NASA-TM-108651

OAET

SSTAC/ARTS REVIEW OF THE DRAFT INTEGRATED TECHNOLOGY PLAN (ITP)

Volume I: June 24-25

Plenary Session

Briefings from the
June 24-28, 1991 Conference
McLean, Virginia

National Aeronautics and Space Administration
Office of Aeronautics, Exploration and Technology
Washington, D.C. 20546

(NASA-TM-108651) SSTAC/ARTS REVIEW OF THE DRAFT INTEGRATED TECHNOLOGY PLAN (ITP). VOLUME 1: PLENARY SESSION (NASA) 306 p

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SSTAC/ARTS REVIEW OF THE DRAFT ITP
McLean, Virginia
June 24-28, 1991

Volume I: June 24-25

Plenary Session

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INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

EXTERNAL ITP REVIEW

OAST

AGENDA

DAY I (6/24/91)

8:30 AM	Welcome and Overview	A. Aldrich (OAET)
9:00 AM	Workshop Logistics	G. Reck (OAET/RS)
9:30 AM	Space Exploration Initiative Plans and Technology Needs	M. Craig (OAET/RZ)
10:15 AM	BREAK	
10:30 AM	NASA Office of Space Science and Applications Plans and Technology Needs	J. Alexander/Panel (OSSA)
12:00 NOON	LUNCH	
1:00 PM	NASA Office of Space Flight Plans and Technology Needs	R. Harris/Panel (OSF)
2:30 PM	NASA Office of Space Operations Plans and Technology Needs	C. Force (OSO)
3:00 PM	BREAK	
3:15 PM	Panel Discussion	Chair: J. Shea/Panel (SSTAC)
5:00 PM	CLOSE	
6:00 PM	RECEPTION	

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

EXTERNAL ITP REVIEW

OAST

AGENDA

DAY II (6/25/91)

8:30 AM	Integrated Technology Planning Overview	G. Reck (OAET/RS)
10:30 AM	BREAK	
10:45 AM	Thrust Summaries I: Space Science and Planetary Surface Exploration	W. Hudson (RS) J. Mankins (RS)
12:00 NOON	LUNCH	
1:00 PM	Thrust Summaries II: Transportation, Space Platforms and Operations	D. Stone (RS) J. Ambrus (RS) G. Giffin (RS)
2:30 PM	BREAK	
2:45 PM	R&T Base Summaries: Information Sciences & Human Factors, Aerodynamics, Materials and Structures, Power & Propulsion, Flight Programs, and Systems Analysis & University Programs	L. Holcomb (RC K. Hessenius (RF) S. Venneri (RM) E. VanLandingham (RP) J. Levine (RX) G. Reck (RS)
5:00 PM	CLOSE	

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

EXTERNAL ITP REVIEW

OAST

AGENDA

DAY III (6/26/91)

8:30 AM	NASA Administrator's Perspective and Discussion	**R. Truly (NASA)**
9:30 AM	BREAK	
9:45 AM	Technology Working Sessions — Computing, Data, Communications — Power and Thermal — Materials and Structures — Propulsion — Human Support — Aerothermodynamics — Automation & Robotics — Controls, Sensors & Microdevices	**All**
12:00 NOON	LUNCH	
1:00 PM	Technology Working Sessions (cont.)	**All**
2:45 PM	BREAK	
3:00 PM	Technology Working Sessions (cont.)	**All**
5:00 PM	CLOSE	
6:00 PM	BANQUET	**J. R. Thompson (Invited)**

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

EXTERNAL ITP REVIEW

OAST

AGENDA

DAY IV (6/27/91)

8:30 AM	Technology Working Sessions — Computing, Data, Communications — Power and Thermal — Materials and Structures — Propulsion — Human Support — Aerothermodynamics — Automation & Robotics — Controls, Sensors & Microdevices	**All**
10:15 AM	BREAK	
10:30 AM	Technology Working Sessions (cont.)	**All**
12:00 NOON	LUNCH	
1:00 PM	External Review Team Working Meetings - Specifics TBD	**All**
2:45 PM	BREAK	
3:00 PM	External Review Team Working Meetings - Specifics TBD (continued)	**All**
5:00 PM	CLOSE	

AGENDA
DAY V (6/28/91)

8:30 AM	External Review Team Working Meetings - Specifics TBD	**All**
10:15 AM	BREAK	
10:30 AM	External Review Team Working Meetings - Specifics TBD (continued)	**All**
12:00 NOON	LUNCH	
1:00 PM	External Review Team Working Meetings - Specifics TBD (continued)	**All**
2:45 PM	BREAK	
3:00 PM	External Review Team Working Meetings - Specifics TBD (continued)	**All**
5:00 PM	CLOSE	

INTEGRATED TECHNOLOGY PLAN OVERVIEW

Presentation to:

THE ITP EXTERNAL REVIEW TEAM

Gregory M. Reck
Director for Space Technology
Office of Aeronautics, Exploration and Technology

June 24, 1991

O-A-E-T

NASA ACTION PLAN

ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

RECOMMENDATION 8:

That NASA, in concert with the Office of Management and Budget and appropriate Congressional committees, establish an augmented and reasonably stable share of NASA's total budget that is allocated to advanced technology development. A two- to three-fold enhancement of the current modest budget seems not unreasonable.

In addition, we recommend that an agency-wide technology plan be developed with inputs from the Associate Administrators responsible for the major development programs, and that NASA utilize an expert, outside review process, managed from headquarters, to assist in the allocation of technology funds.

NASA ADMINISTRATOR ACTION:

Codes R/M/S/O/AA for Exploration (Code R lead): Provide an integrated agency-wide technology development plan (using the FY 91 appropriated budget as the base, and based on two- and three-fold budget increase); due at macro level 6/91; refined plan 11/91

RECOMMENDATION 7:

That Technology Be Pursued Which Will Enable A Permanent, Possibly Man-Tended Outpost To Be Established On The Moon For The Purposes of Exploration And For The Development Of The Experience Base Required For The Eventual Human Exploration Of Mars.

That NASA Should Initiate Studies Of Robotic Precursor Missions and Lunar Outposts.

NASA ADMINISTRATOR ACTION:

Include Technology Aspects in The Technology Planning Action Responding to Recommendation 8

INTEGRATED TECHNOLOGY PLAN PROCESS

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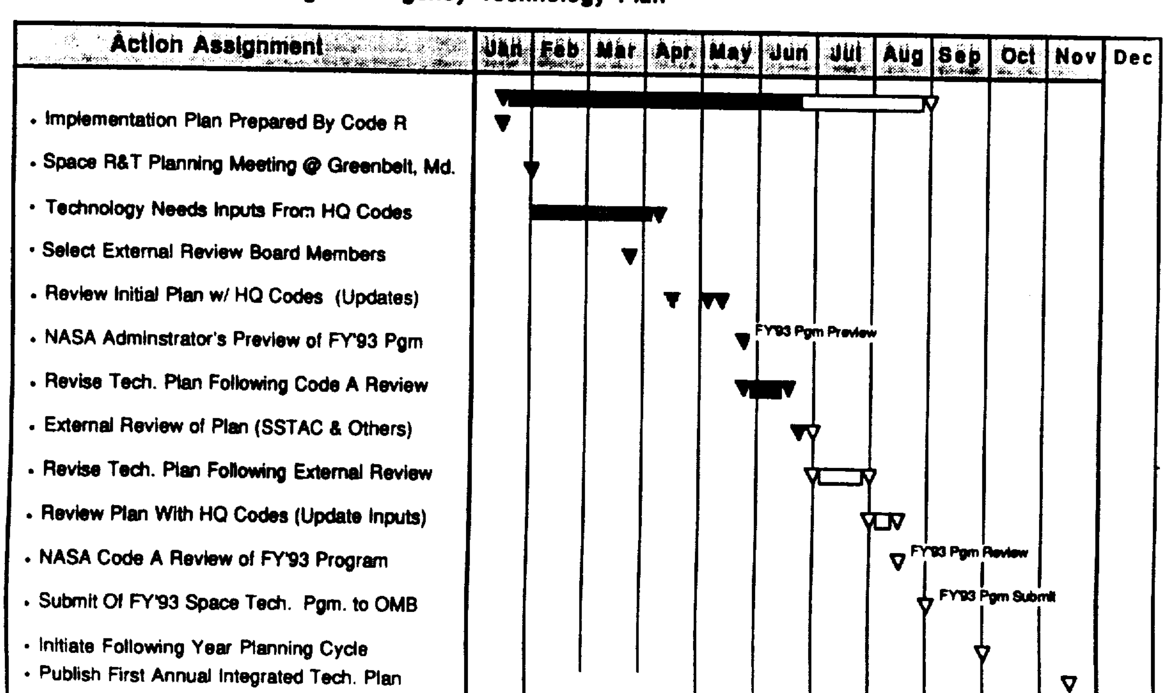
- **INTERNAL NEEDS**
  - AGENCY PROGRAM OFFICES REQUESTED TO DEFINE AND PRIORITIZE MISSION TECHNOLOGY NEEDS AS RECOMMENDED BY AUGUSTINE
- **EXTERNAL NEEDS**
  - SSTAC/ARTS MEMBERS REQUESTED TO PROVIDE INPUTS ON OVERALL CIVIL SPACE TECHNOLOGY NEEDS
  - COMSTAC RECOMMENDATIONS ON ELVs, COMMUNICATIONS ADVISORY GROUP RECOMMENDATIONS AND OTHER KEY TECHNOLOGY ASSESSMENTS UNDER EVALUATION
- **DEVELOPMENT OF INTEGRATED TECHNOLOGY PLAN**
  - PLANNING TEAMS FORMED TO REEXAMINE EXISTING TECHNOLOGY PLANS, ASSESS INCOMING USER OFFICE TECHNOLOGY NEEDS, AND PREPARE TECHNOLOGY PLANS
- **EXTERNAL REVIEW**
  - SSTAC/ARTS WILL CONDUCT REVIEW WITH PARTICIPATION BY ASEB, OTHER EXTERNAL EXPERTS IN JUNE
- **STRUCTURE FOR ANNUAL PLANNING AND REVIEW PROCESS ESTABLISHED**

SBF-0169

NASA ACTION PLAN

ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

Recommendation 8: Integrated Agency Technology Plan



JUNE 24, 19..

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

EXTERNAL REVIEW APPROACH

OAET

OBJECTIVES

"NASA (SHOULD) UTILIZE AN EXPERT, OUTSIDE REVIEW PROCESS, MANAGED FROM HEADQUARTERS, TO ASSIST IN THE ALLOCATION OF TECHNOLOGY FUNDS"

- REVIEW THE PROCESS USED FOR DEVELOPING THE INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM
- ASSESS THE TECHNICAL CONTENT OF THE PROPOSED ITP
  - IDENTIFY KEY TECHNOLOGY AREAS THAT NEED TO BE ADDRESSED
  - FIRST-ORDER EVALUATION OF THE ESTIMATES OF "COST FOR ACCOMPLISHMENT"
  - RECOMMEND ADJUSTMENTS IN PRIORITIES AND RESOURCE PLANNING
- ASSESS THE ACCOMMODATION OF USER NEEDS
  - EVALUATE STRATEGIC AND NEAR-TERM TECHNOLOGY PLANS AGAINST TECHNOLOGY NEEDS OF FUTURE MISSIONS
  - RECOMMEND POTENTIAL CHANGES IN THE PHASING OF NEW PROGRAMS TO BETTER MEET TECHNOLOGY NEEDS

MAY 13, 19[illegible]
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NASA ACTION PLAN

ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

INTEGRATED TECHNOLOGY PLAN EXTERNAL REVIEW

<u>PRINCIPAL REVIEWERS</u>

- SPACE SYSTEMS & TECHNOLOGY ADVISORY COMMITTEE (SSTAC)
- SSTAC AEROSPACE R&T SUBCOMMITTEE (ARTS)
- NATIONAL RESEARCH COUNCIL AERONAUTICS AND SPACE ENGINEERING BOARD (INVITED BY SSTAC)

<u>SELECTED INDIVIDUALS FROM OTHER GROUPS</u>

- SPACE SCIENCE AND APPLICATIONS ADVISORY COMMITTEE
- AEROSPACE MEDICINE ADVISORY COMMITTEE
- NATIONAL RESEARCH COUNCIL SPACE STUDIES BOARD
- DEPARTMENT OF DEFENSE
- OTHER GOVERNMENT AGENCIES (DEPARTMENTS OF TRANSPORTATION, COMMERCE, ENERGY, AND DEFENSE)
- NATIONAL SPACE COUNCIL STAFF
- AEROSPACE INDUSTRIES ASSOCIATION (AIA)

APRIL 22, 19[illegible]

ITP REVIEW MEMBERS

6/21/9

DISCIPLINE GROUPS	SSTAC MEMBERS	ARTS MEMBERS	ASEB	INDUSTRY/UNIV	GOV'T/COMMITTEE
OTHER	Shea	Young	Beggs Titland	Bangsund-AIA Winkler-AIA Swihart-NCAT	DOD Siewert Bevin Granato Bolino Russel DOT Rappaport Scott SSAAC Hoffmann AMAC Holloway Mohler DOC Pace Schneider SSB Landgrebe Hart DOE Finn
AEROTHERMODYNAMICS	Bogdonoff	Bunting		Masek Lordi	
POWER	Rose	Gerrels Mullin Schoenfeld A. Hertzberg Massie			
PROPULSION	Constantine Colladay	Mosler Weiss Sackheim Weldon Smith	F. Moore	Woodcock Kerrebrock-MIT Fuller	
MATERIALS & STRUCTURES	Mar Morra	Woods Hoggatt	Hedgepeth	Garibotti McGovern	
INFORMATION SCIENCES Communications	Dorfman			Barberis Golding	
Info Sci/Data		Hubbarth		Palermo	
HTSC		Gamota Yasensky			
Sensors	Janni			Hinkley Guenther	
A&R Systems		Daly	Cannon		
Controls	Fraser	Redless		Karas	
Photonics	Weiss				
HUMAN SYSTEMS	O'Neal		McRuer	Malone Overmyer Spurlock Brouillet	

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SPACE EXPLORATION INITIATIVE STRATEGY & TECHNOLOGY NEEDS

PRESENTED TO SSTAC/EXTERNAL REVIEW OF ITP

Lewis Peach
Assistant Director for Exploration (Program Definition)

June 24, 1991

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CONTENT

- Introduction/Overview
- SEI and the Synthesis Group
- SEI Current Content and Budget
- SEI FY93 Budget Development
- SEI Technology Ranking
- Summary

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INTRODUCTION/OVERVIEW

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Barros2/Peach/Strategy and Technology Needs/SSTAC External Review of ITP

Ver 1/6 19 91

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SEI: A STRATEGIC HORIZON

- The Space Exploration Initiative establishes a long-term goal for the civil space program as it reaches out beyond Earth orbit. The goal is to return to the Moon, this time to stay, and to carry out the human exploration of Mars
- In stating this goal, SEI makes explicit what has long been implicit. It builds upon mankind's heritage of exploring the planet Earth and upon 30 years of exploring the solar system with both human beings and robotic spacecraft
- SEI is not "the next manned hardware program" nor is it a "program" in the classic sense. NASA is not yet proposing to build manned spacecraft hardware for the Moon and Mars, nor are there contractor teams in place to help do so
- Rather, SEI is a strategic horizon needed to focus and integrate many current and future activities. As such, it establishes a framework for coherent investment and effective use of limited resources. It also provides a yardstick against which progress can be measured
- For years critics of the space program have complained that NASA lacked a vision of space exploration. Now we have that vision. And with it, we have a responsibility to plan, and prepare for its implementation

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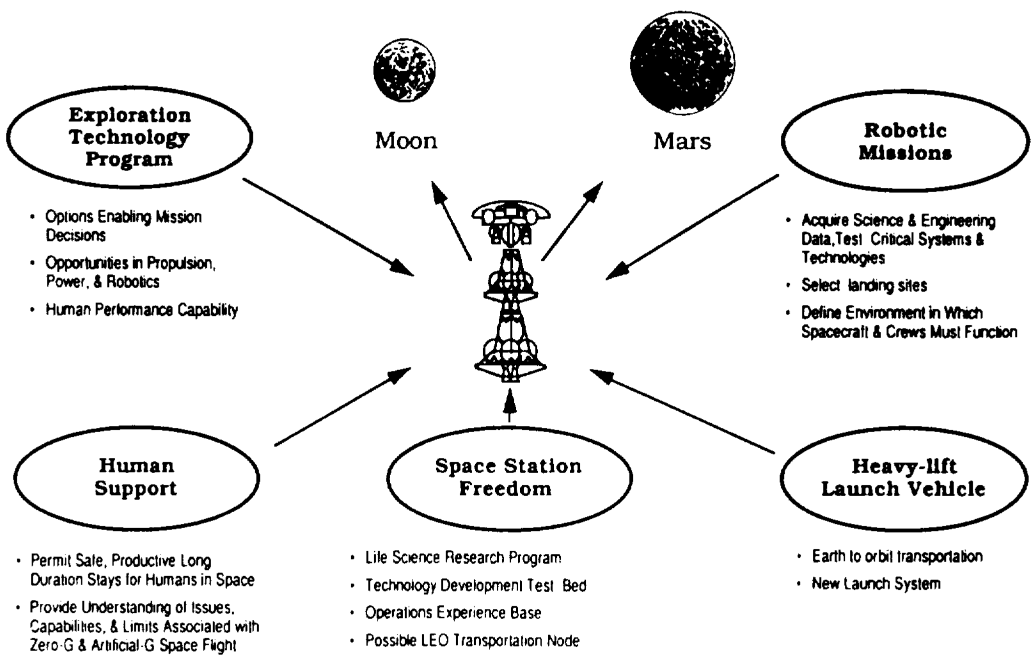
HUMAN EXPLORATION - KEY PREREQUISITES



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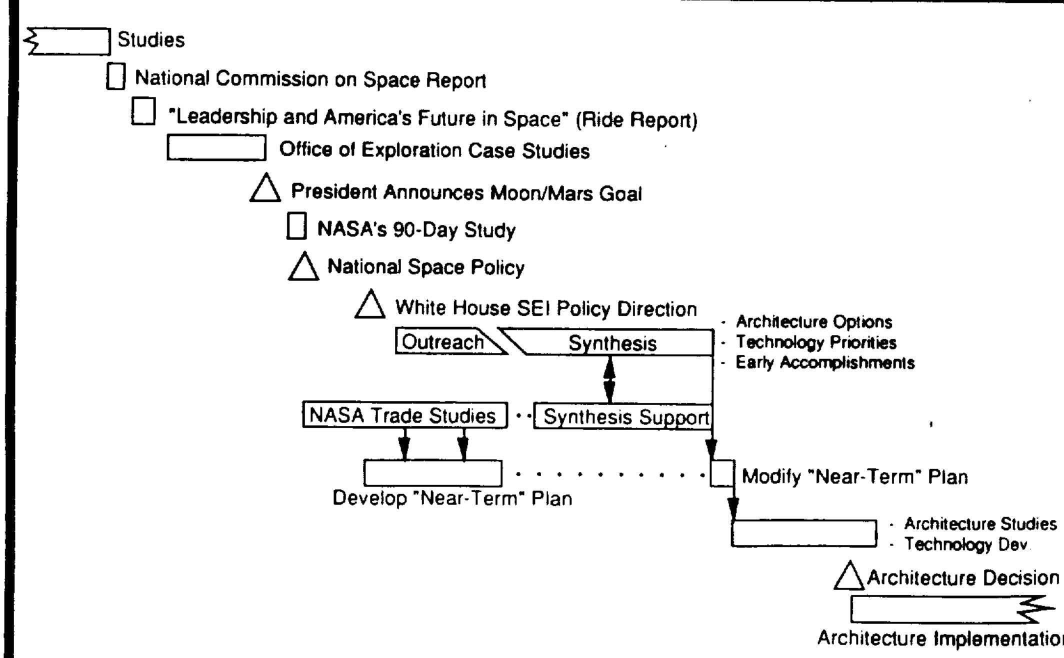
SEI OVERVIEW



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SEI AND THE SYNTHESIS (STAFFORD) GROUP

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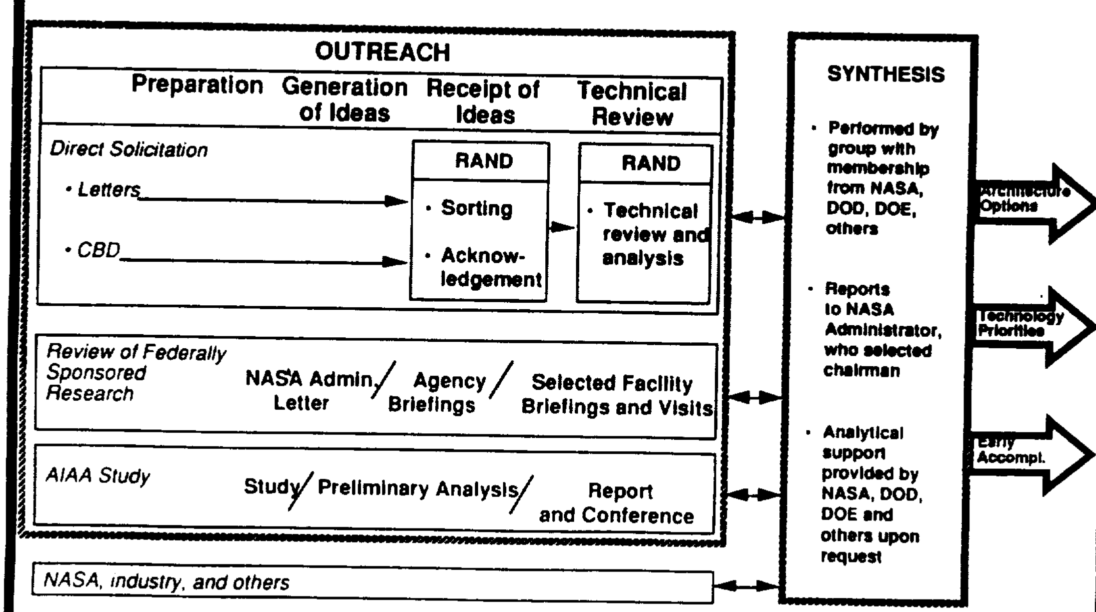
OUTREACH AND SYNTHESIS PROCESS



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SYNTHESIS STATUS

- Report delivered to Vice President Quayle and NASA Administrator on June 11, 1991
- Four distinct "architectures" (approaches) for SEI
- Fourteen long-lead critical technologies identified . . .
- Assumes major role of lunar phase is test-bed for Mars systems
- Supports Space Station Freedom as essential for life science research
- Initial assessment of Report in progress
  - Strip out top level recommendations
  - Finalize study/work plans
- Formal study to be initiated with Codes and Centers July 1-2, 1991

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SYNTHESIS GROUP REPORT

ARCHITECTURES

Pursuant to its charter, the Synthesis Group, chaired by retired USAF Lt. General Thomas Stafford, presented four alternative architectures for SEI. The Group defined an architecture as "both a set of objectives ordered to achieve an overall capability and the sequential series of missions (including specific technical activities) to implement these objectives."

- **Mars Exploration**
  - emphasis on Mars, lunar activities simply support Mars missions
- **Science Emphasis for the Moon and Mars**
  - exploration of both Moon and Mars, using the Moon as an observation platform
- **The Moon to stay and Mars Exploration**
  - emphasis on a human presence on the Moon, with smaller crews engaged in exploration and science at Mars
- **Space Resource Utilization**
  - emphasis on developing lunar resources for energy on Earth and for launch vehicle propellants

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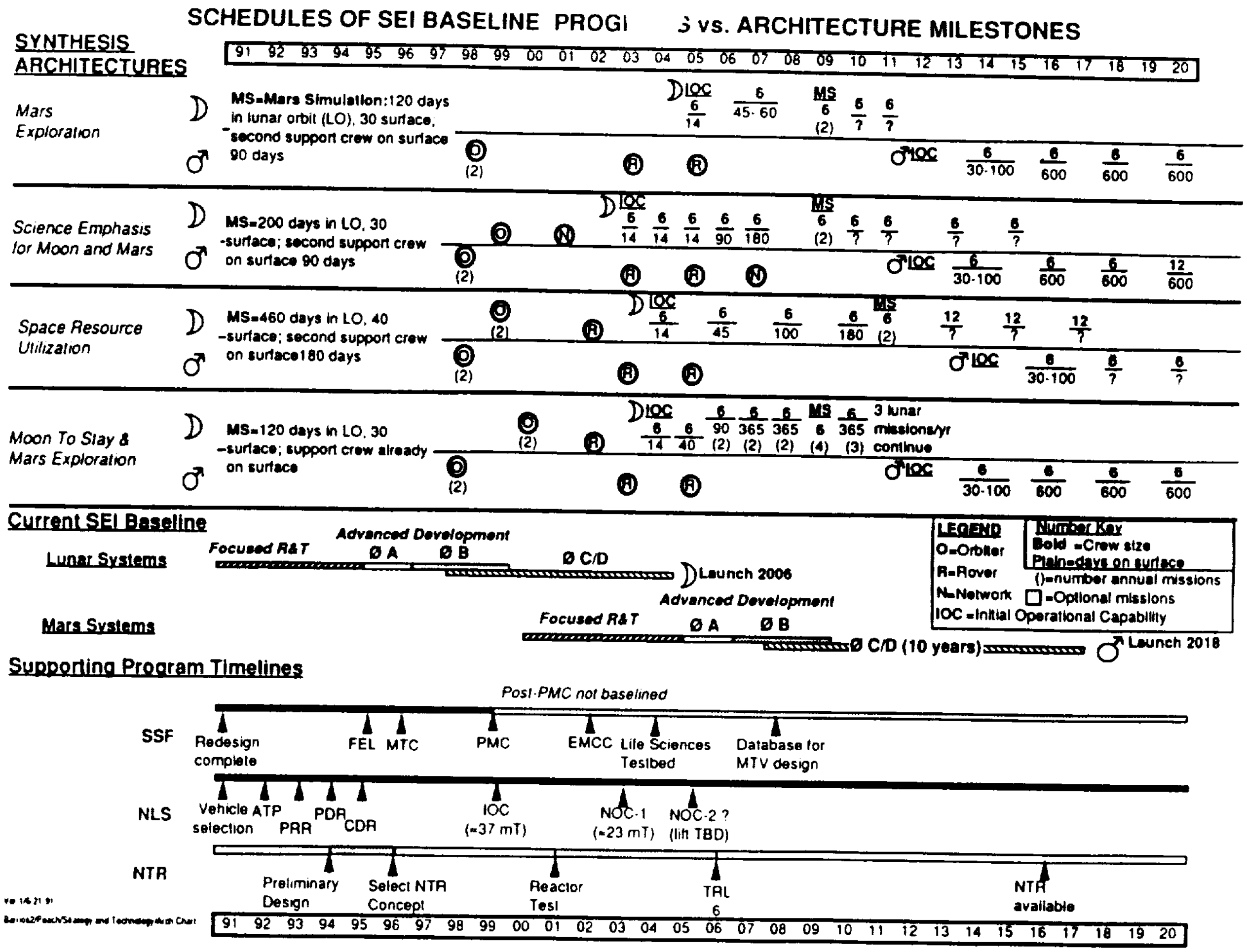

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SYNTHESIS GROUP REPORT

SUPPORTING TECHNOLOGIES

1. Heavy lift launch with a minimum capability of 150 metric tons with designed growth to 250 metric tons
2. Nuclear thermal propulsion
3. Nuclear electric surface power to megawatt levels
4. Extravehicular activity suit
5. Cryogenic transfer and long term storage
6. Automated rendezvous and docking of large masses
7. Zero gravity countermeasures
8. Radiation effects and shielding
9. Telerobotics
10. Closed loop life support systems
11. Human factors for long duration space missions
12. Lightweight structural materials and fabrication
13. Nuclear electric propulsion for follow-on cargo missions
14. In situ resource evaluation and processing

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SYNTHESIS GROUP REPORT

RECOMMENDATIONS

1. Establish within NASA a long range strategic plan for the nation's civil space program, with the Space Exploration Initiative as its centerpiece
2. Establish a National Program Office by Executive Order
3. Appoint NASA's Associate Administrator for Exploration as the Program Director for the National Program Office
4. Establish a new, aggressive acquisition strategy for the Space Exploration Initiative
5. Incorporate Space Exploration Initiative requirements into the joint NASA-Department of Defense Heavy Lift Program
6. Initiate a nuclear thermal rocket technology development program
7. Initiate a space nuclear power technology development program based on the Space Exploration Initiative requirements
8. Conduct focused life sciences experiments
9. Establish education as a principal theme of the Space Exploration Initiative
10. Continue and expand the Outreach Program

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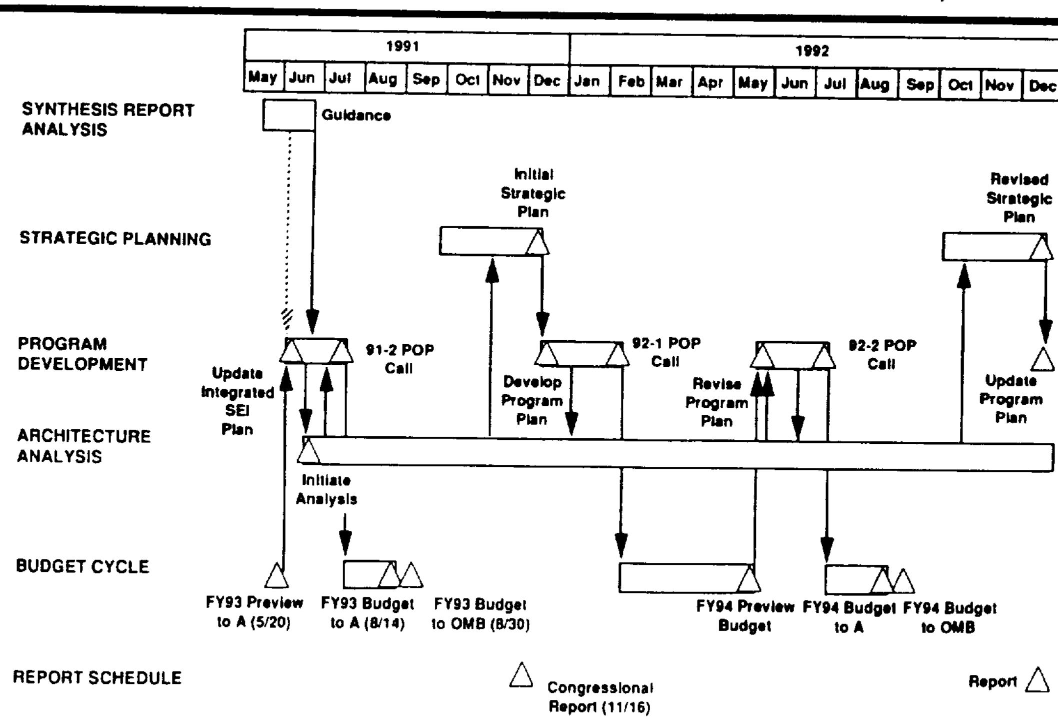
TOP LEVEL SEI MANAGEMENT PLAN



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NEAR-TERM STRATEGY FOR SEI

- Analyze alternative mission architectures
- Perform wide array of system level studies
- Continue critical technology development
- Define enabling science requirements and opportunities for SEI science
- Focus key enabling activities that are transparent to architecture:
  - Human support research
  - Lunar/Mars robotic missions
  - Heavy-lift launch vehicle
  - Advanced propulsion and power

Near-term goal is the definition of program options for review and approval by the NASA Administrator, the National Space Council, the President and the Congress

NASA

SEI CURRENT CONTENT AND BUDGET

NASA

FY 1992 SEI BUDGET REQUEST

Exploration mission studies ($15m)

- Perform an in-depth analysis of SEI architectures and technologies identified by the Synthesis Group
- Develop mission, systems, and operations concepts for SEI as a basis for an integrated set of requirements and program plan

Exploration technology ($52m)

- Develop a focused set of human support technologies to enable implementation of architecture options
- Initiate a limited set of critical long-lead technologies to enable future space exploration missions

Life sciences research ($27m)

- Characterize micro-gravity and radiation risks
- Develop and validate technologies and countermeasures

FOR FY 1992
15 m
52 m
27 m
$94 m

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NASA FY 1992 BUDGET REQUEST
DOLLARS IN MILLIONS

	FY92 REQUEST
Exploration Mission Studies	15.0
Exploration Technology	52.0
- SP-100	20.0*
- Space-based engine	9.0
- Nuclear propulsion	7.0*
- Nuclear thermal propulsion	5.0
- Nuclear electric propulsion	2.0
- Humans in space	16.0
- Regenerative life support	8.0
- Radiation protection	3.0
- EVA systems	4.0
- Exploration human factors	1.0
Life Science Research	10.0
- Artificial gravity	1.5
- Countermeasures	1.0
- Human factors	1.0
- Life support	3.0
- Medical care	1.0
- Planetary protection	1.0
- Radiation	1.5
Radiation Research	2.0
LIFESAT	15.0
	94.0

* Joint programs with DOE and DOD

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SEI FY93 BUDGET DEVELOPMENT

SEI PROGRAM CRITERIA

- Support the President's exploration goals
- Establish an integrated set of activities
  - Provide "critical mass" to allow integrated set of activities
  - Avoid arbitrary funding allotments across program elements
- Implement activities that move the Initiative forward
  - Measurable accomplishments against an integrated plan
- Be politically viable and sustainable over time (build a constituency)
  - Significant accomplishments in reasonable time-frame
  - Attainment of major goals and objectives in a reasonable time-frame
- Avoid real or apparent buy-in
  - Content
  - Cost

NASA

INTEGRATED SEI CONTENT

- **Human support research**
  - LIFESAT studies of joint radiation/microgravity effects
  - Ground research on radiation protection requirements
  - Ground research on medical care and life support for lunar and Mars missions
  - Ground and space-based research on artificial gravity and zero-gravity countermeasures
  - Ground and space-based human factors research
  - Research on planetary protection methods and requirements
  - Analog activities
- **Planning and selected development for exploration robotic missions**
  - Mars Observer mission
  - Development start on Lunar Observer mission
  - Define integrated set of robotic missions
  - Preliminary design initiation on Mars Sample Return class mission
- **Joint NASA/DOD NLS development initiation**
  - NLS approach and content decision in 1991
  - 125 -150 mT launch capability
  - orbiter circularization and cargo transfer capability
- **Advanced development activities on SSF exploration support capability**
  - Leads to life science/technology test-bed on SSF
  - Leads to a possible transportation node capability
- **Development initiation of lunar exploration systems**
  - Leads to a lunar transportation system capability
  - Leads to a lunar surface system infrastructure (power/hab/construction capability)
- **Exploration technology/advanced development**
  - Primary focus on lunar evolution and Mars technology options
  - Augmented by an advanced development program for initial lunar exploration systems
  - Technology/advanced development phased to meet planning milestones

BEGIN ACTIVITIES THAT ENABLE A VARIETY OF ARCHITECTURES
maintain options — support architecture decisions — provide enabling capabilities

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Barnes1/PeachSEI Plan/SEI Integrated Plan 6/21/91 Ver 1/6 21 91

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HUMAN SUPPORT OBJECTIVE AND STRATEGY

Objective

- Develop SEI science, technologies, and procedures to satisfy requirements for crew human factors, medical care, and life support

Strategy

- Determine acceptable biomedical, environmental and performance parameters to ensure crew health, safety, and productivity
- Characterize human needs and risks encountered on SEI missions
- Develop, and verify ground-based models, simulations, and assessment methods
- Develop, test, and validate technologies and countermeasures

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HUMAN SUPPORT ELEMENTS

Science, Technology and Operations will be integrated within each element to provide the required human support

- Zero Gravity Countermeasures and Artificial Gravity
  - Understand mechanisms underlying physical debilitation and develop countermeasures
  - Determine adequacy of countermeasures on SSF
  - In parallel, develop artificial gravity concepts and simulations using ground based research and SSF
- Radiation Health and Radiation Protection
  - Develop Solar Energetic Particle prediction capability
  - Develop and validate measures of biological effects of galactic cosmic rays
  - Develop and validate materials shielding analysis codes
  - Characterize shielding materials in a design database
  - Define shielding and other radiation countermeasure requirements
  - Validate radiation health requirements using LIFESAT
- LIFESAT
  - Two spacecraft, six missions planned around four launches; 6/96, 2/97 (2 s/c), 3/98 (2 s/c), 12/98
    - Determine the relationship between radiation and microgravity/gravitational effects on biological systems
    - Validate ground based assessments, models and simulations
- Life Support Systems
  - Further develop applicable science and technology of regenerative life support, to include bioregenerative concepts as well as physical/chemical
  - Develop and validate systems for contamination monitoring and control and for partial/full closure of air, water, food and waste, utilizing ground bases and SSF research
  - Develop concepts for lunar and Mars in-situ resource utilization (water, oxygen, etc.) to support exploration and other goals

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HUMAN SUPPORT ELEMENTS (continued)

- EVA (Surface)
  - Evolve planetary EVA systems to maximize productive EVA time through enhanced crew performance, more efficient portable life support functions, and improved durability, reliability, and maintainability
  - Validate surface EVA systems using developed lunar and Mars test-beds
- Human Factors
  - Use analog facilities (e.g., Antarctica base, undersea habitat) to develop systems and procedures that will establish a physical, psychological and sociological climate favorable to crew living and work environments
  - Verify approaches using habitat and transfer vehicle simulation facilities
  - Use Space Station Freedom and lunar outpost as validation test-beds
- Advanced Medical Care
  - Develop in-flight and ground-based support systems to provide remote medical care in event of injury or illness
  - Verify and validate systems using STS, SSF, lunar missions and analogs (Antarctica)
- Planetary Protection
  - Define the potential threats of planetary forward and back contamination
  - Develop, validate, and perform operational tests of protection equipment and procedures
  - Define and develop flight hardware for planetary protection management on Mars robotic and human missions

NASA

ROBOTIC MISSIONS

Objectives

- Reduce risk of manned missions by obtaining data to support their development
- Validate technology and operations to be used on subsequent manned missions
- Obtain scientific knowledge of the Moon and Mars

Strategy

- Develop engineering, operations, and science data bases
- Confirm models of planets with surface data
- Obtain detailed data on specific sites for manned landings
- Establish integrated mission set to satisfy robotic requirements
- Determine suitable/desirable landing and outpost sites
- Conduct science investigations and develop basis for human science exploration

Elements

- For the Moon, emphasis on selecting landing/outpost site
  - Lunar Observer
- For Mars, emphasis on science and human mission success
  - Mars Observer
  - Mars Characterization/Verification } *a candidate mission set*
  - Mars Sample Return/Rover }

NASA

EARTH-TO-ORBIT TRANSPORTATION

Objectives

- Provide the transportation systems for cargo and crew delivery from Earth surface to Earth orbit

Strategy

- New Launch System (NLS)
  - NLS is a key enabling system for any SEI architecture
  - NASA/DOD Advanced Launch System and Shuttle-Derived Vehicles are two possible approaches
  - NLS decision planned by end of 1991
  - Initiation of prototype engine development in 1992
  - Initiate development on NLS in 1993 — enable first launch in 1999 (37 mT)
    - NASA Lunar (125 -150mT) • NASA Mars (225-275mT)
- Crew support
  - Use Shuttle fleet to transport crew to/from Earth orbit
- Robotic Mission Support
  - Use Expendable Launch Vehicles to support Robotic missions

NASA

SPACE STATION FREEDOM SEI ACCOMMODATIONS

Objectives

- Support life sciences research and technology verification activities required for the Space Exploration Initiative
- Maintain the design flexibility to support on-orbit processing of lunar and Mars spacecraft

Strategy

- Identify architecture independent requirements on SSF to support SEI and define corresponding program
  - Primarily R&D activities (Life Sciences and technology verification)
  - Supports continued development of SSF into a life sciences and technology test-bed configuration by 2004
- Continue a broad research program which maintains Space Station Freedom development options to support architecture specific roles
  - Includes transportation node (vehicle processing) activities
  - Supports continued development of SSF into a transportation node by 2007 if needed while minimizing near-term costs
- Focus near-term efforts on advanced studies and long lead time advanced development for selected technologies

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SPACE STATION FREEDOM SEI ACCOMMODATIONS (Continued)

Content

- Space Station Freedom augmentations for life sciences and R&T to support to SEI
  - Systems definition and integration studies
  - Additional habitation module for increased crew size
  - Increased power through addition of high-efficiency power generation systems (e.g., solar dynamic)
  - Subsystem upgrades associated with adding power (thermal, utility distribution, etc.)
  - Advanced technology development
- Space Station Freedom augmentations to provide SEI transportation node
  - Additional structure for attaching facilities
  - Advanced suit and second airlock for increased EVA
  - Lunar Transfer Vehicle accommodations facility
  - Cargo Transfer Vehicle accommodations (option)
  - Advanced propulsion system
  - Advanced Automation and Robotics program to reduce EVA requirements

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EXPLORATION SYSTEMS

Objectives

- Define and implement the transportation systems for transfer of crew and cargo from Earth orbit to the lunar/Mars surfaces
- Define and implement the lunar/Mars surface systems (habitats, power, launch/landing, etc.) to support the crew and surface operations

Strategy

- Studies on transportation and surface systems to enable early lunar options and to support technology downselect milestones for Mars options

Content

- Lunar Transportation and Surface Systems
- Mars Transportation and Surface Systems

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Barnes1/Peach/SEI Plan/SEI Integrated Plan 6/20/91 Ver 1/3 6 91

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EXPLORATION TECHNOLOGY/ ADVANCED DEVELOPMENT

Objectives

- Initiate high-leveraged technologies to enable a range of SEI options
- Initiate advanced development activities in critical areas of lunar elements to reduce program risk and provide high visibility early accomplishments
- Establish integrated technology planning to support advanced development activities
- Produce early results and demonstrations to support SEI decisions

Strategy

- Establish critical technology areas based on past studies — emphasize those technologies supporting permanence ("back to stay")
  - Reusability
  - Logistics reduction
  - Efficiency
  - Operations

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3/Peach/SEI Integrated Plan 6/20/91 Ver 1/3 6 91

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EXPLORATION TECHNOLOGY/ ADVANCED DEVELOPMENT

Content

- Space Transportation
- In-Space Operations
- Surface Operations
- Lunar and Mars Science
- Information Systems and Automation
- Nuclear Propulsion

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3Peach/SEI Integrated Plan 6/20/91 Ver. 1/3-8-91

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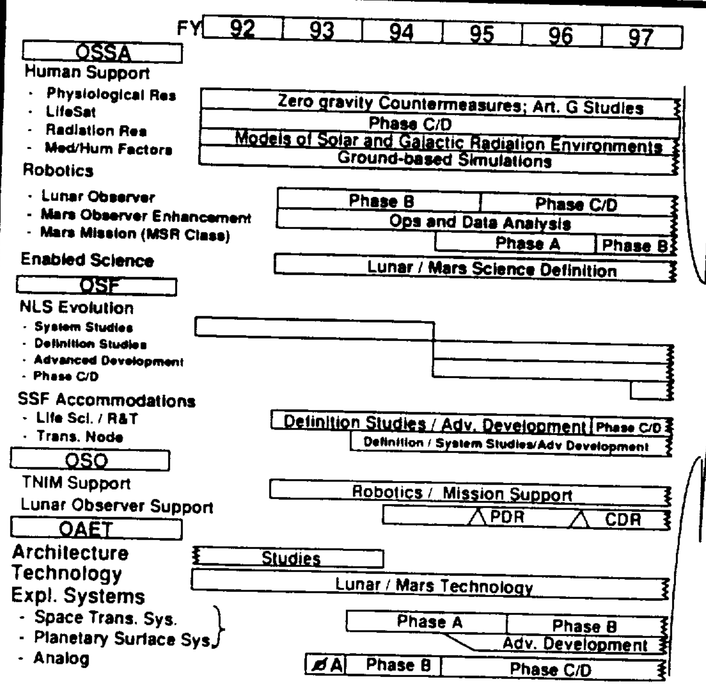
SEI MILESTONES



Planning Milestones (Outyear Funding Dependent)

FY	Event
96	LifeSat Mission (1)
97	LifeSat Missions (1) SSF Transportation Node Decision
98	LifeSat Mission (1)
99	LifeSat Mission (1) First Baseline NLS Launch
00	SSF Perm. Manned Capability Zero G countermeasures capability enabled
01	Lunar Observer
02	SSF Eight Crew Capability
03	
04	SSF Life Science / Tech Test-Bed Complete
05	Mars Mission (MSR Class) Lunar HLLV Test Flight
06	Human Lunar Landing
07	SSF Transportation Node
18	Human Mission to Mars

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Barrios2/Peach/Strategy and Technology Needs/SSTAC-Milestones Ver 5/6-21-91

NASA

SEI TECHNOLOGY RANKING

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SEI TECHNOLOGY RANKING

Ranking Criteria

- Commonality
  - 1 - Applicable to ALL or MOST architecures
  - 2 - Applicable to SPECIFIC architecures

- Need
  - A - Enabling
  - B - High leverage

Prioritization

Category 1 - 1A

Category 2 - 1B/2A

Category 3 - 2B

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SEI TECHNOLOGY RANKING

NOTE:
- This prioritization reflects the pre-Synthesis view of SEI technology needs
- There is no implied prioritization within each category

Category 1:

- Radiation Protection
- EVA Systems
- Nuclear Thermal Propulsion
- Regenerative Life Support
- Cryo Fluid Management, Storage, and Transfer
- Micro-g Countermeasures/Artificial Gravity
- Aerobraking

Category 2:

- Autonomous Rendezvous and Docking
- Health Maintenance and Care
- In-Space Systems Assembly and Processing
- Surface System Construction and Processing
- Cryo Space Engines
- In Situ Resource Utilization
- Surface Power

Category 3:

- Autonomous Landing
- Human Factors
- Surface System Mobility and Guidance (manned/unmanned)
- Electric Propulsion (nuclear/solar)
- Sample Acquisition, Analysis, and Preservation

Barrios : Peach/Technology Prioritization 6/20/91 Ver 4/6 20 91 **Office of Aeronautics, Exploration and Technology**

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TECHNOLOGY DESCRIPTIONS
CATEGORY 1

- Aerobraking
  - Lightweight, reusable materials which can withstand high simultaneous aerothermal & dynamic loads
  - Advanced GN&C technologies
  - Technologies required to minimize on-orbit construction/deployment
- EVA Systems
  - Lightweight, regenerable, PLSS technologies
  - High mobility, low maintenance, suit & glove technologies
  - Dust seals or other dust protection systems to minimize habitat contamination
  - Advanced computer/robotic mobility aids
- Cryo Fluid Management, Storage, and Transfer
  - Refrigeration and thermal protection systems to reduce boil-off rate
  - Fluid gauging and health monitoring systems
  - Transfer leakage reduction technologies
- Micro-G Countermeasures/Artificial Gravity
  - Lightweight, high-strength tethers
  - Centrifuge technologies
  - Countermeasures technologies
- Nuclear Thermal Propulsion
  - Lightweight, high-efficiency, reliable reactor design
  - High-efficiency, increased ISP, fuel development
  - Lightweight shielding materials
- Radiation Protection
  - Lightweight, deployable, durable radiation shielding technologies
  - Shielding against solar flares and galactic cosmic radiation
- Regenerative Life Support
  - Biological atmospheric revitalization technologies
  - System contamination monitoring and control technologies
  - Food production technologies
  - Waste recycling technologies

Barrios2/Peach/Strategy and Technology Needs/SSI AC External Review of ITP 6/21/91 Ver 1/6 19 91 **Office of Aeronautics, Exploration and Technology**

TECHNOLOGY DESCRIPTIONS
CATEGORY 2

- Autonomous Rendezvous and Docking
  - Laser radar terminal guidance technologies
  - Structural attachment systems
  - Autonomous connection verification technologies
- Cryo Space Engines
  - Multiple restart, high maintainability, wide throttle range, high ISP engine technologies
  - Automated health monitoring and failure prediction technologies
- Health Maintenance and Care
  - Health monitoring technology
  - Emergency surgery technology
- In-Space Systems Assembly and Processing
  - AI/expert systems for vehicle checkout
  - Non-destructive evaluation of assembled elements
  - Advanced controls and displays
  - Hazard detection systems
  - Built-in diagnostics
- Surface Power
  - Advanced efficiency photovoltaic systems
  - Safe, efficient, nuclear energy systems
  - Advanced energy storage systems
  - Power conversion technoloiges
  - Advanced heat rejection technologies
  - Power management technologies
- Surface Systems Construction and Processing
  - Technologies for raditation shielding emplacement
  - Technologies for surface stabilization
- In-Situ Resource Utilization
  - LLOX production technologies including:
    - -- Feedstock benefication
    - -- Fluidized bed reactor
    - -- Vapor phase water electrolysis cell
    - -- Oxygen liquefaction

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TECHNOLOGY DESCRIPTIONS
CATEGORY 3

- Autonomous Landing
  - Guidance Navigation & Control
  - Transition from aero to propulsion
  - Landing aids
  - Hazard avoidance technologies
- Electric Propulsion
  - Nuclear electric propulsion technologies including:
    - -- Low specific mass nuclear power source
    - -- Nuclear conversion technologies
    - -- NEP radiation protection
  - Solar electric propulsion technologies
  - Electric propulsion thruster development
- Human Factors
  - Human/machine interface technologies
  - Automated training aids
- Sample Acquisition, Analysis, and Preservation
  - Teleoperation
  - Sample analysis/preservation technologies
  - Sensor technologies
- Surface Systems Mobility and Guidance
  - Hazard avoidance technologies
  - AI/expert systems mobility technologies
  - Advanced mobility aids

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SUMMARY

- Strongly support the need to increase the Agency's investment in technology
- Coordination of agency technology efforts should be pursued with DOD, DOE, NSF, etc. where practical
- Near-term SEI activities will result in a program plan which links SEI technology and advanced development activities to mission milestones
- Need to pursue long-lead, architecture independent technologies now

Office of Aeronautics, Exploration and Technology

Office of Space Science and Applications

STRATEGIC PLANNING AND TECHNOLOGY ISSUES

Presentation to the
Space Systems and Technology
Advisory Committee

June 24, 1991

J. K. Alexander
Assistant Associate Administrator
for Space Science and Applications

NASA

STRATEGIC PLANNING

Strategy

- Establish a Set of Programmatic Themes
- Establish a Set of Decision Rules
- Establish a Set of Priorities for Missions and Programs within each Theme
- Demonstrate that the Strategy can Yield a Viable Program
- Check the Strategy for Technology Readiness and for Consistency with Resource Constraints, Such as Budget, Manpower, Facilities, and Launch Vehicle Availability

STRATEGIC PLANNING

Three Program Themes

MISSION TO PLANET EARTH

- On-going Program
- Major & Moderate Missions
- Small Missions
- Research Base Enhancements

MISSION FROM PLANET EARTH

- Meeting Human Needs
- Robotic Exploration
- In Situ Science

OSSA CORE PROGRAM STRATEGIC PLAN

- Ongoing Program
- Major and Moderate Missions
- Small Missions
- Space Station Utilization
- Research Base

CORE SCIENCE PROGRAM

Year	Ongoing Program	Major & Moderate Missions	Small Missions	Space Station Freedom Utilization	Research Base Enhancements
1989	Research and Analysis	Advanced X-Ray Astrophysics Facility	Scout-Class Explorers	Microgravity Facilities 1.8m Centrifuge Attached Payloads Earth Observing System Payload Definition	SETI Microwave Observing Project CRAF/Cassini Advanced Technology Development Supernova 1987A Suborbital Observation ER-2 Purchase
1990	Mission Operations and Data Analysis	CRAF/Cassini	Total Ozone Mapping Spectrometer	Space Biology Initiative Definition Earth Observing System Payload Definition	Research and Analysis and Missions Operations and Data Analysis Corrections
1991	Aerospace Medicine Flight Projects	Earth Observing System*	Earth Probes*	Space Biology Initiative Biomedical Monitoring and Countermeasures†	
1992	Spacelabs and Other Carriers		Lifesat* Earth Probes Augmentation*		Resources to Augment Research Community Data Revitalization Initiative Studies of Mesosphere and Lower Thermosphere
1993 Through 1997		Orbiting Solar Laboratory† Space Infrared Telescope Facility Lunar Observer† Gravity Probe-B Solar Probe	Microgravity Fundamental Science	Small & Rapid-Response Payloads	Stratospheric Observatory for Infrared Astronomy Focused Research and Analysis, Suborbital, Advanced Technology Development, Data Systems Enhancements

* Also See Mission to Planet Earth Strategy
† Also See Mission from Planet Earth Strategy

SP-015-8c
6/20/91

MISSION TO PLANET EARTH (MTPE) STRATEGY

Phase	On-Going Program	Major & Moderate Missions	Small Missions	Research Base Enhancements
Near Term Monitoring and Focused Studies	Research and Analysis Mission Operations and Data Analysis Upper Atmosphere Research Satellite (UARS) Ocean Topography Experiment (TOPEX/Poseidon) Atlas/SSBUV Flights Shuttle Imaging Radar (SIR) Flights Global Ocean Color Measurements Radarsat		Total Ozone Mapping Spectrometer (TOMS) NASA Scatterometer (NSCAT) Tropical Rainfall Measuring Mission (TRMM)	EOS Interdisciplinary Investigations EOS Data and Information System (EOSDIS)
Comprehensive Long-Term Studies		Earth Observing System (EOS) – "A" Platform Series – "B" Platform Series EOS Synthetic Aperture Radar (SAR)	Follow-On Earth Probe Missions	Preliminary Global Climate Modeling
In-Depth Studies		Geostationary Platforms		Comprehensive Global Climate Models

MISSION FROM PLANET EARTH (MFPE) STRATEGY

Phase	Meeting Human Needs	Robotic Exploration	In Situ Science
Robotics and Space Station Freedom	Space Biology Initiative*† Biomedical Monitoring and Countermeasures*† Lifesat**† Orbiting Solar Laboratory† Advanced Technology Development Life Sciences Test-Beds for Lunar Outpost	Mars Observer† Lunar Observer† Mars Environmental Survey	Opportunities Definition Advanced Technology Development
Lunar Emplacement and Mars Robotics Lunar Consolidation	Lunar Mission Systems Global Solar Monitors	Mars Sample Return with Local Rover Mars Site Reconnaissance Orbiter Mars Rovers	Teleoperated Rover Lunar Transit Telescope Lunar Geology Pressurized Rover Pressurized Laboratories
Lunar Operations and Mars Emplacement	Mars Life Sciences Test-Beds Mars Mission Systems	Additional Mars Rovers	Advanced Lunar Astronomical Facilities Mars Geology Meteorological Stations Unpressurized Rover Mars Science Network

*FY 1991 Initiatives
**FY 1992 Initiative
† Also Part of Core Science Program

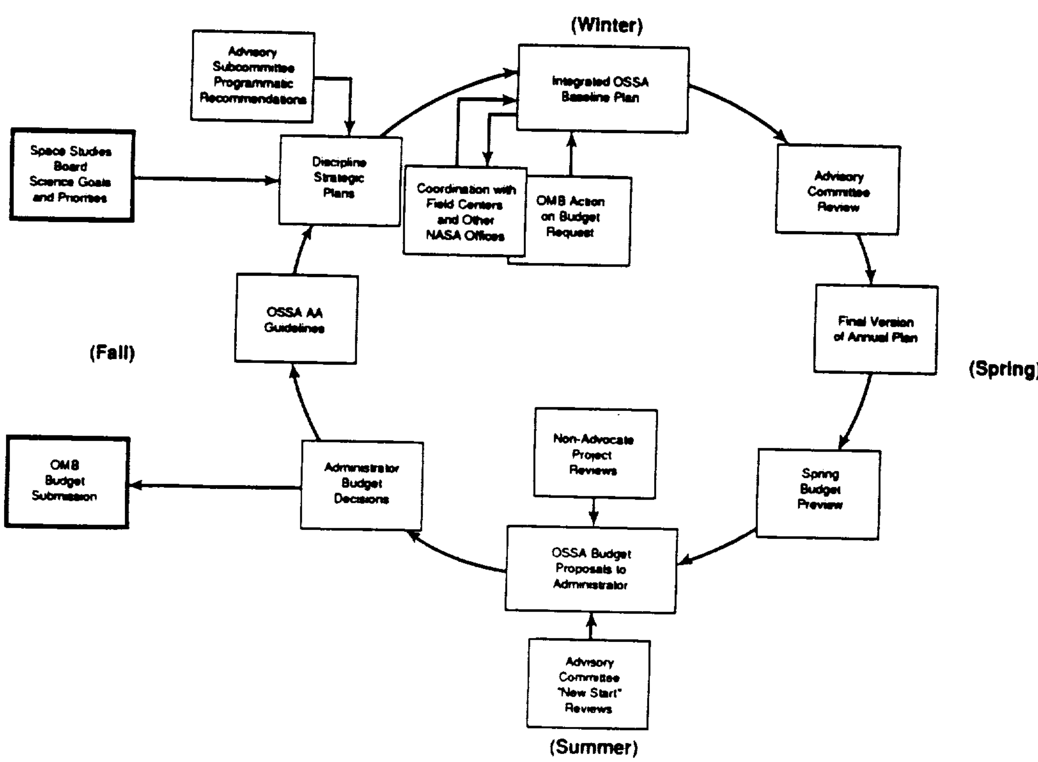
DECISION RULES FOR INTEGRATING OVERARCHING INITIATIVES

OSSA

- Establish Realistic Budget Level
  - Strength of Core Science Program Requires Stable Level of Resources Comparable to Historical Allocation
  - Both Mission to Planet Earth and Mission from Planet Earth Require Resources Beyond the Core Level
- Match the Pace of the OSSA Program for Overarching Initiatives to the Pace at which NASA and the Nation Proceed as a Whole
- Establish a Feasible Pace and Scale
- Preserve Program Balance
  - Always Adhere to Principle of Scientific Balance Among Disciplines within the Core Science Program
  - Proceed with Core Science Program in Parallel with Overarching National Initiatives

ANNUAL STRATEGIC PLANNING AND BUDGETING CYCLE

OSSA



SP-015-03d
6/17/91

1991 STRATEGIC PLAN REVISION

- 1991 OSSA Strategic Plan Reflects Current Strategy for Mid-1990's
  - All Major Flight Projects in 1992 Ongoing Core Science Program will be Launched by 1998
- Next Step is to Select Successors to the Ongoing Program
  - Each OSSA Division Advisory Subcommittee of the Space Science and Applications Advisory Committee (SSAAC) Assessing Candidate Missions and Initiatives for Each Strategic Plan Theme
  - SSAAC will Hold First Triennial Review of Division Strategies and Proposed Mission Queues in the Summer of 1991
    - Recommendations will be Made for Inclusion in 1992 OSSA Strategic Plan
    - Themes and Decision Rules will Also be Reevaluated
    - SSAAC Recommendations will be Discussed with Space Studies Board and with Other Representative Groups in the Space Science Community Prior to Release of Draft 1992 Plan in Early 1992

ADVANCED TECHNOLOGY PROGRAMS

Advanced Instrument Technology Development and Pre-Phase-A Mission Studies	$25 M
Phase-A Mission Studies—e.g. Future Explorers, Solar Probe, Mars Environmental Survey, Future Earth Probes, Lunar Observer, Thermosphere-Ionosphere-Mesosphere Energetic and Dynamics Mission	20
Phase-B Mission Studies—e.g. Orbiting Solar Laboratory, Space Infrared Telescope Facility, Lifesat, Future Explorers, Centrifuge, Stratospheric Observatory for Infrared Astronomy	50
Approximate Total (FY 1991)	**$95 M**

OSSA TECHNOLOGY COORDINATION PROCESS

- COORDINATION BUILT ON PROCESS INITIATED IN 1987
- PROCESS STRENGTHENED IN FALL OF 1990:
  - -- OAET TECHNOLOGY INTERFACES ASSIGNED FOR EACH OSSA DIVISION
  - -- GRASSROOTS APPROACH TO DEFINING TECHNOLOGY REQUIREMENTS
  - -- OAET LIAISON
- DIVISION TECHNOLOGY REQUIREMENTS DERIVED FROM OSSA INTEGRATED MISSION LIST AND STRATEGIC PLAN
- OSSA FRONT OFFICE PARTICIPATION AND ENDORSEMENT OF PRIORITIES
- PRIORITY REQUIREMENTS TO BE UPDATED FOLLOWING THE OSSA/SSAAC SUMMER STRATEGIC PLANNING RETREAT
- JOINTLY SPONSORED WORKSHOPS & TECHNOLOGY INFORMATION MEETINGS ONGOING

INTERIM
OSSA TECHNOLOGY NEEDS
Grouped According to Urgency & Commonality

TO BE UPDATED FOLL[illegible]G THE OSSA/SSAAC SUMMER WORKSHOP

REVISED: APRIL 12, 1991

Term	HIGHEST PRIORITY		2nd-HIGHEST PRIORITY			3rd HIGHEST PRIORITY			
Near Term	Submm & Microwave Tech: -- SIS 1.2 THz Heterodyne Rec. -- Active SAR integrated circuits -- Passive submm 600 GHz diodes (SZ,SE,)	Long-life Mechanical & Cryogenic Coolers/Cryo Shielding (SZ,SE,SS)	High Frame Rate, High Resolution Video& Data Compression (SN, SL)	2.5 - 4m, 100K Lightweight, PSR (SZ)	Fluid Diagnostics (SN)	Real-Time Radiation Monitoring (SB)	Descent Imager (SL)	Mini-RTG (SL)	Mini-Camera (SL)
	Detectors (SE, SL, SZ, SS) -- optical, Ge, Xe, non-cryo 1.6 to 150μ IR, extended μ CCD, high energy detectors, sensor readout electronics & tunnel sensors	Vibration Isolation Technology (SN, SZ, SB)	Solar Arrays/Cells (SL, SZ, SE)	Automated Biomedical Analysis (SB)	Rad Hard Parts & Detectors (SZ, SL)	Solid/Liquid Interface Characterization (SN)	Laser Light Scattering (SN)	High Temperature Materials For Furnaces (SN)	K-band Transponders (SZ)
	Efficient, Quiet Refrigerator/Freezer (SB)	Extreme Upper Atmosphere Instrument Platforms (SS)	Batteries -- Long life time -- High energy density (SL, SZ)	Real-Time Environmental Control & Monitoring (SB)	Space Qualified maser & ion Clocks (SZ)	Field Portable Gas Chromatographs (SB)	Advanced Furnace Technology (SN)	Ultra-high Gigabit/sec Telemetry (SZ)	Mini S/C Subsystems (SL)
	Lasers: Long-life, Stable & Tunable (SE, SZ, SL, SB)	Solar Probe/ Mercury Orbiter Thermal Shield & Protection (SS, SL)	Auto Sequencing & Command Generation, Auto S/C Monitoring & Fault Recovery (SL)	Combustion Diagnostics (SN)	Plasma Wave Antennas/ Thermal (SS)	Regenerative Life Support (SB)	Non-Contact Temperature Measurement (SN)	3-D packaging for 1 MB Solid State Chips (SZ)	Microbial Decontamination Methods (SB)
	Data -- High Volume, High Density, High Data Rate, On-board Storage (SE, SL, SN)	Interferometer-specific Tech: -- picometer metrology -- active delay lines -- control-structures interact. (SZ, SL, SB)	32 Ghz TWT Optical Communication (SL, SS)	Telescience, Telepresence, & AI (SN, SL, SB)	Improved EVA Suit/ PLSS (EMU) (SB)	Thermal Control System (SZ)	Special Purpose Bioreactor Simulator Syst. (SB)	Rapid Subject/ Sample Delivery & Return Capability (SB)	Animal & Plant Reproduction Aids (SB)
	Controlled Structures/ Large Antenna Structure Arrays/Deployable (SE, SZ, SS, SB)	Robotics (SN, SL)	SIS 3 Thz Heterodyne Receiver (SZ)	SETI Technologies -- Microwave & Optical/Laser Detection (SB)	Mini Ascent Vehicle/ Lander Deceleration (SL)	Auto Rendezvous Auto Sample Transfer, Auto Landing (SL)	Non-Destructive Monitoring Capability (SB)	Low-drift Gygos, Trackers, Actuators (SZ)	Non-Destructive Cosmic Dust Collection (SB)
	Interspacecraft Ranging & Positioning Precision Sensing Pointing & Control (SS, SZ, SL)	Parallel Software (SE, SL) Environment for Model & Data Assimilation, Visualization Computational Techniques	Sample Acquisition & Preservation, Probe, In-situ Inst., Drills, Corers, Penetrators (SL, SB)	Returned-Sample Biobarrier Analysis Capabilities (SB, SL)	High Resolution Spectrometer (SB)	Heat Shield for 16 Km/s Earth Entry (SL)	Partial-g/ μg Medical Care Delivery Systems (SB)	Dust Protection/ Jupiter's Rings (SL)	
Far Term	Large Filled Apertures -- lightweight & stable optics -- Cryo optical ver., fab., test. -- Deformable mirrors -- 15-25m PSR (SL, SZ, SE)	50-100Kw Ion Propulsion (NEP) (SL)	Radiation Shielding for Crews (SB)	X-ray Optics Tech: -- imaging system -- low cost optics -- Bragg concentrators -- coated apertures (SZ)	Human Artificial Gravity Systems (SB)	CELSS Support Technologies (SB)			

