NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

OAST SPACE THEME WORKSHOP

VOLUME II

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THEME SUMMARY

IV. SOLAR SYSTEM EXPLORATION (#10)

A. STATEMENT OF THEME

B. APRIL 26, 1976, PRESENTATION

C. SUMMARY

D. INITIATIVE ACTIONS (FORM V)

HELD AT THE
LANGLEY RESEARCH CENTER
APRIL 26-30, 1976

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Foreword

The attached material represents the working papers from the OAST Space Theme Workshop held at the Langley Research Center, April 26-30, 1976, and contains a quick-look analysis of the proceedings. The material is unedited and intended for further use by the participants of the workshop and the planning elements of NASA concerned with space mission research and technology. It should be understood that the data do not represent official plans or positions but are part of the process of evolving such plans and positions.

Nearly 100 of the Agency's top technologists and scientists joined with another 35 theme specialists to produce this working document - a document that provides a technical foundation, including research and technology base candidates, for each of the six space themes.

The material in this report is considered essential to the development of Center initiatives in support of these themes. Copies of the report will be made available to the Center Management Board and the individuals at the Centers responsible for the FY'78 program planning cycle. The timing of this planning activity has caused us to distribute this document in this unedited form. Thus, it possibly contains errors, hopefully, more of a typographical rather than a technological nature. Nonetheless, the information contained is of a high professional level, reflecting the efforts of the workshop participants and will be invaluable to the planning and successful execution of the Agency's near- and far-term advanced technology program.

Stanley R. Sadin
OAST Space Theme Workshop
Chairman
NASA Headquarters
Study, Analysis, & Planning Office
Office of Aeronautics and
Space Technology

RANKING OF CRITICAL TECHNOLOGY NEEDS FOR EXPLORATION OF THE SOLAR SYSTEM THEME

The single most essential component of this theme, which is focused on enabling intensive study of the outer solar system, is nuclear electric propulsion and power capability. Thus, the first four initiatives, in order of priority, are directly related to this critical area as follows:

The thruster system (no. 1) is the propulsion unit for the nuclear reactor. Time phasing brings it to technology readiness in the 1990 period when the reactor is scheduled to be operational, assuming items 2,3, and 4 have been successfully developed. They are technologies where readiness must be demonstrated before the decision to proceed with the nuclear reactor can be made with confidence. Initiatives 2, 3, and 4 can be demonstrated within the next 5 years.

Autonomy (no. 5) is essential for missions beyond real time communication response. End-to-end data management (no. 6) is required to reduce the quantities of data to essentially a real-time flow of desired information. Artificial intelligence (no. 7) is required to exert autonomous control in a logical, goal-oriented manner. The imaging arrays (no. 8) are an essential component of several advanced remote analytical sensors. The earth return, heating, flow field, and stability initiative (no. 9) addresses survival and control of atmospheric probes in planetary atmospheres and during sample return to earth.

STRAWMAN PACKAGE FOR THEME # 10

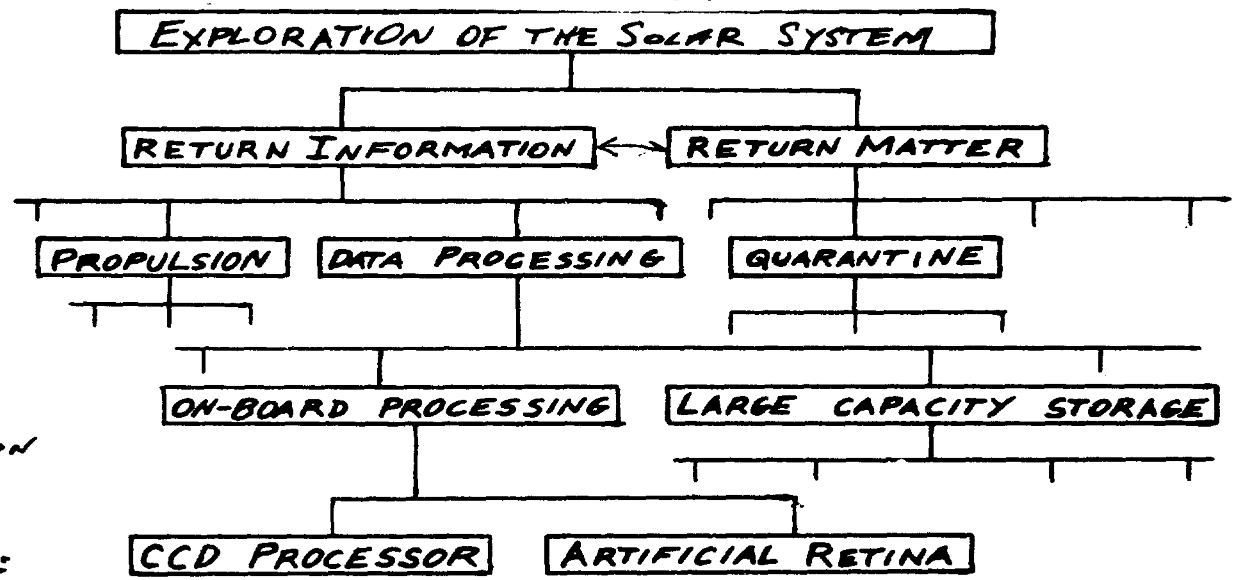
EXPLORATION OF THE SOLAR SYSTEM

The attached strawman theme package follows the hierarchical structure outlined on the attached figure, omitting the first item, the theme; the package starts with the two missions and builds from there.

It is provided to give the working groups something to react to and to indicate the format desired.

THEME PACKAGE ORGANIZATION

SOLAR SYSTEM STUDY FACILITY



THEME:
- DESCRIPTION
- ADVOCACY

MISSIONS:
- DESCRIPTION
- OBJECTIVE

FUNCTIONS:
- DESCRIPTION
- OBJECTIVE

TECHNOLOGIES:
- DESCRIPTION
- OBJECTIVE

INITIATIVES:
- DESCRIPTION
- OBJECTIVE
- BENEFITS
- WHEN START
- SCHEDULE
- COST
- ?? MANPOWER

April 12, 1976
R. V. Powell
L. Friedman

EXPLORATION OF THE SOLAR SYSTEM

OAST THEME PACKAGE

Missions

Two major strategies for exploring the solar system have been identified; one focuses on the return of information, the other focuses on the return of matter. These two approaches are necessary for realizing exploration objectives: detection of life, understanding of dynamic processes affecting our environment, comparative planetology investigation, understanding the origin and evolution of the planets, etc.

The approaches are not exclusive and a judicious mix of the two will most likely yield the highest return. E.G. atmospheric investigations are not good candidates for sample return -- the sample containment and preservation is difficult; and the in-situ instrumentation for analysis is well-developed. On the other hand, remote age-dating is thought to be very difficult compared with geo-laboratory techniques, while the return of rocks is not a terribly difficult technological problem. Thus solid surface sample return is a good mission candidate.

The idea of a Planetary Exploration Facility has been developed to facilitate the return of information. The facility is a generic concept to (1) perform remote sensing of the planet or target, its atmosphere, gravitation distribution, magnetic field, etc., (2) serve as a launch platform for atmospheric probes, penetrators and rovers to a planet's surface with in-situ sample collection and analysis capability, and (3) have on-board data processing capability for transmitting final information to Earth. The Facility is very much an orbiting automated space station with the component vehicles such as probes and landers serving as its remote "arms". Elaboration on the functions and required technologies is given below.

The Sample Return Mission concept logically breaks into functions based on the mission scenario. These are also discussed below. It might be thought that the Sample Return and Exploration Facility are alternative concepts, but study of each shows that not only are they complementary (as discussed above) but they lead to similar requirements. They both require laboratory capability to identify, retrieve, analyze and react to sample data. In the Facility more advanced instrumentation and data management functions prevail, while in the Sample Return there is more of a premium on Propulsion and Mission Performance. But both mission concepts are needed in parallel and both require development of new enabling, lower cost technology to manage and acquire scientific data about the targets being investigated. Partial autonomy in mission navigation is required for Sample Return Rendezvous, as well as with the Facility's Orbit operations; similarly for certain in-situ analysis techniques. Further examples and specific recommendations are discussed in the following sections.

For the purpose of identifying functions and technologies for the return of information and the return of matter, an effort was made to assure inclusion of the technologies required by the Exploration Facility; however, technologies identified were not limited to that mission.

Functions

Functional capabilities have been identified in Table 1 separately for the return of information and for the return of matter classes of missions. Since all of the functions for return of information appear to be required for return of matter, the functions listed under return of matter may be assumed to apply to both and the functions under return of matter are limited to those which are unique to the return of matter missions. The functional capabilities were selected to provide an umbrella for all the required technologies.

April 12, 1976
R. V. Powell

Theme: Exploration of Space

Missions:

Return of Information

Functions:

1. Acquiring Information
   (a) Insitu
   (b) Remote
2. Data Processing
   (a) Science
   (b) Engineering
3. Communication
4. Utilization of stored energy and external energy for power.
5. Utilization of stored energy and external energy for propulsion.
6. Electromagnetic transfer of energy.
7. Processing micro structures.
8. Processing of macro structures.
9. ~~Attitude~~ control.
10. Navigation.
11. Environmental protection.
12. Atonomous systems.

Return of Matter

1. Acquire sample.
   (a) Solid body
   (b) Atmosphere
   (c) Comet
2. Preservation of sample.
3. Quarantine handling:
4. Ascent propulsion.
5. Ascent navigation.
6. Recovery of sample.
7. Sample receiving and storage.

(All functions from Return of Information apply).

Table 1

1. ACQUIRING INFORMATION (IN-SITU & REMOTE)

SENSORS FOR PLANETARY AND SATELLITE INFORMATION ACQUISITION

The Sensors New Initiatives address several mission-driven sets of sensors. Several assumptions are made in putting forth these initiatives. The assumptions are:

1. A set of mission models will be established as policy guides so the priority of development of particular sensors within each initiative can be established.
2. Mission analysis and spacecraft design concepts will evolve in parallel with sensor technology so that sensor development will advance in concert with practical applicability (i.e., priority adjustments).
3. A program of instrument development will be established to bridge the gap between evolution of basic sensor technology under these initiatives and actual flight project phasing.

