62	4	66	59.5	Concurrent	*	*	*	Stab., Man., Perf, Hi Alt.	450	Basic, Airf, Subs.
18.2	62	4	66	59.5		*	*	*		450	
19.1	62	5	67	60	Concurrent	*	*	*	Stab., Perf.	350	Basic, Airf.
19.2	62	5	67	60		*	*	*		450	
20.1	62	10	72	65	B/U Conc Test Pri	*	*	*	Man., Perf.	950	Basic, Airf.
20.2	62	4	66	59.5		*	*	*	Stab., Man., Perf, Hi Alt.	200	
20.4	62	10	72	65		*	*	*	Man., Perf.	750	
22.1	62	10	72	65	B/U Conc Test Pri	*	*	*	Man., Perf.	350	Basic, Airf.
22.2	62	10	72	65		*	*	*		350	
22.3	62	10	72	65		*	*	*		350	
24.1	62	10	72	65	B/U Conc Test Pri	*	*	*	Man., Perf.	950	Basic, Airf.
24.2	62	10	72	65		*	*	*		950	
24.3	62	10	72	65		*	*	*		950	
25.1	62	10	72	65	B/U Conc Test Pri	*	*	*	Man., Perf.	450	Basic, Airf.
25.2	62	10	72	65		*	*	*		450	
25.3	62	10	72	65		*	*	*	Stab., Man., Perf, Hi Alt.	450	
25.4	62	10	72	65		*	*	*		950	
26.1	62	10	72	65	B/U Conc Test Pri	*	*	*	Man., Perf.	750	Basic, Airf.
26.2	62	10	72	65		*	*	*		750	
26.3	62	10	72	65		*	*	*		750	
27.1	62	6	68	61	B/U Conc Test Pri	*	*	*	Man., Perf.	350	Basic, Airf.
27.2	62	6	68	61		*	*	*		350	
27.3	62	6	68	61		*	*	*		350	
28.2	62	8	70	63	B/U Conc Test Pri	*	*	*	Man., Perf.	550	Basic, Airf.
28.4	62	8	70	63		*	*	*		550	
30.3	62	8	70	63	B/U Conc Test Pri	*	*	*	Man., Perf.	250	Basic, Airf.
32.3	62	8	70	63	B/U Conc Test Pri	*	*	*	Man., Perf.	250	Basic, Airf.
33.3	62	18	80	72	Concurrent	*	*	*	Man., Perf.	350	Basic, Airf.
35.1	62	8	70	63	Concurrent	*	*	*	Man., Perf.	550	Basic, Airf.
35.2	62	18	80	72		*	*	*		950	
36.3	62	8	70	63	B/U Conc Test Pri	*	*	*	Man., Perf.	950	Basic, Airf.
38.3	62	4	66	59.5	Concurrent	*	*	*	Man., Perf.	250	Basic, Airf.
39.1	62	8	70	63	Concurrent	*	*	*	Man., Perf.	500	Basic, Airf.
39.2	62	8	70	63		*	*	*		500	
40.3	62	38	100	90	Concurrent	*	*	*	Man., Perf.	300	Basic, Airf.
42.1	62	18	80	72	B/U Conc Test Pri	*	*	*	Man., Perf.	950	Basic, Airf.
43.1	62	18	80	72	Concurrent	*	*	*	Man., Perf.	750	Basic, Airf.
43.2	62	18	80	72		*	*	*		750	
44.2	62	38	100	90	Concurrent	*		*	Man., Perf.	550	Basic, Airf.
45.2	62	8	70	63	B/U Conc Test Pri	*	*	*	Man., Perf.	450	Basic, Airf.
45.3	62	8	70	63		*	*	*		450	
46.2	62	38	100	90	Concurrent	*	*	*	Man., Perf.	250	Basic, Subs.

FIGURE 4-2 (CONTINUED)
Basic Vehicle (Continued)

Research Task No.	No. of Flights and Utilization			Est. Time Span A/C Mo.	Test Basis	Test Phase (1)			Test Method		
	Build-Up	Test	Total			P	E	R	Type of Flight Tests	Instrumentation Parameters No. Req'd.	Instrumentation Parameters Type
48.1	62	10	72	65	B/U Conc Test Pri	*	*	*	Man., Perf, Prop.	500	Basic, Airf, Airb Prop.
48.2	62	10	72	65		*	*	*		500	
48.3	62	10	72	65		*	*	*		500	
48.4	62	10	72	65		*	*	*		500	
48.5	62	10	72	65		*	*	*		500	
52.4	62	20	82	74	Concurrent	*	*	*	Man., Perf.	400	Basic, Airf, Airb Prop.
55.1		5	5	4.5	Concurrent	*			T.O., Lnd.	150	Basic, Airb Prop.
55.2		5	5	4.5		*				150	
57.4	62	20	82	74	B/U Conc Test Pri	*	*	*	Man., Perf, Prop.	300	Basic, Airf, Airb Prop.
57.5	62	20	82	74		*	*	*		300	
57.6	62	20	82	74		*	*	*		400	
58.3	62	20	82	74	Concurrent	*	*	*	Man., Perf, Prop.	300	Basic, Airf Airb Prop.
59.4	62	20	82	74	B/U Conc Test Pri	*	*	*	Man., Perf, Prop.	300	Basic, Airf, Airb Prop.
59.5	62	20	82	74		*	*	*		300	
59.6	62	20	82	74		*	*	*		400	
63.1	62	10	72	65	B/U Conc Test Pri	*	*	*	Man., Perf.	250	Basic, Airf, Airb Prop.
63.2	62	10	72	65		*	*	*		250	
63.3	62	10	72	65		*	*	*		250	
64.1		5	5	4.5	Concurrent	*			Lnd, Stab., Prop.	150	Basic, Airf.
64.2		5	5	4.5		*				150	
65.2	62		62	56	Concurrent	*	*	*	Man., Perf.	250	Basic, Airf, Airb Prop.
65.3	62		62	56		*	*	*	Man., Perf, Prop.	300	
67.2	62	10	72	65	B/U Conc Test Pri	*	*	*	Man., Perf.	400	T.O., Lnd, Stab.
67.3	62	10	72	65		*	*	*		400	
69.3	62	3	65	58.5	Concurrent	*	*	*	T.O., Man., Perf.	400	Basic, Airf, Subs.
70.5	62	10	72	65	Concurrent	*	*	*	Man., Perf.	350	Basic, Arf, Subs.
71.1	62	20	82	74	Concurrent	*		*	Man., Perf, Prop.	150	Basic, Airb Prop.
71.2	62	20	82	74		*		*		250	Basic, Airf, Subs., Airb, Prop.
71.3	62	20	82	74		*	*	*		150	Basic, Airb Prop.
73.1	62	38	100	90	Concurrent	*	*	*	Man., Perf, Prop.	350	Basic, Airf, Subs.
73.2	62	38	100	90		*	*	*		350	
73.3	62	38	100	90		*	*	*		350	
75.3	62	28	90	81	Concurrent	*	*	*	Stab., Man., Perf, Prop.	200	Basic, Airb Prop., Subs.
77.2	62	8	70	63	Concurrent	*	*	*	Man., Perf.	200	Basic, Subs.
78.2	62	10	72	65	Concurrent	*	*	*	Stab., Man., Perf, Prop.	250	Basic, Subs.
78.3	62	10	72	65						200	Basic
79.2	62	10	72	65	Concurrent	*	*	*	T.O., Lnd, Man., Perf.	150	Basic
80.1	62	38	100	90	Concurrent	*	*	*	T.O., Lnd, Stab., Man., Perf.	250	Basic, Arf, Subs.
80.2	62	38	100	90		*	*	*		250	
82.3	62	39	100	90	Concurrent	*	*	*	Man., Perf.	200	Basic, Subs.
83.2	62	39	100	90	Concurrent	*	*	*	Man., Perf.	200	Basic, Subs.
84.2	62	38	100	90	Concurrent	*	*	*	Man., Perf.	200	Basic, Subs.
87.3		20	20	18	15 Conc 5 Pri	*	*	*	T.O., Lnd.	150	Basic

FIGURE 4-2 (CONTINUED)
Basic Vehicle (Continued)

Research Task No.	No. of Flights and Utilization			Est. Time Span A/C Mo.	Test Basis	Test Phase (1)			Test Method	Instrumentation Parameters	
	Build-Up	Test	Total			P	E	R	Type of Flight Tests	No. Req'd.	Type
89.2	62		62	56	Concurrent	*	*		Stab., Man., Perf.	200	Basic, Subs.
89.3	62		62	56		•	•			200	
93.2	62		62	56	Concurrent	•	•		T.O., Lnd, Man., Perf.	150	Basic
96.1	62	38	100	90	Concurrent	•	•	*	T.O., Lnd, Stab., Perf, Prop.	250	Basic, Subs.
96.2	62	38	100	90		•	•	*		250	
102.1	62	38	100	90	Concurrent	*	*	*	Man., Perf.		
102.2	62	38	100	90		•	*	•			

Thermal Protection System Option

23.1	3	3	6	5.4	B/U Conc Test Pri			*	Man., Perf.	700	Basic, Airf.
23.2	3	3	6	5.4				*		700	
23.3	3	3	6	5.4				*		700	
25.1	3	3	6	5.4	B/U Conc Test Pri			*	Man., Perf.	500	Basic, Airf.
25.2	3	3	6	5.4				*	Perf, Hi Alt.	700	
28.2	3	3	6	5.4	B/U Conc Test Pri			*	Man., Perf.	700	Basic, Airf.
28.4	3	3	6	5.4				*		700	
43.1	3	6	9	7	B/U Conc Test Pri			*	Man., Perf.	700	Basic, Airf.
43.2	3	6	9	7				*		700	

Armament Option

77.2		17	17	15	12 Conc 5 Pri			*	Man., Perf, Wpn.	300	Basic, Subs.
85.2		12	12	15	Primary			*	Wpn.	300	Basic, Subs.
85.3		12	12	15				*		300	

(a) Build-up flights - Includes those flights expended, when necessary, during the development phases of the research vehicle program. In most cases, research applying to the task is accomplished during these flights.

(b) Test flights - Those flights expended to accomplish any remaining unfulfilled research requirements after the buildup flights or to accomplish the Research Task in its entirety when buildup flights are not required.

2. TESTING TIME SPAN - Estimated time spans shown in these test plans are the number of months required for one research aircraft to perform the total number of flights needed to accomplish the Research Task. These estimates are based on average fly rates consistent with the total research program estimate of 200 flights flown by three vehicles over a five year period, i.e. 1.1 flights per month per vehicle. Two exceptions to this fly rate are employed:

(a) Mach 6 and Mach 12 vehicle TPS options - 1.3 flights/month are used because these options would be incorporated on the fully developed vehicle without adding a significant degree of complexity.

(b) Mach 12 vehicle Subsonic TJ option - five flights/month are used because the subsonic HTO flight operations can be more conventional in nature without the complexities associated with mother-ship operations, cryogenic fuels, long high-Mach-number flight profiles, and a large number of data parameters.

3. TEST BASIS - The purpose of the test basis column in the test plans is to indicate the degree of overlap of the tests between Research Tasks. This overlap is identified by the following terms:

(a) Concurrent - the Research Task can be accomplished on a concurrent basis with other Research Tasks during the same flights.

(b) Primary - these flights are more restrictive and would be devoted to accomplishment of a specific Research Task. It should be reiterated here that each task is evaluated with respect to its own requirements without regard to other tasks. Therefore, some concurrency of testing is also available during primary flights for tasks of a similar nature and, in particular, for other Research Tasks which are applicable to the same Research Objective.

Seventy build-up flights are estimated for the Mach 12 research vehicle and sixty-two build-up flights are estimated for the Mach 6 vehicle. These build-up flights are concurrent (identified as B/U conc.) and serve as the foundation for the entire test program. In most cases, a few flights are needed to achieve specific data applying to the task (identified as Test Pri.).

4. TEST PHASE - The test phase column defines that phase of the research program during which the research would be performed. The program is divided into three phases:

Pre-delivery phase

Envelope expansion phase

Research phase

It should be emphasized that research can be accomplished during all three phases, but most of the data is expected from the latter two phases.

5. TEST METHODS - The test methods column describes the type of flight tests and instrumentation that would be employed to accomplish the Research Tasks.

(a) Type of flight tests - this column presents abbreviated terms describing the kinds of tests needed to accomplish the Research Task. A more detailed description of the tests denoted by the abbreviation is presented as follows.

(1) T. O. - Take-off tests

- o ground roll distance and control
- o rotation effects
- o lift-off attitude/stability
- o acceleration forces
- o trim changes and directional control

(2) Lnd - Landing tests

- o glide slope
- o approach angle of attack
- o control response
- o flare control
- o effects of high-lift devices
- o cockpit visibility
- o touchdown accuracy
- o stopping distance
- o rollout steering, breaking, and control

(3) Stab. - Static and dynamic stability tests

- o lateral-directional stability
- o longitudinal stability
- o neutral point
- o short and long period damping
- o trim changes
- o turning performance
- o spiral stability
- o sideslips
- o descents

(4) Man - Maneuvering flight tests

- o wind-up turns
- o pullups
- o pushovers
- o rolling pullouts

(5) Perf. - Performance tests

- o climbs
- o accelerations
- o steady state cruise

(6) Prop - Propulsion tests

- o engine handling (accelerations/decelerations)
- o shutdowns
- o starts and restarts

(7) Hi Alt - High altitude tests

- o climb profiles
- o reaction control response
- o re-entry profiles

(8) Stg - Stage separation tests

(9) Wpn - Weapon separation tests

(b) Instrumentation parameters - This column presents the estimated number of parameters required to acquire the necessary data, and an abbreviation term denoting the type of parameters. The following describes the parameter types.

(1) Basic - This group is comprised of a variety of parameters which would be considered essential for all flights. They include:

- o flight regime - altitude, airspeed, temperature, and inertial data.
- o vehicle attitude/control - three axis load factor; pitch, roll, yaw angle/rate; fuel quantity, angle of attack; control surface positions.
- o safety of flight - pressures, temperatures, loads, electrical signals, warning circuits, and positions of critical airframe and subsystems.

(2) Airf - Airframe - external surfaces, compartments, boundary layer, control surfaces.

- o pressures - external surfaces, compartments, boundary layer, control surfaces.
- o temperatures - external surfaces, substructure, compartment air, subsystem components, fuel cells, control surfaces.
- o strain/loads - external surfaces, substructure, control surface/actuator/hinges.
- o acceleration/vibration-external surfaces, substructure, control surfaces.
- o acoustic energy-compartments.

(3) Airb Prop. - Airbreathing propulsion

- o pressures and temperatures - inlet, exit, internal engine, engine compartment, engine control/subsystems/accessories/fuel, inlet cooling system.
- o strain/loads - inlet control mechanisms, engine mounts, inlet/exit structure.
- o acceleration/vibration - engine, engine accessories, fuel/oil plumbing.
- o positions - inlet/exit control, engine control.

(4) Rkt Prop - Rocket propulsion

- o pressure and temperature - engine and accessories, fuel systems
- o positions - engine control, engine gimballing.

(5) Subs - Subsystems - including avionics, flight control, propellant, environmental control, auxiliary power.

- o pressures, temperatures, strain/loads, position, and electrical signals as required to monitor performance and operation of the subsystems.

4.1.2 COST OF PERFORMING RESEARCH - The cost of accomplishing each of the research tasks can be indicated in terms of the flight research vehicle operating costs. The cost of conducting a test program, involving any combination of Research Tasks, can be easily determined from the operating costs presented in this paragraph. The operating costs on a per flight basis are presented below for the Mach 12 and Mach 6 basic vehicles. These costs are determined by dividing the total program operating costs for the Mach 12 vehicle (87.836 million dollars as derived in Section 4.12 of Volume IV, Part I) and the Mach 6 vehicle (92.047 million dollars as derived in Section 5.12 of Volume IV, Part I) by 200 flights.

FLIGHT VEHICLE CONFIGURATION	OPERATING COST PER FLIGHT
Mach 12 basic	$440,000
Mach 6 basic	$460,000

4.2 GROUND FACILITY TEST METHODS

The new ground facilities, including wind tunnels, airbreathing engine test facilities, and structural test facilities which have been defined in this study, will provide the required test environment within a reasonable range of obtainable power, materials, structure, technology, and funding.

The conceptual ground research facilities selected for Phase III refinement are summarized in Figure 4-3. Design criteria, arrangement, and operational capability of these new facilities are described in detail in Volume IV, Part 2.

These types of facilities are common to aeronautical systems R&D, but present an extension of the capability which exists in today's facilities. Since these types of facilities are familiar to R&D engineers, it can be assumed that the methods of testing are generally known. It is to be expected that new methods will need to be developed based on first-hand experience of facility operation, test conducting, and data analysis; historically, this has been required either to fulfill the basic purpose of new facilities or to extend their capabilities. However, the methods presented in the following paragraphs are judged to be a representative approach to utilizing the facilities in an experimental program.

FIGURE 4-3
PHASE III GROUND FACILITIES

FACILITY	TYPE	MACH RANGE	RUN DURATION-sec		R_{e_m} / R_{e_f} xxx	P_o PSIA (N/cm^2)	T_o °F MAX/(°C)	TEST SPEC. SIZE	REMARKS
GD7	HYPERSONIC IMPULSE GAS DYNAMIC RESEARCH FACILITY	8-13	1-4		1/5	1000 (630) TO 18,000 (11,700)	2500 (1370)	L = 6.1 ft (1.9m)	
GD20	INTEGRATED SUB/TRANS/SUPERSONIC BLOWDOWN GAS DYNAMIC RESEARCH FACILITY	(LEG 1) .5-5 (LEG 2) 4.5-8.5	$10-30$ sec $10-30$ sec		1/5 1/5	17(11.7) TO 300(207) 50(34.5) TO 2360(1620)	250 (120) 800 (426)	L = 12.4 ft (3.8m) L = 9.3 ft (2.8m)	
E9	SCRAMJET ENGINE RESEARCH FACILITY	3-11*	AIR 60	VITIATED AIR CONT.	1.0 xx	84 TO (58) 3000 (2070)	6540 (3600)	A_o 30 ft^2 (2.8 m^2)	MODIFIED DIRECT CONNECT
E20	INTEGRATED TURBO-MACHINERY/RAMJET ENGINE RESEARCH FACILITY	(LEG 1) 0 - 5.5 (LEG 2) 0 - 5.0	CONTINUOUS		1.0	3 (2.07) TO 350 (241)	2000 (1090)	D_e = 90m (FULL SCALE) (2.3m)	DIRECT CONNECT + FREE JET
S20	INTEGRATED STRUCTURES/FLUID SYSTEMS RESEARCH FACILITY	SIMULATES MECHANICAL, THERMAL, VIBRATION, ACOUSTIC, ALTITUDE, AND THERMAL/ACOUSTIC ENVIRONMENTS ON COMPONENTS, MAJOR SECTIONS AND FULL SCALE VEHICLES.							

*ALSO PROVIDES AERODYNAMIC NOZZLES FOR M = 6, 9, 10 & 12 AERO/THERMO/STRUCTURAL TESTING

xx FOR A SINGLE ENGINE MODULE

xxx RATIO OF MODEL REYNOLDS NUMBER TO FLIGHT REYNOLDS NUMBER

4.2.1 DATA REQUIRED - Each Research Task has been examined from the standpoint of determining the data required to accomplish the task. In general, these data can be categorized as follows:

(a) Aerodynamics - data which is basically oriented toward definition of flow field and boundary layer conditions and mechanisms on and about configuration surfaces as well as Reynolds and scale effects so that results obtained with scale models can be extrapolated with confidence and applied to the full-scale vehicle. The data which is to be used in the evaluation of flight concept designs reduces to parameters which describe vehicle performance, stability, control effectiveness, component loads, acoustic noise environment, buffet onset and intensity limitations, and how shaping and performance of integrated systems affect the levels of these parameters.

(b) Thermodynamics - testing provides data describing aerodynamic heating distributions and critical areas which must be protected or designed to withstand the environment. These data also are subject to flow field, boundary layer, Reynolds and scale effects which must be evaluated and accounted for in a design. Thermodynamic data acquisition not only covers aerodynamic heating, but definition of cooling and heating requirements and definition and evaluation of the systems which must be incorporated in a flight vehicle to provide the thermal protection required to survive the flight environment.

(c) Structures and Materials - tests are generally defined as those which provide data describing the physical properties, the physical/chemical compatibility of material as well as mechanical, thermal, service, and fabrication properties. Gleaned from tests of a variety of models and test specimens are results which provide guidelines for establishing fabrication, inspection, integration and repair methods. Many of the structural tests are conducted for the purpose of evaluating the performance, reliability, and limitations of structures and integrated subsystems to environments of static and dynamic loading, temperature, and altitude.

(d) Propulsion - data are defined as those which provide definition of performance of the integrated inlet, engine and exhaust system as well as engine component, environment, performance, reliability, and limitations. These data also provide a basis for the design of engine thermal protection systems, accessory drives, fuel systems, air data sensor control systems, and integrated engine design refinements.

(e) Subsystems - tests produce performance data relative to flight control systems, environmental control systems, heat exchangers, energy conversion for auxiliary power units, fuel systems, mass transfer systems, abort/escape systems, antenna and air data sensor systems. Results are in terms of aerodynamic, thermodynamic, structural, propulsion, and operational performance and limitations.

(f) Operations - data pertain to ground and flight operations such as approach, landing, takeoff, flight safety, course alteration, crew and passenger comfort, abort and escape, ground hold, inspection, and repair. Results are obtained largely by means of combined flight systems and existing airport facilities. However, some elements require data obtained in the aforementioned technical areas using existing and new ground research facilities. Those that require extensive ground research facility testing include landing, takeoff, and escape systems.

4.2.2 MODELS AND TEST SPECIMENS - Models and test specimens for obtaining experimental ground research data may be separated into categories which are identified by the type of facility in which they are to be tested. In general, these categories are simply: (a) wind tunnel models, (b) experimental engines and components, and (c) structural test specimens. These items are considered basic to any test program and do not include integrated subsystems which are described in Section 4.2.3.

(a) Wind Tunnel Models are designed to provide basic aerodynamic, thermodynamic, and inlet performance data. If limited strictly to configuration evaluation, investigation capability is also limited; therefore, a number of special model designs are necessary to provide proper simulation of overall flight environment and to provide the various means of instrumenting and measuring the described incremental effects. These models are designed to provide investigations of the contributions of configuration components, the effects of staging and separation, effects of surface irregularities, evaluation of dynamic stability derivatives, the effects of aerothermoelasticity, effects of inlet and exit flow, evaluation of base and boattail drag, skin friction drag, net thrust (T-D), evaluation of inlet and engine face and exhaust environment, effects of cooling by means of mass addition to the boundary layer, and the effects and effectiveness of reaction control and surface control devices.

(b) Experimental Engines and Components are required for evaluation of propulsion concepts as well as the investigation of component designs. Experimental engines include inlet components and engine core components, such as compressors, combustors, turbines, and nozzles, all of which are integrated into a test setup. The experimental engine concept may be characterized as a turbojet, turboramjet, ramjet, scramjet, or convertible scramjet,and its facility installation could provide for measurement of integrated performance and the performance of its components and accessory drives.

(c) Structural Test Specimens provide a means of evaluating a wide range of structural concepts from simple material coupons to a full-scale structural vehicle. Some of the test items in this range include coated material coupons, TPS insulation panels, leading edge structures, control surface structures, substructures, major full-scale structural sections, tankage structure, integrated TPS, and tankage. In many cases, subscale tankage is used in lieu of more costly full-scale structures to develop and substantiate analytical models. In these cases, several models varying in size may be necessary to evaluate scale effects on the evaluation of a given concept.

4.2.3 TEST EQUIPMENT AND SUBSYSTEMS - Test equipment and subsystems are required by the particular test program on a very selective basis,depending on the nature of the test to be conducted. Furthermore, a great variety of such equipment and subsystems may be required,depending on the number of variables and/or concepts which are to be evaluated. Since many of these systems incorporate design criteria developed from concurrent research, they are considered to be items independent of models and test specimens. Often they are necessarily integrated with the model and test specimen to produce the appropriate effects which are to be measured or to provide the appropriate environment within which the system is to be investigated or evaluated. Like the models themselves, test equipment and subsystems may vary in size to suit the model or test specimen and to obtain scale effects. In addition, it is of primary importance that the subsystem provide the desired degree of simulation relative to the flight article and, therefore, requires careful attention to design details, the parameters to be simulated, and the facility environment in which it is to be tested. These considerations indicate that several subsystems may be required to achieve simulation consistent with the facility in which the test is conducted. Test equipment and subsystems may be considered to fall in the following categories: Simulation Systems, Control Systems, Thermal Protection Systems, Fuel Systems, Environmental Control Systems, Miscellaneous Systems, and Test Hardware.

(a) Simulation Systems are pertinent to wind tunnel testing and include remotely controlled engine simulators, exhaust gas simulators, and boundary layer removal and mass addition systems. The requirement of these systems is to produce the desired simulation of the full-scale device and the flow field/boundary layer interaction effects which are to be evaluated. It should be noted that special attention must be given to these simulators because considerable costs will be incurred in design, development, and calibration if both suitable simulation and data acquisition are to be achieved.

(b) Control Systems include inlet systems (remotely-controlled ramps, bleeds and throttling systems), actuator systems, control limit systems, and reaction control systems.

(c) Thermal Protection Systems include structural and engine cooling system concepts such as ablation materials, transpiration cooling and regenerative cooling. These systems also cover material and structural coatings, heat exchangers and fluid flow systems.

(d) Fuel Systems include cooling systems, loading systems, tankage, and leak detection systems.

(e) Environmental Control Systems include liquid cryogen and hydrocarbon types and the associated heat exchanger components, panels, and integrated system as well as heaters for those areas which require high heat flux.

(f) Miscellaneous Subsystems include antenna systems, armament systems, abort/escape systems, crew warning systems, auxiliary power systems, and crew/passenger modules. It should be noted that research of escape systems (which involve separation and deployment of crew modules from the integrated aircraft) could be a very significant research program in itself and should be treated accordingly.

(g) Miscellaneous Test Equipment includes wind tunnel model support systems, engine installation hardware, and support fixtures and jigs for structural and environmental tests. Special attention is given only to automated dual support systems for separation effects testing using wind tunnel models. This system is considered to be a relatively costly item, since extensive instrumentation and computer equipment is required as well as programming and maintenance support.

4.2.4 INSTRUMENTATION - Collective test programs as discussed herein present a broad requirement for instrumentation devices. While there are many types of instruments, they can be categorized by the parameters which are measured such as:

- Strain
- Acceleration
- Pressure
- Temperature
- Deflection/Displacement
- Voltage
- Current
- Frequency
- Power
- Radiation, Light, and Acoustics.

High degrees of sophistication of the instrumentation have been attained by refining and/or combining the principles of measurement associated with the above. Extension of basic instrumentation for the purpose of measuring such data as gas composition and density, fluid film thickness, frequency spectral densities, transmission patterns, hazard detection such as fuel system leaks, automatic checkout, radiation, light, and acoustics has been achieved,and it can be expected that future refinements will be made to meet the needs of measurement. Because the choice of specific instruments is so broad, only a few of the most obvious instrumentations are presented in Figure 4-4 to illustrate the needs of specific test programs.

4.2.5 APPLICABLE RESEARCH TASKS - The Research Tasks presented in Section 3 provide a basis for the Research Test Methods Matrix presented in Figure 4-4. Each Research Task is listed by number in Figure 4-5 along with data requirements, type tests to be conducted, and facilities to be used. While both existing and new facilities are specified, only those tasks which require testing in new ground facilities are shown in Figure 4-4 to illustrate the potential capabilities of the new facilities as well as the desirability of using multiple facilities to provide a high degree of verification of results.

4.2.6 COST OF PERFORMING RESEARCH - The elements considered to affect the cost of conducting research in new ground test facilities are basically the cost of test hardware and the cost of facility operation. Summation of these elements yields research costs.

(a) Test Hardware Costs are accurately derived from definitive descriptions of every part which is required for a particular test program. The definition of test hardware presented in this section is not considered to be precise, but rather a first order estimate of typical models, test specimens, subsystems, support systems, and instrumentation which may be used to conduct experimental research. Thus, the test hardware costs presented in Figure 4-4 are judged reasonable approximations.

(b) Facility Operating Costs are discussed in detail in Part 2 of Volume IV. It is sufficient to say that costs are presented in this volume in dollars per occupancy hour; therefore, the cost of a particular research program depends on the amount of testing or the duration of testing in each facility.

(c) Research costs for a given Research Task are obtained as follows:

- o Determine data required
- o Determine cost of models or test specimen to be provided
- o Determine cost of subsystems and test equipment required
- o Determine cost of instrumentation required
- o Determine facilities to be used, the duration of testing required, and the product of occupancy hours times dollars per occupancy hour
- o Sum elements 2 through 5 for each data required item.

4.2.7 FACILITY UTILIZATION CONSIDERATIONS - The capability of a facility to accomplish experimental research is a direct function of the degree of simulation and the accuracy with which desired parameters can be measured. The new ground facilities provide significant increases in environmental simulation over that which is available today, but the techniques of exploiting this capability become important tasks in themselves. Areas requiring major improvement include the following:

(a) Engine Inlet/Exit Flow Simulation - This type of simulation is important for all propulsion concepts involved in wind tunnel tests in which the objectives are to evaluate the effects of inlet flow and spillage on drag and stability and/or the effects of exhaust gas impingement, interaction, and radiation on local fuselage contouring and structure and the effects on net thrust and stability. Simultaneous simulation of these effects is considered to be paramount if inlet spillage flows are large enough to interact and affect exit flows. Achievement of these investigations will require development of small engine simulators with remote controls to provide the necessary induced inlet flow and exit thrust with simulation of plume pressure ratios and exhaust temperatures. Current state of the art provides near-future promise of the development of supersonic engine simulators of the turbojet and high bypass-turbofan type. Anticipation is that thrust and temperatures will be closely simulated while pressure ratios will be somewhat less than desired because of reduced efficiency of small compressors. Plumes, of course, can be adjusted by varying nozzle configuration and exhaust pressures.

Ramjet, scramjet, and convertible scramjet engine simulation is considered to be somewhat less complex because of the absence of rotating machinery. Some complexities, however, can be expected in provisions of thermal protection in these simulators as well as their integration into airframes which require contouring to obtain optimum net thrust.

(b) Acoustic Noise Research - Extensive research has been performed relative to jet engine and rocket exhaust noise, as well as to its propagation. This research has considered both the near and far-field effects relating to vehicle acoustic pressure loading and to the problems of community noise. Empirical methods of predicting noise levels have been derived and acoustic source regions about, through, and downstream of flowing systems can be identified. The factors which affect noise energy loss, such as geometric spreading, scattering and refraction of the sound waves, molecular absorption and other irreversible processes, may be expressed empirically. The fundamental sources of noise, however, are not known and, therefore, analytical models cannot be written which describe, in detail, the effects of flutter, fluctuating boundary layers, vortex shed and shock wave interaction.

It has been said that this area of research is one of the most fundamental unexplored areas of fluid mechanics and involves the generation of noise through aerodynamic interaction with various bodies. Since investigations of the fundamentals have just begun, it can be expected that a considerable effort will be required to attain the desired level of knowledge with which to write the mathematical models.

(c) Buffet Intensity Research - This is another relatively new area of investigation which requires study of the methods of analyzing the transmission of dynamic loads through the airframe and of predicting the effects on structural components such as skin, shingles, and panels, and upon the pilot or crew relative to performing their in-flight functions. Methods of measurement of the dynamic intensity exist today, but the major problem in applying these measurements will lie in the scaling of data to be obtained from subscale models. Obtainable data accuracy depends largely on the degree of structural and flight environment simulation which can be achieved.

(d) Temperature and Heat Transfer - Instrumentation for measurements at temperatures greater than 2000°F (1366°K) present a basic problem. Optical pyrometers provide some capability for high-temperative measurement, but are not suitable for many investigations of structural heating and boundary layer investigations. Improved thermocouple materials, coatings, and sensing techniques will be required to provide the necessary capability in this area.

(e) Thrust and Engine Mass Flow - Instrumentation and measurement techniques are considered to be a significant problem in this area, since the quantities to be measured are beyond the capabilities of existing airbreathing engine test facilities. Engine thrust will be in the range of 100,000 to 350,000 lb (444,800 to 1,553,000 N/sec) and airflow will range from 1000 to 2000 lb/sec (4,448 to 8,896 N/sec). The new ground test facilities will provide sufficient airflows, but it is not clear at this time how these flows will be measured. Facility capability will be limited to about 100,000 lb (444,800 N) of thrust which will require special balance designs. A greater problem in thrust measurement is the fact that testing of scramjets will be limited to single modules and the total thrust must be assumed to be additive unless testing of scaled engines can yield accurate correction factors. Any resulting errors in thrust measurements will be reflected in performance through specific fuel consumption factors obtained from the new facilit

FIGURE 4-4
EXPERIMENTAL GROUND RESEARCH METHODS

Data Required \ Special Provisions	Configuration Components	Staging/Separation Models	Surface Irregularity Models	Elastic Configuration	Dynamic Stability Models	Aerothermoelastic Models	Inlet/Exit Flow Models	Boom/Boat Tail Drag Models	Skin Friction Drag Models	Net Thrust (T-D) Models	Component Loads Models	Inlet Air Flow Models	Inlet Heat Transfer Models	Configuration Heating Models	Jet Exit Heating Models	Sonic Boom Models	Mass Transfer Models	Reaction Control System Models	Jet Nozzle Models	Full Scale Inlets	Compressors	Combustors	Turbines	Nozzles	Accessory Drives	TJ Integrated Engine	TRJ Integrated Engine	RJ Integrated Engine	SJ Integrated Engine	CSJ Integrated Engine
Major Test Hardware	Models and Test Specimens																													
Order of Magnitude Costs of Conducting Experimental Research (Dollars): Sub Scale	5×10^4	6×10^5	4×10^5	4×10^5	3×10^5	4×10^5	4×10^5	5×10^5	4×10^5	5×10^5	4×10^5	4×10^5	5×10^5	6×10^5	$.5\times10^5$	1×10^5	4×10^5	4×10^5	3×10^5	5×10^5	1×10^5	5×10^5	1.5×10^5	5×10^5			3×10^5	1×10^5	1×10^5	15×10^5
Full Scale																				2×10^6	1×10^7	2×10^6	7×10^6	1×10^6	5×10^5	2×10^6	3×10^6	8×10^5	11×10^5	15×10^5
1. Flow Field/Boundary Layer State	●	●	●	●		●	●	●	●			●	●	●	●		●	●	●	●	●			●						
2. Reynolds/Scale Effects	●		●	●		●	●	●	●	●	●	●	●	●	●		●	●	●	●										
3. Aerodynamic Performance		●	●	●		●	●	●	●	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●	●
4. Aerodynamic Stability and Control		●		●	●	●	●										●	●												
5. Aerodynamic Loads	●	●		●		●					●										●		●	●						
6. Aerodynamic Heating/Heat Transfer	●	●	●	●									●	●	●		●	●	●	●	●	●	●	●		●	●	●	●	●
7. Acoustic Noise Environment	●	●	●	●			●			●		●				●			●	●										
8. Inlet/Engine Face Environment							●					●	●				●			●	●					●	●	●	●	●
9. Inlet Control System Performance							●					●								●						●	●	●	●	●
10. Engine Component Performance/Environment																					●	●	●	●	●	●	●	●	●	●
11. Engine Cooling Concepts Performance																	●			●	●	●	●	●	●	●	●	●	●	●
12. Integrated Engine Performance																										●	●	●	●	●
13. Aerodynamic Buffet Onset/Intensity	●	●		●		●																								
14. Shaping Effects	●	●	●	●			●	●	●	●		●	●	●	●	●			●	●		●								
15. Physical/Fluid Properties																					●	●	●	●	●					
16. Physical/Chemical Compatibility																						●	●	●						
17. Mechanical Properties																					●	●	●	●	●					
18. Thermal Properties/Effects																				●	●	●	●	●	●					
19. Service Properties/Failure Mechanisms																				●	●	●	●	●	●					
18. Fabrication Properties/Effects																				●	●	●	●	●	●					
19. Oxidation/Corrosion Resistance																				●		●	●	●						
29. Actuator Systems Performance																				●	●				●					
21. Structural Cooling System Performance																				●	●									
22. Fuel Slosh Modes/Intensities																														
23. Inertial Forces/C.G. Perturbations																														
24. Near Field Noise Effects																				●										
25. Fabrication Methods																				●	●	●	●			●	●	●	●	●
26. Inspection Methods																				●	●	●	●			●	●	●	●	●
27. Repair Methods																					●	●	●			●	●	●	●	●
28. Integration Methods																					●	●	●			●	●	●	●	●
29. TPS Performance																						●	●							
30. ECS Performance																														
31. APU Performance																														
32. Mechanical Load Capability																														
33. Dynamic Loads Effects																				●	●									
34. Combined Environment Effects																				●	●									
35. Fluid Flow Systems Performance																										●	●	●	●	●
36. Antenna Performance																														
37. AAM/ASM Launch Systems Integration	●	●		●																										
38. Sensor/Control System Performance	●					●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●
38. Energy Conversion Efficiency																														
39. Procedures, Methods, Techniques																														
40. Performance, Reliability, Limits																					●	●	●		●					
41. Qualification/Verification																					●	●	●		●					

Data Required \ Special Provisions	Fuels	Material Coupons	Coated Material Coupons	Insulation/TPS Panels	Sub-Structures	Tankage Structure	Integrated TPS and Tankage	Fuel Slosh Tankage	LE Structures and TPS	Control Surface Structure	Major Structural Sections	Full Scale Structural Vehicle	Fuel Storage Tankage	R/C Inlet Ramps, Bleeds, Mass Flow	P/C Engine Simulators	Exhaust Gas Simulation	BL Mass Addition	BL Control Systems	Automated Separation Rig	Misc. Stings, Adaptors, Supports	Fuel System Components	Cooling Systems	Fuel Leak Detection Systems	Fuel Loading Systems	Integrated Fuel System/Tankage	Actuator Systems	Antenna Systems	AAM & ASM Systems	Abo/Escape Systems	
Major Test Hardware														Test Equipment and Subsyste																
Order of Magnitude Costs of Conducting Experimental Research (Dollars): Sub Scale														12×10^4	12×10^4	6×10^4	6×10^4	4×10^4	1×10^6	1×10^4								1×10^5	5×10^4	
Full Scale	1×10^4	1×10^4	3×10^4	3×10^5	2×10^6	1×10^6	2×10^6	3×10^6	5×10^6	5×10^6	15×10^6	2×10^7	2×10^7	12×10^5							2×10^5	2×10^5	1×10^6	25×10^5	25×10^5	5×10^5	1×10^5	1×10^6	4×10^6	
1. Flow Field/Boundary Layer State														●	●	●	●	●	●	●								●	●	
2. Reynolds/Scale Effects														●	●	●	●	●	●	●								●	●	
3. Aerodynamic Performance	●													●	●	●	●	●		●								●	●	
4. Aerodynamic Stability and Control														●	●		●		●	●								●	●	
5. Aerodynamic Loads														●	●		●		●	●								●	●	
6. Aerodynamic Heating/Heat Transfer														●	●	●	●	●	●	●								●	●	
7. Acoustic Noise Environment														●	●	●				●								●	●	
8. Inlet/Engine Face Environment														●		●	●			●										
9. Inlet Control System Performance														●	●			●		●										
10. Engine Component Performance/Environment	●																				●	●	●	●	●					
11. Engine Cooling Concepts Performance	●																					●								
12. Integrated Engine Performance	●																				●	●	●	●	●					
13. Aerodynamic Buffet Onset/Intensity																				●										
14. Shaping Effects					●	●	●	●	●	●	●	●																●	●	
15. Physical/Fluid Properties	●	●	●	●	●	●	●	●	●	●	●	●	●								●	●			●	●	●	●	●	
16. Physical/Chemical Compatibility	●	●	●			●		●	●				●								●	●			●	●		●		
17. Mechanical Properties		●	●	●	●	●	●	●	●	●	●	●	●								●	●			●	●	●	●	●	
18. Thermal Properties/Effects	●	●	●	●	●	●	●	●	●	●	●	●	●								●	●			●	●	●	●	●	●
19. Service Properties/Failure Mechanisms		●	●	●	●	●	●	●	●	●	●	●	●								●	●			●	●	●	●	●	●
18. Fabrication Properties/Effects		●	●	●	●	●	●	●	●	●	●	●	●								●	●			●	●	●	●	●	●
19. Oxidation/Corrosion Resistance		●	●		●			●	●	●	●	●									●	●			●	●	●			
29. Actuator Systems Performance										●	●	●														●		●	●	
21. Structural Cooling System Performance											●									●		●								
22. Fuel Slosh Modes/Intensities						●	●	●												●					●					
23. Inertial Forces/C.G. Perturbations						●	●	●												●					●					
24. Near Field Noise Effects																														
25. Fabrication Methods				●	●	●	●	●	●	●	●	●	●								●	●			●	●	●	●	●	
26. Inspection Methods				●	●	●	●	●	●	●	●	●	●								●	●			●	●	●	●	●	
27. Repair Methods				●	●	●	●	●	●	●	●	●	●								●	●			●	●	●	●	●	
28. Integration Methods				●	●	●	●	●	●	●	●	●	●								●	●	●		●	●	●	●	●	
29. TPS Performance				●	●	●	●	●	●	●	●	●	●									●		●	●		●	●	●	
30. ECS Performance										●		●	●									●								
31. APU Performance													●																	
32. Mechanical Load Capability				●	●	●	●	●	●	●	●	●	●																	
33. Dynamic Loads Effects				●	●	●		●	●	●	●											●			●	●			●	
34. Combined Environment Effects		●	●	●	●	●	●	●	●	●	●	●									●	●			●	●	●		●	
35. Fluid Flow Systems Performance	●						●	●					●									●	●	●	●					
36. Antenna Performance																											●			
37. AAM/ASM Launch Systems Integration									●	●	●																	●		
38. Sensor/Control System Performance								●				●		●								●	●		●	●				
38. Energy Conversion Efficiency																														
39. Procedures, Methods, Techniques																												●	●	
40. Performance, Reliability, Limits	●																						●		●			●	●	●
41. Qualification/Verification									●	●	●	●	●										●		●			●	●	

FOLDOUT FRAME 1

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Group	Columns
Test Equipment and Subsystems	R/C Inlet; R/C Engine Simulators; Exhaust Gas Simulation; BL Mass Addition; BL Control Systems; Automated Separation Rig; Misc. Slings, Adapters, Supports; Fuel System Components; Cooling Systems; Fuel Leak Detection Systems; Fuel Loading Systems; Integrated Fuel Systems/Tankage; Actuator Systems; Antenna Systems; AAM & ASM Systems; Abort/Escape Systems; Crew Warning Systems; Control Limit Systems; Liquid Cryogen ECS; Hydrocarbon ECS; Heat Exchanger Components; Heat Exchanger Panels; Integrated Heat Exchangers; High Heat Flux Heaters; Auxiliary Power Systems; Crew/Passenger Modules
Instrumentation	High Load/Sensitivity Balances; Dynamic Stability Balances; Component Balances; Hinge Moment/C.P. Balances; Misc. Strain Instrumentation; High Freq. Response P'ducers; Steady State P'ducers; High Sensitivity Heat Flux Gages; Skin Friction Gages; Misc. Press. Rakes, Orifices; Thermocouples; Temp. Sensitive Coatings; Pyrometers; Gas Composition Analyzers; Fluid Film Thickness Gages; Displacement Sensors; Liquid and Gas Flow Meters; Spectral Density Analyzers; Transmission Volt Meters; Frequency/RPM Meters; Torque Meters; Spectroscopes; Accelerometers
Test Facilities	Transonic/Supersonic M 0.5-5; Hypersonic Tunnel M 4.5-8.5; Hypersonic Impulse GDRF M 8-13; MDC SI Facility M 3-5.5; Aero Nozzles M 6,9,10,12; CTR Facility (DC) M 6-5.5; CTR Facility (F) M 6-5.0; Mechanical/Structural Flow; Internal/Structural Flow; Thermal/Mech Structural Flow; Thermal/Altitude Chamber; Thermal/Mech. Alt. Chamber; Acoustic Test Cell; Thermal Acoustic Test Cell; Fluid Systems Facility

Test Equipment and Subsystems, upper unit row: 12×10^{4}, 12×10^{4}, 6×10^{4}, 6×10^{4}, 4×10^{4}, 1×10^{4}, 1×10^{4}, …, 1×10^{5}, 5×10^{5}

Test Equipment and Subsystems, lower unit row: 12×10^{3}, …, 2×10^{3}, 2×10^{3}, 1×10^{3}, 20×10^{3}, 20×10^{3}, 5×10^{3}, 1×10^{3}, 1×10^{3}, 4×10^{3}, 5×10^{3}, 2×10^{3}, 25×10^{3}, 20×10^{3}, 2×10^{3}, 4×10^{3}, 1×10^{3}, 5×10^{3}, 5×10^{3}, 5×10^{3}

Test Facility	CG20	CG20	CG7	E3	E3	E20	E20	S20	S20	S20	S20	S20	S20	S20	S20
Runs Per Shift	8	8	4	32	10	32	32	N A							
Facility Operating Costs Dollars Occ. Hr.	1525	1525	1730	7300	7300	7000	7000	1250	1250	1250	1250	1250	1250	1250	1250

Row										
1	2.2	3.3	4.3	6.1	6.2	6.3	10.1	11.2	12.1	12.2 …
2	4.2	12.2	14.3	16.2	16.3	17.1	60.3	75.2		
3	2.2	2.3	3.1	[illegible]	3.4	6.1	6.2	6.3	7.2	7.3
4	2.1	2.3	3.1	3.2	3.3	3.4	6.1	6.2	6.3	9.1
5	2.1	3.2	7.2	10.1	10.2	11.2	33.1	94.3		
6	4.1	7.2	10.2	11.2	12.1	16.1	16.2	16.3	18.1	19.2
7	7.2	11.2	15.1	15.2	15.3	17.1	55.1	55.2		
8	12.2	48.1	48.2	48.4	57.6	59.6	60.6	61.6	63.1	
9	48.2	53.6	53.6	58.6	61.6	63.1	63.3			
10	57.4	57.5	57.6	58.4	59.5	59.6	60.4	60.5	60.6	61.4 …
11	52.5	57.6	59.6	60.6	61.6	71.1				
12	57.6	59.6	60.6	61.6	71.1					
13	2.3	14.1	14.2	14.3						
14	2.2	3.1	7.3	12.2	12.3	15.2	22.1	22.2	30.1	30.3 …
15	28.1	33.1	34.1	34.2	34.3	36.1	43.1	70.2	70.3	70.4 …
16	28.1	32.3	34.2	36.1	43.1	70.3	73.1			
17	28.1	32.1	33.1	36.1	40.2	43.1	70.3	70.4	73.1	77.2 …
18	26.3	28.1	28.2	34.2	35.2	36.1	40.2	43.1	70.2	70.4 …
19	28.1	30.3	32.1	32.2	33.3	34.3	36.3	39.2	40.2	40.3 …
20	28.2	30.3	34.1	45.2	70.3	77.2	94.3			
21	32.1	32.2	32.3	36.1						
22	33.2	33.2	42.1	[illegible]	94.3					
23	34.1	42.[illegible]								
24	30.3	30.1	30.3							
25	30.2	30.3								
26	39.1	39.2								
27	28.3	30.2	32.1	32.3	33.2	34.1	43.3	62.2	70.3	94.3
28	28.3	30.2	34.1	40.2	46.3	63.3	94.3	98.1		
29	28.3	30.2	42.1	43.3	94.3	98.1				
30	34.1	42.2	94.3							
31	34.3	42.1	[illegible]							
32	88.2	88.[illegible]								
33	70.4	82.2	86.3							
34	23.4	35.2	40.2	40.3	42.1	75.2	77.2			
35	30.3	40.2	40.3	42.1	75.2	77.2	98.2			
36	28.4	30.3	32.1	32.2	33.1	33.3	34.2	34.4	35.2	36.1 …
37	34.2	34.3	42.1	75.2						
38	77.2									
39	86.2	86.3								
40	40.2	63.2	70.1	75.3	79.2	86.2	97.2			
41	70.4	82.2	82.3							
42	94.3									
43	33.1	42.1	46.2	73.2	73.3	82.2	96.1			
44	42.1	77.2	78.2	94.3	+ All Other Tasks Above to Se…					

FOLDOUT FRAME 2

	GDRF	MDC SJ Facility	Aero Nozzles	CTM Facility (DC)	(FJ)	Mechanical/Structural Floor	Tolerand/Structural Floor	Thermal/Mech/Structural Floor	Thermal/Altitude Chamber	Thermal/Mech. Alt. Chamber	Acoustic Test Cell	Thermal/Acoustic Test Cell	Fluid Systems Facility	Applicable Research Tasks
	M 0-13	M 3-5.5	M 6,9,10,12	M 0-5.5	M 0-5.0									
	GD7	E9	E9	E20	E20	S20	S20	S20	S20	S20	S20	S20	S20	
Facility Operating Costs Dollars Occ. Hr	1730	7300	7300	7000	7000	1250	1250	1250	1250	1250	1250	1250	1250	
Runs Per Shift	4	32	10	32	32	N A								
	●		●											2.2 3.3 4.3 6.1 6.2 6.3 10.1 11.2 12.1 12.2 12.3 14.2 14.3 16.1 16.2 16.3 17.1 17.2 20.4 23.1 23.2 23.3 24.1 24.2 24.3 27.1 27.2 27.3 48.1
	●		●											4.2 12.2 14.3 16.2 16.3 17.1 40.3 75.2
	●		●											2.2 2.3 3.1 3.3 3.4 6.1 6.2 6.3 7.2 7.3 9.1 9.2 9.3 9.4 10.1 11.2 16.2 22.3 23.1 23.2 23.3 24.3 35.1 40.4 62.2 62.3 64.1 65.3 85.2 85.3 94.3
	●		●											2.1 2.3 3.1 3.2 3.3 3.4 6.1 6.2 6.3 9.1 9.2 9.3 9.4 10.1 10.2 11.2 18.1 19.1 25.3 30.2 30.3 40.4 57.6 62.2 62.3 64.2 70.2 85.2 85.3 94.3
														2.1 3.2 7.2 10.1 10.2 11.2 33.1 94.3
	●		●											4.1 7.2 10.2 11.2 12.1 16.1 16.2 16.3 18.1 19.2 20.1 20.2 20.3 20.4 22.1 22.2 22.3 23.1 23.2 23.3 25.1 25.3 25.4 27.1 27.2 27.3 35.1 94.3
	●		●											7.2 11.2 15.1 15.2 15.3 17.1 55.1 55.2
	●	●	●	●	●									12.2 40.1 40.2 40.4 57.6 59.6 60.6 61.6 63.1
	●	●	●	●	●									40.2 59.6 59.6 60.6 61.6 63.1 63.3
	●	●		●									●	57.4 57.5 57.6 59.4 59.5 59.6 60.4 60.5 60.6 61.4 61.5 61.6 65.2
		●		●	●								●	52.5 57.5 59.6 60.6 61.6 71.1
		●		●	●									57.6 59.6 60.6 61.6 71.1
														2.3 14.1 14.2 14.3
	● ●	●	●	●	●	●	●	●	●	●	●	●	●	2.2 3.1 7.3 12.2 12.3 15.2 22.1 22.2 30.1 30.3 40.4 65.2
														28.1 33.1 34.1 34.2 34.3 36.1 43.1 70.2 70.3 70.4 73.1 94.3
						●								28.1 32.3 34.2 36.1 43.1 70.3 73.1
						●	●	●	●	●	●	●		28.1 32.1 33.1 36.1 40.2 43.1 70.3 70.4 73.1 77.2 94.3
						●	●	●	●	●	●			26.3 28.1 28.2 34.2 35.2 36.1 40.2 43.1 70.2 70.4 73.1 75.2 77.2 94.3
						●	●	●	●	●	●	●		28.1 30.3 32.1 32.2 33.3 34.3 36.3 39.2 40.2 40.3 43.1 43.2 46.2 70.5 77.2 82.3 94.3
						●								28.2 30.3 34.1 45.2 70.3 77.2 94.3
			●							●				32.1 32.2 32.3 36.1
		●		●	●	●	●	●	●	●	●	●	●	33.2 33.2 42.1 80.1 94.3
		●		●			●	●	●	●	●			34.1 42.1
													●	30.3 38.1 38.3
													●	38.2 38.3
	●	●	●	●	●						●	●		39.1 39.2
						●								28.3 30.2 32.1 32.3 33.2 34.1 43.3 62.2 70.3 94.3
						●								28.3 30.2 34.1 40.2 46.3 43.3 94.3 82.1
						●								28.3 30.2 42.1 43.3 94.3 82.1
						●								34.1 62.2 94.3
		●		●			●	●	●	●		●		34.3 42.1 94.3
						●	●							80.2 84.2
		●				●	●	●	●	●	●	●	●	70.4 82.2 82.3
						●				●				28.4 35.2 40.2 40.3 42.1 75.2 77.2
						●	●	●		●	●	●		30.3 40.2 40.3 42.1 75.2 77.2 93.2
									●	●		●		28.4 30.3 32.1 32.2 33.1 33.3 34.2 34.4 35.2 36.1 36.3 39.1 40.2 40.3 43.1 45.3 73.3 75.2 75.3 77.2 82.3
	●	●	●	●	●	●	●	●	●	●	●	●	●	34.2 34.3 42.1 75.2
						●	●	●	●	●				77.2
						●	●	●	●	●	●	●	●	85.2 85.3
	●	●	●	●	●	●	●	●	●	●	●	●	●	40.2 63.2 70.4 75.3 79.2 96.2 97.2
		●		●	●	●	●	●	●	●				70.4 82.2 82.3
						●	●	●	●	●				94.3
						●	●	●	●	●	●	●	●	33.1 42.1 46.2 73.2 73.3 82.2 96.1
	●	●	●	●	●	●	●	●	●	●	●	●	●	42.1 77.2 78.2 94.3 + All Other Tasks Above to Some Degree

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
1.1	High Lift Stability and Control Aerodynamic Loads	Aerodynamic	Existing Low Speed Wind Tunnels
1.2	High Lift Takeoff/Landing Performance	Aerodynamic Propulsive Lift Effects	Existing Low Speed Wind Tunnels
1.3	High Lift Performance	Aerodynamic Power Effects Ground Effects Buffet Onset	Existing Low Speed Wind Tunnels
1.4	Stability and Control	Handling Characteristics Adverse C.G. Effects Trim Capability Available Control Power	Flight Simulators
2.1	Stability and Control Aerodynamic Loads	Aerodynamic	Existing Subsonic/Transonic Wind Tunnels + GD 20 (Leg 1)
2.2	Performance Stability and Control Boundary Layer State	Aerodynamic Shaping Effects Jet Effects Inlet Position	Existing Subsonic/Transonic Wind Tunnels + GD 20 (Leg 1)
2.3	Performance Stability and Control Maximum Lift	Aerodynamic Net Thrust Buffet Onset	Existing Subsonic/Transonic Wind Tunnels + GD 20 (Leg 1)
2.4	Stability and Control	Handling Characteristics Adverse C.G. Effects Trim Capability Available Control Power	Flight Simulators
3.1	Performance Stability and Control	Aerodynamic Shaping Effects	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7
3.2	Stability and Control Aerodynamic Loads	Aerodynamic	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7
3.3	Performance Aerodynamic Stability Boundary Layer State Reynolds/Scale Effects	Aerodynamic	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7
3.4	Performance Aerodynamic Stability	Aerodynamic Jet Effects	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7
4.1	Aerodynamic Heating	Heat Transfer	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7, E 9, E 20.
4.2	Aerodynamic Heating	Heat Transfer	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7, E 9, E 20.
4.3	Aerodynamic Heating Boundary Layer State Reynolds/Scale Effects	Heat Transfer	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7, E 9, E 20.
5.1	Stability and Control	Flying Qualities	Flight Simulators
5.2	Control System Response	Flying Qualities	Flight Simulators
5.3	Central System Dynamics	Pilot Response Control Capability Structural Flexibility Effects	Flight Simulators

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(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
6.1	Flow Field Characteristics Performance Stability and Control	Aerodynamic Control Surface Positioning	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7
6.2	Flow Field Characteristics Performance Stability and Control	Aerodynamic Engine Duct Inlet Positioning	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7
6.3	Flow Field Characteristics Performance Stability and Control	Aerodynamic Integrated Configuration	Existing High Supersonic/Hypersonic Wind Tunnels + GD 20, GD 7
7.1	Jet Effects Simulation Requirements	Analytical Task	None
7.2	Flow Field Characteristics Aerodynamic Loads Pressure Distributions Aerodynamic Heating Acoustic Noise	Aerodynamic Jet Effects/Net Thrust Heat Transfer Fluctuating Pressure	Existing Low Speed, Transonic, Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7
7.3	Performance Stability and Control Shaping Effects	Aerodynamic Jet Effects	Existing Low Speed, Transonic, Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7
9.1 9.2 9.3	Performance Stability and Control	Aerodynamic Inlet/Exit Flow Effects	Existing Low Speed, Transonic, Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20, and E 9.
9.4	Performance Stability and Control	Aerothermoelastic Effects	Existing Low Speed, Transonic, Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20, and E 9.
10.1 10.2	Performance Stability and Control Aerodynamic Loads/Pressures Aerodynamic Heating	Aerodynamic Stage Integration Evaluation Heat Transfer	Existing Low Speed, Transonic, Supersonic and Hypersonic Wind Tunnels + GD 20 and GD 7.
11.1	Separation Concepts	Analytical Task	None
11.2	Flow Field Characteristics Aerodynamic Loads/Pressures Acoustic Noise Shaping Effects	Aerodynamic Heat Transfer Jet Effects Separation/Proximity Effects	Existing Hypersonic Wind Tunnels + GD 20 and GD 7
11.3	Second Stage Control During Separation	Flight Test only	None
12.1	Boundary Layer State Aerodynamic Heating	Aerodynamic Heat Transfer	Existing Hypersonic Wind Tunnels + GD 20 and GD 7
12.2	Flow Field/Boundary Layer State Reynolds/Scale Effects Shaping Effects	Aerodynamic Surface Irregularity Effects	Existing Hypersonic Wind Tunnels + GD 20 and GD 7
12.3	Boundary Layer State	Aerodynamic Boundary Layer Control on Inclined Surfaces and Inlet Ramps	Existing Hypersonic Wind Tunnels + GD 20 and GD 7
14.1	Buffet Onset/Intensity Shaping Effects	Aerodynamic Buffet Onset and Intensity Tests	Existing Transonic Wind Tunnels and GD 20
14.2	Flow Field Characteristics	Effects of Unsteady Flow Field Condition on Buffet Onset	Existing Transonic Wind Tunnels and GD 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
14.3	Buffet Onset/Intensity	Basic Configuration Buffet Onset and Intensity Tests	Existing Transonic Wind Tunnels + GD 20
15.1 15.3	Acoustic Noise Environment	Sonic Boom Frequency and Intensity Near and Far Field Noise Measurements	Existing Supersonic and Hypersonic Wind Tunnels + GD 20 and GD 7
15.2	Acoustic Noise Environment Shaping Effects	Sonic Boom Frequency and Intensity Near and Far Field Noise Measurements	Existing Supersonic and Hypersonic Wind Tunnels + GD 20 and GD 7
16.1	Boundary Layer State Aerodynamic Heating	Windward Surface Heat Transfer and Skin Friction Tests	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
16.2	Aerodynamic Heating Reynolds/Scale Effects	Windward Surface Heat Transfer and Skin Friction Tests	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
16.3	Aerodynamic Heating	Windward Surface Heat Transfer and Skin Friction Tests	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
17.1	Boundary Layer State Reynolds Number Effects Acoustic Noise Environment	Aerodynamic Flow Gradient Effects Fluctuating Surface Pressure Tests	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
17.2	Boundary Layer State Surface Shaping Effects	Aerodynamic Surface Irregularity Effects	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
18.1	Control Effectiveness Aerodynamic Heating	Aerodynamic Reaction Control Jet Effects Heat Transfer	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
19.1	Control Effectiveness Aerodynamic Heating	Aerodynamic Control Surface Effectiveness	Existing Wind Tunnels in All Speed Ranges + GD 20 and GD 7
19.2	Aerodynamic Heating	Aerodynamic Heat Transfer on Deflected Control Surfaces	Existing Wind Tunnels in All Speed Ranges + GD 20 and GD 7
20.1	Aerodynamic Heating Reynolds Number Effects	Thermodynamic Heat Transfer Distributions on Complete Configurations	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
20.2	Aerodynamic Heating	Thermodynamic Reaction Control Jet Effects	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
20.3	Aerodynamic Heating	Thermodynamic Staging/Separation Effects	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
20.4	Flow Field/Boundary Layer State Aerodynamic Heating	Thermodynamic Prediction/Substantiation	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
22.1	Aerodynamic Heating	Thermodynamic Heat Transfer and Skin Temperatures	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
22.2	Aerodynamic Heating Shaping Effects	Thermodynamic Protuberance Shape Effects on Local Skin Temperatures	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
22.3	Performance Aerodynamic Heating	Thermodynamic Surface Irregularities Effects	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
23.1	Aerodynamic Heating	Thermodynamic Mass Transfer Effects Heat Transfer Skin Friction	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
23.2	Aerodynamic Heating	Thermodynamic Mass Transfer Effects Substantiation Heat Transfer Skin Friction	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
23.3	Performance Aerodynamic Heating	Thermodynamic Time Varient Condition Effects Ablation Effects Transpiration Effects	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
24.1	Flow Field State	Thermodynamic Leeside Flow Conditions	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
24.2	Boundary Layer State	Thermodynamic Leeside Boundary Layer Conditions	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
24.3	Aerodynamic Heating	Thermodynamic Leeside Heat Transfer Leeside Skin Friction	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
25.1 25.2 25.3 25.4	Aerodynamic Heating	Thermodynamic Gap Flow Effects Heat Transfer	Existing Supersonic and Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
26.3	Aerodynamic Heating	Thermodynamic Effects of Internal and External View Factors on Equilibrium Surface Temperatures	Existing Supersonic and Hypersonic Wind Tunnels and Thermal Facilities + GD 20, GD 7, E 20, E 9 and S 20
27.1 27.2 27.3	Flow Field/Boundary Layer State Aerodynamic Heating Reynolds/Scale Effects	Thermodynamic Heat Transfer Jet Effects	Existing Supersonic and Hypersonic Wind Tunnels and Thermal Facilities + GD 20, GD 7, E 20, E 9 and S 20
28.1	Physical Properties Physical/Chemical Compatibility Service Properties Thermal Properties/Effects	Materials Tankage Thermal Protection System	Existing Thermal/Structural Facilities + S 20
28.2	Fabrication Properties Fabrication Methods Thermal Properties/Effects	Structures Tankage Thermal Protection System	Existing Thermal/Structural and Mechanical/Structural Facilities + S 20
28.3	Fabrication Methods Inspection Methods Repair Methods	Structures Tankage NDE Techniques	Existing Mechanical/Structural Facilities + S 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
28.4	Combined Environment Effects	Structures Tankage Structure and TPS Verification Thermal/Mechanical/ Altitude and Fuel Flow Tests	Existing Combined Environment Facilities + S 20
30.1	Integration Methods Shaping Effects Combined Environment Effects	Structures Integrated Fuselage and Tankage Thermal/Mechanical/ Altitude and Fuel Flow Tests	Existing Combined Environment Facilities + S 20
30.2	Fabrication Methods Inspection Methods Repair Methods	Structures Integrated Fuselage and Tankage NOE Techniques	Existing Mechanical/Structural Facilities + S 20
30.3	Combined Environment Effects	Structures Integrated Fuselage and Tankage Thermal/Mechanical/ Altitude and Fuel Flow Tests	Existing Combined Environment Facilities + S 20
32.1 32.2	Thermal Properties/Effects Mechanical Properties Physical Properties Service Properties Oxidation Resistance	Materials Coated Leading Edge Material Tests in a High Temperature Oxidizing Environment	Existing Thermal/Mechanical Structural and High Temperature Flow Facilities + S 20, E 20 and E 9
32.3	Fabrication Methods Physical/Chemical Compatibility Oxidation Resistance	Structures Coated Leading Edge Structural Tests in a High Temperature Oxidizing Environment	Existing Thermal/Mechanical Structural and High Temperature Flow Facilities + S 20, E 20 and E 9
33.1	Control Surface Physical and Environmental Boundaries	Analytical Task	None
33.2	TPS Performance Actuator Systems Performance Fabrication Methods	Structures Control Surface TPS and Actuator Systems Tests Under Conditions of Temperature and Load	Existing Thermal/Mechanical Structural and High Temperature Air Flow Facilities and Wind Tunnels + GD 20, GD 7, E 9, E 20 and S 20
33.3	Service Properties Performance, Reliability, Limits	Structures Control Surface TPS and Actuator Systems Tests Under Conditions of Temperature and Load	Existing Thermal/Mechanical Structural and High Temperature Air Flow Facilities and Wind Tunnels + GD 20, GD 7, E 9, E 20 and S 20
34.1	Physical Properties Thermal Properties Fabrication Techniques	Structures and Materials Heat Exchanger System Panel Tests Under Operating Conditions of Temperature, Pressure and Fluid Flow	Existing Thermal/Structural, Fluid Flow and High Temperature Air Flow Facilities + S 20, E 20 and E 9
34.2	Physical/Chemical Compatibility	Materials Heat Exchanger Materials and Fluid Compatibility Tests Under Conditions of Temperature and Pressure	Existing Thermal/Structural and Fluid Flow Facilities + S 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
34.3	Heat Exchanger Flow Passage Geometry	Analytical Task	None
34.4	Performance, Reliability, Limits Qualification, Verification	Structures Heat Exchanger Panel Environment Tests Under Conditions of Flight Heat Transfer Rates and Fluid Flow	Existing Thermal/Structural, Fluid Flow, High Temperature Air Flow Facilities and Wind Tunnels + GD 20, GD 7, E 9 and S 20
35.1 35.2	Limits of Surface Smoothness and Irregularity	Structures Major Structural Section Tests Under Conditions of Temperature and Mechanical Load	Existing Thermal/Mechanical/ Structural, High Temperature Air Flow Facilities and Wind Tunnels + GD 20, GD 7, E 9 and S 20
36.2	Physical Properties Thermal Properties Physical/Chemical Compatibility Oxidation Resistance Service Properties	Materials Coupon Tests Under Conditions of Temperature and Mechanical Load	Existing Thermal/Mechanical/ Structural, and High Temperature Flow Facilities + E 20, E 9, and S 20
36.3	Service Properties Oxidation Resistance	Structures Full Scale Structural Component Tests Under Conditions of Temperature and Mechanical Load	Existing Thermal/Mechanical/ Structural, and High Temperature Flow Facilities + E 20, D 9, and S 20
38.1	Fuel Slosh Modes/Intensities	Structures Fuel Slosh Tests to Evaluate the Fluid Dynamics Effects on Structural Loading and Tank Design	Existing Fuel Slosh Facilities + S 20
38.2	Inertial Forces/C.G. Perturbations, Stability and Control	Structures Fuel Slosh Tests to Evaluate the Effects of Fluid Inertial Forces and C.G. Perturbations on Aircraft Handling Qualities	Existing Fuel Slosh Facilities + S 20
38.3	Fuel Slosh Modes/Intensities Inertial Forces/C.G. Perturbations, Stability and Control	Structures Fuel Slosh Tests to Evaluate Slosh Suppression Devices	Existing Fuel Slosh Facilities + S 20
39.1 39.2	Acoustic Noise Environment Near Field Noise Effects	Structures and Materials Thermal/Acoustic Tests of Thin Gauge Structural Components	Existing Thermal/Acoustic, High Temperature Air Flow Facilities and Wind Tunnels + GD 20, GD 7, E 20, E 9 and S 20
40.1	Inspection Methods (NDE)	Analytical Task	None
40.2	Inspection Methods (NDE)	Structures Combined Environmental Tests of Calibrated Failure Specimens	Existing Thermal/Mechanical Structural and Thermal/Acoustic Facilities, and High Temperature Flow Facilities + E 9 and S 20
40.3	Service Properties	Structures Combined Environmental Tests of Calibrated Failure Specimens	Existing Thermal/Mechanical Structural and Thermal/Acoustic Facilities, and High Temperature Flow Facilities + E 9 and S 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
41.1 41.2	Component Weight Accounting Systems	Analytical Tasks	None
42.1	Performance, Reliability, Limits Physical, Thermal and Mechanical Properties and Repair Techniques	Structures Thermal/Mechanical/ Structural Tests of Major Structural Sections	Existing Thermal/Mechanical Structural Facilities + S 20
43.1	Physical Thermal Fabrication and Service Properties and Physical /Chemical Compatibility	Materials Thermal/Mechanical/ Altitude Tests of Reusable TPS Material Coupons	Existing Thermal/Mechanical/ Altitude Faciltiies, High Temperature Air Flow Facilities + E 20, E 9 and S 20
43.2	Service Properties Inspection Methods Repair Methods	Structures and Materials Thermal/Mechanical/ Altitude Tests of Reusable TPS Structural Components	Existing Thermal/Mechanical Altitude Facilities + E 20, E 9 and S 20
43.3	Fabrication, Inspection and Repair Methods	Structures Thermal/Mechanical/ Altitude Tests of Major Structural Sections with Reusable TPS.	Existing Thermal/Mechanical Altitude Facilities + S 20
43.4	Reusable TPS Experimental Data Correlations	Analytical Task	None
44.1	Identification of Advanced Materials	Analytical Task	None
44.2	Physical, Chemical, Thermal, Fabrication and Service Properties	Materials Thermal/Mechanical/ Structural Tests of Advanced Material Coupons	Existing Thermal/Mechanical/ Structural Facilities
45.1	Suitability of Fabrication Techniques	Analytical Task	None
45.2	Fabrication Methods, Properties and Effect	Structural Fabrication Experiments on Advanced Materials and Complex Structural Components	Existing Mechanical/Structural Facilities, High Temperature Air Flow Facilities + E 20, E 9 and S 20
45.3	Fabrication Methods Qualification and Verification	Structures Combined Environment Tests of Coupons and Structural Elements and Assemblies	Existing Thermal/Mechanical/ Structural, and Thermal/Acoustic Facilities and High Temperature Air Flow Facilities + E 20, E 9 and S-20
46.1	Estimated Environments for Bearings, Lubricants, Closure Seals, Tires, Wind Shields and Radomes	Analytical Task	None
46.2	Performance, Reliability, Limits Service Properties	Structures and Materials Combined Environment Tests of System Components Such as Bearings, Lubricants, Closure Seals, Tires, Wind Shields and Radomes	Existing Thermal/Mechanical/ Altitude Facilities + S 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
48.1	Flow Field State	Propulsion Fuselage Flow Field Tests to Determine Potential Inlet Locations	Existing Wind Tunnels + GD 7, GD 20, E 20 and E 9
48.2 48.3	Inlet Control System Performance Inlet/Engine Force Environment Shaping Effect Reynolds/Scale Effects	Propulsion Airflow Performance Tests of Different Inlet Classes and Sizes	Existing Wind Tunnels + GD 7, GD 20, E 20 and E 9.
48.4	Inlet Control System Performance Inlet Engine Face Environment Performance, Shaping Effects, Stability and Control	Propulsion Inlet Air Flow Tests of Different Inlet Designs and Forebody Shapes to Determine Performance, Stability and Control Effects	Existing Wind Tunnels + GD 7, GD 20, E 20 and E 9
52.1 52.2 52.3	Engine Cooling Concepts Ablation and Transpiration Cooling Technology Regeneration and Radiative Cooling Technology	Analytical Tasks	None
52.4	Engine Cooling Concepts Performance	Propulsion Engine Component Tests to Determine Cooling System and Engine Performance	Existing Engine Test and High Temperature Air Flow Facilities + E 9 and E 20
55.1	Acoustic Noise Environment	Propulsion Engine Inlet Noise Abatement Systems Tests	Existing Engine Test and Wind Tunnel Facilities + GD 20 and E 20
55.2	Acoustic Noise Environment	Propulsion Airbreathing Engine Nozzle Noise Abatement, Systems Tests	Existing Engine Test and Wind Tunnel Facilities + GD 20 and E 20
55.3	Acoustic Noise Environment	Propulsion Rocket Engine Nozzle Noise Abatement Systems Tests	Existing Engine Test and Wind Tunnel Facilities + GD 20 and E 20
57.1 57.2 57.3	Turboramjet Cycle Analyses Turboramjet Component Design Concepts Definition of Qualification Program	Analytical Tasks	None
57.4 57.5	Engine Component Performance	Propulsion Turboramjet Component and Integrated Core Engine Tests in Operating Environments	Existing Turboramjet Engine and Component Test Facilities + E 20 and E 9
57.6	Integrated Engine Performance	Propulsion Integrated Turboramjet Inlet/Engine/Nozzle Performance Tests	Existing Turboramjet Engine Test Facilities + E 20 and E 9
58.1 58.2	Definition of Mission Profiles Multi-Mode Engine Cycle Analyses	Analytical Tasks	None