← HIGHEST PRIORITY → | ← 2nd-HIGHEST PRIORITY → | ← 3rd HIGHEST PRIORITY →

Tally	HIGHEST PRIORITY		2nd-HIGHEST PRIORITY		3rd HIGHEST PRIORITY	
	SB: 5	SN: 3	SB: 10	SN: 4	SB: 11	SN: 5
	SE: 8	SS: 6	SE: 1	SS: 2	SE: 0	SS: 0
	SL: 11	SZ: 9	SL: 9	SZ: 6	SL: 8	SZ: 5

- Openness of Technology Research Program
  - Selection and Progress Evaluations by Peer Review
  - Extramural Participation in Reviews and in Research
- Balance in Priorities
  - Near-Term Needs vs Out-Year Plans
  - Big Technology Tasks vs Small Projects
  - Enabling Technologies vs Enhancing Technologies
- Technology Transfer from the Laboratory Environment to Flight—Provision for Space Qualification of New Technologies
- Multidisciplinary Integration in OSSA
  - Improving the Planning and Prioritization Process
  - Funding Strong Multidivisional Programs
- OAET (OSSA) Participation in OSSA (OAET) Advanced Studies
  - Early Involvement
  - Ownership

SSED Technology Needs

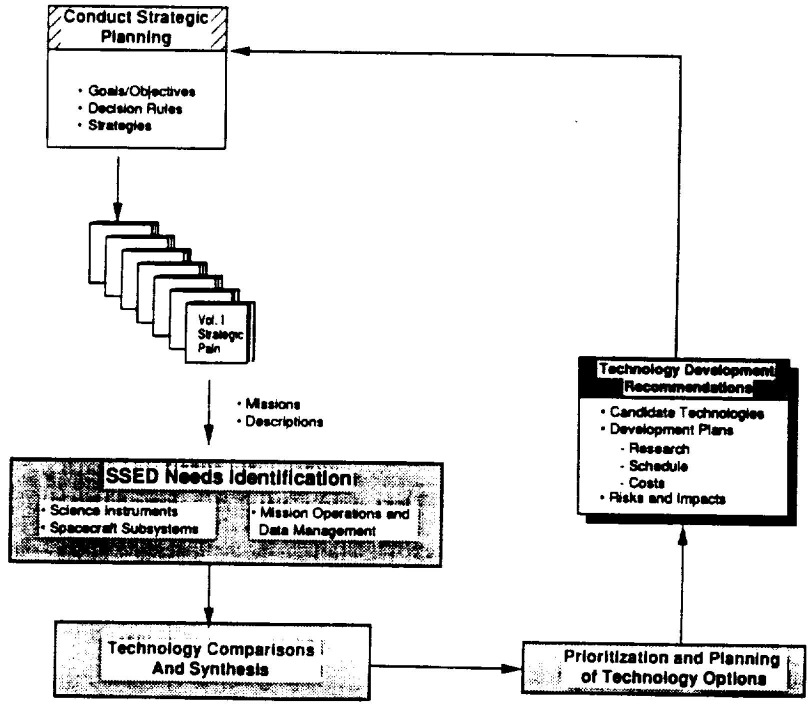
June 24, 1991

Dudley McConnell

Solar System Exploration Division
Advanced Programs Branch

NASA

SSED's Technology Planning Process



SSED's Technology Themes

- Develop instruments and sensors that enable or enhance the capability for achieving desired measurement objectives
- Enhance the cost effectiveness, reliabillity, and performance of spacecraft systems and subsystems
- Expand the operational capabilities, cost effectiveness, and efficiencies of ground- and space-based operations and data analysis systems

APPLICATION	HIGHEST PRIORITY	2nd HIGHEST PRIORITY	3rd HIGHEST PRIORITY
NEAR TERM	• Mission Operations and Data Management (Ground) - Visualization - Rapid Sequencing - Adaptive Spacecraft Analysis	• On-Board Computation - Signal Processing • High Rate Telemetry • Intelligent Spacecraft • Instrument Coolers	• Advanced Propulsion (Chemical)
FAR TERM	• Microsystems [1] • Sample Acquisition, Analysis and Preservation • Advanced Propulsion (NEP) [1]	• Detectors • Lightweight, Stable, Supersmooth Optics • Long Life, Stable Optics • Controlled Structures	• Power (Batteries) • Resistant Spacecraft and Instrumentation • Accurate Landing • Orbit Insertion Techniques • Orbital Rendezvous/ Docking

[1] Technology will require extended development schedules, and must be initiated early

Table 5. SSED's Technology Priorities, Grouped According to Anticipated Time Frame of Application

Missions	Technologies: Optical Systems · Lasers	Controlled Structures	Lightweight Optics	Detectors	Coolers	SAAP
FY94-98						
Lunar Observer						
Mars Lander Network						
Pluto Flyby/Neptune Orbiter/Probe				√	√	
Discovery NEAR						
TOPS (Keck II)						
Discovery OPT						
CDCF						
FY 99-03						
Mars Sample Return						√
Lunar Surface Missions						√
Mercury Orbiter						
Venus Probe						
Uranus Orbiter/Probe				√		
Jupiter Grand Tour				√	√	
CNSR						√
Main Belt Rendezvous						
TOPS (Orbital)	√	√	√			

Table 2. Science Instrumentation: Summary of Technology Needs for SSED Missions

Missions	TECHNOLOGIES: Ground Based Systems · Workstations · Visualization · Advanced Techniques	On Board Computation · Processors · Fault Protection/Recovery · Signal Processors	High Rate Telemetry
FY94-98			
Lunar Observer	√	√	
Mars Lander Network	√	√	
Pluto Flyby/Neptune Orbiter/Probe	√	√	
Discovery NEA	√	√	
TOPS (Keck II)	√	√	
Discovery OPT	√	√	
CDCF	√	√	
FY 99-03			
Mars Sample Return	√	√	
Lunar Surface Missions	√	√	
Mercury Orbiter	√	√	
Venus Probe	√	√	
Uranus Orbiter/Probe	√	√	√
Jupiter Grand Tour	√	√	√
CNSR	√	√	
Main Belt Rendezvous	√	√	
TOPS (Orbital)	√	√	

Table 4. Information and Data Management Systems: Summary of Technology Needs for SSED Missions

Missions	TECHNOLOGIES: Microsystems*	Power Solar	Batteries	Advanced Prop NEP/SEP	Advanced Prop Chemical	Data Storage	Orbit Insertion Techniques	Accurate Landing	Orbital Rendezvous & Docking	Resistant Spacecraft/ Instrumentation	Intelligent Spacecraft
FY94-98											
Lunar Observer											
Mars Lander Network		**	**								
Pluto Flyby/Neptune Orbiter/Probe			√			√				√	
Discovery NEAR											
TOPS (Keck II)											
Discovery OPT											
CDCF											
FY 99-03											
Mars Sample Return	√				√		√	√	√		√
Lunar Surface Missions	√										√
Mercury Orbiter									√	√	√
Venus Probe										√	√
Venus Orbiter/Probe			√			√	√				√
Jupiter Grand Tour			√	√		√				√	√
CNSR	√		√		√		√		√		√
Main Belt Rendezvous		√		√							√
TOPS (Orbital)											√

* Includes technology requirements for Spacecraft, science instrumentation, and surface systems
** Possible technology option

Table 3. Spacecraft Systems: Summary of Technology Needs for SSED Missions

SSED Perspective: Technology Planning Challenges

• Strategic Planning

- Maturing and institututionalizing a vigorous technology planning process within the Division - User-driven thrust, based on joint cooperation withOAET

- Developing an enduring, acceptable template for prioritizing and selecting technology development initiatives

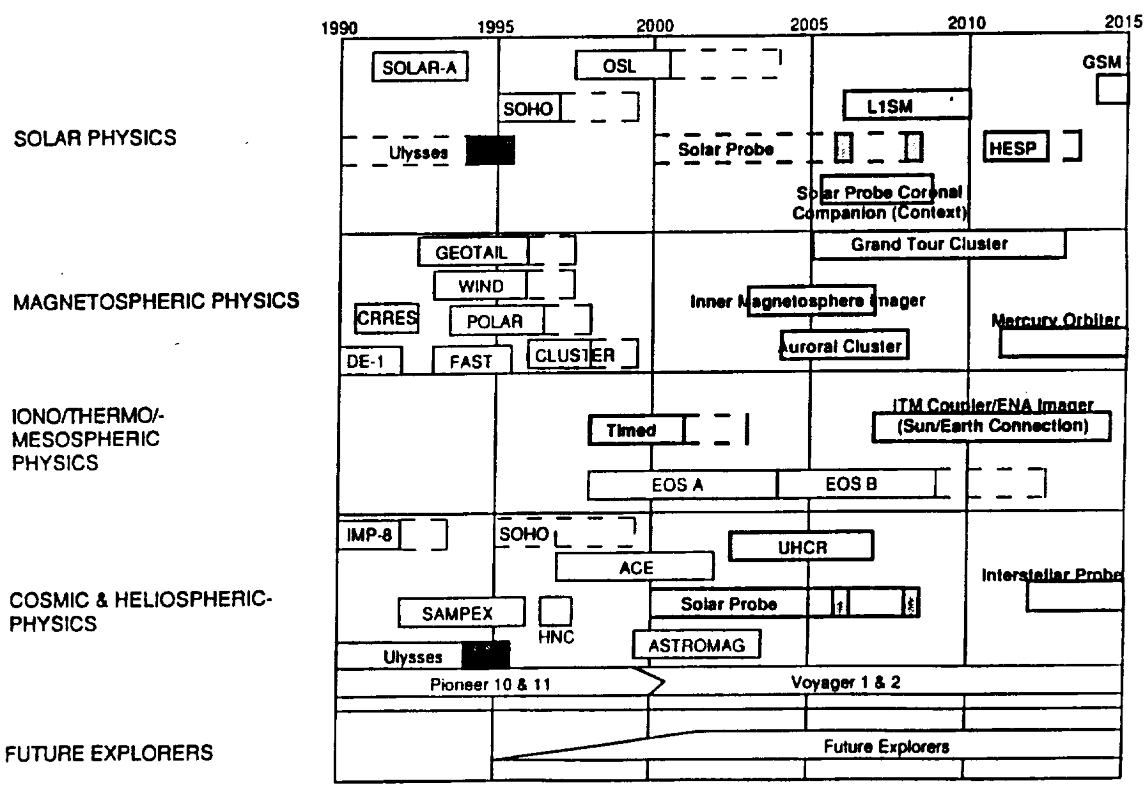
• Technology Implementation

- Optimizing the mix of joint OAET/OSSA technologies (enabling versus enhancing, high risk versus low risk, large versus small investments, etc.)

- Formulating focused, joint projects with other OSSA divisions that reflect and balance the participant's development needs, fiscal constraints, and schedules

- Improving the capability to effectively apply technologies, i.e., transition the technology to the flight project

CONSENSUS SCENARIO W/O SEI



SPACE PHYSICS TECHNOLOGY/MISSIONS NEEDS

ASTROMAG (FREE FLYER)** - NO PRESENTLY IDENTIFIED TECHNOLOGY ISSUES

THERMOSPHERE/IONOSPHERE/MESOSPHERE ENERGETICS AND DYNAMICS** - NO KNOWN ISSUES

SOLAR PROBE** - THERMAL SHIELD MATERIALS AND CONFIGURATION
COMMUNICATIONS WHICH OPERATE IN THE PLASMA TURBULANCE NEAR THE SUN
PLASMA WAVE ANTENNAS (ELECTRICALLY CONDUCTING) WHICH OPERATE AT HIGH T

INNER MAGNETOSPHERE IMAGER** - NO KNOWN TECHNOLOGY ISSUES

GRAND TOUR CLUSTER** - INTERSPACECRAFT POSITIONING AND RANGING SYSTEM

HIGH ENERGY SOLAR PHYSICS - CRYOGENIC COOLERS FOR SOLAR X-RAY AND GAMMA RAY DETECTORS

SPACE PHYSICS *ENABLING* TECHNOLOGY NEEDS

MESOSPHERE/LOWER THERMOSPHERE INSTRUMENT PLATFORM:
A PLATFORM WHICH CAN SUPPORT *IN SITU* MEASUREMENTS OF ATMOSPHERIC PARAMETERS (PREFERABLY AT SUB-MACH VELOCITIES) IN THE ALTITUDE RANGE OF 60 - 150 KILOMETERS. NEED TO PERFORM GLOBAL MEASUREMENTS OF CONSTITUENT DENSITIES, TEMPERATURES AND DYNAMICS.

NON-CRYOGENIC LONG WAVELENGTH INFRARED DETECTORS:
NEED FOR A NON-CRYOGENIC LONG WAVELENGTH (1.6-150 MICRON SPECTRAL REGION) INFRARED DETECTOR ARRAY FOR OBSERVATIONS OF SOLAR STRUCTURES AND DYNAMICS.

**NOTE: AT THE RECENT SPACE PHYSICS TECHNOLOGY WORKSHOP SEVERAL TECHNOLOGY AREAS WERE IDENTIFIED WHICH WOULD *ENHANCE* FUTURE SPACE PHYSICS MISSIONS (PROPULSION, DATA SYSTEMS, POWER SYSTEMS, SENSORS AND DETECTORS, ETC.)

SSA

Microgravity Science and Applications Division

Primary Goal – **To develop a comprehensive research program in fundamental sciences, materials science, and biotechnology for the purpose of attaining a structured understanding of gravity-dependent physical phenomena in both Earth and non-Earth environments.**

Approach – **To perform ground-based research, followed by experiments in PI-specific hardware or multi-user facilities on manned carriers such as the Space Transportation System and Space Station Freedom, and unmanned carriers such as Eureca and suborbital sounding rockets.**

Technology Needs – **MSAD mission model has identified technology developments as shown on the following chart.**

TABLE 2 - MSAD TECHNOLOGY REQUIREMENTS PRIORITIZATION

	HIGHEST PRIORITY		2nd-HIGHEST PRIORITY			3rd-HIGHEST PRIORITY			
1996	VIT	FLUID DIAG.	HHVT	HIGH VOLUME RECORDING	TELESCIENCE	COMBUSTION DIAG.	ROBOTICS	IFC	LLS
1997	HHVT	COMBUSTION DIAG.	HIGH VOLUME RECORDING	VIT	TELESCIENCE	ROBOTICS	AFT	IFC	
1998	VIT	HHVT	FLUID DIAG.	TELESCIENCE	IFC	ROBOTICS	HIGH VOLUME RECORDING	AFT	HTMF
1999	HHVT	VIT	FLUID DIAG.	TELESCIENCE	HIGH VOLUME RECORDING	ROBOTICS	NCTM		
2000	HHVT	COMBUSTION DIAG.	VIT	TELESCIENCE	HIGH VOLUME RECORDING	ROBOTICS			
2001	VIT	FLUID DIAG.	HHVT			TELESCIENCE	ROBOTICS	HIGH VOLUME RECORDING	IFC

ABBREVIATIONS:

HHVT=HIGH FRAME RATE HIGH RESOLUTION VIDEO
VIT= VIBRATION ISOLATION TECHNOLOGY
LLS= LASER LIGHT SCATTERING
IFC=SOLID/LIQUID INTERFACE CHARACTERIZATION
AFT = ADVANCED FURNACE TECHNOLOGY
NCTM = NON-CONTACT TEMPERATURE MEASUREMENT
HTMF = HIGH TEMPERATURE MATERIALS FOR FURNACES

SSA

Consequences of Not Developing Required Technology

- Reduced science return (i.e., less than optimal instrument accuracy, precision, resolution, or quantity of video data, and less than optimal experimental conditions (i.e., vibration/acceleration environment)
- Flight experiments delayed until critical technology developed (i.e., telescience, robotics)
- Flight experiments more costly, if technology development must be undertaken in a fragmented approach by each flight project, or if experiment-specific vs. general purpose hardware is flown/qualified (i.e., need for common high-rate/high-resolution video)

SSA

MSAD Concerns and Issues

- Vibration Isolation Technology (VIT) and High-Rate/High-Resolution Video Technology (HHVT) among MSAD's highest priority needs; until now, OAET had not developed programs to specifically address MSAD requirements
- OAET has now initiated efforts to address HHVT needs, but VIT program plan still not defined
- OAET has indicated additional MSAD technology needs in second and third priority category may not be funded without augmentations
- Concerns are that OAET program plans may not address time-criticality of MSAD needs, and may not produce desired products. Long-term commitment by OAET to meeting MSAD requirements is critical.

1108-023-03CAW 08/21/91

SSA

MSAD Requests

- OAET involve MSAD HQ and center personnel in developing technology development plan
- OAET involve MSAD personnel in all major program reviews
- OAET utilize existing MSAD expertise where it makes sense (i.e., ongoing ATD projects)

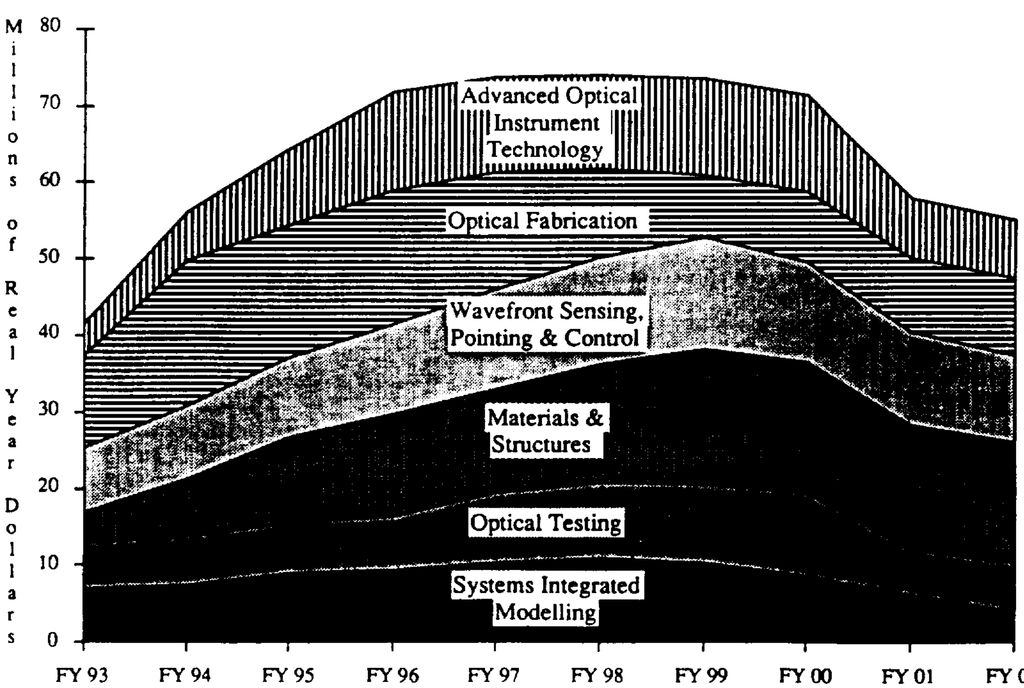
THESE ACTIONS WILL RESULT IN MORE RESPONSIVE MSAD-OAET INTERACTIONS, USEFUL, AND TIMELY TECHNOLOGY DEVELOPMENT

-023-04CAW 08/21/91

How OAET Can Support Astrophysics Division Needs?

- **Focused technology development** aimed at specific astrophysics missions in the **OSSA Strategic Plan**
- **Long-term, core technology development** principally in two area - sensors/detectors and optics - to enable small and moderate missions (Explorers) and sub-orbital instruments
- **Integrated technology demonstrations and test-beds,** both ground- and space-based
- **Well managed technology development program** within OAET
  - •• Use of *peer-review* of programs at NASA centers
  - •• Actively involve the astrophysics community of "instrument builders"

Astrophysics Technology Needs in Optics



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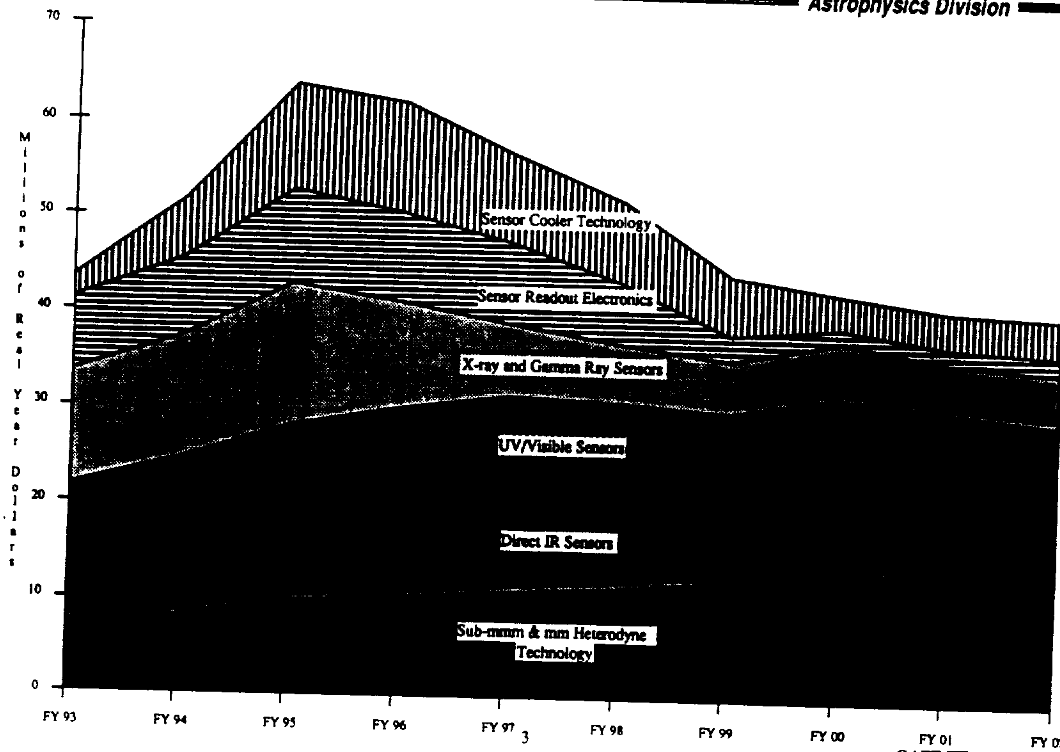
OAET ITP-MSK-6/24/91

NASA

Astrophysics Technology Needs in Sensors

Astrophysics Division



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OAET ITP-MSK-6/24/91

Life Sciences Division
Basic Science Technology Requirements

Space Shuttle/ Space Station/ LifeSat	Efficient, Quiet Refrigerator-Freezer Automated Biomedical Analysis - Minimally invasive Centrifuge Enhancements - Vibration isolation - Torque damping - Maintainable on-orbit	Non-Destructive Monitoring Capability - Animals, plants, cells - Physiological status and behavior New-Concept Plant and Animal Habitats - Automated provisioning/cleaning - Simplified access/subject handling - Compatible with centrifuge systems	Rapid Subject/Sample Delivery and Return Capability (Late Access) Animal and Plant Reproduction Aids Non-Destructive Cosmic Dust Collection - Hypervelocity capture capability - Trajectory and velocity measuring
Lunar and Planetary Exploration	Mars Penetrators/Small Stations - Integral exobiology instruments Telescience Capabilities - Telepresence - Telemanipulation - Real-time analysis	High-Resolution Spectrometer - Very high spatial resolution - Very high spectral resolution Sample Analysis and Preservation - Biological sample preservation - Planetary protection compatibility	Improved Analysis Instrumentation - Differential Scanning Calorimeter - GC/MS - Laser Diode Spectrometer - Scanning Electron Microscope - Life Detection Systems
Ground-Based and Observatory Science	Enhanced Signal Processing and Detection Systems for SETI - Microwave signal detection - Optical/laser signal detection Field-Portable Gas Chromatographs	Special-Purpose Bioreactor Systems - Deep-sea simulators - Planetary surface simulators Returned-Sample Biobarrier Analysis Capabilities - Telemanipulation - Enhanced biological analysis Lunar Far-Side SETI and Radio Astronomy Facilities	Lunar Surface Infrared Astronomy Facilities Very-Long Baseline Interferometry Systems - Lunar surface mounted - Jupiter orbital, etc.
	← Highest Priority →	← 2nd-Highest Priority →	← 3rd-Highest Priority →

Life Sciences Division
Human Support Technology Requirements

	Highest Priority	2nd-Highest Priority	3rd-Highest Priority
Space Shuttle	Improved EVA Suit/PLSS (EMU) – Dexterity/Manueverability – Zero prebreathe	Real-time Environmental Control – Contaminant monitoring – Contaminant removal	Real-time Radiation Monitoring – Personal dosimetry – Vehicle event-monitoring capability
Space Station	Improved EVA Suit/PLSS (EMU) – Dexterity/Manueverability – Zero prebreathe – Maintainable on-orbit Regenerative Life Support – Water reuse/storage – Air recycling – Waste Processing	Real-time Environmental Control – Contaminant/microbial monitoring – Contaminant/microbe control Real-time Radiation Monitoring – Personal dosimetry – Vehicle event-monitoring capability	Automated Biomedical Analysis – Minimally invasive Efficient, Quiet Refrigerator-Freezer Microbial decontamination methods Expert Systems for Medical Care
SEI	Regenerative Life Support – Water reuse/storage – Air recycling – Waste Processing – Food Production Planetary EVA Suit/PLSS – Light Weight – Dexterity/Manueverability – Zero prebreathe – Maintainable by crew Radiation Shielding for Crews Partial-g/μ-g Medical Care Delivery Systems	Real-time Environmental Control – Contaminant/microbial monitoring – Contaminant/microbe control Real-time Radiation Monitoring – Personal dosimetry – Vehicle event-monitoring capability CELSS Support Technologies – Low-energy illumination/light-piping – Nutrient monitoring and control – Waste proc. w/ nutrient recovery – Remote sensing of plant condition – Robotic cultivation/harvesting – Miniature food processing systems – Advanced food systems – Model-based process & system control	Human Artificial Gravity Systems – Torque-neutralized – Tethered or rigid systems – Human-machine interface – μ-g or Partial-g applications

← Highest Priority → ← 2nd-Highest Priority → ← 3rd-Highest Priority →

LAUNCH DATE/MISSION

Code SE Technology Needs (Priority Order)	1998 EOS-A1	2001 EOS-B1/SAR	2003 EOS-A2	2015 GEO
1.	**5-yr-Life Mechanical Coolers**			
2.		**Sub-MN & Microwave Technology**		
3.			**Detector Technology ESP 13-18nm**	
4.		**Long-Life Space Qual Lasers**		
5.			**Hi-Density Hi-Data-rate On-Board Storage**	
6.				**Large Antenna Structure Arrays**
7.	**Parallel Software Environment for Model & Data Assimilation**			
8.		**More Efficient Solar Arrays**		

COST ISSUES/RECOMMENDATIONS FOR OAET ADVISORY GROUP

- TO THE EXTENT THAT OUT-YEAR PLANNING IS TO BE REALIZED, WE NEED TO BUILD-ON AND AUGMENT EXISTING NEAR-TERM CODE S/R EFORTS:

  -- MECHANICAL COOLERS
  -- LAWS BRASSBOARD
  -- OPTICAL DISC RECORDERS

- ENCOURAGE USE OF PEER-REVIEW PROCESS TO TRACK PROGRESS

NASA

NASA OFFICE OF SPACE FLIGHT

Mission User Technology Needs & Applications Integrated Technology Plan External Review

Presentation to Space Systems & Technology Advisory Committee

June 24, 1991

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AGENDA

- **INTRODUCTION**
  - OSF Mission
  - OSF Strategic Planning
- **SPACE SHUTTLE**
  - Strategic Planning
- **FLIGHT SYSTEMS**
  - Strategic Planning
  - Technology Development Activities
- **SPACE STATION FREEDOM**
  - Strategic Planning
  - Technology Development Activities
- **OSF FUTURE TECHNOLOGY NEEDS**
  - Process of Identification
  - NASA Program Unique Technologies (16)
  - Industry Driven Technologies (5)
- **SUMMARY**

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THE OSF MISSION

- The mission of the Office of Space Flight (OSF) is to provide launch vehicles, space transportation, manned space-based facilities and operations in support of the Nation's civil space goals

- In fulfilling its mission, OSF plans, develops, operates and maintains manned space-based facilities and space transportation systems and services

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OSF STRATEGIC PLAN
Basic Themes For Planning

- Continue to provide reliable, timely and cost-efficient services to our customers with the Space Shuttle while developing new and robust transportation systems
- Develop and assemble the Space Station Freedom to begin permanently manned operations in this decade
- Provide the necessary transportation vehicles in support of the Space Exploration Initiative (SEI)
- Continue to honor international commitments and investigate future opportunities for cooperation
- Support the commercial space industry, seeking to maintain U.S. technological leadership in this industry

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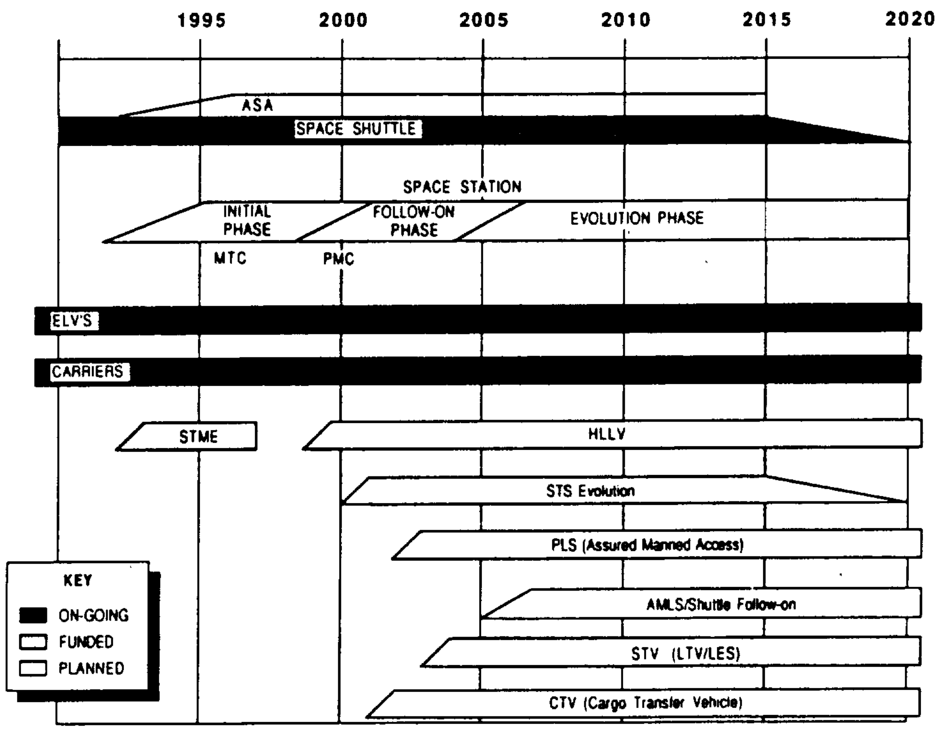
REFERENCE SCHEDULE FOR TECHNOLOGY IDENTIFICATION



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SPACE SHUTTLE PROGRAM
Strategic Plan

- **Provide space transportation to and from low Earth orbit for all programs requiring human presence for the next twenty to thirty years**
  - Major programs to be supported in the future include:
    - Mission to and from planet Earth
    - Space Station Freedom assembly and crew transportation
    - Transportation for scientific and engineering community requiring human presence
- **Preserve or increase safety margins**
  - Major propulsion elements are being developed with part of the benefit being higher safety margins
    - Advanced Solid Rocket Motor
    - Alternate High Pressure Turbopumps

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SPACE SHUTTLE PROGRAM
Strategic Plan

- **Maintain a reasonable and safe flight rate**

  – Flights have been scheduled to live within the requirements of processing the Shuttle system. Current flight schedule: 1991-8, 1992-8; 1993-9; 1994-10

- **Assure Shuttle availability and viability**

  – An Assured Shuttle Availability (ASA) program has been established to provide for specific upgrades to the Shuttle program hardware and software. Initial candidates which have been selected include:
    - Multi-function electronic display to upgrade outdated cockpit displays
    - Replace obsolete hardware interface module cards interfacing between the Shuttle and the launch complex
    - Advanced fabrication effort to improve safety and manufacturability of main engine nozzles, combustion chambers and ducts

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SPACE SHUTTLE PROGRAM
Strategic Plan

- **Enhance Shuttle capability**

  – Modify orbiters to allow the extension of time in space to 16 days
  – Study the feasibility of a 28 day mission with a modified orbiter
  – Increase the payload delivery performance and reduce exposure to some abort contingencies through the use of the Advanced Solid Rocket Motor, now under development

- **Support next-generation vehicle development**

  – Support materials and electronics developments wherever feasible and work closely with propulsion elements on new component designs. Also support advances in manufacturing, vehicle health management, advanced avionics, and electro-mechanical control systems

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NASA Flight Systems

FLIGHT SYSTEMS PROGRAM
Strategic Plans

Advanced Space Transportation

- Establish requirements and define manned systems to initiate Shuttle replacement in 2005 and personnel transport for SEI
- Develop NLS and define growth of HLLV capability for SEI

Commercial Launch Vehicles

- Acquire ELV launch services for U.S. Government Civil Customers
- Provide access to unique/special NASA facilities
- Exploit and support U.S commercial launch vehicle industry

NASA Flight Systems

FLIGHT SYSTEMS PROGRAM
Strategic Plans

Upper Stage/Payload Carrier

- Sustain Spacelab until SSF PMC and provide Shuttle payload carriers
- Improve spacecraft servicing and retrieval in LEO
- Develop a CTV for payload transfer from NLS to SSF
- Establish requirements and initiate concept definition programs for Lunar/Mars transfer vehicles

Technology

- Sustain advanced development activities for critical emerging technologies

FLIGHT SYSTEMS PROGRAM
Technology Development Activities

- Advanced Space Systems
- Advanced Operations
- Advanced Transportation
- Unmanned Launch Vehicles/Upper Stages

NASA Flight Systems

FLIGHT SYSTEMS PROGRAM
Technology Development Activities

Advanced Space Systems

- **Orbital Debris**
  - Measurements (HAYSTACK, GEODSS,LDEF, IRAS,etc)
  - Modeling
  - Protection (Shield development & collision avoidance)
- **Flight Demos**
  - Shuttle secondary payloads (OCTW, FARE, SHOOT, DEE, FSS SAT)
  - Free-Flyer secondary payloads (GPS)
- **Tether Applications**
  - Demo on SEDS-1, PMG, & SEDS-2
  - Future flight demos (ELF/ULF,Trash Disposal, RSR & Station Reboost)

FLIGHT SYSTEMS PROGRAM
Technology Development Activities

Advanced Operations

- **Shuttle Only Projects (12)**
  - Tile processing enhancements
  - SSME testing improvements
  - STS radiator and ET/SRB insulation inspection automation
- **Future Launch Vehicle Projects (12)**
  - Operations optimization studies
  - Automated mechanisms
  - Advanced software applications (Neural Nets, Fuzzy Logic, Virtual Imaging)
- **Current & Future Program Projects (34)**
  - Application of expert systems, advanced graphics & optical data systems to mission operations
  - Fiber optics application to ground audio/video/data communications
  - Advanced sensors & instrumentation development

FLIGHT SYSTEMS PROGRAM
Technology Development Activities

Advanced Transportation

- **Bridging Programs**
  - Electrical actuation
  - Autonomous guidance, navigation & control
  - Aluminum-Lithium alloys
  - Potential new bridging programs:
    - Vehicle Health Management
    - Propulsion
    - Avionics
    - Manufacturing
- **Advanced Recovery**
  - Demos (drop tests of payloads with parafoils)
  - Wind tunnel tests
- **Autonomous Rendezvous & Docking (CTV, MTV, LTV)**
  - Define requirements and develop ground prototypes
  - Flight demonstrations
- **Cryofluid Management**

FLIGHT SYSTEMS PROGRAM
Technology Development Activities

Unmanned Launch Vehicles/Upper Stages

- **ELV Technology Validation and Demonstration (Proposed)**
  - With industry, identify mature technologies ready for infusion into current production/operations
  - Bridge gap between R&T and adaptation into current flight systems
  - Conduct validation/demonstration; build and test projects to prove design/cost/benefits/implementation

- **Solid Propulsion Integrity Program (SPIP)**
  - Put in place the engineering capability for improving the success rate of U.S. built solid rocket motors
  - Improve science and engineering in design, manufacture, verification, and in a functional community culture
  - Establish a nationally recognized NASA leadership role in the solid rocket motor field

SPACE STATION FREEDOM PROGRAM
Strategic Plans

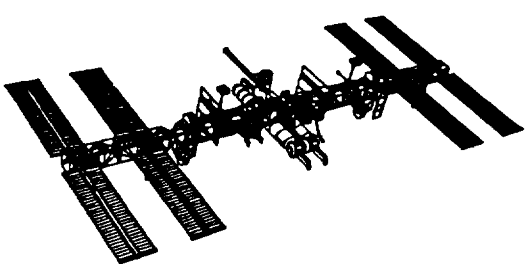
- **Design, develop, assemble and test the initial phase of Space Station Freedom**
  - Launch the first element of SSF in 1996
  - Provide a Man Tended Capability (MTC) by 1997
  - Provide a Permanently Manned Capability (PMC) by 1999
- **During MTC, provide user operations capability during untended periods**
  - Three utilization Shuttle flights per year to resupply/operate user experiments
  - Optimal conditions for microgravity science
- **Provide continuous operations with four person crew during PMC**
  - Significant life sciences capabilities including a centrifuge facility
  - Continued opportunities for microgravity and technology experiments
  - Assured return-to-earth capability for entire crew at all times

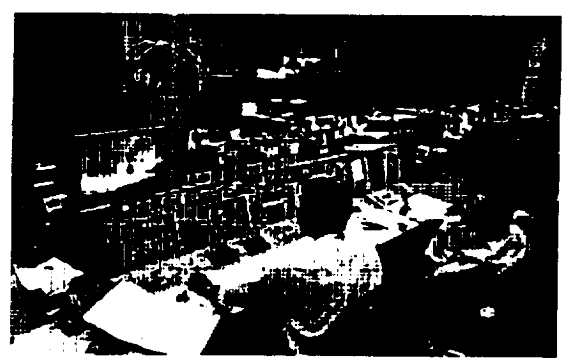
SPACE STATION FREEDOM PROGRAM
Strategic Plans

- **Increase the capabilities beyond PMC during a follow-on phase with planned and candidate additions**
  - Planned additions include added power (to 75 kW total) and 8 person crew size
  - Pace of augmentation based on budget and user demand
- **Provide flexibility to grow and evolve the Space Station in the long term**
  - Support capability and function growth to support exploration and changing research and development user needs
  - Capability targets (for planning purposes) include 150 kW, crew size of 14, and structure augmentations for technology payloads and SEI vehicle processing
  - Milestone targets (for planning purposes) include SEI Life Sciences/Technology Test Bed capability in 2004 and SEI Lunar Vehicle Processing capability in 2007

SPACE STATION FREEDOM PROGRAM
TECHNOLOGY DEVELOPMENT ACTIVITIES

<u>Flight & Ground Systems Automation</u>





OBJECTIVES:

- **In the areas of SSF distributed systems monitoring, fault detection, isolation, and repair:**
  - **Provide mature technology base for Space Station Freedom**
  - **Identify and document required design accommodations**
- **Demonstrate fault detection, isolation, and repair and data monitoring for payloads**

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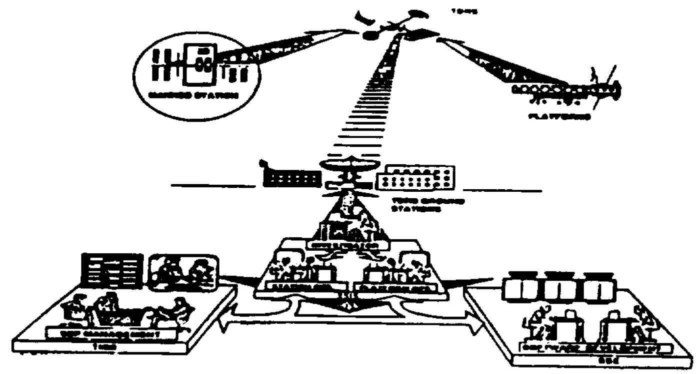
SPACE STATION FREEDOM PROGRAM

TECHNOLOGY DEVELOPMENT ACTIVITIES

Information Systems



OBJECTIVES:

- **Increase Space Station Data Management System performance and reliability**
- **Demonstrate advanced processors, mass storage devices, displays, and network components and document long-range growth requirements**
- **Develop and demonstrate advanced ground-based and on-board mission planning and scheduling tools**

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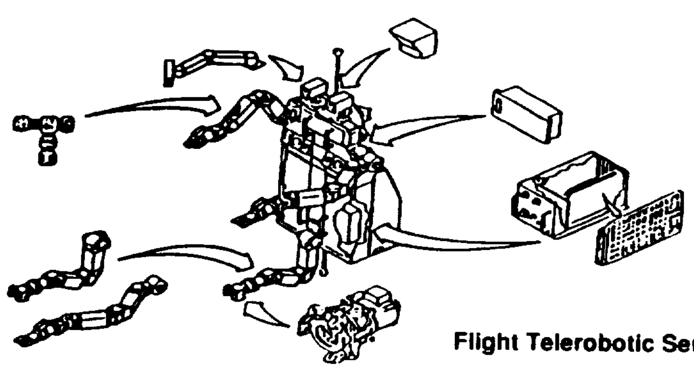
SPACE STATION FREEDOM PROGRAM

TECHNOLOGY DEVELOPMENT ACTIVITIES

Telerobotics



Flight Telerobotic Servicer (FTS)

OBJECTIVES:

- **Reduce EVA demand thru increased use of SSF robotic systems**
- **Reduce the on-orbit time required for SSF robotic tasks**
- **Increase autonomy for simple, frequently performed tasks**
- **Develop and demonstrate capability to perform ground-based operations of SSF robots**

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OSF TECHNOLOGY REQUIREMENTS

- In July 1990, AA/OAET requested periodic update of "technology requirements" from OSF
- OSF response based on re-evaluation of OSF technology needs
  - "Bottoms-up" and "top-down" assessment performed
- Technology requirements evaluation process conducted from August 1990 thru February 1991
- "OSF Technology Requirements - Planning and Definition for Coordinated Programs" Report transmitted to OAET in April 1991

NASA

OFFICE OF SPACE FLIGHT TECHNOLOGY REQUIREMENTS

Submittals from OSF Centers

- **From Centers**
  MSFC....184
  JSC........336
  KSC........37
  SSC........27
  TOTAL....584
- **From ALS/ADP**
  46 Tasks
- **From COMSTAC**
  13 Tasks
- **From SSF**
  115 Tasks

→

Combined for Common Theme

192 Technology Requirements within 22 Technology Categories

→

Priority Requirements

TOTAL....21

Program Unique.....16

Industry Driven........5

NASA

OSF TECHNOLOGY REQUIREMENTS

REPORT OUTLINES:
- CONTINUING PROCESS OF COORDINATION BETWEEN OSF AND OAET
- ANNUAL JOINT REVIEW OF TECHNOLOGY REQUIREMENTS

REPORT RECOGNIZES:
- NEED FOR FORMAL TECHNOLOGY TRANSFER BETWEEN OSF AND OAET
- NEED TO ACCOMPLISH TECHNOLOGY TRANSFER BETWEEN NASA RESEARCH AND FLIGHT CENTERS

REPORT COMMITS OSF:
- JOINT ACTIVITIES DIRECTED TO ACCOMPLISHMENT OF SPECIFIC CAPABILITIES
- TO SUSTAINED SUPPORT OF TECHNOLOGY REQUIREMENTS DEVELOPMENT

THE REPORT PRESENTS 21 OSF TECHNOLOGY REQUIREMENTS TO OAET FOR CONSIDERATION OF JOINT ACTIVITIES

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OSF Technology Requirements Evaluation

NASA Program Unique Technologies

1 Vehicle Health Management
2 Advanced Turbomachinery Components & Models
3 Combustion Devices
4 Advanced Heat Rejection Devices
5 Water Recovery & Management
6 High Efficiency Space Power Systems
7 Advanced Extravehicular Mobility Unit Technologies
8 Electromechanical Control Systems/Electrical Actuation
9 Crew Training Systems
10 Characterization of Al-Li Alloys
11 Cryogenic Supply, Storage & Handling
12 Thermal Protection Systems for High Temperature Applications
13 Robotic Technologies
14 Orbital Debris Protection
15 Guidance, Navigation & Control
16 Advanced Avionics Architectures

Industry Driven Technologies

Signal Transmission & Reception
Advanced Avionics Software
Video Technologies
Environmentally Safe Cleaning Solvents, Refrigerants & Foams
Non-Destructive Evaluation

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OSF TECHNOLOGY REQUIREMENTS

Vehicle Health Management

- **Drivers**
  - Limited on-orbit crew time requires sophisticated monitoring and diagnostic systems to maximize crew support to users on SSF
  - New launch systems in the 1995-2000 timeframe will require low operating costs and high mission success probability

- **Technology Areas**
  - Smart sensors and sensor redundancy
  - Processors and data networks
  - Maintenance diagnostics and intelligent algorithms
  - Component/system integration and demonstration

- **Challenges**
  - Robust, highly reliable sensors for hostile environments
  - Highly reliable, real time process and control
  - Interoperable and extensible components, subsystems, and systems
  - System accessibility for testability, maintainability, and reliability

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OSF TECHNOLOGY REQUIREMENTS

Advanced Turbomachinery Components & Models

- **Drivers**
  - To design and develop advanced turbomachinery hardware for next generation of vehicles that:
    - Operates with greater reliability
    - Reduces production and operation costs
    - Reduces maintenance time

- **Technology Areas**
  - Large scale bearings, seals and structures for launch vehicle LOX, LH2 & LHC turbines and pumps
  - Design and demonstrate smaller scale T/P components and systems for STV

- **Challenges**
  - Extend and demonstrate ALS-ADP technologies in systems tests
  - Understand technologies required of commercial turbopumps and demonstrate through NASA R&T
  - Continue component tests and initiate systems demonstration of ALS/NLS wide margin, high operability T/P configurations
  - Verify evolving CFD/CAE/CAD models during ground testing program

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OSF TECHNOLOGY REQUIREMENTS

Combustion Devices

- **Drivers**
  - To design and fabricate low cost, durable, reliable launch vehicle rocket motors compatible with space-based, fully reusable spacecraft propulsion systems for future space transportation vehicles

- **Technology Areas**
  - Fabrication methods for thrust chambers & related component for robust wide margin designs
  - Expander cycle engine definition for STV
  - Test program to assure design to cost capability

- **Challenges**
  - Demonstrate thrust chamber, nozzle, & injector concepts through ground testing program
  - Define, build and test an advanced expander cycle engine
  - Establish design and verify cost models for rocket thrust chambers

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OSF TECHNOLOGY REQUIREMENTS

Advanced Heat Rejection Devices

- **Drivers**
  - Space Station Freedom Thermal Control System capability will be augmented commensurate with increased power generation capability in the 2000 to 2005 timeframe

- **Technology Areas**
  - Heat pumps
  - Heat pipes

- **Challenges**
  - Heat pump that operates in microgravity with COP>4
  - 60% mass reduction in heat pipes over state-of-the-art without reduction in performance
  - Heat pipes which operate above 120 degrees Fahrenheit with >90% efficiency

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OSF TECHNOLOGY REQUIREMENTS

Water Recovery & Management

- **Drivers**
  - The water loop for Space Station Freedom is planned to be closed in the post 2000 timeframe, giving an opportunity to include new technologies
  - Increases in SSF permanent crew size in the 2003 - 2006 timeframe will require reduced logistics and increased safety
- **Technology Areas**
  - Real-time microbial analysis
  - Water reclamation and waste processing
- **Challenges**
  - Analysis methods and detectors which provide real-time detection and quantification of microorganisms using small sample sizes
  - 100% recovery of water in the waste stream
  - Simultaneous liquid / heterogeneous waste processing within a single unit
  - Membranes and filters which resist fouling and have a long life

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OSF TECHNOLOGY REQUIREMENTS

Advanced EMU Technologies

- **Drivers**

  A need for reducing the crew time overhead and logistics associated with EVA will develop

  -- As Space Station Freedom evolves and EVA maintenance requirements grow

  -- If SSF is used as an assembly / transportation node for on-orbit vehicle processing in the 2008 timeframe
- **Technology Areas**
  - Suit components
  - Portable life support systems
- **Challenges**
  - Gloves which operate at 8.3 psi
  - Regenerable carbon dioxide removal systems which operate for 8 hours
  - Regenerable heat storage & rejection systems

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OSF TECHNOLOGY REQUIREMENTS

Electromechanical Control Systems/Electrical Actuation

- **Drivers**
  - To design and develop next generation of control effectors that:
    - Provide significant reductions in ground checkout operations, vehicle maintenance cost/complexity associated with the conventional hydraulic power systems
    - Eliminates hazardous fluids (hydrazine) and high pressure hydraulics
- **Technology Areas**
  - EMA component development and demonstration
  - Power conditioning & distribution system
  - Integrated electrical power systems
- **Challenges**
  - Develop and demonstrate Electro-Mechanical (EMA) and Electro-Hydraulic (EHA) Actuation devices
  - Demonstrate advanced electric power systems with surge/demand capability
  - Breadboard/Ironbird test of integrated power control system

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OSF TECHNOLOGY REQUIREMENTS

Crew Training Systems

- **Drivers**
  - Long mission durations aboard Space Station Freedom will require enhanced procedure retention techniques
  - Overall training life cycle costs for SSF crews must be reduced
- **Technology Areas**
  - Intelligent training development and support environments
  - Virtual reality
  - Large scale simulation and network communication
- **Challenges**
  - On-board accessibility to large ground-based training simulations
  - Virtual reality with multisensory I/O
  - Integration of training models, simulation S/W, and high-res displays
  - Computer aided training utilizing autonomous learning techniques

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OSF TECHNOLOGY REQUIREMENTS

Characterization of Al-Li Alloys

- **Drivers**
  - Significantly reduced weight in spacecraft and launch vehicles
- **Technology Areas**
  - Characterization of Al-Li plate materials and joining processes
  - Characterization of Al-Li alloy materials and joining processes for thin gauge applications
  - Screen alloy combinations for compatibility and reusability
- **Challenges**
  - Continue activities initiated in ALS-ADP directed to heavy gauge fabrication and demonstrations for launch vehicle tanks
  - Sustain screening and characterization and fabrication methods definition for reusable spacecraft tank and structural applications
  - Explore alloy formulations compatible with oxygen, hydrogen, high radiation environments, etc.

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OSF TECHNOLOGY REQUIREMENTS

Cryogenic Supply, Storage & Handling

- **Drivers**
  - To design and develop Cryogenic Fluid Systems that must perform under critical zero-g conditions in support of propulsion and surface operations for Lunar/Mars as well as space-based operations
  - Zero-g cryo technologies critical for pressure control, low boil-off, long-term fluid storage & contingency (refill/fill/drain) capability
- **Technology Areas**
  - Zero-g LN2/LH2 model validation & design codes
  - Zero-g LH2 validation
- **Challenges**
  - Conduct test programs at MSFC and LeRC to develop necessary ground based technology base
  - Initiate and sustain NRA Tasks identified by universities and industry in Cryo-technologies
  - Evaluate viable long duration in-space flight experiments
  - Sustain funding support of sub-critical zero-g cryogenic technologies to provide necessary flight tests for Lunar /Mars missions

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OSF TECHNOLOGY REQUIREMENTS

Robotic Technologies

- **Drivers**
  - Space Station Freedom maintenance in the 2005 timeframe will be enhanced by increased autonomy and robustness for telerobots
  - Vehicle assembly and processing in the 2008 timeframe will require increased capability for complex telerobotic tasks
- **Technology Areas**
  - Telerobotic control system software
  - Sensing and sensor fusion
  - Simplified collision avoidance and trajectory replanning
  - Automated task planning and sequencing
- **Challenges**
  - Generalized solutions to 7-dof motion
  - Multi-arm coordinated/cooperative control
  - Reduced on-orbit computational capability
  - Computational or communications-induced time delays

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OSF TECHNOLOGY REQUIREMENTS

Orbital Debris Protection

- **Drivers**
  - Uncertainties exist in prediction of the orbital debris environment
  - Addition of pressurized modules on Space Station Freedom in the post 2000 timeframe will benefit from enhanced debris protection
- **Technology Areas**
  - Advanced Shielding
  - High Velocity Impact (HVI) Testing
- **Challenges**
  - Significant protection / lb-on-orbit increases over current whipple and multi-shock designs
  - HVI testing for particles up to 2 cm diameter at 15 km/sec

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OSF TECHNOLOGY REQUIREMENTS

Guidance, Navigation & Control

- **Drivers**
  - Increased launch probability with real-time wind profiling
  - Improvements in flight safety
  - Reductions in operating costs
- **Technology Areas**
  - GN&C sensors and sensing devices
  - Ground & onboard guidance algorithms
  - Navigation & control algorithms
  - LIDAR systems development and demonstration
- **Challenges**
  - Ground demonstrations & flight experience in GN&C autonomous systems operations
  - All weather launch envelope with in-flight GN&C capability
  - Active real-time vehicle dynamics, flight dynamics, and flight path control programs
  - Demonstrate real-time atmosphere dynamics measurements

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OSF TECHNOLOGY REQUIREMENTS

Advanced Avionics Architecture

- **Drivers**
  - Provide modular, scalable architectures with common interfaces; core concepts to allow support of multiple programs
  - Autonomous real-time operating systems; automated FDIR & dormancy support
  - Checkout automation & on-board built-in-test
- **Technology Areas**
  - Software technologies
  - Data processing system & network components
- **Challenges**
  - Avionics system packaging technology
  - Apply advanced avionics architectures/software to SSF systems
  - Incorporate data processing, networking, monitoring and control architecture to NLS integrate-transport-and launch processes

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OSF TECHNOLOGY REQUIREMENTS

Industry Driven Requirements

- **In these five technologies, OSF assessment identified/recognized some or all of the following:**
  - State-of-the-art moving rapidly
  - Industry funding/market forces dominate; industry capabilities clearly superior to NASA
  - No urgency for NASA to freeze technology prematurely

- **NASA can defer to industry for evolution and development**
  - Apply limited funding to NASA unique technology requirements

- **NASA must monitor evolving industry technologies**
  - Assure evolving technologies will satisfy NASA needs
  - Understand how NASA will apply new technology

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SUMMARY

- **OSF strategic planning and advanced development activities have been described for each of the three OSF Program Directorates**

- **OSF technology needs presented today have been developed from a bottoms-up identification process with the OSF Centers and a top-down assessment with the OSF Associate Administrator and the program directorates**
  - 21 OSF Technology Needs have been transmitted to OAET and are represented in the Integrated Technology Plan for consideration of joint activities
    - **16 are NASA Program Unique Technologies**
    - **5 are Industry Driven**

Office Of Space Flight

OFFICE OF SPACE OPERATIONS

PRESENTATION TO SPACE SYSTEMS AND TECHNOLOGY ADVISORY COMMITTEE

JUNE 24, 1991

HUGH S. FOSQUE, DIRECTOR
ADVANCED SYSTEMS OFFICE

NASA **OFFICE OF SPACE OPERATIONS** Office of Space Operations

ADVANCED SYSTEMS PROGRAM
PROGRAM DESCRIPTION

- OBJECTIVES: TO IMPROVE SYSTEM PERFORMANCE AND CAPABILITY TO MEET MISSION REQUIREMENTS WITH MINIMUM COST
- EMPHASIS: APPLIED RESEARCH, DEVELOPMENT, AND TECHNOLOGY TRANSFER TO IMPLEMENTATION
- APPROACH: ANTICIPATE REQUIREMENTS AND STIMULATE APPROPRIATE RESEARCH, DEVELOPMENT AND DEMONSTRATIONS
- RESOURCES: FY91 NOA - $20 MILLION

NASA OFFICE OF SPACE OPERATIONS

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ADVANCED SYSTEMS PROGRAM
CRITERIA FOR SELECTING TASKS

- TECHNOLOGY NEED ANTICIPATED BUT CURRENTLY UNAVAILABLE AND R&D PROGRESS NOT SUFFICIENT IN OTHER FEDERAL PROGRAMS OR INDUSTRY
- TECHNOLOGY IS SUITABLE FOR USE IN FUTURE MISSION OPERATIONS
- TECHNOLOGY HAS A HIGH POTENTIAL FOR:
  - INCREASING NETWORK VERSATILITY, RELIABILITY AND COST EFFECTIVENESS
  - MEETING PERFORMANCE NEEDS OF MULTIPLE USERS
- MATCHING SPACECRAFT DEVELOPMENT IS ANTICIPATED
- SUFFICIENT RESOURCES ARE AVAILABLE

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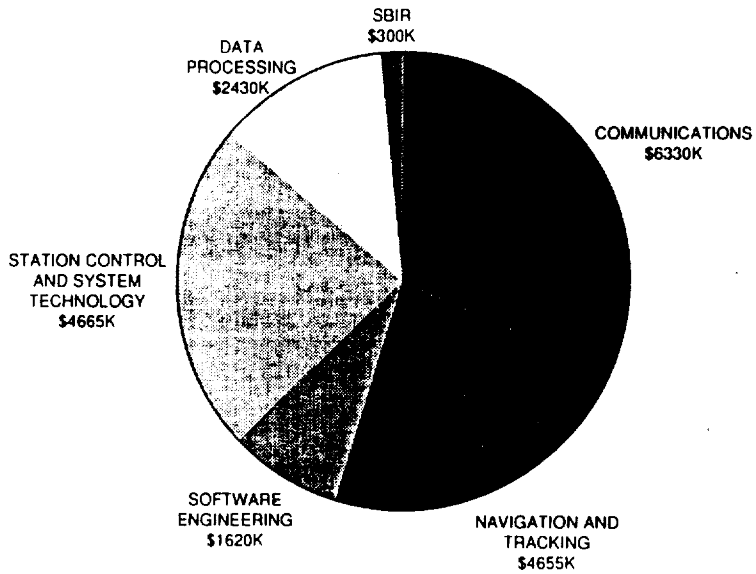
ADVANCED SYSTEMS PROGRAM
AREAS OF INVESTIGATION

- COMMUNICATIONS
- NAVIGATION AND TRACKING
- SOFTWARE ENGINEERING
- STATION CONTROL AND SYSTEM TECHNOLOGY
- DATA PROCESSING

NASA OFFICE OF SPACE OPERATIONS

Office of Space Operations

ADVANCED SYSTEMS PROGRAM
FY91 BUDGET



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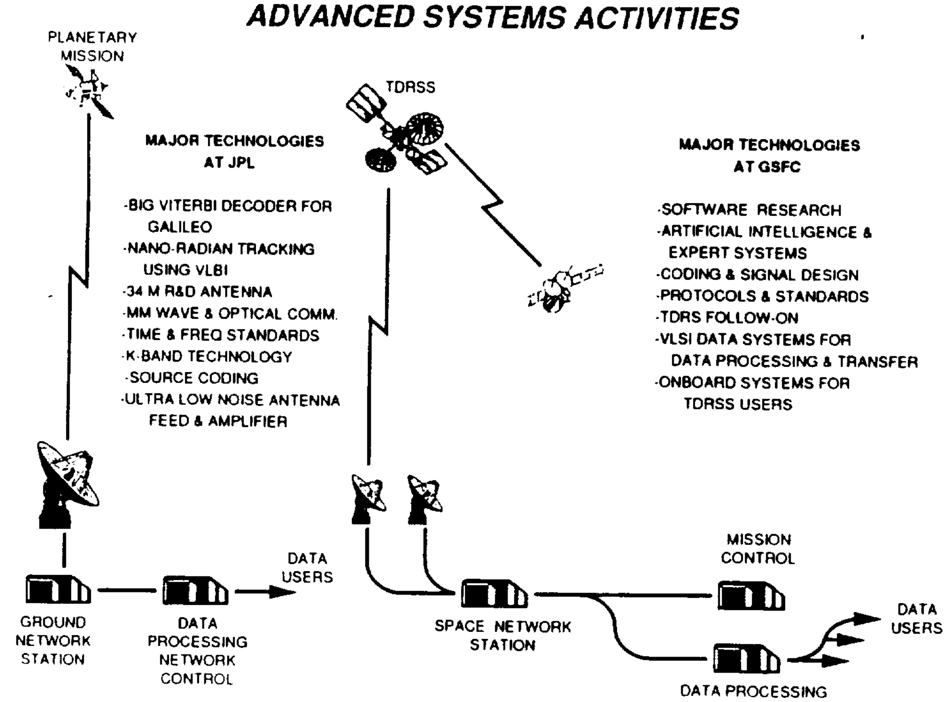
Office of Space Operations

ADVANCED SYSTEMS ACTIVITIES



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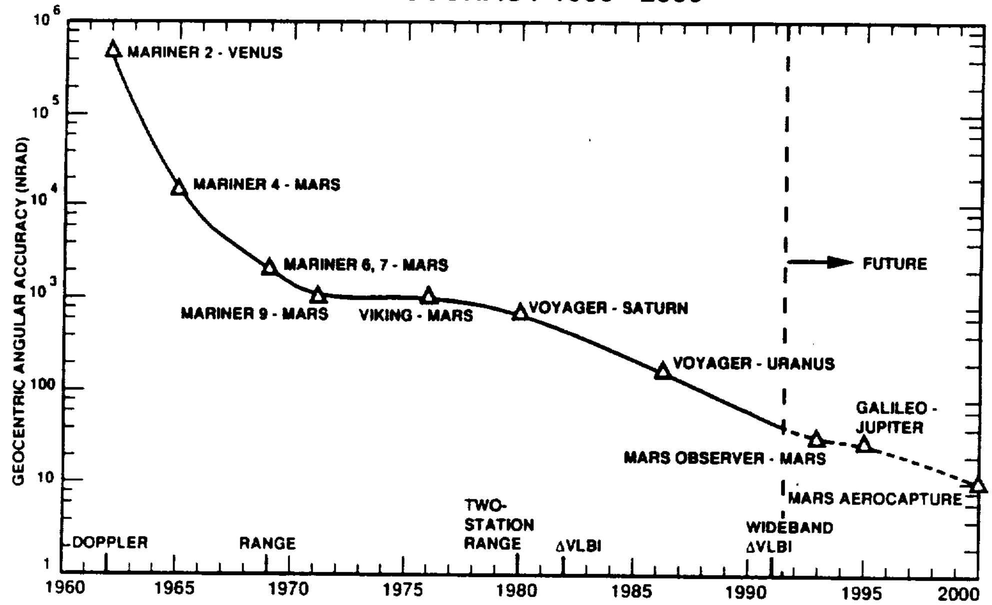
DEEP SPACE COMMUNICATIONS
EVOLUTION OF DSN RADIO NAVIGATION SYSTEM ACCURACY 1960 - 2000



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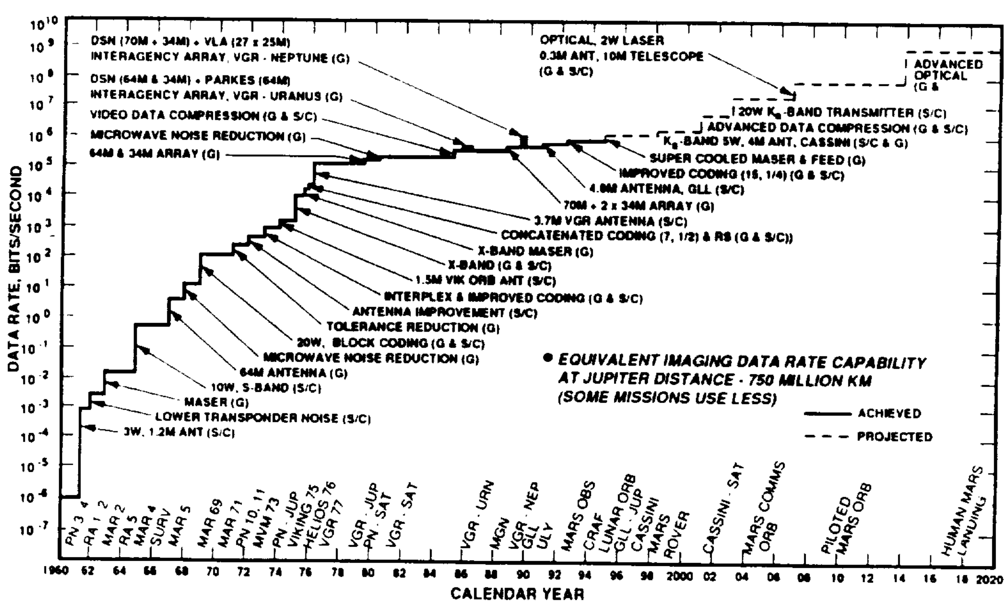
ADVANCED SYSTEMS
PROFILE OF DEEP SPACE TELEMETRY CAPABILITY IMPROVEMENTS



