NASA TECHNICAL MEMORANDUM

NASA TM X-3486

NASA TM X-3486

OAST SPACE THEME WORKSHOP

Stanley R. Sadin

Held at
Langley Research Center
Hampton, Va. 23665
April 26 - 30, 1976

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16. Abstract

This report summarizes the working papers from the OAST Space Theme Workshop held at Langley Research Center, April 1976. The workshop was attended by nearly 100 of the Agency's top technologists and scientists who joined with 35 Theme specialists to produce a document that provides a technical foundation including research and technology base candidates for each of six space themes – space power, space industrialization, search for extraterrestrial intelligence, exploration of the solar system, global service, and advanced transportation systems. The material is mainly intended for further use by workshop participants and NASA elements concerned with space research and technology. While the data presented do not represent official plans or positions, they are part of the process of evolving such plans and positions. The information contained in the report reflects the efforts of workshop participants and should be an aid in the successful implementation and execution of the Agency's near- and far-term advanced technology program.

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FOREWORD

This report summarizes the working papers from the OAST Space Theme Workshop held at Langley Research Center, 26-30 April 1976, and contains a quick-look analysis of the proceedings. The material was 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 six space Themes.

The material in this report was considered essential to the development of Center initiatives in support of these Themes. Due to the timing of the planning activity, an unedited version of this report was distributed earlier. The information contained in this report reflects the efforts of the Workshop participants and was invaluable to the planning and successful execution of the Agency's near- and far-term advanced technology program.

Since the time this Workshop was held, the six specific space Themes have evolved into three broad Themes: Industrialization of Space, Exploration of the Universe, and Global Services. Contained in these three Themes are components from the six specific Themes used in the Workshop. The final Themes require significant technological advancement which will also provide substantial benefit to the missions of the 80's. The "proposed new initiatives" presented in these reports indicate the types of technology developments which are required to support the Themes. Appearance of a proposed new initiative in these reports should in no way be construed as indicating that funding for the initiative is or will be available. The intent of including the proposed new initiatives in these reports is to provide a record of the research and technology needs which the Workshop participants considered applicable to the Workshop Themes.

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

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Part 2—Space Industrialization

Part 3—Search for Extraterrestrial Intelligence

Part 4—Solar System Exploration

Part 5—Global Service

Part 6—Advanced Transportation Systems

SECTION III—RESEARCH AND TECHNOLOGY BASE SUMMARY

Section I

SUMMARY REPORT

INTRODUCTION

BACKGROUND

OAST is instituting a new approach to the identification of technology initiatives and supporting program requirements. Rather than selecting and advocating new initiatives and programs from among a large number of loosely associated candidates submitted by the Centers, OAST is in the process of developing a technique using Program (Mission) Themes to focus initiative and program requirements. The Space Themes selected by OAST, resulting from the Outlook for Space Study, consideration of National needs and OAST technology goals, and with confirmation from appropriate NASA Program Offices, are:

- Space Power Station
- Search for Extraterrestrial Intelligence
- Space Industrialization
- Global Service Station
- Exploration of the Solar System
- Advanced Space Transportation System

These Themes were selected as exciting future space opportunities capable of driving technology R&T and acquiring internal and external advocacy support on a program-focused basis. In addition to these Themes, special attention is given to the implications of the Themes on the Research and Technology Base program.

The work of helping to identify these initiatives and their supporting programs has been assigned to newly developed Working Groups (WG) and Theme Teams (TT) made up of Headquarters and Center representatives covering NASA's major space activities. This representation is noted in Attachments 1 and 2.

WORKSHOP ORGANIZATION AND ATTENDANCE

To assist OAST in the development of its FY '78 program plan and its candidate technical initiative, and supporting program plans the "Space Theme Workshop," being reported here, was promulgated. Workshop attendance is reported in Attachments 3, 4, and 5; Working Group, Theme Team, and Operations, respectively.

The major objective of the Workshop was to develop technology needs, requirements, and proposed program plans in support of each Space Theme. In this process, the Workshop identified possible changes and additions to initiatives submitted by the Centers pertinent to the Themes.

INTRODUCTION (Cont.)

In addition, the Working Groups generated candidate disciplinary technology programs that will be used to test OAST's technology goals.

The Workshop was structured to provide maximum interaction of the Space Theme Teams with the Working Groups in order to more fully and meaningfully develop the technology initiatives and program projected to support the initiatives. The work flow plan is shown in Fig. 1.

Report Content

This report presents an overview of the Workshop activity and the working papers of the Workshop TT's and WG's. No attempt was made to have the assembled group develop a consensus position on the complex matters considered. Rather, the material is intended to provide basic information for further study and comparative analysis with ongoing activity and plans, and to assist in the modification of these plans to enhance NASA's technology program.

This Summary volume (Sect. I) of the report contains some general observations and key findings. The following two volumes present summary comments and the working papers of the Theme Teams (Sect. II) and the R&T Base (Sect. III).

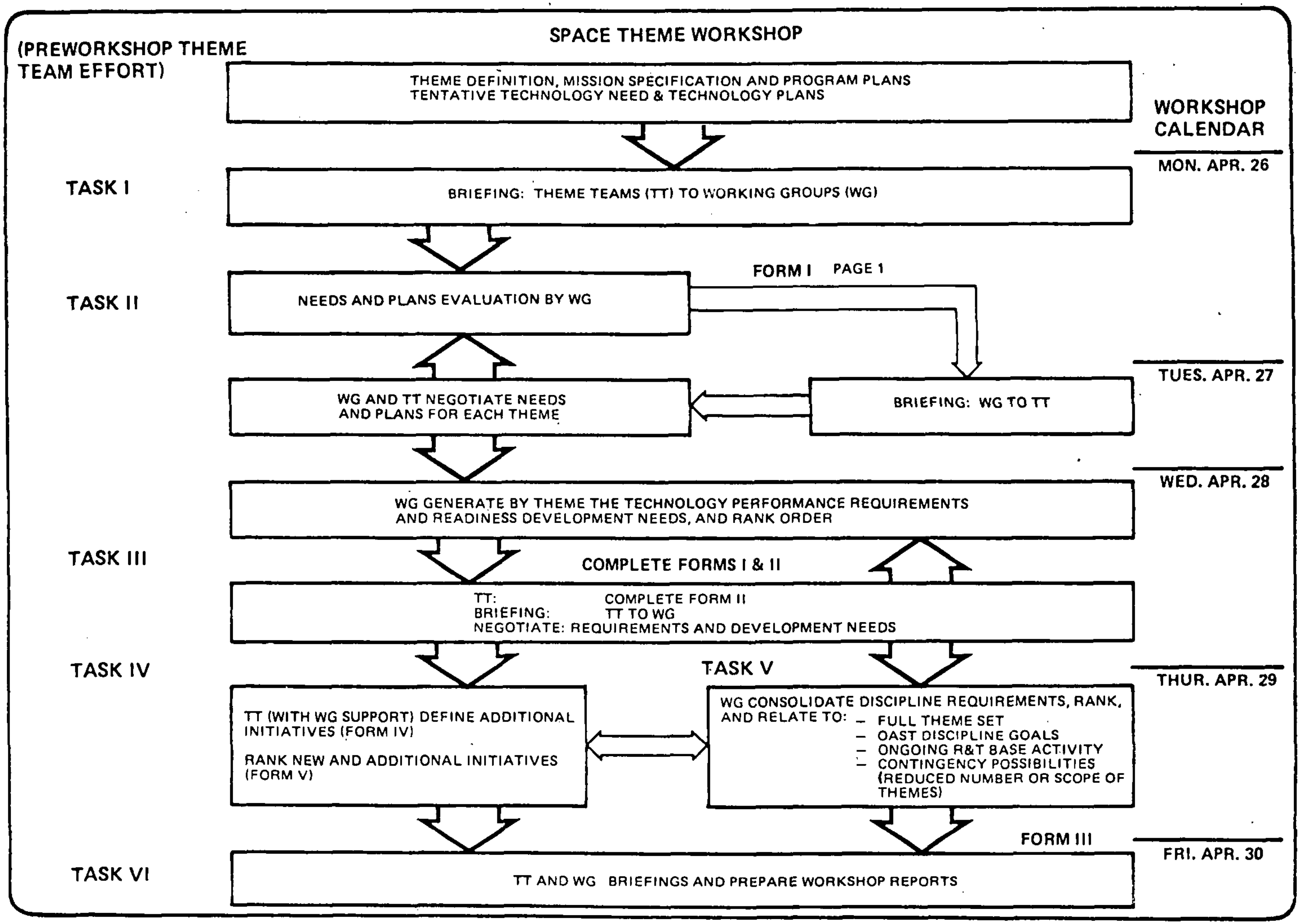
SPACE THEME WORKSHOP
(PREWORKSHOP THEME TEAM EFFORT)
THEME DEFINITION, MISSION SPECIFICATION AND PROGRAM PLANS
TENTATIVE TECHNOLOGY NEED & TECHNOLOGY PLANS
WORKSHOP CALENDAR
MON. APR. 26
TASK I
BRIEFING: THEME TEAMS (TT) TO WORKING GROUPS (WG)
TASK II
NEEDS AND PLANS EVALUATION BY WG
FORM I PAGE 1
TUES. APR. 27
WG AND TT NEGOTIATE NEEDS AND PLANS FOR EACH THEME
BRIEFING: WG TO TT
WED. APR. 28
WG GENERATE BY THEME THE TECHNOLOGY PERFORMANCE REQUIREMENTS AND READINESS DEVELOPMENT NEEDS, AND RANK ORDER
TASK III
COMPLETE FORMS I & II
TT: COMPLETE FORM II
BRIEFING: TT TO WG
NEGOTIATE: REQUIREMENTS AND DEVELOPMENT NEEDS
TASK IV
TASK V
THUR. APR. 29
TT (WITH WG SUPPORT) DEFINE ADDITIONAL INITIATIVES (FORM IV)
RANK NEW AND ADDITIONAL INITIATIVES (FORM V)
WG CONSOLIDATE DISCIPLINE REQUIREMENTS, RANK, AND RELATE TO:
– FULL THEME SET
– OAST DISCIPLINE GOALS
– ONGOING R&T BASE ACTIVITY
– CONTINGENCY POSSIBILITIES (REDUCED NUMBER OR SCOPE OF THEMES)
FORM III
FRI. APR. 30
TASK VI
TT AND WG BRIEFINGS AND PREPARE WORKSHOP REPORTS

FIGURE 1

GENERAL OBSERVATIONS AND SOME KEY FINDINGS

Figure 2 presents a summary of a few general observations about the Workshop. The Theme concept proved successful in stimulating the Working Groups to develop extensive list of technology needs which were jointly ranked, from a disciplinary perspective, by both the Theme Teams and Working Groups through a negotiation process. The Theme Teams, based on the negotiated disciplinary rankings, prepared a technology needs ranking for their respective Themes. These Theme rankings are presented in their entirety in Section II. Using only the top five technology needs for each Theme, a preliminary assessment of Theme technology needs was made. Figure 3 was prepared to identify key supportive technologies among the Themes. This list is summarized in Fig. 4. A more detailed examination and interaction of the data base developed by the Workshop will be undertaken by OAST in the program selection/budget process.

The Workshop activity closed with presentations by the Workshop Chairman and OAST Technology Panel Chairman.[1] These presentations covered:

- R&T Base — Attachment 7
- Electronics — Attachment 8
- Materials and Mechanics — Attachment 9
- Power — Attachment 10
- Propulsion — Attachment 11
- Theme Summary — Attachment 12

FOLLOW-ON ACTIVITY

This Workshop material will be reviewed and assessed at NASA Headquarters and at the Centers. It will be used to assist in the updating of OAST space technology plans, the modification of previously proposed "New Initiatives," and the generation of totally "New" FY 78 Initiatives.

The present plan is to have the OAST divisions and Offices request the update of earlier program and initiative submissions. The Workshop report and recommendations will be processed through OAST Working Group Panels, Management Board and Steering Committee, and into the program/budget cycle within the Agency--leading to submission to the Administrator in August.

The Theme Teams and OAST Management will complete the Workshop technical plans and further develop the Themes and their advocacies. Consideration will be given to establishing task teams to pursue more complex interdisciplinary technology programs.

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[1] NOTE: An outline of the "OAST Space Technology Working Group Process" is Attachment 6.

WORKSHOP OBSERVATIONS

- THEMES PROVED EXTREMELY STIMULATING
- WORKSHOP SHARPENED THEME TECHNOLOGY REQUIREMENTS
- HIGH LEVEL OF INTEREST & SUPPORT OF THEME PROCESS
- MANY ON-THE-SPOT CREATIVE CONCEPTS AND APPROACHES
- IDENTIFIED UNANTICIPATED PROBLEMS AND POSSIBLE SOLUTIONS
- EXCELLENT TRANSFER OF THEME AND TECHNOLOGY UNDERSTANDING
- OUTSTANDING COMPETENCE AND DEDICATION
- GOOD INTERPERSONAL INTERACTIONS
- LITTLE CENTER PAROCHIALISM
- NEAR-TERM NEEDS NOT IN THEMES IDENTIFIED BY WGs
- OUT-OF-SCOPE PROBLEMS - PREDICTIVE MODELING
  OPERATIONAL SYSTEMS
  LUNAR MATERIALS PROCESSING
  COMPREHENSIVE SENSOR R & T PROGRAM

Figure 2

PRELIMINARY THEME ASSESSMENT OF TECHNOLOGY NEEDS

TECHNOLOGY NEED \ THEME	7 SPACE POWER	8 SPACE INDUST.	9 SETI	10 SOLAR SUP. EXPL.	11 GLOBAL SERVICE	12 ADV. TRANS.
• Autonomous Operations and Systems, Teleoperators,		4		3		4
and Software for Autonomous Operations						3
• End-to-End Data Mgt. Systems Hardware and Software			3	4	1	
• Software for Data Analysis			2		2	
• Sensing and Signal Conditioning			1	5	3	
• Attitude Control & Precision Pointing		3			4	
• Large Space Structures (Assembly, Deployment and Control)	2	1	5			
• Advanced Propulsion (High-Pressure Engine, NEP, MPD)		5		1		1
• Advanced Materials for Structures, Cryogenics, Power Generation	5		4		5	2
• Space Power Generation	3	2		2		
• Theory and Experiments on High Voltage Space Plasma Interactions	1					
• Laser Power Transfer	4					5

Figure 3

KEY THEME TECHNOLOGY NEEDS SUMMARY

- Software for Data Analysis
- Advanced Propulsion (NEP, MPD, and High Pressure Engines)
- Space Power Generation
- Large Space Structures (Assembly, Deployment, and Control)
- End-to-End Data Management (Hardware and Software)
- Sensing and Signal Conditioning
- Autonomous Operations and Systems (Robotics and Teleoperators)
- Precision Pointing (Non-Inertial)

Figure 4

ATTACHMENT No. 1

OAST SPACE TECHNOLOGY WORKING GROUPS

MEMBERSHIP AS OF APRIL 30, 1976

CENTERS	NGC E-1	E-2 COMM/DATA HANDLING	SENSORS E-3	SOFTWARE E-4	M-1 MATERIALS	STRUCTURES/ DYNAMICS M-2	M-3 AEROTHERMO/ DYNAMICS	P-1 PROPULSION	POWER P-2
ARC	K.R.Lorell	Dale Lumb	Henry Lum	W.P. Jones	H. Nelson H. Larson	---	B. Swenson	---	---
DFRC				(NO MEMBERS APPOINTED)					
GSFC	D.L.Brandel	Ron Muller	J.Eckerman L. Korb	L.Koschmeder	S.Ollendorf C. Vest	Joe Young	---	A. Yetman	F. Ford
JPL	R.Powell T.W.Hamilton W.E.Bachman	R. Powell R.H. Nixon J.C.Springett	D. Morris	W. F. Scott	C. N. Savage	F.VanBiene	B. Dayman	D.Dipprey	L.D.Runkle P. Weiner J. Stearns
JSC	R.C.Kennedy	M. Engert	T.K.Sampsel A.E. Potter	J.D.Axelander	R.L.Johnston	B.W.Holder	L.O.Hayman R.C. Ried	C.W.Yodzis	W.Dusenbury
KSC	M.Chambers	T.P.Hershey	H.Williams	F.R.Penovich	R. Arbic	W.E.Clautice	G. Ely	W.Mahorey	W. Chandler
LaRC	W.W.Anderson	W.M.Moore	J.A. Dodgen	E.C.Foudriat	B. Stein	M. F. Card	G.D.Walberg	---	---
LeRC	---	J. Bagwell C. Anzig	H. Mark	---	N.Saunders	R. Johns	---	R. Fink P.Petrash J.Gregory	J.Fordyce/ R.Migra N.Stevens/ J.Morris P. Thollot
MSFC	S.Seltzer	G.Wallace	John Gould	Bobby Hodges	C. Cataldo	C. Lifer	T.Greenwood	K.Chandler	C. Graff
HQ. Chairmen	Wm.Gevarter	H.Alsberg	B. Rubin	C.Pontious	B.Achhammer	D. Gilstad	P. Cerreta	F.Stephenson	J. Lazar (Acting)

ATTACHMENT No. 2

OAST ADVOCACY TEAM MEMBERSHIP - SPACE

AS OF APRIL 30, 1976

No.	Theme Title	Hdqtrs (Code)	Center/Other Organizations
7	Multipurpose Space Power Platforms	F. Schwenk (RR) --Leader J. Lazar (RP)	R. Hook - LaRC Plohr - LeRC L. D. Runkle - JPL J. Craig - JSC Charles H. Guttman - MSFC Plotkin - GSFC Billman - ARC
8	Industrialization of Space	G. Deutsch (RW) --Leader J. Gangler (RW)	Kruszewski - LaRC Chambers - ARC Blankenship - LeRC Stearns- JPL McKay - JSC Cataldo - MSFC Fogelson (BuMines) D. Criswell (Lunar Sci. Inst.)
9	Search for Extra-terrestrial Intelligence	S. Sadin (RX) --Leader W. Gilbreath (RX) F. Schwenk (RR) H. Alsberg (RE) I. Rasool (S) R. Young (S) R. Freitag (M) L. Fero (M) F. Bryant (T)	J. Billingham - ARC Edelson - JPL Pieper - GSFC C.Seegar - ARC J. Wolfe - ARC
10	Exploration of the Solar System	A. Henderson (RC) --Leader B. Rubin (RE) F. Stephenson (RP) J. Lundholm (RR) J. Maltz (RW) R. Chase (RX) D. Herman (S)	Friedman - JPL Powell - JPL

OAST ADVOCACY TEAM MEMBERSHIP - SPACE (Cont.)

No.	Theme	Hdqtrs (Code)	Center/Other Organizations
11	Global Service Systems	C. Pontious (RE) --Leader	Sivo - LeRC
		D. Gilstad (RW)	Hibbs - JPL
		E. Cohn (RP)	(None) - JSC
		W. Gilbreath (RX)	Wallace - MSFC
		McConnell (E)	Peake - GSFC
		Kauffman (S)	Moore - LaRC
			J. Deerwester - ARC
12	Advanced Space Transportation Systems	W. Hayes (RS) --Leader	Swenson - ARC
		P. Herr (RS)	Henry - LaRC
		P. Cerreta (RA)	Thompson - DFRC
		W. Gevarter (RE)	Douglas - LeRC
		F. Stephenson (RP)	Davis - JSC
		J. Gangler (RW)	Spears - MSFC
		R. Chase (RX)	Col. Graetch - SAMSO
		K. Hodge (RO)	Ginn - JPL
		Fero (MT)	Nichols - KSC

ATTACHMENT No. 3

SPACE THEME WORKSHOP

WORKING GROUP PARTICIPANTS

CENTERS	NGC E-1	E-2 COMM/DATA HANDLING	SENSORS E-3	SOFTWARE E-4	M-1 MATERIALS	STRUCTURES/ DYNAMICS M-2	M-3 AEROTHERMO/ DYNAMICS	P-1 PROPULSION	POWER P-2
ARC	K.R.Lorell	E. VanVleck	J.Vorreiter	---	H. Nelson H. Larson	---	B.Swenson	---	---
GSFC	C.E. Velez	John Sos	J.Eckerman L. King L. Korb	R.desJardins T. Taylor L.Koschmeder	S.Ollendorf	---	---	A.Yetman	F. Ford
JPL	W.E.Bachman J.P.McDanell D.W.Curkendall C. Ivie	R.H. Nixon G.Garrison	D. Norris	R.V. Morris	C.N. Savage L.Stimpson	M. Trubert F. VanBiene	F.Livingston	E. Pawlik W. Gin	P. Weiner J. Stearns
JSC	R.C.Kennedy	M. Engert	T.K.Sampsel A.E. Potter F. Gibson D. Bogard	J.D.Alexander R. Stokes	L. Leger	B.W. Holder	L.O. Hayman	C.W.Yodzis	
KSC	M.Chambers	---	H. Williams	F.R.Penovich	W.E.Clautice	W.E.Clautice	G. Ely		B. Brown
LaRC	W.Anderson	W.M.Moore	A. Keafer J.A. Dodgen C. Swift	E.Foudriat	W. Slemp R. Swann	E.Naumann	Dr.Walberg	C. Eldred	---
LeRC	---	J. Bagwell G. Anzig	H.Mark	---	N.Saunders	G.T. Smith	---	R. Finke P.Petrash J.Gregory	J. Fordyce N.Stevens/ J.Morris P.Thollot
MSFC	S. Seltzer	G. Wallace	John Gould	Bobby Hodges	C.Cataldo	E.E.Engler C. Lifer	T.Greenwood	K.Chandler	C. Graff
HQ Chairmen	Wm.Gevarter	H.Alsberg D. Serice OTDA	B. Rubin	C.Pontious	B.Achhammer	D. Gilstad	P. Cerreta	P. Herr F.Stephenson	J. Lazar

ATTACHMENT No. 4

SPACE THEME WORKSHOP THEME PARTICIPANTS

	MULTI-PURPOSE SPACE POWER #7	SPACE INDUSTRIALIZATION #8	SETI #9	EXPLORATION OF SOLAR SYSTEM #10	GLOBAL SERVICE SYSTEM #11	ADV. SPACE TRANSPORTATION #12	R&T BASE #1
ARC			J.Billingham J. Wolfe C. Seeger				
GSFC					H. Plotkin		
JPL			R. Edelson	R. Powell R.R.McDonald C. Ivie K. Atkins	A. Hibbs		
JSC	J. Craig				P.D. Gerbe	H. Davis	
LaRC	R. Hook	E.Kruszewski			W. Moore	B.Z. Henry J. Decker	T.N.Shoosmith H. D. Orr W. Erickson
MSFC			J. Dozier		G. Wallace	L. Spears	
HQ:	C.Schwenk OAST	J. Gangler, OAST	S.Sadin OAST W.Gilbreath OAST	A.Henderson OAST R. Chase OAST	C.Pontious OAST	B.Hayes OAST	P. Kurzhels OAST
OTHERS:		D. Criswell Lunar Science Institute		D.Herman OSS	H.Ernst OA	L. Fero OSF R. Davis Samso/Aero-Space	

ATTACHMENT No. 5

SPACE THEME WORKSHOP

-OPERATIONS-

S. Sadin W. Gilbreath R. Chase	Headquarters
C. Tynan G. Boswick J. Yates A. Dunkley	LaRC
B. Maggin	System Consultants, Inc.
W. Cobb	West Virginia Graduate Inst.

ATTACHMENT No. 6

OAST SPACE TECHNOLOGY WORKING GROUP PARTICIPANTS

PURPOSE

OAST is responsible for providing NASA with technology required to accomplish future space objectives. To effectively accomplish this it is essential that R&T activities be planned and coordinated among responsible Headquarters and Field Center organizations. A competent interorganizational process is needed to accomplish this integration and to assess Agency technology. This process is primarily involved with the activities of a set of CENTER WORKING GROUPS. Their general guidance and direction derive from appropriate HEADQUARTERS PANELS and a CENTER MANAGEMENT BOARD. The overall process is reviewed and assessed by the HEADQUARTERS STEERING COMMITTEE.

THE WORKING GROUP PROCESS, FUNCTIONS, OPERATION, AND STAFFING

CENTER WORKING GROUPS, each covering a major technical discipline, constitute the main activity and are therefore central and critical to the success of the process. Each Center Working Group serves as a body of common discipline knowledge and interest representing all of the Agency's operating field centers. The Center Working Groups, meeting or teleconferencing at least quarterly, will maintain an awareness of all relevant activities within the Agency and, to the extent feasible, within the discipline as a whole. They will assess the composite results of ongoing Agency programs and, in an annual report, advise their Headquarters Panel of evaluations and recommendations regarding the quality of the total program and its individual parts. Each group will maintain or have generated, for incorporation in its annual report, an update of the Technology Forecast for its discipline responsibility. This report will also serve to identify voids and unproductive overlap of activities considering efforts internal and external to the Agency. Additionally, the report will recommend to OAST priorities within the Group's discipline. The Center Working Groups will, as requested, provide counsel and support to other Headquarters planning activities.

The Working Groups will meet as a body at an annual Technology Workshop. The annual Working Group reports serve as an input to, and starting point for, the Workshop. The results of this Workshop will be documented in a report for submittal to the Headquarters Steering Committee and the Center Management Board. The Working Groups will support the Headquarters Panels in the preparation of this Workshop document.

Center Working Groups will be staffed with Field Center members from each of those facilities conducting significant R&T in the designated disciplines. DoD members are to be included where appropriate. The Group members are to be recognized leaders in their technical disciplines and knowledgeable representatives of their Center activities. Working Group Chairmen will be Headquarters personnel selected by the Headquarters Panel and will, with the Center Management Board and the Panel, staff their respective groups.

OAST SPACE TECHNOLOGY WORKING GROUP PARTICIPANTS (Cont.)

The HEADQUARTERS PANELS will implement the Headquarters Steering Committee policies, directives, and other recommendations. They will be responsible for generating, with the assistance of their Working Groups, the Annual Workshop output reports. They will review and evaluate technology plans, including goals, objectives, an targets, of all relevant Agency R&T activity and organize joint reviews of technology programs as appropriate. The Panels will meet semiannually.

The Panels will provide direction to the Center Working Groups. They will evaluate, and respond to insofar as possible, Group recommendations for Headquarters action. The Panels will regulate task assignments to the Groups, and make any required arrangements for interagency, industry, or university participation in Working Group activities. With the assistance of the Center Management Board the Panels will ensure that the Center Working Groups are properly staffed, organized, and performing their function satisfactorily.

The INTERDISCIPLINE PANEL will deal with technology at the systems and/or multidiscipline level. It is essential that it work closely with the Center Working Groups, drawing upon the latters' expertise and providing them with needs and requirements. In support of the needs and requirements definition, a major responsibility of the Interdiscipline Panel will be to ensure information flow from the Headquarters Program Offices to the Center Working Groups. As part of this process a Users Workshop will be held one month prior to the annual Technology Workshop. A report of this activity will be submitted to the Working Groups as rapidly as possible, but at least one week prior to the Annual Technology Workshop. Working Groups supporting the Interdiscipline Panel will be established as required.

Panels will consist of representatives from each of the Headquarters Offices sponsoring R&T and will be chaired by an appropriate OAST Division Director. Panel members must carry the authority of their Offices relative to technology questions, thereby minimizing the number of issues to be referred for resolution.

The CENTER MANAGEMENT BOARD provides, for each Field Center, a focal point for its Working Group activities. Each Board member will provide guidance to his Center's Working Group participants by interpreting Center missions and roles, defining its needs and prioritizing Center technology interests. The Board member coordinates Working Group participation from his Center, insuring support, nominating candidates, and assuring appropriate dissemination of Working Group, Workshop, and other reports of value to the Working Group process.

The Board, as a body, attends the Annual Technology Workshop where it receives and evaluates the Headquarters Panel Reports. A broad critique is presented to the Steering Committee at the close of the Workshop; separate Board member reports may be submitted to expand on material of special interest or to establish unique Center positions. The Board shall call attention to issues requiring resolution by the Headquarters Steering Committee.

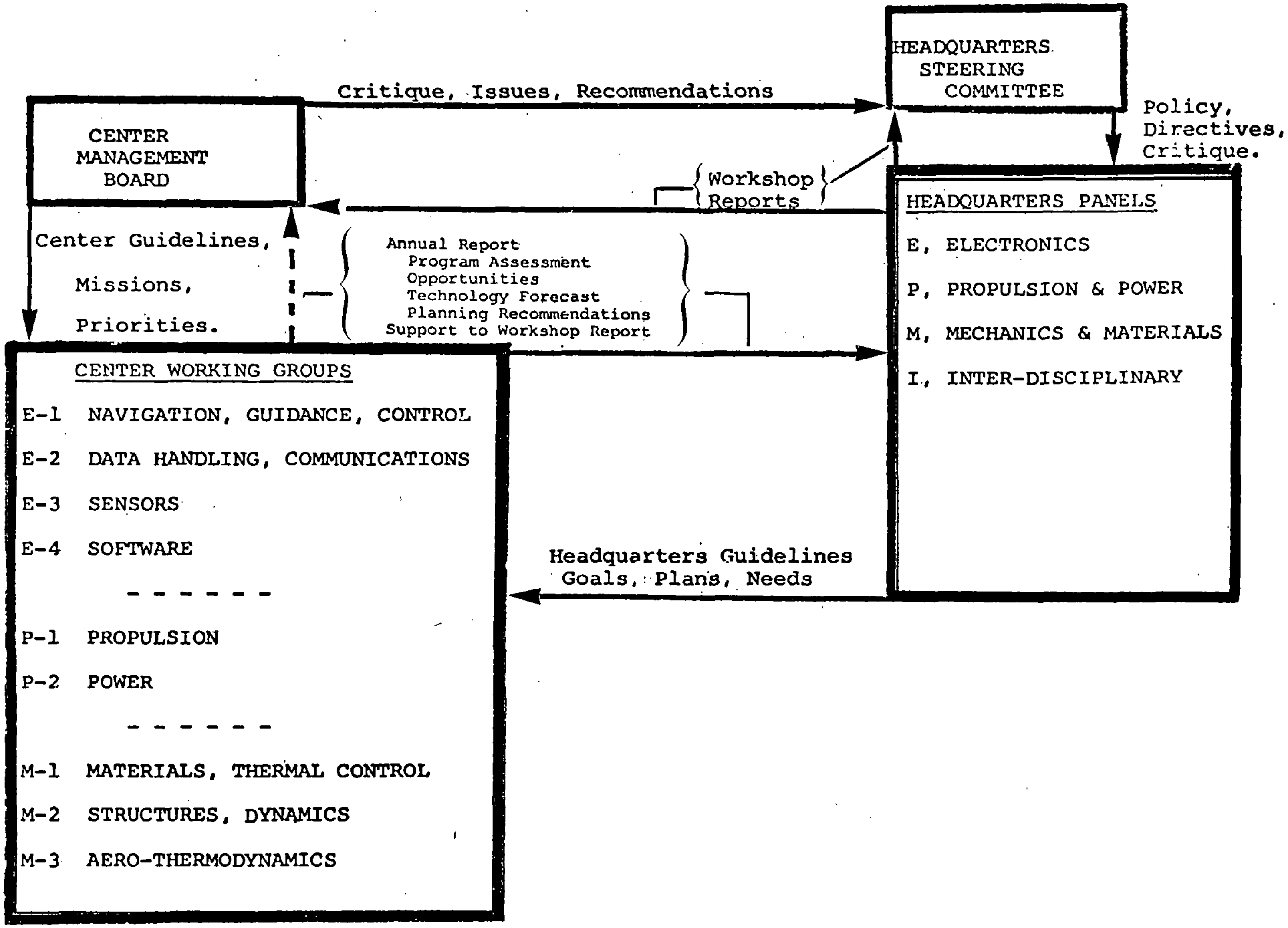
OAST SPACE TECHNOLOGY WORKING GROUP PARTICIPANTS (Cont.)

The Board Members, designated by their respective Center Directors, will be at the management levels normally responsible for the planning or execution of technology programs. A rotating Chairman will be selected by the Steering Committee at the Annual Workshop. The Annual Workshop is the only planned meeting of the Board, but informal communication among Board members is expected and encouraged.

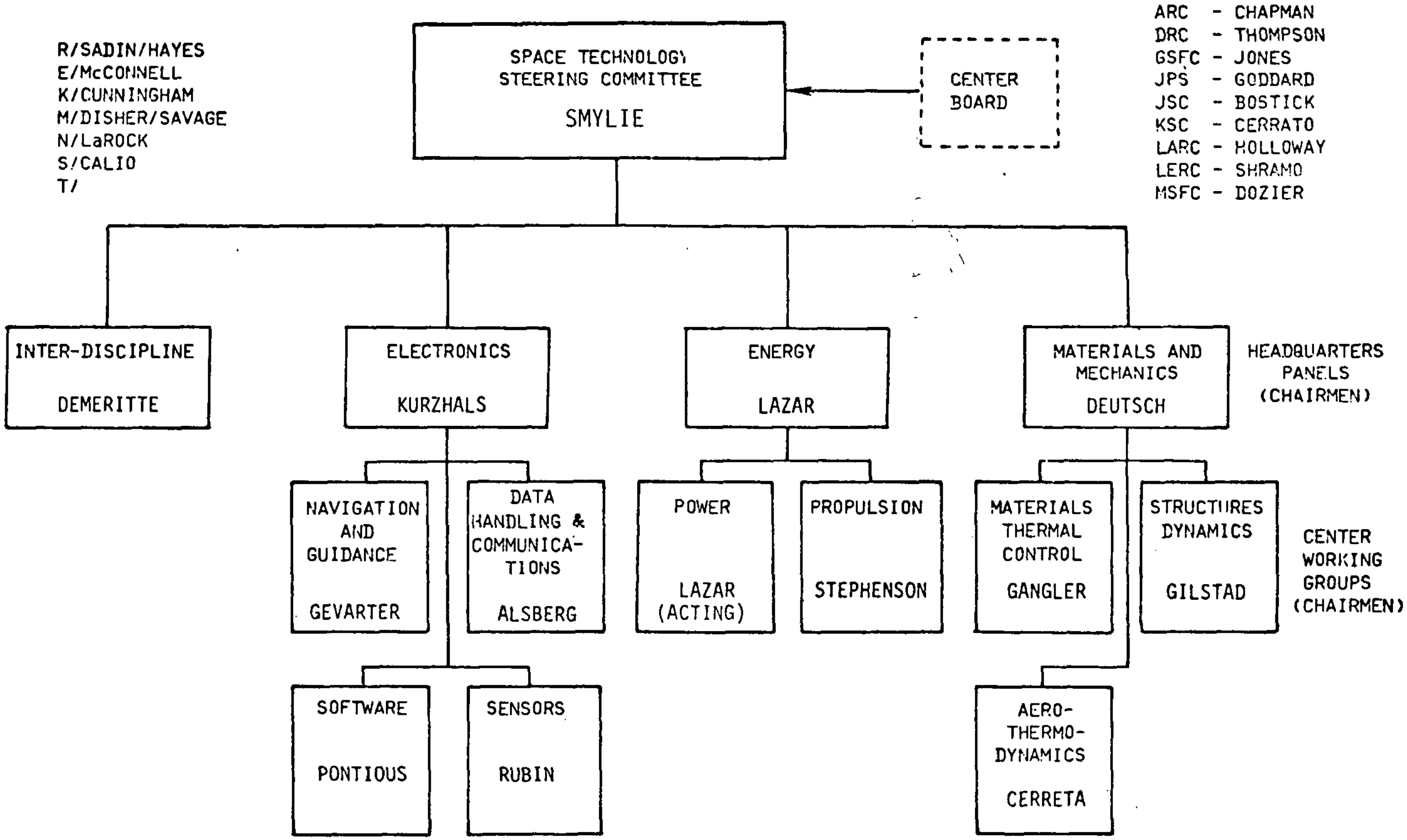
The HEADQUARTERS STEERING COMMITTEE FOR SPACE TECHNOLOGY will be convened annually for the Technology Workshop and further only as required to direct special actions or to resolve issues. The Steering Committee will receive and respond to reports from the Headquarters Panels and the Center Working Groups. The Committee will meet at the close of the Workshop with the Center Management Board, to receive and discuss the Board's critique. Immediately thereafter, the Committee will generate recommendations to the Associate Administrator, OAST, regarding organizational goals, objectives and plans. Issues involving policy interpretation, budget, or authority constraints will either be resolved or referred appropriately for decision.

The Steering Committee, chaired by the Deputy Associated Administrator, OAST, will be staffed by Headquarters management personnel from all offices sponsoring Space Research and Technology. The OAST, Study, Analysis and Planning Office, Code RX, will ensure the smooth functioning and coordination of the operations aspects of the Working Group systems. It will set objectives, procedures, standards, and schedules, and provide necessary support for the annual Workshops. To strengthen the interorganization quality of the Working Group operation, it is proposed that a rotating Center assignee to RX will serve full time as one of this staff.

THE SPACE TECHNOLOGY WORKING GROUP PROCESS



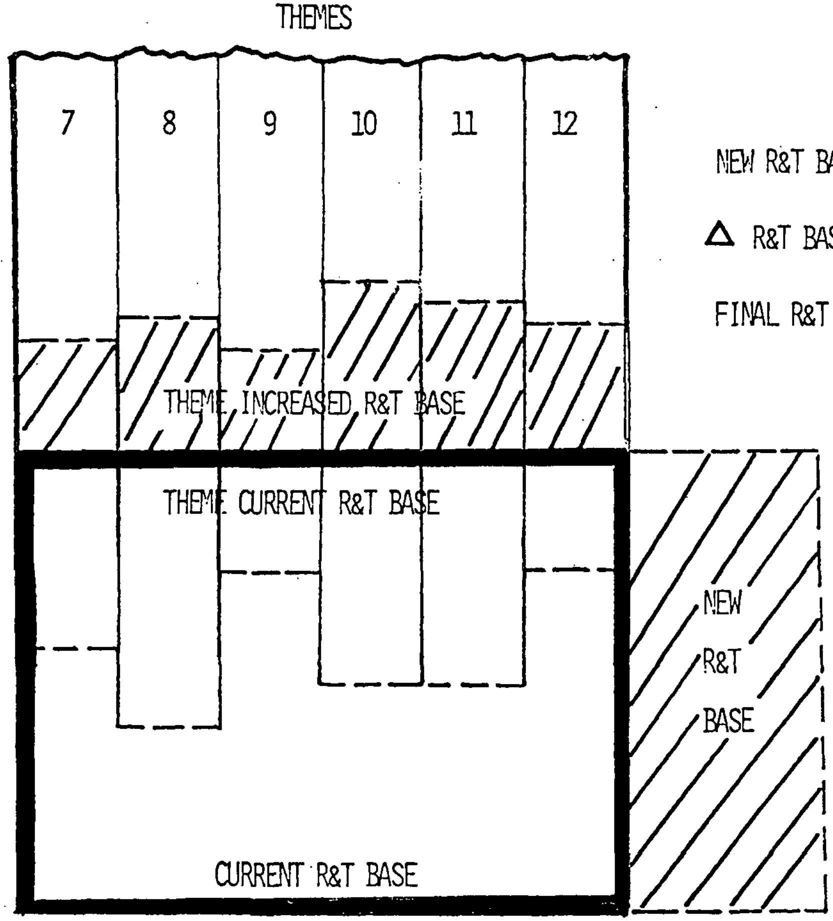
THE WORKING GROUP PROCESS



ATTACHMENT No. 7

R&T BASE

R & T BASE APPROACH

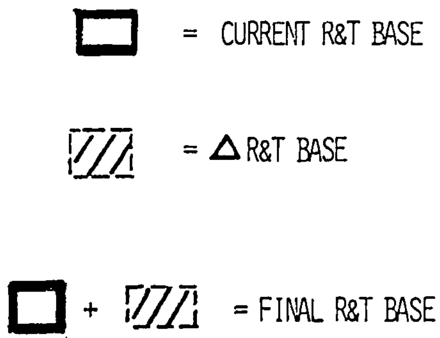


NEW R&T BASE = THEME CURRENT R&T BASE

Δ R&T BASE = (THEME INCREASED + NEW) R&T BASE

FINAL R&T BASE = (CURRENT + Δ) R&T BASE

WHERE



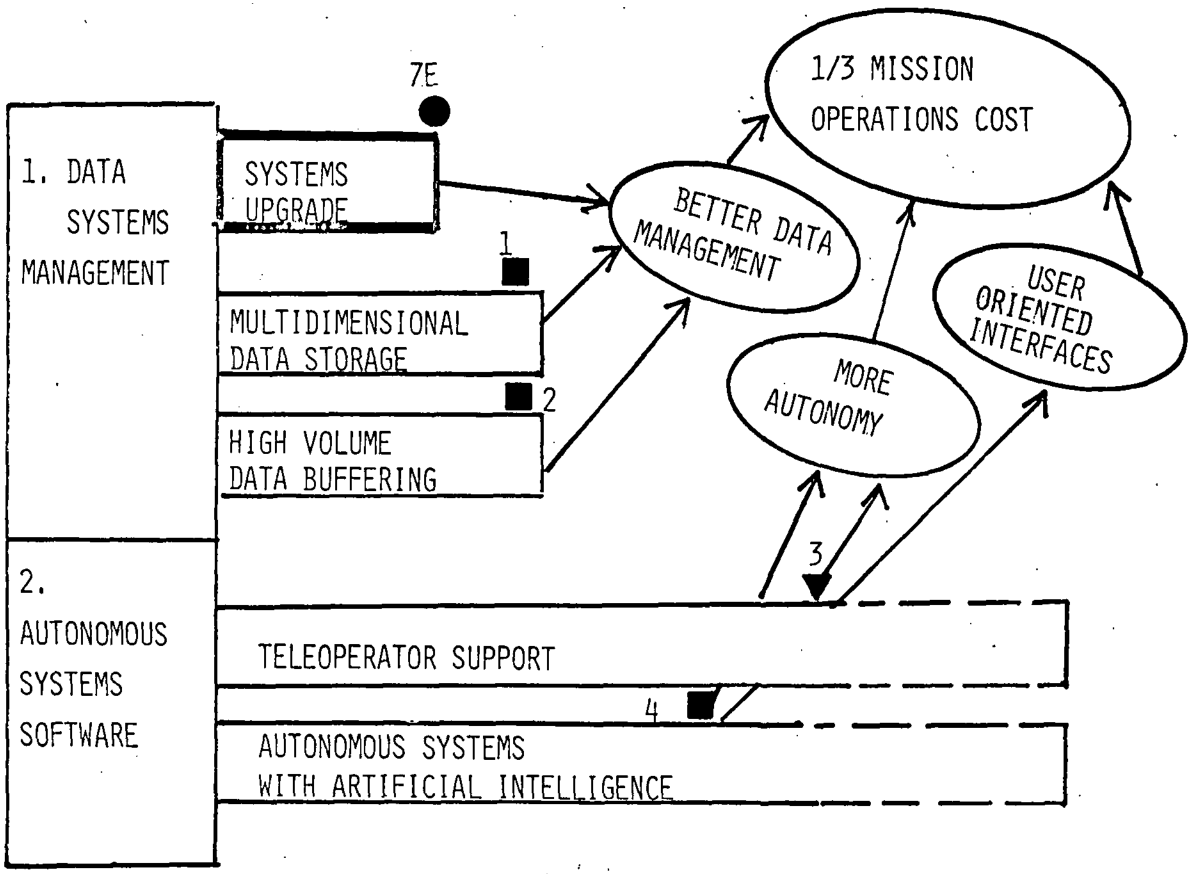
R&T BASE

- EXTENSIVE SUPPORT OF THEMES
  - MANY IN ENABLING CATEGORY — 213 TASKS
  - MOST REPRESENT EXPANSION OR ACCELERATION OF R&T BASE PROGRAMS TO MEET THEME OBJECTIVE — 174 TASKS
  - SOME ARE ONGOING PROGRAMS CONSIDERED CRITICAL TO THEMES — 39 TASKS
- LIMITED THEME-INDEPENDENT CANDIDATES — 7 TASKS
- IN-DEPTH ASSESSMENT & PRIORITIZATION OF TOTAL R&T BASE SUBMISSIONS
- NOT POSSIBLE IN REAL-TIME BUT PLANNED AS WORKSHOP FOLLOW-ON

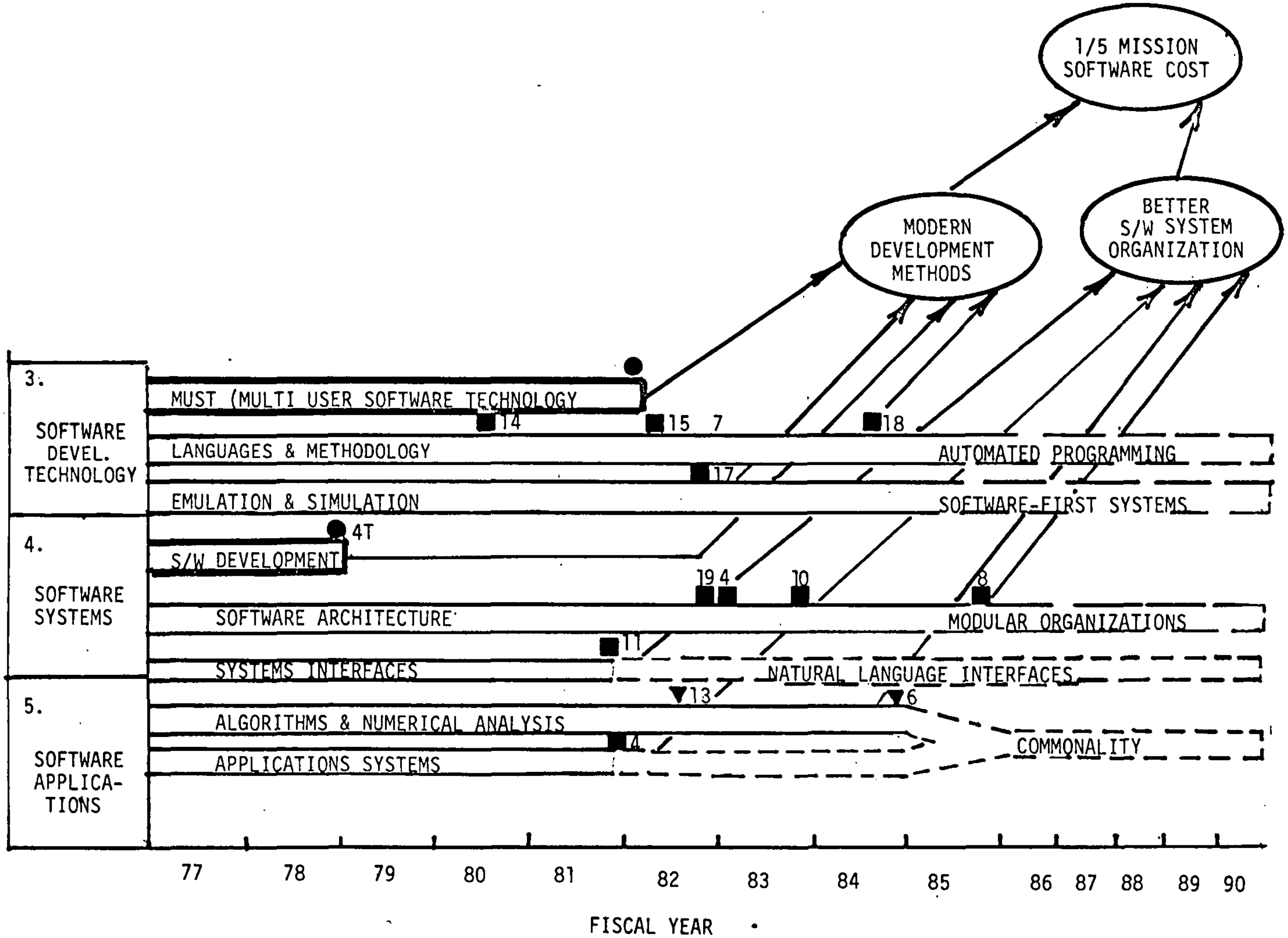
NOTE: OTHER MATERIAL COVERED IS CONTAINED IN SECTION III, R&T BASE

ATTACHMENT No. 8

SOFTWARE (1)



SOFTWARE (2)


1/5 MISSION SOFTWARE COST
MODERN DEVELOPMENT METHODS
BETTER S/W SYSTEM ORGANIZATION
3. SOFTWARE DEVEL. TECHNOLOGY
MUST (MULTI USER SOFTWARE TECHNOLOGY
14
15
7
18
LANGUAGES & METHODOLOGY
AUTOMATED PROGRAMMING
17
EMULATION & SIMULATION
SOFTWARE-FIRST SYSTEMS
4. SOFTWARE SYSTEMS
4T
S/W DEVELOPMENT
19
4
10
8
SOFTWARE ARCHITECTURE
MODULAR ORGANIZATIONS
11
SYSTEMS INTERFACES
NATURAL LANGUAGE INTERFACES
5. SOFTWARE APPLICA-TIONS
13
6
ALGORITHMS & NUMERICAL ANALYSIS
COMMONALITY
4
APPLICATIONS SYSTEMS
77
78
79
80
81
82
83
84
85
86
87
88
89
90
FISCAL YEAR