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
58.3	Integrated Engine Performance Aerodynamic Performance	Propulsion Integrated Multi-Mode Engine Performance Tests Plus Aerodynamic Inlet/Exit Flow Effects Tests	Existing Engine Test and Wind Tunnel Facilities
59.1 59.2 59.3	Ramjet Cycle Analyses Ramjet Component Design Concepts Definition of Qualification Program	Analytical Tasks	None
59.4 59.5	Engine Component Performance	Propulsion Ramjet Component and Integrated Core Engine Tests in Operating Environments	Existing Ramjet Engine, and Component Tests Facilities + E 20 and E 9
59.6	Integrated Engine Performance	Propulsion Integrated Ramjet Inlet/Engine Nozzle Performance Tests	Existing Ramjet Engine Test Facilities + E 20 and E 9
60.1 60.2 60.3	Convertible Scramjet Cycle Analyses CSJ Component Design Concepts Definition of Qualification Program	Analytical Tasks	None
60.4 60.5	Engine Component Performance	Propulsion Convertible Scramjet Components and Integrated Core Engine Tests in Operating Environments	Existing CSJ/RJ Engine and Component Test Facilities + E 20 and E 9
60.6	Integrated Engine Performance	Propulsion Integrated Convertible Scramjet Inlet/Engine/Nozzle Performance Tests	Existing CSJ/RJ Engine Test Facilities + E 20 and E 9
61.1 61.2 61.3	Scramjet Cycle Analyses Scramjet Component Design Concepts Definition of Qualification Program	Analytical Tasks	None
61.4 61.5	Engine Component Performance	Propulsion Scramjet Components and Integrated Core Engine Tests in Operating Environments	Existing Scramjet Engine and Component Test Facilities + E 9
61 6	Integrated Engine Performance	Propulsion Integrated Scramjet Inlet/Engine/Nozzle Performance Tests	Existing Scramjet Engine Test Facilities + E 9
62.1	Candidate HTO Aircraft Configurations and Rocket Engines for Integration	Analytical Tasks	None
62.2	Aerodynamic, Thermodynamic, Structural, Material, Propulsion, Subsystem and Operations Data as Required	Propulsion Development Tests for Integration of a Rocket Engine into a HTO Aircraft Configuration	All Applicable Types of Existing Ground Test Facilities + GD 20, GD 7 and S 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATE REQUIRED	TYPE TESTS	FACILITIES
62.3	Performance, Reliability, Limits Qualification/Verification	Propulsion Developmental and Qualification Tests of a Rocket Powered HTO Aircraft	All Applicable Types of Existing Ground Facilities + GD 20, GD 7 and S 20
63.1	Inlet/Engine Face Environment Flow Field/Boundary Layer State Aerodynamic Loads and Heating	Propulsion Inlet Airflow, Tests of Subscale and Full Scale Models to Determine Inlet Control Surface Environment	Existing Wind Tunnels and High Temperature Airflow Facilities + GD 7, GD 20, E 9 and E 20
63.2	Sensor Control System Performance	Propulsion Inlet Airflow Tests of Subscale and Full Scale Models to Determine Inlet Control System Sensor Performance	Existing Wind Tunnels, High Temperature Airflow Facilities, and Thermal/Mechanical/Structural Facilities + GD 7, GD 20, E 20, E 9 and S 20
63.3	Actuator Systems Performance	Propulsion Inlet Airflow Tests of Subscale and Full Scale Models to Define and Demonstrate Actuator Positioning	Existing Wind Tunnels, High Temperature Airflow Facilities, and Thermal/Mechanical/Structural Facilities + GD 7, GD 20, E 20, E 9 and S 20
64.1 64.2	Performance Stability and Control	Aerodynamic Jet Effects Ground Effects Flying Qualities	Existing Low Speed Wind Tunnels and Flight Simulators + GD 20 and E 20
65.1	Engine Exhaust Nozzle Requirements for TRJ, RJ, CSJ & SJ Engines	Analytical Task	None
65.2	Shaping Effects	Propulsion Jet Nozzle Concept Evaluation Tests	Existing Wind Tunnels and Engine Component Test Facilities + GD 7, GD 20, E 20 and E 9
65.3	Performance Shaping Effects	Aerodynamics Jet Thrust, Base and Boattail Drag Tests of Candidate Nozzle Concepts Integrated in an Airframe Shape	Existing Wind Tunnels and Engine Component Test Facilities + GD 7, GD 20, E 20 and E 9
67.1	Inlet/Engine Environment	Propulsion Inlet Airflow Tests to Measure Pneumatic Acoustic Impedences	Existing Wind Tunnels and High Temperature Flow Facilities + GD 20, E 20 and E 9
67.2 67.3	Inlet/Engine Face Environment	Propulsion Inlet Flow Simulation Tests of Inlets Without Forebodies to Develop Methods of Duplicating Forebody Flow Disturbances	Existing Wind Tunnels and High Temperature Flow Facilities + GD 20, E 20 and E 9
68.1	Procedures, Methods, Techniques	Subsystems Subcooled Cryogenic Propellant Tests to Determine Characteristics of Low Pressure Boiloff, Helium Refrigeration and Isentropic Expansion	Existing Cryogenic Fuel Systems Facilities + S 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

R.	DATA REQUIRED	TYPE TESTS	FACILITIES
68.2	Procedures, Methods, Techniques	Subsystems Subcooling Pilot Plant Tests to Determine Continuous Cooled Storage and Pumping Requirements of Cryogenic Fuels	Existing Cryogenic Fuel Systems Facilities + S 20
68.3	Procedures, Methods, Techniques	Subsystems Storage, Handling and Transport Tests of Subcooled Cryogenic Fuels	Existing Cryogenic Fuel Systems Facilities + S 20
69.1	Cryogenic Fuel Fluid Dynamic and Thermodynamic Characteristics in Horizontal Tankage	Analytical Task	None
69.2	Combined Environment Effects	Subsystems Thermal/Mechanical Load/Altitude Tests of Subscale Cryogenic Fuel Tankage	Existing Combined Environment Facilities + S 20
69.3	Fluid Systems Performance	Subsystems Fuel Tankage Slosh Suppression Effects	Existing Cryogenic Fuel Slosh Facilities + S 20
70.1	Regenerative Cryogenic Heat Exchange Requirements	Analytical Task	None
70.2	Fluid Properties	Subsystems Heat Exchanger Cryogenic Fluid Flow Tests at Conditions of Critical Pressure and Temperautre	Existing Cryogenic Fluid Systems Test Facilities + S 20
70.3	Physical, Mechanical, Thermal Properties, Physical/Chemical Compatibility and Fabrication Techniques	Subsystems Heat Exchanger Materials Tests Under Conditions of High Temperature Hydrogen Environment	Existing Cryogenic Fluid Flow Systems Test Facilities with Thermal/Mechanical Load Capability + S 20
70.4	Fluid Flow Systems Performance	Subsystems Heat Exchanger Components Tests in a Simulated Operating Environment	Existing Cryogenic Fluid Flow Systems Test Facilities with Thermal/Mechanical Load Capability and High Temperature Airflow Facilities + E 20, E 9 and S 20
70.5	Fluid Flow Systems Performance Service Properties Sensor Control System Performance	Subsystems Integrated Heat Exchanger Tests in a Simulated Operating Environment	Existing Cryogenic Fluid Flow Systems Test Facilities with Thermal/Mechanical Load Capability and High Temperature Airflow Facilities + E 20, E 9 and S 20
71.1	Performance, Reliability, Limits	Subsystems Fuel Combustion and Coolant Performance Tests	Existing Hydrocarbon Fuels Test and Engine Test Facilities
71.2	Performance, Reliability, Limits	Subsystems Fuel Combustion and Coolant Performance Tests	Existing Endothermic Fuels Test and Engine Test Facilities
71.3	Performance, Reliability, Limits	Subsystems Fuel Combustion Properties and Performance Tests	Existing Fuels Test and Engine Test Facilities

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
72.1	Performance, Reliability, Limits	Subsystems Fuel System Tests to Determine Effects of Fuel Properties on Service Life of System Component	Existing Fuel/Fluid Systems Test Facilities
72.2	Performance, Reliability, Limits	Subsystems Fuel System/Tankage Inerting Tests	Existing Fuel/Fluid Systems Test Facilities
72.3	Procedures, Methods, Techniques	Subsystems Fuel Systems Ground Support Equipment, Fuel Handling and Logistics Tests	Existing Fuel/Fluid Systems Test Facilities
73.1	Service Properties Combined Environment Effects	Subsystems Fuel Systems Component Materials Tests	Existing Combined Environment Test Facilities + S 20
73.2	Performance, Reliability, Limits	Subsystems Fuel Systems Component Design Concepts Tests	Existing Cryogenic Fuel System Test Facilities with Combined Environment Capability + S 20
73.3	Performance, Reliability, Limits	Subsystems Subscale Ground and Vehicle Cryogenic Fuel System and Tankage Tests Under Simulated Ground Support Conditions	Existing Cryogenic Fuel System Test Facilities
74.1	Definition of Fuel Loading Rates	Analytical Task	None
74.2	Scale Effects Pefformance, Reliability, Limits	Subsystems Subscale Cryogenic Fuel Tankage Tests to Determine Limiting Geometric and Operational Parameters and Scale Effects	Existing Cryogenic Fuel System Test Facilities
74.3	Performance, Reliability, Limits	Subsystems Subscale Tankage Cryogenic Fuel Systems and Tankage Design Evaluation	Existing Cryogenic Fuel System Test Facilities
75.1	Performance, Reliability, Limits	Subsystems Aircraft Fuel Tankage/ Insulation Concepts Tests	Existing Cryogenic Fuel System Test Facilities
75.2	Performance, Reliability, Limits Scale Effects Combined Environment Effects	Subsystems Subscale Fuselage/ Tankage/Fuel System Tests in a Combined Thermal, Mechanical and Structural Load Simulated Environment	Existing Thermal/Mechanical and Structural Load Test Facilities + S 20
75.3	Procedures, Methods, Techniques	Subsystems Subscale Fuselage/ Tankage/Fuel System Tests in a Combined Thermal, Mechanical and Structural Load Simulated Environment to Evaluate Fuel System Control Tests	Existing Thermal/Mechanical and Structural Load Test Facilities + S 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
77.1	Antenna Requirements and Conceptual Designs	Analytical Task	None
77.2	Antenna Performance Thermal, Physical Properties Combined Environment Effects	Subsystems Combined Environment Tests of Antenna Systems to Evaluate Performance at Simulated Flight Conditions	Existing Antenna Facilities. Combined Thermal, Mechanical, Structural Load and High Temperature Airflow Facilities + E 20, E 0 and S 20
78.1	Stability Augmentation Requirements	Analytical Task	None
78.2 78.3	Stability Performance, Reliability, Limits Procedures, Methods, Techniques	Subsystems Wind Tunnel Test to Evaluate Effectiveness of Stability Augmentation Devices	Existing Hypersonic Wind Tunnels + GD 20, GD 7, E 20 and E 9
79.1	Air Data Measurement Techniques	Analytical Task	None
79.2	Performance, Reliability, Limits Qualification and Verification	Subsystems Demonstration Tests of Sensors and Air Data System in Simulated Flight Environment	Existing Wind Tunnels, High Temperature Airflow Facilities and Combined Environment Test Facilities + GD 20, GD 7, E 20, E 9 and S 20
80.1 80.2	Actuator Systems Performance, Reliability and Limits	Subsystems Control Surface Actuator System Performance Tests Under Simulated Thermal and Airloads	Existing Wind Tunnels, High Temperature Airflow Facilities and Combined Environment Test Facilities + GD 20, GD 7, E 20, E 9 and S 20
82.1 82.2 82.3	Procedures, Methods, Techniques Energy Conversion Efficiency APU Performance	Subsystems APU Concepts, Components and Prototype Auxiliary Power Units Performance Tests Under Simulated Flight Conditions	Existing Wind Tunnels, High Temperature Airflow Facilities and Combined Environment Test Facilities + GD 20, GD 7, E 20, E 9 and S 20
83.1	Liquid Cryogen ECS Operational Requirements	Analytical Task	None
83.2	Performance, Reliability, Limits	Subsystems Prototype ECS Concept Performance Tests Under Simulated Operational Conditions	Existing Combined Thermal, Mechanical Load Test Facilities + S 20
84.1	Candidate ECS Concepts for M=4.6 Hydrocarbon Fueled Vehicles	Analytical Task	None
84.2	Performance, Reliability, Limits	Subsystems Prototype ECS Concept Performance Tests Under Simulated Operational Conditions	Existing Combined Thermal, Mechanical Load Test Facilities + S 20
85.1	Evaluation of Candidate AAM/ASM Systems	Analytical Task	None
85.2 85.3	Integration Methods Procedures, Methods, Techniques	Subsystems AAM/ASM Systems Development and Integration Tests Under Simulated Flight Conditions	Existing Wind Tunnels, High Temperature Airflow and Combined Environment Facilities + GD 20, GD 7, E 20, E 9 and S 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
87.1	Operational Procedures - Differences Between Current and Potential Hypersonic Aircraft	Analytical Task	None
87.2	Adequacy of Existing Air Bases/ Facilities to Accommodate Operational Requirements of Potential Hypersonic Aircraft	Analytical Task	None
87.3	Demonstration of Ground System Capability	Operation Flight Test	Flight Only
89.1	Navigational Requirements of Potential Operational Vehicles	Analyticcal Task	None
89.2	Performance, Reliability, Limits	Operations Navigational Systems Evaluation Tests	Existing Ground Systems
89.3	Performance, Reliability, Limits	Operations Navigational and Information Display Systems Evaluation	Existing Ground Systems
93.1	Performance, Reliability, Limits Stability and Control	Analytical Task	None
93.2	Procedures, Methods, Techniques Performance, Reliability, Limits	Operations Evaluation of Dynamic Environment Effects on Ride Quality and Structural Transmission of Abrupt Forces and Motions	Existing Wind Tunnels, and Mechanical/Structural Test Facilities + GD 20, GD 7, E 20, E 7 and S 20
94.1 94.2	Abort and Crew Escape System Criteria, Procedures, Methods, Techniques	Analytical Task	None
94.3	Procedures, Methods, Techniques Qualification and Verification	Operations Evaluation of Abort/ Escape Systems Environment and System Qualification Tests	Existing Wind Tunnels, High Temperature Flow Facilities and Combined Environment Structural Facilities + GD 20, GD 7, E 20, E 7 and S 20
96.1	Performance, Reliability, Limits Qualification and Verification	Operations Flight System Evaluation Tests	Existing Wind Tunnels, High Temperature Flow Facilities and Combined Environment Structural Facilities + GD 20, GD 7, E 20, E 7 and S 20
96.2	Sensor System Performance	Operations Sensing System Effectiveness Tests Under Simulated Flight Conditions	Existing Wind Tunnels, High Temperature Flow Facilities and Combined Environment Structural Facilities + GD 20, GD 7, E 20, E 7 and S 20
97.1	Sensor System Performance	Operations Fuel Leak Detection System Evaluation Tests	Existing Fuel/Fluid Systems Facilities
97.2	Sensor System Performance, Reliability, Limits Combined Environment Effects	Operations Fuel Leak Sensing Systems Effectiveness in a Simulated Thermal/ Mechanical Load Environment	Existing Combined Environment Fuel/Fluid Systems Test Facilities + [illegible] 20

(U) FIGURE 4-5
RESEARCH TASK CORRELATION WITH TESTING REQUIREMENTS (Continued)

RT	DATA REQUIRED	TYPE TESTS	FACILITIES
99.1 99.2	Performance Stability and Control Procedures, Methods, Techniques	Operations Fuel Leak Sensing Systems Effectiveness in a Simulated Thermal/ Mechanical Load Environment	Existing Low Speed Wind Tunnels and Flight Simulators
100.1 100.2	Performance, Reliability, Limits Procedures, Methods, Techniques	Operations Cryogenic Fuel Loading/ Pumping Tests	Existing Fuel/Fluid Systems Test Facilities and Ground Systems
1C2.1	Inspection and Repair Methods	Analytical Task	None
102.2	Qualification and Verification	Operations Demonstration of Inspection and Repair Methods Under Simulated Operational Conditions	Existing Mechanical/Structural Test Facilities + S 20

5. DESCRIPTION OF RESEARCH REQUIREMENTS AND FACILITY CAPABILITY ANALYSES

The research potential of new ground and flight facilities to contribute to the confidence needed to initiate development of operational hypersonic systems is quantified in terms of Facility Research Value. This dimensionless value provides a means for comparing various candidate new facilities with one another, with existing facilities, and with the total value of research defined as necessary for achievement of the required confidence level to proceed to operational system development.

Two primary factors are reflected in the Facility Research Value for each flight research vehicle and ground test facility:

(1) The importance of the Research Tasks which the facility performs, and

(2) The extent to which the facility can perform the Research Tasks with which it is associated.

The intent of this section is to describe in detail how Facility Research Values are determined. Although the basic methodology has been explained in Volumes II and III, some refinements have been implemented during Phase III. Facility Research Values have been developed on both a focused and a characteristic basis. As a result, the value of a facility can be expressed in terms of its ability to perform specific research for which it is designed, as well as in terms of its versatility. In addition, the Research Tasks have been refined somewhat during Phase III, and the capability of each facility has been quantified relative to each task considered individually, rather than with respect to the tasks for a given Research Objective taken collectively.

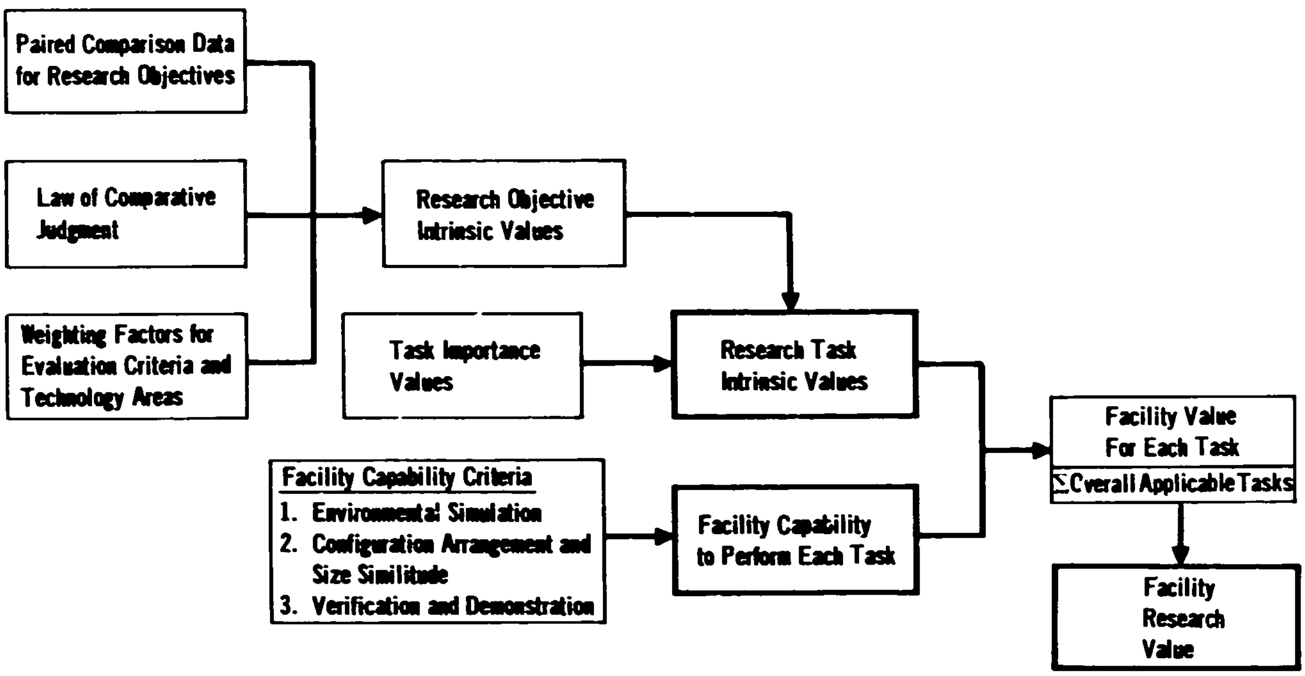
Figure 5-1 illustrates in flow-diagram format the relationship between factors influencing the Facility Research Value for a particular facility in relation to a given operational system. The heavily outlined blocks represent the primary elements discussed in the remainder of Section 5. This figure is an amplification of the diagram presented in Section 2.

The process for determining Facility Research Values described in this section is presented in relation to Operational System C1 (a Mach 6, turboramjet-powered, hypersonic transport). This operational system was chosen for illustration primarily because of its intermediate position within the operational system spectrum with regard to maximum speed attainable and complexity of propulsion system development. This selection of Operational System C1 for illustrative purposes is in no way intended, however, to imply that a higher degree of consideration has been given to this system than to the other three involved (Operational Systems L2, M1, and M2) throughout the analysis. A complete set of data for these three operational systems can be found in the Appendix.

5.1 RESEARCH TASK INTRINSIC VALUES FOR OPERATIONAL SYSTEM C1.

The first factor reflected in the Facility Research Values, the importance of the Research Tasks, is measured in terms of Research Task intrinsic value. For perspective, these intrinsic values are meaningful only when considered in relation to the values of other tasks. They then reflect the relative importance of the

FIGURE 5-1
RESEARCH REQUIREMENTS AND FACILITY CAPABILITY ANALYSIS



tasks in contributing to the technological confidence level required to initiate the development of one or more potential operational systems.

The methodology for computing intrinsic values for the Research Objectives and Tasks is described in detail in Volumes II and III. A description of the process is repeated here in an abbreviated form for the sake of illustration.

Four primary factors are involved in the calculation of the Research Objective intrinsic values:

A) Paired-comparison data from 66 industry, NASA, and Air Force evaluators who compared each Research Objective, one against the other, within their areas of specialty;

B) Relative weighting factors determined for the two evaluation criteria (Technology Advancement and Cost/Schedule) used to rank the objectives.

C) The Law of Comparative Judgement, which assumes that the normal distribution best describes the differences of opinion among a large number of evaluators concerning which of two items in a pairing is the more important; and

D) Relative weighting factors for the six technological areas by which the objectives are categorized.

An illustration of how these factors are combined to yield Research Objective intrinsic values for two representative objectives, No. 57 and No. 77, is presented in Figure 5-2. In addition, this figure illustrates how these objective intrinsic values are used to determine the intrinsic values of tasks associated with each objective. At the top of the figure, the results of the paired comparison analysis are summarized for Objective 57. The number of evaluators choosing Objective 57 is listed versus each of the other objectives in the Propulsion area. Results are shown for both evaluation criteria, and the average values appear in the final column.

The tables in the center of Figure 5-2 depict how the four factors listed above (A through D) influence the objective intrinsic values. Results are presented for both Objective 57 and Objective 77 for comparative purposes. The first values shown in the derivation, designated Value A, are the average favorable votes for the objective in the paired-comparison analysis. The two evaluation criteria and the six technological areas were assigned relative weightings by the evaluators; the composite weightings which result are indicated in the figure for the Propulsion and Subsystems areas and for the two evaluation criteria. The weighted average for the two criteria (Value B) is based on the corresponding weightings for these criteria (.607 and .393). The relationship between this weighted-average value and the Comparative Judgement Value (Value C) is illustrated in the graph at the lower left of the figure. The effect of the normal distribution is to concentrate values more toward the center of the scale, except for values near zero and 100, in which case little effect is produced. Finally, the objective intrinsic value (Value D) is expressed as the product of Value C and the technological area weighting factor. In this example, since the weighting factor for Propulsion is above 1.00, Value D is increased over Value C for Objective 57, while a decrease results for Objective 77, because Subsystems has a weighting factor below 1.00. The resulting intrinsic values of 73.6 and 29.0 for Objectives 57 and 77, respectively, are those used in the subsequent analysis for these objectives.

The chart in the lower right portion of Figure 5-2 shows how task intrinsic values are determined for Research Tasks 57-4 and 77-2. The task importance values indicate that, while both tasks are highly important to the fulfillment of their respective objectives, Task 77-2 is the more important in this respect. The task intrinsic value is found in each case by multiplying the objective intrinsic value by the task importance value. The resulting values of 62.6 and 29.0 for Tasks 57-4 and 77-2, respectively, are those shown in the subsequent figures of this section for these tasks.

Intrinsic values for all of the Research Objectives and Tasks applicable to Operational System C1 are presented in Figure 5-3. Each line of the figure represents one Research Objective, with the objective's code number indicated in the first column. The second column contains the intrinsic value determined for each objective during Phases I and II. As mentioned previously, 24 of the original 102 Research Objectives identified in Phase I were deleted and incorporated as Research Tasks under other objectives early in Phase II, reducing the final number of objectives to 78. Many of these 78 objectives apply to all operational systems considered, while others apply to as few as one operational system. The 66 lines of Figure 5-3 represent those objectives from the total of 78 which have application to Operational System C1. The importance of these 66 objectives, in terms of their

FIGURE 5-2
DERIVATION OF INTRINSIC VALUES – ILLUSTRATIVE EXAMPLE
OPERATIONAL SYSTEM C1

Paired Comparison Results

R.O. 57: DEVELOPMENT AND DEMONSTRATION OF TURBORAMJET SYSTEMS

Total Number of Evaluators for Propulsion Objectives = 32

Research Objectives to Which R.O. 57 is Compared		R.O. 48	R.O. 52	R.O. 55	R.O. 58	R.O. 59	R.O. 63	R.O. 65	R.O. 67	Avg.
Number of Evaluators (Out of 32) Choosing R.O. 57	Tech. Adv.	19	22	30	17	14	21	20	17	20.0
	Cost & Sch.	20	24	32	18	19	25	21	21	22.5

Objective Intrinsic Value Derivation

R.O. 57: DEVELOPMENT AND DEMONSTRATION OF TURBORAMJET SYSTEMS

Technological Area: Propulsion
Weighting Factor for Propulsion = 1.25
No. of Propulsion Evaluators = 32

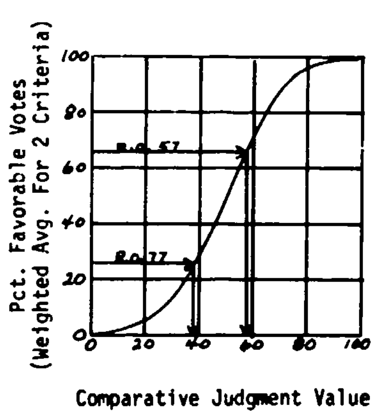
	Tech. Adv. (.607)	Cost & Schedule (.393)
A. Avg. Votes Out of 32	20.0	22.5
Pct. (Based on 32)	62.5%	70.3%
B. Wtd. Avg. For 2 Criteria	65.6%	
C. Comparative Judgment Value	58.6	
D. Objective Intrinsic Value (Including Effect of Tech. Area Weighting)	73.6	

R.O. 77: FLUSH OR RECESSED ANTENNA DESIGN TECHNIQUES

Technological Area: Subsystems
Weighting Factor for Subsystems = 0.76
No. of Subsystems Evaluators = 18

	Tech. Adv. (.607)	Cost & Schedule (.393)
A. Avg. Votes Out of 18	4.46	5.00
Pct. (Based on 18)	24.8%	27.8%
B. Wtd. Avg. For 2 Criteria	26.0%	
C. Comparative Judgment Value	38.4	
D. Objective Intrinsic Value (Including Effect of Tech. Area Weighting)	29.0	

Normal Distribution (Cumulative)



Task Intrinsic Value Derivation

Task No.	R.T. 57-4	R.T. 77-2
Objective Intrinsic Value	73.6	29.0
Task Importance Value	0.85	1.00
Task Intrinsic Value	62.6	29.0

FIGURE 5–3 RESEARCH TASK INTRINSIC VALUES

Operational System C1

OBJ. NO.	OBJECTIVE INTRINSIC VALUE	TASK INTRINSIC VALUES					
		TASK= 1	2	3	4	5	6
1	55.9	55.9	47.5	33.5	16.8		
2	56.0	56.0	47.6	33.6	16.8		
3	70.6	60.0	70.6	21.2	42.4		
4	64.9	55.2	38.9	38.9			
5	56.0	56.0	47.6	47.6			
6	53.8	45.7	45.7	53.8			
7	56.4	47.9	47.9	33.8			
9	60.7	51.6	51.6	36.4	51.6		
12	59.0	50.1	35.4	17.7			
14	37.7	32.0	22.6	37.7			
15	39.6	23.8	39.6	23.8			
16	55.5	47.2	47.2	55.5			
17	50.5	42.9	42.9				
19	56.1	47.7	47.7				
20	53.5	53.5	45.5	45.5	32.1		
22	50.8	50.8	43.2	43.2			
24	54.9	46.7	32.9	54.9			
25	43.0	36.5	43.0	36.5	25.8		
26	54.6	32.8	46.4	54.6			
27	40.2	40.2	24.1	34.2			
28	73.5	62.5	62.5	44.1	73.5		
30	57.8	49.1	34.7	57.8			
32	58.4	35.0	58.4	49.6			
33	61.6	61.6	52.4	37.0			
34	70.9	N/A	42.5	60.3	N/A		
35	36.5	36.5	31.0				
36	61.5	36.9	52.3	61.5			
38	37.4	31.8	37.4	31.8			
39	41.3	24.8	41.3				
40	59.0	59.0	50.1	35.4			
41	51.4	43.7	43.7				
42	62.5	62.5					
43	72.6	61.7	72.6	43.6	43.6		
44	64.8	55.1	64.8				
45	64.0	38.4	54.4	64.0			
46	53.4	45.4	45.4				
48	69.4	59.0	59.0	41.6	69.4	69.4	
52	61.8	52.5	52.5	52.5	61.8		
55	30.5	25.9	25.9	N/A			
57	73.6	44.2	44.2	44.2	62.6	62.6	73.6
58	68.0	40.8	40.8	57.8			
59	70.2	42.1	42.1	42.1	59.7	59.7	70.2
63	57.9	34.7	49.2	57.9			
65	64.1	38.5	54.5	64.1			
67	68.9	41.3	41.3	58.6			
68	40.8	24.5	34.7	34.7			
69	37.4	22.4	31.8	31.8			
70	46.4	27.8	27.8	39.4	39.4	46.4	
71	33.7	28.6	28.6	33.7			
72	37.0	22.2	31.4	37.0			
73	42.4	25.4	36.0	42.4			
74	32.0	19.2	19.2	32.0			
75	46.4	27.8	39.4	46.4			
77	29.0	24.6	29.0				
78	39.9	23.9	33.9	39.9			
79	30.3	25.8	30.3				
80	41.4	35.2	41.4				
82	33.3	20.0	28.3	33.3			
83	39.1	23.5	39.1				
87	37.9	22.7	22.7	37.9			
89	42.7	25.6	25.6	36.3			
93	29.3	29.3	24.9				
94	39.4	23.6	33.5	39.4			
96	35.1	21.1	35.1				
97	36.4	21.8	36.4				
102	37.5	31.9	37.5				

intrinsic values, ranges from the 73.6 of Objective 57 (Development and Demonstration of Turboramjet Systems) down to the 29.0 of Objective 77 (Flush or Recessed Antenna Design Techniques). For purposes of reference, the average intrinsic value of these 66 objectives is 50.7.

The remaining columns of Figure 5-3 present the intrinsic values of all the Research Tasks applying to Operational System C1. It should be noted that, since the list of tasks was refined and condensed early in Phase III, the number of tasks per objective and the task intrinsic values shown in Figure 5-3 are slightly different from those presented previously in Volume III. The tasks identified as elements of the 66 objectives relating to Operational System C1 total 198, with the number of tasks per objective varying from one to six. Task importance values ranging from 0 to 100 percent are assigned to the Research Tasks, indicating the relative importance of the tasks in contributing to the fulfillment of their Research Objectives. The intrinsic value for each task is then computed by multiplying the importance value of the task by the intrinsic value of the objective under which the task is listed. The task intrinsic values are thereby constrained to fall within the interval between the intrinsic value of their particular Research Objectives and zero. The intrinsic value of an objective, then, serves as the upper limit on the intrinsic values of the tasks associated with it. In this way, the intrinsic value relationship among the various objectives is carried over to the tasks defined as subelements of these objectives.

The task intrinsic values for Operational System C1 range from 73.6 down to 16.8 and average 41.9. All tasks with intrinsic values over 41.9 have above-average influence on research potential results, while those tasks rated less than this value have below-average influence on such results. Furthermore, the difference in the degree of influence of two tasks is directly proportional to the ratio of their intrinsic values. For instance, a task with an intrinsic value of 60.0 has twice the effect on research potential results than a task with an intrinsic value of 30.0.

5.2 FACILITY CAPABILITY TO ACCOMPLISH RESEARCH TASKS FOR OPERATIONAL SYSTEM C1

Each new conceptual research facility, ground and flight, was examined to determine the extent of its capability to accomplish the research associated with each of the tasks and objectives listed in Section 3. The result, in general terms, is a judgment of the percentage of the research which could be completed in each facility prior to commitment of resources for operational system development. In this sense, the values reflect the parametric breadth of the facility operating envelope, in terms of Mach Number, Reynolds Number, test section size, and class of research accomplished. Specific evaluation criteria were established in order to arrive at a consistent set of values, to eliminate potential parochial bias by either technological or facility proponents, and to nullify the advocacy of a particular operational concept. All capability assessments were made in terms of relative fulfillment of the research as it applies to the specific operational system. The results of the facility capability assessment represent an evaluation of the matching of facility parametric range with operational vehicle envelope as illustrated by the altitude-Mach Number variations in Sections 6 and 7.

Facility Capability results are presented in Figure 5-4 for the five ground facilities and the two basic flight vehicles included in Phase III. Also shown is the capability of combined existing ground facilities. Values are included for each of the 198 Research Tasks which apply to Operational System C1. Dashes indicate that the particular facility has no application to the corresponding task. No assessment was made for those tasks which are strictly analytic in nature.

Analysis of the facility capabilities at the Research Task level was based on the following criteria:

(a) Physical Environmental Simulation
- ° To what extent are key parameters (e.g. noise, pressure, temperature, Mach no., loads, etc.) simulated, either individually or in combination, in a static or time-variant manner?
- ° What is the capability of the facility to accommodate a wide range of test conditions contributing to a broad research base, in terms of multi-point research, wide parametric variation capability, and research time available for satisfying the objective as it relates to a reasonable research program?

(b) Configuration Arrangement and Size Similitude
- ° What is the capability of the facility to accommodate a model or experimental specimen, in terms of the limits of scaling factors, experimental section, and model size?
- ° To what extent can unknown interactions be uncovered?

(c) Verification and Demonstration Capability
- ° To what extent can operational flight hardware be tested?
- ° To what extent can operational flight profiles and vehicle utilization be simulated?
- ° To what extent can the actual operational flight environment characteristics be proven?

The relative weightings for these three criteria are as follows for an overall facility assessment:

	Flight Research Vehicles	Ground Facilities
° Physical Environmental Simulation	25%	33%
° Configuration Arrangement and Size Similitude	25%	33%
° Verification and Demonstration Capability	50%	33%

Although this may appear to represent a double standard for evaluation, in reality it allows evaluation of facility potential capability against research which the facility can be expected to accomplish. As a result, ground facilities are neither charged with the requirement to provide flight verification nor penalized for their failure to do so. On a uniform base, the above criteria expand to the following

FIGURE 5–4
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM C1

% PERCENTAGE OF RESEARCH ACHIEVABLE IN EACH FACILITY
OPERATIONAL SYSTEM C1

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES GDT	GD20	F20	F8	S20	BASIC FLT. VEHICLES M6	M12
1-1	45	-	-	-	-	-	[illegible]	[illegible]
1-2	45	-	-	-	-	-	[illegible]	[illegible]
1-3	45	-	-	-	-	-	[illegible]	[illegible]
1-4	[illegible]	-	-	-	-	-	[illegible]	55
2-1	37	-	[illegible]	-	-	-	[illegible]	[illegible]
2-2	37	-	53	-	-	-	[illegible]	[illegible]
2-3	37	-	53	-	-	-	[illegible]	[illegible]
2-4	[illegible]	-	-	-	-	-	[illegible]	[illegible]
3-1	49	-	62	-	-	-	[illegible]	[illegible]
3-2	49	-	67	-	-	-	[illegible]	[illegible]
3-3	45	-	50	-	-	-	[illegible]	[illegible]
3-4	49	-	67	-	-	-	[illegible]	68
4-1	31	-	43	[illegible]	-	-	[illegible]	[illegible]
4-2	31	-	43	[illegible]		-	[illegible]	[illegible]
4-3	31	-	43	37	-	-	[illegible]	[illegible]
5-1	63	-	-	-	-	-	[illegible]	[illegible]
5-2	63	-	-	-	-	-	[illegible]	[illegible]
5-3	63	-	-	-	-	-	[illegible]	[illegible]
6-1	36	-	52	-	-	-	[illegible]	[illegible]
6-2	36	-	52	-	-	-	[illegible]	[illegible]
6-3	36	-	52	-	-	-	[illegible]	[illegible]
7-1	ANALYTIC							
7-2	[illegible]	-	68	-	-	-	[illegible]	45
7-3	32	-	68	-	-	-	[illegible]	[illegible]
9-1	32	-	47	47	[illegible]	-	[illegible]	[illegible]
9-2	[illegible]	-	48	47	49	-	[illegible]	[illegible]
9-3	[illegible]	-	48	47	43	-	[illegible]	32
9-4	[illegible]	-	48	47	40	-	[illegible]	[illegible]
12-1	[illegible]	-	[illegible]	-	-	-	[illegible]	[illegible]
12-2	26	-	55	-	-	-	[illegible]	[illegible]
12-3	26	-	53	-	-	-	[illegible]	[illegible]
14-1	[illegible]	-	53	-	-	-	[illegible]	[illegible]
14-2	24	-	44	-	-	-	[illegible]	[illegible]
14-3	12	-	22	-	-	-	[illegible]	[illegible]
15-1	23	-	55	-	-	-	[illegible]	[illegible]
15-2	23	-	55	-	-	-	[illegible]	[illegible]
15-3	12	-	20	-	-	-	[illegible]	[illegible]
16-1	28	-	30	33	35	-	[illegible]	[illegible]
16-2	28	-	30	33	35	-	[illegible]	[illegible]
16-3	14	-	20	17	10	-	[illegible]	[illegible]
17-1	22	-	47	26	20	-	[illegible]	[illegible]
17-2	[illegible]	-	45	26	20	-	[illegible]	[illegible]
19-1	[illegible]	-	50	-	-	-	[illegible]	[illegible]
19-2	[illegible]	-	53	-	-	-	[illegible]	[illegible]
20-1	25	-	45	35	45	-	[illegible]	[illegible]
20-2	25	-	45	35	[illegible]	-	[illegible]	[illegible]
20-3	[illegible]	-	41	32	37	-	[illegible]	[illegible]
20-4	15	-	23	-	-	-	[illegible]	[illegible]
22-1	25	-	45	35	40	-	[illegible]	[illegible]
22-2	25	-	45	35	40	-	[illegible]	[illegible]
22-3	25	-	45	35	40	-	[illegible]	[illegible]
24-1	[illegible]	-	45	32	36	-	[illegible]	[illegible]
24-2	[illegible]	-	45	32	36	-	[illegible]	[illegible]
24-3	[illegible]	-	45	32	36	-	[illegible]	[illegible]
25-1	[illegible]	-	45	36	32	-	[illegible]	[illegible]
25-2	[illegible]	-	40	36	36	-	[illegible]	[illegible]
25-3	[illegible]	-	40	32	-	-	[illegible]	[illegible]
25-4	[illegible]	-	25	26	22	-	[illegible]	[illegible]
26-1	75	-	-	-	-	-	[illegible]	[illegible]
26-2	75	-	-	-	-	-	[illegible]	[illegible]
26-3	[illegible]	-	50	65	71	37	[illegible]	[illegible]
27-1	42	-	47	56	53	44	[illegible]	75
27-2	42	-	47	56	53	44	[illegible]	75
27-3	42	-	56	[illegible]	48	44	[illegible]	[illegible]
28-1	55	-	-	-	-	75	GROUND TEST	
28-2	38	-	-	-	-	75	[illegible]	[illegible]
28-3	38	-	-	-	-	[illegible]	GROUND TEST	
28-4	19	-	-	-	-	[illegible]	[illegible]	[illegible]
30-1	68	-	-	-	-	72	GROUND TEST	
30-2	68	-	-	-	-	72	GROUND TEST	
30-3	68	-	-	-	-	72	100	100
32-1	34	-	-	41	40	67	GROUND TEST	
32-2	37	-	-	44	43	68	GROUND TEST	
32-3	42	-	-	[illegible]	49	[illegible]	100	100
	EXISTING	GDT	GD20	F20	F8	S20	M6	M12

FIGURE 5-4
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM C1 (CONTINUED)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES GD7	GD20	F20	F8	S20	BASIC FLT. VEHICLES M6	M12
33-1	ANALYTIC							
33-2	43	-	51	56	61	65	GROUND	TEST
33-3	23	-	23	26	70	60	95	100
34-2	75	-	-	-	-	-	GROUND	TEST
34-3	ANALYTIC							
35-1	28	-	36	36	36	49	90	95
35-2	28	-	36	36	36	49	100	100
36-1	ANALYTIC							
36-2	41	-	-	70	73	62	GROUND	TEST
36-3	41	-	-	52	65	62	100	100
38-1	60	-	-	-	-	72	GROUND	TEST
38-2	65	-	-	-	-	75	GROUND	TEST
38-3	65	-	-	-	-	70	100	100
39-1	44	-	51	50	58	50	95	95
39-2	56	-	51	50	58	50	95	95
40-1	ANALYTIC							
40-2	58	-	-	-	64	62	GROUND	TEST
40-3	58	-	-	-	64	62	100	100
41-1	ANALYTIC							
41-2	ANALYTIC							
42-1	38	-	-	-	-	75	100	95
43-1	38	-	-	51	52	57	90	95
43-2	38	-	-	56	55	60	88	90
43-3	49	-	-	-	-	65	GROUND	TEST
43-4	ANALYTIC							
44-1	ANALYTIC							
44-2	75	-	-	-	-	-	95	100
45-1	ANALYTIC							
45-2	45	-	-	65	58	53	100	100
45-3	45	-	-	65	58	53	100	100
46-1	ANALYTIC							
46-2	70	-	-	-	-	75	90	95
48-1	47	-	60	55	53	-	90	90
48-2	42	-	63	55	53	-	75	90
48-3	37	-	55	50	48	-	73	55
48-4	44	-	63	57	55	-	80	75
48-5	ANALYTIC							
52-1	ANALYTIC							
52-2	ANALYTIC							
52-3	ANALYTIC							
52-4	30	-	-	60	41	-	80	38
55-1	53	-	50	67	60	-	95	53
55-2	52	-	50	65	55	-	95	52
57-1	ANALYTIC							
57-2	ANALYTIC							
57-3	ANALYTIC							
57-4	30	-	-	62	50	-	70	30
57-5	30	-	-	62	50	-	95	30
57-6	26	-	-	60	52	-	95	26
58-1	ANALYTIC							
58-2	ANALYTIC							
58-3	26	-	-	-		-	60	6
59-1	ANALYTIC							
59-2	ANALYTIC							
59-3	ANALYTIC							
59-4	32	-	-	62	55	-	70	32
59-5	32	-	-	62	55	-	70	32
59-6	32	-	-	67	60	-	70	32
63-1	32	-	37	67	60	-	85	32
63-2	42	-	55	57	55	-	80	42
63-3	32	-	37	67	60	37	85	32
65-1	ANALYTIC							
65-2	27	-	36	67	65	-	75	27
65-3	32	-	42	57	44	-	60	32
67-1	25	-	42	60	36	-	GROUND	TEST
67-2	25	-	42	60	36	-	70	25
67-3	ANALYTIC							
68-1	67	-	-	-	-	75	GROUND	TEST
68-2	65	-	-	-	-	75	GROUND	TEST
68-3	65	-	-	-	-	79	GROUND	TEST
69-1	ANALYTIC							
69-2	55	-	-	-	-	70	GROUND	TEST
69-3	55	-	-	-	-	70	100	100
	EXISTING	GD7	GD20	F20	F8	S20	M6	M12

FIGURE 5-4
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM C1 (CONTINUED)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES					BASIC FLT. VEHICLES	
		GD7	GD20	E20	F9	S20	M6	M12
70-1	ANALYTIC							
70-2	57	-	-	-	-	75	GROUND	TEST
70-3	57	-	-	-	-	75	GROUND	TEST
70-4	32	-	-	47	56	64	GROUND	TEST
70-5	32	-	-	47	56	64	100	40
71-1	75	-	-	-	-	-	95	75
71-2	75	-	-	-	-	-	95	75
71-3	75	-	-	-	-	-	95	75
72-1	75	-	-	-	-	-	GROUND	TEST
72-2	75	-	-	-	-	-	GROUND	TEST
72-3	75	-	-	-	-	-	GROUND	TEST
73-1	65	-	-	-	-	75	100	95
73-2	65	-	-	-	-	75	100	95
73-3	65	-	-	-	-	75	100	95
74-1	ANALYTIC							
74-2	71	-	-	-	-	-	100	100
74-3	71	-	-	-	-	-	100	100
75-1	75	-	-	-	-	-	GROUND	TEST
75-2	27	-	-	-	-	67	GROUND	TEST
75-3	27	-	-	-	-	71	100	100
77-1	ANALYTIC							
77-2	60	-	-	70	70	75	95	95
78-1	ANALYTIC							
78-2	40	-	56	56	42	-	95	90
78-3	40	-	56	56	42	-	90	95
79-1	ANALYTIC							
79-2	35	-	59	48	44	40	90	95
80-1	60	-	65	65	70	75	90	95
80-2	52	-	57	57	62	67	90	95
82-1	ANALYTIC							
82-2	60	-	65	68	70	75	GROUND	TEST
82-3	56	-	61	64	64	71	100	100
83-1	ANALYTIC							
83-2	65	-	-	-	-	75	100	100
87-1	ANALYTIC							
87-2	ANALYTIC							
87-3	35	-	-	-	-	-	95	59
88-1	ANALYTIC							
88-2	65	-	-	-	-	-	90	95
88-3	65	-	-	-	-	-	90	95
93-1	ANALYTIC							
93-2	35	-	45	45	62	48	95	95
94-1	ANALYTIC							
94-2	ANALYTIC							
94-3	24	-	44	44	40	44	75	70
96-1	14	-	24	22	24	34	95	70
96-2	19	-	24	24	26	34	95	75
97-1	75	-	-	-	-	-	GROUND	TEST
97-2	30	-	-	-	-	70	100	90
102-1	ANALYTIC							
102-2	65	-	-	-	-	75	100	95
	EXISTING	GD7	GD20	E20	F9	S20	M6	M12

weightings which allow a direct comparison of ground and flight capabilities at the task level:

	Flight Research	Ground Research
° Physical Environmental Simulation	25%	25%
° Configuration Arrangement and Size Similitude	25%	25%
° Verification and Demonstration Capability		
Ground Research	25%	25%
Flight Research	25%	0%

When a ground facility is isolated and its individual capability to perform the described research is assessed, a measure of its performance is that percent of the applicable research attained in the facility compared to the capability of an ideal ground facility. At this point, the sum of 75% generally becomes the maximum attainable by an ideal ground facility, as a point of reference, with equal weighting then given to the environmental, size similitude, and demonstration criteria. When multiplied by the task intrinsic values, these percentages yield the ideal ground-facility values noted in the remainder of this section. These values do not degrade facility capability but, on the contrary, provide insight into that portion of each task which can be realistically attained in ground facilities. In this way, the values for the various proposed ground facilities can be considered in relation to the types of research which these facilities are intended to perform, and penalties are not incurred by ground facilities for failing to provide flight-test verification and demonstration.

5.3 FACILITY RESEARCH VALUE

Research Task intrinsic values and the facility capabilities described previously in this section are combined to yield Facility Research Values for the conceptual flight research vehicles and ground facilities. The research potential for each facility in relation to each task for which it has capability, is found by multiplying the intrinsic value of the task by the capability of the facility to perform the task. The sum of these products over all applicable tasks is designated the Facility Research Value for the particular facility.

An illustrative example of the manner in which Facility Research Values are derived is presented in Figure 5-5. These data correspond to the focused research for GD20 as applied to Operational System C1. Accordingly, the nineteen tasks listed are judged to be those which GD20 would be specifically designed to accomplish. The task intrinsic values contained in the second column correspond to those presented in Figure 5-3 for these tasks. The third column presents the research potential of the spectrum of existing facilities which are of the same general class as GD20. These values are obtained by multiplying the task intrinsic values by the

FIGURE 5-5
COMPUTATION OF FOCUSED FACILITY RESEARCH VALUE – ILLUSTRATIVE EXAMPLE
Facility GD20
Operational System C1

Task No.	Task Intrinsic Value	Value of Existing Facilities Related To GD20	Ideal Ground Facility Value	Value of GD20 + Related Existing Facilities
3-3	21.2	9.5	13.6	12.5
4-1	55.2	17.1	35.3	23.7
4-2	38.9	12.1	24.9	16.7
4-3	38.9	12.1	24.9	16.7
9-4	51.6	11.4	26.8	24.8
12-1	50.1	13.0	28.1	25.1
12-2	35.4	9.2	19.8	17.7
12-3	17.7	4.6	11.3	8.8
14-1	32.0	9.6	17.9	17.0
14-2	22.6	5.4	12.7	10.0
16-1	47.2	13.2	26.4	18.4
16-2	47.2	13.2	30.2	18.4
17-1	42.9	9.4	24.0	21.0
17-2	42.9	9.4	28.8	21.0
20-1	53.5	13.4	38.0	24.1
24-1	46.7	14.0	33.1	21.0
24-2	32.9	9.9	23.4	14.8
27-3	34.2	14.4	20.5	19.1
48-1	59.0	24.8	39.5	35.4
Total		225.7	479.2	366.2 = GD20 Facility Research Value (Focused)

capability of existing facilities to perform each task. These capability percentages correspond to those presented in the existing facilities column of Figure 5-4 for the nineteen tasks involved. The fourth column of Figure 5-5 presents the values corresponding to the maximum portion of the various tasks attainable by ground facilities, in terms of ideal ground-facility value. Finally, in the last column of Figure 5-5, the value for GD20 in conjunction with existing facilities is presented corresponding to each Research Task, with the Facility Research Value for GD20 shown at the bottom of the column as the sum of these individual task values. The numbers in the third and fourth columns for the individual tasks, as well as their sums, serve as reference points for the values in the final column. Each value in the final column lies within the interval bounded at the lower end by the value of existing facilities considered alone and at the upper end by the ideal value for ground facilities.

Research values are listed in Figure 5-6, on a task-by-task basis, for all facility-task combinations which apply to Operational System C1. The format is similar to that of Figure 5-5 but includes all five ground facilities and both basic

FIGURE 5–6 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM C1

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES GDT	GP20	E2C	F9	S2P	FLIGHT VEHICLES M6 BASIC	M12 BASIC
1-1	55.9	25.2	37.5	-	-	-	-	-	53.1	27.9
1-2	47.5	21.4	31.0	-	-	-	-	-	45.1	23.8
1-3	33.5	15.1	22.5	-	-	-	-	-	31.9	16.9
1-4	16.8	8.4	11.2	-	-	-	-	-	15.9	9.7
2-1	56.8	20.7	37.5	-	25.0	-	-	-	53.2	44.8
2-2	47.6	17.6	31.9	-	23.8	-	-	-	45.2	35.7
2-3	33.6	12.4	22.5	-	16.8	-	-	-	31.9	26.9
2-4	16.8	9.4	10.8	-	-	-	-	-	16.0	13.4
3-1	68.5	28.8	60.2	-	37.2	-	-	-	57.0	54.0
3-2	70.6	33.9	47.3	-	43.8	-	-	-	67.1	67.1
3-3	21.2	5.5	13.6	-	12.50	-	-	-	20.1	20.1
3-4	42.4	20.3	29.4	-	26.3	-	-	-	40.2	28.3
4-1	55.2	17.1	35.3	-	23.70	21.5	-	-	48.6	52.4
4-2	38.9	12.1	24.9	-	16.70	16.0	-	-	35.0	37.0
4-3	38.9	12.1	24.9	-	16.70	12.9	-	-	35.0	37.0
5-1	56.0	5.3	42.0	-	-	-	-	-	53.2	44.8
5-2	47.6	30.8	35.7	-	-	-	-	-	45.2	38.1
5-3	47.6	30.0	35.7	-	-	-	-	-	45.2	40.5
6-1	45.7	16.5	32.5	-	23.0	-	-	-	43.4	43.4
6-2	45.7	16.5	32.5	-	23.0	-	-	-	43.4	36.6
6-3	53.8	15.4	30.2	-	20.8	-	-	-	51.1	45.7
7-1	47.9	ANALYTIC								
7-2	47.5	15.3	30.7	-	23.0	-	-	-	45.5	21.6
7-3	33.0	10.0	19.6	-	16.2	-	-	-	32.1	11.9
9-1	51.6	16.5	20.9	-	24.2	21.7	20.6	-	46.6	19.1
9-2	51.6	16.5	20.9	-	24.8	21.7	20.6	-	49.0	19.1
9-3	36.4	11.7	21.9	-	17.5	15.3	14.6	-	34.6	11.7
9-4	51.6	11.4	26.8	-	24.00	21.7	20.6	-	49.0	49.0
12-1	50.1	13.9	29.1	-	25.10	-	-	-	47.6	45.1
12-2	35.4	5.2	19.8	-	17.70	-	-	-	33.6	28.3
12-3	17.7	4.6	11.3	-	8.00	-	-	-	16.9	14.2
14-1	37.0	5.6	17.9	-	17.00	-	-	-	30.6	28.8
14-2	22.4	5.4	12.7	-	10.00	-	-	-	21.5	20.4
14-3	37.7	4.5	13.9	-	9.3	-	-	-	35.8	33.9
15-1	22.8	5.5	15.9	-	13.1	-	-	-	22.6	22.6
15-2	35.6	5.1	26.5	-	21.0	-	-	-	35.6	33.7
15-3	23.0	2.9	8.8	-	6.7	-	-	-	21.4	22.6
16-1	47.2	13.2	26.4	-	18.40	15.6	16.5	-	44.8	42.5
16-2	47.2	13.2	30.2	-	19.40	15.6	16.5	-	44.8	44.8
16-3	55.5	1.9	20.5	-	11.1	9.4	10.0	-	52.7	52.7
17-1	42.9	5.4	24.0	-	21.00	11.2	12.0	-	40.8	38.6
17-2	42.9	5.4	28.8	-	21.00	11.2	12.0	-	40.8	38.6
19-1	47.7	14.3	33.9	-	23.8	-	-	-	45.3	45.3
19-2	47.7	14.3	30.5	-	23.8	-	-	-	45.3	45.3
20-1	53.5	13.4	30.8	-	26.10	18.7	21.4	-	50.8	50.8
20-2	45.5	11.4	32.3	-	20.5	15.9	18.2	-	43.2	43.2
20-3	45.5	11.4	20.1	-	18.6	14.6	16.8	-	11.4	15.9
20-4	32.1	4.8	11.9	-	7.6	-	-	-	30.5	20.9
22-1	50.8	12.7	36.1	-	22.9	17.0	20.3	-	48.3	48.3
22-2	43.2	10.8	30.7	-	19.4	15.1	17.3	-	41.0	41.0
22-3	43.2	10.8	28.9	-	19.4	15.1	17.3	-	41.0	41.0
24-1	46.7	14.0	33.1	-	21.00	16.9	15.9	-	42.0	44.3
24-2	32.9	5.9	23.4	-	14.80	10.5	11.2	-	29.6	31.3
24-3	54.9	16.5	39.0	-	24.7	17.4	18.7	-	49.4	52.2
25-1	36.5	11.0	24.5	-	14.6	12.4	11.7	-	34.7	34.7
25-2	43.0	12.9	28.8	-	21.5	15.5	14.6	-	40.8	40.8
25-3	36.5	11.9	24.5	-	18.3	11.7	-	-	34.7	34.7
25-4	25.8	5.2	14.6	-	6.6	6.2	5.7	-	24.5	24.5
26-1	32.8	24.6	24.6	-	-	-	-	-	31.1	24.2
26-2	44.4	34.0	34.8	-	-	-	-	-	44.1	44.1
26-3	54.6	16.4	38.8	-	27.3	35.5	30.8	20.2	49.1	51.9
27-1	40.2	16.9	24.1	-	19.9	22.50	21.30	18.5	38.2	38.1
27-2	24.1	10.1	14.5	-	11.3	13.5	12.8	11.1	22.9	18.1
27-3	34.2	14.4	20.5	-	18.10	17.1	16.4	15.7	32.5	20.0
28-1	62.5	34.4	44.9	-	-	-	-	46.00	GROUND	TEST
28-2	62.5	23.7	44.9	-	-	-	-	46.00	55.1	54.2
28-3	44.1	18.8	33.1	-	-	-	-	38.00	GROUND	TEST
28-4	73.5	14.0	52.2	-	-	-	-	25.7	42.5	66.1
30-1	49.1	33.4	36.8	-	-	-	-	35.6	GROUND	TEST
30-2	34.7	23.6	26.0	-	-	-	-	25.0	GROUND	TEST
30-3	57.8	35.3	43.3	-	-	-	-	41.6	57.8	57.8
32-1	35.0	11.9	26.3	-	-	16.4	16.0	23.90	GROUND	TEST
32-2	58.4	21.6	43.8	-	-	29.7	29.1	30.70	GROUND	TEST
32-3	49.6	20.9	37.2	-	-	26.0	26.3	34.70	49.6	49.6
		EXISTING	IDEAL GND.	GDT	GP20	E2C	F9	S2P	M6	M12

FIGURE 5-6 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM C1 (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES — GROUND FACILITIES: GDT	GD20	F20	F9	S20	FLIGHT VEHICLES: M6 BASIC	M12 BASIC
33-1	61.6	ANALYTIC								
33-2	52.4	22.5	30.3	-	26.7	29.3	31.9	34.0	GROUND	TEST
33-3	37.0	7.4	24.0	-	8.5	9.6	10.3	22.2*	39.1	37.0
34-2	42.5	31.9	31.9	-	-	-	-	-	GROUND	TEST
34-3	60.3	ANALYTIC								
35-1	36.5	10.2	24.5	-	13.1	12.4	12.4	17.9	32.8	34.7
35-2	31.0	8.7	23.3	-	11.2	10.5	10.5	19.2	31.0	31.0
36-1	36.9	ANALYTIC								
36-2	57.3	21.4	39.2	-	-	36.6	38.2	32.4	GROUND	TEST
36-3	61.5	25.2	44.1	-	-	32.0	40.0	38.1*	61.5	61.5
38-1	31.0	15.1	23.0	-	-	-	-	27.0*	GROUND	TEST
38-2	37.4	14.0	28.0	-	-	-	-	28.0*	GROUND	TEST
38-3	31.0	14.3	23.0	-	-	-	-	22.3*	31.0	31.0
39-1	24.0	11.9	16.0	-	12.4	12.4	14.4	12.4	23.5	23.5
39-2	41.3	1[illegible]	27.7	-	21.1	29.6	24.0	29.6	39.2	39.2
40-1	59.8	ANALYTIC								
40-2	50.1	29.1	37.6	-	-	-	32.1	31.1	GROUND	TEST
40-3	35.4	20.5	25.1	-	-	-	22.7	21.9	35.4	35.4
41-1	43.7	ANALYTIC								
41-2	43.7	ANALYTIC								
42-1	62.5	21.9	46.9	-	-	-	-	46.9*	62.5	59.6
43-1	61.7	23.4	41.3	-	-	31.5	32.1	35.2	49.4	57.5
43-2	72.6	27.6	51.5	-	-	39.7	39.9	43.6	61.7	65.3
43-3	43.6	20.9	32.7	-	-	-	-	28.3	GROUND	TEST
43-4	43.6	ANALYTIC								
44-1	55.1	ANALYTIC								
44-2	64.8	40.6	48.6	-	-	-	-	-	61.6	64.8
45-1	38.4	ANALYTIC								
45-2	54.4	24.5	49.0	-	-	35.4	31.6	28.0	54.4	54.4
45-3	64.0	28.0	44.0	-	-	41.6	37.1	33.9	64.0	64.0
46-1	45.4	ANALYTIC								
46-2	45.4	31.0	34.0	-	-	-	-	34.0	40.9	43.1
48-1	59.0	24.0	39.5	-	35.4*	32.4	31.3	-	53.1	47.2
48-2	55.0	24.0	39.5	-	35.4	32.4	31.3	-	44.7	47.2
48-3	41.6	15.4	26.6	-	22.9	20.0	20.0	-	30.4	22.9
48-4	69.4	30.5	44.5	-	43.0	39.6	38.2	-	55.5	52.0
48-5	65.4	ANALYTIC								
52-1	52.5	ANALYTIC								
52-2	52.5	ANALYTIC								
52-3	52.5	ANALYTIC								
52-4	61.0	10.5	41.4	-	-	37.1	29.3	-	49.4	10.5
55-1	25.9	13.7	17.4	-	15.0	17.4	15.4	-	24.6	13.7
55-2	25.9	13.5	19.4	-	15.3	16.9	14.3	-	24.6	13.5
57-1	44.2	ANALYTIC								
57-2	44.2	ANALYTIC								
57-3	44.2	ANALYTIC								
57-4	62.6	10.0	44.4	-	-	30.0*	31.3	-	43.0	10.0
57-5	62.6	10.9	44.4	-	-	30.0*	31.3	-	55.4	10.9
57-6	73.6	19.1	49.3	-	-	44.2*	39.3	-	69.9	19.1
58-1	40.0	ANALYTIC								
58-2	40.0	ANALYTIC								
58-3	57.0	15.0	30.7	-	-	-	-	-	23.1	15.0
59-1	42.1	ANALYTIC								
59-2	42.1	ANALYTIC								
59-3	42.1	ANALYTIC								
59-4	59.7	19.1	44.0	-	-	37.0*	32.0*	-	41.0	19.1
59-5	59.7	19.1	42.4	-	-	37.0*	32.0*	-	41.0	19.1
59-6	70.2	22.5	49.0	-	-	47.0*	42.1*	-	49.1	22.5
63-1	34.7	11.1	24.7	-	12.9	23.3	20.0	-	29.9	11.1
63-2	49.2	20.7	33.0	-	27.1	29.1	27.1	-	44.3	20.7
63-3	57.9	10.5	41.1	-	21.4	38.0	34.7	21.4	49.2	10.5
65-1	38.5	ANALYTIC								
65-2	54.5	14.7	36.5	-	19.6	25.6	24.9	-	40.9	14.7
65-3	64.1	20.5	42.9	-	26.9	33.3	29.5	-	38.5	20.5
67-1	41.3	10.3	27.7	-	17.4	19.0	14.9	-	GROUND	TEST
67-2	41.3	10.3	26.5	-	17.4	19.0	14.9	-	20.9	10.3
67-3	58.6	ANALYTIC								
68-1	24.5	16.4	18.4	-	-	-	-	18.4	GROUND	TEST
68-2	34.7	22.5	26.0	-	-	-	-	26.0	GROUND	TEST
68-3	34.7	22.5	26.0	-	-	-	-	26.0	GROUND	TEST
69-1	22.4	ANALYTIC								
69-2	31.0	17.5	22.6	-	-	-	-	22.3	GROUND	TEST
69-3	31.0	17.5	22.6	-	-	-	-	22.3	31.0	31.0
		EXISTING	IDEAL GND.	GDT	GD20	F20	F9	S20	M6	M12

FIGURE 5-6 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM C1 (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES / GROUND FACILITIES GDT	GD20	F20	F9	S20	FLIGHT VEHICLES M6 BASIC	M12 BASIC
70-1	27.8	ANALYTIC								
70-2	27.8	19.9	29.9	-	-	-	-	20.9	GROUND TEST	GROUND TEST
70-3	39.4	22.5	29.6	-	-	-	-	29.6	GROUND TEST	GROUND TEST
70-4	39.4	12.6	26.4	-	-	16.6	22.1	29.2	GROUND TEST	GROUND TEST
70-5	46.4	14.8	31.1	-	-	19.5	26.0	29.7	46.4	18.6
71-1	28.6	21.5	21.5	-	-	-	-	-	27.2	21.5
71-2	28.6	21.5	21.5	-	-	-	-	-	27.2	21.5
71-3	33.7	29.3	29.3	-	-	-	-	-	32.8	29.3
72-1	22.2	16.6	16.6	-	-	-	-	-	GROUND TEST	GROUND TEST
72-2	31.4	23.6	23.6	-	-	-	-	-	GROUND TEST	GROUND TEST
72-3	37.8	27.8	27.8	-	-	-	-	-	GROUND TEST	GROUND TEST
73-1	[illegible]	16.5	19.1	-	-	-	-	19.1	29.4	21.6
73-2	34.8	23.4	27.8	-	-	-	-	27.8	36.8	30.6
73-3	42.4	27.6	31.8	-	-	-	-	31.8	42.4	36.8
74-1	19.2	ANALYTIC								
74-2	19.2	13.6	13.6	-	-	-	-	-	19.2	19.2
74-3	32.0	22.7	22.7	-	-	-	-	-	32.0	32.0
75-1	27.8	20.9	20.9	-	-	-	-	-	GROUND TEST	GROUND TEST
75-2	35.4	16.9	26.4	-	-	-	-	26.4	GROUND TEST	GROUND TEST
75-3	46.4	12.5	32.9	-	-	-	-	32.9	46.4	46.4
77-1	24.6	ANALYTIC								
77-2	29.0	17.4	21.8	-	-	20.3	20.3	21.8	29.6	29.6
78-1	23.9	ANALYTIC								
78-2	33.9	13.4	24.1	-	19.0	19.0	14.2	-	28.8	27.1
78-3	39.9	16.8	28.3	-	22.3	22.3	16.8	-	35.9	33.9
79-1	25.8	ANALYTIC								
79-2	30.3	10.6	21.5	-	15.1	14.5	13.9	12.1	27.3	20.8
80-1	35.2	21.1	26.4	-	22.9	22.9	24.4	26.4	31.7	33.4
80-2	41.4	21.5	27.7	-	23.6	23.6	25.7	27.7	37.3	30.3
82-1	20.0	ANALYTIC								
82-2	20.3	17.0	21.2	-	18.6	19.2	19.8	21.2	GROUND TEST	GROUND TEST
82-3	33.3	18.6	23.6	-	20.3	21.3	22.0	23.6	33.3	33.3
83-1	23.5	ANALYTIC								
83-2	39.1	17.6	29.3	-	-	-	-	29.3	39.1	39.1
87-1	22.7	ANALYTIC								
87-2	22.7	ANALYTIC								
87-3	37.9	13.3	26.9	-	-	-	-	-	36.9	18.9
89-1	25.6	ANALYTIC								
89-2	25.6	16.7	18.2	-	-	-	-	-	29.1	24.3
89-3	36.3	23.6	25.8	-	-	-	-	-	32.7	30.9
93-1	29.3	ANALYTIC								
93-2	24.9	8.7	14.9	-	11.2	11.2	10.5	12.0	23.7	23.7
94-1	23.6	ANALYTIC								
94-2	32.5	ANALYTIC								
94-3	39.4	13.4	23.4	-	17.3	17.3	15.0	18.1	29.5	27.6
96-1	21.1	3.4	12.6	-	5.1	4.6	5.1	7.2	20.0	16.7
96-2	35.1	6.3	22.5	-	9.1	8.4	9.1	12.4	33.3	26.3
97-1	21.8	16.4	16.4	-	-	-	-	-	GROUND TEST	GROUND TEST
97-2	34.4	10.9	27.3	-	-	-	-	25.9	34.4	32.8
102-1	31.9	ANALYTIC								
102-2	37.5	24.4	28.1	-	-	-	-	29.1	37.5	31.9
		EXISTING	IDEAL GND.	GDT	GD20	F20	F9	S20	M6	M12

FACILITY RESEARCH VALUE SUMMARY
OPERATIONAL SYSTEM C1

CHARACTERISTIC RESEARCH

	GDT	GD20	F20	F9	S20	M6 BASIC	M12 BASIC
RELATED EXISTING-FACILITIES VALUE	0	1136	1208	1216	1164	2176	2176
FACILITY RESEARCH VALUE (NEW + EXIST.)	0	1437	1715	1674	1438	4131	4320
RELATED IDEAL-FACILITY VALUE	0	2232	2498	2306	1868	5644	5446

FOCUSED RESEARCH

	GDT	GD20	F20	F9	S20
RELATED EXISTING-FACILITIES VALUE	0	226	134	78	257
FACILITY RESEARCH VALUE (NEW + EXIST.)	0	366	265	129	462
RELATED IDEAL-FACILITY VALUE	0	679	299	161	687

flight research vehicles evaluated in Phase III. As in Figure 5-4, the dashes indicate that the particular facility does not have application to the corresponding Research Task. Those facility-task combinations which involve focused research for a particular facility are designated by asterisks. Tasks which are appropriate for accomplishment only in ground facilities are identified in the flight research vehicle columns.