NASA OFFICE OF SPACE OPERATIONS

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SPACE TECHNOLOGY REQUIREMENTS
TECHNOLOGY DEVELOPMENT DRIVERS

NEAR TERM:

- REFINE AND EXTEND STATE OF THE ART TECHNOLOGY TO MEET DEMANDS FOR ENHANCED CAPABILITIES
- BASICALLY UPGRADE EXISTING EQUIPMENT AND TECHNIQUES
- MORE POWER, HIGHER DATA RATES, LOWER ERROR RATE

LONGER TERM:

- DEVELOP NEW TECHNOLOGIES NEEDED FOR FUTURE MISSIONS
- DEPENDENT ON MISSION CHARACTERISTICS TO BE DEFINED BY USERS:
  - SPACE STATION, EOS, OTHERS

FAR TERM:

- LINKED TO EMERGENCE OF MISSION CHARACTERISTICS DEFINED BY USERS:
  - DEVELOP NEW TECHNOLOGIES FOR LUNAR AND MARTIAN EXPLORATION (TECHNOLOGIES HAVE BEEN IDENTIFIED AND INCLUDED UNDER THE OAET EXPLORATION PROGRAM)

NASA OFFICE OF SPACE OPERATIONS

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SPACE TECHNOLOGY REQUIREMENTS
MAJOR AREAS OF TECHNOLOGY DEVELOPMENT NEEDS

HIGH DATA RATE COMMUNICATIONS

- OPTICAL AND MILLIMETER WAVE FREQUENCIES FOR SPACE-TO-GROUND AND SPACE-TO-SPACE LINKS
- EXAMPLES: HIGH DATA RATE LINKS BETWEEN:
  - USER S/C AND TDRSS
  - CROSS LINKS BETWEEN MULTIPLE TDRSS SPACECRAFT
  - TDRSS AND GROUND CONTROL STATIONS

ADVANCED DATA SYSTEMS

- DATA STORAGE, DATA COMPRESSION, AND INFORMATION MANAGEMENT SYSTEMS
- EXAMPLES:
  - HIGH CAPACITY OPTICAL AND MAGNETIC STORAGE SYSTEMS
  - ORDERS OF MAGNITUDE DATA COMPRESSION
  - INFORMATION MANAGEMENT SYSTEMS FOR CDOS, EOS, AND EXPLORATION PROGRAMS

NASA **OFFICE OF SPACE OPERATIONS**

Office of Space Operations

SPACE TECHNOLOGY REQUIREMENTS
MAJOR AREAS OF TECHNOLOGY DEVELOPMENT NEEDS (CONT)

ADVANCED NAVIGATION TECHNIQUES

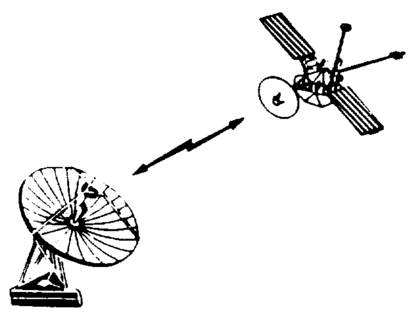
- ADVANCED TECHNIQUES FOR CRUISE, APPROACH, AND IN-ORBIT NAVIGATION FOR MANNED AND UNMANNED PLANETARY MISSIONS
- TRACKING ACCURACIES ON THE ORDER OF ONE NANORADIAN OR LESS

MISSION OPERATIONS

- INTRODUCE INCREASED AUTOMATION THRU THE USE OF ARTIFICIAL INTELLIGENCE, EXPERT SYSTEMS AND NEURAL NETWORKS
- DEVELOP TEST BEDS FOR TEST AND PROTOTYPING OF ADVANCED SOFTWARE
- DEVELOP TECHNIQUES FOR COORDINATION OF DISTRIBUTED SOFTWARE
- AUTOMATED PERFORMANCE ANALYSIS OF NETWORKED COMPUTING ENVIRONMENTS

NASA **TELECOMMUNICATIONS TECHNOLOGY**

Office of Space Operations



TECHNOLOGY NEEDS

Ka-BAND:
- 10-200 W TWTA TRANSMITTERS
- 1-20 W SSPA TRANSMITTERS
- PRECISION 5m REFLECTOR ANTENNA
- ELECTRONICALLY STEERED MBA
- MMIC PHASED ARRAYS
- RECONFIGURABLE ANTENNAS
- MMIC TRANSMIT/RECEIVE DEVICES
- LARGE (10-20m) DEPLOYABLE ANTENNAS

OPTICAL:
- 5W LASER TRANSMITTER
- LOWER NOISE DETECTOR
- LARGE PRECISION OPTICS

TECHNOLOGY BENEFITS

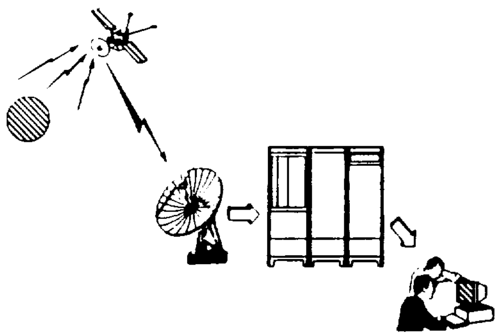
- Ka-BAND OFFERS HIGH GAIN WITH REDUCED ANTENNA DIMENSIONS OVER PRESENT X-BAND
- Ka BAND ACHIEVES REQUIRED DATA RATE WITH PRACTICABLE DESIGNS
- OPTICAL OFFERS HIGHER GAIN WITH POTENTIALLY LOWER MASS THAN RF SYSTEMS
- Ka-BAND MORE MATURE THAN OPTICAL

TECHNOLOGY APPLICATIONS

- LUNAR SURFACE TERMINAL
- MARS SURFACE TERMINAL
- MARS, LUNAR, AND MARS RELAY SATELLITES
- COMMUNICATIONS FOR TRANSIT USERS
- COMMUNICATIONS FOR ROVERS
- COMMUNICATIONS FOR SCIENCE INSTRUMENTS
- COMMUNICATIONS FOR LOW ORBIT IMAGING PAYLOADS

INFORMATION MANAGEMENT TECHNOLOGY

NASA — Office of Space Operations



TECHNOLOGY NEEDS

- DATA COMPRESSON ALGORITHMS AND HARDWARE TO PROVIDE 10:1 LOSSLESS COMPRESSION
- DATA STORAGE DEVICES CAPABLE OF 10^{12} BYTES OF STORAGE WITH FAST DATA RETRIEVAL
- POWER/BANDWIDTH EFFICIENT MODULATION AND CODING TECHNIQUES
- UNATTENDED NETWORK OPERATIONS
- FAULT TOLERANT DESIGNS
- DATA STANDARDS AND PROTOCOLS

TECHNOLOGY BENEFITS

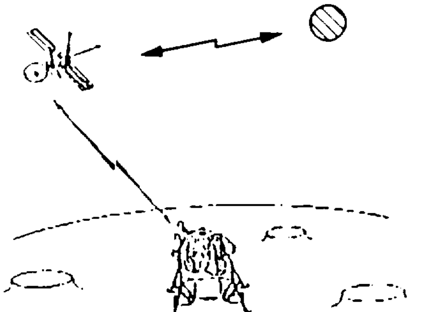
- DATA COMPRESSION REDUCES REAL-TIME DATA TRANSMISSION RATES AND DATA STORAGE REQUIREMENTS
- DATA STORAGE REDUCES PEAK DATA TRANSMISSION RATES AND PREVENTS LOSS OF DATA DURING EMERGENCIES AND PLANNED OUTAGES
- UNATTENDED NETWORK OPERATIONS REDUCES MANPOWER REQUIREMENTS AND LOWERS OPERATING COSTS
- REMOVES POTENTIAL HUMAN ERROR/INCREASES RELIABILITY
- AUTOMATIC SCHEDULING PROVIDES MAXIMUM USE OF A LIMITED RESOURCE

TECHNOLOGY APPLICATIONS

- DATA COMPRESSION CODERS/DECODERS FOR VIDEO AND SCIENCE IMAGING CAMERAS, TELEROBOTICS VIDEO, AND TELEMETRY APPLICATIONS
- OPTICAL DATA STORAGE DEVICES (CD-ROM, WORM, EOD) FOR ARCHIVING AND BUFFERING DATA
- ADVANCED DIGITAL SIGNAL PROCESSING HARDWARE
- FULLY UNATTENDED NETWORK OPERATIONS

NAVIGATION TECHNOLOGY

NASA — Office of Space Operations



TECHNOLOGY NEEDS

- NAVIGATION TRANSPONDERS
- GPS-TYPE NAVIGATION RECEIVERS
- ALTIMETERS/PRESSURE/TEMPERATURE SENSORS NARROW-ANGLE AND WIDE-ANGLE CAMERAS
- INERTIAL MEASUREMENT UNITS
- STABLE LONG-LIFE CLOCKS AND OSCILLATORS

TECHNOLOGY BENEFITS

- A MARS-BASED NAVIGATION SYSTEM ELIMINATES THE TIME DELAY IN PROCESSING THE SIGNALS AT EARTH
- ON-BOARD NAV CAPABILITY WILL INCREASE ACCURACY AND PROVIDE SAFE AEROBRAKING
- REAL-TIME NAVIGATION REDUCES RISK AND INCREASES ACCURACY
- PROVIDES INCREASED SCIENTIFIC BENEFITS

TECHNOLOGY APPLICATIONS

LUNAR:
- PRECISION ORBIT DETERMINATION OF SCIENTIFIC ORBITERS
- EARTH-BASED POSITION/VELOCITY DETERMINATION FOR ALL SYSTEM ELEMENTS

MARS:
- REAL-TIME ON-BOARD NAV CAPABILITY FOR APPROACH, AEROCAPTURE, LANDING, EXPLORATIONS, ASCENT, RENDEZVOUS AND DOCKING
- AUTONOMOUS NAVIGATION COMPUTERS
- MARS-BASED NAVIGATION NETWORK
- 2-5 MARS NAVIGATION SATELLITES

PL-6

INTEGRATED TECHNOLOGY PLAN

EXTERNAL REVIEW

SSTAC / ARTS / ET AL

M	T	W	Th	Fri
		ADMIRAL TRULY	TECH PANELS	PLENARY REVIEW OF PANEL SUMMARIES — 3 hrs
		CHAIRMAN		
		TECH PANELS	PREPARE TECH PANEL SUMMARIES	

TECHNICAL DISCIPLINE LEADERS

POWER - ROSE

PROPULSION - MOORE

HUMANS - O'NEAL / HOLLOWAY

MTLS/STRUCTURES - MAR

SENSORS/INFO - JANNI / HUPBARTH

A & R / G & C - DALY / REDIESS

COMMUNICATIONS/PHOTONICS/HTSC - GOLDING

AEROTHERMO - BOGDONOFF

SPACE R & T PRIORITIES

- REDUCE DEVELOPMENTAL UNCERTAINTIES
  - COST, SCHEDULE
- REDUCE COST OF ACCESS TO SPACE
  - TRANSPORTATION
  - OPERATIONS
  - S/C SIZE
- INCREASE RELIABILITY
- ENHANCE MISSION PERFORMANCE
- ENABLE NEW CAPABILITIES
- BREADTH OF APPLICATIONS
- KEEP NASA TECHNICALLY CURRENT

POSSIBLE EVALUATION CRITERIA

- WHAT NEW OR IMPROVED CAPABILITY WILL RESULT IF SUCCESSFUL?
- WHO ARE THE POTENTIAL CUSTOMERS?
- IS IT A MAJOR STEP IN TECHNOLOGY?
- DOES EFFORT OVERLAP OTHER NATIONAL PROGRAMS?
- WHAT IS POSSIBLE TIME FRAME?
- ARE CLEAR ACCOMPLISHMENTS AND MILESTONES PLANNED?
- IS EFFORT FOCUSSED OR SPREAD AROUND?
- FOR EACH AREA, ARE PRIORITIES IN CORRECT ORDER?
- WHAT IS PERCEIVED VALUE OF ITEMS NOT RECOMMENDED FOR FUNDING?

SUGGESTED OUTLINE FOR TECH PANEL SUMMARIES

- BACKROUND
- STATUS
- KEY TECHNOLOGY OPPORTUNITIES
- POTENTIAL PAY OFFS
- CONSEQUENCE OF NO ACTION
- RECOMMENDATIONS
- ASSESSMENT OF PLAN

REFERENCE

SPACE TECHNOLOGY TO
MEET FUTURE NEEDS
NRC : 1987

INTEGRATION GROUP :

SSTAC

ASEB

AMAC

SSAAC

(CO)CHAIR'S OF TECH PANEL

INTEGRATED TECHNOLOGY PLAN OVERVIEW

Presentation to:
THE ITP EXTERNAL REVIEW TEAM

Gregory M. Reck
Director for Space Technology
Office of Aeronautics, Exploration and Technology

June 25, 1991

O-A-E-T

ITP OVERVIEW

OAET

- SPACE R&T PROGRAM APPROACH
- INTEGRATED TECHNOLOGY PLAN DEVELOPMENT
- INTEGRATED TECHNOLOGY PLAN STRUCTURE
- BUDGET DEVELOPMENT
- SUMMARY COMMENTS

NASA ACTION PLAN

ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

RECOMMENDATION 8:

That NASA, in concert with the Office of Management and Budget and appropriate Congressional committees, establish an augmented and reasonably stable share of NASA's total budget that is allocated to advanced technology development. A two- to three-fold enhancement of the current modest budget seems not unreasonable.

In addition, we recommend that an agency-wide technology plan be developed with inputs from the Associate Administrators responsible for the major development programs, and that NASA utilize an expert, outside review process, managed from headquarters, to assist in the allocation of technology funds.

NASA ADMINISTRATOR ACTION:

Codes R/M/S/O/AA for Exploration (Code R lead): Provide an integrated agency-wide technology development plan (using the FY 91 appropriated budget as the base, and based on two- and three-fold budget increase); due at macro level 6/91; refined plan 11/91

RECOMMENDATION 7:

That Technology Be Pursued Which Will Enable A Permanent, Possibly Man-Tended Outpost To Be Established On The Moon For The Purposes of Exploration And For The Development Of The Experience Base Required For The Eventual Human Exploration Of Mars.

That NASA Should Initiate Studies Of Robotic Precursor Missions and Lunar Outposts.

NASA ADMINISTRATOR ACTION:

Include Technology Aspects in The Technology Planning Action Responding to Recommendation 8

INTEGRATED TECHNOLOGY PLAN PROCESS

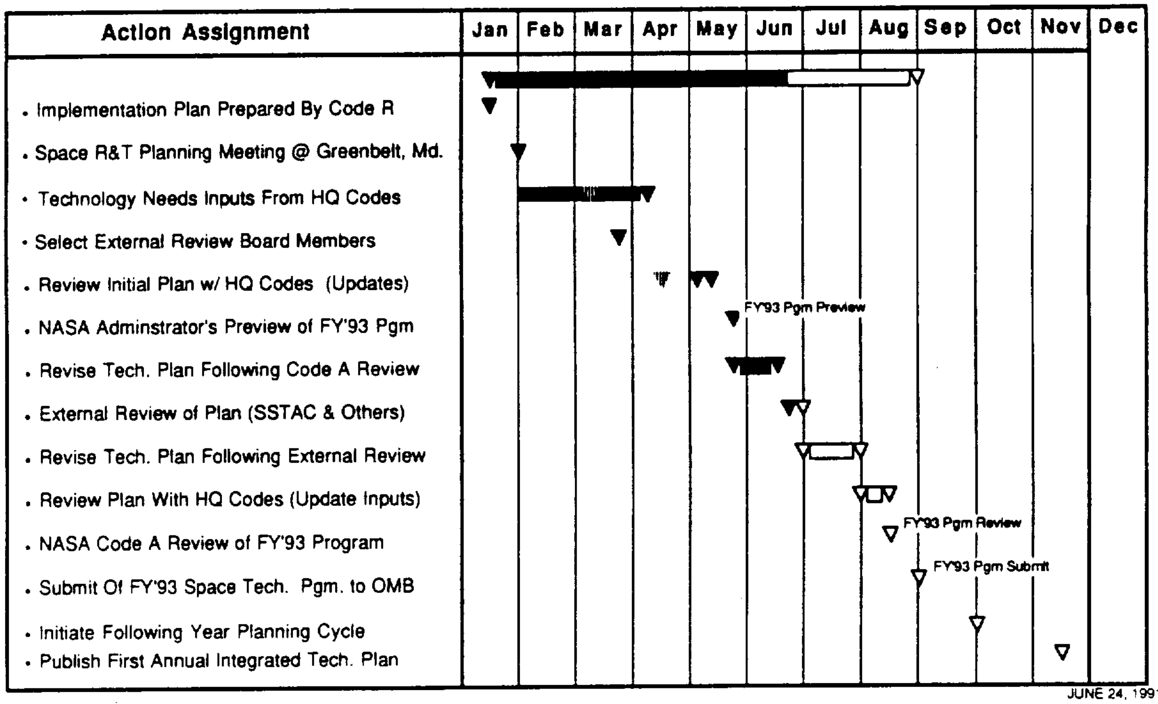
OAET

- **INTERNAL NEEDS**
  - AGENCY PROGRAM OFFICES REQUESTED TO DEFINE AND PRIORITIZE MISSION TECHNOLOGY NEEDS AS RECOMMENDED BY AUGUSTINE
- **EXTERNAL NEEDS**
  - SSTAC/ARTS MEMBERS REQUESTED TO PROVIDE INPUTS ON OVERALL CIVIL SPACE TECHNOLOGY NEEDS
  - COMSTAC RECOMMENDATIONS ON ELVs, COMMUNICATIONS ADVISORY GROUP RECOMMENDATIONS AND OTHER KEY TECHNOLOGY ASSESSMENTS UNDER EVALUATION
- **DEVELOPMENT OF INTEGRATED TECHNOLOGY PLAN**
  - PLANNING TEAMS FORMED TO REEXAMINE EXISTING TECHNOLOGY PLANS, ASSESS INCOMING USER OFFICE TECHNOLOGY NEEDS, AND PREPARE TECHNOLOGY PLANS
- **EXTERNAL REVIEW**
  - SSTAC/ARTS WILL CONDUCT REVIEW WITH PARTICIPATION BY ASEB, OTHER EXTERNAL EXPERTS IN JUNE
- **STRUCTURE FOR ANNUAL PLANNING AND REVIEW PROCESS ESTABLISHED**

NASA ACTION PLAN

ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

Recommendation 8: Integrated Agency Technology Plan



JUNE 24, 1991
JCM-7267a

SPACE R&T LONG RANGE PLAN

OAET

- **IN JUNE 1990, DEVELOPMENT OF LONG RANGE PLAN (LRP) WAS INITIATED**
  - TO IMPROVE PLANNING, RESPONSIVENESS AND MANAGEMENT OF THE SPACE R&T PROGRAM
  - FOLLOW ON TO THE SPACE R&T ASSESSMENT IN 1989

- **OAET-LED EFFORT WITH STRONG CENTER AND MISSION OFFICE USER PARTICIPATION**

- **REACHED CONSENSUS ON SPACE R&T MISSION, GOALS, AND OBJECTIVES**
  - TECHNOLOGY REQUIREMENTS TO MEET MISSION OFFICES' NEEDS IDENTIFIED IN 5 TECHNOLOGY THRUSTS
  - RESULTED IN RECOGNITION THAT SPACE R&T PROGRAM SHOULD BE REALIGNED SO THAT THRUSTS AND BUDGET LINES ARE CONSISTENT

SPACE R&T MISSION STATEMENT

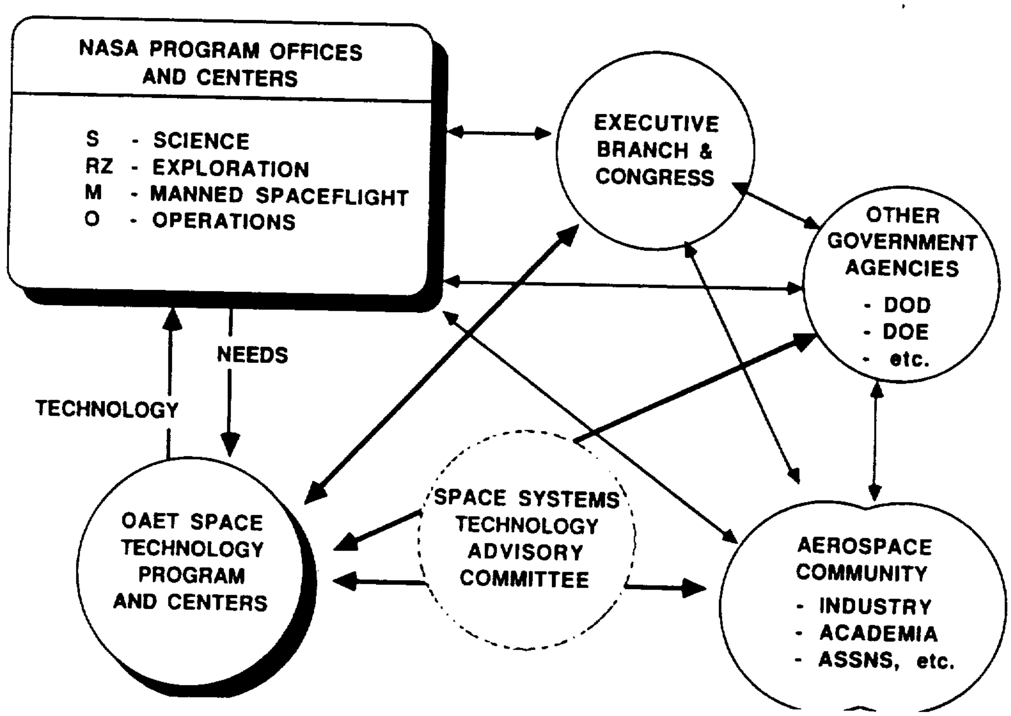
OAET

OAET SHALL PROVIDE TECHNOLOGY FOR FUTURE CIVIL SPACE MISSIONS AND PROVIDE A BASE OF RESEARCH AND TECHNOLOGY CAPABILITIES TO SERVE ALL NATIONAL SPACE GOALS

- *IDENTIFY, DEVELOP, VALIDATE AND TRANSFER TECHNOLOGY TO:*
  - INCREASE MISSION SAFETY AND RELIABILITY
  - REDUCE PROGRAM DEVELOPMENT AND OPERATIONS COST
  - ENHANCE MISSION PERFORMANCE
  - ENABLE NEW MISSIONS
- *PROVIDE THE CAPABILITY TO:*
  - ADVANCE TECHNOLOGY IN CRITICAL DISCIPLINES
  - RESPOND TO UNANTICIPATED MISSION NEEDS

COMPLEX OAET CUSTOMER RELATIONSHIPS

OAET



INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

PROGRAM PRINCIPLES

- STRESS TECHNICAL EXCELLENCE AND QUALITY IN ALL ACTIVITIES & ENSURE THE AVAILABILITY OF APPROPRIATE SUPPORT & FACILITIES
- BE RESPONSIVE TO THE CUSTOMERS & ASSURE TECHNOLOGY TRANSFER & UTILIZATION
- SUSTAIN COMMITMENT TO ON-GOING R&T PROGRAMS
- MAINTAIN THE UNDERLYING TECHNOLOGICAL SKILLS WHICH ARE THE WELL-SPRING OF NASA'S TECHNICAL CAPABILITY
- ASSURE THE INTRODUCTION OF NEW TECHNOLOGY ACTIVITIES ON A REGULAR BASIS
- MAINTAIN BALANCE AMONG NASA CUSTOMERS, CRITICAL DISCIPLINES, AND NEAR & FAR-TERM GOALS
- SUPPORT SCIENCE & ENGINEERING EDUCATION IN SPACE RESEARCH & TECHNOLOGY
- MAKE EFFECTIVE USE OF TECHNOLOGIES AND CAPABILITIES OF OTHER AGENCIES, INDUSTRY, ACADEMIA AND INTERNATIONAL PARTNERS
- ENHANCE THE NATION'S INTERNATIONAL COMPETITIVENESS

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

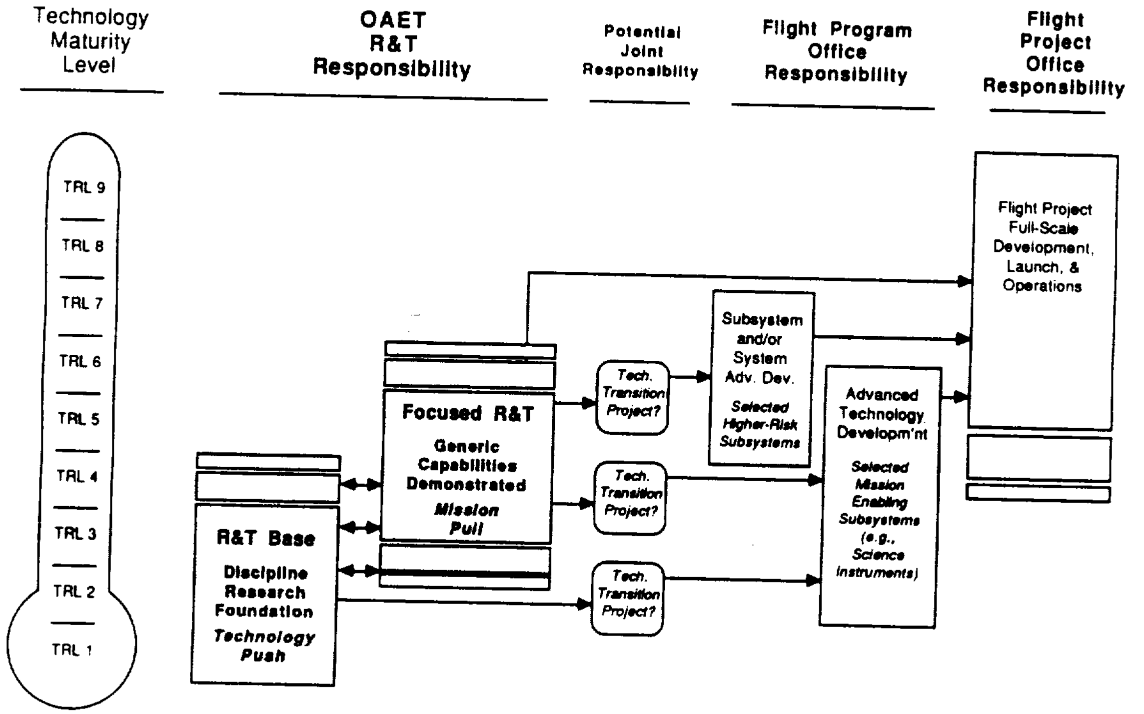
TECHNOLOGY READINESS LEVELS

Basic Technology Research	LEVEL 1	BASIC PRINCIPLES OBSERVED AND REPORTED
Research To Prove Feasibility	LEVEL 2	TECHNOLOGY CONCEPT AND/OR APPLICATION FORMULATED
	LEVEL 3	ANALYTICAL & EXPERIMENTAL CRITICAL FUNCTION AND/OR CHARACTERISTIC PROOF-OF-CONCEPT
Technology Development	LEVEL 4	COMPONENT AND/OR BREADBOARD VALIDATION IN LABORATORY ENVIRONMENT
Technology Demonstration	LEVEL 5	COMPONENT AND/OR BREADBOARD VALIDATION IN RELEVANT ENVIRONMENT
	LEVEL 6	SYSTEM/SUBSYSTEM MODEL OR PROTOTYPE DEMONSTRATION IN A RELEVANT ENVIRONMENT (Ground or Space)
System/Subsystem Development	LEVEL 7	SYSTEM PROTOTYPE DEMONSTRATION IN A SPACE ENVIRONMENT
System Test, Launch and Operations	LEVEL 8	ACTUAL SYSTEM COMPLETED AND "FLIGHT QUALIFIED" THROUGH TEST AND DEMONSTRATION (Ground or Flight)
	LEVEL 9	ACTUAL SYSTEM "FLIGHT PROVEN" THROUGH SUCCESSFUL MISSION OPERATIONS

TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

NASA TECHNOLOGY MATURATION STRATEGY

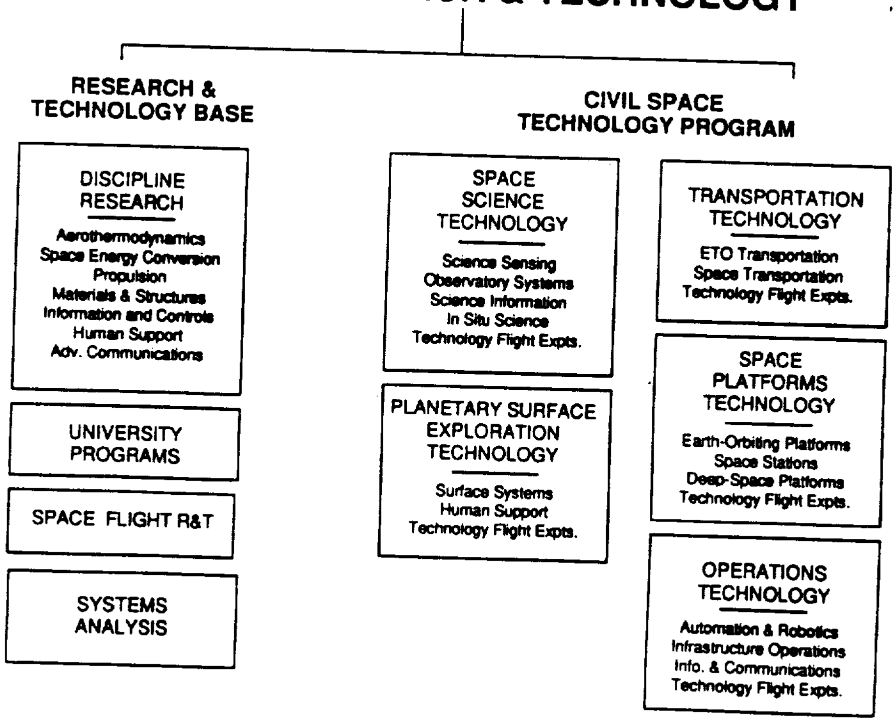
OAET



APRIL 15, 19

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

SPACE RESEARCH & TECHNOLOGY



NASA ACTION PLAN

ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

PLANNING TEAMS

Focused Program Teams

TRANSPORTATION

- CO-CAPTAINS
  OAET/RS (D. Stone)
  MSFC (G. Wallace)
- TEAM MEMBERS
  OSF, JSC, LeRC, KSC, MSFC, JPL, LaRC
- ELEMENT PLANNERS
  OAET (RC,RF,RM,RP,RX)
  Centers (All)
- USER INTERFACES
  OSF, OSSA, OAET/RZ

SPACE PLATFORMS

- CO-CAPTAINS
  OAET/RS (J. Ambrus)
  LaRC (R. Hook)
- TEAM MEMBERS
  OSF, LeRC, GSFC, JPL
  OAET(RP,RM)
- ELEMENT PLANNERS
  OAET (RC,RM,RP,RX)
  Centers (LaRC,JPL,LeRC,JSC,GSFC)
- USER INTERFACES
  OSSA, OSF, OAET/RZ

OPERATIONS

- CO-CAPTAINS
  OAET/RS (G. Giffin)
  KSC (W. Rock)
- TEAM MEMBERS
  GSFC, JPL, JSC, OSO, OSF, OAET/RC, RS,RM
- ELEMENT PLANNERS
  OAET (RC,RM,RP,RX)
  Centers (JSC,KSC,MSFC,JPL,GSFC)
- USER INTERFACES
  OSF, OSO, OSSA, OAET/RZ

SPACE SCIENCE

- CO-CAPTAINS
  OAET/RS (W. Hudson)
  JPL (W. Weber)
- TEAM MEMBERS
  GSFC, JPL, LaRC, ARC, OAET/RS
- ELEMENT PLANNERS
  OAET (RC,RF,RM,RP,RX)
  Centers (JPL,LaRC,ARC,GSFC)
- USER INTERFACES
  OSSA (All)

EXPLORATION

- CO-CAPTAINS
  OAET/RS (J. Mankins)
  JSC (A. Dula)
- TEAM MEMBERS
  JSC, OSSA/SB,MSFC, JPL, ARC, OAET/RZ
- ELEMENT PLANNERS
  OAET (RC,RM,RP,RX)
  Centers (JPL,LaRC,ARC,LeRC,JSC)
- USER INTERFACES
  OAET/RZ, OSSA

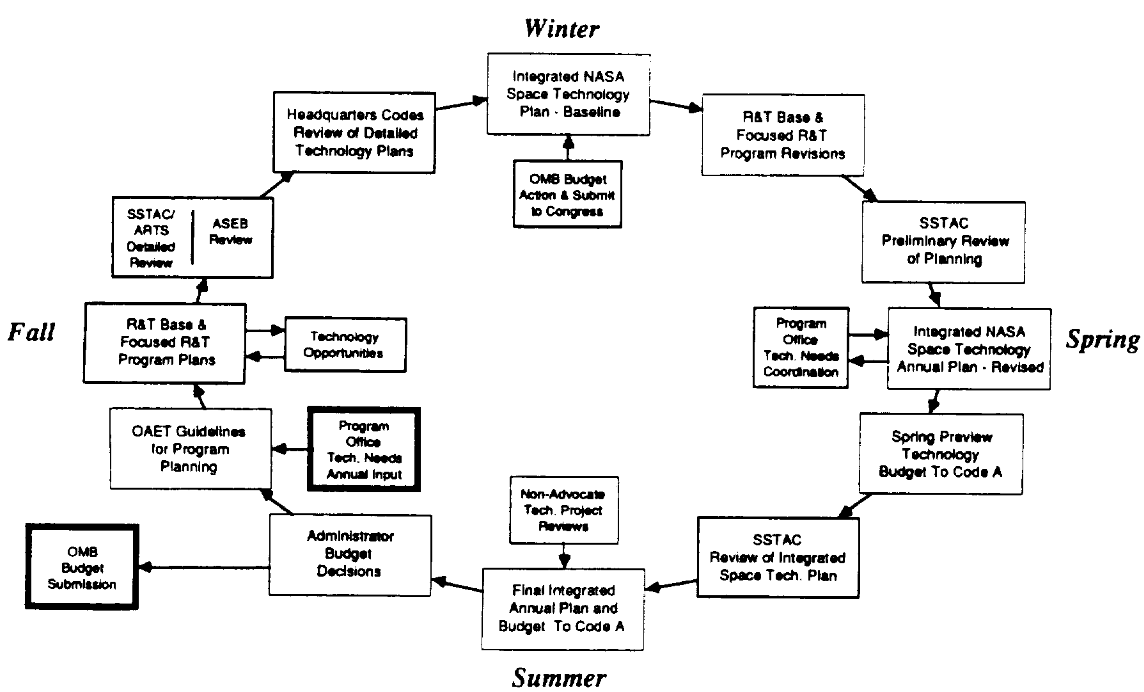
R&T Base Teams

- Aerodynamics
  Captain: K. Hessenius (RF)
- Info. Sciences & HF
  Captain: L. Holcomb (RC)
- Materials & Structures
  Captain: S. Venneri (RM)
- Propulsion, Power & Energy
  Captain: E. VanLandingham (RP)
- Flight Projects
  Captain: J. Levine (RX)

MARC

SPACE TECHNOLOGY PLANNING CYCLE

OAET



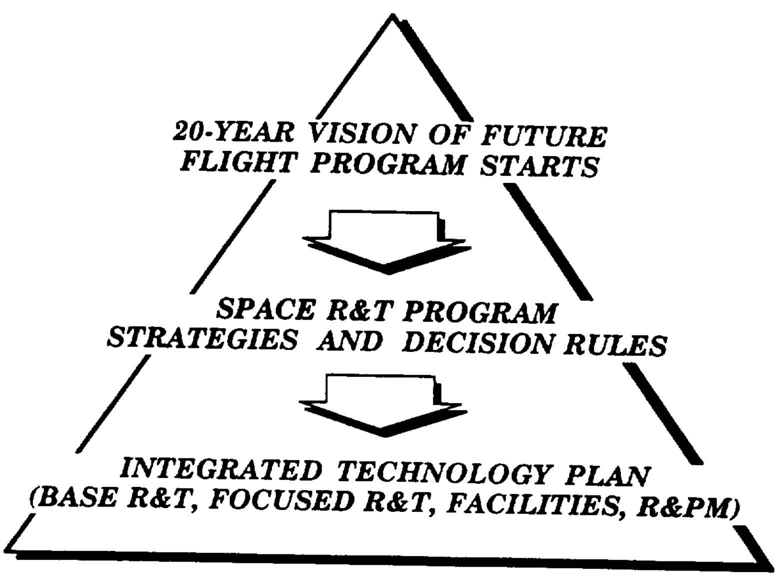
March 25, 1991
JCM-7207

ITP OVERVIEW

- SPACE R&T PROGRAM APPROACH
- ⇨ INTEGRATED TECHNOLOGY PLAN DEVELOPMENT
- INTEGRATED TECHNOLOGY PLAN STRUCTURE
- BUDGET DEVELOPMENT
- SUMMARY COMMENTS

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

SPACE R&T PROGRAM DEVELOPMENT



INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

RESEARCH & TECHNOLOGY STRATEGY

OAET

FLIGHT PROGRAMS FORECAST

- **5-YEAR FORECAST INCLUDES**

'93 THRU '97: LIMITED NEW STARTS

COMPLETION OF INITIAL SSF
SOME SHUTTLE IMPROVEMENTS
INITIAL EOS & EOSDIS
SELECTED SPACE SCIENCE STARTS
NLS DEVELOPMENT
INITIAL SEI ARCHITECTURE SELECTION
EVOLVING GEO COMMERCIAL COMMSATS
MINOR UPGRADES OF COMMERCIAL ELVS

- **10-YEAR FORECAST INCLUDES**

'98 THRU '03: MULTIPLE NEW STARTS TO BE LAUNCHED IN 2003 THRU 2010

SSF EVOLUTION/INFRASTRUCTURE
FINAL SHUTTLE ENHANCEMENTS
ADVANCED LEO EOS PLATFORMS/FULL EOSDIS
MULTIPLE SPACE SCIENCE STARTS
NLS OPERATIONS/EVOLUTION
EVOLVING LAUNCH/OPERATIONS FACILITIES
INITIAL SEI/LUNAR OUTPOST START
DSN EVOLUTION (KA-BAND COMMUNICATIONS)
NEW GEO COMMERCIAL COMMSATS
NEW COMMERCIAL ELVS

- **20-YEAR FORECAST INCLUDES**

'04 THRU '11 MULTIPLE OPTIONS FOR NEW STARTS TO BE LAUNCHED IN 2009 THRU 2020

SSF-MARS EVOLUTION
BEGINNING OF AMLS/PLS DEVELOPMENT
MULTIPLE SPACE SCIENCE STARTS
DSN EVOLUTION (OPTICAL COMM)
INITIAL MARS HLLV DEVELOPMENT
EVOLVING LUNAR SYSTEMS
MARS SEI ARCHITECTURE CHOSEN
LARGE GEO COMMSATS
NEW COMMERCIAL ELVS

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INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

RESEARCH & TECHNOLOGY STRATEGY

OAET

FY'93 SPACE R&T PROGRAM STRATEGY

- **FOR NEAR-TERM NEEDS**

IN '93-'97 COMPLETE THE ONGOING PROGRAM; IMPLEMENT KEY SELECTED NEW TASKS

BY 1993 THRU' 1997:
DELIVER SELECTED HIGH-LEVERAGE SUBSYSTEM CAPABILITIES

- **FOR END-OF-DECADE NEEDS**

IN '93-'97 COMPLETE THE ONGOING PROGRAM; BEGIN HIGH PRIORITY R&T; BEGIN TO PUT CRITICAL R&T TESTBEDS & FACILITIES IN PLACE

BY 1998 THRU' 2003:
DELIVER MAJOR NEW SYSTEM CAPABILITIES
CONDUCT MAJOR DEMONSTRATIONS/FLIGHT EXPERIMENTS
BEGIN SIGNFICANT USE OF SSF FOR R&T
LEVERAGE NASP DEMONSTRATIONS

- **FOR LONG-TERM NEEDS**

IN '93-'97 COMPLETE THE ONGOING PROGRAM; BEGIN SELECTED, LONG-TERM R&T EFFORTS

BY 2004 THRU' 2011
DELIVER MAJOR NEW SYSTEM CAPABILITIES
BEGIN USE OF LUNAR OUTPOST FOR R&T
ACHIEVE MARS TECHNOLOGY READINESS

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

DECISION RULES: R&T BASE

OAET

GENERAL RULES

- USE EXTERNAL REVIEWS TO AID IN ASSURING PROGRAM TECHNICAL QUALITY
- PROVIDE STABILITY BY COMPLETING ON-GOING DISCRETE EFFORTS

DISCIPLINE RESEARCH

- ASSURE ADEQUATE SUPPORT TO MAINTAIN HIGH-QUALITY IN-HOUSE RESEARCH IN AREAS CRITICAL TO FUTURE MISSIONS
  - PROVIDE CAPABILITIES FOR AD HOC SUPPORT R&T FOR FLIGHT PROGRAMS
- PROVIDE GROWTH IN R&T BASE AREAS NEEDED FOR FUTURE FOCUSED PGMS
  - COORDINATE WITH ANNUAL FOCUSED PROGRAM PLANNING
- CREATE ANNUAL OPPORTUNITIES FOR THE INSERTION OF NEW R&T CONCEPTS
  - GOAL: PROVIDE APPROXIMATELY 15-20% "ROLL-OVER" PER YEAR
- SUPPORT TECHNOLOGY PUSH FLIGHT EXPERIMENTS WHERE SPACE VALIDATION IS REQUIRED.

IN-STEP FLIGHT PROGRAMS

- MAINTAIN COMPETITIVELY-SELECTED STUDIES/IMPLEMENTATION OF IN-HOUSE AND INDUSTRY/UNIVERSITY SMALL-SCALE FLIGHT EXPTS, ORIENTED ON NASA'S TECHNOLOGY NEEDS

UNIVERSITY PROGRAMS

- EVALUATE TO FOCUS PARTICIPATION IN NASA SPACE R&T BY U.S. UNIVERSITIES AND COLLEGES - USING COMPETITIVE SELECTION

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

DECISION RULES: FOCUSED PROGRAMS

OAET

GENERAL

- ANNUALLY ASSESS AND FUND PROJECTS IN ORDER OF PRIORITY AGAINST MISSION-DERIVED INVESTMENT CRITERIA
  - EXTERNAL REVIEW WILL BE USED TO AID IN ASSURING QUALITY
  - REVIEW WITH USER OFFICES WILL BE USED TO AID IN ASSURING RELEVANCE AND TIMELINESS
- PROVIDE STABILITY BY COMPLETING ON-GOING DISCRETE EFFORTS
- START A MIX OF TECHNOLOGY PROJECTS WITH SHORT-, MID- AND LONG-TERM OBJECTIVES EACH YEAR
- ASSURE BALANCED INVESTMENTS TO SUPPORT THE FULL RANGE OF SPACE R&T USERS
- FUND NEW TECHNOLOGY PROJECTS THAT HAVE PASSED INTERNAL REVIEWS AS REQUIRED (E.G., NON-ADVOCATE REVIEW FOR MAJOR EXPERIMENTS)

MAJOR FLIGHT EXPERIMENTS

- SUPPORT COMPETITIVELY-SELECTED IMPLEMENTATION OF IN-HOUSE AND INDUSTRY MAJOR TECHNOLOGY FLIGHT EXPTS IN ACCORDANCE WITH MISSION-DERIVED PRIORITIZATION CRITERIA
- FUND MAJOR FLIGHT EXPERIMENTS WHERE ADEQUATE GROUND-BASED R&T IS UNDERWAY OR HAS BEEN COMPLETED

INVESTMENT PRIORITIZATION CRITERIA

OAET

MISSION NEED

Engineering Leverage
- Performance (Including Reliability) Leverage of the Technology to A System
- Importance of That Technology/System Performance To A Mission And Its Objectives

Cost Leverage
- Projected Cost Reduction For A Given System/Option
- Projected Cost Reduction for A Mission of That Savings

Breadth Of Application
- Commonality Across Missions/Systems Options
- Commonality Across Systems in Alternative Mission Designs

PROGRAMMATICS & TIMING

Timeliness Of Planned Deliverables
- Timing of the Mission Need for Technology Readiness
- Projected Duration of R&T Needed To Bring Technology to Readiness

Criticality Of Timely R&T Results To Mission Decisions
- Timing of Mission Planning Need for Technology Results
- Importance of Technology To Mission Objectives/Selection

Uncertainty in Planned R&T Program Success/Schedule

SPECIAL ISSUES

Readiness to Begin A Focused Technology Project
Commitment To An Ongoing R&T Program
Interrelationships To Other Government Program(s)
Projected "National Service" Factors

LBF40285

INTERI...

OSSA TECHNOLOGY NEEDS
Grouped According to Urgency & Commonality

TO BE UPDATED FOLL...ING THE OSSA/SSAAC SUM...ER WORKSHOP

REVISED APRIL 12, 1991

	HIGHEST PRIORITY		2nd-HIGHEST PRIORITY			3rd HIGHEST PRIORITY			
Near Term	Submm & Microwave Tech: - SIS 1.2 THz Heterodyne Rec. - Active SAR integrated circuits - Passive submm 600 GHz diodes (SZ,SE,)	Long-life Mechanical & Cryogenic Coolers/Cryo Shielding (SZ,SE,SS)	High Frame Rate, High Resolution Video& Data Compression (SN, SL)	2.5 - 4m, 100K Lightweight, PSR (SZ)	Fluid Diagnostics (SN)	Real-Time Radiation Monitoring (SB)	Descent Imager (SL)	Mini-RTG (SL)	Mini-Camera (SL)
	Detectors (SE, SL, SZ, SS) -- optical, Ge, Xe, non-cryo 1.6 to 150μ IR, extended μ CCD, high energy detectors, sensor readout electronics & tunnel sensors	Vibration Isolation Technology (SN, SZ, SB)	Solar Arrays/Cells (SL, SZ, SE)	Automated Biomedical Analysis (SB)	Rad Hard Parts & Detectors (SZ, SL)	Solid/Liquid Interface Characterization (SN)	Laser Light Scattering (SN)	High Temperature Materials For Furnaces (SN)	K-band Transponders (SZ)
	Efficient, Quiet Refrigerator/Freezer (SB)	Extreme Upper Atmosphere Instrument Platforms (SS)	Batteries -- Long life time -- High energy density (SL, SZ)	Real-Time Environmental Control & Monitoring (SB)	Space Qualified maser & ion Clocks (SZ)	Field Portable Gas Chromato-graphs (SB)	Advanced Furnace Technology (SN)	Ultra-high Gigabit/sec Telemetry (SZ)	Mini S/C Subsystems (SL)
	Lasers: Long-life, Stable & Tunable (SE, SZ, SL, SB)	Solar Probe/ Mercury Orbiter Thermal Shield & Protection (SS, SL)	Auto Sequencing & Command Generation, Auto S/C Monitoring & Fault Recovery (SL)	Combustion Diagnostics (SN)	Plasma Wave Antennas/ Thermal (SS)	Regenerative Life Support (SB)	Non-Contact Temperature Measurement (SN)	3-D packaging for 1 MB Solid State Chips (SZ)	Microbial Decontamination Methods (SB)
	Data -- High Volume, High Density, High Data Rate, On-board Storage (SE, SL, SN)	Interferometer-specific Tech: -- picometer metrology -- active delay lines -- control-structures interact. (SZ, SL, SB)	32 Ghz TWT Optical Communication (SL, SS)	Telescience, Telepresence, & AI (SN, SL, SB)	Improved EVA Suit/ PLSS (EMU) (SB)	Thermal Control System (SZ)	Special Purpose Bioreactor Simulator Syst. (SB)	Rapid Subject/ Sample Delivery & Return Capability (SB)	Animal & Plant Reproduction Aids (SB)
	Controlled Structures/ Large Antenna Structure Arrays/Deployable (SE, SZ, SS, SB)	Robotics (SN, SL)	SIS 3 Thz Heterodyne Receiver (SZ)	SETI Technologies -- Microwave & Optical/Laser Detection (SB)	Mini Ascent Vehicle/ Lander Deceleration (SL)	Auto Rendezvous Auto Sample Transfer, Auto Landing (SL)	Non-Destructive Monitoring Capability (SB)	Low-drift Gyros, Trackers, Actuators (SZ)	Non-Destructive Cosmic Dust Collection (SB)
	Interspacecraft Ranging & Positioning Precision Sensing Pointing & Control (SS, SZ, SL)	Parallel Software (SE, SL) Environment for Model & Data Assimilation, Visualization Computational Techniques	Sample Acquisition & Preservation, Probe, In-situ Inst., Drills, Corers, Penetrators (SL, SB)	Returned-Sample Biobarrier Analysis Capabilities (SB, SL)	High Resolution Spectrometer (SB)	Heat Shield for 16 Km/s Earth Entry (SL)	Partial-g/ μg Medical Care Delivery Systems (SB)	Dust Protection/ Jupiter's Rings (SL)	
Far Term	Large Filled Apertures – lightweight & stable optics – Cryo optical ver., fab., test. – Deformable mirrors -- 15-25m PSR (SL, SZ, SE)	50-100Kw Ion Propulsion (NEP) (SL)	Radiation Shielding for Crews (SB)	X-ray Optics Tech: -- imaging system -- low cost optics -- Bragg concentrators -- coated apertures (SZ)	Human Artificial Gravity Systems (SB)	CELSS Support Technologies (SB)			

	HIGHEST PRIORITY	2nd-HIGHEST PRIORITY	3rd HIGHEST PRIORITY
Tally	SB: 5 SN: 3	SB: 10 SN: 4	SB: 11 SN: 5
	SE: 8 SS: 6	SE: 1 SS: 2	SE: 0 SS: 0
	SL: 11 SZ: 9	SL: 9 SZ: 6	SL: 8 SZ: 5

NASA

SEI TECHNOLOGY RANKING

NOTE:
- This prioritization reflects the pre-Synthesis view of SEI technology needs
- There is no implied prioritization within each category

Category 1:

- Radiation Protection
- EVA Systems
- Nuclear Thermal Propulsion
- Regenerative Life Support
- Cryo Fluid Management, Storage, and Transfer
- Micro-g Countermeasures/Artificial Gravity
- Aerobraking

Category 2:

- Autonomous Rendezvous and Docking
- Health Maintenance and Care
- In-Space Systems Assembly and Processing
- Surface System Construction and Processing
- Cryo Space Engines
- In-Situ Resource Utilization
- Surface Power

Category 3:

- Autonomous Landing
- Human Factors
- Surface System Mobility and Guidance (manned/unmanned)
- Electric Propulsion (nuclear / solar)
- Sample Acquisition, Analysis, and Preservation

Barnos 1/Peach/Technology Prioritization 4/10/91

Office of Aeronautics, Exploration and Technology

Ver 2/4-8-91

OSF Technology Requirements Evaluation

Technology Areas

Program Unique Technologies

1	Vehicle Health Management
2	Advanced Turbomachinery Components and Models
3	Combustion Devices
4	Advanced Heat Rejection Devices
5	Water Recovery and Management
6	High Efficiency Space Power Systems
7	Advanced Extravehicular Mobility Unit Technologies
8	Electromechanical Control Systems/Electrical Actuation
9	Crew Training Systems
10	Characterization of Al-Li Alloys
11	Cryogenic Supply, Storage, and Handling
12	Thermal Protection Systems for High Temperature Applications
13	Robotic Technologies
14	Orbital Debris Protection
15	Guidance, Navigation and Control
16	Advanced Avionics Architectures

Industry Driven Technologies

- Signal Transmission and Reception
- Advanced Avionics Software
- Video Technologies
- Environmentally Safe Cleaning Solvents, Refrigerants and Foams
- Non-Destructive Evaluation

Figure 3-1

MAJOR CODE OSO TECHNOLOGY NEEDS

1. High Data Rate Communications. This includes optical and millimeter wave radio frequencies for both space-to-ground and space-to-space applications to handle the high volumes of data transported in future programs. An example of space-to-space communication might be future communications cross links between our tracking and data relay satellites.

2. Advanced Data Systems. This includes development of advanced data storage, data compression, and information management systems, which are required to meet the sophisticated needs of future planetary and exploration programs.

3. Advanced Navigation Techniques. This includes development of new techniques for navigation and their application to cruise, approach, and in-orbit navigation for manned and unmanned planetary missions.

4. Mission Operations. This includes incorporation of artificial intelligence, expert systems, neural networks, and increased automation in mission operations. Other work includes development of test beds to check out advanced software, coordination of distributed software, and automated performance analysis of networked computing environments.

Code O will be pleased to work with you on further definition of the requirements that affect our operations. The above-mentioned technologies are all high priorities for Code O. Those associated with the exploration program are obviously longer range needs.

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

EXTERNAL TECHNOLOGY PERSPECTIVES SUMMARY

SPACE SCIENCE

Precision Space Structures and Pointing Accuracy

PLANETARY SURFACE EXPLORATION

Regnerative Life Support Systems
Radiation Protection for Long Missions
Utilization of In Situ Materials/Propellants
Artificial Intelligence Techniques
Robotic & Microrobotic Systems
Advanced EMUs
Surface Rover Technologies (Pressurized and Unpressurized)
Nuclear Electric Power
High-Efficiency Lunar Radiators & Thermal Energy Storage
Power Beaming
Human Health Maintenance
Reduced Gravity Countermeasures/Artificial Gravity
Bioprocess-Grade Fluid Management Systems

SPACE PLATFORMS

Composite Lightweight Structures
Micrometeoroid and Debris Protection
Long-Life Structures and Mechanisms
Regnerative Life Support Systems
Advanced EMUs
Expanded Atomic Oxygen Database
High-Efficiency, Radiation-Resistant, Lightweight PV Arrays
High-Efficiency Power Processing Units
Lightweight Batteries

TRANSPORTATION

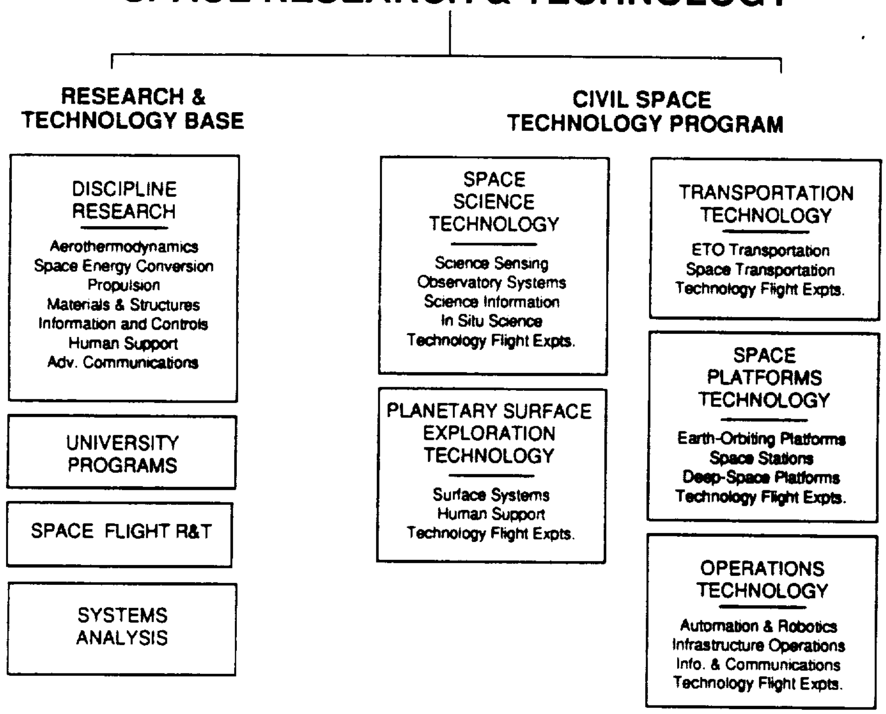
Economical Launch Systems (Manned and Unmanned)
Software Productivity Enhancers
Integrated Vehicle Health Monitoring and Maintenance
Advanced Cryogenic (Oxygen/Hydrogen) Engines
Fault-Tolerant Advanced Avionics with Open Architectures
High-Performance/Composite Lightweight Structures
Long-Life Structures and Mechanisms
High-Performance, Storable Space Thrusters
High-Power Electric Propulsion
Nuclear Thermal Propulsion for Manned Interplanetary Missions
Cryogenics Long-Duration Storage and Management
Gun-Type Launch Systems
Aerobraking (Thermal Protection Systems)
Integrated RCS/Auxiliary Propulsion
Lightweight, Fuel-Efficient Airbreather Propulsion Systems

OPERATIONS

Data Management System Architecture and Software
Systems Integration technologies (Software, etc.)
Artificial Intelligence Techniques
Safe Robotic Systems
Advanced Communications (e.g., Laser & Millimeter Wave Technology)

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

SPACE RESEARCH & TECHNOLOGY



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ITP OVERVIEW

- SPACE R&T PROGRAM APPROACH
- INTEGRATED TECHNOLOGY PLAN DEVELOPMENT
- ⇨ INTEGRATED TECHNOLOGY PLAN STRUCTURE
- BUDGET DEVELOPMENT
- SUMMARY COMMENTS

SPACE RESEARCH & TECHNOLOGY BASE

CONDUCT RESEARCH TO IDENTIFY, DEVELOP AND VALIDATE HIGH-LEVERAGE CONCEPTS IN KEY TECHNOLOGY DISCIPLINES (TECHNOLOGY PUSH)

- DISCIPLINE RESEARCH
- UNIVERSITY PROGRAMS
- SPACE FLIGHT RESEARCH & TECHNOLOGY
- SYSTEMS ANALYSIS

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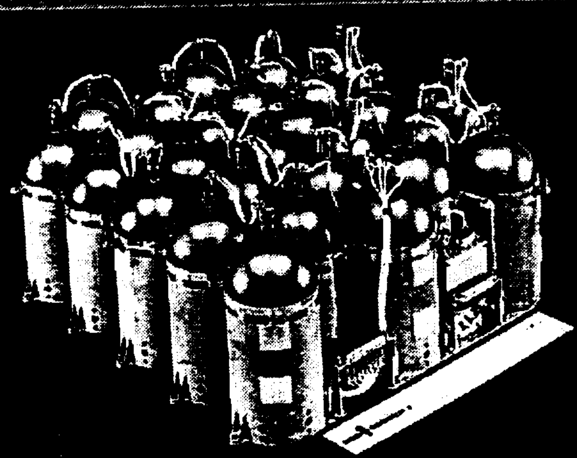
DISCIPLINE RESEARCH

CONCEIVE, DEVELOP AND VALIDATE NEW TECHNOLOGY CONCEPTS AND APPROACHES FOR ENHANCING OR ENABLING FUTURE SPACE MISSIONS INCLUDING REVOLUTIONARY IMPROVEMENTS IN SPACE



DISCIPLINE RESEARCH TECHNOLOGY
- AEROTHERMODYNAMICS
- SPACE ENERGY CONVERSION
- PROPULSION
- MATERIALS & STRUCTURES
- INFORMATION & CONTROLS
- HUMAN SUPPORT
- ADVANCED COMMUNICATIONS

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UNIVERSITY PROGRAMS

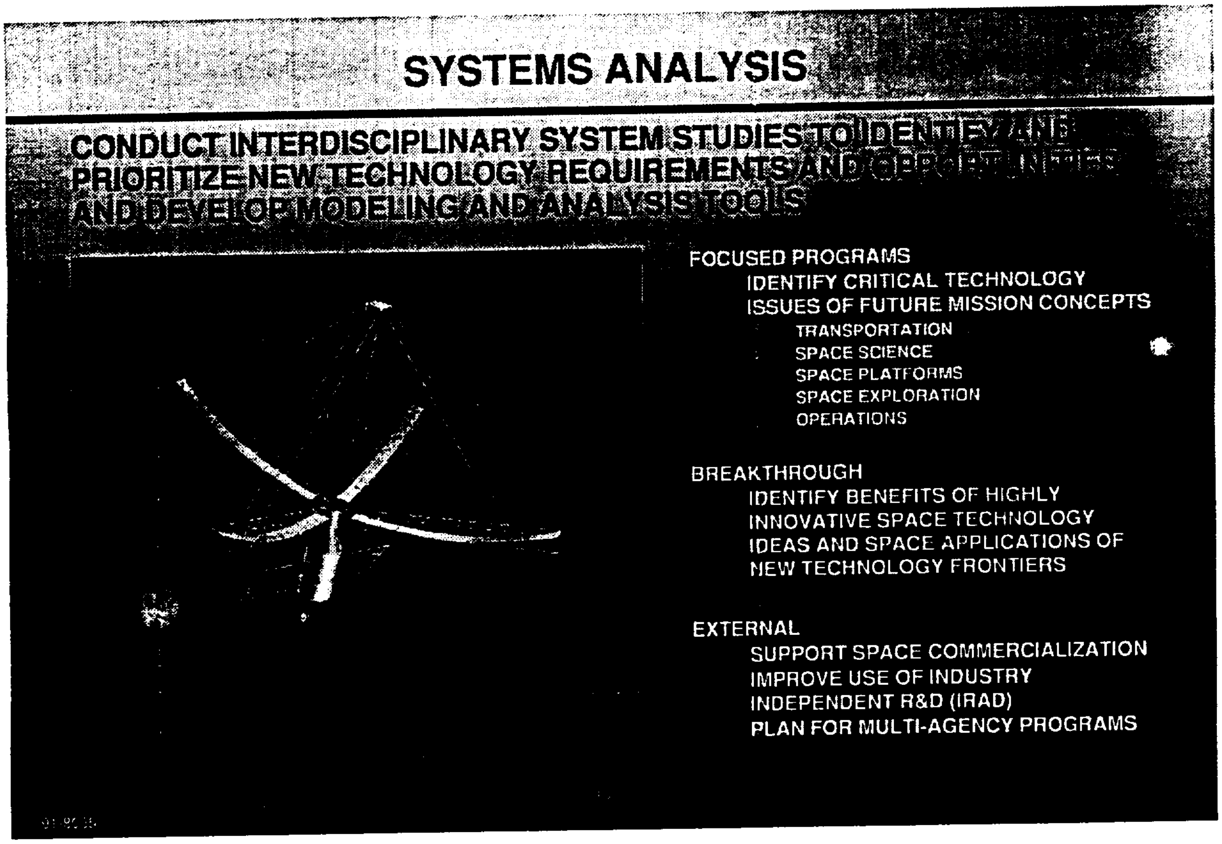
BROADEN THE CAPABILITIES OF THE NATION'S ENGINEERING COMMUNITY TO PARTICIPATE IN THE U.S. CIVIL SPACE PROGRAM THROUGH UNIVERSITY-BASED RESEARCH AND EDUCATION

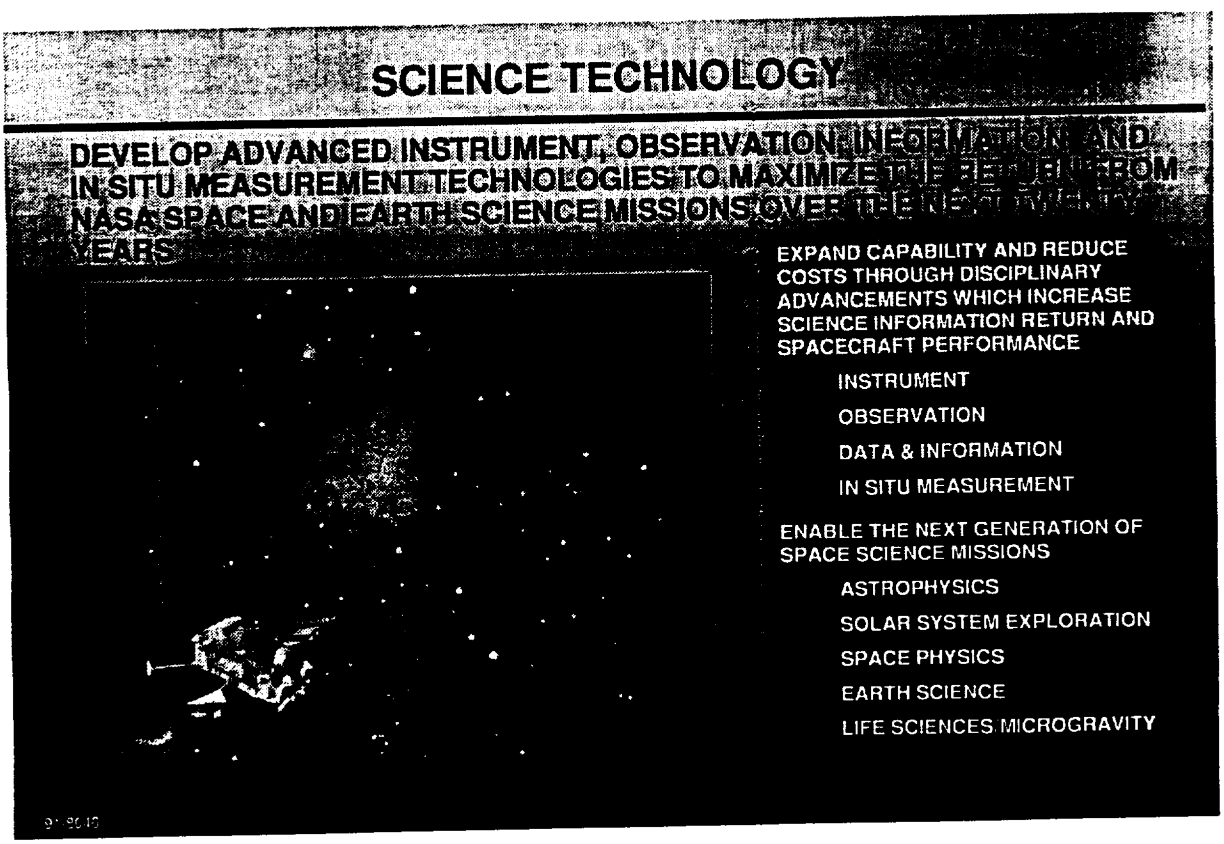
- UNIVERSITY SPACE ENGINEERING RESEARCH CENTERS
  - FOSTER CREATIVE AND INNOVATIVE CONCEPTS OF FUTURE SPACE SYSTEMS
  - EXPAND THE NATION'S ENGINEERING TALENT BASE FOR RESEARCH AND DEVELOPMENT
- UNIVERSITY INVESTIGATORS RESEARCH
  - SPONSOR INDIVIDUAL RESEARCH ON HIGHLY INNOVATIVE SPACE TECHNOLOGY CONCEPTS AND APPROACHES
- UNIVERSITY ADVANCED DESIGN
  - FOSTER INTERDISCIPLINARY ENGINEERING DESIGN EDUCATION

SPACE FLIGHT RESEARCH & TECHNOLOGY

PROVIDE FOR EXPERIMENT STUDIES, DEVELOPMENT AND SUPPORT FOR IN-SPACE FLIGHT RESEARCH AND VALIDATION OF ADVANCED SPACE TECHNOLOGIES

- IN-SPACE TECHNOLOGY EXPERIMENT PROGRAM (IN-STEP)
  - DESIGN, DEVELOP AND FLIGHT TEST INDUSTRY, UNIVERSITY AND NASA TECHNOLOGY FLIGHT EXPERIMENTS
- FLIGHT OPPORTUNITIES VIA
  - SPACE SHUTTLE
  - EXPENDABLE LAUNCH VEHICLES
  - SPACE STATION FREEDOM


SYSTEMS ANALYSIS
CONDUCT INTERDISCIPLINARY SYSTEM STUDIES TO IDENTIFY AND
PRIORITIZE NEW TECHNOLOGY REQUIREMENTS AND
AND DEVELOP MODELING AND ANALYSIS TOOLS
FOCUSED PROGRAMS
IDENTIFY CRITICAL TECHNOLOGY
ISSUES OF FUTURE MISSION CONCEPTS
TRANSPORTATION
SPACE SCIENCE
SPACE PLATFORMS
SPACE EXPLORATION
OPERATIONS
BREAKTHROUGH
IDENTIFY BENEFITS OF HIGHLY
INNOVATIVE SPACE TECHNOLOGY
IDEAS AND SPACE APPLICATIONS OF
NEW TECHNOLOGY FRONTIERS
EXTERNAL
SUPPORT SPACE COMMERCIALIZATION
IMPROVE USE OF INDUSTRY
INDEPENDENT R&D (IRAD)
PLAN FOR MULTI-AGENCY PROGRAMS


SCIENCE TECHNOLOGY
DEVELOP ADVANCED INSTRUMENT, OBSERVATION, INFORMATION AND
IN SITU MEASUREMENT TECHNOLOGIES TO MAXIMIZE THE RETURN FROM
NASA SPACE AND EARTH SCIENCE MISSIONS OVER THE NEXT
YEARS
EXPAND CAPABILITY AND REDUCE
COSTS THROUGH DISCIPLINARY
ADVANCEMENTS WHICH INCREASE
SCIENCE INFORMATION RETURN AND
SPACECRAFT PERFORMANCE
INSTRUMENT
OBSERVATION
DATA & INFORMATION
IN SITU MEASUREMENT
ENABLE THE NEXT GENERATION OF
SPACE SCIENCE MISSIONS
ASTROPHYSICS
SOLAR SYSTEM EXPLORATION
SPACE PHYSICS
EARTH SCIENCE
LIFE SCIENCES MICROGRAVITY

SCIENCE TECHNOLOGY

INSTRUMENT

IR Detectors
Active Microwave
Optoelectronics

Submillimeter Detectors
High Energy Detectors

Passive Microwave
Laser Sensors
Sensor Readouts

OBSERVATION

Cryocoolers
Micro Precision CSI

Precision Pointing

Telescope Systems
Sensor Optics

IN SITU MEASUREMENT

Sample Acquisition, Analysis, and Preservation
Probes and Penetrators

DATA & INFORMATION

Data Archives
Information Visualization

PLANETARY SURFACE EXPLORATION

PROVIDE KEY TECHNOLOGIES FOR ROBOTIC AND
SURFACE EXPLORATION SYSTEMS INCLUDING
ON THE MOON AND EXPLORATION OF THE

INCREASE RELIABILITY AND REDUCE RISK; REDUCE DEVELOPMENT AND OPERATIONS COST; AND ENABLE NEW AND INNOVATIVE CAPABILITIES IN THE AREAS OF:

- SURFACE SYSTEMS
- HUMAN SUPPORT

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PLANETARY SURFACE EXPLORATION TECHNOLOGY

SURFACE SYSTEMS

- Space Nuclear Power
- In Situ Resource Utilization
- Planetary Rover
- High Capacity Power
- Surface Power and Thermal Management
- Surface Habitats & Construction
- Laser-Electric Power Beaming

HUMAN SUPPORT

- Regenerative Life Support
- Radiation Protection
- Extravehicular Activity Systems
- Exploration Human Factors
- Artificial Gravity
- Remote Medical Care Systems

TRANSPORTATION TECHNOLOGY

PROVIDE TECHNOLOGIES THAT SUBSTANTIALLY INCREASE OPERABILITY, IMPROVE RELIABILITY, PROVIDE NEW CAPABILITIES, WHILE REDUCING LIFE CYCLE COSTS

- ENHANCE SAFETY, RELIABILITY, AND SERVICEABILITY OF CURRENT SPACE SHUTTLE
- PROVIDE TECHNOLOGY OPTIONS FOR NEW MANNED SYSTEMS THAT COMPLEMENT THE SHUTTLE AND ENABLE NEXT GENERATION VEHICLES WITH RAPID TURNAROUND AND LOW OPERATIONAL COSTS
- SUPPORT DEVELOPMENT OF ROBUST, LOW-COST HEAVY LIFT LAUNCH VEHICLES
- DEVELOP AND TRANSFER LOW-COST TECHNOLOGY TO SUPPORT COMMERCIAL EVL's AND UPPER STAGES
- IDENTIFY AND DEVELOP HIGH LEVERAGE TECHNOLOGIES FOR IN-SPACE TRANSPORTATION, INCLUDING NUCLEAR PROPULSION, THAT WILL ENABLE NEW CLASSES OF SCIENCE AND EXPLORATION MISSIONS

TRANSPORTATION TECHNOL

SHUTTLE ENHANCEMENT

- SSME Improvements
- Durable Thermal Protection Systems
- Improved Health Monitoring
- Light Structural Alloys
- Lidar-Based Adaptive Guidance & Control

NEXT GENERATION MANNED TRANSPORTS

- Configuration Assessment
- High Frequency, High Voltage Power Management/Distribution Systems
- LOX/LH2 Propellant for OMS/RCS
- Maintenance-free TPS
- Advanced Reusable Propulsion
- GPS-Based Autonomous GN&C
- Composites & Advanced Lightweight Metals
- Vehicle-Level Health Management For Autonomous Operations

HEAVY-LIFT CAPABILITY

- Advanced Fabrication (Forming & Joining)
- STME Improvements
- On-Vehicle Adaptive Guidance & Control
- Systems & Components for Electric Actuators
- Health Monitoring for Safe Operations
- AL-Li Cryo Tanks

LOW-COST COMMERCIAL

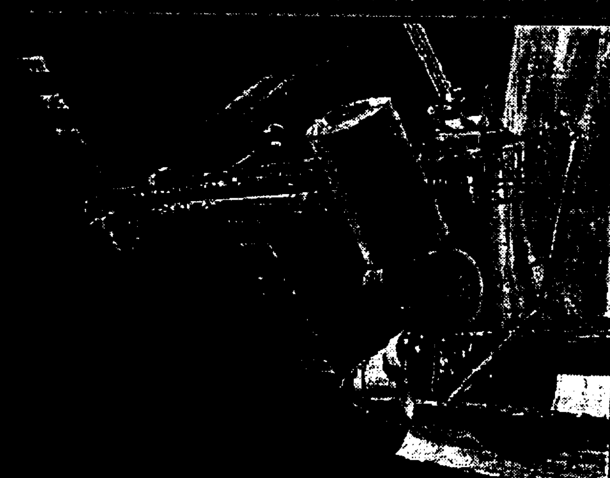
- Alternate Booster Concepts
- Advanced Cryogenic Upper Stage Engines
- Low-Cost Fab./Automated Processes/NDE
- Continuous Forging Processes for Cryogenic Tanks
- Fault-Tolerant, Redundant Avionics

IN-SPACE TRANSPORT

- High-Power Nuclear Thermal & Electric Propulsion
- High Performance, Multiple Use Cryogenic Chemical Engine
- Highly Reliable, Autonomous Avionics
- Low Mass, Space Durable Materials
- Long-Term, Low-Loss Management of Cryogenic Hydrogen
- Autonomous Rendezvous, Docking & Landing
- Aeroassist Technologies

SPACE PLATFORMS TECHNOL

DEVELOP TECHNOLOGIES THAT WILL ENHANCE ... UNMANNED SCIENCE, EXPLORATION AND COMME... WILL DECREASE LAUNCH AND LIFE CYCLE COST... ON-ORBIT MISSION EFFICIENC...