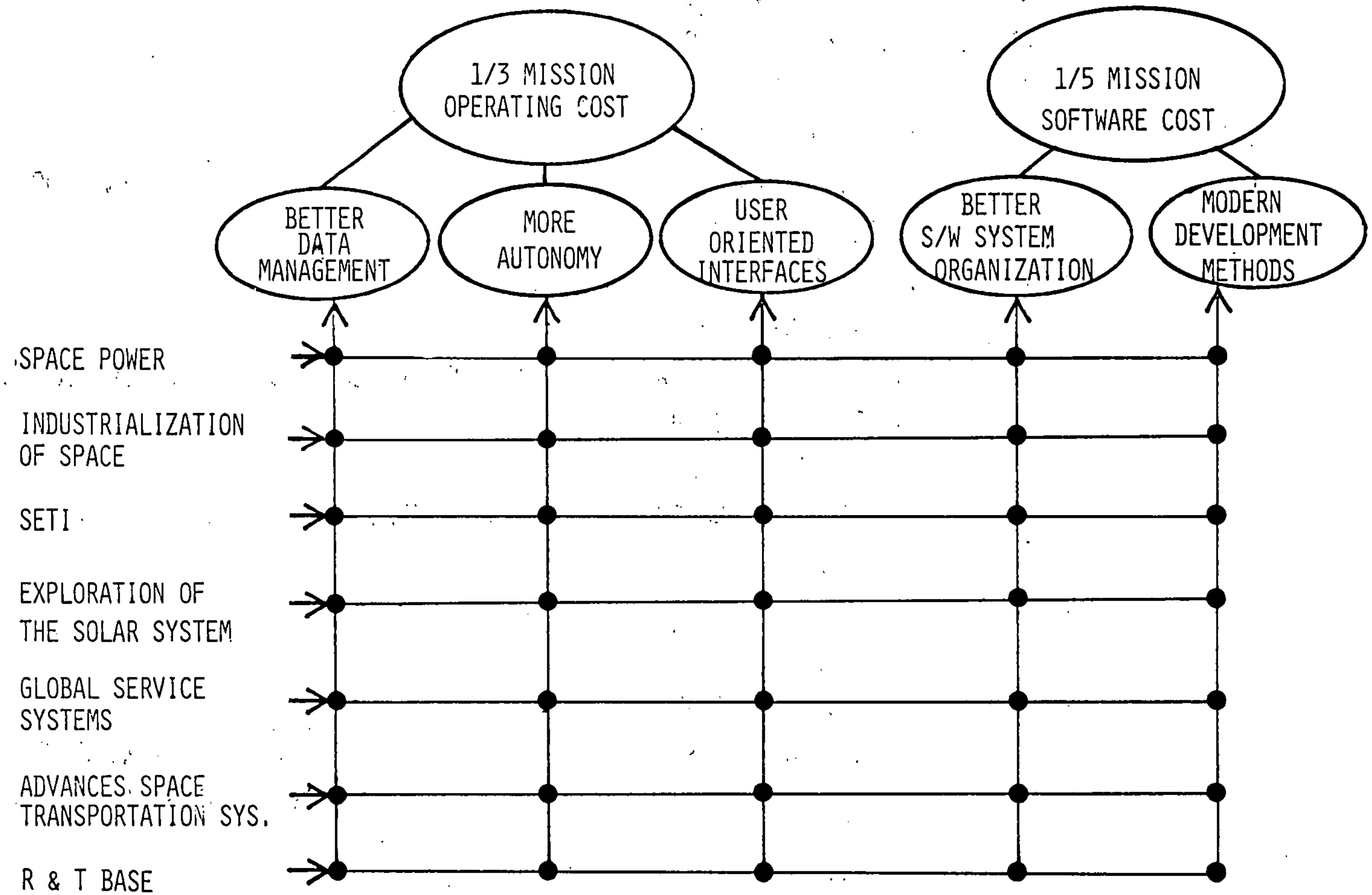
ROADMAP GUIDE

SOFTWARE TECHNOLOGY (E-4)

TECHNICAL AREA	MILESTONE	TITLE	STATUS/FY	THEME
1. DATA SYSTEMS MANAGEMENT	7E	SYSTEMS UPGRADE	●/80	
	1	MULTIDIMENSIONAL DATA STORAGE	■/81	7-8-9-10-11-1
	2	HIGH-VOLUME DATA BUFFERING	■/81	9-10-11
2. AUTONOMOUS SYSTEMS SOFTWARE	4	AUTONOMOUS SYSTEMS W/ARTIFICIAL INTELL.	■/84	7-8-9-10-11-12
	3	TELEOPERATOR SUPPORT	▼/86	7-8-11-12
3. SOFTWARE DEVELOPMENT TECHNOLOGY	A1	MUST (MULTIUSER SOFTWARE TECHNOLOGY)	●/82	
	17	SIMULATION TECHNOLOGY	■/82	10-11-12-1
	18	PROGRAMING METHODOLOGY	■/84	9-10-11-12-1
4. SOFTWARE SYSTEMS	4T	SOFTWARE DEVELOPMENT	●/79	
	11	USER-ORIENTED OPERATIONS LANGUAGE	■/82	7-8-10-11-12-1
	8	SYS. SECURITY SOFTWARE	■/86	7-11
5. SOFTWARE APPLICATIONS	4	THEME-UNIQUE APPL. TECH.	■/82	EACH
	6	PATTERN RECOG. ALGORITHMS	■/86	9-10-11-1

E-4 SOFTWARE TECHNOLOGY

THEME SUPPORT



E-4 SOFTWARE

KEY ISSUES

- **BROADEN TECHNOLOGY BASE**
    - COMMONALITY AND EVOLUTIONARY SOFTWARE
    - SYSTEM INTEGRITY AND AUTONOMY
    - COMMUNICATION AMONG USERS, DEVELOPERS, AND PROGRAMS
- **MAKE QUANTUM IMPROVEMENT IN DEVELOPMENT METHODS**
    - GO FROM MAGIC TO METHOD
    - USE PEOPLE FOR IDEAS AND MACHINES FOR ROUTINE
- **INCREASE AWARENESS OF SOFTWARE CRITICALITY**
    - SOFTWARE LIB (EQUAL STATUS)
    - MORE EMPHASIS IN SYSTEM PLANNING
    - OPPORTUNITY FOR ENLIGHTENED MANAGEMENT

ATTACHMENT No. 9

MATERIALS AND MECHANICS WORKING GROUP

- MATERIALS & THERMAL CONTROL
- STRUCTURES & DYNAMICS
- AEROTHERMODYNAMICS

FINAL REPORT - W.G. M-1

A. IMPACT OF THEME ON DISCIPLINE PLANNING

I. MANY THEME HIGH-PRIORITY MATERIAL NEEDS ARE NOT NOW EMPHASIZED BY RW

- EXAMPLES - MATERIALS ARE ADVANCED PROPULSION, POWER GENERATION AND POWER STORAGE/TRANSMISSION

II. THEME INDICATED INCREASE IN NEED FOR THERMAL CONTROL VS. DECLINING LEVEL OF PLANNED SUPPORT IN THIS AREA

- EXAMPLE - THEME 10 CHANGED W.G. PRIORITY FROM 10 TO 2

III. NEED FOR CONCENTRATED EFFORT IN CRYOGENIC COOLING SYSTEMS FOR SENSORS WAS SURFACED BY W.G./T.T. INTERACTIONS

- EXAMPLES - T.T.s 9, 10 & 11

IV. THEME TEAMS INDICATED SPECIFIC PROGRAM VOIDS

- EXAMPLE - NEED FOR LIGHTWEIGHT NUCLEAR SHIELDING MATERIALS

V. LITTLE COMMONALITY BETWEEN NEEDS OF VARIOUS THEMES IN DISCIPLINE PROGRAMS

- EXAMPLE - THERMAL CONTROL NEEDS

VI. THEMES TEND TO SUPPORT NEAR-TERM DEVELOPMENT RATHER THAN EXPLORATORY: PROBLEM FOR R&T ACCEPTANCE?

- EXAMPLE - THEME 11 LOWERED PRIORITY FOR CONDUCTIVE COATINGS - JEOPARDIZED FUNDING

FINAL REPORT - W.G. M-1 (CONT.)

B. COMMENTS ON THEME & NEW INITIATIVES

I. OF TOTAL NUMBER OF NEEDS IDENTIFIED, 70% REQUIRE NEW INITIATIVES

- EXAMPLE - ABOUT 3/4 OF NEEDS REQUIRE FOLDING/DEVELOPMENT OF NEW INITIATIVES

II. NEW INITIATIVES SUBMITTED BEFORE THEME DEVELOPMENT APPLY TO LESS THAN 10% OF NUMBER OF THEME NEEDS (TASKS)

- EXAMPLE - NEW INITIATIVES NOW EXISTING COVER ONLY 10% OF THEME NEEDS

III. NUMBER OF NEWER INITIATIVES REQUIRED TO SUPPORT TOTAL THEME NEEDS IS 60%

- EXAMPLE - WE NEED TO INCREASE THE NEW INITIATIVES BY 60% FOR TEXT

M-1 MATERIALS & THERMAL CONTROL

THEME 7 - MULTIPURPOSE SPACE POWER PLATFORM

TECHNOLOGY NEEDS

INCREASED PROGRAM

- POWER GENERATION MATERIALS/PROCESSES
- POWER STORAGE AND TRANSMISSION MATERIALS/PROCESSES
- COMPOSITES FOR LARGE SPACE STRUCTURES

NEW INITIATIVES

- #309 SPACE DEGRADATION OF COMPOSITE MATERIALS
- IN SITU SPACE MANUFACTURING OF LARGE STRUCTURES
- LONG-TERM SPACE EFFECTS ON MATERIALS

M-1 MATERIALS & THERMAL CONTROL

<u>THEME 8 - INDUSTRIALIZATION OF SPACE</u>

TECHNOLOGY NEEDS

NEW INITIATIVES

- # 111 THERMAL SYSTEM DESIGN
- # 123 SPACELAB COMBUSTION EXPANDED FACILITY
- DEVELOPMENT OF FABRICATION TECHNIQUES FOR SPACE ERECTABLE STRUCTURES
- EFFECT OF SPACE ENVIRONMENT ON MATERIALS
- EXTRACTION OF STRUCTURAL MATERIALS FROM LUNAR SURFACE MATERIALS

M-1 MATERIALS & THERMAL CONTROL

THEME 9 - SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI)

TECHNOLOGY NEEDS

INCREASED PROGRAM

- LONG-LIFE CRYOGENIC SYSTEMS FOR MASERS, ETC.

NEW INITIATIVES

- # 111 THERMAL SYSTEM DESIGN
- STABLE MATERIALS FOR LARGE ANTENNA STRUCTURES
- LARGE-AREA THIN-FILM STRUCTURES FOR RFI PROTECTION

M-1 MATERIALS & THERMAL CONTROL

THEME 10: EXPLORATION OF THE SOLAR SYSTEM

TECHNOLOGY NEEDS

INCREASED PROGRAM

- CRYOGENICS FOR SCIENCE
- CRYOGENICS FOR MASERS
- MATERIALS FOR POWER CONVERSION

NEW INITIATIVES

- NUCLEAR SHIELDING MATERIALS
- ELECTRONIC MATERIALS FABRICATION
- SOLAR SAIL MATERIALS

M-1 MATERIALS & THERMAL CONTROL

THEME 11: GLOBAL SERVICE SYSTEMS

TECHNOLOGY NEEDS

INCREASED PROGRAM

- CONDUCTIVE THERMAL CONTROL COATINGS

NEW INITIATIVES

- # 309 SPACE DEGRADATION OF COMPOSITES
- CRYO SYSTEMS FOR SENSORS
- MANUFACTURING IN SPACE
- ULTRA-HIGH CONDUCTIVITY HEAT PIPES
- DIMENSIONALLY STABLE STRUCTURAL MATERIALS
- CONTAMINATION

M-1 MATERIALS & THERMAL CONTROL

THEME 12: ADVANCED SPACE TRANSPORTATION

TECHNOLOGY NEEDS

INCREASED PROGRAM

- THERMAL CONTROL SYSTEMS & MATERIALS

NEW INITIATIVES

- #131 ORBITER EXPERIMENTS (OEX)
- #309 SPACE DEGRADATION OF COMPOSITES
- #123 SPACELAB COMBUSTION EXPANDED FACILITY
- MATERIALS FOR ADVANCED PROPULSION
- NDT/NDE FOR STRUCTURES

M-2 STRUCTURES/DYNAMICS

SUMMARY COMMENTS ON THEME IMPACT

TWO MAJOR THRUSTS IN STRUCTURES TECHNOLOGY

1) LARGE SPACE STRUCTURES (THEMES 7, 8, 9, 10, 11)

   CREATIVE EFFORTS REQUIRED TO ACHIEVE BREAKTHROUGHS FOR VERY LARGE ACCURATE STRUCTURES

2) ADVANCED TRANSPORTATION (THEME 12)

   REQUIRES RENEWED EMPHASIS ON THERMAL STRUCTURES TECHNOLOGY

M-2 STRUCTURES/DYNAMICS

LARGE SPACE STRUCTURES (7, 8, 9, 10, 11)	W.G. PRIORITIES
SPACE DEPLOYABLE	1
SPACE ASSEMBLED	2
ORBITAL MODULE ASSEMBLY	5
LONG LIFE HABITABLE STRUCTURES	6
SPACE MANUFACTURED STRUCTURES	7
DEPLOYABLE LASER MIRROR	12
SETI ANTENNA & SHIELD	23
SOLAR SAIL STRUCTURE	15

M-2 STRUCTURES/DYNAMICS

PRIORITIZED NEEDS

ADVANCED SPACE TRANSPORTATION SYSTEMS (12)	W.G. PRIORITIES
ADV. HIGH TEMPERATURE REUSABLE STRUCTURE	3
RECOVERY AND LANDING TECHNOLOGY	4
IN-SERVICE NDE TECHNIQUES	8
PAYLOAD DYNAMICS AND ACOUSTICS	9
L/V LOADS ANALYSIS OPTIMIZATION	10
DAMAGE TOLERANCE	11

M-3 AEROTHERMODYNAMICS

THEME # 10 EXPLORATION OF THE SOLAR SYSTEM

SPACECRAFT

- ATMOSPHERIC PROBES
- SURFACE PENETRATORS
- SAMPLE RETURN VEHICLES
- SURFACE LANDERS

TECHNOLOGY NEEDS (IN PRIORITY)

- HEATING AND FLOW FIELD DEFINITION
- STABLE CONFIGURATION AERODYNAMICS FOR PROBES
- PENETRATOR CAPABILITY
- PLUME-PLANETARY SURFACE INTERACTION
- EFFICIENT LANDER CONFIGURATION

NEW INITIATIVES

- SHUTTLE-LAUNCHED EXPERIMENTAL REENTRY SYSTEM

M-3 AEROTHERMODYNAMICS

THEME # 12 ADVANCED SPACE TRANSPORTATION

SPACECRAFT

- ADVANCED VEHICLE
- HEAVY LIFT VEHICLE
- ORBITAL TRANSFER VEHICLE

TECHNOLOGY NEEDS (IN PRIORITY)

- ESTABLISH AEROTHERMAL DESIGN CRITERIA
- PERFORM FLIGHT VERIFICATION TESTS
- OPTIMIZE CONFIGURATIONAL CHARACTERISTICS
- DETERMINE TPS WALL SURFACE EFFECTS

NEW INITIATIVES RECOMMENDED

- # 108 SHUTTLE WINDWARD HEATING EXPERIMENT
- # 113A SHUTTLE LEESIDE HEATING EXPERIMENT
- # 113E SHUTTLE AIR DATA SYSTEM
- DEVELOPMENT OF THE TECHNOLOGY BASE FOR ADV. STS

M-3 AEROTHERMODYNAMICS

THEME #1 R&T BASE

TECHNOLOGY NEEDS (IN PRIORITY)

- INCREASE COMPUTATIONAL FLUID DYNAMICS CAPABILITY
- DEVELOP ENERGY CONSERVATIVE FACILITIES
- CONDUCT RESEARCH IN MULTI-ENGINE BASE FLOW

NEW INITIATIVES RECOMMENDED

- # 202 OPTIMIZED FLUID DYNAMICS PROCESSOR

ATTACHMENT No. 10

MULTIPURPOSE SPACE POWER PLATFORM #7

AND

INDUSTRIALIZATION OF SPACE #8

1983 100-200kW LEO

Critical Technology	FY 78 Program Augmentation	FY 78 New Start
● Oasis		X
● Sphinx B/C		X
● Solar Array Tech. for SEP & P/L Appl.	X	
● Large Ni-Cd Battery		X
● Microwave Transmission	X	
● Multi-Kilowatt Distribution System		
● Hi Power/Hi Voltage/Low Loss Components	X	
● Advanced Electronic Pwr. Cond. Tech.	X	
● Heat Pipes for High Thermal Densities	X	
● Remote Power Controller Technology	X	
▲Funding Required	2615K	6600K

POWER REQUIREMENTS - MSPP(#7)

LAUNCH DATE	1983	1988	2000+
● ORBIT LOCATION	LEO	GSO(P); LEO (S)	GSO
● POWER - KW	100(P) 200(S)	1,000	10,000
● VOLTS - DC	120	120	440
● LOADS	OFF-THE-SHELF HARDWARE	20 KV LASER PROPULSION; INDUSTRIAL	LASER PROP; HABITAT; M'F'G
● LIFE - YRS.	5	10	30
● AUTONOMOUS	YES	YES	YES
● MAINTENANCE	BY MAN	BY MAN	BY MAN
● PROPULSION	STATIONKEEPING	SAME	● SAME ● POSSIBLE ORBIT TRANSFER

(P) PRIMARY

(S) SECONDARY

MULTIPURPOSE SPACE POWER PLATFORM #7

AND

INDUSTRIALIZATION OF SPACE #8

1988   1MW   GSO

Critical Technology	FY 78 Program Augmentation	FY 78 New Start
● Oasis		X
● Lightweight, Radiation Resist. Solar Array	X	
● Sphinx B/C		X
● Laser Power Converter/Transmission		
● Photovoltaic/Electrolysis/Fuel Cell Tech.		X
● Lightweight, Low Cost Silicon Arrays		
● Auto. Power Systems Management (APSM)	X	
● High Power, High Voltage, Low Loss Components	X	
● Auto. Test Techniques & Technology	X	
● Multi-Kilowatt Distribution System		
● Heat Pipes for High Thermal Densities	X	
● Advanced Electronic P.C. Technology	X	
● Tech. for Improving Perf. & Life: Alk. Battery		
▲Funding Required	1865K	4500K

POWER REQUIREMENTS - INDUSTRIALIZATION OF SPACE (#8)

LAUNCH DATE	1983	1988	2000
● POWER - kW	10s	10^3	TO 10^5
● VOLTS - DC	120	120	100 TO 440
● LOADS	-	-	1000 OUTLETS
● ORBIT	LEO	LEO, GSO	LEO, GSO, LUNAR BASE (100 MEN)
● LIFE-YRS	5-10	10-15	25-30
● AUTONOMOUS	YES	YES	YES
● MAINTENANCE	YES	YES	YES
● PROPULSION	STATIONKEEPING	SAME	SAME

POWER REQUIREMENTS - SETI (No. 9)

LAUNCH DATE	1984	1990	2000
• Power - kW	2	3-Plus Propulsion	10
• Volts	?	?	?
• Special Loads	-	Order of megawatt for shield and dish propulsion	-
• Orbit	Leo/GSO	GSO/Lunar distance	GSO/Lunar distance
• Unique environment	o S/C charging o Half time shadow	same same	same same
• Life - Years	10	10	30
• Autonomous	Yes	Yes	Yes
• Maintenance	Yes	Yes	Yes
• Propulsion; orbit transfer and positioning	Yes	Yes	Yes
• Special EMI;RFI;Etc.	Yes	Yes	Yes

SETI #9

Critical Technology	FY 78 Program Augmentation	FY 78 New Start
• Environment Charging of Surfaces	X	
• Lightweight, Radiation-Resistant Solar Arrays	X	
• Photovoltaic Electrolysis Fuel-Cell Technology		X
• Advanced Regenerative Hydrogen, Oxygen Fuel Cell		X
• Advanced Electronic Power Conditioning Technology	X	
• Lightweight, Low-Cost Silicon-Cell Arrays		
• Silicon-Solar-Cell Technology		
• Oasis		X
• Automatic Power-Systems Management	X	
• Remote Power-Controller Technology	X	
• Sphinx B/C		X
• Nuclear Thermionic Space Power System	X	
• Tech. for Improving Performance and Life: Alk. Battery		
▲Funding Required	3990K	4720K

POWER REQUIREMENTS - EXPLORATION FACILITY (#10)

LAUNCH DATE	1990	1995
• ORBIT LOCATION	EARTH	OUTER PLANET
• POWER - KW [PROP + SCIENCE]	200	500
• VOLTS	≤200, 1000	SAME
• REGULATION [SCIENCE]	1%	SAME
• LIFE - YRS	≤10	20
• AUTONOMOUS	YES	YES
• MAINTENANCE	MAN	RESUPPLY, SAMPLE-RETURN
• PROPULSION [ORBITER]	SEP OR NEP	NEP
• ENVIRONMENTS		
- RADIATION	LEO TO GEO, NEP	NEP, JUPITER
- OTHER PLANETARY		-150 K, HIGH G IMPACT, RFI
• FACILITY SUPPORT	FREE FLYER	FREE FLYERS (RTG) PROBES (RTG, BATT'Y) LANDERS (RTG, BATT'Y) SAMPLE-RETURN (RTG, BATT'Y)

*YEAR 2000 STUDY FACILITY UNDEFINED

EXPLORATION OF SOLAR SYSTEM #10

Critical Technology	FY 78 Program Augmentation	FY 78 New Start
● Nuclear Thermionic Space Power Module	X	
● Autonomous Power Systems Management	X	
● Advanced Planetary Power System Tech.		X
● Planetary Power Processing		
● Automated Test Techniques	X	
● Long-Life Lightweight Ni-Dc Batteries		
● Probe Battery Technology		
● Battery Technology		
● Thermoelectrics		
● Solar Array for SEP	X	
● Lightweight Array		
● Silicon Solar Cell Technology		
▲Funding Required	3700K	1000K

CONCERN

- SOLAR EXPLORATION THEME
  - EMPHASIZES EXPLORATION FACILITY, STARTING 1990
  - ABRUPT JUMP IN TECHNOLOGY IS REQUIRED
  - NOT PRECEDED BY EVOLUTIONARY GROWTH PROGRAM IN 1980'S
  - 1980 EXPLORATION PROGRAM UNDEFINED

POWER REQUIREMENTS - GLOBAL SYSTEMS (#11)

LAUNCH DATE	1983	1988	2000
• POWER - kW (ORBIT)	20 (LEO)	50 (LEO) 20 (GSO)	500 (LEO) 20 (GSO)
• VOLTS - DC	120, HIGHER FOR SENSORS	SAME	SAME
• STORAGE FOR ECLIPSES	YES	YES	YES
• UNIQUE ENVIRONMENT	-	SPACECRAFT CHARGING	YES
• LIFE - YEARS	3 - 5	3 - 5 LEO 5 - 10 GSO	10 LEO 20 GSO
• AUTONOMOUS	NO	PARTIAL	TOTAL
• MAINTENANCE	ONCE/YEAR	ONCE/YEAR	ONCE IN 3 YEARS
• PROPULSION	STATIONKEEPING -	SAME ORBIT TRANSFER?	SAME SAME
• EMI, RFI	QUIET PREFERRED	SAME	SAME

GLOBAL SERVICE #11

CRITICAL TECHNOLOGY	FY 78 PROGRAM AUGMENTATION	FY 78 NEW START
● SOLAR ARRAY TECHNOLOGY FOR SEP & P/L APPLICATION	X	
● LONG LIFE, LIGHTWEIGHT NI-CD BATTERY		
● ADVANCED ELECTRONIC P.C. TECHNOLOGY	X	
● MULTIKILOWATT DISTRIBUTION SYSTEM		
● TECHNOLOGY FOR IMPROVING PERFORMANCE & LIFE (ALK. BATTERY)		
● REMOTE POWER CONTROLLER TECHNOLOGY	X	
● SILICON SOLAR CELL TECHNOLOGY		
● LIGHTWEIGHT, LOW COST SILICON CELL ARRAY		
● LIGHTWEIGHT, RADIATION RESIST. SOLAR ARRAY	X	
● LARGE NI-CD BATTERY		X
● SILVER-HYDROGEN RECHARGEABLE BATTERY	X	
● POWER TRANSFER ACROSS ROTORY JOINTS		X
● INTEGRALLY REGULATED SOLAR ARRAY TECH.	X	
● ENVIRONMENTAL CHARGING OF SURFACES	X	
▲FUNDING REQUIRED	2900K	650K

ADVANCED SPACE TRANSPORTATION SYSTEM #12

Critical Technology	FY 78 Program Augmentation	FY 78 New Start
● Lightweight Fuel Cell		
● Integrally Regulated Solar Array	X	
● Hi Power/Hi Voltage/Low Loss Components	X	
● Remote Power Controller Technology	X	
● Hi Performance Thermionic Conversion Technology	X	
● Advanced Electronic Power Condit. Technology	X	
● Long Life, Lightweight Ni-Cd Battery		
● Solar Array Technology for SEP and Payload Appl.	X	
▲FUNDING REQUIRED	2950K	

ATTACHMENT No. 11

PROPULSION TECHNOLOGY WORKING GROUP

APPROACH

(1) EXAMINED VEHICLE MATRIX FROM THEME 12

(2) DETERMINE TRANSPORTATION NEEDS OF OTHER SPACE THEMES AGAINST THEME 12 REQUIREMENTS

(3) IDENTIFIED TWO ADDITIONAL PROPULSION FUNCTIONS

(4) IDENTIFIED TOTAL PROPULSION NEEDS AGAINST REVISED MATRIX

(5) PRIORITIZED & EVALUATED ALL PROPULSION "NEEDS" FOR EACH VEHICLE

(6) PROVIDED DOCUMENTATION (Rx FORMS)

PROPULSION NEED REQUIREMENTS FOR THEME SUPPORT

SPACE THEMES / VEHICLE CLASSES	S.P. 7	I 8	SETI 9	SOLAR SYS. 10	G. SER. 11	ATS 12
● (P) OTV	●	●	●			●
● (C) OTV	●	●	●	●	●	●
● $HLLV_1$ (1985)		●	●	●		●
● $HLLV_2$ (1995)		●	●			●
● ADV. VEH.	●	●	●		●	●
● PLANETARY				●		
● ON-ORBIT STAB.	●	●	●	●	●	

PROPULSION TECHNOLOGY WORKING GROUP

PROPULSION NEED RATING CRITERIA

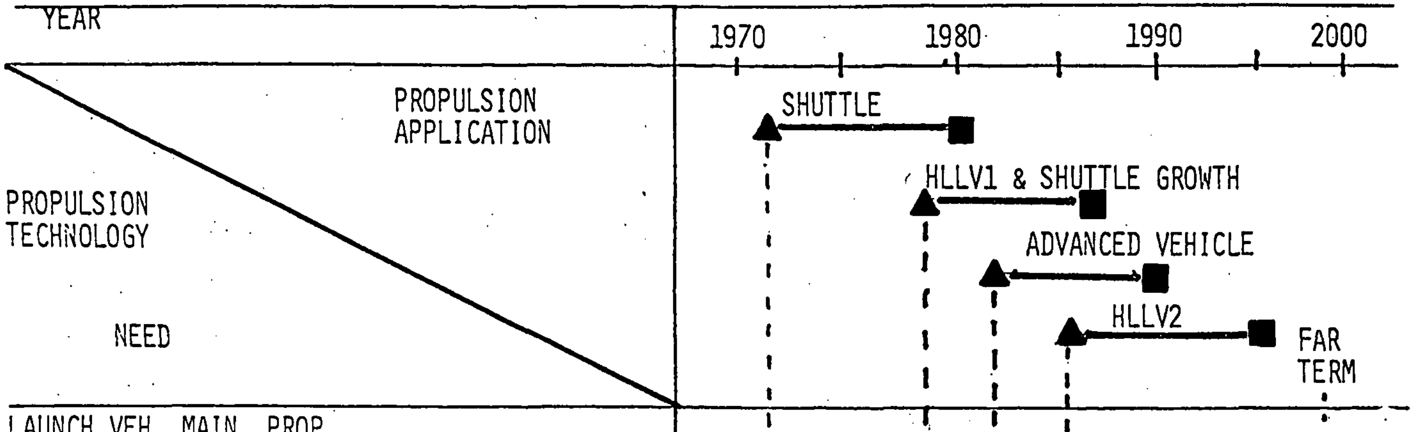
- USE DATE
- CRITICALITY
  - ENABLING
  - ENHANCING
    - HIGH
    - MEDIUM
    - LOW
- PROBABILITY OF MEETING TECHNOLOGY GOAL

PROPULSION TECHNOLOGY WORKING GROUP

CONCLUSIONS

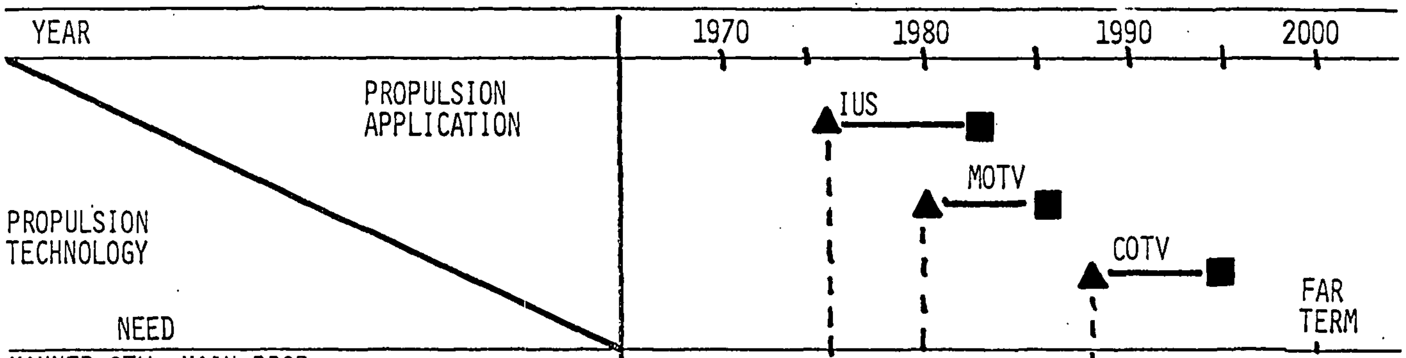
- THEME 12 UNDERLYING TO ALL OTHERS
- ENABLING PROPULSION TECHNOLOGY AREA KEY TO REDUCED TRANSPORTATION COSTS AND INCREASED SPACE CAPABILITY
- FURTHER OAST EVALUATION OF ALL PROPULSION NEEDS NECESSARY TO ESTABLISH RESOURCE REQUIREMENTS

PROPULSION WORKING GROUP SUMMARY



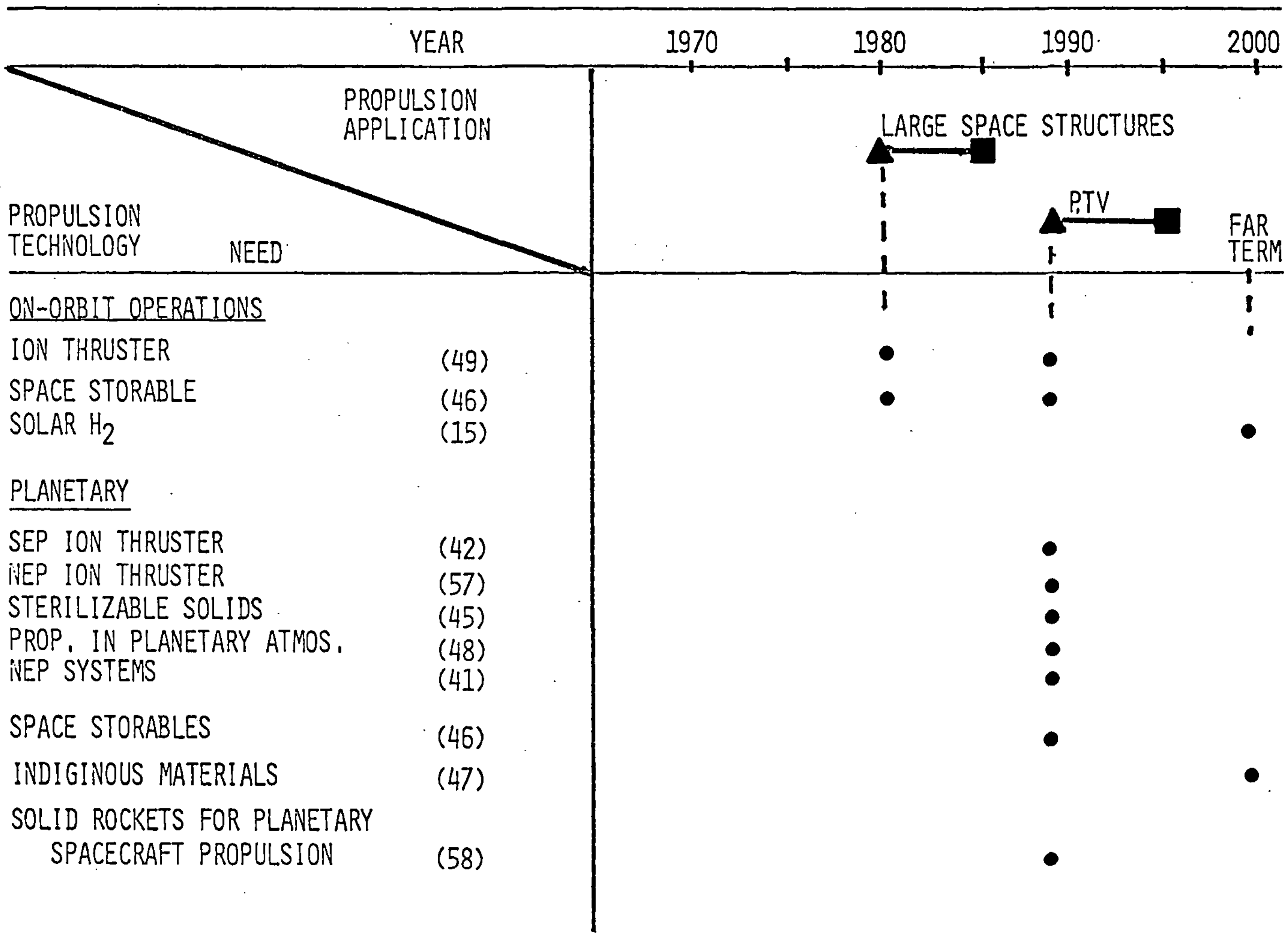
PROPULSION TECHNOLOGY NEED		SHUTTLE	HLLV1 & SHUTTLE GROWTH	ADVANCED VEHICLE	HLLV2	FAR TERM
LAUNCH VEH. MAIN. PROP.						
ENABLING TECH. FOR ROCKET PROPULSION	(56)			●	●	
AIR AUGMENTATION	(19)		●			
ADVANCED SOLIDS	(4)		●			
HYDROGEN/OXYGEN MAIN PROPULSION	(22)			●	●	
ADVANCED SSME	(17)			●	●	
HC/LOX, HI PC ADV. VEH.	(30)			●		
HC/LOX, HI PC $HLLV_2$	(23)				●	
DUAL FUEL ADV. VEH.	(31)			●	●	
COMPOSITE ENGINES	(32)			●		
LV AUXILIARY PROPULSION						
LOX/HYDROCARBON	(21)			●	●	
LOX/LH_2 FOR $HLLV_1$	(20)		●			
MONOPROPELLANT N_2H_4	(51)			●	●	
EARTH STORABLES	(9)			●	●	
LOX/LH_2 FOR $HLLV_2$	(25)				●	
LOX/LH_2 FOR OMS	(26)			●	●	

PROPULSION WORKING GROUP SUMMARY



NEED		MOTV	COTV	FAR TERM
MANNED OTV, MAIN PROP.				
CRYOGENIC STORAGE & TRANSFER	(7)	●		
HYDROGEN/OXYGEN MAIN PROP.	(1)	●		
MIXED MODE (DUAL FUEL)	(2)	●		
L/S HYBRIDS	(3)	●		
ATOMIC/METALLIC HYDROGEN	(6)			●
MOTV, AUX. PROP.				
LOX/LH_2 FOR OTV	(8)	●		
CARGO OTV, MAIN				
HI ISP ION THRUSTER	(13)		●	
MPO THRUSTER TECH.	(12)		●	
NEP SYSTEMS	(41)		●	
RESISTO JET	(11)		●	
SOLAR SAILS	(44)			●
SOLAR H_2	(15)			●
LASER PROP.	(16)			●

PROPULSION WORKING GROUP SUMMARY



ATTACHMENT No. 12

THEME SUMMARY

WORKSHOP OBSERVATIONS

- THEMES PROVED EXTREMELY STIMULATING
- WORKSHOP SHARPENED THEME TECHNOLOGY REQUIREMENTS
- HIGH LEVEL OF INTEREST & SUPPORT OF THEME PROCESS
- MANY ON-THE-SPOT CREATIVE CONCEPTS AND APPROACHES
- IDENTIFIED UNANTICIPATED PROBLEMS AND POSSIBLE SOLUTIONS
- EXCELLENT TRANSFER OF THEME AND TECHNOLOGY UNDERSTANDING
- OUTSTANDING COMPETENCE AND DEDICATION
- GOOD INTERPERSONAL INTERACTIONS
- LITTLE CENTER PAROCHIALISM
- NEAR-TERM NEEDS NOT IN THEMES (IDENTIFIED BY WG'S)
- OUT-OF-SCOPE PROBLEMS - PREDICTIVE MODELING
  OPERATIONAL SYSTEMS
  LUNAR MATERIALS PROCESSING
  COMPREHENSIVE SENSOR R & T PROGRAM

MULTIPURPOSE SPACE POWER PLATFORM No. 4

WORKSHOP RESULTS

- EFFECT OF SPACECRAFT CHARGING, HIGH VOLTAGES, AND SPACE PLASMAS, BIG UNKNOWN
- MUCH COMMONALITY WITH TECHNOLOGY NEEDED FOR SPS
- USE OF TRANSMITTED POWER FOR PROPULSION
  BIG POWER REQUIREMENT, BIG PAY-OFF
- DEFINITION OF PACING TECHNOLOGIES IN POWER, PROPULSION, G & C, STRUCTURES
  AND DYNAMICS, MATERIALS
- BENEFITS DEMONSTRATED TO OTHER THEMES

TECHNOLOGY FOR INDUSTRIALIZATION OF SPACE No. 8

KEY FINDINGS

- IDENTIFIED & PRIORITIZED 5 NEW INITIATIVES
  - TWO EXISTING
  - THREE NEW
  - TWO INITIATIVES TO BE DEVELOPED IN TANDEM
- CRITICAL PROBLEM
  - LARGE NUMBER OF SMALL TASKS DIFFICULT TO ASSEMBLE INTO THEME-ORIENTED INITIATIVES
- CURRENT R&T BASE INADEQUATE

SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE No. 9

KEY WORKSHOP FINDINGS

- BROAD PROGRAM NEW INITIATIVE REFINED INTO SPECIFIC TECHNOLOGY INITIATIVES
- CENTER MANAGEMENT PLAN AND CENTER ROLES DEFINED
- GOOD COMMUNICATION OF THEME REQUIREMENTS WITH WORKING GROUPS
- IDENTIFIED LARGE ANTENNA FIGURE CONTROL AS THE MOST CHALLENGING TECHNICAL PROBLEM
- DISCOVERED TECHNOLOGY PROGRAMS VALUABLE FOR SETI (E.G. MASS MEMORIES)
- REFINED SETI REQUIREMENTS (E.G. SPACECRAFT CHARGING) AND SETI MILESTONES
- PRODUCTIVE PEOPLE INTERACTIONS
- OPPORTUNITY TO EXPLAIN OBJECTIVES, RATIONALE AND APPROVAL OF SETI PROGRAM

EXPLORATION OF SOLAR SYSTEM No. 10

KEY FINDINGS

- Broad base of technical competence available for key technology concerns
  - Autonomy, artificial intelligence, robotics
  - Long life
  - End-to-end data management
  - Pre-nuclear reactor technology
- Software technology holds great promise in many areas, e.g.,
  - Mission planning and scheduling
  - Autonomy
  - Simulation
- Many imaginative and exciting sensors and instruments proposed; OAST must study our proper role
- Close coordination between OAST Theme and Agency thrust activities required - Concern is to maintain orderly evolution of technology - avoid step functions

GLOBAL SERVICE SYSTEMS No. 11

KEY FINDINGS

- MISSION SCENARIO: TWO-STAGE APPROACH REASONABLE
- THEME CREDIBILITY: GOOD COUPLING BETWEEN TECHNOLOGY DEVELOPMENT AND NASA PROGRAM THRUSTS
- TECHNOLOGY: EMPHASIS ON DATA SYSTEMS, SOFTWARE, SENSOR TECHNOLOGY, GUIDANCE AND CONTROL, POWER, LARGE STRUCTURES, THERMAL CONTROL

  CRITICAL AREAS IN DATA SYSTEMS AND SOFTWARE

  STATUS - NO INSOLUBLE PROBLEMS BUT... TECHNOLOGY IS CORNUCOPIA, E.G., WE NEED TRADE-OFF BETWEEN COST AND CAPABILITY.
- CRITICAL ISSUES:
  - THEME AREA HIGHLY DEPENDENT ON PREDICTIVE MODELING THEORY, NOT PRESENTLY OAST ACTIVITY
  - MISSION DEFINITION NEEDS MORE EFFORT
  - NEED BETTER APPRECIATION/COUPLING WITH REAL USERS

ADVANCED SPACE TRANSPORTATION SYSTEMS No. 12

- DETAILED QUESTIONS BY DISCIPLINE WORKING GROUPS CAUSED RE-EXAMINATION OF MISSION/SYSTEMS REQUIREMENTS, I.E., ELECTRICAL vs CHEMICAL PROPULSION (POWER/PROPULSION RELATIONSHIPS).
- IMPLEMENTATION OF MPPS COULD PROVIDE PROPULSION/POWER FOR SOME OTV SYSTEMS.
- SOFTWARE OFFERS POTENTIAL FOR AUTOMATED CHECKOUT AND REDUCED OPERATIONS (RECURRENT) COSTS.
- COMPLETE CONCURRENCE WITH POWER STRUCTURES WORKING GROUPS (MAKES US NERVOUS).
- PROPULSION TREATED AS A MULTI-DISCIPLINE TECHNOLOGY, I.E., FOUR FIRST PRIORITIES, ETC.
- USUALLY DIFFICULT TO PRIORITIZE ITEMS BELOW FOURTH RANK.
- ASTS OPERATIONS REMAINS FERTILE FIELD FOR ADVANCED TECHNOLOGY - RECOMMEND OPERATIONS WORKING GROUP.
- SOLID PROPULSION AND NEP MUST NOT FALL IN CRACKS BETWEEN THEMES.
- SYSTEM ENGINEERING STUDIES NOT IDENTIFIED BY WORKING GROUPS - MUST BE ADVANCED.
- "THEME TEAM" APPROACH HAS PROVIDED AN EFFECTIVE FOCUS FOR TECHNOLOGY DEVELOPMENT WHICH HAS BEEN REFLECTED IN THE WORKING GROUP PLANNING.

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Section II

THEME SUMMARIES

Part 1

SPACE POWER

THEME DESCRIPTION

The Multipurpose Space Power Platform (MSPP) concept assumes the eventual beneficial use of central space power plants to meet energy needs of missions in space. The MSPP would provide energy for such functions as life support, space manufacturing, experimentation, communications, and include transmission to other space vehicles and stations. The MSPP concept will emphasize support of design, research, and technology advancements in Solar Power Systems; large space structure engineering and operations; guidance and propulsion systems; and mass power transmittals.

In one view of the future of this concept, the requirements for MSPPs would evolve to meet eventual power needs for missions in space. In this case, while the MSPPs would certainly provide technology and operational experience related to Satellite Power Stations (SPS) for terrestrial utility use, there would be no schedule impact of SPS on the early phase of the MSPP planning. That is, a decision to proceed with specific SPS technology development would be delayed indefinitely while the MSPP effort proceeds to meet space needs. On the other extreme, the needs of SPS could dominate particularly if a time period of the late 1990's is assumed for first operational use of an SPS. This schedule target has been used in NASA planning for SPS technology. These two extreme views of the future needs for space power systems lead to two strawman schedules, Figures 1 and 2, for consideration in technology planning. Figure 1 assumes a space-mission focus for the MSPP concept; while Figure 2 illustrates the impact on power technology when early operation of an SPS is assumed. In this report, a space-mission focus is assumed for technology needs.

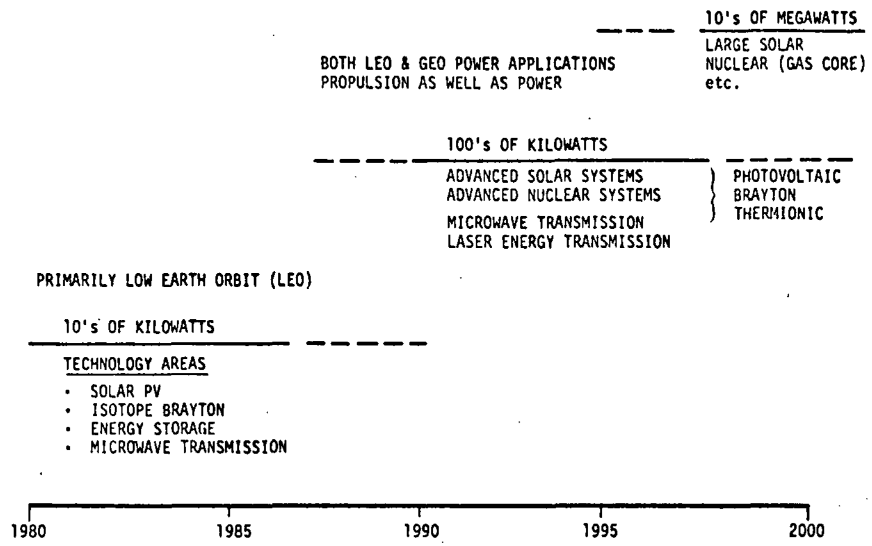

FIGURE 1. STRAWMAN MSPP SCHEDULE FOR SPACE USES

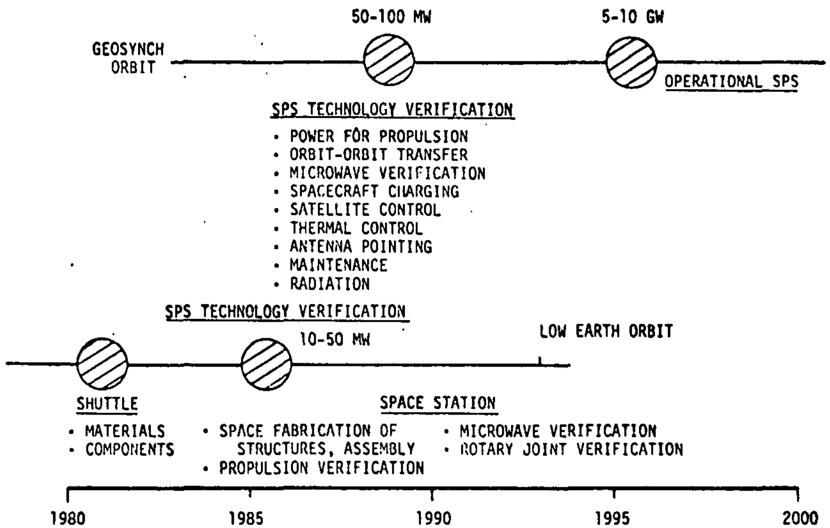

FIGURE 2. STRAWMAN SCHEDULE FOR EARLY SPS

MISSION APPLICATIONS IN SPACE FOR MSPP

In concept, the MSPP is an independent, long-lived space-based system that converts on-orbit solar and/or nuclear energy to a suitable form for distribution to using space systems. Initially, MSPPs would be launched as a single Shuttle payload. As power demands grow, assembly and, perhaps, fabrication or manufacture would be employed to construct MSPPs of the future. Uses and deployment of MSPPs will depend on the availability of manned Space Stations and bases.