The following initiatives are broken down by categories that internally allow for maximum synergism in a mission sequence, and where sensor and supporting electronics have overlapping characteristics and/or commonality.

A. Electromagnetic Spectral Sensors

Sensors in the spectrum from 0.2 microns through S-band radar are needed for remote sensing of planetary and satellite atmospheres and remote sensing of surface and subsurface geological features. This category includes both passive and active sensing, and some supporting technology, such as sensor cooling. Interactions with attitude control and platform pointing developments will be required to achieve maximum data return. These sensors can be useful both in planetary orbiters and flybys, and from large telescopes in Earth orbit.

B. Remote High Energy Particle and Radiation Sensors

Sensors designed to detect high-energy particles as well as X-rays and gamma rays can be used to obtain planetary surface and subsurface compositional data. Along with the basic sensor elements, long-term sensor cooling is required as enabling technology.

C. Fields and Particles Sensors

The interaction between the solar wind, planetary atmospheres and atmosphereless planetary surfaces are fundamental to planetary evolution and also yield much information of basic plasma physics which can help lead the way to developing technology for energy development here on Earth. These sensors will help define the total mass and energy distribution in the solar system, as well as establish interactions with galactic and extra-galactic fields and particles sources.

D. Atmospheric In-Situ Sensors

The direct measurement of atmospheric characteristics through the use of sensors on entry probes provides the most specific chemical information gathering and the most definitive compositional gradient data. Current probe developments point the way for future strategies, but are limited by size, weight, power, and data transmission constraints. The information increase that will be afforded by future increases in payload capability can be several orders of magnitude over that under present development.

E. In-Situ Sensors

Direct measurements of planetary surface and near-surface composition as well as weather behavior can be measured by fixed and roving landers. The basic model for such sensing will be evolutionary from the Venus and Mars probes presently under development. Advances in sample handling and compositional specificity are required to obtain definitive new data on planetary evolution. Also, the current dynamics of planetary geology can be studied through use of gravity and seismic sensors.

F. Biological Sensors

The search for extraterrestrial life will continue with varying degrees of intensity, pending the outcome of the Viking findings. The sensing techniques required for biological studies have proven to demand long and intensive developmental activities. The strategy for future developments in this area depend so strongly on the imminent findings from Viking that no new initiative is proposed here, though one should be developed as soon as definitive findings are available from the life detection studies of Mars.

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: The Development of Remote Electromagnetic Sensors for Planetary Exploration

Lead Field Center: JPL

Supporting Field Centers: Goddard, Langley

Specific Objectives and Targets: The objective of this initiative is to develop sensors for remote sensing of planetary bodies in a continuous spectrum from 0.2 microns to S-band radar. Sensing in this spectral range allows sensing and internal consistency checks for both composition and distribution of atmospheric constituents and surface and subsurface structure. Also, significant inferences as to planetary weather can be done by sensing in this region. Some of the specific sensor development proposed is: middle-UV large-area ICCD's, near-UV large-area imaging arrays, large-area array visual imagers, large-area image array mosaics, near-IR area arrays, middle and far-IR line arrays, submillimeter and microwave sensors, optics, antennas, and appropriate cooling systems.

Justification: Advances in this sensor technology will allow complete synergistic data on planetary atmospheres and significant data on unobscured surfaces. With attendant advances in on-board data processing, it will be possible to send back data on the distribution (compositon) and migration (weather) of planetary surfaces in a form which will be directly useful (weather maps, vertical distributions, chemical reactions sources and sinks, etc.). The increase in planetary information is explosive - far exceeding the goal of 1000 times increase - between development of new sensors, increased data rates, and expanded mission opportunities with Shuttle launch capability. The cost per bit of information will be reduced more than an order of magnitude over current missions. These same sensors and application techniques can be used directly from Earth orbit both to study the planets from large telescopes and to monitor similar parameters on the Earth. Also, with appropriate telescopes and pointing accuracies, significant observatory phase data can be obtained during interplanetary cruise.

Resources: (FY '78 $)	FY '78	FY '79	FY '80	FY '81	FY '82	ATC	Total
Total R/AD NOA ($ M)	1.0	2.0	3.0	3.0	3.0	12.0	24.0

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: The Development of High-Energy Particle and Radiation Sensors

Lead Field Center: JPL

Supporting Field Center: Goddard

Specific Objectives and Targets: Sensors for detecting X-rays, gamma rays, alpha particles, beta particles, and neutrons can be used to assess surface and subsurface compositional elements by remote measurements from satellite altitudes. Technology advances are required in both sensor technology and long-life, low-temperature cooling apparatus to enable this technique on long-duration missions.

Justification: This sensing technique has been limited to Earth orbital and Lunar measurements because of sensor weight and size. Shuttle launch capabilities and advances in cooling technology will allow improvements in sensor capability and extension of this powerful method to a number of bodies in the solar system. Several orders of magnitude increase in information can be achieved.

Resources: (FY '78 $)	FY '78	FY '79	FY '80	FY '81	FY '82	Δ TC	Total
Total R/AD NOA ($ M)	0.5	0.5	1.0	1.0	1.0	2.0	6.0

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: The Development of Planetary and Interplanetary Fields and Particles Sensors

Lead Field Center: Goddard

Supporting Field Centers: JPL

Specific Objectives and Targets: In order to achieve an increase in data return on the planetary and interplanetary fields and particles, sensors need to be developed which allow for lower noise, higher speed, and greater directionality. Applications of channel multiplier arrays are an example of new technology which will allow increased plasma probe sensitivty and directivity. Fundamental sensor research is required to achieve reductions of noise in magnetometers. Possibly, cryogenic techniques can be applied with future payload capability to allow new sensors to be employed, and improvements are feasible with fluxgate sensors and vector helium magnetometers.

Justification: As missions farther out in the solar system become possible, better insights into galactic and extra-galactic influences on the solar system can be achieved because the dominance of the Sun on field and particle environments lessens, and will not mask other sources. Also, interactions between fields and particles and planets must be better understood to determine planetary evolutionary processes.

Resources: (FY '78 $)	FY '78	FY '79	FY '80	FY '81	FY '82	Δ TC	Total
Total R/AD NOA ($M)	0.3	0.5	0.8	0.8	0.8	1.6	4.0

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: The Development of Atmospheric In-Situ Sensors

Lead Field Center: Ames

Supporting Field Centers:

Specific Objectives and Targets: The performance goals of probe instruments is severely constrained by present weight, power, volume, and data transmission capability. With future payload growth and evolution of data analysis, compression, and transmission capabilities, orders of magnitude more information can be gathered by probes descending or ascending a planet's atmosphere. Physical properties can be handled with much greater finesse with existing sensor technology and chemical analysis can be more greatly extended to developing faster GC's and MS's with higher resolution, and developing new atmospheric sensing techniques.

Justification: Much of the definitive assessment of planetary atmospheres is presently constrained by current payload limiations. Future increases in payload capabilities will allow significant advances in probe sensor techniques.

Resources: (FY '78 $)	FY '78	FY '79	FY '80	FY '81	FY '82	Δ TC	Total
Total R/AD NOA ($ M)	0.3	0.5	0.8	1.2	1.2	2.4	5.4

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: The Development of Planetary Surface of In-Situ Sensors

Lead Field Center: JPL

Supporting Field Centers: Ames, Langley

Specific Objectives and Targets: The following sensors will allow significant increases in the knowledge of planetary surface/subsurface composition: 1) multispectral imaging in the visible and IR; 2) mass spectrometers with increased mass range and spectral sensitivity, and with solids analysis capability; 3) nuclear magnetic resonance spectrometers with higher magnetic fields and dust sampling capability; 4) X-ray fluorescence sensors with improved solid-state detectors, optimized X-ray sources, and geometric improvements; 5) ion, electron, and visible microscopes with vacuum handling capability; 6) alpha scattering sensors of higher resolution; 7) thermodynamic analysis sensor using gas release mass spectroscopy for enthalpy property studies; 8) radar sensors for subsurface sounding; 9) cryostats, sample manipulators, and vacuum processing systems to support the above.

Justification: Analysis of planetary surfaces will greatly increase knowledge on the evolution of the solar system. Methods employed for these analyses are very sophisticated and require long lead-time developments.

Resources: (FY '78 $)	FY '78	FY '79	FY '80	FY '81	FY '82	Δ TC	Total
Total R/AD NOA ($ M)	1	2	3	4	4	12	26

2. Data Processing

A. On-Board Processing

Improved on-board data processing and information extraction systems are needed. Especially important is the need for real time processing of imaging data, including high rate data from radar and multispectoral instruments, algorithm development for on-board information extraction, and an advanced modular computor architecture having fault tolerant characteristics with an improvement of 10 to 100 times in on-board computing capability.

Relevant New Initiatives:

1. CCD Unified Data Processor (summary attached)
2. Artificial Retina System (summary attached)

B. Information Management

Information management technology is needed to coordinate and quantitatively relate space program objectives with all elements of NASA's end-to-end data system in an attempt to optimize cost effectiveness associated with space information sciences.

Relevant New Initiatives:

1. The development of an Information-Management System for Space Exploration (summary attached)

C. Large Capacity Data Storage Systems

Large capacity data storage systems (10^9-10^{12} bits) will be needed in the next decade for the exploration of space. Optical memories and high density semiconductor memories need to be exploited to meet this requirement.

Proposed New Initiatives:

1. Holographic memory (not written)
2. Large capacity semiconductor memories (not written)

D. Software Research

Software research is needed to curtail the rising cost of software applications in our space missions. Techniques are needed for designing and developing computer programs, testing them, verifying their correctness, and maintaining them. Contributing disciplines include higher-order languages, automated programming and program verification, operating systems, compilers and assemblers, data system architecture, structured programming, and others.