- DEVELOP TECHNOLOGIES THAT WILL DECREASE LAUNCH WEIGHT AND INCREASE THE EFFICIENCY OF SPACE PLATFORM FUNCTIONAL CAPABILITIES
- DEVELOP TECHNOLOGIES THAT WILL INCREASE HUMAN PRODUCTIVITY AND SAFETY OF MANNED MISSIONS
- DEVELOP TECHNOLOGIES THAT WILL INCREASE MAINTAINABILITY AND REDUCE LOGISTICS RESUPPLY OF LONG DURATION MISSIONS
- IDENTIFY AND DEVELOP FLIGHT EXPERIMENTS IN ALL TECHNOLOGY AND THRUST AREAS THAT WILL BENEFIT FROM THE UTILIZATION OF SSF FACILITIES

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SPACE PLATFORMS TECHNOLOGY

EARTH-ORBITING PLATFORMS

- Structural Dynamics
- On-Orbit Non-Destructive Evaluation Techniques
- Space Environmental Effects
- Power Systems
- Thermal Management
- Advanced Information Systems

SPACE STATIONS

- Regenerative Life Support
- Integrated Propulsion and Fluid Systems Architecture
- Extravehicular Mobility
- Telerobotics
- Artificial Intelligence

SPACE BASED LABORATORY AND TESTBED

Exploit Microgravity and Crew Interactive Capability to Advance and Validate Selected Technologies

DEEP SPACE MISSIONS

- Power and Thermal Management
- Propulsion
- Guidance, Navigation and Control

OPERATIONS TECHNOLOGY

DEVELOP AND DEMONSTRATE TECHNOLOGIES TO REDUCE THE COST OF NASA OPERATIONS, IMPROVE THE SAFETY AND RELIABILITY OF THOSE OPERATIONS, AND ENABLE NEW, MORE COMPLEX ACTIVITIES TO BE UNDERTAKEN

THE OPERATIONS THRUST SUPPORTS THE FOLLOWING MAJOR ACTIVITIES:

- IN-SPACE OPERATIONS
- FLIGHT SUPPORT OPERATIONS
- GROUND SERVICING AND PROCESSING
- PLANETARY SURFACE OPERATIONS
- COMMERCIAL COMMUNICATIONS

THE FOLLOWING TECHNOLOGY AREAS ARE INCLUDED:

- AUTOMATION & ROBOTICS
- INFRASTRUCTURE OPERATIONS
- INFORMATION & COMMUNICATIONS
- FLIGHT EXPERIMENTS

OPERATIONS TECHNOLOGY

AUTOMATION & ROBOTICS

Mission Control Support
Planning & Scheduling
Ground Servicing & Support Roles
In-Space Teleoperation & Telerobotics

INFRASTRUCTURE OPERATIONS

In-Space Assembly & Construction
Space Processing & Servicing
Training & Human Factors
Ground Test & Processing
Flight Control & Space Operations

INFORMATION & COMMUNICATIONS

Space Data Systems
Ground Data Systems
Commercial Satellite Communications
Photonics Systems
High Rate Communications

FLIGHT EXPERIMENTS

Flight Telerobotic Servicer
Commercial Satellite Communications
Optical Communications

OAET

ITP OVERVIEW

- SPACE R&T PROGRAM APPROACH
- INTEGRATED TECHNOLOGY PLAN DEVELOPMENT
- INTEGRATED TECHNOLOGY PLAN STRUCTURE
- ⇨ BUDGET DEVELOPMENT
- SUMMARY COMMENTS

"Strategic Plan" ITP: CSTP Element Categorization

OAET

Space Science Technology	Submillimeter Sensing	Direct Detectors Microprecision CSI	Active µwave Sensing Laser Sensing	Sample Acq., Analysis & Preservation	Passive Microwave Sensing	—	Optoelectrnics Sensing & Processing	Probes and Penetrators	—
	Cooler and Cryogenics	Data Visualization	Data Archiving and Retrieval	Telescope Optical Systems	Sensor Electronics & Processing	—	Precision Instrument Pointing	Sensor Optical Systems	—
Planetary Surface Exploration Technology	Radiation Protection	Regenerative Life Support (Phys-Chem.)	Space Nuclear Power (SP-100)	High Capacity Power	Planetary Rovers	Surface Habitats and Construction	Exploration Human Factors	—	Artifical Gravity
	—	—	Extravehicular Activity Systems	Surface Solar Power and Thermal Mgt.	In Situ Resource Utilization	Laser-Electric Power Beaming	Medical Support Systems	—	—
Transportation Technology	ETO Propulsion	Aeroassist Flight Expt Nuclear Thermal Propulsion	Aeroassist/ Aerobraking	Transfer Vehicle Avionics	ETO Vehicle Avionics	ETO Vehicle Structures & Materials	Autonomous Rendezvous & Docking	COHE	Auxiliary Propulsion
	Cryogenic Fluid Systems	Adv. Cryo. Engines	Low-Cost Commercial ETO XPort	Nuclear Electric Propulsion	CONE	SEPS TFE	Autonomous Landing	TV Structures and Cryo Tankage	HEAb
Space Platforms Technology	Platform Structures & Dynamics	Platform Power and Thermal Mgt.	Zero-G Life Support	Platform Materials & Environ. Effects	Station-Keeping Propulsion	—	Spacecraft On-Board Propulsion	Earth-Orbiting Platform Controls	Advanced Refrigerator Systems
	—	—	Zero-G Advanced EMU	Platform NDE-NDI	Deep-Space Power and Thermal	—	Spacecraft GN&C	Debris Mapping Experiment	—
Operations Technology	Space Data Systems	High-Rate Comm.	Artificial Intelligence	Ground Data Systems	Optical Comm Flight Expt Navigation & Guidance	Flight Control and Operations	Space Assembly & Construction	Space Processing & Servicing	Photonics Data Systems
	—	CommSat Communicat'ns	TeleRobotics	FTS DTF-1	Operator Syst./Training	CommSat Communicat'ns Flight Expts	—	Ground Test and Processing	—
	HIGHEST PRIORITY ◊◊◊			2nd-HIGHEST PRIORITY ◊◊			3rd-HIGHEST PRIORITY ◊		

JUNE 18, 1991
JCM-68001

SPACE RESEARCH & TECHNOLOGY PROGRAM

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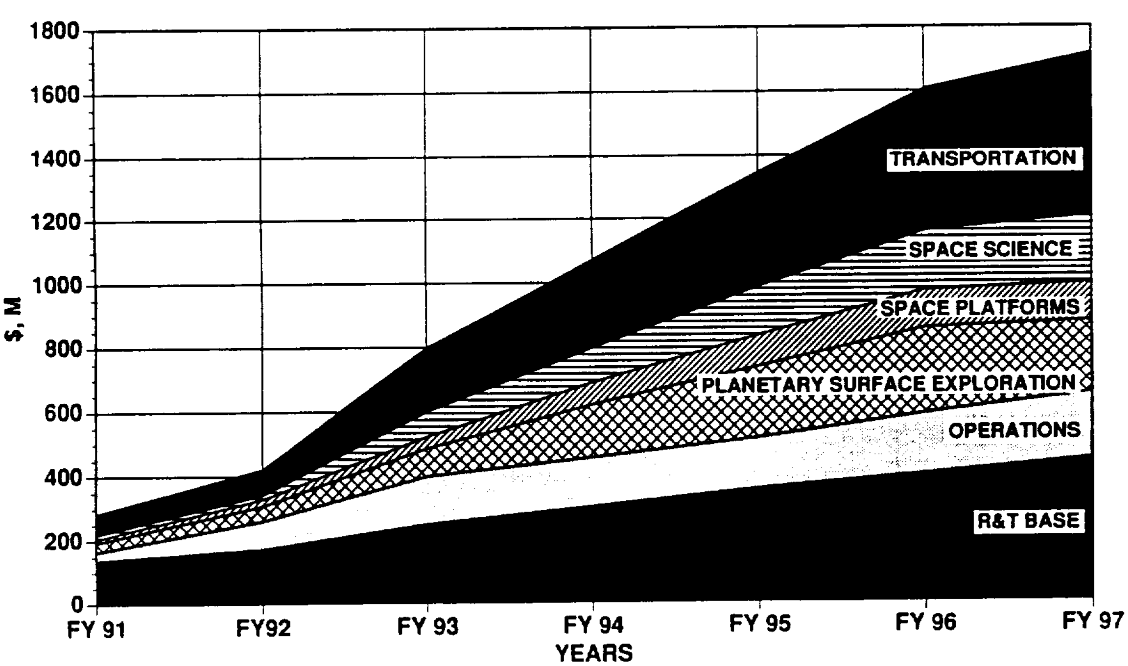
"STRATEGIC PLAN" FY 91 - 97 BUDGET BY THRUSTS



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SPACE RESEARCH & TECHNOLOGY PROGRAM

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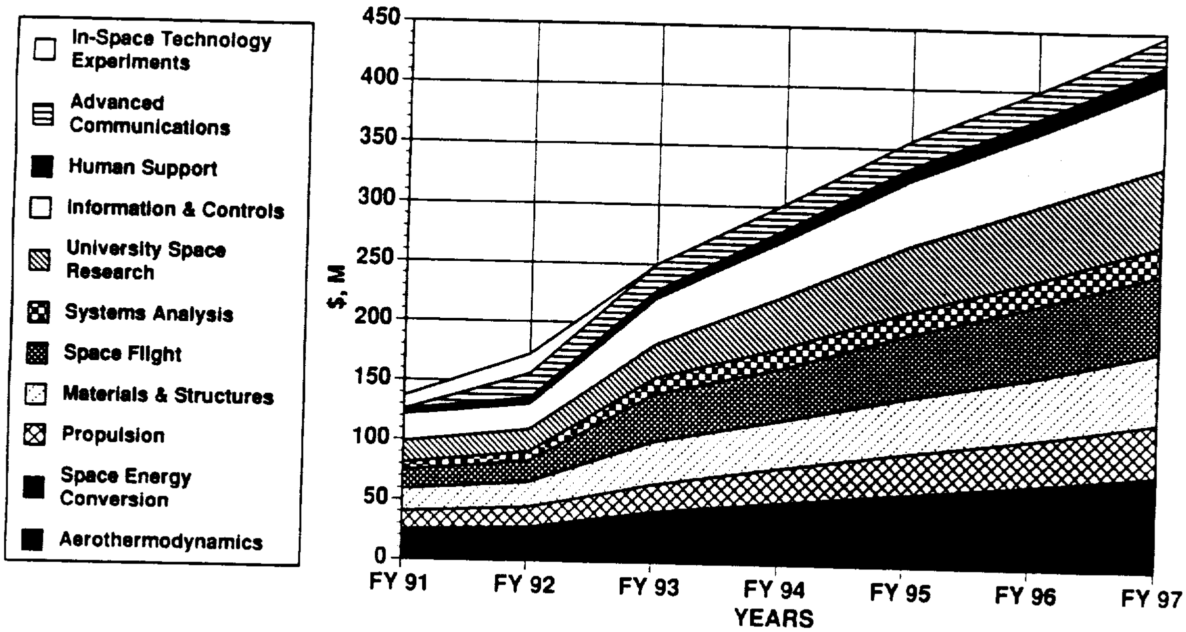
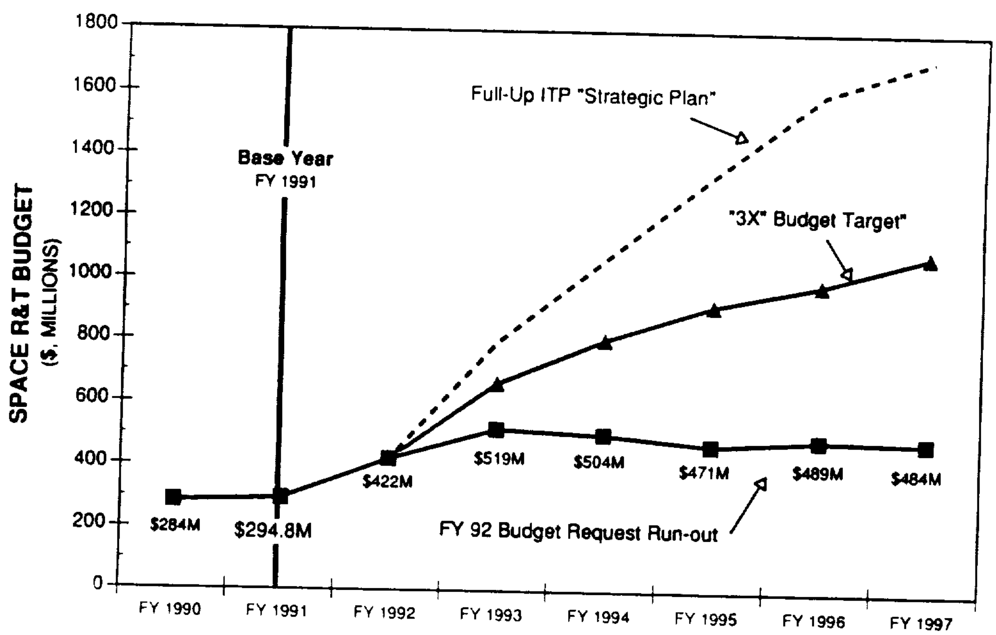
"STRATEGIC PLAN" FY 91 - 97 SPACE R&T BASE BY DISCIPLINE



INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

SPACE R&T BUDGET IMPLICATIONS

OAET



"3x Program" ITP: CSTP Element Categorization ('93)

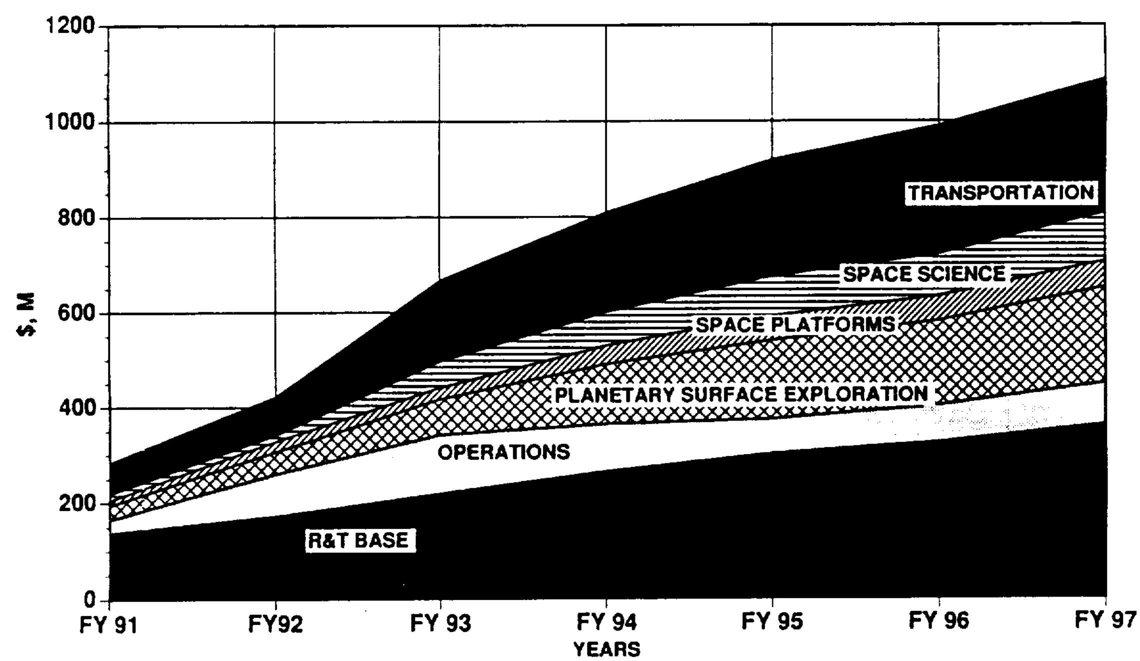
OAET

	HIGHEST PRIORITY ^^^			2nd-HIGHEST PRIORITY ^^			3rd-HIGHEST PRIORITY ^		
Space Science Technology	Submillimeter Sensing	Direct Detectors Microprecision CSI	Active μwave Sensing Laser Sensing	Sample Acq., Analysis & Preservation	—	—	—	—	—
	Cooler and Cryogenics	Data Visualization	Data Archiving and Retrieval	Telescope Optical Systems	Sensor Electronics & Processing	—	—	—	—
Planetary Surface Exploration Technology	Radiation Protection	Regenerative Life Support (Phys-Chem.)	Space Nuclear Power (SP-100)	High Capacity Power	Planetary Rovers	—	Exploration Human Factors	—	—
	—	—	Extravehicular Activity Systems	Surface Solar Power and Thermal Mgt.	In Situ Resource Utilization	Laser-Electric Power Beaming	—	—	—
Transportation Technology	ETO Propulsion	Aeroassist Flight Expt Nuclear Thermal Propulsion	Aeroassist/ Aerobraking	Transfer Vehicle Avionics	ETO Vehicle Avionics	ETO Vehicle Structures & Materials	—	—	—
	Cryogenic Fluid Systems	Adv. Cryo. Engines	Low-Cost Commercial ETO XPort	Nuclear Electric Propulsion	CONE	—	—	—	—
Space Platforms Technology	Platform Structures & Dynamics	Platform Power and Thermal Mgt.	Zero-G Life Support	Platform Materials & Environ. Effects	—	—	Spacecraft On-Board Propulsion	—	—
	—	—	Zero-G Advanced EMU	—	—	—	—	—	—
Operations Technology	Space Data Systems	High-Rate Comm.	Artificial Intelligence	—	—	—	—	—	—
	—	CommSat Communicat'ns	TeleRobotics	FTS DTF-1	Operator Syst./Training	—	—	—	—

SPACE RESEARCH & TECHNOLOGY PROGRAM

OAET

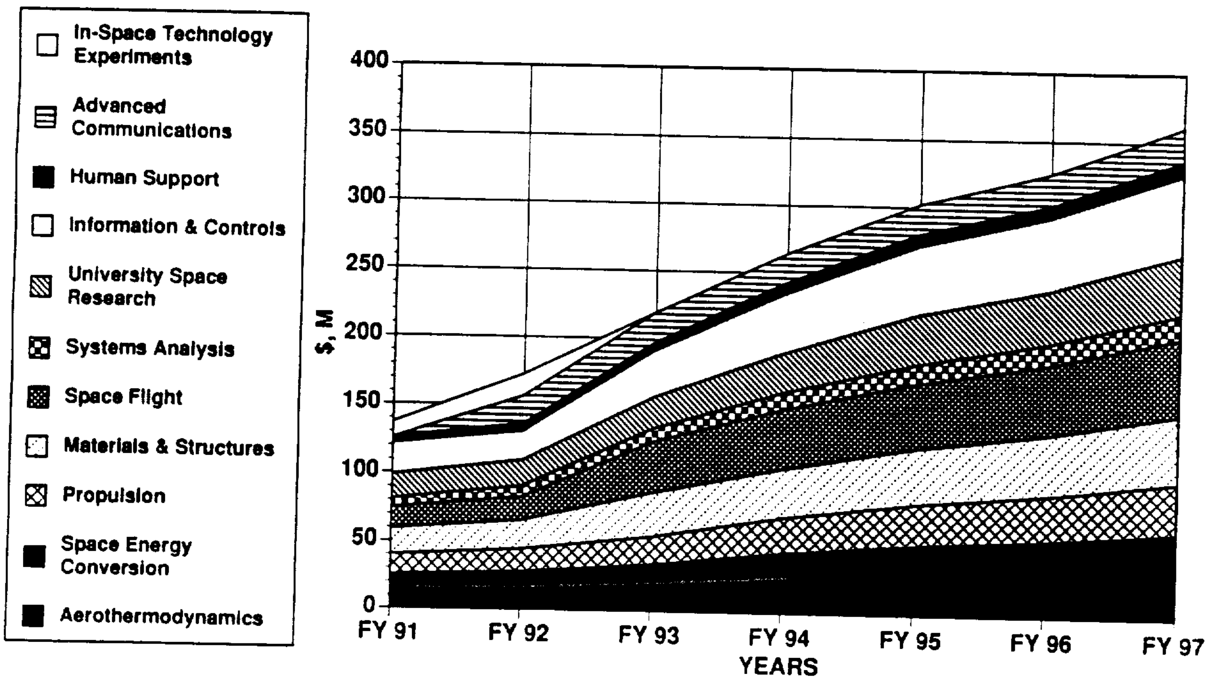
"3X PROGRAM" FY 91 - 97 BUDGET BY THRUSTS



SPACE RESEARCH & TECHNOLOGY PROGRAM

OAET

"3X PROGRAM" FY 91 - 97 SPACE R&T BASE BY DISCIPLINE



INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

Current Program ITP: CSTP Element Categorization

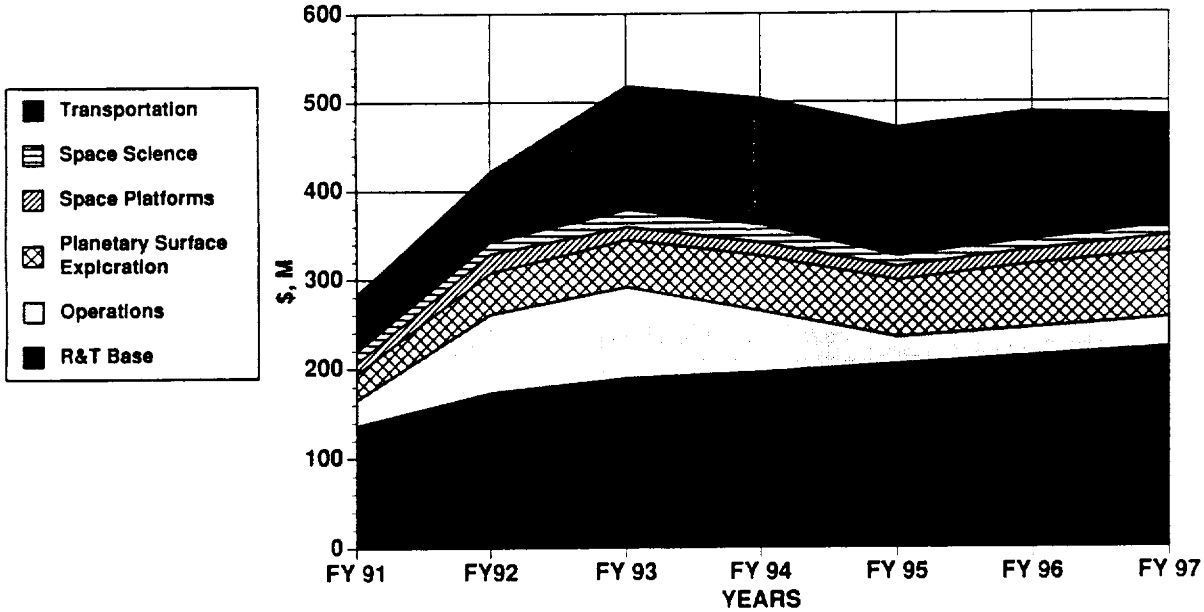
OAET

	HIGHEST PRIORITY ◊◊◊			2nd-HIGHEST PRIORITY ◊◊			3rd-HIGHEST PRIORITY ◊		
Space Science Technology	Submillimeter Sensing	Direct Detectors	—	—	—	—	—	—	—
	Cooler and Cryogenics	Microprecision CSI	—	—	—	—	—	—	—
Planetary Surface Exploration Technology	Radiation Protection	Regenerative Life Support (Phys-Chem.)	Space Nuclear Power (SP-100)	High Capacity Power	—	—	Exploration Human Factors	—	—
	—	—	Extravehicular Activity Systems	—	—	—	—	—	—
Transportation Technology	ETO Propulsion	Aeroassist Flight Expt	Aeroassist/ Aerobraking	—	—	—	—	—	—
	—	Adv. Cryo. Engines	Nuclear Thermal Propulsion	Nuclear Electric Propulsion	—	—	—	—	—
Space Platforms Technology	Platform Structures & Dynamics	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—
Operations Technology	Space Data Systems	—	Artificial Intelligence	—	—	—	—	—	—
	—	—	TeleRobotics	FTS DTF-1	—	—	—	—	—

SPACE RESEARCH & TECHNOLOGY PROGRAM

OAET

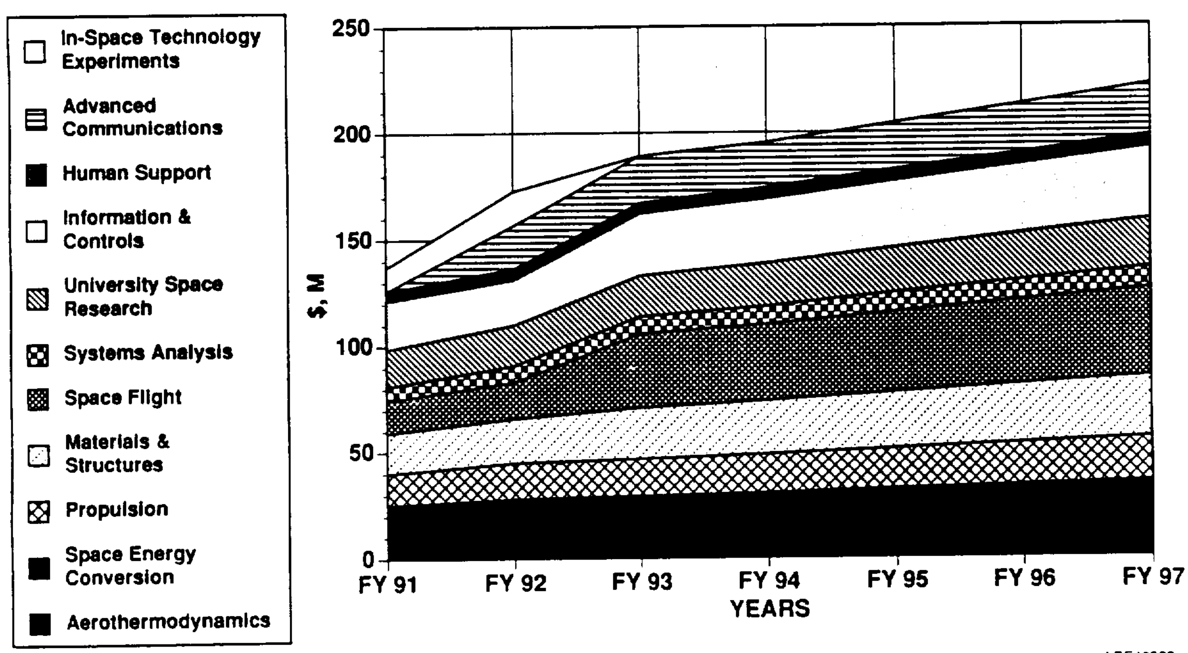
CURRENT FY 91 - 97 BUDGET BY THRUSTS



SPACE RESEARCH & TECHNOLOGY PROGRAM

OAET

CURRENT FY 91 - 97 SPACE R&T BASE BY DISCIPLINE



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ITP OVERVIEW

- SPACE R&T PROGRAM APPROACH
- INTEGRATED TECHNOLOGY PLAN DEVELOPMENT
- INTEGRATED TECHNOLOGY PLAN STRUCTURE
- BUDGET DEVELOPMENT
- ⇨ SUMMARY COMMENTS

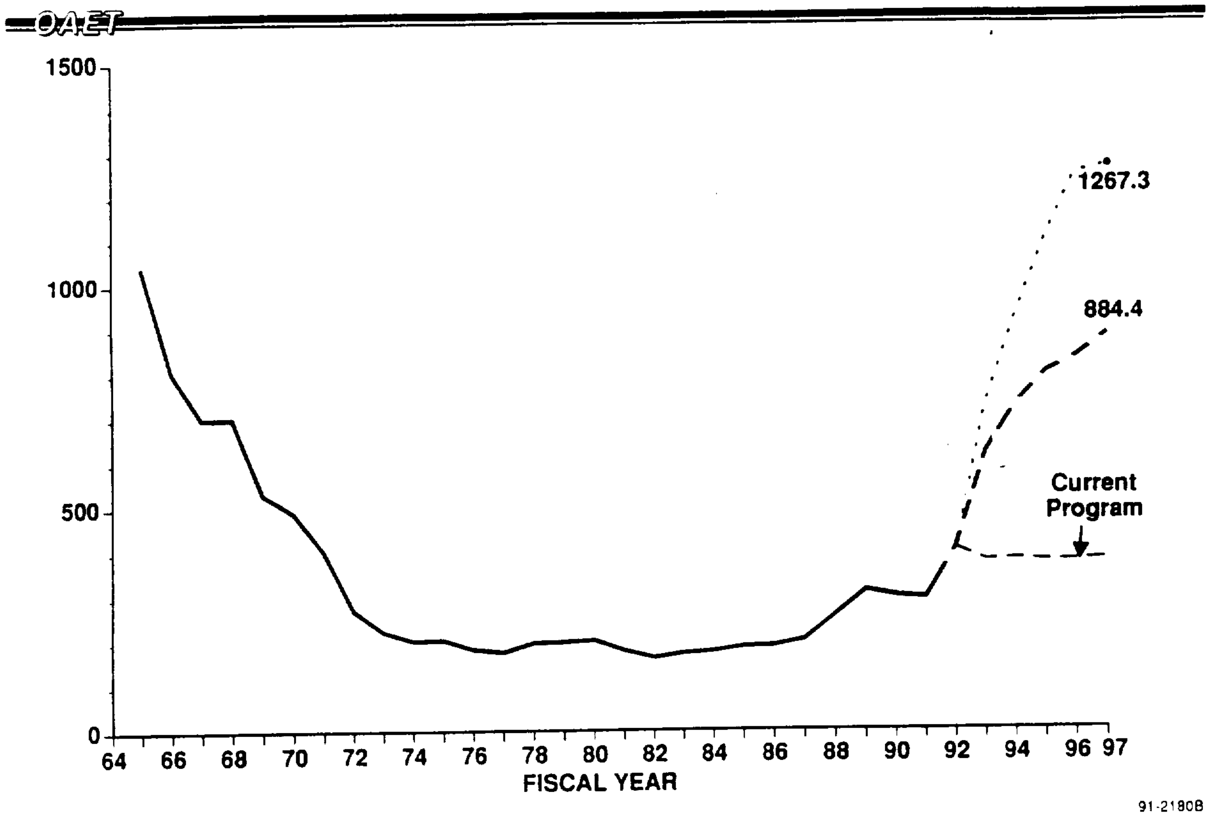
Office of Aeronautics, Exploration and Technology

FY 1992 BUDGET

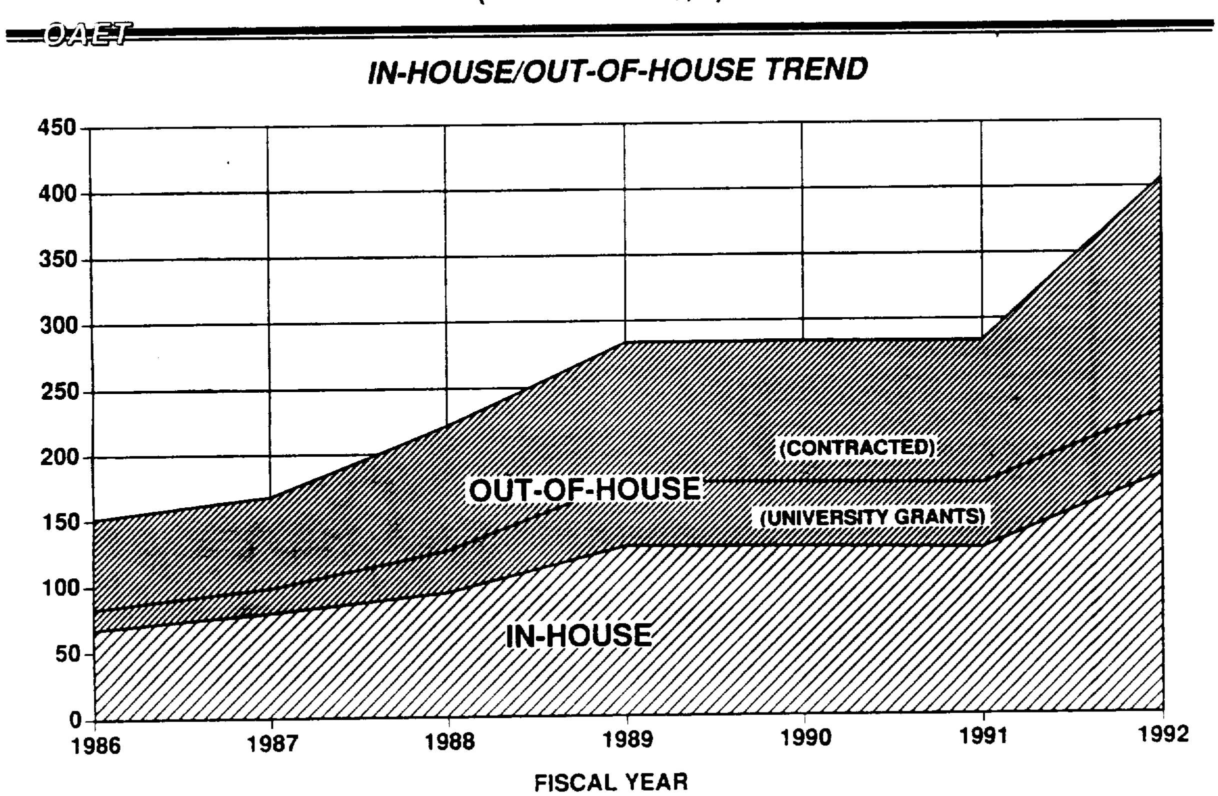
($,M)

APPROP.	AERO	TRANSAT.	SPACE	TOTAL
R&D	591.2	72.0	421.8	1085.0
R&PM	386.3	21.1	222.2	629.6
CofF	51.6	-	-	51.6
TOTAL	1029.1	93.1	644.0	1766.2

OAET SPACE R&Γ FUNDING TREND
(SPACE R&D IN CONSTANT 1991 $,M)



SPACE R&T
(REAL YEAR $,K)



SPACE TECHNOLOGY INTERDEPENDENCY GROUP

OAET

PURPOSE

PROVIDE A FORUM FOR PARTICIPATING GOVERNMENT AGENCIES TO IDENTIFY AND PROMOTE THE PURSUIT OF NEW OPPORTUNITIES FOR COOPERATIVE RELATIONSHIPS AND MONITOR ONGOING COOPERATIVE ACTIVITIES.

BACKGROUND/STRUCTURE

- INITIATED IN 1973, FORMALIZED WITH AF/NASA MOU IN 1984
- EXECUTIVE OVERSIGHT: AFSC and NASA OAET
- OPERATES THROUGH TECHNICAL COMMITTEES COMPOSED OF LABORATORY AND CENTER MANAGERS
- IDENTIFIES AND MONITORS STATUS OF:
  - DEPENDENT PROGRAMS
  - INTERDEPENDENT PROGRAMS
  - INDEPENDENT PROGRAMS

STIG EXPANDING TO INCLUDE ARMY, NAVY AND OTHER GOVERNMENT ORGANIZATIONS

STIG COMMITTEE STRUCTURE

OAET

ELECTRONICS AND INFORMATION PROCESSING
- *MICROWAVE & MILLIMETER WAVE TECHNOLOGY*
- *MICROELECTRONIC*
- *E-O & SENSOR TECHNOLOGY*

PROPULSION
- *LAUNCH VEHICLE PROPULSION*
- *ORBIT TRANSFER/AUXILIARY PROPULSION*

POWER
- *ENERGY PRODUCTION*
- *ENERGY STORAGE*
- *POWER MANAGEMENT*
- *THERMAL MANAGEMENT*

SPACE MATERIALS, STRUCTURES, DYNAMICS AND CONTROLS
- *MATERIALS*
- *STRUCTURAL CONCEPTS*
- *LARGE STRUCTURE DYNAMICS*
- *LARGE STRUCTURES*
- *FIGURE CONTROL*
- *MODELING*

FLIGHT DYNAMICS AND CONTROL
- *FLIGHT DYNAMICS*
- *FLIGHT CONTROL*

SPACE OPERATIONS TECHNOLOGY
- *HUMAN FACTORS*
- *ENVIRONMENT*
- *REMOTE OPERATIONS*
- *FLUID STORAGE AND TRANSFER*

SPACE FLIGHT EXPERIMENTS

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

EXTERNAL REVIEW APPROACH

O-A-E-T

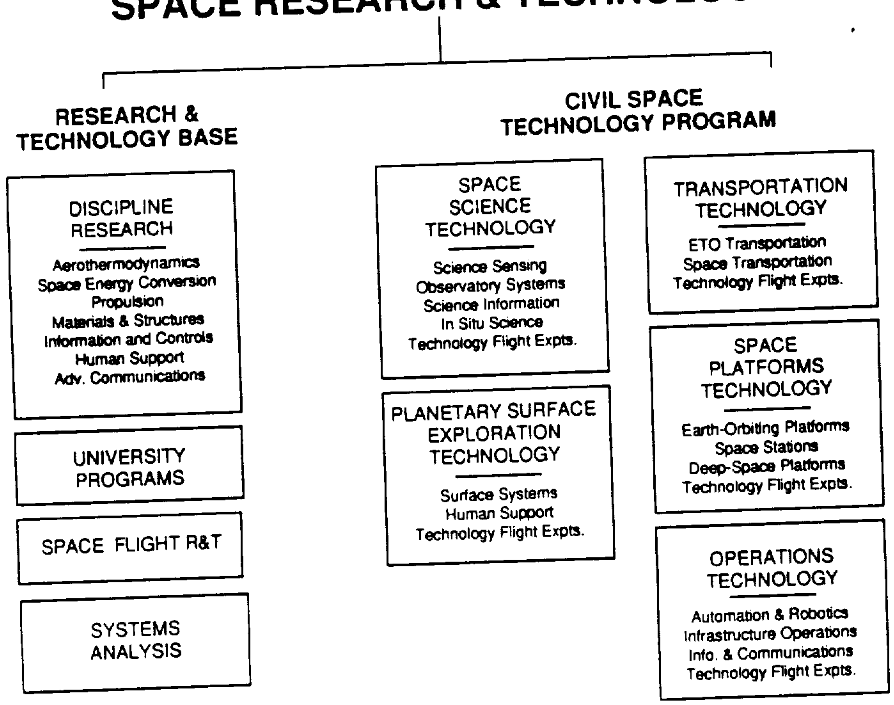
OBJECTIVES

"NASA (SHOULD) UTILIZE AN EXPERT, OUTSIDE REVIEW PROCESS, MANAGED FROM HEADQUARTERS, TO ASSIST IN THE ALLOCATION OF TECHNOLOGY FUNDS"

- REVIEW THE PROCESS USED FOR DEVELOPING THE INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM
- ASSESS THE TECHNICAL CONTENT OF THE PROPOSED ITP
  - IDENTIFY KEY TECHNOLOGY AREAS THAT NEED TO BE ADDRESSED
  - FIRST-ORDER EVALUATION OF THE ESTIMATES OF "COST FOR ACCOMPLISHMENT"
  - RECOMMEND ADJUSTMENTS IN PRIORITIES AND RESOURCE PLANNING
- ASSESS THE ACCOMMODATION OF USER NEEDS
  - EVALUATE STRATEGIC AND NEAR-TERM TECHNOLOGY PLANS AGAINST TECHNOLOGY NEEDS OF FUTURE MISSIONS
  - RECOMMEND POTENTIAL CHANGES IN THE PHASING OF NEW PROGRAMS TO BETTER MEET TECHNOLOGY NEEDS

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

SPACE RESEARCH & TECHNOLOGY



Office of
Aeronautics,
Exploration and
Technology

INTEGRATED TECHNOLOGY PLAN USER ACCOMMODATION SUMMARY

presentation to

THE ITP EXTERNAL EXPERT REVIEW TEAM

John C. Mankins

June 25, 1991

NASA
National Aeronautics and
Space Administration

INTEGRATED TECHNOLOGY PLAN EXTERNAL REVIEW

USER NEEDS ACCOMMODATION SUMMARY

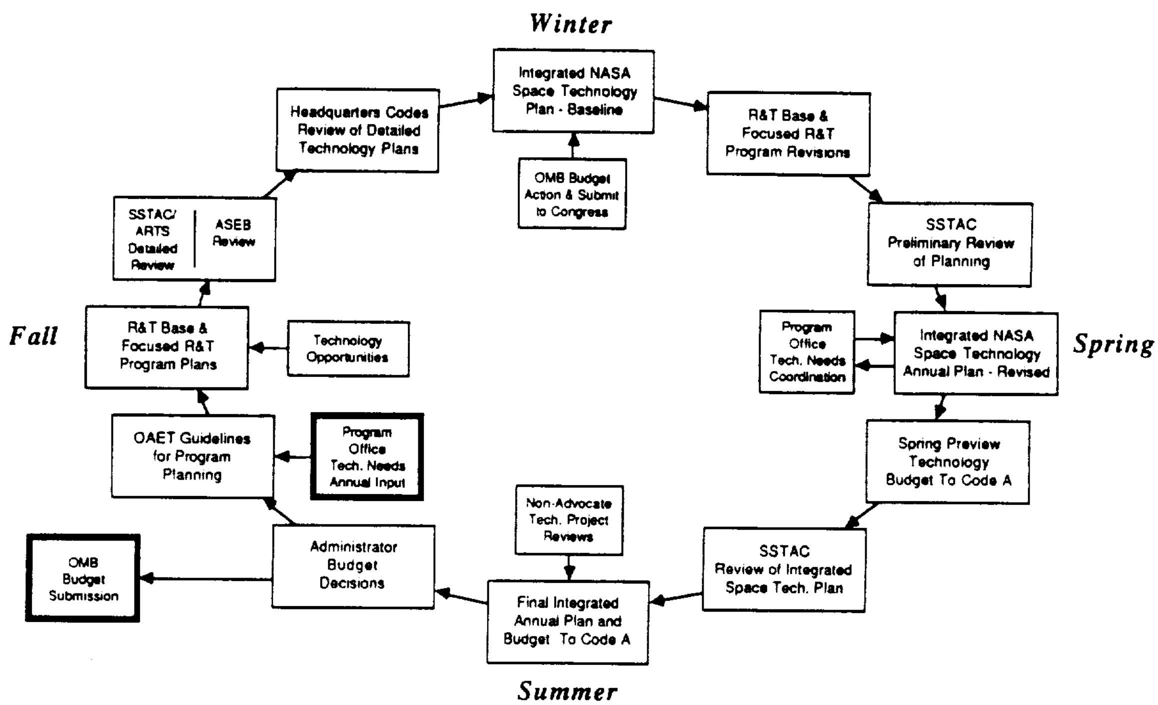
O-A-E-T

CONTENTS

- INTEGRATED TECHNOLOGY PLAN USER NEEDS OVERVIEW
- USER NEEDS ACCOMMODATION ASSESSMENT
- SPECIAL ASSESSMENT: ITP VS. PREVIOUS NATIONAL-LEVEL RECOMMENDATIONS
- SUMMARY

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM
ANNUAL SPACE R&T PLANNING AND BUDGETING CYCLE

OAET



INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM
OSSA TECHNOLOGY NEEDS

OAET

	NEAR-TERM NEED	MID-TERM NEED	FAR-TERM NEED
HIGHEST PRIORITY	Sub-mm & μ-wave Sensing Long-Life Cryo Coolers/Cryo Shielding High-Energy Detectors Sensor Readout Electronics Vibration Isolation Technology Efficient/Quiet Refrigerator/Freezer Extreme Upper Atmosphere Instr. Platforms	Long-Life, Stable, Tunable Lasers Solar Probe/Mercury Orbiter Thermal Protect. High -Vol./Density/Rate Onboard Data Storage Interferometer-Specific Technology	Structures: Large/Controlled/Deployed/Ant'a Robotics Precision Inter-S/C Ranging/Positioning 50-100 Kilowatt Ion Propulsion (NEP) Large Filled Apertures Parallel S/W Env. for Model&Data Visualization Computational Techniques
2ND HIGHEST PRIORITY	High Frame Rate/Res. Video/Data Compress. 2.4 to 4 Meter, 100 K Lightweight PSR Solar Arrays/Cells Automated Biomedical Analysis Radiation Hardened Parts/Detectors Long-Life/High-Energy Density Batteries Real-Time Environmental Control Space-Qualified Masers/Ion Clocks Fluid Diagnostics	Auto-Sequencing & CMD Generation Auto S/C Monitoring & Fault Recovery 32 GHz TWT/Optical Communications Telescience/Telepresence/Art. Intelligence Improved EVA Suit/PLSS (EMU) Combustion Devices Plasma Wave Antenna/Thermal	SIS 3 THz Heterodyne Receiver SETI Detector Technologies Mini-Ascent Vehicle/Lander Deceleration Radiation Shielding for Crews SAAP/Probes/In Situ Instr's/Penetrators Human Artificial Gravity Systems X-Ray Optics Technology Returned-Sample Biobarrier Analysis Cap. High-Resolution Spectrometer
3RD HIGHEST PRIORITY	Descent Imaging/Mini RTG/Mini Camera K-Band Transponders Ultra-High Gigabit/sec. Telemetry Mini-Spacecraft Subsystems Real-Time Radiation Monitoring Solid/Liquid Interface Characterization Laser Light Scattering High-Temperature Mat'ls for Furnaces Field-Portable Gas Chromatographs Adv. Furnace Technology	Regenerative Life Support Thermal Control System Non-Contact Temp. Measurement 3-D Packaging for 1MB Solid State Chips Microbial Decontamination Methods Animal and Plant Reproduction Aids Special-Purpose Bioreactor Simulator Syst. Rapid Subject/Sample Delivery & Return Capability	Autonomous Rendezvous/Sample Xfer/Landing Non-Destructive Monitoring Capability Low-Drift Gyros/Trackers/Actuators Heat Shield for 16 km/sec Earth entry Partial-G/μ-G Medical Care Systems Dust Protection/Jupiter's Rings Non-Destructive Cosmic Dust Collection CELSS Support Technologies

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

OSF TECHNOLOGY NEEDS

O-A-E-T

	Technology	MSSION/SYSTEM APPLICATIONS FORECAST
NASA R&T DRIVEN (Technology Transfer to Industry)	Vehicle Health Management	SSF, ACRV, STS, STV, CTV, PLS, NLS/HLLV, AMLS
	Advanced Turbomachinery (Components/Models)	SSF, STS, STV, ELVs, NLS/HLLV, AMLS
	Combustion Devices	SSF, STS, STV, ELVs, NLS/HLLV, AMLS
	Advanced Heat Rejection Technologies	SSF
	High-Efficiency Space Power Systems	SSF
	Water Recovery and Management	SSF
	Advanced Extravehicular Mobility Unit	SSF
	Electromechanical Control Systems	STS, STV, CTV, NLS/HLLV, AMLS
	Crew Training Systems	SSF
	Characterization of Al-Li Alloys	STS, STV, CTV, NLS/HLLV, AMLS
	Cryogen Storage, Handling & Supply	SSF, STS, STV, CTV, AMLS
	TPS for High-Temp. Applications	STV, PLS, NLS/HLLV, AMLS
	Guidance, Navigation & Control	SSF, ACRV, STS, STV, CTV, PLS, NLS/HLLV, AMLS
	Robotic Systems	SSF, STV, CTV, AMLS
	Orbital Debris	SSF, CTV, AMLS
	Advanced Avionics Architectures	SSF, ACRV, STS, STV, CTV, PLS, NLS/HLLV, AMLS
INDUSTRY R&T DRIVEN (NASA Leverage from Industry)	Signal Transmission and Reception	SSF, STS, CTV, AMLS
	Advanced Avionics Software	SSF, ACRV, STS, STV, CTV, PLS, NLS/HLLV, AMLS
	Non-Destructive Evaluation	SSF, ACRV, STV, CTV, NLS/HLLV, AMLS
	Environ. Safe Cleaning Solvents, Refrig./Foams	SSF, STV, CTV, AMLS
	Video Technologies	SSF, STS, PLS, AMLS (?)