The energy thus provided by MSPPs furnishes part or all of users' needs for electric power. Platforms for use in the 80's will have power conversion capability in the 10's of kilowatt range and will lead to more advanced platforms having higher power capability, large energy storage capability, and utilizing advanced energy transfer concepts.

POTENTIAL MSPP APPLICATIONS

<u>1980's</u>

- SPACE PROCESSING
- ALL SHUTTLE MISSIONS WHERE POWER/ENERGY REQUIREMENTS EXCEED SHUTTLE CAPABILITY
- ALL SHUTTLE MISSIONS WHERE COSTS TO LAUNCH SHUTTLE POWER/ENERGY CAPABILITIES ARE EXCESSIVE
- ALL FREE FLYER SPACECRAFT WHERE THE ECONOMICS OF A MSPP PREVAIL OVER USING INDIVIDUAL POWER SYSTEMS

<u>1990's</u>

- CONTINUATION OF 1980's MISSIONS
- HIGHER ORBIT APPLICATIONS
- HUNDREDS OF KILOWATTS APPLICATIONS
- LASER POWERED ROCKETS
- SPACE CONSTRUCTION NEEDS

<u>2000's</u>

- CONTINUATION OF 1990's MISSIONS
- SPACE OR LUNAR COLONIZATION

MISSION REQUIREMENTS

In the 1980's a Space Power Platform could become operational. To meet this timetable, this first generation Space Power Station would necessarily use, for the most part, existing technology. Operation would be relatively simple, a solar array of perhaps the 20 to 100 kW class could provide the energy to the user either as electricity or in a stored form via docking. Operations would take place in Low Earth Orbit and perhaps could involve a fleet of power platforms. Some means of orbital transportation for rendezvous purposes would be required of either the power platforms or the users so that multiple users could be serviced.

By the 1990's advanced generations of Space Power Platforms could be realized. The power range would likely be in the 100's of kilowatts range. Very large solar arrays, or, also likely, solar thermal techniques with rotating machinery such as Brayton cycle, could generate the power. Synchronous Orbits could be attained by the power platforms. Microwave radiation to the user could become practical early in the decade and thus obsolete the propulsion systems needed earlier for direct power transfer.

Nuclear or solar sources could provide power in the megawatt range by the post 2000 era. Power transfer by laser is predicted possible in an early state by 1995 and would open up new space opportunities.

The power/energy requirements on a space platform for the 1980's are expected to be inextricably tied to Shuttle users. Current Shuttle plans to provide only 7 kWh continuous and 12 kW peak power, energy of 50 kWh with 840 kWh add-on kits, and two-week mission times undoubtedly discourage some potential high power, long mission users. For example, a recent JSC study reportedly identifies a potential need for from 2300 to 68,000 kWh/year in the late 80's for space processing alone. Shuttle/Spacelab traffic are estimated to be $1721/kWh for a yearly cost of from $4M to $115M. Consequently, a Space-Based Power Platform capability that improves upon the Shuttle capabilities and costs would find many interested potential users.

By the 1990's space processing may grow to require 100's of kilowatts per process. Construction of large objects in space could require huge amounts of power for welding, for lighting during eclipses, and for other assembly needs. Also, laser powered rockets could effectively use large amounts of power. Appendix A presents estimates of power needs for these applications.

During the post-2000 era, the expected need for space-derived power is unlimited. Colonization in space or on the Moon, and eventual power transmission to Earth, are examples of megawatt applications.

MISSION REQUIREMENTS

1980's

- SUPPORT HIGH POWER, LONG SHUTTLE MISSIONS (> TWO WEEKS)
- 2300-68,000 kWh/YEAR FOR SPACE PROCESSING

1990's

- 100's OF KILOWATTS FOR
  - SPACE PROCESSING
  - CONSTRUCTION OF LARGE OBJECTS IN SPACE
  - LASER POWERED ROCKETS

2000's

- 10's OF MEGAWATTS - GIGAWATTS FOR
  - SPACE PROCESSING & CONSTRUCTION
  - POWER TRANSMISSION TO EARTH
  - LASER POWERED ROCKETS
  - SPACE COLONIZATION

THEME ADVOCACY

ISSUES/PROBLEMS

Issues that drive advocacy of the MSPP approach:

- *High cost of energy transportation to orbit*
- Eventual need for large power supplies for Space Missions
- Solar energy is available in orbit, if tapped--does not diminish Earth resources

- Should all NASA technology efforts in power be directed at this Theme? If so, how?
- How to convince potential users of reliability and availability of Power Platform for their use?
- *Should this Theme be ultimately aimed at SPS which probably rules out nuclear? Or should the nuclear be picked* up again even though it may not lead to SPS?
- Will the need for power in space continue to grow as expected?
- Is the lack of Space Power inhibiting space activities now? Will it in the future?
- Should NASA go for an early (1980's) Space Power Platform with current technology and the resulting "simple" system, or should NASA go for a more sophisticated approach aimed at a later time?
- How would energy costs be paid for, i.e., will users pay on a KWh used basis?

BENEFITS

- Less $/kWh for users encourages greater space exploration to meet human needs.
- Launch weight capabilities can be used for productive hardware instead of round-tripping power systems.
- Use of solar energy for space reduces exhaustion of Earth's energy resources (technology for SPS).
- New space capabilities, e.g., laser propulsion, nuclear electric propulsion.
- Stimulation of advanced technology developments with high payoff in commerical applications on Earth.

THEME ADVOCACY (Cont.)

BENEFITS (Cont.)

1980's

- Removes one serious restraint now impeding space processing.
- Permits extended life (greater than two weeks) of Shuttle missions without paying launch weight penalty for add-on power kits.
- Enforces the need for 20 kW to 100 kW class solar array and possibly the prime and auxiliary electric propulsion now in technology program.
- Might make it practical to use existing ground designed processing or manufacturing equipment in space--saves redesign costs.
- Unlimited power from Sun might diminish the need for super-high power handling efficiencies, i.e., Space Platform design costs might be low.
- Uses current technology to obtain operational and planning experience for future.

1990's

- Laser rockets may be possible.
- First application for microwave and/or laser energy transfer.
- Can provide power to aid in construction of large space structure, possibly its own successor. Permits construction to continue throughout eclipse.
- Development of advanced nuclear power units would support advanced propulsion systems.

2000's

- Colonization, very large space factories.

TECHNOLOGY NEEDS

In order to meet the mission requirements of the 1980's and beyond, several broad technology thrusts have been identified. Mission planning is required to provide detailed specifications and requirements for MSPP. Large lightweight solar photovoltaic systems must be pursued to meet the near-term requirements. Advanced power systems must be developed for the missions of the 1990's. Research into means of advanced energy storage and transmission is needed. Since the MSPP concepts currently postulated envision large space structures, it will be necessary to develop advanced attitude control, stationkeeping, and propulsion techniques.

TECHNOLOGY THRUSTS

- MISSION PLANNING FOR MSPP CONCEPTS
- LARGE LIGHTWEIGHT SOLAR PHOTOVOLTAIC SYSTEMS (RADIATION RESISTANCE)
- ADVANCED HIGH POWER CONDITION CAPABILITY
- HIGH CAPACITY, RECYCLABLE ENERGY STORAGE SYSTEMS
- LASER & MICROWAVE POWER TRANSMISSION
- NEW SPACE-TO-SPACE ENERGY TRANSFER SYSTEMS
- ADVANCED SPACE POWER SOURCES/CONVERTERS FOR SPACE-BASED SYSTEMS
- ADVANCED ATTITUDE CONTROL TECHNIQUES FOR LARGE, FLAT STRUCTURES
- OPERATIONAL TECHNIQUES, ATTITUDE CONTROL, & STATIONKEEPING DURING MSPP ASSEMBLY
- PROPULSION & ATTITUDE CONTROL OF MSPP DURING ORBITAL TRANSFER

TECHNOLOGY AREAS OF EMPHASIS

The technology areas of emphasis provide a preliminary checklist for evaluating ongoing technology efforts and planning new initiatives and program augmentations.

TECHNOLOGY AREAS OF EMPHASIS

1. HIGH EFFICIENCY, LOW COST, LARGE SPACE POWER CONVERSION SYSTEMS
2. ADVANCED HIGH CAPACITY ENERGY STORAGE METHODS
3. ASSEMBLY, ATTITUDE/THERMAL CONTROL OF LARGE SCALE, LIGHTWEIGHT SPACE STRUCTURES
4. ADVANCED MATERIAL TECHNOLOGY
5. TRANSPARENT STRUCTURE TECHNOLOGY (MICROWAVE)
6. HIGH POWER, FREE SPACE POWER TRANSMISSION
7. HIGH POWER, SPACE POWER DISTRIBUTION & CONTROL
8. PRECISION POINTING & NAVIGATION
9. POWER TRANSMISSION ANTENNA ROTARY JOINTS
10. HEAT REJECTION/THERMAL CONTROL SYSTEMS

TECHNOLOGY AREAS OF EMPHASIS (Cont.)

11. HIGH EFFICIENCY ABSORBERS/RECEIVERS
12. THIN FILM SOLAR CONCENTRATORS
13. MAGNETIC COMPENSATION SYSTEMS
14. SPACECRAFT CHARGING CONTROL
15. LARGE MOMENTUM EXCHANGE DEVICES
16. LARGE STRUCTURE ACTIVE SURFACE CONTROL
17. LARGE STRUCTURE ALIGNMENT SENSING & DETERMINATION
18. ADVANCED POWER SUPPLIES
19. ANTENNA ROTARY JOINT
20. RECTENNA DESIGN/MAINTENANCE

PRIORITY TECHNOLOGY AREAS

The major need of the MSPP concept is a study of its applications and benefits in NASA, military, and commercial space missions. The highest priority technology area for MSPP is that dealing with the problems of high-power generation and interaction of high-voltage systems with space plasmas. The remaining technology areas are ranked in decreasing priority.

PRIORITY TECHNOLOGY AREAS

- MSPP SYSTEMS STUDY
- HIGH VOLTAGE/POWER SYSTEM TECHNOLOGY
- LARGE STRUCTURES
- SOLAR POWER
- POWER TRANSFER
- MATERIALS TECHNOLOGY
- ENERGY STORAGE

FY 78 CANDIDATE NEW START

MSPP SYSTEMS STUDY

OASIS STUDY (LEWIS RESEARCH CENTER)

Determine the needs, feasibility, and conceptual configurations of long-life, orbiting electrical power utility stations for multimission space applications. The study will consider evolution of the concept from initial uses to replenish and augment spacecraft electrical power to the use of the Power Platform as a continuous supplier of power for Space Stations, Space Industrialization, and Space Propulsion. The likely power range for these applications is from 10-100 kW for initial uses to megawatts in the long term.

FY 78 CANDIDATE NEW START
MSPP SYSTEMS STUDY

OASIS STUDY

	FY 77	FY 78	FY 79	FY 80
FUNDING (TOTAL)	0-0.25	1.5	3.0	2.6
MANPOWER	8.0	11.0	14.0	14.0

FY 78 CANDIDATE NEW START

HIGH VOLTAGE/POWER SYSTEM TECHNOLOGY

NUCLEAR THERMIONIC POWER SYSTEM TECHNOLOGY (JPL AND LEWIS RESEARCH CENTER)

Augments a current OAST effort to provide demonstration of technology readiness for power system development in the early 1980's. A non-nuclear test of an advanced power conversion module would be conducted along with critical R&T activities in materials, heat-pipes, component analyses, and system studies. This initiative is also applicable to space propulsion as well as power, and applies to solar as well as nuclear energy.

SPHINX B/C (LEWIS RESEARCH CENTER)

Provides engineering data on high voltage space systems exposed for a long time to the environment of space and demonstrates technology readiness for auxiliary electric propulsion systems. This new start is a vital element of many future space requirements including the generation of large amounts of solar power in space and the stabilization and control of large structures.

GASEOUS FUEL POWER REACTOR (OAST-RR)

Expands the current level of effort in research on gaseous fuel reactors to demonstrate the feasiblity of gaseous-fuel reactors for space power use by FY 1981. This test would use uranium hexafluoride fuel in a test rig currently in operation at the Los Alamos Scientific Laboratory. The technical goals would be operation in the power range of 10-100 kW with a fuel temperature of 1500 K. A successful test at these conditions should demonstrate all essential features of a gaseous fuel reactor for space power use and would be the precursor for later high temperature tests related to propulsion applications. This program would also have substantial benefits for the terrestrial use of nuclear power. No long-range commitment beyond FY 1981 is implied by this initiative.

FY 78 CANDIDATE NEW START
HIGH VOLTAGE POWER SYSTEM TECHNOLOGY

	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83
NUCLEAR THERMIONIC POWER SYSTEM TECHNOLOGY						
FUNDING (TOTAL)	3.0	3.7	3.3	2.7	1.0	
MANPOWER	10.0	15.0	20.0	20.0	20.0	
SPHINX B/C						
FUNDING (TOTAL)	2.1	3.4	1.8	0.3	0.2	0.1
MANPOWER	35.0	42.0	30.0	13.0	10.0	5.0
GASEOUS FUEL POWER REACTOR						
FUNDING						
CURRENT PLAN	1.0	1.0	1.0	1.0		
AUGMENTED	1.0	2.0	2.0	2.0		
MANPOWER	3.0	4.0	4.0	4.0		

FY 78 CANDIDATE NEW START

SOLAR POWER

GALLIUM ARSENIDE SOLAR CELL ARRAYS (JPL)

Procure and evaluate in space a 1-kW GaAs solar cell array with an efficiency greater than 18%. Gallium arsenide cells are potentially superior to silicon solar cells because: (1) they may have greater efficiency, (2) they are more radiation resistent, (3) they can operate at higher temperatures to take advantage of solar concentrators, and (4) they are potentially lighter in weight and lower in cost because GaAs cells need be only several micrometers in thickness compared to 100-200 μm in silicon. Gallium arsenide arrays could also be effective as converters for laser beams in energy transmission applications.

FY 78 CANDIDATE NEW START
SOLAR POWER

	FY 78	FY 79	FY 80	FY 81	FY 82	BTC	TOTAL
GALLIUM ARSENIDE SOLAR CELL ARRAYS							
FUNDING (TOTAL	0.5	0.5	1.0	1.0	1.0	3.0	7.0
DIRECT MANPOWER	5.0	5.0	7.0	7.0	7.0		

RELATED NEW INITIATIVES - FY 1978
IN OTHER THEMES

104 DEVELOPMENT OF DEXTEROUS MANIPULATOR

105 ATTITUDE CONTROL & FIGURE CONTROL OF LARGE DEFORMABLE STRUCTURES

114 LARGE SPACE STRUCTURES TECHNOLOGY

120 DEVELOPMENT & DEMONSTRATION OF SILVER/HYDROGEN RECHARGEABLE BATTERY SYSTEMS

128 ADVANCED TECHNOLOGY LABORATORY

DEFERRED NEW INITIATIVES

130 ORBITAL FLIGHT DEMONSTRATION OF LARGE SPACE STRUCTURES FOR SOLAR POWER SATELLITE (MSFC) FROM 1978 TO 1979 OR LATER

POTENTIAL NEW INITIATIVES 1979 & BEYOND

303 PHOTOCHEMICAL SOLAR CONVERSION

306 LOW-COST ISOTOPE-FUELED SPACE POWER SYSTEM

308 SECOND GENERATION H_2/O_2 FUEL CELLS

312 BRAYTON ISOTOPE POWER SYSTEM FLIGHT DEMONSTRATION

313 SOLAR SPECTRUM MEASUREMENTS

314 SOLAR ARRAY MATERIALS TESTS IN SPACE
315 AND CORRELATION WITH GROUND TESTS

320 SPACE CALIBRATION OF SOLAR CELLS

SUMMARY COMMENTS ON WORKSHOP ACTIVITY

During the early phase of the Workshop activity, the Theme Team for Multipurpose Space Power Platforms (MSPP) developed a target schedule for technology planning. This schedule was constructed by considering planning activities currently under way in the Offices of Space Flight and the Offices of Energy Programs. As far as the MSPP concept is concerned, this schedule shows a Platform in Low Earth Orbit with a power rating of 100 to 200 kWe in the 1983 time period and a 1 to 10 MW platform in Geosynchronous Earth Orbit in 1988.

These ambitious goals required the Working Group to consider technologies which could be made available in the near time period. In consequence, technology for Advanced Power System concepts does not appear as supportive of this Theme. A more relaxed MSPP schedule would allow the investigation of a wider range of technical options for future Platforms. This is an issue the Theme Team must consider with OAST and other program offices to assure that the MSPP Theme uses the proper schedules for planning technologies and, thereby, advocates the best mix of technologies.

The application of MSPPs in transferring power for OTV propulsion received considerable interest in the Working Groups. It is an area for further study to assess capabilities and determine requirements, because this application could develop major needs for MSPPs.

THEME TEAM MEMBERSHIP

HEADQUARTERS

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CENTERS

R. Hook	LaRC
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L. Runkle	JPL
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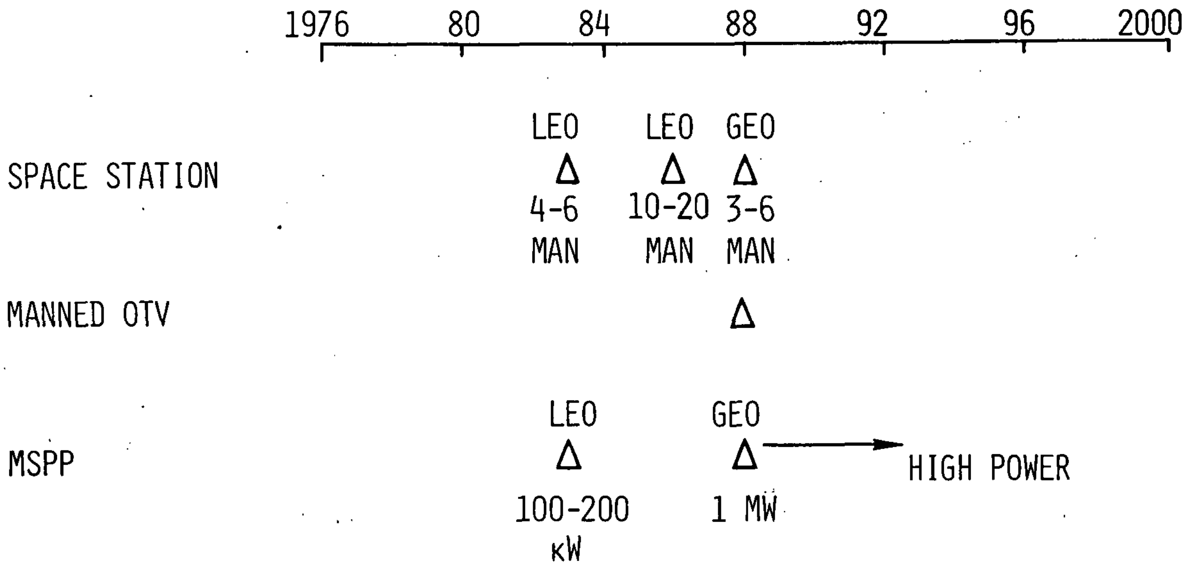
Plotkin	GSFC
Billman	ARC

MULTIPURPOSE SPACE POWER PLATFORM



<u>LEO MSPP</u>

- DEVELOP SEPS & SPS TECHNOLOGY
- POWER INITIAL LEO SPACE STATION
- DEVELOP LASER TRANSFER TECHNOLOGY
- DEVELOP LASER POWERED OTV CONCEPT

<u>GEO MSPP</u>

- LASER POWER FOR 50-100 KLB PAYLOAD OTV
- DEPLOY WITH MANNED OTV
- POWER INITIAL GEO SPACE STATION
- VERIFY SPS TECHNOLOGY
- PROVIDE POWER FOR INITIAL SPS CONSTRUCTION BASE

APPENDIX A

MSPP POWER REQUIREMENTS

Estimates have been made of power requirements for three categories of future space missions (1990-). For the space manufacturing, and satellite and Space Station operational power categories, a range of at least 10-100 kW is required. Two megawatts are needed for one proposed passive radar system, and propulsion system requirements are in the range 100 kW to 100 MW.

MISSIONS (Applications):

I. Propulsion Systems

A. Low-Thrust Hydrogen Monopropellant Tug (Altitude = 350 km to Synchronous). Estimated requirements for transfer of a 1000-lb payload from a 350-km circular orbit to Geosynchronous:

Initial mass, m_0 = 1500 kg

Propellant mass, m_p = 500 kg

Specific impulse, I_{sp} = 1000 sec (Ref. 1)

Burn time, t_b = 10 days

The total Δv required, if a conventional 2-burn maneuver accomplished the transfer, would be

$$\Delta v_{2\text{-burn}} \simeq 3875 \text{ m/sec}$$

The "equivalent" Δv for the continuous low-thrust burn will be somewhat larger, say 50% more. The required thrust is then calculated for the mean total mass and an averaged acceleration:

$$\begin{aligned} T &= \overline{m}\,\overline{a} \\ &= 1250 \text{ kg} \frac{3875 \text{ m/sec} \times 1.5}{10 \text{ days} = 864{,}000 \text{ sec}} \\ &= 8.4 \text{ N, less than 2 lb} \end{aligned}$$

The power required to heat the hydrogen to achieve the exhaust velocity needed is then given by:

$$P = \frac{1}{2}\,\dot{m}V_{EXH}^2 = \frac{1}{2}\,TV_{EXH}$$

$$V_{EXH} = I_{sp}g = 9807 \text{ m/sec}$$

Thus,

$$P = \frac{1}{2}\,(8.4\text{ N}) \times 9807 \text{ m/sec} = 41.2 \text{ kW}$$

Assuming an efficiency of a little less than 1/2 for the power conversion system, the input power required at the receiver is

$$P_{input} = 100 \text{ kW}$$

B. Larger Thrust Remotely Powered Propulsion Systems (Altitude = 350 km to Synchronous). From the equation for the power P in Part A above, it is seen that for a constant exhaust velocity, the required power is proportional to the thrust T. For acceleration of the same payload at about 1 g vs. $\sim 10^{-3}$ g above, an input power $\sim$ 100 MW is required. This latter number is supported by the statement in Ref. 1, p. 4-21, calling for a laser of the scale 10-100 MWe for effective use in propulsion.

II. Manufacturing in Space

A. A Strong Candidate for Space Manufacture Is High-Purity Tungsten for x-ray Tube Targets (Altitude = 250 to 600 km). The power required to keep a mass of tungsten molten is quite large because of its high melting temperature. Making the assumption that the molten sphere radiates with an emissivity of unity (blackbody), and that none of the thermal radiation is reflected back upon the surface, the power required to just hold a 1-kg mass molten is

APPENDIX A - MSPP POWER REQUIREMENTS (CONT.)

$$P = q_{RAD} = \sigma A_{surf} T^4_{melt}$$

$$= \sigma \left[36\pi \left(\frac{m}{\rho} \right)^2 \right]^{1/3} T^4_{melt}$$

$$= 5.6686 \times 10^{-15} \frac{kW}{cm^2 K^4} \left[36\pi \left(\frac{1000\ g}{18.85\ g/cm^3} \right)^2 \right]^{1/3} (3643\ K)^4$$

$$P = 68\ kWt$$

This can be reduced by use of reflector to conserve heat, and will decrease proportionally as the actual emissivity, which is less than 1.

In Ref. 2, a heating power of 21 kW is estimated for a 2-cm radius (647 g) sphere of molten tungsten, and 1.3-kW for a 10-g sample, assuming an emissivity of 0.4. An inductive heating system was studies, with a 6250-turns coil and 400 kHz excitation frequency. A 10% efficiency was estimated, requiring a heating system power up to 200 kW for a mass of only 647 g.

B. Production of Si Crystals by the Floating Zone Method (Ref. 3) (Altitude = 250 to 600 km). "Up to 20 kW may be required to produce a 3-4 in. diameter specimen. A reflector could reduce this to around 5 kW."

Using an electron bombardment heating system, much more efficient than induction heating, the input power required for melting at very high temperatures is of the order

$$P_{input} = 10\text{-}100\ kW$$

III. Operational Power for Satellites and Space Stations (Altitude = 250 km to Synchronous)

A. Space Station, 10-Man Crew. A number of studies have conclusively shown that the required operational power is of the order

$$P_{REQ} = 10\text{-}100\ kW\ (250\text{-}600\ km)$$

B. Unmanned Satellites. Communications, weather, Earth observations, surveillance (Ref. 4) (altitude = 250 km to Synchronous)

Medium Power

P_{REQ} = 1-10 kW (10's of them operational)

High Power

R_{REQ} = 1-2 MW (1 or 2 of this scale)

REFERENCES

1. A Forecast of Space Technology, 1980-2000.

2. General Electric Company, Study of Identification of Beneficial Uses of Space (BUS), Contractors Report CR-120287, 1 November 1973.

3. McDonnell Douglas, Manned Orbital Systems Concepts (MOSC) Study, Second Monthly Report, November 1974, p. 19.

4. Aerospace Corporation, Study of the Commonality of Space Vehicle Applications to Future National Needs, Report No. ATR-75 (7365)-2, March 1975.

APPENDIX B

MULTIPURPOSE SPACE POWER PLATFORM(S)

VUGRAPH PRESENTATION ON 26 APRIL 1976

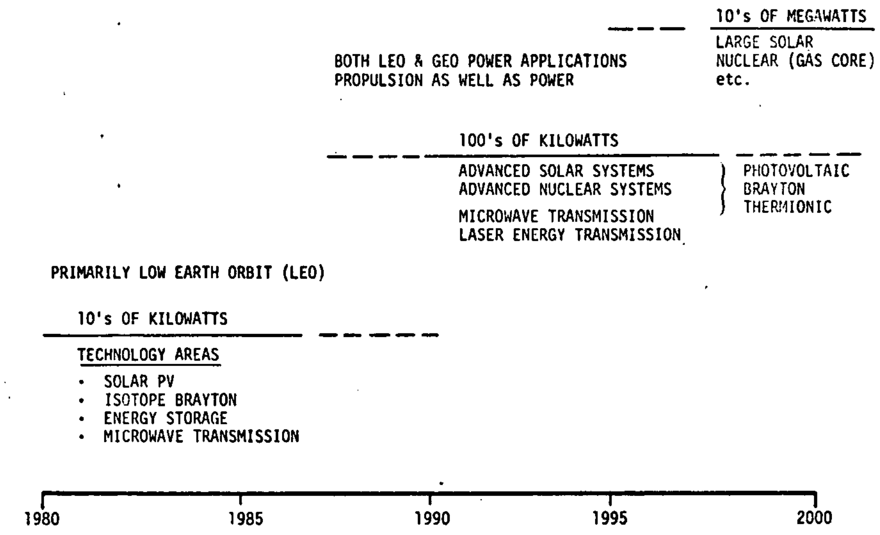


FIGURE 1. STRAWMAN MSPP SCHEDULE FOR SPACE USES

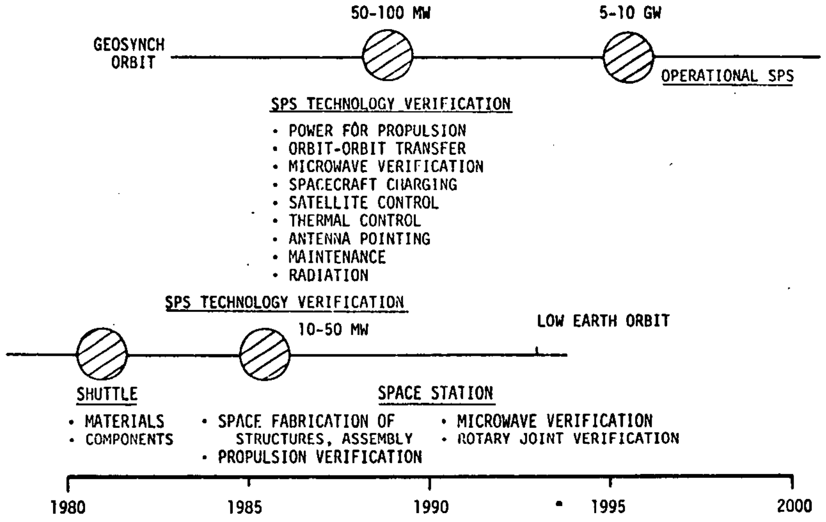


FIGURE 2. STRAWMAN SCHEDULE FOR EARLY SPS

MSPP THRUSTS

- MEGAWATT SOLAR
- ADVANCED ENERGY CONVERSION
- ENVIRONMENTAL
- LASER POWER TRANSFER
- NUCLEAR POWER OPTION

MSPP

— A CONCEPT

CENTRAL

POWER STATIONS

FOR

SPACE MISSIONS

MSPP

— TECHNOLOGY FOR SPS

MSPP FUNCTIONS

- GENERATION
- STORAGE
- TRANSFER
- OTHER

MSPP PROFILE

1980

LEO - GEO

KWs - MWs

SOLAR - NUCLEAR

MSPP USERS

- SHUTTLE PAYLOADS
- SPACE STATIONS
- SPACE MANUFACTURE
- APPLICATIONS
- OTV PROPULSION

MSPP ENERGY TRANSFER

- WIRE, BUSBAR
- MICROWAVE
- LASER
- STORAGE UNIT

ENERGY TRANSFER BY LASER

- CO ELECTROGASDYNAMIC
- 60% LASER EFFICIENCY
- 70% RECEIVER EFFICIENCY
- 40,000 KM RANGE WITH 30 M OBJECTIVE

MSPP STRAWMAN SCHEDULES

- MEGAWATTS BY 2000
- MEGAWATTS BY 1990

APPENDIX C

OVERALL THEME TEAM RANKINGS
AND OBJECTIVES
FOR SPACE POWER THEME

DESCRIPTIONS OF THEME TECHNOLOGIES

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
MSPP Theme Study			
P-2-7-S6	POWER SYSTEMS: Project Oasis		Determine the need, feasibility, and configuration of a long-life Orbiting Electrical Power Station for multimission space application.
High Voltage Power System Technology		1	
P-2-7-E1/3A	Environmental Interactions: Space Plasma-High Voltage Interaction Experiment Satellites (SPHINX B/C)		Spaceflight program to accomplish: obtain space data for design of high voltage systems for space, investigate charge control techniques and demonstrate operation of qualifiable 8-cm ion thruster system.
E-3-7-8	Charge State Measurement		Determine charge state of storage cells.
Technologies for Use of Large Structures in Space Platforms		2	
E-1-7-15	Attitude, Figure and Stabilization Control of Large Space Structures and Arrays		To stabilize and control the attitude of a large flexible structure whose geometry, mass distribution, attitude, and orbit may change while in orbit.
E-3-7-1	Alignment Sensing		Provide physical alignment data for the assembly of large lightweight structures.
M-2-8-1	Space-Deployed Large Structures		Design and develop structural concepts for booms, arrays, reflectors, antennas, and Platforms using space-deployment of ground assembled components.

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
Technologies for Use of Large Structures in Space Platforms (Cont.)			
M-2-8-2	Space-Assembled Large Structures		Design and develop structural concepts for booms, arrays, reflectors/antennas, and Space Platforms using space assembly of ground fabricated components. (Components can include deployable structures.)
Solar Power Technology		3	
P-2-7-PC-2	Photovoltaic Conversion Lightweight Radiation-Resistent Solar Arrays		To develop thin, lightweight, radiation resistant, low-cost solar cells.
P-2-7-PC-7	Photovoltaic Conversion Technology for SEP and Payload Applications		Design, fabricate, and demonstrate large lightweight solar array 25 kWe, 30 W/lb 5-yr life, retractable, 400 V.
E-3-7-9	Radiation Dosage Meter		Provide information to correlate solar cell performance with expected degradation from cumulative radiation. Provides warning of approaching end of life.
Power Transfer		4	
E-2-7-24	Laser Power Transmission		Develop system design and components for space-to-space laser power transmission.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
Power Transfer (Cont.)			
P-2-7-TX-2	Transmission: Laser Power Converter		Provide efficient means to receive and convert laser radiation (5 μm) to electrical power.
P-2-7-TX-3	Transmission: Laser Power Transmitter		Provide high power laser transmitter for use in space.
---	Research on Advanced Propulsion Based on Power Transfer		---
M-2-7-1	Deployable Laser Mirror		Develop structures technology for deployable mirrors for high power laser transmission.
Materials Technology		5	
M-1-7-1	Power Generation Materials and Processes		To develop materials and processing technology to permit the development of higher efficiency, longer life space power generation systems.
M-1-7-2	Power Storage and Transmission Materials and Processing		To develop materials and processing technology to permit development of high-efficiency, long-life space power storage and transmission systems.
Energy Storage		6	
P-2-7-ES6	Large NiCd Battery		Develop a 100 Ah NiCd battery having five-year life cycle.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
Energy Storage (Cont.)			
P-2-7-ES8	Photovoltaic/Electrolysis Fuel Cell Technology		Establish an operational breadboard using available technology for discrete portions of the system.
Supporting Mission Needs			
---	OTV for GEO in 1988 Data Management		---

Section II

THEME SUMMARIES

Part 2

SPACE INDUSTRIALIZATION

THEME DESCRIPTION

BACKGROUND

The U.S. space program has proven that man can live and work effectively in space. The time is now ripe to put man permanently in space so he can exploit the opportunities that are offered by the environment, the moon, and perhaps the asteroids and Mars - that is, the time is ripe for Space Industrialization.

DESCRIPTION

The practical industrialization of space will require the technology to live, explore, and manufacture in the space environment at the lowest possible cost. The initial development of Space Industrialization will be driven by the exploration of solar energy for use on Earth and in space. Other early large projects, largely involving assembly and maintenance, will likely provide the basis for development of fabrication and manufacturing of specialized products in the near Earth environment. Full exploitation of Space Industrialization must await the creation of long-term habitat/manufacturing facilities in deep space which utilize materials from the moon, the asteroids, and in limited cases from the Earth. This activity will include the fabrication of structural elements for the construction of space habitats, large antennas and telescopes, Solar Power Stations, etc.; the gathering of extraterrestrial material resources for processing and the development and operation of manufacturing facilities.

In the beginning, the Shuttle will transport the elements of large structures to make up large space structures. Later, a Large Lift Vehicle and then still later the SSTO will perform the transportation. Ultimately, the moon will become a platform for advanced operations such as the production of structural metals and life supporting oxygen. By then, man will have the means to live permanently in space. He can assist in conserving Earth's diminishing resources, using solar power directly as a substitute for fossil fuels and extraterrestrial materials for construction of space systems.

SPACE INDUSTRIALIZATION

OBJECTIVE: PROVIDE TECHNOLOGIES FOR THE USE OF THE RESOURCES AND THE ENVIRONMENT OF SPACE

SCENARIO: 1978 - 1990

FABRICATION AND MANUFACTURING IN NEAR EARTH ENVIRONMENT

- ORBITING POWER SOURCES
- SPACE STRUCTURES
- LONG-TERM HABITAT DEVELOPMENT
- ROBOTICS/TELEOPERATOR FACILITIES

1990 - 2000

DEEP SPACE UTILIZATION OF EXTRATERRESTIAL MATERIAL RESOURCES

- LUNAR MANUFACTURING
- PERMANENT MANNED DEEP SPACE SITES

THEME ADVOCACY

The ultimate goal of Space Industrialization is to use the environment of space to: (a) provide a site for the location of hazardous processing of materials and energy; (b) provide resources which on Earth are either in limited supply or are obtainable only at the expense of a greatly degraded biosphere; (c) provide long duration weightless and vibration free conditions which are impossible to attain on Earth; and (d) provide a substantially increased efficiency for other space operations.

A. Space offers a unique opportunity to minimize the polluting effects and potentially hazardous aspects of many of our currently Earth based industries. Large nuclear power plants could be placed in Geosynchronous Orbit with microwave or laser transmission of the energy back to Earth. This would virtually eliminate all the environmental and safety concerns currently plaguing the development of energy independence through the use of nuclear power. Toxic chemicals could be processed in space, where no chance of contamination of people or the biosphere would exist.

B. Much of the non-Western world is now consuming energy at a growth rate greater than the U.S. and it is expected that the world as a whole will use up as much energy between 1970 and 2000 as it did for the total period of time up until 1970. Clearly, alternate means of obtaining energy are necessary. Through solar power stations, the undiminishing energy from the Sun can be made available directly in almost unlimited quantities.

At some point in the future, it may become cost effective to process some minerals into products on the moon and ship them to Earth or to facilities in Earth orbit. The effects of obtaining cheap resources from space would be to ease the demand for energy and minerals obtained from Earth, to reduce international tensions generated by competition for these resources, and to increase the average standard of living for all nations.

C. Space offers the environment of long duration weightlessness, an environment that can only be created for a few seconds on Earth. This extraordinary environment promises humanity opportunities for research in the physical and life sciences for processing organic and inorganic materials, and for creating products heretofore unavailable or too expensive to produce on Earth. Space also offers a unique vibration free environment. Nowhere on Earth can this same condition be created.

D. Space Industrialization will provide an additional benefit--that is, virtually all other space activities, certainly all those requiring large structures, will be able to be implemented more easily and efficiently. The materials being processed in space will be available for use without needing to be transported from Earth. The many tools, techniques, facilities developed for Space Industrialization will also be available.

SPACE INDUSTRIALIZATION

USE OF THE SPACE ENVIRONMENT

- PROCESSING OF HAZARDOUS MATERIALS
- PROVIDE RESOURCES TO EARTH
  - POWER
  - BIOLOGICALS
- WEIGHTLESS AND VIBRATION FREE CONDITIONS
- INCREASED EFFICIENCY FOR OTHER SPACE OPERATIONS

BENEFITS

- PROTECT BIOSPHERE
- REPLACE DWINDLING FOSSIL FUELS
- SPACE PROCESSED MATERIALS FOR EARTH CONSUMPTION
- SCIENCE

SCENARIO

The scenario identified for the technology development required to support the practical industrialization of space begins with near-Earth specialized manufacturing facilities and extends out in time and space to long-term facilities using the resources of the moon, and perhaps asteroids and Mars. The early near-Earth facilities will require new light weight materials (composites) technologies and structural technologies which are compatible with space transport technology beginning with the Shuttle. Automated manipulators are needed to process hazardous materials and to control energy (nuclear) sources. In the 1980's, the demonstration of simple, large structures in space and modest (10s of kilowatts) space power (nuclear and solar) will lay the foundation design of extended space processing facilities including extended term Space Stations and lunar bases. Beyond the 1990s, the technology for utilization of lunar materials will pave the way for the full exploitation of Space Industrialization involving long-term habitat/manufacturing facilities in deep space utilizing the materials from the moon.

SPACE INDUSTRIALIZATION

PRESENT	• LIGHTWEIGHT MATERIALS (COMPOSITES) • STRUCTURES CONCEPTS/DESIGNS • THERMAL CONTROL • TPS
1978	• LARGE SPACE STRUCTURE DESIGNS • ORBITING POWER SOURCE • AUTOMATED MANIPULATORS
1980	• DEMONSTRATION OF SIMPLE STRUCTURES IN SPACE • SPACE STATION STRUCTURES CONCEPTS AND DESIGNS • SPACE POWER DEVELOPMENT (10'S kW) • COMPOSITES FOR ADVANCED STS
1985	• SPACE POWER (MW) • DEMON./ASSEMBLE SPACE STATION STRUCTURES • LUNAR BASE STRUCTURES CONCEPTS/DESIGNS • UTILIZATION OF LUNAR MATERIALS • STRUCTURES FOR SPACE PROCESSING FACILITY • ROBOTICS/TELEOPERATORS FOR MFG. FACILITIES
1990	• LUNAR MFG./MATERIAL HANDLING FACILITIES

TECHNOLOGY NEEDS

Early Space Industrialization projects will require those technologies which will support the development of fabrication and manufacturing facilities in the near Earth environment. This will require the design and fabrication of large structures which can be transported (via the Shuttle). Later, a Large Lift Vehicle will perform the transportation. As deep space manufacturing sites are deployed, advanced Space Transportation Systems will be required. All industrialization projects from the initial near Earth facilities to the long-term facilities in deep space will require power systems which will require development of new technologies for the practical utilization of solar and nuclear power systems in space. Large nuclear power plants could be placed in Geosynchronous Orbit with microwave or laser transmissions of energy back to Earth. This would virtually eliminate all the environmental and safety concerns currently plaguing the development of nuclear power. Advances in robotics and teleoperations are needed to perform the assembly, process control, repairs, etc. in early unmanned or hazardous facilities.

Full exploitation of Space Industrialization must await the development of long-term habitats in deep space which will effectively allow man to live permanently in space. This will depend on advances in medical and biological technologies needed to sustain life at deep space manufacturing facilities. If the deep space sites on the moon are to become the platform for advanced operations, the technology for the production of structural metals and life supporting oxygen from lunar material must be developed.

TECHNOLOGY NEEDS

- LARGE SPACE STRUCTURES
  - DESIGN
  - FABRICATION
  - ASSEMBLY
  - CONTROL
- ADVANCED SPACE TRANSPORTATION SYSTEMS
- SPACE POWER SYSTEMS
  - NUCLEAR
  - SOLAR
- ROBOTICS/TELEOPERATORS
- BIOTECHNOLOGY IN SPACE
- UTILIZATION OF LUNAR MATERIALS
  - OXYGEN
  - METALS

FY 1978 INITIATIVE NEEDS (PROJECTED)

The following FY 78 "New Initiatives" are those identified as being pertinent to this Theme. The first eleven were submitted by the NASA Centers; the last two were identified as being necessary and recommended for implementation by Headquarters for FY 78. The complete write-up for each of the Center-submitted initiatives will be available in a separate package.

SUPPORTING INITIATIVES NEEDS

DIRECT SUPPORT

1.	N.I. NO. 114	LARGE AREA SPACE STRUCTURES
2.	N.I. NO. 127	STEV/MIPTL
3.	N.I. NO. 122	OASIS
4.	N.I. NO. 104	DEXTEROUS MANIPULATOR

GENERICALLY OR PARTLY RELATED

5.	N.I. NO. 106	NUCLEAR THERMIONIC POWER
6.	N.I. NO. 130	ORBITAL DEMONSTRATION OF LARGE STRUCTURES
7.	N.I. NO. 116	STRUCTURES FOR ADVANCED TRANSPORTATION SYSTEMS
8.	N.I. NO. 117	ADVANCED DUAL FUEL PROPULSION SYSTEMS
9.	N.I. NO. 118	SPHINX B/C
10.	N.I. NO. 119	RECEST (CRYOGENIC ENGINE SYSTEMS)
11.	N.I. NO. 111	THERMAL SYSTEM DESIGN

TASK TEAM IDENTIFIED

12.	N.I. NO.	EXTRATERRESTRIAL MATERIALS PROCESSING
13.	N.I. NO.	HABITAT/LIFE SUPPORT

WORKING GROUP DIRECTIVES

The function of the OAST Technology Working Groups was to identify and develop the required technologies for each of the Space Themes. In regard to the Theme on Technology for Industrialization of Space, all Working Groups first ascertained if they could contribute to this Theme. If affirmative, the Working Groups then reviewed/revised the FY 78 New Initiatives from the standpoint of their completeness. Technology gaps were then identified, developed in terms of brief descriptions, objectives, schedule, and resources. Finally, the technologies/initiatives were prioritized.

THEME TEAM MEMBERSHIP

<u>HEADQUARTERS</u>	
G. C. Deutsch (Chairman)	OAST
J. J. Gangler	OAST
J. H. Von Puttkamer	OAST
<u>CENTER</u>	
A. Chambers	ARC
E. Kruszewski	LaRC
C. Blankenship	LeRC
J. W. Stearns	JPL
D. S. McKay	JSC
E. C. Cataldo	MSFC

WORKING GROUP DIRECTIVES

- REVIEW/MODIFY/RECOMMEND NEW INITIATIVES
- IDENTIFY TECHNOLOGY GAPS
- CONSTRUCT TIME TABLE FOR TECHNOLOGY TASKS (PRIORITIZE)

SUMMARY

The ultimate goal of Space Industrialization is to use the environment and resources of space. Primary benefits will be to provide: (a) a site for the location of hazardous processing of materials and energy source in order to protect the biosphere from contamination; (b) resources such as solar and nuclear energy which on Earth are either in limited supply or are obtainable only at the expense of a threatened biosphere; (c) long duration weightless and vibration free conditions impossible to attain on Earth; (d) a substantially increased efficiency for all space operations.

The practical industrialization of space will require the technology to live, explore, and manufacture in the space environment at the lowest possible cost. Initial development will be of fabrication and manufacturing in a near Earth environment to yield specialized products for consumption on Earth. Technologies required include: large space structures, advanced Space Transportation Systems, space power systems, design and control, manipulators, life support systems, artificial gravity, and lunar material processing. Full exploitation of space industrialization must await the creation of long-term habitat and manufacturing facilities in deep space which utilize materials from the moon, the asteroids, and limited Earth resources.

SUMMARY

GOAL:

COST EFFECTIVE USE OF THE ENVIRONMENT AND RESOURCES IN SPACE

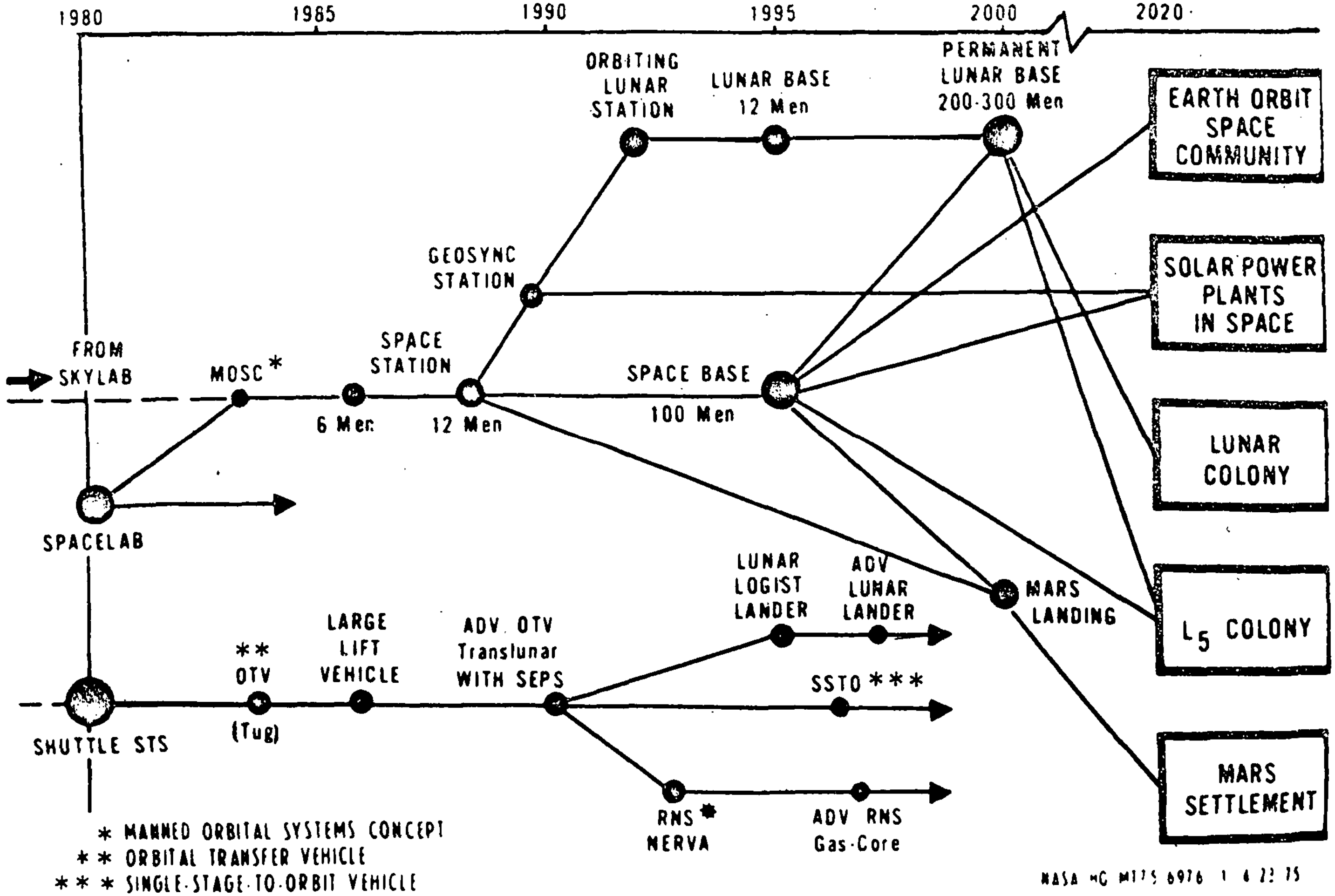
BENEFITS:

- PROTECTION OF BIOSPHERE
- REPLACE DWINDLING FOSSIL FUELS
- SPACE PROCESSED MATERIALS FOR EARTH CONSUMPTION
- ADVANCES IN PURE AND APPLIED SCIENCE

MAJOR TECHNOLOGY NEEDS:

- LARGE SPACE STRUCTURES
- SPACE POWER STATIONS
- CONTROL OF LARGE SPACE STRUCTURES
- MANIPULATORS, TELEOPERATORS, ROBOTICS
- HIGH SPECIFIC IMPULSE ORBIT TRANSFER VEHICLE

EVOLUTIONARY PATHS TO FAR-FUTURE SPACE ENDEAVORS (RELEVANCE TREE)



* MANNED ORBITAL SYSTEMS CONCEPT
** ORBITAL TRANSFER VEHICLE
*** SINGLE-STAGE-TO-ORBIT VEHICLE
✸ REUSABLE NUCLEAR STAGE

ENCLOSURE A

OVERALL THEME TEAM RANKINGS AND OBJECTIVES FOR

SPACE INDUSTRIALIZATION THEME

DESCRIPTIONS OF THEME TECHNOLOGIES

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
M-1/02	Large Space Structures	1	Develop methods and techniques for manufacturing large structures in space.
P-2/S-6	Project OASIS	2	Determine the need, feasibility, and configuration of a long-life orbiting electrical power utility station for multimission space applications.
E-1/15	Control of Large Structures	3	To stabilize and control the attitude of a large flexible structure whose geometry, mass distribution, attitude, and orbit may change while in orbit.
E-1/23	Robotics and Teleoperators	4	Develop a general class of robotic devices with sufficient dexterity to permit mechanical operations in space.
P-1/12, 13	MPD Thruster System Technology Readiness (SEP and NEP)	5	The MPD thruster propulsion system, now seen as essential for economical large cargo Earth orbit operations, will be brought to technology readiness. Provide the technology for an efficient high specific impulse ion thruster system for orbit raising from Low Earth Orbit to a higher orbit using low cost inert fuels.
M-1/5	Methods of Extraction	(Not ranked)	To make use of lunar materials to produce structural materials and/or supplies for lunar habitat uses.
M-1/7	Fabrication Techniques for Space Erectable Structures	(Not ranked)	To develop fabrication techniques for constructing space structures from both composite materials and conventional materials in space for manned and unmanned structures.