Relevant New Initiatives:

(To Be Determined)

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: CCD-Unified Data Processor

Program:

Lead Field Center: JPL

Supporting Field Center: LARC

Specific Objectives and Targets: The objective of this program is to develop and demonstrate a CCD-Unified Data Processor System (UDPS) to provide greatly increased on-board and ground data reduction capability at reduced costs. The UDPS will utilize the newest CCD and microprocessor technology to achieve a design which is modular and programmable for multiple applications. The processor capabilities will be applicable to a wide range of microwave and multi-spectral imaging systems and will include radar data processing, data compression, clustering, classification, registration, filtering, convolution, and transformation. The output of this task will be a fully tested breadboard which will demonstrate the technology. The breadboard will be completed in 1980 and will undergo final tests in 1981.

Justification: Imaging radar and higher resolution multi-spectral imaging systems produce data rates which are difficult to handle in an efficient and cost effective manner. CCD and microprocessor technology offer a practical solution to the problem. This program supports the NASA goals of 1000X increase in mission capability and 10X reduction in cost. The UDPS is expected to increase data processing speeds by 10 to 100, reduce data storage requirements by 5 to 50, and provide an overall 1000-fold increase in ground reduction capability.

Resources: (FY'78 $)	FY'78	FY'79	FY'80	FY'81	FY'82	BTC	Total
Total R&AD NOA ($,M)	0.8	1.1	0.6	0.5	0.2	0	3.2

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: Artificial Retina System

Program:

Lead Field Center: JPL

Supporting Field Center:

Specific Objectives and Targets: Develop an artificial retina system which will reduce the quantity of data transmitted from a spacecraft imaging system, and increase the information level of that data. A photoreceptor array imbedded in a logic matrix on a silicon LSI chip will provide real-time parallel image processing, which is considerably faster than serial (raster) readout; the logic will execute algorithms which pre-process the raw data to a level where features can be extracted (contour, texture, motion, etc.). A stereo pair will provide depth information; sets of spectrally filtered elements determine color. These features, on primitives, will be transmitted to central facilities for further processing by high-level software programs which will interrelate and interpret them under interactive human control. Under operator guidance, the high-level programs will control the (low-level) algorithms on the LSI chip. For adequate spatial resolution, the LSI chips will be fabricated in a high-density technology.

JUSTIFICATION: Planetary and Earth-orbiting missions will rely heavily on imaging systems for information gathering. Current methods use TV cameras to transmit raw gray-level data to Earth in serial streams. Because of the large quantity of data (10^6 bits/frame) this is slow, cumbersome and expensive. The artificial retina system will be faster, more efficient, and less expensive to operate. The silicon technologies required for this system exist separately today: silicon TV vidicons, large logic arrays (e.g. microprocessors), high-density lithography (electron-beam or x-ray). Algorithms for parallel image processing and feature extraction have been developed to a very limited extent, using small hard-wired breadboard systems to simulate simple image patterns. High-level programs are being developed for serial data systems, for want of parallel-data hardware. A different approach to the problem is being pursued at Goddard Space Flight Center: if the wires and logic elements of a general-purpose computer were replaced one-for-one by bundles of fiber optics and arrays of photoconductors, existing—or slightly modified—programs would simultaneously process the data of all channels, thus achieving parallel processing.

Resources: (FY'78 $)	FY'78	FY'79	FY'80	FY'81	FY'82	ΔTC	Total
Total R/AD NOA ($,M)	0.5	0.8	1.2	1.5	1.5	1.5	7.0

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: The Development of an Information-Management System for Space Exploration

Program:

Lead Field Center: JPL

Supporting Field Center:

Specific Objectives and Targets: The objective of this initiative is to develop a methodology for managing, in a coordinated manner, all elements of NASA's space information system. The emphasis of the objective is to be able to quantitatively relate space program objectives with all elelents of NASA's end-to-end data system in an attempt to optimize cost effectiveness associated with space information sciences. The program will include: (1) the identification and analysis of the elements of the NASA space-information system; (2) the relationship between bit rates and information transfer; (3) the development of a methodology for: (a) specifying quantitative information-related program objectives; (b) establishing an information-management rationale for the acquisition processing, storage, retrieval, and distribution of spacecraft data; (c) allocation of data channel capacities and bandwidths for competing experimental data types; (d) quantitatively determining and allocating the quality of data processing required for each element of the end-to-end data system to assure overall compatibility of the system; (3) measurement of end-to-end data system performance; (f) controlling the performance characteristics of the end-to-end data system.

Justification: In 1962, the telemetry bit rate from the Mariner II spacecraft to Venus was 8 1/3 bps at encounter. By 1972 the telemetry bit rate for Mariner X had increased to 117,600 bps. It is projected that by 1990 the bit rate from only one Earth-orbiting mission will be 10^{13} bits/day; this is enough data to fill approximately one million 300-page books in one day. Presently, there exists no overall plan, nor even a methodology for developing a plan, for either limiting or coping with all the data being transmitted from space vehicles. If this situation is permitted to continue, missions will become progressively more cost ineffective due to our inability to relate data-handling costs to mission objectives.

Resources: (FY'78 $)	FY'78	FY'79	FY'80	FY'81	FY'82	ATC	Total
Total R/AD NOA ($,M)	1.0	3.0	5.0	5.0	5.0	5.0	24.0

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

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Program:

Lead Field Center: JPL

Supporting Field Center:

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G. Garrison
12 April 1976

3. Communication.

A. Active, modular, multi-beam, multi-frequency, phased array antennas.

These antennas, with self-contained, distributed transmitters and low-noise preamplifiers can provide high reliability with graceful failure. The modular aspect provides extreme flexibility in gain or spatial coverage for different missions. Beams are electronically steered and individually controlled. Thus one antenna can provide a link to Earth, plus a probe link (or probe links) simultaneously. May also be applicable to probes, landers, or sub-vehicles (in lower orbit than master spacecraft).

Relevant New Initiatives

B. Technology for high data rates from outer planets.

Perform analyses and tradeoffs on techniques for high rate data return to Earth from Jupiter and beyond. Consider data rates to 5-10 mbps, perhaps even higher. Consider high-power transmission vs. large antennas, plus appropriate modulation and coding. Potential for optical communications to Earth orbiter should also be considered.

Relevant New Initiatives

C. Relay Communications

Perform analyses and system studies of cost effective configurations for relay communications from probes, landers, or sub-orbiters thru the master spacecraft to Earth. Consider relay link modulation and coding, relay point data processing, and communications constraints due to mission geometry. Applicable to Jupiter Exploration Facility plus numerous precursor probes, penetrator and lander missions.

Relevant New Initiatives

G. Garrison
12 April 1976

D. Doppler and Ranging on Spacecraft

Perform study of system requirements, develop alternative system configurations, and analyze system performance for doppler and ranging measurements performed on spacecraft. This measurement may provide information for autonomous navigation of a master spacecraft or for locating landers, probes, or sub-orbiters from a master spacecraft. This task will identify stability requirements for the spacecraft reference oscillator. A separate development for this ultra-stable oscillator may be required.

Another spinoff may be requirements for secondary probe oscillator stability to meet location accuracy requirements with one-way doppler measurements.

Relevant New Initiatives

E. Data Compression/Pre-Processing

Techniques for data compression, and on-board pre-processing to reduce data trasnfer rate is required for high data volume outer planets missions. This activity, conjunction with high data rate technology should provide information for cost effective trade-offs of the two options (high rate vs. compression/processing).

Relevant New Initiatives

F. Radar Mapping

Develop technology for high resolution, long range mapping of outer planets/satellites from orbiters.

Relevant New Initiatives

G. Garrison
12 April 1976

G. Fault Tolerant Hardware

Develop technology for hardware with self-diagnostic, self-repairing capability.

Relevant New Initiatives

4. Utilization of Stored Energy and External Energy for Power

A. Solar Energy Conversion and Storage

Advancements in solar energy conversion and storage systems are required to satisfy future needs for large amounts of on-board power, increased array lifetime and reliability, and reduced cost. These goals include (1) thin, high end-of-life efficiency, radiation-resistant solar cells; (2) high-power-density solar array; and (3) automated module fabrication methods. These efforts are all presently part of the R&T base effort.

Relevant New Initiatives

(1) Gallium Arsenide Solar Cell Arrays

(2) Photochemical Solar Energy Conversion

(3) Automated Module Fabrication is a potential New Initiative candidate.

B. Chemical Energy Conversion and Storage

More reliable, higher-energy-density primary and secondary batteries with useful lifetime of up to 10 years are needed for deep space missions, planetary orbiters, and planetary probes. These goals are being achieved by developing long-life, lightweight nickel-cadmium cells, batteries for advanced missions (including probes), and advanced battery controls.

Relevant New Initiatives

(None. R&T base program)

C. Nuclear Energy Conversion and Storage

Radioisotope thermoelectric generator (RTG) power systems of greater performance, lifetime, and reliability and lower cost are needed for planetary missions in the 1980's. For the period starting in the early 1990's, missions requiring power levels of 100 Kw or more are being considered, and for such applications, reactor power represents either an enabling technology or potential major cost savings.

Relevant New Initiatives

(1) Nuclear Thermionic Power System Technology

(2) RTG power is presently an R&T base program, but a potential New Initiative candidate in this area is: High-Performance Thermoelectric Material Development.

D. Power Processing and Distribution

Advancements in the technology of power processing and distribution are required to provide higher performance, longer life, higher reliability, lower weight, and reduced cost. Modular designs for the major power processing elements (such as regulators and inverters) having active, rather than standby, redundancy are being developed as are system configuration and integration concepts, to meet the stringent requirements which are foreseen. Also being developed are the techniques and hardware required to ground test, control, and verify the performance of these new flight-type systems.

Relevant New Initiatives

(None. R&T base program)

E. Energy Systems

Planetary missions under consideration for the future pose requirements which make increased autonomy of power system operation not only beneficial but required. Also to achieve technology readiness for near-Sun missions (e.g., Mercury orbiter), certain advancements in power system technology are required.

Relevant New Initiatives

(1) Automated Power Systems Management (presently in R&T base program, but is potential New Initiative candidate).