The values presented in the Facility Research Value summary at the bottom of Figure 5-6 are the sums of research values over all applicable tasks. Characteristic Facility Research Values for the Phase III facilities, listed in the middle row, are the sums of values presented in the above portion of the figure for all applicable Research Tasks. The related existing-facilities total in the top row is the sum of the existing-facilities values for all tasks for which the research facility has application. Similarly, the related ideal-facility totals in the bottom row are determined by summing the corresponding ideal-facility values over the tasks for which the research facility has an application. The characteristic Facility Research Values for the two flight research vehicles are the sums of the values corresponding to all tasks except those designated as involving strictly ground-test research. The related existing-facilities total for the flight vehicles corresponds to the values for the combination of all existing facilities summed over these same flight-test related tasks, while the related ideal-facility total is the summation of the intrinsic values, again, over all tasks other than those involving only ground testing or which are strictly analytic.

The Facility Research Values presented in the focused research summary of Figure 5-6 are developed in a similar manner to the characteristic Facility Research Values. The only difference is that only those task-facility combinations designated by asterisks are involved in the summing process which yields these focused values. Therefore, the magnitude of the focused values is significantly reduced from that of the characteristic values.

The values presented in this summary of characteristic and focused research form the basis for the results shown for Operational System C1 in the remainder of this volume. The development of the corresponding data for the flight vehicle options relative to Operational System C1, as well as all data corresponding to Operational Systems L2, M1, and M2, is presented in the Appendix.

6. FLIGHT VEHICLE RESEARCH POTENTIAL

Facility Research Value is the measure of research potential used in this study. It measures the capability of a facility to fulfill the expressed intent of the relevant Research Tasks applicable to an operational vehicle.

Facility Research Value, as determined for the flight research vehicle concepts, is viewed as the contribution of a flight research program to provide confidence in the technology base to proceed with initiation of an operational system. This follows the original premise used in the "Hypersonic Research Requirements Survey" early in the study, i.e. accomplishment of the identified research and development will provide a minimum-risk procurement in the event that it is found desirable to initiate procurement of one or more of the potential aircraft systems. Assessment of the Facility Research Value considers: 1) the research contributions of the flight research vehicle and 2) the composite contributions of existing ground facilities to accomplishment of applicable Research Tasks.

The data presented allows a direct comparison of the research potential of the selected Mach 6 and Mach 12 flight research vehicles in a consistent set of terms. An assessment is also presented for the enhancement of basic vehicle research obtained by incorporation of the following flight research options:

Mach 12 Research Vehicle
- Convertible Scramjet (CSJ)
- Scramjet (SJ)
- Thermal Protection System (TPS)
- Subsonic Turbojet (S-TJ)
- Horizontal Take-off (HTO)
- Armament (ARM)

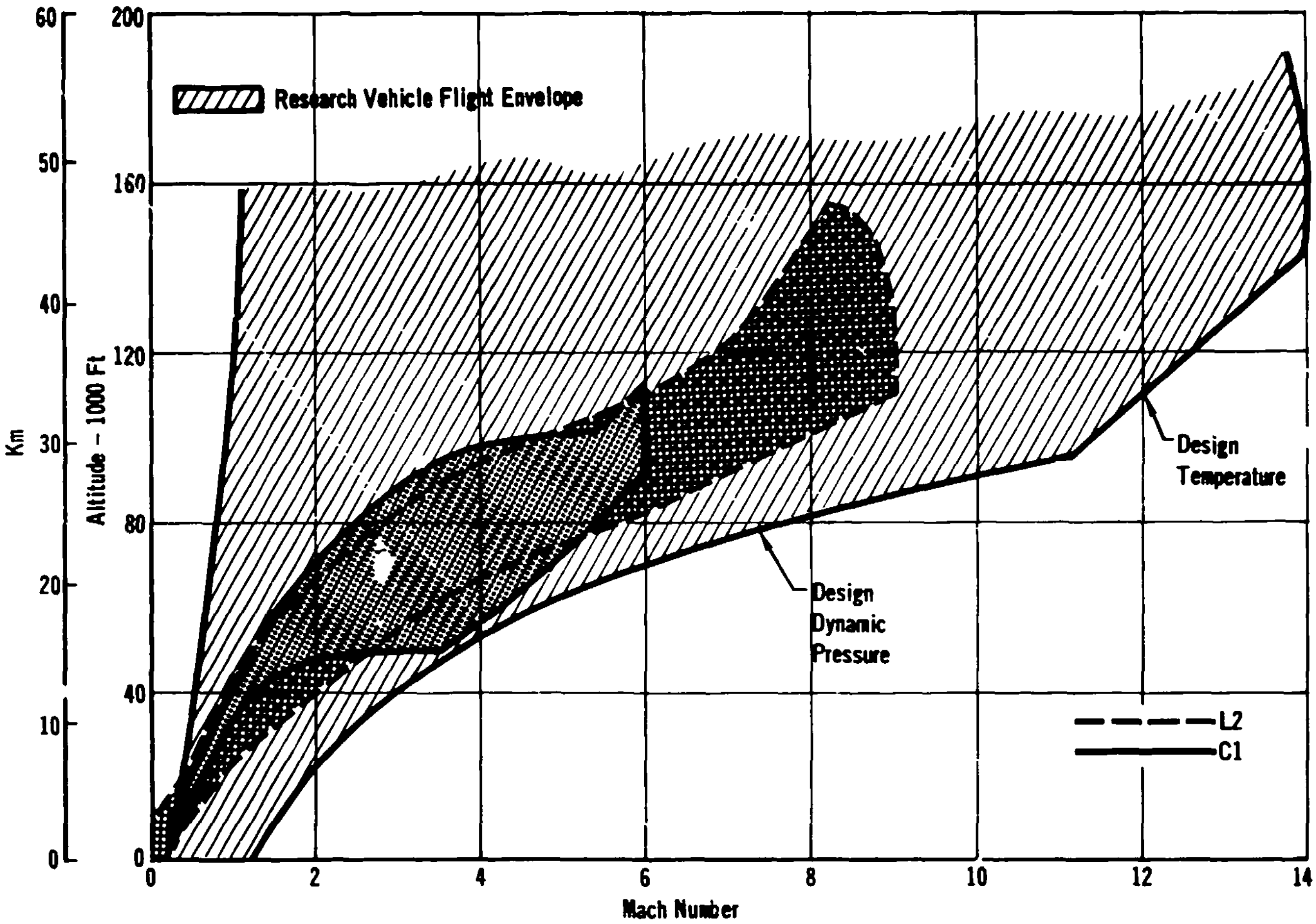
Mach 6 Research Vehicle
- Thermal Protection System (TPS)
- Armament (ARM)

The research potential, or Facility Research Value, is broken into two distinct categories, "characteristic" and "focused" as previously discussed, to provide a measure of overall and specific research potential, respectively. The characteristic research value is a measure of the versatility of a facility to accomplish the complete spectrum of research tasks applicable to a given operational system. This enables consideration of facility capabilities to accomplish all Research Tasks which are accommodated by flight test. Focused research values illustrate the research potential of new facilities in those areas of research for which the added flight research options are specifically designed to provide research data.

6.1 RESEARCH VEHICLE/OPERATIONAL VEHICLE COMPARISONS

The selected flight research vehicles are designed to provide the combined capability to explore the entire flight profile defined for the representative potential operational vehicles. However, there are several design and operational factors unique to each flight vehicle. These influence the assessment of research vehicle capability to perform the identified Research Tasks as each applies to a specific operational vehicle. A brief summary of the major vehicle characteristics is tabulated in Figure 6-1.

FIGURE 6-1
HYFAC FLIGHT RESEARCH VEHICLES ALLOW FULL EXPLORATION OF THE OPERATIONAL VEHICLE FLIGHT PROFILES



General Vehicle Characteristics

Vehicle	Function	Configuration	Propulsion	Mach Class
C210	Research	Wing/Body	TRJ	6
C233	Research	All Body	Air Launched Rocket	12
Potential Operational System				
L2	Launch Vehicle	All Body	TJ + CSJ	8 - 10
C1	Commercial	Blended Wing Body	TRJ	6
M1	Military	Wing/Body	TRJ	4.5
M2	Military	All Body	Rocket + SJ	12

Each of the flight research vehicles satisfies unique as well as mutually overlapping areas of research. The basic C210 is a Mach 6 airbreathing cruise vehicle with conventional wing-body configuration that incorporates take-off and landing capabilities typical of current high-speed aircraft. The basic C233 vehicle is a Mach 12 rocket-powered all-body configuration, airlaunched from a C-5, offering a versatile capability to accommodate many research options.

A composite flight envelope for the research aircraft is presented in Figure 6-1, in order to relate the research vehicle characteristics with operational vehicle flight profiles. It is readily apparent that the flight research vehicles combine to allow exploration of the entire range of temperature, pressure and Mach number for the operational vehicle flight profiles. For a rocket-powered vehicle, maximum-altitude envelope is a function of overall thrust, total propellants, and vehicle control capability. The absolute upper flight envelope is governed by vehicle recovery limits (set by structural and thermal considerations as explained in Volume IV, Part I); but these enable flight up to 250,000 feet (76.2 km). This enables high-altitude exploration of the environment and research into vehicle return/recovery techniques, although some test time and speed reduction may be necessary, depending upon the exact ascent trajectory selected. The Mach 6 vehicle operational envelope is governed by the engine operating envelope, but Pratt and Whitney anticipates full ramjet mode capability operation for the engine to 110,000 feet (33.5 km) and Mach 7.

Both vehicles are designed with a 2500 psf (11.97 N/cm^2) dynamic pressure design capability. The Mach 6 vehicle is placarded between Mach 3.8 and its cruise Mach number by a ramjet duct pressure limit of 150 psi (103.4 N/cm^2). The design equilibrium skin temperature for the Mach 12 vehicle is 2800°F (1811 °K). The airlaunched rocket vehicle employs constant-altitude acceleration to its design dynamic pressure. This represents a fairly realistic lower operating envelope for that vehicle, since the rocket engines are designed for full expansion at an altitude of 35,000 feet (9.14 km) and extensive maneuvering would result in substantial nozzle flow separation. The HTO option with lower expansion ratio nozzles, would allow exploration of this portion of the envelope with minimum performance losses.

Although the basic Mach 12 research vehicle exhibits the potential to cover the entire operational spectrum, the basic vehicle does not incorporate an airbreathing propulsion capability. However, both the Convertible Scramjet and Scramjet options will provide this capability within the defined envelope. One particularly attractive research approach includes use of the basic Mach 12 vehicle to provide aerothermodynamic configuration data with sufficient flow field and shock interference definition to enable relatively high-confidence incorporation of the airbreathing research options at a later date. The payoff, in terms of attainment of Facility Research Value, is illustrated in subsequent sections.

6.2 POTENTIAL OF BASIC RESEARCH AIRCRAFT

Each flight research aircraft was analyzed to determine its contribution toward fulfillment of the research tasks as they apply to the potential operational systems. The assessment represents the parametric matching of research vehicle and operational vehicle characteristics. The results provide insight into how well either the Mach 6 or Mach 12 aircraft can perform the research required for each potential operational system in terms relative to that system. Although the results may be indicative of current confidence levels for development of a particular operational system, they do not depict the difficulty of accomplishing the research on an absolute scale, nor do they define operational system levels of risk.

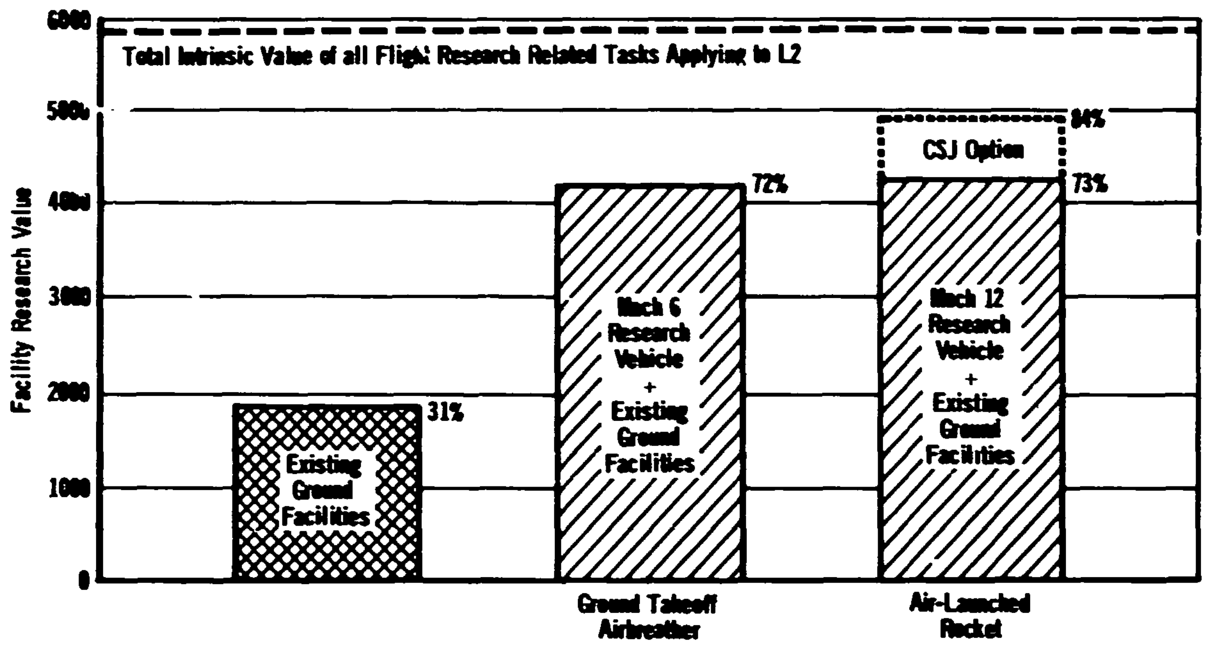
Results are presented in terms of both Facility Research Value and percent of total intrinsic value for all flight-research-related tasks applying to the particular operational vehicle. The value of all combined existing ground facilities, evaluated on the same basis, is also shown and provides a point of reference for comparison of facility capabilities. The evaluation includes a broad base of potential research, cutting across all technology lines. The relatively high research values attained by the flight vehicles is indicative of the importance of flight demonstration and their inherent versatility, i.e. the ability to accomplish simultaneous research and examine interactions of individual technological contributions.

In an assessment of the capabilities of the flight research vehicles as applied to operational systems requirements, it is evident that the closer the match between research vehicle characteristics and operational vehicle characteristics, the higher the Facility Research Value for that specific research vehicle. When examining the basic Mach 12 research vehicle capabilities for the L2 and M2 operational vehicles, it is quite apparent that a significant increase in research potential may be derived by the addition of an airbreathing option to the basic vehicle. As a result, the Convertible Scramjet option (CSJ) contribution to the Facility Research Value has been identified with the basic Mach 12 vehicle contribution for each operating vehicle. Of the airbreathing modifications, the CSJ is chosen for illustration because it offers increased flexibility on a research basis over the scramjet (SJ). The dual mode (subsonic combustion) feature offers potential for component development which may also be applicable to conventional ramjet or turboramjet engines, and enables airbreathing cruise operation of the all body configuration below Mach 7.

6.2.1 RESEARCH POTENTIAL CHARACTERIZED FOR OPERATIONAL SYSTEM L2 - The research tasks applicable to the recoverable launch vehicle include specific requirements to investigate staging techniques, use of reaction control motors, and investigation of ablation cooling techniques. Propulsion tasks are limited to those which affect turbojet and convertible scramjet engine development and integration, while tasks characteristic of military operation and rapid turnaround are excluded. Considerable emphasis is placed on the entire aerothermodynamic research envelope and on utilization of cryogenic propellants.

A comparison of relative capability between the basic Mach 12 and Mach 6 vehicles reveals that the Mach 6 vehicle, with airbreathing take-off and landing capability, can satisfy some of the low-speed aerodynamic and operational tasks along with operation of inlet controls and component development through the transonic regime up to Mach 6. This advantage is slightly more than offset by the basic Mach 12 performance in the higher-speed envelope, providing increased aerothermodynamic and structural data in that environment for a configuration more representative of the operational vehicle L2. The addition of the Convertible Scramjet option to the basic Mach 12 vehicle provides a near-prototype configuration, as illustrated by the Facility Research Value improvement depicted in Figure 6-2.

FIGURE 6-2
FLIGHT RESEARCH VEHICLES GREATLY INCREASE RESEARCH POTENTIAL OVER EXISTING GROUND FACILITIES
Operational System L2: Recoverable Launch – M8 to 10 – TJ/CSJ

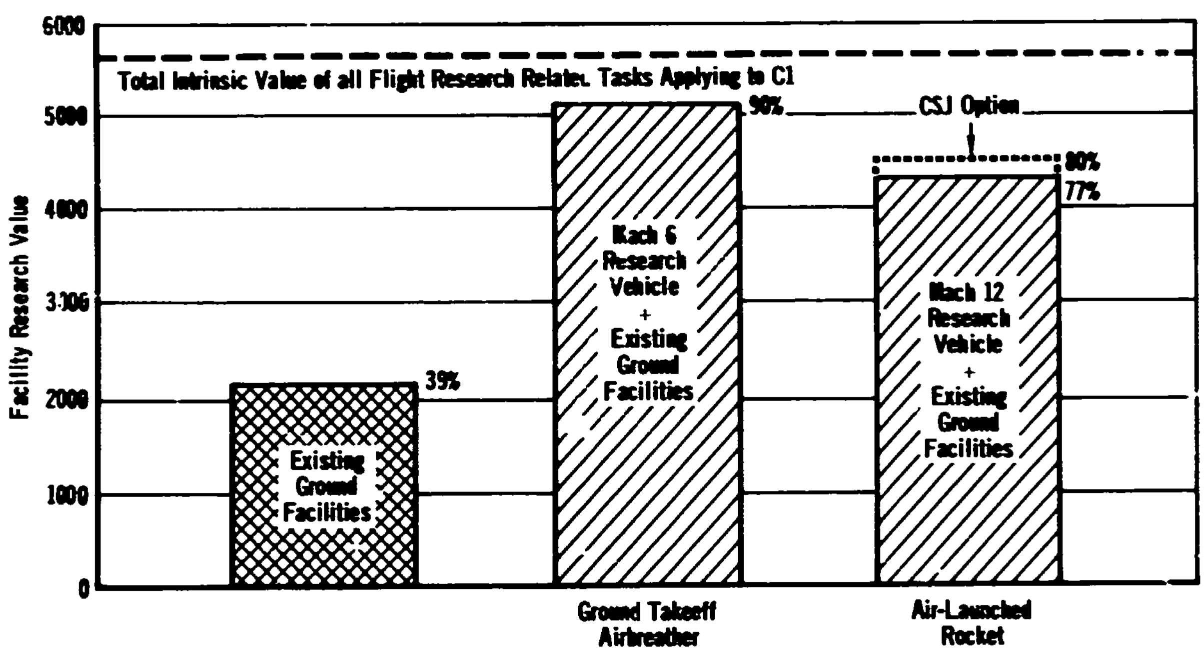


Although there is still a significant configuration difference, the basic research vehicle is capable of fully exploring the projected operational vehicle flight profile as discussed above. The values shown include the use of existing ground facilities as a foundation in the development of the basic flight research vehicle. Using the existing facilities as a point of reference, the basic flight vehicles each increase the existing research potential by about 135%. The addition of the Convertible Scramjet option to the basic Mach 12 vehicle increases the existing potential to accomplish research relevant to the recoverable launch vehicle by 170%.

6.2.2 RESEARCH POTENTIAL CHARACTERIZED FOR OPERATIONAL SYSTEM C1 - Several of the Research Tasks identified in Section 3 have specific relevance to the operational Mach 6 hypersonic transport, while others have been deleted because of their lack of application. For commercial transport operations, tasks involving investigation of engine noise reduction and provision of rapid turnaround with cryogenic systems gain in importance. Developmer' the hydrogen-fueled turboramjet engine and research into mode transition, engin' tion techniques and inlet unstart are essential elements in the acquisit .igh-confidence data base for development of a C1-class vehicle. Tasks ve been identified as inappropriate, (and not included in the assessment of re .n potential applicable to C1) are those dealing with staging or resulting in long turnaround times, military response and armament, and specific research into propulsion concepts other than the turboramjet.

Figure 6-3 illustrates the extent to which the basic Mach 6 and Mach 12 research vehicles increase the research potential of existing facilities. The basic Mach 6 vehicle provides significantly greater research capability related to C1 than the basic Mach 12 vehicle for all major technical areas except structures and materials development, where comparable research value exists. The results reflect the general similarity between the basic Mach 6 research vehicle and the operational system studied. Although specific configuration differences exist, such as overall size, inlet location and structural arrangement, the flight demonstration capabilities allow full exploration of the operational vehicle flight profile. Existing ground facilities are used to provide a base for the flight research facilities, as noted on the bar charts. The Facility Research Value for existing facilities equals 39% of the task intrinsic value total for those tasks which are amenable to flight research. The basic Mach 6 flight facility attains 90% of the task intrinsic value total, while the air-launched Mach 12 rocket vehicle attains only 77% of the research goal. Inclusion of the Convertible Scramjet option, as shown by the dashed line, provides some airbreathing propulsion development (components and integration studies). The result is a modest increase in facility research potential.

FIGURE 6-3
A MACH 6 RESEARCH VEHICLE HAS A LARGE RESEARCH VALUE ADVANTAGE FOR A MACH 6 OPERATIONAL SYSTEM
Operational System C1: Hypersonic Transport – M6 – TRJ



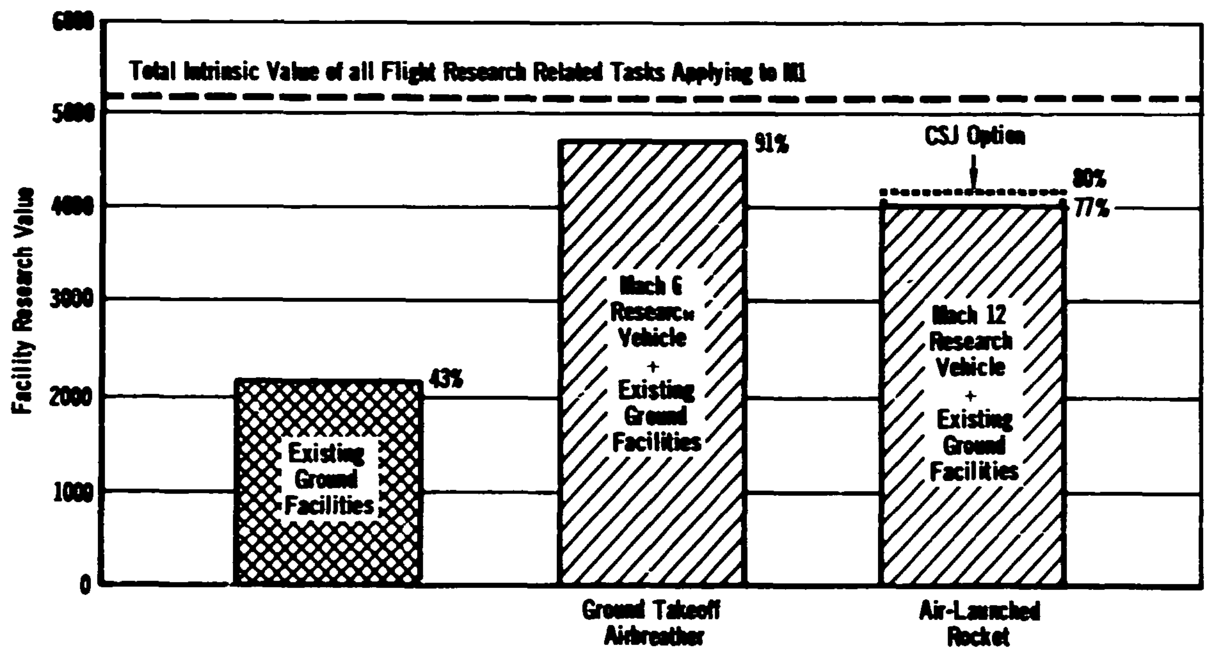
6.2.3 RESEARCH POTENTIAL CHARACTERIZED FOR OPERATIONAL SYSTEM M1 - The overall research scope is somewhat reduced for Operational System M1. This particular system concept is a Mach 4.5-class, storable-hydrocarbon fueled, turboramjet-powered interceptor. As a result, all the cryogenic tasks are eliminated, along with supersonic combustion research, staging, and the use of ablative thermal protection schemes. Emphasis is placed on engine/airframe integration, hydrocarbon fuels, and research into satisfactory armament storage and launch techniques.

A measure of current capability is illustrated in Figure 6-4. The basic Mach 6 vehicle with turboramjet propulsion offers the greatest research potential, with a Facility Research Value equaling 91% of the total intrinsic value of all flight Research Tasks applicable to M1. This vehicle, although not identical in configuration to M1, offers considerable potential for low-speed and transonic aerodynamic investigation as well as propulsion integration techniques, particularly mode transition and inlet operation at appropriate points in the flight profile. As a result, significant increases over basic Mach 12 vehicle capability have been registered for the aerodynamic and propulsion technologies, with moderate improvements noted in all other areas. The addition of the airbreathing option increases the Mach 12 research potential from 77% to 80% by virtue of increased vehicle flexibility and exploration of the subsonic combustion mode (and its integration/vehicular effects). As a point of comparison, existing ground facilities have a research potential of 43% for M1.

FIGURE 6-4

A TURBORAMJET MACH 6 RESEARCH VEHICLE SATISFIES MOST RESEARCH REQUIREMENTS FOR A MACH 4.5 INTERCEPTOR

Operational System M1: Interceptor – M4.5 – TRJ



6.2.4 RESEARCH POTENTIAL CHARACTERIZED FOR OPERATIONAL SYSTEM M2 - Research Tasks required for high-confidence development of the Military Strike system involve (1) aerodynamic/thermodynamic hypersonic flow characteristics, (2) low-speed configuration development, (3) operation and integration of the scramjet engine, (4) cryogenic propellant systems, (5) research into advanced structural/thermal protection systems, and (6) investigation of armament integration/weapons release techniques. Research Tasks involving integration of primary low-speed airbreathing propulsion, propulsion mode transition (in either the TJ/RJ or subsonic-to-supersonic combustion), or stage separation are not pertinent.

In all technology areas, the basic Mach 12 research vehicle shows an increase in research potential over the basic Mach 6 vehicle. The greatest proportional increases are in propulsion (because the configuration allows research into definition of external compression and expansion), aerothermodynamics (because of Mach number extremes,even though the Mach 12 vehicle cannot perform basic low-speed and take-off and landing research) and subsystems research into cryogenics, armament, flight data systems, and controls. Significant increases are also noted in the structures and materials area, primarily at the high-temperature end for research involving coated refractory metals, radiative shingles, and high-temperature components (bearings, seals, radomes, etc.)

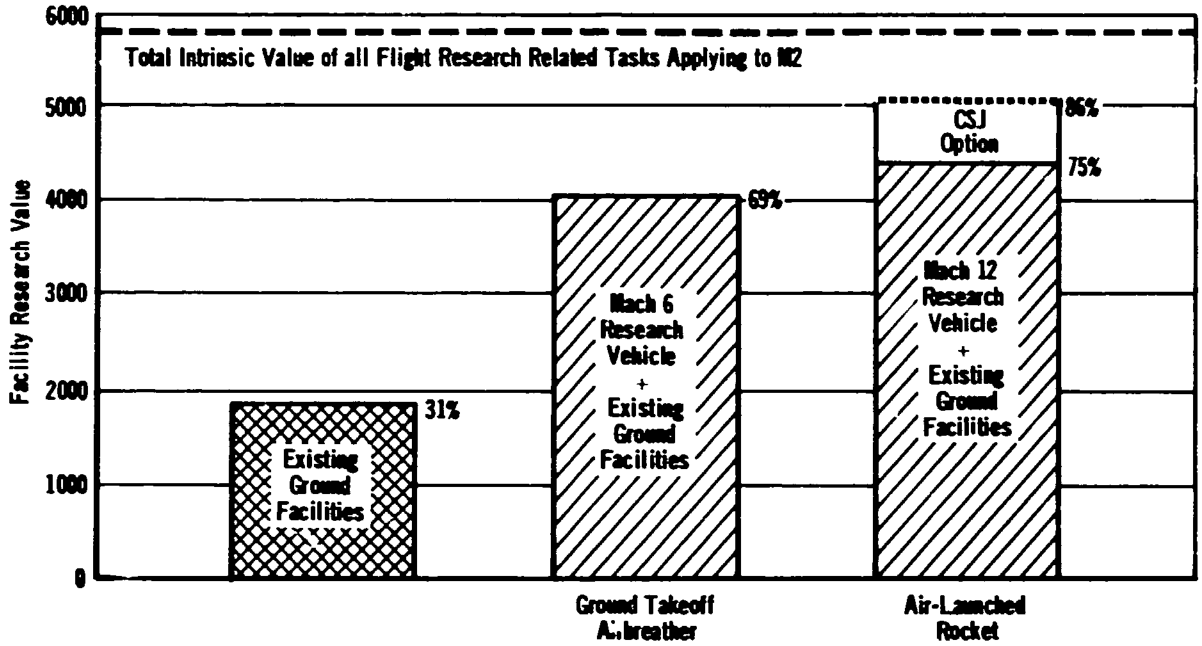
Figure 6-5 contrasts the basic Mach 6 and Mach 12 vehicle capabilities with addition of the CSJ option to the basic Mach 12 vehicle. The dramatic facility enhancement provided by this option is evident. It impacts virtually all technology areas to enable attainment of a Facility Research Value equivalent to 86% of the total intrinsic value of all flight research relevant to M2. If the Scramjet option were used in place of the Convertible Scramjet,thereby closely duplicating the operational vehicle except for weapons capability, the research potential would reach 87%. As a point of reference, existing ground facilities attain 31% of the research goals, with very minor hypersonic propulsion capability included.

6.3 POTENTIAL OF RESEARCH AIRCRAFT ENHANCED BY OPTIONS

The addition of other research options, or modifications to the basic research vehicles, can significantly enhance the basic vehicle research potential, as just illustrated. The sum of all research options will approach total parametric exploration of the operational vehicle profiles. The end result is major improvement in confidence for operational systems development for the entire flight spectrum. It is anticipated that systems demonstration, paralleled by ground facility investigations of configuration alternatives, will allow attainment of confidence levels for development which approach the research goal even though exact configuration similitude may not be demonstrated.

The dramatic increase illustrated for the Convertible Scramjet option to the basic Mach 12 research vehicle extends also to the Scramjet option for that same vehicle. On a characteristic research scale (i. e. in terms of attainment of the total intrinsic value of all flight-research-related tasks applying to a given operational vehicle), the remaining options show only modest increases. Their individual merit, and absolute value, is lost in the mass of numbers unless specific attention is focused to those areas, or Research Tasks, to which these options apply. For this reason, when specific attention is devoted to such areas, the term "Focused Research Value" is employed, as opposed to the "Characteristic Research Value", which applies to the entire set of flight-research-related tasks applying to an operational system.

FIGURE 6-5
A SCRAMJET ADDED TO THE MACH 12 RESEARCH VEHICLE SIGNIFICANTLY INCREASES ITS VALUE FOR A SCRAMJET-POWERED OPERATIONAL SYSTEM
Operational System M2: Military Strike – M12 – RKT/SJ



6.4 FOCUSED RESEARCH POTENTIAL FOR MACH 6 VEHICLE OPTIONS

The basic Mach 6 vehicle, with only two research options, can serve as a good example to further clarify the role of focused research in the analysis of capability enhancement through the addition of options. Figure 6-6 illustrates the characteristic Facility Research Value for the basic vehicle and for each option in terms of attainment of the total intrinsic value of all flight-research-related tasks which apply to each operational vehicle. The options are Thermal Protection System (TPS) and Armament (ARM). The TPS option applies to all operational vehicles, while the Armament option applies only to the military vehicles M1 and M2. On a characteristic basis the increased research value can barely be measured, being no greater than 1%, although the option is absolutely essential for operational vehicle development.

By summing intrinsic values over only those tasks applicable to the options ... operational vehicle, attention is focused on the improvement in re... ...ial for only the relevant tasks, and the differences are no longer ... related research. The research potential attained is indicative ... envelope covered and does not differentiate between ... in regard to difficulty of performing a given objective. ... ...used research assessment are shown in Figure 6-7 for the same options which are evaluated in characteristic terms in Figure 6-6. For the armament option, increases in research potential, on a focused basis, are 68% and 74% of the basic values for M1 and M2, respectively. It was generally found that the unfulfilled portion of the total applicable research (on a focused basis after incorporation of the options) is indicative of the difficulty of attainment of those specific research goals for each operational system. The closer the research vehicle resembles a specific operational system, the greater the research potential in relation to that system. The use of focused values places emphasis on the specific nature of the research in question for each option and allows a quantitative ranking by operational systems.

FIGURE 6–6
ALL MACH 6 FLIGHT RESEARCH OPTIONS SHOW MODEST IMPROVEMENT IN FACILITY RESEARCH VALUE OVER BASIC VEHICLE CAPABILITY

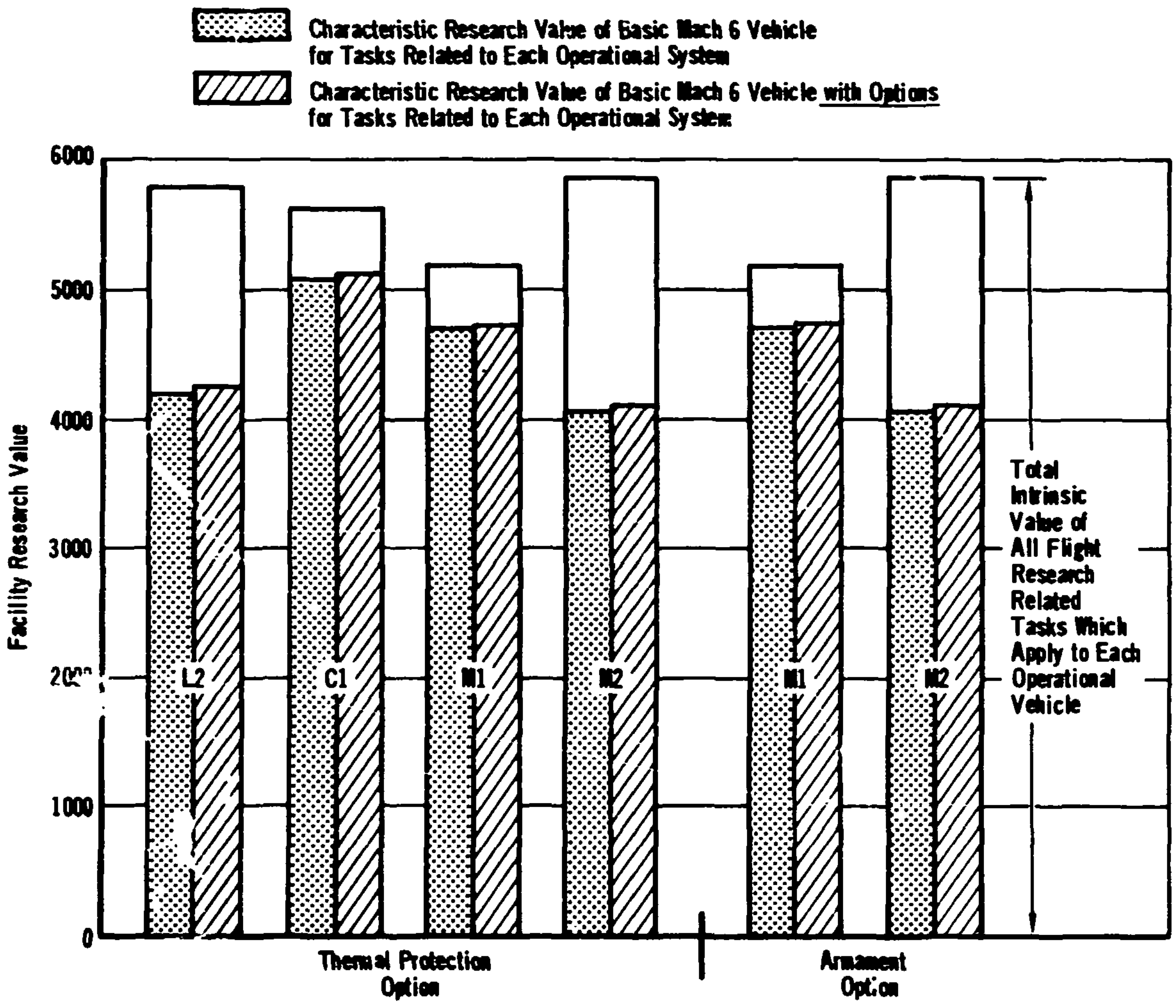
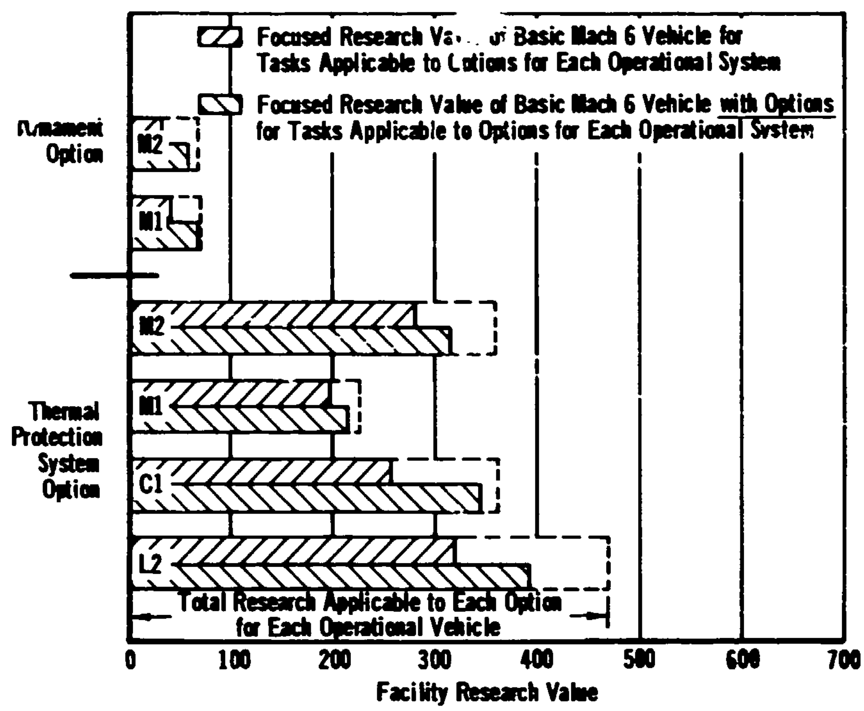


FIGURE 6-7
FOCUSED RESEARCH PROVIDES EMPHASIS FOR THOSE TASKS RELEVANT TO EACH MACH 6 VEHICLE OPTION



6.5 FOCUSED RESEARCH POTENTIAL FOR MACH 12 VEHICLE OPTIONS

Facility Research Values are discussed in this section for each of the operational vehicles on a focused research basis for all Mach 12 vehicle options. The options which apply to all operational vehicles are the airbreathing propulsion options (including subsonic turbojets which provide landing and take-off data), Thermal Protection, and Horizontal Take-off options. The Armament option applies strictly to the military vehicles, while the staging option relates solely to the launch vehicle. The dominant increases shown for the airbreathing propulsion research options are due to their wide impact in all technological areas. This is especially true for the Scramjet and Convertible Scramjet options as they relate to their nearest operational counterparts, M2 and L2, respectively. In addition to showing the improvement in research potential produced by each of these options on a focused basis, Figure 6-8 illustrates again that the research contribution is proportional to simulation of the operational system envelope.

6.5.1 FOCUSED RESEARCH POTENTIAL FOR OPERATIONAL SYSTEM L2 - Research contributions of all individual options for the Mach 12 vehicle are illustrated on a focused basis in Figure 6-9 for the recoverable launch vehicle. As noted earlier, the principal benefit attained is a result of the addition of airbreathing propulsion to the airlaunched rocket. The staging option now comes into prominence and increases the research potential over the basic vehicle by 56% for research related

FIGURE 6–8
RELATIVE FOCUSED RESEARCH VALUE CONTRIBUTION OF SCRAMJET OPTIONS IS INFLUENCED BY OPERATIONAL SYSTEM CRUISE PROPULSION

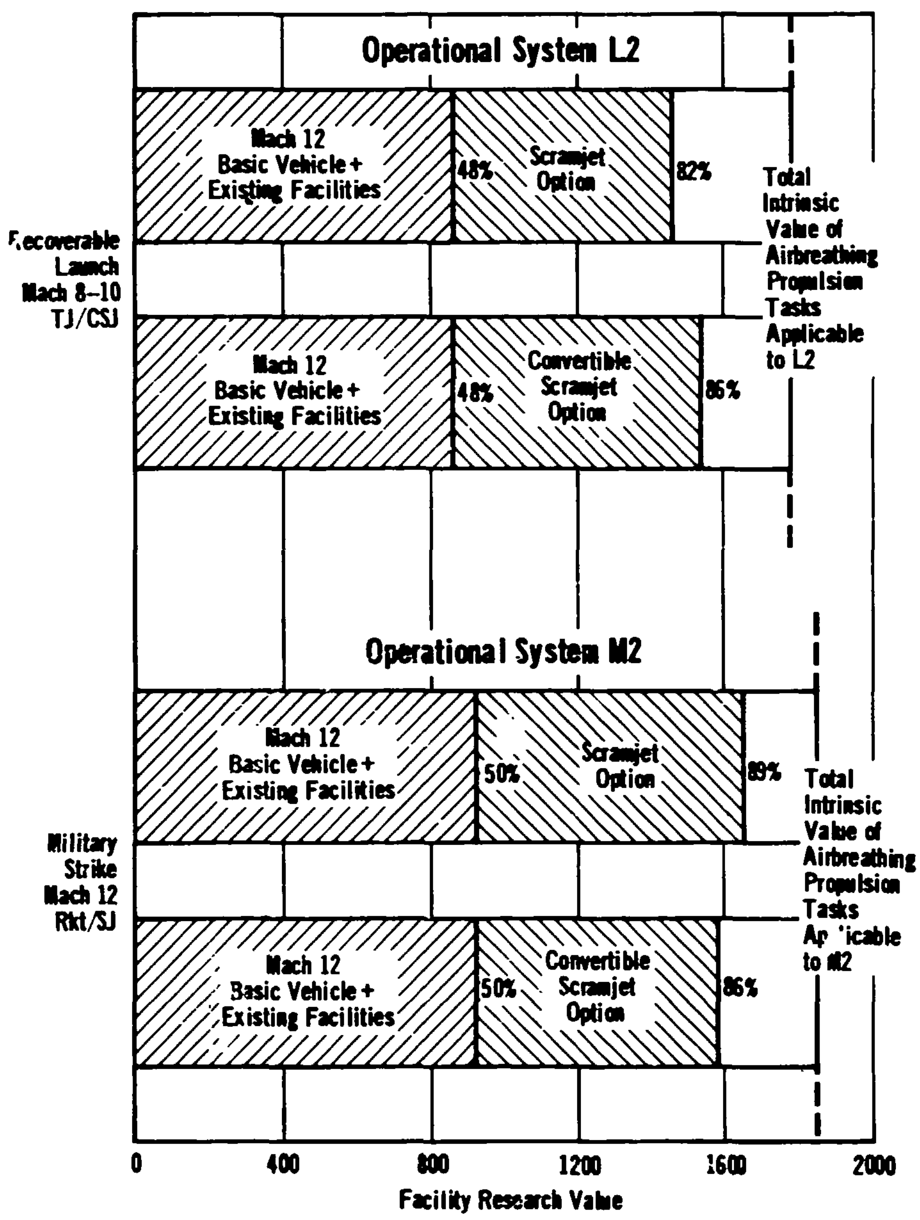
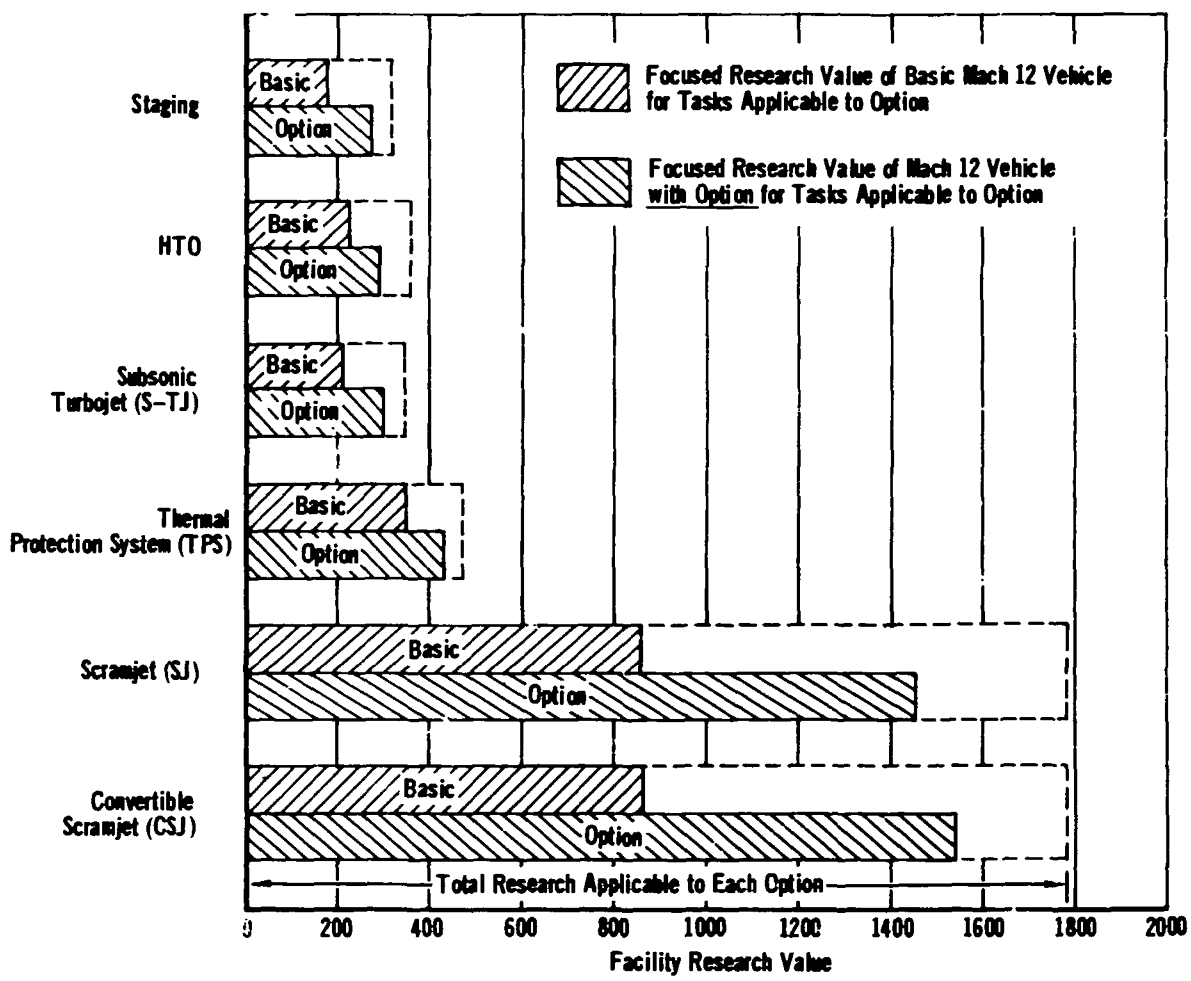


FIGURE 6-9
AIRBREATHING PROPULSION OPTIONS SIGNIFICANTLY IMPROVE FOCUSED RESEARCH POTENTIAL FOR OPERATIONAL SYSTEM L2

Operational System L2: Recoverable Launch M8 to 10 – TJ/CSJ



to staging. The basic vehicle has some capability through definition of a representative undisturbed flow field and operation in the appropriate aerothermal environment. The Horizontal Take-off option provides an increase of about 28.5% over the basic Facility Research Value by virtue of its contribution to low-speed performance definition and configuration development for the all-body shape. The Subsonic Turbojet option provides research in the same flight regime, and also allows investigation of airbreathing inlet controls up to the transonic flight regime while providing steady state operation and extensive maneuvering capability. The relative increase in research potential is 45% for that particular option. The Thermal Protection option provides flexibility for research into other systems concepts, which is reflected by an increase of about 25% over the basic value on a focused basis.

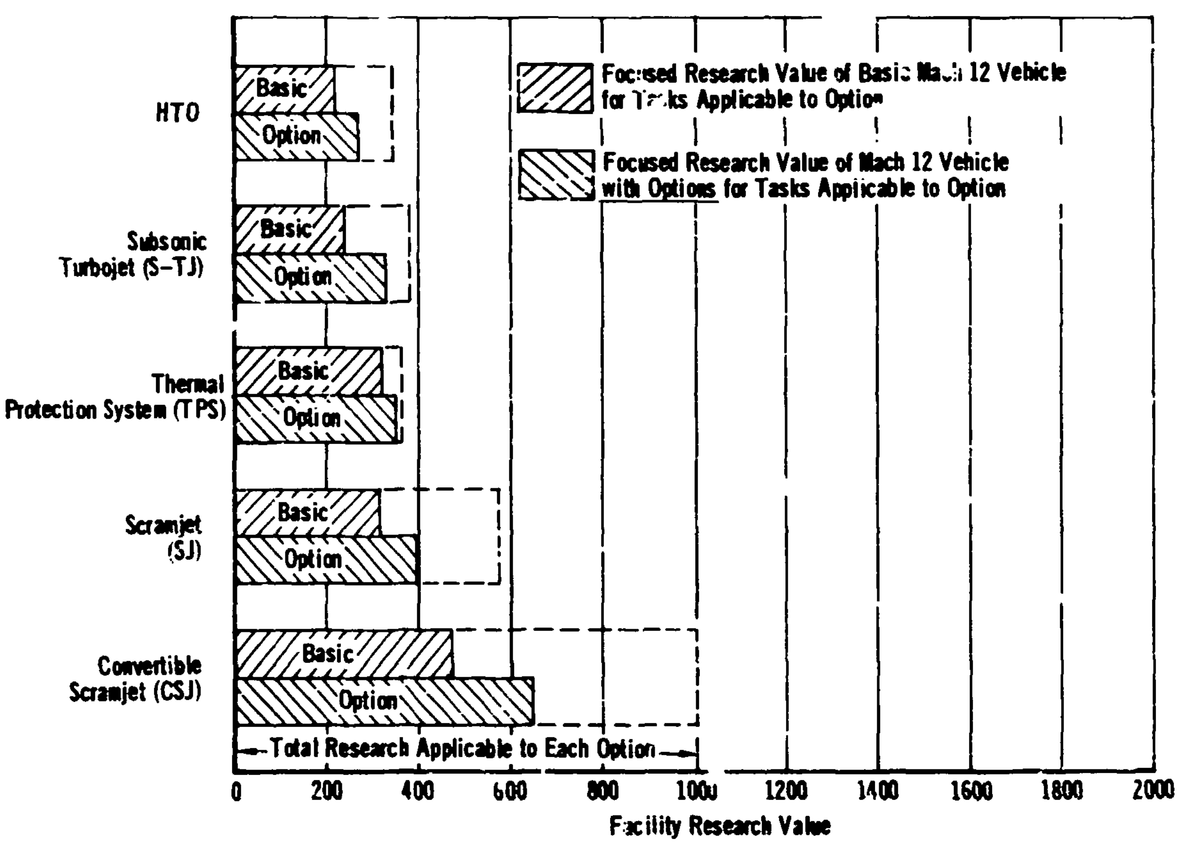
The Facility Research Value in absolute terms represents the quantity of research (in terms of the number of objectives and tasks) applicable to each option. Exact identification of the tasks relating to each option on a focused basis appears in the appendix, along with the quantification of focused research value for each task.

6.5.2 FOCUSED RESEARCH POTENTIAL FOR OPERATIONAL SYSTEM C1 - The basic Mach 12 all-body configuration provides somewhat limited capability (for attainment of the full measure of research goals applicable to the commercial Mach 6 hypersonic transport) when compared to the basic Mach 6 vehicle capabilities noted in the previous sections and illustrated in Figure 6-3. However, even this relatively limited capability can be enhanced by incorporation of the research options to the extent noted in Figure 6-10.

Again, the airbreathing propulsion modifications offer the greatest potential, primarily due to integration tasks and research into component development. The relative increase over the basic vehicle is about 25% and 47% for the Scramjet and Convertible Scramjet options, respectively. For a Mach 6 hypersonic transport with 2-D ramjets, the Convertible Scramjet option would be even more valuable than shown for the turboramjet powered C1 operational system. Since the basic Mach 12 vehicle has little low-speed aerodynamic capability and no ground takeoff provisions, the Subsonic Turbojet and Horizontal Take-off options exhibit a prominent increase in research potential. The Facility Research Value increases 40% and 24% for the Subsonic Turbojet and Horizontal Take-off options, respectively. The thermal protection system for the basic vehicle provides a Facility Research Value which is equivalent to 90% of the total research applicable to the TPS option. This option provides only a modest 8% increase in value over the basic vehicle for tasks related to TPS. Of course, the relatively high research value for the basic vehicle is due to the fact that the research vehicle is equipped with the same thermal protection system as the operational system C1. If the basic research vehicle is equipped with a different TPS, the research value for the basic vehicle decreases and an increase in the value of the TPS option is noted.

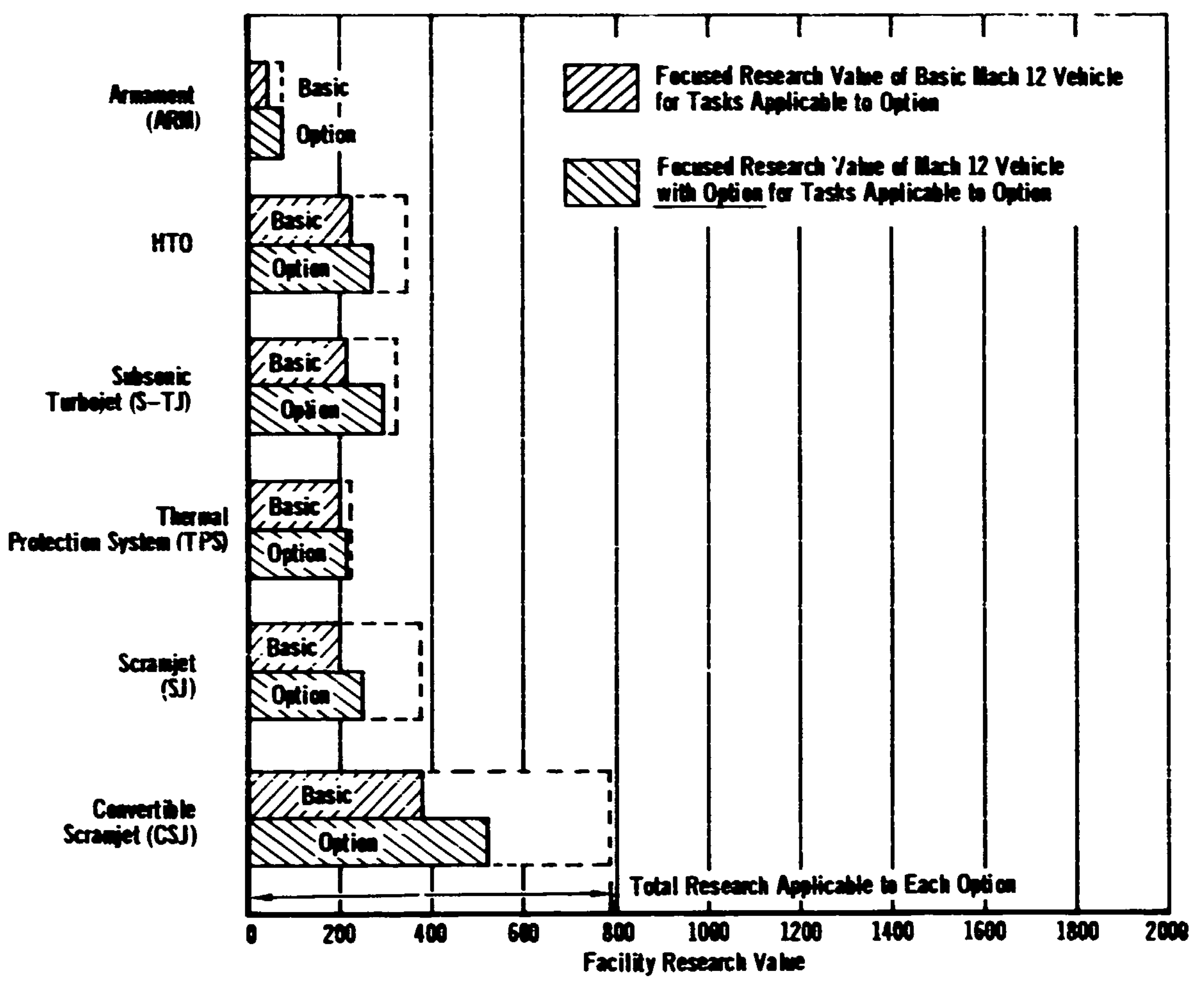
6.5.3 FOCUSED RESEARCH POTENTIAL FOR OPERATIONAL SYSTEM M1 - A similar situation exists for the M1 operational system to that discussed above for C1. The basic Mach 12 vehicle has a substantial flight potential that far exceeds requirements for this operational system. In addition, applicable thermal protection and structural problems are significantly reduced in scope because the operational system employs storable hydrocarbon fuels with an order-of-magnitude reduction in specific fuel volume. Again, the operational capabilities and generally increased flexibility offered by the airbreathing propulsion and horizontal take-off options offer the greatest increase in research potential.