DESCRIPTIONS OF THEME TECHNOLOGIES (Cont.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
M-1/4	Manufacture of Composite Materials in Space	(Not ranked)	Development of processes and equipment to fabricate structural members in space - to provide light weight large structures.
M-2/1	Deployable Laser Mirror	(Not ranked)	Develop structures technology for deployable mirrors for high power laser transmission.
M-2/2	Space-Assembled Large Structures	(Not ranked)	Design and develop structural concepts for booms, arrays, reflectors/antennas, and Space Platforms using space assembly of ground fabricated components. (Components can include deployable structures.)
M-2/3	Space-Manufactured/ Assembled Large Structures	(Not ranked)	Design and develop structural concepts for booms, arrays, reflectors/antennas and platforms using space assembly of space fabricated/manufactured components.

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Section II

THEME SUMMARIES

Part 3

SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

THEME DESCRIPTION

A program to search for signals of extraterrestrial origin should be initiated now and expanded over the next decade into one of the major thrusts of our total space program.

Although such a program, if it enjoyed stable support, would in fact expand more or less continuously into a mature long-term effort, it is convenient to describe the program as having three distinct phases: (1) a preliminary phase, (2) an intermediate phase, and (3) a long-term search phase. These phases involve progressive increases in sensitivity, hardware complexity, system capability, and cost. Extraterrestrial intelligent signals may be detected at any time, with the a priori probability being small at the start of Phase I, and growing in proportion to the system sensitivity and number of targets searched. Each phase serves to gather experience useful in the design of the larger scale efforts of the next phase, should these be required. Below is outlined what is conceived to be the content and time periods of the phases.

I. The Preliminary Phase (1976-1981)

This is essentially the system analysis and prototype construction phase during which the most likely search strategies are evaluated, the trade-offs between system parameters are studied, and prototype hardware to implement selected search strategies is designed, constructed, and tested. Existing equipment, supplemented with the prototypes as these come "on-line," is used to conduct initial wide area and wide frequency band surveys (SETI Mark I) for high powered (beam) signals. Existing observatories will examine selected areas and targets over especially likely frequency bands. Although sky survey efforts should cover as much of the radio spectrum as possible, the present search strategy indicates that the low end of the microwave window should be given high priority. The receivers and data processors proposed for Phase I will achieve at least a ten thousand-fold increase in sensitivty over existing systems, at a cost that is negligible compared with a thousand-fold increase in collecting area. In addition, steps must be taken during this period to protect the selected portion or portions of the spectrum against interference that would destroy the effectiveness of the search. Finally, it appears desirable during this period to define and design certain ancillary programs needed to give further confidence in the probability of success of a search, and to identify the targets to be searched.

II. The Intermediate Phase (1982-1988)

This phase continues the search for extraterrestrial intelligence while building the first dedicated search system incorporating the best ideas that have evolved during the preliminary phase, and uses this system to refine the earlier techniques and strategy. It is also the phase during which the nature of a large search system and of the ancillary systems is resolved. The intermediate phase efforts are expected to involve space as well as Earth-based antennas (SETI Mark II) and will utilize the technology developed during the preliminary phase.

THEME DESCRIPTION (Cont.)

III. Long-Term Phase (1989-)

Since the nature of the large-scale systems (SETI Mark III and IV) depend upon decisions to be arrived at during the preliminary and intermediate phases, only general comments can be given at this time:

a. This phase may be unnecessary, or at least greatly altered if detection has already been achieved.

b. Here a "long-term" search is defined as the examination of something on the order of 10^6 likely stars with system parameters appropriate to this task, as determined by prior studies.

c. The required search time is expected to be on the order of two to three decades if only one observation is made per star. During this time, it would be prudent to search the relatively few nearby stars several times.

d. The long search times make it imperative that the system be largely automatic.

e. If the decision is to build a system in space or on the Moon, an initial size commitment or a series of sizes for successively larger systems must be decided upon. If an Earth-based array is chosen, it becomes necessary to expand the pilot antenna by 2-3 orders of magnitude over perhaps a 20-year period. The overriding consideration in the final decision of antenna location is expected to involve the question of radio frequency interference (RFI).

THEME ADVOCACY

There is widespread and growing interest in the whole subject of extraterrestrial life, and particularly of extraterrestrial intelligent life. This interest is evident from the rapidly increasing numbers of scientific publications in the area, from the corresponding increase in the numbers of popular books and magazine articles, and from the general level of public interest as reflected in Congressional inquiries and testimony.

NASA has provided the major existing stimulus for the search for extraterrestrial life in its research programs in exobiology and in the Viking program. If Viking should discover microbial life on Mars, our confidence that life is widespread in the universe will be substantially improved, and the argument for SETI given a powerful impetus. If, on the other hand, the results of Viking are clearly negative, it may be that the only way of detecting extraterrestrial life will be to search for signals of intelligent origin. In either case, the Agency should initiate a SETI program now so that the momentum of exobiology programs and missions can be maintained. In view of the timing of the Viking landing, a SETI program should actually be initiated in FY 77.

The electromagnetic spectrum is rapidly becoming saturated. It is important to begin the program as soon as possible so that good use can be made of the spectrum and protection from radio frequency interference can be provided most economically.

It is possible that the SETI program will be shown to be most efficiently and economically carried out with a spaceborne system. Should this in fact be the result of the systems studies carried out in the preliminary phase, the space system could then become a major user of the Space Shuttle and associated Space Transportation Systems in the second phase of a SETI program after 1984. In view of the lead times involved for projects involving Shuttle use, the first phase of the program should begin as soon as possible.

The Soviets have a major interest in SETI programs and are already conducting preliminary searches. A Soviet long-range program plan, comprehensive in nature, has been published in "Soviet Astronomy," and describes extensive ground-based and space systems. While their system designs do not appear to be as sophisticated as those envisaged here, it would seem to be important to maintain the U.S. lead.

Political circumstances may lead at any time to a demand for a bold and imaginative new element of our national space program. Political circumstances could also lead to the demand for an international space program, and in particular for a joint U.S.-USSR venture as a follow-on to the Apollo-Soyuz mission. In either case, a SETI program could be a promising candidate. An early start on the development of the science and technology base, in FY 77 or FY 78, is indicated in the interest of preparedness.

BENEFITS

- THE DISCOVERY OF EXTRATERRESTRIAL CIVILIZATIONS WOULD HAVE ENORMOUS BENEFITS THAT GREATLY EXCEED THOSE OF ANY OTHER VENTURE EVER UNDERTAKEN BY THE HUMAN RACE. THE POTENTIAL GAIN IN KNOWLEDGE IN THE ARTS AND SCIENCES AND IN TECHNOLOGY ARE INCALCULABLE. IN ADDITION, KNOWLEDGE OF THE PATHWAYS TAKEN BY EXTRATERRESTRIAL CULTURES, WHICH ALLOWED THEM TO ACHIEVE LONG-TERM STABILITY, MAY INDEED BE ESSENTIAL TO OUR OWN LONGEVITY.

- WHETHER OR NOT SIGNALS OF INTELLIGENT ORIGIN ARE FOUND, MAJOR DISCOVERIES WILL SURELY BE FORTHCOMING IN THE SCIENCE OF RADIO ASTRONOMY.

- THE DATA PROCESSING SYSTEMS THAT WILL BE DEVELOPED WOULD HAVE A MAJOR INTEREST IN A NUMBER OF FIELDS WHERE MULTICHANNEL SPECTRAL PROCESSING IS REQUIRED.

- THE DETECTION OF EXTRASOLAR PLANETS IS A FUNDAMENTAL SCIENTIFIC INTEREST QUITE APART FROM ITS IMPORTANCE FOR SETI.

- THE STELLAR CENSUS, GIVING AN AUTOMATED RECORD OF ALL STAR TYPES, LOCATIONS, MAGNITUDES AND DISTANCES DOWN TO 14TH MAGNITUDE, WILL BE OF ENORMOUS VALUE TO THE ASTRONOMICAL COMMUNITY.

TECHNOLOGY NEEDS

It is generally recognized that in the search for signals of extraterrestrial intelligent origin, the key requirement is a highly sensitive search system. The three most important parameters which relate to the system sensitivity are the effective collecting area, the system noise temperature, and the frequency resolution bandwidth or bin width. Substantial improvement in effective collecting area, over that presently available, is by far the most expensive and is highly dependent on unknowns such as antenna design, location, and RFI compatability. On the other hand, vast improvements (40-60 dB) over present instrumentation in system noise temperature and bandwidth resolution is well within the state of the art and could be achieved at relatively modest costs. The hardware thus developed could then be utilized with existing antennas (Arecibo, DSN, etc.) to begin an active SETI effort to look for signals from fortuitously close civilizations, or equivalently, civilizations at greater distances but of higher effective radiating power. Concurrently, the questions with regard to antenna design, location, and RFI compatability have to be addressed by in-depth studies in order to provide the information required to enable a confident final decision on the construction of a more sensitive search system that will be both cost effective and reliable. Finally, there is a strong expectation that the signals of interest will originate on or near planets of solar type stars. Within 1000 light years there are far fewer of these stars than there are separate pointing directions on the sky for even a single 100-m antenna. Therefore, a catalog of likely targets is required if the signal search duration is to be minimized. Present star catalogs contain about 10^{-3} of the solar type stars believed to be within 1000 light years of the Earth. It is necessary to carry out a stellar census of the sky down to the 14th-15th apparent magnitude so that a reasonably complete target list can be prepared for the search.

SYSTEM INDEPENDENT TECHNOLOGY

MULTICHANNEL SPECTRUM ANALYZER (MCSA)

The optimum architecture for a 10^6 to 10^9 bin Fourier Transform Processor, or MCSA, is now being studied by simulation on the Ames 7600 computer. A 10^6 bin unit, using off-the-shelf chips, would be constructed for on-air testing by the start of FY 78. Economical special LSI chip designs will be required in FY 77-78 along with the architecture of an MCSA design expandible to 10^9 and more bins. A prototype subunit of the final 10^9 MCSA design should be completed and tested in FY 79. The construction of the final 10^9 MCSA would then start at the end of FY 79.

LOW NOISE RECEIVER

It is vital to carry out realistic, operational tests of the new electronic components during development, and to characterize the new spectral range of prime interest. JPL can fabricate a MASER (tunable over this spectral range, having an instantaneous bandwidth 20-40 MHz; 2-3 K equivalent terminal temperature) for tests by extrapolating the design of the DSN S-band MASER. This will improve the sensitivity of the tests by about 10 dB over the better L-band receivers now in use. It should be completed in time for use with the first experimental models in the multichannel spectrum analyzer and pattern recognition analyzer development.

Following this, it will be necessary to study and develop a wide band ($\approx$300 MHz) low noise input amplifier system. A final prototype design should be available by the beginning of FY 80.

PATTERN RECOGNITION ANALYZER

Two types of analyzers are required in order to study the spectral data developed by the MCSA. These should be developed in parallel over FY 77-80. The first is a scanning, zoom-type display optimized for human pattern recognition capability. This unit will be used for diagnostic purposes, on-air tests, and to assist in determining the precise characteristics required for the second, or automatic analyzer. In addition, other data processing approaches require examination.

The automatic analyzer is required to deal effectively (at a sufficiently low false-alarm rate) with the enormous data rate provided by the MCSA, sorting out possible intelligent signals, interfering signals due to both human activities and astronomical phenomena, and monitoring the overall system performance.

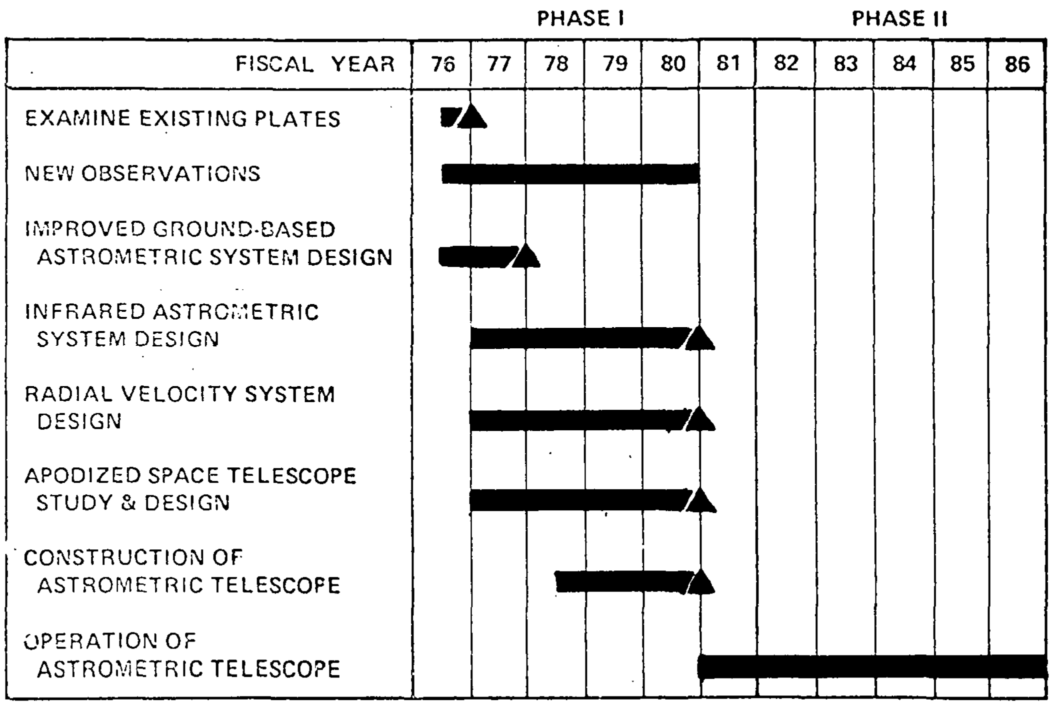
The knowledge of experienced researchers in visual and automatic pattern recognition systems and in data processing should be applied in the development of these analyzers. Both the analyzers and the MCSA should be major advances in the state of the art and of great value in areas outside SETI.

EXTRASOLAR PLANETARY DETECTION

It is important to the fundamental arguments for SETI that a program be implemented for the design and development of an extrasolar planetary detection system. The first step should be the design of dedicated astrometric telescope and a concurrent detailed feasibility study of promising new techniques such as space telescope apodization, IR, and radio VLBI astrometry and photometric and radial velocity determination.

Detailed design studies of new techniques should follow the conclusion of the feasibility study, completed by January 1980. The design study may interact with the similar study on a dedicated astrometric telescope, as some of the potential new techniques (radial velocity) could use the same telescope systems.

EXTRASOLAR PLANETARY DETECTION PROGRAM



STELLAR CENSUS SYSTEM

There is a strong expectation that the signals of interest will originate on or near planets of solar type stars. Within 1000 light years there are far fewer of these stars than there are separate pointing directions on the sky for even a single 100-m antenna. Therefore, a catalog of likely targets is required if the signal search duration is to be minimized. Present star catalogs contain about 10^{-3} of the solar type stars believed to be within 1000 light years of the Earth. It is necessary to carry out a stellar census of the sky down to the 14th-15th apparent magnitude so that a reasonably complete target list can be prepared for the search.

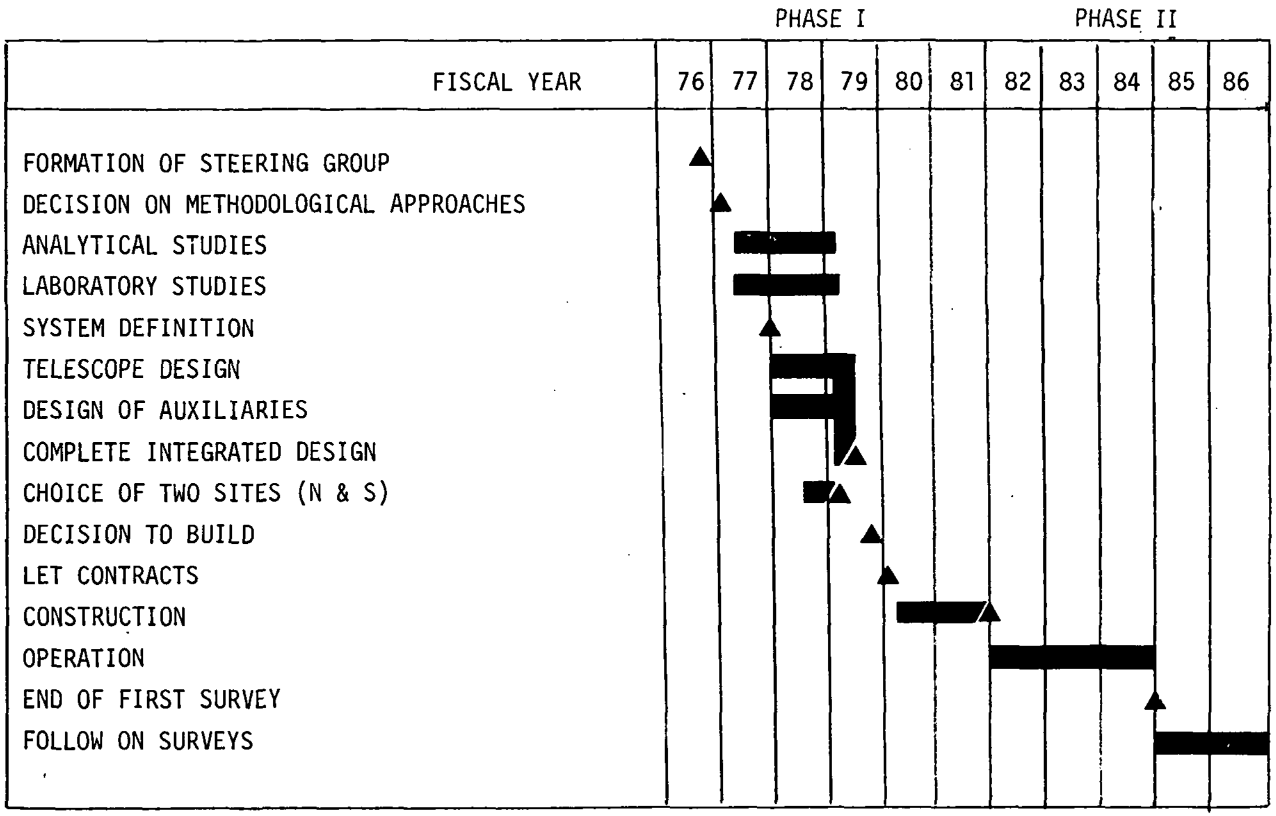
After preliminary examination of the relevant problems, it is believed that an optical telescope system equipped and fully automated for multicolor photographic photometry can provide a stellar census from which target priority lists can be constructed. Further detailed study is required in order to verify this belief. (If the photographic approach should prove inadequate, an alternative type system; probably photoelectric, will have to be developed.)

Assuming the photographic approach is reasonable, it is planned to complete the detailed system design (already begun) by the end of FY 79. The system envisaged involves developing the following major characteristics:

1. Identical telescopic systems located at suitable sites at roughly 30N and 30S latitudes.
2. The moderate field telescopes will be equipped with a fully automatic calibration, exposure, and plate development system for multicolor photometry.
3. The nature of the color system has yet to be established. This must be determined. Stellar classification is expected to be on the MK system, but further study is planned in this connection.
4. All plates will be measured on computer-controlled measuring machines, and the computer will provide best estimates of spectral type, luminosity, etc.
5. The stellar census will consist of magnetic storage containing nearly all objects in the sky down to perhaps 15th apparent magnitude, all classified by a uniform, well defined color system. Unless unforeseen problems arise, detailed system design should be complete by FY 80.

Telescopes having apertures on the order of 60 in. are envisioned. Construction at good northern and southern hemisphere sites should take two or, at the most, three years, starting in FY 80.

STELLAR CENSUS PROGRAM



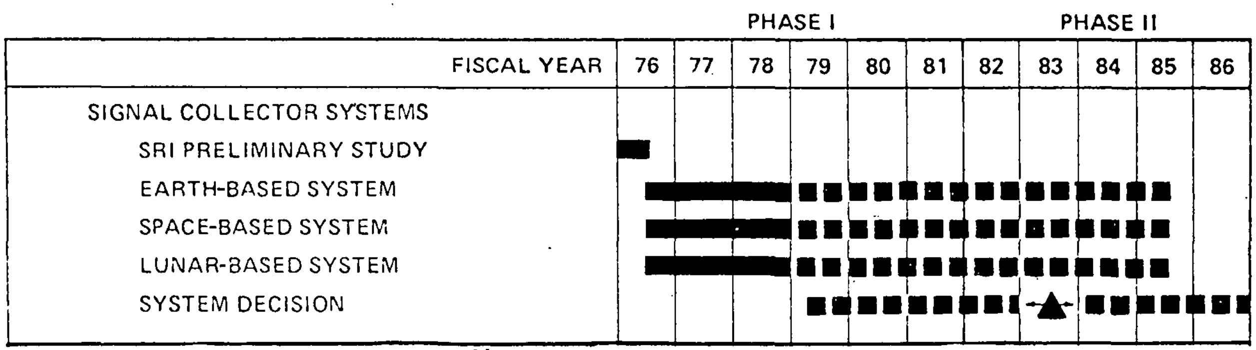
ANTENNA DESIGN/LOCATION TECHNOLOGY

In order to assist the decision on whether to build a large system on Earth, or in space, or on the far side of the Moon, more accurate cost, feasibility, and risk evaluation data are required than are available at the end of FY 76. The SRI study asserts that a space system may be comparable in cost with a ground-based system.

A decision on where to site a large interstellar search system should be made only when hard estimates of cost, feasibility, risk, and capability associated with the basic alternatives are available.

Three separate parallel studies are required to develop this information in a reasonable time. An effort will be made to see that each study is carried out by capable proponents of the design study entrusted to them. At least two years, and perhaps six or more years, may be required to develop sufficient basic data for a second decision, whether to base a large search system (if still required) on Earth, in space, or on the Moon; and what the optimum form of each system should be.

COMPARATIVE SYSTEM STUDIES

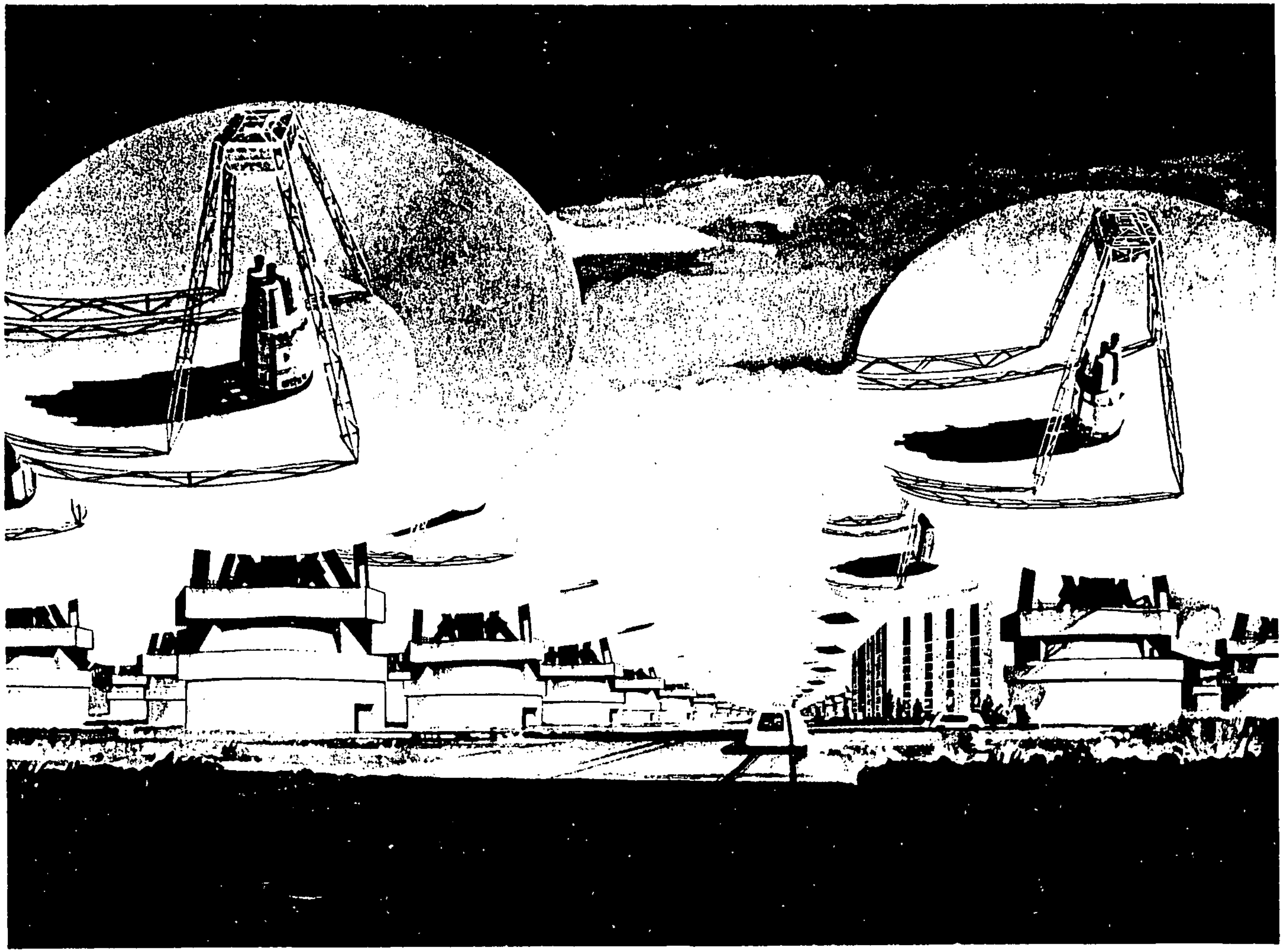


EARTH-BASED SYSTEMS

For ground-based operation, an array similar to that of the Cyclops study is the system of choice at the present time. Studies and technical developments since Cyclops, particularly in materials technology, show that an Earth-based array system can be developed at a cost appreciably less than projected in the 1971 study.

It is planned to refine the proposed Earth-based system by studies and model exercises until the design reaches the state of the art and projected costs are understood to a precision of 10 to 15%. These studies will be carried on at a moderate level of effort for the next three to six years, or until a point of diminishing returns is clearly evident. These studies will be of value in areas outside SETI.

CYCLOPS



SPACE-BASED SYSTEMS

For space-based systems, the SRI study shows a shielded, multifeed, large spherical antenna to be the system of choice. But costs, feasibility, and risk are most uncertain. Therefore, a major study should be carried out, starting in FY 77 and continuing until a clear decision can be made. This study will involve at least these major items:

a. Development of the long-lived, lightweight, low thermal coefficient of expansion materials, or alternatively, the use of a sun shield to stabilize the system at a low temperature

b. Antenna design alternatives

c. Transporation methods

d. Space assembly, operations, and maintenance

e. The satellite relay systems required to line the data flow with Earth operations

f. The optimum division of the electronic system between space and Earth

The increase in sensitivity for space-based systems is expected to occur in a step-wise fashion with an increase in antenna aperture on the order of a factor of ten for each successive system.

Outlined on the facing page are important parameters of three space antenna systems suitable for SETI and general physical studies that represent the successive steps in a possible search strategy starting with small and intermediate size systems in Phase II and the large system for Phase III. Mark II is based on a Boeing design, III and IV on a Lockheed design.

CHARACTERISTICS OF SPACE-BASED SYSTEMS

	Characteristic	Mark II	Mark III	Mark IV
1.	Diameter (m)	30	300	3000
2.	Antenna system	Off-axis rigid parabolic cassegrain	Maypole soft spherical	Maypole soft spherical
3.	Surface tolerance (mm)	0.05	1	1
4.	Nominal maximum frequency (GHz)	300	15	15
5.	3 dB beamwidth/pointing precision; f = 1.5 GHz	24'/2.5'	2.5'/15"	15"/1.5"
	f = 15 GHz	2.5"/15"	15"/1.5"	1.5"/0.1"
	f = 300 GHz	7.2"/0.7"	NA	NA
6.	Feed(s) pointing control range	NA	±2°	±7°
7.	*Number of feeds; secondary diameter*	*1; 6 m*	*1; 30 m*	*3; 130 m*
8.	Slew time: collector	10^2	10^3	10^6
	feed(s) (sec)	NA	10^2	10^2
9.	Mass of antenna (kg)	10^4	10^6	10^7
10.	Mass of RFI shield (kg)	NA	10^6	10^7
11.	Electrical power requirements (kW)		(To be added)	
	Receivers, Data Link(s), Control Telemetry, Figure monitor(s), Figure Servos	2	2	6
	Collector ion thrustors (If required)	10	30	1500
	RFI Shield thrusters (May be chem.)	5	15	700
12.	Circular polarization channels	2	2	6
13.	Total data link bandwidth (MHz)	600	600	1800
14.	System noise temperature (K)	5-100	5-10	5-10
15.	Frequency resolution (min. bin width)	0.1 Hz	0.1 Hz	0.1 Hz
16.	Equivalent isotropic power sensitivity (dBW/Hz minimum in 1000 sec)	-255	-255	-255
17.	Lifetime: antenna and shield	10	10	10
	subsystems	*3*	*3*	*5*
18.	Operational Date	1984	1990	1995

SPACE-BASED SYSTEMS (Cont.)

- Assembly (or unfurling) and tests are assumed to take place in low Earth orbit (275 km). Then, systems are ferried to synchronous altitude or to L-4(5) lunar position (or beyond). One or two manned visits per decade should be sufficient for routine service, replacement of consumables, and repair.

- Due to rapid motion relative to ground stations, low Earth orbit appears highly impractical for SETI. A geostationary orbit is nearly ideal for SETI since the Earth blocks only about 0.6% of the sky. At synchronous altitude, a direct link with the Earth signal processing system is possible. At other altitudes, two relay satellites are required. In Mark III and IV, where the feeds are physically independent of the main reflector system, a third relay is required. The shield also complicates the solar power supply system because of shadowing.

- A SETI system in space needs either greater RFI allocation protection (than on Earth), or an RFI shield. Such a shield needs to be appreciably larger than the SETI antenna and held close to it. A shield diminishes the advantages mentioned above. It complicates the links-to-Earth and the solar power problems. A shielded system is best placed at lunar distance, to avoid interference from satellites. A good shield does allow complete freedom of choice in operating frequency.

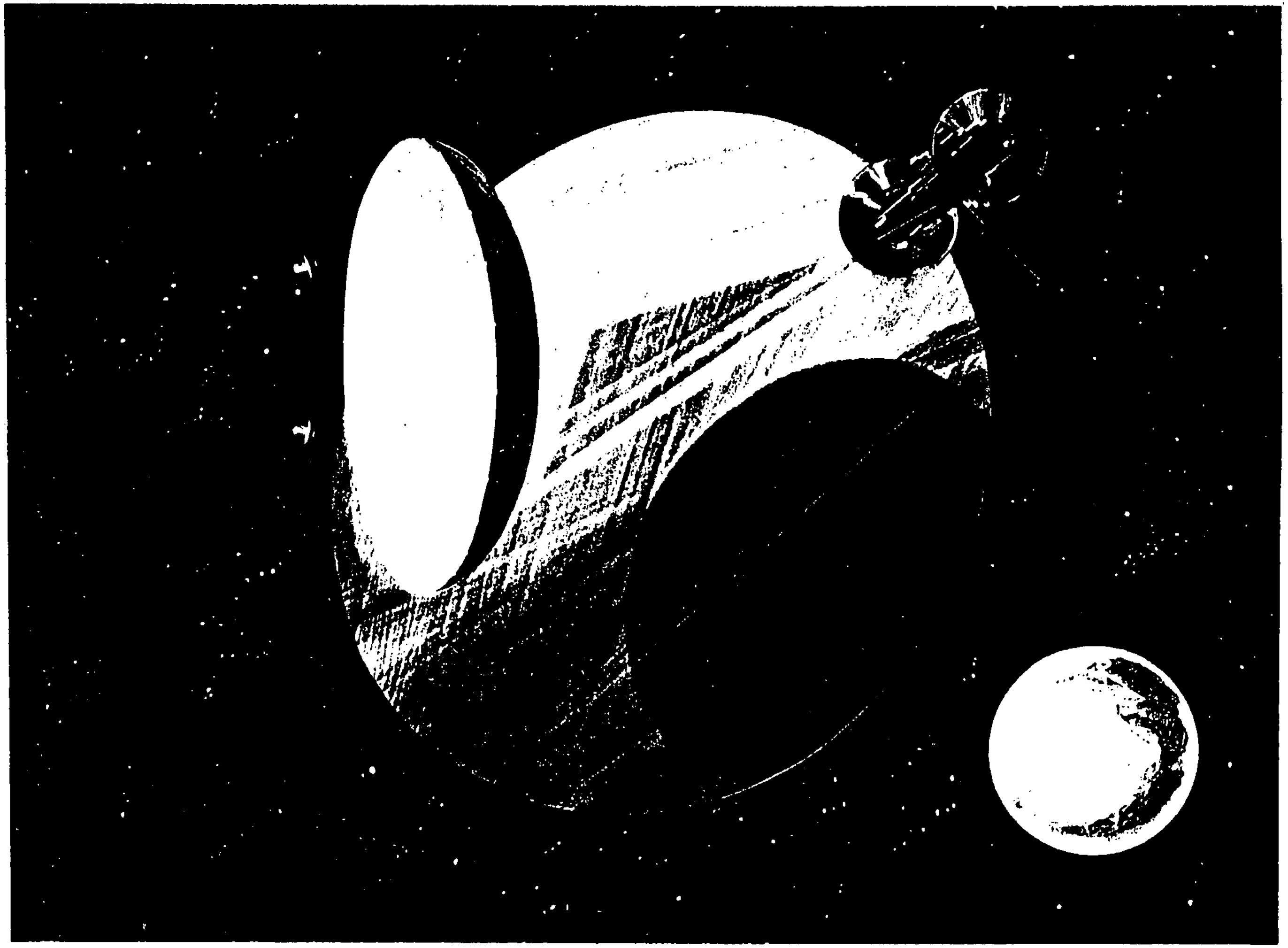
- A shielded Mark II system has much to recommend it now. It can look for strong signals over the entire microwave window; and its value to radio astronomy is considerable. This is because of its atmosphere-free spectral coverage and resolution. Nothing on Earth could match it for broad frequency capability. It would have a long life time independent of SETI.

- The multiple feed arrangement of Mark IV, triples the data processing system costs while cutting the search time to perhaps one-third.

- In all systems it is assumed all data processing is on Earth. Signal collection is straightforward. Besides the collector and feed, it requires only low noise amplifiers, atomic frequency standards, frequency synthesizers, and a relay system to Earth. For the foreseeable future, the data processing system must be on Earth or in a stable space colony of considerable capability.

SPACE SETI SYSTEMS

Artist's Concept of Spherical Space SETI System Antenna and Two Feeds, Showing Relay Satellite and Radio Frequency Interference Shield: Located at Lunar Libration Point L4.



LUNAR-BASED SYSTEMS

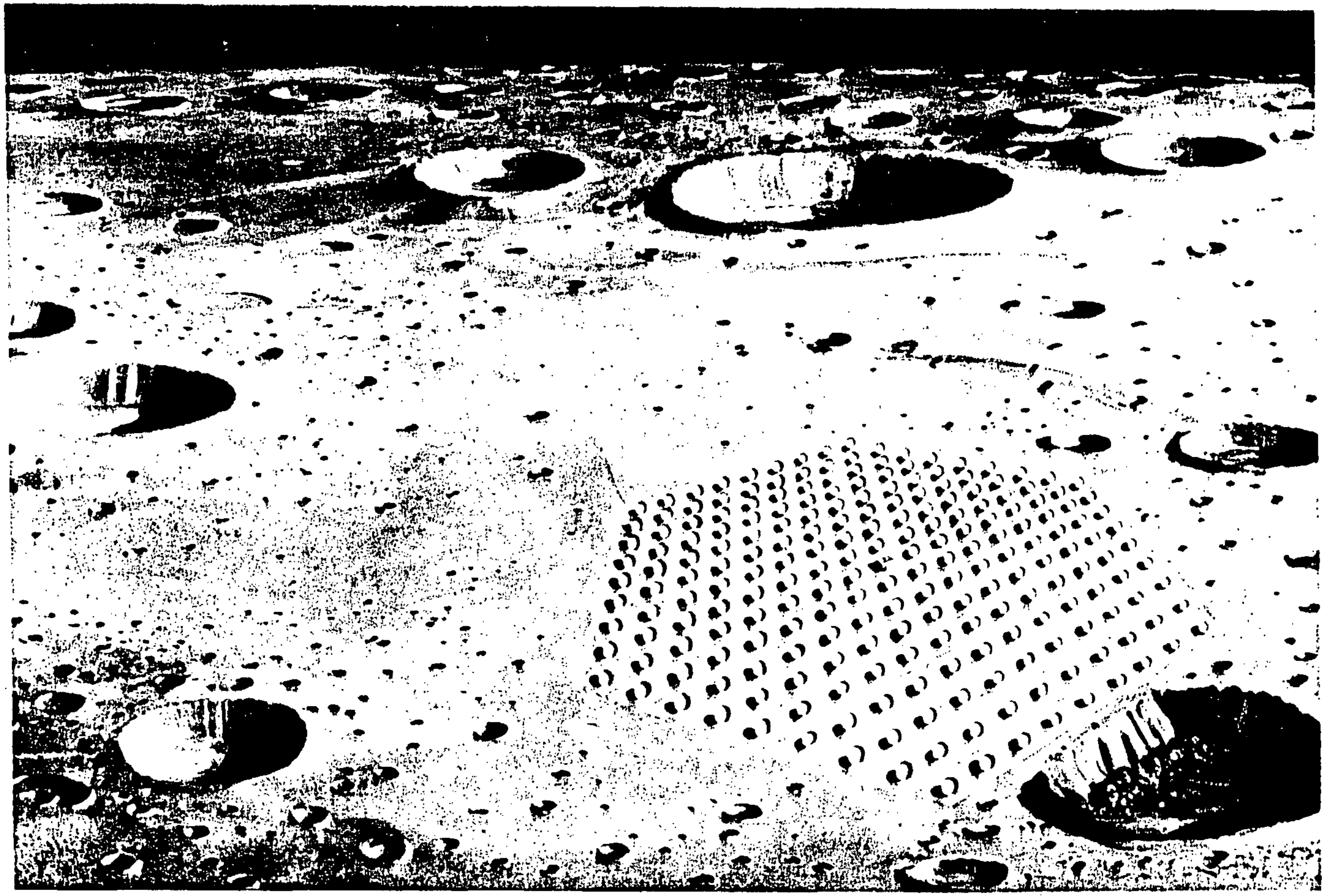
A search system based on the far side of the Moon has some obvious advantages stemming chiefly from the shielding from the Earth provided by the Moon itself.

The SRI study determined a Cyclops-type array as the system of choice for this site. Extrapolating soft engineering and cost data, they estimated the Lunar site could be exploited perhaps by FY 2000 or later. Lunar colonization would be required and could be developed by then.

It is clear that more detailed studies are required in order to soundly evaluate the possibility of a lunar site for SETI.

LUNAR CYCLOPS

Artist's Concept of High Altitude View of Lunar Cyclops Array, Showing Central Control and Processing Building and Lunar Base in Left Middle Distance.



SEARCH STRATEGY AND CRITERIA

- LISTEN RATHER THAN TRANSMIT
- CONCENTRATE ON LOW END OF MICROWAVE WINDOW
- BEGIN NOW WITH EXISTING ANTENNAS
- OPERATE MODEST PILOT SYSTEM WHILE CONTINUING TO INCREASE SENSITIVITY
- MULTICHANNEL SPECTRAL ANALYSIS
- EXTRASOLAR PLANETARY DETECTION
- DEVELOP SEARCH PRIORITIES: SUITABLE STARS OUTWARDS FROM EARTH, RANDOM IN GALACTIC PLANE, OTHER GALAXIES
- NEED PROTECTION OF OPTIMUM FREQUENCY BAND
- MAKE AVAILABLE PART TIME FOR RADIOASTRONOMY
- PRODUCE VALUABLE SCIENTIFIC RESULTS
- HAVE REASONABLE CHANCE OF SUCCESS WITHIN A DECADE OR TWO AFTER ACHIEVING A SIGNIFICANT SEARCH CAPABILITY
- HAVE THE LEAST COST FOR GIVEN PROBABILITY OF SUCCESS

COMPARISONS OF INTERSTELLAR SEARCH SYSTEMS

PARAMETER \ ANTENNA CONCEPT	CYCLOPS TYPE ARRAY ON EARTH	SPACE SYSTEM SPHERICAL REFLECTOR		CYCLOPS TYPE ARRAY ON THE MOON
		WITH 1 BEAM	WITH 3 BEAMS	
SYSTEM TEMPERATURE, K	10	7	7	7
ANTENNA EFFICIENCY, percent	80	72	46	84
SKY COVERAGE, percent	82	100	100	94
MAXIMUM SEARCH RANGE, light years	405	379	379	387
AREA, km^2	4	3	4	2
SEARCH TIME, years	8	17	4	8
OVERALL COST, billions of 1975$	6	6	9	14

ASSUMPTIONS: 10^6 CIVILIZATIONS IN THE GALAXY WITH 1 GW EFFECTIVE RADIATED POWER
95% PROBABILITY OF RECEIVING AN INTELLIGENT SIGNAL
10% OF TIME ALLOCATED TO RADIO ASTRONOMY

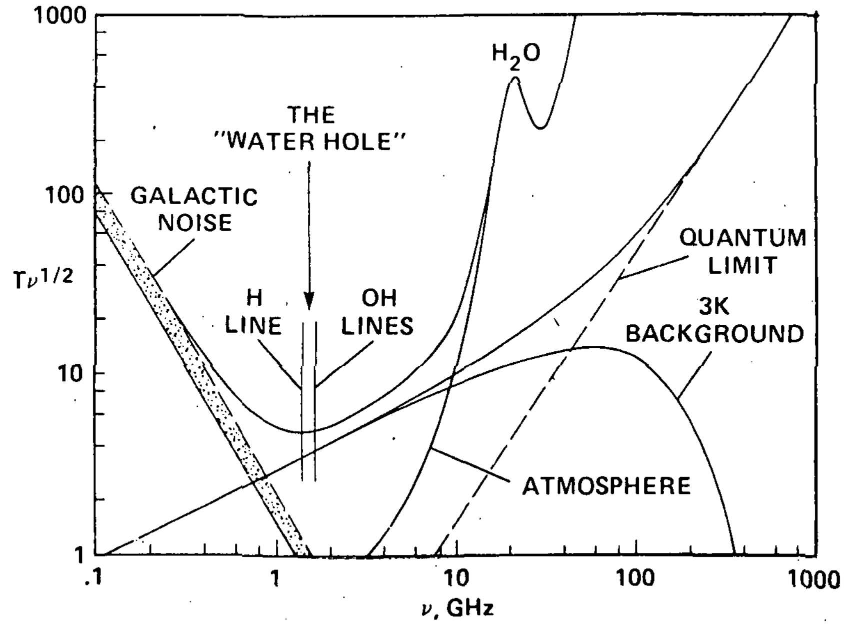
MICROWAVE WINDOW

- MINIMUM NOISE SPECTRAL DENSITY
- GREATEST RANGE FOR GIVEN TRANSMITTED POWER

LOW END OF MICROWAVE WINDOW

- COLLECTING SURFACE CHEAPEST PER UNIT AREA
- LOWER DOPPLER DRIFT RATES PERMIT NARROWER BANDWIDTHS
- BROADER BEAMS
- HYDROGEN & HYDROXYL LINES

MICROWAVE WINDOW



RADIO-FREQUENCY INTERFERENCE (RFI)

RFI blocks access to that part of the electromagnetic spectrum occupied by the interfering signal. If the signal is strong enough, it can paralyze the low noise input amplifiers of any search system, thus putting the entire system out of operation.

RFI System Studies are underway in FY 76 because it is clear Phase I activities will require protection by suitable frequency allocation procedures. Further, protective allocation procedures are required for any Earth-based search system regardless of size and siting; they are required for a space system unless a separate and adequate shield is provided--a costly matter. For an Interstellar Search System (ISS) based on the far side of the Moon, allocation procedures are required only for space vehicles launched on trajectories going beyond the lunar orbit.

A major effort in RFI system studies is planned for FY 77-78. This will have two aspects: (1) how the contemplated search systems may be designed and operated to be least susceptible to RFI, and (2) what frequency allocation procedures are required by a search system while at the same time least restrictive with respect to other uses of the same portion of the spectrum.

RFI PROTECTION

SYSTEM	DEGREE OF LEGAL PROTECTION REQUIRED (IMPACT ON SPECTRUM USE)	IMPACT ON SETI SYSTEM HARDWARE
EARTH-PRELIMINARY	MODERATE	NONE
EARTH-FULL SCALE	MODERATE	NONE
SPACE-UNSHIELDED	MAJOR	NONE
SPACE-SHIELDED	INSIGNIFICANT	CONSIDERABLE
MOON	INSIGNIFICANT	NONE

- PREFERRED BANDS FOR DETECTING SIGNALS
  -1.400 TO 1.427 GHz (HYDROGEN LINE)
  -1.427 TO 1.727 GHz (NOISE MINIMUM)
- CERTAIN TRANSMISSIONS IN THESE BANDS, PARTICULARLY FROM SATELLITES, WILL MASK SIGNALS AND PREVENT THEIR DETECTION
- LEGAL PROTECTION NECESSARY FOR SUCCESSFUL SEARCH
- DEGREE OF PROTECTION REQUIRED DEPENDS ON SEARCH SYSTEM USED

WORKING GROUP DIRECTIVE

Priorities have been established within the following three major research areas:

1. <u>System Independent Technology</u>

   The prototype MCSA and the low noise maser must be available as early as possible since their use on existing antennas allows an early preliminary search/survey effort and will address, in a timely fashion, many of the downstream technology requirements.

2. <u>System Studies</u>

   By far, the greatest technology development effort at the Workshop should be directed toward a space-located antenna, rather than Earth or Lunar options. A great deal of work has already addressed the large-scale Earth-based system (Cyclops) and, with the possible exception of new signal handling and materials considerations, the system concept is fairly well established. The space systems, on the other hand, have received only modest attention and, therefore, present the greatest unknowns. Preliminary studies tend to indicate that a lunar-based search system would be cost prohibitive. Further studies of lunar possibilities seem warranted, however, before sound decisions can be made.