(2) Advanced Power Systems Technology for Near-Sun Missions (not written yet, submitted over-guideline for FY'77 R&T base program).

(3) Gallium Arsenide Solar Cell Arrays

PRELIMINARY PROGRAM PLAN

FY 1978

TITLE: Gallium Arsenide Solar Cell Arrays

PROGRAM: R&T Base-Multidisciplinary R&T

LEAD FIELD CENTER: JPL

SPECIFIC OBJECTIVES AND TARGETS: Proof of concept demonstration of high-efficiency, light weight GaAs solar cell array at 1 kW output for space power applications.

JUSTIFICATION: Large amounts of electrical power will be required for multi-purpose space power platforms (MPSPP), space laboratories, and certain spacecraft in the period beyond 1980. The required large power would be most economically generated with solar cells. However, the solar cells must be low cost, light weight, highly efficient and have long lifetimes in space since the initial fabrication and launch costs will be a significant part of the total system cost. This is particularly true for the space power satellite concept. Gallium arsenide (GaAs) solar cells are potentially far superior to silicon solar cells because: (1) they have greater efficiency as already demonstrated by laboratory devices, (2) are more radiation resistant leading to much longer lifetimes in space, (3) can operate at higher temperatures more efficiently allowing for the use of solar concentration, and (4) potentially lighter weight and lower in cost because GaAs cells require only several micrometers thickness as compared to 100-200 micrometers for silicon. The latter benefit comes about from the high light absorption in GaAs and the concomittant ability to use either polycrystalline thin films or ultra thin single crystals which can be grown by vapor phase epitaxy on reusable crystalline substrates. Moreover, the large array applications require technical development well beyond current silicon solar cell state-of-the-art or even potential.

RESOURCES: (FY 1978 $)	FY'78	FY'79	FY'80	FY'81	FY'82	Total
Total R&D NOA ($M)	0.5	0.5	1	1	1	4
Direct Manpower	5	5	7	7	7	31

PRELIMINARY PROGRAM PLAN

FY 1979 NEW INITIATIVE

TITLE: Photochemical Solar Energy Conversion

PROGRAM: R & T Base-Multidisciplinary R & T

LEAD FIELD CENTER: Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

SUPPORTING FIELD CENTER(S):

SPECIFIC OBJECTIVES AND TARGETS:

Conversion of solar energy directly into storable chemical energy or more efficient conversion to electrical energy. TARGETS: Photochemical hydrogen and photovoltage generation - end 1980. Hydrogen generator device - 1981. Solar cell device - 1982. Scale-up systems - end 1983.

JUSTIFICATION:

Present solar energy conversion systems suffer from inefficiency and the need for storage of the energy produced, e.g. by batteries. The proposal is predicated on sufficient Research Program support to more firmly lay the foundation for the work and to assess some preliminary systems. The work proposed here would expand these results and by 1983-85 carry the investigation to the point where assuming success, pilot plant studies could begin.

RESOURCES: (FY 1978 $)	FY77	FY78	FY79	FY80	FY81	FY82	BTC	TOTAL
TOTAL R&D NOA ($,K)*			126	123	120	183	148	700
DIRECT CIVIL SERVICE MANPOWER								
DIRECT SUPPORT SERVICE CONTRACTOR MANPOWER								
RESOURCES SUPPORT ASSUMED FROM OTHER SOURCES (R&D $, K) (NASA, CODE RR)	110	125	114	124				473

*CONTRACTED R&D + IN-HOUSE DIRECT RESEARCH + IMS

PRELIMINARY PROGRAM PLAN

FY 1978 NEW INITIATIVE

TITLE: Nuclear Thermionic Power System Technology

PROGRAM: Nuclear Energy R&T

LEAD FIELD CENTER: Jet Propulsion Laboratory

SUPPORTING FIELD CENTER(S): Lewis Research Center

SPECIFIC OBJECTIVES AND TARGETS: Nuclear space power represents an enabling technology and/or potentially large cost improvement for advanced NASA missions. Prior to commitment to a major space nuclear system development program that is presently estimated at $300M, a low-cost system demonstration is needed that will: (1) prove the readiness of nuclear system technology for full scale development, (2) provide detailed technical and programmatic inputs for NASA management planning, (3) test our ability to integrate a complete, large power subsystem, (4) qualify the system design, (5) quantify system inputs to NASA mission design, and (6) reduce significantly the follow-on nuclear system development risks.

JUSTIFICATION: NASA's payload model and advanced mission studies are indicating a requirement for full-scale nuclear reactor systems development commencing by approximately 1982. The System Technology Program proposed for FY 1978 is the most cost effective approach to that requirement. Integrated system demonstration will reduce costs by eliminating development risks and assuring optimum development planning prior to a final management decision to commit major resources. Close coordination between nuclear power system technology direction and applications planning is emphasized to insure that all NASA large power needs can be met over approximately 10 years of flight applications.

RESOURCES: (FY 1978 $)	FY78	FY79	FY80	FY81	FY82	BTC	TOTAL
TOTAL R&D NOA ($, M)*	3.0	3.7	3.3	2.7	1.5	0	13.7
DIRECT CIVIL SERVICE MANPOWER	5	5	5	5	5	0	25.0
DIRECT SUPPORT SERVICE CONTRACTOR MANPOWER							
RESOURCES SUPPORT ASSUMED FROM OTHER SOURCES (R&D $, M) (SPECIFY SOURCE)							

*CONTRACTED R&D + IN-HOUSE DIRECT RESEARCH + IMS

5. Utilization of Stored Energy and External Energy for Propulsion

A. Chemical Propulsion, Near Term (1980-'85)

The chemical Propulsion program objective is to provide the technology to meet the continuing need for cost reduction in propulsion, for versatile, high performance systems suitable for long duration planetary missions including suitable ascent propulsion for sample return missions.

(1) Space Storable (F_2/N_2H_4) Liquid Propulsion

<u>Relevant New Initiatives</u>

(a) None. This program already has been established.

(2) High-Performance, Low Cost Solids

<u>Relevant New Initiatives</u>

(a) Quench Thrust-Termination Assembly (QTTA)

B. Solar Electric Propulsion Near Term (1980-'85)

The solar electric propulsion program objective is to provide the technology for high specific impulse (greater than 1000 seconds) electric propulsion systems needed for advanced capabilities in near-earth and planetary/interplanetary applications; and, in addition, establish and demonstrate the technology for long life, efficient, lightweight, station keeping and attitude control systems.

(1) Primary Propulsion (Ref. Paragraph 4.A. Solar Energy Conversion and Storage)

<u>Relevant New Initiatives</u>

(a) Initiatives for near-term applications (1980-1990) to be determined.

(2) Auxiliary Propulsion

<u>Relevant New Initiatives</u>

To be determined

C. Nuclear Electric Propulsion Far Term ('90 on)

(Ref. Paragraph 4.C. Nuclear Energy Conversion and Storage)

The utilization of nuclear energy for electric propulsion is dependent on the successful development of energy conversion devices several of which are listed under Paragraph 4.C. Nuclear Energy Conversion and Storage.

Relevant New Initiatives

To be determined

D. Advanced Propulsion Concepts (New Horizons) Beyond 2000

The propulsion new horizons program objective is to generate new propellants and propulsion concepts which have the potential for specific impulse of 1000 seconds or greater. A list of tasks currently under consideration within the discipline R and T category is as follows:

(1) Metallic/Atomic Hydrogen

(2) Excited Species

(3) Laser Propulsion

(4) Solar Sailing

(5) Detonation Propulsion

(6) Utilization of Planetary Atmospheres for Propulsion

(7) Use of Indigenous Materials for Propulsion

(8) Energy Exchange Mechanisms

(9) Matter-Antimatter

Relevant New Initiatives

To be determined

PROPULSION CONCEPTS

	EXTERNAL ENERGY	STORED ENERGY		
		ELECTRONIC	NUCLEAR	MASS ANNIHILATION
READY FOR ADVANCED DEVLOPMENT	PLANETARY ATMOSPHERES SOLAR ELECTRIC INDIGENOUS MATERIALS	CHEMICAL DETONATION	FISSION SOLID CORE	
ON THE TECHNOLOGY FRONTIER (10 TO 20 yr FROM NOW)	LASER PROPULSION	HYDRIDES	FISSION FLUID CORE NUCLEAR ELECTRIC	
IN A CONCEPTUAL EXPLORATORY STAGE (MORE THAN 20 yr FROM NOW)	ENERGY EXCHANGE MECHANISMS	ACTIVATED SPECIES METALLIC HYDROGEN	FUSION MICRO-EXPLOSION	MATTER-ANTIMATTER

PRELIMINARY PROGRAM PLAN - EXECUTIVE SUMMARY

FY 1979 NEW INITIATIVE

TITLE: QUENCH THRUST TERMINATION ASSY (QTTA)

PROGRAM: OAST

LEAD CENTER: JPL

SUPPORTING FIELD CENTER: MSFC

SPECIFIC OBJECTIVES AND TARGETS:

(A) OBJECTIVES

Provide a two-burn on-command liquid-quench thrust-termination system suitable for adaption and use on the upper stage of the Shuttle/IUS transportation system.

(B) PHASE DESCRIPTION

- Phase 0 (FY77/78 on-going OAST Technology Program) Complete analytical and small experimental research motor demonstration firings to verify liquid quenchability of Class 2 solid propellants. Full scale quench demonstrations using Class 7 double base propellants have been successfully demonstrated to date.
- Phase 1 (FY79/80)
  - Define stop/restart stage requirements
  - Complete preliminary stage design
  - Complete full scale motor/quench design
  - Complete 6 subscale stop/restart solid rocket test firings
- Phase 2 (FY81/82)
  - Complete stage design and performance estimates; complete 4 full scale stop/restart solid rocket test firings.
- Phase 3 (FY83/84)
  - Complete 3 full scale prototype stage propulsion ground tests.
- Phase 4 (FY85/86)
  - Complete 1 flight proof test demonstration

JUSTIFICATION:

The addition of a simple low-cost quench thrust termination system, which provides multi-burn capability to traditional single burn solid rocket motors will:

- Increase payload capability by allowing optimum orbit transfers and/or reduce the number of shuttle launches required.
- Provide greater Shuttle/IUS operational flexibility to more effectively accommodate a wide variation of payload weights and differing payload orbit requirements.
- Continue to maintain basic advantages of solid propulsion's low-cost, simplicity, high reliability and minimal launch support effort.