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

OSO TECHNOLOGY NEEDS

O-A-E-T

OSO HIGHEST-PRIOITY TECHNOLOGY NEEDS

High-Rate Communications

Optical and Millimeter Wave Radio Frequencies
(for space-to-ground and space-to-space)

Advanced Data Systems

Advanced Data Storage, Data Compression, and
Information Management Systems

Mission Operations

Artificial Intelligence, Expert Systems, Neural Networks, Increased Automation in Mission Operations, Testbeds for Advanced Software, Coordination of Distributed Software, and Automated Performance Analysis of Networking Computing Environments

Advanced Navigation Techniques

New techniques for cruise, approach,
and in-orbit navigation

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

SEI OFFICE TECHNOLOGY NEEDS

OAET

Category	Technology	MSSION/SYSTEM APPLICATIONS FORECAST
Category 1 (Enabling and Common)	Radiation Protection	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	EVA Systems	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	Nuclear Thermal Propulsion	INITIAL MARS MISSION
	Regenerative Life Support	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	Cryo. Fluid Mgt. Storage & Transfer	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	Micro-G Countermeasures/Art. Gravity	INITIAL MARS
	Aerobraking	INITIAL LUNAR, EVOLUTION, ROBOTIC MARS, INITIAL MARS
Category 2 (Enabling and Unique or High-Leverage and Common)	Auto. Rendezvous & Docking	INITIAL LUNAR, EVOLUTION, ROBOTIC MARS, INITIAL MARS
	Health Maintenance & Care	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	In-Space Systems Assy/Processing	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	Surface Systems Construction/Processing	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	Cryogenic Space Engines	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	In Situ Resource Utilization	EVOLUTION, INITIAL MARS
	Surface Power	INITIAL LUNAR, EVOLUTION, INITIAL MARS
Category 3 (High-Leverage and Unique)	Autonomous Landing	INITIAL LUNAR, EVOLUTION, ROBOTIC MARS, INITIAL MARS
	Human Factors	INITIAL LUNAR, EVOLUTION, INITIAL MARS
	Surface System Mobility & Guidance	INITIAL LUNAR, EVOLUTION, ROBOTIC MARS, INITIAL MARS
	Electric Propulsion	EVOLUTION, INITIAL MARS
	Sample Acquisition, Analysis & Preserv.	INITIAL LUNAR, EVOLUTION, ROBOTIC MARS, INITIAL MARS

NOTE: THIS LISTING WAS DEVELOPED PRIOR TO THE RELEASE OF THE SYNTHESIS REPORT

APRIL 23, 1991
JCM-6836a

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

SYNTHESIS GROUP SEI TECHNOLOGY NEEDS

OAST

HIGH PRIORITY AREAS

Heavy Lift Launch
Nuclear-electric Surface Power
Nuclear Thermal Propulsion
Closed-loop Life Support System
Telerobotics
EVA Suits
Radiation Effects/Shielding
Long-duration Human Factors
In Situ Resource Evaluation & Processing
Autonomous Rendezvous/Docking
Cryogen Transfer/Storage
Light-weight Structural Mat'ls & Fabrication
Nuclear Electric Prop. (Cargo)
Zero-gravity Countermeasures

OTHER TECHNOLOGIES CITED

(SELECTED EXAMPLES)

Virtual Reality
Surface Habitats
Regenerative Fuel Cells
Solar Arrays
Power Beaming
Lunar Surface Factory Operations
Mining, Excavation And Construction
Sample Acquisition/Analysis
High Rate Comm. & Navigation
Lunar Surface Instrument Coolers
Submillimeter/Optical Interferometers
Remote Sensors
Large Filled Aperture Telescopes
Robotic Probes
Aerobraking (Cited As Back-up Option)
Chemical Propulsion (Back-up Option)
Helium-3 Fusion

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

EXTERNAL TECHNOLOGY PERSPECTIVES SUMMARY

OAET

SPACE SCIENCE

Precision Space Structures and Pointing Accuracy

PLANETARY SURFACE EXPLORATION

Regnerative Life Support Systems
Radiation Protection for Long Missions
Utilization of In Situ Materials/Propellants
Artificial Intelligence Techniques
Robotic & Microrobotic Systems
Advanced EMUs
Surface Rover Technologies (Pressurized and Unpressurized)
Nuclear Electric Power
High-Efficiency Lunar Radiators & Thermal Energy Storage
Power Beaming
Human Health Maintenance
Reduced Gravity Countermeasures/Artificial Gravity
Bioprocess-Grade Fluid Management Systems

SPACE PLATFORMS

Composite Lightweight Structures
Micrometeoroid and Debris Protection
Long-Life Structures and Mechanisms
Regnerative Life Support Systems
Advanced EMUs
Expanded Atomic Oxygen Database
High-Efficiency, Radiation-Resistant, Lightweight PV Arrays
High-Efficiency Power Processing Units
Lightweight Batteries

TRANSPORTATION

Economical Launch Systems (Manned and Unmanned)
Software Productivity Enhancers
Integrated Vehicle Health Monitoring and Maintenance
Advanced Cryogenic (Oxygen/Hydrogen) Engines
Fault-Tolerant Advanced Avionics with Open Architectures
High-Performance/Composite Lightweight Structures
Long-Life Structures and Mechanisms
High-Performance, Storable Space Thrusters
High-Power Electric Propulsion
Nuclear Thermal Propulsion for Manned Interplanetary Missions
Cryogenics Long-Duration Storage and Management
Gun-Type Launch Systems
Aerobraking (Thermal Protection Systems)
Integrated RCS/Auxiliary Propulsion
Lightweight, Fuel-Efficient Airbreather Propulsion Systems

OPERATIONS

Data Management System Architecture and Software
Systems Integration technologies (Software, etc.)
Artificial Intelligence Techniques
Safe Robotic Systems
Advanced Communications (e.g., Laser & Millimeter Wave Technology)

INTEGRATED TECHNOLOGY PLAN EXTERNAL REVIEW

USER NEEDS ACCOMMODATION SUMMARY

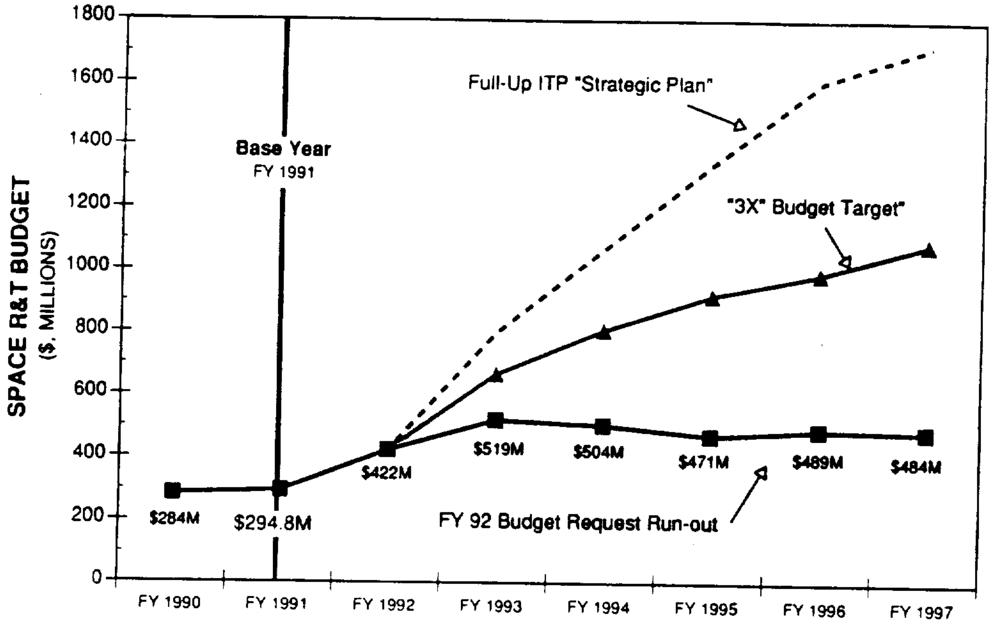
OAET

CONTENTS

- INTEGRATED TECHNOLOGY PLAN USER NEEDS OVERVIEW
- ⇨ USER NEEDS ACCOMMODATION ASSESSMENT
- SPECIAL ASSESSMENT: ITP VS. PREVIOUS NATIONAL-LEVEL RECOMMENDATIONS
- SUMMARY

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM
SPACE R&T BUDGET IMPLICATIONS

OAET



ITP FOCUSED PROGRAMS ASSESSMENT
OSSA TECHNOLOGY NEEDS COVERAGE - HIGHEST PRIORITY

OAET

		Current	3x Program	Strategic
Near-Term Needs	Sub-mm & μ-wave Sensing	Marginally Funded	Constrained Progress	Adequate Coverage
	Long-Life Cryo Coolers/Cryo Shielding	Marginally Funded	Adequate Coverage	Adequate Coverage
	High-Energy Detectors	Marginally Funded	Constrained Progress	Adequate Coverage
	Sensor Readout Electronics		Adequate Coverage	Adequate Coverage
	Vibration Isolation Technology	Marginally Funded	Marginally Funded	Adequate Coverage
	Efficient/Quiet Refrigerator/Freezer			Outyear "Start"
	Extreme Upper Atmosphere Instr. Platforms			
	Long-Life, Stable, Tunable Lasers	Marginally Funded	Adequate Coverage	Adequate Coverage
	Solar Probe/Mercury Orbiter Thermal Protect.			Adequate Coverage
	High -Vol./Density/Rate Onboard Data Storage	Marginally Funded	Adequate Coverage	Adequate Coverage
	Interferometer-Specific Technology	Constrained Progress	Constrained Progress	Adequate Coverage
	Structures: Large/Controlled/Deployed/Ant'a	Constrained Progress	Constrained Progress	Adequate Coverage
	Robotics	Marginally Funded	Constrained Progress	Adequate Coverage
	Precision Inter-S/C Ranging/Positioning			Outyear "Start"
	50-100 Kilowatt Ion Propulsion (NEP)	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Large Filled Apertures		Constrained Progress	Adequate Coverage
Far-Term Needs	Parallel S/W Env. for Model&Data Visualization		Adequate Coverage	Adequate Coverage
	Computational Techniques		Adequate Coverage	Adequate Coverage

LEGEND: Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

JUNE 24, 19

ITP FOCUSED PROGRAMS ASSESSMENT
OSSA TECHNOLOGY NEEDS COVERAGE - 2nd HIGHEST PRIORITY

OAET

Term	Need	Current	3x Program	Strategic
Near-Term Needs	High Frame Rate/Res. Video/Data Compress.	Marginally Funded	Constrained Progress	Adequate Coverage
	2.4 to 4 Meter, 100 K Lightweight PSR		Constrained Progress	Adequate Coverage
	Solar Arrays/Cells		Constrained Progress	Adequate Coverage
	Automated Biomedical Analysis			Outyear "Start"
	Radiation Hardened Parts/Detectors	Marginally Funded	Adequate Coverage	Adequate Coverage
	Long-Life/High-Energy Density Batteries		Constrained Progress	Adequate Coverage
	Real-Time Environmental Control	Constrained Progress	Constrained Progress	Adequate Coverage
	Space-Qualified Masers/Ion Clocks			
	Fluid Diagnostics			Adequate Coverage
	Auto-Sequencing & CMD Generation			Adequate Coverage
	Auto S/C Monitoring & Fault Recovery			Adequate Coverage
	32 GHz TWT/Optical Communications		Constrained Progress	Adequate Coverage
	Telescience/Telepresence/Art. Intelligence	Constrained Progress	Constrained Progress	Adequate Coverage
	Improved EVA Suit/PLSS (EMU)	Constrained Progress	Adequate Coverage	Adequate Coverage
	Combustion Devices			
	Plasma Wave Antenna/Thermal			
	SIS 3 THz Heterodyne Receiver	Constrained Progress	Constrained Progress	Adequate Coverage
	SETI Detector Technologies			
	Mini-Ascent Vehicle/Lander Deceleration		Constrained Progress	Constrained Progress
	Radiation Shielding for Crews	Adequate Coverage	Adequate Coverage	Adequate Coverage
	SAAP/Probes/In Situ Instr's/Penetrators		Adequate Coverage	Adequate Coverage
Far-Term Needs	Human Artificial Gravity Systems			Outyear "Start"
	X-Ray Optics Technology		Constrained Progress	Adequate Coverage
	Returned-Sample Biobarrier Analysis Cap.			
	High-Resolution Spectrometer		Constrained Progress	Adequate Coverage

LEGEND: Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

JUNE 24, 1991

ITP FOCUSED PROGRAMS ASSESSMENT
OSSA TECHNOLOGY NEEDS COVERAGE - 3nd HIGHEST PRIORITY

OAET

Term	Need	Current	3x Program	Strategic
Near-Term Needs	Descent Imaging/Mini RTG/Mini Camera			Adequate Coverage
	K-Band Transponders		Constrained Progress	Adequate Coverage
	Ultra-High Gigabit/sec. Telemetry		Constrained Progress	Adequate Coverage
	Mini-Spacecraft Subsystems			Adequate Coverage
	Real-Time Radiation Monitoring			
	Solid/Liquid Interface Characterization			
	Laser Light Scattering			
	High-Temperature Mat'ls for Furnaces			
	Field-Portable Gas Chromatographs			
	Adv. Furnace Technology			
	Regenerative Life Support	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Thermal Control System	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Non-Contact Temp. Measurement			
	3-D Packaging for 1MB Solid State Chips		Adequate Coverage	Adequate Coverage
	Microbial Decontamination Methods			
	Animal and Plant Reproduction Aids			
	Special-Purpose Bioreactor Simulator Syst.			
	Rapid Subject/Sample Delivery & Return Capability			Adequate Coverage
	Autonomous Rendezvous/Sample Xfer/Landing		Constrained Progress	Adequate Coverage
	Non-Destructive Monitoring Capability		Constrained Progress	Adequate Coverage
	Low-Drift Gyros/Trackers/Actuators			Adequate Coverage
	Heat Shield for 16 km/sec Earth entry		Constrained Progress	Adequate Coverage
Far-Term Needs	Partial-G/μ-G Medical Care Systems			Outyear "Start"
	Dust Protection/Jupiter's Rings			
	Non-Destructive Cosmic Dust Collection			
	CELSS Support Technologies			Outyear "Start"

LEGEND: Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

ITP FOCUSED PROGRAMS ASSESSMENT
OSF TECHNOLOGY NEEDS COVERAGE

O-A-E-T

		Current	3x Program	Strategic
NASA R&T DRIVEN (Technology Transfer to Industry)	Vehicle Health Management	Marginally Funded	Constrained Progress	Adequate Coverage
	Advanced Turbomachinery (Components/Models)	Constrained Progress	Constrained Progress	Adequate Coverage
	Combustion Devices	Constrained Progress	Adequate Coverage	Adequate Coverage
	Advanced Heat Rejection Technologies		Constrained Progress	Adequate Coverage
	High-Efficiency Space Power Systems		Constrained Progress	Adequate Coverage
	Water Recovery and Management		Constrained Progress	Adequate Coverage
	Advanced Extravehicular Mobility Unit		Constrained Progress	Adequate Coverage
	Electromechanical Control Systems		Constrained Progress	Adequate Coverage
	Crew Training Systems		Constrained Progress	Adequate Coverage
	Characterization of Al-Li Alloys		Constrained Progress	Adequate Coverage
	Cryogen Storage, Handling & Supply		Constrained Progress	Adequate Coverage
	TPS for High-Temp. Applications		Adequate Coverage	Adequate Coverage
	Guidance, Navigation & Control		Constrained Progress	Adequate Coverage
	Robotic Systems	Constrained Progress	Constrained Progress	Adequate Coverage
	Orbital Debris		Constrained Progress	Adequate Coverage
	Advanced Avionics Architectures		Constrained Progress	Adequate Coverage
Industry R&T Driven (NASA Leverage from Industry)	Signal Transmission and Reception		Constrained Progress	Adequate Coverage
	Advanced Avionics Software		Constrained Progress	Adequate Coverage
	Non-Destructive Evaluation			Adequate Coverage
	Environ. Safe Cleaning Solvents, Refrig./Foams			
	Video Technologies			

LEGEND — Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

JUNE 24 1991

ITP FOCUSED PROGRAMS ASSESSMENT
OSO TECHNOLOGY NEEDS COVERAGE

O-A-E-T

		Current	3x Program	Strategic
High Priority Areas	**Mission Operations** Artificial Intelligence, Expert Systems, Neural Networks, Increased Automation in Mission Operations, Testbeds for Advanced Software, Coordination of Distributed Software, and Automated Performance Analysis of Networking Computing Environments	Constrained Progress	Constrained Progress	Adequate Coverage
	Advanced Navigation Techniques New techniques for cruise, approach, and in-orbit navigation		Marginally Funded	Marginally Funded
	High-Rate Communications Optical and Millimeter Wave Radio Frequencies (for space-to-ground and space-to-space)		Constrained Progress	Adequate Coverage
	Advanced Data Systems Advanced Data Storage, Data Compression, and Information Management Systems	Marginally Funded	Adequate Coverage	Adequate Coverage

LEGEND — Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

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ITP FOCUSED PROGRAMS ASSESSMENT

SEI OFFICE TECHNOLOGY NEEDS COVERAGE

OAET

Category	Technology	Current	3x Program	Strategic
Category 1 (Enabling and Common)	Radiation Protection	Adequate Coverage	Adequate Coverage	Adequate Coverage
	EVA Systems	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Nuclear Thermal Propulsion	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Regenerative Life Support	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Cryo. Fluid Mgt. Storage & Transfer		Constrained Progress	Adequate Coverage
	Micro-G Countermeasures/Art. Gravity			Outyear "Start"
	Aerobraking		Constrained Progress	Adequate Coverage
Category 2 (Enabling and Unique or High-Leverage and Common)	Auto. Rendezvous & Docking	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Health Maintenance & Care			Outyear "Start"
	In-Space Systems Assy/Processing			Constrained Progress
	Surface Systems Construction/Processing			Adequate Coverage
	Cryogenic Space Engines	Constrained Progress	Constrained Progress	Adequate Coverage
	In Situ Resource Utilization		Constrained Progress	Adequate Coverage
	Surface Power		Constrained Progress	Adequate Coverage
Category 3 (High-Leverage and Unique)	Autonomous Landing		Constrained Progress	Adequate Coverage
	Human Factors	Marginally Funded	Constrained Progress	Adequate Coverage
	Surface System Mobility & Guidance		Marginally Funded	Adequate Coverage
	Electric Propulsion	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Sample Acquisition, Analysis & Preserv.		Constrained Progress	Adequate Coverage

LEGEND: Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

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ITP FOCUSED PROGRAMS ASSESSMENT

SYNTHESIS SEI TECHNOLOGY NEEDS COVERAGE

OAET

Area	Technology	Current	3x Program	Strategic
High Priority Areas	Heavy Lift Launch	Marginally Funded	Constrained Progress	Adequate Coverage
	Nuclear-electric Surface Power	Constrained Progress	Constrained Progress	Adequate Coverage
	Nuclear Thermal Propulsion	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Closed-loop Life Support System	Constrained Progress	Adequate Coverage	Adequate Coverage
	Telerobotics	Constrained Progress	Constrained Progress	Adequate Coverage
	EVA Suits	Constrained Progress	Adequate Coverage	Adequate Coverage
	Radiation Effects/Shielding	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Long-duration Human Factors	Marginally Funded	Constrained Progress	Adequate Coverage
	In Situ Resource Evaluation & Processing		Constrained Progress	Adequate Coverage
	Autonomous Rendezvous/Docking		Constrained Progress	Adequate Coverage
	Cryogen Transfer/Storage		Adequate Coverage	Adequate Coverage
	Light-weight Structural Mat'ls & Fabrication		Adequate Coverage	Adequate Coverage
	Nuclear Electric Prop. (Cargo)	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Zero-gravity Countermeasures			
Other Technologies Cited (Selected Examples)	Virtual Reality	Marginally Funded	Constrained Progress	Adequate Coverage
	Surface Habitats			Adequate Coverage
	Regenerative Fuel Cells		Constrained Progress	Adequate Coverage
	Solar Arrays		Constrained Progress	Adequate Coverage
	Power Beaming		Constrained Progress	Adequate Coverage
	Lunar Surface Factory Operations			Adequate Coverage
	Mining, Excavation And Construction			Adequate Coverage
	Sample Acquisition/Analysis		Adequate Coverage	Adequate Coverage
	High Rate Comm. & Navigation		Constrained Progress	Adequate Coverage
	Lunar Surface Instrument Coolers	Marginally Funded	Adequate Coverage	Adequate Coverage
	Submillimeter/Optical Interferometers	Constrained Progress	Constrained Progress	Adequate Coverage
	Remote Sensors	Marginally Funded	Adequate Coverage	Adequate Coverage
	Large Filled Aperture Telescopes		Constrained Progress	Adequate Coverage
	Robotic Probes			Adequate Coverage
	Aerobraking (Cited As Back-up Option)		Constrained Progress	Adequate Coverage
	Chemical Propulsion (Back-up Option)	Constrained Progress	Constrained Progress	Adequate Coverage
	Helium-3 Fusion			

LEGEND: Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

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ITP FOCUSED PROGRAMS ASSESSMENT
EXTERNAL TECHNOLOGY NEEDS COVERAGE - I

O-A-E-T

		Current	3x Program	Strategic
Space Science	Precision Space Structures and Pointing Accuracy	Marginally Funded	Constrained Progress	Adequate Coverage
Planetary Surface Exploration	Regnerative Life Support Systems	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Radiation Protection for Long Missions	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Utilization of In Situ Materials/Propellants		Constrained Progress	Adequate Coverage
	Artificial Intelligence Techniques		Marginally Funded	Adequate Coverage
	Robotic & Microrobotic Systems		Marginally Funded	Adequate Coverage
	Advanced EMUs	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Surface Rover Technologies (Pressurized and Unpressurized)		Marginally Funded	Adequate Coverage
	Nuclear Electric Power	Adequate Coverage	Adequate Coverage	Adequate Coverage
	High-Efficiency Lunar Radiators & Thermal Energy Storage		Constrained Progress	Adequate Coverage
	Power Beaming		Constrained Progress	Adequate Coverage
	Human Health Maintenance			Outyear "Start"
	Reduced Gravity Countermeasures/Artificial Gravity			Outyear "Start"
	Bioprocess-Grade Fluid Management Systems			

LEGEND: Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

ITP FOCUSED PROGRAMS ASSESSMENT
EXTERNAL TECHNOLOGY NEEDS COVERAGE - II

O-A-E-T

		Current	3x Program	Strategic
Transportation	Economical Launch Systems (Manned and Unmanned)	Marginally Funded	Constrained Progress	Adequate Coverage
	Integrated Vehicle Health Monitoring and Maintenance		Constrained Progress	Adequate Coverage
	Advanced Cryogenic (Oxygen/Hydrogen) Engines	Constrained Progress	Adequate Coverage	Adequate Coverage
	Fault-Tolerant Advanced Avionics with Open Architectures		Constrained Progress	Adequate Coverage
	High-Performance/Composite Lightweight Structures		Constrained Progress	Adequate Coverage
	Long-Life Structures and Mechanisms		Constrained Progress	Adequate Coverage
	High-Performance, Storable Space Thrusters			Outyear "Start"
	High-Power Electric Propulsion	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Nuclear Thermal Prop. for Manned Interplanetary Missions	Adequate Coverage	Adequate Coverage	Adequate Coverage
	Cryogenics Long-Duration Storage and Management		Constrained Progress	Adequate Coverage
	Gun-Type Launch Systems			
	Aerobraking (Thermal Protection Systems)		Adequate Coverage	Adequate Coverage
	Integrated RCS/Auxiliary Propulsion			Outyear "Start"
	Lightweight, Fuel-Efficient Airbreather Propulsion Systems			
Space Platforms	Long-Life/Composite Lightweight Structures & Mechanisms	Constrained Progress	Constrained Progress	Adequate Coverage
	Micrometeoroid and Debris Protection		Constrained Progress	Adequate Coverage
	Regnerative Life Support Systems		Constrained Progress	Adequate Coverage
	Advanced EMUs		Constrained Progress	Adequate Coverage
	Expanded Atomic Oxygen Database		Constrained Progress	Adequate Coverage
	High-Efficiency, Radiation-Resistant, Lightweight PV Arrays		Constrained Progress	Adequate Coverage
	High-Efficiency Power Processing Units		Constrained Progress	Adequate Coverage
	Lightweight Batteries		Constrained Progress	Adequate Coverage
Operations	Data Management System Architecture and Software	Marginally Funded	Adequate Coverage	Adequate Coverage
	Software Productivity Enhancers			Adequate Coverage
	Systems Integration technologies (Software, etc.)			Adequate Coverage
	Artificial Intelligence Techniques	Constrained Progress	Constrained Progress	Adequate Coverage
	Robotic Systems	Constrained Progress	Constrained Progress	Adequate Coverage
	Advanced Communications (e.g., Laser & mm-Wave Tech.)		Constrained Progress	Adequate Coverage

LEGEND: Adequate Coverage; Constrained Progress; Marginally Funded; Outyear "Start"

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USER NEEDS ACCOMMODATION SUMMARY

CONTENTS

- INTEGRATED TECHNOLOGY PLAN USER NEEDS OVERVIEW
- USER NEEDS ACCOMMODATION ASSESSMENT
- ⇨ SPECIAL ASSESSMENT: ITP VS. PREVIOUS NATIONAL-LEVEL RECOMMENDATIONS
- SUMMARY

ASSESSMENT VS. NATIONAL RECOMMENDATIONS

"KEY" TECHNOLOGY IDENTIFICATIONS

TECHNOLOGY THRUSTS	Augustine (1990)	Commerce (1990)	Defense (1990)	NRC (on HEI) (1990)	NRC/ASEB (1987)	NCOS (1986)
• SPACE SCIENCE	□	□	□	□	■	■
– (REMOTE) SENSING	□	■	■	□	■	■
– OBSERVATORY SYSTEMS	□	□	□	□	■	■
– IN SITU SCIENCE	□	□	□	■	■	■
– SCIENCE INFORMATION	□	□	□	□	■	■
• SURFACE EXPLORATION	■	□	□	■	■	■
– SURFACE SYSTEMS	■	□	■	■	■	■
– HUMAN SUPPORT	■	■	□	■	■	■
• TRANSPORTATION	■	□	□	■	■	■
– ETO TRANSPORTATION	■	□	□	■	■	■
– SPACE TRANSPORTATION	■	■	■	■	■	■
• SPACE PLATFORMS	□	□	□	□	■	■
– EARTH-ORBITING PLATFORMS	□	□	□	□	■	■
– SPACE STATIONS	□	□	□	□	■	■
– DEEP-SPACE PLATFORMS	□	□	□	□	□	■
• OPERATIONS	■	■	■	■	■	■
– AUTOMATION & ROBOTICS	■	■	■	■	■	■
– INFRASTRUCTURE OPERATIONS	□	■	□	■	□	■
– INFO AND COMMUNICATIONS	■	■	■	■	■	■

ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

FINAL REPORT (1990)

OAST

SEVERAL PRIORITY TECHNOLOGY AREAS

- HEAVY LIFT LAUNCH VEHICLE
  - Evolutionary Inclusion of ALS Adv. Development Technology
- SHUTTLE
  - Enhanced Reliability And Reduced Costs
- PROPULSION
  - Advanced Rocket Engines That Don't Harm The Environment
- AERODYNAMICS/AEROBRAKING
  - Including Flight Evaluations
- NUCLEAR-ELECTRIC SPACE POWER
  - 10 to 100 MW Range
- SOLAR ELECTRIC GENERATORS
  - 10+ MW Range
- SPACE TETHERS AND ARTIFICIAL GRAVITY
- MATERIALS
- IN-SPACE MATERIALS PROCESSING
- AUTOMATED PLANTS TO PROCESS INDIGENOUS MATERIALS
- TRANSPORTATION AND COMMUNICATIONS FACILITIES
- AUTOMATION AND ROBOTICS
- INFORMATION MANAGEMENT SYSTEMS
- DECENTRALIZED COMPUTERS
- LIFE SUPPORT TECHNOLOGIES
  - Long Duration Closed Ecosystems and Life Support Systems
- RADIATION PROTECTION
- IMPROVED (SURFACE) SPACE SUITS

DEPARTMENT OF DEFENSE

CRITICAL TECHNOLOGIES PLAN (1990)

OAST

1990 LISTING*

- SEMICONDUCTOR MAT'LS & MICRO-ELECTRONIC CIRCUITS
- SOFTWARE PRODUCIBILITY
- PARALLEL COMPUTER ARCHITECTURES
- MACHINE INTELLIGENCE AND ROBOTICS
- SIMULATION AND MODELING
- PHOTONICS
- SENSITIVE RADARS
- PASSIVE SENSORS
- SIGNAL PROCESSING
- SIGNATURE CONTROL
- WEAPON SYSTEM ENVIRONMENT
- DATA FUSION
- COMPUTATIONAL FLUID DYNAMICS
- AIR-BREATHING PROPULSION
- PULSED POWER
- HYPERVELOCITY PROJECTILES
- HIGH ENERGY DENSITY MATERIALS
- COMPOSITE MATERIALS
- SUPERCONDUCTIVITY
- BIOTECHNOLOGY MATERIALS AND PROCESSES

**Note: Nuclear Technologies Excluded From Assessment*

DEPARTMENT OF COMMERCE

EMERGING TECHNOLOGIES (1990)

O-A-S-T

SUMMARY

"AN EMERGING TECHNOLOGY IS ONE IN WHICH RESEARCH HAS PROGRESSED FAR ENOUGH TO INDICATE A HIGH PROBABILITY OF TECHNICAL SUCCESS FOR NEW PRODUCTS AND APPLICATIONS THAT MIGHT HAVE SUBSTANTIAL MARKETS WITHIN APPROXIMATELY 10 YEARS."

"IN LARGE DEVELOPED ECONOMIES SUCH AS THE UNITED STATES, ECONOMIC GROWTH REQUIRES THAT A SUBSTANTIAL NUMBER OF EMERGING TECHNOLOGIES BE UNDER DEVELOPMENT SIMULTANEOUSLY TO DIVERSIFY RISK AND BROADEN THE FUTURE INDUSTRIAL BASE."

"EMERGING TECHNOLOGIES ARE ALSO IMPORTANT BECAUSE THEY WILL DRIVE THE NEXT GENERATION OF R&D AND SPIN-OFF APPLICATIONS."

"... LEADERSHIP IN AN EMERGING TECHNOLOGY PROVIDES THE BASIS TO BECOME A MAJOR PLAYER IN DEVELOPING OR COMMERCIALIZING SUCCESSIVE GENERATIONS OF BREAKTHROUGHS IN THAT OR A RELATED TECHNOLOGY."

"TO REMAIN COMPETITIVE ... U.S. INDUSTRY MUST MATCH (INTERNATIONAL) DEVELOPMENTS BY INCREASING EMPHASIS ON RESEARCH AND DEVELOPMENT OF NEW PRODUCTS AND EMERGING TECHNOLOGIES..."

DEPARTMENT OF COMMERCE

EMERGING TECHNOLOGIES (1990)

O-A-S-T

1990 LIST

- ADVANCED MATERIALS
- ADVANCED SEMICONDUCTOR DEVICES
- ARTIFICIAL INTELLIGENCE
- BIOTECHNOLOGY
- DIGITAL IMAGING TECHNOLOGY
- FLEXIBLE COMPUTER-INTEGRATED MANUFACTURING
- HIGH-DENSITY DATA STORAGE
- HIGH-PERFORMANCE COMPUTING
- MEDICAL DEVICES AND DIAGNOSTICS
- OPTOELECTRONICS
- SENSOR TECHNOLOGY
- SUPERCONDUCTORS

NATIONAL RESEARCH COUNCIL
ASSESSMENT OF NASA'S 90-DAY STUDY (1990)

OAST

TECHNOLOGY DEVELOPMENT
SUMMARY

"STRATEGIES ARE NEEDED TO DEVELOP AND EMPLOY NEW TECHNOLOGIES THAT WILL ENABLE MORE RAPID OR COST-EFFECTIVE ACCESS TO AND HABITATION IN SPACE."

"DEVELOPING THESE STRATEGIES IMPLIES MAKING TRADE-OFFS AMONG ALTERNATIVE APPROACHES. AN IMPORTANT FACTOR IN THESE DECISIONS IS THE LEVEL OF HUMAN AND TECHNICAL RISK THAT IS ACCEPTABLE."

"A BALANCED TECHNOLOGY DEVELOPMENT PROGRAM WITH EMPHASIS ON CRITICAL LONG-TERM TECHNOLOGIES CAN HELP REDUCE RISKS AND PROVIDE IMPORTANT OPTIONS FOR THE FUTURE."

"DEVELOPMENT OF TECHNOLOGY FOR ARTIFICIAL GRAVITY AND COUNTERMEASURES TO MITIGATE ZERO-GRAVITY EXPOSURE SHOULD PROCEED IN PARALLEL WITH STUDIES OF THE PHYSIOLOGICAL EFFECTS OF MICROGRAVITY."

"SECOND TO THE NEED FOR SCIENTIFIC RESEARCH AND TECHNOLOGY DEVELOPMENT TO SUPPORT HUMANS IN SPACE IS THE NEED TO ADVANCED NATIONAL SPACE TRANSPORTATION CAPABILITIES."

"AN EMPHASIS ON ADVANCED HUMAN/MACHINE SYSTEMS CAN ENHANCE THE PRODUCTIVITY OF HUMANS IN SPACE AND INCREASE THEIR SAFETY."

ADI

NATIONAL RESEARCH COUNCIL
ASSESSMENT OF NASA'S 90-DAY STUDY (1990)

OAST

KEY TECHNOLOGIES
TRANSPORTATION

- HEAVY LIFT LAUNCH SYSTEMS
  - KEY TECHNOLOGY GOALS:
    - INCREASED MASS AND DECREASED COSTS
    - ADVANCED MANUFACTURING
    - ADVANCED GN&C
- ADVANCED PERSONNEL LAUNCH SYSTEMS
  - KEY TECHNOLOGY GOALS:
    - ROBUST, RELIABLE, COST-EFFECTIVE OPERATIONS
    - REDUCED GROUND SUPPORT AND LAUNCH OPERATIONS REQ'TS
- SPACE TRANSPORTATION SYSTEMS
  - KEY TECHNOLOGY GOALS:
    - NUCLEAR THERMAL PROPULSION
    - NUCLEAR ELECTRIC POWER & PROPULSION
    - AEROBRAKING (DEMONSTRATIONS NEEDED)

NATIONAL RESEARCH COUNCIL
ASSESSMENT OF NASA'S 90-DAY STUDY (1990)

OAST

KEY TECHNOLOGIES
HUMAN & MACHINE OPERATIONS

- HUMAN SUPPORT AND SAFETY
  - KEY TECHNOLOGY GOALS:
    - CREW SAFETY
    - RADIATION PROTECTION/SHIELDING
    - ARTIFICIAL GRAVITY
    - CLOSED-LOOP LIFE SUPPORT SYSTEMS
- ADVANCED HUMAN-MACHINE SYSTEMS
  - KEY TECHNOLOGY GOALS:
    - INTEGRATED, VARIABLE CONTROL OPERATIONS & TELEOPERATIONS
    - ADVANCED INFORMATION MANAGEMENT SYSTEMS
    - VEHICLE MANEUVERING
    - VEHICLE SERVICING IN SPACE
    - IN-SPACE AND PLANET SURFACE ASSEMBLY & CONSTRUCTION
    - PLANETARY ROVERS AND SURFACE OPERATIONS
    - EXTRAVEHICULAR ACTIVITY AND EXPLORATION SYSTEMS
    - SAMPLE ACQUISITION, ANALYSIS & PRESERVATION
    - SCIENTIFIC PROBES/PENETRATORS

SPACE LEADERSHIP PLANNING GROUP
RIDE REPORT TO THE NASA ADMINISTRATOR (1987)

OAST

TECHNOLOGY DEVELOPMENT
SUMMARY

"THE STRATEGY (FOR THE U.S. SPACE PROGRAM SHOULD) BEGIN BY INCREASING OUR CAPABILITIES IN TRANSPORTATION AND TECHNOLOGY -- NOT AS ENDS IN THEMSELVES, BUT AS THE NECESSARY MEANS TO ACHIEVE OUR GOALS IN SCIENCE AND EXPLORATION."

- "WE MUST ASK OURSELVES: 'WHERE DO WE WANT TO BE AT THE TURN OF THE CENTURY?' AND 'WHAT DO WE HAVE TO DO NOW TO GET THERE?' WITHOUT AN EYE TOWARD THE FUTURE, WE FLOUNDER IN THE PRESENT.
- "A CLEAR VISION PROVIDES A FRAMEWORK FOR CURRENT AND FUTURE PROGRAMS: IT ENABLES US TO KNOW WHICH TECHNOLOGIES TO PURSUE, WHICH LAUNCH VEHICLES TO DEVELOP, AND WHICH FEATURES TO INCORPORATE INTO OUR SPACE STATION AS IT EVOLVES."
- "THE MOST CRITICAL AND IMMEDIATE NEEDS ARE RELATED TO ADVANCED TRANSPORTATION SYSTEMS TO SUPPLEMENT AND COMPLEMENT THE SPACE SHUTTLE, AND ADVANCED TECHNOLOGY TO ENABLE THE BOLD MISSIONS OF THE NEXT CENTURY."

SPACE LEADERSHIP PLANNING GROUP

RIDE REPORT TO THE NASA ADMINISTRATOR (1987)

OAET

KEY TECHNOLOGIES
MISSION TO PLANET EARTH

- TECHNOLOGY GOALS:
  - ENHANCED OBSERVATIONS
    - SOPHISTICATED SENSORS
  - HANDLING & DELIVERY OF ENORMOUS QUANTITIES OF DATA
    - ADVANCED INFORMATION SYSTEMS
  - LONG OPERATING LIFE
  - ADVANCED AUTOMATION AND ROBOTICS
    - FOR SPACECRAFT SERVICING
  - TECHNOLOGIES FOR LEO-TO-GEO SPACE TRANSFER VEHICLES
  - IN-SPACE ASSEMBLY AND CONSTRUCTION CAPABILITIES AT THE SPACE STATION

SPACE LEADERSHIP PLANNING GROUP

RIDE REPORT TO THE NASA ADMINISTRATOR (1987)

OAET

KEY TECHNOLOGIES
SOLAR SYSTEM EXPLORATION

- TECHNOLOGY GOALS:
  - AEROBRAKING
    - ROBOTIC MISSION AEROASSIST AT MARS
  - SOPHISTICATED AUTOMATION AND ROBOTICS
  - ADVANCED SAMPLING METHODS
  - HEAVY LIFT LAUNCH VEHICLE SYSTEMS

SPACE LEADERSHIP PLANNING GROUP
RIDE REPORT TO THE NASA ADMINISTRATOR (1987)

OAET

KEY TECHNOLOGIES
LUNAR OUTPOST

- TECHNOLOGY GOALS:
  - HEAVY LIFT LAUNCH VEHICLE SYSTEMS
  - LIFE SUPPORT SYSTEMS
  - AUTOMATION AND EXPERT SYSTEMS
  - SURFACE POWER TECHNOLOGIES
  - LUNAR MINING AND MATERIALS PROCESSING
  - REUSABLE SPACE TRANSFER VEHICLES
  - LEO-BASED VEHICLE STAGING
    - INCLUDING PROPELLANT MANAGEMENT/STRANSFER

SPACE LEADERSHIP PLANNING GROUP
RIDE REPORT TO THE NASA ADMINISTRATOR (1987)

OAET

KEY TECHNOLOGIES
HUMANS TO MARS

- TECHNOLOGY GOALS:
  - HEAVY LIFT LAUNCH VEHICLE SYSTEMS
  - AUTOMATION AND ROBOTICS
  - FAULT-TOLERANT SYSTEMS
  - AEROBRAKING
  - EFFICIENT INTERPLANETARY PROPULSION
  - LEO-BASED VEHICLE STAGING
    - INCLUDING CRYOGEN MANAGEMENT/STRANSFER
  - ADVANCED MEDICAL TECHNOLOGY
  - LIFE SUPPORT SYSTEMS

NATIONAL RESEARCH COUNCIL
ASEB: "SPACE TECHNOLOGY TO MEET FUTURE NEEDS" (1987)

OAET

TECHNOLOGY DEVELOPMENT
SUMMARY

"WE BELIEVE THAT IF A REASONABLE INVESTMENT IN R&T IS MADE, THE NATION WILL HAVE THE TECHNOLOGICAL OPTIONS READY WHEN NEEDED."

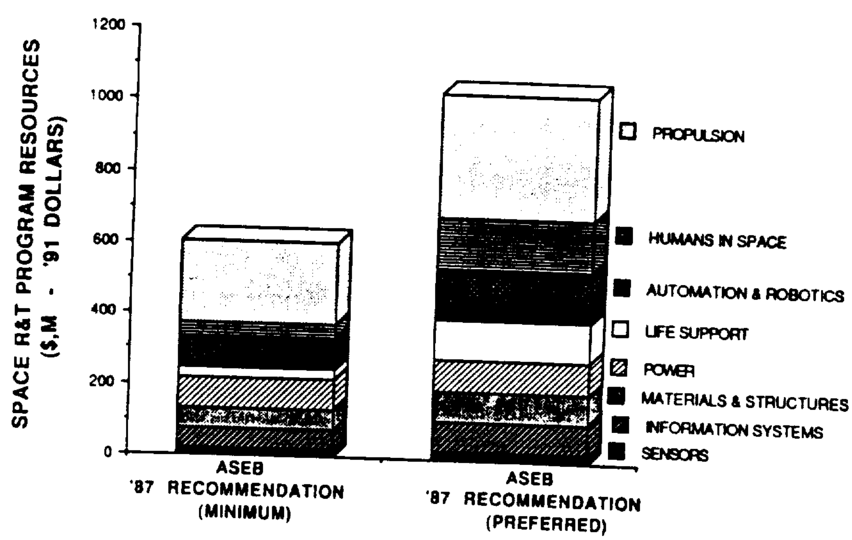
- "...OVER THE PAST 15 YEARS, (THE SPACE R&T) PROGRAM HAS BEEN SEVERELY RESTRICTED AND MAINLY FOCUSED ON RELATIVELY MODEST ADVANCES IN STATE-OF-THE-ART SUPPORT OF NEAR-TERM NASA MISSIONS."
- "... NASA'S PREOCCUMPATION WITH SHORT-TERM GOALS HAS LEFT THE AGENCY WITH A TECHNOLOGY BASE INADEQUATE TO SUPPORT ADVANCED SPACE MISSIONS."
- "FOR THE PAST 15 YEARS, LESS THAN 3 PERCENT OF THE TOTAL NASA BUDGET HAS BEEN INVESTED IN SPACE R&T. OF THAT, VIRTUALLY NONE HAS BEEN SPENT ON TECHNOLOGY DEVELOPMENT FOR MISSIONS MORE THAN FIVE YEARS IN THE FUTURE."

"...WE CONCLUDE THAT THE ADVANCED SPACE R&T PROGRAM (IS) SERIOUSLY UNDERFUNDED -- BY AT LEAST A FACTOR OF THREE."

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM
ASSESSMENT OF PREVIOUS RECOMMENDATIONS

OAST

1987 ASEB RECOMMENDATIONS



NATIONAL RESEARCH COUNCIL
ASEB: "SPACE TECHNOLOGY TO MEET FUTURE NEEDS" (1987)

OAET

KEY TECHNOLOGIES
ADVANCED PROPULSION

- A RANGE OF ADVANCED EARTH-TO-ORBIT ENGINES
  - REUSABLE, FAULT-TOLERANT, RELIABLE, ECONOMICAL
- REUSABLE CRYOGENIC ORBITAL TRANSFER VEHICLES
  - RELIABLE, FAULT-TOLERANT, LONG-LIVED
- HIGH-PERFORMANCE ORBITAL TRANSFER PROPULSION SYSTEMS (E.G., FOR HUMANS TO MARS MISSIONS)
  - THRUST GREATER THAN 10,000 LBS
  - Isp GREATER THAN 800 SECONDS
- NEW SPACECRAFT PROPULSION SYSTEMS FOR SOLAR SYSTEM EXPLORATION
  - Isp GREATER THAN 1,200 SECONDS
  - LOW-THRUST PRIMARY PROPULSION (NUCLEAR-ELECTRIC PROPULSION)

NATIONAL RESEARCH COUNCIL
ASEB: "SPACE TECHNOLOGY TO MEET FUTURE NEEDS" (1987)

OAET

KEY TECHNOLOGIES
HUMANS IN SPACE

- RADIATION PROTECTION
  - THREAT EVALUATION, PLUS SHIELDING
- CLOSED-CYCLE LIFE SUPPORT SYSTEMS
- IMPROVED EXTRAVEHICULAR ACTIVITY EQUIPMENT
  - HIGH-PRESSURE SUITES, GLOVES, TOOLS AND MOBILITY AIDS
- AUGMENTATION OF HUMAN CAPABILITIES WITH AUTONOMOUS SYSTEMS AND ROBOTICS
  - AUTOMATED, TELEOPERATED AND ROBOTIC SYSTEMS
- HUMAN FACTORS
  - CREW SELECTION & TRAINING, PSYCHOLOGICAL STRESS, AND MAN-COMPUTER INTERFACES
- ARTIFICIAL GRAVITY

NATIONAL RESEARCH COUNCIL

ASEB: "SPACE TECHNOLOGY TO MEET FUTURE NEEDS" (1987)

OAET

KEY TECHNOLOGIES

AUTONOMOUS SYSTEMS & ROBOTICS

- LIGHTWEIGHT, LIMBER MANIPULATORS
  - RAPID, PRECISE CONTROL
  - TOOLS AND EFFECTORS
- ADVANCED SENSING AND CONTROL TECHNIQUES
  - COOPERATION BETWEEN MANIPULATORS AND ROBOTS
- TELEOPERATION
  - HUMAN INTERACTION AND EFFECTIVE DISPLAYS
- ARTIFICIAL INTELLIGENCE AND ADVANCED INFO. PROCESSING (INCLUDING "TRAINABLE" SYSTEMS
  - MODEL-BASED SYSTEMS TO BE USED IN UNKNOWN ENVIRONMENTS
  - REAL-TIME EXPERT SYSTEMS AND PREDICTORS
  - ADVANCED IN-SPACE COMPUTING SYSTEMS

NATIONAL RESEARCH COUNCIL

ASEB: "SPACE TECHNOLOGY TO MEET FUTURE NEEDS" (1987)

OAET

KEY TECHNOLOGIES

SPACE POWER SUPPLIES

- ADVANCED PHOTOVOLTAIC ARRAYS
- SOLAR DYNAMICS POWER SYSTEMS
- SPACE NUCLEAR REACTOR POWER SYSTEMS

NATIONAL RESEARCH COUNCIL

ASEB: "SPACE TECHNOLOGY TO MEET FUTURE NEEDS" (1987)

OAET

KEY TECHNOLOGIES

MATERIALS AND STRUCTURES

- ADVANCED METALLIC MATERIALS
- COMPOSITE MATERIALS
- THERMAL PROTECTION SYSTEMS MATERIALS
- "HOT" STRUCTURES
- SPACE ENVIRONMENTAL EFFECTS ON MATERIALS
- DYNAMICS AND CONTROL OF LARGE, FLEXIBLE SPACE STRUCTURES
- DESIGN AND ANALYSIS TOOLS FOR STRUCTURAL DEVELOPMENT

NATIONAL RESEARCH COUNCIL

ASEB: "SPACE TECHNOLOGY TO MEET FUTURE NEEDS" (1987)

OAET

KEY TECHNOLOGIES

INFORMATION AND CONTROL SYSTEMS

- AUTONOMOUS COMPUTING SYSTEMS DESIGNED FOR THE SPACE ENVIRONMENT
- HIGH-SPEED, LOW-ERROR RATE DIGITAL TRANSMISSION OVER LONG DISTANCES
- VOICE AND/OR VIDEO COMMUNICATIONS FOR CONTINUOUS REAL-TIME COMMUNICATIONS
- SPACE-BORNE TRACKING AND DATA-RELAY CAPABILITIES
- ENHANCED ON-BOARD COMPUTING CAPABILITIES
- INSTRUMENTATION TO MONITOR EQUIPMENT CONDITION AND TO AVOID HAZARDS
- GROUND DATA HANDLING, STORAGE, DISTRIBUTION AND ANALYSES

NATIONAL RESEARCH COUNCIL

ASEB: "SPACE TECHNOLOGY TO MEET FUTURE NEEDS" (1987)

OAET

KEY TECHNOLOGIES

SENSORS

PRINCIPLE AREAS

- LARGE APERTURE OPTICAL AND QUASI-OPTICAL SYSTEMS
- DETECTION DEVICES AND SYSTEMS
- CRYOGENIC SYSTEMS
- IN-SITU ANALYSIS AND SAMPLE RETURN SYSTEMS

SUPPORTING AREAS

- RADIATION INSENSITIVE ON-BOARD COMPUTATIONAL SYSTEMS (HARDWARE AND SOFTWARE)
- HIGH-PRECISION ATTITUDE SENSORS AND AXIS TRANSFER SYSTEMS

NATIONAL COMMISSION ON SPACE

"PIONEERING THE SPACE FRONTIER" (1986)

OAST

TECHNOLOGY DEVELOPMENT

SUMMARY

"NASA IS STILL LIVING ON THE INVESTMENT MADE (DURING THE APOLLO ERA), BUT CANNOT CONTINUE TO DO SO IF WE ARE TO MAINTAIN UNITED STATES LEADERSHIP IN SPACE."

- "TECHNOLOGICAL ADVANCE IS CRITICAL TO ALL ... MAJOR ELEMENTS OF OUR RECOMMENDED PROGRAM: SCIENCE, EXPLORATION AND ENTERPRISE."
- "BECAUSE OF ITS CRITICAL ROLE IN GENERATING TECHNOLOGICAL OPPORTUNITIES, NASA'S SPACE RESEARCH AND TECHNOLOGY PROGRAM SHOULD BE TRIPLED, MOVING FROM ITS CURRENT TWO PERCENT OF NASA'S BUDGET TO SIX PERCENT."
- "AMERICAN LEADERSHIP ON THE SPACE FRONTIER REQUIRES AGGRESSIVE PROGRAMS IN TECHNOLOGY DEVELOPMENT."

"THE UNITED SATES MUST SUBSTANTIALLY INCREASE ITS INVESTMENT IN ITS SPACE TECHNOLOGY BASE."

NATIONAL COMMISSION ON SPACE
"PIONEERING THE SPACE FRONTIER" (1986)

O-A-E-T

KEY TECHNOLOGIES

CRITICAL DEMONSTRATIONS NEEDED

- AEROSPACE PLANE PROPULSION/AERODYNAMICS
- ADVANCED ROCKET VEHICLES
- AEROBRAKING FOR ORBIT TRANSFER
- LONG-DURATION CLOSED-ECOSYSTEMS
- ELECTRIC LAUNCH AND PROPULSION SYSTEMS
- NUCLEAR-ELECTRIC SPACE POWER
- SPACE TETHERS AND ARTIFICIAL GRAVITY

NATIONAL COMMISSION ON SPACE
"PIONEERING THE SPACE FRONTIER" (1986)

O-A-E-T

KEY TECHNOLOGIES

TECHNOLOGY FOR SPACE SCIENCE

Remote Observations
- ASTROPHYSICS/EARTH SENSING
  - E.G., RF, Cosmic Ray, Gamma Ray, Visible
- INTERFEROMETRY (Visible Light And Radio Frequency)
- SEGMENTED TELESCOPES
- PRECISION POINTING SYSTEMS

In Situ Science
- PLANETARY ROVER SYSTEMS
- PROBES (High & Low Temperature, Surface & Atmospheric)

Transportation
- ORBITAL MANEUVERING & SPACE TRANSFER VEHICLES
- AUTONOMOUS SPACECRAFT/LANDEERS
- AEROCAPTURE/AEROMANEUVERING
- NUCLEAR ELECTRIC OR SOLAR ELECTRIC PROPULSION
- TETHER CONCEPTS

Platforms
- ATTITUDE CONTROL/STATIONKEEPING SYSTEMS
- PRECISE CONTROL OF LARGE STRUCTURES

Operations
- IN-SPACE ASSEMBLY AND CONSTRUCTION
- AUTOMATION AND ROBOTICS
- ADVANCED INFORMATION SYSTEMS

NATIONAL COMMISSION ON SPACE
"PIONEERING THE SPACE FRONTIER" (1986)

O-A-E-T

KEY TECHNOLOGIES

TECHNOLOGY FOR PILOTED SPACEFLIGHT

Surface Exploration	• TELEOPERATIONS
Exploration Human Support	• RADIATION DETECTION AND PROTECTION • ADVANCED LIFE SUPPORT SYSTEMS • ARTIFICIAL GRAVITY
Transportation	• SEMI-AUTONOMOUS ON-BOARD REPAIR, MAINTENANCE, AND REPLANNING
Platforms	• ZERO-GRAVITY SPACE SUITS • NON-SUIT ASTRONAUT EVA-CAPSULES
Operations	• AUTOMATION AND ROBOTICS

NATIONAL COMMISSION ON SPACE
"PIONEERING THE SPACE FRONTIER" (1986)

O-A-E-T

KEY TECHNOLOGIES

TECHNOLOGY FOR NUCLEAR SPACE POWER

- ADVANCED RADIOISOTOPE THERMOELECTRIC GENERATORS (RTG'S)
- DYNAMIC NUCLEAR POWER SYSTEMS (E.G., DYNAMIC ISOTOPE POWER SYSTEMS - DIPS)
- SP-100 SPACE NUCLEAR REACTOR POWER PLANT
- MULTI-MEGAWATT REACTOR POWER SYSTEMS

NATIONAL COMMISSION ON SPACE
"PIONEERING THE SPACE FRONTIER" (1986)

OAET

KEY TECHNOLOGIES

TECHNOLOGY FOR SPACE TRANSPORTATION

Earth-to-Orbit Transportation
- ADVANCED MANUFACTURING
- MATERIALS AND STRUCTURES (INCLUDING TPS)
- ENGINES
- GUIDANCE AND CONTROL
- ADVANCED FAULT-TOLERANT COMPUTERS
- REDUCED COST/COMPLEXITY LAUNCH OPERATIONS
- ADVANCED HYPERSONIC VEHICLES (NASP)

In-Space Transportation
- AEROBRAKING
- LONG-LIVED HYDROGEN/OXYGEN ENGINES
- NUCLEAR OR SOLAR ELECTRIC PROPULSION
- TETHER CONCEPTS
- NUCLEAR OR SOLAR ELECTRIC PROPULSION

Surface Operations
- PROCESSING OF EXTRATERRESTRIAL MATERIALS

NATIONAL COMMISSION ON SPACE
"PIONEERING THE SPACE FRONTIER" (1986)

OAET

KEY TECHNOLOGIES

TECHNOLOGY FOR SPACE INDUSTRY

- COMMUNICATIONS
  - E.G., FOR TELECOMUNICATIONS SATELLITES
- TRANSPORTATION
  - E.G., FOR EARTH-TO-ORBIT
- REMOTE SENSING
  - E.G., FOR EARTH RESOURCES/WEATHER SATELLITES
- SPACE MANUFACTURING
  - E.G., FOR MICROGRAVITY MATERIALS PROCESSING

INTEGRATED TECHNOLOGY PLAN EXTERNAL REVIEW

USER NEEDS ACCOMMODATION SUMMARY

CONTENTS

- INTEGRATED TECHNOLOGY PLAN USER NEEDS OVERVIEW
- USER NEEDS ACCOMMODATION ASSESSMENT
- SPECIAL ASSESSMENT: ITP VS. PREVIOUS NATIONAL-LEVEL RECOMMENDATIONS
- SUMMARY

INTEGRATED TECHNOLOGY PLAN EXTERNAL REVIEW

USER NEEDS ACCOMMODATION SUMMARY

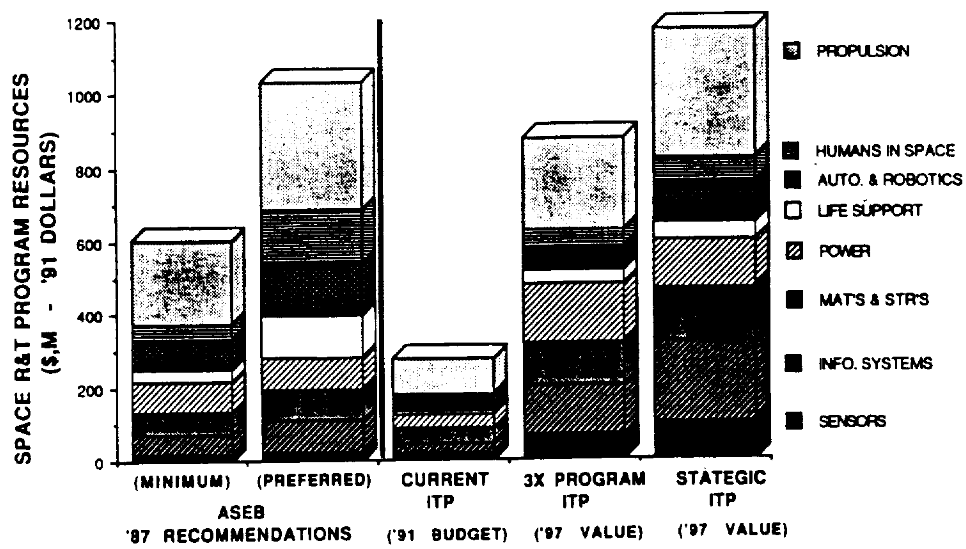
SUMMARY

- "STRATEGIC" INTEGRATED TECHNOLOGY PLAN PROVIDES STRONG COVERAGE OF NUMEROUS USER-IDENTIFIED TECHNOLOGY NEEDS
  - SEVERAL OSSA TECHNOLOGY NEEDS NOT YET INTEGRATED INTO THE ITP
- INTEGRATED TECHNOLOGY PLAN CONSISTENT WITH RECOMMENDATIONS DEVELOPED BY EARLIER NATIONAL-LEVEL EXAMINATIONS OF U.S. CIVIL SPACE R&T INVESTMENTS
- ASSESSMENT OF ITP AGAINST USER NEEDS, EXTERNAL RECOMMENDATIONS WILL BE A CONTINUING, ANNUAL PROCESS
  - THIS EXTERNAL REVIEW IS A CRITICAL PART OF THIS PROCESS

ASSESSMENT OF PREVIOUS RECOMMENDATIONS

OAST

1987 ASEB vs. ITP RESOURCES



NASA

INTEGRATED TECHNOLOGY PLAN

SCIENCE THRUST

JUNE 25, 1991

Wayne R. Hudson
Assistant Director for
Space Technology

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

WORK BREAKDOWN STRUCTURE

OAET — ITP

SPACE RESEARCH & TECHNOLOGY

RESEARCH & TECHNOLOGY BASE

DISCIPLINE RESEARCH
- Aerothermodynamics
- Space Energy Conversion
- Propulsion
- Materials & Structures
- Information and Controls
- Human Support
- Adv. Communications

UNIVERSITY PROGRAMS

SPACE FLIGHT R&T
- Flight Experiment Studies
- IN-STEP

SYSTEMS ANALYSIS

CIVIL SPACE TECHNOLOGY PROGRAM

SPACE SCIENCE TECHNOLOGY
- Science Sensing
- Observatory Systems
- Science Information
- In Situ Science
- Technology Flight Expts.

SPACE EXPLORATION TECHNOLOGY
- Surface Systems
- Human Support
- Technology Flight Expts.

TRANSPORTATION TECHNOLOGY
- ETO Transportation
- Space Transportation
- Technology Flight Expts.

SPACE PLATFORMS TECHNOLOGY
- Earth-Orbiting Platforms
- Space Stations
- Deep-Space Platforms
- Technology Flight Expts.

OPERATIONS TECHNOLOGY
- Automation & Robotics
- Infrastructure Operations
- Info. & Communciations
- Technology Flight Expts.

MAY 15, 199
JCM-7650

SCIENCE TECHNOLOGY PLAN

SCIENCE THRUST

OAET ITP

DEVELOP THE ADVANCED TECHNOLOGY REQUIRED FOR ACQUIRING AND UNDERSTANDING SCIENCE OBSERVATIONS FROM FUTURE NASA SPACE AND EARTH SCIENCE MISSIONS.

Space Based Instrument Component and Detector Technologies to Enable New Space Science Measurements

Space Instrument Support and Observation Technologies to Maximize Science Return

Information Technology to Enable the Efficient and Effective Archiving, Retrieval, and Visualization of High Rate Data

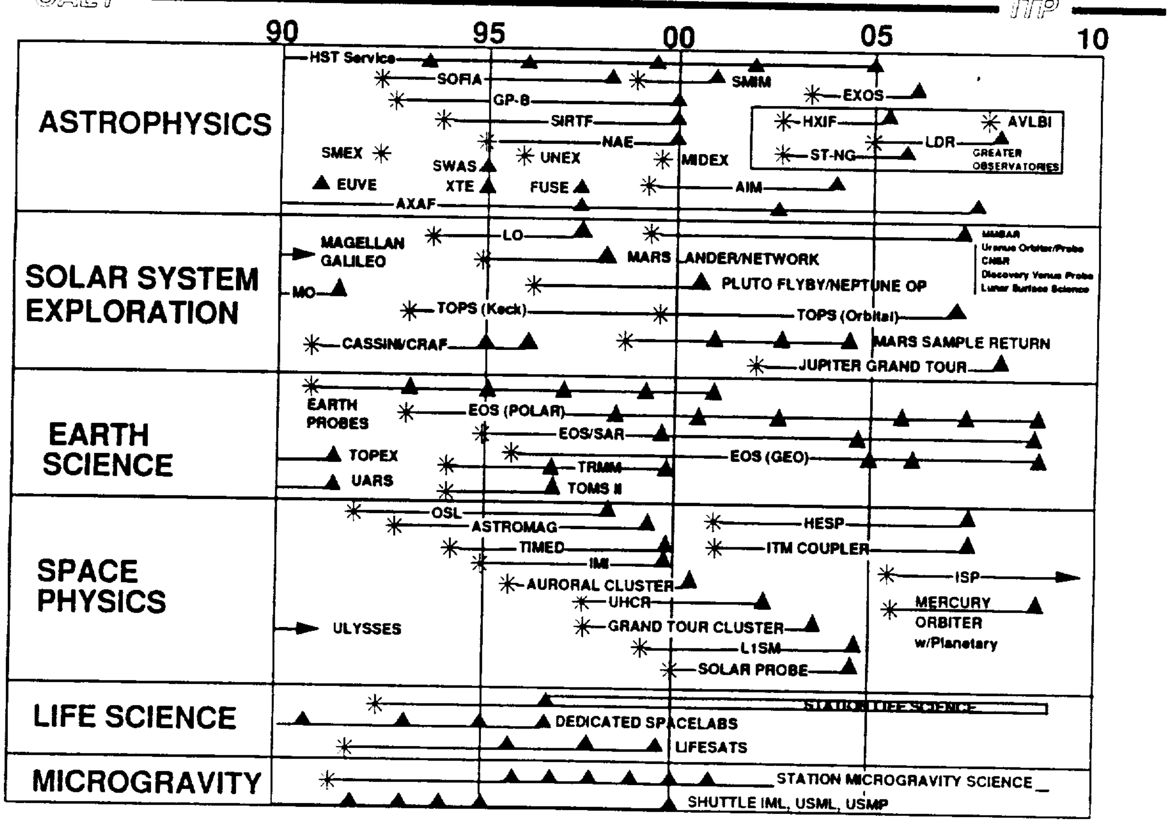
Probes and Robotic Sample Handling to Enable Effective Remote In Situ Science on Planetary Surfaces

Validate Critical Technologies Through Space Flight Experiments to Facilitate Technology Transition to Future Programs

OAET

SCIENCE TECHNOLOGY MISSION MODEL

ITP



6/19/91

TO BE UPDATED FOLLOWING THE OSSA/SSAAC SUMMER WORKSHOP

INTER...

OSSA TECHNOLOGY NEEDS
Grouped According to Urgency & Commonality

REVISED APRIL 12, 1991

	Highest Priority		2nd-Highest Priority			3rd Highest Priority			
Near Term	Submm & Microwave Tech: -- SIS 1.2 THz Heterodyne Rec. -- Active SAR integrated circuits -- Passive submm 600 GHz diodes (SZ,SE.)	Long-life Mechanical & Cryogenic Coolers/Cryo Shielding (SZ,SE,SS)	High Frame Rate, High Resolution Video& Data Compression (SN, SL)	2.5 - 4m, 100K Lightweight, PSR (SZ)	Fluid Diagnostics (SN)	Real-Time Radiation Monitoring (SB)	Descent Imager (SL)	Mini-RTG (SL)	Mini-Camera (SL)
Near Term	Detectors (SE, SL, SZ, SS) -- optical, Ge, Xe, non-cryo 1.6 to 150μ IR, extended μ CCD, high energy detectors, sensor readout electronics & tunnel sensors	Vibration Isolation Technology (SN, SZ, SB)	Solar Arrays/Cells (SL, SZ, SE)	Automated Biomedical Analysis (SB)	Rad Hard Parts & Detectors (SZ, SL)	Solid/Liquid Interface Characterization (SN)	Laser Light Scattering (SN)	High Temperature Materials For Furnaces (SN)	K-band Transponders (SZ)
Near Term	Efficient, Quiet Refrigerator/Freeze (SB)	Extreme Upper Atmosphere Instrument Platforms (SS)	Batteries -- Long life time -- High energy density (SL, SZ)	Real-Time Environmental Control & Monitoring (SB)	Space Qualified maser & ion Clocks (SZ)	Field Portable Gas Chromatographs (SB)	Advanced Furnace Technology (SN)	Ultra-high Gigabit/sec Telemetry (SZ)	Mini S/C Subsystems (SL)
Near Term	Lasers: Long-life, Stable & Tunable (SE, SZ, SL, SB)	Solar Probe/ Mercury Orbiter Thermal Shield & Protection (SS, SL)	Auto Sequencing & Command Generation, Auto S/C Monitoring & Fault Recovery (SL)	Combustion Diagnostics (SN)	Plasma Wave Antennas/ Thermal (SS)	Regenerative Life Support (SB)	Non-Contact Temperature Measurement (SN)	3-D packaging for 1 MB Solid State Chips (SZ)	Microbial Decontamination Methods (SB)
Near Term	Data -- High Volume, High Density, High Data Rate,On-board Storage (SE, SL, SN)	Interferometer-specific Tech: -- picometer metrology -- active delay lines -- control-structures interact. (SZ, SL, SB)	32 Ghz TWT Optical Communication (SL, SS)	Telescience, Telepresence & AI (SN, SL, SB)	Improved EVA Suit/ PLSS (EMU) (SB)	Thermal Control System (SZ)	Special Purpose Bioreactor Simulator Syst. (SB)	Rapid Subject/ Sample Delivery & Return Capability (SB)	Animal & Plant Reproduction Aids (SB)
Near Term	Controlled Structures/ Large Antenna Structure Arrays/Deployable (SE, SZ, SS, SB)	Robotics (SN, SL)	SIS 3 Thz Heterodyne Receiver (SZ)	SETI Technologies -- Microwave & Optical/Laser Detector (SB)	Mini Ascent Vehicle/ Lander Deceleration (SL)	Auto Rendezvous Auto Sample Transfer, Auto Landing (SL)	Non-Destructive Monitoring Capability (SB)	Low-drift Gygos, Trackers, Actuators (SZ)	Non-Destructive Cosmic Dust Collection (SB)
Far Term	Interspacecraft Ranging & Positioning Precision Sensing Pointing & Control (SS, SZ, SL)	Parallel Software (SE, SL) Environment for Model & Data Assimilation, Visualization Computational Techniques	Sample Acquisition & Preservation, Probe, In-situ Inst., Drills, Corers, Penetrators (SL, SB)	Returned-Sample Biobarrier Analysis Capabilities (SB, SL)	High Resolution Spectrometer (SB)	Heat Shield for 16 Km/s Earth Entry (SL)	Partial-g/ μg Medical Care Delivery Systems (SB)	Dust Protection/ Jupiter's Rings (SL)	
Far Term	Large Filled Apertures -- lightweight & stable optics -- Cryo optical ver., fab., test. -- Deformable mirrors -- 15-25m PSR (SL, SZ, SE)	50-100Kw Ion Propulsion (NEP) (SL)	Radiation Shielding for Crews (SB)	X-ray Optics Tech: -- imaging system -- low cost optics -- Bragg concentrators -- coated apertures (SZ)	Human Artificial Gravity Systems (SB)	CELSS Support Technologies (SB)			

HIGHEST PRIORITY	2nd-HIGHEST PRIORITY	3rd HIGHEST PRIORITY
Tally: SB: 5, SN: 3, SE: 8, SS: 6, SL: 11, SZ: 9	SB: 10, SN: 4, SE: 1, SS: 2, SL: 9, SZ: 6	SB: 11, SN: 5, SE: 0, SS: 0, SL: 8, SZ: 5

SCIENCE TECHNOLOGY PLAN

OSSA TECHNOLOGY NEEDS

OAET ITP

* MERGED OSSA DIVISION NEEDS
* TECHNOLOGY NEEDS PRIORITIZED BY URGENCY AND COMMONALITY
* NEEDS PRIORITIZATION WILL REFLECT OSSA STRATEGIC PLAN
* COMPARED CURRENT PROGRAM AGAINST NEED
* TECHNOLOGY RESPONSES ARE IN ALL THRUSTS

SCIENCE TECHNOLOGY PLAN

STRATEGIC WORK BREAKDOWN STRUCTURE

OAET ITP

Science Sensing	Observatory Systems	In Situ Science	Science Information
DIRECT DETECTORS	TELESCOPE OPTICAL SYSTEMS	PROBES AND PENETRATORS	ARCHIVING AND RETRIEVAL
SUB-MILLIMETER	SENSOR OPTICAL SYSTEMS	SAMPLE ACQUISITION ANALYSIS AND PRESERVATION	DATA VISUALIZATION AND ANALYSIS
LASER SENSING	COOLERS & CRYOGENICS		
ACTIVE MICROWAVE	PRECISION INSTRUMENT POINTING		
PASSIVE MICROWAVE	MICRO-PRECISION CSI		
SENSOR READOUTS			
OPTO-ELECTRONICS			

SCIENCE TECHNOLOGY PLAN

SCIENCE SENSORS

OAET ITP

DEVELOP AND DEMONSTRATE SCIENCE SENSING COMPONENTS ACROSS THE ELECTRO-MAGNETIC SPECTRUM FOR INCREASED SENSITIVITY AS WELL AS GREATER SPATIAL AND SPECTRAL RESOLUTION.

- DIRECT DETECTORS - IR, VISIBLE, GAMMA, XRAY
- SUBMILLIMETER - ARRAYS, MIXERS, LOCAL OSCILLATOR
- LASER - NEW WAVELENGTHS, LIFE, ARRAYS
- ACTIVE MICROWAVE - BROADEN FREQ BAND, HIGHER EFFICIENCY
- PASSIVE MICROWAVE - MMIC COMPONENTS, ELECTRONIC STEERING
- ELECTRONIC READOUTS - REDUCED HEAT LOAD, LOWER NOISE
- OPTOELECTRONICS - SEMICONDUCTOR LASER, TUNABILITY

EVERY SCIENCE MISSION REQUIRES SENSING TO MEET ITS SCIENTIFIC OBJECTIVES; THE QUALITY AND QUANTITY OF SCIENCE IS INCREASED BY IMPROVED SENSORS.