3. <u>Radio Frequency Interference (RFI)</u>

   In recognition of the rapidly advancing national preparations for the 1979 general World Administrative Radio Conference (WARC), it is essential that the SETI position on RFI protection be established as soon as possible. This is extremely important since, with the exception of the lunar system, RFI will directly impact the feasibility and costs of any SETI concept regardless of design and location.

The Working Groups are asked to assess the intrinsic value of the SETI developed technology. In particular, it is necessary to determine, as soon as possible, which specific SETI technical advances would apply to other fields of endeavor, with the various specific applications clearly identified.

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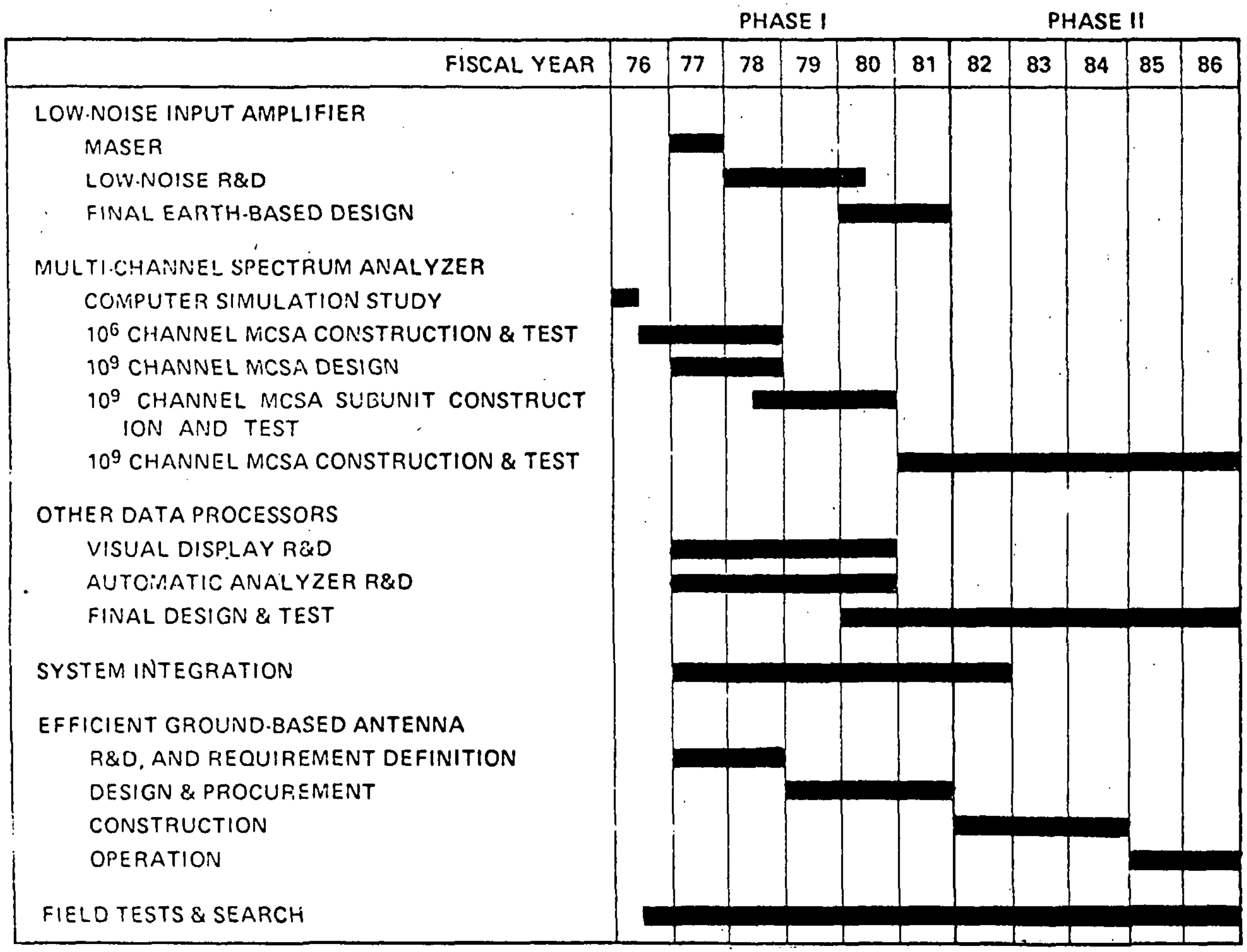
SEARCH SYSTEM DEVELOPMENT



SETI PROGRAM PLAN

Phase I Costs

	MILLIONS OF FY' 76 DOLLARS						TOTAL
	76	77	78	79	80	81	
COMPARATIVE SYSTEM STUDIES							
SRI PRELIMINARY	0.12						0.12
EARTH-BASED		0.2	0.3	0.4	0.3	0.2	1.4
SPACE-BASED		0.7	1.0	1.4	1.4	0.7	5.2
LUNAR-BASED		0.3	0.4	0.5	0.4	0.2	1.8
RFI EVALUATION		0.1	0.2	0.2			0.5
SYSTEM INDEPENDENT TECHNOLOGY DEVELOPMENT							
STELLAR CENSUS	0.02	0.3	0.6	0.9	2.5	2.5	6.8
PILOT MODEL RECEIVER AND DATA PROCESSOR	0.14	0.9	2.5	5.0	10.0	10.0	28.5
DEDICATED SINGLE ANTENNA		0.3	0.4	0.5	0.5	10.0	11.7
SCIENCE, INCLUDING PLANETARY DETECTION	0.03	0.3	0.4	0.6	0.9	1.5	3.7
IMPACT STUDIES		0.1	0.1	0.1	0.2	0.2	0.7
TOTAL	0.31	3.2	5.9	9.6	16.2	25.3	60.5

SETI

New Initiatives Plan

- Antenna Independent Technology
  - a. Low Noise Front End
    - i. 40 MHz Bandwidth
    - ii. 300 MHz Bandwidth
    - iii. Parametric Upconverters
    - iv. Spaceborne cryostat
  - b. Receiver
  - c. Data processing
- Multichannel Spectral Analyzer and Pattern Analyzer
  - a. 10^6 channel
  - b. 10^9 channel
- World Administrative Radio Conference
- Preliminary Searches Using Mark I Systems - Sky Survey
- Preliminary Searches Using Mark I Systems - Targeted Search
- Mark II Systems (Phase I Study)
  - a. Spaceborne
  - b. Ground
- Data Relay and Communications Systems
  - a. Space
  - b. Ground
- Archival System
- Radio Frequency Interference
  - a. Studies and Design (Receiver Protection)
  - b. Hardware Test and Evaluation (Receiver Protection)
  - c. Shield Requirements
- Antenna Design (Space) Mark III & IV
  - a. Reflector
  - b. Feed
  - c. Shield
  - d. Transportation
  - e. Stabilization and Control
- Antenna Arraying Techniques
- Stellar Census
- Comparative Systems Studies (Trade-off Mark II, IV)
- Planetary Detection
- Science of SETI
- Impact Studies

Those proposals and activities which relate to, and would be supportive of, the SETI initiative are listed below. As shown, only one new initiative currently submitted totally supports SETI, but specific tasks in others are of value to the SETI program.

SUPPORTING PROPOSALS--#9 SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE SUPPORTING INITIATIVES

		N.I. NO.	
● DIRECT SUPPORT	1.	110	SETI (PHASE I)
● GENERICALLY OR PARTLY RELATED	2.	103	CCD-UNIFIED DATA PROCESSOR (10)
	3.	104	DEXTEROUS MANIPULATOR (11)
	4.	105	ATTITUDE CONTROL OF STRUCTURES (11)
	5.	111	THERMAL SYSTEM DESIGN
	6.	114	LARGE AREA SPACE STRUCTURES (8)
	7.	115	CCD ON-BOARD PROCESSOR (10)
	8.	118	SPHINX C (7)
	9.	127	STEV/MIPTOL (8)
	10.	128	ATL
	11.	129	HELIUM CRYOGENICS/SPACE
	12.	130	ORBITAL DEMONSTRATING OF LARGE STRUCTURES
	13.	301	AUTONOMOUS GUIDANCE AND NAVIGATION

THEME SUMMARY

SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

The goal of SETI is the detection of radio signals of extraterrestrial intelligent origin. The SETI Theme Program Plan consists of three phases: (1) a preliminary or near-term phase, (2) an intermediate phase, and (3) a long-term phase.

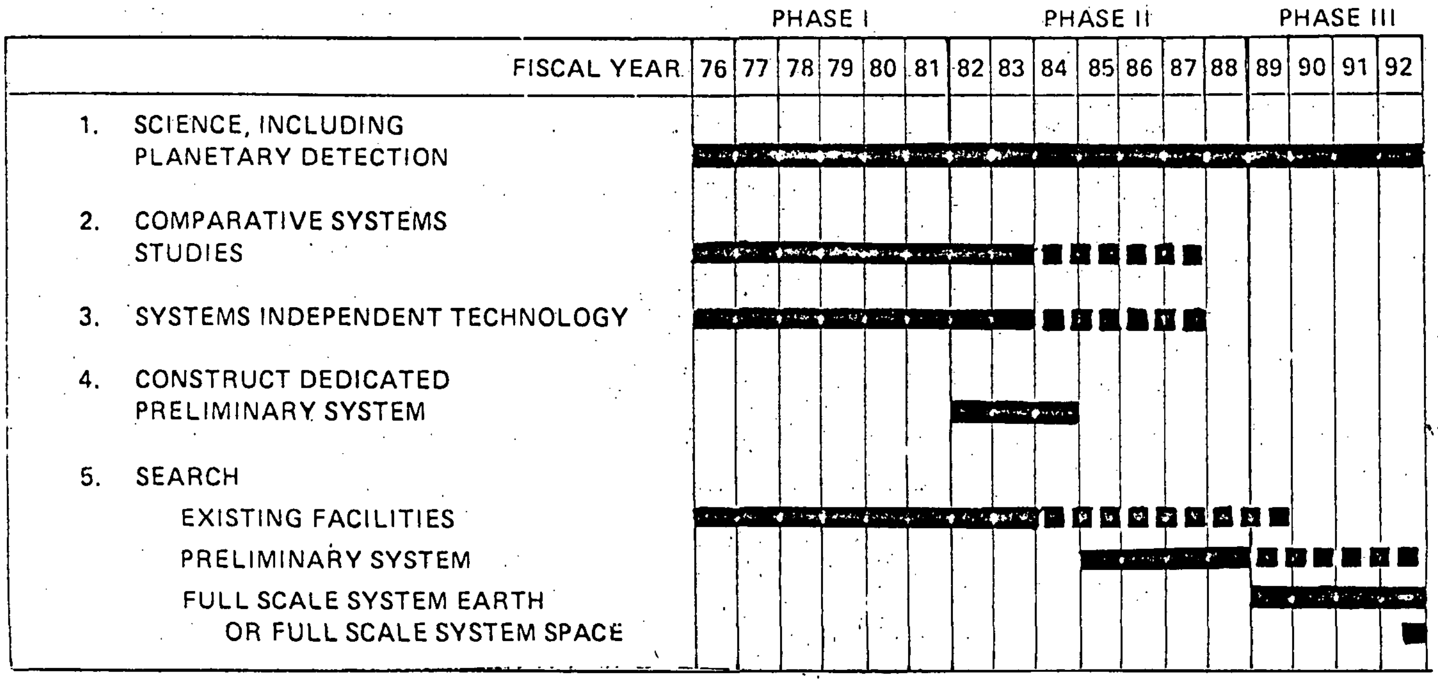
Phase One employs modest improvements on available technology in the areas of radio frequency signal detection and processing and utilizes existing facilities (radio antennas) to initiate a preliminary search (defined as MARK I Search Systems) and to address future technology need and requirements.

Phase Two continues the search while building the first dedicated, small scale search systems (one Earth-based and one spaceborne) incorporating all of the knowledge gained in Phase One. These dedicated facilities have been defined as MARK II Search Systems and are envisioned to be a 100-m diameter ground system and approximately 30-m diameter space system. Phase Two also resolves the nature of intermediate (MARK III) and large-scale (MARK IV) search systems and their ancillary requirements.

Phase Three is the long-term phase which may never be required if signals of extraterrestrial intelligent origin are detected during Phase One or Phase Two. If necessary, however, Phase Three calls for the detailed design and construction of large search systems of ever increasing sensitivity and will involve either a large, expanding Earth-based array of 100-m dishes or spaceborne dishes with equivalent diameters in the 300- to 3000-m class.

The results of the Space Technology Workshop have not changed the key elements of the SETI Theme Program Plan. The Workshop has, however, provided the technological interchange necessary to identify the specific technology needs and initiatives required to implement a serious SETI effort. The SETI Theme Team feels that the Workshop experience has been invaluable in setting priorities for a realistic program plan and search strategy based on sound step-by-step technology advancements.

SETI PROGRAM PLAN



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Section II

THEME SUMMARIES

Part 4

SOLAR SYSTEM EXPLORATION

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STRAWMAN PACKAGE FOR EXPLORATION OF THE SOLAR SYSTEM

EXPLORATION OF THE SOLAR SYSTEM

The attached strawman Theme package follows the hierarchical structure outlines on the attached figure, omitting the first item; 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.

A revised strawman Theme package appears in Appendix C.

THEME PACKAGE ORGANIZATION

THEME:
- DESCRIPTION
- ADVOCACY

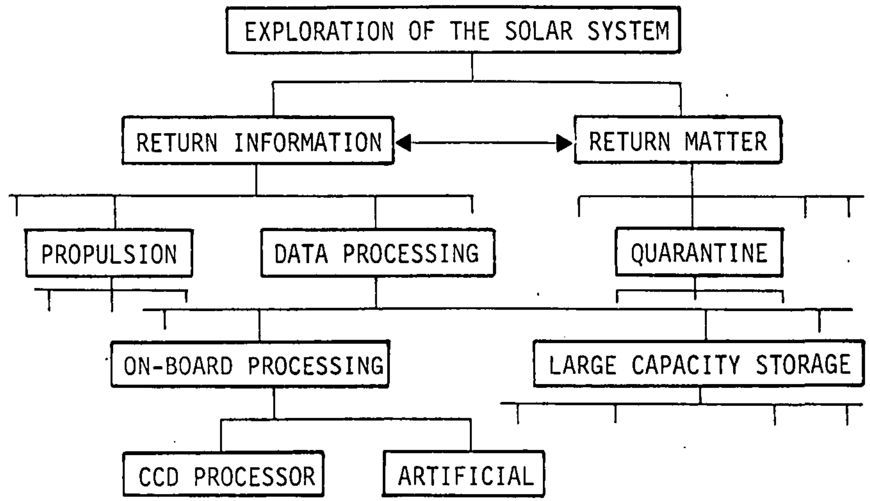
MISSIONS:
- DESCRIPTION
- OBJECTIVE

FUNCTIONS:
- DESCRIPTION
- OBJECTIVE

TECHNOLOGIES:
- DESCRIPTION
- OBJECTIVE

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

SOLAR SYSTEM STUDY FACILITY



THEME DESCRIPTION

This Theme is directed toward the understanding of the planets, other bodies, and the Sun that collectively form our solar system. It includes research and engineering support in propulsion systems, sensors, automation, data management and control, and space-proof mechanical-electrical-optical systems design.

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 geolaboratory 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.

EXPLORATION OF THE SOLAR SYSTEM

OBJECTIVE:	INCREASED UNDERSTANDING OF ALL ASPECTS OF THE SOLAR SYSTEM
PHASED APPROACH:	RECONNAISSANCE, EXPLORATION, INTENSIVE STUDY
MISSIONS:	RETURN INFORMATION; RETURN MATTER
IMPLEMENTATION:	PLANETARY EXPLORATION FACILITY; SAMPLE RETURN CAPABILITY
APPLICATION:	OUTER PLANETS & THEIR SATELLITES; TERRESTRIAL PLANETS, ASTEROIDS, COMETS, JUPITER SATELLITES

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

TIME

DISTANCE

TECHNOLOGY READINESS DATES

1990 — EARTH STUDY FACILITY

AUTOMATED
SYNCHRONOUS ORBIT
SEP
SOLAR POWER
SELF-REPAIR
CHECKOUT

1990 — INNER PLANET STUDY FACILITY

AUTOMATED
SOLAR POWER
SEP
10-YEAR OPERATING LIFE
SELF-REPAIR

1995 — OUTER PLANET STUDY FACILITY

AUTOMATED
NUCLEAR POWER
NEP
20-YEAR OPERATING LIFE
SELF-REPAIR

2000 — EXTRA SOLAR SYSTEM STUDY FACILITY

AUTOMATED
NUCLEAR POWER
NEP
25-YEAR OPERATING LIFE
SELF-REPAIR

KEY ISSUES
FOR SOLAR SYSTEM STUDY FACILITY

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

REQUIRED TECHNICAL FUNCTIONS

Functional capabilities have been identified in the table on the opposite page 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.

On the following pages, each of these functions and their required technologies are discussed in detail.

TECHNICAL FUNCTIONS SUPPORTING MISSIONS

MISSIONS:	RETURN OF INFORMATION	RETURN OF MATTER
FUNCTIONS:	1. Acquiring information (a) In situ (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. Control 10. Navigation 11. Environmental protection 12. Autonomous systems	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)

TECHNOLOGY REQUIREMENTS FOR ACQUIRING INFORMATION

(In Situ and Remote)

SENSORS FOR PLANETARY AND SATELLITE INFORMATION ACQUISITION

The sensor new initiatives are described in general on the following page and in detail in Appendix A-1. The initiatives address several mission-driven sets of sensors. Several assumptions are made in putting forth these initiatives. These 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.

NEW INITIATIVES - SENSORS

ELECTROMAGNETIC SPECTRAL SENSORS. Sensors in the spectrum from 0.2 μm 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.

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.

FIELDS AND PARTICLES SENSORS. The interaction between the solar wind, planetary atmospheres, and atmosphereless planetary surfaces are fundamental to planetary evoluation 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 extragalactic fields and particles sources.

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 than under present development.

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 studies through use of gravity and scismic sensors.

BIOLOGICAL SENSORS. The search for extraterrestrial life will continue with varying degrees of intensity, pending the outcome of the Viking finds. The sending techniques required for biological studies have proven to demand long and intensive development activities. The strategy for further 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.

TECHNOLOGY REQUIREMENTS FOR DATA PROCESSING

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 multi-spectoral instruments, algorithm development for on-board information extraction, and an advanced modular computer architecture having fault tolerant characteristics with an improvement of 10 to 100 times in on-board computing capability.

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.

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.

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.

NEW INITIATIVES - DATA PROCESSING

ON-BOARD PROCESSING (SEE APPENDIX A-2)

- CCD UNIFIED DATA PROCESSOR
- ARTIFICIAL RETINA SYSTEM

INFORMATION MANAGEMENT (SEE APPENDIX A-2)

- DEVELOPMENT OF AN INFORMATION-MANAGEMENT SYSTEM FOR SPACE EXPLORATION

LARGE CAPACITY DATA STORAGE SYSTEMS (NOT WRITTEN)

- HOLOGRAPHIC MEMORY
- LARGE CAPACITY SEMICONDUCTOR MEMORIES

SOFTWARE RESEARCH (UNDETERMINED)

TECHNOLOGY REQUIREMENTS FOR COMMUNICATION

Seven specific areas of interest were studied as indicated below; however, no new initiatives were proposed in any of these areas.

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 subvehicles (in lower orbit than master spacecraft).

TECHNOLOGY FOR HIGH DATA RATES FROM OUTER PLANETS. Perform analysis and trade-offs 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.

RELAY COMMUNICATIONS. Perform analyses and system studies of cost-effective configurations for relay communications from probes, landers, or suborbiters through 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.

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 automous navigation of a master spacecraft or for locating landers, probes, or suborbiters 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 spin-off may be requirements for secondary probe oscillator stability to meet location accuracy requirements with one-way Doppler measurements.

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

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

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

NEW INITIATIVES--COMMUNICATION

No New Initiatives were Proposed

TECHNOLOGY REQUIREMENTS
FOR UTILIZATION OF STORED AND EXTERNAL ENERGY FOR POWER

SOLAR ENERGY CONVERSION AND STORAGE. Advancements in solar 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.

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.

NUCLEAR ENERGY CONVERSION AND STORAGE. Radioisotrope 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.

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.

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.

NEW INITIATIVES - UTILIZATION OF STORED ENERGY AND EXTERNAL ENERGY FOR POWER

- SOLAR ENERGY CONVERSION AND STORAGE
  - GALLIUM ARSENIDE SOLAR CELL ARRAYS (SEE APPENDIX A-3)
  - PHOTOCHEMICAL SOLAR ENERGY CONVERSION (SEE APPENDIX A-3)
  - AUTOMATED MODULE FABRICATION IS A POTENTIAL NEW INITIATIVE CANDIDATE
- CHEMICAL ENERGY CONVERSION AND STORAGE (NO NEW INITIATIVES, R&T BASE PROGRAM)
- NUCLEAR ENERGY CONVERSION AND STORAGE
  - NUCLEAR THERMIONIC POWER SYSTEM TECHNOLOGY (SEE APPENDIX A-3)
  - RTG POWER IS PRESENTLY AN R&T BASE PROGRAM, BUT A POTENTIAL NEW INITIATIVE CANDIDATE IN THIS AREA IS HIGH-PERFORMANCE THERMOELECTRIC MATERIAL DEVELOPMENT
- POWER PROCESSING AND DISTRIBUTION (NO NEW INITIATIVES, R&T BASE PROGRAM)
- ENERGY SYSTEMS
  - AUTOMATED POWER SYSTEMS MANAGEMENT (PRESENTLY IN R&T BASE PROGRAM, BUT IS POTENTIAL NEW INITIATIVE CANDIDATE)
  - ADVANCED POWER SYSTEMS TECHNOLOGY FOR NEAR-SUN MISSIONS (NOT WRITTEN YET, SUBMITTED OVER-GUIDELINE FOR FY 77 R&T BASE PROGRAM).
  - GALLIUM ARSENIDE SOLAR CELL ARRAYS (SEE APPENDIX A-3)

TECHNOLOGY REQUIREMENTS FOR UTILIZATION OF STORED ENERGY AND EXTERNAL ENERGY FOR PROPULSION

CHEMICAL PROPULSION, NEAR TERM (1980-'85). The chemical propulsion 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.

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 stationkeeping and attitude control systems.

NUCLEAR ELECTRIC PROPULSION FAR TERM ('90 on). The utilization of nuclear energy for electric propulsion is dependent on the successful development of energy conversion devices several of which are listed under Nuclear Energy Conversion and Storage.

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 sec or greater. A list of tasks currently under consideration within the discipline R&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

NEW INITIATIVES - UTILIZATION OF STORED ENERGY ENERGY AND EXTERNAL ENERGY FOR PROPULSION

- CHEMICAL PROPULSION
  - SPACE STORABLE (F_2/N_2H_4) LIQUID PROPULSION (NO NEW INITIATIVES, THIS PROGRAM ALREADY HAS BEEN ESTABLISHED)
  - HIGH-PERFORMANCE, LOW-COST SOLIDS (QUENCH THRUST-TERMINATION ASSEMBLY [QTTA]; SEE APPENDIX A-4)
- SOLAR ELECTRIC PROPULSION
  - PRIMARY PROPULSION (INITIATIVES TO BE DETERMINED)
  - AUXILIARY PROPULSION (INITIATIVES TO BE DETERMINED)
- NUCLEAR ELECTRIC PROPULSION
  - SEE NEW INITIATIVES UNDER NUCLEAR ENERGY CONVERSION AND STORAGE
- ADVANCED PROPULSION CONCEPTS
  - NEW INITIATIVES TO BE DETERMINED

UTILIZATION OF STORED ENERGY AND EXTERNAL ENERGY FOR PROPULSION - STATUS OF CONCEPT

	EXTERNAL ENERGY	STORED ENERGY		
		ELECTRONIC	NUCLEAR	MASS ANNIHILATION
READY FOR ADVANCED DEVELOPMENT	PLANETARY ATMOSPHERE 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

TECHNOLOGY REQUIREMENTS FOR ELECTROMAGNETIC TRANSFER OF ENERGY

There is potential for energy transfer from a master spacecraft to a subvehicle 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.

Relevant New Initiatives. None proposed.

TECHNOLOGY REQUIREMENTS PROCESSING MICRO STRUCTURES

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 micro circuits, ultra high density silicon micro electronics, and integrated optics.

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.

NEW INITIATIVES - PROCESSING
MICRO STRUCTURES

- ELECTRON BEAM LITHOGRAPHY
  - ELECTRONIC MATERIALS RESEARCH BASED ON ELECTRON BEAM LITHOGRAPHY (SEE APPENDIX A-5)
- LSI DESIGN
  - QUALIFICATION AND TESTING OF LSI DEVICES (TO BE DETERMINED)
  - LSI DESIGN CRITERIA FOR FAULT TOLERANT APPLICATIONS (TO BE DETERMINED)

TECHNOLOGY REQUIREMENTS FOR CONTROL

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 ultimately be tied to improvements in hardware technology.

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.

NEW INITIATIVES - CONTROL

- ATTITUDE CONTROL
  - ATTITUDE AND FIGURE CONTROL OF LARGE DEFORMABLE STRUCTURES (SEE APPENDIX A-6)
  - DYNAMIC SYNTHETIC ESTIMATORS (NOT WRITTEN AT THIS TIME)
  - AUTONOMOUS ADAPTIVE CONTROL (NOT WRITTEN AT THIS TIME)
  - CONTROL HARDWARE AND DEVICE DEVELOPMENTS (NOT WRITTEN AT THIS TIME)
  - PRECISION LONG-RANGE SUN SENSOR DEVELOPMENT (NOT WRITTEN AT THIS TIME)
- INSTRUMENT POINTING
  - SCIENCE PLATFORM PRECISION POINTING AND TRACKING SYSTEM FOR UNMANNED PLANETARY SPACECRAFT (SEE APPENDIX A-6)
  - MODULAR INSTRUMENT POINTING TECHNOLOGY LABORATORY (SEE APPENDIX A-6)
  - EXPERIMENT POINTING MOUNT FOR SPACELAB (NOT WRITTEN AT THIS TIME)
  - APPLICATION OF MICROPROCESSOR CONTROLLED CCD SENSORS TO INSTRUMENT POINTING (NOT WRITTEN AT THIS TIME)

TECHNOLOGY REQUIREMENTS FOR NAVIGATION

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 (occulation 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 in situ information/sample acquisition. This is covered under autonomous systems.

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.

NEW INITIATIVES - NAVIGATION

NAVIGATION

- AUTONOMOUS RENDEZVOUS & DOCKING (SEE APPENDIX A-7)
- AUTONOMOUS GUIDANCE & NAVIGATION FLIGHT/GROUND DEMONSTRATION (SEE APPENDIX A-7)
- AUTONOMOUS GUIDANCE & NAVIGATION OPERATIONAL SYSTEM (SEE APPENDIX A-7)
- LOW COST NAVIGATION SYSTEM DEVELOPMENT (SEE APPENDIX A-7)

LOW THRUST NAVIGATION

- LOW THRUST NAVIGATION SYSTEM TECHNOLOGY DEVELOPMENT (SEE APPENDIX A-7)

TECHNOLOGY REQUIREMENTS FOR AUTONOMOUS SYSTEMS

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.

NEW INITIATIVES - AUTONOMOUS SYSTEMS

- ROVING VEHICLES
  - PROTOTYPE ROVING VEHICLE FOR PLANETARY SURFACE EXPLORATION (SEE APPENDIX A-8)

TECHNOLOGY REQUIREMENTS FOR RETURN OF MATTER

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 overridden 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.

NEW INITIATIVES - RETURN OF MATTER

- AUTONOMOUS RENDEZVOUS AND DOCKING (SEE APPENDIX A-9)

- SOFTWARE DEVELOPMENT FOR RETURN OF MATTER MISSION DESIGN (SEE APPENDIX A-9)

SUMMARY COMMENTS
ON TECHNICAL AND PROGRAM APPROACHES RESULTING
FROM WORKSHOP ACTIVITY

GENERAL. The individual Working Groups exhibited considerable innovative thinking in support of our Theme. The major technology drivers of power, propulsion, and data handling/control were considered in depth. Programmatic 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 warrant consideration as future hardware.

With regard to power conversion and storage systems, the recyclable H_2/O_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 affect 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 programming 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 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 programmatic 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.

Some comments on priority for the new initiatives for this Theme are contained in Appendix B.

THEME TEAM MEMBERSHIP

HEADQUARTERS

A. Henderson (Leader)	OAST/RC
B. Rubin	OAST/RE
F. Stephenson	OAST/RP
J. Lundholm	OAST/RR
J. Maltz	OAST/RW
R. Chase	OAST/RX
D. Herman	OSS

CENTERS

Friedman	JPL
Powell	JPL

APPENDIX A

SPECIFIC NEW INITIATIVES

A-1 SENSOR

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: The Development of Remote Electromagnetic Sensors for Planetary Exploration

Program:

Lead Field Center: JPL

Supporting Field Center: 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 μm 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 are: middle-UV large-area ICCDs, near-UV large-area imaging arrays, large-area array visual imagers, large-area image array mosaics, near-IR area array, 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 (composition) 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 $)	FY 78	FY 79	FY 80	FY 81	FY 82	ΔTC	Total
Total R/AD NOA ($, 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:

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 composition 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 technonology 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 $)	FY 78	FY 79	FY 80	FY 81	FY 82	ΔTC	Total
Total R/AD NOA ($, 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 Center: 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 increase plasma probe sensitivity and directivity. Fundamental sensor research is required to achieve reductions of noise in magnetometers. Possible, 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 $)	FY 78	FY 79	FY 80	FY 81	FY 82	ΔTC	Total
Total R/AD NOA ($, 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 Center:

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 exising sensor technology and chemical analysis can be more greatly extended to developing faster GCs and MSs with higher resolution, and developing new atmospheric sensing techniques.

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

Resources: (FY 78 $)	FY 79	FY 79	FY 80	FY 81	FY 82	ΔTC	Total
Total R/AD NOA ($, 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 In Situ Sensors

Lead Field Center: JPL

Supporting Field Center: 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 spectrocopy 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 $)	FY 78	FY 79	FY 80	FY 81	FY 82	ΔTC	Total
Total R/AD NOA ($, M)	1	2	3	4	4	12	26

A-2 DATA PROCESSING

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 $)	FY 78	FY 79	FY 80	FY 81	FY 82	ΔTC	TOTAL
	Total R&AD NOA ($,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 (master) 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. microprocessing), high-density lithography (electron-beam or x-ray). Algorithms for parallel image processing and feature extractions 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 elements 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; (e) 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} bit/day; this is enough data to fill approximately one million 300-page books in one day. Presently, there exists no overall plan, for 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 $)	FY 78	FY 79	FY 80	FY 81	FY 82	ΔTC	Total
Total R/AD NOA ($, M)	1.0	3.0	5.0	5.0	5.0	5.0	24.0

A-3 — STORED ENERGY AND EXTERNAL ENERGY FOR POWER

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-efficienty, lightweight GaAs solar cell array at 1 kW output for space power application.

Justification: Large amounts of electrical power will be required for multipurpose space power platforms (MSPP), 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, lightweight, 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 (GaSa) 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 GaSa and the concomitant 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	1.0	1.0	1.0	4.0
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

Support 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 $)	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	BTC	Total
Total R&D NOA ($, 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 plus in-house direct research plus 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

Support 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 ensure that all NASA large power needs can be met over approximately 10 years of flight applications.

Resources: (FY 1978 $)	FY 78	FY 79	FY 80	FY 81	FY 82	BTC	Total
Total R&D NOA ($, 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 plus in-hours direct research plus IMS

A-4 — PROPULSION

PRELIMINARY PROGRAM PLAN - EXECUTIVE SUMMARY

FY 1979 New Initiative

Title: Quench Thrust Termination ASSY (QTTA)

Program: OAST

Lead Center: JPL

Support 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 (FY 77/78 Ongoing 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 (FY 79/80)
  - 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 (FY 81/82)
  - Complete state design and performance estimates; complete 4 full-scale stop/restart solid rocket test firings

B. PHASE DESCRIPTION (Cont.)

- Phase 3 (FY 83/84)
  - Complete 3 full-scale prototype stage propulsion ground tests

- Phase 4 (FY 85/86)
  - Complete 1 flight proof test demonstration

Justification: The addition of a simple low-cost quench thrust termination system which provides multiburn 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	0.7	1.8	1.2	--	--	--	--
	(MSFC)	0.1	0.2	0.3	0.3	--	--	--	--
Direct Civil Service Manpower	(MSFC)	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3
Direct Support Service Contractor Manpower		--	--	--	--	--	--	--	--
Resources Support Assumed from Other Sources (R&D $, M)/OSF	(JPL + CONTRACTOR)	--	--	--	--	1.8	0.6	1.5	0.6
		1.3	1.0	2.2	1.6	2.0+	0.8+	1.8+	0.9

A-5 — PROCESSING MICRO STRUCTURES

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 electronic 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

A-6 — CONTROL

PRELIMINARY PROGRAM PLAN

FY 1977 New Initiative

Title: Attitude and Figure Control of Large Deformable Structures

Program: Guidance and Control R&T

Lead Field Center: JPL

Support Field Center(s): None

Specific Objectives and Targets: Develop conceptual design for distributed control, development 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 actuation variables 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 times 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: (FY 77 $)	FY 77	FY 78	FY 79	FY 80	FY 81	ΔTC	Total
Total R/AD NOA ($, 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: 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 FY 79 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 10-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 spectrocopy 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 pizel of an image; (2) surface feature determination of outer planet satellites, where light levels are low, to 1 km resolution (a 10-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: (FY 76 $)	TR	FY 77	FY 78	FY 79	FY 80	FY 81	ΔTC	Total
Total R/AD NOA ($, K)	25	250	400	200	-	-	-	875

PRELIMINARY PROGRAM PLAN

FY 1977 New Initiative

Title: Modular Instrument Pointing Technology Laboratory (MIPTL)

Program: Guidance and Control R&T

Lead Field Center: JPL

Supporting Field Center: 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: (FY 77 $)	FY 77	FY 78	FY 79	FY 80	FY 81	ΔTC	Total
Total R/AD NOA ($, M)	0.5	0.6	0.4	-	-	-	1.5

A-7 — NAVIGATION

PRELIMINARY PROGRAM PLAN

FY 1979 New Initiative

Title: Autonomous Guidance and Navigation Flight/Ground Demonstration

Program:

Lead Field Center: JPL

Supporting Field Center:

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 preflight 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

- Image processing of star and target data
- Target acquisition and automatic tracking
- Target center finding
- Pointing adjustment for reposition target image in field of view
- Modification of science instrument pointing sequence

Specific Objectives and Targets (Cont.):

B. Simulated On-Board Activities (Ground-Based)

- Processing of target-star data to update the estimated spacecraft position
- Calculation and execution of a trajectory correction maneuver
- 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 in-flight demonstration.

Resources: (FY 1978 $)	FY 78	FY 79	FY 80	FY 81	FY 82	BTC	Total
Total R&D NOA ($, 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 plus in-house direct research plus IMS

PRELIMINARY PROGRAM PLAN

FY 1980 New Initiative

Title: Autonomous Guidance and Navigation Operational System Development

Program:

Lead Field Center: JPL

Supporting Field Center:

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 know 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 prespecified 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)	0.3	0.5	1.0		

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, and (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, suboptimum 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 experience similar complexity increases as greater accuracy at larger distances has been sought. Currently in development are data system techniques such as differential very long base-line interferometry (ΔVLBI), promising unprecedented 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.

Justification (Cont.):

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		

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 base-line 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)	0.1	0.2	0.1	0	0	0	0.4

A-8 — AUTONOMOUS SYSTEMS

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 subtask 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

A-9 — RETURN OF MATTER

PRELIMINARY PROGRAM PLAN

FY 1978 New Initiative

Title: Autonomous Rendezvous and Docking

Program:

Lead Field Center: JPL

Supporting Field Center: JSC

Specific Objectives and Targets: Sample return missions at distant target bodies will be required 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)	0.3	0.35	0.4	

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:

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 or 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

APPENDIX B

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.

APPENDIX C

NEW THEME PACKAGE ORGANIZATION

THEME:

- DESCRIPTION
- ADVOCACY

MISSIONS:

- DESCRIPTION
- OBJECTIVE

FUNCTIONS:

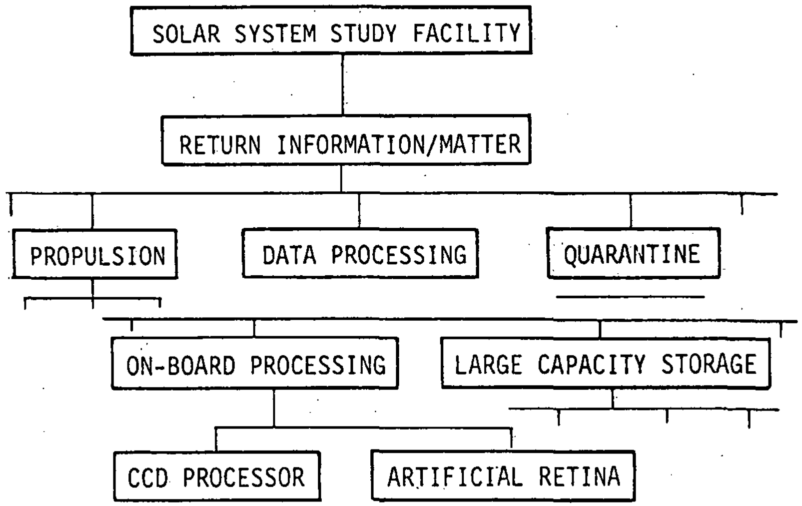
- DESCRIPTION
- OBJECTIVE

TECHNOLOGIES:

- DESCRIPTION
- OBJECTIVE

INITIATIVES:

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



Section II

THEME SUMMARIES

Part 5

GLOBAL SERVICE

THEME DESCRIPTION

INTRODUCTION

The focus of the Global Service Systems Theme is on technology for spacecraft and space operations usually identified with the roles and missions of the Office of Applications. Because of the broad range of user-oriented activities covered by that Office's responsibilities, no attempt is made in this Theme to establish a single mission as a model or standard for defining future technology requirements. Instead, a series of potential missions representative of the types of service needed by man and available from space have been selected to exemplify typical technology requirements in this Theme. These missions correlate with the Earth-oriented activities identified as future objectives in the Outlook for Space and can be easily identified with the definition of "Thrust" packages now being undertaken in the Applications program area.

DESCRIPTION

Space provides a unique vantage point for global observation of the Earth, its environment, and its natural and man-made features. The objective of this Theme is to provide the technology needed to expand our ability to operate in that unique arena.

The Global Service Systems Theme is directed toward providing space-based systems for environmental monitoring, resources cataloging, disaster prediction and/or assessment, world-wide navigation and communications capability. It will support research and technology advances in systems configuration; sensors; guidance and control; and management of data processing, reduction, and transmission.

The definition and assessment of technology requirements for Global Service Systems is based on a time-phased mission scenario. In the initial phase (1978-1985 era) it is postulated that user-oriented space missions would operate in varied orbits designed to evaluate the potential payoffs of global space observations and operations, and to serve as precursors or first-generation operational systems. Each mission would be dedicated to a particular function such as Earth observation, hazard warning, weather prediction or pollution monitoring. Functional operation would be controlled through a central ground-based facility responsible for acquisition of data from a satellite and distribution of that data to the user community. Primary technical emphasis during this phase of the scenario would be placed on the development of data management techniques and a refinement of sensor technology.

The second phase of the mission scenario (1985-2000 era) contemplates a limited number of multifunction satellites located in Geosynchronous Orbit and supported by a series of dedicated, single-function satellites in Low-Earth or Sun-Synchronous Orbits. The principal operational change in this era would be user access to satellite-generated information on a direct, real-time basis. Implicit in this mode of operation is the technical requirement for high-speed, on-board data processing technology, and low-cost user terminals. Large antenna structures in space, high levels of power generation and storage, long life, auxiliary propulsion, precision pointing, autonomous operational capability, and improved sensors would also be technical requisites to mission operations in this phase.

GLOBAL SERVICE SYSTEMS

OBJECTIVE: 1000-FOLD INCREASE IN EFFECTIVE USE OF SPACE FOR PRACTICAL GLOBAL OBSERVATION AND OPERATION SERVICES

SCENARIO: <u>1978-1985</u>

INDIVIDUAL MISSIONS PROVIDING SERVICES TO USER COMMUNITY THROUGH CENTRAL DATA FACILITY

- VARIED ORBITS
- SENSOR DEVELOPMENT
- DATA MANAGEMENT
- USER EDUCATION

- 10-FOLD INCREASE

<u>1985-2000</u>

MULTIFUNCTION MISSIONS SERVING USER COMMUNITY DIRECTLY ON REAL-TIME BASIS

- LOW COST USER TERMINALS
- HIGH SPEED, ON-BOARD DATA PROCESSING
- ON-ORBIT REPAIR AND REFURBISHMENT
- ADVANCED SENSORS

- 1000-FOLD INCREASE

APPROACH

Examples of typical spacecraft and missions which could enhance the benefits of space operations are appended as Enclosure A. Rough estimates of mission characteristics and technology requirements for each of these missions are included in the enclosure. Enclosure B is an excerpt from a recently completed survey of Space Electronics Technology R&D and establishes technology needs in that discipline as an expansion of current knowledge and forecast of future capability. These needs closely follow the technology advances forecast in the Outlook for Space and, in many cases, were the source of, or directly resulted from, those forecasts.

The purpose of this Theme is to combine those two approaches to technology definition into a viable technical program which can greatly increase the return on our space investment. The technical characteristics of Enclosure A should provide examples of performance capabilities sufficient to identify technology needs. The bottom-up approach of Enclosure B provides some idea of the approaches and schedules needed to achieve the 1000-fold increase in effectiveness.

GLOBAL SERVICE SYSTEMS

APPROACH:

- ESTABLISH MISSION SET CONSISTENT WITH NEEDS IDENTIFIED BY OUTLOOK FOR SPACE
- DETERMINE COMMON TECHNOLOGIES, TECHNICAL PLANS, NEW INITIATIVES
- ESTIMATE CHARACTERISTICS OF MULTIFUNCTION MISSION CONCEPT
- DEFINE TECHNOLOGY NEEDS, TECHNICAL PLANS

THEME ADVOCACY

Rationale. Application spacecraft operating in Earth-oriented modes can provide practical global observation and operational services which will enable man to comprehend the physical impact and effect of his existence on the Earth and its environment, to predict the cause and effect of natural and man-made changes in the Earth's ecological characteristics, and to control and regulate the consumption and exploitation of our natural resources. Use of these services depends heavily on the ability to accumulate great quantities of data, and to effectively and efficiently convert that data to information or knowledge important to the user.

Need/Benefits. Operational Global Service Systems can directly contribute to many of our national needs. Information management and distribution technologies applied in individual communications, electronic mail, and large-scale information handling can stimulate and support the national economy. Automated pollution monitoring from space can provide the key to preservation of the environment. Global monitoring and prediction of weather, crop conditions, and water availability can significantly aid efficient food production. Similar systems can be used to protect life and property through early warning of natural disasters and can help in the discovery and mapping of natural resoruces. In addition, the data handling capabilities developed for Global Service Systems will reduce the cost of information reduction in the quest for new knowledge through the exploration of space.

Problem. Cost-effective, Global Service Systems will require quantum improvements in the technical ability to acquire, reduce, and distribute user-oriented information in near real time. These topics are discussed in subsequent paragraphs. An equally important problem requiring attention in this Theme area is to obtain public and political acceptance of the concept that benefits derived from remote observation of the Earth and its environment can outweigh concerns over personal and political privacy and/or security.

GLOBAL SERVICE SYSTEMS

GLOBAL OBSERVATIONS AND OPERATIONS ENABLE THE APPLICATION OF SPACE FOR LOCAL, NATIONAL, AND INTERNATIONAL BENEFITS

- ENABLE COMPREHENSION OF THE PHYSICAL IMPACT AND EFFECT OF MAN'S EXISTENCE ON EARTH AND ITS ENVIRONMENT
- PREDICT THE CAUSE AND EFFECT OF NATURAL AND MAN-MADE CHANGES IN EARTH'S ECOLOGICAL CHARACTERISTICS
- ENABLE THE CONTROL AND REGULATION OF THE CONSUMPTION AND EXPLOITATION OF NATURAL RESOURCES

COST-EFFECTIVE, GLOBAL SERVICE SYSTEMS REQUIRE QUANTUM IMPROVEMENTS IN THE TECHNICAL ABILITY TO ACQUIRE, REDUCE, AND DISTRIBUTE USER-ORIENTED INFORMATION IN NEAR REAL TIME

TECHNOLOGY NEEDS

Areas of Emphasis. Global Service Systems operating in space will require technical advances in a number of functional areas. A 10-fold increase in the dimensions of deployable (100 m) and erectable (1 km) structures will be needed to provide booms, antennas, and platforms for Global Sensor Systems. Control and stabilization systems capable of pointing accuracies of 1 arc sec or less will be needed to locate targets of interest and maintain platform or sensor orientation during operations. A factor of five improvement in spacecraft power capacity will be required to support payloads of multiple sensors and supporting electronics. Auxiliary propulsion systems capable of 5-10 years operation on orbit will be needed to satisfy operating life requirements of cost-effective service platforms. Multipurpose sensors capable of 10 times better resolution (10 m), extended spectral range, and increased sensitivity will be necessary to provide detection and identification of Earth and atmospheric characteristics. End-to-end data management systems capable of a 1000-fold improvement in the conversion of raw data to useful information will be required to ensure transfer of knowledge to the user community on a near real time basis.

Approach. Development of the technical base needed to support practical Global Service Systems will build on the current OAST R&T Base programs in Materials and Structures, Space Power and Propulsion, and Guidance, Control and Information Systems. New initiatives and/or program augmentations will be implemented to provide an orderly evolution to the necessary levels of technical capability in each of the above functional areas.

TECHNOLOGY AREAS OF EMPHASIS

- LARGE SPACE STRUCTURES FOR ANTENNAS, SENSOR PLATFORMS (TO >100 M DEPLOYABLE, 1 KM ERECTABLE)
- CONTROL & STABILIZATION FOR SENSOR POINTING & ORIENTATION (>>1 ARC SEC)
- SPACECRAFT POWER FOR MULTIPLE SENSORS, SIGNAL PROCESSORS, & COMMUNICATIONS (>>2 KW)
- AUXILIARY PROPULSION FOR LONG LIFE ORBITS & STATIONKEEPING (5-10 YEAR OPERATING LIFE)
- MULTIPURPOSE SENSORS FOR INCREASED RESOLUTION, SENSITIVITY SPECTRAL RANGE (<<10 M GROUND RESOLUTION)
- END-TO-END DATA MANAGEMENT FOR CONVERTING RAW DATA TO USER-ORIENTED KNOWLEDGE IN NEAR REAL TIME

FY 1978 NEW INITIATIVE NEEDS

The specific FY 1978 new initiative needs for the Global Service Systems Theme are divided into six major areas:

1. Large Structures
   - Develop and demonstrate erection, assembly, and deployment of large space structures in space
2. Control and Stabilization
   - Develop and demonstrate precise Earth-pointing system capability
   - Develop and demonstrate remote manipulator technology for assemblying large structures in space
3. Power
   - Design and demonstrate highly efficient energy storage system in space
4. Auxiliary Propulsion
   - Demonstrate ion thruster technology for satellite stationkeeping (SPHINX B/C)
5. Multipurpose Sensors
   - Develop and demonstrate uncooled IR and submillimeter sensors for measuring atmospheric constituents
6. End-to-End Data Management
   - Develop and demonstrate on-board CCD data processor
   - Design, develop, and demonstrate modular end-to-end information management system

These technical activities are amplified in the succeeding discussions.

SPECIFIC TECHNICAL ACTIVITIES

- LARGE STRUCTURES
  - ERECTION, ASSEMBLY, & DEPLOYMENT IN SPACE
- CONTROL & STABILIZATION
  - PRECISE EARTH-POINTING SYSTEM CAPABILITY
  - REMOTE MANIPULATOR TECHNOLOGY
- POWER
  - HIGHLY EFFICIENT ENERGY STORAGE SYSTEM IN SPACE
- AUXILIARY PROPULSION
  - ION THRUSTER TECHNOLOGY FOR SATELLITE STATIONKEEPING
- MULTIPURPOSE SENSORS
  - UNCOOLED IR & SUBMILLIMETER SENSORS
- END-TO-END DATA MANAGEMENT
  - ON-BOARD CCD DATA PROCESSING
  - MODULAR END-TO-END INFORMATION MANAGEMENT SYSTEM

DISCUSSION OF INITIATIVE NEEDS

LARGE STRUCTURES. Current technology programs are aimed at definitions of structural concepts, thermal control, and dynamic response of large area space structures. A proposed new initiative (Large Space Structures Technology) in FY 1978 will collect these conceptual studies into a comprehensive design, demonstration, and verification program culminating in-flight tests on board the Shuttle/Spacelab in the CY 1984-85 time frame.