RESOURCES: (FY 1978 $ M)

		Phase 1		Phase 2		Phase 3		Phase 4	
	FY	79	80	81	82	83	84	85	86
TOTAL R&D NOA ($,M)	(JPL)	1.1	.7	1.8	1.2	--	--	--	--
	(MSFC)	.1	.2	.3	.3	--	--	--	--
DIRECT CIVIL SERVICE MANPOWER	(MFSC)	.1	.1	.1	.1	.2	.2	.3	.[illegible]
DIRECT SUPPORT SERVICE CONTRACTOR MANPOWER		--	--	--	--	--	--	--	--
RESOURCES SUPPORT ASSUMED FROM OTHER SOURCES (R&D $, M)/OSF	(JPL + Contractor)	--	--	--	--	1.8	.6	1.5	.[illegible]
	(MSFC)					TBD	TBD	TBD	TB[illegible]
		1.3	1.0	2.2	1.6	2.0+	.8+	1.8+	.[illegible]

G. Garrison
12 April 1976

6. Electromagnetic Transfer of Energy.

A. Electromagnetic Transfer of Energy

There is potential for energy transfer from a master spacecraft to a sub-vehicle or lander via microwave, where the master vehicle has excess power availability, i.e., NEP, SEP. Technology development is required in DC-RF conversion, large modular phased arrays with electronic beam steering, and receiving antennas.

Energy transfer by LASER should also be considered as potential alternate technique.

<u>Relevant New Initiatives</u>

7 Processing Micro Structures

A. Electron Beam Lithography

Electron beam lithography will enable the processing of micro circuits/devices with lateral dimensions of the order of one micron. The development of this technology will enhance the performance of superconducting microcircuits, ultra high density silicon microelectronics, and integrated optics.

Relevant New Initiatives:

1. Electronic materials research based on electron beam lithography (summary attached)

B. LSI Design

The availability and projected usage of microprocessors and other complex LSI devices is changing the way in which we view system and subsystem architecture. Chips have become systems in themselves and have opened the door to an array of new problems and opportunities. Problems in testing and qualification need to be addressed; opportunities for new design approaches are becoming increasingly prevalent. In particular, fault tolerant systems can be realized more efficiently if fault tolerant considerations are an integral part of chip designs. There exists a need to specify design criteria and rules for achieving such results.

Suggested New Initiatives:

1. Qualification and testing of LSI devices (to be determined)
2. LSI design criteria for fault tolerant applications (to be determined)

PRELIMINARY PROGRAM PLAN

FY 1978

TITLE: Electronic Materials Research Based on Electron Beam Lithography

PROGRAM: R&T Base-Multidisciplinary R&T

LEAD FIELD CENTER: JPL

SPECIFIC OBJECTIVES AND TARGETS: Superconducting microcircuits, ultra high density silicon microelectronics, integrated optics, superconducting weak link IR detectors.

JUSTIFICATION: Processing of pictorial data on board spacecraft and autonomous rovers will require an electronics technology greatly advanced over that available today. Superconducting microcircuits and silicon devices with lateral sizes on the order of one micron could be the basis of such a technology. Information transfer in the 1980's will most probably be by optical communication links. Integrated optics are a vital part of such links. Astronomy from shuttle will require the most sensitive IR detectors possible. Arrays of superconducting weak link devices are potentially such detectors. All of these devices will come about only if research on them is started today. This research will require the establishment of an electron beam lithography facility.

RESOURCES: (FY 1978 $)	FY'78	FY'79	FY'80	FY'81	FY'82	Total
Total R&D NOA ($M)	1	1	1	1	1	5
Direct Manpower	10	20	20	20	20	90

9. Control

A. Attitude Control

Improved attitude control technologies are needed in the next decade to provide capability to meet control requirements in the late 1980's. Control of very large deformable space structures used for antennas, solar power satellites, and large space stations will require new control concepts to meet required accuracies and prevent damage from control forces. Planetary vehicle control will ultimately be limited by factors such as structural damping effects and environments. Therefore, adaptive in-flight control techniques must be developed which can automatically reduce these errors. Also future control capabilities will intimately be tied to improvements in hardware technology.

Relevant New Initiatives

1. Attitude and Figure Control of Large Deformable Structures (summary attached).
2. Dynamic Synthetic Estimators (not written at this time).
3. Autonomous Adaptive Control (not written at this time).
4. Control Hardware and Device Developments (not written at this time).
5. Precision Long-Range Sun Sensor Development (not written at this time).

B. Instrument Pointing

The ability to maintain precise instrument pointing to an observational target will be critical to advanced imaging spectroscopy, surface feature determination, and reduced costs of data reduction and processing. In situ testing and evaluation of new experiments related to advanced pointing technology will be needed to validate performance. The use of a shuttle based test facility will accommodate these tests at a potentially lower cost.

Relevant New Initiatives

1. Science Platform Precision Pointing and Tracking System for Unmanned Planetary Spacecraft (summary attached).
2. Modular Instrument Pointing Technology Laboratory (summary attached).
3. Experiment Pointing Mount for Spacelab (not written at this time).
4. Application of Microprocessor Controlled CCD Sensors to Instrument Pointing (not written at this time).

PRELIMINARY PROGRAM PLAN

FY77 New Initiative

Title: Attitude and Figure Control of Large Deformable Structures

Program: Guidance and Control R & T

Lead Field Center: JPL

Supporting Field Center(s): None

Specific Objectives and Targets: Develop conceptual design for distributed control, develop analysis tools and performance analysis. Identify component development needs.

Justification: For large deformable space structures surface form control will be required for accuracy and to prevent damage from attitude control forces. This program will address development of distributed control concepts and technology (sensors and actuators) required for this control. Also new analysis techniques to minimize the number of distributed elements and new performance analysis techniques which include deformation variables with sensing and actuationvariables are needed. JPL's developments in advanced control/structures interaction technology will form the basis for these new requirements. This development is consistent with NASA's pointing and control improvements for 10 x larger structure with active surface control to 1 mm.

This technology provides for active control of: 1. large antennas and multiple feeds for simultaneous multiple Earth pointing needed to increase communication channels. Scientists need these antenna for radio astronomy and interferometry; 2. Solar power satellites which could provide 15% of National power needs by 2020; 3. Large space stations needed for zero "g" manufacturing plants, science platforms, and even space colonies; and 4. Any very large structure where deformations must be controlled.

Resources: (FY77 $)	FY77	FY78	FY79	FY80	FY81	ΔTC	Total
Total R/AD NOA ($, k)	125	125	125	152	-	-	527

PRELIMINARY PROGRAM PLAN

FY TR/77 New Initiative

Title: Science Platform Precision Pointing and Tracking System for Unmanned Planetary Spacecraft

Program: Guidance and Control R & T

Lead Field Center: JPL

Supporting Field Center(s): None

Specific Objectives and Targets: To design and develop a target body referenced, inertially stabilized platform pointing and Tracking system, culminating in an engineering model breadboard demonstration in FY79 that will meet the science pointing requirements for a wide range of unmanned, planetary missions.

Justification: Desired planetary science return cannot be achieved with current S/C attitude and articulation control system designs. The NASA Space Electronics Technology goal of providing a ten-fold increase in data acquisition through precise pointing by 1990 will be achieved for planetary science. Spacelab Experiment Pointing Mount (EPM) and advanced ELACS technology areas will provide base for design implementation. Ability to maintain precise instrument pointing to an observational target is critical to: 1. An advanced imaging spectroscopy capability to define the constituents, their spatial distribution, and their motions within the atmospheres at Jupiter, Saturn, Uranus, Titan, Venus, etc., through utilization of recently developed multispectral imagers to provide simultaneous chemical spectra for each pixel of an image. 2. Surface feature determination of outer planet satellites, where light levels are low, to 1 km resolution (a ten-fold improvement). 3. Up to 50% reduction in total number of images required, resulting in further sequence time for competing users and cost savings in data reduction and processing can be achieved by the improved pointing, tracking, and stability of the science platform.

Resources: (FY76 $)	TQ	FY77	FY78	FY79	FY80	FY81	ΔTC	Total
Total R/AD NOA ($, k)	25	250	400	200	-	-	-	875

PRELIMINARY PROGRAM PLAN

FY77 New Initiative

Title: Modular Instrument Pointing Technology Laboratory (MIPTL)

Program: Guidance and Control R & T

Lead Field Center: JPL

Supporting Field Center(s): None

Specific Objectives and Targets: The objective is to define a laboratory facility to be carried on the Shuttle for testing in situ a variety of experiments associated with instrument pointing technologies. The facility would consist of accommodations and support systems for the mount, stabilization subsystems, and associated controls and displays.

Justification: A shuttle based test facility would allow testing and evaluating in situ, a variety of new experiments related to advanced pointing technology at a potentially lower cost. A MIPTL provides a pointing technology test facility in an operational environment free from gravitational and atmospheric effect. MIPTL provides a cost effective means of obtaining user acceptance of new technology items.

Resources: (FY77 $)	FY77	FY78	FY79	FY80	FY81	BTC	Total
Total R/AD NOA ($, M)	.5	.6	.4	-	-	-	1.5

10. **NAVIGATION**

Both return of information and return of matter missions envisioned in the period 1985-2000 will require navigation technology beyond extensions anticipated through evolution of current state of the art. Requirements of maximum information return per unit cost will require critical delivery of the science instruments field of view at the target through both flight path control and instrument pointing control. In addition, sample return from a solid body will require advances in ascent, and rendezvous and docking guidance/navigation technologies. The role of autonomous on-board systems will be unprecedented by today's standards. This will be particularly true on missions to distant targets where the round-trip communication time exceeds the required reaction time (interval between the last navigation measurement and thrust or instrument pointing maneuver) or periods of communication blackout (occultation or radio/tracking system anomaly). The development of Autonomous Guidance and Navigation System technology is just now beginning.