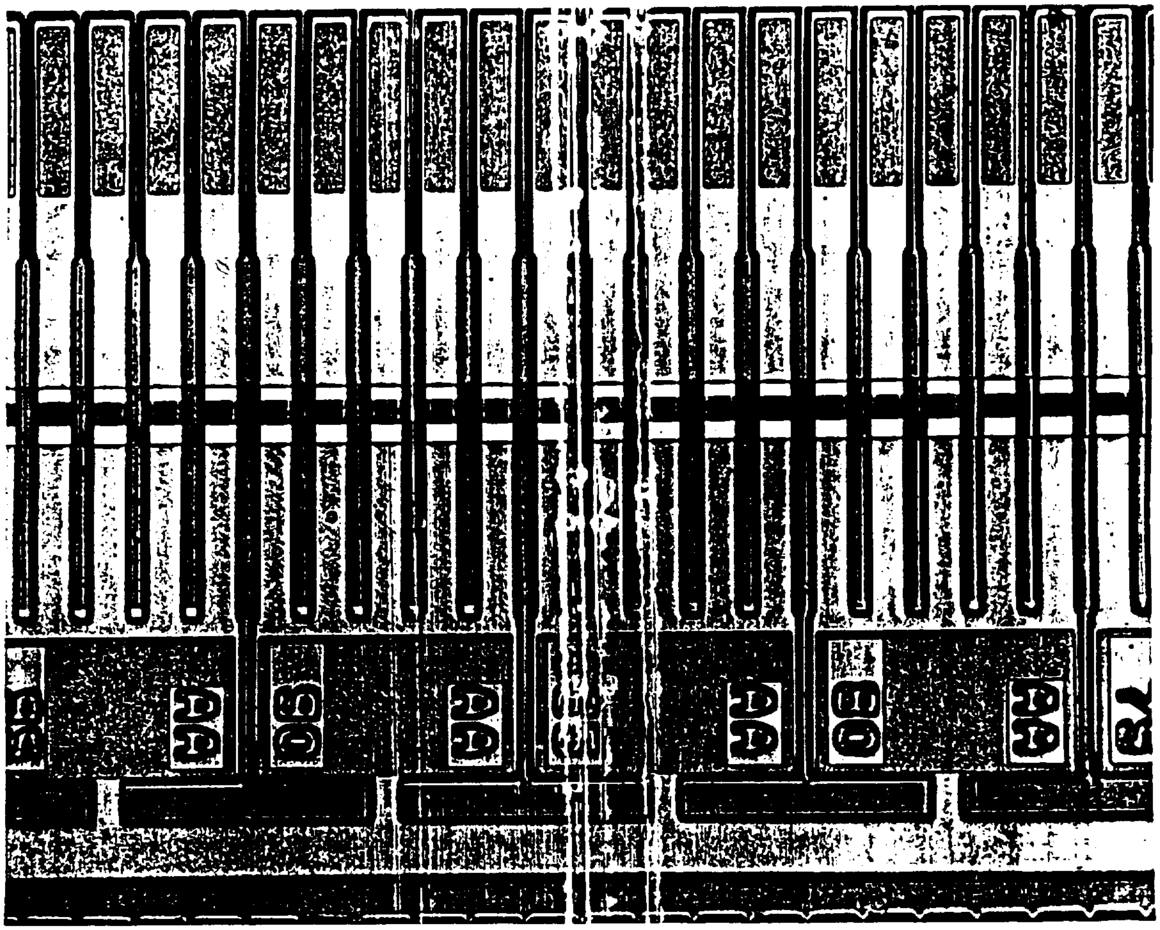
CURRENT EMPHASIS IS IR DETECTORS FOR EOS & SIRTF.

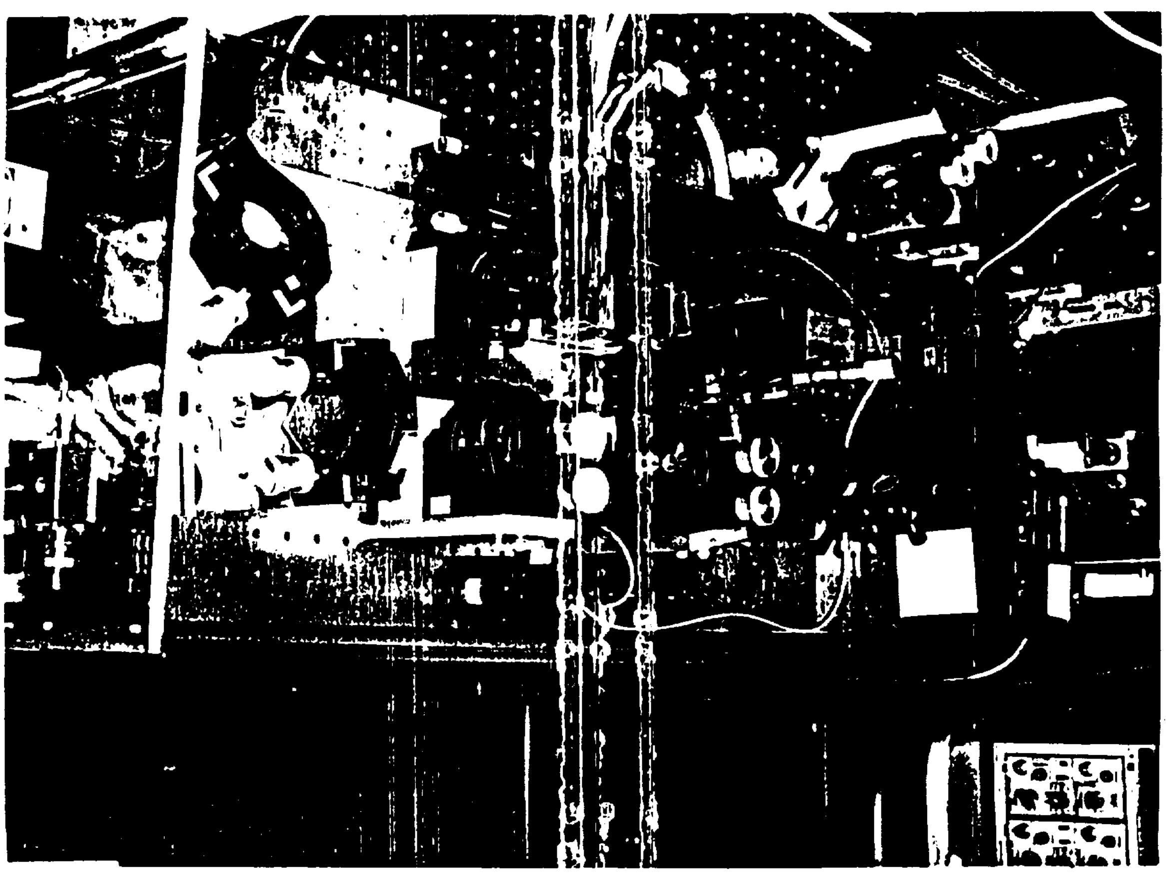
SUBMILLIMETER SENSORS ARE USED FOR O3 DEPLETION AND C02; ARE FOCUS OF BAHCALL REPORT.

LASERS USED FOR WIND MEASUREMENT AND ATMOSPHERIC CONSTITUENTS.

MICROWAVE USED FOR SOIL MOISTURE AND GEOLOGY.

RADIOMETERS USED FOR GLOBAL PRECIPITATION.





OBSERVATORY SYSTEMS

OAET ITP

DEVELOP AND DEMONSTRATE SPACE INSTRUMENT SUPPORT AND OBSERVATION TECHNOLOGIES IN ORDER TO MAXIMIZE SCIENCE RETURN BY PROVIDING THE OPTIMUM OPERATING CONDITIONS FOR SCIENCE INSTRUMENTS.

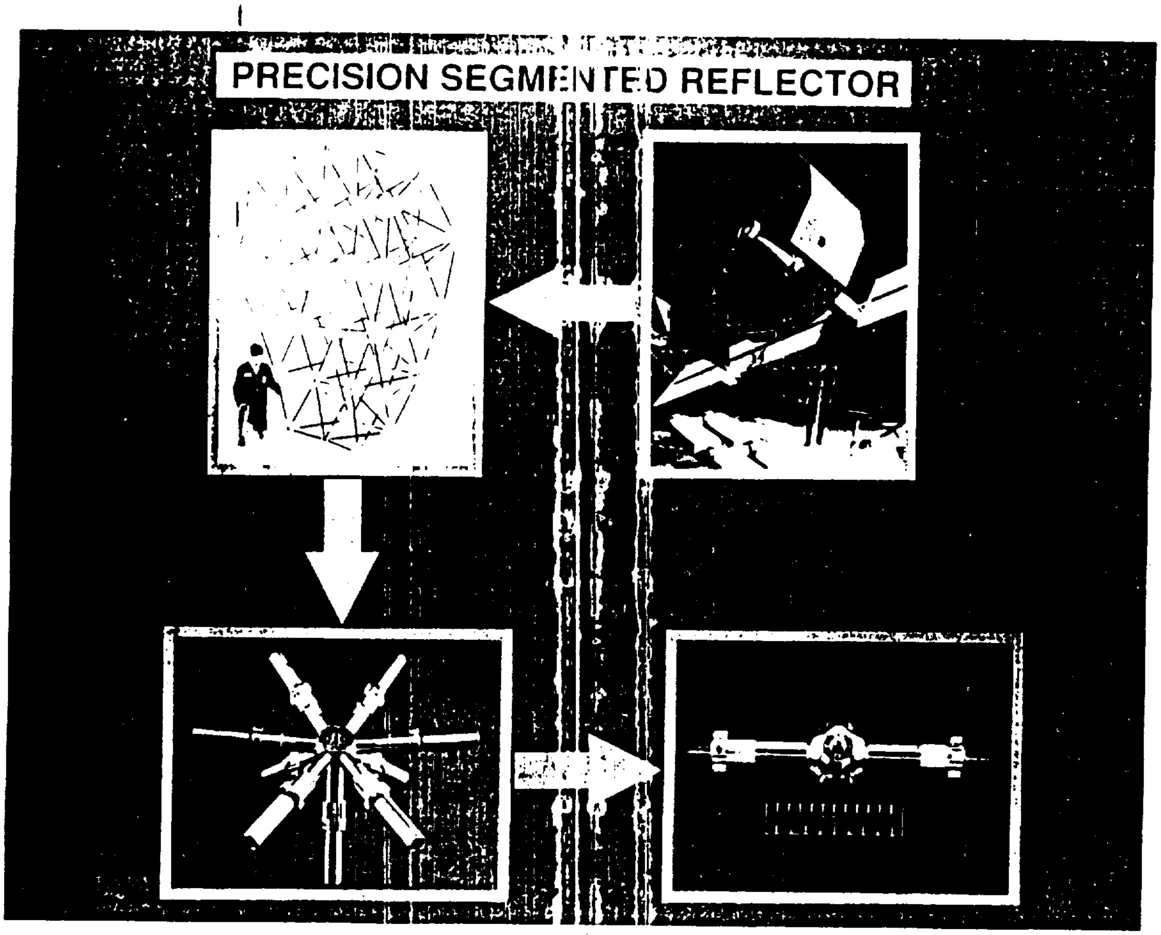
- TELESCOPE OPTICAL – LT WEIGHT MIRRORS, SEGMENTED REFLECTOR METEOROLOGY
- SENSOR OPTICAL –MODELLING, GRATINGS, FILTERS
- COOLERS & CRYOGENICS – 2-300K TEMPERATURE
- PRECISION POINTING – TWO ORDERS MAGNITUDE
- MICROPRECISION CSI – SUBMICRON POSITIONING AND STABILIZATION

ACHIEVING FULL UTILIZATION OF SCIENTIFIC OBSERVATORIES REQUIRES THAT THEY ARE DYNAMICALLY CONTROLLED, THAT THEY OPERATE AT THE OPTIMUM THERMAL CONDITIONS, AND THAT THEY CAN BE STABLY POINTED AT DESIRED SCIENTIFIC EVENTS.

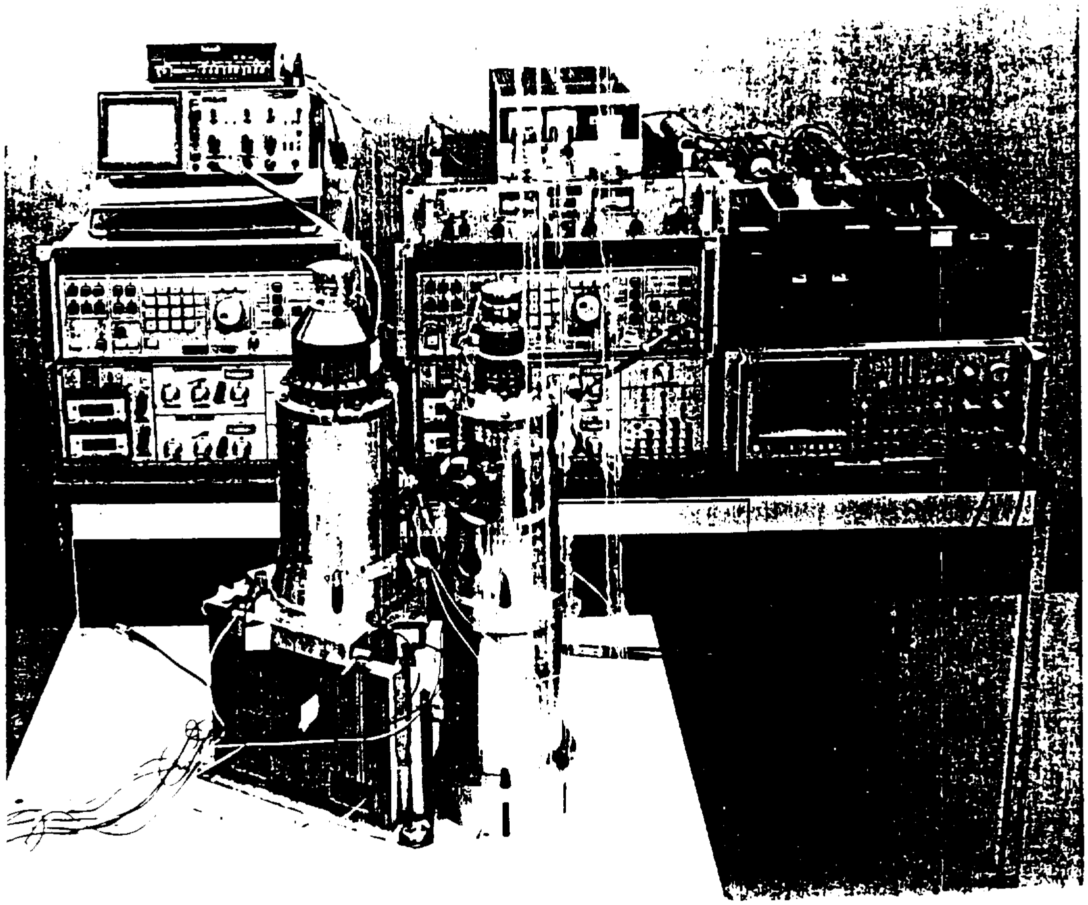
CURRENT EMPHASIS IS ON COOLERS FOR EOS IR INSTRUMENTS; WORK WOULD BE EXTENDED TO COVER COMPLETE 2K TO 300K RANGE FOR EOS, AXAF, SMMM

STABILIZATION FOR MICROGRAVITY PLATFORMS AND FIRST SPACE OPTICAL INTERFEROMETERS MOI, TOPS

REFLECTOR SMOOTHNESS, FACET FIGURE CONTROL



JPL 6-degree-of-freedom Cooler   at on Dynamometer Facility
with British Aerospace Oxford   ler under test



SCIENCE TECHNOLOGY PLAN

IN SITU SCIENCE

OAET   ITP

DEVELOP PLANETARY PROBES AND ROBOTIC SAMPLE ANALYSIS AND PRESERVATION TO ENABLE REMOTE IN SITU SCIENCE

<u>PROBES, PENETRATORS AND LANDERS</u> - AEROMANEUVERING, IMPLANTING, ANCHORING AND IMPACT ABSORBERS

<u>SAMPLE ACQUISITION, ANALYSIS AND PRESERVATION</u> - SAMPLE SPECTRAL IDENTIFICATION, PHYSICAL AND CHEMICAL ANALYSIS; PRISTINE CONTAINMENT (THREE YEARS)

ROBOTIC EXPLORATION OF PLANETARY SURFACES WILL REQUIRE THE DEVELOPMENT OF INNOVATIVE CONCEPTS FOR PRECISE TARGETING OF HIGHLY ROBUST AND VERSATILE PROBES. ACQUISITION AND ANALYSIS OF SAMPLES IN SITU WILL BE REQUIRED TO OBTAIN HIGH QUALITY SAMPLES.

POTENTIAL MISSION APPLICATIONS INCLUDE NEPTUNE, URANUS, PLUTO, ASTEROIDS, AND COMETS.

PROBES AND SAMPLE ACQUISITION COULD BE TESTED ON MOON BEFORE APPLICATION TO MARS SCIENCE PROGRAMS.

SCIENCE INFORMATION

DEVELOP AND DEMONSTRATE KEY TECHNOLOGIES TO ENABLE SUSTAINED, NEAR REAL-TIME CONVERSION OF MASSIVE DATA SETS FROM SPACE SCIENCE MISSIONS INTO SCIENTIFIC INFORMATION WHICH LEADS TO GREATER UNDERSTANDING OF SCIENTIFIC PHENOMENA

ARCHIVING AND RETRIEVAL - AUTONOMOUS CLASSIFICATION AND ASSOCIATIVE REFERENCE

VISUALIZATION AND ANALYSIS - REAL-TIME PARAMETRIC DATA TOURING

SCIENCE INFORMATION TECHNOLOGIES ARE NEEDED TO SUPPORT THE UNPRECEDENTED VOLUME OF OBSERVATIONAL DATA WHICH WILL BE PRODUCED BY MISSION TO PLANET EARTH AS WELL AS ASTROPHYSICS AND PLANETARY MISSIONS.

OVER THE HISTORY OF THE SPACE PROGRAM DATA RATES HAVE INCREASED AT THE RATE OF TWO ORDERS OF MAGNITUDE PER DECADE

EOS PLATFORMS MAY GENERATE TERABYTES OF SCIENTIFIC DATA PER DAY

EOSSAR WILL ADD GREATLY TO THIS DATA RATE

GREAT OBSERVATORIES HST, GRO, AXAF, SIRTF

SCIENCE THRUST

	SCIENCE SENSING	OBSERVATORY SYSTEMS	IN-SITU SCIENCE	SCIENCE INFORMATION
ASTROPHYSICS	DIRECT DETECTORS SUBMILLIMETER SENSOR READOUTS OPTOELECTRONICS	TELESCOPE OPTICAL SYSTEMS SENSOR OPTICAL SYSTEMS COOLERS & CRYOGENICS PRECISION POINTING MICROPRECISION CSI		ARCHIVING & RETRIEVAL DATA VISUALIZATION & ANALYSIS
SOLAR SYSTEM EXPLORATION	DIRECT DETECTORS SUBMILLIMETER ACTIVE MICROWAVE SENSOR READOUTS OPTOELECTRONICS	TELESCOPE OPTICAL SYSTEMS SENSOR OPTICAL SYSTEMS COOLERS & CRYOGENICS PRECISION POINTING MICROPRECISION CSI	PROBES & PENETRATORS SAMPLE ACQUISITION ANALYSIS & PRESERVATION	
EARTH SCIENCE	DIRECT DETECTORS SUBMILLIMETER LASER SENSING ACTIVE MICROWAVE PASSIVE MICROWAVE SENSOR READOUTS OPTOELECTRONICS	TELESCOPE OPTICAL SYSTEMS SENSOR OPTICAL SYSTEMS COOLERS & CRYOGENICS PRECISION POINTING MICROPRECISION CSI		ARCHIVING & RETRIEVAL DATA VISUALIZATION & ANALYSIS
SPACE PHYSICS	DIRECT DETECTORS SUBMILLIMETER SENSOR READOUTS OPTOELECTRONICS	SENSOR OPTICAL SYSTEMS COOLERS & CRYOGENICS PRECISION POINTING	PROBES & PENETRATORS	
MICROGRAVITY	DIRECT DETECTORS SENSOR READOUTS OPTOELECTRONICS	SENSOR OPTICAL SYSTEMS MICROPRECISION CSI	SAMPLE ACQUISITION ANALYSIS & PRESERVATION	ARCHIVING & RETRIEVAL DATA VISUALIZATION & ANALYSIS

"Strategic Plan" ITP: CSTP Element Categorization

OAET — ITP

	HIGHEST PRIORITY ◊◊◊			2nd-HIGHEST PRIORITY ◊◊			3rd-HIGHEST PRIORITY ◊		
Space Science Technology	Submillimeter Sensing	Direct Detectors	Active μwave Sensing	Sample Acq., Analysis & Preservation	Passive Microwave Sensing	....	Optoelectrncs Sensing & Processing	Probes and Penetrators	....
	Cooler and Cryogenics	Microprecision CSI Data Visualization	Laser Sensing Data Archiving and Retrieval	Telescope Optical Systems	Sensor Electronics & Processing	....	Precision Instrument Pointing	Sensor Optical Systems	....
Planetary Surface Exploration Technology	Radiation Protection	Regenerative Life Support (Phys-Chem.)	Space Nuclear Power (SP-100)	High Capacity Power	Planetary Rovers	Surface Habitats and Construction	Exploration Human Factors	---	Artifical Gravity
	---	---	Extravehicular Activity Systems	Surface Solar Power and Thermal Mgt.	In Situ Resource Utilization	Laser-Electric Power Beaming	Medical Support Systems	---	....
Transportation Technology	ETO Propulsion	Aeroassist Flight Expt Nuclear Thermal Propulsion	Aeroassist/ Aerobraking	Transfer Vehicle Avionics	ETO Vehicle Avionics	ETO Vehicle Structures & Materials	Autonomous Rendezvous & Docking	COHE	Auxiliary Propulsion
	Cryogenic Fluid Systems	Adv. Cryo. Engines	Low-Cost Commercial ETO XPort	Nuclear Electric Propulsion	CONE	SEPS TFE	Autonomous Landing	TV Structures and Cryo Tankage	HEAb
Space Platforms Technology	Platform Structures & Dynamics	Platform Power and Thermal Mgt.	Zero-G Life Support	Platform Materials & Environ. Effects	Station-Keeping Propulsion	....	Spacecraft On-Board Propulsion	Earth-Orbiting Platform Controls	Advanced Refrigerator Systems
	---	---	Zero-G Advanced EMU	Platform NDE-NDI	Deep-Space Power and Thermal	....	Spacecraft GN&C	Debris Mapping Experiment	....
Operations Technology	Space Data Systems	High-Rate Comm.	Artificial Intelligence	Ground Data Systems	Optical Comm Flight Expt Navigation & Guidance	Flight Control and Operations	Space Assembly & Construction	Space Processing & Servicing	Photonics Data Systems
	---	CommSat Communicat'ns	TeleRobotics	FTS DTF-1	Operator Syst./Training	CommSat Communicat'ns Flight Expts	....	Ground Test and Processing	....

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

CSTP GROWTH STRATEGIES

OAET — ITP

FY 1993 SPACE SCIENCE TECHNOLOGY

	CURRENT PROGRAM	"3x PROGRAM"	STRATEGIC PLAN
Science Sensing	▥ Direct Detectors ▥ Submillimeter Sensing ▥ Laser Sensing	■ Direct Detectors ■ Submillimeter Sensing ■ Laser Sensing ■ Sensor Electronics ▥ Active Microwave Sensing	■ Direct Detectors ■ Submillimeter Sensing ■ Laser Sensing ■ Sensor Electronics ■ Active Microwave Sensing ■ Passive Microwave Sensing □ Optoelectronics Sensors
Observatory Systems	▥ Coolers & Cryogenics ▦ Micro-Precision CSI	■ Coolers & Cryogenics ▦ Micro-Precision CSI ▦ Telescope Optical Systems	■ Coolers & Cryogenics ■ Micro-Precision CSI ■ Telescope Optical Systems □ Precision Instr. Pointing □ Sensor Optics
Science Information		■ Data Visualization ■ Data Archiving/Retrieval	■ Data Visualization ■ Data Archiving/Retrieval
In Situ Science		■ SAAP	■ SAAP ■ Probes/Penetrators
Tech. Flight Expts.			□ TBD

LEGEND ■ Adequately Funded ▦ Constrained Progress ▥ Marginally Funded □ Outyear "Start"

STRATEGIC SCIENCE THRUST BUDGET

	FY91	FY92	FY93	FY94	FY95	FY96	FY97
SPACE SCIENCE TECHNOLOGY	17.2	17.5	72.8	98.7	136.7	169.5	191.1
SCIENCE SENSING	6.6	9.7	36.3	46.6	63.0	69.3	73.4
DIRECT DETECTORS	1.9	5.2	8.7	9.9	11.1	10.7	11.1
SUBMILLIMETER SENSING	1.2	1.3	7.1	7.8	8.1	8.7	9.3
LASER SENSING	3.5	3.2	8.7	9.8	11.2	12.9	13.3
ACTIVE MICROWAVE SENSING			5.2	8.9	12.4	11.7	11.6
PASSIVE MICROWAVE SENSING			4.0	7.0	12.0	16.0	16.5
SENSOR ELECTRONICS & PROC			2.6	3.2	3.6	4.4	4.8
OPTOELECTRONICS SENSORS					4.6	4.9	6.8
OBSERVATORY SYSTEMS	9.9	7.8	24.9	29.1	40.5	55.3	69.2
TELESCOPE OPTICAL SYSTEMS	4.7		8.0	9.0	11.0	15.9	19.3
COOLER & CRYOGENICS	1.2	3.8	9.5	9.9	10.4	12.1	12.7
SENSOR OPTICS					5.0	9.4	13.5
MICRO-PRECISION CSI	4.0	4.0	7.4	8.2	10.1	10.9	11.2
PRECISION INSTRUMENT POINTING				2.0	4.0	7.0	12.5
IN SITU SCIENCE	0.7	0.0	5.1	11.8	16.5	26.1	29.7
SAMPLE ACQ., ANALS. & PRES.	0.7		2.1	5.3	7.5	9.7	8.0
PROBES AND PENETRATORS			3.0	6.5	9.0	16.4	21.7
SCIENCE INFORMATION	0.0	0.0	6.5	11.2	16.7	18.8	18.8
DATA VISUALIZATION			4.0	6.7	8.7	9.8	10.2
DATA ARCHIVING AND RETRIEVAL			2.5	4.5	8.0	9.0	8.6

3X SCIENCE THRUST BUDGET

	FY91	FY92	FY93	FY94	FY95	FY96	FY97
SPACE SCIENCE TECHNOLOGY	13.2	13.5	55.2	70.6	83.4	87.8	103.2
SCIENCE SENSING	6.6	9.7	27.0	31.2	34.9	35.4	43.1
DIRECT DETECTORS	1.9	5.2	8.6	9.7	10.9	10.0	10.1
SUBMILLIMETER SENSING	1.2	1.3	7.0	7.6	7.8	8.3	8.4
LASER SENSING	3.5	3.2	8.6	9.6	10.8	11.0	14.3
ACTIVE MICROWAVE SENSING			1.3	1.6	2.0	2.0	4.3
PASSIVE MICROWAVE SENSING							
SENSOR ELECTRONICS & PROC			1.5	2.7	3.4	4.1	6.0
OPTOELECTRONICS SENSORS							
OBSERVATORY SYSTEMS	9.9	7.8	20.4	23.1	25.9	27.2	32.3
TELESCOPE OPTICAL SYSTEMS	4.7		7.9	9.0	11.1	11.7	14.4
COOLER & CRYOGENICS	1.2	3.8	8.4	9.9	10.1	10.3	12.7
SENSOR OPTICS							
MICRO-PRECISION CSI	4.0	4.0	4.1	4.2	4.7	5.2	5.2
PRECISION INSTRUMENT POINTING							
IN SITU SCIENCE	3.7	0.0	1.5	5.2	7.0	7.9	9.4
SAMPLE ACQ., ANALS. & PRES.	0.7		1.5	5.3	7.0	7.9	9.4
PROBES AND PENETRATORS							
SCIENCE INFORMATION	0.0	0.0	6.3	11.1	15.6	17.3	18.4
DATA VISUALIZATION			4.0	6.6	8.6	9.0	9.3
DATA ARCHIVING AND RETRIEVAL			2.4	4.5	7.0	8.3	9.1

Office of
Aeronautics,
Exploration and
Technology

EXPLORATION TECHNOLOGY THRUST SUMMARY

presentation to

THE ITP EXTERNAL EXPERT REVIEW TEAM

John C. Mankins
Manager, Exploration Technology Program (act.)

June 25, 1991

NASA
National Aeronautics and
Space Administration

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

THRUST OVERVIEW

OAET

CONTENTS

- THRUST GOALS AND OBJECTIVES
- PLANETARY SURFACE EXPLORATION USER NEEDS
- OBJECTIVES AND CONTENT OF THE THRUST STRATEGIC PLAN
- CATEGORIZATION/PRIORITIZATION OF THE THRUST STRATEGIC PLAN
- GROWTH STRATEGIES SUMMARY
- ACCOMMODATION OF USER NEEDS

WORK BREAKDOWN STRUCTURE

OAET

SPACE RESEARCH & TECHNOLOGY

RESEARCH & TECHNOLOGY BASE

- DISCIPLINE RESEARCH
  - Aerothermodynamics
  - Space Energy Conversion
  - Propulsion
  - Materials & Structures
  - Information and Controls
  - Human Support
  - Adv. Communications
- UNIVERSITY PROGRAMS
- SPACE FLIGHT R&T
  - Flight Experiment Studies
  - IN-STEP
- SYSTEMS ANALYSIS

CIVIL SPACE TECHNOLOGY PROGRAM

- SPACE SCIENCE TECHNOLOGY
  - Science Sensing
  - Observatory Systems
  - Science Information
  - In Situ Science
  - Technology Flight Expts.
- PLANETARY SURFACE EXPLORATION TECHNOLOGY
  - Surface Systems
  - Human Support
  - Technology Flight Expts.
- TRANSPORTATION TECHNOLOGY
  - ETO Transportation
  - Space Transportation
  - Technology Flight Expts.
- SPACE PLATFORMS TECHNOLOGY
  - Earth-Orbiting Platforms
  - Space Stations
  - Deep-Space Platforms
  - Technology Flight Expts.
- OPERATIONS TECHNOLOGY
  - Automation & Robotics
  - Infrastructure Operations
  - Info. & Communciations
  - Technology Flight Expts.

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

PROGRAM OVERVIEW

OAST

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

- **THRUST GOAL:**
  - DEVELOP AND DEMONSTRATE THE CRITICAL TECHNOLOGIES NEEDED FOR HUMAN AND ROBOTIC EXPLORATION OF PLANETARY SURFACES AND THE EMPLACEMENT OF HUMAN OUTPOSTS ON THE MOON AND MARS

- **THRUST R&T OBJECTIVES:**
  - TECHNOLOGIES TO ENABLE ADVANCED, COST-EFFECTIVE SURFACE SYSTEM OPERATIONS ON THE MOON AND MARS
  - TECHNOLOGIES TO SUPPORT SAFE AND EFFICIENT HUMAN ACTIVITIES DURING VERY LONG DURATION MISSIONS IN DEEP-SPACE AND ON PLANETARY SURFACES
  - VALIDATE CRITICAL TECHNOLOGIES THROUGH FLIGHT EXPERIMENTS AND FACILITATE TECHNOLOGY TRANSITION TO FUTURE PROGRAMS

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

THRUST OVERVIEW

OAET

CONTENTS

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- ACCOMMODATION OF USER NEEDS

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

SEI TECHNOLOGY NEEDS

OAET

Category		Technology	MSSION/SYSTEM APPLICATIONS FORECAST
Category 1 (Enabling and Common)	■	RADIATION PROTECTION	Initial Lunar, Evolution, Initial Mars
	■	EVA SYSTEMS	Initial Lunar, Evolution, Initial Mars
	■	REGENERATIVE LIFE SUPPORT	Initial Lunar, Evolution, Initial Mars
	■	MICRO-G COUNTERMEASURES/ART. GRAVITY	Initial Mars Mission
	☒	AEROBRAKING	Initial Lunar, Evolution,Robotic Mars, Initial Mars
	☒	NUCLEAR THERMAL PROPULSION	Initial Mars Mission
	☒	CRYO. FLUID MGT, STORAGE & TRANSFER	Initial Lunar, Evolution, Initial Mars
Category 2 (Enabling and Unique or High-Leverage and Common)	■	HEALTH MAINTENANCE & CARE	Initial Lunar, Evolution, Initial Mars
	■	SURFACE SYSTEMS CONSTRUCTION/PROCESSING	Initial Lunar, Evolution, Initial Mars
	■	IN SITU RESOURCE UTILIZATION	Evolution, Initial Mars
	■	SURFACE POWER	Initial Lunar, Evolution, Initial Mars
	☒	AUTONOMOUS RENDEZVOUS & DOCKING	Initial Lunar, Evolution, Robotic Mars, Initial Mars
	☒	IN-SPACE SYSTEMS ASSY/PROCESSING	Initial Lunar, Evolution, Initial Mars
	☒	CRYOGENIC SPACE ENGINES	Initial Lunar, Evolution, Initial Mars
Category 3 (High-Leverage and Unique)	■	HUMAN FACTORS	Initial Lunar, Evolution, Initial Mars
	■	SURFACE SYSTEM MOBILITY & GUIDANCE	Initial Lunar, Evolution, Robotic Mars, Initial Mars
	☒	ELECTRIC PROPULSION	Evolution, Initial Mars
	☒	AUTONOMOUS LANDING	Initial Lunar, Evolution, Robotic Mars, Initial Mars
	☒	SAMPLE ACQUISITION, ANALYSIS & PRESERV.	Initial Lunar, Evolution, Robotic Mars, Initial Mars

■ *Covered In Planetary Surface Exploration Thrust Strategic Planning*
☒ *Covered In Another Thrust Strategic Planning*
❑ *Not Yet Addressed By ITP Strategic Planning*

NOTE: THIS LISTING WAS DEVELOPED BEFORE THE RELEASE OF THE SYNTHESIS GROUP REPORT

JUNE
JC

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

TECHNOLOGY NEEDS

OAST

SEI PLANETARY SURFACE EXPLORATION TECHNOLOGY NEEDS

<u>Category I</u>

- Radiation Protection
- EVA Systems
- Regenerative Life Support
- Micro-G Countermeasures/Artificial Gravity

<u>Category II</u>

- Health Maintenance/Care
- Surface Construction and Processing
- In Situ Resource Utilization
- Surface Power

<u>Category III</u>

- Human Factors
- Surface System Mobility and Guidance (manned and unmanned

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

OSSA TECHNOLOGY NEEDS

OAET

	NEAR-TERM NEED	MID-TERM NEED	FAR-TERM NEED
HIGHEST PRIORITY	Sub-mm & μ-wave Sensing Long-Life Cryo Coolers/Cryo Shielding High-Energy Detectors Sensor Readout Electronics Vibration Isolation Technology Efficient/Quiet Refrigerator/Freezer Extreme Upper Atmosphere Instr. Platforms	Long-Life, Stable, Tunable Lasers Solar Probe/Mercury Orbiter Thermal Protect. High -Vol./Density/Rate Onboard Data Storage Interferometer-Specific Technology	Structures: Large/Controlled/Deployed/Ant'a Robotics Precision Inter-S/C Ranging/Positioning 50-100 Kilowatt Ion Propulsion (NEP) Large Filled Apertures Parallel S/W Env. for Model&Data Visualization Computational Techniques
2ND HIGHEST PRIORITY	High Frame Rate/Res. Video/Data Compress. 2.4 to 4 Meter, 100 K Lightweight PSR Solar Arrays/Cells Automated Biomedical Analysis Radiation Hardened Parts/Detectors Long-Life/High-Energy Density Batteries Real-Time Environmental Control Space-Qualified Masers/Ion Clocks Fluid Diagnostics	Auto-Sequencing & CMD Generation Auto S/C Monitoring & Fault Recovery 32 GHz TWT/Optical Communications Telescience/Telepresence/Art. Intelligence Improved EVA Suit/PLSS (EMU) Combustion Devices Plasma Wave Antenna/Thermal	SIS 3 THz Heterodyne Receiver SETI Detector Technologies Mini-Ascent Vehicle/Lander Deceleration Radiation Shielding for Crews SAAP/Probes/In Situ Instr's/Penetrators Human Artificial Gravity Systems X-Ray Optics Technology Returned-Sample Biobarrier Analysis Cap. High-Resoultion Spectrometer
3RD HIGHEST PRIORITY	Descent Imaging/Mini RTG/Mini Camers K-Band Transponders Ultra-High Gigabit/sec. Telemetry Mini-Spacecraft Subsystems Real-Time Radiation Monitoring Solid/Liquid Interface Characterization Laser Light Scattering High-Temperature Mat'ls for Furnaces Field-Portable Gas Chromatographs Adv. Furnace Technology	Regenerative Life Support Thermal Control System Non-Contact Temp. Measurement 3-D Packaging for 1MB Solid State Chips Microbial Decontamination Methods Animal and Plant Reproduction Aids Special-Purpose Bioreactor Simulator Syst. Rapid Subject/Sample Delivery & Return Capability	Autonomous Rendezvous/Sample Xfer/Landing Non-Destructive Monitoring Capability Low-Drift Gyros/Trackers/Actuators Heat Shield for 16 km/sec Earth entry Partial-G/μ-G Medical Care Systems Dust Protection/Jupiter's Rings Non-Destructive Cosmic Dust Collection CELSS Support Technologies

APRIL 20,
JCM-

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

TECHNOLOGY NEEDS

OAST

OSSA PLANETARY SURFACE TECHNOLOGY NEEDS

<u>Highest Priority</u>

- Robotics (Rovers)

<u>2nd-Highest</u>

- Real-Time Environmental Control & Monitoring
- Improved EVA Suit/PLSS (EMU)
- Human Artificial Gravity Systems
- Radiation Shielding for Crews

<u>3rd-Highest</u>

- Real-Time Radiation Monitoring
- Regenerative Life Support
- Partial-G/μ-G Medical Care Delivery Systems
- CELSS Support Technologies

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

SEI SYNTHESIS GROUP IMPLICATIONS

OAST

<u>OVERVIEW</u>

NATIONAL SPACE VISIONS

- Increase our knowledge of our solar system and beyond
- Rejuvenate interest in science and engineering
- Refocus U.S. position in world leadership (from military to economic and scientific)
- Develop technology with terrestrial application
- Facilitate further space exploration and commercialization
- Boost the U.S. economy

WAYPOINTS

MOON WAYPOINTS

- Lunar Exploration
- Preparation for Mars
- Habitation
- Lunar Based Observation
- Fuels
- Energy to Earth

ASTEROIDS WAYPOINT

MARS WAYPOINT

ARCHITECTURES

- Mars Exploration
- Science Emphasis For The Moon And Mars
- Moon To Stay And Mars Exploration
- Space Resource Utilization

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

SYNTHESIS GROUP STUDY TECHNOLOGY NEEDS

OAST

HIGH PRIORITY AREAS

- ■ CLOSED-LOOP LIFE SUPPORT SYST.
- ■ TELEROBOTICS
- ■ NUCLEAR-ELECTRIC SURFACE POWER
- ■ EVA SUITS
- ■ RADIATION EFFECTS/SHIELDING
- ■ LONG-DURATION HUMAN FACTORS
- ■ IN SITU RESOURCE EVALUATION AND PROCESSING
- ☒ AUTO. RENDEZVOUS/DOCKING
- ☒ CRYOGEN TRANSFER/STORAGE
- ☒ NUCLEAR THERMAL PROPULSION
- ☒ HEAVY LIFT LAUNCH
- ☒ LIGHT-WEIGHT STRUCTURAL MAT'LS & FABRICATION
- ☒ NUCLEAR ELECTRIC PROP. (CARGO)
- ☐ ZERO-GRAVITY COUNTERMEASURES

■ In Surface Explor. Thrust ☒ In Other Thrust ☐ Not Addressed In A Thrust

OTHER TECHNOLOGIES CITED

- ■ VIRTUAL REALITY
- ■ SURFACE HABITATS
- ■ REGENERATIVE FUEL CELLS
- ■ SOLAR ARRAYS
- ■ POWER BEAMING
- ■ LUNAR SURFACE FACTORY OPERATIONS
- ■ MINING, EXCAVATION AND CONSTRUCTION
- ☒ SAMPLE ACQUISITION/ANALYSIS
- ☒ HIGH RATE COMM. & NAVIGATION
- ☒ LUNAR SURFACE INSTRUMENT COOLERS
- ☒ SUBMILLIMETER/OPTICAL INTER-FEROMETERS, & REMOTE SENSORS
- ☒ LARGE FILLED APERTURE TELESCOPES
- ☒ ROBOTIC PROBES
- ☒ AEROBRAKING (Cited as Back-up Option)
- ☒ CHEMICAL PROPULSION (Back-Up Option)
- ☐ HELIUM-3 FUSION

JUNE 20, 1991
JCM-7297

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

THRUST OVERVIEW

OAET

CONTENTS

- THRUST GOALS AND OBJECTIVES
- PLANETARY SURFACE EXPLORATION USER NEEDS
- ⇨ OBJECTIVES AND CONTENT OF THE THRUST STRATEGIC PLAN
- CATEGORIZATION/PRIORITIZATION OF THE THRUST STRATEGIC PLAN
- GROWTH STRATEGIES SUMMARY
- ACCOMMODATION OF USER NEEDS

WORK BREAKDOWN STRUCTURE

PLANETARY SURFACE EXPLORATION TECHNOLOGY PROGRAM

- SURFACE SYSTEMS
  - Space Nuclear Power
  - Planetary Rovers
  - High Capcity Power
  - Surface Habitats and Construction
  - Surface Power & Thermal Management
  - Laser-Electric Power Beaming
  - In Situ Resource Utilization
- HUMAN SUPPORT
  - Regenerative Life Support
  - Extravehicular Activity Systems
  - Radiation Protection
  - Exploration Human Factors
  - Artificial Gravity
  - Medical Support Systems
- EXPLORATION TECH. FLT EXPTS
  - TBD

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

SURFACE SYSTEMS TECHNOLOGY AREA

- **AREA GOAL:**
  - DEVELOP AND VALIDATE TECHNOLOGIES REQUIRED FOR RELIABLE, CAPABLE, AND SAFE SURFACE SYSTEMS OPERATIONS DURING LUNAR OUTPOST AND MARS EXPEDITION EXTENDED MISSIONS

- **AREA R&T OBJECTIVES:**
  - SAFE AND RELIABLE SPACE NUCLEAR POWER SYSTEMS TO SUPPORT EXPLORATION MISSIONS (10 Kwe to 1000 Kwe POWER)
  - DEVELOP AND DEMONSTRATE LOW MASS, RELIABLE LONG LIFE POWER CONVERSION FOR SPACE NUCLEAR REACTOR POWER SYSTEMS
  - DEVELOP NON-REACTOR SURFACE POWER AND LOW-GRADE HEAT THERMAL MANAGEMENT TECHNOLOGIES TO SUPPORT EXPLORATION SURFACE OPERATIONS
  - DEVELOP MOBILE SURFACE SYSTEMS TECHNOLOGIES TO ENABLE ROBUST, FLEXIBLE AND EFFICIENT VEHICLE SYSTEMS FOR PLANETARY SURFACE EXPLORATION/OPERATIONS
  - CAPABILITY TO EMPLACE AND BUILD PLANETARY OUTPOST AND CONCEPTS FOR HABITATS AND SURFACE ENCLOSURES
  - TECHNOLOGIES FOR UTILIZATION OF EXTRATERRESTRIAL MATERIALS FOR EXPLORATION OR OUTPOST OPERATIONS ON THE SURFACE OF THE MOON OR MARS
  - DEMONSTRATE POWER BEAMING FOR HIGH POWER DEEP-SPACE APPLICATIONS

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

PLANETARY SURFACE EXPLORATION TECHNOLOGY

OAET

SURFACE SYSTEMS

JUSTIFICATION

Surface Systems technologies are needed to enable a wide range of planetary surface exploration and operations; specific mission timing includes:

- 1997 Technology readiness needed for early initial Lunar mission options
- 2000 Technology readiness needed for later Lunar Outpost emplacement/evolution
- 2005 Technology readiness needed for initial Humans-to-Mars mission(s)

OBJECTIVES

- **Programmatic**

  Develop and validate technologies for reliable, capable, and safe surface system operations during Lunar Outpost and Mars expedition extended missions

- **Technical**

Space Nuclear Power	SP-100 FQS (10-1000 kWe)
High Capacity Power	High-efficiency T-E conversion
In Situ Resource Utilization	Volatiles extraction/limited fabrication
Planetary Rovers	Long-range robotic and piloted systems
Surface Power and Thermal Mgt	Solar arrays, RFCs, local PMAD
Surface Habitats/Construction	Site preparation, dust mgt, habitats
Laser-Electric Power Beaming	Point-to-point, compact power beaming

MILESTONES

- 1993 Select RFC component technologies
- 1994 Go/No-Go decision on laser/beam expander/PV R&T for laser power beaming
- 1995 Restart nuclear assembly test site
- 1997 Complete testbed evaluation for early unpressurized robotic rovers (piloted options); early RFC demos
- 1999 Complete Ground-to-Space laser power beaming breadboard demonstration
- 2000 Complete R&T for lunar construction vehicles; ISRU testbed operational; permanent habitat concepts demo's
- 2002 Complete flight-like integrated assembly test and nuclear assembly test for Lunar nuclear power systems

RESOURCES

Budget Options ($,M)	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
Current	24.0	30.6	29.5	29.6	24.8	25.0	25.2
3x Program	24.0	24.0	53.6	97.0	129.8	139.2	159.0
Strategic ITP	24.0	30.6	65.7	137.6	189.0	229.1	188.0

JUNE 18, 1991

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

HUMAN SUPPORT TECHNOLOGY AREA

OAET

- **AREA GOAL:**
  - DEVELOP AND VALIDATE TECHNOLOGIES REQUIRED FOR RELIABLE, EFFICIENT, AND SAFE ASTRONAUT OPERATIONS DURING LUNAR OUTPOST AND MARS EXPLORATION MISSIONS
- **AREA R&T OBJECTIVES:**
  - SAFE, RELIABLE , AND EFFICIENT REGENERATIVE LIFE SUPPORT SYSTEMS
  - DEVELOP SHIELDING MATERIALS DATA AND BREADBOARDS TO PROTECT ASTRONAUTS FROM SOLAR AND COSMIC RADIATION DURING LONG-DURATION EXPLORATION MISSIONS
  - DEVELOP AND VALIDATE TECHNOLOGIES FOR MOBILE LIGHTWEIGHT, MULTI-USE EXTRAVEHICULAR ACTIVITY SUITS & PORTABLE LIFE SUPPORT FOR PLANETARY SURFACE OPERATIONS
  - INCREASE UNDERSTANDING OF HUMAN PERFORMANCE FACTORS UNDER LONG-DURATION MISSION CONDITIONS AND INCORPORATE RESULTS INTO DATABASE AND REQUIREMENTS TO SUPPORT ENHANCED EXPLORATION SYSTEM DESIGNS
  - DEFINE AND DEVELOP CONCEPTS FOR ARTIFICIAL GRAVITY FOR PILOTED MARS VEHICLES
  - PROVIDE CAPABILITY TO DEVELOP SYSTEMS AND EQUIPMENT REQUIRED TO MAINTAIN CREW FITNESS AND MEDICAL HEALTH

PLANETARY SURFACE EXPLORATION TECHNOLOGY

OAET

HUMAN SUPPORT

JUSTIFICATION

Human support technologies are needed to assure safe and effective human operations during Lunar Outpost and Mars expedition missions; specific mission needs timing includes:

- 1997 Technology readiness needed for early initial Lunar mission options
- 2000 Technology readiness needed for later Lunar Outpost emplacement/evolution
- 2005 Technology readiness needed for initial Humans-to-Mars mission(s)

OBJECTIVES

- **Programmatic**

  Develop and validate technologies for reliable, safe and efficient astronaut operations during future deep-space (Lunar and Mars) exploration missions

- **Technical**

Regen. Life Support	Closed, Low-Cost Life Support Systems
Radiation Protection	Shielding (with ≤10% uncertainty)
EVA Systems	Locally-maintained EVA for Lunar/Mars
Exploration Human Factors	Safe/Efficient Human/Machine Ops
Artificial Gravity	A-G Systems/Technology Assessments
Remote Medical Care	Emergency Lunar/Mars Medical Care

MILESTONES

- 1992 Complete models of human locomotion in 1/6-gravity
- 1993 Deliver initial Lunar shielding concepts
- 1995 Initiate Adv. RLSS technology testbed; define initial remote medical care concepts
- 1997 Complete EVA Suit technology for early Lunar mission options (preliminary PLSS); radiation code with ≤ 25% uncertainty
- 1999 Complete Lunar EVA R&T; guidelines for Lunar habitats; definition of advanced workstations; radiation to ≤ 10%
- 2000 Complete integrated Lunar Outpost advanced RLSS man-rated demonstrations
- 2000 Complete laboratory breadboards, analytical models of mechanisms/controls for artificial gravity vehicles

RESOURCES

Budget Options ($,M)	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
Current	3.8	16.0	24.0	33.5	39.0	47.0	51.6
3x Program	3.8	16.0	21.3	29.5	35.5	39.0	42.4
Strategic ITP	**3.8**	**16.0**	**25.9**	**38.9**	**50.9**	**60.3**	**65.8**

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

THRUST OVERVIEW

OAET

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- THRUST GOALS AND OBJECTIVES
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"Strategic Plan" ITP: CSTP Element Categorization

OAET

Space Science Technology	Submillimeter Sensing Cooler and Cryogenics	Direct Detectors Microprecision CSI Data Visualization	Active μwave Sensing Laser Sensing Data Archiving and Retrieval	Sensor Electronics & Processing Telescope Optical Systems	Passive Microwave Sensing Sample Acq., Analysis & Preservation	— —	Optoelectrnics Sensing & Processing Precision Instrument Pointing	Probes and Penetrators Sensor Optical Systems	— —
Planetary Surface Exploration Technology	Radiation Protection —	Regenerative Life Support (Phys-Chem.) —	Space Nuclear Power (SP-100) Extravehicular Activity Systems	High Capacity Power Surface Solar Power and Thermal Mgt.	Planetary Rovers In Situ Resource Utilization	Surface Habitats and Construction Laser-Electric Power Beaming	Exploration Human Factors Medical Support Systems	— —	Artifical Gravity —
Transportation Technology	ETO Propulsion Cryogenic Fluid Systems	Aeroassist Flight Expt Nuclear Thermal Propulsion Adv. Cryo. Engines	Aeroassist/ Aerobraking Low-Cost Commercial ETO XPort	Transfer Vehicle Avionics Nuclear Electric Propulsion	ETO Vehicle Avionics CONE	ETO Vehicle Structures & Materials SEPS TFE	Autonomous Rendezvous & Docking Autonomous Landing	COHE TV Structures and Cryo Tankage	Auxiliary Propulsion HEAb
Space Platforms Technology	Platform Structures & Dynamics —	Platform Power and Thermal Mgt. —	Zero-G Life Support Zero-G Advanced EMU	Platform Materials & Environ. Effects Platform NDE-NDI	Station-Keeping Propulsion Deep-Space Power and Thermal	— —	Spacecraft On-Board Propulsion Spacecraft GN&C	Earth-Orbiting Platform Controls Debris Mapping Experiment	Advanced Refrigerator Systems —
Operations Technology	Space Data Systems —	High-Rate Comm. CommSat Communicat'ns	Artificial Intelligence TeleRobotics	Ground Data Systems FTS DTF-1	Optical Comm Flight Expt Navigation & Guidance Operator Syst./Training	Flight Control and Operations CommSat Communicat'ns Flight Expts	Space Assembly & Construction —	Space Processing & Servicing Ground Test and Processing	Photonics Data Systems —
	HIGHEST PRIORITY ◊◊◊			2nd-HIGHEST PRIORITY ◊◊			3rd-HIGHEST PRIORITY ◊		

JUNE 18, 1991

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

THRUST OVERVIEW

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CSTP GROWTH STRATEGIES

FY 1993 PLANETARY SURFACE EXPLORATION TECHNOLOGY

	CURRENT PROGRAM	"3x PROGRAM"	STRATEGIC PLAN
Surface Systems	Space Nuclear Power High Capacity Power	Space Nuclear Power High Capacity Power Planetary Rovers Surface Power/Thermal ISRU Power Beaming	Space Nuclear Power High Capacity Power Planetary Rovers Surface Power/Thermal ISRU Power Beaming Surface Hab/Construct.
Human Support	Regen. Life Support Radiation Protection EVA Systems Explor. Human Factors	Regen. Life Support Radiation Protection EVA Systems Explor. Human Factors	Regen. Life Support Radiation Protection EVA Systems Explor. Human Factors Remote Medical Care Artificial Gravity
Tech. Flight Expts.			TBD

LEGEND Adequately Funded — Constrained Progress — Marginally Funded — Outyear "Start"

JUNE 17, 199
JCM-751

THRUST OVERVIEW

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PLANETARY SURFACE EXPLORATION TECHNOLOGY

TECHNOLOGY NEEDS ACCOMMODATION

OAET

	USER NEEDS	SURFACE SYTEMS	HUMAN SUPPORT
Lunar Outpost	**SEI** Category I: Radiation Protection, EVA Systems, Regenerative Life Support Category II: Health Maintenance and Care, Surface System Construction & Processing, In Situ Resource Utilization, Surface Power Category III: Human Factors, Surface Mobility and Guidance (manned/unmanned) **OSSA** Highest: Robotics (Rovers) 2nd-High: Environ. Control; EMU; Artificial-G 3rd-High: Rad. Monitor;RLSS;Med Care;CELSS	Space Nuclear Power High Capacity Power Planetary Rovers Surface Power/Thermal ISRU Surface Hab/Construct. Power Beaming	Regen. Life Support Radiation Protection EVA Systems Explor. Human Factors Remote Medical Care
Humans to Mars	**SEI** Category I: Radiation Protection, EVA Systems, Regenerative Life Support, Micro-G Countermeasures/Artificial Gravity Category II: Health Maintenance and Care, Surface System Construction & Processing, In Situ Resource Utilization, Surface Power Category III: Human Factors, Surface Mobility and Guidance (manned/unmanned) **OSSA** Highest: Robotics (Rovers) 2nd-High: Environ. Control; EMU; Artificial-G 3rd-High: Rad. Monitor;RLSS;Med Care;CELSS	Space Nuclear Power High Capacity Power Planetary Rovers Surface Power/Thermal ISRU Surface Hab/Construct. Power Beaming	Regen. Life Support Radiation Protection EVA Systems Explor. Human Factors Remote Medical Care Artificial Gravity
Robotic Lunar & Mars Exploration	**SEI** Category III: Surface Mobility and Guidance (manned/unmanned) Highest: Robotics (Rovers)	Planetary Rovers Surface Power/Thermal High Capacity Power	

JUNE 20, 1991

PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST

TECHNOLOGY NEEDS ACCOMMODATION

OAST

- **STRONG COVERAGE IN PLANETARY SURFACE EXPLORATION TECHNOLOGY THRUST OF USER NEEDS FROM OAET/RZ AND OSSA IN THE AREAS OF:**
  - **Lunar Outpost**
  - **Human to Mars**
  - **Robotic Lunar & Mars Missions**

- **PRELIMINARY ASSESSMENTS OF SEI SYNTHESIS GROUP REPORT UNDERWAY**
  - **Initial Impression: Coverage Of Surface Systems Related Technologies Needs Is Good**

BACK-UP CHARTS

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

PLANETARY SURFACE EXPLORATION THRUST

OAET

"STRATEGIC PROGRAM" ITP RESOURCES

	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
THRUST TOTALS ($,M)	**27.8**	**46.6**	**91.6**	**176.5**	**239.9**	**289.4**	**253.8**
SURFACE SYSTEMS	**24.0**	**30.6**	**65.7**	**137.6**	**189.0**	**229.1**	**188.0**
Space Nuclear Power	10.0	20.0	25.0	25.0	26.0	27.0	28.0
High Capacity Power	10.4	10.6	11.1	16.8	23.0	30.5	23.0
Planetary Rovers	3.0	----	5.3	13.4	17.6	24.4	30.1
Surface Power & Thermal	0.6	----	5.0	11.7	18.5	24.2	25.3
In Situ Resource Utilization	----	----	3.5	6.0	9.7	14.5	15.7
Surface Habitats & Construction	----	----	2.3	4.8	8.5	9.7	14.5
Laser-Electric Power Beaming	----	----	13.5	56.9	82.5	90.8	41.0
HUMAN SUPPORT	**3.8**	**16.0**	**25.9**	**38.9**	**50.9**	**60.3**	**65.8**
Regenerative Life Support	1.9	8.0	12.0	18.0	20.0	24.0	25.1
Radiation Protection	0.5	3.0	6.9	7.8	8.5	9.7	10.0
EVA Systems (Surface)	0.9	4.0	5.0	8.0	11.0	12.0	12.5
Exploration Human Factors	0.5	1.0	2.0	3.1	5.8	6.3	6.7
Artificial Gravity	----	----	----	----	1.3	1.4	3.6
Remote Medical Care Systems	----	----	----	2.0	4.3	6.9	7.9

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

PLANETARY SURFACE EXPLORATION THRUST

OAET

"3x PROGRAM" ITP RESOURCES

	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
THRUST TOTALS ($M)	**27.8**	**46.6**	**74.9**	**126.5**	**165.3**	**178.2**	**201.4**
SURFACE SYSTEMS	**24.0**	**30.6**	**53.6**	**97.0**	**129.8**	**139.2**	**159.0**
Space Nuclear Power	10.0	20.0	25.0	25.0	26.0	27.0	28.0
High Capacity Power	10.4	10.6	10.9	12.0	12.3	12.6	18.0
Planetary Rovers	3.0	----	4.8	8.0	8.4	8.9	12.0
Surface Power & Thermal	0.6	----	3.4	9.0	12.6	14.0	18.0
In Situ Resource Utilization	----	----	1.5	3.0	6.2	6.7	8.0
Surface Habitats & Construction	----	----	----	----	----	----	----
Laser-Electric Power Beaming	----	----	8.0	40.0	64.3	70.0	75.0
HUMAN SUPPORT	**3.8**	**16.0**	**21.3**	**29.5**	**35.5**	**39.0**	**42.4**
Regenerative Life Support	1.9	8.0	10.0	15.0	17.0	17.5	18.0
Radiation Protection	0.5	3.0	5.8	6.5	7.0	8.0	8.4
EVA Systems (Surface)	0.9	4.0	4.5	7.0	8.5	9.5	11.0
Exploration Human Factors	0.5	1.0	1.0	1.0	3.0	4.0	5.0
Artificial Gravity	----	----	----	----	----	----	----
Remote Medical Care Systems	----	----	----	----	----	----	----

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

PLANETARY SURFACE EXPLORATION THRUST

OAET

"CURRENT RUN-OUT PROGRAM" ITP RESOURCES

	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
THRUST TOTALS ($M)	**27.8**	**46.6**	**53.5**	**63.1**	**63.8**	**72.4**	**76.8**
SURFACE SYSTEMS	**24.0**	**30.6**	**29.5**	**29.6**	**24.8**	**25.0**	**25.2**
Space Nuclear Power	10.0	20.0	25.0	25.0	20.0	20.0	20.0
High Capacity Power	10.4	10.6	4.5	4.6	4.8	5.0	5.2
Planetary Rovers	3.0	----	----	----	----	----	----
Surface Power & Thermal	0.6	----	----	----	----	----	----
In Situ Resource Utilization	----	----	----	----	----	----	----
Surface Habitats & Construction	----	----	----	----	----	----	----
Laser-Electric Power Beaming	----	----	----	----	----	----	----
HUMAN SUPPORT	**3.8**	**16.0**	**24.0**	**33.5**	**39.0**	**47.0**	**51.6**
Regenerative Life Support	1.9	8.0	12.0	18.0	20.0	24.0	25.1
Radiation Protection	0.5	3.0	6.0	6.5	7.0	8.0	10.0
EVA Systems (Surface)	0.9	4.0	5.0	8.0	11.0	12.0	12.5
Exploration Human Factors	0.5	1.0	1.0	1.0	1.0	3.0	4.0
Artificial Gravity	----	----	----	----	----	----	----
Remote Medical Care Systems	----	----	----	----	----	----	----

TRANSPORTATION FOCUSED TECHNOLOGY PROGRAM

Presentation to

THE ITP EXTERNAL EXPERT REVIEW TEAM

David R. Stone
Assistant Director for Space Technology
(Transportation Systems)

June 25, 1991

OAET

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

WORK BREAKDOWN STRUCTURE

OAET

SPACE RESEARCH & TECHNOLOGY

RESEARCH & TECHNOLOGY BASE

- DISCIPLINE RESEARCH
  - Aerothermodynamics
  - Space Energy Conversion
  - Propulsion
  - Materials & Structures
  - Information and Controls
  - Human Support
  - Adv. Communications
- UNIVERSITY PROGRAMS
- SPACE FLIGHT R&T
  - Flight Experiment Studies
  - IN-STEP
- SYSTEMS ANALYSIS

CIVIL SPACE TECHNOLOGY PROGRAM

- SPACE SCIENCE TECHNOLOGY
  - Science Sensing
  - Observatory Systems
  - Science Information
  - In Situ Science
  - Technology Flight Expts.
- PLANETARY SURFACE EXPLORATION TECHNOLOGY
  - Surface Systems
  - Human Support
  - Technology Flight Expts.
- **TRANSPORTATION TECHNOLOGY**
  - ETO Transportation
  - Space Transportation
  - Technology Flight Expts.
- SPACE PLATFORMS TECHNOLOGY
  - Earth-Orbiting Platforms
  - Space Stations
  - Deep-Space Platforms
  - Technology Flight Expts.
- OPERATIONS TECHNOLOGY
  - Automation & Robotics
  - Infrastructure Operations
  - Info. & Communciations
  - Technology Flight Expts.