CONTROL AND STABILIZATION. Current technology programs are exploring potential capabilities of several pointing system concepts including supporting technologies such as sensors, support systems, and actuators. Several new initiatives relative to instrument pointing and control and the erection and control of large space structures have been proposed for FY 1978 and subsequent years. Key technology needs are the development of an Experiment Isolation and Pointing System aimed at the demonstration of precision Earth-pointing capability on a Shuttle payload in the CY 1981-82 period and development of remote manipulator technology for assembly of large structures in space by the CY 1981-82 period.

POWER. Current technology programs center on the development of high efficiency, low cost solar cells, and long life energy conversion and storage components. Key technology needs are to develop and demonstrate radiation resistant solar cells and long life, highly efficient batteries. Battery programs are proposed as FY 1978 new initiatives culminating in-flight demonstrations during the CY 1981-83 time frame. Solar cell demonstration programs are proposed for initiation in FY 1979 with flight demonstrations in CY 1981-82.

AUXILIARY PROPULSION. Current technology programs concentrate on the development of ion thrusters for auxiliary propulsion and north-south stationkeeping functions. Key technology needs are demonstration of thruster life in space and assessment of contamination on sensors and spacecraft structures due to ion thruster firings. This data is expected to be available from the proposed FY 1978 SPHINX new initiatives, but will require alternate approaches if that activity is not approved.

MULTIPURPOSE SENSORS. Current programs are concentrated on active and passive optical sensors for measuring atmospheric constituents. Key technology needs are spaceborne active microwave systems to permit day-night measurements of the Earth's characteristics and uncooled sensors operating in the IR, millimeter, and submillimeter frequency bands to broaden the scope of sensor spectral sensitivity. New initiatives in these areas are needed and should be started in FY 1978 to ensure available technology in the 1985 time frame.

DISCUSSION OF INITIATIVE NEEDS (Cont.)

END-TO-END DATA MANAGEMENT. Current technology programs are focussed on a variety of component and subsystem concepts, all of which serve as elements in a comprehensive data management system. These include experimental CCD devices for data processing, parallel processors for high speed data handling, microwave and optical components for data transfer, and a multipurpose user-oriented software development program. To provide a 1000-fold increase in data management, new initiatives are needed to flight test and demonstrate on-board processors, to demonstrate high-data-rate space-to-space communication links and to develop and demonstrate low-cost ground-based user terminals. A significant part of this program should be to design and demonstrate, for Shuttle payload flight, a total end-to-end information system which can be configured to accept new components or concepts in data handling as they develop and evaluate their performance in a system capability context.

SPECIFIC TECHNICAL ACTIVITIES

Enclosure C lists classes of new initiatives required to support the Global Service Systems Theme. A summary of new initiatives submitted by the Centers in response to the request for FY 1978 inputs follows. Enclosure C presents an overall technology ranking and initiative actions for the Global Service Systems Theme. These data do not represent official plans or positions but are part of the process of evolving such plans and positions.

SUPPORTING PROPOSALS: #11 - GLOBAL SERVICE SYSTEMS SUPPORTING INITIATIVES

● DIRECT SUPPORT

	N.I. NO.		FY 78	T.I.C.
1.	103	CCD - UNIFIED DATA PROCESSOR (10)	---	---
2.	104	DEXTEROUS MANIPULATOR	0.3	2.8
3.	105	ATTITUDE CONTROL OF LARGE STRUCTURES	0.2	0.6
4.	112	NICKEL/HYDROGEN BATTERY	0.2	0.6
5.	113B	LASER HETERODYNE SPECTROMETER (10)	---	---
6.	113C	EXPERIMENT ISOLATION & POINTING SYSTEM	0.6	4.1
7.	113D	MICROWAVE RADIOMETER	0.3	4.0
8.	114	LARGE AREA SPACE STRUCTURES (8)	---	---
9.	115	ON-BOARD CCD PROCESSOR (10)	---	---
10.	118	SPHINX B/C (7)	---	---
11.	120	SILVER/HYDROGEN BATTERN (10)	---	---
12.	121	41-43 GHF TRANSPONDER (11)	0.5	3.0
13.	306	50-500 WE ISOTOPE POWER SYSTEM	---	---

SUPPORTING PROPOSALS: #11 - GLOBAL SERVICE SYSTEMS SUPPORTING INITIATIVES (CONT.)

- GENERICALLY OR PARTLY RELATED

	N.I. NO.		FY 78	T.T.C
14.	110	SETI (9)	---	---
15.	125	CRYOGENIC FLUID MANAGEMENT	---	---
16.	128	ATL	---	---
17.	303	PHOTO CHEMICAL SOLAR CONVERSION	---	---
18.	308	HYDROGEN/OXYGEN FUEL CELL	---	---
19.	310	HIGH POWER DENSITY COMPONENTS	---	---
20.	312	BRAYTON ISOTOPE POWER	---	---

- TASK TEAM IDENTIFIED

21.	---	MULTIPURPOSE SENSORS	---	---
22.	---	MODULAR END-TO-END INFORMATION	0.5	6.0
		MANAGEMENT	1.0	13.0

PRELIMINARY FY 78 TOTAL TO AA: $3.6M, T.T.C. $34.1M

SUMMARY

GLOBAL SERVICE SYSTEMS. The objective of the Global Service Systems Theme is to provide the technology needed to enable a 1000-fold increase in man's ability to use space for his own betterment and benefit. The Workshop activity has centered on a review of the Theme concept and a more detailed evaluation of technology requirements. Results of the Workshop activity are summarized in the following paragraphs.

1. THEME CONCEPT. The definition and assessment of technology requirements for Global Service Systems was based on a time-phased mission scenario. In the initial phase (1978-1985 era) it was postulated that user-oriented space missions would operate in varied orbits designed to evaluate the potential payoffs of global space observations and operations, and to serve as precursors or first-generation operational systems. Each mission would be dedicated to a particular function such as Earth observation, hazard warning, weather prediction, or pollution monitoring. Functional operation would be controlled through a central ground-based facility responsible for acquisition of data from a satellite and distribution of that data to the user community. Primary technical emphasis during this phase of the scenario would be placed on the development of data management techniques and a refinement of sensor technology.

The second phase of the mission scenario (1985-2000 era) contemplated a limited number of multifunction satellites located in Geosynchronous Orbit and supported by a series of dedicated, single-function satellites in Low Earth or Sun-Synchronous Orbits. The principal operational change in this era would be user access to satellite-generated information on a direct, real time basis. Implicit in this mode of operation was the technical requirement for high speed, on-board data processing technology and low-cost user terminals. Large antenna structures in space, high levels of power generation and storage, long life, auxiliary propulsion, precision pointing, autonomous operational capability, and improved sensors would also be technical requisites to mission operations in this phase.

Review of the mission scenario by the Theme Team assembled at the Workshop produced general agreement with the overall approach. Exchanges between Working Group and Theme Team representatives emphasized the basic need for effective data management as a major technical prerequisite to operational Global Service Systems.

The Theme Team also considered the credibility of the Global Service Systems Theme as a coupling mechanism for OAST technology efforts with future NASA and national needs. Their conclusions generally supported the validity of this Theme as a focus for OAST technical activities, especially in the data handling and sensors area. They found direct couplings between the Theme concept and the new program thrusts being developed by the Office of Applications, e.g., Communications and Environmental/Resources/Earth Sciences. The overall relevance of global observations and operations to the application of space for local, national, and international benefits further substantiates the credibility of this Theme area.

SUMMARY (Cont.)

2. TECHNOLOGY. Technology needs identified in the Theme concept generally covered the total discipline spectrum of OAST with emphasis on quantum improvements in performance capability and system cost reduction. The Working Group reviews of the mission scenario and conceptual program descriptions reiterated the need for substantial performance gains. Emphasis on data systems, software, sensor technology, power, thermal control, large structures, and precision point and control systems was substantiated. The most critical areas identified were data systems and software which would be expected in a Theme area heavily oriented toward the acquistion of data and the translation of that data into useful information for a broad spectrum of users.

Practical attainment of needed technology did not present an insoluble problem to the Working Groups. Of the 34 highest priority technology needs identified for this Theme, half were considered enabling technology by the technical experts. The remainder were classed as enhancing technology with varying degrees of risk. A very limited amount of current R&T Base activities were associated directly with this Theme, possibly because of the heavy emphasis on SETI, Solar System Exploration, and Multiple Space Power Platforms by many of thw Working Groups. The limits of achievable technology are probably governed by the availability of resources to support its development; therefore, a trade-off between technology cost and capability should be considered. A very important part of such a trade-off is an explicit definition of technology needs and, for this Theme, the emphasis on modeling techniques which can predict system requirements.

3. CRITICAL ISSUES. Reviews by both the Theme Team and the Working Groups identified three issues of vital importance to further development of technology for Global Service Systems. The first issue is the need for prediction modeling capability within the Agency which was discussed in preceding paragraphs. The second critical issue was the need for more emphasis on mission definition. This issue was emphasized in discussions with the Working Groups where a better definition of mission characteristics was needed to properly assess technical requirements and capabilities. The third critical issue was a need for a better appreciation or coupling with the ultimate users of Global Service Systems. This last issue involves both credibility of Theme and mission models of which reflect real user needs. It is necessary to instill confidence in the technical tasks undertaken to support the development of Global Service Systems.

GLOBAL SERVICE SYSTEMS

ISSUES & PROBLEMS

- TECHNICAL
  - QUANTUM JUMPS IN TECHNICAL CAPABILITY NEEDED
  - LARGE NUMBER OF RELEVANT NEW INITIATIVES: SPHINX B/C, LASS, EIPS, LHS, CCD DATA PROCESSORS, END-TO-END DATA MANAGEMENT
- SOCIO-POLITICAL
  - INDIVIDUAL PRIVACY, SECURITY
  - NATIONAL BOUNDARIES, SECURITY
  - AGENCY RESPONSIBILITIES

THEME TEAM

- NASA

CHAIRMAN - PONTIOUS, RE	HIBBS, JPL	MOORE, LARC
ERNST, EC	WALLACE, MSFC	PLOTKIN, GSFC
SIVO, LERC	WOLFF, GSFC	DEERWESTER, ARC

- EXTERNAL

RTAC	DDR&E, NOAA, EPA, DEPT. OF AGRIC.,
ASEB	GE, AEROSPACE, TRW, HUGHES

WORKING GROUP DIRECTIVE

The principal need in the Global Service Systems Theme is a more detailed and careful analysis of technical activities necessary to ensure technology availability in the 1990 time frame. Areas the Theme team feels are particularly weak or inadequately defined include structures, power, auxiliary propulsion, end-to-end data systems with particular emphasis on software and data reduction, and advanced sensor technology.

Comment and critique of the overall Theme is urgently solicited and any assistance the Working Groups can provide in quantifying and strengthening the needs/benefits aspects of this Theme would be sincerely welcomed.

THEME TEAM MEMBERSHIP

<u>Headquarters</u>

Pontious	OAST/RES Team Leader
Gilstad	OAST/RW
Lazar	OAST/RP
Ernst	OA/EC
Kaufman	OSS/ST

<u>Center</u>

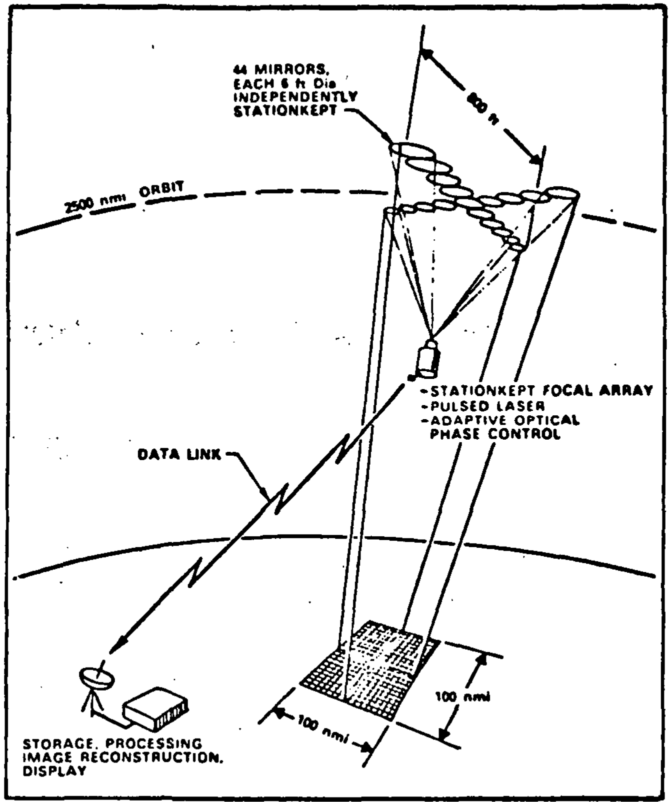
Deerwester	ARC
Plotkin	GSFC
Wolff	GSFC
Hibbs	JPL
Moore	LaRC
Sivo	LeRC
Wallace	MSFC

ENCLOSURE A

EXAMPLES OF TYPICAL SPACECRAFT AND MISSIONS

EXTREMELY HIGH RESOLUTION OBSERVATION (CO-4)

- **PURPOSE**
  To observe the surface with extreme resolution.



- **RATIONALE**
  Crop yield forecasts, insect control, resource conservation, etc., may be aided by imaging with extreme resolution.

- **CONCEPT DESCRIPTION**
  Adaptive stationkept optical array is used in conjunction with laser illumination to reduce effects of atmospheric scintillation.

- **CHARACTERISTICS**
  - WEIGHT 40,000 lb
  - SIZE 800 ft
  - RAW POWER 10 kW
  - ORBIT 2500 nmi circular, 45^{0} inclination
  - CONSTELLATION SIZE 1
  - LIFE/SERVICING PERIOD 10/3 yrs
  - TIME FRAME 2000
  - IOC COST 300 M

- **PERFORMANCE**
  Less than a few feet ground resolution (passive); up to one order of magnitude improvement in resolution with pulsed laser illumination.

- **BUILDING BLOCK REQUIREMENTS**
  - TRANSPORTATION: Shuttle and large tug and/or SEPS
  - ON-ORBIT OPERATIONS: Automated or manned "assembly" and servicing
  - SUBSYSTEMS: Stationkept mirrors; focal plane; high rate communication
  - TECHNOLOGY: Image processing in focal plane; adaptive corrections; shielding
  - OTHER: None

OCEAN RESOURCES AND DYNAMICS SYSTEM (CO-15)

- **PURPOSE**
  To locate schools of fish and to map ocean dynamic signatures.

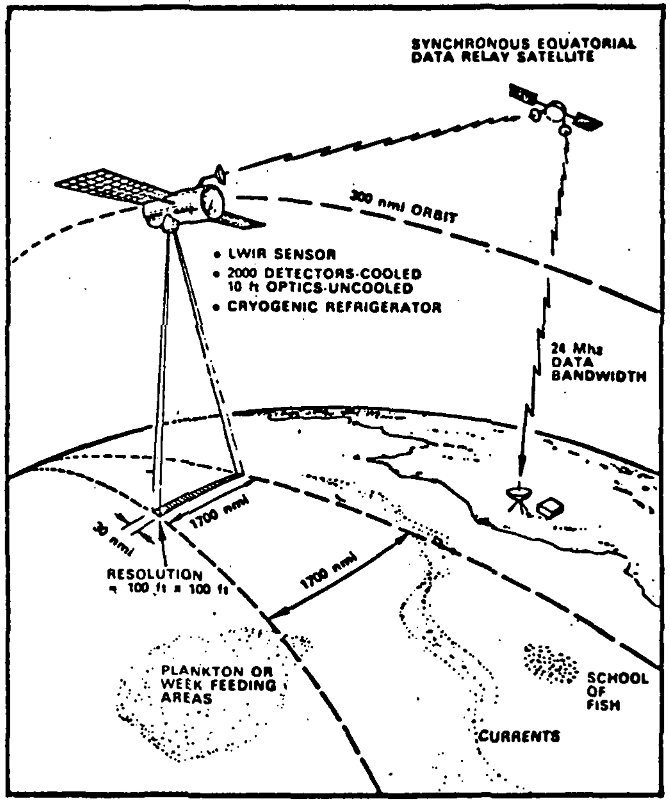
- **RATIONALE**
  Fish protein resource yield needs to be maximized due to world protein shortage. Mapping instruments needed.

- **CONCEPT DESCRIPTION**
  Temperature and emissivity differences in surface water caused by schools of fish, currents, and plankton concentrations are detected by the differences in their self-emission in the long-wave infrared.

- **CHARACTERISTICS**

• WEIGHT	15,000 lb
• SIZE	10 x 60 ft
• RAW POWER	25 kW
• ORBIT	300 nmi polar
• CONSTELLATION SIZE	1
• RISK CATEGORY	1 (Low)
• TIME FRAME	1985
• IOC COST (SPACE ONLY)	300 M

- **PERFORMANCE**
  100-ft resolution attained over all ocean surfaces every 12 hours. Sensitivity equivalent to 0.002 deg C achieved.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle
• ON-ORBIT OPERATIONS	Shuttle attached manipulator
• SUBSYSTEMS	Thermal dissipation, sensor, cryogenic cooler
• TECHNOLOGY	Large LWIR sensor: cryogenic refrigerator; LSI data processor
• OTHER	None

ATMOSPHERIC TEMPERATURE PROFILE SOUNDER (CO-11)

- **PURPOSE**
  To measure actual profiles of temperature in the atmosphere.

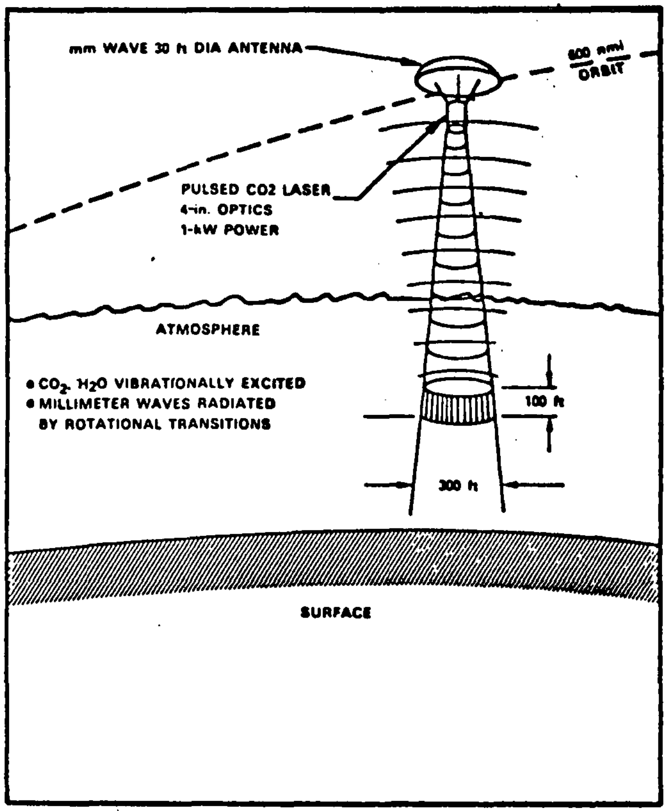
- **RATIONALE**
  Weather prediction requires knowledge of temperature profiles, as well as other phenomena.

- **CONCEPT DESCRIPTION**
  Pulsed laser vibrationally excites CO_2 or H_2O molecules. Subsequent rotational transitions in the millimeter wave spectrum show temperature dependence which is measured by ratio of energy in several lines.

- **CHARACTERISTICS**

• WEIGHT	4000 lb
• SIZE	30-ft dia antenna
• RAW POWER	5 kW
• ORBIT	600-nmi polar
• CONSTELLATION SIZE	4
• RISK CATEGORY	III (Moderate)
• TIME FRAME	1990
• IOC COST (SPACE ONLY)	250 M

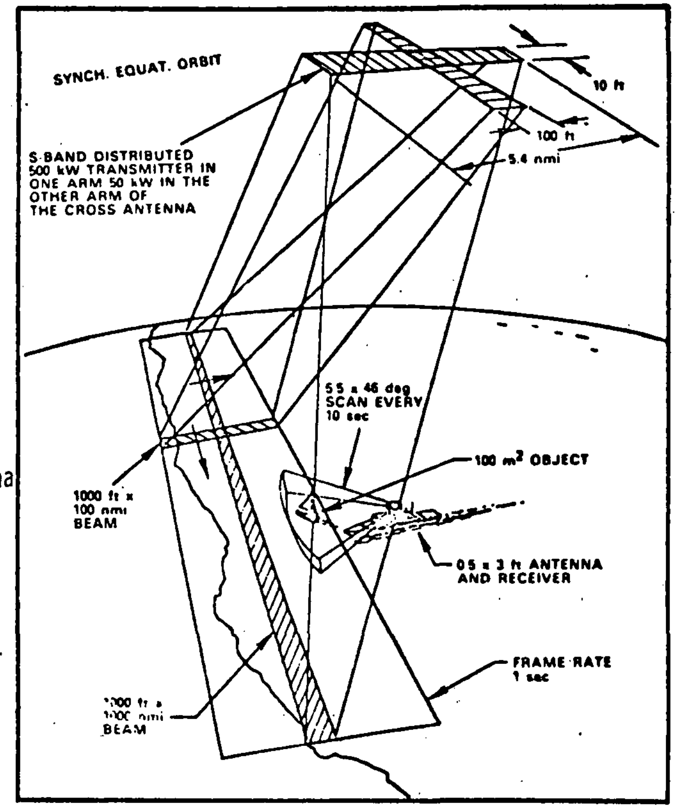
- **PERFORMANCE**
  Entire atmosphere measured, with resolution of 300 ft horizontally and 100 ft vertically, every four hours. Emission lines and signal strength imprecisely defined at present.



- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and tug/IUS
• ON-ORBIT OPERATIONS	Automated service unit/Shuttle-attached manipulator
• SUBSYSTEMS	Antenna, laser, attitude control
• TECHNOLOGY	Laser, power dissipation, antenna, pointing, sensitive heterodyne receiver
• OTHER	

COASTAL ANTI-COLLISION PASSIVE RADAR (CO-9)



- **PURPOSE**
  Inexpensive and lightweight radar for all surface vessels - navigation; collision avoidance
- **RATIONALE**
  Conventional radar too heavy, expensive, and interferrence prone. Pleasure craft usually denied radar benefits.
- **CONCEPT DESCRIPTION**
  Use space illuminator of seacoasts with scanning microwave beams. Scanning receiving antennas on boats obtain range and angle data.
- **CHARACTERISTICS**

• WEIGHT	110,000 lb
• SIZE	5.4 nmi crossed antenna
• RAW POWER	2 MW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1995
• IOC COST	1.1 B

- **PERFORMANCE**
  Relative location of all objects > 100 m^2 to within 100 ft in range and 300 ft in angle in 50^0 sector. 3 x 0.5 ft antenna in vessel.
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large tug or large SEPS
• ON-ORBIT OPERATIONS	Automated or manual servicing unit; Assemble in orbit
• SUBSYSTEMS	Structures; attitude control; antenna
• TECHNOLOGY	Large adaptive microwave antenna; laser master measuring and control unit
• OTHER	None

HIGH RESOLUTION EARTH MAPPING RADAR (CO-13)

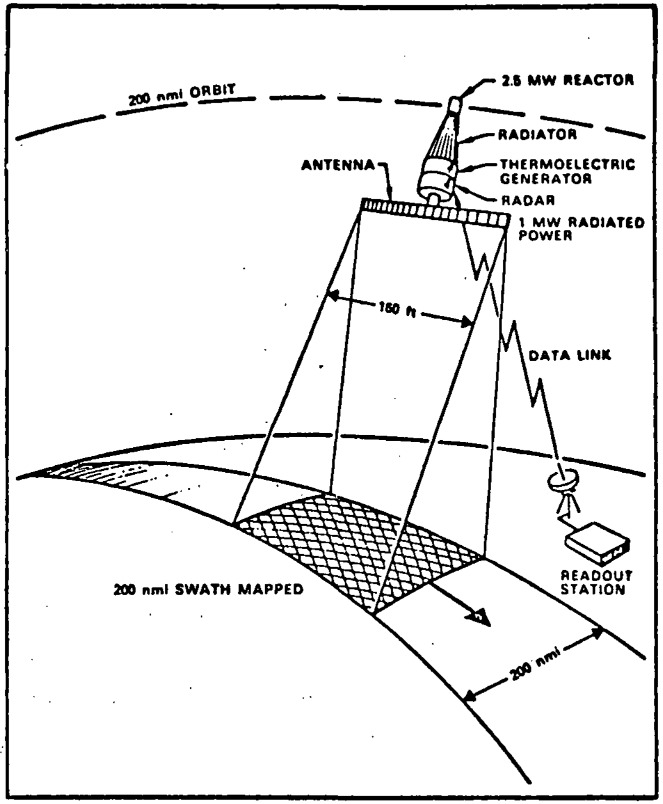
- **PURPOSE**
  To provide maps of the surface with high resolution through cloud cover.

- **RATIONALE**
  Resources, pollution, crop, water, and other observations may be aided by high resolution and frequent coverage regardless of weather.

- **CONCEPT DESCRIPTION**
  Synthetic array radar of very high power provides high resolution. On-board image processing allows microwave data link for all weather capability.

- **CHARACTERISTICS**

• WEIGHT	110,000 lb
• SIZE	15 x 160 ft
• RAW POWER	2.5 MW
• ORBIT	200 nmi polar
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/1 yr
• TIME FRAME	1990
• IOC COST	500 M



- **PERFORMANCE**
  200 nmi ground swath mapped to less than a few feet resolution once a day. U. S. covered every six days.

- **BUILDING BLOCK REQUIREMENTS**

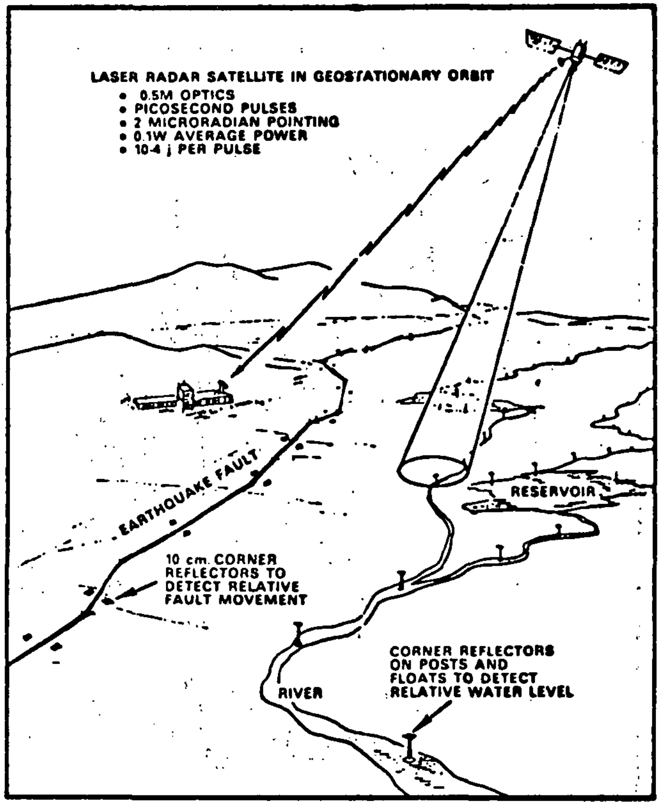
• TRANSPORTATION	Shuttle
• ON-ORBIT OPERATIONS	Shuttle manipulator; servicing
• SUBSYSTEMS	Thermal, nuclear, power generator, radar
• TECHNOLOGY	High power transmitter; automated image processor, reactor, shielding
• OTHER	None

WATER LEVEL AND FAULT MOVEMENT INDICATOR (CO-3)

- **PURPOSE**
  To make precision measurements in many places in rapid succession for aid in earthquake prediction, water resources establishment, disaster use, etc.

- **RATIONALE**
  Prediction of earthquakes, floods, droughts, and accurate water resources would be of great social and economic benefit.

- **CONCEPT DESCRIPTION**
  Picosecond (10^{-12} sec) pulsed laser radar in orbit obtains precision differential range measurements from corner reflectors implaced on both sides of faults, river banks and floats, etc.



- **CHARACTERISTICS**

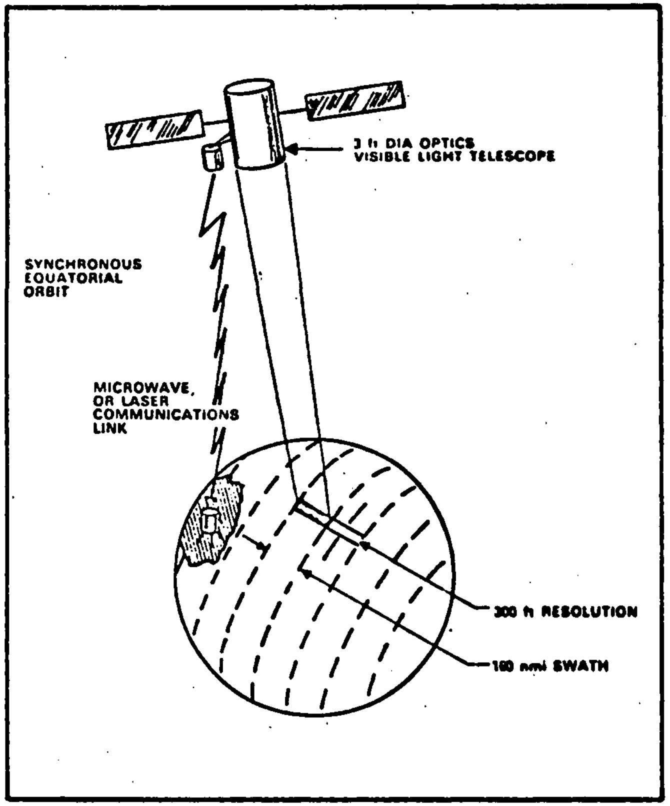
• WEIGHT	800 lb
• SIZE	0.5 m optics
• RAW POWER	250 W
• ORBIT	Geostationary
• CONSTELLATION SIZE	1
• RISK CATEGORY	1 (Low)
• TIME FRAME	1985
• IOC COST (SPACE ONLY)	50 M

- **PERFORMANCE**
  Relative range obtained to ± 0.03 millimeters at any number of points separated by 100 meters or more. 10^5 instrumented points can be measured every hour.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle, IUS/Tug
• ON-ORBIT OPERATIONS	Automated or manned servicing
• SUBSYSTEMS	Picosecond receiver, transmitter, 2 μr pointing
• TECHNOLOGY	Streak camera converter, mode locked laser and switch
• OTHER	

SYNCHRONOUS METEOROLOGICAL SATELLITE (CO-12)



- **PURPOSE**
  To collect worldwide atmospheric data for global weather prediction.

- **RATIONALE**
  High resolution and frequent coverage of globe are needed for forecasts..

- **CONCEPT DESCRIPTION**
  Optical sensor with 1 meter mirror collects visible light data on gross meteorological features. Same instrument makes spectrum measurements for detailed information on atmosphere.

- **CHARACTERISTICS**

• WEIGHT	3000 lb
• SIZE	5 x 20 ft
• RAW POWER	1 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	3
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1985
• IOC COST	190 M

- **PERFORMANCE**
  Ground resolution 300 ft dia. Scan rate: Earth coverage in 20 sec for clouds, etc. Detailed measurements of spectrum every 200 sec.

- **BUILDING BLOCK REQUIREMENTS**

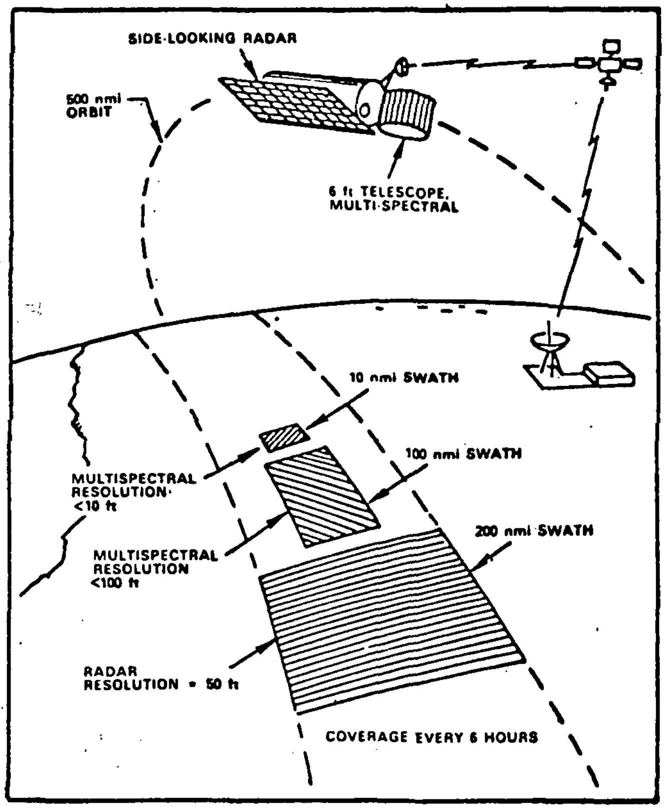
• TRANSPORTATION	Shuttle and tug
• ON-ORBIT OPERATIONS	Automated or Manual Servicing Unit
• SUBSYSTEMS	Laser
• TECHNOLOGY	Comm. link: 10 gigabits/sec from each satellite. Ground computer center.
• OTHER	Weather calculation method.

ADVANCED RESOURCES/POLLUTION OBSERVATORY (CO-1) (U)

- **PURPOSE**
  To provide high quality, multispectral earth resources and pollution data.

- **RATIONALE**
  Integrated ERTS-like system, real-time data distribution to world-wide users, active sensors needed.

- **CONCEPT DESCRIPTION**
  Active and passive sensors, large aperture, high, medium, and low resolution imaging obtained in multispectral region and radar. Data disseminated by laser link through relay satellite.



- **CHARACTERISTICS**

• WEIGHT	30,000 lb
• SIZE	10 x 60 ft
• RAW POWER	12 kW
• ORBIT	500 nmi sun synch.
• CONSTELLATION SIZE	1
• LIFE/SERVICING PERIOD	10/3 Years
• TIME FRAME	1985
• IOC COST	350 M

- **PERFORMANCE**
  Multispectral resolutions varying from < 10 to < 100 ft obtained world-wide.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and Tug
• ON-ORBIT OPERATIONS	Shuttle attached manipulator, servicing stages
• SUBSYSTEMS	Guidance and navigation; attitude control; transmitter
• TECHNOLOGY	Large radar antenna; high power tubes and modulator; LSI data processor
• OTHER	None

PERSONAL COMMUNICATIONS WRIST RADIO (CC-9)

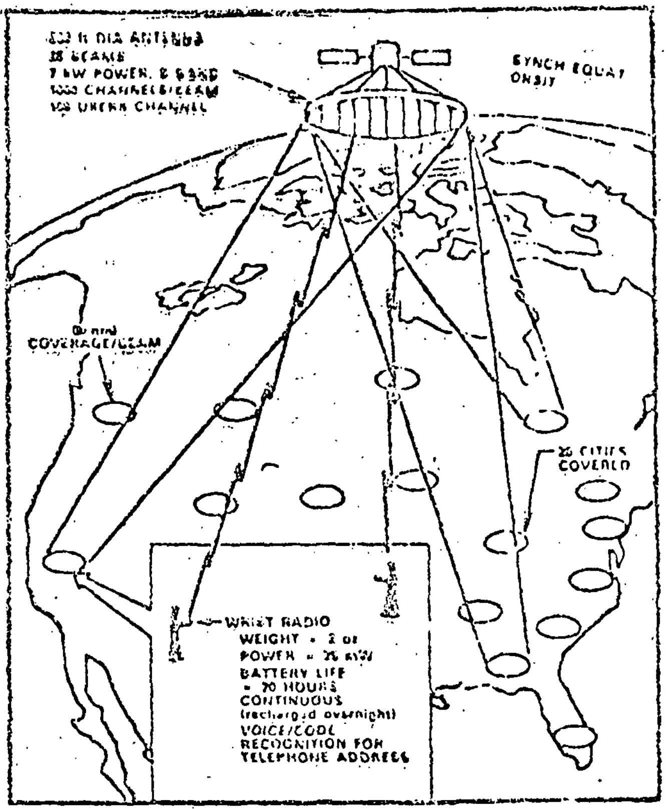
- **PURPOSE**
  To allow citizens to communicate through exchanges by voice, from anywhere.

- **RATIONALE**
  Mobile telephones are desirable, but should be wrist worn. Uses include emergency, recreation, business, rescue, etc.

- **CONCEPT DESCRIPTION**
  Multichannel switching satellite and wrist transmitter-receivers connect people anywhere to each other directly or to telephone networks. Analog or vocoded voice used.

- **CHARACTERISTICS**

• WEIGHT	16,000 lb
• SIZE	200 ft dia antenna
• RAW POWER	21 kW
• ORBIT	Synch. Equat.
• CONSTELLATION SIZE	1
• RISK CATEGORY	I (Low)
• TIME FRAME	1990
• IOC COST (SPACE ONLY)	300M



- **PERFORMANCE**
  25,000 simultaneous voice channels, each shared by up to 100 users: 2.5 million people communicate by normal voice.

- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and large/tandem tug or SEPS
• ON-ORBIT OPERATIONS	Automated or manual servicing unit; assembly on orbit
• SUBSYSTEMS	Attitude control; antenna; processor; repeater
• TECHNOLOGY	Large multibeam antenna; multi-channel repeater; LSI processor, multiple-access techniques
• OTHER	Wrist transceiver, LSI technology

- **PURPOSE**

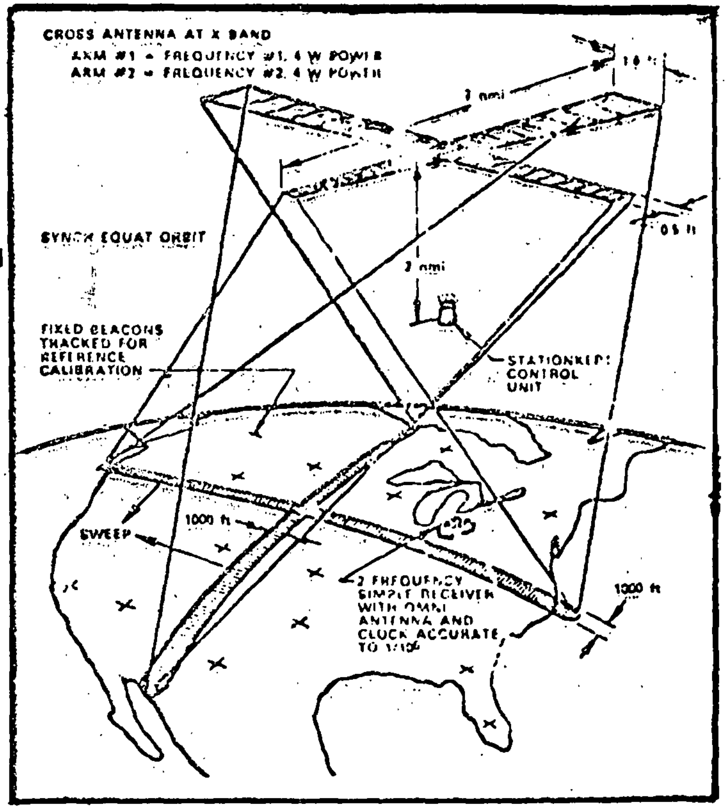
  To provide accurate relative position location with very inexpensive user equipment.

- **RATIONALE**

  Navigation system costs are dominated by user equipment costs.

- **CONCEPT DESCRIPTION**

  Narrow beams are swept over the U. S. by large phased arrays in space. Very simple receivers measure time elapsed between pulses received and display distances (N-S, E-W) to fixed point.



- **CHARACTERISTICS**

• WEIGHT	3000 lb
• SIZE	2 nmi cross
• RAW POWER	2 kW
• ORBIT	Sync. Equat.
• CONSTELLATION SIZE	1
• RISK CATEGORY	II (Moderate)
• TIME FRAME	1990
• IOC COST (SPACE ONLY)	100 M

- **PERFORMANCE**

  User position located to 300 ft every 10 sec relative to a fixed location < 100 nmi away.

  User receiver can cost less than $10 in mass production.

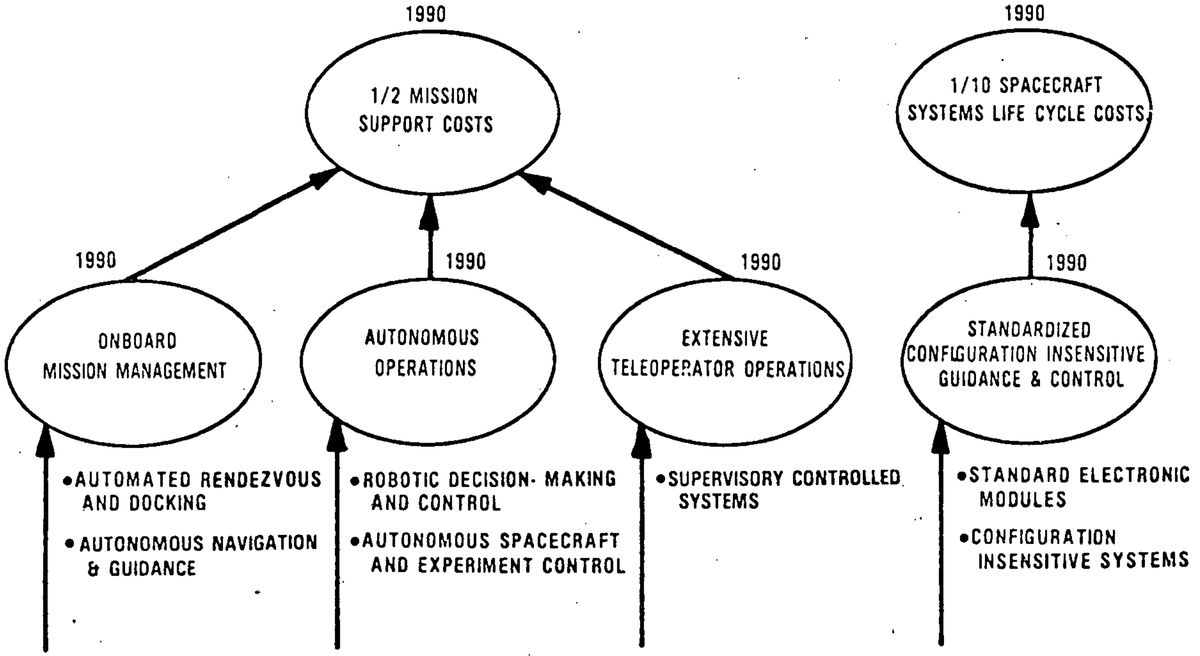
- **BUILDING BLOCK REQUIREMENTS**

• TRANSPORTATION	Shuttle and Tug
• ON-ORBIT OPERATIONS	Manned or automated assembly and servicing units
• SUBSYSTEMS	Antenna with independently stationkept subunits.
• TECHNOLOGY	Ion thruster, adaptive RF phase control, laser master measuring unit
• OTHER	LSI receivers

ENCLOSURE B

EXCERPT FROM SURVEY OF SPACE ELECTRONICS TECHNOLOGY R&D

NAVIGATION, GUIDANCE AND CONTROL



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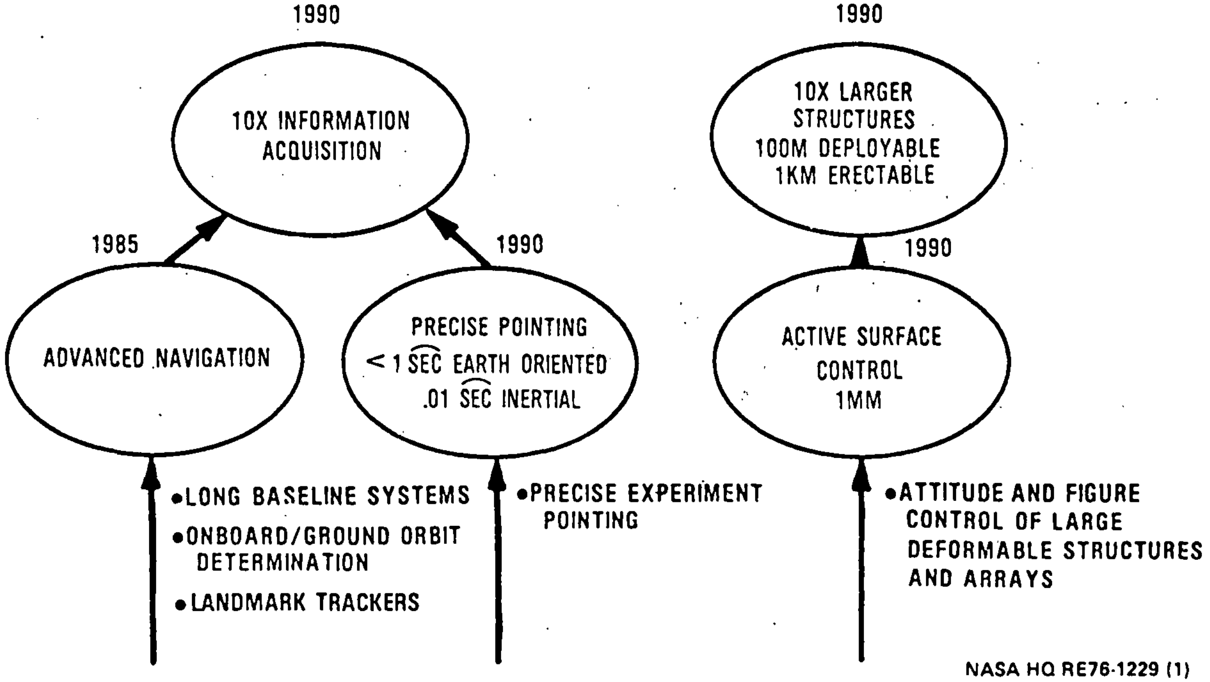
NAVIGATION, GUIDANCE AND CONTROL