This material does not address the navigation and guidance technology developments required for remote roving vehicles for insitu information/sample acquisition. This is covered under autonomous systems.

RELEVANT NEW INITIATIVES

1. Autonomous Guidance and Navigation Flight/Ground Demonstration

2. Autonomous Guidance and Navigation Operational System

3. Low Cost Navigation System Development

LOW THRUST NAVIGATION

It appears that Low Thrust capabilities will be required for certain high energy missions which would be of scientific interest. The navigation techniques for Low Thrust missions are different than those required for ballistic missions, and need further development. Low thrust includes NEP, SEP and Solar Sailing concepts. Existing mission design and analysis software to support Phase A and B studies is not adequate for the navigation analysis prior to project approval.

RELEVANT NEW INITIATIVES

1. Low Thrust Navigation System Technology Development

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: **Autonomous Rendezvous and Docking**

Program:

Lead Field Center: JPL

Supporting Field Center(s): JSC

Specific Objectives and Targets: Sample return missions at distant target bodies will require autonomous rendezvous and docking capability. The portion of the total technology addressed within this new initiative is limited to the development of appropriate sensors, data calibration and processing software, and software for mission operations support (MOS). The technology will be applicable to both conventional (single spacecraft) sample return missions under consideration and the Planetary Exploration Facility concept. The technology would also be applicable for rendezvous and docking at Earth return.

Justification: Direct ascent Earth return capability appears to be prohibitively expensive, requiring extremely large payload capabilities, and characteristically displaying large injection errors which must subsequently be corrected.

Resources: (FY'78 $)	FY'78	FY'79	FY'80	TOTAL
Total R/AD NOA ($, M)	.3	.35	.4	

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PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: LOW THRUST NAVIGATION SOFTWARE DEVELOPMENT

Program:

Lead Field Center: JPL

Specific Objectives and Targets: Low thrust systems are unique in that they employ a continuous mode of thrusting. Ballistic trajectory software must be modified in some cost efficient way in order to appropriately model the trajectories. Continuous thrusting is a continuous source of process noise, obscuring the orbit determination process. Hence, efficient methods of locating the spacecraft with precision need to be developed. Low thrust is unlike ballistic maneuvers since maneuvers are made continuously. Efficient methods will be developed to integrate the trajectory prediction, and orbit determination processes in a way which supports meaningful maneuver control schemes.

Justification: JPL's operational software is not adequate for supporting a low thrust mission. Mission design software exists which is capable of supporting phase A and B activities. However, a serious gap persists between design and analysis software and flight operational software. All three areas of navigation software; trajectory, orbit determination and maneuver analysis, need to be upgraded for the unique low thrust system. Trajectory software requirements, now under change control, need to be updated according to the new MJS baseline software system. In addition, software requirements for the orbit determination and maneuver processes need to be generated and maintained. This development generates the necessary enabling software technology for low thrust mission starts in the early 80's.

Resources: (FY'78 $)	FY'78	FY'79	FY'80	FY'81	FY'82	BTC	Total
Total R&AD NOA ($,M)	.1	.2	.1	0	0	0	.4

13 April 1976

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: Low Cost Navigation System Development

Program:

Lead Field Center: JPL

Supporting Field Center:

Specific Objectives and Targets: To provide the systems analysis necessary for the planning and integration of the developing navigation technology into NASA's planetary exploration program so that the navigation process can be delivered for the lowest total cost over a time span with a 20-25 year horizon. The effort would begin by 1) providing a review of the navigation technology status, 2) apply the technology to the NASA mission model using several scenarios of navigation technology developments in order to arrive at a projection of the total navigation end-of-century cost using an optimum strategy, 3) isolate specific deficiencies now occurring under the single project planning horizon mode currently used, 4) publish a report of findings with a scenario for navigation over the next 25 years and an action plan to achieve the desired scenario.

Justification: While OAST and OTDA sponsored navigation subsystem developments are being vigorously pursued and each individual flight project employs those techniques which are flight-ready, long-term systems leadership and planning over an extended mission set is left unsupported.

With a planning horizon little more than the next mission, sub-optimum development strategies are being pursued which over several missions result in higher than necessary costs both in terms of dollars and mission risk.

The Navigation Data System has evolved from one employing Earth-based doppler data alone to a system using dual-station, dual-frequency doppler and ranging data complemented with precision on-board optical data for current missions such as MJS. Other elements of the Navigation System such as the maneuver strategy employed and the orbit determination process itself have experienced similar complexity increases as greater accuracy at larger distances has been sought. Currently in development are data system techniques such as differential very long-baseline interferometry (ΔVLBI), promising unprecendented orbit accuracy as well as much lower tracking time requirements. Finally, an integrated on-board autonomous navigation system is being developed for special circumstances where the Earth-spacecraft round-trip light-time is too long for time-critical data taking, processing, decision and maneuvering sequences to be accomplished in the traditional maneuver. Due to its self-contained nature and relatively small Earth-based support requirements, the autonomous approach promises cost savings as well.

It is clear that what system is perceived to be the system of choice for the "next" mission is a sensitive function of one's planning horizon and that perception feeds back to the technology development areas and influences those development realities. Support is needed for the Navigation System's planning leadership with an explicit horizon of 25 years.

Resources: (FY'78 $)	FY'78	FY'79	FY'80	FY'81	FY'82	ΔTC	TOTAL
Total R/AD NOA ($,M)	0.1	0.1	0.1	0.1	0.1		

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PRELIMINARY PROGRAM PLAN

FY 1980 New Initiative

Title: Autonomous Guidance and Navigation Operational System Development

Program:

Lead Field Center: JPL

Supporting Field Center(s):

Specific Objectives and Targets: The existing AG&N development activity will produce the capability of on-board measurement and data processing to perform orbit estimates, calculate and execute trajectory correction maneuvers and adjust planned science data sequences. This capability can be augmented by providing adaptive on-board decision making capabilities. These include the ability to adjust or reselect encounter aimpoints, and to reschedule science activities, changing their order and/or duration.

Justification: Post-mission analysis often reveals new data that would have been used to modify the mission as planned, had it been known at the time. Increasing the on-board mission planning activities of the AG&N System will allow certain information about the target to be interpreted and encounter conditions modified so that science objectives are met or exceeded. Outer planet satellite tour missions would benefit from the capability of adaptive selection and execution of pre-specified off-nominal trajectories for flybys of alternate targets. Potential collisions with foreign objects could be prevented by detection and recognition of such a situation resulting in a flight path alteration.

Resources: (FY'78 $)	FY'80	FY'81	FY'82	ΔTC	TOTAL
Total R/AD NOA ($, M)	.3	.5	1.0		

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4. Pointing adjustment for repositioning target image in field-of-view.

5. Modification of science instrument pointing sequence.

B. Simulated On-Board Activities (Ground Based)

1. Processing of target-star data to update the estimated spacecraft position.

2. Calculation and execution of a trajectory correction maneuver.

3. Redesign/optimization of a science instrument pointing sequence.

JUSTIFICATION: The era of spacecraft autonomy is of necessity entered as unmanned vehicles probe further into deep space and the round trip radio transmission time (light time) exceeds the permitted reaction time. Needs for autonomy may arise during periods when communication with Earth is impossible (e.g., during occultations) or prevented by some constraint (i.e., antenna pointing, radio system failure, etc). During approach and encounter phases with distant targets, spacecraft will be required to notice and correct, with no time for Earth consultations, deviations from the high-science return trajectory as well as adjust the science instruments. Establishment of technology readiness requires the completion of an inflight demonstration.

RESOURCES: (FY 1978 $)	FY78	FY79	FY80	FY81	FY82	BTC	TOTAL
TOTAL R&D NOA ($,M)*		0.945	1.146	0.477	0.614	1.025	4.207
DIRECT CIVIL SERVICE MANPOWER		NA	NA	NA	NA	NA	NA
DIRECT SUPPORT SERVICE CONTRACTOR MANPOWER		NA	NA	NA	NA	NA	NA
RESOURCES SUPPORT ASSUMED FROM OTHER SOURCES (R&D $, M) (SPECIFY SOURCE)		NA	NA	NA	NA	NA	NA

*CONTRACTED R&D + IN-HOUSE DIRECT RESEARCH + IMS

4/13/76

PRELIMINARY PROGRAM PLAN

FY 1979 NEW INITIATIVE

TITLE: Autonomous Guidance and Navigation Flight/Ground Demonstration

PROGRAM:

LEAD FIELD CENTER: JPL

SUPPORTING FIELD CENTER(S):

SPECIFIC OBJECTIVES AND TARGETS: A flight/ground demonstration is proposed to develop and verify Autonomous Guidance and Navigation Technology for future unmanned planetary missions. The development plan is consistent with a demonstration on the Jupiter Orbiter mission launch opportunity in December 1981. A similar mission is possible thirteen months later.

The flight/ground demonstration will demonstrate the ability to carry out all the functions that an autonomous on-board system would perform. The proposed arrangement of flight equipment and ground equipment is most cost effective and allows optimum flexibility to complete the demonstration during the mission lifetime. The earliest demonstration will result from observations of the Moon against a star background shortly after launch. This data will be compared to conventional ground based radio tracking. The orbiter phase allows multiple satellite encounters during which parts of the design can be evaluated and retried.

Since the computer is on the ground and accessible, it is possible to continue software development after the spacecraft is launched. During the near-Earth mission phase pre-flight versions of the software will be used to process the optical data of the Earth-Moon system and the experience gained will influence the final software design.

Specific objectives are to develop and demonstrate:

A. On-Board Activities

1. Image processing of star and target data.

2. Target acquisition and automatic tracking.

3. Target center finding.

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12.