OAET — TRANSPORTATION TECHNOLOGY PROGRAM — ITP

GOAL AND OBJECTIVES

PROVIDE VEHICLE SYSTEMS TECHNOLOGIES THAT SUBSTANTIALLY IMPROVE SAFETY & RELIABILITY, INCREASE SYSTEM AVAILABILITY AND PROVIDE NEW CAPABILITIES, WHILE REDUCING LIFE CYCLE COSTS

- INCREASE <u>SHUTTLE</u> SAFETY MARGINS AND ON-TIME PERFORMANCE BY IMPROVING MAIN ENGINE COMPONENTS, AVIONICS AND OTHER SELECTED VEHICLE SYSTEMS
- PROVIDE TECHNOLOGY OPTIONS FOR <u>NEW MANNED SYSTEMS</u> THAT COMPLEMENT THE SHUTTLE AND ENABLE NEXT GENERATION VEHICLES WITH RAPID TURNAROUND AND LOW OPERATIONAL COSTS
- SUPPORT DEVELOPMENT OF ROBUST, LOW-COST <u>HEAVY LIFT LAUNCH VEHICLES</u>
- DEVELOP AND TRANSFER LOW-COST TECHNOLOGY TO SUPPORT <u>COMMERCIAL ELV's AND UPPER STAGES</u>
- IDENTIFY AND DEVELOP HIGH LEVERAGE TECHNOLOGIES FOR <u>SPACE TRANSPORTATION</u>, INCLUDING NUCLEAR PROPULSION, THAT WILL ENABLE NEW CLASSES OF SCIENCE AND EXPLORATION MISSIONS

OAET — Transportation Technology Program — ITP

SUMMARY OF USER NEEDS

OFFICE OF SPACE FLIGHT

Program Unique Requirements

- Vehicle Health Management
- Advanced Turbomachinery Components & Models
- Combustion Devices
- Electromechanical Control Systems
- Characterization of Al-Li Alloys
- Cryogen Storage Handling & Supply
- TPS for High-Temp. Applications
- Guidance Navigation & Control
- Advanced Avionics Architectures

Industry Driven Technologies

- Advanced Avionics Software
- ■ Environ. Safe Cleaning Solvents, Refrig./Foams
- Non-Destructive Evaluation

SPACE EXPLORATION INITIATIVE

<u>Category 1</u>

- Nuclear Thermal Propulsion
- Cryo. Fluid Management Storage & Transfer
- Aerobraking

<u>Category 2</u>

- Autonomous Rendezvous & Docking
- Cryogenic Space Engines

<u>Category 3</u>

- Autonomous Landing
- Electric Propulsion

OFFICE OF SPACE SCIENCE & APPLICATIONS

<u>Category 1</u>

- 50-100 kw Ion Propulsion (NEP)
- ■ Extreme Upper Atmosphere Instrument Platforms

<u>Category 2</u>

- ■ Miniture Ascent Vehicle/ Lander Deceleration

<u>Category 3</u>

- Autonomous Rendezvous/Sample Transfer & Landing

COMMERCIAL SPACE SECTOR

<u>Propulsion & Fluid Systems</u>

- Low Cost Liquid Booster Engines
  - New LOX/LH2
  - Evolutionary Hydrocarbon
- Hybrid Propulsion Boosters
- Advanced LO2/LH2 Upper Stage Engines
- Pressure-Fed Engine & Turbo Pump
- ■ Clean Burning Solids
- Cryo Storage & Management
- Leak Free Tubing & Fittings
- Nuclear Thermal Propulsion
- Electric Propulsion (Solar & Nuclear)

<u>Avionics</u>

- Low Cost Fault-Tolerant, Redundant Adaptive GN&C
- GPS Based Guidance
- Electromechanical Actuators/PMAC
- Automated Health Monitoring

<u>Advanced Structures</u>

- Al-Li Alloy Structure/Cryotanks
- Lightweight Composites and Metal Matrix Structures

<u>Manufacturing & OPS</u>

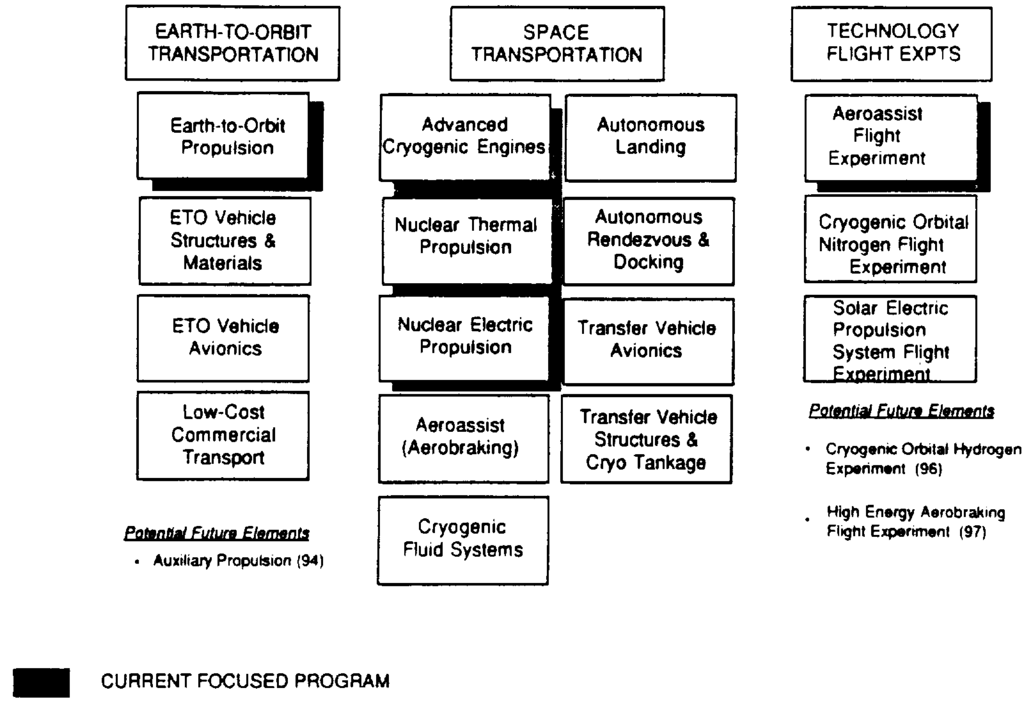
- Adaptive Computer Controlled Welding
- Automated Inspection
- Computer Integrated Design, Man & Test
- Automated Pre-Post Flight Data Analysis

■ Not Yet Addressed By ITP Strategic Planning

TRANSPORTATION TEC OLOGY PROGRAM

STRATEGIC PROGRAM

OAET ITP



TRANSPORTATION TECHNOLOGY PROGRAM

EARTH-TO-ORBIT TRANSPORTATION

OAET ITP

EARTH-TO-ORBIT PROPULSION

HIGH RELIABILITY, HIGH DESIGN MARGINS & SERVICE LIFE, AUTONOMY IN GROUND & FLIGHT OPERATIONS, REDUCED COSTS AND HIGHER PERFORMANCE

- ADVANCED TURBOMACHINERY,COMBUSTORS, SYSTEM MONITORING, VALIDATED DESIGN METHODOLOGIES & TOOLS, AND MANUFACTURING PROCESSES
- ADVANCED CONCEPTS WHICH WILL ENABLE ROUTINE, AFFORDABLE ACCESS TO SPACE

ETO VEHICLE STRUCTURES & MATERIALS

WEIGHT AND COST SAVINGS THROUGH ADVANCED METAL ALLOYS & COMPOSITES COUPLED WITH EFFICIENT FABRICATION, AUTOMATED PROCESSING & TEST

- CHARACTERIZATION OF AL-Li ALLOYS/ PROCESSING FOR CRYO TANKS, BUILT-UP STRUCTURES WITH MINIMUM WELD, AND AUTOMATED WELDING/NDE
- INTEGRAL STRUCTURAL DESIGN/ANALYSIS AND METALLIC TPS FOR ADVANCED VEHICLES

ETO VEHICLE AVIONICS

REMOVAL OF MOST WEATHER CONSTRAINTS, GREATLY REDUCED TURNAROUND TIMES, AUTOMATED OPERATIONS, HIGHLY FAULT TOLERANT AND LOW MAINTENANCE SYSTEMS

- REAL-TIME WIND PROFILING, ADAPTIVE GN&C, MODULAR, SCALABLE ARCHITECTURES,
- AUTOMATED SOFTWARE, SENSORS AND ALGORITHMS FOR VHM, AND SMART EMA's

LOW-COST COMMERCIAL TRANSPORT

TAILOR R&T TO INDUSTRY NEEDS BY APPLYING AERONAUTICS APPROACH

- INDUSTRY IDENTIFIED ENHANCEMENTS FOR TECHNOLOGY DEVELOPMENT

ADVANCED CRYOGENIC ENGINES

HIGH-PERFORMANCE, WIDE THRUST RANGE, MULTI-START LOX/LH2 ENGINE FOR LONG-DURATION IN-SPACE APPLICATION WITH MINIMAL CHECK-OUT/ OPERATIONS

- ADVANCED DESIGN/ANALYSIS TOOLS, COMPONENT-LEVEL IMPROVEMENTS, AND HARDWARE-REPRESENTATIVE ADVANCED EXPANDER CYCLE TEST BED TO PROVIDE REALISTIC ENGINE OPERATING ENVIRONMENT

NUCLEAR THERMAL PROPULSION

HIGH ISP OPTION WHICH HAS POTENTIAL TO GREATLY REDUCE EXPLORATION MISSION MASS IN LOW EARTH ORBIT, REDUCE MISSION TIME IN TRANSIT, AND INCREASE BOTH LAUNCH OPPORTUNITIES AND MISSION FLEXIBILITY

- CONCEPTUAL DESIGNS, COMPONENT IMPROVEMENTS, VALIDATE CONCEPTS IN GROUND TESTS COOPERATIVELY WITH DOE AND DOD

NUCLEAR ELECTRIC PROPULSION

HIGH ISP OPTION WHICH COULD ENABLE FAR PLANETARY MISSIONS WITH EXPANDED SCIENCE CAPABILITIES AND EXPAND EXPLORATION MISSION OPTIONS

- DESIGN AND CONDUCT LONG-DURATION TESTS OF HIGH POWER ELECTRIC THRUSTERS
- DESIGN FLIGHT TEST OF SUBSCALE NEP SYSTEM WITH SP-100 CLASS SPACE REACTOR

CRYOGENIC FLUID SYSTEMS

TECHNOLOGY NECESSARY TO REDUCE COST AND PERFORMANCE PENALTIES ASSOCIATED CRYOGENIC HYDROGEN SYSTEMS, PARTICULARLY FOR LONG-DURATION SPACE MISSIONS

- FLUID HANDLING, STORAGE, TRANSFER, SUPPLY, PRESSURE AND THERMAL CONTROL

TRANSPORTATION TECHNOLOGY PROGRAM

OAET SPACE TRANSPORTATION ITP

AEROASSIST/AEROBRAKING

PROVIDE SUBSTANTIAL REDUCTION IN MASS OR INCREASED PAYLOAD FOR ATMOSPHERIC CAPTURE MISSIONS

- VALIDATED AERODYNAMIC CODES, TPS MATERIALS, ADAPTIVE GUIDANCE AND LIGHT WEIGHT STRUCTURAL CONCEPTS

AUTONOMOUS LANDING

REQUIRED FOR SAFE ROBOTIC PLANETARY LANDINGS NEAR SURFACE HAZARDS

- HAZARD DETECTION SENSORS, AVOIDANCE MODELING & ALGORITHMS, TERRAIN NAVIGATION TEST BED

AUTONOMOUS RENDEZVOUS & DOCKING

ENABLES ORBITAL OPERATIONS WITHOUT CREW FOR OPERATIONS TOO REMOTE FOR TELEOPERATIONS

- ADVANCED LASER-BASED SENSOR DEVELOPMENT, ALGORITHMS AND MECHANISMS

TRANSFER VEHICLE AVIONICS

PROVIDE NEARLY AUTONOMOUS OPERATIONS WITH GREATLY REDUCED IN-SPACE LOGISTICS

- ADVANCED OPEN AVIONICS ARCHITECTURES, COMPONENTS, AND SOFTWARE; SMART, ROBUST SENSORS AND ALGORITHMS FOR VHM; AVIONICS TEST BEDS FOR VALIDATION

TRANSFER VEHICLE STRUCTURES & CRYO TANKAGE

LOW-MASS, SPACE DURABLE MATERIALS REQUIRED FOR SAFE, COST-EFFECTIVE MISSIONS

- ADVANCED AL Li AND TITANIUM ALLOY CHARACTERIZATION, METAL MATRIX COMPOSITE CRYOTANK FABRICATION TECHNIQUES WITH INTEGRAL INSULATION

TRANSPORTATION TECHNOLOGY PROGRAM

TECHNOLOGY FLIGHT EXPERIMENTS

OAET ITP

AEROASSIST FLIGHT EXPERIMENT

FLIGHT VALIDATE CRITICAL DESIGN REQUIREMENTS AND ENVIRONMENT

- RESOLVE RADIATIVE HEATING ISSUES & WALL CATALYSIS EFFECTS
- DEMONSTRATE NON-ABLATIVE TPS MATERIALS
- VERIFY AERODYNAMIC AND CONTROL CFD CODES

CRYOGENIC ORBITAL NITROGEN FLIGHT EXPERIMENT

VALIDATE DESIGN AND ANALYSIS TOOLS FOR CRYO FLUID MANAGEMENT IN SPACE

- DEMONSTRATE 0-G ACQUISITION, TANK CHILLDOWN, NO-VENT FILL AND PRESSURE CONTROL TECHNOLOGIES
- PARTIALLY VALIDATE LH2 MANAGEMENT MODELS

SOLAR ELECTRIC PROPULSION SYSTEM FLIGHT EXPERIMENT•

DEMONSTRATE SYSTEM READINESS AND IDENTIFY ENVIRONMENTAL EFFECTS

- CRITICAL PROPULSION, POWER, AND GN&C, TECHNOLOGIES FOR INERT GAS ION AND HYDROGEN ARCJET
- ADDED VALIDATION OF LH2 FLUID MANAGEMENT AND ADVANCED LIGHT-WEIGHT SOLAR ARRAYS

TRANSPORTATION TECHNOLOGY PROGRAM

ACCOMMODATION OF USER NEEDS

OAET ITP

TECH. USERS / PROGRAM AREAS	ETO TRANSPORTATION	SPACE TRANSPORTATION	TECHNOLOGY FLIGHT EXPERIMENTS	MAJOR USER NEEDS ADDRESSED
OFFICE OF SPACE FLIGHT	ETO Propulsion ETO Vehicle Avionics ETO Vehicle S & M Auxiliary Propulsion	Trans Veh Avionics Trans Veh Structs Cryo Fluid Systems Adv. Cryo. Engine	CONE Flt. Exp COHE Flt. Exp	Vehicle Health Management Advanced Turbomachinery Comps & Models Combustion Devices Electromechanical Control Systems Characterization of Al-Li Alloys Cryo Storage, Handling, & Supply TPS for High Temperature Applications Advanced GN&C Advanced Avionics Architectures & Software Non-Destructive Evaluation
OFFICE OF SPACE SCIENCE AND APPLICATIONS		NEP Auto Rend & Docking Auto Landing	SEP Flight Exp. Aero assist Flt. Exp.	50-100 kw Electric Propulsion (NEP) Miniture Ascent Vehicle/Lander Deceleration Autonomous Rendezvous Autonomous Sample Transfer Autonomous Landing
SPACE EXPLORATION INITIATIVE		NTP/NEP Cryo Fluid Systems Aeroassist Auto Rend./Landing Adv. Cryo. Engine Trans Veh Avionics Trans Veh Structs	Aero assist Flt. Exp. CONE Flt. Exp. Hi Energy AFE COHE Flt. Exp.	Nuclear Thermal Propulsion Cryo Fluid Management, Storage, & Transfer Aerobraking Autonomous Rendezvous and Docking Advanced Cryo Space Engines Autonomous Landing Electric Propulsion (Nuclear/Solar)
COMMERCIAL SPACE SECTOR	ETO Propulsion ETO Vehicle S & M ETO Vehicle Avionics Low-Cost Com. Trans Auxiliary Propulsion	Adv. Cryo Engines Nuclear Electric Prop. Trans. Veh. Avionics Trans. Veh. Structures Cryo. Fluid Systems	Solar Elec. Prop. Exp	Low-cost Booster Engine/Reuse Hybrid & Pressure-Fed Boosters Advanced LOX/LH2 Upper Stage Engine Electric Propulsion (Solar & Nuclear) Cryo Storage & Management Leak free Tubes & Fittings Adaptive, Fault Tolarant GN&C GPS Based Guidance Electromechanical Actuators/PMAC Automated Health Monitoring Al Li Alloy Structure/Cryo tanks Composite & Metal Matrix Structure/Tanks Advanced Manufacturing Processes & Welding Computer Integrated Design, Man. & Test Automated Pre Post Flight Data Analysis

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

"Strategic Plan" ITP: CSTP Element Categorization

O-A-E-T

	HIGHEST PRIORITY ◊◊◊			2nd-HIGHEST PRIORITY ◊◊			3rd-HIGHEST PRIORITY ◊		
Space Science Technology	Submillimeter Sensing Cooler and Cryogenics	Direct Detectors Microprecision CSI Data Visualization	Active µwave Sensing Laser Sensing Data Archiving and Retrieval	Sensor Electronics & Processing Telescope Optical Systems	Passive Microwave Sensing Sample Acq., Analysis & Preservation	— —	Optoelectrnics Sensing & Processing Precision Instrument Pointing	Probes and Penetrators Sensor Optical Systems	— —
Planetary Surface Exploration Technology	Radiation Protection —	Regenerative Life Support (Phys-Chem.) —	Space Nuclear Power (SP-100) Extravehicular Activity Systems	High Capacity Power Surface Solar Power and Thermal Mgt.	Planetary Rovers In Situ Resource Utilization	Surface Habitats and Construction Laser-Electric Power Beaming	Exploration Human Factors Medical Support Systems	— —	Artifical Gravity —
Transportation Technology	ETO Propulsion Cryogenic Fluid Systems	Aeroassist Flight Expt Nuclear Thermal Propulsion Adv. Cryo. Engines	Aeroassist/ Aerobraking Low-Cost Commercial ETO XPort	Transfer Vehicle Avionics Nuclear Electric Propulsion	ETO Vehicle Avionics CONE	ETO Vehicle Structures & Materials SEPS TFE	Autonomous Rendezvous & Docking Autonomous Landing	COHE TV Structures and Cryo Tankage	Auxiliary Propulsion HEAb
Space Platforms Technology	Platform Structures & Dynamics —	Platform Power and Thermal Mgt. —	Zero-G Life Support Zero-G Advanced EMU	Platform Materials & Environ. Effects Platform NDE-NDI	Station-Keeping Propulsion Deep-Space Power and Thermal	— —	Spacecraft On-Board Propulsion Spacecraft GN&C	Earth-Orbiting Platform Controls Debris Mapping Experiment	Advanced Refrigerator Systems —
Operations Technology	Space Data Systems —	High-Rate Comm. CommSat Communicat'ns	Artificial Intelligence TeleRobotics	Ground Data Systems FTS DTF-1	Optical Comm Flight Expt Navigation & Guidance Operator Syst./Training	Flight Control and Operations CommSat Communicat'ns Flight Expts	Space Assembly & Construction —	Space Processing & Servicing Ground Test and Processing	Photonics Data Systems —

JUNE 18 1

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

CSTP GROWTH STRATEGIES

O-A-E-T

FY 1993 TRANSPORTATION TECHNOLOGY

	CURRENT PROGRAM	"3x PROGRAM"	STRATEGIC PLAN
ETO Transport.	■ ETO Propulsion	■ ETO Propulsion ■ ETO Mat'ls & Structures ■ ETO Avionics ■ Low-Cost Transport	■ ETO Propulsion ■ ETO Mat'ls & Structures ■ ETO Avionics ■ Low-Cost Transport
Space Transport.	■ Adv. Cryo. Engines ■ Nuclear Thermal Prop. ■ Nuclear Electric Prop.	■ Adv. Cryo. Engines ■ Nuclear Thermal Prop. ■ Nuclear Electric Prop. ■ Aerobraking ■ Auto. Rend. & Dock. ■ Auto. Landing ■ Cryo Fluid Systems ■ ST Avionics	■ Adv. Cryo. Engines ■ Nuclear Thermal Prop. ■ Nuclear Electric Prop. ■ Aerobraking ■ Auto. Rend. & Dock. ■ Auto. Landing ■ Cryo Fluid Systems ■ ST Avionics ■ ST Mat'ls & Structures □ Auxiliary Propulsion
Tech. Flight Expts.	■ AFE	■ AFE ■ CONE	■ AFE ■ Cryo. Orbital Nitrogen Expt ■ SEPS □ Cryo Orbital Hydrogen Expt □ High-Energy Aerobr. Expt

LEGEND — Adequately Funded; Constrained Progress; Marginally Funded; □ Outyear "Start"

JUNE 17, 1!
JCM 7!

TRANSPORTATION TECHNOLOGY PROGRAM

THRUST OVERVIEW

OAET — TTP

BACK-UP CHARTS

TRANSPORTATION TECHNOLOGY PROGRAM

CURRENT PROGRAM BUDGET

OAET — TTP

	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
THRUST TOTALS ($,M)	64.7	79.5	140.3	143.0	145.2	144.4	124.0
EARTH-TO-ORBIT TRANS.	21.8	28.7	33.9	25.1	26.4	27.6	28.8
ETO Propulsion	21.8	28.7	33.9	25.1	26.4	27.6	28.8
SPACE TRANSPORTATION	7.9	16.0	31.6	51.1	76.0	91.0	95.2
Advanced Cryogenic Engines	4.0	9.0	12.6	13.2	14.0	14.7	15.4
Nuclear Thermal Propulsion	0.5	5.0	13.0	22.0	39.0	50.3	52.6
Nuclear Electric Propulsion	---	2.0	6.0	15.9	23.0	26.0	27.2
TECH. FLIGHT EXPERIMENTS	35.0	34.8	74.8	66.8	42.8	25.8	---
Aeroassit Flight Experiment	35.0	34.8	74.8	66.8	42.8	25.8	---

TRANSPORTATION TECHNOLOGYPROGRAM

(3X) PROGRAM BUDGET

	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
THRUST TOTALS ($.M)	**64.7**	**79.5**	**170.0**	**209.7**	**246.2**	**270.5**	**279.0**
EARTH-TO-ORBIT TRANS.	**21.8**	**28.7**	**42.9**	**45.1**	**61.6**	**78.6**	**97.8**
ETO Propulsion	21.8	28.7	33.9	25.1	26.4	27.6	28.8
ETO Vehicle Structures & Materials	---	---	3.0	6.0	12.0	19.0	27.5
ETO Vehicle Avionics	---	---	1.8	4.0	6.2	9.0	12.5
Low Cost Commercial Transport	---	---	4.2	10.0	17.0	23.0	29.0
Auxiliary Propulsion	---	---	---	---	---	---	---
SPACE TRANSPORTATION	**7.9**	**16.0**	**49.0**	**83.0**	**118.3**	**143.1**	**162.5**
Advanced Cryogenic Engines	4.0	9.0	14.9	16.7	19.6	20.2	28.0
Nuclear Thermal Propulsion	0.5	5.0	13.0	22.0	39.0	50.3	52.6
Nuclear Electric Propulsion	---	2.0	6.0	15.9	23.0	26.0	27.2
Aeroassist/Aerobraking	0.9	---	3.5	8.0	12.1	18.0	22.0
Cryogenic Fluid Systems	1.5	---	7.4	10.0	10.3	10.8	10.0
Autonomous Landing	0.5	---	1.2	2.8	3.5	4.0	4.5
Autonomous Rendezvous & Docking	0.5	---	1.3	3.5	4.5	4.8	5.5
Transfer Vehicle Avionics	---	---	1.7	4.1	6.3	9.0	12.7
Transfer Vehicle Structures & Materials	---	---	---	---	---	---	---
TECH. FLIGHT EXPERIMENTS	**35.0**	**34.8**	**78.1**	**81.6**	**66.3**	**48.8**	**18.7**
Aeroassit Flight Experiment	35.0	34.8	74.8	66.8	42.8	25.8	---
Cryogenic Orbital Nitrogen Experiment	---	---	3.3	14.8	23.5	23.0	18.7
Solar Electric Propulsion System Flt. Exp.	---	---	---	---	---	---	---
Cryogenic Orbital Hydrogen Experiment	---	---	---	---	---	---	---
High-Energy Aerobraking Flight Exp.	---	---	---	---	---	---	---

TRANSPORTATION TECHNOLOGY PROGRAM

STRATEGIC PROGRAM BUDGET

	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
THRUST TOTALS ($.M)	**64.7**	**79.5**	**199.7**	**274.1**	**360.3**	**447.8**	**512.5**
EARTH-TO-ORBIT TRANS.	**21.8**	**28.7**	**56.9**	**71.7**	**125.3**	**171.2**	**175.6**
ETO Propulsion	21.8	28.7	33.9	35.4	36.9	42.7	45.1
ETO Vehicle Structures & Materials	---	---	4.0	8.0	15.9	24.9	31.0
ETO Vehicle Avionics	---	---	7.0	11.0	23.0	35.0	36.5
Low Cost Commercial Transport	---	---	12.0	15.0	44.1	57.7	47.1
Auxiliary Propulsion	---	---	---	2.3	5.4	10.9	15.9
SPACE TRANSPORTATION	**7.9**	**16.0**	**58.3**	**104.6**	**156.1**	**214.6**	**284.5**
Advanced Cryogenic Engines	4.0	9.0	15.0	24.0	31.0	45.8	42.4
Nuclear Thermal Propulsion	0.5	5.0	13.0	22.0	39.0	50.3	83.0
Nuclear Electric Propulsion	---	2.0	6.0	15.9	23.0	26.0	45.0
Aeroassist/Aerobraking	0.9	---	4.8	9.3	14.8	20.4	23.8
Cryogenic Fluid Systems	1.5	---	8.5	11.0	11.3	11.8	11.0
Autonomous Landing	0.5	---	2.0	4.5	6.0	7.0	7.3
Autonomous Rendezvous & Docking	0.5	---	2.0	5.0	7.0	7.3	7.7
Transfer Vehicle Avionics	---	---	5.0	9.0	15.0	32.0	44.3
Transfer Vehicle Structures & Materials	---	---	2.0	3.9	9.0	14.0	20.0
TECH. FLIGHT EXPERIMENTS	**35.0**	**34.8**	**84.5**	**97.8**	**78.9**	**62.0**	**52.4**
Aeroassit Flight Experiment	35.0	34.8	74.8	66.8	42.8	25.8	---
Cryogenic Orbital Nitrogen Experiment	---	---	3.4	19.4	24.6	25.0	14.5
Solar Electric Propulsion System Flt. Exp.	---	---	6.3	11.6	11.5	7.6	0.9
Cryogenic Orbital Hydrogen Experiment	---	---	---	---	---	3.6	17.0
High-Energy Aerobraking Flight Exp.	---	---	---	---	---	---	20.0

EARTH-TO-ORBIT TRANSPORTATION

OAET ITP

JUSTIFICATION

- **Mission Needs**

Safe, reliable, and cost effective transportation for cargo and personnel to Earth orbit. Validation of technologies by/for:

- 1996 Personnel Launch System
- 2000 Shuttle Evolution , NLS evolution for initial lunar mission and Low-Cost ELV's
- 2005 Advanced Manned Launch System
- 2010 NLS evolution for initial mars mission

OBJECTIVES

- **Programmatic**

Develop and validate technologies that improve existing systems and enable new design-to-cost vehicles

- **Technical**

Main Engine: 3 fold reduction in cost; 10 fold increase in life

Aux. Propulsion: Storable propellants near term; Integrated H/O for AMLS and OTV's

Structures: 20-40% reduction in weight; 25% reduction in manufacturing cost

Avionics: Adaptive/autonomous G&C; fault tolerant, resilant architectures with electric actuators & vehicle health management

MILESTONES

- 1995 Low cost manufacturing processes for SSME & STME thrust chamber
- 1996 Engine monitoring capability for pre-flight servicing & checkout; safe shutdown
- 1996 PLS technology validation complete: Al-Li structure; EMA's; Storable OMS/RCS propellants; Advanced TPS
- 1998 Test Bed Demo of Advanced Power Management System with 50 hp. EMA
- '00-'05 AMLS technology validation complete: Integral thermostructural concept tested; AdvancedManufacturing &design tools for main engine; Integrated H/O OMS/RCS system

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
CURRENT	21.8	28.7	33.9	25.1	26.4	27.6	28.8
STRATEGIC			56.9	71.7	125.3	171.2	175.6
(3X)			42.9	45.1	61.6	78.6	97.8

SPACE TRANSPORTATION

OAET ITP

JUSTIFICATION

- **Mission Needs**

High performance, safe, and reliable space transportation for cargo and personnel using ground-based and space-based systems. Validation of technology by/for:

- 1995 Capability Upgrades for Current Upper Stages
- 1996 Initial Lunar Chemical Transfer Vehicle/Lander
- 1998 Solar Electric Propulsion Upper Stage
- 2002 Evolutionary Lunar Transfer Vehicle/Lander
- 2003 100 KW Nuclear Electric Propulsion Upper Stage
- 2010 Mars Nuclear Space Transfer Vehicle

OBJECTIVES

- **Programmatic**

Develop and validate technologies to enable high energy, high performance upper stages and cargo & personnel vehicles for Lunar and Mars missions

- **Technical**

Adv. Cryo. Engines: Multi-application LOX/LH2 expander cycle engine

NTP: 4.5 hrs. fuel lifetime, autonomous robotic operations

NEP: 10 MWe power with 3-10 years lifetime

Aeroassist: Validated codes for Lunar/Mars missions

Cryo Fluid Systems: In-space management of cryogenic fluids

Structures & Cryo Tank: Lightweight Al-Li structure & composite cryo tank

Avionics: Adaptive/autonomous G&C, VHM; fault-tolerant, open architectures; electric actuators

MILESTONES

- 1995 AETB Test Beds Delivered
- 1995 Mars Entry Probes Code Validation
- 1998 AETB-1 System Fully Characterized
- 1998 AFE Flight Data Code & TPS Assessment Complete for MRSR Aerocapture Validation
- 1998 Complete Demo in Avionics Lab of Advanced Avionics Electric Power Management System
- 1999 Light-weight Materials Qualified for Space
- 2000 Lunar LTV Codes, TPS & Assembly Validated
- 2000 Verify 1000 Hours operating lifetime of 500 kw NEP
- 2001 First NTR Reactor Test Complete
- 2006 Full System Ground Test of NTR Reactor Complete

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
CURRENT	8.0	16.0	31.6	51.1	76.0	91.0	95.2
STRATEGIC			58.3	104.6	156.1	214.6	284.5
(3X)			49.0	83.0	118.3	143.1	162.5

OAET

TECHNOLOGY FLIGHT EXPERIMENTS

ITP

JUSTIFICATION

- **Mission Needs**

Enable safe, reliable and cost-effective transportation for cargo and personnel to Earth orbit, beyond and return to Earth. Validation of technologies by/for:

- 1996 Initial Lunar Transfer Vehicle/Lander
- 1998 SEP Upper Stage
- 2002 Evolution Lunar Transfer Vehicle/Lander
- 2003 NEP Upper Stage
- 2005 AMLS
- 2006 Mars Nuclear Space Transfer Vehicle
- 2010 NLS Evolution for Initial Mars Mission

OBJECTIVES

- **Programmatic**

Demonstrate Earth-to-Orbit and Space Transportation technologies and collect critical flight research data through the implementation of in-space technology experiments that support all vehicle systems.

- **Technical**

AFE: Investigate critical design & environmental technologies applicable to design of aeroassisted space transfer vehicles

SEPS: 30-cm, inert gas ion propulsion and an arcjet operated on cryogenically stored H2

CONE: Partial model validation of non-vented liquid transfer analytical models using nitrogen; low-g demo of critical components.

COHE: Full model validation of non-vented liquid transfer analytical models using hydrogen; low-g demo of critical components.

MILESTONES

- 1996 AFE Flight Test from Shuttle
- 1996 SEPS FlightExperiment on DOD S/C
- 1997 CONE STS Flight Experiment on Shuttle
- 2001 COHE Flight Experiment launched on ELV
- 2002 High Energy Flight Experiment

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
CURRENT	35.0	34.8	74.8	66.8	42.8	25.8	----
STRATEGIC			84.5	97.8	78.9	62.0	52.4
(3X)			78.1	81.6	66.3	48.8	18.7

SPACE PLATFORMS FOCUSED TECHNOLOGY PROGRAM

Presentation to

THE ITP EXTERNAL EXPERT REVIEW TEAM

Dr. Judith H. Ambrus
Assistant Director for Space Technology

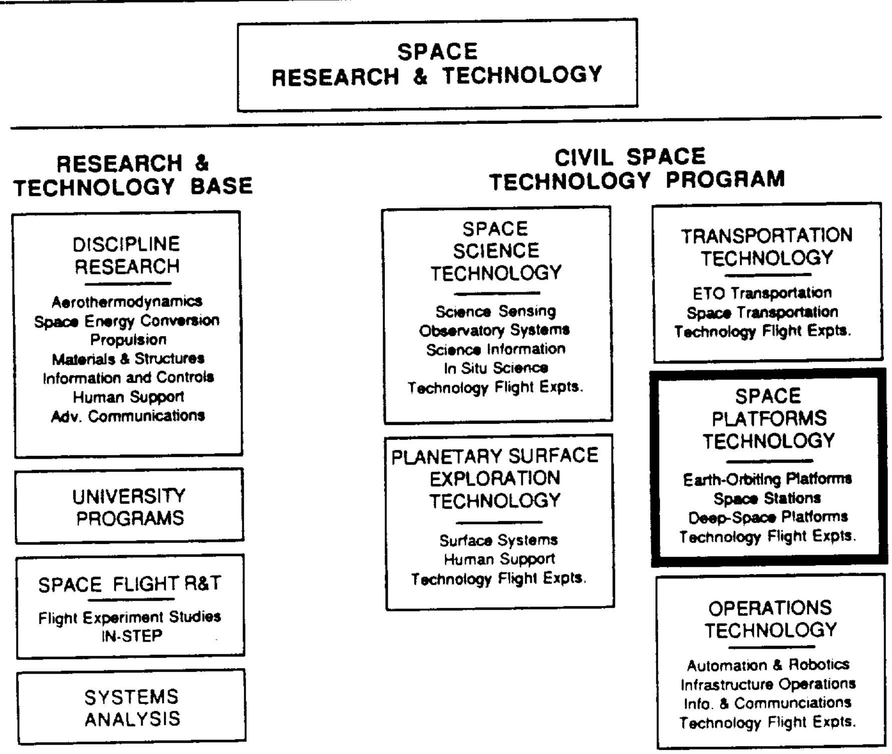
June 25, 1991

OAET

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

WORK BREAKDOWN STRUCTURE

OAET



MAY 15, 1991
JCM-7650a

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — FOCUSED TECHNOLOGY PROGRAM GOAL — ITP

THE GOAL OF THIS FOCUSED TECHNOLOGY PROGRAM IS TO ENHANCE FUTURE SCIENCE, EXPLORATION AND COMMERCIAL MISSIONS BY DEVELOPING AND VALIDATING TECHNOLOGIES THAT WILL

- ENABLE REDUCTIONS IN LAUNCH WEIGHT
- INCREASE LIFETIME,
- INCREASE MAINTAINABILITY, AND
- DECREASE LOGISTICS RESUPPLY NEEDS

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — OBJECTIVES — ITP

THESE GOALS WILL BE ACHIEVED BY DEVELOPING TECHNOLOGIES THAT WILL LEAD TO

- ADVANCED, LIGHTWEIGHT STRUCTURES WITH INTERACTIVE CONTROLS
- THE CHARACTERIZATION OF THE SPACE ENVIRONMENT AND ADVANCED MATERIALS TO WITHSTAND THAT ENVIRONMENT
- ON-ORBIT NON-DESTRUCTIVE EVALUATION METHODS
- ADVANCED SPACECRAFT ATTITUDE CONTROL AND GUIDANCE TECHNIQUES
- ADVANCED POWER AND THERMAL MANAGEMENT SUBSYSTEMS
- REGENERATIVE HUMAN LIFE SUPPORT SYSTEMS FOR BOTH ON-ORBIT PRESSURIZED ENVIRONMENTS AND EXTRAVEHICULAR ACTIVITIES
- DEVICES THAT WILL AID THE CREW IN PERFORMING ON-ORBIT EXPERIMENTS

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — **SUMMARY OF USER NEEDS** — ITP

OFFICE OF SPACE SCIENCE & APPLICATIONS	OFFICE OF SPACE FLIGHT	COMMERCIAL SPACE SECTOR
VIBRATION ISOLATION TECHN. EFFICIENT/QUIET REFRIG./FREEZER CONTROLLED LARGE STRUCTURES SOLAR ARRAYS/CELLS LONG LIFE, LT. WT. BATTERIES REAL TIME ENV. MONITORING IMPROVED EMU MINI RTG MINI-S/C SUBSYSTEMS REGENERATIVE LIFE SUPPORT MICROBIAL DECONT. METHODS THERMAL CONTROL SYSTEMS NON-DESTR. MONITORING CAP. LOW DRIFT GYROS, TRACKERS, ACTUATORS	VEHICLE HEALTH MANAGEMENT ADV. HEAT REJECTION HIGH EFF. POWER SYSTEMS WATER RECOVERY & MGMT. ADV. EMU ORBITAL DEBRIS GN&C	MICROMET. & DEBRIS PROT. EXPANDED AT. O DATABASE LT. WT/ HIGH EFF. PV ARRAYS LIGHT WT. BATTERIES ADV. EMU THERMAL ENERGY STORAGE LARGE SPACE STRUCTURES HIGH TEMP. .MATERIALS

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — **WORK BREAKDOWN STRUCTURE** — ITP

EARTH ORBITING PLATFORMS	SPACE STATIONS	DEEP SPACE PLATFORMS	FLIGHT EXPERIMENTS
POWER & THERMAL MGMT	REGENERATIVE ECLSS	POWER & THERMAL MGMT	INSTEP EXPERIMENTS
STRUCTURES & DYNAMICS	ADVANCED EMU	ON-BOARD PROPULSION	ORBITAL DEBRIS SENSOR
MATERIALS & ENV. EFFECTS	STATION KEEPING PROPULSION	GN&C	
NDE / NDI	SSF USER SUPPORT		
CONTROLS			

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — EARTH ORBITING PLATFORMS — ITP

POWER AND THERMAL MANAGEMENT

- PLANAR AND CONCENTRATOR ARRAYS
- SOLAR DYNAMIC MODULE GROUND TEST
- LONG LIFE, HIGH ENERGY DENSITY BATTERIES
- HIGH TEMPERATURE PMAD
- HIGH CAPACITY HEAT REJECTION

STRUCTURES AND DYNAMICS

- CONTROLS/STRUCTURES INTERACTIONS
- ADVANCED ADAPTIVE STRUCTURES
- STRUCTURAL DYNAMICS ON-ORBIT VERIFICATION

CONTROLS

- CONTROL HARDWARE FOR PRECISE ATTITUDE DETERMINATION

MATERIALS AND ENVIRONMENTAL EFFECTS

- DESCRIPTION OD SPACE ENVIRONMENT
- ADVANCED MATERIALS FOR SPACE ENVIRONMENT

NDE/NDI

- METHODOLOGY FOR ON-ORBIT DIAGNOSIS OF STRUCTURAL DEFECTS

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — SPACE STATIONS — ITP

REGENERATIVE ENVIRONMENTAL CONTROL AND LIFE SUPPORT

- WATER RECLAMATION
- SOLID WASTE MANAGEMENT
- AIR REVITALIZATION
- MICROBIAL AND CHEMICAL SENSORS AND CONTROLS
- GROUND AND SPACE BASED TESTBEDS

ADVANCED EXTRAVEHICULAR MOBILITY UNIT

- 8.3 PSI CAPABILITY
- ON-ORBIT MAINTAINABILITY
- 52 EVA PER YEAR CAPACITY

PROPULSION

- RESISTOJET OPERABLE WITH ALL GASEOUS WASTE

SSF USER SUPPORT

- LOW NOISE, ENERGY EFFICIENT REFRIGERATOR WITH NON-TOXIC REFRIGERANT

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — DEEP SPACE PLATFORMS — ITP

POWER AND THERMAL MANAGEMENT

- VERY LIGHTWEIGHT SOLAR ARRAYS
- REDUCED RADIO ISOTOPOE INVENTORY RTGs
- FAULT TOLERANT, RECONFIGURABLE PMAC
- CRYOGENIC THERMAL BUS

PROPULSION

- LOW CONTAMINATION, HIGH PERFORMANCE "HOT ROCKET" DESIGN, FAB AND TEST

GUIDANCE NAVIGATION AND CONTROL

- ADAPTIVE GUIDANCE TECHNIQUES WITH SYSTEMS AUTONOMY
- NAVIGATION TECHNIQUES, HARDWARE AND SOFTWARE
- FAULT TOLERANT CONTROL SYSTEMS, SENSORS AND ACTUATORS

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — FLIGHT EXPERIMENTS — ITP

DEBRIS MAPPING SENSOR

- CHARACTERIZE ORBITAL DEBRIS ENVIRONMENT IN 1 TO 10 mm RANGE
- LEO OPERATIONS ALTITUDE
- VISIBLE AND INFRARED SENSORS
- REPEATABLE SHUTTLE EXPERIMENT
- PHASE B NEARING COMPLETION

INSTEP FLIGHT EXPERIMENTS

- MEASUREMENTS AND MODELING OF JOINT DAMPING IN SPACE, 1994
- MIDDECK ACTIVE CONTROL EXPERIMENT, 1995
- MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT, 1991
- THERMAL ENERGY STORAGE MATERIALS, 1993
- SOLAR ARRAY PLASMA INTERACTION EXPERIMENT, 1993
- TANK PRESSURE CONTROL EXPERIMENT, 1991
- PERMEABLE MEMBRANE EXPERIMENT, 1993
- TWO PHASE FLOW, 1994
- ELECTROLYSIS EXPERIMENT, 1992

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — USER SUPPORT ASSESSMENT — ITP

	User Need / Program Area	Earth Orbiting Platforms	Space Stations	Deep Space Platforms	Flight Experiments	Coll. Benefits
OSF	Vehicle Health Management High Efficient Power Systems Advanced Heat Rejection Devices Orbital Debris Water Recovery & Management Advanced EMU	NDE/NDI P & TH Mgmt Mats & Env .Eff	Reg. ECLS AEMU		InSTEP Debris Exp	OSO
OSSA	Vibration Isolation Techn. Adv. Refrigerator/Freezer Controlled Large Structures Solar Arrays/Cells Long Life, Lt. Wt. Batteries Improved EMU Mini-RTG Mini-S/C Subsystems Regenerative Life Support Microbial Decontam. Methods Thermal Control Systems Non-Destr. Monitoring Cap. Low Drift Gyros, Trackers, Actuators	Controls S & DYN P & Th Mgmt NDE/NDI	SS User Supp AEMU Reg. ECLS	P & Th Mgmt P & Th Mgmt GN&C	InSTEP InSTEP InSTEP InSTEP	SEI
COMM	Micromet. & Debris Protection Expanded AO Data Base High temp. materials High Eff PV Arrays/ Light wt. batteries Adv. EMU Thermal energy storage Large space structures	Mats & Env. Eff P & Th Mgmt Str. & Dyn.	AEMU		InSTEP	

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

"Strategic Plan" ITP: CSTP Element Categorization

OAET

	HIGHEST PRIORITY ◊◊◊			2nd-HIGHEST PRIORITY ◊◊			3rd-HIGHEST PRIORITY ◊		
Space Science Technology	Submillimeter Sensing	Direct Detectors Microprecision CSI	Active µwave Sensing Laser Sensing	Sensor Electronics & Processing	Passive Microwave Sensing	—	Optoelectrnics Sensing & Processing	Probes and Penetrators	—
	Cooler and Cryogenics	Data Visualization	Data Archiving and Retrieval	Telescope Optical Systems	Sample Acq., Analysis & Preservation	—	Precision Instrument Pointing	Sensor Optical Systems	—
Planetary Surface Exploration Technology	Radiation Protection	Regenerative Life Support (Phys-Chem.)	Space Nuclear Power (SP-100)	High Capacity Power	Planetary Rovers	Surface Habitats and Construction	Exploration Human Factors	—	Artifical Gravity
	—	—	Extravehicular Activity Systems	Surface Solar Power and Thermal Mgt.	In Situ Resource Utilization	Laser-Electric Power Beaming	Medical Support Systems	—	—
Transportation Technology	ETO Propulsion	Aeroassist Flight Expt Nuclear Thermal Propulsion	Aeroassist/ Aerobraking	Transfer Vehicle Avionics	ETO Vehicle Avionics	ETO Vehicle Structures & Materials	Autonomous Rendezvous & Docking	COHE	Auxiliary Propulsion
	Cryogenic Fluid Systems	Adv. Cryo. Engines	Low-Cost Commercial ETO XPort	Nuclear Electric Propulsion	CONE	SEPS TFE	Autonomous Landing	TV Structures and Cryo Tankage	HEAb
Space Platforms Technology	Platform Structures & Dynamics	Platform Power and Thermal Mgt.	Zero-G Life Support	Platform Materials & Environ. Effects	Station-Keeping Propulsion	—	Spacecraft On-Board Propulsion	Earth-Orbiting Platform Controls	Advanced Refrigerator Systems
	—	—	Zero-G Advanced EMU	Platform NDE-NDI	Deep-Space Power and Thermal	—	Spacecraft GN&C	Debris Mapping Experiment	—
Operations Technology	Space Data Systems	High-Rate Comm.	Artificial Intelligence	Ground Data Systems	Optical Comm Flight Expt Navigation & Guidance	Flight Control and Operations	Space Assembly & Construction	Space Processing & Servicing	Photonics Data Systems
	—	CommSat Communicat'ns	TeleRobotics	FTS DTF-1	Operator Syst./Training	CommSat Communicat'ns Flight Expts	—	Ground Test and Processing	—

JUNE 18, 1991
JCM-6800f

CSTP GROWTH STRATEGIES

OAET

FY 1993 SPACE PLATFORMS TECHNOLOGY

	CURRENT PROGRAM	"3x PROGRAM"	STRATEGIC PLAN
Earth Orbiting Platforms	▦ Plat. Structures/Dynamics	▦ Plat. Structures/Dynamics ▦ Plat. Power/Thermal Syst. ▦ Mat'ls/Environ. Effects	■ Plat. Structures/Dynamics ■ Plat. Power/Thermal Syst. ■ Mat'ls/Environ. Effects ■ Platform NDE-NDI □ Platform Controls
Space Stations		▦ Zero-G Life Support ▦ Zero-G EMU	■ Zero-G Life Support ■ Zero-G EMU □ Adv. Refrigerator Systems □ Station-Keeping Propulsion
Deep-Space Platforms		▦ S/C On-Board Propulsion	■ S/C On-Board Propulsion ■ S/C Power & Thermal □ S/C GN&C
Tech. Flight Expts.			□ Debris Mapping Flt Expt

LEGEND ■ Adequately Funded ▦ Constrained Progress ▥ Marginally Funded □ Outyear "Start"

JUNE 17, 199
JCM-751

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — SUMMARY — ITP

THE SPACE PLATFORM IS THE BACKBONE OF ALL ACTIVITIES IN SPACE

IMPROVEMENTS IN SPACE PLATFORM STRUCTURE AND UTILITIES WILL PAY OFF IN LOWER LIFE CYCLE COSTS AND MORE EFFICIENT OPERATIONS

THE STRATEGIC PLAN ADDRESSES ALL USER NEEDS AND HAS BEEN CONSTRUCTED TO HAVE TIMELY IMPACT ON PLANNED MISSIONS

THE "3X" FY 1993 BUDGET WILL DELAY OR SLOW DOWN SOME OF THE NEEDED TECHNOLOGY PRODUCTS, BUT WILL ENABLE A GOOD START TOWARD SOLVING THE MOST PRESSING PROBLEMS

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — EARTH ORBITING PLATFORMS — ITP

JUSTIFICATION

- **Mission Needs**

Advanced spacecraft structure and spacecraft bus technologies are needed to support

1998 + Earth Orbiting Science
2000 + Space Station Freedom beyond PMC
2000 + Robotic and Human Exploration

OBJECTIVES

- **Programmatic**

Develop and validate technologies that will decrease spacecraft launch weight, increase utility efficiency, increase lifetime and decrease life cycle costs

- **Technical**

Power &Thermal Mgmt	Increase efficiency
Structures &Dynamics	Enhance predictive capability
Materials & Env. Effects	Long lifetimes
NDE / NDI	Increase maintainability
Controls	Increase fault tolerance, lifetime

MILESTONES

1992 CSI ground testbed operational
1994 Compl SSF model with preintegrated truss
1995 Demo 100 Wh/kg, 1000 cycle battery cells
1997 Demo 300 W/m2 array
1997 Demo advanced star tracker
1997 Adv. materials ready for flight testing
1998 Thermal NDE method for coatings
1998 Heat pump demo
1999 New structural verification model
2000 Demo autonomous, fault tolerant PMAD

RESOURCES

Budget ($M)	1991	1992	1993	1994	1995	1996	1997
Current	6.5	10.7					
Strategic	6.5	10.7	27.5	40.8	50.5	55.5	60.0
3X	6.5	10.7	18.6	24.6	26.7	27.5	33..2

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — SPACE STATIONS — ITP

JUSTIFICATION

- **Mission Needs**

Advanced human support technologies are needed to support humans in LEO to support

2000 + Space Station Freedom beyond PMC
2000 + Human Exploration

OBJECTIVES

- **Programmatic**

Develop and validate technologies that will increase human productivity and safety in and around space station

- **Technical**

Regenerative ECLS	Decrease logistics resupply
Adv. EMU	Increase EVA effectiveness
Propulsion	Control waste gas management
SSF User Support	Increase utilization efficiency

MILESTONES

1993 Assess SOA microbial sensors
1994 Develop component testbed
1995 Design Thermal Control Testbed
1996 Resistojet with humid waste gas lifetime demo
1997 Demo single train water reclamation
1997 Prototype 8.3 psi suit delivered
1997 Demo water train sensor/control/computer interface
1998 AEMU Env. testing complete
1999 Demo solid waste oxidation system

RESOURCES

Budget ($M)	1991	1992	1993	1994	1995	1996	1997
Current	------------ 0 ---------------						
Strategic	0	0	8.4	18.1	24.2	27.5	24.6
3X	0	0	4.5	9.5	15.6	19.0	20.0

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — DEEP SPACE PLATFORMS — ITP

JUSTIFICATION

- **Mission Needs**

Advanced spacecraft bus technologies ar needed to support

1998 + Deep Space Missions, i.e.
Mars Sample Return,
Mercury Orbiter,
Uranus Orbiter/Probe,
Jupiter Grand Tour, etc

OBJECTIVES

- **Programmatic**

Develop and validate technologies that will increase utility efficiency, increase lifetime and decrease life cycle costs

- **Technical**

Power & Thermal Mgmt	Increase efficiency, lifetime
Propulsion	Decrease plume contamination
GN&C	Increase performance

MILESTONES

1993 Assess RTG alternatives
1994 Hot rocket fab. complete
1995 Design Thermal Control Testbed
1996 Demo 300 + W/kg Planar PV blanket
1997 Complete dev. of GN&C components
1997 Demo adv. isotope PCU
1998 Demo lightweight radiator technology
1999 Develop GN&C software and system evaluation

RESOURCES

Budget ($M)	1991	1992	1993	1994	1995	1996	1997
Current				0			
Strategic	0	0	3.2	9.6	14.9	13.7	14.3
3X	0	0	1.2	3.0	4.3	1.2	0.0

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — FLIGHT EXPERIMENTS — ITP

JUSTIFICATION

- **Mission Needs**

All missions, depending on technology discipline, including

1998 + Earth Orbiting Science
2000 + Space Station Freedom beyond PMC
2000 + Robotic and Human Exploration

OBJECTIVES

- **Programmatic**

Obtain data that can not be obtained on the ground and validate technologies to reduce risk to flight projects

- **Technical**

Debris mapping	Reduce risk to platforms
Structures & dynamics	Understand 0 g effects
Space plasma effects	Advance power system techn.
Fluid systems	Engineering data
Combustion techn.	Decrease risk to crew

MILESTONES

1992 Conclude Phase B
1993 Study cost reduction potential
1994 Begin Phase C/D
1998 Launch

Advocate other experiments within InSTEP AO process

RESOURCES

Budget ($M)	1991	1992	1993	1994	1995	1996	1997
Current	[redacted]						
Strategic			0	2.0	8.1	22.0	20.0
3X			0	0	0	0	0

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — STRATEGIC BUDGET — ITP

	FY91	FY92	FY93	FY94	FY95	FY96	FY97
TOTAL	11.4	21.8	38.9	70.5	97.7	118.7	119.9
EARTH ORBITING PLATFORMS	11.4	21.8	27.3	40.8	50.5	55.5	60.0
POWER & THERMAL MANAGEMENT	-	-	5.1	10.2	13.5	14.3	14.7
STRUCTURES & DYNAMICS	11.4	21.8	17.1	18.6	19.7	20.3	20.9
MATERIALS & ENV. EFFECTS	-	-	3.1	5.0	6.1	6.3	6.8
NDE/NDI	-	-	2.0	3.9	5.0	6.1	6.3
CONTROLS	-	-	-	3.1	6.2	8.5	11.3
SPACE STATIONS	-	-	8.4	18.1	24.2	27.5	24.6
REGENERATIVE ECLS	-	-	2.5	6.4	8.2	15.5	16.3
ADVANCED EMU	-	-	3.0	5.3	8.2	9.6	8.3
SSF USER SUPPORT	-	-	0.0	2.0	3.2	1.5	0.0
PROPULSION	-	-	2.9	4.4	3.6	0.9	0.0-
DEEP SPACE PLATFORMS	-	-	3.2	9.6	14.9	13.7	14.3
POWER & THERMAL MANAGEMENT	-	-	2.0	3.5	6.0	7.5	9.1
ON-BOARD PROPULSION	-	-	1.2	3.0	4.3	1.2	-
GN&C	-	-	-	3.1	4.6	5.0	5.2
FLIGHT EXPERIMENTS	-	-	0.0	2.0	8.1	22.0	20.0
(INSTEP)	(5.8)	(7.6)	(5.3)	(4.9)	(6.3)	(5.1)	(6.5)
ORBITAL DEBRIS	(1.0)	-	-	2.0	8.1	22.0	20.0

SPACE PLATFORMS TECHNOLOGY PROGRAM

OAET — 3X BUDGET — ITP

	FY91	FY92	FY93	FY94	FY95	FY96	FY97
TOTAL	11.4	21.8	24.6	39.1	51.1	51.6	54.4
EARTH ORBITING PLATFORMS	11.4	21.8	27.3	40.8	50.5	55.5	60.08
POWER & THERMAL MANAGEMENT	-	-	3.5	6.5	7.5	8.0	10.0
STRUCTURES & DYNAMICS	11.4	21.8	14.6	17.6	18.7	19.3	21.2
MATERIALS & ENV. EFFECTS	-	-	1.5	3.0	5.0	5.1	5.2
NDE/NDI	-	-	-	-	-	-	-
CONTROLS		-	-	-	-	-	-
SPACE STATIONS	-	-	4.0	9.0	15.6	18.0	18.0
REGENERATIVE ECLS	-	-	1.8	4.7	8.2	10.0	13.0
ADVANCED EMU	-	-	2.2	4.3	7.4	8.0	5.0
SSF USER SUPPORT	-	-	-	-	-	-	-
PROPULSION	-	-	-	-	-	-	-
DEEP SPACE PLATFORMS	-	-	1.0	3.0	4.3	1.2	-
POWER & THERMAL MANAGEMENT	-	-	-	-	-	-	-
ON-BOARD PROPULSION	-	-	1.0	3.0	4.3	1.2	-
GN&C	-	-	-	-	-	-	-
FLIGHT EXPERIMENTS	-	-	-	-	-	-	-
(INSTEP)	(5.8)	(7.6)	(5.3)	(4.9)	(6.3)	(5.1)	(6.5)
ORBITAL DEBRIS	(1.0)	-	-	-	-	-	

OAET

INTEGRATED TECHNOLOGY PLAN

OPERATIONS THRUST

June 25, 1991

Geoff Giffin

Office of Aeronautics, Exploration and Technology
National Aeronautics And Space Administration

Washington, D.C. 20546

OPERATIONS TECHNOLOGY PROGRAM

- PROGRAM GOAL
- SUMMARY OF USER NEEDS
- THRUST STRUCTURE
- CURRENT PROGRAM
  - PROGRAM AREAS
  - PROGRAM ELEMENTS

OPERATIONS TECHNOLOGY PROGRAM
PROGRAM GOAL

THE GOAL OF THE OPERATIONS THRUST IS TO DEVELOP AND DEMONSTRATE TECHNOLOGIES TO REDUCE THE COST OF NASA OPERATIONS, IMPROVE THE SAFETY AND RELIABILITY OF THOSE OPERATIONS, AND ENABLE NEW, MORE COMPLEX ACTIVITIES TO BE UNDERTAKEN.

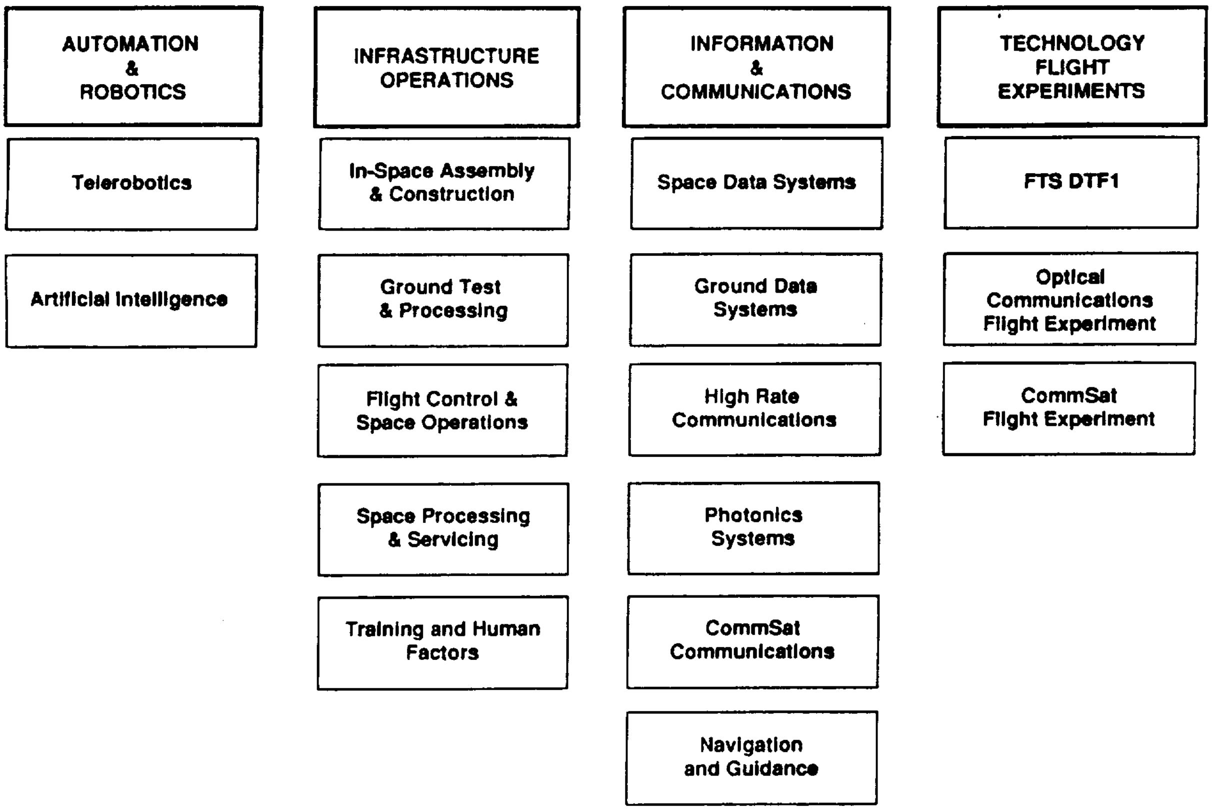
THE OPERATIONS THRUST SUPPORTS THE FOLLOWING MAJOR ACTIVITIES:

- IN-SPACE OPERATIONS
- FLIGHT SUPPORT OPERATIONS
- GROUND SERVICING AND PROCESSING
- PLANETARY SURFACE OPERATIONS
- COMMERCIAL COMMUNICATIONS

OPERATIONS TECHNOLOGY PROGRAM
SUMMARY OF USER NEEDS FOR OPERATIONS THRUST

OFFICE OF SPACE SCIENCE AND APPLICATIONS	OFFICE OF SPACE FLIGHT	OFFICE OF SPACE OPERATIONS	SPACE EXPLORATION INITIATIVE	COMMERCIAL SECTOR
• HIGH-VOLUME/ DENSITY/ RATE ON-BOARD DATA STORAGE • STRUCTURES-LARGE/ CONTROLLED/ DEPLOYED/ANTENNA • ROBOTICS • 32 GHZ TWT/OPTICAL COMMUNICATIONS • TELESCIENCE/ TELEPRESENCE/AI • SIS 3 THZ HETERODYNE RECEIVER • K-BAND TRANSPONDERS • ULTRA-HIGH GIGABIT TELEMETRY • REAL TIME RADIATION MONITORING	• CREW TRAINING SYSTEMS • ROBOTIC SYSTEMS • GUIDANCE, NAVIGATION AND CONTROL • AUTOMATION	• OPTICAL/MM-WAVE HIGH RATE DATA COMMUNICATIONS FOR SPACE TO GROUND AND SPACE TO SPACE APPLICATIONS • DEVELOPMENT OF ADVANCED DATA STORAGE, DATA COMPRESSION, AND INFORMATION MANAGEMENT SYSTEMS • NAVIGATION TECHNIQUES AND APPLICATIONS TO CRUISE, APPROACH, AND IN-ORBIT NAVIGATION FOR MANNED & UNMANNED PLANETARY MISSIONS • MISSION OPERATIONS: AI, EXPERT SYSTEMS, NEURAL NETS, INCREASED AUTOMATION • ADVANCED SOFTWARE TEST BED DEVELOPMENT, DISTRIBUTED SOFTWARE COORDINATION, AUTOMATED NETWORK PERFORMANCE ANALYSIS	• IN-SPACE SYSTEMS ASSEMBLY AND PROCESSING • HUMAN FACTORS • SPACE DATA SYSTEMS • HIGH-RATE COMMUNICATIONS • TELEROBOTICS • ARTIFICIAL INTELLIGENCE • DEEP SPACE NAVIGATION	• SPACE DATA SYSTEMS • HIGH RATE COMMUNICATIONS • FLIGHT CONTROL AND SPACE OPERATIONS

OPERATIONS THRUST STRUCTURE



OPERATIONS TECHNOLOGY PROGRAM
AUTOMATION & ROBOTICS TECHNOLOGY

JUSTIFICATION

- Automation and robotic technologies are needed to complement and support human activities in space and in ground operations
  - Artificial Intelligence
  - Telerobotics

OBJECTIVES

- Develop and validate technologies to enable increasing levels of automation in all areas of space and ground operations
  - Artificial Intelligence will increase capability and mission flexibility in all areas of manned and unmanned activities
  - Telerobotic technologies will support in-space operations (EVA & IVA) in support of both science & operations. Further needs for telerobotics exist in ground processing

MILESTONES

- 1992 Begin RANGER development and flight test planning
- 1994 Demonstrate PI-in-a-box in flight test Insert AI Tools in all MCC stations
- 1995 Perform RANGER flight test
- 1997 Complete development of AI analysis tools for planetary science

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	22.2	27.9	22.3	23.0	24.5	25.9	27.4

OPERATIONS TECHNOLOGY PROGRAM
INFRASTRUCTURE OPERATIONS TECHNOLOGY

JUSTIFICATION

- Infrastructure operations technologies are needed to support complex missions and large space structures in a safe, cost-effective and reliable manner
  - Space Assembly & Construction
  - Ground Test & Processing
  - Flight Control & Space Operations
  - Space Servicing & Processing
  - Training & Human Factors

OBJECTIVES

- Develop and validate technologies for reliable, safe, and efficient vehicle ground processing, space construction and mission operations activities
  - Reduce mission operations costs, enable more complex, multiple missions with fewer people
  - Enable automated construction of large space platforms & structures to support science, exploration and humans in space
  - Apply human factors technologies to training and operations to improve effectiveness

MILESTONES

- 1993 Implement crew coordination training program
- 1994 Implement countermeasure strategies for circadian disruption
- 1997 Demonstrate intelligent support system for NASA Task Director

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	0.5	----	2.1	3.0	4.0	4.3	4.0

OPERATIONS TECHNOLOGY PROGRAM
INFORMATION & COMMUNICATIONS TECHNOLOGY

JUSTIFICATION

- All areas of space activities can greatly benefit from improved capabilities in data processing, management and communications, which are necessary for new missions
  - Space Data Systems
  - Ground Data Systems
  - High Rate Communications
  - Photonics
  - Commercial Satellite Communications
  - Navigation & Guidance

OBJECTIVES

- Develop and validate technologies to greatly expand capabilities in data, communications and deep space navigation systems
  - Powerful space processors & computers
  - Large space storage systems
  - High bandwidth communications capability
  - Photonic technologies for new data systems

MILESTONES

- 1994 Begin advanced tool development for software reuse, reliability assessment, risk management and software development process control
- 1995 Flight demo of SODR drive unit
  Demonstrate 3-D RAM technology
- 1997 Demonstrate phased array antenna
  Demonstrate integrated data systems testbed

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	5.7	4.9	24.0	33.1	43.5	47.0	56.0

OPERATIONS TECHNOLOGY PROGRAM
TECHNOLOGY FLIGHT EXPERIMENTS

JUSTIFICATION

- Technology Flight Experiments are needed to validate in space the robotic technologies developed by the focused technology program
  - FTS
  - Optical Communications
  - Commercial Communications

OBJECTIVES

- Develop and validate technologies for reliable, safe, and efficient operations for future use of space robotics missions
  - Flight demonstration of telerobotic capabilities is a necessary precursor to use of telerobots in a variety of space missions
  - New Deep space missions and Earth orbiting satellites will rely on optical communications to achieve necessary data rates and communications bandwidth.