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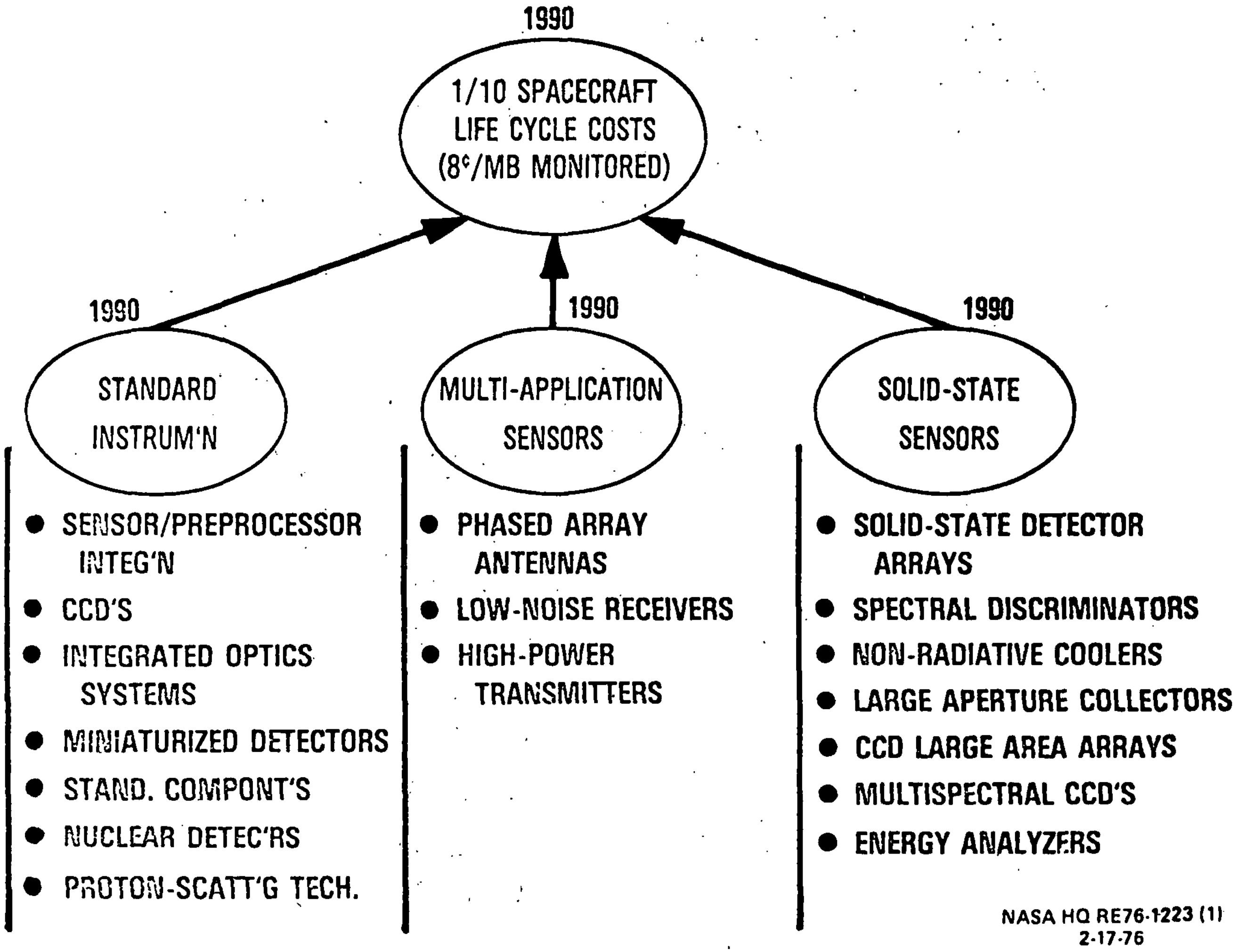
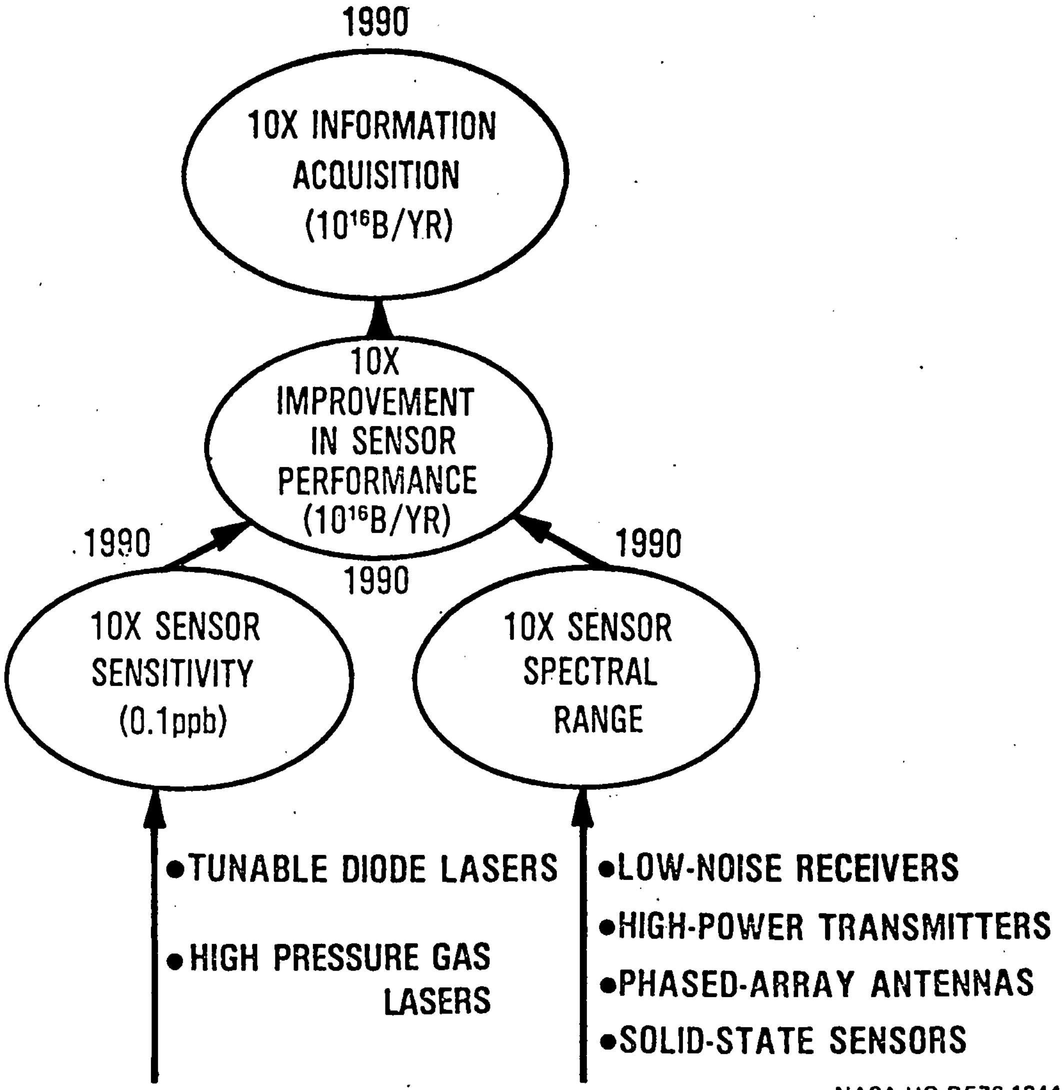
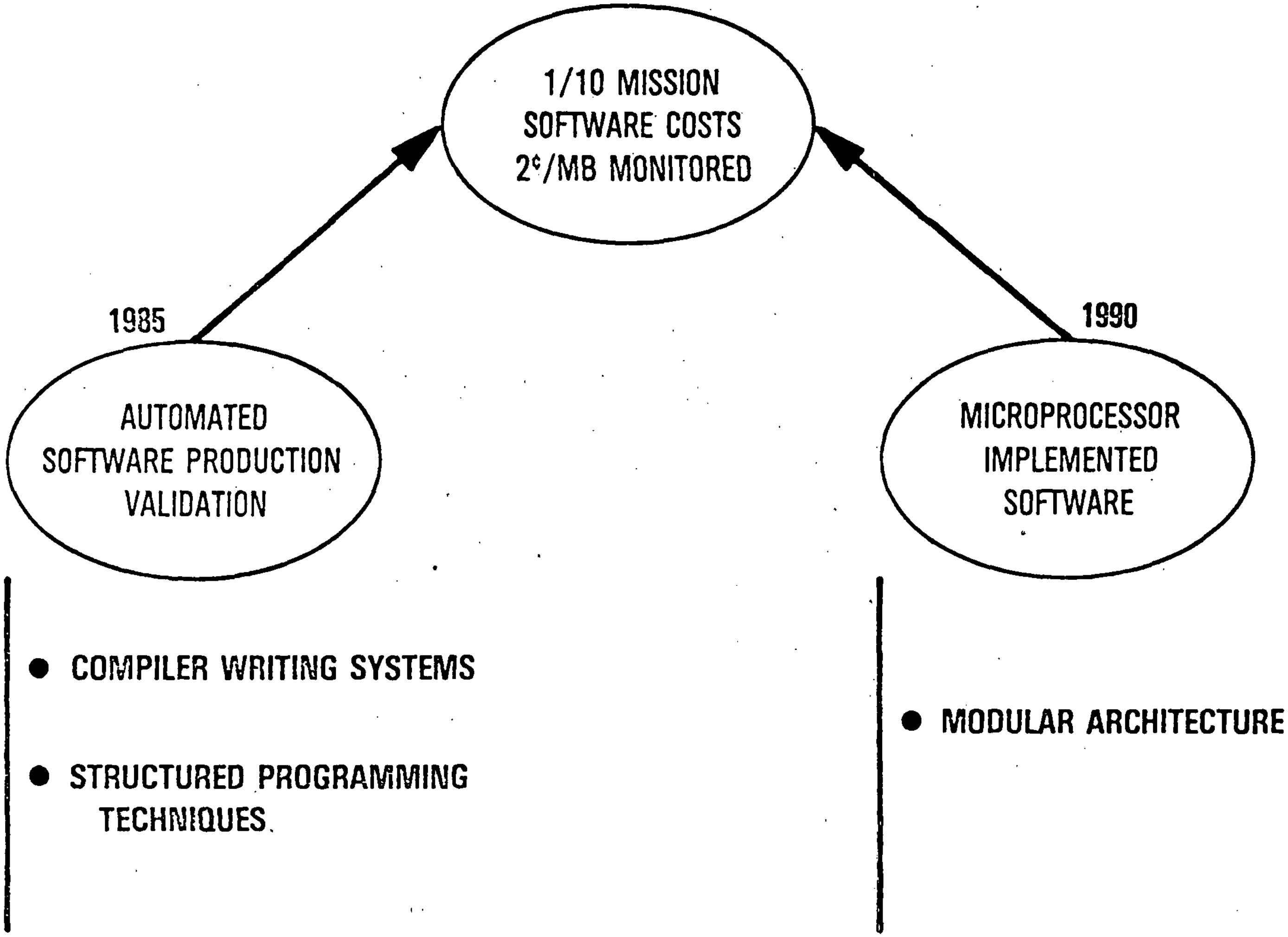
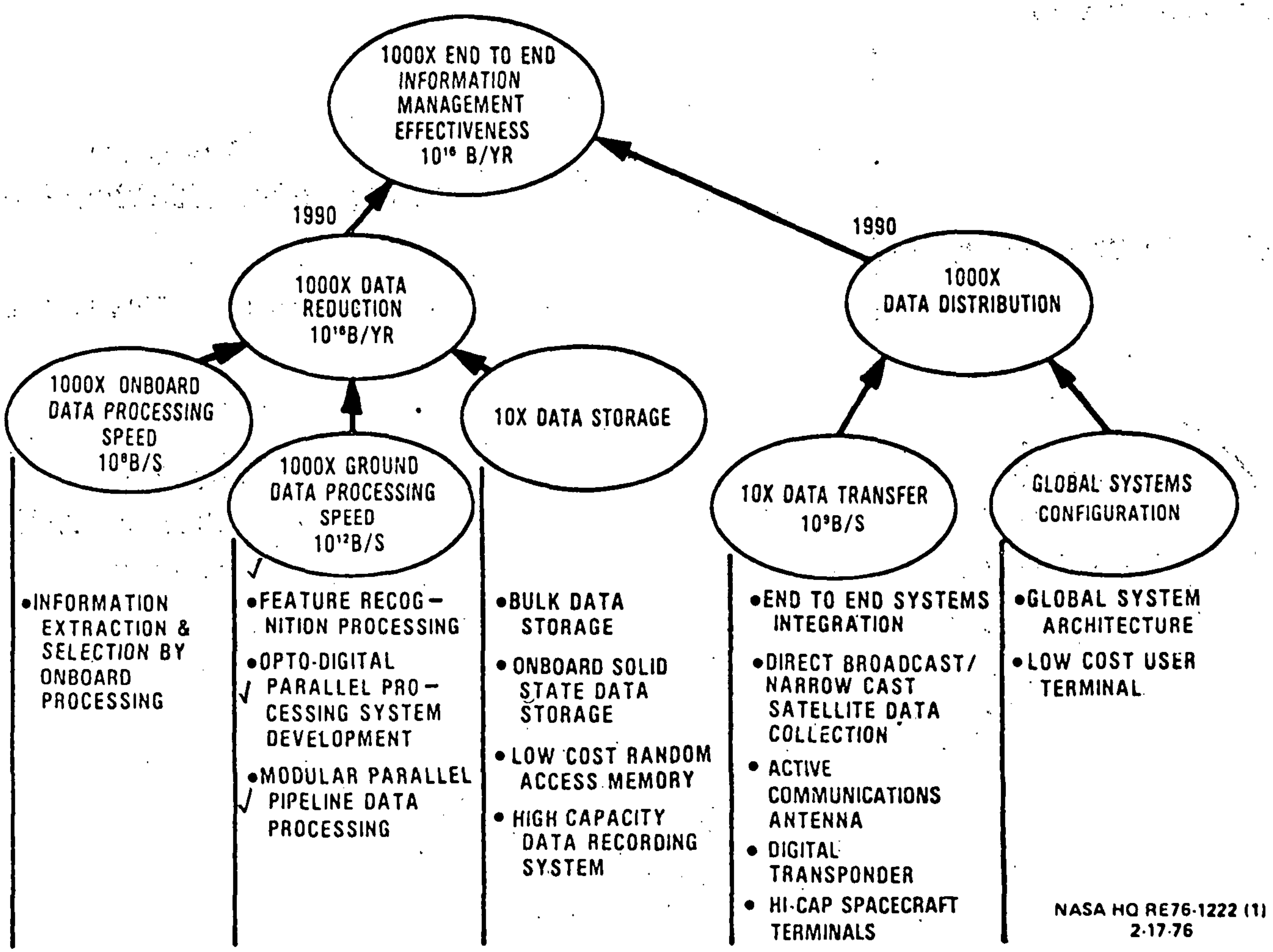

1990
1/10 SPACECRAFT
LIFE CYCLE COSTS
(8¢/MB MONITORED)
1990
STANDARD
INSTRUM'N
1990
MULTI-APPLICATION
SENSORS
1990
SOLID-STATE
SENSORS
● SENSOR/PREPROCESSOR INTEG'N
● CCD'S
● INTEGRATED OPTICS SYSTEMS
● MINIATURIZED DETECTORS
● STAND. COMPONT'S
● NUCLEAR DETEC'RS
● PROTON-SCATT'G TECH.
● PHASED ARRAY ANTENNAS
● LOW-NOISE RECEIVERS
● HIGH-POWER TRANSMITTERS
● SOLID-STATE DETECTOR ARRAYS
● SPECTRAL DISCRIMINATORS
● NON-RADIATIVE COOLERS
● LARGE APERTURE COLLECTORS
● CCD LARGE AREA ARRAYS
● MULTISPECTRAL CCD'S
● ENERGY ANALYZERS
NASA HQ RE76-1223 (1)
2-17-76



NASA HQ RE76-1244 (1)
2-17-76

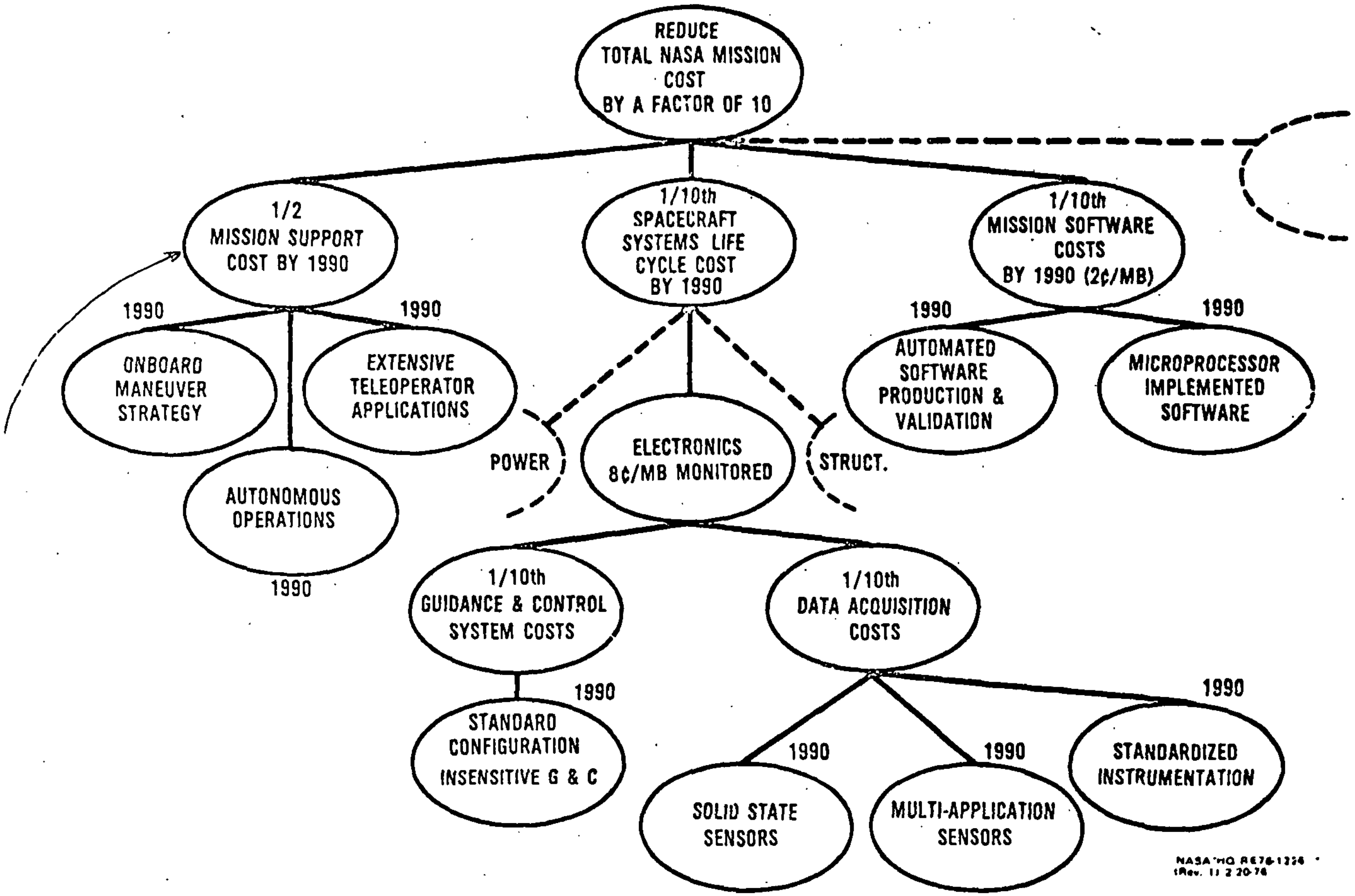


NASA HQ RE76-1225 (1)
2-17-76


1000X END TO END INFORMATION MANAGEMENT EFFECTIVENESS 10^16 B/YR
1990
1000X DATA REDUCTION 10^16 B/YR
1990
1000X DATA DISTRIBUTION
1000X ONBOARD DATA PROCESSING SPEED 10^8 B/S
1000X GROUND DATA PROCESSING SPEED 10^12 B/S
10X DATA STORAGE
10X DATA TRANSFER 10^9 B/S
GLOBAL SYSTEMS CONFIGURATION
•INFORMATION EXTRACTION & SELECTION BY ONBOARD PROCESSING
•FEATURE RECOG-NITION PROCESSING
•OPTO-DIGITAL PARALLEL PRO-CESSING SYSTEM DEVELOPMENT
•MODULAR PARALLEL PIPELINE DATA PROCESSING
•BULK DATA STORAGE
•ONBOARD SOLID STATE DATA STORAGE
•LOW COST RANDOM ACCESS MEMORY
•HIGH CAPACITY DATA RECORDING SYSTEM
•END TO END SYSTEMS INTEGRATION
•DIRECT BROADCAST/ NARROW CAST SATELLITE DATA COLLECTION
•ACTIVE COMMUNICATIONS ANTENNA
•DIGITAL TRANSPONDER
•HI-CAP SPACECRAFT TERMINALS
•GLOBAL SYSTEM ARCHITECTURE
•LOW COST USER TERMINAL
NASA HQ RE76-1222 (1)
2-17-76

SPACE ELECTRONICS TECHNOLOGY REVIEW

MAJOR THRUSTS



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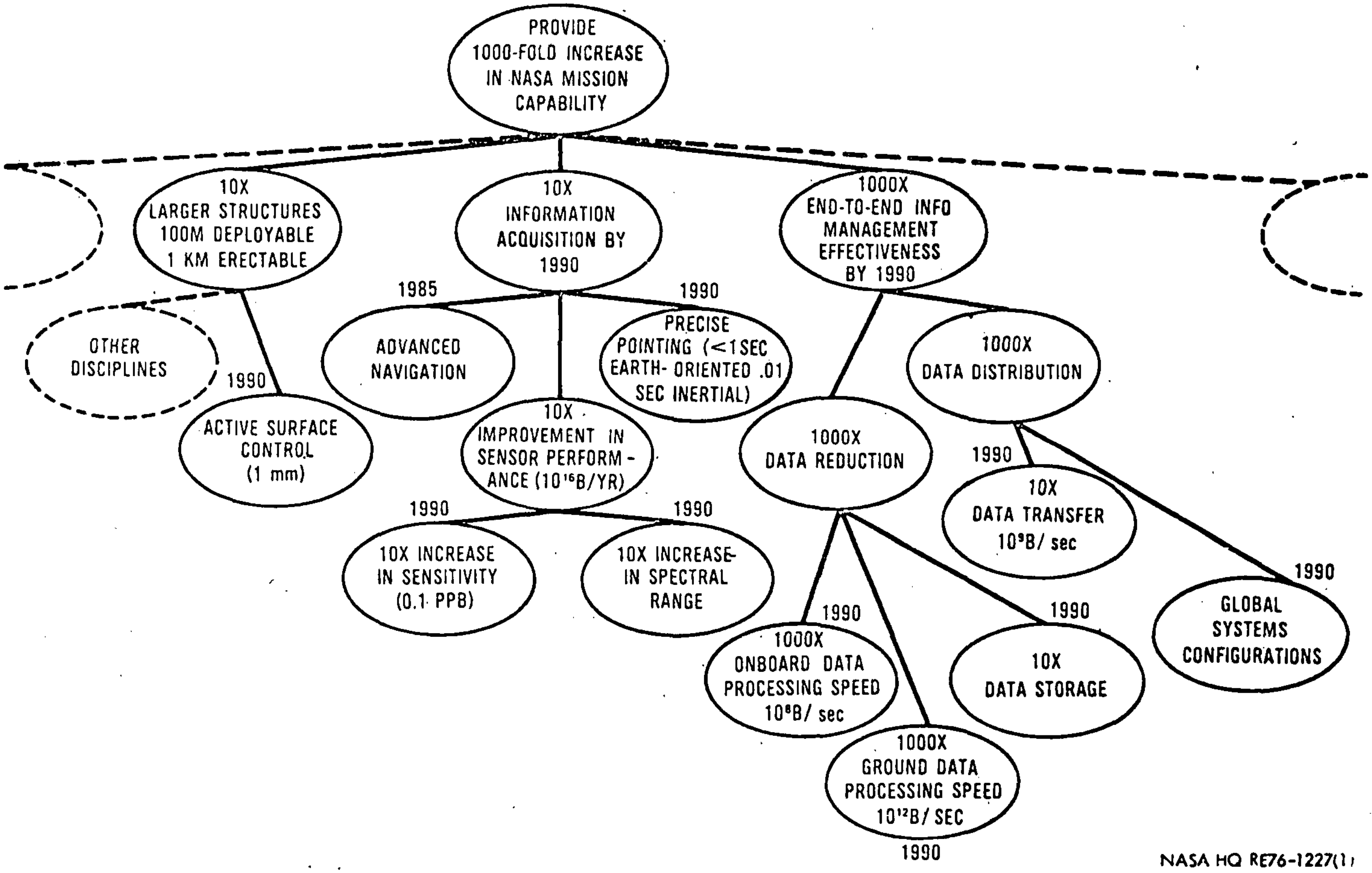
SPACE ELECTRONICS TECHNOLOGY REVIEW

MAJOR THRUSTS



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ENCLOSURE C

OVERALL THEME TEAM RANKINGS AND OBJECTIVES

FOR GLOBAL SERVICE SYSTEMS THEME

DESCRIPTIONS OF THEME TECHNOLOGIES

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
E-2-01	End-to-End Data Management	1	To develop and utilize techniques, simulation tools, and a reconfigurable flight experiment to enable design, analysis, and proof of concept with the purpose of allowing and demonstrating cost effective, throughput optimization.
E-4-01	Multidimension Data Systems	2	To provide efficient means of storing and retrieving high volumes of data and maintaining file security for multidimensional data.
E-2-05	High Rate Data Processor	3	Develop a general modular processing capability to handle high rate data from imaging systems, multispectral scanners, and other remote sensing systems for both on-board and ground applications.
E-3xx	Microwave Sensor & Comp.	4	---
E-1-04	Precision Pointing (Noninertial)	5	A comprehensive program to provide systems capable of precisely pointing and tracking at high rates (0.1°/sec) noninertial targets. This technology is applicable to planetary and earth pointing spacecraft and platforms.
E-4-11	Operations Languages	6	Develop languages and interpreters for effective expression and execution of systems directives and procedures.
E-2-04	Data Set Selection	7	Develop system concepts/demonstrate feasibility for automated on-board go/no-go data set selection on the basis of such parameters as spatial, spectral characteristics, data thresholds, etc.
M-1-03	Long Life Cryogenic Systems	8	To develop advanced cryogenic systems for sensors.
E-2-14	Large Capacity Ground Storage	9	Develop a high capacity (10^{15} bits), high transfer rate (10^{10} bits/sec), ground data archival storage system. The data cataloging function will also be considered.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.	OVERALL THEME TEAM RANKING	OBJECTIVE
E-2-08 Large Capacity On-Board Storage	10	Development of high density data storage technologies for space applications capable of storing 10^9-10^{10} bits and containing no moving parts.
E-1-11 Autonomous Operations	11	Extend the autonomous navigation technology to include capability to provide adaptive on-board sequence modification to autonomously react to received science data.
E-3-xx UV/Visible/IR Components	12	---
E-2-09 Low Cost User Distribution	13	Develop the incremental (only) technology for processing, routing, and distributing remote sensing and DCP data to user networks on a "fixed order" and interactive basis. Assumes pre-existence of an operational centralized system.
P-2-PC7 Solar Arrays	14	Design, fabricate, and demonstrate large light weight solar array 25 KWe, 30 W/lb, 5-year life, retractable, 400 V.
M-2-08-1 Large Structures Deployed	15	Design and develop structural concepts for booms, arrays, reflectors, antennas, and platforms using space-deployment at ground-assembled components.
M-2-08-2 Large Structures Assembled	16	Design and develop structural concepts for booms, arrays, reflectors/antenna, and space platforms using space assembly of ground fabricated components. (Components can include deployable structures.)
E-1-15 Control of Large Structures	17	To stabilize and control the attitude of a large flexible structure whose geometry, mass distribution, attitude, and orbit may change while in orbit.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.	OVERALL THEME TEAM RANKING	OBJECTIVE
P-1/12, 13 MPD; Elec. Prop., OTV	18	The MPD thruster propulsion system, now seen as essential for economical large cargo earth orbit operations, will be brought to technology readiness. Provide the technology for an efficient high specific impulse ion thruster system for orbit raising from low earth orbit to a higher orbit using low lost inert fuels.
E-4/9 System Integrity	19	Technology to format program and test software architecture and procedure to maintain system integrity in the face of failure or data error.
P-2/ES-3 Long-Life, Light Nicads	20	Develop long-life, lightweight (55 Wh/kg) nickel-cadmium battery.
P-2/PP-1 Electron Power Condition	21	Develop to technology ready status unique hardware items required to enable advanced high power electrical power system concept implementation.
E-1/23 Robotics and Teleoperators	22	Develop a general class of robotic devices with sufficient dexterity to permit mechanical operations in space.
E-4/6 Pattern Recognition	23	Develop theory and implementations for semantic perception and interpretation of patterns and objects in multi-dimensional dimensional feature space.
E-4/13 Algorithm/Numerical Analysis	24	To develop theoretical computation and implementation algorithms for flight and ground S/W consistent with computer architecture requirements and constraints for advanced space missions.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.	OVERALL THEME TEAM RANKING	OBJECTIVE
E-2/3 Modular Data Sys. Architec.	25	Provide a system of modular components and functions to meet the needs of future spacecraft such as lower cost, adaptability, fault tolerance, software simplification.
P-2/PP-8 Multi-kW Distribution	26	To demonstrate the technology readiness at high voltage DC power distribution system through use at a lab simulator.
E-3/(misc.) UV/Vis/IR Instru.	27	---
E-3/(misc.) Laser Technology	28	---
E-1/5 Autonomous Navigation	29	To reduce mission operations costs by utilizing on-board systems to perform mission planning, orbit stationkeeping, altitude control.
E-4/12 Intelligent Executive	30	To design, develop, and test executive programs capable of interpreting plans and guidelines and executing operational sequences and data management functions to accomplish system operational goals.
E-4/10 Evolutionary Software	31	To develop advanced concepts which will provide for evolutionary software within expanding computer architectures.
E-2/13 Pattern Recognition Analyzer	32	(1) Develop visual interactive system for identifying intelligent signals in the massive output file of the Fourier Analyzer (FTP); (2) automated pattern recognition scanner for identifying intelligent signals with high probability and acceptably low false alarm rate.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
M-2-08-3	Large Structures Manufactured	33	Design and develop structural concepts for booms, arrays, reflectors/antennas, and platforms using space assembly of space fabricated/manufactured components.
M-1-02	Materials for In Situ Manufacture	34	Develop methods and techniques for manufacturing large structures in space.

Section II

THEME SUMMARIES

Part 6

ADVANCED TRANSPORTATION SYSTEMS

THEME DESCRIPTION

INTRODUCTION

The Advanced Space Transportation Advocacy Theme has defined as its goal: To assure the technology readiness for an integrated space transportation system capability which will permit the Nation to utilize space efficiently, reliably, and routinely in the years between 1985 and 2000, with a significant return on invested resources. Contributing technologies should include those which support:

a. Total reliability with minimal refurbishment.

b. Responsiveness to high launch rate requirements when operation and energy are the predominant recurring costs.

c. Maximum flexibility in operation between Earth and LEO and between LEO and GEO.

With respect to this stated goal, the objective of the Workshop is to provide information which is useful for technology program planning for future systems which will be needed to support the increasing requirements projected for construction/assembly, manning, and logistics of near-permanent, manned, or man-tended facilities operating in both Low Earth Orbit (LEO) and Geosynchronous Orbit (GEO).

The precept of this effort is that the technology requirements will build upon the base which will have been established by successful operation of the Space Transportation Systems as currently defined, i.e., Shuttle, Spacelab, and Interim Upper Stage (IUS), and an advanced upper stage such as the Solar Electric Propulsion Systems (SEPS).

Basic guidelines must also include protection of the environment and conservation of energy.

ADVANCED SPACE TRANSPORTATION SYSTEMS

TECHNOLOGY FOR ADVANCED SPACE TRANSPORTATION SYSTEMS (ASTS)

GOAL: ASSURE TECHNOLOGY READINESS FOR AN INTEGRATED ASTS TO PERMIT EFFICIENT, RELIABLE, ROUTINE USE OF SPACE WITH A SIGNIFICANT REDUCTION OF UNIT AND TOTAL TRANSPORTATION COSTS IN THE 1985 AND 2000 TIME FRAME

A. TOTAL REUSABILITY/MINIMAL REFURBISHMENT

B. RESPONSIVE TO HIGH LAUNCH RATE REQUIREMENTS WHEN OPERATIONS AND ENERGY ARE PREDOMINANT RECURRING COSTS

C. MAXIMUM FLEXIBILITY FOR OPERATION BETWEEN EARTH AND GEOSYNCHRONOUS ORBIT

PRECEPT: BUILD ON STATE OF TECHNOLOGY DEMONSTRATED BY SUCCESSFUL SHUTTLE/SPACELAB/IUS OPERATIONS

BACKGROUND

Missions and systems which address national needs and which are currently under study by NASA include Space Stations in LEO and GEO which provide integral or staging support to broader activities such as Multipurpose Space Power Platforms, Space Industrialization, the Search for Extraterrestrial Intelligence, Solar Systems Exploration, and Global Service Systems. The dominant characteristic of the ASTS should support manning and resupply of these activities on a regular basis. However, as a boundary, the ASTS should have the flexibility for rapid response to manned emergencies or critical resupply needs, and the capability to lift very large weights and/or volumes on a non-routine or irregular basis.

The program remains essentially the same as presented in the original Theme paper. One modification to the precept is as follows:

PRECEPT: The Space Shuttle will commence operational use in 1980 and with improvement may obviate the need for a new Heavy Lift Launch Vehicle ($HLLV_1$) until the 1990's.

In-house studies have identified attractive program options for solid booster replacement or modification which could further reduce Shuttle transportation costs. This reduction could be realized in the mid-80's through a block change which would cause little impact on the Orbiter. It is the booster system which has the greatest effect on cost per flight; therefore OSF has initiated studies for Shuttle growth to analyze these booster options and further quantify the operational cost savings achievable and investment required for each option. OAST work will be taken into consideration in the Shuttle Growth Studies.

For the purpose of identification of requirements for technology for an integrated Advanced Space Transportation System, the state-of-technology of the Shuttle systems available in 1985 will be considered as the base for this effort.

A typical scenario includes a strawman Space Station (operational schedule is shown on p. 5), along with the project elements of the ASTS. The initial phase of activity includes a 3-6 man and a 10-20 man Space Station in LEO supported by the current Space Shuttle in 1983 and 1985, respectively. The second step includes a 3-6 man Station in GEO in 1987 and establishes the requirement for a shuttle-transportable manned Orbital Transfer Vehicle (OTV) for rapid transit from LEO to GEO.

Further advances in transportation capability are predicted by the potential for increased utilization of the Space Stations which may be continuously or intermittently manned, or, in some instances, only man tended for repair or renovation operations.

ADVANCED SPACE TRANSPORTATION SYSTEMS (ASTS)

NEEDS/BENEFITS

PERMITS MORE COST-EFFECTIVE EXPLOITATION OF SPACE

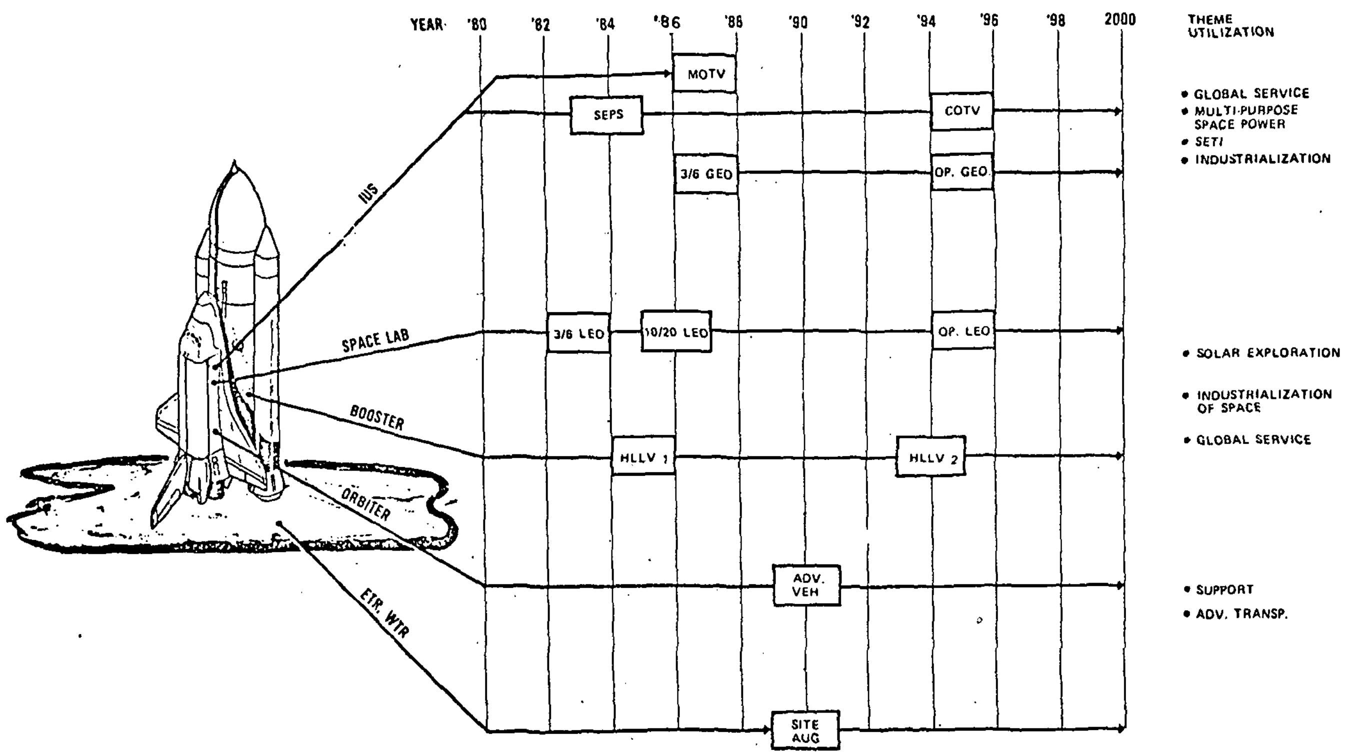
SUPPORTS: MULTIPURPOSE SPACE POWER PLATFORMS
INDUSTRIALIZATION OF SPACE
SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE
EXPLORATION OF THE SOLAR SYSTEM
GLOBAL SERVICE SYSTEMS

BACKGROUND (Cont.)

The advent in the 90's of a new Heavy Lift Launch Vehicle ($HLLV_2$) will permit the transportation of large structural elements or consumables to LEO in support of the 3-6 man or 10-20 man Space Stations operating as core modules or staging bases. The desire for rapid response or delivery of personnel and limited amounts of critical cargo can be met by an advanced Earth-to-LEO vehicle, such as a single-stage-to-orbit concept in the 1990-92 time frame. The necessity for this vehicle is directly proportional to our capability to exploit LEO.

The advent of one OTV, based perhaps on SEPS technology, to move large amounts of cargo from LEO to GEO in order to enhance our capability to exploit this arena.

SPACE TRANSPORTATION SYSTEM



WORKSHOP APPROACH

-INPUTS

ADVANCED SPACE TRANSPORTATION SYSTEM (ASTS)

<u>INPUT</u>

THEME TEAM PRODUCTS

- MISSION/SYSTEMS REQUIREMENTS
- ASTS VEHICLE CLASSES
- PROJECTED TIME FRAME FOR VEHICLE UTILIZATION
- OPERATING MODES/OPTIONS
- BROAD TECHNOLOGY ISSUES/CONCERNS

WORKSHOP APPROACH

-OUTPUTS

ADVANCED SPACE TRANSPORTATION SYSTEM (ASTS)

WORKSHOP PRODUCTS

- SPECIFIC INFORMATION FOR TECHNOLOGY PROGRAM PLANNING FOR AN ASTS TO PERMIT COST-EFFECTIVE CONSTRUCTION/ASSEMBLY, MANNING AND LOGISTICS OF LARGE, NEAR-PERMANENT, MANNED OR MAN-TENDED FACILITIES IN LEO AND GEO.

- INCLUDE

    EARLY TECHNOLOGY NEEDS

    ADVANCED STUDIES

    BASIC RESEARCH

    FLIGHT EXPERIMENTS

- AND

    R.O.M. RESOURCE AND SCHEDULE REQUIREMENTS

IDENTIFIED TECHNOLOGY AREAS

TECHNOLOGY FOR ADVANCED SPACE TRANSPORTATION SYSTEM (ASTS)

- AEROTHERMODYNAMICS - PARAMETRIC ANALYSES TO IDENTIFY CONCEPTS AND DEFINE SUPPORTING DESIGN AND EXPERIMENTAL EFFORTS.
- GUIDANCE, CONTROL, NAVIGATION - INCREASE EFFICIENCY OF ON-BOARD SYSTEMS: ASSESS AUTONOMOUS NAVIGATION SYSTEMS CONCEPTS: ASSESS GLOBAL POSITIONING SYSTEMS FOR NAVIGATION AIDS: ADVANCE OPTICAL ATTITUDE AND TRACKING SYSTEMS: LASER RENDEZVOUS AND DOCKING SYSTEMS: INCREASE AUTONOMY.
- POWER - IMPROVE ENERGY CELL CONVERSION EFFICIENCY AND LIFE OF FUEL CELLS, BATTERIES: DEMONSTRATE ADVANCED SYSTEMS, I.E., SOLAR ARRAYS, ETC.
- PROPULSION - PROVIDE BASIS FOR ADVANCED PROPULSION CONCEPTS W/HIGHER PERFORMANCE, LESS WEIGHT, SMALLER VOLUME, LONGER LIFE USING ADVANCED SYSTEMS, COMPONENTS, ETC.
- STRUCTURES AND MATERIALS - ADVANCED MATERIALS: STRUCTURAL DESIGN CONCEPTS/TECHNIQUES: ADVANCED THERMAL CONTROL SYSTEMS AND TPS; NDE TECHNIQUES
- OPERATIONS* - SUBSYSTEM AND VEHICLE DESIGN TECHNOLOGY TO IMPROVE OPERABILITY AND MAINTAINABILITY
- INTERDISCIPLINARY* - (WORK IN REAL TIME)

*ALL WORKING GROUPS

IDENTIFIED TECHNOLOGY DRIVER

ADVANCED SPACE TRANSPORTATION SYSTEM
TECHNOLOGY MATRIX

VEHICLE CLASS \ FUNCTION	PAY LOAD	TECHNOLOGY READINESS TIME PERIOD	TIME FRAME (IOC)	TECHNOLOGY DRIVERS (ISSUES): AERO-THERMO	STRUCT/ MATLS	GUID./ NAV/ CONT.	POWER/ PROP.	OPERA-TIONS	
O.T. VEH. (PERSONNEL)	3-6 MEN & > 40K P/L	1982	1987	√	√	√	√	√	
O.T. VEH. (CARGO)	> 100K P/L	1990	1995		√	√	√	√	
HLL V_1	200K	1980	1985	√	√		√	√	
HLL V_2	1000K	1990	1995		√		√	√	
ADV. VEH.	20 MEN & 30K P/L	1985	1990	√	√	√	√	√	

THE ISSUES

FIVE CATEGORIES HAVE BEEN DEFINED:

- MISSION/SYSTEMS REQUIREMENTS
- COST REDUCTION
- CRITICAL MATERIALS
- STRUCTURES
- GUIDANCE, NAVIGATION, & CONTROL
- TECHNOLOGY

MISSION/SYSTEMS REQUIREMENTS ISSUES

NUCLEAR WASTE DISPOSAL

Concern. Large heat-shield mass fraction is required.

Objective. Develop heat shield, impact, and shielding technology to withstand abort entry heating and subsequent impact.

Requirement. Develop safe disposal packages to withstand abort reentry impact. Lower heat shield mass fractions.

AD HOC PAYLOAD RETURN

Concern. Return to Earth of massive structures exceeding shuttle capability.

Objective. To develop techniques to permit the safe return to the Earth of large structures such as a part of satellite power station.

Requirement. Enable NASA to return to Earth at will those items deemed necessary.

AERO-BRAKING/OTV

Concern. Heating is governed by rate processes and requires tailoring by trajectory shaping.

Objective. To develop the aerothermo technology to enable orbital transfer.

Requirement. To achieve the proper mix of aero braking and propulsion to provide efficient OT.

DIRECT GEOSYNCH TO EARTH-MANNED TRANSFER

Concern. A manned geosynch to Earth return vehicle carrying 4-10 persons to provide safe entry of the Earth's atmosphere at speeds of 36,000 fps is required.

Objective. To develop a large lifting vehicle capable of withstanding radiative heating loads.

Requirement. Heat shield configuration to survive manned Earth reentry.

MISSION/SYSTEMS REQUIREMENTS ISSUES (Cont.)

BOUNDARY LAYER TRANSITION

Concern. Understanding of boundary layer transition.

Objective. Development of design criteria.

Requirement. Reduced conservatism in TPS and control system design.

VISCOUS INTERACTION AND REAL GAS EFFECTS

Concern. Understanding of basic phenomena.

Objective. Improved performance predictions of vehicles.

Requirement. Elimination of uncertainties in performance predictions and extrapolation of small scale data to flight.

SEPARATED FLOW

Concern. Understanding flow separation characteristics ahead of control surfaces and on lee surfaces.

Objective. Design of control systems and TPS.

Requirement. Reduced conservatism and improved design criteria.

LEE SURFACE HEATING

Concern. Develop means for accurately predicting the heating to lee surfaces of complex vehicle shapes.

Objective. Accurate estimations of lee side heating for design.

Requirement. Improved design criteria and resulting impact on TPS.

WINDWARD HEATING

Concern. Development of means for accurately predicting the heating to the windward surface of complex vehicle shapes.

Objective. Accurate estimates of windward heating for design.

Requirement. Improved design criteria and resulting impact on TPS.

MISSION/SYSTEMS REQUIREMENTS ISSUES (Cont.)

ROCKET PLUME INTERFERENCE AND BASE HEATING

Concern. Aerodynamic and heating interference effects.

Objective. Quantitative estimation capability for these effects.

Requirement. Vehicle design criteria in areas of performance, stability, control heating, and acoustics.

BASE DRAG

Concern. Quantitative estimation of base drag of complex shapes.

Objective. Develop techniques for accurate estimation and means for reducing base drag.

Requirement. Improved ascent and recovery performance for aerodynamic type vehicles.

RCS INTERFERENCE AND HEATING

Concern. Interactive heating, aerodynamic coupling, and vehicle environmental contamination effects.

Objective. Provide single valved vectoring capability.

Requirement. Reduced complexity of control system, improved design criteria, and fuel savings.

MEASUREMENT TECHNIQUES

Concern. Ability to extract useful data from flight.

Objective. Development of accurate non-obtrusive flight measurement techniques.

Requirement. Acquisition of data of full scale measurements to verify extrapolation techniques.

DESIGN INTEGRATION

Concern. Optimal design which considers the interactive effect of all disciplines, systems, and the impact of optimal trajectory guidance.

Objective. Develop automated design techniques and capabilities to accomplish total design integration.

Requirement. Maximum system capability at reduced cost.

MISSION/SYSTEMS REQUIREMENTS ISSUES (Cont.)

SUBSONIC/HYPERSONIC CAPABILITY AND HIGH VOLUMETRIC EFFICIENCY

Concern. Conflicting requirements which lead to design compromises.

Objective. Development of vehicle design criteria to provide capability for traversing the mission profile in an efficient and controlled manner.

Requirement. Improve performance and reduce weight of vehicles.

CONTROL CONFIGURED DESIGN

Concern. Design philosophy for achieving maximum advantages offered by control configured design.

Objective. Development of design criteria for control configured vehicles.

Requirement. Improved flight performance of the vehicle at significantly reduced weight.

CATALYTIC WALL EFFECTS

Concern. Recombination of atomic oxygen at the wall can release large amounts of energy and hence increase the heating.

Objective. Understand chemical state of boundary layer at the wall.

Requirement. Improved TPS design.

REUSABILITY

Concern. Increased reusability and reduced costs of TPS.

Objective. Develop improved TPS materials.

Requirement. Eliminate uncertainties of reusability and improve reliability.

MISSION/SYSTEMS REQUIREMENTS ISSUES (Cont.)

INTERDISCIPLINARY

Concern. The development of lightweight structures which perform multiple roles of load bearing, tankage, and TPS.

Objective. Develop approaches, i.e., hot structures, insulated, or a combination, to achieve lightweight integrated designs.

Requirement. Develop lightweight long-life inspectability and efficient packaging structures, all of which lead to lower costs.

BALLISTIC RETURN

Concern. Assure safe return to launch site of propulsive package.

Objective. To develop improved prediction techniques to target flyback stage back to launch site.

Requirement. Assure aerodynamic stability of configuration to achieve safe return.

FLYBACK/GLIDEBACK

Concern. To understand base heating and aerodynamics of propulsion assisted gliding vehicles.

Objective. Develop aerothermodynamic technology to predict the aerodynamic characteristics and leeside heating of propulsive assisted glide vehicles.

Requirement. Eliminate uncertainties of vehicle range and permit accuracy retrieval prediction.

GROUND OPERATIONS COST REDUCTION ISSUES

Ground operations constitute a major area of cost reduction potential. Saturn Apollo prelaunch preparations at the launch site required several months to accomplish. The Space Shuttle Program requires a turnaround of the orbiter in 160 h. In each case, less than 15% of the launch preparation is spent in "power-on" testing.

On-going avionics technology growth is contributing to shortening of the "power-on" testing requirements. Substantial improvement must be realized in the other 85% of the required preparation time to effectively cut ground operations cost. The drivers in this area are primarily:

1. Handling/erection
2. Installation/removal of access equipment
3. Scheduled maintenance
4. Fluid system integrity verification
5. Servicing/deservicing

New technology must be applied to subsystem and vehicle design to improve both operability and maintainability of future hardware.