Autonomous Systems

A. Roving Vehicles

Autonomous systems are required for many of NASA's future missions. Of particular importance are roving vehicles which could provide the means for surface exploration of the planets in our solar system. There is a need to demonstrate the abilities of prototypes to interact with complex and unpredictable environments as well as with the ground system.

Relevant New Initiatives:

1. Prototype roving vehicle for planetary surface exploration. (Summary attached)

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: Prototype Roving Vehicle for Planetary Surface Exploration

Program:

Lead Field Center: JPL

Supporting Field Center:

Specific Objectives and Targets: To develop and demonstrate a prototype roving vehicle and ground system capable of supporting scientific studies on other planets and planetary satellites under direction of Earth-based scientists. The remote system (robot) will incorporate hardware providing resistance to the harsh environments anticipated, great mobility, sensing for automated system maintenance, and self-regulated energy and communication systems. The computing system will capitalize on the new microprocessor system architectures and ultra-high density mass storage technology to provide the necessary power and compactness. The remote software will incorporate the algorithms needed for planning and decision-making at the commanded sub-task level, the error-detection, self-diagnosis and self-repair facilities of partially automated system maintenance, and budgeting of energy.

The ground system will be designed to capitalize on the increased autonomy of the remote machine to simplify ground operations. Computer generated displays will keep the operators fully informed on machine status. The robot will respond to simplified commands and reply in kind. The mission operations system will be designed to be more transparent to the scientist-user than are present systems. The prototype rover and ground system will be completed by 1984 and undergo testing and modifications during 1985 and 1986.

Justification: Missions of great interest are those concerned with the detailed scientific exploration of the outer planets and their satellites to search for life and to ascertain the history of the solar system. Such missions are characterized by scientific complexity and unpredictable environments. The remoteness precludes direct human control. The feasibility of constructing machines with the necessary autonomy is now being demonstrated. The feasibility study neglects questions of reliability, energy management, self-repair, computer architecture and miniaturization, and ruggedness. Instead it concentrates on advancing the state-of-the-art of machine intelligence and integration of selected functions. The proposed initiative will establish the necessary degree of confidence in all system functions to undertake missions that will employ robots. The prototype will also demonstrate the large increase in information delivered by the mission (100X) made possible by its employment, and the decrease in mission support costs due to simplified ground procedures.

Resources: (FY'78 $)	FY'78	FY'79	FY'80	FY'81	FY'82	FY'83	FY'84	FY'85	FY'86	Total
Total R/AD NOA ($,M)	3	4	5	6	6	6	7	7	7	50

RETURN OF MATTER: ASCENT NAVIGATION

Autonomous ascent and rendezvous and docking techniques will have to be developed for implementation when leaving the target body. Earth-based control will not allow such functions to be performed due to the significant round-trip light-time delay compared to the rapid reaction time required between observation and action. The system that performs autonomous rendezvous and docking at a distant planet could also be used upon return to Earth, or could be over-ridden by ground controllers.

Mission design and analysis software appropriate for Phase A and B studies is currently non-existant. This precludes the ability to perform parametric trade-off studies which are critical to the design of many hardware subsystems.

RELEVANT NEW INITIATIVES

1. Autonomous Rendezvous and Docking

2. Software Development for Return of Matter Mission Design

4/13/76

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2. Software Development for Return of Matter Mission Design

NAVIGATION

Both return of information and return of matter missions envisioned in the period 1985-2000 will require navigation technology beyond extensions anticipated through evolution of current state of the art. Requirements of maximum information return per unit cost will require critical delivery of the science instruments field of view at the target through both flight path control and instrument pointing control. In addition, sample return from a solid body will require advances in ascent, and rendezvous and docking guidance/navigation technologies. The role of autonomous on-board systems will be unprecedented by today's standards. This will be particularly true on missions to distant targets where the round-trip communication time exceeds the required reaction time (interval between the last navigation measurement and thrust or instrument pointing maneuver) or periods of communication blackout (occultation or radio/tracking system anomaly). The development of Autonomous Guidance and Navigation System technology is just now beginning.

This material does not address the navigation and guidance technology developments required for remote roving vehicles for insitu information/sample acquisition. This is covered under autonomous systems.

RELEVANT NEW INITIATIVES

1. Autonomous Guidance and Navigation Flight/Ground Demonstration

2. Autonomous Guidance and Navigation Operational System

3. Low Cost Navigation System Development

LOW THRUST NAVIGATION

It appears that Low Thrust capabilities will be required for certain high energy missions which would be of scientific interest. The navigation techniques for Low Thrust missions are different than those required for ballistic missions, and need further development. Low thrust includes NEP, SEP and Solar Sailing concepts. Existing mission design and analysis software to support Phase A and B studies is not adequate for the navigation analysis prior to project approval.

RELEVANT NEW INITIATIVES

1. Low Thrust Navigation System Technology Development

NAVIGATION

Both return of information and return of matter missions envisioned in the period 1985-2000 will require navigation technology beyond extensions anticipated through evolution of current state of the art. Requirements of maximum information return per unit cost will require critical delivery of the science instruments field of view at the target through both flight path control and instrument pointing control. In addition, sample return from a solid body will require advances in ascent, and rendezvous and docking guidance/navigation technologies. The role of autonomous on-board systems will be unprecedented by today's standards. This will be particularly true on missions to distant targets where the round-trip communication time exceeds the required reaction time (interval between the last navigation measurement and thrust or instrument pointing maneuver) or periods of communication blackout (occultation or radio/tracking system anomaly). The development of Autonomous Guidance and Navigation System technology is just now beginning.

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RELEVANT NEW INITIATIVES

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PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

TITLE: Software Development for Return of Matter in Mission Design

PROGRAM:

Lead Field Center: JPL

Supporting Field Center(s):

Specific Objectives and Targets: A broad development of specialized software to support mission design is proposed. These softwares are needed to analyze mission-related spacecraft and subsystem parameters for: (1) "Round Trip"(i.e. typical of sample return) missions, (2) autonomous surface ascent to orbit and (3) autonomous acquisition, rendezvous and docking.

Justification: At the present time, capability to define nominal spacecraft and subsystem parameters and evaluate the interplay of changes in subsystem operations for these three specialized areas is extremely limited due to near non-existant software. These analytical tools are critical to establish preliminary estimates of such factors as mass, geometry, power requirements, etc.; they are equally important in establishing the impact on total system operation as a consequence of a change in some subsystem function or specification (e.g. the interplay of rendezvous closure rates, propulsive gates and tracking sensor specifications). This solution is required for any Phase A and B mission planning activities. Availability of this software in FY'80 is appropriate for the FY'88 Mars surface sample return opportunity.

Resources: (FY'78 $)	FY'78	FY'79	FY'80	TOTAL
Total R/AD NOA ($, M)	0.4	0.4	-	0.8

SOLAR SYSTEM SCIENCE

PHASED APPROACH

- RECONNAISSANCE
- EXPLORATION
- INTENSIVE STUDY

THEME:	EXPLORATION OF THE SOLAR SYSTEM	
MISSIONS:	RETURN INFORMATION	RETURN MATTER
IMPLEMENTATION:	PLANETARY EXPLORATION FACILITY	SAMPLE RETURN CAPABILITY
APPLICATION:	OUTER PLANETS AND THEIR SATELLITES	TERRESTRIAL PLANETS, ASTEROIDS, COMETS, JUPITER SATELLITES