FIGURE 6-10
FOCUSED FACILITY RESEARCH POTENTIAL FOR OPERATIONAL SYSTEM C1 IS ENHANCED BY ALL OPTIONS
Operational System C1: Hypersonic Transport – M6 – TRJ



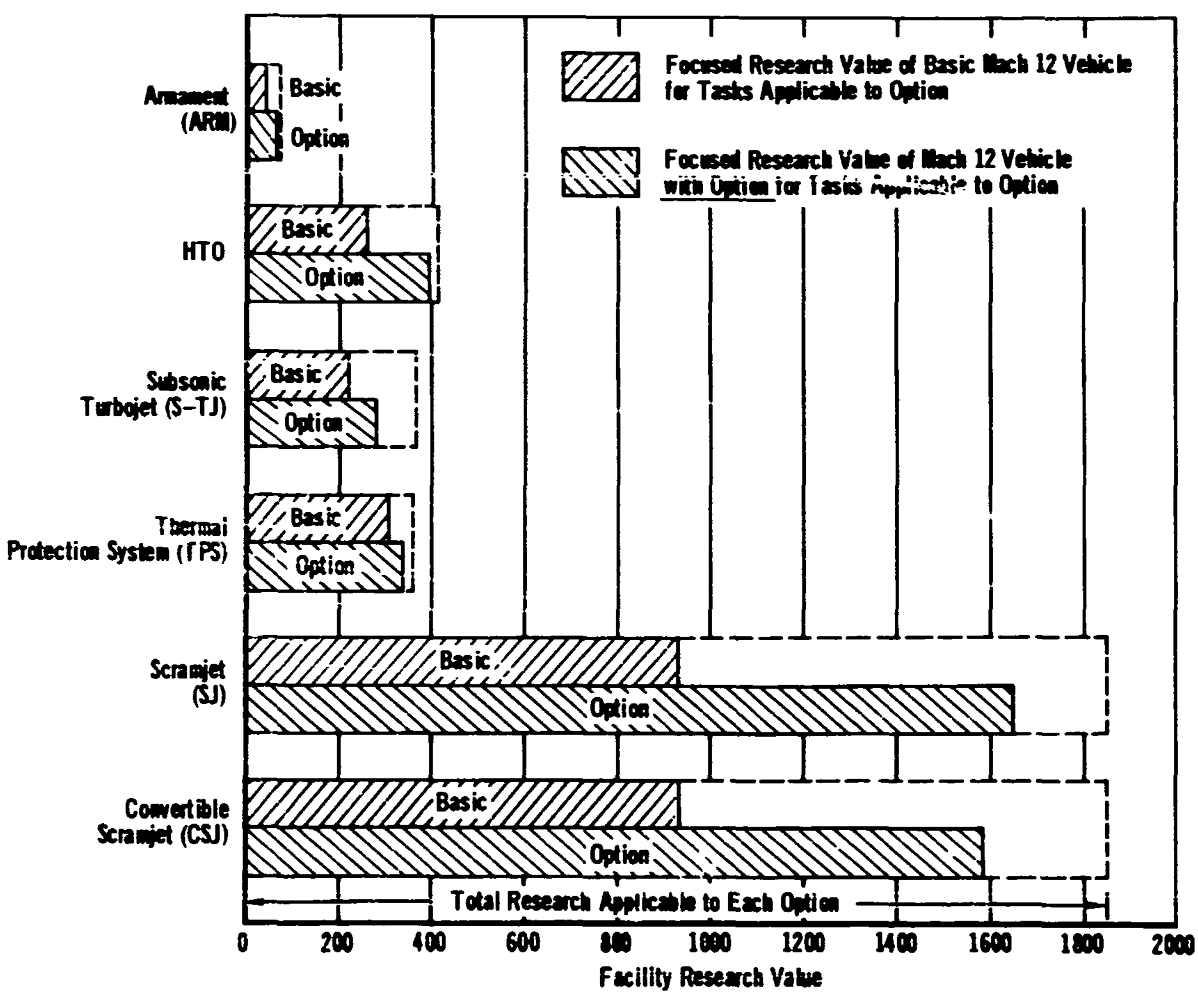
Specific values are illustrated in Figure 6-11 for both the basic vehicle and the options. Again, the thermal protection research requirements are virtually satisfied by the basic vehicle to the extent necessary for high-confidence development of M1. The Armament option is an absolute necessity for the military vehicles, and on a focused basis it provides an increase of 67% over the basic vehicle (which identifies flow field and thermal envelope).

FIGURE 6-11
MODEST IMPROVEMENT IN FOCUSED RESEARCH VALUE IS OBTAINED BY ALL OPTIONS FOR OPERATIONAL SYSTEM M1
Operational System M1: Interceptor – M4.5 – TRJ



6.5.4 <u>FOCUSED RESEARCH POTENTIAL FOR OPERATIONAL SYSTEM M2</u> - The impact of generically tailoring the research vehicle to resemble its operational counterpart is again dramatically demonstrated by Figure 6-12. The addition of the airbreathing options to the basic Mach 12 research vehicle increases the research potential of the basic vehicle by 78% and 72% for the Scramjet and Convertible Scramjet options, respectively. Since the operational system is also rocket-powered for initial acceleration, the Subsonic Turbojet option provides only modest improvement in research potential applicable to the operational vehicle. The Horizontal Take-off option does provide a significant improvement in research potential, however, over the basic airlaunched research vehicle. The improvement for these systems, as referenced to the basic research potential, is 28% for the S-TJ option and 35% for the HTO option. The Thermal Protection option provides an increase in the total research applicable to that option from 85% for the basic vehicle to 95% for the option on a focused research basis. Again, research into armament stowage and delivery techniques is an absolute necessity for development of the operational vehicle. In terms of focused research potential, the armament option provides an increase of 88% over the basic vehicle capability. The use of the research option allows investigation of second body/flow interaction effects as well as enabling active exercise of fire control and antenna systems in the hypersonic environment under equivalent combat conditions.

FIGURE 6-12
MAJOR RESEARCH GOALS FOR SCRAMJET OPERATIONAL VEHICLE CAN BE ATTAINED WITH SJ/CSJ OPTIONS
Operational System M2: Military Strike – M12 – RKT/SJ



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7. GROUND FACILITY RESEARCH POTENTIAL

Facility Research Value is also the measure of research potential used for ground facility evaluation. In this context, the facility research value combines the intrinsic value of the research tasks applicable to an operational vehicle with the capability of a particular ground facility to fulfill the expressed intent of the relevant research tasks.

The data presented allows a direct comparison of the research potential of a particular new ground facility with existing ground facilities of the same class in a consistent set of terms. The following new ground facilities are briefly described and their capabilities presented in terms of improvement over existing capabilities:

GD20	Polysonic Gas Dynamic Research Facility
GD7	Hypersonic Impulse Gas Dynamic Research Facility
E20	Compound Turbomachinery Engine Research Facility
E9	Dual-Mode Ramjet Engine Research Facility
S20	Structures/Fluid Systems Research Facility

A comparison of facility capability to attain research goals for each operational system is presented on both a characteristic and focused basis. The result is a quantified measure of the individual facility potential to provide a high confidence base for development of operational systems.

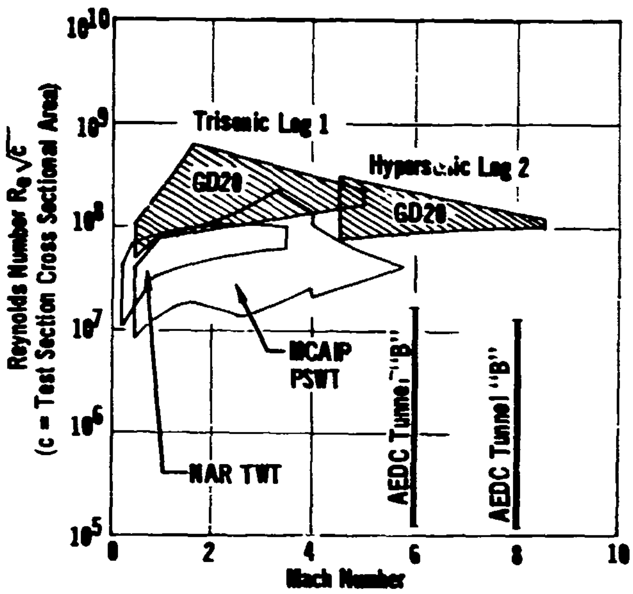
7.1 COMPARISON OF NEW GROUND FACILITIES WITH EXISTING FACILITIES

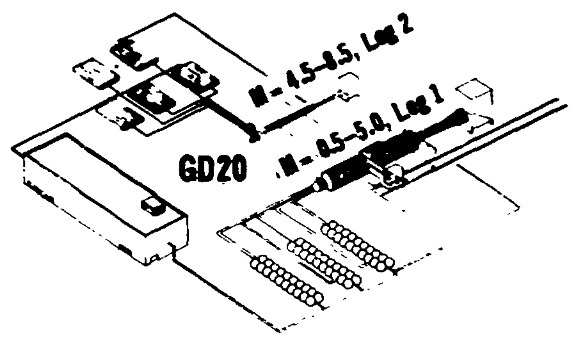
Principal design characteristics are presented for the five selected new ground facilities and compared to existing facilities capabilities. Comparisons are made on the basis of basic characteristics (Reynolds number Mach number, total temperature, pressure and air-flow), size, facility availability (test time), costs, and research potential. Facility Research Values are presented on a characteristic basis and are expressed in terms of relative improvement over existing capability.

7.1.1 POLYSONIC GAS DYNAMIC RESEARCH FACILITY (GD20) - One of the selected new ground facilities is a polysonic intermittent blowdown wind tunnel which incorporates two test legs, trisonic (Mach .5 to 5.0) and hypersonic (Mach 4.5 to 8.5). The test section size for each leg is considerably larger than currently available in existing facilities, and run time is comparable. Specific details of the Reynolds number/Mach number envelope are compared in Figure 7-1 along with operating costs, geometric characteristics, and an isometric view of the facility layout.

Figure 7-2 illustrates the incremental improvement in Facility Research Values attained by the use of GD20 for each of the operational systems. Values shown reflect research relative to the requirements for each operational system. For the comparison, greater confidence in facility capability to perform the required research is generally indicated by increased absolute values for research potential.

FIGURE 7-1
POLYSONIC GAS DYNAMICS RESEARCH FACILITY





Facility Comparisons

Facility Characteristics		$GD20_1$	$GD20_2$	**NAR TWT	MCAIR PSWT	AEDC Tunnel "B"
Test Section Size	(Ft)	16 x 16	12 x 12	7 x 7	4 x 4	4.2 D
	(M)	4.9x4.9	3.7 x 3.7	2.1 x 2.1	1.2 x 1.2	1.3D
Mach Number Range		0.5–5.0	4.5–8.5	0.2–3.5	0.5–5.8	6.8
Run Time (Sec)		10–90	10–50	0.5–4.5	3–4.5	Continuous
Runs Per Shift		8	8	16	16	16
Acquisition Cost (1970 Dollars)		145,943,000		26,000,000	7,000,000	28,300,000
Operating Costs (Dollars Per Shift)		1525	1525	Not Avail.	2000*	8,000

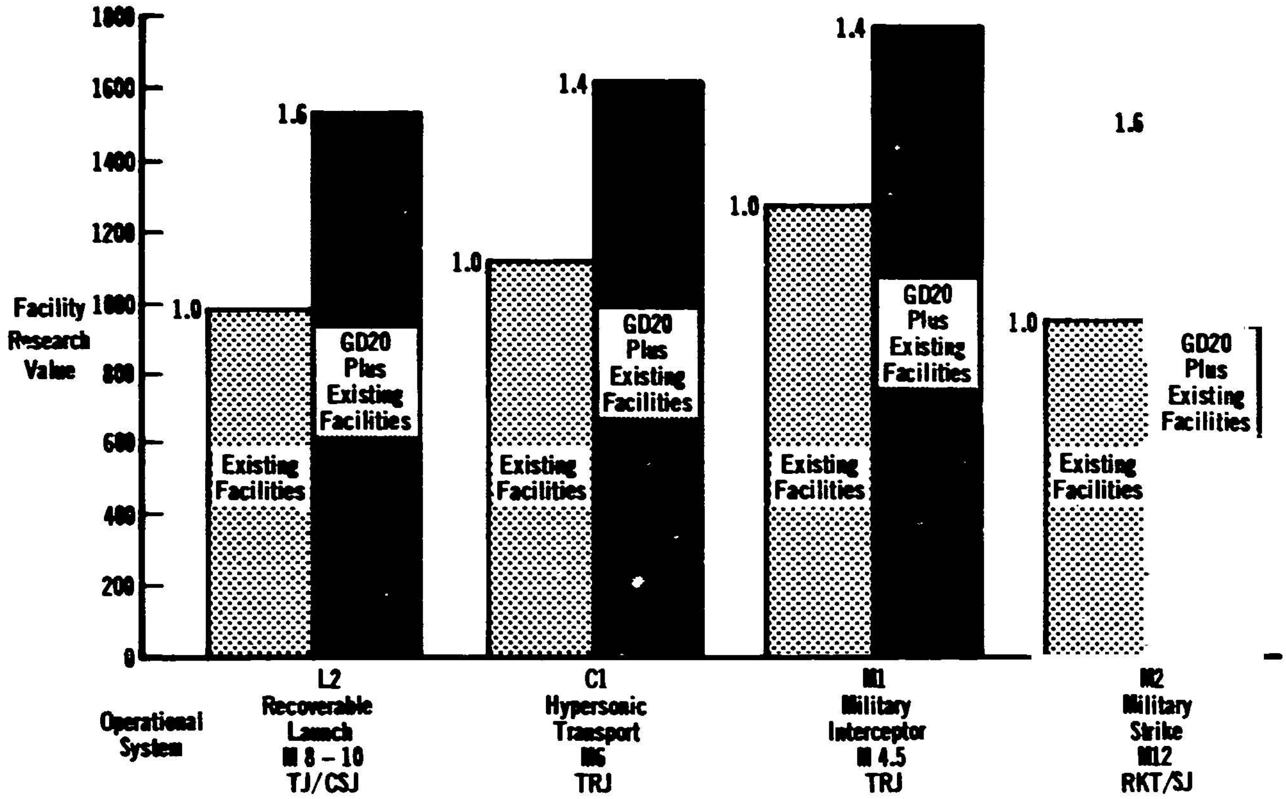
**North American Rockwell Trisonic

*Government

GD20 Average Facility Research Value Improvement Over Existing Facilities $\boxed{50\%}$

FIGURE 7-2
VERSATILE NEW GAS DYNAMIC FACILITY INCREASES HYPERSONIC RESEARCH POTENTIAL

GD20 Range = M 0.5 to 8.5

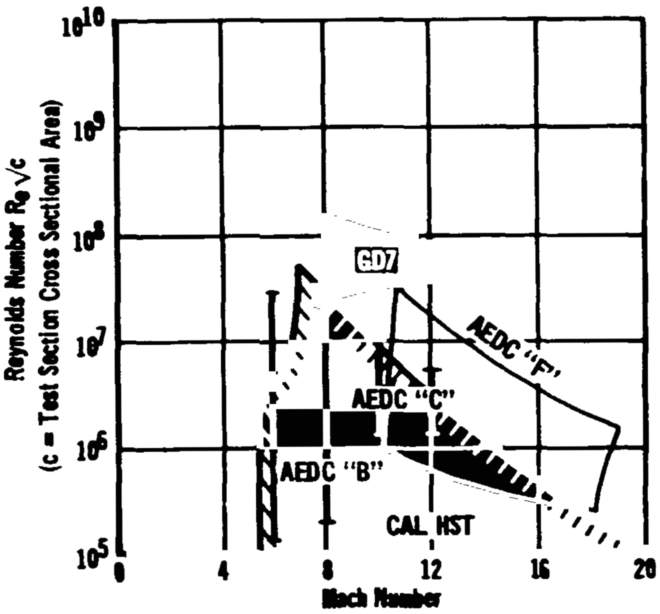


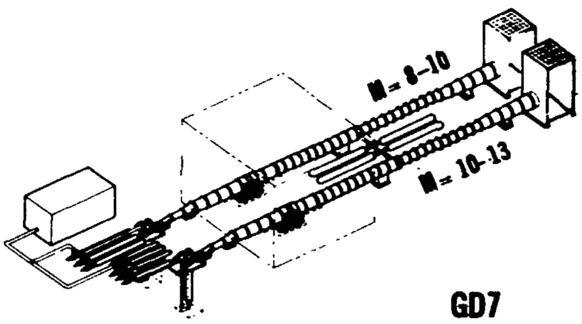
Relative improvement is a function of both new capability and existing levels. For example, a greater relative improvement is shown for Research Tasks related to L2 and M2. The slightly lower improvement shown for C1 and M1-related tasks reflects two major factors: (1) higher confidence in existing facility capabilities to perform aerodynamic research to Mach 6 and (2) operational vehicle (M1 and C1) high speed requirements less than the full potential available in the new polysonic tunnel, with its Mach 8.5 capability. The lower confidence levels resulting from generally decreased existing facility capability (to cover the entire Mach number range) for M2 and L2, coupled with the increased capability provided by GD20, are reflected in the attainment of a larger relative improvement for the M2 and L2 vehicles, as illustrated in the bar chart.

Typical use of the GD20 facility is directed toward aerodynamic configuration development from a performance, stability and control standpoint; propulsion system integration; shock interaction/flow field definition throughout the applicable flight regime; and buffet onset for particular vehicle configurations.

7.1.2 <u>HYPERSONIC IMPULSE GAS DYNAMIC RESEARCH FACILITY</u> (GD7) - The second new wind tunnel facility is a gas piston impulse tunnel with two test legs and an additive operational range from Mach 8 to 13. Run time can reach four seconds, and the test section is substantially larger than those existing in comparable existing wind tunnel facilities. The operating profile is compared with existing facility capabilities in Figure 7-3, which also tabulates fundamental size and cost data. A three-dimensional illustration of the facility is included.

FIGURE 7-3
HYPERSONIC IMPULSE GAS DYNAMIC RESEARCH FACILITY





Facility Comparisons

Facility Characteristics		GD7	AEDC "B"	AEDC "C"	AEDC "F"	*CAL HST
Test Section Size	(Ft)	10 D	9.2 D	9.2 D	4.5 D	2D
	(M)	3.0D	1.3 D	1.3 D	1.4 D	0.6 D
Mach Number Range		8-13	6,8	10,12	10-19	7-22
Run Time		1-4 Sec	Continuous	Continuous	50-200 ms	2-6 ms
Runs Per Shift		4	16	16	2	6-8
Typical Data Points Per Run		30	30	30	1	1
Acquisition Cost (1970 Dollars)		26,606,000	28,300,000	26,900,000	7,150,000	1,000,000
Operating Costs (Dollars Per Shift)		13,840	8,000	10,400	7,200	2,600

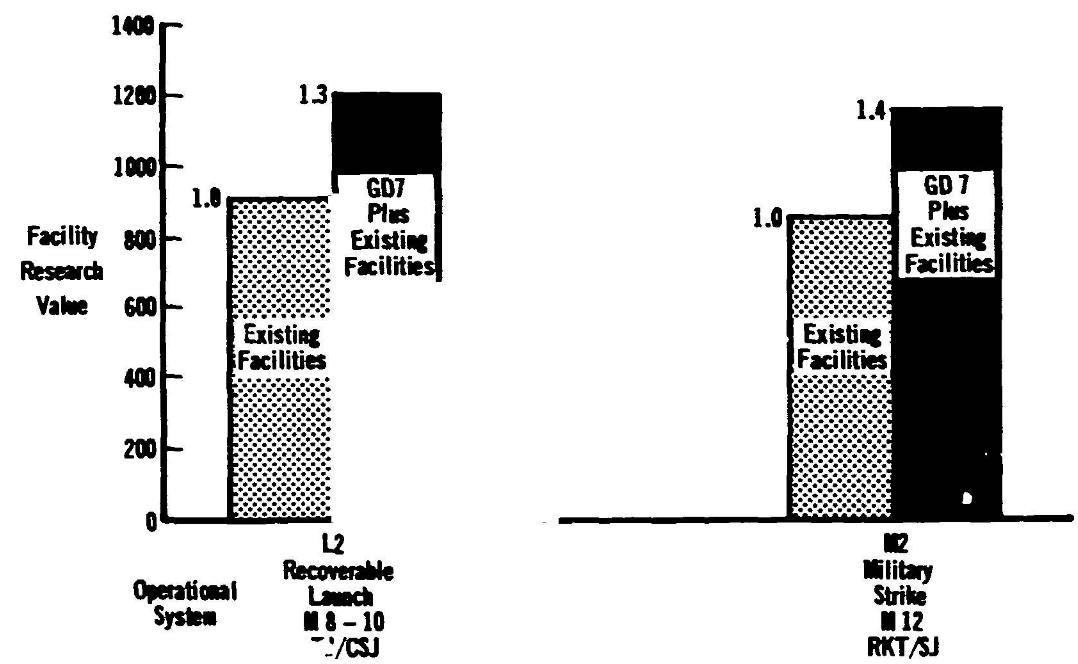
*Cornell Aero. Lab. Hypersonic Shock Tunnel

GD7 Average Facility Research Value Improvement Over Existing Facilities $\boxed{35\%}$

The overall capability provided allows extension of characteristic aerodynamic configuration development well into the hypersonic range. Typical studies include flow field definition and shock wave interaction phenomena as well as incorporation of performance, stability, and control data. Additional use may be gained in the examination of inlet location, hypersonic boundary layer transition, and investigation of scaling laws for hypersonic flight.

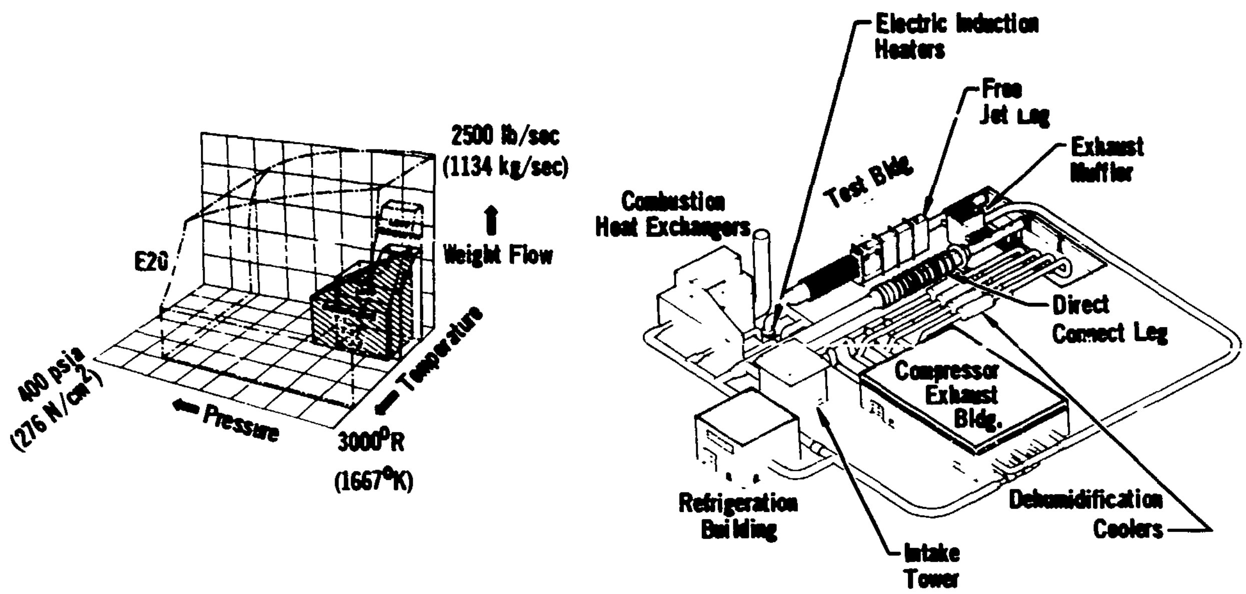
The GD7 facility operational range is higher than the maximum speed requirements of either the M1 or C1 operational vehicles. Therefore, application of that facility is limited to Operational Vehicles L2 and M2. For each of the latter, the new facility provides the same absolute increment in research value. Because existing capabilities are used as a basis for comparison in Figure 7-4, the relative improvement of 1.3, as applied to the L2 vehicle, is less than that for the operational vehicle M2 (with a relative value of 1.4). The evaluation primarily reflects adaptation of facility parametric capability (e.g., Mach number) to operational system requirements.

FIGURE 7-4
NEW HYPERSONIC TUNNEL INCREASES RESEARCH POTENTIAL FOR APPLICABLE OPERATIONAL SYSTEMS
GD7 Range = M 8 to 13



7.1.3 COMPOUND TURBOMACHINERY ENGINE RESEARCH FACILITY (E20) - An attractive new engine test facility has been designed and compared with both existing and planned turbine engine test facilities, in terms of fulfillment of required research goals for the operational vehicles. Figure 7-5 depicts the facility operating envelope in terms of air flow and true temperature similitude. As shown in the accompanying sketch of the facility, both direct connect and free jet legs are included, with Mach number simulation from .3 to 5.5.

FIGURE 7-5
COMPOUND TURBOMACHINERY ENGINE RESEARCH FACILITY



Facility Comparisons

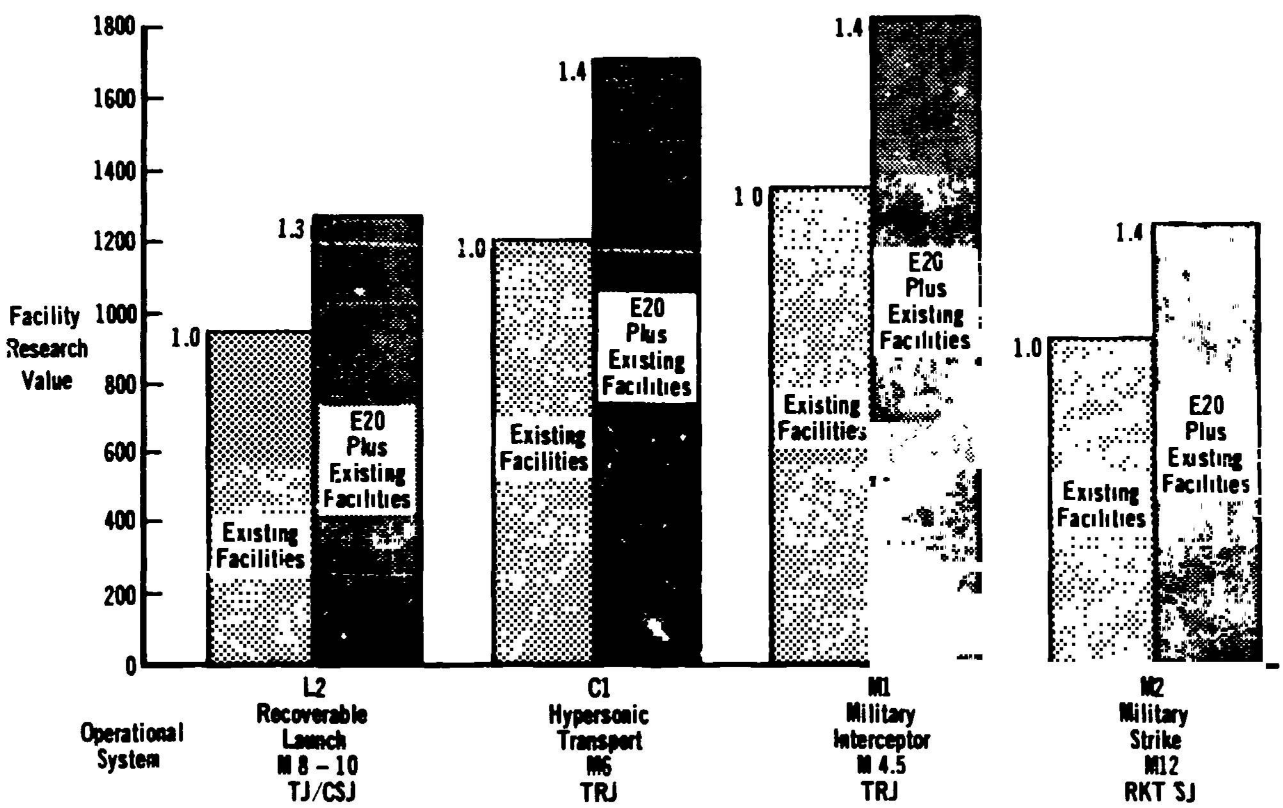
Facility Characteristics		E20 Direct Connect	E20 Free Jet	AEDC LETF Dir. Connect	AEDC T-1,T-2 Dir. Connect	AEDC J-2 Free Jet
Test Cell Size	(ft)	7.5 D	8x4.5	12 D	13.3D	20 D
	(m)	2.3 D	2.4 x 1.4	3.7 D	4.1 D	6.1 D
Mach No. Range		0.3-5.5	0.3-5.0	0-3.0	0-3.0	0-3.0
Maximum Thrust Measurements	(lb_f)	100,000	100,000	75,000	30,000	40,000
	(kg)	45,359	45,359	34,019	13,608	18,144
Maximum Altitude	(ft)	120,000	116,000	80,000	80,000	80,000
	(m)	36,576	35,357	24,384	24,384	24,384
Maximum Run Time		Continuous	Continuous	Continuous	Continuous	Continuous
Acquisition Cost (1970 Dollars)		381,262,000		Planned	Not Avail.	Not Avail.
Operating Costs (Dollars Per Shift)		56,000		Facility	Not Avail.	Not Avail.

E20 Average Facility Research Value Improvement Over Existing Facilities $\boxed{38\%}$

The facility provides a capability to perform extensive high-mass-flow, full-scale turboramjet research with a continuous run capability in an equivalent Mach 5 environment at flight dynamic pressures (2000 psf, 9.6 N/cm^2). In addition, true temperature structural and thermodynamic testing can be accomplished in an oxidizing environment. Reduced test section size at high flow rates and pressures enable simulation of up to Mach 1.2 at sea level conditions. As a result, incorporation of this facility into the research inventory provides a significant increase in research potential for the operational vehicles.

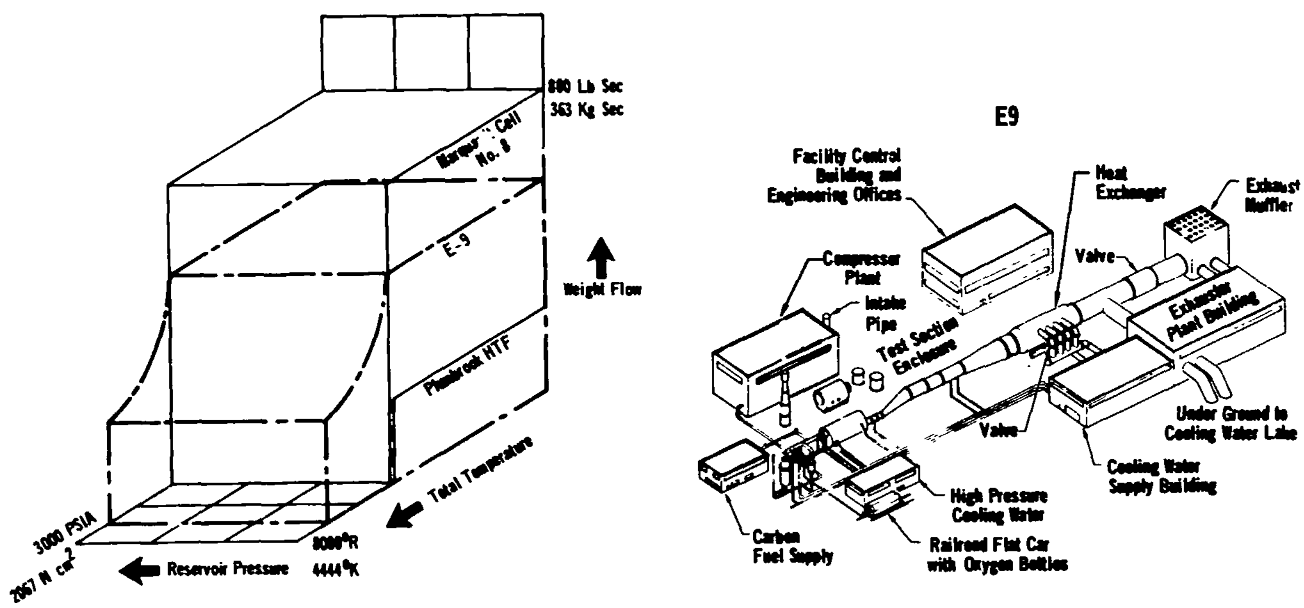
Figure 7-6 illustrates the improvement in research potential on both an absolute and relative scale for each operational vehicle. Principal contribution on an absolute basis is realized for research applicable to development of the Mach 4.5 and Mach 6 turboramjet engines through near conventional PFRT and MQT ratings. The bulk of the capability for research applicable to the higher Mach number vehicles involves structures, materials, and controls development up to about 2500°R (1384°K). Since L2 incorporates both a turbojet and subsonic combustion ramjet (convertible scramjet), some engine research potential can be realized up to the limits of facility capability (Mach 5.5).

FIGURE 7-6
NEW TURBINE/RAMJET ENGINE TEST FACILITY IMPROVES RESEARCH CAPABILITY ACROSS OPERATIONAL SPECTRUM
E20 Range = M 0 to 5.5



7.1.4 <u>DUAL MODE RAMJET ENGINE RESEARCH FACILITY (E9)</u> - Airbreathing propulsion research into the hypersonic flight regime requires a significant extension of current facility capability in terms of true temperature capability at high Mach number and relatively large size. The E9 engine research facility, illustrated in Figure 7-7, represents a breakthrough in heated facility capability by permitting low-cost

FIGURE 7-7
DUAL MODE RAMJET ENGINE RESEARCH FACILITY



Facility Comparisons

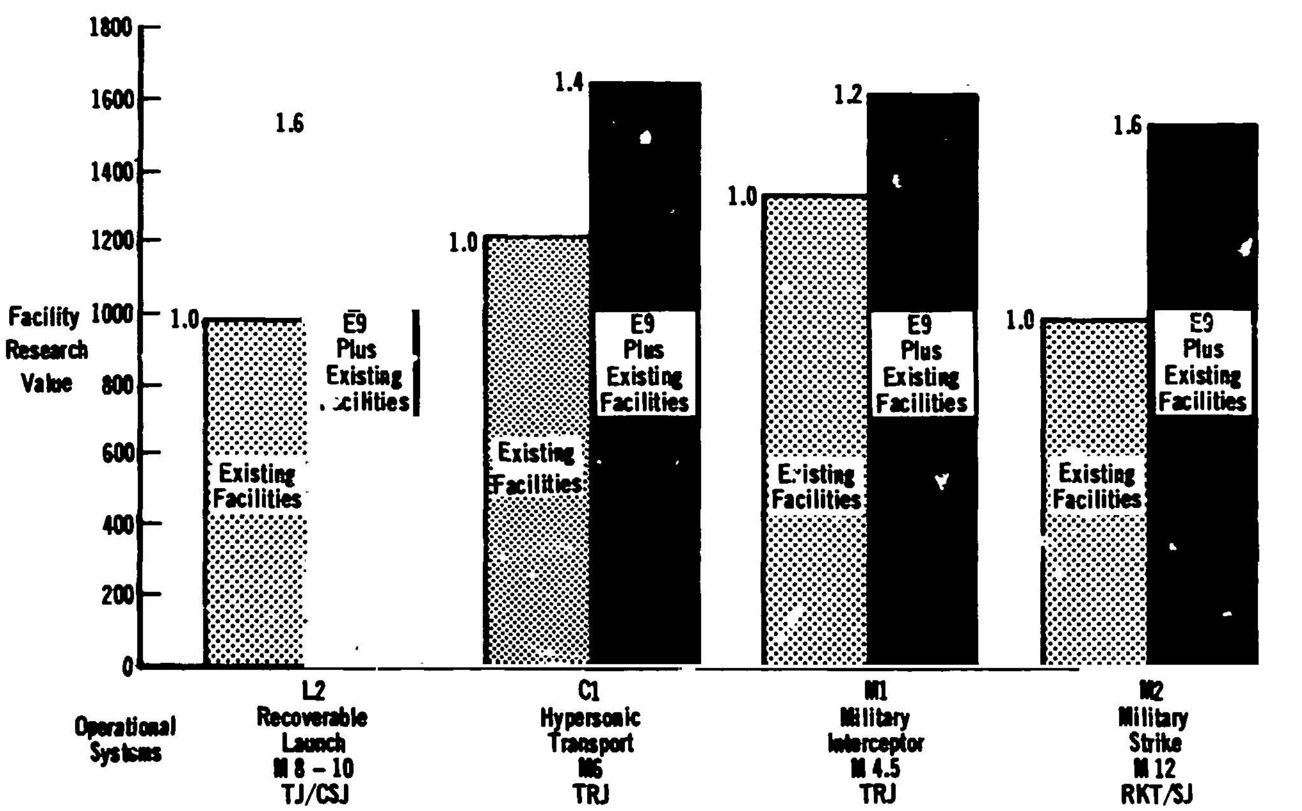
Facility Characteristics		E9	Plumbrook	Marquardt Cell No. 8
Maximum Engine Inlet Area	(ft^2)	10	9.6	5.6
	(m^2)	3.0	2.9	1.7
Mach No. Range		3-9	5,6,7	1-6
Maximum Thrust Measurement	(lb$_f$)	100,000	20,000	100,000
	(kg)	45,359	9,072	45,359
Maximum Altitude	(ft)	145,000	130,000	170,000
	(m)	44,196	39,624	51,816
Maximum Run Time		Continuous	120-180 Sec	Continuous
Acquisition Cost (1970 Dollars)		$147 Million	Not Available	3,000,000
Operating Costs (Dollars Per Shift)		58,400	Not Available	24,560

E9 Average Facility Research Value Improvement Over Existing Facilities **45%**

operation with an intermittent clean air capability to a true temperature of 4500°R (2500°K). A continuous run capability with vitiated (but combustible) air to 7000°R (3889°K) is also available. The principal improvements over existing facilities are: (1) the greatly increased model size; (2) duplication of flight conditions from Mach 3 to Mach 10; (3) availability of 20% free oxygen for combustion; and (4) a new concept in heating using a carbon combustion process for inexpensive operation and less than 4% water vapor in the vitiated stream. In addition, the use of an aerodynamic nozzle allows non-true temperature testing to Mach 12.

Although designed primarily for scramjet engine research at representative flight conditions, the E9 facility provides an excellent capability to enable low-cost PFRT and MQT of a hypersonic ramjet engine module. Other advantages include a capability to perform hypersonic aerothermodynamic research, thermal protection systems evaluation and basic materials research/structural tests in a realistic flight environment. Facility application is not restricted to the M2 and L2 operational vehicles. The lower facility limit is Mach 3, which enables thorough coverage of the upper end of the C1 and M1 aerothermal and ramjet propulsion mode research requirements. Inspection of Figure 7-8 reveals about the same absolute capability in terms of Research Value for the specific kinds of research relevant to each oper-

FIGURE 7–8
NEW RAMJET ENGINE TEST FACILITY SHOWS DOMINANT IMPROVEMENT FOR SCRAMJET-POWERED OPERATIONAL SYSTEMS
E9 Range = M 3 to 12



ational system. As might be anticipated, a slightly higher absolute value of research potential is noted for the C1 and M1 operational systems. Again, this is an indication of the matching of the vehicle Mach range with facility capabilities, and is even more dramatically explained by a comparison of the research potential of existing facilities. A comparable absolute value of research potential exists for the M2 and L2 vehicles. The latter point becomes evident when comparing facility environmental envelope with vehicle environmental envelope. The high relative research values obtained by comparing new facility capabilities with existing values denotes the extent of existing facility shortcomings for research involving hypersonic airbreathing propulsion.

7.1.5 <u>INTEGRATED STRUCTURES/FLUID SYSTEMS RESEARCH FACILITY S20</u> - The S20 facility represents an integration of the major static research capabilities into a single complex. There are three independent facilities in one location. These consist of: structural static test facility with thermal, acoustic, and altitude simulation capabilities; hazardous fuels test area with thermal and cryogenic capabilities; and a dynamic slosh/acceleration track for large-scale cryogenic tankage.

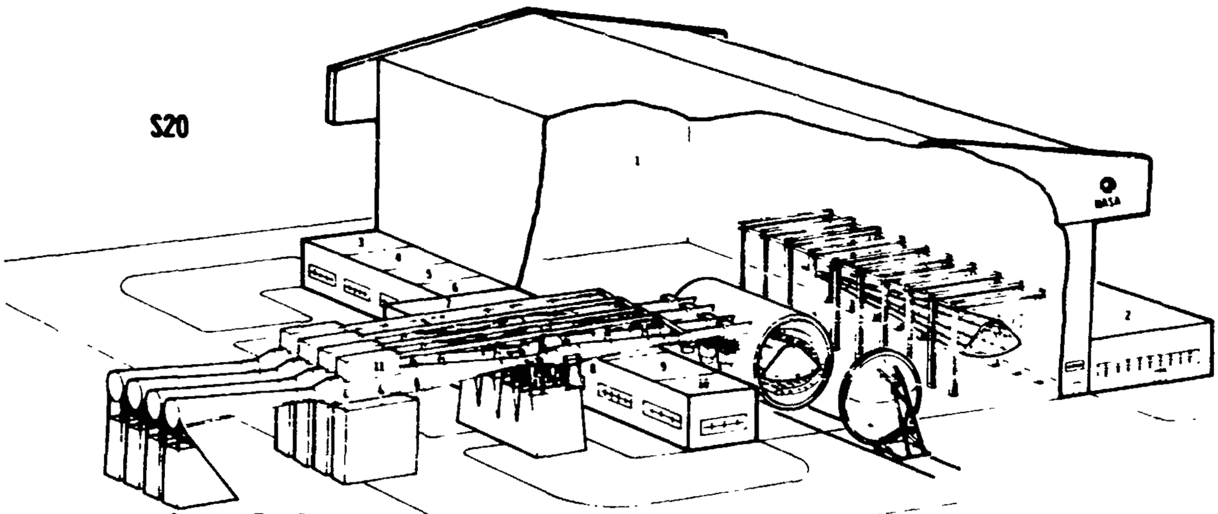
The structural facility is large enough to enable full-scale research of major structural assemblies with combined mechanics/thermal loads, and simulation of altitude and acoustical environments to allow in-depth examination of significant interactions. The slosh test track will subject realistically-sized tank configurations to sustained acceleration and vibration similitude throughout the operating envelope. Hazardous testing, such as research into regenerative hydrogen heat exchange and rapid servicing techniques, can also be accommodated within the complex illustrated in Figure 7-9. Representative capabilities of existing facilities are presented in tabular form for comparison with the parametric range of values shown for S20.

Facility Research Value increases markedly for S20, as shown in Figure 7-10, and is influenced by two factors. The dominant influence is whether or not the cryogenic capability is applicable. Since M1 is a storable hydrocarbon system, the Facility Research Value is noticeably low relative to other operational systems. L2, C1, and M2 all employ cryogenic hydrogen. Since the primary activity accomplished in the facility is structures, thermal protection, and subsystems research, the absolute Facility Research Value can be interpreted as representative of the difficulty of accomplishing the research as it applies to a given operational system. The increase in research potential relative to existing facilities is slightly greater for the higher Mach number system, reflecting the increased influence of the thermal simulation capability.

7.2 FOCUSED RESEARCH POTENTIAL FOR NEW GROUND FACILITIES

Improvements in research potential over existing facilities have been identified in terms of both characteristic and focused facility research values. The data presented in Section 7.1 is an assessment of the research potential of each of the new facilities in the manner in wh[illegible] the facility would be used - in a role which is characteristic of actual facility potentia[illegible] Since it is also desirable to have a means by which the specific performanc[illegible] [illegible]ility can be quantified in terms indicative of how well specific [illegible] may be satisfied, attention was focused on those specific tasks which do[illegible] [illegible]equirement for design and construction of a new research facility. The [illegible]ch Tasks were screened according to their

FIGURE 7–9
INTEGRATED STRUCTURES/FLUID SYSTEMS RESEARCH FACILITY



1 High Bay Structural Test Area
2 Offices
3 Acoustic Research Cell
4 Vibration and Acoustic Control Room
5 Thermal Acoustic Research Cell
6 Vibration Shaker Power Supply and Equipment Room

To Remote Site

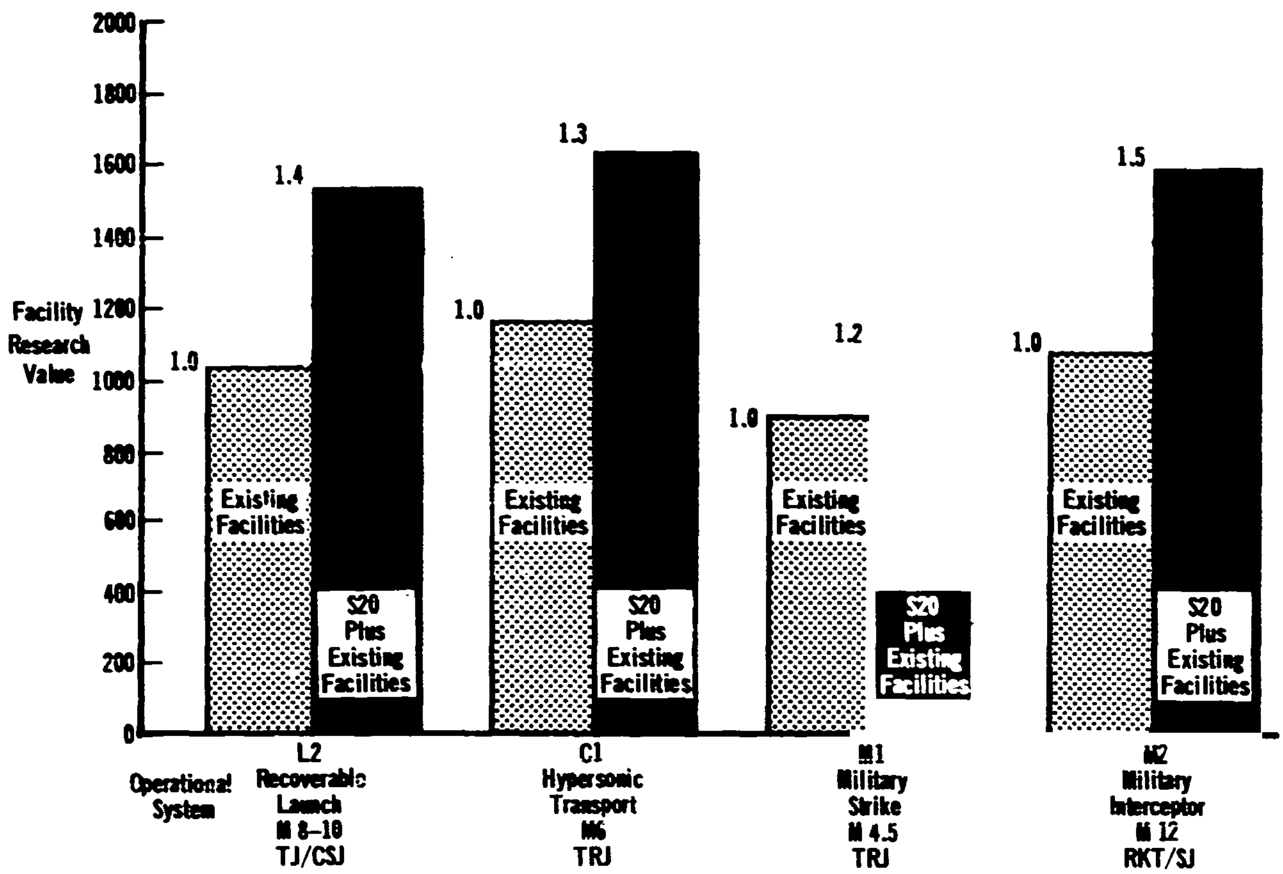
7 430 MW Substation for Thermal Testing
8 Mechanical Equipment Room
9 Altitude Chamber Control Room
10 Steam Ejector Control Room
11 Chemical Steam Ejector for Altitude Chamber

Facility Comparisons

Facility Characteristics	S20 Capability	Existing Capability	Existing Facility	Acquisition Cost – $
Max. Thermal System Power (kVA) Heating Rates Attainable (°F/Sec) (°C/Sec)	400,000 0–30 0–17	50,400 (5 Min.) Not Available Not Available	Air Force Flight Dynamics Lab - Structural Test Facility	19,965,000
Altitude Chamber Size (Ft) (m) Max. Altitude (Ft)/Time to Altitude (Sec) (m)/Time to Altitude (Sec)	8 D x 110 L 2.4 D x 33.5 L 146,000/4 44,500/4	39 D Sphere 11.9 D 400 000/27.000 121,920/27.000	McDonnell Douglas Astronautics Company Western Division- Space Simulation Lab.	5,000,000
Acoustic SPL/Power (db/MW) Acoustic Frequency (Hz)	170/4.8 15/10,000	174/1.0 50/10,000	Air Force Flight Dynamics Lab - Sonic Fatigue Facility	19,000,000
Mechanical Load Channels Max. Load/Channel (Lb) (Newtons) Max. Load Rate (Lb/Sec)/ Cycling Rate (Hz) (N/Sec)/Cycling Rate (Hz)	200 50,000 222,400 400,000/0–5 1,779,200/0–5	55 0–100,000 0–445,000 Not Available Not Available	Naval Air Development Center - Aero Structures Test Facility	29,000,000
Number of Shakers/Max. Force (Lb, RMS) (N, RMS) Frequency Range (Hz)	20/39,000 20/148,000 30–3000	46/28,000 46/125,000 5–10,000	National Aeronautics and Space Admin Manned Spacecraft Center - Vib & Acoustic Test Facility	7,000,000
Cryogenic Tankage and Control System (Ft^3) (m^3) Cryogenic Pumping (gpm) (lpm)	50,000 1415 60,000 227,100	1340 38 Not Available Not Available	Air Force Flight Dynamics Lab - Structural Test Facility	Included Above
Acquisition Costs (1970 Dollars) Operating Costs (Dollars/Shift)	239,351,000 80,000			79,965,000 Not Available

S20 Average Facility Research Value Improvement Over Existing Facilities $\boxed{35\%}$

FIGURE 7-10
NEW STRUCTURES FACILITY INCREASES RESEARCH POTENTIAL
OVER EXISTING BASE



defined technology area and facility application as determined in the analysis of facility capability and test methods described in Sections 4 and 5. A matrix is presented in Figure 7-11 to illustrate, by facility, the numbers of focused and characteristic tasks and their distribution by technology category. The coding used is explained immediately to the right of the matrix, i.e., the upper left portion of each box defines how many focused tasks exist for each facility in a technical area;

FIGURE 7-11
IDENTIFICATION OF FOCUSED RESEARCH REQUIREMENTS

Technical Area \ Ground Facilities	GD7	GD20	E9	E20	S20
Aerodynamics	12 / 33	14 / 33	0 / 13	0 / 13	0 / 0
Thermodynamics	4 / 20	4 / 21	2 / 21	2 / 21	0 / 4
Structures and Materials	0 / 7	0 / 7	0 / 18	0 / 17	12 / 32
Propulsion	1 / 17	1 / 17	9 / [illegible]	6 / 25	0 / 3
Subsystems	0 / 10	0 / 10	0 / 12	0 / 12	2 / 22
Operation	0 / 4	0 / 4	0 / 4	0 / 4	0 / 8
Total	17 / 87	19 / 98	11 / 94	8 / 92	14 / 69

Number of Focused Research Tasks / Number of Characteristic Research Tasks

Primary Research Contribution

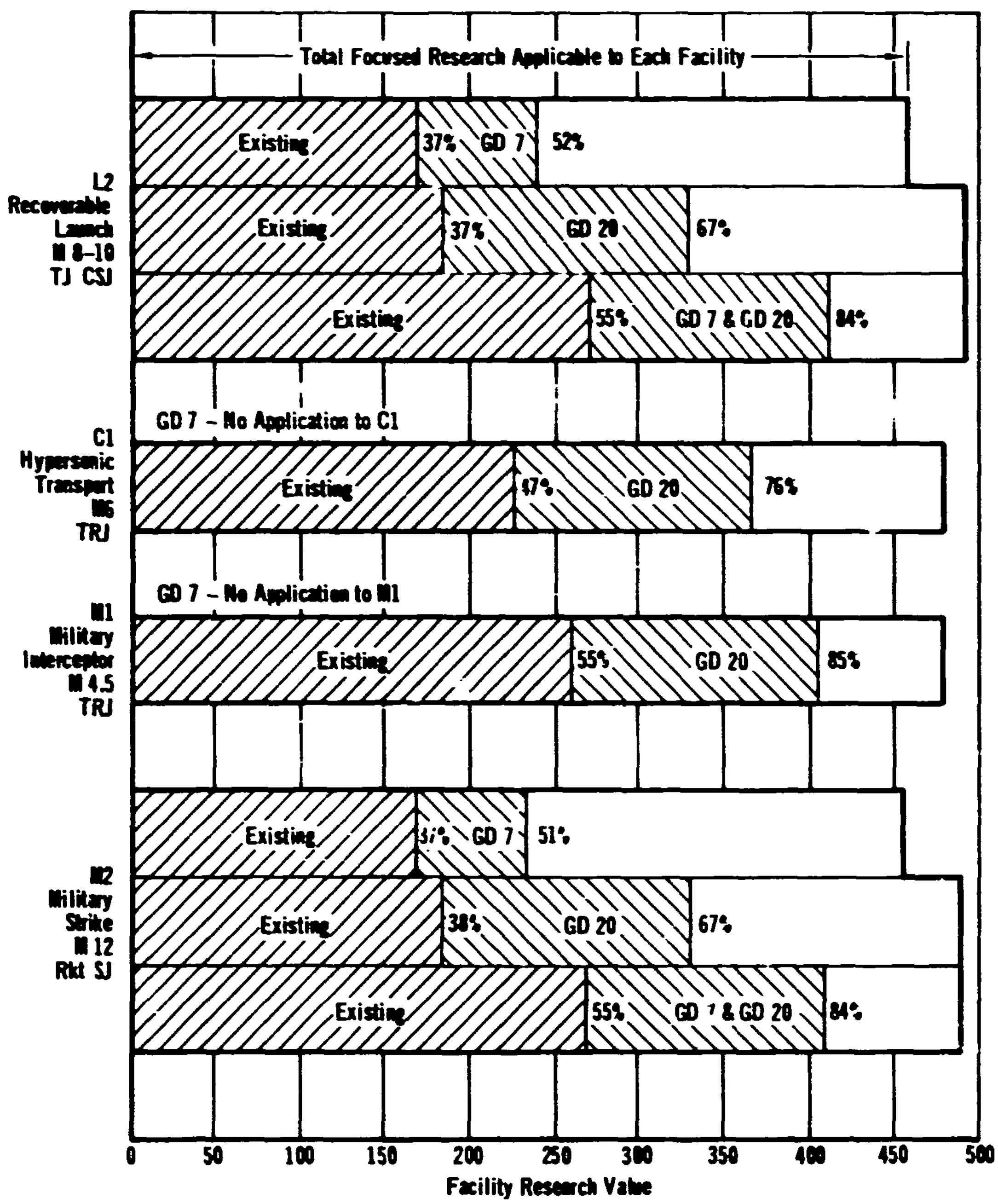
Secondary Research Contribution

Minor Research Contribution

the lower right portion defines how many characteristic tasks from each technical area can be performed (in whole or in part) in each ground facility. The heavily shaded boxes in the matrix denote primary contribution, reflecting the matching of each technology area with particular facility capabilities. Lightly shaded boxes denote those areas where facilities provide research capability, but do not predominate the facility design requirement. There are several areas where considerable overlap in facility capability exists for two or more ground facilities. Specific contribution of a facility for each Research Task is tabulated in the Appendix, and all focused tasks are identified as they apply to each new ground facility.

For the gas dynamic facilities, duplication of focused task identification exists in many cases. Because of the general task definition, GD7 and GD20 provide a somewhat additive contribution by fulfillment of specific portions of the Research Task. The results of the focused research comparison for gas dynamic facilities are illustrated in Figure 7-12. Research potential is identified as a function of the relationship between the tasks, facilities, and operational vehicles. Since GD7 operates in an equivalent flight regime beyond the C1 and M1 envelope, its evaluation has been limited to L2 and M2. In all cases, the ground facilities (and combinations where applicable) provide a marked increase over existing facilities of that same research class. The unfulfilled portion of the research applicable to each facility reflects the requirement for additional facilities (e.g., simulators for handling qualities or true temperature capability for thermal confidence level) due to the broadness of task description.

FIGURE 7–12
FOCUSED RESEARCH VALUES SHOW A NEED
FOR A GAS DYNAMIC FACILITY MIX AT HIGHER SPEEDS
GD 7 Range = M 8 to 13
GD 20 Range = M 0.5 to 8.5



Focused research capability for the engine test facilities is illustrated in Figure 7-13, on a comparable basis with existing facility capability to provide a uniform degree of environmental similitude. For focused research the E20 compound turbomachinery research facility nearly doubles existing capability for C1 and M1 turboramjet engine development. E20 also provides some capability for subsonic combustion ramjet and component development work applicable to the L2 and M2 vehicles, but E9 allows nearly full development of a scramjet propulsion module, yielding high research potential on a focused basis.

Focused research capability for integrated structural/fluid systems research is illustrated in Figure 7-14 for each of the operational vehicles. The total research applicable is substantially reduced for the non-cryogenic system (Operational System M1) because of the non-applicability of the cryogenic capability existing in S20. The capability for structural, acoustic, thermal environment, and altitude simulation enables a substantial increase over existing Facility Research Values for the M1 vehicle. This research potential improvement also applies to the C1 vehicle and is complemented by the addition of cryogenic systems research potential. Although the S20 facility capability does not change, a slight reduction in relative value (with respect to C1) is shown for the M2 and L2 vehicles. This relative reduction results from decreased size similitude and environmental envelope applicable to the larger, higher-temperature M2 vehicle, and even larger L2 vehicle.

When making any of the noted comparisons it is necessary to retain a proper perspective of facility capability and operational system requirements. The relative capabilities illustrated in the bar charts are indicative of how well the facilities can fulfill the research requirements and simulate the overall operational environment required for each operational vehicle on a basis relative to that vehicle.

7.3 GROUND FACILITY SUMMARY

Ground facilities were designed to provide a similitude of flight parameters in each specific field of endeavor, as noted in the shaded portions of the matrix shown in Figure 7-11. The design goals emphasize attainment of simulation in each ground facility, without imposing excessive cost burdens or development risk for the facility itself.

The major flow facilities were designed to provide mass flow (true temperature clean air for engine research) within the dynamic pressure range, 200 to 2000 psf (.95 to 9.5 N/cm^2), and Mach range, 0-12, which nominally bound the operational vehicle flight profile. Model scaling, and hence, test section size were selected to provide meaningful data return, up to one-fifth the full-scale flight Reynolds number, as indicated by the envelope shown in the facility comparisons presented earlier (Figures 7-1 and 7-3). The integrated structures facility was sized to accommodate full-scale major structural elements; provide altitude, thermal, and acoustic simulation for those elements; incorporate a capability to perform combined heating and cryogenic flow testing (e.g., regenerative heat exchangers) on a large scale; and provide a capacity for large-scale cryogenic tankage testing in a horizontal position and dynamic environment.

FIGURE 7–13
FOCUSED FACILITY RESEARCH VALUES FOR ENGINE TEST FACILITIES REFLECT DEGREE OF ENVIRONMENTAL SIMULATION FOR OPERATIONAL SYSTEMS

E 20 Range = M 0 to 5.5
E 9 Range = M 3 to 12

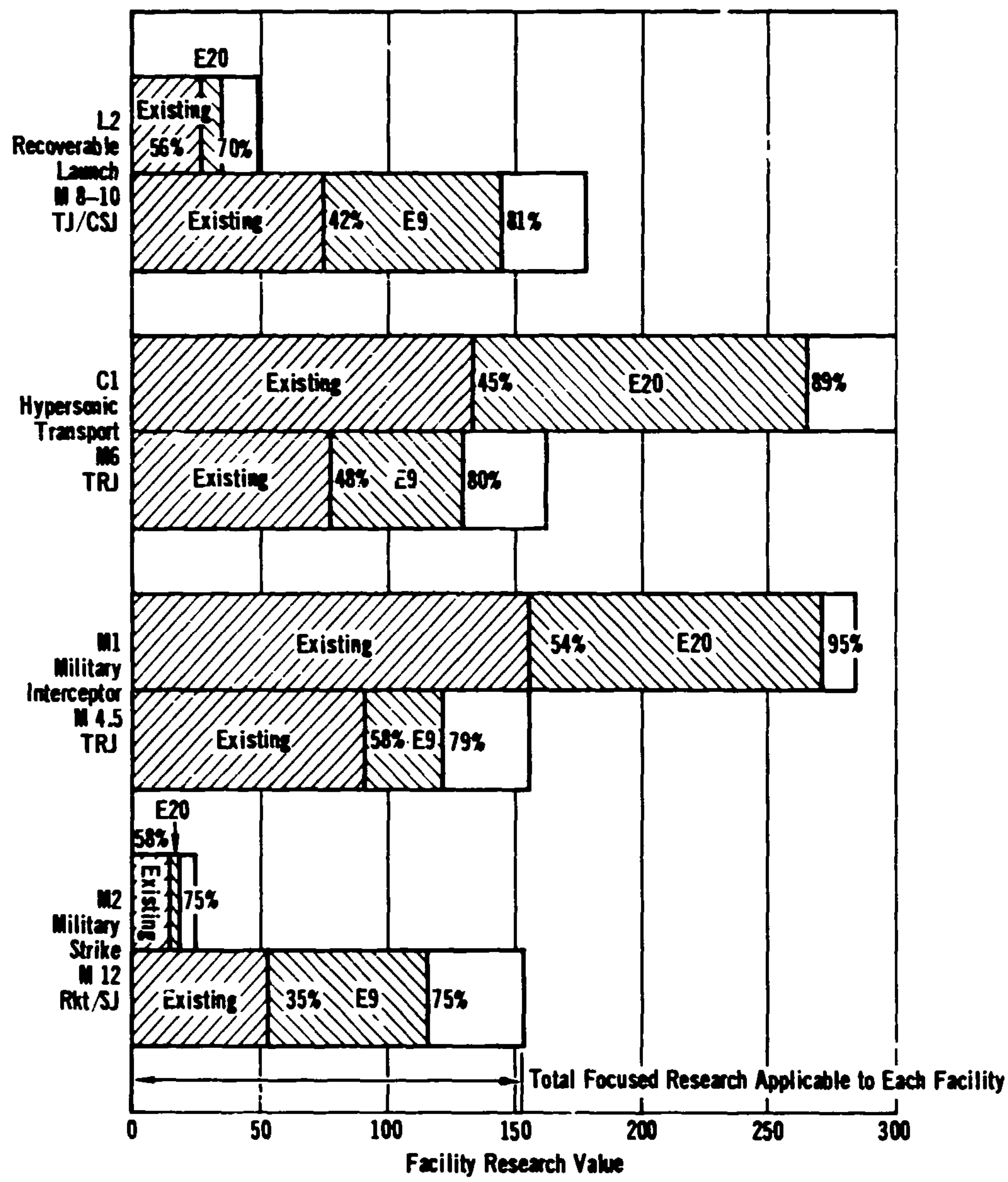


FIGURE 7-14
CONCEPTUAL STRUCTURAL TEST FACILITY IS
HIGHLY EFFECTIVE FOR FOCUSED RESEARCH TASKS

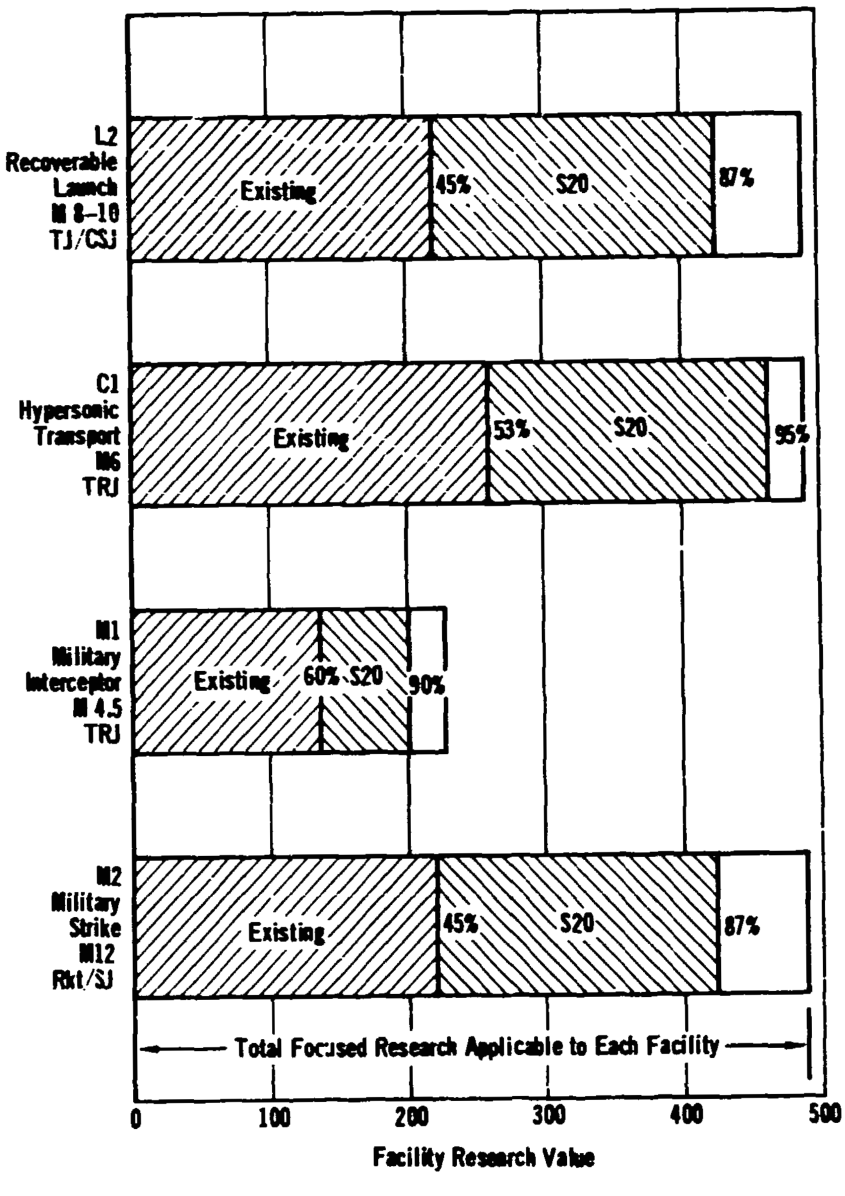


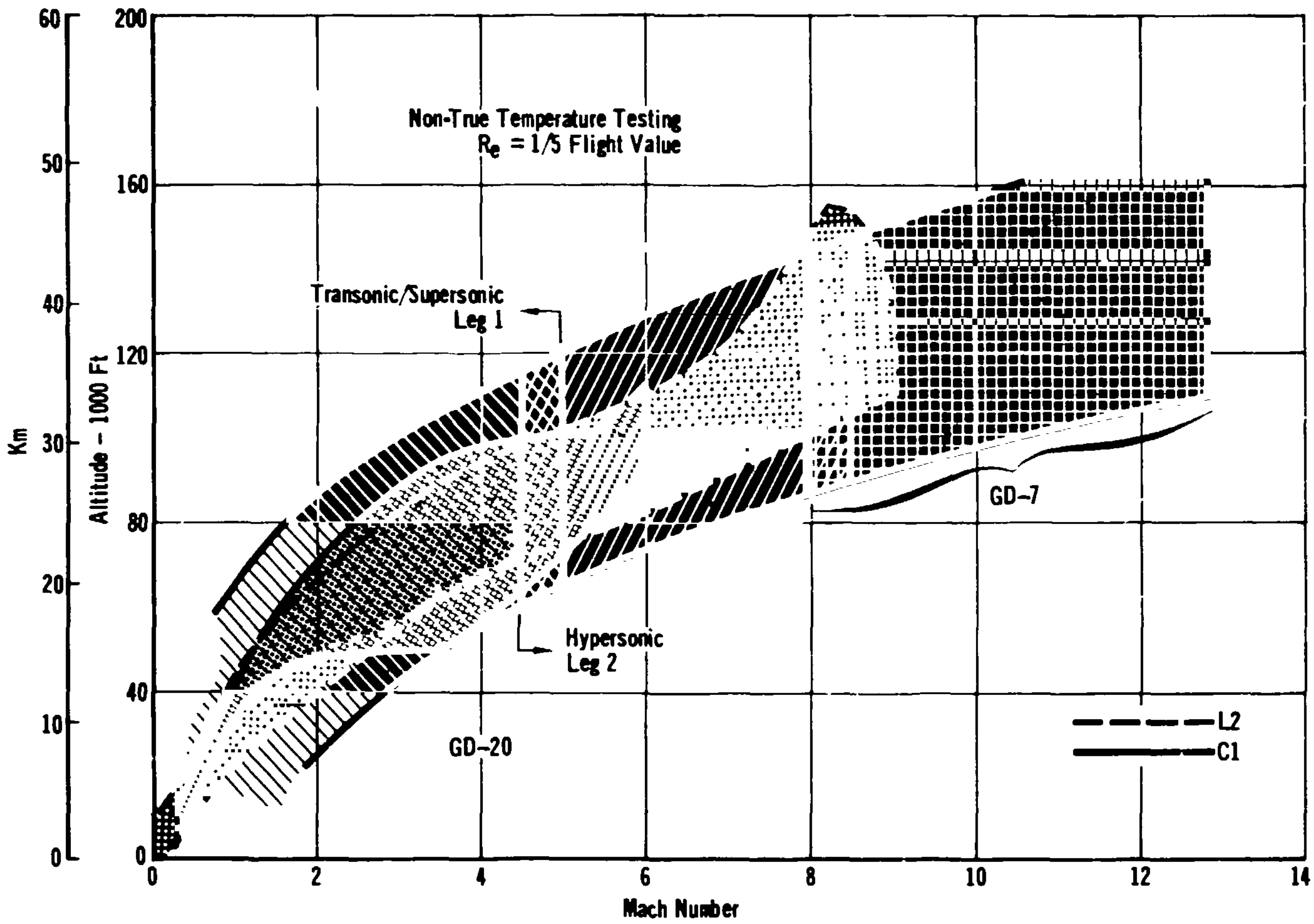
Figure 7-15 illustrates the aerodynamic flow facility capability for CD7 and GD20 in relation to the operational vehicle flight profiles. The transonic/supersonic leg of GD20 extends from Mach .3 to 5, while the hypersonic leg covers the range from Mach 4.5 to 8.5. GD7 picks up the high end of the hypersonic range, from Mach 8 to 13. Both facilities operate within the Reynolds number and dynamic pressure ranges noted above. The aerodynamic facilities attain peak Reynolds number capability with cold flow. Sufficient heat is added to avoid liquefaction in the test section. Research values, indicative of facility capabilities, are presented in tabular form for each operational vehicle. The values are presented on a characteristic basis and compared with research values for existing facilities of the same class. Each of these are referenced to the value considered attainable in an ideal ground facility for a specific set of Research Tasks as they apply to each operational vehicle. It is obvious from a comparison of facility and operational vehicle requirements that GD7 capabilities are not applicable to M1 and C1. It is also evident that additive capability exists for the L2 and M2 vehicles. Examination of the specific tasks involved in performing the research reveals the need for an assessment of combined GD7/GD20 facility potential, since different portions of these Research Tasks are appropriately performed in different facilities. An assessment of the combined value is presented on a focused research basis in Figure 7-12.