Examples:

1. Better compatibility/lifetime of hypergolic system softgoods
2. Cryogenic V.J. system elimination/improvement
3. Mechnical system health measuring techniques
4. Fluid system leak check methods
5. Improved mechanical corrections for fluid systems
6. Acceptability of prelaunch failures without excessive mission risk
7. Standardized vehicle-to-payload interfaces (minimize mission kits)
8. Less critical hardware mating interfaces (mechanical and fluid)

GROUND OPERATIONS COST REDUCTION ISSUES

- MAJOR AREA OF COST REDUCTION POTENTIAL
- THE DRIVES IN THIS AREA ARE:
    1. HANDLING/ERECTION
    2. INSTALLATION/REMOVAL OF EXCESS EQUIPMENT
    3. SCHEDULED MAINTENANCE
    4. FLUID SYSTEM INTEGRITY VERIFICATION
    5. SERVICING/DESERVICING
- EXAMPLES
    1. BETTER COMPATIBILITY/LIFETIME OF HYPERGOLIC SYSTEM SOFTGOODS
    2. CRYOGENIC V.J. SYSTEM ELIMINATION/IMPROVEMENT
    3. MECHANICAL SYSTEM HEALTH MEASURING TECHNIQUES
    4. FLUID SYSTEM LEAK CHECK METHODS
    5. IMPROVED MECHANICAL CORRECTIONS FOR FLUID SYSTEMS
    6. ACCEPTABILITY OF PRELAUNCH FAILURES WITHOUT EXCESSIVE MISSION RISK
    7. STANDARDIZED VEHICLE-TO-PAYLOAD INTERFACES (MINIMIZE MISSIONS KITS)
    8. LESS CRITICAL HARDWARE MATING INTERFACES (MECHANICAL AND FLUID)

CRITICAL MATERIALS TECHNOLOGY ISSUES

<u>HEAVY LIFT LAUNCH VEHICLES</u>

- TPS MATERIALS FOR ASCENT BASE HEATING & ENTRY - REUSABLE WITH MINIMUM MAINTENANCE
- MATERIALS COMPATIBILITY WITH SEA WATER FOR LANDING & RECOVERY

<u>ORBITAL TRANSFER VEHICLES</u>

- LONG-TERM INTEGRITY OF COMPOSITES IN SPACE ENVIRONMENTS
- THERMAL CONTROL - COATINGS, TPS, HEAT PIPES
- MATERIALS COMPATIBILITY WITH PROPELLANTS

<u>SINGLE STAGE TO ORBIT</u>

- ADVANCED MATERIALS FOR INTEGRATED TPS, STRUCTURES, TANKAGE
  - RESIN & METAL MATRIX COMPOSITES
  - HIGH-TEMPERATURE CONEYCOMB MATERIALS
  - RSI & METALLIC TPS MATERIALS
- MATERIALS COMPATIBILITY WITH PROPELLANTS (Ti WITH LOX?)

STRUCTURES TECHNOLOGY ISSUES

VEHICLE CLASS/CHARACTERISTICS	CRITICAL STRUCTURES TECHNOLOGIES
Heavy Lift Launch Vehicles	
1. Shuttle Derivative P/L ≈ 150 Klb 1985; water landing & recovery of booster engines & propellant tanks 2. New Vehicle P/L ≈ 500 Klb 1995; ballistic one or two-stage or winged two-stage; completely reusable--water or land landing	Vertical landing impact loads & attenuation (water & land landings); large parachutes; high-temperature structures; thermal protection systems
Single Stage to Orbit Vehicle	
P/L ≈ 40 Klb 1995; completely reusable, no refurbishment between flights; horizontal land landing	Integrated structure, tankage, TPS; long life, minimum maintenance; advanced high-temperature metallic & composite structures; light-weight land gear; NDE for assuring integrity between flights
Orbital Transfer Vehicles	
1. IUS Derivative + SEPS 1987; orbital assembly of IUS stages & SEPS for planetary missions 2. OTV for geosynch. Space Station 1987; two-stage orbital assembly-aerobraking return from geosynch. 3. OTV for large space facilities >1990 geosynch., lunar, & beyond	Orbital structural assemply; long-life thin gage metal & composite structures; integral structure-propellant tanks; light-weight solar array structures; deployable aerobrake structures; NDE for assuring integrity in orbit

GUIDANCE, NAVIGATION, & CONTROL TECHNOLOGY ISSUES

AUTOMATED CHECKOUT/STATUS SYSTEMS

- ON ORBIT
- PRELAUNCH
- RECYCLE, REFURBISH

REAL TIME FLIGHT REGIME OPTIMIZATION

- TRAJECTORY
- CONFIGURATION CONTROL
- CONSUMABLES

IMPROVED G, N, & C COMPONENTS

- IMPROVED RELIABILITY
- FAULT TOLERANT LOGIC SYSTEMS
- INCREASED INTERVAL BETWEEN MAINTENANCE OPERATIONS
- INCREASED POINTING ACCURACY
- LOWER COST HARDWARE & SOFTWARE

REDUCED GROUND SUPPORT REQUIREMENTS

- AUTONOMOUS NAVIGATION
- ON-BOARD TRACKING & DOCKING DETERMINATIONS

GUIDANCE, NAVIGATION, & CONTROL TECHNOLOGY ISSUES (Cont.)

REMOTE MANIPULATIONS

- P/L SERVICING
- ON-ORBIT MAINTENANCE

AUTOMATED MISSION PLANNING

- P/L

GENERAL TECHNOLOGY ISSUES

AEROTHERMODYNAMICS

Concern. Complete understanding of basic flow phenomena.

Objective. To develop prediction techniques based on a complete understanding of the phenomena to enable the development of accurate design criteria.

Requirement. The development of optimal aerodynamic designs.

Elements of the Problem

Boundary Layer Transition
Viscous Interaction and Real Gas Effects
Separated Flow
Lee Surface Heating
Windward Heating
Rocket Plume Interference and Base Heating
Base Drag
RCS Interference and Heating
Measurement Techniques

CONFIGURATIONS

Concern. Definition of optimal configuration characteristics.

Objective. Development of criteria and techniques to achieve an optimal integrated design.

Requirement. Development of optimal configuration design criteria compatible with mission requirements.

Elements of the Problem

Design Integration
Subsonic/Hypersonic Capability and High Volumetric Efficiency
Control Configured Design

TPS

Concern. Development of materials capable of multimission full reusability.

Objective. To develop materials, fabrication, and systems capable of reusability.

Requirement. Increased vehicle utilization at reduced cost.

Elements of the Problem

Catalytic Wall Effects
Reusability
Integrated Thermal Structures

GENERAL TECHNOLOGY ISSUES (Cont.)

PERFORMANCE

Concern. Impact of trajectory and other factors on vehicle design cannot be ascertained without measurements of vehicle performance.

Objective. Development of techniques for real time accurate measurement of the environment and attitude of the vehicle.

Requirements. Ability to fly an optimal trajectory throughout the entire mission profile to save weight and reduce costs.

POWER/PROPULSION

Orbital Transfer Vehicle (OTV) Class

Space Power

A. Description of Problems. Provide the technology base to support both current and future space programs requiring greater power capability, life, and versatility.

B. Objectives

1. Support for current NASA program goals through 1991.
2. Develop the technical capability to implement an aggressive space station program, including geosynchronous operations by 1987.
3. Define potential space system capabilities to support ambitious goals beyond 1990:
   - Solar system exploration
   - Construction of large facilities in LEO and GEO
   - Lunar orbit and surface operations
   - Nuclear waste disposal

GENERAL TECHNOLOGY ISSUES (Cont.)

POWER PROPULSION (Cont.)

Orbital Transfer Vehicle (OTV) Class (Cont.)

Space Power (Cont.)

C. Technology Concerns (Issues)

1. Delivery and deployment of large space structure.
2. Usable life of power components (i.e., solar cells and battery).
3. In-space servicing and refurbishment of power components.
4. Safety aspects of microwave energy transmission

Space Propulsion

A. Description of Problems. Provide the technical upgrading capability in areas of solid-propellant rocket motors, liquid chemical propulsion, and space electric propulsion systems to accomplish future OTV and Lunar Transfer Vehicle missions.

B. Objectives

1. Improve solid-propellant motor performance.
2. Integrate propulsive subsystems with other "on-board" energy systems where desirable.
3. Develop techniques to permit on-orbit assembly of propulsive stages.
4. Improve basic electric thruster system components.

C. Requirements

1. Advancement of overall propulsion technology
2. Capability to provide reusable chemical propulsion systems for OTV applications.

D. Technology Concerns (Issues)

1. Long life, reusable chemical propulsion components and subsystems; space-based operations; lunar orbit and surface operations.
2. Space-based electrical propulsion and power subsystems life and reusability.

GENERAL TECHNOLOGY ISSUES (Cont.)

POWER PROPULSION (Cont.)

Orbital Transfer Vehicle (OTV) Class (Cont.)

Space Propulsion (Cont.)

D. Technology Concerns (Issues) (Cont.)

3. Orbital facility for propulsion subsystem testing and demonstrations.
4. Mass drivers
5. Nuclear waste as a propulsive energy source

Advanced Vehicles - Shuttle Growth

Space Power

A. Description of Problem. Provide technology for improved space power capability, reusability, longer life, and higher energy density systems for application to advanced space vehicle concepts.

B. Objectives. Provide demonstration of higher energy H_2/O_2 auxiliary power unit for an updated shuttle system.

C. Requirements. Provide higher performance power subsystem.

D. Technology Concerns (Issues)

1. H_2O_2 APU flight demonstration.
2. High density rechargeable batteries
3. Long life, commercial grade reactant fuel cell demonstrations.
4. Integration of "common reactant" energy subsystems (i.e., RCS, APU fuel cells, and life support systems)

Space Propulsion

A. Description of Problem. Provide propulsion technology advancements to permit consideration of uprating the Space Shuttle Vehicle.

B. Objective. Develop propulsion components for SSME, RCS/OMS and SRM performance improvements and cost reductions.

GENERAL TECHNOLOGY ISSUES (Cont.)

POWER PROPULSION (Cont.)

Advanced Vehicles - Shuttle Growth (Cont.)

Space Propulsion

C. Requirements. Technological advancements in SSME, RCS/OMS and SRM have a readiness need data of approximately 1985.

D. Technology Concerns (Issues)

1. Lower cost non-polluting solid propellants
2. Low-cost, non-toxic RCS OMS propellants
3. Two-position SSME nozzle
4. Lightweight cryogenic feedlines (composites)
5. Low-cost SRM replacements (liquids)
6. Longer life SSME components
7. Higher density cryogenic propellants (slush H_2O_2)

Advanced Shuttle-Type Vehicle (SSTO)

Space Power

Same as uprated shuttle.

Space Propulsion

A. Description of Problem. Provide advanced propulsion approach to accommodate the advanced vehicle concepts evolving during the 1990's.

B. Objective. Develop the component and subsystem technology required to design and demonstrate advanced propulsion system concepts.

C. Requirements. High-performance main and auxiliary propulsion systems are required to make feasible a single-stage-to-orbit vehicle concept, i.e., 475-500 sec, I_{sp}, and high-density impulse concepts.

GENERAL TECHNOLOGY ISSUES (Cont.)

POWER PROPULSION (Cont.)

Advanced Shuttle-Type Vehicle (SSTO) (Cont.)

Space Propulsion (Cont.)

D. Technology Concerns (Issues)

1. Slush cryogenics
2. Idle mode main engines
3. High density liquid engines
4. Dual mode engine concepts
5. Dual fuel engine concepts
6. Zero NPSH pumps
7. Common reactant RCS/OMS/fuel cell integration
8. Altitude compensation nozzles
    - Two positions
    - Aerospike (linear)
9. Long life (up 500 reuses)

Heavy Launch Life Vehicles (HLLV)

A. Description. Same as Adv. Shuttle

B. Objective. Provide technology for very large HLLV payload > 500,000 lb

C. Requirements. Provide propulsion technology advances to accommodate the HLLV class of vehicle.

GENERAL TECHNOLOGY ISSUES (Cont.)

POWER PROPULSION (Cont.)

Heavy Launch Life Vehicles (HLLV) (Cont.)

D. Technology Concerns (Issues)

1. Tripropellant systems
2. Plug Custer systems
3. Ducted-rocket toroidal engines
4. Linear engines
5. Larger SRMs
6. Large high-density liquid-propellant engines
7. Supercheap throwaway boosters
8. Integrated ACS systems

THEME TEAM MEMBERSHIP

HEADQUARTERS

W. Hayes (Leader)	OAST/RS
P. Herr	OAST/RS
P. Cerreta	OAST/RA
W. Gevarter	OAST/RE
T. Stephenson	OAST/RP
J. Gangler	OAST/RW
R. Chase	OAST/RX
K. Hodge	OAST/RO
L. Fero	OSF/MT

CENTERS

B. Swenson	ARC
B. Henry	LaRC
R. Day	DFRC
H. Douglass	LeRC
R. Davis	JSC
L. Spears	MSFC
J. Graetch	SAMSO
N. Ginn	JPL
G. Nichols	KSC

OVERALL THEME TEAM RANKINGS AND OBJECTIVES FOR ADVANCED SPACE TRANSPORTATION SYSTEMS THEME

DESCRIPTIONS OF THEME TECHNOLOGIES

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
12-M1-6	Materials for Advanced Propulsion	1	Develop materials and manufacturing processes for higher performance, longer life, reusable, cost-effective propulsion systems.
12-M1-1	Advanced TPS/Materials for Advanced Vehicle, OT Vehicle, HLL Vehicle	2	Provide minimum weight TPS with required service life.
12-M1-2	Optimization of High Strength Structural Alloy and Composite Systems	3	Develop medium to high strength structural metal matrix composites having improved fracture toughness and failure resistance.
12-M1-4	Improved and/or Predicted Compatibility of Metallic Structures Exposed to Chemical Environments	4	Develop an adequate understanding of the compatibility of metallic structures and chemical environments to predict and extend structural life.
12-M1-5	NDT/NDE Techniques Particularly Related to Structural Reusability	5	To advance the technology of nondestructive methods for the evaluation and detection of flaws in metallic structures.
12-M1-3	Thermal Control Systems/Materials	6	Develop long-life capability for in-orbit thermal control of advanced space transportation system.
12-M2-2	Advanced Vehicle Structures	1	Development of structures which satisfy the weight, life, and temperature requirements of advanced launch and orbital transfer vehicles.
12-M2-1	Recovery and Landing Technology for Launch Vehicles	2	Develop reliable design approaches and analytical methods for water and land recovery, utilizing parachutes, impact attentuation devices, or landing gears.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
8-M2-4	Orbital Assembly of Modules	3	Develop and verify techniques for manned space stations and orbital transfer propulsion stages.
12-M2-3	In-Service NDE Techniques	4	Develop automated, in situ durable, NDE instrumentation and recording techniques for SSTO and orbital transfer vehicle structures.
12-M2-5	Payload Dynamics and Acoustics	5	Methods to determine and reduce dynamic/acoustic response of LV payloads.
12-M2-6	Damage Tolerance for Long Life, Resuable Structures	6	Provide design methodology and material flaw initiation and growth data required for design of highly loaded elements requiring minimal service inspection and maintenance.
12-M2-4	Launch Vehicle Structural Loads Analysis Optimization	7	Improve by order of magnitude the efficiency and speed of loads analysis methods for large structural systems under launch and flight conditions.
12-M3-1,	Advanced STS--Establish Aerothermodynamic Design Criteria	1	To develop prediction techniques based on a complete understanding of flow phenomena to enable the development of accurate design criteria.
12-M3-3	Advanced STS--Determination of TPS Wall Surface Effects	4	To develop the technology for TPS systems of improved reusability.
12-M3-2	Advanced STS--Definiation of Configuration Characteristics	3	Develop parametric data base for candidate configurations to achieve "optimal" design.
12-M3-4	Advanced STS--Verification of Aerothermal Performance by Flight or Advanced Ground Test	2	Develop the techniques for accurate measurements of aerothermal environments in flight and advnaced ground test facilities.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
12-E4-4	Mission Planning and Scheduling Tools and Techniques	1	To develop concepts for mission planning and scheduling techniques and S/W tools compatible with the rapid/complex requirements of advanced space missions.
12-E4-9	Software for Systems Integrity-Safety Diagnostic Reliability, Fault Tolerance and Redundancy	2	Technology to format program and test software architecture and procedure to maintain system integrity in the face of failure or data error.
12-E4-12	Intelligent Executive Programs	3	To design, develop and test executive programs capable of intepreting plans and guidelines and executing operational sequences and data management functions to accomplish system operational goals.
12-E4-17	Software Simulation Technology	4	Develop S/W technology to provide improved simulation software techniques.
12-E4-3	Teleoperator support S/W Technology for Materials Handling and Large Construction	5	Develop S/W technology which will provide the efficient (time, cost, implementation, operation) use of teleoperator systems in the construction of space structures (power station, manned stations, etc.) and operation of hazardous processor facilities.
12-E1-1	Autonomous Guidance and Control of Launch Vehicles	3	To minimize or eliminate the necessity for ground support (tracking, communication) from lift-off to orbit insertion.
12-E1-5	Autonomous Navigation - Earth Orbiters	3	To reduce mission operations costs by utilizing on-board systems to perform mission planning, orbit station keeping, altitude control.
12-E1-11	Autonomous Operations and Mission Modification	3	Extend the autonomous navigation technology to include capability to provide adaptive on-board sequence modification to autonomously react to received science data.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
12-E1-13	Low Thrust Guidance and Navigation	5	Develop low thrust guidance and navigation systems.
12-E1-14	Autonomous Rendezvous and Docking	2	To develop a cooperative rendezvous and docking capability between a "target" vehicle and the rendezvous vehicle.
12-E1-18	Checkout, Self Test, and Repair (Star)	4	To provide STAR capabilities for GNC systems in order to support ambitious missions with long life term requirements, and to reduce costs, ground support, turnaround time and to prevent massive abort.
12-E1-27	Dynamics and Control of Manned Aerospace Vehicles	1	To improve the flying qualities of manned aerospace vehicles.
12-E2-1	End-To-End Data Management	-	To develop and utilize techniques, simulation tools, and a reconfigurable flight experiment to enable design, analysis and proof of concept with the purpose of allowing & demonstrating cost effective, througput optimization.
12-E2-2	Autonomous, Fault Tolerant Data Handling, Control, and Communication Systems	-	To establish a comprehensive systems technology to permit the development of total spacecraft data management systems which are fault tolerant and permit the long operational lifetimes required.
12-E2-3	Modular Architecture for Data Processing and Transfer Systems	-	Provide a system of modular components and functions to meet the needs of future spacecraft such as lower cost, adaptability, fault tolerance, software simplification.
12-E2-25	Space-to-Space Wide Band Communications	-	Develop communication systems for multiple point-to-point communications in space between Advanced Space Transportation Vehicles and those used in Industrialization of Space.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
12-E2-26	On-Board Multi-Loop, Multi-Channel Communications System	-	Develop systems which meet the onboard (internal) voice, video, data and command communications requirements of large multi-man space stations.
12-E2-30	Global Positioning System Navigation and Tracking Data Communications	-	Provide G, N&C data from global position system (NAVSTAR).
12-E2-35	Near Field Communications Systems Including Visual Communications	-	Develop communications systems to meet near field requirements of space station and other vehicles employing multiple EVA astronauts, subsatellites or detached teleoperators.
12-P1-30 12-P1-23	High Performance LOX/Hydrocarbon Propulsion Systems for Booster Applications	1	Develop technology for high performance LOX/hydrocarbon propulsion systems including bell nozzle types, aerospike/linear engines, and plug cluster engines for booster vehicles.
12-P1-22	Advanced Hydrogen/Oxygen Propulsion System for Launch Vehicles	2	Provide the technology base for large hydrogen/oxygen engines operating at chamber pressures greater than 3000 psi, and employing unconventional configurations.
12-P1-17	H/O Bell Nozzle Engine (Advanced SSME)	3	Provide an advanced SSME for HLLV, $HLLV_2$, and advanced vehicle. Improvements with increase Isp, expand operational capability and decrease ullage & vehicle weight.
12-P1-31 12-P1-24	High Performance Dual Fuel Engines for Booster Applications	4	Develop technology for advanced dual fuel engines for hydrocarbon/LOX/hydrogen propellants for use on advanced boosters using mixed mode propulsion.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
12-P1-7	Storage, Supply and Transfer of Cryogenic Fluids in Space	1	Provide a subcritical storage and supply system for cryogenic fluids to minimize system weight and provide the means to replenish fluids on-orbit.
12-P1-1 12-P1-26	H_2-O_2 High Performance, Reusable Main Propulsion Systems for Orbit Transfer Vehicles	2	Develop technology for high performance, reusable H_2-O_2 space propulsion systems, including staged combustion bell nozzle, expander cycle bell nozzle, aerospike, and plug cluster.
12-P1-2	Dual Fuel Engine Technology for Mixed Mode Orbit Transfer Vehicle	3	Develop technology for dual fuel engines burning hydrocarbon or amine fuel and LH_2/LOX in the same engine.
12-P1-21	Auxiliary Propulsion, Low Cost Space Propellants for OTV, $HLLV_2$, and Advanced Vehicle	1	To evaluate the ignition, combustion, and cooling characteristics of low cost, high density impulse propellants (such as LOX-Propane) under space start, restart, and steady state conditions. This technology is required at this time so that development can be initiated if FY 81 to meet the 1985 operational use date.
12-P1-8	Liquid Hydrogen/Liquid Oxygen Attitude Control Systems for OTV Application	2	Develop technology for components of a LH_2/LOX APS, such as thrusters, pumps, zero g reservoirs, and accumulators, and perform systems testing.
12-P1-20	Liquid Hydrogen/Liquid Oxygen Attitude Control Systems for Launch Vehicles ($HLLV_1$)	3	Develop technology for components of a LH_2/LOX APS, such as thrusters, pumps, zero "g" reservoir, and accumulators, and perform systems testing.
12-P1-12	MPD Thruster System Technology Readiness (SEP and NEP)	1	The MPD thruster propulsion system, now seen as essential for economical large cargo earth orbit operations, will be brought to technology readiness.

DESECIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
12-P1-13	High Specific Impulse Electric Propulsion for Orbital Transfer Vehicle (OTV)	2	Provide the technology for an efficient high specific impulse ion thruster system for orbit raising from low earth orbit to a higher orbit using low cost inert fuels.
12-P1-11	Resistojet for (c) OTV Main Propulsion, Auxiliary Propulsion SEP-NEP	3	Develop a long life, high performance resistojet capable of using monopropellant hydrazine or low freezing point monopropellants utilizing electrical heater power from either NEP or SEP sources.
12-P1-16	Laser Propulsion System for Orbit Transfer Vehicle	4	Provide high Isp (1000 to 2000 sec) laser heated rocket engine for orbit to orbit transfer of unmanned payloads and to provide attitude control capability.
12-P1-56	Enabling Technology for Chemical Rocket Systems to Improve Performance, Increase Life, Reduce Cost & Simplify Operations	-	Provide constituent and component technology to enable the development of advanced space transportation system chemical propulsion systems.
12-P2-ECC1	Electrochemical Conversion Light-Weight Fuel Cell	1	Design, fabricate, test and demonstrate a lightweight fuel cell power plant to operate on propellant grade reactants.
12-P2-S6	Power Systems: Project OASIS	2	Determine the need, feasibility, and configuration of a long-life orbiting electrical power utility station for multimission space application.
12-P2-PP2	Power Processing Distribution and Control: Integrally Regulated Solar Array Technology	3	Develop to technology-ready status, the applicability of direct on the array regulation of electrical power for dedicated loads.

DESCRIPTIONS OF THEME TECHNOLOGIES (CONT.)

TECHNOLOGY NEED NO.		OVERALL THEME TEAM RANKING	OBJECTIVE
12-P2-PP3	Power Processing, Distribution and Control: High Power/High Voltage/Low Loss Electronic Component Development	4	Develop to a technology ready status identified electronic components (i.e., rectifiers, power transistors, capacitors, power magnetics, etc.) presently limiting advanced power system concepts.
12-P2-PP5	Power Processing, Distribution and Control: Remote Power Controller (RPC) Technology for High Power dc Distribution Systems	5	Provide technology ready development base for RPC's in the range of 10's to 100's of amperes and 100's to 1000's of volt dc (that is, solid-state switch gear).
12-P2-PC7	Photovoltaic Conversion Technology for SEP and Payload Applications	6	Design, fabricate, and demonstrate large light weight solar array 25 kWe, 30 watts/lb. 5-year life, retractable, 400 v.
12-P2-PP1	Power Processing Distribution and Controls: Advanced Electronic Power Conditioning Technology	7	Develop to technology ready status unique hardware items required to enable advanced high power electricl power system concept implementation.
12-P2-ES3	Energy Storage Long-Life, Lightweight Ni-Cd Battery	8	Develop long life, lightweight (55 wh/kg) nickel-cadmium battery.

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Section III

RESEARCH AND TECHNOLOGY BASE SUMMARY

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R&T BASE THEME

DEFINITION

R&T Base generally includes tasks culminating in:

1. Basic phenomena observed and reported
2. Theory formulated to describe phenomena
3. Theory tested by physical experiment or mathematical model
4. Pertinent function or phenomena demonstrated
5. Component or breadboard tested in laboratory

for purposes of this Workshop.

R&T BASE THEME

OBJECTIVE

Strengthen and increase the R&T Base through:

A. Advocacy and support of relevant ongoing R&T Base program elements as an integrated part of the other Themes

B. Identification and support of other new and promising program elements as candidates for the resultant freed R&T Base resources

R&T BASE THEME

APPROACH

1. Identify R&T Base candidates for both Category A (Theme-relevant) and Category B (new and nonalined) using Form No. I.

   - For ongoing work to be transferred to a Theme, indicate RTOP number and estimated FY 78 funding (NOA, $K) as Item 3F of Form No. I.
   - For new work, indicate estimated FY 78 funding only as Item 3F of Form No. I.

2. Rank all R&T Base candidates in priority order using R&T base column of Form II. Circle rankings if candidates are ongoing work in Category A.

3. Use Form VI (or similar approach) to assess contribution to both Category A and B candidates to OAST goals.

4. Identify other new R&T Base candidates needed to support goals using Form IV.

↓

Note that contribution to the OAST goals will be the primary criteria for ranking of new R&T Base candidates. Writeups for these candidates should specify the expected contribution and goal(s) they support.

FORM No. I

OAST SPACE TECHNOLOGY NEED — FORM NO. I

1. TITLE ______________________

NO. ________ THEME / W.G. / TASK

PAGE 1 OF ___

DATE / /

2. OBJECTIVE ______________________

3. NEED ANALYSIS

a) LEVEL NOW ☐, WILL BE LEVEL ☐ UNDER EXISTING PLANS.

b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL ☐ FOR OPERATIONAL SYSTEM USE BY [DATE:]

c) RISK IN ACHIEVING ADVANCEMENT:
HIGH ☐ MEDIUM ☐ LOW ☐

d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING ☐ OR
ENHANCING: HIGH ☐ MEDIUM ☐ LOW ☐

e) TASKS NEEDED: STUDY ☐ ANALYSIS ☐ RESEARCH ☐
GRD TEST ☐ FLIGHT TEST [A] [B]
OTHER (Specify) ☐ ________ (Check one or more)

f) R&T BASE CANDIDATE [506-19-11, $400K]

4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY ______________________

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED ______________________

LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED
2. THEORY FORMULATED TO DESCRIBE PHENOMENA
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT
7. MODEL TESTED IN SPACE ENVIRONMENT

FORM No. II

FORM II

OAST SPACE TECHNOLOGY NEED PRIORITY ASSESSMENT

(List in numerical order, 1 — Highest Priority)

WORKING GROUP ____________

THEME / TECHNOLOGY NEED NO.	SPACE POWER 7	SPACE INDUST. 8	SETI 9	SOLAR SYS. EXPL. 10	GLOBAL SERVICE 11	ADV.TRANS. SYS. 12	RKT BASE 1	SUMMARY PRIORITY ASSESSMENT WG	TT#	OAST DIV.	
							1				
							(2)				
							4				
							(3)				

THE OAST MISSION...

- TO PRODUCE AND ASSURE USE OF ADVANCED AEROSPACE TECHNOLOGY WHICH MEETS THE NATION'S NEEDS AND IS SAFE, RELIABLE, AND COST-EFFECTIVE

THROUGH 3 MAJOR PROGRAM THRUSTS...

- SUPPORT APPROVED MISSIONS
- ENABLE 1000-FOLD INCREASE IN EFFECTIVENESS OF FUTURE SPACE SYSTEMS
- EXPLORE ADVANCED CONCEPTS FOR NEW MISSION OPPORTUNITIES

(1) SUPPORT APPROVED SPACE MISSIONS — GOALS

- SPACE TRANSPORTATION
- EARTH OBSERVATIONS
- COMMUNICATIONS
- ENERGY SYSTEMS
- LUNAR/PLANETARY EXPLORATION
- ASTRONOMY/PHYSICS

(2) ENABLE 1000 X SPACE SYSTEMS EFFECTIVENESS → GOALS

- 10 X INFORMATION ACQUISITION (10^{16} BITS/YR)
- 10 X LARGER STRUCTURES (1 KM)
- 5 X POWER CAPACITY (200 W/KG, 100 WH/KG)
- 1000 X INFORMATION MGMT (10^{16} BITS/YR)
- 1000 X PROPULSION EFFICIENCY (10^{5} KG/YR PLANETARY)
- $1/10^{TH}$ TRANSPORTATION COST ($50/LB TO LEO)
- $1/10^{TH}$ SPACECRAFT COST (8¢/MEGABIT)
- 1/2 MISSION SUPPORT COSTS
- $1/10^{TH}$ SOFTWARE COSTS (2¢/MEGABIT)

- POWER PRODUCTION AND DISTRIBUTION
- NOVEL PROPULSION
- INFORMATION SYSTEMS
- STRUCTURES AND MATERIALS
- SPACE PROCESSING
- BASIC RESEARCH

FOR NATIONAL NEEDS...

- TO STIMULATE AND SUPPORT THE ECONOMY
- TO PROVIDE ALTERNATE SOURCES OF ENERGY
- TO PRESERVE THE ENVIRONMENT
- TO ASSURE A VIABLE DEFENSE
- TO EFFICIENTLY MANAGE FOOD AND NATURAL RESOURCES
- TO PROTECT LIFE AND PROPERTY
- TO SATISFY MAN'S QUEST FOR NEW KNOWLEDGE

R&T BASE PROGRAM

As part of the Space Theme Workshop, each Working Group viewed the R&T Base Program to identify those tasks which either enabled or enhanced a Theme and should be incorporated into that Theme, and to identify new and promising R&T Base candidates which should be incorporated into the R&T Base to meet essential long-range space technology goals not addressed by the Themes. The results of this assessment, based on the Working Group inputs, are summarized here to provide an initial overview of the potential impact of the Themes on the R&T Base. As the Themes evolve and specific R&T Base tasks are selected for support under a Theme, this first-cut assessment will obviously be modified and refined. However, this early look at the possible R&T Base changes associated with the Themes should permit more effective plannings of the Themes and future R&T Base program elements.

R&T Base here was defined as any activity providing an end product which did not involve aircraft or spacecraft demonstrations of components or systems. All technology tasks which were carried to State-of-the-Art Level 5 on Form I were thus considered.

The basic approach used for the R&T Base assessment is illustrated in Figure 1. Recommended R&T Base changes were indicated in three categories. These were (1) Theme-current R&T Base or ongoing tasks which should be included in a Theme, (2) Theme-increased R&T Base or new/increased tasks suggested for Theme support, and (3) new R&T Base or high-payoff tasks recommended for fundings in the R&T Base. Current R&T Base resource runouts picked up by the Themes will provide the opportunity for the initiation of new efforts in the R&T Base. The total R&T Base increase thus becomes the sum of Theme-increased and Theme-current R&T Base tasks funded by the Themes.

R&T BASE APPROACH

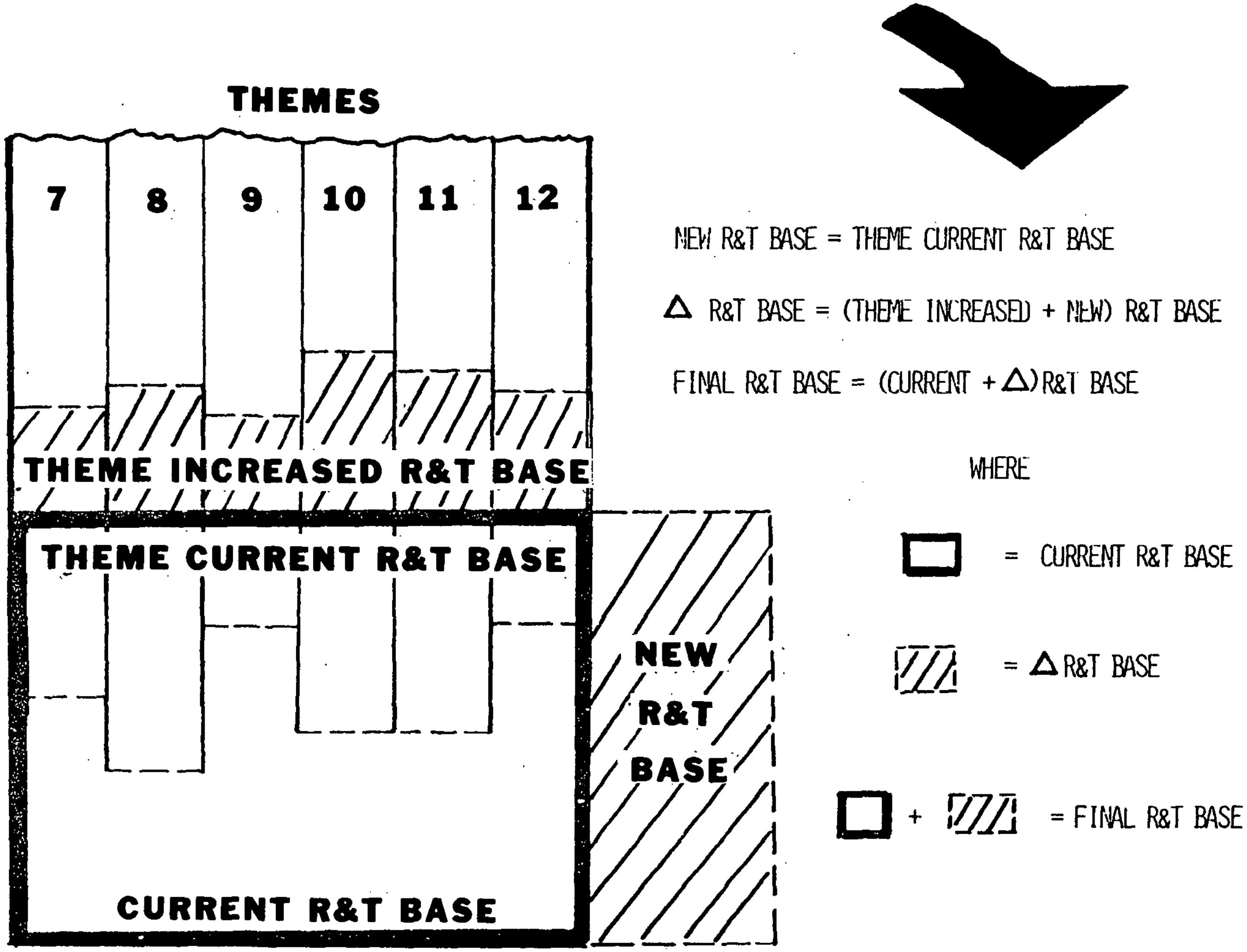

Figure 1

R&T BASE CATEGORIES

The Working Group raw inputs were collected to determine the overall changes proposed for the R&T Base. These inputs were then grouped into the three R&T Base categories and arranged in accordance with the Working Group priority rankings for each category. Figure 2 illustrates representative candidates in the Theme - current category resulting from this process. These candidates, which generally reflect the reorientation or pursuit of an ongoing RTOP on specific Theme objectives, primarily involved the development and ground testing of new-technology components and systems. Only high-priority tasks are shown in the figure; a total of 39 candidates were proposed in the Theme-current category.

THEME CANDIDATES

CURRENT R&T BASE	FY 78, $K
NAVIGATION, GUIDANCE AND CONTROL	
• EXTENDED LIFE ATTITUDE CONTROL SYSTEM	450
COMMUNICATIONS AND DATA HANDLING	
• AUTONOMOUS, FAULT TOLERANT DATA HANDLING CONTROL AND COMMUNICATION SYSTEM	250
SENSORS	
• LASER HETERODYNE RADIOMETER	250
• LOW-COST ELECTRONIC SUBSYSTEM TECHNOLOGY	

Figure 2.

THEME CANDIDATES (Cont.)

CURRENT R&T BASE

	FY 78, $K
PROPULSION	
• HIGH SPECIFIC IMPULSE ELECTRIC PROPULSION FOR ORBITAL TRANSFER VEHICLE	250
• HYDROGEN-OXYGEN HIGH PERFORMANCE, REUSEABLE MAIN PROPULSION SYSTEM FOR ORBIT TRANSFER VEHICLES	1000
• STORAGE, SUPPLY AND TRANSFER OF CRYOGENIC FLUIDS IN SPACE	300
POWER	
• LIGHTWEIGHT FUEL CELL	260
• LIGHTWEIGHT SOLAR ARRAY	320
• SILICON SOLAR CELL TECHNOLOGY	850
• MULTI-KW POWER DISTRIBUTION	70
• THERMOELECTRICS	265
MATERIALS	
• THERMAL PROTECTION SYSTEMS	500
• MIN K REFRIGERATORS	200
• ADVANCED LUBRICANTS	100
• PLANETARY PROBES	400
• HIGH STRENGTH ALLOYS AND COMPOSITES	400

Figure 2 (Cont.)

THEME CANDIDATES (Cont.)

CURRENT R&T BASE	FY 78, $K
STRUCTURES/DYNAMICS	
• ADVANCED VEHICLE STRUCTURES	800
• PAYLOAD DYNAMICS AND ACOUSTICS	500
• DEPLOYABLE LASER MIRROR	200
AEROTHERMODYNAMICS	
• ADVANCED STS VERIFICATION AEROTHERMODYNAMICS BY FLIGHT TEST	1000
• ATMOSPHERIC PROBES/EARTH RETURN-HEATING AND FLOW FIELD DEFINITION	800
• ADVANCED STS CONFIGURATION CHARACTERIZATION	300

Figure 2 (Cont.)

CURRENT ONGOING R&T BASE SUMMARY

Figure 3 summarizes the current ongoing R&T Base resource recommended for Theme support. About $33M of FY 78 funding was included in the Working Group submissions. Note that no Theme assignments are indicated since the Theme Teams have not yet selected their Theme tasks and since most of the proposed candidates support several Themes.

THEME CANDIDATES

CURRENT R&T BASE SUMMARY

WORKING GROUP \ THEME TEAM		7 SPACE POWER	8 SPACE INDUST.	9 SETI	10 SOLAR SYS EXPL.	11 GLOBAL SERVICE SYSTEM	12 ADV. TRANS. SYS.	TOTAL $ K
E-1	NAVIGATION, GUIDANCE, AND CONTROL							3450
E-2	COMMUNICATIONS AND DATA HANDLING							5290
E-3	SENSORS							1610
E-4	SOFTWARE							0
P-1	PROPULSION							7525
P-2	POWER							5430
M-1	MATERIALS							4450
M-2	STRUCTURES/ DYNAMICS							1500
M-3	AEROTHERMODYNAMICS							3300
	TOTAL							32,555

Figure 3

THEME-INCREASED BASE SUMMARY

Figures 4 and 5 illustrate corresponding Working Group inputs in the Theme increased category. About 174 candidates were recommended by the Working Groups. The majority of these involved acceleration of current R&T Base programs to meet Theme objectives; many of the related tasks culminated in flight tests to demonstrate technology readiness. Funding estimates here only include additional resources required for the increased programs; roughly $67M fall in this category in FY 78.

THEME CANDIDATES

INCREASED R&T BASE	FY 78, $K
NAVIGATION, GUIDANCE, AND CONTROL	
• ATTITUDE, FIGURE, AND STABILIZATION CONTROL OF LARGE SPACE STRUCTURES	900
• PRECISION POINTING AND TRACKING SYSTEMS FOR NON-POINT -SOURCE TARGETS	450
• PRECISION POINTING OF SPACECRAFT AND INSTRUMENTS AT INERTIAL TARGETS	2725
• AUTONOMOUS OPERATING AND MISSION MODIFICATION	150
• ROBOTIES AND TELEOPERATORS FOR SPACECRAFT ASSEMBLY AND MAINTENANCE	1300
COMMUNICATIONS AND DATA HANDLING	
• END-TO-END DATA MANAGEMENT	600
• DATA SET SELECTION	300
• MODULAR DATA SYSTEM ARCHITECTURE	65
• PATTERN RECOGNITION ANALYZER	1400
• HIGH-RATE DATA PROCESSOR	400

Figure 4

THEME CANDIDATES (Cont.)

INCREASED R&T BASE	FY 78, $K
SENSORS	
• UV/VISIBLE/IR IMAGING ARRAYS	200
• MICROWAVE SOUNDING RADIOMETERS	300
• HIGH-POWER LASERS/LIDAR TECHNOLOGY	120
• PLANETARY SURFACE CHEMISTRY ANALYSIS BY ALPHA PARTICLES GAMMA-RAY, AND X-RAY SPECTR.	150
• MULTI-FREQUENCY MICROWAVE IMAGING RADIOMETER	200
SOFTWARE	
• MULTIDIMENSIONAL DATA SYSTEMS	300
• PATTERN RECOGNITION	500
• SOFTWARE FOR SYSTEM INTEGRITY	300
• PROGRAMMING LANGUAGE & TRANSLATORS	700
• PROGRAMMING METHODOLOGY	400

Figure 4 (Cont.)

THEME CANDIDATES (Cont.)

INCREASED R&T BASE	FY 78, $K
PROPULSION	
• MPD THRUSTER SYSTEM TECHNOLOGY READINESS	600
• SOLID PROPULSION ADVANCED TECHNOLOGY MOTOR	850
• HIGH SPECIFIC IMPULSE ION THRUSTER FOR ON-ORBIT OPERATIONS	250
• AIR AUGMENT EARTH-TO-ORBIT CHEMICAL ROCKET ENGINES	50
POWER	
• OASIS STUDY	2000
• SEP ARRAY	500
• PHOTOVOLTAIC ELECTROLYSIS FOR FUEL CELL	500
• AUTOMATED POWER SYSTEMS MANAGEMENT	215
• ENVIRONMENTAL CHARGING OF SURFACES	225
MATERIALS	
• MATERIALS FOR ADVANCED PROPULSION	300
• POWER GENERATION MATERIALS/PROCESSES	400
• POWER STORAGE & TRANSMISSION MATERIALS	100
• DEVELOPMENT OF FABRICATION TECHNIQUES FOR SPACE-ERECTABLE STRUCTURES	500
• LARGE ANTENNA STRUCTURES	200

Figure 4 (Cont.)

THEME CANDIDATES (Cont.)

INCREASED R&T BASE

	FY 78, $K
STRUCTURES/DYNAMICS	
• SPACE DEPLOYED LARGE STRUCTURES	600
• SPACE ASSEMBLED LARGE STRUCTURES	700
• LAUNCH VEHICLE LOADS ANALYSIS OPTIMIZATION	300
• DAMAGE TOLERANCE	700
• SOLAR SAIL STRUCTURE	300
AEROTHERMODYNAMICS	
• ADVANCED STS BASIC FLOW PHENOMENA	100
• ATMOSPHERIC PROBES/EARTH RETURN-DEVELOPMENT OF STABLE CONFIGURATION	500

Figure 4 (Cont.)

THEME CANDIDATES

INCREASED R&T BASE SUMMARY

WORKING GROUP	THEME TEAM	7 SPACE POWER	8 SPACE INDUST.	9 SETI	10 SOLAR SYS EXPL.	11 GLOBAL SERVICE SYSTEM	12 ADV. TRANS. SYS.	TOTAL $ K
E-1	NAVIGATION, GUIDANCE, AND CONTROL							9,325
E-2	COMMUNICATIONS AND DATA HANDLING							13,125
E-3	SENSORS							5,590
E-4	SOFTWARE							4,930
P-1	PROPULSION							9,275
P-2	POWER							11,230
M-1	MATERIALS							10,400
M-2	STRUCTURES/ DYNAMICS							2,600
M-3	AEROTHERMODYNAMICS							820
	TOTAL							67,305

Figure 5

NEW R&T BASE

New R&T Base candidates which are independent of the Themes are indicated in Figures 6 and 7. Because of the predominant Workshop focus on the Theme requirements, little or no time was available to address potential nonalined R&T Base candidates and only seven inputs were received in this category. These were photochemical production of hydrogen and oxygen for propellants and ion thruster and ion beam research under propulsion and computational fluid dynamics, multi-engine base flow, and an energy conservative aerothermodynamics test facility under Aerothermodynamics. About $5M was requested to support these efforts in FY 78.

THEME CANDIDATES

NEW R&T BASE	FY 78, $K
AEROTHERMODYNAMICS	
• INCREASE COMPUTATIONAL FLUID DYNAMICS CAPABILITY	750
• CALCULATE MULTI-ENGINE BASE FLOW	200
• DEVELOPMENT OF ENERGY-CONSERVATIVE AEROTHERMODYNAMICS TEST FACILITY	2200
PROPULSION	
• PHOTOCHEMICAL PRODUCTION OF HYDROGEN AND OXYGEN FOR PROPELLANTS	150
• ION THRUSTER BASELINE R&T	500
• ION BEAM APPLICATION RESEARCH	500
• ION BEAM APPLICATION TO SPACE MANUFACTURING	500

Figure 6

NEW CANDIDATES

WG \ R&T BASE		TOTAL $ K
E-1	NAVIGATION, GUIDANCE, AND CONTROL	0
E-2	COMMUNICATIONS AND DATA HANDLING	0
E-3	SENSORS	0
E-4	SOFTWARE	0
P-1	PROPULSION	1,650
P-2	POWER	0
M-1	MATERIALS	0
M-2	STRUCTURES/DYNAMICS	0
M-3	AEROTHERMODYNAMICS	3,150
	TOTAL	5,800

Figure 7

SUMMARY

The maximum possible R&T Base impact of the Theme effort is summarized in Figure 8. If all Working Group inputs were adopted, the effective R&T Base could increase by as much as $100M in FY 78. Since most of the R&T Base inputs were not identified until late in the Workshop process, it was unfortunately impossible to review and prioritize this mass of inputs during the Workshop. An attempt was made to screen the number of Theme-relevant R&T Base candidates by obtaining feedback on the tasks which the Theme Teams would plan to incorporate into their programs. However, returns from this activity are not yet all in. A more definitive evaluation of the R&T Base candidates will be evaluated when this feedback is received from the Theme Teams.

In addition, other new R&T Base candidates will be identified in the coming months and assessed relative to their contribution to NASA's long range technology goals. This assessment will include the definition of new research areas which should be supported. One of these areas, discussed at the Workshop, is applied mathematics illustrated in Figure 9.

A significant reorientation and increase in the R&T Base made possible by successful advocacy of the Themes will hold the key to NASA's future in space.

△ R&T BASE

△ R&T BASE ≤ 33 + $67M = $100M

- THEMES OFFER POTENTIAL OF A SIGNIFICANT INCREASE IN THE EFFECTIVE R&T BASE
- ADDITIONAL WORK IS REQUIRED TO PRIORITIZE R&T BASE TASKS IDENTIFIED AT THE WORKSHOP

Figure 8

APPLIED MATHEMATICS

AREA	REPRESENTATIVE SUBJECTS	REPRESENTATIVE TASKS	POTENTIAL IMPROVEMENT
MATHEMATICAL MODELING	SOLUTION OF DIFF. EQUATIONS	VEHICLE DYNAMICS	HUMAN TIME 5X
	PARAMETER ESTIMATION	CRACK AND DAMAGE PROPOGATION	COMPUTER TIME 5X
	NON-LINEAR EQUATIONS	AERODYNAMICS AND ATMOSPHERES	ENABLE NEW SOLUTIONS
	NUMERICAL ANALYSIS	SIMULATION	
DESIGN	OPTIMIZATION	CONTROL SYSTEM DESIGN	HUMAN TIME 10X
	MATHEMATICAL PROGRAMING	ANTENNA CONFIGURATIONS	COMPUTER TIME 5X
	GRAPHICS	SOLAR SAIL STRUCTURES	MORE DETAILED DESIGN
		DECELERATOR DESIGN	
DATA ANALYSIS	APPLIED STATISTICS	SIGNAL ANALYSIS (SETI)	COMPUTER TIME 10X
	PATTERN RECOGNITION	MULTISPECTRAL ANALYSIS	COMPUTER STORAGE 10X
	APPROXIMATION THEORY	SOIL SAMPLE ANALYSIS	ENABLE NEW SOLUTIONS
CONTROL	CONTROL THEORY	AUTONOMOUS NGC	COMPUTER TIME 10X
	DECISION THEORY	THERMAL CONTROL SPACE HABITATS	COMPUTER STORAGE 10X
	ARTIFICIAL INTELLIGENCE	PRECISION POINTING	ENABLE AUTONOMOUS CONTROL
		STABIL. OF LARGE STRUCTURES	
COMPUTATIONAL EFFICIENCY	NUMERICAL METHODS	DATA MANAGEMENT	COMPUTER TIME 10X
	DATA STORAGE AND RETRIEVAL	MOST COMPUTATIONAL TASKS	COMPUTER STORAGE 10X
	DATA COMPRESSION		
	SYMBOLIC MANIPULATION		

Figure 9

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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