THEME PACKAGE ORGANIZATION

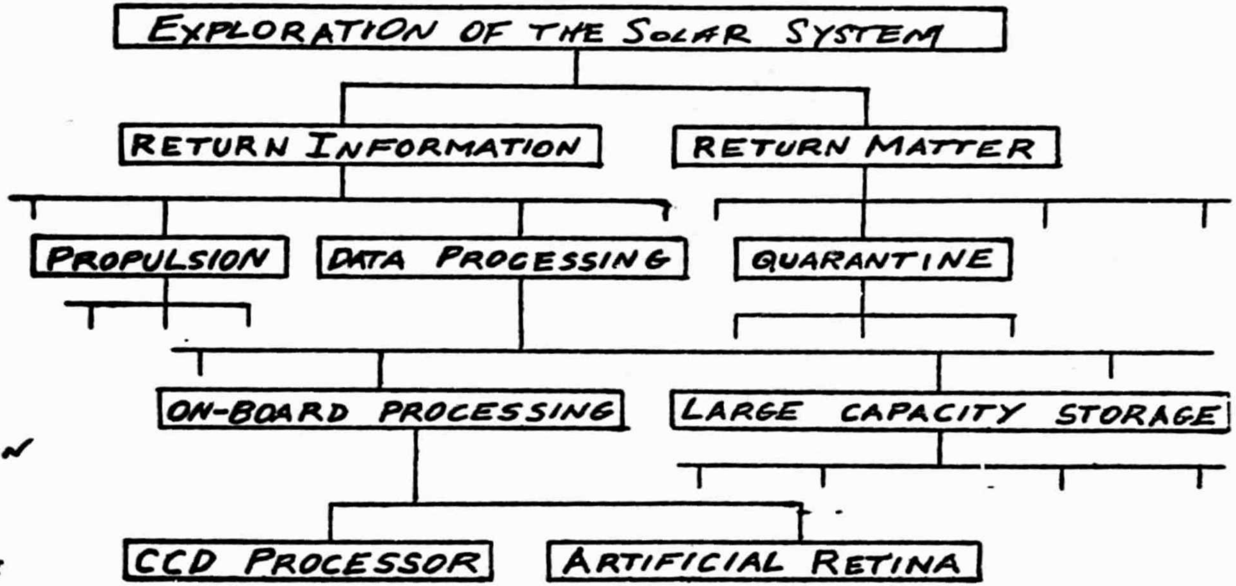
THEME:
- DESCRIPTION
- ADVOCACY

MISSIONS:
- DESCRIPTION
- OBJECTIVE

FUNCTIONS:
- DESCRIPTION
- OBJECTIVE

TECHNOLOGIES:
- DESCRIPTION
- OBJECTIVE

INITIATIVES:
- DESCRIPTION
- OBJECTIVE
- BENEFITS
- WHEN START
- SCHEDULE
- COST
- MANPOWER



NEW THEME PACKAGE ORGANIZATION

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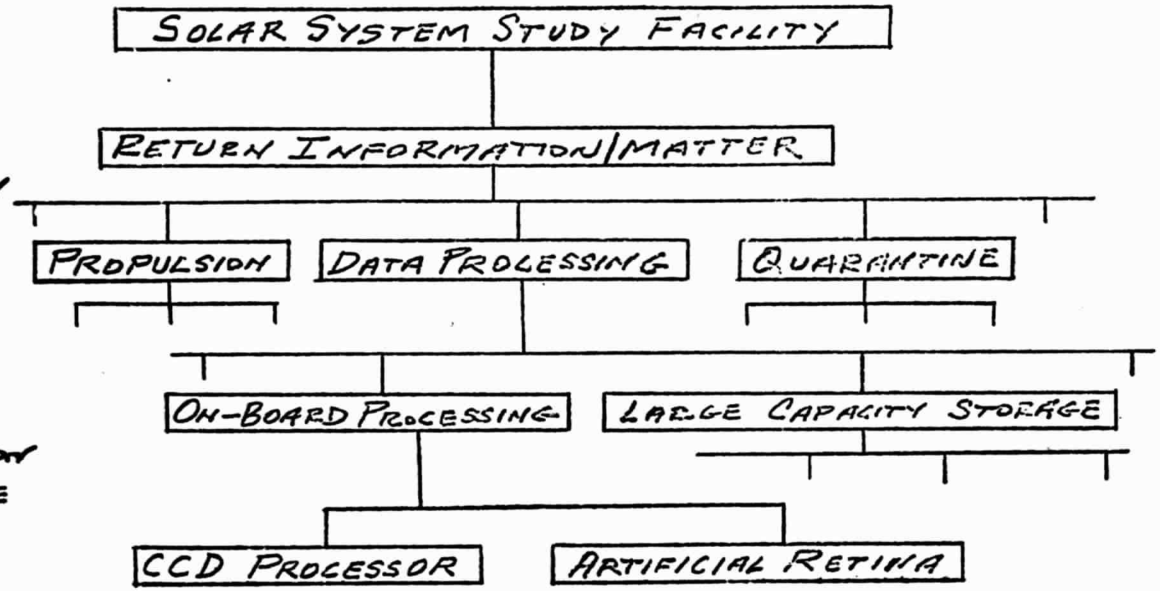
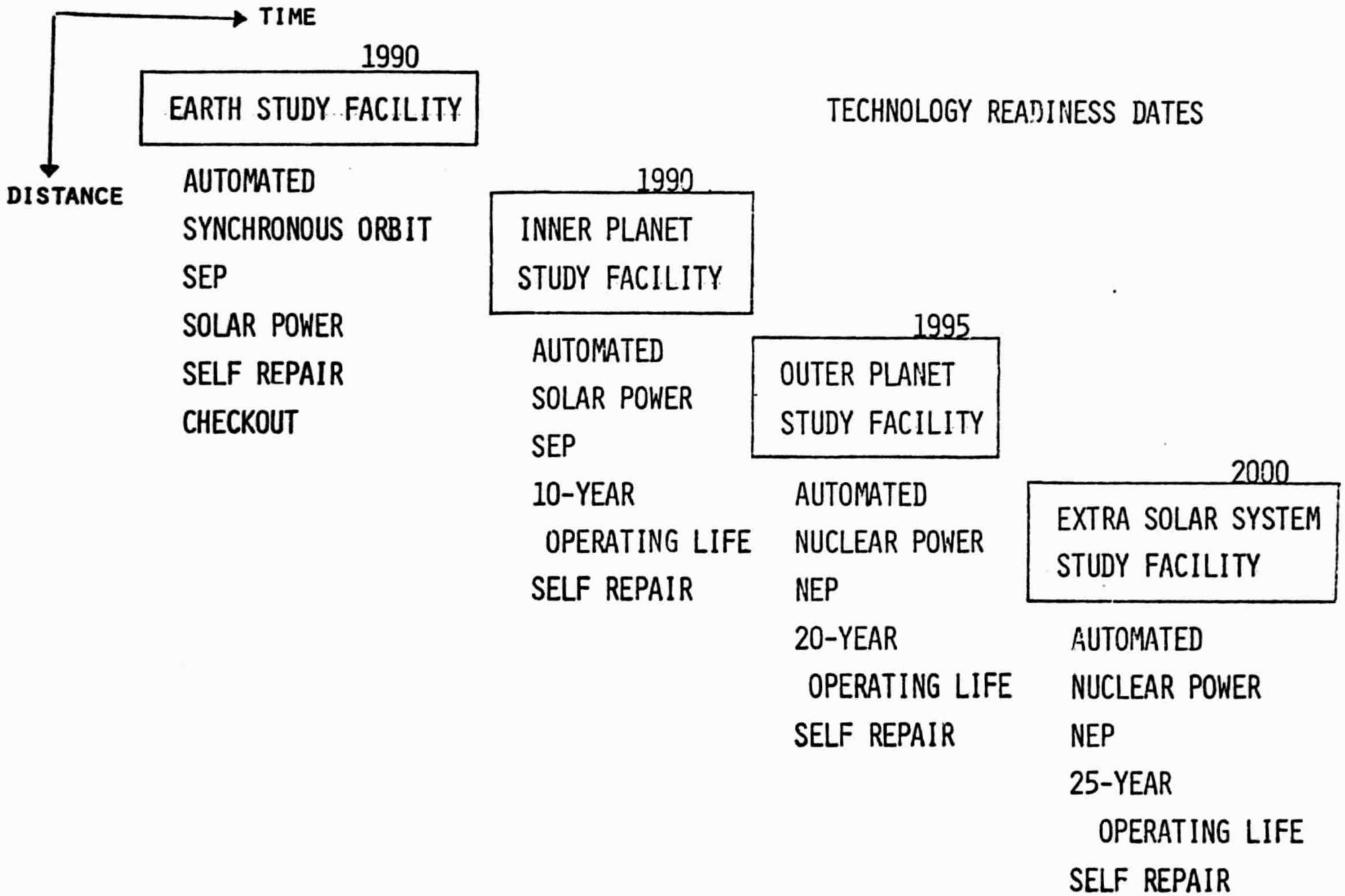


SOLAR SYSTEM STUDY FACILITY

- PROPULSION (NUCLEAR ELECTRIC)
- REMOTE SENSING
  - SURFACE
  - ATMOSPHERE
  - MAGNETIC FIELD
  - GRAVITY
- IN SITU SENSING
  - ATMOSPHERIC PROBES
  - SURFACE PENETRATORS
  - ROVERS
- AUTONOMOUS ANALYSIS LABORATORY
- ON BOARD DATA PROCESSING
- SAMPLE RETURN
  - SELECTION
  - ACQUISITION
  - PROCESSING
    - PRESERVATION
    - QUARANTINE
    - PACKAGING
  - RECOVERY
    - RECEIVING
    - STORAGE

SOLAR SYSTEM STUDY FACILITY DEVELOPMENT AND UTILIZATION SCENARIO



KEY ISSUES

- LONG LIFE
  - o RELIABILITY
  - o SELF CHECK AND REPAIR
- AUTONOMOUS OPERATIONS
  - o DECISION MAKING
  - o SELF REPAIR
  - o ON BOARD PROCESSING AND ANALYSIS OF DATA
- UNIVERSAL UTILITY

VOLUME II

IV - C

1. SOLAR SYSTEM EXPLORATION FACILITY

Summary Comments on Technical and Program Approaches Resulting from Workshop Activity

GENERAL:

The individual working groups exhibited considerable inovative thinking in support of our theme. The major technology drivers of power, propulsion, and data handling/control were considered in depth. Programatic factors such as severe step functions in technology development and mission evolution were identified as the most disturbing aspects of the theme.

Changes in thinking due to the workshop:

Propulsion and power system concepts were expanded to consider such technologies as MPD thrusters, laser powered propulsion systems, metallic hydrogen fuels and others. While the technological future of such systems is uncertain their potential benefits warrent consideration as future hardware.

With regard to power conversion and storage systems the recycable H_2O_2 fuel cell may prove to be a superior energy storage device even when compared to advanced electrochemical storage systems such as lithium batteries. Radiation shielding and management pose special problems on operations such as rendezvous and docking and may effect sample processing activity.

Lightweight shielding development as suggested by the materials working group may reduce this problem significantly.

Data Systems and Autonomous Control

The requirement for complex data systems and large memories were addressed and pleasant surprises occurred when new software techniques were suggested. Automated programing techniques and validation/verification processes can be available and will be required for proper software development. Computer system emulation techniques will assure compatibility between hardware and software as these two components must be developed concurrently and in fact can be viewed as two sides of the same coin.

A vast selection of candidate instruments and sensors were proposed for the scientific payload. Without exception the instruments were regarded as scientifically valuable. The problem we experienced was in trying to assign priorities. Ultimately we adopted the position that the exploration facility should be viewed at least in part as a service mechanism to the scientific community in much the same way that a large astronomical telescope is constructed as a service to the astronomical community. In short, we as spacecraft and mission designers should not (and possibly cannot) attempt to foresee the detailed scientific objectives likely to occur over the next 25 to 50 years. What we must do however, is recognize that scientific objectives with regard to observational and measurement requirements will continue to expand and must be supported.

We recommend that a special activity be initiated by OAST to select and develop candidate sensor systems for future space missions. In this way the scientific objectives can be coordinated into a science enhancement structure.

The most significant problem by far to be identified is related to programatic rather than technical factors. The orderly development of supportive technology is dependent upon the nature of evolution of spacecraft missions. The currently envisioned mission set for the 1980's depends upon development of high temperature solar cells, solar sailing technology, solar electric propulsion, etc. However, the solar system exploration facility depends upon nuclear sources of electrical energy and very advanced autonomous systems. This results in a sharp step function in technological requirements at the beginning of the 1990's unless a more uniform technology growth can be established.