The new engine test facilities also provide extensive coverage of the defined operational vehicle profiles, but have an increased dimension of heat addition, enabling testing with true temperature flow conditions as noted in Figure 7-16. The integrated turbomachinery/ramjet facility, E20, is capable of true temperature testing with clean air at a mass flow rate up to 1000 lb/sec (454 kg/sec) on a continuous flow basis to Mach 5 (equivalent to 2500°R, 1389°K). This is sufficient capability to provide ground PFRT/MQT up to Mach 5 for LH_2 fueled turboramjet engines in the 100,000 lb (45,400 kg) thrust class. The ramjet facility, E9, allows continuous clean air capability at an air flow rate of 600 lb/sec (272kg/sec), subsonic combustion ramjet testing to near Mach 4 (temperatures to 1500°R, 833°K), and intermittent clean air tests to the Mach 7 range (temperatures to 4500°R, 2500°K). Vitiated tests can be accomplished with representative gas characteristics and true temperature capability to 7000°R (3889°K), or near Mach 10. An aerodynamic nozzle allows extension of capability to near Mach 12, but sacrifices total temperature capability in the range between Mach 10 and Mach 12.

Research values for the engine test facilities are tabulated on a characteristic basis and compared with existing facility capabilities. The Research Tasks which enter into the evaluation include a large number of tests involving high-temperature component and basic materials research. As a result, capability figures are fairly representative of facility Mach number and temperature capability relative to requirements for the operational vehicle. The focused research value comparisons presented in Figure 7-13 provide insight into the facility capability for research into the propulsion concepts applicable to the operational vehicles.

The integrated structures/fluid systems research facility provides a broad scope of research potential by virtue of its incorporation of many static and dynamic environmental simulation capabilities. Many of these can be produced simultaneously to attain the characteristic values presented in Figure 7-17. Because of the broadness of the research, the percent accomplished is indicative of the matching of facility capability with flight vehicle research requirements. Absolute values for M1 are reduced, reflecting the elimination of cryogenic research requirements. However, capability for attainment of M1 research goals on a basis relative to its needs is equivalent to that for the other operational vehicles.

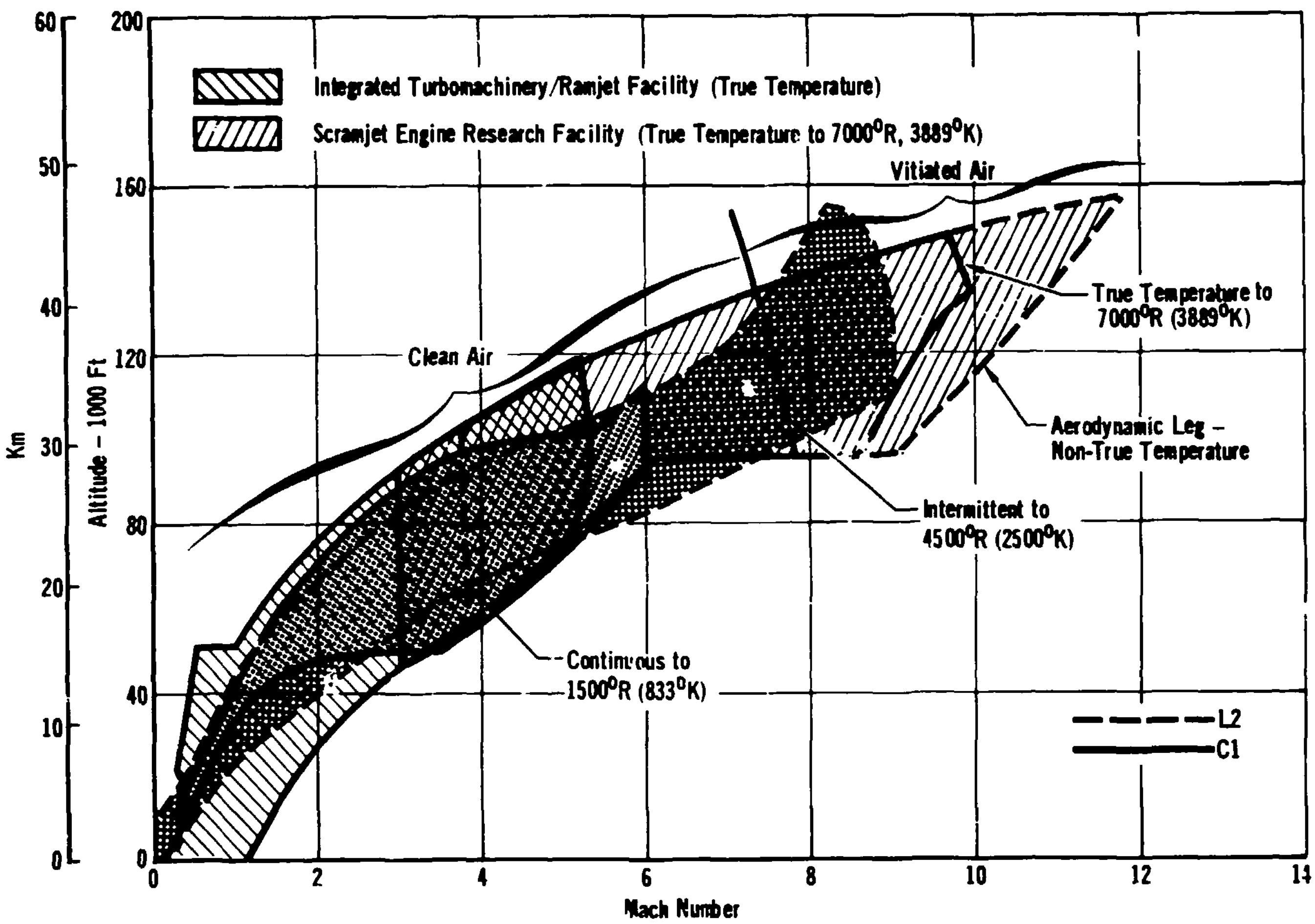
FIGURE 7-15
NEW AERODYNAMIC TEST FACILITIES
COVER ENTIRE OPERATIONAL VEHICLE FLIGHT SPECTRUM



Characteristic Facility Research Values

New Facilities	GD 20				GD 7			
Operational Systems	L2	C1	M1	M2	L2	C1	M1	M2
Related Existing Facilities	995 41%	1136 51%	1288 58%	971 40%	922 41%	N/A	N/A	876 39%
Research Value with New Facility	1550 63%	1637 73%	1793 81%	1523 63%	1224 54%	N/A	N/A	1187 54%
Ideal Ground Facility Value	2445	2232	2228	2437	2262	N/A	N/A	2213

FIGURE 7-16
NEW ENGINE TEST FACILITIES ENABLE HIGH CONFIDENCE VERIFICATION THROUGHOUT THE OPERATIONAL ENVELOPE



Characteristic Facility Research Values

New Facilities	E20				E9			
Operational Systems	L2	C1	M1	M2	L2	C1	M1	M2
Related Existing Facilities	945 40%	1208 50%	1348 58%	922 40%	998 41%	1216 51%	1339 59%	990 40%
Research Value with New Facility	1270 54%	1715 71%	1828 78%	1251 55%	1561 64%	1674 70%	1636 72%	1558 63%
Ideal Ground Facility Value	2354	2408	2330	2287	2439	2386	2285	2458

FIGURE 7-17
INTEGRATED STRUCTURES/FLUID SYSTEMS RESEARCH FACILITY

(S 20) Simulates:

Mechanical
Thermal
Vibration
Acoustic
Altitude
Thermal/Acoustic

Environments

On

Components
Major Sections
Full Scale Vehicles

Characteristic Facility Research Values

New Facility	S 20			
Operational Systems	L2	C1	M1	M2
Related Existing Facilities	1044 54%	1164 62%	889 68%	1077 54%
Research Value With New Facility	1539 80%	1630 87%	1124 86%	1594 79%
Ideal Ground Facility Value	1929	1868	1305	2019

8. INTERPRETATION OF RESEARCH POTENTIAL RESULTS

In a path-finding study of this kind, interpretation of the results is especially important. The intent of this section is to relate the study results to the primary question of what research facilities are necessary for the extension of U. S. operational capability into the hypersonic flight regime.

Effectiveness of candidate hypersonic research facilities is defined in this study as research potential. This effectiveness measure, expressed in terms of Facility Research Value, is a non-dimensional parameter reflecting the capability of each research facility to accomplish fundamental Research Tasks. Facility Research Values have been presented for candidate ground facilities and flight research vehicles in the previous two sections. Interpretation of these study results is based on their applicability to the real need for new hypersonic research facilities.

In order to establish the basis for interpretation of results, a short discussion of the research requirements survey, conducted during the first phase of the study, is presented. The results of this survey served as the basic input to the determination of the Research Task intrinsic values. Some of the information generated by this survey directly impacts the HYFAC study results.

Research potential of conceptual new ground facilities and flight vehicles is summarized in this section. Two basic measures of research values are presented in this report. One measure of Facility Research Value is based on the "characteristic" capability, a measure of the versatility of a facility to accomplish the spectrum of Research Tasks leading to an operational system. The other basic measure "Focused" Facility Research Value is presented to illustrate the potential of new facilities in areas of research for which they are primarily designed.

An illustration of the utility of the HYFAC study results is presented in the form of a typical high-priority research program for the development of a scramjet engine and integration into an airframe. This example research program is used as the framework for discussion both of methods of accomplishing Research Tasks and of the cost of a representative research program.

Since the research potential of new ground facilities and flight vehicles has been determined by consistent evaluation techniques, some comparisons of the research potential and acquisition costs of the candidate flight vehicles and typical ground facility mixes can be made.

8.1 RESEARCH REQUIREMENTS SURVEY

Two surveys were conducted during Phase I regarding the definition and evaluation of Research Objectives. In the initial survey, a proposed list of 84 objectives was submitted to NASA, military, and industry specialists in hypersonic systems technology. The technical specialists were asked to indicate whether they felt that the research involved in attaining each objective was essential, desirable, or unnecessary in contributing to a potential hypersonic aircraft program. In addition, the participants were invited to list any additional objectives which they felt should be included in a comprehensive statement of the necessary research for such a program and to submit suggested modifications to the identified objectives.

Approximately three-fourths of the original list of 84 objectives were clearly placed into one of the three categories by the 35 evaluators responding to this initial survey. Although none of the objectives was considered by a majority of the participants to be unnecessary, some of those receiving a significant number of "unnecessary" votes were later deleted from the list or included within other objectives. These modifications were combined with many of the additional Research Objectives suggested by the survey participants to produce the list of 102 objectives presented in Volume II, Part 1.

The second survey involved a paired-comparison analysis of these 102 Research Objectives, designed to provide data based on expert opinion for determing the relative importance of the objectives in contributing to a hypersonic research program. The methodology involved and the values which resulted are contained in Section 5 of this volume, as well as in Volumes II and III. Also included in this survey was an assessment of the relative weightings to be assigned to the six technological areas into which the various objectives were divided. The composite distribution which resulted is illustrated in Figure 8-1. These six technological areas were selected to provide a convenient grouping for identification of specialty areas. However, due to the inherent overlapping and interaction of technologies when considering an aircraft configuration, many of the stated Research Objectives within a technical area encompassed a much broader area than indicated by the category title. Furthermore, the survey participants weighted the two evaluation criteria which were used in comparing the various objectives with one another, and the resulting distribution is as follows:

Evaluation Criterion	Relative Weighting
A. Technology Advancement	60.7%
B. Cost and Schedule	39.3%
TOTAL	100.0%

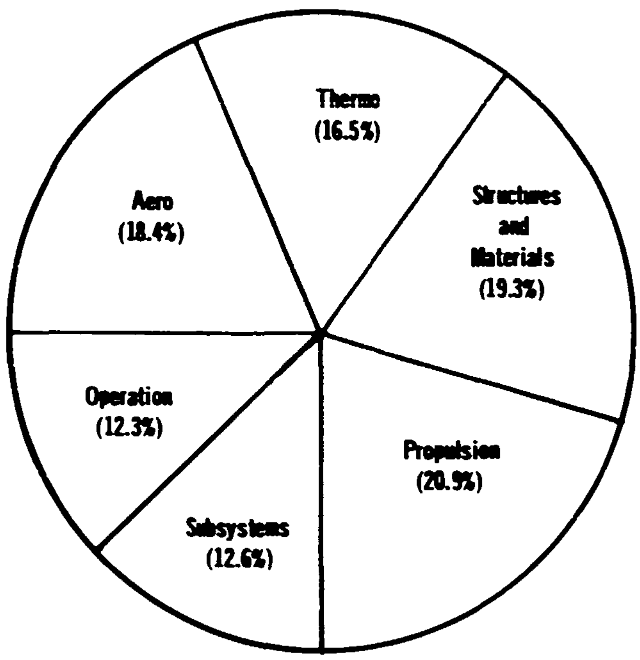
These evaluation criteria are defined as:

(a) Technology Advancement - This criterion can be considered as the extent to which the Research Objective contributes to the technical knowledge required to achieve an operational hypersonic vehicle. This contribution involves:

- o Understanding of fundamental physical or physiochemical behavior and interactions.
- o Application of principles to design concepts.
- o Confirmation of adequacy of design or manufacture.
- o Reduction in overdesign penalties.

(b) Cost and Schedule - This criterion indicates the extent to which the research contributes to obtaining a sound cost and schedule basis for achieving an operational hypersonic vehicle. This contribution includes:

FIGURE 8-1
RESEARCH REQUIREMENTS SURVEY
WEIGHTING OF TECHNOLOGICAL AREAS



- o Establishment of a sound system costing base.
- o Achievement of major time savings relative to system development.
- o Uncovering of design problems that would be costly and time-consuming to correct during a system procurement cycle.

The research requirements survey results show that the technical community believes that technology advancement is significantly more important than cost and schedule considerations as the output of applied research programs.

8.2 FLIGHT VEHICLE RESEARCH VALUE SUMMARY

Results of the research requirements and facility capability analysis are summarized in this section for the two candidate flight research vehicles. The parameters which describe the desirability of hese candidate flight research vehicles for achieving hypersonic research requirements are: (1) characteristic Facility Research Value, (2) focused Facility Research Value, and (3) facility acquisition costs.

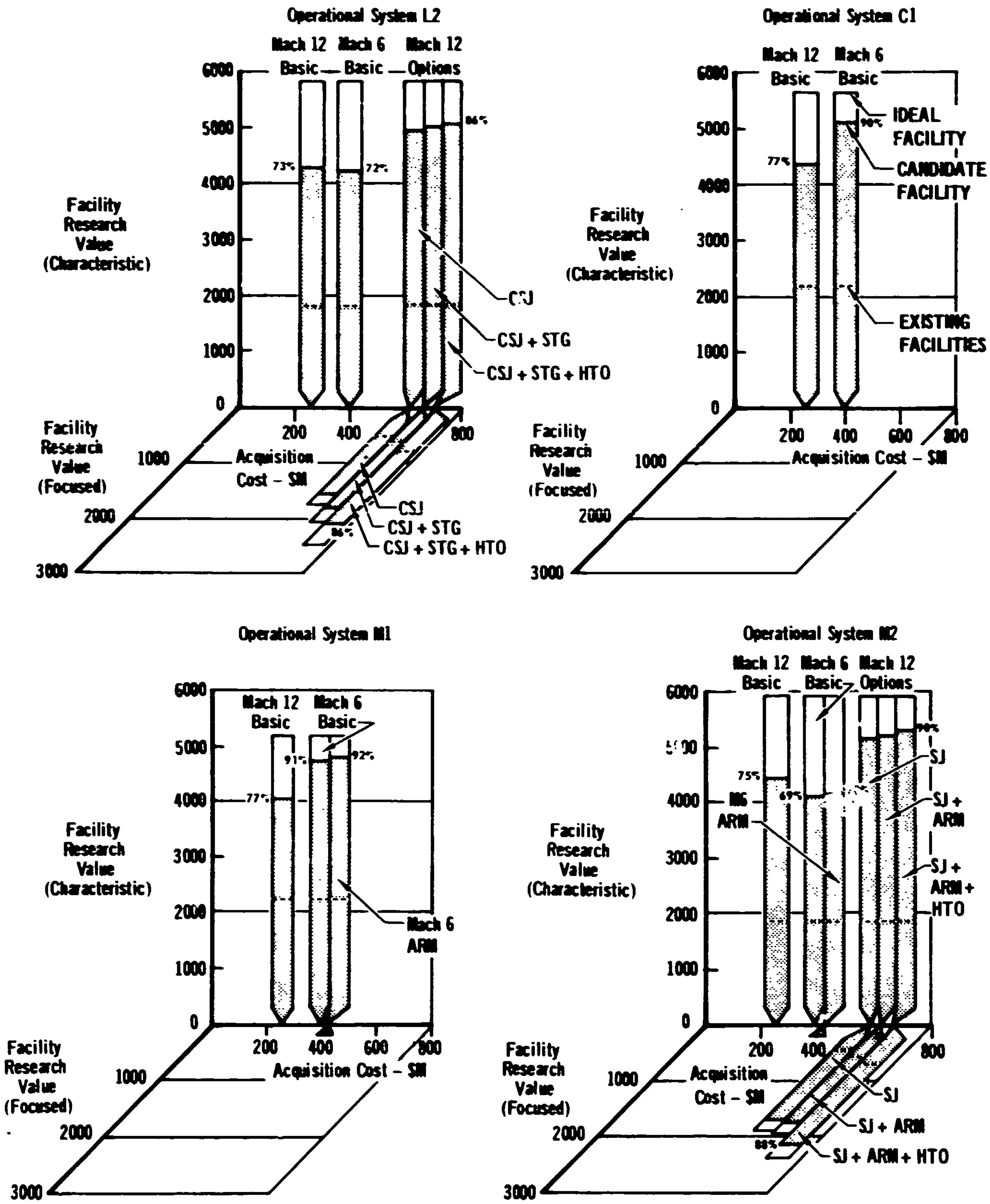
Characteristic and focused research values are presented in Figure 8-2 for the Mach 6 and Mach 12 basic flight vehicles and for the flight vehicle research options which are most appropriate for each operational system. In this method of summarizing research potential results, the shaded portion of the bar represents the Facility Research Value of the Phase III flight vehicles (in conjunction with existing ground facilities). The research value of all applicable existing ground facilities is indicated within the bar by the dotted line. The upper limit of the open bar represents the sum of the intrinsic values of all Research Tasks at least partially applicable to flight tests appropriate for the particular operational system. This value is the research value goal or capability of an ideal facility. The only tasks excluded from this total, in addition to the Research Tasks which obviously do not apply to the operational system, are tasks of an analytic nature and those appropriate only for ground test accomplishment.

The Mach 12 basic research vehicle can accomplish, in conjunction with existing facilities, from 73% to 77% of the applicable research for all representative operational systems. This relatively consistent research potential across the spectrum of candidate operational hypersonic vehicles is a result of the Mach 12 research vehicle's broad contribution to fundamental hypersonic Research Tasks. A significant increase in Facility Research Value due to matching of the research vehicle's propulsion mode with an operational system does not occur. This is because the Mach 12 vehicle duplicates only the rocket-boost mode of the M2 operational system, and rocket Research Tasks possess relatively low intrinsic values. The Mach 6 basic research vehicle, by contrast,shows a wide variance in research potential as a function of the degree of simulation of the operational system's characteristics. For instance, the accomplishment of characteristic Research Tasks varies from 69% for Operation System M2 and 72% for Operational System L2, for which the Mach 6 vehicle fails to duplicate the higher-speed end of the flight regime and the cruise propulsion system, to 90% for Operational System C1 and 91% for Operational System M1. For Operational Systems C1 and M1, operating characteristics, speed capability, and propulsion system of the flight research vehicle result in a near-prototype of the operational systems.

The research potential of the Mach 12 vehicle is considerably enhanced by the vehicle options which contribute to the development of a particular operational system. For the recoverable launch system L2, the cumulative effect of adding the Convertible Scramjet, Staging, and Horizontal Take-off options to the Mach 12 vehicle is shown in Figure 8-2. These three options provide the Mach 12 research vehicle with a capability to achieve 86% of the research value of an ideal Mach 12 research vehicle. These options also provide a high Facility Research Value on a focused basis, primarily because only the vehicle options which match the operational system characteristics are presented.

Mach 12 vehicle options are presented in a similar manner for the scramjet-powered Operational System M2. The options which match this system are Scramjet, Armament, and Horizontal Take-off. The cumulative effect of these options on Facility Research Value results in an increase from 75% of ideal for the basic vehicle to 90% of the ideal-facility value for the options. Again, focused Facility Research Values are high since only the options applying to the operational system configuration are considered.

FIGURE 8–2
FLIGHT VEHICLE RESEARCH VALUE SUMMARY



The only Mach 6 option which is appropriate to consider in this summary is the armament option for the military operational systems. The research potential contribution of this Mach 6 vehicle option is very small but is matched by the relatively small increase in acquisition cost of four million dollars.

8.3 GROUND FACILITY RESEARCH VALUE SUMMARY

Research potential is summarized for the spectrum of Phase III ground research facilities in Figure 8-3. The presentation format is the same as used in the previous section for the candidate flight research vehicles. Characteristic Facility Research Values describe the particular facility's capability to accomplish broad research characteristic of the facility class, while focused research describes each facility's effectiveness in accomplishing Research Tasks which the facility would be specifically designed to accomplish. The shaded portion of each bar represents the capability of each facility, in conjunction with appropriate existing facilities, while the top of the bar represents the research value goal for an ideal ground facility. Facility acquisition cost is the research facility characteristic used to differentiate the facilities. This cost includes the design and development costs and the construction costs. In other words, it is the estimated cost of a facility from initiation of the facility design until NASA acceptance.

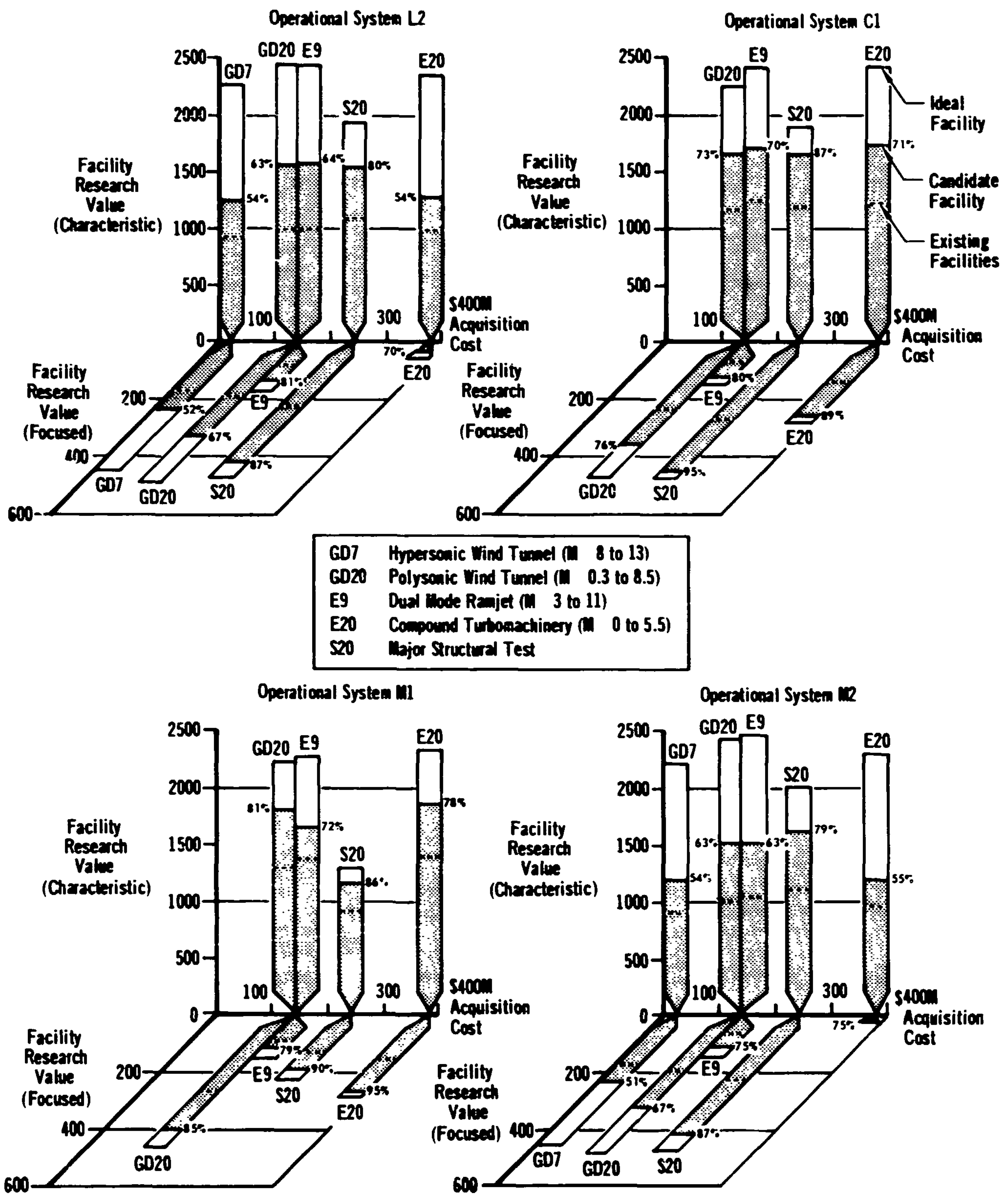
It can be seen that GD7 (the hypersonic-impulse tunnel operating from Mach 8 to Mach 13) does not contribute to the Mach 4.5 and Mach 6 operational systems development. Its characteristic and focused research values are modest even for the higher-speed operational systems to which it does apply. An important factor in the evaluation of its attractiveness,however, is its relatively low acquisition cost.

The new polysonic gas dynamic facility, GD20, exhibits considerable research potential on both a characteristic and focused basis across the spectrum of representative operational systems. It is the wind tunnel facility which exhibits the broadest application to all operational systems, due principally to its two test legs providing test environments from Mach 0.5 to Mach 8.5. This facility provides a simulation capability which, when added to the complex of existing wind tunnels, can accomplish from 63 to 81 percent of the characteristic Research Tasks applying to the representative operational systems. On a focused research task basis, this facility shows a Facility Research Value range from 67 to 85 percent of the total applicable research.

The E9 engine test facility is identified as a dual-mode ramjet engine research test facility, with both subsonic and supersonic ramjet test capability. That this facility has a broad capability can be seen by reference to Figure 8-3 and the following table.

Operational System	Percent of Accomplishment: Characteristic Research Tasks	Percent of Accomplishment: Focused Research Tasks
L2	64	81
C1	70	80
M1	72	79
M2	63	75

FIGURE 8-3
GROUND FACILITY RESEARCH VALUE SUMMARY



GD7	Hypersonic Wind Tunnel (M 8 to 13)
GD20	Polysonic Wind Tunnel (M 0.3 to 8.5)
E9	Dual Mode Ramjet (M 3 to 11)
E20	Compound Turbomachinery (M 0 to 5.5)
S20	Major Structural Test

The E9 facility has both a characteristic and focused research application to all operational systems. Its large research value results from the broad operating range of the facility, from Mach 3 to Mach 12. This wide operating range allows the facility to accomplish Research Tasks related to the scramjet, convertible scramjet, and the ramjet portion of the turboramjet Research Tasks. Each operational system is represented by a portion of these propulsion tasks which, in addition, generally possess relatively high intrinsic values.

The compound turbomachinery engine test facility (E20) has specific application to turboramjet-powered operational systems. For these systems (C1 and M1) E20 can achieve 71% to 78% of the total applicable characteristic research and 89% to 95% of the tasks applicable on the focused research basis. Unfortunately, its high cost would indicate that a clear need for an operational system employing advanced turbojet/ramjet engines be identified prior to committing to construction of the facility.

The major structural test facility (S20) has a broad research potential for all operational systems, as is evident from Figure 8-3. The general applicability of this new facility to all candidate operational systems is illustrated by its ability to accomplish from 79% to 87% of the identified research on a characteristic basis and 87% to 95% on a focused research basis. The principal advantages of the S20 facility include its ability to test large aircraft sections and the extensive simulations achievable in a single facility.

On the basis of the data presented in Figure 8-3, some observations on the desirability of the candidate ground facilities may be in order. New facility recommendations are dependent on the class of operational system being considered. However, a foreknowledge of the exact direction of operational hypersonic aircraft systems development cannot be assured. In the expected environment, a wide range of operational aircraft must be considered; the four systems used in this report are representative of this spectrum. Considering the four operational system possibilities, the most desirable new gas dynamic facility is GD20. This conceptual wind tunnel has broad application to all operational programs. The relatively low acquisition cost of GD7 does not counterbalance the fact that it has no application to one-half of the representative operational systems and is not particularly effective in research applications associated with the remaining operational systems. A choice between the two engine test facilities is relatively easy to make. E9 facility has a superior research value, compared to the E20 facility, for the two operational systems not powered by turboramjets and can be built for less than one-half of E20's cost. The decision on whether to build the major structural research facility S20 must be based on more data than is presented in Figure 8-3. Although S20 shows a high research potential for all of the operational systems, existing facilities contribute a substantial portion of the identified research potential. It appears that S20 falls in the desirable but not necessary class, at least under predicted near-term budget levels.

8.4 RESEARCH REQUIREMENTS FOR A TYPICAL HIGH-PRIORITY PROGRAM

The entire HYFAC program has been devoted to establishing relevant research requirements, identifying importance of the Research Tasks and defining facilities which accomplish the required research in an efficient and economical manner. A considerable portion of the study effort was devoted to definition of research requirements and facility research potential in terms relative to operational vehicle needs.

One vehicle which is representative of the hypersonic speed regime is Operational System M2. This aircraft cruises at Mach 12 with a supersonic combustion ramjet engine. This vehicle has been selected for use as an example with which to illustrate the scope of development effort which may be required for a particular development program. With this technique, specific research requirements may be emphasized, the extent of interactions (with the vehicle and other research progrms) illustrated, and importance of the research shown relative to the operational vehicle.

The criteria used to select the applicable Research Objectives for a scramjet development and airframe integration program demand that they involve research directly related to:

- Developing components of the scramjet engine
- Developing a scramjet engine system
- Integrating this SJ system with the vehicle
- Identifying interactions between the SJ and the vehicle.

The list of Research Objectives presented in Section 3 was reviewed to determine the level of applicability of each as related to scramjet research. Of the 78 objectives identified, 22 are of fundamental importance (must be accomplished) for operation of a scramjet, another 21 must be performed in part to identify changes with respect to the basic vehicle and 35 are either not applicable or the vehicle research potential is not affected by the addition of a scramjet. The directly applicable objectives which are identified represent all six of the technology groupings: aerodynamics, thermodynamics, structures and materials, propulsion, subsystems, and operations. A listing of these twenty-two objectives follows:

RO 3 - Determine supersonic and hypersonic aerodynamic characteristics of hypersonic aircraft. (Tasks 3 and 4 apply)

RO 6 - Evaluate design techniques for obtaining favorable aerodynamic interference effects through surface or inlet positioning. (All tasks apply)

RO 7 - Evaluate design techniques of using the aircraft body for engine exhaust expansion, thereby providing lift. Determine the effect of propulsive gas flow interactions. (Tasks 2 and 3 apply)

RO 9 - Investigate the effects of variable inlet and nozzle geometry, bypass airflow, propulsion mode changes, and aerothermoelastic effects on hypersonic aircraft stability and aerodynamic forces. (All tasks apply)

RO 12 - Improve fundamental knowledge of hypersonic boundary layer behavior in the presence of adverse pressure gradients and shock interactions. (All tasks apply)

RO 16 - Develop correlation methods for the prediction of heat transfer and friction drag for turbulent boundary layers with pressure gradients and three-dimensional windward flows. (Task 1 applies)

RO 22 - Investigate shaping of aerodynamic surfaces to reduce skin temperatures, and the effects of protuberances and surface irregularities on hypersonic aircraft drag and aerodynamic heating. (All tasks apply)

RO 27 - Develop methods for predicting heat transfer due to radiation or gas impingement from engine exhaust. (All tasks apply)

RO 34 - Develop long life regeneratively cooled structural concepts for application in high heat flux areas such as leading edges and propulsion systems. (All tasks apply)

RO 35 - Provide a structure which maintains aerodynamic smoothness under actual operational conditions and use. (Task 2 applies)

RO 36 - Define the effects of combined mechanical loading and thermal stress cycling under actual environmental conditions on the life of the structural components. (Task 3 applies)

RO 42 - Verify and demonstrate the integrity of the structural and thermal-structural concepts by testing full-scale structural sections. (All tasks apply)

RO 46 - Develop high-temperature bearings, lubricants, closure seals, tires, windshields, and radomes. (All tasks apply)

RO 48 - Develop inlet configurations for the desired flight conditions and engine operating modes to enable the propulsion system to achieve the desired performance. (Tasks 1, 3 and 4 apply)

RO 58 - Perform sufficient cycle analysis and mission analysis to select the best multi-mode cycle and size engine for application to a specific hypersonic mission aircraft. (All tasks apply)

RO 61 - Develop and integrate engine components into a complete, significantly-sized scramjet module. Demonstrate compatibility and overall performance throughout an applicable flight envelope. (All tasks apply)

RO 63 - Develop inlet controls for hypersonic aircraft which are simple, reliable, accurate, and have rapid response. (All tasks apply)

RO 65 - Determine nozzle configurations to produce high net thrust while maintaining efficient integration with the airframe. (All tasks apply)

RO 67 - Determine inlet/engine compatibility criteria (both steady-state and time-varying) for high-total-pressure-recovery, wide Mach range inlets. (All tasks apply)

RO 70 - Develop regenerative cryogenic heat exchangers, thermodynamic correlations, and control systems for structural and engine cooling which are compatible with representative heat loads and material temperature limits. (All tasks apply)

RO 96 - Define and demonstrate the capability to stay within specified operational margins and not exceed aircraft placards (i.e., duct pressure, temperature, stability, dynamic pressure, and load factor limits). (All tasks apply)

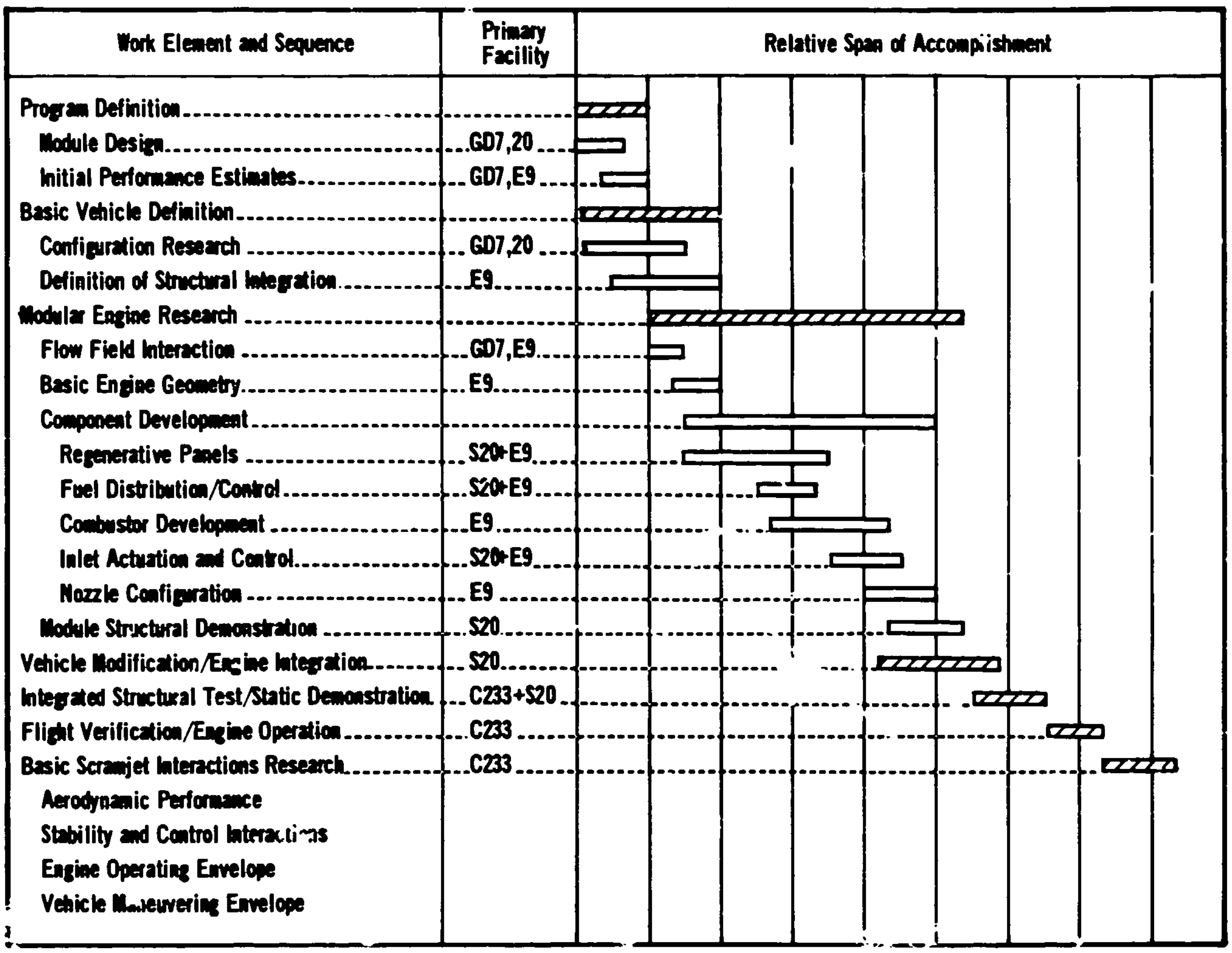
RO 102 - Develop inspection and repair techniques for hypersonic vehicle structures. (All tasks apply)

A measure of the importance of this particular high-priority program can be gained by examining the intrinsic values for the above applicable Research Objectives (1280) in relationship to the total intrinsic value for Operational System M2 (3440), as derived from Figure A-3 of the Appendix. This program provides research potential equivalent to 37.2% of the research applicable to this Operational System.

The Research Objectives identified were subsequently grouped into major schedule elements and sequenced according to priority (governed by lead time and element interactions). These form the basis for the development plan identified in Figure 8-4. Primary new research facility use is also identified for each major element. Effect proceeds from definition of specific scramjet requirements and vehicle modifications through research into engine integration (flow field and structural), component research and development, and structural demonstration of the engine module. Following ground test and demonstration of the engine concept, the flight module is integrated into the vehicle and flight test initiated to provide increased confidence in the vehicle/engine interactions throughout the flight profile. Since the development plan is meant to provide an illustration example,development timing is shown on a relative basis, thereby avoiding definition of required funding commitment and program emphasis.

Typical methods for accomplishing the required research are presented in Section 4, broken out on a task-by-task basis. Since a broad number of tasks apply to varying degrees for actual system integration and demonstration, an orderly ground-test and flight-test program was identified using the detailed methods as a guide. The approach is consistent with the development plan, assuming "normal" development emphasis, as typified by past vehicle modification programs. Research methods and task identifications were used as a guide to identify facility occupancy and flight test requirements. This approach provides insight into operating costs for performing the research. Models, test equipment, and instrumentation costs were also identified, using Section 4 methods as a guide. Rationale included full assessment of costs for models and test equipment specifically relevant to engine development, with 10% of model costs used for integration tasks. This is equivalent to an

FIGURE 8-4
DEVELOPMENT PLAN FOR TYPICAL HIGH-PRIORITY PROGRAM
Scramjet Development and Airframe Integration



assumption that all facilities already exist, including ground test models for the basic Mach 12 flight vehicle. The 10% represents assumed cost of modification of existing models to accomplish related research for configuration performance interactions.

The resulting facility operating cost breakdown is summarized in Figure 8-5. This cost summation indicates that the example incremental scramjet research program costs less than $100 million dollars. Although this estimate is based on the assumption that all research facilities exist, the example program has been charged for all flight test after Basic Vehicle Development and Envelope Expansion (first 70 flights), as noted in Section 4. Chargeable flight test includes; 1) basic vehicle research applicable to flight envelope and flow field definition to form a substantive data base, 2) envelope extension using the scramjet, and 3) basic research into interactions of the scramjet and basic vehicle to provide the necessary high degree of confidence to proceed with operational vehicle development.

FIGURE 8-5
OPERATING COSTS TO ACCOMPLISH RESEARCH FOR SCRAMJET DEVELOPMENT AND AIRFRAME INTEGRATION

GROUND TESTS

Models and Specimens		$ 11.3 M	
Test Equipment and Subsystems		7.3	
Instrumentation		5.2	
	Cost Sub-Total	23.8 M	
GD20 Occupancy		$ 4.6 M	(3200 hr.)
GD7 Occupancy		4.2	(2450 hr.)
E9 Occupancy		31.8	(4350 hr.)
S20 Occupancy		10.0	(8000 hr.)
	Cost Sub-Total	$ 50.6	
	Program Ground Tests Cost	$ 74.4 M	

FLIGHT TESTS

Research on Basic Vehicle Applicable to Scramjet Integration		13.2	(30 flights)
Scramjet-Powered Vehicle Development and Envelope Expansion		4.4	(10 flights)
Scramjet Interactions Research		6.2	(14 flights)
	Program Flight Tests Cost	$ 23.8 M	
	Program Total Cost	$ 98.2 M	

8.5 RESEARCH POTENTIAL COMPARISONS OF GROUND FACILITY COMBINATIONS AND FLIGHT VEHICLES

It is not possible, or desirable, to determine the effectiveness of the ground and flight research facilities on a consistent basis which would allow straight-forward comparisons of the flight vehicles with selected ground facility mixes. However, some comparisons are of interest in terms of research value.

Two different presentations of ground and flight research program comparisons are contained in Figures 8-6 and 8-7. Relative facility capability is presented in Figure 8-6 for a combination of ground facilities and for the Mach 12 research vehicle. In Figure 8-7 is shown how the Facility Research Values accumulate for existing ground facilities and new ground and flight facilities across the research tasks within the technology categories listed along the bottom of the graph. The relative width of these categories is proportional to the sum of the intrinsic values of all of the applicable Research Tasks within these technology areas. The contribution of each task within an area is not specifically identified; rather, the contribution is shown as a straight line identifying the technology area's overall contribution. In Figure 8-7, the relative contribution of a facility across a technology area is coded in terms of primary, supplementary, or negligible impact on Facility Research Value.

The ground research facilities possessing the highest research potential with respect to Operational System L2 are combined in a typical facility mix. The relative Facility Research Value contribution of the ground facilities and flight vehicles can be compared as follows:

Comparison of Research Facilities for Operational System L2

	Facility Research Value Contribution Over Existing Facilities
Ground Facilities (GD20 + E9 + S20)	1614
Flight Vehicle (Mach 12 Basic)	2408
(Mach 12 Basic + CSJ)	3088

The above comparison indicates that, considering the research requirements specified in this study, the Mach 12 flight vehicle can contribute more than new ground facilities.

For the hypersonic transport operational system (C1), comparisons of the Facility Research Value of a ground facilities mix and of the Mach 6 basic flight vehicle are presented in Figures 8-8 and 8-9. The ground facility mix is changed from that previously presented for Operational System L2 by substituting the E20 engine test facility for the E9 facility. Another difference between the facility comparisons for Operational Systems C1 and L2 is that the Mach 6 flight research vehicle does not have a vehicle option which contributes significantly to the development of a hypersonic transport. Primary contribution is provided by the basic vehicle in all technology areas, relative to Operational Systems C1 and M1, therefore, negating the need for options. The Facility Research Values of the ground facilities mix and the flight research vehicle most suitable for Operational System C1 are compared as follows:

FIGURE 8-6
FACILITY CONTRIBUTIONS TO OPERATIONAL SYSTEM L2
MACH 8-10 TJ/CSJ RECOVERABLE LAUNCH VEHICLE

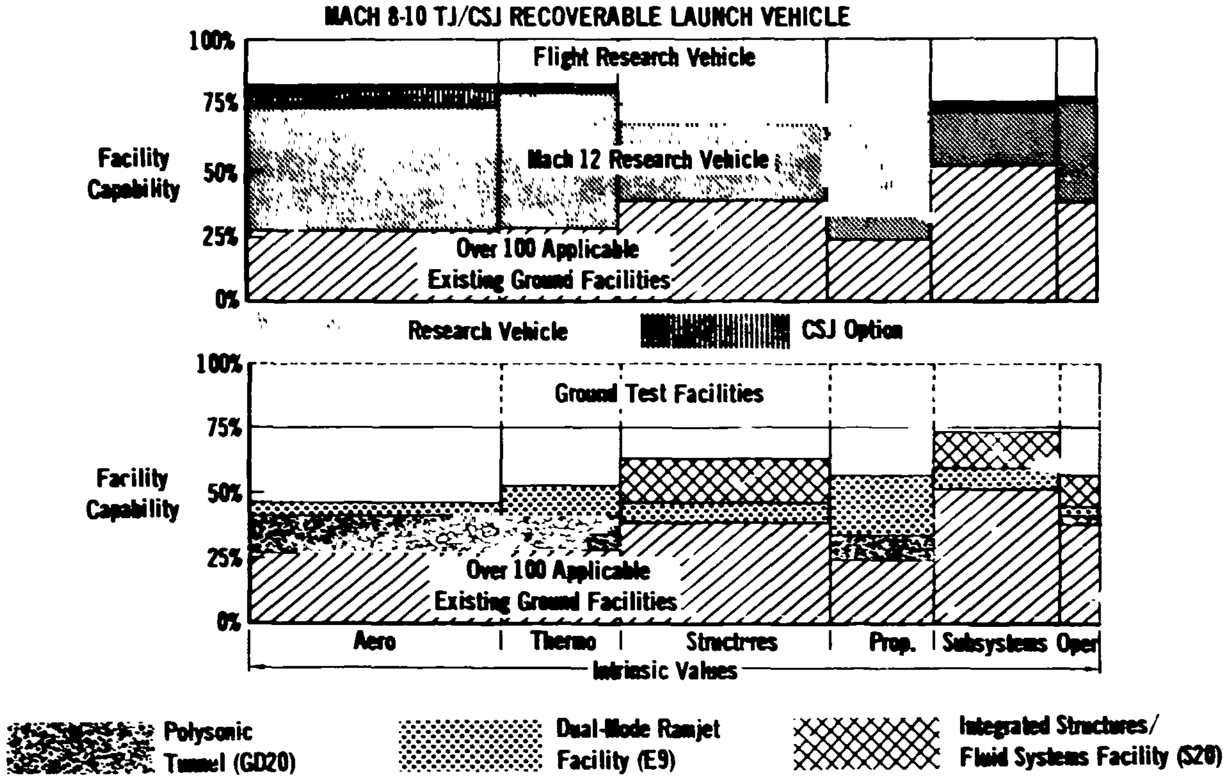


FIGURE 8-7
RESEARCH PROGRAM COMPARISONS FOR OPERATIONAL SYSTEM L2

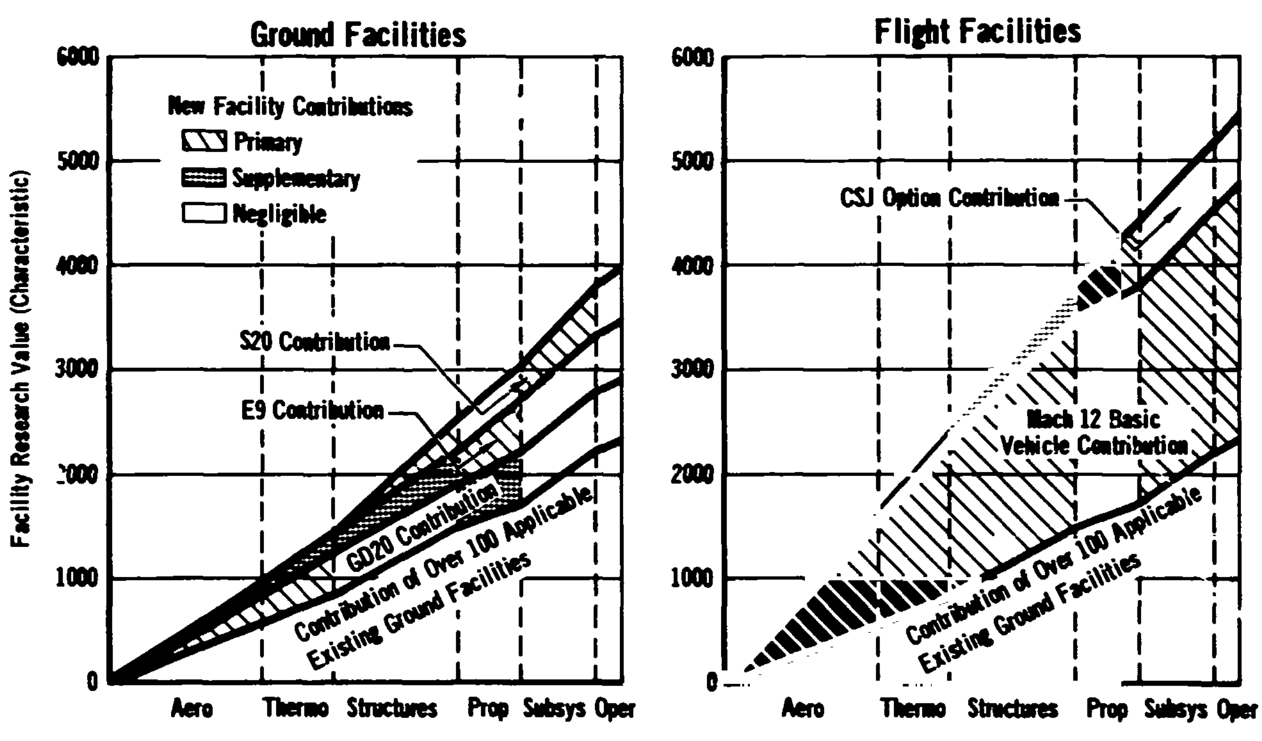


FIGURE 8-8
FACILITY CONTRIBUTIONS TO OPERATIONAL SYSTEM C1

MACH 6 TRJ HYPERSONIC TRANSPORT

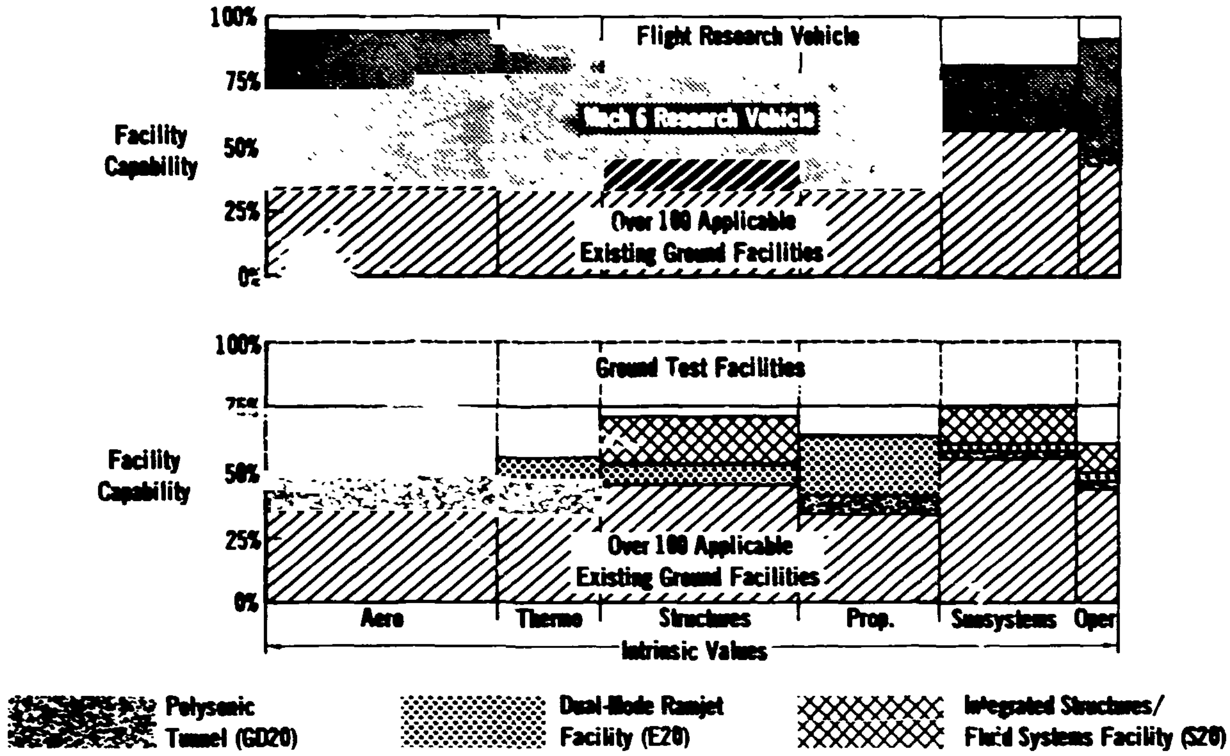
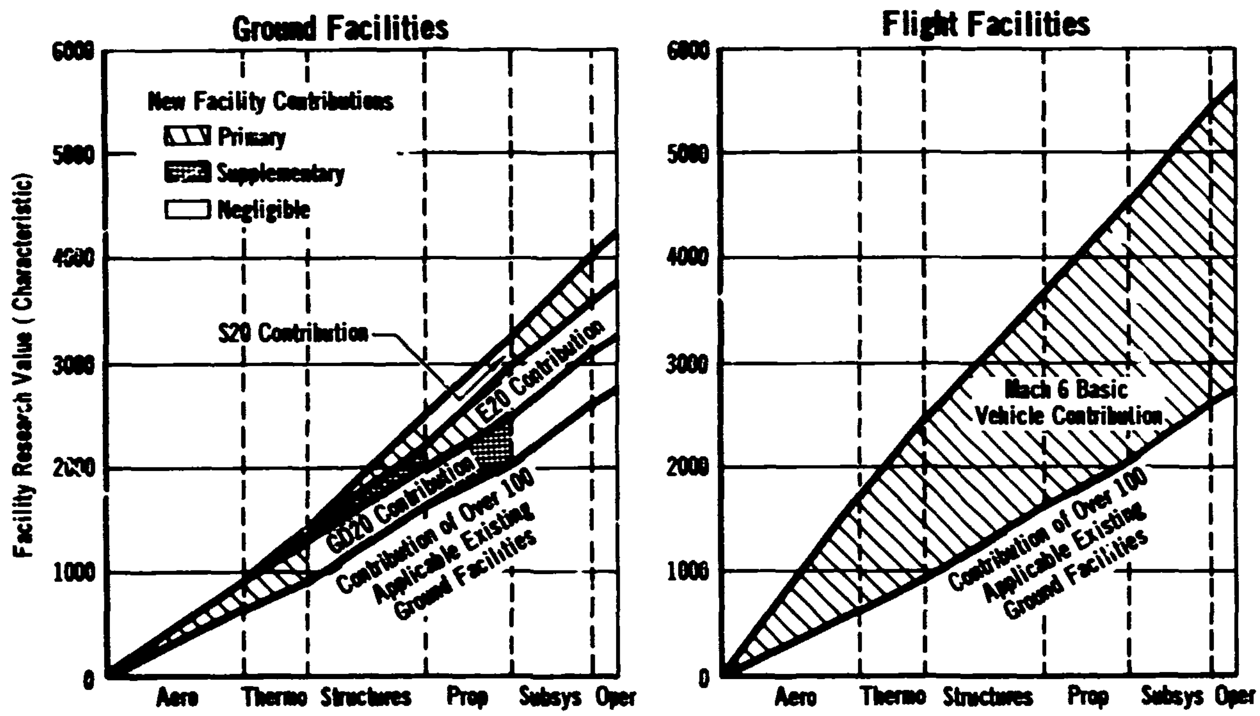


FIGURE 8-9
RESEARCH PROGRAM COMPARISONS FOR OPERATIONAL SYSTEM C1



Comparison of Research Facilities
for Operational System C1

	Facility Research Value Contribution Over Existing Facilities
Ground Facilities (GD20 + E20 + S20)	1474
Flight Vehicle (Mach 6 Basic)	2926

Again, for the Research Tasks identified in this study, a flight vehicle appears to be the most effective way to conduct a research program.

The facility research comparison for Operational System M1, displayed in Figure 8-10, is very similar to the previous comparison for Operational System C1. The ground facility mix and the flight vehicle selected for comparison are the same as shown for C1. On the basis of the Research Tasks applicable to Operational System M1, Facility Research Values for the appropriate ground facilities and the Mach 6 flight vehicle are summarized below.

Comparison of Research Facilities
for Operational System M1

	Facility Research Value Contribution Over Existing Facilities
Ground Facilities (GD20 + E20 + S20)	1221
Flight Vehicle (Mach 6 Basic)	2496

The research program comparison for Operational System M2 is presented in Figure 8-11. This comparison is very similar to that shown previously for Operational System L2 in Figure 8-7. A scramjet option is shown for Operational System M2, following the ground rule of presenting Facility Research Values for flight research vehicle options which make the most substantial contribution to accomplishment of the research required to initiate development of an operational system. A Facility Research Value comparison between the most effective ground facility mix and the Mach 12 research vehicle is presented as follows:

FIGURE 8-10
RESEARCH PROGRAM COMPARISONS FOR OPERATIONAL SYSTEM M1

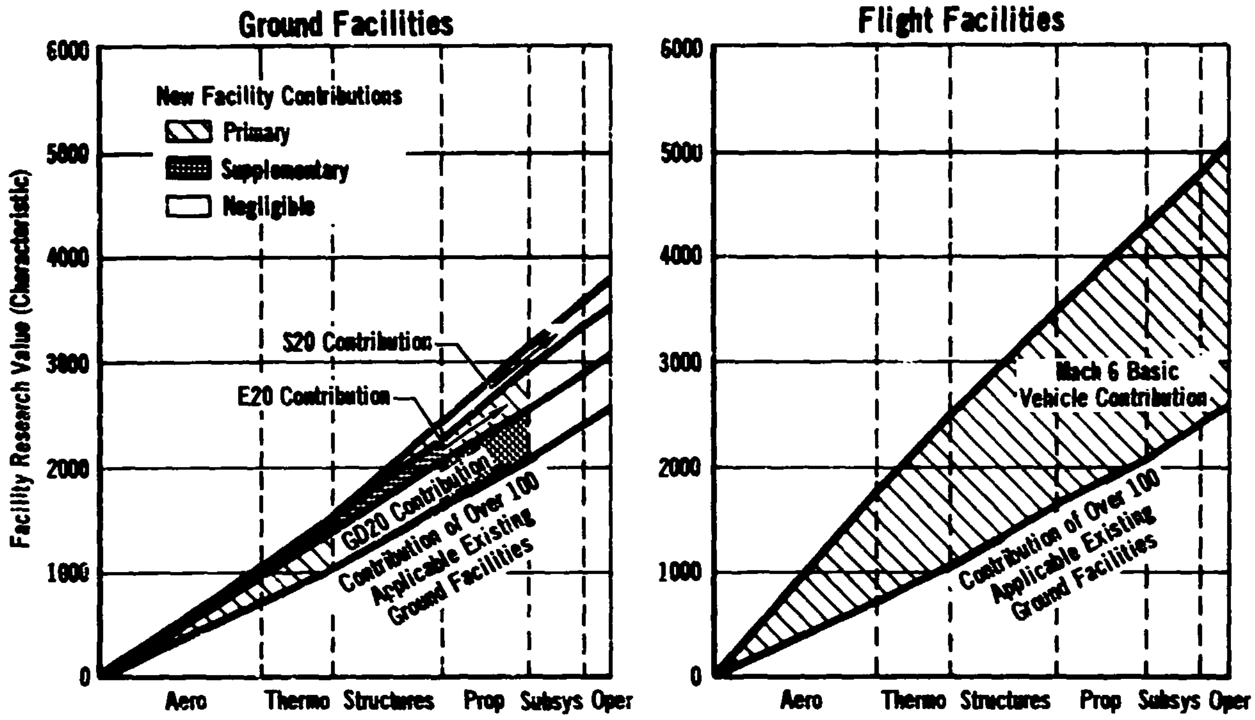
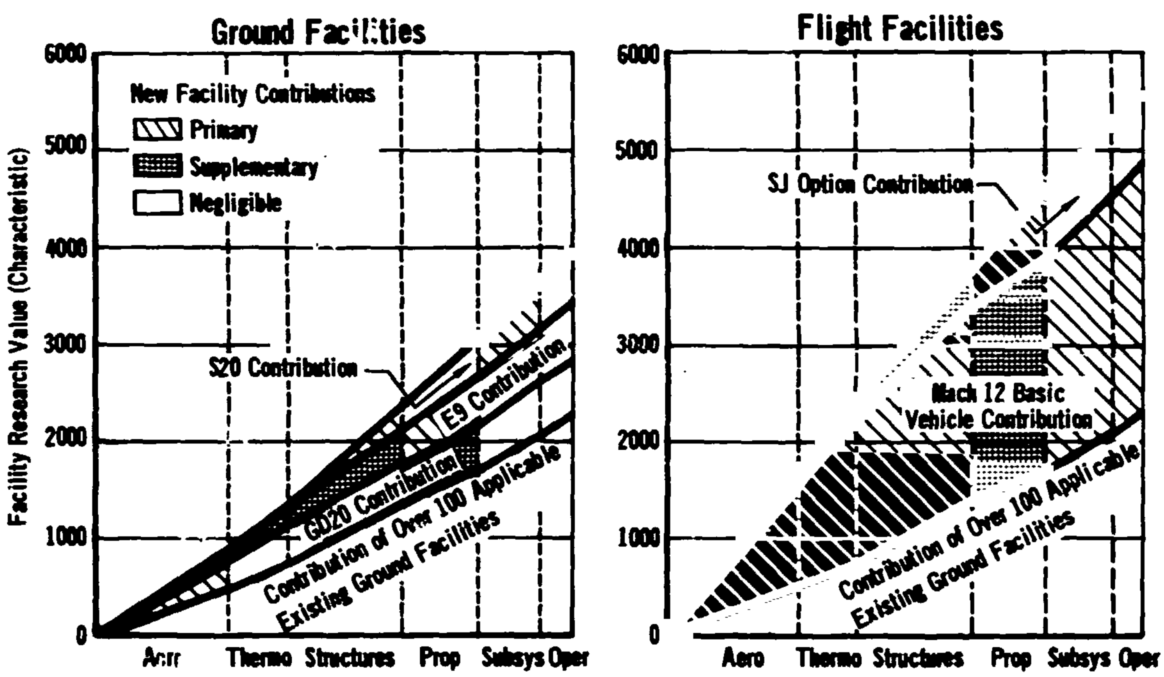


FIGURE 8-11
RESEARCH PROGRAM COMPARISONS FOR OPERATIONAL SYSTEM M2



<u>Comparison of Research Facilities for Operational System M2</u>

	Facility Research Value Contribution Over Existing Facilities
Ground Facilities (GD20 + E9 + S20)	1636
Flight Vehicle	
(Mach 12 Basic)	2565
(Mach 12 Basic + SJ)	3285

As with the comparison presented for the other operational systems, the flight vehicle appears to be superior to a mix of ground facilities.

9. OBSERVATIONS

The principal objective of the Hypersonic Research Facilities Study is to assess the research and development requirements for hypersonic aircraft and define several desirable hypersonic research facilities based on these requirements. Assessment of hypersonic research requirements and evaluation of the potential of several attractive research facilities to satisfy these requirements is presented in this report. At this point, one question becomes pertinent: "What impact should this study have on the maintenance of U.S. aerospace superiority through extension of its operational capability into the hypersonic flight regime?" Observations on the relevance of the HYFAC study results is the theme of this section.

The potential applications of hypersonic vehicle technology are extremely wide-ranging. At the present time, there is considerable interest in hypersonic commercial transports. Several studies have concluded that commercial transports cruising at Mach 6 and above are potentially competitive with current and proposed long-range transports at ranges on the order of 5000 nm. There has also been considerable interest over the past several years in a recoverable launch system for many earth-to-orbit launch operations. Application of hypersonic aircraft to this mission holds strong promise for the future. Many potential military applications of hypersonic cruise aircraft have been studied. These include weapon systems designed to satisfy national requirements in the categories of strategic offense, strategic reconnaissance, and strategic defense. In all of these missions, hypersonic systems provide the advantages of reliability, operational flexibility, and high performance necessary for mission effectiveness and survival. The requirements for all of these civil and military missions were considered in this study, and the conceptual research facilities have the potential for contributing to the development of any one of these classes of hypersonic aircraft.

Although the potential of the hypersonic flight regime is broad, there is no specific systems requirement presently in this regime to lend a sense of urgency and stimulate dedication to hypersonic research. However, the development of hypersonic aircraft represents a somewhat greater challenge than did the development of civil and military aircraft now in operation. This longer development cycle necessarily demands an early start on applied research programs in order to provide the option for operational hypersonic systems in the 1980's. A key element in this development cycle is the acquisition time-span for new research facilities. This time element is summarized in Figure 9-1. Elapsed time from program go-ahead to delivery of a research facility to NASA is presented for each of the new facilities developed during the study. Relative research capability is also shown to indicate the importance of the facility to the overall hypersonic research program. As shown in Figure 9-1, the flight research vehicles can be delivered in less than five years from go-ahead. New ground facility acquisition time-spans vary from nearly four years to over eight years. These facility acquisition time-spans prohibit a quick reaction capability to a high-priority need for an operational hypersonic system.

A gross idea of the time needed to introduce an operational hypersonic system may be obtained from a look at the DOD weapon system procurement cycle. The principal elements of this cycle are identified in Figure 9-2, with the acquisition and testing program of a flight research vehicle shown in parallel to illustrate the interfaces. Acquisition of new ground facilities are not shown in this gross

FIGURE 9–1
FACILITY ACQUISITION COST AND TIME SUMMARY

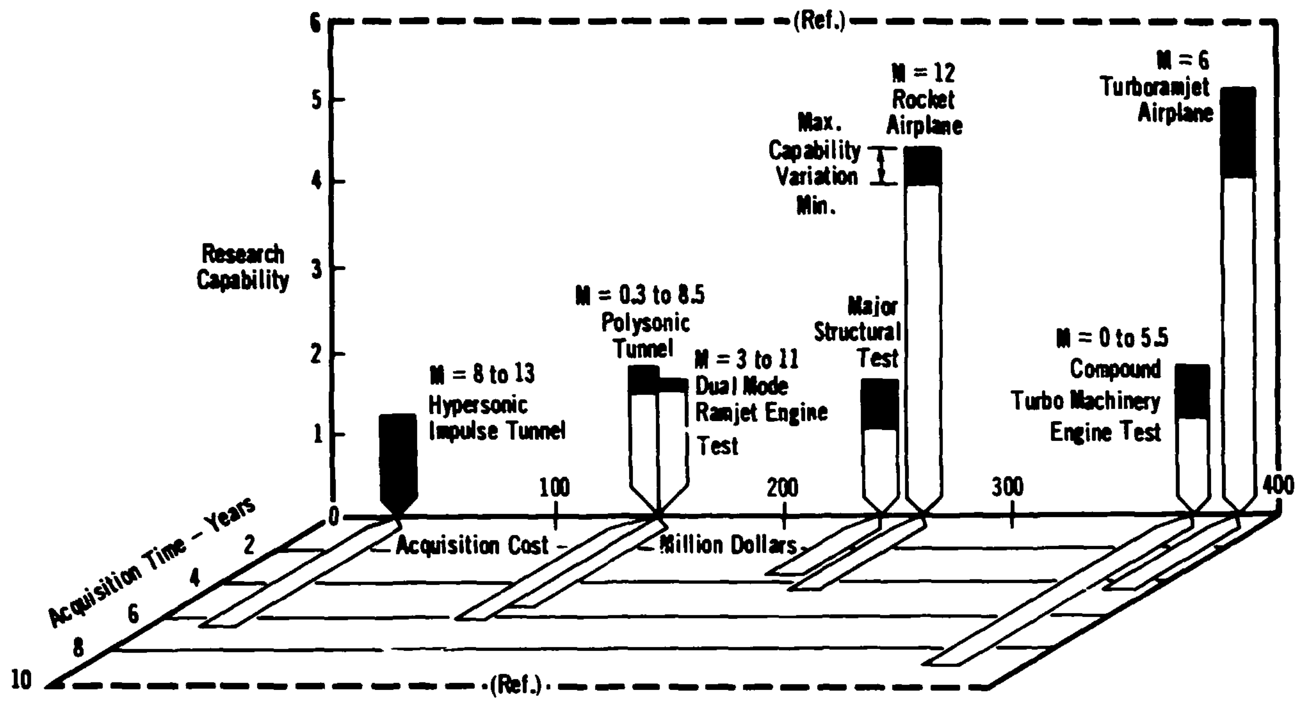
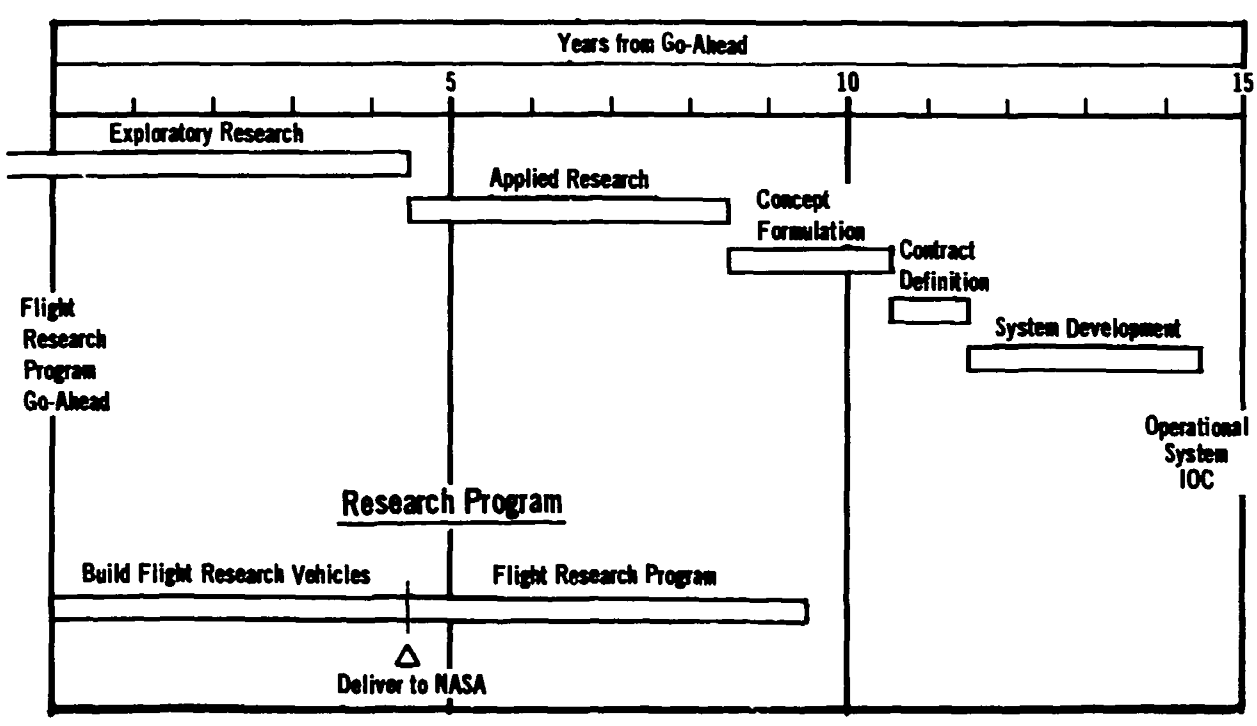


FIGURE 9–2
FIVE-YEAR LEAD TIME IS NEEDED FOR HYPERSONIC RESEARCH PROGRAM TO IMPACT OPERATIONAL SYSTEM DEVELOPMENT CYCLE



example, but would be expected to be phased into a comprehensive research program in a manner which would not affect the conclusions of this analysis. Considering only a flight research vehicle program aimed at accomplishing the applied research required to establish confidence to proceed with development of an operational system, almost fifteen years would elapse between research vehicle go-ahead and introduction of an operational capability (IOC). This analysis is not rigorous, but it emphasizes that the U. S. cannot wait for a firm operational need to be identified prior to initiation of a hypersonic research program. What are the alternatives to this flight research program for operational system development? A prototype approach is one alternative. Such a program would have to be examined in some depth for a specific operational system, but it is not believed that any time could be saved in the development cycle. In addition, the broad application of a disciplined research program to hypersonic technology and other operational hypersonic aircraft systems would be sacrificed. A development approach utilizing only ground facilities is another possibility. However, in addition to applying only to a narrow band of the required research spectrum, none of the new ground facilities can be acquired in significantly less time than a flight vehicle. Also, existing ground facilities have not shown the ability to provide the level of confidence needed to proceed with development of advanced operational systems.

To present a program rationale for the initiation of new research facility programs that can survive the necessarily critical evaluation of decision makers is a challenging task. A practical overall assessment must recognize:

1) Competing national priorities for new programs, including the impact of the space shuttle on resources within the aerospace budget.

2) The declining appeal of research and exploratory development programs that are not specifically directed toward a particular application

3) The absence of any generally accepted need and sense of urgency for hypersonic cruise aircraft, yet the prevailing presence of almost limitless attractive applications for such aircraft

4) A generally accepted conviction that knowing what problems need to be solved is more difficult than finding the solution to known problems

5) An environment of conflicting views represented by advocates who claim we have reached a "Technological Plateau";and an equal number who claim there is no such thing as a "Technological Plateau"; advocates who claim we must continue research programs as a margin of safety to ensure we have many options available to use and an equal number who claim every technological effort must have a clearly defined need which cannot be met adequately by other means.

The aeronautical flight regime between high-supersonic and orbital flight has been leapfrogged by space systems which operate transiently in this regime and cannot fully exploit its potential. It is evident that without a defined specific goal the progress in aeronautical technology in this flight regime will stagnate rather than move forward. This study provides the framework for a strong, determined effort to explore and utilize the hypersonic flight regime.

APPENDIX A

This appendix contains all data which influence the Facility Research Values and which were not presented in the main body of this report. A computer program was used to store the multitude of individual elements involved in the analysis and to combine them in such a way as to yield the totals presented for each facility. The data shown here, as well as the corresponding information presented in the illustrative examples for Operational System C1 in Section 5, are reproductions of the printouts produced by this program.

The appendix is divided into three parts, with each section containing all of the data for each operational system not previously presented in Section 5. In Section A.1, Figures A-1 through A-3 list the intrinsic values of the Research Objectives and Research Tasks as they apply to Operational Systems L2, M1, and M2. Section A.2 presents the capabilities of the various facilities to perform each of the applicable Research Tasks. These capabilities, expressed as the percent of the Research Task achievable by each facility, are shown for the ground facilities and basic flight vehicles relative to Operational Systems L2, M1, and M2 in Figures A-4 through A-6. A similar format is used to present facility capabilities for the flight vehicle options, relative to all four operational systems, in Figures A-7 through A-10. Research values on an individual task basis are presented in Section A.3 in terms of task intrinsic values multiplied by facility capabilities, with a summary also included at the end of each figure for each facility relative to the operational system involved. As in the previous section, values are first shown for the ground facilities and the basic flight vehicles in relation to Operational Systems L2, M1, and M2 (in Figures A-11 through A-13), and then in relation to these three systems, and to Operational System C1 as well, for the flight vehicle options (in Figures A-14 through A-17).

A.1 RESEARCH TASK INTRINSIC VALUES

The intrinsic value of each of the Research Tasks relative to Operational Systems L2, M1, and M2 is shown in Figures A-1 through A-3. Corresponding data are presented for Operational System C1 in Figure 5-1.

FIGURE A-1
RESEARCH TASK INTRINSIC VALUES FOR OPERATIONAL SYSTEM L2

OBJ. NO.	OBJECTIVE INTRINSIC VALUE	TASK INTRINSIC VALUES TASK= 1	2	3	4	5	6
1	58.1	58.1	49.4	34.9	17.4		
2	58.0	58.0	49.3	34.8	17.4		
3	70.9	60.3	70.9	21.3	42.5		
4	66.1	56.2	39.7	39.7			
5	58.1	58.1	49.4	49.4			
6	56.2	47.8	47.8	56.2			
7	58.9	50.1	50.1	35.3			
9	62.0	52.7	52.7	37.2	52.7		
10	48.9	48.9	41.6				
11	53.5	53.5	53.5	15.0			
12	61.4	52.2	36.8	18.4			
14	40.9	34.8	24.5	40.9			
15	41.6	25.0	41.6	25.0			
16	57.8	49.1	49.1	57.8			
17	53.2	45.2	45.2				
18	34.4	29.2	29.2				
19	58.4	49.6	49.6				
20	54.8	54.8	46.6	46.6	32.9		
22	52.6	52.6	44.7	44.7			
23	39.5	39.5	33.[illegible]	33.6			
24	56.5	48.0	33.9	56.5			
25	45.9	39.0	45.9	39.0	27.5		
26	55.3	33.2	47.0	55.3			
27	41.9	41.9	25.1	35.6			
28	73.5	62.5	62.5	44.1	73.5		
30	57.8	49.1	34.7	57.8			
32	58.4	35.0	58.4	49.6			
33	61.6	61.6	52.4	37.0			
34	70.9	70.9	42.5	60.3	60.3		
35	36.5	36.5	31.0				
36	61.5	36.9	52.3	61.5			
38	37.4	31.8	37.4	31.8			
39	41.3	24.8	41.3				
40	59.0	59.0	50.1	35.4			
41	51.4	43.7	43.7				
42	62.5	62.5					
43	72.6	61.7	72.6	43.6	43.6		
44	64.8	55.1	64.8				
45	64.0	38.4	54.4	64.0			
46	53.4	45.4	45.4				
48	66.6	56.6	56.6	40.0	66.6	66.6	
52	58.8	50.0	50.0	50.0	58.8		
56	65.1	39.1	39.1	55.3			
60	72.4	43.4	43.4	43.4	61.5	61.5	72.4
63	52.3	31.4	44.5	52.3			
65	58.1	34.9	49.4	58.1			
67	65.6	39.4	39.4	55.8			
68	40.3	24.2	34.3	34.3			
69	36.9	22.1	31.4	31.4			
70	46.1	27.7	27.7	39.2	39.2	46.1	
71	33.4	28.4	28.4	33.4			
72	36.6	22.0	31.1	36.6			
73	41.9	25.1	35.6	41.9			
75	45.8	27.5	38.9	45.8			
77	28.5	24.2	28.5				
78	39.5	23.7	33.6	39.5			
79	29.9	25.4	29.9				
80	41.0	34.8	41.0				
82	32.8	19.7	27.9	32.8			
83	38.7	23.2	38.7				
87	37.9	22.7	22.7	37.9			
89	42.7	25.6	25.6	36.3			
93	29.3	29.3	24.9				
94	39.4	23.6	33.5	39.4			
96	35.1	21.1	35.1				
97	36.4	21.8	36.4				
102	37.5	31.9	37.5				

FIGURE A-2
RESEARCH TASK INTRINSIC VALUES FOR OPERATIONAL SYSTEM M1

OBJ. NO.	OBJECTIVE INTRINSIC VALUE	TASK INTRINSIC VALUES TASK= 1	2	3	4	5	6
1	55.9	55.9	47.5	33.5	16.8		
2	56.0	56.0	47.6	33.6	16.8		
3	70.6	60.0	70.6	21.2	42.4		
4	64.9	55.2	38.9	38.9			
5	56.0	56.0	47.6	47.6			
6	53.8	45.7	45.7	53.8			
7	56.4	47.9	47.9	33.8			
9	60.7	51.6	51.6	36.4	51.6		
12	59.0	50.1	35.4	17.7			
14	37.7	32.0	22.6	37.7			
15	39.6	23.8	39.6	23.8			
16	55.5	47.2	47.2	55.5			
17	50.5	42.9	42.9				
1[illegible]	56.1	47.7	47.7				
20	53.5	53.5	45.5	45.5	32.1		
22	50.8	50.8	43.2	43.2			
24	54.9	45.7	32.9	54.9			
25	43.0	36.5	43.0	36.5	25.8		
26	54.6	32.8	46.4	54.6			
27	40.2	40.2	24.1	34.2			
30	58.2	49.5	34.9	58.2			
32	58.3	35.0	58.3	49.6			
33	61.3	61.3	52.1	36.8			
34	59.[illegible]	N/A	41.6	59.9	N/A		
35	3[illegible]	34.0	30.6				
35	[illegible]	36.5	51.8	60.9			
39	40.4	24.2	40.4				
40	58.5	[illegible]8.5	49.7	35.1			
41	51.5	43.8	43.8				
42	52.3	62.3					
43	72.9	62.0	72.9	43.7	43.7		
44	64.6	54.9	64.6				
45	63.4	38.0	53.9	63.4			
46	53.0	45.0	45.0				
49	66.0	56.1	56.1	39.6	66.0	66.0	
52	58.3	49.6	49.6	49.6	58.3		
57	68.8	41.3	41.3	41.3	58.5	58.5	68.8
58	64.4	38.6	38.6	54.7			
59	67.4	40.4	40.4	40.4	57.3	57.3	67.4
63	52.5	31.5	44.6	52.5			
65	58.7	35.2	49.9	58.7			
67	65.4	39.2	39.2	55.6			
71	35.7	30.3	30.3	35.7			
72	38.5	23.1	32.7	38.5			
77	30.4	25.8	30.4				
78	42.6	25.6	36.2	42.6			
79	31.2	26.5	31.2				
80	44.4	37.7	44.4				
82	35.0	21.0	29.7	35.0			
84	40.7	24.4	40.7				
85	41.7	25.0	35.4	41.7			
87	37.9	22.7	22.7	37.9			
89	42.7	25.6	25.6	36.3			
93	29.3	29.3	24.9				
94	39.4	23.6	33.5	39.4			
95	35.1	21.1	3[illegible].1				
97	36.4	21.8	[illegible]6.4				
102	37.5	31.9	37.5				

FIGURE A-3
RESEARCH TASK INTRINSIC VALUES FOR OPERATIONAL SYSTEM M2

OBJ. NO.	OBJECTIVE INTRINSIC VALUE	TASK INTRINSIC VALUES TASK= 1	2	3	4	5	6
1	58.3	58.3	49.6	35.0	17.5		
2	57.6	57.6	49.0	34.6	17.3		
3	71.1	60.4	71.1	21.3	42.7		
4	66.1	56.2	39.7	39.7			
5	57.8	57.8	49.1	49.1			
6	55.5	47.2	47.2	55.5			
7	58.1	49.4	49.4	34.9			
8	62.0	52.7	52.7	37.2	52.7		
12	60.8	51.7	36.5	18.2			
14	39.9	33.9	23.9	39.9			
15	41.0	24.6	41.0	24.6			
16	57.0	49.4	48.[illegible]	57.0			
17	52.1	44.3	44.3				
18	32.9	28.0	28.0				
19	57.8	49.1	49.1				
20	53.5	53.5	45.5	45.5	32.1		
22	50.8	50.8	43.2	43.2			
24	54.9	46.7	32.9	54.9			
25	43.0	36.5	43.0	36.5	25.8		
26	54.6	32.8	46.4	54.6			
27	40.2	40.2	24.1	34.2			
28	73.5	62.5	62.5	44.1	73.5		
30	57.8	49.1	34.7	57.8			
32	58.4	35.0	58.4	49.6			
33	61.6	61.6	52.4	37.0			
34	70.9	70.9	42.5	60.3	60.3		
35	36.5	36.5	31.0				
36	61.5	36.9	52.3	61.5			
38	37.4	31.8	37.4	31.8			
39	41.3	24.8	41.3				
40	59.0	59.0	50.1	35.4			
41	51.4	43.7	43.7				
42	62.5	62.5					
43	72.6	61.7	72.6	43.6	43.6		
44	64.8	55.1	64.8				
45	64.0	38.4	54.4	64.0			
46	53.4	45.4	45.4				
48	73.7	62.6	62.6	44.2	73.7	73.7	
52	67.7	57.5	57.5	57.5	67.7		
58	70.0	42.0	42.0	59.5			
61	73.0	43.8	43.8	43.8	62.0	62.0	73.0
62	41.8	25.1	35.5	41.8			
63	61.6	37.0	52.4	61.6			
64	36.6	31.1	31.1				
65	66.9	40.1	56.9	66.9			
67	73.1	43.9	43.9	62.1			
68	39.9	23.9	33.9	33.9			
69	37.0	22.2	31.4	31.4			
70	46.2	27.7	27.7	39.3	39.3	46.2	
73	41.5	24.9	35.3	41.5			
74	31.3	18.8	18.8	31.3			
75	46.0	27.6	39.1	46.0			
77	28.6	24.3	28.6				
78	39.6	23.8	33.7	39.6			
79	30.6	26.0	30.6				
80	40.8	34.7	40.8				
82	32.6	19.6	27.7	32.6			
83	38.2	[illegible].9	38.2				
85	39.1	[illegible].5	33.2	39.1			
87	39	[illegible].8	23.8	39.6			
89	4[illegible].	26.2	26.2	37.1			
93	30.8	30.8	26.2				
94	40.9	24.5	34.8	40.9			
96	36.4	21.8	36.4				
97	37.9	22.7	37.9				
99	31.3	18.8	18.8				
100	32.4	27.5	32.4				
102	39.1	33.2	39.1				

A.2 FACILITY CAPABILITIES

The capabilities of the various ground facilities and basic flight vehicles to perform the research described by each Research Task is shown in Figures A-4 through A-6 for Operational Systems L2, M1, and M2. The basis for the determination of this data is described in detail in Section 5.2, and the corresponding values for Operational System C1 are presented in Figure 5-3.

The capabilities of the flight vehicle options to perform applicable Research Tasks are illustrated in Figures A-7 through A-10 for all four operational systems considered in this study. The values indicated for the basic vehicles are identical with those shown previously for these vehicles and are included here for reference. A dash indicates that the particular option adds no capability to the basic vehicle for the corresponding task. No vehicle option assessment was made for tasks designated as analytic or of a strictly ground-test nature.

FIGURE A–4
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM L2

PERCENTAGE OF RESEARCH ACHIEVABLE IN EACH FACILITY
OPERATIONAL SYSTEM L2

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES GDT	GR29	F20	F9	S2C	BASIC FLT. VEHICLES MB	M12
1-1	38	-	-	-	-	-	90	45
1-2	38	-	-	-	-	-	90	45
1-3	38	-	-	-	-	-	90	45
1-4	40	-	-	-	-	-	90	45
2-1	30	-	52	-	-	-	80	95
2-2	30	-	52	-	-	-	85	80
2-3	30	-	52	-	-	-	90	85
2-4	40	-	-	-	-	-	90	95
3-1	35	50	55	-	-	-	90	90
3-2	35	50	55	-	-	-	70	90
3-3	32	47	52	-	-	-	70	90
3-4	35	53	55	-	-	-	70	75
4-1	26	32	43	30	43	-	80	90
4-2	26	32	43	36	43	-	80	90
4-3	26	32	43	32	43	-	90	90
5-1	45	-	-	-	-	-	80	80
5-2	45	-	-	-	-	-	90	80
5-3	45	-	-	-	-	-	80	95
6-1	30	36	46	-	-	-	80	90
6-2	30	36	46	-	-	-	70	75
6-3	30	36	46	-	-	-	70	80
7-1	ANALYTIC							
7-2	26	37	42	-	-	-	90	60
7-3	26	37	42	-	-	-	90	90
8-1	26	36	41	36	43	-	90	70
8-2	26	37	42	36	43	-	90	30
8-3	26	37	42	36	43	-	70	26
8-4	19	32	42	36	43	-	75	80
10-1	30	36	46	-	-	-	45	55
10-2	30	36	46	-	-	-	45	55
11-1	ANALYTIC							
11-2	38	44	54	-	-	-	40	50
11-3	[illegible]	-	-	-	-	-	[illegible]	[illegible]
12-1	20	30	44	-	-	-	80	90
12-2	23	33	44	-	-	-	80	79
12-3	20	30	44	-	-	-	80	70
14-1	26	-	49	-	-	-	90	95
14-2	20	-	49	-	-	-	90	95
14-3	10	-	20	-	-	-	90	95
15-1	20	50	49	-	-	-	90	95
15-2	23	53	40	-	-	-	80	90
15-3	10	25	22	-	-	-	85	95
16-1	23	20	30	26	30	-	90	95
16-2	20	20	33	26	30	-	80	95
16-3	10	14	15	13	15	-	80	95
17-1	20	29	33	26	26	-	80	95
17-2	20	29	39	26	26	-	90	90
18-1	40	49	49	47	49	-	90	95
18-2	ANALYTIC							
19-1	26	32	30	-	-	-	90	95
19-2	26	32	39	-	-	-	90	95
20-1	23	30	33	30	35	-	90	95
20-2	20	30	33	30	35	-	90	95
20-3	20	26	20	26	31	-	70	75
20-4	11	15	17	15	18	-	85	90
22-1	20	30	33	30	35	-	80	95
22-2	20	30	33	30	35	-	85	95
22-3	20	33	33	30	35	-	85	95
23-1	32	35	38	42	52	-	32	32
23-2	32	35	38	42	52	-	35	35
23-3	20	32	35	30	40	-	20	20
24-1	22	33	47	26	26	-	80	90
24-2	22	33	47	26	26	-	80	90
24-3	22	33	47	26	26	-	80	90
25-1	22	35	38	26	20	-	85	90
25-2	22	38	44	28	31	-	85	95
25-3	22	30	44	26	27	-	85	95
25-4	12	25	29	14	17	-	85	90
26-1	78	-	-	-	-	-	95	75
26-2	78	-	-	-	-	-	80	90
26-3	22	-	40	28	40	37	85	90
27-1	36	42	45	44	50	40	95	70
27-2	36	42	45	44	50	40	75	75
27-3	36	44	49	38	44	40	85	95
28-1	40	-	-	-	-	65	GROUND TEST	
28-2	30	-	-	-	-	65	80	85
28-3	36	-	-	-	-	70	GROUND TEST	
28-4	15	-	-	-	-	35	80	85
	EXISTING	GDT	GR29	F20	F9	S2C	MB	M12

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FIGURE A-4
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM L2 (CONTINUED)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES G07	GD20	F29	F9	S2C	BASIC FLT. VEHICLES M6	M12
30-1	68	-	-	-	-	72	GROUND	TEST
30-2	68	-	-	-	-	72	GROUND	TEST
30-3	68	-	-	-	-	72	100	100
32-1	26	-	-	33	32	63	GROUND	TEST
32-2	29	-	-	36	35	63	GROUND	TEST
32-3	32	-	-	39	38	65	90	100
33-1	ANALYTIC							
33-2	13	35	35	43	44	52	GROUND	TEST
33-3	15	16	16	20	21	48	85	95
34-1	22	-	-	26	20	39	26	22
34-2	75	-	-	-	-	-	GROUND	TEST
34-3	ANALYTIC							
34-4	16	17	17	-	26	21	25	14
35-1	22	26	30	28	38	43	80	80
35-2	23	26	30	28	38	43	100	100
36-1	ANALYTIC							
36-2	34	-	-	51	44	56	GROUND	TEST
36-3	36	-	-	45	40	56	90	100
38-1	53	-	-	-	-	65	GROUND	TEST
38-2	43	-	-	-	-	68	GROUND	TEST
38-3	60	-	-	-	-	65	90	100
39-1	43	45	45	44	52	44	95	90
39-2	40	45	45	44	52	44	95	90
40-1	ANALYTIC							
40-2	50	-	-	-	60	58	GROUND	TEST
40-3	50	-	-	-	60	58	95	[illegible]
41-1	ANALYTIC							
41-2	ANALYTIC							
42-1	27	-	-	-	-	68	85	90
43-1	33	-	-	42	43	48	70	90
43-2	30	-	-	45	46	52	75	85
43-3	60	-	-	-	-	57	GROUND	TEST
43-4	ANALYTIC							
44-1	ANALYTIC							
44-2	75	-	-	-	-	-	85	95
45-1	ANALYTIC							
45-2	37	-	-	40	50	45	80	85
45-3	37	-	-	45	50	48	90	85
46-1	ANALYTIC							
46-2	70	-	-	-	-	75	85	90
48-1	31	30	49	43	41	-	58	45
48-2	31	30	49	43	41	-	55	45
48-3	26	34	44	30	36	-	50	44
48-4	33	41	51	45	43	-	60	42
48-5	ANALYTIC							
52-1	ANALYTIC							
52-2	ANALYTIC							
52-3	ANALYTIC							
52-4	18	-	-	40	47		60	18
58-1	ANALYTIC							
58-2	ANALYTIC							
58-3	23	-	-	-	-		20	20
60-1	ANALYTIC							
60-2	ANALYTIC							
60-3	ANALYTIC							
60-4	26	-	-	33	53	-	50	26
60-5	26	-	-	33	53	-	60	26
60-6	26	-	-	33	53	-	50	26
63-1	22	46	47	49	56	-	45	35
63-2	35	55	53	51	58	-	50	35
63-3	22	27	33	40	56	27	45	22
65-1	ANALYTIC							
65-2	19	28	32	35	42	-	19	19
65-3	26	32	34	44	52	-	26	26
67-1	17	27	35	41	38	-	GROUND	TEST
67-2	17	27	35	41	38	-	20	20
67-3	ANALYTIC							
68-1	67	-	-	-	-	75	GROUND	TEST
68-2	65	-	-	-	-	75	GROUND	TEST
68-3	65	-	-	-	-	75	GROUND	TEST
69-1	ANALYTIC							
69-2	55	-	-	-	-	70	GROUND	TEST
69-3	58	-	-	-	-	70	80	100
	EXISTING	G07	GD20	F29	F9	S2C	M6	M12

FIGURE A-4
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM L2 (CONTINUED)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES					BASIC FLT. VEHICLES	
		GROUND FACILITIES						
		GD7	GD20	F20	F9	S20	M6	M12
70-1	ANALYTIC							
70-2	42	-	-	-	-	60	GROUND	TEST
70-3	42	-	-	-	-	60	GROUND	TEST
70-4	24	30	28	34	52	58	GROUND	TEST
70-5	24	-	-	34	52	58	60	60
71-1	75	-	-	-	-	-	95	75
71-2	75	-	-	-	-	-	95	75
71-3	75	-	-	-	-	-	95	75
72-1	75	-	-	-	-	-	GROUND	TEST
72-2	75	-	-	-	-	-	GROUND	TEST
72-3	75	-	-	-	-	-	GROUND	TEST
73-1	65	-	-	-	-	75	85	95
73-2	65	-	-	-	-	75	85	85
73-3	65	-	-	-	-	75	85	85
75-1	75	-	-	-	-	-	GROUND	TEST
75-2	27	-	-	-	-	67	GROUND	TEST
75-3	27	-	-	-	-	71	80	100
77-1	ANALYTIC							
77-2	55	-	-	60	65	75	80	95
78-1	ANALYTIC							
78-2	32	40	48	34	38	-	65	70
78-3	32	40	48	34	38	-	70	95
79-1	ANALYTIC							
79-2	27	37	42	38	48	37	80	80
80-1	55	60	63	60	65	70	85	90
80-2	42	52	52	52	57	67	85	90
82-1	ANALYTIC							
82-2	55	60	60	60	65	70	GROUND	TEST
82-3	51	56	56	56	61	66	95	100
83-1	ANALYTIC							
83-2	45	-	-	-	-	75	90	100
87-1	ANALYTIC							
87-2	ANALYTIC							
87-3	75	-	-	-	-	-	65	50
88-1	ANALYTIC							
88-2	55	-	-	-	-	-	80	95
88-3	55	-	-	-	-	-	90	80
93-1	ANALYTIC							
93-2	28	35	39	35	38	45	90	90
94-1	ANALYTIC							
94-2	ANALYTIC							
94-3	26	32	36	34	32	42	65	70
96-1	12	18	22	20	22	32	80	70
96-2	14	20	24	27	24	34	80	75
97-1	75	-	-	-	-	-	GROUND	TEST
97-2	30	-	-	-	-	70	90	90
102-1	ANALYTIC							
102-2	60	-	-	-	-	70	90	95
	EXISTING	GD7	GD20	F20	F9	S20	M6	M12

FIGURE A-5
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M1

PERCENTAGE OF RESEARCH ACHIEVABLE IN EACH FACILITY
OPERATIONAL SYSTEM M1

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES					BASIC FLT. VEHICLES	
		GD7	GD20	E20	F9	S20	M6	M12
1-1	53	-	-	-	-	-	95	55
1-2	52	-	-	-	-	-	95	55
1-3	52	-	-	-	-	-	95	55
1-4	60	-	-	-	-	-	95	60
2-1	52	-	59	-	-	-	95	95
2-2	52	-	59	-	-	-	95	75
2-3	52	-	59	-	-	-	95	95
2-4	60	-	-	-	-	-	95	95
3-1	52	-	67	-	-	-	95	95
3-2	52	-	67	-	-	-	95	95
3-3	45	-	64	-	-	-	95	95
3-4	52	-	67	-	-	-	95	52
4-1	37	-	52	47	-	-	95	95
4-2	37	-	52	48	-	-	95	95
4-3	37	-	52	48	-	-	95	95
5-1	72	-	-	-	-	-	95	95
5-2	72	-	-	-	-	-	95	95
5-3	72	-	-	-	-	-	95	95
6-1	39	-	55	-	-	-	95	95
6-2	39	-	55	-	-	-	95	95
6-3	35	-	55	-	-	-	95	95
7-1	ANALYTIC							
7-2	35	-	51	-	-	-	95	50
7-3	35	-	51	-	-	-	95	60
8-1	35	-	50	45	38	-	95	60
8-2	35	-	51	45	38	-	95	60
8-3	35	-	51	45	38	-	95	35
8-4	25	-	51	45	38	-	95	95
12-1	29	-	53	-	-	-	95	95
12-2	29	-	53	-	-	-	95	95
12-3	29	-	53	-	-	-	95	95
14-1	32	-	58	-	-	-	95	95
14-2	26	-	44	-	-	-	95	95
14-3	13	-	23	-	-	-	95	95
15-1	26	-	60	-	-	-	95	95
15-2	26	-	60	-	-	-	95	95
15-3	13	-	33	-	-	-	95	95
16-1	37	-	49	43	46	-	95	95
16-2	37	-	49	43	46	-	95	95
16-3	19	-	25	21	23	-	95	95
17-1	24	-	49	29	25	-	95	95
17-2	24	-	49	28	25	-	95	95
18-1	34	-	54	-	-	-	95	95
18-2	34	-	54	-	-	-	95	95
20-1	29	-	52	35	43	-	95	95
20-2	29	-	52	38	43	-	95	95
20-3	29	-	49	36	40	-	90	35
20-4	17	-	26	19	22	-	95	95
22-1	29	-	52	35	43	-	95	95
22-2	29	-	52	35	43	-	95	95
22-3	29	-	52	35	43	-	95	95
24-1	33	-	52	35	37	-	95	95
24-2	33	-	52	35	37	-	95	95
24-3	33	-	52	35	37	-	95	95
25-1	34	-	48	38	36	-	95	95
25-2	34	-	53	40	38	-	95	95
25-3	34	-	53	34	35	-	95	95
25-4	24	-	29	29	25	-	95	95
26-1	75	-	-	-	-	-	95	90
26-2	75	-	-	-	-	-	95	95
26-3	33	-	53	71	71	37	95	95
27-1	45	-	59	52	48	52	95	75
27-2	69	-	59	56	52	57	95	75
27-3	65	-	63	60	55	69	95	95
30-1	68	-	-	-	-	72	GROUND TEST	
30-2	68	-	-	-	-	72	GROUND TEST	
30-3	68	-	-	-	-	72	100	100
	EXISTING	GD7	GD20	E20	F9	S20	M6	M12

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

FIGURE A-5
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M1 (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES GD7	GD23	F20	F9	S20	BASIC FLT. VEHICLES M6	M12
[illegible]	62	-	-	49	48	[illegible]	GROUND	TEST
[illegible]	65	-	-	52	51	[illegible]	GROUND	TEST
[illegible]	58	-	-	68	67	[illegible]	100	100
[illegible]	ANALYTIC							
[illegible]	60	-	56	61	66	70	GROUND	TEST
[illegible]	27	-	26	28	31	36	95	100
[illegible]	75	-	-	-	-	-	GROUND	TEST
[illegible]	ANALYTIC							
[illegible]	33	-	63	38	-	53	90	95
[illegible]	32	-	63	38	-	53	100	100
[illegible]	ANALYTIC							
[illegible]	66	-	-	73	70	65	GROUND	TEST
[illegible]	66	-	-	52	65	65	100	100
[illegible]	69	-	56	53	61	53	95	95
[illegible]	65	-	56	53	61	53	95	95
[illegible]	ANALYTIC							
[illegible]	62	-	-	-	66	64	GROUND	TEST
[illegible]	62	-	-	-	66	64	100	100
41-1	ANALYTIC							
41-2	ANALYTIC							
[illegible]	68	-	-	-	-	75	100	95
[illegible]	66	-	-	63	42	67	90	85
[illegible]	46	-	-	53	45	70	85	90
[illegible]	56	-	-	-	-	75	GROUND	TEST
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	75	-	-	-	-	-	95	100
[illegible]	ANALYTIC							
[illegible]	53	-	-	72	58	61	100	100
[illegible]	53	-	-	72	58	61	100	100
[illegible]	ANALYTIC							
[illegible]	67	-	-	-	-	61	90	95
[illegible]	63	-	65	45	-	-	90	95
[illegible]	53	-	75	65	-	-	75	95
[illegible]	48	-	63	60	-	-	80	60
[illegible]	58	-	67	47	-	-	85	89
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	36	-		67	66		90	36
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	36	-	-	48	55	-	80	36
[illegible]	36	-	-	48	55	-	95	36
[illegible]	32	-	-	47	57	-	85	32
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	20	-					50	28
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	60	-	-	48	55	-	80	60
[illegible]	60	-	-	49	55	-	80	60
[illegible]	60	-	-	71	60	-	80	60
[illegible]	37	-	62	70	67	-	90	37
[illegible]	45	-	55	60	55	-	95	45
[illegible]	37	-	62	70	67	62	90	37
[illegible]	ANALYTIC							
[illegible]	31	-	60	51	60	-	90	31
[illegible]	35	-	65	58	60	-	65	35
[illegible]	30	-	66	51	32	-	GROUND	TEST
[illegible]	20	-	66	51	32	-	75	28
[illegible]	ANALYTIC							
	EXISTING	GD7	GD23	F20	F9	S20	M6	M12

FIGURE A-5
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M1 (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: M6 FLIGHT VEHICLE BASIC	TPS	ARM	M12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
71-1	75	100	-	-	75	-	-	-	-	-	-	-
71-2	75	100	-	-	75	-	-	-	-	-	-	-
71-3	75	100	-	-	75	-	-	-	-	-	-	-
72-1	GND. TEST											
72-2	GND. TEST											
72-3	GND. TEST											
77-1	ANALYTIC											
77-2	60	85	90	95	85	-	-	-	90	95	-	-
78-1	ANALYTIC											
78-2	44	90	-	-	85	-	-	-	-	-	-	-
78-3	44	95	-	-	90	-	-	-	-	-	-	-
79-1	ANALYTIC											
79-2	35	60	-	-	95	-	-	-	-	-	-	-
80-1	[illegible]	[illegible]	-	-	95	-	-	-	-	-	-	-
80-2	59	60	-	-	95	-	-	-	-	-	-	-
82-1	ANALYTIC											
82-2	GND. TEST											
82-3	63	100	-	-	100	-	-	-	-	-	-	-
84-1	ANALYTIC											
84-2	65	100	-	-	75	-	-	-	-	-	-	-
85-1	ANALYTIC											
85-2	36	90	-	-	95	-	-	-	-	-	-	-
85-3	36	36	-	[illegible]	36	-	-	-	-	95	-	-
87-1	ANALYTIC											
87-2	ANALYTIC											
87-3	40	55	-	-	50	-	-	85	-	-	85	-
89-1	ANALYTIC											
89-2	70	90	-	-	95	-	-	-	-	-	-	-
89-3	70	90	-	-	85	-	-	95	-	-	-	-
93-1	ANALYTIC											
93-2	38	95	-	-	85	-	-	-	-	-	-	-
94-1	ANALYTIC											
94-2	ANALYTIC											
94-3	38	75	-	-	70	-	-	-	-	-	-	-
96-1	18	95	-	-	70	80	80	-	-	-	-	-
96-2	20	95	-	-	75	90	90	-	-	-	-	-
97-1	GND. TEST											
97-2	30	100	-	-	90	-	-	-	-	-	-	-
102-1	ANALYTIC											
102-2	70	100	-	-	85	-	-	-	-	-	-	-
	EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

FIGURE A-6
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M2

PERCENTAGE OF RESEARCH ACHIEVABLE IN EACH FACILITY
OPERATIONAL SYSTEM M2

TASK NO.	EXISTING FACILITY PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES						
		GROUND FACILITIES					BASIC FLT. VEHICLES	
		GDT	GD20	F20	F9	S20	M4	M12
1-1	38	-	-	-	-	-	70	45
1-2	38	-	-	-	-	-	65	45
1-3	38	-	-	-	-	-	70	45
1-4	40	-	-	-	-	-	65	45
2-1	30	-	52	-	-	-	85	90
2-2	30	-	52	-	-	-	85	90
2-3	30	-	52	-	-	-	85	90
2-4	43	-	-	-	-	-	88	90
3-1	35	50	55	-	-	-	85	95
3-2	23	50	63	-	-	-	70	90
3-3	32	67	82	-	-	-	70	90
3-4	35	50	55	-	-	-	35	50
4-1	26	30	43	30	43	-	80	90
4-2	26	30	43	30	43	-	80	90
4-3	26	30	43	30	43	-	90	90
5-1	45	-	-	-	-	-	75	90
5-2	45	-	-	-	-	-	75	90
5-3	45	-	-	-	-	-	75	90
6-1	30	36	46	-	-	-	80	90
6-2	30	36	46	-	-	-	70	75
6-3	30	35	46	-	-	-	75	80
7-1	ANALYTIC							
7-2	26	32	42	-	-	-	30	85
7-3	26	37	42	-	-	-	30	40
9-1	26	34	41	36	43	-	20	30
9-2	26	37	42	36	43	-	50	30
9-3	26	37	42	36	43	-	70	35
9-4	11	37	42	34	43	-	80	90
12-1	26	30	46	-	-	-	80	90
12-2	20	30	46	-	-	-	80	90
12-3	23	30	46	-	-	.	80	80
14-1	26	-	43	-	-	-	90	95
14-2	20	-	40	-	-	-	90	95
14-3	10	-	29	-	-	-	90	95
15-1	23	50	43	-	-	-	90	95
15-2	20	50	43	-	-	-	80	90
15-3	10	25	29	-	-	-	85	95
16-1	20	23	33	26	33	-	90	95
16-2	23	28	30	26	30	-	90	95
16-3	10	16	15	13	15	-	80	95
17-1	20	26	33	26	24	-	80	95
17-2	20	28	30	24	26	-	85	90
18-1	40	46	48	42	48	-	90	95
18-2	ANALYTIC							
19-1	24	32	38	-	-	-	90	95
19-2	24	32	38	-	-	-	90	95
20-1	20	30	33	30	35	-	90	95
20-2	20	30	33	30	35	-	90	95
20-3	20	26	29	26	31	-	20	35
20-4	11	15	17	15	18	-	85	90
22-1	20	30	33	30	35	-	85	95
22-2	20	30	33	30	35	-	85	95
22-3	20	30	33	30	35	-	85	95
24-1	22	33	47	26	26	-	80	90
24-2	22	33	47	26	26	-	80	90
24-3	22	33	47	26	26	-	80	90
25-1	22	35	38	26	38	-	85	90
25-2	22	38	44	28	31	-	88	95
25-3	22	38	44	26	27	-	85	95
25-4	17	26	28	14	17	-	85	90
26-1	75	-	-	-	-	-	85	75
26-2	78	-	-	-	-	-	80	90
26-3	22	-	40	28	48	32	85	90
27-1	36	42	45	44	50	60	70	80
27-2	34	42	45	44	50	60	70	80
27-3	36	44	49	38	44	60	85	95
28-1	50	-	-	-	-	65	GROUND	TEST
28-2	30	-	-	-	-	65	80	85
28-3	36	-	-	-	-	70	GROUND	TEST
28-4	15	-	-	-	-	33	80	85
	EXISTING	GDT	GD20	F20	F9	S20	M4	M12

FIGURE A-6
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M2 (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES					BASIC FLT. VEHICLES	
		GROUND FACILITIES						
		GDT	GD20	F20	F9	S20	M6	M12
30-1	68	-	-	-	-	72	GROUND	TEST
30-2	8	-	-	-	-	72	GROUND	TEST
30-3	68	-	-	-	-	72	100	100
32-1	26	-	-	33	32	63	GROUND	TEST
32-2	29	-	-	36	35	63	GROUND	TEST
32-3	32	-	-	39	38	65	90	100
33-1	ANALYTIC							
33-2	33	35	35	43	46	52	GROUND	TEST
33-3	15	16	16	20	21	48	85	95
34-1	22	-	-	26	29	39	30	27
34-2	75	-	-	-	-	-	GROUND	TEST
34-3	ANALYTIC							
34-4	16	17	17	-	26	21	30	16
35-1	22	26	30	28	38	43	80	90
35-2	22	26	30	28	38	43	100	100
36-1	ANALYTIC							
36-2	34	-	-	51	66	56	GROUND	TEST
36-3	34	-	-	45	60	56	90	100
38-1	53	-	-	-	-	65	GROUND	TEST
38-2	60	-	-	-	-	65	GROUND	TEST
38-3	60	-	-	-	-	65	90	100
39-1	40	45	45	44	52	44	80	90
39-2	40	45	45	44	52	44	80	95
40-1	ANALYTIC							
40-2	53	-	-	-	60	58	GROUND	TEST
40-3	50	-	-	-	60	58	90	100
41-1	ANALYTIC							
41-2	ANALYTIC							
42-1	27	-	-	-	-	68	85	90
43-1	30	-	-	42	43	49	70	90
43-2	30	-	-	45	46	52	75	85
43-3	40	-	-	-	-	57	GROUND	TEST
43-4	ANALYTIC							
44-1	ANALYTIC							
44-2	75	-	-	-	-	-	85	95
45-1	ANALYTIC							
45-2	37	-	-	60	90	45	90	95
45-3	37	-	-	60	90	45	90	95
46-1	ANALYTIC							
46-2	70	-	-	-	-	75	80	90
48-1	31	39	49	43	41	-	55	65
48-2	31	39	49	43	41	-	55	65
48-3	26	34	44	38	36	-	58	64
48-4	33	41	51	45	43	-	60	42
48-5	ANALYTIC							
52-1	ANALYTIC							
52-2	ANALYTIC							
52-3	ANALYTIC							
52-4	23	-	-	60	67	-	40	29
58-1	ANALYTIC							
58-2	ANALYTIC							
58-3	20	-	-	-	-	-	20	20
61-1	ANALYTIC							
61-2	ANALYTIC							
61-3	ANALYTIC							
61-4	20	-	-	-	53	-	40	20
61-5	20	-	-	-	53	-	30	20
61-6	20	-	-	-	60	-	20	20
62-1	ANALYTIC							
62-2	25	35	49	-	-	52	25	80
62-3	12	16	19	-	-	18	17	80
63-1	22	46	30	49	56	-	22	35
63-2	35	55	53	51	58	-	35	35
63-3	22	27	30	49	56	27	22	22
64-1	42	-	56	58	-	-	45	42
64-2	35	-	43	47	-	-	40	35
65-1	ANALYTIC							
65-2	19	28	32	35	49	-	19	25
65-3	24	32	34	44	52	-	25	30
	EXISTING	GDT	GD20	F20	F9	S20	M6	M12

FIGURE A-6
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M2 (Continued)

TASK NO.	EXISTING FACILITY PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES — GROUND FACILITIES					BASIC FLT. VEHICLES	
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	M4	M12
67-1	17	27	35	41	38	-	GROUND TEST	
67-2	17	27	35	41	38	-	20	25
67-3	ANALYTIC							
68-1	62	-	-	-	-	75	GROUND TEST	
[illegible]	[illegible]	-	-	-	-	75	GROUND TEST	
[illegible]	[illegible]	-	-	-	-	75	GROUND TEST	
[illegible]	ANALYTIC							
[illegible]	[illegible]	-	-	-	-	70	GROUND TEST	
[illegible]	[illegible]	-	-	-	-	70	80	100
[illegible]	ANALYTIC							
[illegible]	62	-	-	-	-	60	GROUND TEST	
[illegible]	62	-	-	-	-	60	GROUND TEST	
[illegible]	[illegible]	30	29	34	52	58	GROUND TEST	
[illegible]	[illegible]	-	-	34	52	58	[illegible]	[illegible]
[illegible]	[illegible]	-	-	-	-	75	85	95
[illegible]	[illegible]	-	-	-	-	75	85	85
[illegible]	[illegible]	-	-	-	-	75	85	85
[illegible]	ANALYTIC							
[illegible]	71	-	-	-	-	-	100	100
[illegible]	71	-	-	-	-	-	100	100
[illegible]	[illegible]	-	-	-	-	-	GROUND TEST	
[illegible]	[illegible]	-	-	-	-	67	GROUND TEST	
[illegible]	[illegible]	-	-	-	-	71	80	100
[illegible]	ANALYTIC							
[illegible]	[illegible]	-		[illegible]	[illegible]	75	[illegible]	85
[illegible]	ANALYTIC							
[illegible]	[illegible]	[illegible]	[illegible]	36	38	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	36	38	-	[illegible]	85
[illegible]	ANALYTIC							
[illegible]	[illegible]	37	[illegible]	38	48	37	80	[illegible]
[illegible]	55	[illegible]	[illegible]	[illegible]	65	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	57	[illegible]	[illegible]	[illegible]
[illegible]	ANALYTIC							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65	[illegible]	GROUND TEST	
[illegible]	[illegible]	[illegible]	[illegible]	56	61	[illegible]	[illegible]	[illegible]
[illegible]	ANALYTIC							
[illegible]	[illegible]	-		-	-	75	[illegible]	100
[illegible]	ANALYTIC							
[illegible]	[illegible]	35	[illegible]	35	35	[illegible]	80	85
[illegible]	[illegible]	[illegible]	[illegible]	35	35	[illegible]	[illegible]	25
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	ANALYTIC							
[illegible]	55	-	-	-	-	-	[illegible]	85
[illegible]	55	-	-	-	-	-	80	[illegible]
[illegible]	ANALYTIC							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45	80	[illegible]
[illegible]	ANALYTIC							
[illegible]	ANALYTIC							
[illegible]	[illegible]	32	24	36	32	62	[illegible]	75
[illegible]	1	18	22	20	22	32	[illegible]	75
[illegible]	14	20	24	22	24	34	80	[illegible]
[illegible]	[illegible]	-	-	-	-	-	GROUND TEST	
	[illegible]	-	-	-	-	70	[illegible]	[illegible]
[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	-	-	-	-	-	[illegible]	100
[illegible]	[illegible]	-	-	-	-	-	[illegible]	100
[illegible]	ANALYTIC							
[illegible]	[illegible]	-	-	-	-	70	[illegible]	[illegible]
	EXISTING	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	M4	M12

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FIGURE A-7
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM L2
Flight Vehicles with Options

PERCENTAGE OF RESEARCH ACHIEVABLE IN EACH FACILITY
OPERATIONAL SYSTEM L2

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
		8A FLIGHT VEHICLE			812 FLIGHT VEHICLE							
		BASIC	TPS	ABM	BASIC	SJ	CSJ	TJ	TPS	APM	HTO	STG
1-1	38	[illegible]	-	-	45	-	-	[illegible]	-	-	70	-
1-2	38	[illegible]	-	-	45	-	-	[illegible]	-	-	70	-
1-3	38	[illegible]	-	-	45	-	-	[illegible]	-	-	70	-
1-4	40	[illegible]	-	-	45	-	-	[illegible]	-	-	70	-
2-1	30	[illegible]	-	-	85	-	-	-	-	-	[illegible]	-
2-2	30	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
2-3	30	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
2-4	40	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
3-1	34	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
3-2	34	70	-	-	[illegible]	-	-	-	-	-	-	-
3-3	32	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
3-4	35	[illegible]	-	-	35	[illegible]	[illegible]	-	-	-	-	-
4-1	26	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
4-2	26	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
4-3	26	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
5-1	45	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	-	-
5-2	45	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	-	-
5-3	45	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
6-1	30	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
6-2	30	[illegible]	-	-	75	[illegible]	[illegible]	-	-	-	-	-
6-3	30	75	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
7-1	ANALYTIC											
7-2	26	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
7-3	26	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
8-1	26	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
8-2	26	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
8-3	26	[illegible]	-	-	25	[illegible]	[illegible]	-	-	-	-	-
8-4	[illegible]	75	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
10-1	30	45	-	-	55	-	-	-	-	-	-	[illegible]
10-2	30	45	-	-	55	-	-	-	-	-	-	[illegible]
11-1	ANALYTIC											
11-2	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	[illegible]
11-3	0	[illegible]	-	-	[illegible]	-	-	-	-	-	-	[illegible]
12-1	20	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]
12-2	20	[illegible]	-	-	70	[illegible]	[illegible]	-	-	-	-	[illegible]
12-3	20	[illegible]	-	-	70	[illegible]	[illegible]	-	-	-	-	[illegible]
14-1	26	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
14-2	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
14-3	10	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
15-1	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
15-2	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
15-3	10	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
16-1	20	[illegible]	-	-	35	-	-	-	-	-	-	-
16-2	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
16-3	10	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
17-1	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
17-2	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
18-1	40	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
18-2	ANALYTIC											
19-1	24	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
19-2	24	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
20-1	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
20-2	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
20-3	20	[illegible]	-	-	25	-	-	-	-	-	-	[illegible]
20-4	11	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
22-1	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
22-2	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
22-3	20	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
23-1	32	32	73	-	32	-	-	-	[illegible]	-	-	-
23-2	32	35	[illegible]	-	35	-	-	-	[illegible]	-	-	-
23-3	29	25	65	-	20	-	-	-	75	-	-	-
24-1	22	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
24-2	22	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
24-3	22	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
25-1	22	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
25-2	22	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
25-3	22	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
25-4	12	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
26-1	35	[illegible]	-	-	75	-	-	-	-	-	-	-
26-2	35	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
26-3	22	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
27-1	[illegible]	[illegible]	-	-	70	[illegible]	[illegible]	-	-	-	-	-
27-2	[illegible]	75	-	-	75	[illegible]	[illegible]	-	-	-	-	-
27-3	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
28-1	GND. TEST											
28-2	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
28-3	GND. TEST											
28-4	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
	EXISTING	BASIC	TPS	ABM	BASIC	SJ	CSJ	TJ	TPS	APM	HTO	STG

FIGURE A-7
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM L2
Flight Vehicles with Options (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: M4 FLIGHT VEHICLE BASIC	TPS	ABM	M12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ABM	HTO	STO
31-1	ENG. TEST											
31-2	ENG. TEST											
31-3	48	100	-	-	100	-	-	-	-	-	-	-
32-1	ENG. TEST											
32-2	ENG. TEST											
32-3	22	[illegible]	-	-	100	-	-	-	-	-	-	-
33-1	ANALYTIC											
33-2	ENG. TEST											
33-3	15	85	-	-	95	-	-	-	-	-	-	-
34-1	22	35	-	-	22	100	100	-	-	-	-	-
34-2	ENG. TEST											
34-3	ANALYTIC											
34-4	18	25	-	-	18	100	100	-	-	-	-	-
35-1	22	[illegible]	-	-	50	-	-	-	-	-	-	-
35-2	22	100	-	-	100	-	-	-	-	-	-	-
36-1	ANALYTIC											
36-2	ENG. TEST											
36-3	34	50	-	-	100	-	-	-	-	-	-	-
38-1	ENG. TEST											
38-2	ENG. TEST											
38-3	40	60	-	-	100	-	-	-	-	-	-	-
39-1	40	46	-	-	60	-	-	-	-	-	-	-
39-2	40	85	-	-	90	-	-	-	-	-	-	-
40-1	ANALYTIC											
40-2	ENG. TEST											
40-3	50	25	-	-	100	-	-	-	-	-	-	-
41-1	ANALYTIC											
41-2	ANALYTIC											
42-1	27	45	-	-	60	95	95	-	-	-	-	-
43-1	30	70	65	-	80	-	-	-	95	-	-	-
43-2	30	75	85	-	85	-	-	-	65	-	-	-
43-3	ENG. TEST											
43-4	ANALYTIC											
44-1	ANALYTIC											
44-2	75	35	-	-	95	-	-	-	-	-	-	-
45-1	ANALYTIC											
45-2	22	80	-	-	85	-	-	-	-	-	-	-
45-3	22	30	-	-	95	-	-	-	-	-	-	-
46-1	ANALYTIC											
46-2	75	85	-	-	90	-	-	-	-	-	-	-
48-1	31	55	-	-	65	-	-	-	-	-	-	-
48-2	31	55	-	-	65	75	75	-	-	-	-	-
48-3	24	60	-	-	64	65	65	-	-	-	-	-
48-4	22	61	-	-	62	70	70	-	-	-	-	-
48-5	ANALYTIC											
52-1	ANALYTIC											
52-2	ANALYTIC											
52-3	ANALYTIC											
52-4	18	40	-	-	18	50	50	-	-	-	-	-
58-1	ANALYTIC											
58-2	ANALYTIC											
58-3	20	30	-		20	65	65	-	-	-	-	-
60-1	ANALYTIC											
60-2	ANALYTIC											
60-3	ANALYTIC											
60-4	24	50	-	-	24	60	70	-	-	-	-	-
60-5	24	60	-	-	24	70	80	-	-	-	-	-
60-6	24	30	-	-	24	80	85	-	-	-	-	-
63-1	22	45	-	-	35	45	60	-	-	-	-	-
63-2	35	50	-	-	35	70	80	-	-	-	-	-
63-3	22	45	-	-	22	45	80	-	-	-	-	-
65-1	ANALYTIC											
65-2	18	18	-	-	18	80	90	-	-	-	-	-
65-3	24	24	-	-	24	75	90	-	-	-	-	-
67-1	ENG. TEST											
67-2	17	20	-		20	70	80	-	-	-	-	-
67-3	ANALYTIC											
68-1	ENG. TEST											
68-2	ENG. TEST											
68-3	ENG. TEST											
69-1	ANALYTIC											
69-2	ENG. TEST											
69-3	55	80	-	-	100	-	-	-	-	-	-	-
	EXISTING	BASIC	TPS	ABM	BASIC	SJ	CSJ	TJ	TPS	ABM	HTO	STO

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FIGURE A-7
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM L2
Flight Vehicles with Options (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
		[illegible] FLIGHT VEHICLE			[illegible] FLIGHT VEHICLE							
		BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
70-1	ANALYTIC											
70-2	GND. TEST											
70-3	GND. TEST											
70-4	GND. TEST											
70-5	24	40	-	-	60	100	100	-	-	-	-	-
71-1	75	95	-	-	75	-	-	-	-	-	-	-
71-2	75	55	-	-	75	-	-	-	-	-	-	-
71-3	75	95	-	-	75	-	-	-	-	-	-	-
72-1	GND. TEST											
72-2	GND. TEST											
72-3	GND. TEST											
73-1	65	85	-	-	85	100	100	-	-	-	-	-
73-2	65	95	-	-	95	100	100	-	-	-	-	-
73-3	65	95	-	-	95	100	100	-	-	-	-	-
75-1	GND. TEST											
75-2	GND. TEST											
75-3	27	90	-	-	100	-	-	-	-	-	-	-
77-1	ANALYTIC											
77-2	55	90	85	-	85	-	-	-	90	-	-	-
78-1	ANALYTIC											
78-2	32	65	-	-	70	-	-	-	-	-	-	-
78-3	32	70	-	-	85	-	-	-	-	-	-	-
79-1	ANALYTIC											
79-2	27	90	-	-	90	-	-	-	-	-	-	-
80-1	55	95	-	-	90	-	-	-	-	-	-	-
80-2	47	95	-	-	90	-	-	-	-	-	-	-
82-1	ANALYTIC											
82-2	GND. TEST											
82-3	51	95	-	-	100	-	-	-	-	-	-	-
83-1	ANALYTIC											
83-2	45	30	-	-	100	-	-	-	-	-	-	-
87-1	ANALYTIC											
87-2	ANALYTIC											
87-3	25	65	-	-	90	-	-	65	-	-	95	-
89-1	ANALYTIC											
89-2	55	90	-	-	95	-	-	-	-	-	-	-
89-3	55	90	-	-	90	-	-	85	-	-	-	-
93-1	ANALYTIC											
93-2	29	90	-	-	90	-	-	-	-	-	-	-
94-1	ANALYTIC											
94-2	ANALYTIC											
94-3	26	55	-	-	70	-	-	-	-	-	-	-
96-1	12	85	-	-	[illegible]	90	95	-	-	-	-	-
96-2	14	90	-	-	[illegible]	90	95	-	-	-	-	-
97-1	GND. TEST											
97-2	30	95	-	-	90	-	-	-	-	-	-	-
102-1	ANALYTIC											
102-2	60	50	-	-	90	-	-	-	-	-	-	-
	EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FIGURE A-8
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM C1
Flight Vehicles with Options

PERCENTAGE OF RESEARCH ACHIEVABLE IN EACH FACILITY
OPERATIONAL SYSTEM C1

ITEM NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
		NO FLIGHT VEHICLE			M12 FLIGHT VEHICLE							
		BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	MTO	STG
1-1	[illegible]	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	52	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]		-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	ANALYSIS											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	32	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
14-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
14-2	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
14-3	12	[illegible]	-	-	[illegible]	-		-	-	-	-	-
15-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	12	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	14	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
17-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	15	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible] TEST											
[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
[illegible]	[illegible] TEST											
[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
[illegible]	[illegible] TEST											
[illegible]	[illegible] TEST											
[illegible]	[illegible]	100	-	-	100	-	-	-	-	-	-	-
[illegible]	[illegible] TEST											
[illegible]	[illegible] TEST											
[illegible]	[illegible]	100	-	-	100	-	-	-	-	-	-	-
	EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	MTO	STG

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FIGURE A-8
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM C1
Flight Vehicles with Options (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
		[illegible] FLIGHT VEHICLE			[illegible] FLIGHT VEHICLE							
		BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
33-1	ANALYTIC											
33-2	GND. TEST											
33-3	26	95	-	-	100	-	-	-	-	-	-	-
34-2	GND. TEST											
34-3	ANALYTIC											
35-1	28	90	-	-	95		-	-	-	-	-	-
35-2	28	100	-	-	100		-	-	-	-	-	-
36-1	ANALYTIC											
36-2	GND. TEST											
36-3	41	100	-	-	100	-	-	-	-	-	-	-
38-1	GND. TEST											
38-2	GND. TEST											
38-3	45	100	-	-	100	-	-	-	-	-	-	-
39-1	44	95	-	-	95	-	-	-	-	-	-	-
39-2	44	95	-	-	95	-	-	-	-	-	-	-
40-1	ANALYTIC											
40-2	GND. TEST											
40-3	58	100	-	-	100	-	-	-	-	-	-	-
41-1	ANALYTIC											
41-2	ANALYTIC											
42-1	35	100	-	-	95	-	-	-	-	-	-	-
43-1	30	90	95	-	95	-	-	-	100	-	-	-
43-2	30	95	95	-	90	-	-	-	100	-	-	-
43-3	GND. TEST											
43-4	ANALYTIC											
44-1	ANALYTIC											
44-2	75	95	-	-	100	-	-	-	-	-	-	-
45-1	ANALYTIC											
45-2	45	100	-	-	100	-	-	-	-	-	-	-
45-3	45	100	-	-	100	-	-	-	-	-	-	-
46-1	ANALYTIC											
46-2	70	90	-	-	95	-	-	-	-	-	-	-
48-1	42	90	-	-	80	-	-	-	-	-	-	-
48-2	42	75	-	-	80	-	-	-	-	-	-	-
48-3	33	73	-	-	55	-	-	-	-	-	-	-
48-4	44	80	-	-	75	-	-	-	-	-	-	-
48-5	ANALYTIC											
52-1	ANALYTIC											
52-2	ANALYTIC											
52-3	ANALYTIC											
52-4	30	90	-	-	90	60	60	-	-	-	-	-
55-1	53	95	-	-	53	-	-	75	-	-	-	-
55-2	52	95	-	-	52	-	-	75	-	-	-	-
57-1	ANALYTIC											
57-2	ANALYTIC											
57-3	ANALYTIC											
57-4	30	70	-	-	30	-	-	-	-	-	-	-
57-5	30	95	-	-	30	-	-	-	-	-	-	-
57-6	26	95	-	-	26	-	-	-	-	-	-	-
58-1	ANALYTIC											
58-2	ANALYTIC											
58-3	26	60	-	-	26	-	35	-	-	-	-	-
59-1	ANALYTIC											
59-2	ANALYTIC											
59-3	ANALYTIC											
59-4	32	70	-	-	32	-	60	-	-	-	-	-
59-5	32	70	-	-	32	-	60	-	-	-	-	-
59-6	32	70	-	-	32	-	70	-	-	-	-	-
63-1	32	85	-	-	32	-	72	-	-	-	-	-
63-2	42	90	-	-	42	65	80	-	-	-	-	-
63-3	32	85	-	-	32	-	60	-	-	-	-	-
65-1	ANALYTIC											
65-2	27	75	-	-	27	-	-	-	-	-	-	-
65-3	32	60	-	-	32	-	-	-	-	-	-	-
67-1	GND. TEST											
67-2	25	70	-	-	25	-	35	-	-	-	-	-
67-3	ANALYTIC											
68-1	GND. TEST											
68-2	GND. TEST											
68-3	GND. TEST											
69-1	ANALYTIC											
69-2	GND. TEST											
69-3	55	100	-	-	100	-	-	-	-	-	-	-
	EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

FIGURE A-8
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM C1
Flight Vehicles with Options (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
		[illegible] FLIGHT VEHICLE			[illegible] FLIGHT VEHICLE							
		BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
70-1	ANALYTIC											
70-2	GND. TEST											
70-3	GND. TEST											
70-4	GND. TEST											
70-5	32	100	-	-	60	80	90	-	-	-	-	-
71-1	75	95	-	-	75	-	-	-	-	-	-	-
71-2	75	90	-	-	75	-	-	-	-	-	-	-
71-3	75	95	-	-	75	-	-	-	-	-	-	-
72-1	GND. TEST											
72-2	GND. TEST											
72-3	GND. TEST											
73-1	65	100	-	-	80	90	90	-	-	-	-	-
73-2	65	100	-	-	85	90	90	-	-	-	-	-
73-3	65	100	-	-	85	90	90	-	-	-	-	-
74-1	ANALYTIC											
74-2	71	100	-	-	100	-	-	-	-	-	-	-
74-3	71	100	-	-	100	-	-	-	-	-	-	-
75-1	GND. TEST											
75-2	GND. TEST											
75-3	27	100	-	-	100	-	-	-	-	-	-	-
77-1	ANALYTIC											
77-2	60	95	95	-	95	-	-	-	90	-	-	-
78-1	ANALYTIC											
78-2	40	95	-	-	90	-	-	-	-	-	-	-
78-3	40	90	-	-	95	-	-	-	-	-	-	-
79-1	ANALYTIC											
79-2	35	90	-	-	95	-	-	-	-	-	-	-
80-1	40	90	-	-	95	-	-	-	-	-	-	-
80-2	42	90	-	-	95	-	-	-	-	-	-	-
82-1	ANALYTIC											
82-2	GND. TEST											
82-3	56	100	-	-	100	-	-	-	-	-	-	-
83-1	ANALYTIC											
83-2	45	100	-	-	100	-	-	-	-	-	-	-
87-1	ANALYTIC											
87-2	ANALYTIC											
87-3	35	95	-	-	90	-	-	75	-	-	85	-
89-1	ANALYTIC											
89-2	65	90	-	-	95	-	-	-	-	-	-	-
89-3	65	90	-	-	85	-	-	95	-	-	-	-
93-1	ANALYTIC											
93-2	35	95	-	-	95	-	-	-	-	-	-	-
94-1	ANALYTIC											
94-2	ANALYTIC											
94-3	34	75	-	-	70	-	-	-	-	-	-	-
96-1	16	95	-	-	70	90	80	-	-	-	-	-
96-2	18	95	-	-	75	90	90	-	-	-	-	-
97-1	GND. TEST											
97-2	30	100	-	-	90	-	-	-	-	-	-	-
102-1	ANALYTIC											
102-2	65	100	-	-	85	-	-	-	-	-	-	-
	EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

FIGURE A-9
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M1
Flight Vehicles with Options

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
		[illegible] FLIGHT VEHICLE			[illegible]12 FLIGHT VEHICLE							
		BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
1-1	52	[illegible]	-	-	55	-	-	[illegible]	-	-	70	-
1-2	52	[illegible]	-	-	55	-	-	[illegible]	-	-	70	-
1-3	52	[illegible]	-	-	55	-	-	[illegible]	-	-	70	-
1-4	[illegible]	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	70	-
2-1	52	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
2-2	52	55	-	-	75	-	-	-	-	-	[illegible]	-
2-3	52	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
2-4	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
3-1	52	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
3-2	52	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
3-3	45	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
3-4	52	[illegible]	-	-	92	57	70	-	-	-	-	-
4-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
4-2	37	55	-	-	[illegible]	-	-	-	-	-	-	-
4-3	27	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
5-1	72	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	-	-
5-2	72	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	-	-
5-3	72	55	-	-	[illegible]	-	-	-	-	-	-	-
6-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
6-2	[illegible]	[illegible]	-	-	[illegible]	-	[illegible]	-	-	-	-	-
6-3	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
7-1	ANALYTIC											
7-2	35	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
7-3	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
8-1	35	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
8-2	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
8-3	[illegible]	[illegible]	-	-	35	-	-	-	-	-	-	-
8-4	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
12-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
12-2	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
12-3	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
14-1	32	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
14-2	26	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
14-3	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
15-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
15-2	26	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
15-3	13	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
16-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
16-2	37	95	-	-	95	-	-	-	-	-	-	-
16-3	18	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
17-1	24	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
17-2	24	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
18-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
18-2	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
20-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
20-2	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
20-3	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
20-4	17	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
22-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
22-2	[illegible]	[illegible]	-	-	95	-	-	-	-	-	-	-
22-3	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
24-1	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
24-2	33	[illegible]	-	-	95	-	-	-	-	-	-	-
24-3	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
25-1	[illegible]	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
25-2	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
25-3	[illegible]	[illegible]	-	-	95	-	-	-	-	-	-	-
25-4	24	[illegible]	[illegible]	-	[illegible]	-	-	-	[illegible]	-	-	-
26-1	75	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
26-2	75	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
26-3	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
27-1	45	[illegible]	-	-	75	-	-	-	-	-	-	-
27-2	[illegible]	[illegible]	-	-	75	[illegible]	[illegible]	-	-	-	-	-
27-3	45	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
30-1	CND. TEST											
30-2	CND. TEST											
30-3	[illegible]	100	-	-	100	-	-	-	-	-	-	-
	EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

FIGURE A-9
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M1
Flight Vehicles with Options (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: M[illegible] FLIGHT VEHICLE BASIC	TPS	ABM	M12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ABM	HTO	STG
32-1	CAD. TEST											
32-2	CAD. TEST											
32-3	58	100	-	-	100	-	-	-	-	-	-	-
33-1	ANALYTIC											
33-2	CAD. TEST											
33-3	22	95	-	-	100	-	-	-	-	-	-	-
34-1	CAD. TEST											
34-2	ANALYTIC											
35-1	[illegible]	[illegible]	-	-	95	-	-	-	-	-	-	-
35-2	32	100	-	-	100	-	-	-	-	-	-	-
36-1	ANALYTIC											
36-2	CAD. TEST											
36-3	44	100	-	-	100	-	-	-	-	-	-	-
39-1	45	55	-	-	95	-	-	-	-	-	-	-
39-2	45	55	-	-	95	-	-	-	-	-	-	-
40-1	ANALYTIC											
40-2	CAD. TEST											
40-3	62	100	-	-	100	-	-	-	-	-	-	-
41-1	ANALYTIC											
41-2	ANALYTIC											
42-1	45	[illegible]	-	-	95	-	-	-	-	-	-	-
43-1	44	[illegible]	95	-	95	-	-	-	100	-	-	-
43-2	44	35	65	-	90	-	-	-	100	-	-	-
43-3	CAD. TEST											
43-4	ANALYTIC											
44-1	ANALYTIC											
44-2	38	95	-	-	100	-	-	-	-	-	-	-
45-1	ANALYTIC											
45-2	53	100	-	-	100	-	-	-	-	-	-	-
45-3	53	100	-	-	100	-	-	-	-	-	-	-
46-1	ANALYTIC											
46-2	47	90	-	-	95	-	-	-	-	-	-	-
48-1	53	50	-	-	85	-	-	-	-	-	-	-
48-2	53	75	-	-	85	-	-	-	-	-	-	-
48-3	49	80	-	-	60	-	-	-	-	-	-	-
48-4	55	85	-	-	82	-	-	-	-	-	-	-
48-5	ANALYTIC											
52-1	ANALYTIC											
52-2	ANALYTIC											
52-3	ANALYTIC											
52-4	36	60	-		36	65	65	-	-	-	-	-
57-1	ANALYTIC											
57-2	ANALYTIC											
57-3	ANALYTIC											
57-4	36	80	-	-	36	-	-	-	-	-	-	-
57-5	36	95	-	-	36	-	-	-	-	-	-	-
57-6	32	55	-	-	32	-	-	-	-	-	-	-
58-1	ANALYTIC											
58-2	ANALYTIC											
58-3	29	50	-	-	29	-	40	-	-	-	-	-
59-1	ANALYTIC											
59-2	ANALYTIC											
59-3	ANALYTIC											
59-4	40	80	-	-	40	-	70	-	-	-	-	-
59-5	[illegible]	80	-	-	40	-	70	-	-	-	-	-
[illegible]	40	[illegible]	-	-	40	-	80	-	-	-	-	-
61-1	37	80	-	-	37	-	75	-	-	-	-	-
61-2	45	95	-	-	45	-	60	-	-	-	-	-
61-3	37	80	-	-	37	-	60	-	-	-	-	-
[illegible]	ANALYTIC											
65-2	31	80	-	-	31	-	-	-	-	-	-	-
65-3	35	65	-	-	35	-	-	-	-	-	-	-
67-1	CAD. TEST											
67-2	29	75	-	-	29	30	40	-	-	-	-	-
67-3	ANALYTIC											
	EXISTING	BASIC	TPS	ABM	BASIC	SJ	CSJ	TJ	TPS	ABM	HTO	STG

FIGURE A-9
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M1
Flight Vehicles with Options (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES					BASIC FLT. VEHICLES	
		D7	GD20	F20	F9	S20	M6	M12
71-1	75	-	-	-	-	-	100	75
71-2	75	-	-	-	-	-	100	75
71-3	75	-	-	-	-	-	100	[illegible]
72-1	75	-	-	-	-	-	GROUND TEST	
72-2	75	-	-	-	-	-	GROUND TEST	
72-3	75	-	-	-	-	-	GROUND TEST	
77-1	ANALYTIC							
77-2	60	-	-	70	79	75	85	85
78-1	ANALYTIC							
78-2	66	-	63	60	66	-	90	85
78-3	66	-	60	69	66	-	95	90
79-1	ANALYTIC							
79-2	39	-	56	56	-	66	90	95
80-1	67	-	72	72	70	75	90	95
80-2	59	-	66	66	62	67	90	95
82-1	ANALYTIC							
82-2	67	-	70	72	72	75	GROUND TEST	
82-3	63	-	68	68	68	71	100	100
84-1	ANALYTIC							
84-2	65	-	-	-	-	-	100	75
85-1	ANALYTIC							
85-2	36	-	45	47	43	45	90	95
85-3	36	-	45	47	43	45	36	36
87-1	ANALYTIC							
87-2	ANALYTIC							
87-3	60	-	-	-	-	-	95	50
88-1	ANALYTIC							
88-2	70	-	-	-	-	-	90	95
88-3	70	-	-	-	-	-	90	95
93-1	ANALYTIC							
93-2	30	-	49	48	66	52	85	85
94-1	ANALYTIC							
94-2	ANALYTIC							
94-3	30	-	48	48	66	50	75	70
96-1	18	-	26	26	24	36	90	70
96-2	20	-	29	29	26	30	95	75
97-1	75	-	-	-	-	-	GROUND TEST	
97-2	30	-	-	-	-	70	100	90
102-1	ANALYTIC							
102-2	70	-	-	-	-	75	100	95
	EXISTING	GD7	GD20	F20	F9	S20	M6	M12

FIGURE A-10
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M2
Flight Vehicles with Options

TASK M1.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: M[illegible] FLIGHT VEHICLE			M12 FLIGHT VEHICLE							
		BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
1-1	38	70	-	-	45	-	-	70	-	-	95	-
1-2	38	65	-	-	45	-	-	68	-	-	95	-
1-3	38	7[illegible]	-	-	45	-	-	70	-	-	95	-
1-4	40	65	-	-	45	-	-	68	-	-	95	-
2-1	30	85	-	-	90	-	-	-	-	-	-	-
2-2	30	85	-	-	90	-	-	-	-	-	95	-
2-3	30	85	-	-	90	-	-	-	-	-	95	-
2-4	40	85	-	-	80	-	-	-	-	-	95	-
3-1	38	85	-	-	85	-	-	-	-	-	-	-
3-2	23	70	-	-	90	-	-	-	-	-	-	-
3-3	32	70	-	-	90	-	-	-	-	-	-	-
3-4	35	75	-	-	50	95	95	-	-	-	-	-
4-1	26	80	-	-	90	-	-	-	-	-	-	-
4-2	26	80	-	-	90	-	-	-	-	-	-	-
4-3	26	80	-	-	90	-	-	-	-	-	-	-
5-1	45	75	-	-	80	-	-	95	-	-	-	-
5-2	45	75	-	-	80	-	-	95	-	-	-	-
5-3	45	75	-	-	90	-	-	-	-	-	-	-
6-1	30	90	-	-	90	-	-	-	-	-	-	-
6-2	30	70	-	-	75	95	90	-	-	-	-	-
6-3	30	75	-	-	80	95	90	-	-	-	-	-
7-1	ANALYTIC											
7-2	26	30	-	-	85	95	95	-	-	-	-	-
7-3	26	30	-	-	63	95	95	-	-	-	-	-
9-1	26	28	-	-	30	95	95	-	-	-	-	-
9-2	26	50	-	-	30	95	95	-	-	-	-	-
9-3	26	70	-	-	35	90	95	-	-	-	-	-
9-4	19	90	-	-	80	95	95	-	-	-	-	-
12-1	20	80	-	-	90	95	95	-	-	-	-	-
12-2	20	80	-	-	80	95	95	-	-	-	-	-
12-3	20	80	-	-	80	95	95	-	-	-	-	-
14-1	26	90	-	-	95	-	-	-	-	-	-	-
14-2	20	90	-	-	95	-	-	-	-	-	-	-
14-3	10	90	-	-	95	-	-	-	-	-	-	-
15-1	20	90	-	-	95	-	-	-	-	-	-	-
15-2	20	80	-	-	90	-	-	-	-	-	-	-
15-3	10	85	-	-	95	-	-	-	-	-	-	-
16-1	.	90	-	-	95	-	-	-	-	-	-	-
16-2	2	80	-	-	95	-	-	-	-	-	-	-
16-3	10	80	-	-	95	-	-	-	-	-	-	-
17-1	20	80	-	-	85	-	-	-	-	-	-	-
17-2	20	85	-	-	[illegible]	-	-	-	-	-	-	-
18-1	40	[illegible]	-	-	95	-	-	-	-	-	-	-
18-2	ANALYTIC											
19-1	24	50	-	-	95	-	-	-	-	-	-	-
19-2	24	90	-	-	95	-	-	-	-	-	-	-
20-1	20	50	-	-	95	-	-	-	-	-	-	-
20-2	20	90	-	-	95	-	-	-	-	-	-	-
20-3	20	20	-	-	35	-	-	-	-	-	-	-
20-4	11	85	-	-	90	-	-	-	-	-	-	-
22-1	20	85	-	-	95	-	-	-	-	-	-	-
22-2	20	85	-	-	95	-	-	-	-	-	-	-
22-3	20	85	-	-	95	-	-	-	-	-	-	-
24-1	22	80	-	-	90	-	-	-	-	-	-	-
24-2	22	80	-	-	90	-	-	-	-	-	-	-
24-3	22	80	-	-	90	-	-	-	-	-	-	-
25-1	22	85	90	-	80	-	-	-	95	-	-	-
25-2	22	85	.	-	95	-	-	-	-	-	-	-
25-3	22	85	-	-	95	-	-	-	-	-	-	-
25-4	12	85	90	-	90	-	-	-	95	-	-	-
26-1	75	85	-	-	75	-	-	-	-	-	-	-
26-2	75	90	-	-	93	-	-	-	-	-	-	-
26-3	22	95	-	-	90	-	-	-	-	-	-	-
27-1	36	70	-	-	80	95	95	-	-	-	-	-
27-2	36	70	-	-	80	95	95	-	-	-	-	-
27-3	36	95	-	-	90	95	95	-	-	-	-	-
28-1	GND. TEST											
28-2	36	80	90	-	85	-	-	-	95	-	-	-
28-3	GND. TEST											
28-4	15	80	93	-	85	-	-	-	95	-	-	-
	EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

FIGURE A-10
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M2
Flight Vehicles with Options (Continued)

TASK NO.	EXISTING FACILITIES PERCENTAGE	CAPABILITY OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
		MA FLIGHT VEHICLE			M2 FLIGHT VEHICLE							
		BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	MTO	STG
30-1	GND. TEST											
30-2	GND. TEST											
30-3	68	100	-	-	100	-	-	-	-	-	-	-
32-1	GND. TEST											
32-2	GND. TEST											
32-3	22	50	-	-	100	-	-	-	-	-	-	-
33-1	ANALYTIC											
33-2	GND. TEST											
33-3	15	85	-	-	95	-	-	-	-	-	-	-
34-1	22	30	-	-	22	100	100	-	-	-	-	-
34-2	GND. TEST											
34-3	ANALYTIC											
34-4	16	30	-	-	16	100	100	-	-	-	-	-
35-1	22	80	-	-	80	-	-	-	-	-	-	-
35-2	22	100	-	-	100	-	-	-	-	-	-	-
36-1	ANALYTIC											
36-2	GND. TEST											
36-3	36	90	-	-	100	-	-	-	-	-	-	-
38-1	GND. TEST											
38-2	GND. TEST											
38-3	41	80	-	-	100	-	-	-	-	-	-	-
39-1	40	80	-	-	90	-	-	-	-	-	-	-
39-2	40	80	-	-	85	-	-	-	-	-	-	-
40-1	ANALYTIC											
40-2	GND. TEST											
40-3	50	90	-	-	100	-	-	-	-	-	-	-
41-1	ANALYTIC											
41-2	ANALYTIC											
42-1	27	85	-	-	90	95	95	-	-	-	-	-
43-1	30	70	95	-	80	-	-	-	95	-	-	-
43-2	30	75	85	-	85	-	-	-	95	-	-	-
43-3	GND. TEST											
43-4	ANALYTIC											
44-1	ANALYTIC											
44-2	75	85	-	-	95	-	-	-	-	-	-	-
45-1	ANALYTIC											
45-2	33	65	-	-	95	-	-	-	-	-	-	-
45-3	37	90	-	-	95	-	-	-	-	-	-	-
46-1	ANALYTIC											
46-2	70	80	-	-	95	-	-	-	-	-	-	-
48-1	31	55	-	-	65	-	-	-	-	-	-	-
48-2	31	55	-	-	65	75	75	-	-	-	-	-
48-3	26	58	-	-	64	65	65	-	-	-	-	-
48-4	33	60	-	-	62	70	70	-	-	-	-	-
48-5	ANALYTIC											
52-1	ANALYTIC											
52-2	ANALYTIC											
52-3	ANALYTIC											
52-4	20	40	-	-	20	50	50	-	-	-	-	-
58-1	ANALYTIC											
58-2	ANALYTIC											
58-3	20	20	-	-	20	65	65	-	-	-	-	-
61-1	ANALYTIC											
61-2	ANALYTIC											
61-3	ANALYTIC											
61-4	20	40	-	-	20	95	85	-	-	-	-	-
61-5	20	30	-	-	20	95	85	-	-	-	-	-
61-6	20	20	-	-	20	95	85	-	-	-	-	-
62-1	ANALYTIC											
62-2	25	35	-	-	80	-	-	-	-	-	90	-
62-3	12	12	-	-	40	-	-	-	-	-	95	-
63-1	22	22	-	-	35	95	85	-	-	-	-	-
63-2	35	35	-	-	35	80	75	-	-	-	-	-
63-3	22	22	-	-	22	95	85	-	-	-	-	-
64-1	42	65	-	-	42	-	-	60	-	-	-	-
64-2	35	40	-	-	35	-	-	70	-	-	-	-
65-1	ANALYTIC											
65-2	15	15	-	-	25	90	80	-	-	-	-	-
65-3	24	25	-		30	85	75	-	-	-	-	-
	EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	MTO	STG

FIGURE A-10
FACILITY CAPABILITIES FOR OPERATIONAL SYSTEM M2
Flight Vehicles with Options (Continued)

[illegible]	[illegible]	[illegible]										
		[illegible]			[illegible]							
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] TEST											
[illegible]	17	[illegible]	-	-	25	[illegible]	[illegible]	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible] TEST											
[illegible]	[illegible] TEST											
[illegible]	[illegible] TEST											
[illegible]	ANALYTIC											
[illegible]	[illegible] TEST											
[illegible]	[illegible]	[illegible]	-		[illegible]	-	-	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible] TEST											
[illegible]	[illegible] TEST											
[illegible]	[illegible] TEST											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible] TEST											
[illegible]	[illegible] TEST											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	[illegible]	[illegible]	-	
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	27	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible] TEST											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	-	-	-	-	[illegible]	-	-
[illegible]	ANALYTIC											
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	[illegible]	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	
[illegible]	ANALYTIC											
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	12	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	14	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	-	-	-	-
[illegible]	[illegible] TEST											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-						-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	[illegible]	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
[illegible]	ANALYTIC											
[illegible]	[illegible]	[illegible]	-	-	[illegible]	-	-	-	-	-	-	-
	[illegible]	BASIC	TPS	ARM	BASIC	SJ	CTJ	TJ	TPS	ARM	HTO	STO

A.3 FACILITY RESEARCH VALUES

The research values of the various ground facilities and the two basic flight vehicles, in relation to each Research Task, are shown in Figures A-11 through A-13 for Operational Systems L2, M1, and M2. At the end of each figure, the characteristic and focused research values are summarized. The methodology used to determine these values by individual task, as well as to compute the totals presented in the summaries, is described in Section 5.3, and the corresponding data for Operational System C1 are shown in Figure 5-6.

The research values for the flight vehicle options are presented in Figure A-14 through A-17 for each of the operational systems, including System C1. Consistent with the method used for calculating research values for the ground facilities and basic flight vehicles, these vehicle option values are computed by multiplying the intrinsic values of the Research Tasks by the capability of the vehicle to perform the tasks. The task intrinsic values are listed in Figure 5-3 for Operational System C1 and in Figures A-1 through A-3 for Operational Systems L2, M1, and M2, and are repeated in the second column of Figures A-14 through A-17 for reference. The facility capabilities involved are those shown in Figures A-7 through A-10 for the flight vehicle options.

The focused and characteristic Facility Research Values for the options are summarized at the end of Figures A-14 through A-17. The data presented in these summaries are the basis for all flight-vehicle option values summarized in the main body of this report. The Facility Research Value for a vehicle with a given option can be found in the third row of each summary. These values are determined for focused research by summing the values computed on an individual task basis which are shown in the above portion of the corresponding figure. Values are summed only over those tasks for which the option has application, while tasks for which dashes appear are not considered. The related existing-facilities, basic-vehicle, and ideal-facility values are calculated relative to each option by summing over the same subset of tasks used to determine the Facility Research Value for that option. For the related existing-facilities total, the individual task values summed are those appearing in the column labeled "Value of Existing Facilities" for the tasks involved. The related basic-vehicle totals are found by summing the individual task values for the appropriate basic vehicle over the same subset of tasks. Similarly, the related ideal-facility value is computed by adding the intrinsic values of the tasks to which the option applies. Zeros indicate that the option has no application to the operational system under consideration.

The second half of each summary in Figures A-14 through A-17 presents the characteristic research values for each option. The related existing-facilities, basic-vehicle, and ideal-facility values are those shown in the characteristic research summaries presented previously for the corresponding basic vehicles and are based on all Research Tasks except those designated as analytic or as involving only ground testing. The characteristic Facility Research Value for a vehicle with a given option is found by adding the increment provided by the option to the corresponding basic-vehicle value. This increment is equal to the difference shown in the focused research summary between the value of the vehicle with the option and the basic-vehicle value. The characteristic research totals, then, place into perspective the value of a vehicle option in relation to the overall research performed by the flight vehicle.

FIGURE A-11 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM L2

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL CON. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES: COMMON FACILITIES CGT	CGTP	E2P	FP	S2P	FLIGHT VEHICLES MA BASIC	M12 BASIC
1-1	46.1	26.1	50.9	-	-	-	-	-	52.3	26.1
1-2	45.6	19.4	33.1	-	-	-	-	-	44.6	22.2
1-3	34.9	17.2	23.6	-	-	-	-	-	34.6	15.7
1-4	17.4	7.3	11.7	-	-	-	-	-	15.7	7.8
2-1	50.0	17.6	50.0	-	50.2	-	-	-	40.3	40.3
2-2	46.3	[illegible]	33.0	-	25.6	-	-	-	41.9	30.6
2-3	34.0	10.6	23.3	-	10.1	-	-	-	34.3	20.6
2-4	17.4	7.0	11.1	-	-	-	-	-	15.7	14.0
3-1	40.2	21.1	40.6	50.1	33.1	-	-	-	56.2	56.2
3-2	70.5	26.0	47.5	35.6	50.0	-	-	-	40.6	63.0
3-3	21.3	0.0	17.0	10.00	11.10	-	-	-	16.0	19.1
3-4	42.0	10.9	20.5	21.3	23.6	-	-	-	20.0	14.0
4-1	50.2	14.0	50.0	10.00	26.20	21.0	20.2	-	44.0	50.6
4-2	45.3	10.3	30.6	12.70	17.10	16.3	17.1	-	31.7	35.7
4-3	36.7	10.3	26.6	12.70	17.10	17.7	17.1	-	31.7	35.7
5-1	40.1	20.1	43.0	-	-	-	-	-	46.5	46.5
5-2	49.6	22.2	37.8	-	-	-	-	-	30.5	30.5
5-3	40.6	22.2	37.8	-	-	-	-	-	30.5	42.0
6-1	47.0	14.3	33.0	17.2	22.0	-	-	-	30.2	43.0
6-2	47.0	14.3	33.0	17.2	22.0	-	-	-	33.6	35.0
6-3	50.2	10.9	30.0	20.2	20.0	-	-	-	47.1	45.0
7-1	50.1	ANALYTIC								
7-2	50.1	13.5	32.0	16.0	21.0	-	-	-	25.0	30.0
7-3	15.3	5.2	20.5	11.3	14.0	-	-	-	17.7	10.6
8-1	52.7	13.7	20.5	17.0	21.6	10.0	22.7	-	26.3	15.0
8-2	52.7	13.7	20.5	14.0	22.1	10.0	22.7	-	26.3	15.0
8-3	17.2	5.7	22.3	11.0	15.6	13.6	16.0	-	26.0	9.7
8-4	[illegible]	10.0	27.6	16.00	27.10	10.0	22.7	-	30.5	47.6
10-1	40.5	14.7	31.3	17.6	22.5	-	-	-	22.0	26.0
10-2	41.6	12.5	26.6	15.0	19.1	-	-	-	18.7	22.0
11-1	57.5	ANALYTIC								
11-2	57.5	20.3	56.2	23.0	[illegible]	-	-	-	21.6	26.0
11-3	16.0	0.0	0.0	-	-	-	-	-	0.0	0.0
12-1	52.2	10.6	50.2	15.20	21.00	-	-	-	41.0	47.0
12-2	50.0	7.6	27.6	11.10	14.20	-	-	-	20.5	25.0
12-3	10.6	3.7	11.0	5.50	0.10	-	-	-	14.7	12.9
14-1	36.0	5.2	10.5	-	17.00	-	-	-	31.3	33.0
14-2	26.5	4.9	13.7	-	0.80	-	-	-	27.1	23.3
14-3	40.5	4.1	15.1	-	0.7	-	-	-	30.0	50.0
15-1	27.0	5.3	10.7	12.5	10.0	-	-	-	22.5	23.7
15-2	41.6	0.3	27.0	20.0	14.6	-	-	-	33.3	37.6
15-3	25.0	2.5	0.2	6.2	5.0	-	-	-	21.2	23.7
16-1	65.1	5.0	37.5	13.00	16.70	17.0	14.7	-	44.2	44.7
16-2	45.1	5.0	31.6	13.00	16.70	17.0	14.7	-	30.3	46.7
16-3	57.0	0.0	21.6	9.1	0.7	7.5	0.7	-	44.2	54.0
17-1	45.2	5.0	35.3	12.70	17.00	10.0	11.0	-	30.2	30.6
17-2	45.2	5.0	35.3	12.70	17.00	10.0	11.0	-	40.7	40.7
18-1	20.2	11.7	27.0	14.3	14.3	17.3	14.3	-	26.3	27.0
18-2	25.2	ANALYTIC								
19-1	45.6	11.9	35.2	15.0	10.6	-	-	-	44.7	47.2
19-2	45.6	11.9	31.0	15.0	10.6	-	-	-	44.7	47.2
20-1	54.0	11.3	30.0	16.60	10.10	16.6	19.2	-	40.3	52.1
20-2	46.0	5.3	33.1	14.0	15.6	16.0	16.3	-	41.9	44.3
20-3	40.6	5.3	20.0	12.1	13.5	12.1	16.6	-	9.3	11.6
20-4	32.5	3.6	12.2	4.0	5.6	4.0	5.0	-	27.5	20.6
22-1	57.6	10.5	37.3	15.0	17.6	15.0	18.6	-	44.7	50.0
22-2	44.7	0.5	31.2	13.6	16.0	13.6	15.6	-	30.0	42.5
22-3	44.7	0.4	30.0	13.6	16.0	13.6	15.6	-	30.0	42.5
23-1	30.5	12.0	25.3	13.0	15.0	16.60	20.50	-	12.6	17.6
23-2	33.6	10.7	21.5	11.0	12.0	16.1	17.5	-	11.0	11.0
23-3	33.0	5.7	10.0	10.7	11.0	13.1	16.5	-	9.7	9.7
24-1	40.0	17.0	34.1	15.00	22.60	11.5	12.5	-	30.6	43.2
24-2	33.6	7.5	24.1	11.20	15.00	0.1	0.0	-	27.1	30.5
24-3	50.5	12.6	40.1	10.6	26.6	13.6	14.7	-	45.2	50.0
25-1	35.0	0.6	26.1	13.7	15.2	10.1	11.3	-	33.2	35.1
25-2	45.5	10.1	10.0	17.6	20.2	12.0	14.7	-	30.0	43.6
25-3	39.0	0.6	20.1	14.0	17.2	9.6	10.5	-	33.2	37.1
25-4	27.5	5.3	15.6	6.0	9.0	5.0	4.7	-	23.6	24.0
26-1	33.2	26.9	26.9	-	-	-	-	-	20.2	26.0
26-2	47.6	35.3	35.3	-	-	-	-	-	37.6	42.3
26-3	55.3	12.2	30.3	-	27.1	15.5	26.5	20.5	47.0	40.0
27-1	41.0	15.1	25.1	17.0	10.0	10.40	20.00	16.0	35.0	20.3
27-2	25.1	5.1	15.1	10.0	11.3	11.1	12.6	10.1	10.5	10.0
27-3	30.6	12.0	21.6	15.70	17.10	13.5	16.6	14.2	30.3	30.3
28-1	62.5	31.2	64.0	-	-	-	-	40.60	GROUND	TEST
28-2	67.5	10.7	64.0	-	-	-	-	40.60	50.0	53.1
28-3	44.1	15.2	33.1	-	-	-	-	30.90	GROUND	TEST
28-4	72.5	11.3	47.2	-	-	-	-	24.3	50.0	42.5
		EXISTING	IDEAL CON.	CGT	CGTP	E2P	FP	S2P	MA	M12

FIGURE A-11 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM L2 (CONTINUED)

TASK NO.	TASK SYNERGISTIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	FLIGHT VEHICLES [illegible] BASIC	[illegible] BASIC
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	GROUND	TEST
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	[illegible]	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	GROUND	TEST
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	TEST
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	GROUND	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
		EXISTING	IDEAL GND.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FIGURE A-11 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM L2 (CONTINUED)

TASK NO.	TASK INTR. SCI. VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES — COMMON FACILITIES: GD7	GS20	F20	F9	S20	FLIGHT VEHICLES: M6 BASIC	M12 BASIC
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-		-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	ANALYTIC								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	COMMON	TEST
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	ANAL[illegible]IC								
[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	[illegible]
		EXISTING	IDEAL GND.	GD7	GS20	F20	F9	S20	M6	M12

FACILITY RESEARCH VALUE SUMMARY
OPERATIONAL SYSTEM L2

CHARACTERISTIC RESEARCH

	GD7	GS20	F20	F9	S20	M6 BASIC	M12 BASIC
RELATED EXISTING-FACILITIES VALUE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FACILITY RESEARCH VALUE (NEW + EXIST.)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] IDEAL FACILITY VALUE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FOCUSED RESEARCH

	GD7	GS20	F20	F9	S20
RELATED EXISTING-FACILITIES VALUE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FACILITY RESEARCH VALUE (NEW + EXIST.)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RELATED IDEAL FACILITY VALUE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FIGURE A-12 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M1

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES GD7	GD20	F2C	F9	S20	FLIGHT VEHICLES M6 BASIC	M12 BASIC
1-1	55.9	29.1	37.5	-	-	-	-	-	53.1	38.7
1-2	47.5	24.7	31.8	-	-	-	-	-	45.1	36.1
1-3	33.5	17.4	22.5	-	-	-	-	-	31.9	18.6
1-4	16.8	10.1	11.2	-	-	-	-	-	15.9	19.1
2-1	56.0	29.1	37.5	-	33.0	-	-	-	53.2	44.8
2-2	47.6	24.8	31.9	-	28.1	-	-	-	45.2	35.7
2-3	33.6	17.5	22.5	-	19.8	-	-	-	31.9	26.9
2-4	16.8	10.1	10.8	-	-	-	-	-	16.8	13.6
3-1	60.0	31.2	40.2	-	49.2	-	-	-	57.8	56.8
3-2	70.6	36.7	47.3	-	47.3	-	-	-	67.1	67.1
3-3	21.2	10.4	13.6	-	13.6*	-	-	-	20.1	20.1
3-4	42.4	22.0	28.4	-	28.4	-	-	-	40.2	22.0
4-1	55.2	28.4	35.3	-	28.7*	25.9	-	-	52.4	52.4
4-2	30.9	14.4	26.9	-	20.2*	18.7	-	-	37.0	37.0
4-3	30.9	14.4	26.9	-	20.2*	18.7	-	-	37.0	37.0
5-1	56.0	40.3	42.0	-	-	-	-	-	53.2	44.8
5-2	47.6	34.3	35.7	-	-	-	-	-	45.2	38.1
5-3	47.6	34.3	35.7	-	-	-	-	-	45.2	40.5
6-1	45.7	17.0	32.5	-	28.2	-	-	-	43.4	43.4
6-2	45.7	17.8	32.5	-	28.2	-	-	-	43.4	36.6
6-3	53.0	21.0	38.2	-	28.6	-	-	-	51.1	45.7
7-1	47.9	ANALYTIC								
7-2	47.9	10.0	30.7	-	24.4	-	-	-	45.5	24.0
7-3	33.8	11.0	19.6	-	17.3	-	-	-	32.1	13.5
9-1	51.6	18.1	28.9	-	25.0	23.2	19.6	-	44.4	29.6
9-2	51.6	18.1	28.9	-	20.9	23.2	19.6	-	49.9	20.6
9-3	36.4	12.7	21.9	-	18.6	16.4	13.9	-	36.4	12.7
9-4	51.6	12.9	24.8	-	26.3*	23.2	19.6	-	44.0	49.0
12-1	50.1	14.5	20.1	-	20.6*	-	-	-	47.6	45.1
12-2	35.4	10.3	19.8	-	18.0*	-	-	-	33.6	28.3
12-3	17.7	5.1	11.3	-	9.6*	-	-	-	16.8	14.2
14-1	32.0	10.3	17.8	-	17.6*	-	-	-	30.4	20.8
14-2	22.6	5.9	12.7	-	10.6*	-	-	-	21.5	29.6
14-3	37.7	4.9	13.9	-	8.7	-	-	-	35.8	33.9
15-1	23.8	6.2	15.9	-	14.3	-	-	-	22.6	22.6
15-2	35.6	10.3	20.5	-	23.8	-	-	-	35.6	33.7
15-3	23.8	3.1	8.8	-	7.1	-	-	-	21.4	22.6
16-1	47.2	17.5	26.4	-	23.1*	20.3	21.7	-	44.8	47.5
16-2	47.2	17.5	30.2	-	23.1*	20.3	21.7	-	44.8	44.8
16-3	55.5	10.0	20.5	-	13.9	11.7	12.8	-	52.7	52.7
17-1	42.9	10.3	24.0	-	21.9*	12.0	10.7	-	40.8	38.6
17-2	42.9	10.3	20.8	-	21.0*	12.0	10.7	-	40.8	38.6
19-1	47.7	16.2	33.3	-	29.7	-	-	-	45.3	45.3
19-2	47.7	16.2	30.5	-	29.7	-	-	-	45.3	45.3
20-1	53.5	15.0	30.9	-	27.0*	18.7	23.0	-	50.8	50.8
20-2	45.5	12.7	32.3	-	23.6	17.5	19.6	-	43.2	43.2
20-3	45.5	12.7	29.1	-	22.3	16.4	18.2	-	13.6	15.9
20-4	32.1	5.0	11.9	-	8.3	6.1	7.1	-	30.5	20.9
22-1	50.0	14.2	36.1	-	20.4	17.8	21.8	-	48.9	48.3
22-2	43.2	12.1	30.7	-	22.5	15.1	18.6	-	41.0	41.0
22-3	43.2	12.1	20.9	-	22.9	15.1	18.6	-	41.9	41.0
24-1	46.7	15.4	33.1	-	24.3*	16.3	17.3	-	44.3	44.3
24-2	32.9	10.9	23.4	-	17.1*	11.5	12.2	-	31.3	31.3
24-3	54.9	18.1	39.0	-	28.5	19.2	20.3	-	52.7	52.2
25-1	36.5	12.4	24.5	-	17.5	13.9	13.2	-	34.7	34.7
25-2	43.0	14.6	28.9	-	22.8	17.2	15.3	-	40.8	40.8
25-3	36.5	12.6	24.5	-	19.4	13.2	12.9	-	34.7	34.7
25-4	25.8	6.2	14.4	-	7.2	7.2	6.4	-	24.5	24.5
26-1	32.8	24.6	24.6	-	-	-	-	-	31.1	24.2
26-2	46.4	34.9	34.8	-	-	-	-	-	44.1	44.1
26-3	54.6	10.0	30.8	-	27.3	30.8	30.8	20.7	40.1	51.9
27-1	40.2	10.1	24.1	-	23.7	20.0*	19.3*	20.9	38.2	33.1
27-2	24.1	11.0	14.5	-	16.2	13.5	12.5	12.5	22.9	18.1
27-3	34.2	15.4	20.5	-	20.5*	23.5	18.8	16.7	32.5	20.0
30-1	49.5	33.6	37.[illegible]	-	-	-	-	35.6	[illegible]	TEST
30-2	34.9	23.7	25.2	-	-	-	-	25.1	[illegible]	TEST
30-3	58.2	39.6	43.6	-	-	-	-	41.9	58.2	58.7
		EXISTING	IDEAL GND.	GD7	GD20	F2C	F9	S20	M6	M12

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FIGURE A-12 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M1 (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES GD7	GD20	E20	F9	S20	FLIGHT VEHICLES M6 BASIC	M12 BASIC
32-1	35.0	14.7	26.2	-	-	17.1	14.8	25.60	GROUND	TEST
32-2	58.3	24.2	43.7	-	-	30.3	29.7	40.80	GROUND	TEST
32-3	45.6	20.7	37.2	-	-	35.7	35.2	37.20	40.6	49.6
33-1	61.3	ANALYTIC								
33-2	52.1	25.0	39.1	-	29.2	31.8	34.4	34.5	GROUND	TEST
33-3	36.9	8.1	24.6	-	9.6	10.3	11.4	13.20	34.9	34.8
34-2	41.6	31.2	31.2	-	-	-	-	-	GROUND	TEST
34-3	50.9	ANALYTIC								
35-1	36.0	11.5	24.1	-	14.6	13.7	-	19.1	32.4	36.2
35-2	30.6	5.8	22.9	-	17.2	11.6	-	16.2	30.6	30.6
36-1	36.5	ANALYTIC								
36-2	51.0	22.0	38.8	-	-	37.8	36.2	33.4	GROUND	TEST
36-3	60.9	26.0	45.7	-	-	31.7	39.6	39.60	60.9	60.9
39-1	24.2	11.9	16.2	-	13.1	13.8	14.8	17.8	23.0	23.0
39-2	40.6	15.8	27.1	-	21.8	21.4	24.6	21.4	38.4	38.4
40-1	58.5	ANALYTIC								
40-2	49.7	30.8	37.3	-	-	-	32.8	31.8	GROUND	TEST
40-3	35.1	21.9	24.9	-	-	-	23.2	22.5	35.1	35.1
41-1	43.8	ANALYTIC								
41-2	43.0	ANALYTIC								
42-1	67.3	30.5	46.7	-	-	-	-	46.70	62.3	59.7
43-1	62.0	28.5	41.5	-	-	37.2	38.4	41.9	40.6	52.7
43-2	72.9	33.5	51.8	-	-	45.9	47.4	51.8	62.9	65.6
43-3	43.7	24.5	32.8	-	-	-	-	32.8	GROUND	TEST
43-4	43.7	ANALYTIC								
44-1	54.9	ANALYTIC								
44-2	64.6	48.4	48.4	-	-	-	-	-	61.4	64.6
45-1	38.0	ANALYTIC								
45-2	57.9	28.6	40.4	-	-	38.8	31.3	32.9	53.9	53.9
45-3	63.4	33.6	47.5	-	-	45.6	38.8	30.7	63.4	63.4
46-1	45.0	ANALYTIC								
46-2	45.0	21.2	33.8	-	-	-	-	27.5	40.5	42.8
48-1	56.1	29.7	37.6	-	36.50	36.9	-	-	50.5	47.7
48-2	56.1	29.7	37.6	-	36.5	36.5	-	-	42.1	47.7
48-3	39.6	15.0	25.3	-	23.8	23.8	-	-	31.7	23.8
48-4	66.0	36.3	44.2	-	44.2	44.2	-	-	54.1	54.1
48-5	66.0	ANALYTIC								
52-1	49.6	ANALYTIC								
52-2	49.6	ANALYTIC								
52-3	49.6	ANALYTIC								
52-4	58.3	21.0	39.1	-	-	38.1	26.8	-	52.5	21.0
57-1	41.3	ANALYTIC								
57-2	41.3	ANALYTIC								
57-3	41.3	ANALYTIC								
57-4	58.5	21.1	41.5	-	-	39.80	32.2	-	44.8	21.1
57-5	58.5	21.1	41.5	-	-	39.80	32.2	-	45.6	21.1
57-6	68.8	22.0	46.1	-	-	46.10	39.2	-	65.6	22.0
58-1	38.6	ANALYTIC								
58-2	38.6	ANALYTIC								
58-3	54.7	15.9	36.7	-	-	-	-	-	27.4	15.9
59-1	40.4	ANALYTIC								
59-2	40.4	ANALYTIC								
59-3	40.4	ANALYTIC								
59-4	57.3	22.9	43.0	-	-	39.00	31.50	-	45.8	22.9
59-5	57.3	22.9	40.7	-	-	39.00	31.50	-	45.8	22.9
59-6	67.4	27.0	47.9	-	-	47.90	40.40	-	55.9	27.0
63-1	31.5	11.7	22.4	-	13.2	22.0	14.8	-	28.3	11.7
63-2	44.6	20.1	29.9	-	24.5	26.8	24.5	-	42.4	29.1
63-3	52.5	19.4	37.3	-	22.9	36.7	24.7	22.0	47.2	19.4
65-1	35.2	ANALYTIC								
65-2	45.9	15.5	33.6	-	20.8	25.4	20.0	-	39.9	15.5
65-3	58.7	20.5	39.3	-	26.4	32.3	23.5	-	38.2	20.5
67-1	39.2	11.4	26.3	-	18.1	20.0	12.6	-	GROUND	TEST
67-2	39.2	11.4	25.1	-	18.1	20.0	17.6	-	29.6	11.4
67-3	55.6	ANALYTIC								
		EXISTING	IDEAL GND.	GD7	GD20	E20	F9	S20	M6	M12

FIGURE A-12 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M1 (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES — GROUND FACILITIES: GDT	GA20	E20	F9	S20	FLIGHT VEHICLES: M6 BASIC	M12 BASIC
71-1	30.3	22.0	22.0	-	-	-	-	-	30.3	27.0
71-2	30.3	22.0	22.0	-	-	-	-	-	30.3	22.0
71-3	35.7	26.0	26.0	-	-	-	-	-	35.7	26.0
72-1	23.1	17.3	17.3	-	-	-	-	-	GROUND	TEST
72-2	32.7	24.5	24.5	-	-	-	-	-	GROUND	TEST
72-3	30.5	20.9	20.9	-	-	-	-	-	GROUND	TEST
77-1	25.0	ANALYTIC								
77-2	30.4	10.2	22.0	-	-	21.3	21.3	22.0	25.0	25.0
78-1	23.6	ANALYTIC								
78-2	34.2	15.9	25.7	-	21.7	21.7	16.7	-	32.6	30.0
78-3	42.6	10.7	30.2	-	25.6	25.6	19.6	-	40.5	30.3
79-1	26.5	ANALYTIC								
79-2	31.2	12.2	22.2	-	16.0	17.5	-	13.7	20.1	29.6
80-1	37.7	25.3	28.3	-	27.2	27.2	26.4	28.3	36.0	35.0
80-2	44.4	26.2	29.7	-	20.4	20.4	27.5	29.7	40.0	42.2
82-1	21.0	ANALYTIC								
82-2	29.7	19.9	22.3	-	20.0	21.4	21.4	22.3	GROUND	TEST
82-3	35.0	22.0	24.0	-	23.1	23.0	23.0	24.0	35.0	35.0
84-1	24.4	ANALYTIC								
84-2	40.7	26.5	30.5	-	-	-	-	-	40.7	30.9
85-1	25.6	ANALYTIC								
85-2	35.4	12.0	22.7	-	16.0	16.7	15.2	16.0	31.0	33.7
85-3	41.7	15.0	27.9	-	18.0	19.6	17.9	18.0	19.9	15.0
87-1	22.7	ANALYTIC								
87-2	22.7	ANALYTIC								
87-3	37.9	19.2	26.9	-	-	-	-	-	34.0	18.9
89-1	25.6	ANALYTIC								
89-2	25.6	17.9	18.2	-	-	-	-	-	25.1	24.3
89-3	36.3	23.4	25.0	-	-	-	-	-	32.7	30.9
93-1	29.3	ANALYTIC								
93-2	24.9	9.5	14.9	-	12.0	12.0	11.9	13.0	21.2	21.2
94-1	23.6	ANALYTIC								
94-2	33.5	ANALYTIC								
94-3	39.4	15.0	23.6	-	18.9	18.9	17.3	19.7	29.5	27.6
96-1	21.1	3.0	12.6	-	5.5	5.5	9.1	7.6	20.0	14.7
96-2	33.1	7.0	22.5	-	9.4	9.0	9.1	13.3	33.3	26.3
97-1	21.0	16.4	16.4	-	-	-	-	-	GROUND	TEST
97-2	30.4	10.9	27.3	-	-	-	-	25.5	30.4	32.0
102-1	31.9	ANALYTIC								
102-2	37.5	26.2	29.1	-	-	-	-	29.1	37.9	31.0
		EXISTING	IDEAL GND.	GDT	GA20	E20	F9	S20	M6	M12

FACILITY RESEARCH VALUE SUMMARY
OPERATIONAL SYSTEM M1

CHARACTERISTIC RESEARCH

	GDT	GA20	E20	F9	S20	M6 BASIC	M12 BASIC
RELATED EXISTING-FACILITIES VALUE	0	1290	1540	1379	800	2219	2219
FACILITY RESEARCH VALUE (NEW + EXIST.)	0	1792	1824	1634	1126	4719	4904
RELATED IDEAL-FACILITY VALUE	0	2220	2330	2209	1309	5177	5177

FOCUSED RESEARCH

	GDT	GA20	E20	F9	S20
RELATED EXISTING-FACILITIES VALUE	0	360	159	91	139
FACILITY RESEARCH VALUE (NEW + EXIST.)	0	606	272	123	291
RELATED IDEAL-FACILITY VALUE	0	677	309	156	276

FIGURE A-13 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M2

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES						
				GROUND FACILITIES					FLIGHT VEHICLES	
				GD7	GD20	F2C	F9	S2C	M4 BASIC	M12 BASIC
1-1	58.3	22.2	38.1	-	-	-	-	-	60.8	26.2
1-2	49.6	18.8	33.7	-	-	-	-	-	32.3	22.3
1-3	35.C	13.3	23.4	-	-	-	-	-	36.5	15.7
1-4	17.5	7.0	11.7	-	-	-	-	-	11.4	7.8
2 1	57.6	17.3	38.6	-	30.0	-	-	-	69.C	51.8
[illegible]	49.0	14.7	32.8	-	25.5	-	-	-	41.6	44.1
[illegible]	34.6	10.4	23.2	-	19.0	-	-	-	28.4	31.1
. 4	17.1	6.9	11.1	-	-	-	-	-	14.[illegible]	15.8
3 1	66.4	21.2	60.5	30.2	33.2	-	-	-	51.4	57.6
3-2	71.1	16.4	47.6	35.5	30.6	-	-	-	69.8	66.[illegible]
3 3	21.1	6.9	13.7	10.C0	11.10	-	-	-	14.[illegible]	19.2
[illegible]	42.7	14.9	23.6	21.3	23.5	-	-	-	14.1	21.1
4-1	56.	14.6	36.C	16.90	26.20	21.8	26.2	-	44.8	50.6
4-2	38.7	10.3	29.6	11.90	17.10	15.5	17.1	-	31.7	35.7
4-3	38.7	10.3	29.6	11.90	17.10	15.5	17.1	-	31.7	35.7
5-1	47.6	16.C	43.3	-	-	-	-	-	43.3	8.C
5-2	45.1	22.1	36.8	-	-	-	-	-	36.8	44.2
5-3	45.1	22.1	36.8	-	-	-	-	-	36.8	44.2
6-1	47.2	14.2	33.5	17.0	21.7	-	-	-	37.7	42.6
6-2	47.2	14.2	33.5	17.0	21.7	-	-	-	35.	35.6
6-3	45.6	16.6	39.6	20.C	25.5	-	-	-	41.6	44.6
7-1	48.6	ANALYTIC								
7-2	45.	12.8	31.6	15.8	20.7	-	-	-	16.8	42.C
7-3	36.5	5.1	20.2	11.2	14.6	-			10.5	25.8
8-1	52.7	13.7	29.5	17.8	21.6	18.C	22.7	-	16.8	15.8
8-2	52.7	13.7	29.5	16.8	22.1	18.0	22.7	-	36.1	15.8
8-3	37.2	5.7	22.3	11.8	15.6	13.6	16.C	-	26.	13.C
8-4	42.7	10.0	27.6	16.90	22.10	18.0	22.7	-	47.	47.6
1	51.7	10.3	28.8	15.50	22.70	-	-	-	41.3	46.5
12-2	36.5	7.3	20.4	10.90	16.10	-	-	-	29.2	29.2
12-3	18.2	3.6	11.7	5.50	8.C0	-	-	-	16.8	16.6
14-1	33.9	6.8	19.0	-	16.60	-	-	-	30.5	32.2
14-2	23.9	4.8	13.4	-	9.60	-	-	-	21.5	22.7
14-3	30.9	4.0	14.8	-	8.C	-	-	-	35.9	37.8
15 1	26.6	4.5	16.5	12.3	9.8	-	-	-	22.1	33.4
15 2	41.C	8.3	27.5	20.5	16.4	-	-	-	[illegible]	34.9
15 3	24.	2.5	9.1	6.1	4.9	-		-	20.3	23.4
16 1	48.4	5.7	27.1	13.60	16.50	12.6	16.5	-	43.6	64.C
16-2	48.4	5.7	31.C	13.60	14.50	12.6	14.5	-	38.8	64.C
16-3	57.C	5.7	21.1	8.8	8.5	7.6	8.5	-	65.4	56.1
17-1	44.3	6.9	24.8	11.50	17.30	10.6	11.5	-	35.4	37.6
17-2	44.3	6.9	29.7	12.40	17.30	10.6	11.5	-	37.6	39.9
18-1	28.C	11.7	19.9	13.7	13.7	11.7	13.7	-	28.2	36.6
18-2	28.C	ANALYTIC								
19-1	45.1	11.8	36.8	18.7	13.2	-	-	-	44.2	44.7
19-2	45.1	11.8	31.4	15.7	13.2	-	-	-	44.5	44.7
20-1	53.5	17.7	38.0	16.00	17.70	14.C	18.7	-	48.1	50.8
20-2	45.5	5.1	32.3	13.6	15.C	13.6	15.9	-	40.9	43.2
20-3	45.5	5.1	29.1	11.8	13.2	11.8	14.1	-	9.1	15.9
20-4	37.1	3.4	11.5	6.8	4.5	4.8	5.9	-	27.3	28.9
22-1	50.8	10.2	36.1	[illegible]	16.8	15.2	17.8	-	43.2	49.3
22-2	43.2	8.6	[illegible]	13.C	14.2	13.8	15.1	-	36.7	41.8
22-3	43.2	8.6	21.[illegible]	13.6	14.2	13.C	15.1	-	36.7	41.C
1	48.7	15.3	[illegible]	15.60	21.00	11.2	12.1	-	37.3	42
24	37.9	7.2	2.4	10.50	15.50	7.9	8.6	-	36.4	3.6
24 3	54.5	12.1	17.	19.1	25.8	13.7	14.3	-	43.8	49.4
25 1	36.5	8.C	26	12.8	16.3	9.5	10.6	-	31.1	32.5
25-2	43.C	5.5	28.8	16.3	18.9	12.C	13.3	-	34.5	43.8
25-3	36.5	8.C	24.5	13.9	16.1	8.8	9.9	-	31.1	36.7
25 4	25.8	3.3	14.4	4.4	7.5	3.6	4.4	-	21.9	33.[illegible]
26 1	32.8	26.6	26.6	-	-	-	-	-	27.8	26.6
26-2	48.6	36.8	36.8	-	-	-	-	-	37.1	41.8
26-3	54.6	12.5	38.8	-	31.8	15.3	26.2	20.2	46.4	49.1
27 1	40.2	16.5	24.1	16.5	19.1	17.70	20.10	16.1	38.1	32.
27 2	24.1	8.7	14.5	10.1	10.9	13.6	12.1	9.6	16.9	18.1
27 3	34.2	12.3	20.5	15.00	16.60	13.C	15.7	13.7	29.0	30.9
28 1	62.5	31.2	46.9	-	-	-	-	40.60	COMMON TEST	
28-2	62.5	18.7	46.9	-	-	-	-	40.60	59.0	53.1
28 3	44.1	15.0	33.1	-	-	-	-	30.00	COMMON TEST	
28-4	33.5	11.C	32.2	-	-	-	-	26.3	50.8	62.5
		EXISTING	IDEAL GND.	GD7	GD20	F2C	F9	S2C	M4	M12

FIGURE A-13 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M2 (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES GROUND FACILITIES GDT	GD70	E2C	C9	S20	FLIGHT VEHICLES M6 BASIC	M12 BASIC
30-1	49.1	33.4	36.8	-	-	-	-	35.4	GROUND	TEST
30-2	34.7	23.6	26.0	-	-	-	-	29.0	GROUND	TEST
30-3	57.8	39.3	43.3	-	-	-	-	41.6	57.0	57.8
32-1	35.0	5.1	26.3	-	-	11.6	11.2	22.10	GROUND	TEST
32-2	58.4	16.9	43.'	-	-	21.0	20.4	36.00	GROUND	TEST
32-3	49.6	15.9	37.2	-	-	19.4	18.9	37.90	44.7	49.6
33-1	61.6	ANALYTIC								
33-2	52.4	17.3	39.3	18.3	18.3	22.5	24.1	27.2	GROUND	TEST
33-3	37.C	5.5	24.0	5.9	5.9	7.4	7.0	17.70	31.4	35.1
34-1	70.9	15.6	45.4	-	-	17.0	20.4	27.7	21.3	15.6
34-2	42.5	31.9	31.9	-	-	-	-	-	GROUND	TEST
34-3	60.3	ANALYTIC								
34-4	60.3	9.6	22.3	10.2	10.2	-	15.7	12.7	19.1	9.6
35-1	30.5	0.0	24.5	9.5	10.9	9.2	13.9	15.7	29.2	32.8
35-2	31.6	6.8	23.3	9.1	9.3	8.7	11.8	13.3	31.0	31.0
36-1	36.9	ANALYTIC								
36-2	52.3	17.8	39.2	-	-	26.7	33.5	29.3	GROUND	TEST
36-3	61.5	20.9	46.1	-	-	27.7	36.9	34.40	55.9	61.5
38-1	31.8	16.8	23.8	-	-	-	-	20.70	GROUND	TEST
38-2	37.4	15.0	28.8	-	-	-	-	24.30	GROUND	TEST
38-3	31.0	12.7	23.8	-	-	-	-	20.70	29.6	31.8
39-1	24.9	9.9	16.6	11.2	11.2	10.9	12.9	10.9	19.8	22.3
39-2	41.3	16.5	27.7	18.6	18.6	18.2	21.5	18.2	33.0	39.2
40-1	59.8	ANALYTIC								
40-2	58.1	29.1	37.6	-	-	-	30.1	29.1	GROUND	TEST
40-3	35.4	17.7	25.1	-	-	-	21.2	20.5	31.9	35.4
41-1	43.7	ANALYTIC								
41-2	43.7	ANALYTIC								
42-1	62.5	16.9	44.9	-	-	-	-	42.90	53.1	56.2
43-1	61.7	19.5	41.3	-	-	25.9	26.9	30.2	43.0	49.4
43-2	72.6	21.8	51.5	-	-	32.7	33.4	37.8	54.6	41.7
43-3	43.6	17.4	32.7	-	-	-	-	24.8	GROUND	TEST
43-4	43.6	ANALYTIC								
44-1	55.1	ANALYTIC								
44-2	64.8	48.6	49.6	-	-	-	-	-	55.1	61.4
45-1	38.4	ANALYTIC								
45-2	54.4	20.1	40.8	-	-	21.8	27.2	24.5	51.7	51.7
45-3	64.8	23.7	48.8	-	-	25.6	32.0	28.8	57.4	69.8
46-1	45.4	ANALYTIC								
46-2	45.4	31.8	34.8	-	-	-	-	34.0	36.3	40.9
48-1	62.6	15.4	42.8	24.60	30.70	24.9	25.7	-	34.5	40.7
48-2	62.6	15.4	42.8	24.4	30.7	24.9	25.7	-	34.5	40.7
48-3	44.2	11.5	28.3	15.0	19.5	16.0	15.9	-	25.6	19.5
48-4	73.7	24.3	49.4	30.2	37.6	33.2	31.7	-	44.2	45.7
48-5	73.7	ANALYTIC								
52-1	57.5	ANALYTIC								
52-2	57.5	ANALYTIC								
52-3	57.5	ANALYTIC								
52-4	67.7	13.5	45.4	-	-	27.1	45.4	-	27.1	13.5
58-1	42.6	ANALYTIC								
58-2	42.8	ANALYTIC								
58-3	54.5	11.9	30.9	-	-	-	-	-	11.9	11.9
61-1	43.8	ANALYTIC								
61-2	43.8	ANALYTIC								
61-3	43.8	ANALYTIC								
61-4	62.0	12.4	41.6	-	-	-	32.90	-	40.9	12.4
61-5	62.8	12.4	41.6	-	-	-	32.40	-	18.4	12.4
61-6	73.0	14.6	46.7	-	-	-	39.20	-	14.6	14.6
62-1	25.1	ANALYTIC								
62-2	35.5	8.9	26.6	12.4	14.2	-	-	10.5	8.9	20.4
62-3	41.8	5.8	7.9	6.7	7.9	-	-	7.5	5.0	33.4
63-1	37.8	9.1	26.2	17.0	11.1	18.1	20.7	-	9.1	12.9
63-2	52.4	10.3	35.1	28.0	27.0	26.7	30.4	-	10.3	10.3
63-3	61.6	13.6	43.7	16.6	18.5	30.2	34.5	10.6	13.6	13.6
64-1	31.1	13.1	22.1	-	16.0	18.0	-	-	14.0	13.1
64-2	31.1	10.9	20.8	-	13.4	14.6	-	-	12.4	10.9
65-1	40.1	ANALYTIC								
65-2	50.9	10.0	30.1	19.9	18.2	19.9	27.9	-	10.0	14.2
65-3	60.9	16.1	44.0	21.4	22.7	30.4	34.0	-	16.7	30.1
		EXISTING	IDEAL GND.	GDT	GD20	E2C	F9	S20	M6	M12

FIGURE A-13 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M2 (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF IDEAL GND. FACILITY	VALUE OF NEW FACILITIES + EXISTING FACILITIES: GROUND FACILITIES GDT	GD20	E2C	F9	S20	FLIGHT VEHICLES M6 BASIC	M12 BASIC
67-1	63.9	7.5	29.4	11.8	15.4	15.0	16.7	-	GROUND	TEST
67-2	63.5	7.5	29.1	11.8	15.6	15.0	16.7	-	8.8	11.0
67-3	62.1	ANALYTIC								
68-1	23.9	14.0	18.0	-	-	-	-	18.0	GROUND	TEST
68-2	33.9	22.0	29.4	-	-	-	-	29.4	NO	TEST
68-3	33.9	22.9	29.4	-	-	-	-	29.4	GROUND	TEST
69-1	22.2	ANALYTIC								
69-2	31.4	17.3	22.3	-	-	-	-	22.0	GROUND	TEST
69-3	31.4	17.3	22.3	-	-	-	-	22.0	29.2	31.4
70-1	27.7	ANALYTIC								
70-2	27.7	11.6	20.8	-	-	-	-	16.6	GROUND	TEST
70-3	39.3	16.5	29.5	-	-	-	-	23.6	GROUND	TEST
70-4	39.3	5.6	26.3	11.8	11.0	13.4	20.4	22.8	GROUND	TEST
70-5	46.2	11.1	31.0	-	-	19.7	24.0	26.8	18.9	27.7
73-1	24.9	16.2	19.7	-	-	-	-	19.7	21.7	21.7
73-2	35.3	22.9	24.5	-	-	-	-	26.9	30.0	30.0
73-3	41.5	22.0	31.1	-	-	-	-	31.1	39.3	39.3
74-1	18.8	ANALYTIC								
74-2	18.8	13.3	13.3	-	-	-	-	-	18.8	18.8
74-3	31.3	22.2	22.2	-	-	-	-	-	31.3	31.3
75-1	27.6	20.7	20.7	-	-	-	-	-	GROUND	TEST
75-2	39.1	10.6	26.2	-	-	-	-	26.2*	GROUND	TEST
75-3	44.0	12.4	32.7	-	-	-	-	32.7*	41.4	46.0
77-1	24.3	ANALYTIC								
77-2	28.6	15.7	21.4	-	-	17.2	18.6	21.4	22.9	24.3
78-1	23.8	ANALYTIC								
78-2	33.7	10.8	23.9	13.5	16.2	11.4	12.8	-	21.9	23.6
78-3	39.6	12.7	29.1	19.8	19.0	13.5	15.0	-	27.7	33.7
79-1	26.0	ANALYTIC								
79-2	30.6	8.3	21.7	11.3	12.9	11.6	14.7	11.3	26.5	27.5
80-1	34.7	15.1	26.0	20.8	20.8	20.8	22.9	24.3	29.5	31.2
80-2	40.8	19.2	27.3	21.2	21.2	21.2	23.3	25.3	36.7	36.7
82-1	15.6	ANALYTIC								
82-2	27.7	15.2	20.8	16.	16.6	16.6	18.0	19.4	GROUND	TEST
82-3	32.6	16.4	23.1	19.3	18.3	18.3	19.9	21.5	29.3	31.0
83-1	22.9	ANALYTIC								
83-2	38.2	17.2	29.6	-	-	-	-	29.6	34.4	38.2
85-1	23.5	ANALYTIC								
85-2	33.2	8.3	21.3	11.6	13.1	11.6	11.6	11.6	26.6	28.2
85-3	39.1	5.8	26.2	13.7	15.6	13.7	13.7	13.7	9.8	9.8
87-1	23.8	ANALYTIC								
87-2	23.8	ANALYTIC								
87-3	39.6	9.9	28.1	-	-	-	-	-	19.8	19.8
89-1	21.2	ANALYTIC								
89-2	26.7	14.4	19.6	-	-	-	-	-	21.0	22.3
89-3	37.1	20.4	26.4	-	-	-	-	-	29.7	29.7
93-1	30.8	ANALYTIC								
93-2	26.2	7.6	15.7	9.2	10.2	9.2	10.2	11.8	20.9	23.6
94-1	24.5	ANALYTIC								
94-2	34.8	ANALYTIC								
94-3	40.9	10.6	24.5	13.1	14.7	14.7	13.1	17.2	29.8	39.7
96-1	21.8	2.6	13.1	3.9	4.8	4.4	4.8	7.0	18.6	16.4
96-2	36.4	5.1	23.3	7.3	8.7	8.0	8.7	12.4	29.1	29.1
97-1	22.7	17.1	17.1	-	-	-	-	-	GROUND	TEST
97-2	37.9	11.4	29.4	-	-	-	-	26.5	34.1	34.1
99-1	18.8	7.5	12.0	-	-	-	-	-	7.5	7.9
99-2	18.4	7.5	12.8	-	-	-	-	-	7.9	7.9
100-1	27.9	19.3	20.7	-	-	-	-	-	26.8	27.9
100-2	32.4	22.7	24.3	-	-	-	-	-	29.2	32.4
102-1	33.2	ANALYTIC								
102-2	39.1	23.5	29.3	-	-	-	-	27.4	35.2	35.2
		EXISTING	IDEAL GND.	GDT	GD20	F2C	F9	S20	M6	M12

FACILITY RESEARCH VALUE SUMMARY
OPERATIONAL SYSTEM M2

CHARACTERISTIC RESEARCH

	GDT	GD20	E2C	F9	S20	M6 BASIC	M12 BASIC
RELATED EXISTING-FACILITIES VALUE	876	972	922	990	1077	1090	1090
FACILITY RESEARCH VALUE (NEW + EXIST.)	1187	1523	1251	1558	1596	4079	4309
RELATED IDEAL-FACILITY VALUE	2219	2637	2206	2498	2019	5879	5879

FOCUSED RESEARCH

	GDT	GD20	E20	F9	S20
RELATED EXISTING-FACILITIES VALUE	170	186	14	56	218
FACILITY RESEARCH VALUE (NEW + EXIST.)	232	330	18	115	422
RELATED IDEAL-FACILITY VALUE	498	491	24	194	486

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

FIGURE A-14 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM L2 – FLIGHT VEHICLES WITH OPTIONS

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: MACH 6 FLIGHT VEHICLE			MACH 12 FLIGHT VEHICLE							
			BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
1-1	58.1	22.1	52.3	-	-	26.1	-	-	52.3	-	-	60.7	-
1-2	49.4	18.8	44.4	-	-	22.2	-	-	44.4	-	-	34.6	-
1-3	34.9	13.2	31.4	-	-	15.7	-	-	31.4	-	-	24.4	-
1-4	17.4	7.0	15.7	-	-	7.8	-	-	15.7	-	-	12.2	-
2-1	58.0	17.4	49.3	-	-	49.3	-	-	-	-	-	52.2	-
2-2	49.3	14.8	41.9	-	-	39.4	-	-	-	-	-	44.4	-
2-3	34.8	10.4	31.3	-	-	29.6	-	-	-	-	-	31.3	-
2-4	17.4	7.0	15.7	-	-	14.8	-	-	-	-	-	15.7	-
3-1	60.3	21.1	54.2	-	-	54.2	-	-	-	-	-	-	-
3-2	70.9	24.8	49.6	-	-	63.8	-	-	-	-	-	-	-
3-3	21.3	6.8	14.9	-	-	19.1	-	-	-	-	-	-	-
3-4	42.5	14.9	29.8	-	-	14.9	30.3	30.3	-	-	-	-	-
4-1	55.2	14.4	44.5	-	-	50.6	-	-	-	-	-	-	-
4-2	39.7	10.3	31.7	-	-	35.7	-	-	-	-	-	-	-
4-3	39.7	10.3	31.7	-	-	35.7	-	-	-	-	-	-	-
5-1	58.1	26.1	46.5	-	-	46.5	-	-	52.3	-	-	-	-
5-2	49.4	22.2	39.5	-	-	39.5	-	-	44.4	-	-	-	-
5-3	49.4	22.2	39.5	-	-	42.0	-	-	-	-	-	-	-
6-1	47.0	14.3	38.2	-	-	43.0	-	-	-	-	-	-	-
6-2	47.0	14.3	33.4	-	-	35.8	49.4	43.0	-	-	-	-	-
6-3	56.2	16.9	42.1	-	-	45.0	53.4	55.6	-	-	-	-	-
7-1	58.1	ANALYTIC											
7-2	58.1	13.9	29.0	-	-	30.0	42.6	42.4	-	-	-	-	-
7-3	35.3	9.2	17.7	-	-	10.6	33.6	33.6	-	-	-	-	-
9-1	52.7	13.7	26.3	-	-	15.8	47.4	47.4	-	-	-	-	-
9-2	52.7	13.7	26.3	-	-	15.8	44.8	44.8	-	-	-	-	-
9-3	37.2	5.7	26.0	-	-	9.7	26.0	33.5	-	-	-	-	-
9-4	52.7	10.0	39.5	-	-	47.4	50.1	50.1	-	-	-	-	-
10-1	40.9	14.7	22.0	-	-	26.0	-	-	-	-	-	-	39.1
10-2	41.4	12.9	18.7	-	-	22.9	-	-	-	-	-	-	33.3
11-1	53.5	ANALYTIC											
11-2	53.5	20.3	21.4	-	-	26.8	-	-	-	-	-	-	49.5
11-3	16.0	0.0	0.6	-	-	0.9	-	-	-	-	-	-	14.4
12-1	52.2	10.4	41.8	-	-	47.0	40.6	40.6	-	-	-	-	40.6
12-2	36.8	7.4	29.5	-	-	25.9	33.2	39.	-	-	-	-	29.9
12-3	18.4	3.7	14.7	-	-	12.9	16.6	16.6	-	-	-	-	14.7
14-1	34.8	9.0	31.3	-	-	33.0	-	-	-	-	-	-	-
14-2	24.5	4.9	22.1	-	-	23.3	-	-		-	-	-	-
14-3	40.9	4.1	36.8	-	-	38.9	-	-	-	-	-	-	-
15-1	25.0	5.0	22.5	-	-	23.7	-	-	-	-	-	-	-
15-2	41.6	8.3	33.3	-	-	37.4	-	-	-	-	-	-	-
15-3	25.0	2.5	21.2	-	-	23.7	-	-	-	-	-	-	-
16-1	49.1	5.9	44.2	-	-	46.7	-	-	-	-	-	-	-
16-2	49.	5.8	39.3	-	-	46.7	-	-	-	-	-	-	-
16-3	57.	5.8	44.2	-	-	54.9	-	-	-	-	-	-	-
17-1	45.	5.0	36.2	-	-	38.4	-	-	-	-	-	-	-
17-2	45.2	5.	40.7	-	-	40.7	-	-	-	-	-	-	-
18-1	29.2	11.7	26.3	-	-	27.8	-	-	-	-	-	-	-
18-2	29.2	ANALYTIC											
19-1	49.6	11.9	44.7	-	-	47.2	-	-	-	-	-	-	-
19-2	49.6	11.9	44.7	-	-	47.2	-	-	-	-	-	-	-
20-1	54.8	11.0	49.3	-	-	52.1	-	-	-	-	-	-	-
20-2	46.8	5.3	41.9	-	-	44.3	-	-	-	-	-	-	-
20-3	46.6	5.7	9.3	-	-	11.6	-	-	-	-	-	-	44.3
20-4	32.9	3.6	27.9	-	-	29.6	-	-	-	-	-	-	-
22-1	52.6	10.5	44.7	-	-	50.0	-	-	-	-	-	-	-
22-2	44.7	8.9	38.0	-	-	42.5	-	-	-	-	-	-	-
22-3	44.7	8.9	38.0	-	-	42.5	-	-	-	-	-	-	-
23-1	39.5	12.8	12.6	27.6	-	12.6	-	-	-	31.6	-	-	-
23-2	33.6	10.7	11.0	23.5	-	11.0	-	-	-	26.9	-	-	-
23-3	33.6	9.7	9.7	21.8	-	9.7	-	-	-	29.2	-	-	-
24-1	48.8	10.8	38.4	-	-	45.2	-	-	-	-	-	-	-
24-2	33.9	7.5	27.1	-	-	30.9	-	-	-	-	-	-	-
24-3	56.5	12.4	45.2	-	-	50.8	-	-	-	-	-	-	-
25-1	39.0	8.4	33.2	35.1	-	35.1	-	-	-	37.1	-	-	-
25-2	49.9	10.1	39.0	-	-	43.6	-	-	-	-	-	-	-
25-3	39.0	8.4	33.2	-	-	37.1	-	-	-	-	-	-	-
25-4	27.5	3.3	23.4	24.8	-	24.8	-	-	-	26.2	-	-	-
26-1	33.	24.5	28.2	-	-	24.9	-	-	-	-	-	-	-
26-2	47.8	35.3	37.6	-	-	42.3	-	-	-	-	-	-	-
26-3	55.3	12.2	47.8	-	-	49.8	-	-	-	-	-	-	-
27-1	41.9	15.1	35.6	-	-	29.3	39.8	39.8	-	-	-	-	-
27-2	25.	4.1	10.9	-	-	18.9	23.9	23.9	-	-	-	-	-
27-3	35.4	12.0	30.3	-	-	30.3	33.8	33.8	-	-	-	-	-
28-1	62.5	GROUND TEST											
28-2	62.5	18.7	50.0	56.2	-	55.	-	-	-	59.4	-	-	-
28-3	64.1	GROUND TEST											
28-4	73.5	11.8	58.8	66.1	-	62.5	-	-	-	69.8	-	-	-
		EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

FIGURE A-14 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM L2 – FLIGHT VEHICLES WITH OPTIONS (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: MACH 6 FLIGHT VEHICLE			MACH 12 FLIGHT VEHICLE							
			BASIC	TPS	ADM	BASIC	SJ	CSJ	TJ	TPS	ADM	HTR	STG
30-1	49.1	GROUND TEST											
30-2	36.7	GROUND TEST											
30-3	57.8	25.3	57.8	-	-	57.8	-	-	-	-	-	-	-
32-1	35.8	GROUND TEST											
32-2	50.4	GROUND TEST											
32-3	44.6	19.9	44.7	-	-	49.8	-	-	-	-	-	-	
33-1	41.6	ANALYTIC											
33-2	52.4	GROUND TEST											
33-3	37.8	9.5	31.4	-	-	35.1	-	-	-	-	-	-	-
34-1	70.9	19.8	17.7	-	-	15.6	39.0	30.0	-	-	-	-	-
34-2	42.5	GROUND TEST											
34-3	60.3	ANALYTIC											
34-4	48.3	5.8	15.1	-	-	9.6	48.3	48.3	-	-	-	-	-
35-1	36.5	4.6	29.2	-	-	37.8	-	-	-	-	-	-	-
35-2	31.8	6.9	31.5	-	-	31.9	-	-	-	-	-	-	-
36-1	36.5	ANALYTIC											
36-2	52.3	GROUND TEST											
36-3	41.5	26.9	39.3	-	-	41.9	-	-		-	-	-	
38-1	31.8	GROUND TEST											
38-2	37.6	GROUND TEST											
38-3	31.8	12.7	29.8	-	-	31.8	-	-	-	-	-	-	-
39-1	29.8	5.5	21.1	-	-	22.3	-	-	-	-	-	-	-
39-2	41.3	10.3	35.1	-	-	37.2	-	-	-	-	-	-	-
40-1	59.8	ANALYTIC											
40-2	33.1	GROUND TEST											
40-3	35.4	17.7	29.8	-	-	35.4	-		-	-			
41-1	43.7	ANALYTIC											
41-2	43.7	ANALYTIC											
42-1	62.5	10.5	55.1	-	-	56.2	59.4	59.4	-	-	-	-	-
43-1	41.7	18.5	43.2	52.5	-	48.4	-	-	-	58.6	-	-	-
43-2	72.8	21.9	54.4	61.7	-	41.7	-	-	-	69.9	-	-	-
43-3	43.6	GROUND TEST											
43-4	41.6	ANALYTIC											
44-1	55.1	ANALYTIC											
44-2	64.8	49.5	55.1	-	-	41.6	-	-	-	-	-	-	-
45-1	30.4	ANALYTIC											
45-2	54.4	20.1	49.8	-	-	51.7	-	-	-	-	-	-	-
45-3	64.8	27.7	47.6	-	-	48.8	-	-	-	-	-	-	-
46-1	45.4	ANALYTIC											
46-2	45.4	21.9	38.6	-	-	49.9	-	-	-	-	-	-	-
48-1	56.6	17.5	31.1	-	-	36.8	-	-	-	-	-	-	-
48-2	56.8	17.9	31.1	-	-	36.8	42.5	42.5	-	-	-	-	-
48-3	46.8	10.4	23.4	-	-	17.6	26.9	26.9	-	-	-	-	-
48-4	66.6	22.7	48.6	-	-	41.3	46.6	46.6	-	-	-	-	-
48-5	66.6	ANALYTIC											
52-1	50.8	ANALYTIC											
52-2	50.0	ANALYTIC											
52-3	50.0	ANALYTIC											
52-4	50.8	10.8	29.5	-	-	19.6	29.4	29.4	-	-	-	-	-
58-1	39.1	ANALYTIC											
58-2	39.1	ANALYTIC											
58-3	35.3	11.1	11.1	-	-	11.1	26.9	26.9	-	-	-	-	-
60-1	43.4	ANALYTIC											
60-2	43.4	ANALYTIC											
60-3	43.4	ANALYTIC											
60-4	61.9	14.9	39.8	-	-	14.8	38.9	43.1	-	-	-	-	-
60-5	61.5	14.8	24.4	-	-	14.8	45.1	60.7	-	-	-	-	-
60-6	72.4	17.4	21.7	-	-	17.4	57.9	68.8	-	-	-	-	-
63-1	31.4	8.9	14.1	-	-	11.9	16.1	30.2	-	-	-	-	-
63-2	44.5	19.6	22.2	-	-	15.6	31.1	39.6	-	-	-	-	-
63-3	42.3	11.5	23.9	-	-	11.9	23.9	47.1	-	-	-	-	-
65-1	34.9	ANALYTIC											
65-2	49.4	5.4	5.4	-	-	9.4	39.5	44.4	-	-	-	-	-
65-3	58.1	13.9	13.5	-	-	13.9	45.6	44.4	-	-	-	-	-
67-1	39.4	GROUND TEST											
67-2	39.4	6.3	7.5	-	-	7.9	27.8	31.5	-	-	-	-	-
67-3	55.8	ANALYTIC											
68-1	26.2	GROUND TEST											
68-2	34.3	GROUND TEST											
68-3	34.3	GROUND TEST											
69-1	22.1	ANALYTIC											
69-2	31.4	GROUND TEST											
69-3	31.4	17.3	25.1	-	-	31.4	-	-	-	-	-	-	-
		EXISTING	BASIC	TPS	ADM	BASIC	SJ	CSJ	TJ	TPS	ADM	HTR	STG

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

FIGURE A-14 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM L2 – FLIGHT VEHICLES WITH OPTIONS (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: MACH 6 FLIGHT VEHICLE BASIC	TPS	ABM	MACH 12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ABM	HTO	STG
70-1	27.7	ANALYTIC											
70-2	27.7	GROUND TEST											
70-3	39.2	GROUND TEST											
70-4	39.2	GROUND TEST											
70-5	44.1	11.1	18.4	-	-	27.7	44.1	44.1	-	-	-	-	-
71-1	28.4	21.3	27.0	-	-	21.3	-	-	-	-	-	-	-
71-2	28.4	21.3	27.0	-	-	21.3	-	-	-	-	-	-	-
71-3	33.4	25.8	31.7	-	-	25.8	-	-	-	-	-	-	-
72-1	22.0	GROUND TEST											
72-2	31.1	GROUND TEST											
72-3	30.6	GROUND TEST											
73-1	25.1	16.3	21.4	-	-	21.4	25.1	25.1	-	-	-	-	-
73-2	35.6	23.1	30.3	-	-	30.3	35.6	35.6	-	-	-	-	-
73-3	41.9	27.6	35.6	-	-	35.6	41.9	41.9	-	-	-	-	-
75-1	27.5	GROUND TEST											
75-2	38.9	GROUND TEST											
75-3	45.0	12.4	41.2	-	-	45.0	-	-	-	-	-	-	-
77-1	26.2	ANALYTIC											
77-2	20.5	15.7	22.0	26.2	-	26.2	-	-	-	25.6	-	-	-
78-1	23.7	ANALYTIC											
78-2	33.6	10.7	21.0	-	-	23.5	-	-	-	-	-	-	-
78-3	39.5	12.6	27.6	-	-	33.6	-	-	-	-	-	-	-
79-1	25.4	ANALYTIC											
79-2	29.9	8.1	23.5	-	-	26.9	-	-	-	-	-	-	-
80-1	34.0	15.2	29.6	-	-	31.6	-	-	-	-	-	-	-
80-2	41.0	19.3	34.0	-	-	36.9	-	-	-	-	-	-	-
82-1	19.7	ANALYTIC											
82-2	27.9	GROUND TEST											
82-3	32.0	16.7	31.2	-	-	32.0	-	-	-	-	-	-	-
85-1	23.2	ANALYTIC											
85-2	30.7	17.4	36.0	-	-	30.7	-	-	-	-	-	-	-
87-1	22.7	ANALYTIC											
87-2	22.7	ANALYTIC											
87-3	37.9	5.5	24.6	-	-	18.9	-	-	24.6	-	-	32.2	-
89-1	25.6	ANALYTIC											
89-2	25.6	14.1	20.5	-	-	21.0	-	-	-	-	-	-	-
89-3	34.3	20.0	29.0	-	-	29.0	-	-	30.9	-	-	-	-
93-1	29.3	ANALYTIC											
93-2	24.9	3.2	19.9	-	-	22.4	-	-	-	-	-	-	-
94-1	23.6	ANALYTIC											
94-2	33.5	ANALYTIC											
94-3	30.4	10.2	25.6	-	-	27.4	-	-	-	-	-	-	-
96-1	21.1	3.5	17.5	-	-	14.7	19.0	20.0	-	-	-	-	-
96-2	39.1	4.5	29.1	-	-	26.9	33.3	33.3	-	-	-	-	-
97-1	21.0	GROUND TEST											
97-2	36.4	10.9	32.0	-	-	32.0	-	-	-	-	-	-	-
102-1	31.9	ANALYTIC											
102-2	37.5	22.9	33.7	-	-	31.9	-	-	-	-	-	-	-
		EXISTING	BASIC (MACH 6 FLIGHT VEHICLE)	TPS	ABM	BASIC	SJ	CSJ (MACH 12 FLIGHT VEHICLE)	TJ	TPS	ABM	HTO	STG

FACILITY RESEARCH VALUE SUMMARY
FLIGHT VEHICLES WITH OPTIONS
OPERATIONAL SYSTEM L2

FOCUSED RESEARCH

	MACH 6 FLIGHT VEHICLE TPS	ABM	MACH 12 FLIGHT VEHICLE SJ	CSJ	TJ	TPS	ABM	HTO	STG
RELATED EXISTING-FACILITIES VALUE	131	0	404	404	139	191	0	170	78
RELATED BASIC-VEHICLE VALUE	320	0	864	960	206	549	4	224	176
FACILITY RESEARCH VALUE WITH OPTION	906	0	1457	1460	296	420	0	200	278
RELATED IDEAL-FACILITY VALUE	472	0	1784	1784	341	472	0	457	914

CHARACTERISTIC RESEARCH

	MACH 6 FLIGHT VEHICLE TPS	ABM	MACH 12 FLIGHT VEHICLE SJ	CSJ	TJ	TPS	ABM	HTO	STG
RELATED EXISTING-FACILITIES VALUE	1032	0	1032	1032	1032	1032	0	1032	1032
RELATED BASIC-VEHICLE VALUE	4288	0	4288	4288	4288	4288	0	4288	4288
FACILITY RESEARCH VALUE WITH OPTION	4276	0	4097	4030	4330	4336	0	4384	4387
[illegible]	9023	0	9023	9023	9023	9023	0	9023	9023

FIGURE A-15 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM C1 – FLIGHT VEHICLES WITH OPTIONS

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: MACH 6 FLIGHT VEHICLE BASIC	TPS	ABM	MACH 12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ABM	HTO	STG
1-1	55.9	24.2	53.1	-	-	27.9	-	-	40.3	-	-	39.1	-
1-2	47.9	21.4	45.1	-	-	23.8	-	-	42.0	-	-	33.9	-
1-3	33.5	15.1	31.5	-	-	16.8	-	-	30.2	-	-	23.5	-
1-4	16.0	8.4	15.5	-	-	9.2	-	-	15.1	-	-	11.7	-
2-1	56.0	20.7	53.2	-	-	44.0	-	-	-	-	-	47.6	-
2-2	47.6	17.6	45.2	-	-	35.7	-	-	-	-	-	40.9	-
2-3	33.6	12.4	31.9	-	-	26.0	-	-	-	-	-	29.6	-
2-4	16.0	8.4	16.0	-	-	13.4	-	-	-	-	-	14.3	-
3-1	69.0	28.0	57.0	-	-	54.0	-	-	-	-	-	-	-
3-2	70.6	33.9	67.1	-	-	67.1	-	-	-	-	-	-	-
3-3	21.2	5.5	20.1	-	-	29.1	-	-	-	-	-	-	-
3-4	42.4	20.3	40.2	-	-	29.3	22.0	20.7	-	-	-	-	-
4-1	55.2	17.1	49.8	-	-	52.4	-	-	-	-	-	-	-
4-2	38.9	12.1	35.0	-	-	37.0	-	-	-	-	-	-	-
4-3	38.9	12.1	35.0	-	-	37.0	-	-	-	-	-	-	-
5-1	56.0	35.3	53.2	-	-	44.0	-	-	50.4	-	-	-	-
5-2	47.6	30.0	45.2	-	-	30.1	-	-	42.0	-	-	-	-
5-3	47.6	30.0	45.2	-	-	40.9	-	-	-	-	-	-	-
6-1	45.7	16.5	43.4	-	-	43.4	-	-	-	-	-	-	-
6-2	45.7	16.5	43.4	-	-	34.6	-	30.9	-	-	-	-	-
6-3	53.8	15.4	51.1	-	-	45.7	-	-	-	-	-	-	-
7-1	47.9	ANALYTIC											
7-2	47.9	15.3	45.5	-	-	21.6	-	-	-	-	-	-	-
7-3	33.9	10.0	32.1	-	-	11.9	-	-	-	-	-	-	-
9-1	51.6	16.5	44.4	-	-	18.1	31.0	31.9	-	-	-	-	-
9-2	51.6	16.5	49.0	-	-	19.1	31.9	31.9	-	-	-	-	-
9-3	36.4	11.7	34.8	-	-	11.7	12.7	12.7	-	-	-	-	-
9-4	51.6	11.4	49.0	-	-	49.0	-	-	-	-	-	-	-
12-1	50.1	13.0	47.6	-	-	45.1	-	-	-	-	-	-	-
12-2	35.4	5.2	33.6	-	-	29.3	30.1	30.1	-	-	-	-	-
12-3	17.7	4.6	16.8	-	-	14.2	15.0	15.0	-	-	-	-	-
14-1	32.0	5.8	30.4	-	-	29.0	-	-	-	-	-	-	-
14-2	22.6	5.4	21.5	-	-	29.4	-	-	-	-	-	-	-
14-3	37.7	4.5	35.8	-	-	33.9	-	-	-	-	-	-	-
15-1	23.8	5.5	22.6	-	-	22.6	-	-	-	-	-	-	-
15-2	39.6	9.1	35.6	-	-	33.7	-	-	-	-	-	-	-
15-3	23.8	2.9	21.4	-	-	22.6	-	-	-	-	-	-	-
16-1	47.2	13.2	44.8	-	-	42.9	-	-	-	-	-	-	-
16-2	47.2	13.7	44.8	-	-	44.0	-	-	-	-	-	-	-
16-3	55.5	7.0	52.7	-	-	52.7	-	-	-	-	-	-	-
17-1	42.9	5.4	40.8	-	-	38.6	-	-	-	-	-	-	-
17-2	42.9	5.4	40.8	-	-	38.6	-	-	-	-	-	-	-
19-1	47.7	14.3	45.3	-	-	45.3	-	-	-	-	-	-	-
19-2	47.7	14.3	45.3	-	-	45.3	-	-	-	-	-	-	-
20-1	53.5	17.4	50.8	-	-	55.0	-	-	-	-	-	-	-
20-2	45.5	11.4	43.2	-	-	43.2	-	-	-	-	-	-	-
20-3	45.5	11.4	11.4	-	-	15.9	-	-	-	-	-	-	-
20-4	32.1	4.0	30.5	-	-	29.0	-	-	-	-	-	-	-
22-1	50.8	12.7	48.3	-	-	48.3	-	-	-	-	-	-	-
22-2	43.2	10.8	41.0	-	-	41.0	-	-	-	-	-	-	-
22-3	43.2	10.9	41.0	-	-	41.0	-	-	-	-	-	-	-
24-1	46.7	14.0	42.0	-	-	44.3	-	-	-	-	-	-	-
24-2	32.9	5.5	29.8	-	-	31.3	-	-	-	-	-	-	-
24-3	54.9	16.5	49.4	-	-	52.2	-	-	-	-	-	-	-
25-1	36.5	11.0	34.3	35.0	-	34.7	-	-	-	35.0	-	-	-
25-2	43.0	12.5	40.8	-	-	40.8	-	-	-	-	-	-	-
25-3	36.5	11.0	34.7	-	-	34.7	-	-	-	-	-	-	-
25-4	25.8	5.2	24.5	25.3	-	24.5	-	-	-	25.3	-	-	-
26-1	32.0	24.6	31.1	-	-	28.2	-	-	-	-	-	-	-
26-2	46.4	34.8	44.1	-	-	44.1	-	-	-	-	-	-	-
26-3	54.6	16.4	49.1	-	-	51.9	-	-	-	-	-	-	-
27-1	40.2	16.5	38.2	-	-	38.1	-	-	-	-	-	-	-
27-2	24.1	10.1	22.9	-	-	19.1	19.3	19.3	-	-	-	-	-
27-3	34.2	14.4	32.5	-	-	29.0	-	-	-	-	-	-	-
28-1	62.5	GROUND TEST											
28-2	42.5	23.7	43.1	50.4	-	56.2	-	-	-	50.4	-	-	-
28-3	44.1	GROUND TEST											
28-4	73.5	14.0	62.5	60.8	-	66.1	-	-	-	60.8	-	-	-
30-1	49.1	GROUND TEST											
30-2	36.7	GROUND TEST											
30-3	57.0	35.3	57.0	-	-	57.0	-	-	-	-	-	-	-
32-1	35.0	GROUND TEST											
32-2	50.4	GROUND TEST											
32-3	49.6	20.0	49.6	-	-	49.6	-	-	-	-	-	-	-
		EXISTING	BASIC	TPS	ABM	BASIC	SJ	CSJ	TJ	TPS	ABM	HTO	STG

FIGURE A-15 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM C1 – FLIGHT VEHICLES WITH OPTIONS (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: MACH 6 FLIGHT VEHICLE			MACH 12 FLIGHT VEHICLE							
			BASIC	TPS	ABM	BASIC	SJ	CSJ	TJ	TPS	ABM	MTU	STG
33-1	61.6	ANALYTIC											
33-2	52.4	GROUND TEST											
33-3	37.0	1.4	39.1	-	-	37.0	-	-	-	-	-	-	-
34-2	42.5	GROUND TEST											
34-3	60.3	ANALYTIC											
35-1	36.5	10.2	32.0	-	-	34.7	-	-	-	-	-	-	-
35-2	31.6	8.7	31.6	-	-	31.0	-	-	-	-	-	-	-
36-1	36.0	ANALYTIC											
36-2	52.3	GROUND TEST											
36-3	61.5	25.2	61.5	-	-	61.5	-	-	-	-	-	-	
38-1	31.0	GROUND TEST											
38-2	37.6	GROUND TEST											
38-3	31.0	14.2	31.0	-	-	31.0	-	-	-	-	-	-	-
39-1	24.0	11.4	23.5	-	-	23.5	-	-	-	-	-	-	-
39-2	41.3	19.0	39.2	-	-	39.2	-	-	-	-	-	-	-
40-1	59.0	ANALYTIC											
40-2	50.1	GROUND TEST											
40-3	35.4	20.5	35.4	-	-	35.4	-	-	-	-	-	-	-
41-1	43.7	ANALYTIC											
41-2	43.7	ANALYTIC											
42-1	42.5	21.5	42.5	-	-	39.4	-	-	-	-	-	-	-
43-1	61.7	23.4	49.4	50.6	-	52.5	-	-	-	61.7	-	-	-
43-2	72.6	27.4	61.7	69.8	-	69.1	-	-	-	72.6	-	-	-
43-3	43.6	GROUND TEST											
43-4	43.6	ANALYTIC											
44-1	55.1	ANALYTIC											
44-2	64.8	49.0	61.4	-	-	64.0	-	-	-	-	-	-	-
45-1	30.4	ANALYTIC											
45-2	54.4	24.5	54.4	-	-	54.4	-	-	-	-	-	-	-
45-3	64.0	20.0	64.0	-	-	64.0	-	-	-	-	-	-	-
46-1	45.4	ANALYTIC											
46-2	45.4	21.0	46.5	-	-	45.1	-	-	-	-	-	-	-
48-1	50.0	24.0	53.1	-	-	47.2	-	-	-	-	-	-	-
48-2	59.0	24.8	44.2	-	-	47.2	-	-	-	-	-	-	-
48-3	41.6	19.4	38.4	-	-	22.0	-	-	-	-	-	-	-
48-4	60.4	38.5	55.5	-	-	52.0	-	-	-	-	-	-	-
48-5	60.4	ANALYTIC											
52-1	52.5	ANALYTIC											
52-2	52.5	ANALYTIC											
52-3	52.5	ANALYTIC											
52-4	61.0	16.5	49.4	-	-	18.5	37.1	37.1	-	-	-	-	-
55-1	25.9	13.7	24.4	-	-	13.7	-	-	19.4	-	-	-	-
55-2	25.9	13.5	24.4	-	-	13.5	-	-	19.4	-	-	-	-
57-1	44.2	ANALYTIC											
57-2	44.2	ANALYTIC											
57-3	44.2	ANALYTIC											
57-4	62.6	18.0	43.0	-	-	19.0	-	-	-	-	-	-	-
57-5	62.6	18.0	59.4	-	-	18.0	-	-	-	-	-	-	-
57-6	73.6	15.1	69.5	-	-	19.1	-	-	-	-	-	-	-
58-1	40.0	ANALYTIC											
58-2	40.0	ANALYTIC											
58-3	57.0	19.0	23.1	-	-	19.0	-	29.2	-	-	-	-	-
59-1	42.1	ANALYTIC											
59-2	42.1	ANALYTIC											
59-3	42.1	ANALYTIC											
59-4	54.7	19.1	41.0	-	-	19.1	-	39.0	-	-	-	-	-
59-5	50.7	15.1	41.0	-	-	19.1	-	39.0	-	-	-	-	-
59-6	70.2	22.5	40.1	-	-	22.5	-	40.1	-	-	-	-	-
63-1	30.7	11.1	29.5	-	-	11.1	-	26.5	-	-	-	-	-
63-2	49.2	26.7	44.3	-	-	20.7	72.1	26.6	-	-	-	-	-
63-3	57.0	16.5	44.2	-	-	16.4	-	23.2	-	-	-	-	-
65-1	30.5	ANALYTIC											
65-2	50.5	14.7	46.9	-	-	14.7	-	-	-	-	-	-	-
65-3	64.1	26.5	30.5	-	-	24.4	-	-	-	-	-	-	-
67-1	41.5	GROUND TEST											
67-2	41.3	10.2	20.5	-	-	19.5	-	14.5	-	-	-	-	-
67-3	50.6	ANALYTIC											
68-1	26.5	GROUND TEST											
68-2	36.7	GROUND TEST											
68-3	36.7	GROUND TEST											
69-1	22.4	ANALYTIC											
69-2	31.0	GROUND TEST											
69-3	31.0	17.5	31.0	-	-	31.0	-	-	-	-	-	-	-
		EXISTING	BASIC	TPS	ABM	BASIC	SJ	CSJ	TJ	TPS	ABM	MTU	STG

FIGURE A-15 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM C1 – FLIGHT VEHICLES WITH OPTIONS (CONTINUED)

VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	MACH 6 FLIGHT VEHICLE BASIC	TPS	ADM	MACH 12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ADM	HTO	STC
70-1	27.0	ANALYTIC											
70-2	7.0	GROUND TEST											
70-3	30.6	GROUND TEST											
70-4	30.6	GROUND TEST											
70-5	66.6	14.8	46.4	-	-	19.8	37.1	37.1	-	-	-	-	-
71-1	20.6	21.5	27.2	-	-	21.5	-	-	-	-	-	-	-
71-2	[illegible]	21.5	27.2	-	-	21.5	-	-	-	-	-	-	-
71-3	33.7	[illegible]	32.0	-	-	25.3	-	-	-	-	-	-	-
72-1	22.2	GROUND TEST											
72-2	31.6	GROUND TEST											
72-3	37.0	GROUND TEST											
73-1	[illegible]	[illegible]	25.6	-	-	21.6	22.9	27.9	-	-	-	-	-
73-2	[illegible]	[illegible]	36.0	-	-	35.6	32.6	32.6	-	-	-	-	-
73-3	42.4	21.8	42.4	-	-	36.8	30.2	30.2	-	-	-	-	-
74-1	19.2	ANALYTIC											
74-2	19.2	[illegible]	19.2	-	-	19.2	-	-	-	-	-	-	-
74-3	32.0	22.7	32.0	-	-	32.0	-	-	-	-	-	-	-
75-1	22.0	GROUND TEST											
75-2	36.6	GROUND TEST											
75-3	66.6	12.5	66.6	-	-	66.6	-	-	-	-	-	-	-
[illegible]	[illegible]	ANALYTIC											
[illegible]	[illegible]	17.6	24.6	27.5	-	24.6	-	-	-	26.1	-	-	-
78-1	23.9	ANALYTIC											
78-2	33.9	15.0	20.8	-	-	27.1	-	-	-	-	-	-	-
78-3	39.9	16.0	35.5	-	-	33.9	-	-	-	-	-	-	-
79-1	25.0	ANALYTIC											
79-2	30.3	10.0	27.3	-	-	28.8	-	-	-	-	-	-	-
80-1	35.2	21.1	31.7	-	-	33.6	-	-	-	-	-	-	-
80-2	41.6	21.5	37.3	-	-	30.3	-	-	-	-	-	-	-
82-1	30.8	ANALYTIC											
82-2	20.3	GROUND TEST											
82-3	33.3	18.6	33.3	-	-	33.3	-	-	-	-	-	-	-
83-1	23.5	ANALYTIC											
83-2	30.1	17.0	30.1	-	-	30.1	-	-	-	-	-	-	-
87-1	22.7	ANALYTIC											
87-2	32.7	ANALYTIC											
87-3	37.9	17.3	36.0	-	-	18.9	-	-	28.4	-	-	32.7	-
89-1	35.0	ANALYTIC											
89-2	25.6	16.7	23.1	-	-	26.3	-	-	-	-	-	-	-
89-3	36.3	23.6	32.7	-	-	30.9	-	-	34.5	-	-	-	-
93-1	29.3	ANALYTIC											
93-2	26.9	9.7	23.7	-	-	23.7	-	-	-	-	-	-	-
94-1	33.0	ANALYTIC											
94-2	33.5	ANALYTIC											
94-3	33.6	17.6	29.9	-	-	27.6	-	-	-	-	-	-	-
96-1	24.1	3.6	20.0	-	-	[illegible]	16.9	16.9	-	-	-	-	-
96-2	35.1	9.9	33.3	-	-	[illegible]	31.6	31.6	-	-	-	-	-
97-1	21.8	GROUND TEST											
97-2	36.6	10.9	36.6	-	-	32.8	-	-	-	-	-	-	-
102-1	31.9	ANALYTIC											
102-2	37.5	24.6	37.5	-	-	31.9	-	-	-	-	-	-	-
		EXISTING	BASIC	TPS	ADM	BASIC	SJ	CSJ	TJ	TPS	ADM	HTO	STC
			MACH 6 FLIGHT VEHICLE				MACH 12 FLIGHT VEHICLE						

FACILITY RESEARCH VALUE SUMMARY
FLIGHT VEHICLES WITH OPTIONS
OPERATIONAL SYSTEM C1

FOCUSED RESEARCH

	MACH 6 FLIGHT VEHICLE TPS	ADM	MACH 12 FLIGHT VEHICLE SJ	CSJ	TJ	TPS	ADM	HTO	STC
RELATED EXISTING-FACILITIES VALUE	122	0	220	332	190	122	0	142	0
RELATED BASIC-VEHICLE VALUE	311	0	316	468	290	326	0	217	0
FACILITY RESEARCH VALUE WITH OPTION	365	0	399	491	333	351	0	271	0
RELATED IDEAL-FACILITY VALUE	382	0	477	1006	385	362	0	340	0

CHARACTERISTIC RESEARCH

	MACH 6 FLIGHT VEHICLE TPS	ADM	MACH 12 FLIGHT VEHICLE SJ	CSJ	TJ	TPS	ADM	HTO	STC
RELATED EXISTING-FACILITIES VALUE	2176	0	2176	2176	2176	2176	0	2176	0
RELATED BASIC-VEHICLE VALUE	5101	0	4320	4320	4320	4320	0	4320	0
FACILITY RESEARCH VALUE WITH OPTION	5136	0	4404	4593	4616	4367	0	4376	0
RELATED IDEAL-FACILITY VALUE	5646	0	5646	5646	5646	5646	0	5646	0

FIGURE A-16 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M1 – FLIGHT VEHICLES WITH OPTIONS

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
			MACH 6 FLIGHT VEHICLE			MACH 12 FLIGHT VEHICLE							
			BASIC	TPS	ADM	BASIC	SJ	CSJ	TJ	TPS	ADM	HTO	STG
1-1	55.9	25.1	53.1	-	-	39.7	-	-	40.3	-	-	39.1	-
1-2	47.5	24.7	45.1	-	-	26.1	-	-	42.0	-	-	33.3	-
1-3	33.5	17.4	31.5	-	-	19.6	-	-	30.2	-	-	23.5	-
1-4	16.0	10.1	15.5	-	-	10.1	-	-	15.1	-	-	11.7	-
2-1	56.0	29.1	53.2	-	-	44.0	-	-	-	-	-	47.6	-
2-2	47.6	24.0	45.2	-	-	35.7	-	-	-	-	-	40.5	-
2-3	33.6	17.5	31.5	-	-	24.9	-	-	-	-	-	29.6	-
2-4	16.0	10.1	16.0	-	-	13.6	-	-	-	-	-	15.3	-
3-1	60.0	31.2	57.6	-	-	54.0	-	-	-	-	-	-	-
3-2	70.6	30.7	67.1	-	-	67.1	-	-	-	-	-	-	-
3-3	21.2	10.4	20.1	-	-	20.1	-	-	-	-	-	-	-
3-4	42.4	22.0	40.2	-	-	22.0	24.1	29.7	-	-	-	-	-
4-1	55.2	20.4	52.4	-	-	52.4	-	-	-	-	-	-	-
4-2	38.9	14.4	37.0	-	-	37.0	-	-	-	-	-	-	-
4-3	38.9	14.4	37.0	-	-	37.0	-	-	-	-	-	-	-
5-1	54.0	40.3	51.2	-	-	44.0	-	-	50.4	-	-	-	-
5-2	47.6	34.3	45.2	-	-	38.1	-	-	42.8	-	-	-	-
5-3	47.6	34.3	45.2	-	-	40.5	-	-	-	-	-	-	-
6-1	45.7	17.9	43.4	-	-	43.4	-	-	-	-	-	-	-
6-2	45.7	17.0	43.4	-	-	36.6	-	38.9	-	-	-	-	-
6-3	53.8	21.0	51.1	-	-	45.7	-	-	-	-	-	-	-
7-1	47.9	ANALYTIC											
7-2	47.9	16.8	45.5	-	-	24.0	-	-	-	-	-	-	-
7-3	33.0	11.0	32.1	-	-	13.5	-	-	-	-	-	-	-
8-1	51.6	18.1	46.4	-	-	28.6	31.0	31.0	-	-	-	-	-
8-2	51.6	18.1	49.0	-	-	29.6	31.0	31.0	-	-	-	-	-
8-3	36.4	12.7	34.0	-	-	12.7	-	-	-	-	-	-	-
8-4	51.6	12.9	49.0	-	-	40.0	-	-	-	-	-	-	-
12-1	50.1	14.5	47.6	-	-	45.1	-	-	-	-	-	-	-
12-2	35.4	10.3	33.6	-	-	29.3	30.1	30.1	-	-	-	-	-
12-3	17.7	5.1	16.8	-	-	14.2	15.0	15.9	-	-	-	-	-
14-1	32.0	10.3	30.4	-	-	28.0	-	-	-	-	-	-	-
14-2	22.6	5.9	21.5	-	-	20.4	-	-	-	-	-	-	-
14-3	37.7	4.9	35.8	-	-	33.9	-	-	-	-	-	-	-
15-1	23.0	6.2	22.0	-	-	22.6	-	-	-	-	-	-	-
15-2	39.6	10.3	35.0	-	-	33.7	-	-	-	-	-	-	-
15-3	23.0	3.1	21.4	-	-	22.6	-	-	-	-	-	-	-
16-1	47.2	17.5	44.8	-	-	42.5	-	-	-	-	-	-	-
16-2	47.2	17.9	44.0	-	-	44.0	-	-	-	-	-	-	-
16-3	55.5	10.0	52.7	-	-	52.7	-	-	-	-	-	-	-
17-1	42.9	10.3	40.8	-	-	38.6	-	-	-	-	-	-	-
17-2	42.9	10.3	40.8	-	-	38.6	-	-	-	-	-	-	-
18-1	47.7	16.2	45.3	-	-	45.3	-	-	-	-	-	-	-
18-2	47.7	16.2	45.3	-	-	45.3	-	-	-	-	-	-	-
20-1	53.5	19.9	50.8	-	-	50.8	-	-	-	-	-	-	-
20-2	45.5	12.7	43.2	-	-	43.2	-	-	-	-	-	-	-
20-3	45.5	12.7	13.6	-	-	15.9	-	-	-	-	-	-	-
20-4	32.1	9.9	30.5	-	-	20.9	-	-	-	-	-	-	-
22-1	50.0	14.2	40.3	-	-	40.3	-	-	-	-	-	-	-
22-2	43.2	12.1	41.0	-	-	41.0	-	-	-	-	-	-	-
22-3	43.2	12.1	41.0	-	-	41.0	-	-	-	-	-	-	-
24-1	46.7	15.4	44.3	-	-	44.3	-	-	-	-	-	-	-
24-2	32.9	10.9	31.3	-	-	31.3	-	-	-	-	-	-	-
24-3	54.9	18.1	52.2	-	-	52.7	-	-	-	-	-	-	-
25-1	36.5	12.4	34.7	35.0	-	34.7	-	-	-	35.0	-	-	-
25-2	43.0	14.0	40.8	-	-	40.8	-	-	-	-	-	-	-
25-3	36.5	12.4	34.7	-	-	34.7	-	-	-	-	-	-	-
25-4	25.0	6.2	24.5	25.3	-	24.5	-	-	-	25.3	-	-	-
26-1	32.0	24.6	31.1	-	-	24.2	-	-	-	-	-	-	-
26-2	46.4	34.0	44.1	-	-	44.1	-	-	-	-	-	-	-
26-3	54.6	10.0	49.1	-	-	51.9	-	-	-	-	-	-	-
27-1	40.2	18.1	38.2	-	-	39.1	-	-	-	-	-	-	-
27-2	24.1	11.0	22.9	-	-	10.1	19.3	19.3	-	-	-	-	-
27-3	34.2	15.4	32.5	-	-	29.0	-	-	-	-	-	-	-
30-1	49.5	GROUND TEST											
30-2	54.9	GROUND TEST											
30-3	50.2	25.0	50.2	-	-	50.2	-	-	-	-	-	-	-
		EXISTING	BASIC	TPS	ADM	BASIC	SJ	CSJ	TJ	TPS	ADM	HTO	STG

FIGURE A-16 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M1 – FLIGHT VEHICLES WITH OPTIONS (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: MACH 6 FLIGHT VEHICLE BASIC	TPS	ADM	MACH 12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ADM	HTO	STG
32-1	35.0	GROUND TEST											
32-2	50.3	GROUND TEST											
32-3	49.6	26.1	49.6	-	-	49.6	-	-	-	-	-	-	-
33-1	61.3	ANALYTIC											
33-2	52.1	GROUND TEST											
33-3	36.8	8.1	34.5	-	-	36.8	-	-	-	-	-	-	-
34-2	41.6	GROUND TEST											
34-3	50.9	ANALYTIC											
35-1	36.0	11.5	32.4	-	-	34.7	-	-	-	-	-	-	-
35-2	38.6	5.8	39.6	-	-	39.6	-	-	-	-	-	-	-
36-1	36.5	ANALYTIC											
36-2	51.8	GROUND TEST											
36-3	60.9	26.8	60.5	-	-	67.9	-	-	-	-	-	-	-
39-1	26.2	11.9	23.0	-	-	23.0	-	-	-	-	-	-	-
39-2	48.4	15.9	38.4	-	-	38.4	-	-	-	-	-	-	-
40-1	50.5	ANALYTIC											
40-2	49.7	GROUND TEST											
40-3	35.1	21.8	35.1	-		35.1	-	-	-	-	-	-	
41-1	43.8	ANALYTIC											
41-2	43.8	ANALYTIC											
42-1	62.3	30.5	47.3	-	-	59.2	-	-	-	-	-	-	-
43-1	62.0	26.5	49.0	58.5	-	52.7	-	-	-	62.0	-	-	-
43-2	72.9	33.9	62.0	69.3	-	65.6	-	-	-	72.9	-	-	-
43-3	43.7	GROUND TEST											
43-4	43.7	ANALYTIC											
44-1	54.9	ANALYTIC											
44-2	64.6	48.4	61.4	-	-	64.6	-	-	-	-	-	-	-
45-1	38.0	ANALYTIC											
45-2	53.9	20.6	53.5	-	-	53.9	-	-	-	-	-	-	-
45-3	63.4	33.4	63.4	-	-	63.4	-	-	-	-	-	-	-
46-1	45.0	ANALYTIC											
46-2	45.0	21.2	40.5	-	-	42.8	-	-	-	-	-	-	-
48-1	56.1	25.7	50.5	-	-	47.7	-	-	-	-	-	-	-
48-2	56.1	25.7	42.1	-	-	47.7	-	-	-	-	-	-	-
48-3	39.6	15.0	31.7	-	-	23.8	-	-	-	-	-	-	-
48-4	66.0	30.3	54.1	-	-	54.1	-	-	-	-	-	-	-
48-5	66.6	ANALYTIC											
52-1	49.6	ANALYTIC											
52-2	49.6	ANALYTIC											
52-3	49.6	ANALYTIC											
52-4	50.3	21.3	32.8	-	-	21.0	37.9	37.0	-	-	-	-	
57-1	61.3	ANALYTIC											
57-2	41.3	ANALYTIC											
57-3	41.3	ANALYTIC											
57-4	50.5	21.1	46.8	-	-	21.1	-	-	-	-	-	-	-
57-5	50.5	21.1	55.6	-	-	21.1	-	-	-	-	-	-	-
57-6	60.8	22.0	65.4	-	-	22.0	-	-	-	-	-	-	-
58-1	38.6	ANALYTIC											
58-2	38.6	ANALYTIC											
58-3	54.7	15.9	27.4	-		15.9	-	21.9	-	-	-	-	
59-1	40.4	ANALYTIC											
59-2	40.4	ANALYTIC											
59-3	40.4	ANALYTIC											
59-4	57.3	22.9	45.8	-	-	22.9	-	60.1	-	-	-	-	-
59-5	57.3	22.9	45.8	-	-	22.9	-	60.1	-	-	-	-	-
59-6	67.4	27.2	53.5	-	-	27.0	-	53.9	-	-	-	-	-
63-1	31.5	11.7	28.3	-	-	11.7	-	23.6	-	-	-	-	-
63-2	44.6	26.1	42.4	-	-	28.1	-	22.3	-	-	-	-	-
63-3	52.5	15.4	47.2	-	-	18.4	-	26.3	-	-	-	-	-
65-1	35.2	ANALYTIC											
65-2	49.9	15.9	30.5	-	-	15.5	-	-	-	-	-	-	-
65-3	58.7	20.5	38.2	-	-	20.5	-	-	-	-	-	-	-
67-1	39.2	GROUND TEST											
67-2	39.2	11.4	29.6	-	-	11.6	11.8	15.7	-	-	-	-	-
67-3	55.6	ANALYTIC											
		EXISTING	BASIC	TPS	ADM	BASIC	SJ	CSJ	TJ	TPS	ADM	HTO	STG

FIGURE A-16 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M1 – FLIGHT VEHICLES WITH OPTIONS (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES — MACH 6 FLIGHT VEHICLE BASIC	TPS	ABM	MACH 12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ABM	MTR	STG
71-1	30.3	22.0	30.3	-	-	22.0	-	-	-	-	-	-	-
71-2	30.3	22.0	30.3	-	-	22.0	-	-	-	-	-	-	-
71-3	35.7	26.0	35.7	-	-	26.0	-	-	-	-	-	-	-
72-1	23.1	GROUND TEST											
72-2	32.7	GROUND TEST											
72-3	30.5	GROUND TEST											
77-1	25.8	ANALYTIC											
77-2	30.4	18.2	25.6	27.4	28.9	29.0	-	-	-	27.4	28.9	-	-
78-1	25.6	ANALYTIC											
78-2	30.2	15.9	32.4	-	-	30.0	-	-	-	-	-	-	-
78-3	42.6	18.7	40.5	-	-	38.3	-	-	-	-	-	-	-
79-1	26.5	ANALYTIC											
79-2	31.2	12.2	28.1	-	-	29.6	-	-	-	-	-	-	-
80-1	37.7	25.3	34.0	-	-	39.9	-	-	-	-	-	-	-
80-2	44.4	26.2	40.0	-	-	42.2	-	-	-	-	-	-	-
82-1	21.0	ANALYTIC											
82-2	29.7	GROUND TEST											
82-3	35.0	22.0	35.0	-	-	35.0	-	-	-	-	-	-	-
84-1	24.4	ANALYTIC											
84-2	40.7	26.9	40.7	-	-	30.9	-	-	-	-	-	-	-
85-1	25.0	ANALYTIC											
85-2	35.4	12.9	31.5	-	-	33.7	-	-	-	-	-	-	-
85-3	41.7	15.0	15.0	-	30.6	15.0	-	-	-	-	30.6	-	-
87-1	22.7	ANALYTIC											
87-2	22.7	ANALYTIC											
87-3	37.9	15.2	30.0	-	-	18.9	-	-	32.2	-	-	32.2	-
89-1	25.6	ANALYTIC											
89-2	25.6	17.9	23.1		-	24.3	-	-	-	-	-	-	-
89-3	30.3	25.4	32.7	-	-	30.0	-	-	34.5	-	-	-	-
93-1	29.3	ANALYTIC											
93-2	26.9	5.5	21.2	-	-	21.2	-	-	-	-	-	-	-
94-1	23.6	ANALYTIC											
94-2	33.5	ANALYTIC											
94-3	39.4	15.0	29.5	-	-	27.6	-	-	-	-	-	-	-
96-1	21.1	3.0	20.0	-	-	14.7	16.0	16.0	-	-	-	-	-
96-2	35.1	7.0	33.3	-	-	20.3	31.6	31.6	-	-	-	-	-
97-1	21.0	GROUND TEST											
97-2	36.4	10.9	30.4	-	-	32.0	-	-	-	-	-	-	-
102-1	31.9	ANALYTIC											
102-2	37.5	26.2	37.5	-	-	31.9	-	-	-	-	-	-	-
		EXISTING	BASIC MACH 6 FLIGHT VEHICLE	TPS	ABM	BASIC	SJ	CSJ MACH 12 FLIGHT VEHICLE	TJ	TPS	ABM	MTR	STG

FACILITY RESEARCH VALUE SUMMARY
FLIGHT VEHICLES WITH OPTIONS
OPERATIONAL SYSTEM M1

FOCUSED RESEARCH

	MACH 6 FLIGHT VEHICLE TPS	ABM	MACH 12 FLIGHT VEHICLE SJ	CSJ	TJ	TPS	ABM	MTR	STG
RELATED EXISTING-FACILITIES VALUE	90	33	129	206	196	90	33	170	0
RELATED BASIC-VEHICLE VALUE	197	41	197	376	218	203	41	229	0
FACILITY RESEARCH VALUE WITH OPTION	217	60	200	525	290	229	60	271	0
RELATED IDEAL-FACILITY VALUE	228	72	576	790	332	270	72	346	0

CHARACTERISTIC RESEARCH

	MACH 6 FLIGHT VEHICLE TPS	ABM	MACH 12 FLIGHT VEHICLE SJ	CSJ	TJ	TPS	ABM	MTR	STG
RELATED EXISTING-FACILITIES VALUE	2219	2219	2219	2219	2219	2219	2219	2219	0
RELATED BASIC-VEHICLE VALUE	4719	4719	4004	4004	4004	4004	4004	4004	0
FACILITY RESEARCH VALUE WITH OPTION	4755	4763	4050	4154	4006	4026	4054	4047	0
RELATED IDEAL-FACILITY VALUE	9177	9177	9177	9177	9177	9177	9177	9177	0

FIGURE A-17 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M2 – FLIGHT VEHICLES WITH OPTIONS

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
			MACH [illegible] FLIGHT VEHICLE			MACH 12 FLIGHT VEHICLE							
			BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
1-1	58.5	22.2	42.8	-	-	26.2	-	-	40.8	-	-	55.4	-
1-2	49.6	10.9	32.2	-	-	22.3	-	-	32.2	-	-	47.1	-
1-3	35.0	13.1	24.9	-	-	15.7	-	-	24.5	-	-	33.2	-
1-4	17.5	7.0	11.4	-	-	7.9	-	-	11.4	-	-	16.6	-
2-1	57.6	17.5	49.0	-	-	51.8	-	-	-	-	-	-	-
2-2	49.0	14.7	41.6	-	-	44.1	-	-	-	-	-	44.9	-
2-3	34.6	10.4	29.4	-	-	31.1	-	-	-	-	-	32.8	-
2-4	17.3	6.5	14.7	-	-	15.6	-	-	-	-	-	16.4	-
3-1	60.4	21.7	51.4	-	-	57.6	-	-	-	-	-	-	-
3-2	71.1	16.4	49.8	-	-	44.0	-	-	-	-	-	-	-
3-3	21.3	6.9	14.9	-	-	19.7	-	-	-	-	-	-	-
3-4	47.7	14.5	14.5	-	-	21.3	40.5	40.5	-	-	-	-	-
4-1	56.2	14.4	44.5	-	-	50.6	-	-	-	-	-	-	-
4-2	39.7	10.3	31.7	-	-	35.7	-	-	-	-	-	-	-
4-3	39.7	10.3	31.7	-	-	35.7	-	-	-	-	-	-	-
5-1	57.8	26.0	43.3	-	-	52.0	-	-	56.9	-	-	-	-
5-2	49.1	22.1	36.8	-	-	44.2	-	-	46.7	-	-	-	-
5-3	49.1	22.1	34.8	-	-	44.2	-	-	-	-	-	-	-
6-1	47.2	14.2	37.7	-	-	42.5	-	-	-	-	-	-	-
6-2	47.2	14.2	33.0	-	-	35.4	44.8	42.5	-	-	-	-	-
6-3	55.5	15.6	41.8	-	-	44.4	52.7	49.9	-	-	-	-	-
7-1	49.4	ANALYTIC											
7-2	49.4	12.8	14.8	-	-	42.0	44.9	44.9	-	-	-	-	-
7-3	34.9	5.1	10.5	-	-	20.9	33.1	33.1	-	-	-	-	-
9-1	52.7	13.7	14.8	-	-	15.8	50.1	50.1	-	-	-	-	-
9-2	52.7	13.7	26.3	-	-	15.8	50.1	51.1	-	-	-	-	-
9-3	37.2	5.7	24.0	-	-	13.8	35.3	35.3	-	-	-	-	-
9-4	52.7	10.0	42.2	-	-	47.4	50.1	50.1	-	-	-	-	-
12-1	51.7	10.3	41.3	-	-	46.5	49.1	49.1	-	-	-	-	-
12-2	36.5	7.5	29.2	-	-	29.2	34.7	34.7	-	-	-	-	-
12-3	18.2	3.6	14.6	-	-	14.6	17.3	17.3	-	-	-	-	-
14-1	33.9	8.8	30.9	-	-	32.2	-	-	-	-	-	-	-
14-2	23.9	4.8	21.9	-	-	22.7	-	-	-	-	-	-	-
14-3	39.9	4.0	35.5	-	-	37.9	-	-	-	-	-	-	-
15-1	24.6	4.9	22.1	-	-	23.4	-	-	-	-	-	-	-
15-2	41.0	8.2	32.8	-	-	36.9	-	-	-	-	-	-	-
15-3	24.6	2.5	20.9	-	-	23.4	-	-	-	-	-	-	-
16-1	48.4	5.1	43.6	-	-	46.0	-	-	-	-	-	-	-
16-2	48.4	5.7	38.8	-	-	44.0	-	-	-	-	-	-	-
16-3	57.0	5.7	45.6	-	-	54.1	-	-	-	-	-	-	-
17-1	44.3	6.9	35.4	-	-	37.6	-	-	-	-	-	-	-
17-2	44.3	8.9	37.6	-	-	39.9	-	-	-	-	-	-	-
18-1	28.0	11.2	25.2	-	-	26.6	-	-	-	-	-	-	-
18-2	28.0	ANALYTIC											
19-1	49.1	11.9	44.2	-	-	46.7	-	-	-	-	-	-	-
19-2	49.1	11.9	44.2	-	-	46.7	-	-	-	-	-	-	-
20-1	53.5	10.7	40.1	-	-	50.8	-	-	-	-	-	-	-
20-2	45.5	9.1	40.5	-	-	43.2	-	-	-	-	-	-	-
20-3	45.5	5.1	9.1	-	-	15.9	-	-	-	-	-	-	-
20-4	32.1	3.5	27.3	-	-	28.9	-	-	-	-	-	-	-
22-1	50.8	10.2	43.2	-	-	48.3	-	-	-	-	-	-	-
22-2	43.2	8.6	36.7	-	-	41.0	-	-	-	-	-	-	-
22-3	43.2	8.6	36.7	-	-	41.0	-	-	-	-	-	-	-
24-1	44.7	10.3	37.3	-	-	42.0	-	-	-	-	-	-	-
24-2	32.9	7.2	28.4	-	-	29.6	-	-	-	-	-	-	-
24-3	54.9	12.1	43.9	-	-	49.4	-	-	-	-	-	-	-
25-1	36.5	8.0	31.1	32.9	-	32.9	-	-	-	34.7	-	-	-
25-2	43.0	5.5	36.5	-	-	40.8	-	-	-	-	-	-	-
25-3	36.5	8.0	31.1	-	-	34.7	-	-	-	-	-	-	-
25-4	25.8	3.1	21.9	23.2	-	23.2	-	-	-	24.5	-	-	-
26-1	32.8	24.0	27.8	-	-	26.6	-	-	-	-	-	-	-
26-2	40.4	34.9	37.1	-	-	41.8	-	-	-	-	-	-	-
26-3	54.6	12.0	46.4	-	-	49.1	-	-	-	-	-	-	-
27-1	40.2	14.5	28.1	-	-	32.2	38.2	38.2	-	-	-	-	-
27-2	24.1	6.7	16.5	-	-	19.1	22.9	22.9	-	-	-	-	-
27-3	34.2	12.3	29.0	-	-	30.8	32.5	32.5	-	-	-	-	-
28-1	67.5	GROUND TEST											
28-2	67.5	18.7	50.0	56.2	-	53.1	-	-	-	59.4	-	-	-
28-3	66.1	GROUND TEST											
28-4	73.5	11.0	58.8	66.1	-	67.5	-	-	-	69.8	-	-	-
		EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

FIGURE A-17 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M2 – FLIGHT VEHICLES WITH OPTIONS (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES										
			MACH 6 FLIGHT VEHICLE			MACH 12 FLIGHT VEHICLE							
			BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
30-1	49.1	GROUND TEST											
30-2	34.7	GROUND TEST											
30-3	57.8	35.3	57.8	-	-	57.8	-	-	-	-	-	-	-
32-1	35.0	GROUND TEST											
32-2	58.4	GROUND TEST											
32-3	49.6	15.9	44.7	-	-	49.6	-	-	-	-	-	-	-
33-1	61.6	ANALYTIC											
33-2	52.4	GROUND TEST											
33-3	37.0	5.5	31.4	-	-	35.1	-	-	-	-	-	-	-
34-1	70.9	15.6	21.3	-	-	15.6	70.9	70.9	-	-	-	-	-
34-2	42.5	GROUND TEST											
34-3	60.3	ANALYTIC											
34-4	60.3	9.6	18.1	-	-	9.6	60.3	60.3	-	-	-	-	-
35-1	36.5	8.0	29.2	-	-	32.8	-	-	-	-	-	-	-
35-2	31.0	6.8	31.0	-	-	31.0	-	-	-	-	-	-	-
36-1	36.9	ANALYTIC											
36-2	52.3	GROUND TEST											
36-3	41.5	20.5	55.3	-	-	61.5	-	-	-	-	-	-	
38-1	31.8	GROUND TEST											
38-2	37.4	GROUND TEST											
38-3	31.8	12.7	28.6	-	-	31.8	-	-	-	-	-	-	-
39-1	24.8	9.9	19.8	-	-	22.3	-	-	-	-	-	-	-
39-2	41.3	16.5	33.0	-	-	39.2	-	-	-	-	-	-	-
40-1	59.0	ANALYTIC											
40-2	59.1	GROUND TEST											
40-3	35.4	17.7	31.5	-	-	35.4	-	-	-	-	-	-	
41-1	43.7	ANALYTIC											
41-2	43.7	ANALYTIC											
42-1	62.5	16.5	59.1	-	-	56.2	59.4	59.4	-	-	-	-	-
43-1	61.7	18.5	43.2	52.5	-	49.4	-	-	-	58.6	-	-	-
43-2	72.6	21.9	54.4	61.7	-	61.7	-	-	-	68.8	-	-	-
43-3	43.6	GROUND TEST											
43-4	43.6	ANALYTIC											
44-1	55.1	ANALYTIC											
44-2	64.8	48.6	55.1	-	-	61.6	-	-	-	-	-	-	-
45-1	38.4	ANALYTIC											
45-2	54.4	20.1	51.7	-	-	51.7	-	-	-	-	-	-	-
45-3	64.0	23.7	57.6	-	-	58.9	-	-	-	-	-	-	-
46-1	45.4	ANALYTIC											
46-2	45.4	21.9	34.3	-	-	45.9	-	-	-	-	-	-	-
48-1	62.6	15.4	34.5	-	-	40.7	-	-	-	-	-	-	-
48-2	42.4	15.4	34.5	-	-	45.7	47.0	47.0	-	-	-	-	-
48-3	44.2	11.5	25.6	-	-	19.5	28.7	28.7	-	-	-	-	-
48-4	73.7	24.3	44.2	-	-	45.7	51.6	51.6	-	-	-	-	-
48-5	73.7	ANALYTIC											
52-1	57.5	ANALYTIC											
52-2	57.5	ANALYTIC											
52-3	57.5	ANALYTIC											
52-4	67.7	13.5	27.1	-	-	13.5	33.8	33.8	-	-	-	-	-
58-1	42.0	ANALYTIC											
58-2	42.0	ANALYTIC											
58-3	59.5	11.9	11.5	-	-	11.9	26.8	26.8	-	-	-	-	-
61-1	43.8	ANALYTIC											
61-2	43.8	ANALYTIC											
61-3	43.8	ANALYTIC											
61-4	62.0	12.4	24.8	-	-	12.4	58.9	52.7	-	-	-	-	-
61-5	62.0	12.4	18.6	-	-	12.4	58.9	52.7	-	-	-	-	-
61-6	73.8	14.6	14.6	-	-	14.6	69.3	62.8	-	-	-	-	-
62-1	29.1	ANALYTIC											
62-2	35.5	8.5	8.5	-	-	28.6	-	-	-	-	-	32.8	-
62-3	41.8	5.0	5.0	-	-	33.4	-	-	-	-	-	30.7	-
63-1	37.8	8.1	8.1	-	-	17.9	39.1	31.4	-	-	-	-	-
63-2	52.4	18.3	18.3	-	-	18.3	47.1	39.3	-	-	-	-	-
63-3	61.6	13.6	13.6	-	-	13.6	50.5	42.6	-	-	-	-	-
64-1	31.1	13.1	14.6	-	-	13.1	-	-	18.7		-	-	-
64-2	31.1	10.9	12.4	-	-	10.9	-	-	21.8	-	-	-	-
65-1	40.1	ANALYTIC											
65-2	56.9	10.8	10.8	-	-	14.2	51.2	45.9	-	-	-	-	-
65-3	66.9	16.1	16.7	-	-	28.1	56.9	50.2	-	-	-	-	-
		EXISTING	BASIC	TPS	ARM	BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG

FIGURE A-17 FACILITY RESEARCH VALUES FOR OPERATIONAL SYSTEM M2 – FLIGHT VEHICLES WITH OPTIONS (CONTINUED)

TASK NO.	TASK INTRINSIC VALUE	VALUE OF EXISTING FACILITIES	VALUE OF FLIGHT VEHICLES WITH OPTIONS + EXISTING FACILITIES: MACH 6 FLIGHT VEHICLE BASIC	TPS	ARM	MACH 12 FLIGHT VEHICLE BASIC	SJ	CSJ	TJ	TPS	ARM	HTO	STG
67-1	43.9	GROUND TEST											
67-2	43.9	7.9	8.8	-	-	11.0	39.1	26.3	-	-	-	-	-
67-3	42.1	ANALYTIC											
68-1	23.9	GROUND TEST											
68-2	33.9	GROUND TEST											
68-3	33.9	GROUND TEST											
69-1	22.2	ANALYTIC											
69-2	31.4	GROUND TEST											
69-3	31.4	17.3	25.2	-	-	31.4	-	-	-	-	-	-	-
70-1	27.7	ANALYTIC											
70-2	27.7	GROUND TEST											
70-3	39.3	GROUND TEST											
70-4	39.3	GROUND TEST											
70-5	46.2	11.1	18.5	-	-	27.7	46.2	46.2	-	-	-	-	-
73-1	24.9	16.2	21.2	-	-	21.2	24.9	24.9	-	-	-	-	-
73-2	35.3	22.9	30.0	-	-	35.0	35.3	35.3	-	-	-	-	-
73-3	41.5	7.0	35.3	-	-	35.3	41.5	41.5	-	-	-	-	-
74-1	18.8	ANALYTIC											
74-2	18.8	13.3	18.8	-	-	18.8	-	-	-	-	-	-	-
74-3	31.3	22.2	31.3	-	-	31.3	-	-	-	-	-	-	-
75-1	27.6	GROUND TEST											
75-2	39.1	GROUND TEST											
75-3	46.0	12.4	41.4	-	-	46.0	-	-	-	-	-	-	-
77-1	24.3	ANALYTIC											
77-2	28.6	15.7	22.9	24.3	25.7	24.3	-	-	-	25.7	27.2	-	-
78-1	23.8	ANALYTIC											
78-2	33.7	10.8	21.5	-	-	23.6	-	-	-	-	-	-	-
78-3	39.6	12.7	27.7	-	-	33.7	-	-	-	-	-	-	-
79-1	26.8	ANALYTIC											
79-2	30.6	8.3	24.9	-	-	27.9	-	-	-	-	-	-	-
80-1	36.7	19.1	29.5	-	-	31.2	-	-	-	-	-	-	-
80-2	40.8	15.2	34.7	-	-	36.7	-	-	-	-	-	-	-
82-1	19.6	ANALYTIC											
82-2	27.7	GROUND TEST											
82-3	32.6	16.6	29.3	-	-	31.0	-	-	-	-	-	-	-
83-1	22.9	ANALYTIC											
83-2	38.2	17.2	34.4	-	-	38.2	-	-	-	-	-	-	-
85-1	23.5	ANALYTIC											
85-2	33.2	8.3	26.8	-	-	28.2	-	-	-	-	-	-	-
85-3	39.1	5.8	5.8	-	33.2	9.9	-	-	-	-	37.1	-	-
87-1	23.8	ANALYTIC											
87-2	23.8	ANALYTIC											
87-3	39.6	9.5	19.8	-	-	19.8	-	-	-	-	-	37.6	-
89-1	26.2	ANALYTIC											
89-2	26.2	14.4	21.0	-	-	23.3	-	-	-	-	-	-	-
89-3	37.1	20.4	29.7	-	-	29.7	-	-	31.6	-	-	-	-
93-1	30.8	ANALYTIC											
93-2	26.2	1.6	20.9	-	-	23.6	-	-	-	-	-	-	-
94-1	26.5	ANALYTIC											
94-2	34.8	ANALYTIC											
94-3	40.9	18.6	28.6	-	-	30.7	-	-	-	-	-	-	-
96-1	21.8	2.6	18.6	-	-	16.6	20.7	19.7	-	-	-	-	-
96-2	36.4	5.1	29.1	-	-	29.1	34.6	34.6	-	-	-	-	-
97-1	22.7	GROUND TEST											
97-2	37.9	11.6	34.1	-	-	34.1	-	-	-	-	-	-	-
99-1	18.8	7.5	7.5	-	-	7.5	-	-	-	-	-	18.8	-
99-2	18.8	7.5	7.5	-	-	7.5	-	-	-	-	-	18.8	-
100-1	27.5	15.3	24.8	-	-	27.5	-	-	-	-	-	-	-
100-2	32.4	22.7	29.2	-	-	32.4	-	-	-	-	-	-	-
102-1	33.2	ANALYTIC											
102-2	39.1	23.5	35.2	-	-	39.2	-	-	-	-	-	-	-
		EXISTING	BASIC MACH 6 FLIGHT VEHICLE	TPS	ARM	BASIC	SJ	CSJ MACH 12 FLIGHT VEHICLE	TJ	TPS	ARM	HTO	STG

FACILITY RESEARCH VALUE SUMMARY
FLIGHT VEHICLES WITH OPTIONS
OPERATIONAL SYSTEM M2

FOCUSED RESEARCH

	MACH 6 FLIGHT VEHICLE TPS	ARM	MACH 12 FLIGHT VEHICLE SJ	CSJ	TJ	TPS	ARM	HTO	STG
RELATED EXISTING-FACILITIES VALUE	97	26	493	493	154	97	26	132	0
RELATED BASIC-VEHICLE VALUE	202	33	930	930	222	307	34	260	0
FACILITY RESEARCH VALUE WITH OPTION	317	59	1051	1586	282	362	64	399	0
RELATED IDEAL-FACILITY VALUE	361	66	1893	1893	367	361	64	416	0

CHARACTERISTIC RESEARCH

	MACH 6 FLIGHT VEHICLE TPS	ARM	MACH 12 FLIGHT VEHICLE SJ	CSJ	TJ	TPS	ARM	HTO	STG
RELATED EXISTING-FACILITIES VALUE	1050	1050	1890	1890	1890	1890	1890	1890	0
RELATED BASIC-VEHICLE VALUE	4070	4070	4399	4399	4399	4399	4399	4399	0
FACILITY RESEARCH VALUE WITH OPTION	4104	4096	5115	5031	4445	4438	4425	4430	0
RELATED IDEAL-FACILITY VALUE	5075	5075	5075	5075	5075	5075	5075	5075	0