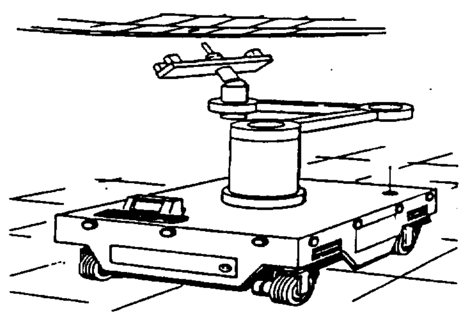
MILESTONES

- 06/93 Deliver DTF-1 to KSC
- 10/93 Flight test DTF-1

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	(106.3)	55.0	75.0	40.0	—	—	—

OPERATIONS TECHNOLOGY PROGRAM
TELEROBOTICS



OBJECTIVES

- Develop, integrate, and demo science and technology of telerobotics which leads to increasing the operational capability, safety, cost effectiveness, and probability of success of NASA missions.
  - Robotics
  - Supervisory Control
  - Advanced Launch Teleoperations
  - Launch Processing
  - Telepresence
  - Remote Science Operations

MILESTONES

- 1993 Complete non-planer truss assembly
- 1993 Perform compliant base Solar Max Repair
- 1995 Complete RANGER development & flight test
- 1995 Perform single operator Solar Max Repair
- 1996 Complete TR solar-dynamic-like structural assembly
- 1996 Complete development & test of serpentine STS inspection tool

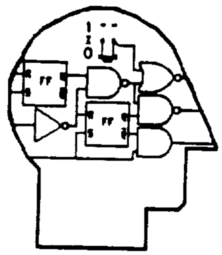
RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	11.0	14.8	12.4	12.8	13.6	14.3	15.1

PARTICIPANTS

Jet Propulsion Lab
Johnson Space Center
Marshall Space Flight Center
Langley Research Center
Goddard Space Flight Center
University of Maryland

OPERATIONS TECHNOLOGY PROGRAM
ARTIFICIAL INTELLIGENCE



OBJECTIVES

- Develop, integrate, and demo science and technology of AI which leads to increasing the operational capability, safety, cost effectiveness, and probability of success of NASA missions.
  - Mission operations assistance
  - Data analysis techniques
  - Autonomous control
  - Knowledge-base technology

MILESTONES

- 1993 Complete automatic STS scheduler
- 1994 AI tools deployed in all MCC stations
- 1994 Flight test PI-in-a-box
- 1995 Complete STS model-based diagnosis
- 1996 Complete development of AI analysis tools for planetary science

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	11.2	13.1	9.9	10.2	10.9	11.6	12.3

PARTICIPANTS

Ames Research Center
Jet Propulsion Lab
Johnson Space Center
Kennedy Space Center
Marshall Space Flight Center
Lewis Research Center
Goddard Space Flight Center

OPERATIONS TECHNOLOGY PROGRAM
TRAINING AND HUMAN FACTORS

OBJECTIVES

- Adapt techniques, countermeasures, workload measures, and support aids for air-transport crews to enable and support space-operations ground, mission control, and flight crews.
  - Crew coordination
  - Circadian countermeasures
  - Crew workload
  - Flight Deck Procedures
  - Test Director Aids

MILESTONES

- 1993 Implement crew coordination training program
- 1994 Implement countermeasure strategies and instrument for circadian distribution
- 1995 Enhance training for high workload situations
- 1996 Combine developments into STS Procedures Advisor
- 1997 Intelligent support system for NASA Test Director

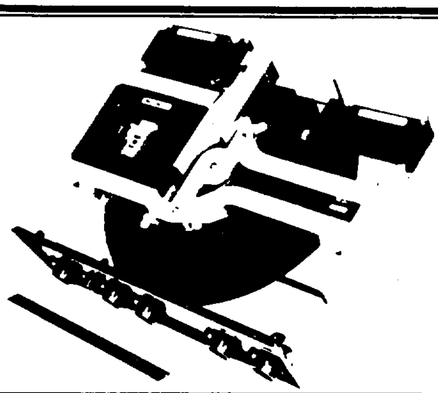
RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	---	---	2.1	3.0	4.0	4.3	4.0

PARTICIPANTS

Ames Research Center
Johnson Space Center

OPERATIONS TECHNOLOGY PROGRAM
SPACE DATA SYSTEMS



OBJECTIVES

- Develop advanced space qualifiable technologies for Space Data Systems to support Earth observing, astrophysics, microgravity and planetary exploration missions.
  - General & special purpose processors
  - Information extraction & data compression
  - Nonvolatile RAM and block access data storage
  - Onboard networks
  - ASIC and system element design & validation libraries

MILESTONES

- 1993 Nonvolatile RAM element experimental results
- 1994 AIP engineering model critical design
- 1995 Flight demonstration of SODR Drive Unit; Demo 3-D RAM technology
- 1996 Adv. Flight Computer brassboard test; Demo of two port, dual head SODR
- 1997 Integrated testbed demonstration

RESOURCES

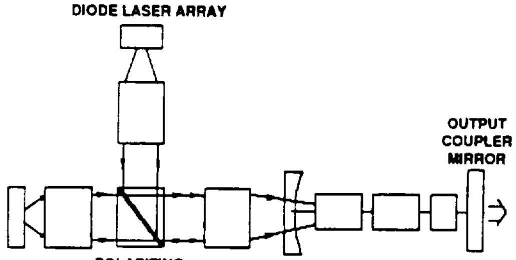
Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	5.7	4.9	14.6	20.0	24.5	25.0	25.0

PARTICIPANTS

Ames Research Center
Johnson Space Center

OPERATIONS TECHNOLOGY PROGRAM
HIGH RATE COMMUNICATIONS

SPACE LASER COMMUNICATION TECHNOLOGY



OBJECTIVES

- Develop technology to support advanced deep-space and near-Earth missions requiring transmission of high data rates (1) between planetary surfaces and spacecraft and (2) between spacecraft.

  Perform technology development in primary areas of interest:
  - Optical Communications
  - RF Communications
  - Digital Communication Systems Integration
  - Communications Systems Integration

MILESTONES

- 1993 Demonstrate an electronic power conditioner for 60 GHz TWT
- 1995 Demonstrate a 60-watt traveling wave tube amplifier breadboard at 32 GHz
- 1995 Demonstrate breadboard coherent optical transponder
- 1996 Demonstrate a multibeam MMIC sub-array at 20 GHz
- 1997 Demonstrate an ultra-fast laser diode module for optical communications
- 1998 Demonstrate a phase-locked two-dimensional diode array

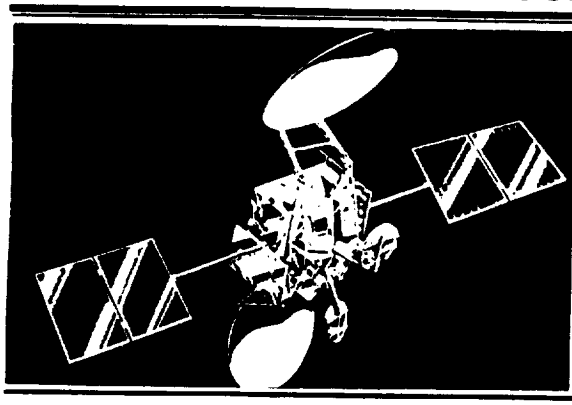
RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	---	---	5.4	7.1	10.0	12.5	18.0

PARTICIPANTS

Goddard Space Flight Center
Ames Research Center
Jet Propulsion Laboratory
Langley Research Center

OPERATIONS TECHNOLOGY PROGRAM
COMMSAT COMMUNICATIONS



OBJECTIVES

- Develop new and enabling satellite and ground technologies to the level needed to remove the risk to the industry of introducing new communications services which will benefit the human race
  - Active phased array satellite antennas
  - Bandwidth- and power-efficient modem, coding and onboard routing and processing systems

MILESTONES

- 1995 Innovative new mobile and small fixed terminal developed; System level MMIC's developed
- 1997 Active phased array antenna developed using digital beam forming; breadboard optical processor/router developed
- 1998 Advanced mobile terminal components developed
- 1998 Proof-of-concept optical beam forming network completed
- 2000 Complete development of advanced onboard communications processing and routing subsystem

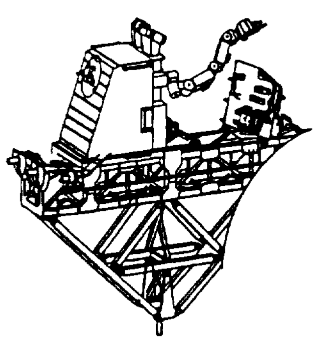
RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	—	—	4.0	6.0	9.0	9.5	13.0

PARTICIPANTS

Jet Propulsion Laboratory
Ames Research Center
Langley Research Center
Johnson Space Center

OPERATIONS TECHNOLOGY PROGRAM
FLIGHT TELEROBOTIC SERVICER



OBJECTIVES

- Demonstrate dexterous arm capabilities
  - On specific building block tasks
  - In microgravity utilizing flight qualifies hardware

MILESTONES

- 1991 Design Complete
- 1992 Fabrication and assembly complete
- 1993 Integration and testing complete
- 1993 Delivery to KSC
- 1993 Launch

RESOURCES

Budget ($,M)	1991	1992	1993	1994	1995	1996	1997
ON-GOING/ RUNOUT	(106.3)	55.0	75.0	40.0	—	—	—

PARTICIPANTS

Goddard Space Flight Center
Martin Marietta Aerospace Group

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INTEGRATED SPACE TECHNOLOGY PLAN

INFORMATION SCIENCES & HUMAN FACTORS DIVISION
R & T BASE STRATEGIC PLAN

JUNE 24 - 28, 1991

LEE HOLCOMB

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INFORMATION SCIENCES & HUMAN FACTORS R&T BASE

R & T BASE PHILOSOPHY

- ESTABLISH R & T BASE IN KEY DISCIPLINES.
- MAINTAIN INNOVATIVE AND LONG RANGE R & T TO ENABLE NEW CAPABILITIES.
- DEVELOP AND DEMONSTRATE CONCEPTS FOR NEW FOCUSED PROGRAMS.
- TECHNOLOGY PUSH.
- PROVIDE TURNOVER AS PROOF - OF- CONCEPT ACHIEVED.

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INFORMATION SCIENCES & CONTROLS

INFORMATION SCIENCE & HUMAN FACTORS RESEARCH AND TECHNOLOGY BASE

INFORMATION SCIENCE & CONTROLS ($ 21.3M)	HUMAN SUPPORT ($ 5.2M)	COMMUNICATIONS ($ 20.4M)
• CONTROLS • SENSORS • COMPUTER SCIENCE / SOFTWARE ENG. • PHOTONICS • NEURAL NETWORKS • HIGH - TEMPERATURE SUPERCONDUCTIVITY • ARTIFICIAL INTELLIGENCE • TELEROBOTICS	• ZERO -G SUIT • CREWSTATION DISPLAY • CHEMICAL PROCESSING • SENSOR & CONTROLS / BIOMEDICAL • THERMAL CONTROL • FIRE SUPPRESSION	• RF TECHNOLOGY • DIGITAL TECHNOLOGY • OPTICAL COMMUNICATIONS • MOBILE COMMUNICATIONS • SYSTEMS INTEGRATION, TEST AND EVALUATION

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INFORMATION SCIENCES & CONTROLS

APPROACH

- TRANSFER GENERIC PROGRAMS FROM FOCUSSED THRUST AREAS TO BASE IN FY '93
  - $ 4 M, ARTIFICIAL INTELLIGENCE
  - $ 3 M, TELEROBOTICS
- AUGMENT R&D AREAS THAT ARE:
  - MINIMALLY FUNDED
    NEURAL NETWORKS, HIGH TEMPERATURE SUPERCONDUCTIVITY, COMPUTATIONAL CONTROLS, PHOTONICS.
  - NEW STARTS
    MICROMACHINES / SENSORS, SENSOR OPTICS
  - ONGOING FUNDAMENTAL AREAS THAT NEED STRENGTHENING
    SENSORS, ARTIFICIAL INTELLIGENCE, TELEROBOTICS.
- TRANSFER MATURE ELEMENTS TO FOCUSSED THRUSTS

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INFORMATION SCIENCES & CONTROLS

PROGRAM ELEMENTS

PROGRAM ELEMENTS	FY 92 $ M	
• CONTROLS • SENSORS • COMPUTER SCIENCE/SOFTWARE ENGINEERING	4.5 1.5 4.1	ON-GOING
• PHOTONICS • NEURAL NETWORKS • HI-TEMPERATURE SUPERCONDUCTIVITY	.6 .4 (.6)	MINIMAL ON-GOING FUNDING
• ARTIFICIAL INTELLIGENCE (TRANSFER FY 93) • TELEROBOTICS (TRANSFER FY 93) • MICROMACHINES & SENSORS	- .8 (.1)	NEW

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INFORMATION SCIENCES & CONTROLS R&T BASE ACCOMPLISHMENTS

- SENSOR:
  - CCD DETECTORS FOR HST AND GALILEO
  - IR DETECTORS FOR SIRTIF
  - MAGNETIC BEARING STERLING CRYOGENIC COOLER
- COMPUTER SCIENCE / SOFTWARE ENGINEERING:
  - ADVANCED DIGITAL SAR PROCESSOR (MAGELLON)
  - DISTRIBUTED HETEROGENEOUS DATA MANAGEMENT TECHNOLOGY FOR ASTROPHYSICS DATA SYSTEM
  - DATA BASE ON SOFTWARE DEVELOPMENT METHODS
- CONTROLS:
  - EVALUATED ADVANCED CONTROL TECHNIQUES ON MSFC LARGE, FLEXIBLE SPACECRAFT TEST FACILITY
  - DEVELOP ORDER N DISCOS
  - COMPLETED TECHNOLOGY FEASIBILITY OF FORS

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INFORMATION SCIENCES & CONTROLS R&T BASE ACCOMPLISHMENTS

- ROBOTICS & AI:
  - SCIENCE INSTRUMENT EXPERT SYSTEM
  - AUTOMATIC DATA CLASSIFICATION AND ANALYSIS OF SPACE DATA (IRAS)
  - FUZZY LOGIC CONTROLLER DEMONSTRATED IN LABORATORY
  - NEUTRAL BUOYANCY SIMULATION OF TELEOPERATOR/EVA REPAIR OF HST ORU CHANGE OUT (U. MD)
  - LEGGED MOBILITY ON INDOOR TESTBED (CMU)
  - END POINT CONTROL OF FLEXIBLE MANIPULATORS (STANFORD)

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INFORMATION SCIENCES & CONTROLS R&T BASE CURRENT PROGRAM MILESTONES

- SENSORS
  - SYNTHETIC MATERIALS FOR IR DETECTORS (10 - 300 μ) (FY '94)
  - LASER DIODES FOR INJECTION LOCKING AND PUMPING (FY '94)
  - DEMONSTRATE ADVANCED OPTICAL CORRELATOR FOR RECOGNITION OF MOVING AND ARBITRARILY ORIENTED OBJECTS (FY '96)
- COMPUTER SCIENCE / SOFTWARE ENGINEERING
  - PROTOTYPE, SAFETY CRITICAL SOFTWARE OPERATING SYSTEM KERNEL (FY '93)
  - PORTABLE, FULLY FUNCTIONAL "ENCYCLOPEDIA OF SOFTWARE COMPONENTS" AND REUSE SYSTEMS (FY '95)
- CONTROLS
  - LARGE SPACE INTERFEROMETER METROLOGY SYSTEM DESIGN (FY '92)
  - ADAPTIVE ON-BOARD ASCENT GUIDANCE ALGORITHMS (FY '93)
  - INTERMITTENT LOOP CLOSURE FOR DISCOS (FY '93)
  - THERMAL AND CONTROL INTEGRATION FOR TREETOPS (FY '94)
  - MICROMACHINE GYRO CONCEPT DEMONSTRATION (FY '95)

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INFORMATION SCIENCES & CONTROLS R&T BASE CURRENT PROGRAM MILESTONES

- AI / TELEROBOTICS
  - LEARNING CAPABILITY ADDED TO SCHEDULER (FY '93)
  - AUTOCLASS FOR STS LAUNCH SITE WEATHER PREDICTION (FY '94)
  - NEXT GENERATION FREE-FLYER TELEOPERATED SERVICER IN NEUTRAL BUOYANCY (FY '94)
  - UNTETHERED LEGGED MOBILITY ON RUGGED OUTDOOR TERRAIN (FY '94)
  - FAULT TOLERANT DUAL ACTUATOR MODULE (FY '94)
  - COOPERATIVE AUTONOMOUS ROBOTS ASSEMBLE STRUCTURE (FY '96)

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INFORMATION SCIENCES & CONTROLS R&T BASE CONSTRAINED "3X" PROGRAM MILESTONES

HIGH TEMPERATURE SUPERCONDUCTIVITY

- *Flight qualification of HTS low current leads - FY '95*
- *Flight qualification of HTS magnetic bearing. - FY '96*
- *HTS Ka band antenna syst. experiment developed - FY '96*
- *Flight integration of cooler/ vibration damper. - FY '97*

SOFTWARE ENGINEERING

- *Domain analysis of representative NASA SW. - FY '94*
- *Establish methods to qualitatively estimate SW reliable. - FY '96*
- *Formal method for safe SW systems. - FY '96*

PHOTONICS

- *Demonstrate the feasibility of an OEIC device for phased array antenna control and steering - FY '94*
- *Demonstrate OEIC device for onboard for WDM. - 1FY '95*
- *Demonstrate smart-skins in-situ sensors for structure property and failure measurements. - FY '96*
- *Demonstrate a high speed spatial light modulator for optical computing. - FY '97*
- *Demonstrate optical interconnects for optical computing. - FY '97*

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INFORMATION SCIENCES & CONTROLS R&T BASE CONSTRAINED "3X" PROGRAM MILESTONES

SENSORS / OPTICS

- *Superconducting detector devices. -FY '95*
- *Sensor optics (IR to Gamma-Ray). - FY '96*
- *Solid state cooler concepts. - FY '97*

MICROMACHINES AND SENSORS

- *Micro seismometers. - FY '96*
- *Micro gas analyzer. - FY 97*
- *Vacuum micro electronics. - FY '97*
- *Micro science instrument systems. - FY '98*

COMPUTATIONAL CONTROLS

- *100 states realtime simulation. - FY '95*
- *200 states multivariable INCA. - FY '96*

ARTIFICIAL INTELLIGENCE R&T

- *Planning tools ported to massively parallel computers. - FY '95*
- *Integrated planning/scheduling/monitoring system for a NASA domain. - FY '96*

TELEROBOTICS R&T

- *Interactive human.computer task planner. - FY '95*
- *Conflict resolution method for sensor fusion. - FY '96*

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INFORMATION SCIENCES & CONTROLS HIGH TEMPERATURE SUPERCONDUCTIVITY

CURRENT PROGRAM

- MATERIALS PROCESSING (THIN FILM AND BULK)
- PROOF-OF-CONCEPT FABRICATION AND DEMONSTRATION OF PASSIVE DEVICES (FILTERS, OSCILLATORS, DETECTORS, LEADS, BEARINGS)
- FLIGHT QUALIFICATION OF MICROWAVE COMPONENTS (X-BAND FILTER)

STATE-OF-THE-ART

- THIN FILM AND BULK MATERIALS DEVELOPMENT (CRITICAL CURRENTS, MAGNETIC PROPERTIES, CRITICAL TEMPERATURES) SUFFICIENTLY ADVANCED TO WARRANT PASSIVE DEVICE DEVELOPMENT FOR SPACE APPLICATIONS.
- LARGE DOD INVESTMENTS (DARPA, SDIO) SUPPORT FULL RANGE OF PASSIVE DEVICE DEMONSTRATIONS (IR DETECTORS, COMMUNICATIONS COMPONENTS).

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INFORMATION SCIENCES & CONTROLS R&T BASE

THRUST(S) SUPPORTED

- SCIENCE
- OPERATIONS
- EXPLORATION

OBJECTIVE:

Develop and demonstrate high temperature superconductivity (HTS) technology that will enable and improve spaceborne applications in communications, data processing, cryogenic systems and sensors.

PRODUCTS (FY 1993 - FY 1996)

- Deliver 3 flight qualified receivers to NRL for HTSSE II experiment. - FY '94.
- *Flight qualification of HTS low current leads - FY '95*
- *Flight qualification of HTS magnetic bearing. - FY '96*
- *HTS Ka band antenna syst. experiment developed - FY '96*
- *Flight integration of cooler/ vibration damper. - FY '97*

HIGH TEMP. SUPERCONDUCTIVITY

PAYOFF

- Large improvements in performance, size and weight of spaceborne electronic and mechanical systems.
- Lower loss, lower noise, microwave components subsystems at reduced size and weight.
- Improved cryocooler performance and reliability.
- Extend mission life of stored cryogenics

CENTERS: LeRC, JPL, JSC, GSFC, LaRC, MSFC

RESOURCE INFORMATION

	FUNDING	NET ($ K)	
	CURRENT	AUGMENTATION	TOTAL
FY 1993	600	2250	2850
FY 1994	600	3000	3600
FY 1995	600	3750	4350
FY 1996	600	3750	4350
FY 1997	600	3750	4350

MAJOR FACILITIES: NONE

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INFORMATION SCIENCES & CONTROLS SOFTWARE ENGINEERING

CURRENT PROGRAM

- CONCEPTS, TOOLS, AND METHODOLOGIES TO DEVELOP AND MAINTAIN MISSION CRITICAL SOFTWARE.
- REUSE OF AEROSPACE SOFTWARE DESIGN AND COMPONENTS.
- EVALUATE CURRENT PRACTICE AND PRODUCE TOOLS TO SUPPORT EFFICIENT MANAGEMENT OF THE SOFTWARE PROCESS.

STATE-OF-THE-ART

- MISSION CRITICAL SOFTWARE EXPENSIVE TO DEVELOP AND MAINTAIN; NOT EXTENSIBLE BEYOND CURRENT APPLICATION.
- SOFTWARE REUSE LIBRARIES ARE NOT UTILIZED EXTENSIVELY.
- EFFECTIVE TOOLS DO NOT EXIST TO MONITOR AND CONTROL SW DEVELOPMENT PROCESSES.

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INFORMATION SCIENCES & CONTROLS R&T BASE

THRUST(S) SUPPORTED

- OPERATIONS
- SCIENCE
- TRANSPORTATION
- EXPLORATION
- PLATFORMS

OBJECTIVE:

- Conduct research programs addressing NASA's critical needs in software technology: very reliable software products and productive software development.
- Keep a core of leading edge development in-house teamed with industry/universities to supply NASA objectives.
- Generate SW concepts for transition to advanced development.

PRODUCTS (FY 1993 - FY 1996)

- Prototype, safety critical SW O/S kernel. - FY '93
- *Domain analysis of representative NASA SW. - FY '94*
- Portable, fully functional "Encyclopedia of Software Components" and reuse systems - FY '95
- *Establish methods to qualitatively estimate SW reliable. - FY '96*
- *Formal method for safe SW systems. - FY '96*

SOFTWARE ENGINEERING

PAYOFF

- Robust and reliable software products.
- Automated software processes.
- Predictable software costs and schedules.
- Maintain critical in-house expertize in software (currently consumes 20% NASA's annual budget).

CENTERS: GSFC, JPL, JSC, LARC

RESOURCE INFORMATION

FUNDING NET ($ K)

	CURRENT	AUGMENTATION	TOTAL
FY 1993	1600	1100	2700
FY 1994	1600	1500	3100
FY 1995	1600	1500	3100
FY 1996	1600	1500	3100
FY 1997	1600	1500	3100

MAJOR FACILITIES: NONE

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INFORMATION SCIENCES & CONTROLS R&T BASE PHOTONICS

CURRENT PROGRAM

- InP OPTOELECTRONIC INTEGRATED CIRCUIT (OEIC'S) DEVELOPMENT (PROGRAM STARTED IN FY 91)
- ADVANCED OPTICAL PATTERN RECOGNITION.

STATE-OF-THE-ART

- THREE COMPONENT GaAs OEIC'S HAVE BEEN DEMONSTRATED; InP TECHNOLOGY IN RESEARCH STAGE.
- OPTICAL COMPUTING AT RESEARCH STAGE; INADEQUATE DEVICE BASE
- NETWORKS DEMONSTRATED AT 100 M BIT/SEC.
- LASER, DETECTORS WELL DEVELOPED; NEW WAVELENGTHS AT RESEARCH STAGES.
- SMART SKINS OPTOELECTRONIC SENSORS DEMONSTRATED IN LABORATORY.
- SPECIAL PURPOSE PROCESSORS FOR SPACECRAFT AT 10 - 100 MIPS/WATT.

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INFORMATION SCIENCES & CONTROLS R&T BASE

THRUST(S) SUPPORTED

- SCIENCE
- OPERATIONS
- EXPLORATION

OBJECTIVE:

Perform fundamental research to develop hybrid photonic devices and systems for sensing information processing, communication and control. The program will include basic research and breadboard development in the following areas:
- Materials and devices
- High capacity networks
- Optical information processing.
- In-situ photonics sensors

PRODUCTS (FY 1993 - FY 1996)

- *Demonstrate the feasibility of an OEIC device for phased array antenna control and steering - FY '94*
- *Demonstrate OEIC device for onboard for WDM. - 1FY '95*
- Demonstrate advanced optical correlator for recognition of moving and arbitrarily oriented objects. - FY '96
- *Demonstrate smart-skins in-situ sensors for structure property and failure measurements. - FY '96*
- *Demonstrate a high speed spatial light modulator for optical computing. - FY '97*
- *Demonstrate optical interconnects for optical computing. - FY '97*

PHOTONICS

PAYOFF

- Order of magnitude performance improvement in communications, sensing and control systems.
- Higher reliability, long life systems.
- Low weight, power, size.
- High speed processors
- High bandwidth systems.
- Immune to EMI and EMP
- Processors with capabilities of 10^4 to 10^5 MIPS/WATT (100x current capability)

CENTERS: ARC, JPL, GSFC

RESOURCE INFORMATION

FUNDING NET ($ K)

	CURRENT	AUGMENTATION	TOTAL
FY 1993	600	2250	2850
FY 1994	600	3000	3600
FY 1995	600	3750	4350
FY 1996	600	4500	5100
FY 1997	600	5250	5850

MAJOR FACILITIES: NONE

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INFORMATION SCIENCES & CONTROLS R&T BASE NEURAL NETWORKS

CURRENT PROGRAM

- DEVELOP SYNAPTIC ARRAY COMPONENTS .
- EVALUATE POTENTIAL NEURAL NETWORK APPLICATIONS.
  - DYNAMIC RESOURCES ALLOCATION
  - SUPERVISED LEARNING
- DEVELOP THE SPARSE DISTRIBUTED MEMORY (SDM) CONCEPT FOR NASA MISSIONS .

STATE-OF-THE-ART

- FUNDAMENTAL CONCEPTS IN NEURAL NETWORK THEORY AND DEVICES HAVE BEEN DEMONSTRATED.
  - ON-BOARD STAR IDENTIFICATION AND ATTITUDE DETERMINATION
  - HEALTH MAINTENANCE / DIAGNOSIS AND FAILURE PREDICTION
  - ROBOTIC CONTROL
- RELIABILITY AND QUALIFICATION ISSUES FOR SPACE APPLICATION HAVE NOT BEEN ADDRESSED.

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INFORMATION SCIENCES & CONTROLS R&T BASE

THRUST(S) SUPPORTED
- SPACE INSTRUMENTS
- MISSION OPERATIONS
- SCIENCE
- TRANSPORTATION

OBJECTIVE:
Develop and demonstrate adaptive, neural information processing concepts;

- Multi-disciplinary science analysis, geophysical modeling & visualization.
- On-board, large-scale science data reduction.
- In-flight resource allocation and diagnostic analysis.

PRODUCTS (FY 1993 - FY 1996)
- *Spectral neural processor brassboard for onboard space science signal processing (e.g., EOS SAR, AIRS). - FY '94*
- *Neural processor for onboard, science data reduction at Gbits/sec data rates. - FY '95*
- *Neurocontroller brassboard for guidance and landing using thruster/velocity control for planetary landers (e.g., Mars Lander) - FY '96*
- *Reconfigurable neural processor for on-board, dynamic resource allocation & system health monitoring, - FY '97*

NEURAL NETWORKS

PAYOFF
- Significant on-board processing improvements:
  - 10^2 to 10^4 faster on many applications
  - Very low noise
  - Adaptive
  - Reconfigurable
  - Fault tolerant
  - Power, weight, and size economical

CENTERS: JPL, ARC, JSC

RESOURCE INFORMATION

FUNDING			NET ($ K)
	CURRENT	AUGMENTATION	TOTAL
FY 1993	400	750	1150
FY 1994	400	1500	1900
FY 1995	400	2250	2650
FY 1996	400	3000	3400
FY 1997	400	3000	3400

MAJOR FACILITIES: NONE

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INFORMATION SCIENCES & CONTROLS R&T BASE SENSORS/OPTICS

CURRENT PROGRAM

- DESIGN, FABRICATE, AND TEST NEW ELECTRO-OPTIC MATERIALS FOR:
  - INJECTING LOCKING
  - LASER PUMPING DIODES
  - HIGH-FREQUENCY AMPLIFIERS (> 500 GHz).
  - NON LINEAR DEVICES .
- DESIGN, FABRICATE, AND TEST NEW SENSING DEVICES USING "BAND-GAP" ENGINEERING.

STATE-OF-THE ART

- UNIFORM MID-IR ARRAYS TO 12 μM OPERATIONS @ T < 65 K
- LASER DIODE PUMP ARRAYS AVAILABLE ONLY FOR Nd YAG
- LOCAL OSCILLATORS FOR FREQUENCIES < 300 GHz.
- VISIBLE / IR PHASE - CONJUGATE OPTICS (NOT SPACE QUALIFIED)
- BULKY, VIBRATION DOMINATED, MECHANICAL, STIRLING COOLERS WITH MIN TEMP. > 60K.

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INFORMATION SCIENCES & CONTROLS R&T BASE

THRUST(S) SUPPORTED

- SCIENCE
- EXPLORATION

OBJECTIVE:

Perform functional research to maintain a broad base for future NASA mission requirements in remote sensing instruments and optics needs:

- Materials research for sensors & optics
- Innovative sensing device concepts.
- Cryo & low temperature physics research
- Optics research
- Facilities & research equip.

PRODUCTS (FY 1993 - FY 1996)

- Synthetic materials for detectors. - FY '94
- Laser diodes for injection locking & pumping. - FY '94
- *Superconducting detector devices. -FY '95*
- *Sensor optics (IR to Gamma-Ray). - FY '96*
- *Solid state cooler concepts. - FY '97*

SENSORS / OPTICS

PAYOFF

- Materials and concepts for;
  - Large imaging array, FIR to Gamma-Ray.
  - Local Oscillators.
  - New tuneable lasers.
- FIR to Gamma-Ray optics.
- Maintain in-house expertise
- Science missions dictate new wavelengths, sensitivity, and imaging sensing instruments.

CENTERS: ARC, LaRC, JPL, GSFC

RESOURCE INFORMATION

FUNDING NET ($ K)

	CURRENT	AUGMENTATION	TOTAL
FY 1993	1500	750	2250
FY 1994	1500	1500	3000
FY 1995	1500	2250	3750
FY 1996	1500	2250	3750
FY 1997	1500	3000	4500

MAJOR FACILITIES:

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INFORMATION SCIENCES & CONTROLS R&T BASE COMPUTATIONAL CONTROLS

CURRENT PROGRAM

- IMPROVEMENT OF EXISTING TOOLS SUCH AS DISCOS, TREETOPS AND INCA.
- MODEST DEVELOPMENT OF NEW GENERATION OF S/W DEVELOPMENT EMPHASING COMPLEX MODEL REDUCTION TECHNIQUES, REALTIME SIMULATION, HIGH ORDER CONTROL SYNTHESIS

STATE-OF-THE-ART

- TOOLS SEVERELY LIMIT TODAY'S CONTROL DESIGN AND TESTING AND ARE INADEQUATE FOR FUTURE NEEDS.
  - TOOLS BREAKDOWN FOR HIGH ORDER SYSTEMS (> 40 STATES)
  - TOOLS ARE TO SLOW TO BE USED EFFECTIVELY FOR DESIGN AND TESTING
  - USER FRIENDLY INTERFACE NEEDED TO INCREASE PRODUCTIVITY
  - CONTROL TOOLS MUST BUILD ON EMERGING HIGHLY PARALLEL COMPUTING TECHNOLOGIES.

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INFORMATION SCIENCES & CONTROLS R&T BASE

THRUST(S) SUPPORTED

- TRANSPORTATION
- SCIENCE
- SPACE PLATFORMS
- EXPLORATION

OBJECTIVE:
Develop a new generation of algorithms and prototype software for articulated multibody spacecraft modeling, control design and simulation tools. These tools will reduce mission risk and enhance productivity.

PRODUCTS (FY 1993 - FY 1996)

- Intermittent loop closure for DISCOS - FY '93
- Thermal and control integration for TREETOPS. - FY '94
- *100 states realtime simulation. - FY '95*
- *200 states multivariable INCA. - FY '96*

COMPUTATIONAL CONTROLS

PAYOFF

- New fast algorithmic approaches.
- Fast efficient integrated tools for control system design (image based), analysis, and simulations including hardware-in-loop.
- Controls system designs for complex space systems.
- Increase productivity of a computer literate workforce through simplified interactive interfaces.

CENTERS: JPL, LeRC, MSFC, GSFC, JSC

RESOURCE INFORMATION

	FUNDING CURRENT	AUGMENTATION	NET ($ K) TOTAL
FY 1993	750	1125	1875
FY 1994	750	1500	2250
FY 1995	750	2625	3375
FY 1996	750	3000	3375
FY 1997	750	3375	4125

MAJOR FACILITIES: NONE

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INFORMATION SCIENCES & CONTROLS R&T BASE ARTIFICIAL INTELLIGENCE

CURRENT PROGRAM

- FUNDAMENTAL WORK ON:
  - PLANNING & SCHEDULING
  - LEARNING
  - KNOWLEDGE BASE DESIGN
  - INTEGRATED COGNITIVE ARCHITECTURES

STATE-OF-THE-ART

- ROBUST OPERATIONAL EXPERT SYSTEMS
- EARLY DEVELOPMENT OF MULTIPLE INTERACTING EXPERT SYSTEMS
- INITIAL APPLICATION OF SCHEDULING TOOLS
- BAYESIAN-BASED AUTOMATIC DATA CLASSIFICATION AND DATA ANALYSIS
- AUTONOMOUS CONTROL OF INTELLIGENT INSTRUMENTS
- RUDIMENTARY MACHINE LEARNING

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INFORMATION SCIENCES & CONTROLS R&T BASE

THRUST(S) SUPPORTED

- OPERATIONS
- EXPLORATION
- SCIENCE
- TRANSPORTATION

OBJECTIVE:

Develop and validate AI technologies which, improve operational capability, efficiency and safety of NASA space projects
- AI with massively parallel computing
- Integrated cognitive architectures (scheduling, planning, learning
- Intelligent interacting agents
- Distributed problem solving
- Machine learning.

PRODUCTS (FY 1993 - FY 1996)

- Learning capability added to scheduler. - FY '93
- Autoclass for STS launch site weather prediction. - FY '94
- *Planning tools ported to massively parallel computers. - FY '95*
- *Integrated planning/scheduling/monitoring system for a NASA domain. - FY '96*

ARTIFICIAL INTELLIGENCE R&T

PAYOFF

- Greater design options for space operations.
- Compensation for system technical limitations
- Reduced workload for users and operations of ground-base systems.
- Improved operational capability, efficiency, and safety of NASA space projects

CENTERS: ARC, JPL, STANFORD, UCB

RESOURCE INFORMATION

FUNDING NET ($.K)

	CURRENT	AUGMENTATION	TOTAL
FY 1993	4000	0	4000
FY 1994	4000	2250	6250
FY 1995	4000	3750	7750
FY 1996	4000	4500	8500
FY 1997	4000	6000	10000

MAJOR FACILITIES: NONE

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INFORMATION SCIENCES & CONTROLS R&T BASE TELEROBOTICS

CURRENT PROGRAM

- MULTIPLE INTERACTIVE ROBOTS (STANFORD)
- TELEROBOTIC SPACE OPERATIONS (U.MD.)
- FAULT TOLERANT TELEROBOT MECHANISMS (U.TX.)
- LARC TELEROBOT/COMPONENT RESEARCH

STATE-OF-THE-ART

- GROUND-BASED COMPONENT DEVELOPMENTS
- GROUND-BASED DEMONSTRATIONS (SUCH AS ROBOTIC ASSEMBLY OF PLANAR TRUSS STRUCTURE)
- IN-SPACE ROBOTIC SYSTEMS OPERATIONS LIMITED TO RMS EXPERIENCE
- DESIGN AND INITIAL DEVELOPMENT OF FTS/DTF, SPDM, AND JEM ARMS.
- LIMITED EXPERIENCE INTEGRATING TELEROBOTS INTO SPACE SYSTEMS

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INFORMATION SCIENCES & CONTROLS R&T BASE

THRUST(S) SUPPORTED
- OPERATIONS
- EXPLORATION
- SCIENCE
- TRANSPORTATION

OBJECTIVE:

Develop state-of-the-art advances in the areas of:
- Telerobot ground simulators
- Man-machine interface
- Smart sensor systems
- Telerobot mechanisms
- Telerobot concepts

PRODUCTS (FY 1993 - FY 1996)
- Next generation free-flyer in neutral buoyancy. - FY '93
- Fault tolerant dual actuator module. - FY '94
- Untethered legged mobility on rugged outdoor terrain - FY '94
- *Interactive human.computer task planner. - FY '95*
- *Conflict resolution method for sensor fusion. - FY '96*
- Cooperative autonomous robots assemble structure. - FY '96

TELEROBOTICS R&T

PAYOFF
- Greater design options for space operations.
- Reduced EVA requirements for on-orbit servicing.
- Increased EVA productivity through cooperative EVA-TR operations.

CENTERS: JPL, LeRC, STANFORD, UTX

RESOURCE INFORMATION

FUNDING NET ($ K)

	CURRENT	AUGMENTATION	TOTAL
FY 1993	800	-	800
FY 1994	3800	2250	6050
FY 1995	3800	3000	6800
FY 1996	3800	4500	8300
FY 1997	3800	6000	9800

MAJOR FACILITIES: NONE

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INFORMATION SCIENCES & CONTROLS R&T BASE MICROMACHINES AND SENSORS

CURRENT PROGRAM

- DDF-FUNDED RESEARCH AT JPL & LeRC

STATE-OF-THE-ART

- MICRO MOTORS FABRICATED & TESTED
- MICRO ACCELEROMETERS DESIGNED & FABRICATION.
- VACUUM MICROELECTRONIC CIRCUITS FABRICATION.
- CONCEPTS, DESIGN, AND DEVICE AT TECHNOLOGY LEVEL 2

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INFORMATION SCIENCES & CONTROLS R&T BASE

MICROMACHINES AND SENSORS

THRUST(S) SUPPORTED

- SCIENCE
- EXPLORATION

OBJECTIVE:

Develop and demonstrate a new class of sensors/instruments using state-of-the-art micro machining technologies for in-situ measurements such as: surface characterization, sub surface characterization, planetary atmospheric analysis and far IR-atmospheric science.

PRODUCTS (FY 1993 - FY 1996)

- Micro gyros - FY '95
- *Micro seismometers. - FY '96*
- *Micro gas analyzer. - FY 97*
- *Vacuum micro electronics. - FY '97*
- *Micro science instrument systems. - FY '98*

PAYOFF

- Lightweight, small, economical instruments.
- Custom design.
- Ease & economy of duplication with VLSI fab. tech.
- Form critical in-house expertise.
- Science & exploration mission options are enabled with smaller instruments.

CENTERS: JPL, LeRC

RESOURCE INFORMATION

	FUNDING CURRENT	AUGMENTATION	NET ($ K) TOTAL
FY 1993	100		100
FY 1994	100		100
FY 1995	100	2250	2350
FY 1996	100	3000	3100
FY 1997	100	3750	3850

MAJOR FACILITIES: NONE

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HUMAN SUPPORT R&T BASE APPROACH

- ACCELERATED DEVELOPMENT OF KEY, HIGH - PAYOFF CAPABILITIES
  - EVA GLOVES
  - VISUALIZATION TECHNOLOGIES
- ENABLE DEMONSTRATIONS / IN - FLIGHT TESTS OF:
  - THERMAL - CHEMICAL CONTROLS AND SENSORS
  - VIRTUAL ENVIRONMENT WORKSHOP
- AUGMENT R & T AREAS THAT ARE MINIMALLY FUNDED
  - DESIGN GUIDELINES FOR HUMAN - INTELLIGENT SYSTEMS
  - PLSS COMPONENTS (BATTERIES, CO PROCESSING)
  - EVA DISPLAY AND CONTROL TECHNIQUES
  - HUMAN COGNITIVE AND PHYSICAL MODELING
  - ADVANCED ECLSS & HABITAT THERMAL CONTROL
- TRANSFER MATURING TECHNOLOGY TO FOCUSED THRUSTS
  - HUMAN - COMPUTER INTERFACE DESIGN GUIDELINES
  - EVA SUIT MOBILITY (JOINT) AND MATERIALS (HARD & SOFT)
  - DISPLAYS FOR PROXIMITY OPERATIONS

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HUMAN SUPPORT

PROGRAM ELEMENTS

	FY 92 $ M	
• ZERO-G SUIT	.6	ON-GOING
• CREWSTATION DESIGN	1.8	

• CHEMICAL PROCESSING	.3	MINIMAL ON-GOING FUNDING
• SENSORS & CONTROLS/BIOMEDICAL	.1	
• HABITAT & PLSS THERMAL CONTROL	.2	

• FIRE SAFETY	-	NEW
• BIOMEDICAL	-	NEW

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HUMAN SUPPORT

- ACCOMPLISHMENTS:
  - AX-5 HIGH-PRESSURE SPACE SUIT DEVELOPMENT
  - VISION MODEL DEMONSTRATION FOR DATA COMPRESSION AND MACHINE VISION
  - HUMAN GRAPHICS SYSTEM DEVELOPED TO SUPPORT CONCEPTUAL DESIGN OF HUMAN/SYSTEM INTERFACES
  - HUMAN-COMPUTER INTERACTION GUIDELINES ADDED TO MAN-SYSTEM INTEGRATION STANDARD
  - DEMONSTRATED EXPLORATION OF THE MARTIAN SURFACE USING VIRTUAL WORKSTATION
  - EVA METABOLIC RESEARCH LABORATORY COMPLETED AND CERTIFIED

- PLANNED MILESTONES
  - TEST 3-D VISUAL MOTION ANALYSIS CONCEPT FOR HAZARD DETECTION. (FY '93)
  - WATER RECOVERY COMPONENT BREADBOARD & PHYSICAL-CHEMICAL PROCESSORS EVALUATED (FY '93)
  - TEST AND DEMONSTRATION OF ADVANCED HIGH-PRESSURE EVA GLOVE CONCEPT (FY '93)
  - COMPLETE TEST AND EVALUATION OF NEW CO_2 ABSORBENT CANISTER CONCEPT (FY '94)
  - COMPLETE TEST OF ADVANCED CREWSTATION WORKSTATION CONCEPT (FY '96)
  - COMPLETE DESIGN GUIDELINES FOR INTERACTIVE VIRTUAL DISPLAY CONCEPT (FY '98)

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HUMAN SUPPORT

CURRENT PROGRAM

- DEMONSTRATE APPLICATIONS OF VIRTUAL ENVIRONMENT.
- DETERMINE BIOMECHANICAL AND KINEMATIC PARAMETERS IN REDUCED AND ZERO GRAVITY MOTION.
- ADVANCED LIFE SUPPORT SYSTEM ANALYSIS SIMULATION MODELS.
- WATER QUALITY CHARACTERIZATION, CONTAMINANT AND TREATMENT MODELING.
- CHARACTERIZE ADVANCED CLOSED-LOOP WATER SYSTEMS.

STATE-OF-THE-ART

- PRELIMINARY KINEMATIC MODELS OF HUMAN MOTION IN ZERO-G.
- VIRTUAL REALITY LIMITED TO NON-REAL TIME OR LOW RESOLUTION SCENES.
- NON-REGENERATIVE LITHIUM HYDROXIDE CANISTERS USED IN PLSS FOR CO2 REMOVAL.
- RE-SUPPLIED AIR AND WATER AND REGENERATIVE CO2 REMOVAL FOR ECLSS.

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HUMAN SUPPORT R&T

THRUST(S) SUPPORTED

- OPERATIONS
- TRANSPORTATION
- EXPLORATION
- PLATFORM

OBJECTIVE:

Perform fundamental research in four major areas of Human support technologies for a wide range of NASA's space programs. The major subelements topics are:
- EVA system support to human performance.
- Life support technologies.
- Crewstation design technology.
- Fire safety technology
- Biomedical support technology

PRODUCTS (FY 1993 - FY 1996)

- Test 3-D motion analysis concept for hazard detectors. - 1993
- *Complete proof of concept of new chemical sensor for toxic gases- 1995*
- Complete test of advanced crewstation workstation concept. -1996
- *Solid waste recycling processors & concepts evaluated -1996*
- *Test probabilistic model of low gravity fire scenario. - 1997*
- Complete design guidelines for interactive virtual display concept. - 1998
- *Complete initial microbial sensor for air and water-1998*
- *complete habitat thermal control - 1998*

HUMAN SUPPORT

PAYOFF

- Increase safety, effectiveness, and reliability of human activities in space.
- Space human support knowledge base established.
- Advanced human-automated systems interfaces for more productive approaches.
- Increase closure of future space life support systems.
- Enable efficient and effective monitoring of critical life support systems.

CENTERS: ARC, JSC, JPL, GSFC

RESOURCE INFORMATION

FUNDING	CURRENT	AUGMENTATION	TOTAL
		NET ($ K)	
FY 1993	2900	1400	4300
FY 1994	2900	3150	6050
FY 1995	2900	4200	7100
FY 1996	2900	4900	7800
FY 1997	2900	7000	9900

MAJOR FACILITIES: NONE

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INFORMATION SCIENCES & CONTROLS
R&T BASE COMMUNICATIONS PROGRAM

OBJECTIVE:

ADVANCED CRITICAL AREAS OF ENABLING AND ENHANCING COMMUNICATION TECHNOLOGIES THAT SUPPORT COMMERCIAL NEEDS, SCIENCE, AND EXPLORATION MISSIONS FOR THE 1990's AND BEYOND. THE TECHNOLOGY PROGRAM CONSISTS OF RESEARCH AND TECHNOLOGY DEVELOPMENT IN:

- RF TECHNOLOGY
- DIGITAL TECHNOLOGY
- OPTICAL COMMUNICATIONS
- MOBILE COMMUNICATIONS
- SYSTEMS INTEGRATION, TEST & EVALUATION

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INFORMATION SCIENCES & CONTROLS
R&T BASE COMMUNICATIONS PROGRAM

ACCOMPLISHMENTS:

RF TECHNOLOGY

- DEMONSTRATED THE FIRST Ka - BAND (32 GHz) TWT WITH 10 W OUTPUT POWER ANS 35 % EFFICIENCY
- DEMONSTRATED THE FIRST Ka BAND (32 GHz) 0.075 W MMIC AMPLIFIER.
- DEMONSTRATED THE FIRST Ka - BAND MMIC PHASED ARRAY ANTENNA WITH 7 WAVEGUIDE ELEMENTS

DIGITAL TECHNOLOGY

- DEVELOPED A HIGH BURST RATE (110 AND 220 Mbps) TDMA GROUND TERMINAL FOR OPERATION AT Ka - BAND IN SUPPORT OF ACTS (WILL TEST THE UPLINK POWER CONTROL FEATURE)
- DEVELOP AND PATENTED A NOVEL, HIGHLY EFFICIENT, AND FADE ROBUST DIGITAL / SPEECH MODEMS

OPTICAL COMMUNICATIONS TECHNOLOGY

- DEVELOPED A SMALL (< 5Kg) OPTICAL COMMUNICATIONS BREADBOARD TRANSCEIVER
- A 50 Mbps DIRECT DETECTION RECEIVER HAS BEEN COMPLETED; A 220 Mbps DEVICE IS IN FABRICATION (TO BE COMPLETED IN 1991)

MOBILE SATELLITE COMMUNICATIONS

- DEMONSTRATED THE FIRST L - BAND MOBILE SATELLITE TERMINAL ON TERRESTRIAL VEHICLES AND AIRCRAFT

SYSTEM INTEGRATION, TEST AND EVALUATION

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INFORMATION SCIENCES & CONTROLS
R&T BASE COMMUNICATIONS PROGRAM

PROGRAM MILESTONES:

RF TECHNOLOGY
- BRASSBOARD DEMONSTRATION OF A Ka - BAND TWTA WITH 20 W INPUT, 7 W OUTPUT - '91
- DEMONSTRATE A Ka - BAND 1 W MMIC AMPLIFIER WITH 10 dB GAIN AND 35 % EFFICIENCY - '92

DIGITAL TECHNOLOGY
- DEMONSTRATE 300 Mbps INFORMATION SWITCHING PROCESSOR - '94
- DEMONSTRATE A 728 CHANNEL MULTICHANNEL DEMULTIPLEXER DEMODULATOR - '95

OPTICAL COMMUNICATIONS TECHNOLOGY
- SCOPE BREADBOARD TEST, 100 Kbps COHERENT RECEIVER DEMONSTRATION - '91
- DEMONSTRATE 1 W 1 Gbps DIODE PUMPED Nd DOPED LASER - '92
- DEMONSTRATE A 2 W MONOLITHIC ACTIVE GRATING MASTER OSCILLATOR POWER AMPLIFIER WITH 1 GHz MODULATION - '93
- SYSTEMS TESTING AND EVALUATION OF OPTICAL COMMUNICATIONS FLIGHT - LIKE PACKAGE, 650 Mbps, 200 W, 250 lbs - '93

MOBILE SATELLITE COMMUNICATIONS
- ACTS MOBILE AERONAUTICAL EXPERIMENT - '93
- ACTS MOBILE SATELLITE EXPERIMENT USING ACTIVE ARRAY ANTENNA - '94

SYSTEMS INTEGRATION, TEST AND EVALUATION
- DEMONSTRATE TWO AND THREE TERMINAL NETWORK EXPERIMENTS - '92

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INFORMATION SCIENCES & CONTROLS
R&T BASE COMMUNICATIONS PROGRAM

PROGRAM ELEMENTS	FY 92 $ M	
• RF COMMUNICATIONS TECHNOLOGY	7.4	ON-GOING
• DIGITAL COMMUNICATIONS TECHNOLOGY	2.4	
• OPTICAL COMMUNICATIONS TECHNOLOGY	4.2	
• MOBILE COMMUNICATIONS TECHNOLOGY	3.2	
• SATELLITE COMM., TEST AND EVALUATION	2.6	

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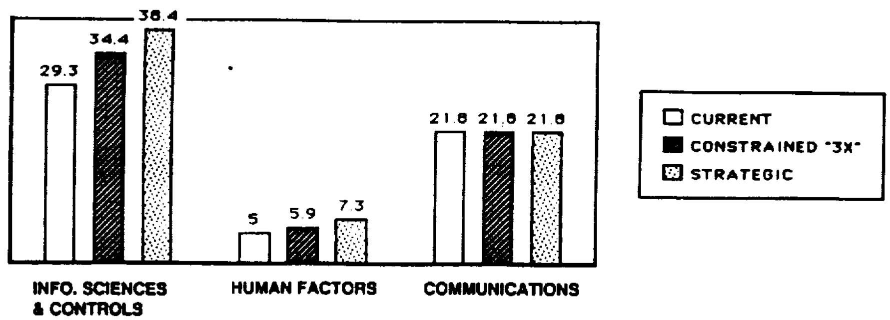
INFORMATION SCIENCES & CONTROLS R&T BASE

FY 1993



	FY '91	FY '92	FY '93	FY '94	FY '95	FY '96	FY '97
INFO. SCIENCE & CONTROLS							
CURRENT	22.6	21.3	29.3	30.4	31.4	32.4	33.5
"3X"22.6	21.3	34.4	43.9	50.4	53.4	59.6	
STRATEGIC	22.6	21.3	38.4	47.4	55.0	60.9	70.6
HUMAN FACTORS							
CURRENT	4.4	5.2	5.0	5.3	5.5	5.6	5.9
"3X"4.4	5.2	5.9	7.7	8.8	9.4	10.6	
STRATEGIC	4.4	5.2	7.3	9.4	11.1	12.8	14.8
COMMUNICATIONS							
CURRENT	(11.4)	20.4	21.8	21.2	22.0	23.1	24.2
"3X"(11.4)	20.4	21.8	21.2	22.0	23.1	24.2	
STRATEGIC	(11.4)	20.4	21.8	21.2	22.0	23.1	24.2

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INTEGRATED TECHNOLOGY PLAN
FOR THE CIVIL SPACE PROGRAM

AEROTHERMODYNAMICS

AN ELEMENT OF THE BASE RESEARCH AND TECHNOLOGY PROGRAM

JUNE 25, 1991

Dr. Kristin A. Hessenius
Deputy Director, Aerodynamics Division
Office Of Aeronautics, Exploration and Technology
National Aeronautics and Space Administration

Washington, D.C.

AEROTHERMODYNAMICS BASE R&T PROGRAM

OAET

- AEROTHERMODYNAMICS BASE R&T PROGRAM DEVELOPS AND APPLIES VALIDATED TOOLS FOR THE DESIGN AND OPTIMIZATION OF VEHICLES REQUIRED TO EXIT, ENTER AND MANEUVER IN EARTH/PLANETARY ATMOSPHERES

- FOR TRANSPORTATION, AEROTHERMODYNAMICALLY EFFICIENT CONFIGURATION DESIGN RESULTS IN:
  - REDUCED DESIGN MARGINS
  - HIGHER PERFORMANCE
  - REDUCED LIFE CYCLE COSTS

- FOR EXPLORATION, AEROTHERMODYNAMICS TECHNOLOGY CAN ALSO BE MISSION ENABLING

AEROTHERMODYNAMICS BASE R&T PROGRAM

OAET

- OAET HAS A RECOGNIZED IN-HOUSE CAPABILITY FOR PERFORMING AEROTHERMODYNAMIC ANALYSES:
  - NASA - OFFICE OF SPACE FLIGHT REFERENCES THEIR RELIANCE ON THIS CAPABILITY FOR ADVANCED TRANSPORTATION SYSTEM CONCEPT DEVELOPMENT
  - SPACE EXPLORATION INITIATIVE (SEI) OFFICE, HAVING IDENTIFIED AEROBRAKING AS A "CATEGORY 1" TECHNOLOGY, REQUIRES THE PRODUCTS OF BOTH THE BASE PROGRAM AND THE FOCUSED "AEROASSIST (BRAKING)" PROGRAM
- AN AUGMENTED AEROTHERMODYNAMICS R&T BASE WILL DIRECTLY ADDRESS THE INSUFFICIENCIES OF OUR PRESENT PROGRAM TO MEET CUSTOMER NEEDS:
  - PACE OF THE DEVELOPMENT OF COMPUTATIONAL DESIGN AND ANALYSIS TOOLS
  - ADEQUACY OF EXPERIMENTAL CAPABILITY TO VALIDATE SUCH TOOLS AND PROVE DESIGN CONCEPTS
  - APPLICATION OF VALIDATED TOOLS AND FACILITIES FOR CONFIGURATION DESIGN AND ASSESSMENT

AEROTHERMODYNAMICS BASE R&T PROGRAM

OAET

NET FY 93 INVESTMENT STRATEGY

$ M CURRENT PROGRAM ($M PROPOSED STRATEGIC PROGRAM)

COMPUTATIONAL TOOL DEVELOPMENT	Detailed Flowfield/Fluid Properties Analysis Tools $1.87 M ($3.5 M)		Vehicle Synthesis Engineering Tools $0.29 M ($0.7 M)
EXPERIMENTAL RESEARCH/ COMPUTATIONAL VALIDATION	Ground-Based Data Acquisition and Analysis $0.44 M ($1.0 M)		Flight Data Analysis $0.14 M ($0.8 M)
FACILITIES RESEARCH/ DEVELOPMENT	Existing Facility Upgrades $0.07 M ($1.5 M)	Test Technique Development $0.16 M ($1.25 M)	Facilities Concept Studies $0.07 M ($1.0 M)
CONFIGURATION ASSESSMENT	Candidate Vehicles: PLS, ACRV, SDIO-SSTO, HLLV, NLS, Shuttle Evolution, AMLS, NDV's $0.75 M ($2.5 M)		

AEROTHERMODYNAMICS BASE R&T PROGRAM BUDGET IMPLICATIONS

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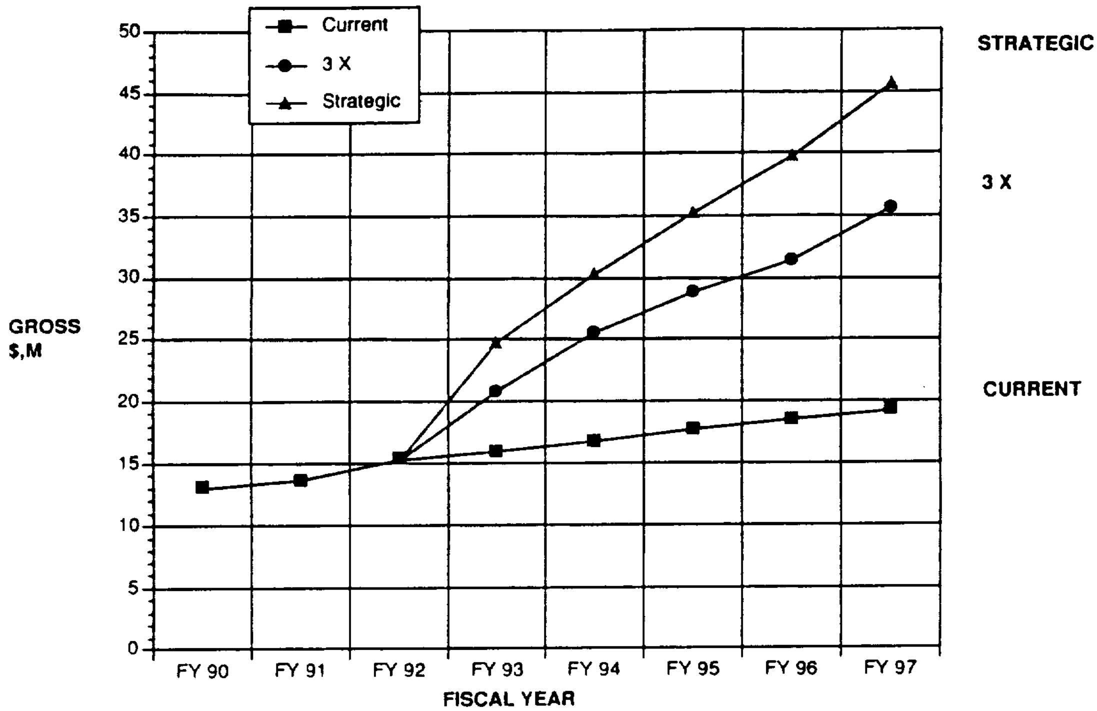

AEROTHERMODYNAMICS BASE R&T PROGRAM TECHNICAL NEEDS

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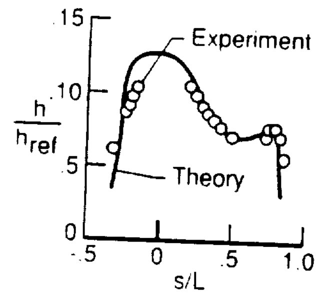
COMPUTATIONAL TOOL DEVELOPMENT	Detailed Flowfield/Fluid Properties Analysis Tools	Vehicle Synthesis Engineering Tools
	• Transition/Turbulence modeling • Thermo-chemical, non-equilibrium modeling • Radiative transport • Complex geometries • Computational efficiency	• Improved CAD interfaces • Enhanced solid modeling • Expert systems • Optimization algorithms

AEROTHERMODYNAMICS BASE R&T PROGRAM
TECHNICAL NEEDS

OAET

EXPERIMENTAL RESEARCH/ COMPUTATIONAL VALIDATION	Ground-Based Data Acquisition and Analysis	Flight Data Analysis
	• Fundamental fluid physics databases • Code validation databases	• OEX (Earth-to-Orbit) • AFE (Aerobraking) • Galileo (Planetary entry)



AEROTHERMODYNAMICS BASE R&T PROGRAM
TECHNICAL NEEDS

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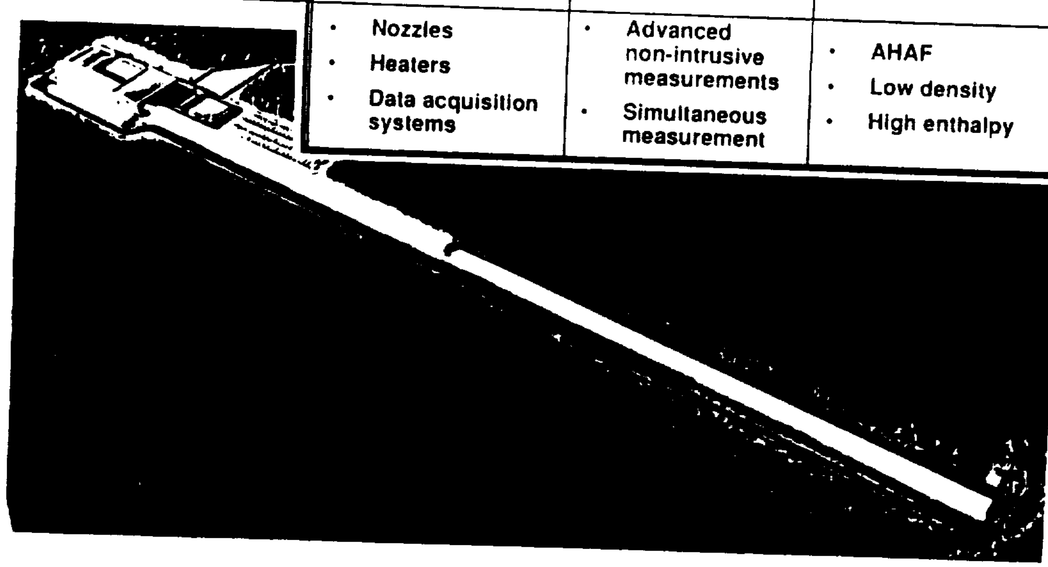
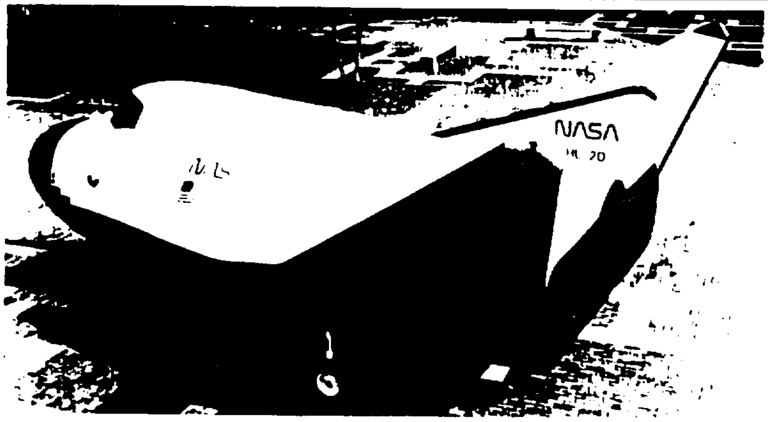
FACILITIES RESEARCH/ DEVELOPMENT	Existing Facility Upgrades	Test Technique Development	Facilities Concept Studies
	• Nozzles • Heaters • Data acquisition systems	• Advanced non-intrusive measurements • Simultaneous measurement	• AHAF • Low density • High enthalpy



AEROTHERMODYNAMICS BASE R&T PROGRAM
TECHNICAL NEEDS

CONFIGURATION ASSESSMENT	Candidate Vehicles		
	• PLS	• NLS	• AMLS
	• ACRV	• Shuttle Evolution	• SDIO/SSTO
			• Foreign



AEROTHERMODYNAMICS BASE R&T PROGRAM

- NASA NOW AT CRITICAL JUNCTURE IN PLANNING FOR OUR FUTURE TRANSPORTATION SYSTEMS

- SYSTEMS DESIGNED FOR PERFORMANCE AT LOWEST LIFE CYCLE COST ARE MANDATORY

- AEROTHERMODYNAMICALLY EFFICIENT DESIGNS ARE KEY TO REDUCED DESIGN MARGINS, HIGHER PERFORMANCE AND RESULTING LOWER COST

- THE OAET AEROTHERMODYNAMICS BASE R&T PROGRAM, WITH ADEQUATE INVESTMENT, WILL SERVE AS A UNIQUE AGENCY RESOURCE FOR THE DESIGN AND OPTIMIZATION OF AEROSPACE VEHICLES

Office of
Aeronautics,
Exploration and
Technology

MATERIALS & STRUCTURES INTEGRATED TECHNOLOGY PLAN OVERVIEW

PRESENTED TO

SSTAC/ARTS REVIEW COMMITTEE

Samuel. L Venneri
Director
Materials & Structures Division
June 25, 1991

MATERIALS AND STRUCTURES FY 1993 ITP PROGRAM

BASE R&T

MATERIAL SCIENCE
- MATERIAL SYNTHESIS
- *COMPUTATIONAL MATERIALS*
- COMPUTATIONAL CHEMISTRY
- *OPTICS*
- POWER & PROPULSION MAT'LS.

SPACE ENVIRONMENTAL EFFECTS
- DEBRIS PROTECTION
- SPACE ENVIRONMENTAL EFFECTS
- SPACECRAFT MATERIALS

AEROTHERMAL STRUCTURES & MATERIALS
- THERMAL PROTECTION SYSTEMS
- *ARCJET RESEARCH*
- *HEAVY LIFT LAUNCH*
- HOT STRUCT./INTEGRATED DESIGN

SPACE STRUCTURES
- STRUCTURAL CONCEPTS
- *SPACE MECHANISMS*
- *SPACE WELDING & BONDING*
- SPACE CONSTRUCTION
- NDE/NDI

DYNAMICS OF FLEXIBLE STRUCTURES
- ADVANCED TEST TECHNIQUES
- ADAPTIVE STRUCTURES
- *SPACE DYNAMIC ANALYSIS*
- *VIBRATION & ACOUSTIC ISOLATION*

FOCUSED PROGRAMS

SCIENCE
- SAMPLE ACQUISITION, ANAL. & PRESER.
- TELESCOPE OPTICAL SYSTEMS
- MICRO-CSI

TRANSPORTATION
- ETO STRUCTURES & CTRYOTANKS
- TRANSFER VEHICLE STRUCTURES & CRYO.

EXPLORATION
- RADIATION PROTECTION
- IN-SITU RESOURCE UTILIZATION
- SURFACE HABITATS & CONSTRUCTION
- ARTIFICIAL GRAVITY
- (POWER BEAMING)

PLATFORMS
- PLATFORM-CSI
- STRUCTURES
- NDE/NDI
- MATERIALS & SPACE ENVIRON. EFFECTS

OPERATIONS
- IN-SPACE ASSEMBLY & CONSTRUCTION

GENERIC HYPERSONICS (BASE R&T)

AERONAUTICS AND SPACE ENGINEERING BOARD REPORT ON SPACE TECHNOLOGY TO MEET FUTURE NEEDS (1987)
TECHNOLOGY ISSUES - MATERIALS AND STRUCTURES

- "Major structures and materials breakthroughs were neither required nor employed in the transition from Apollo to Shuttle. Convevtional (circa 1970) airframe materials technology coupled with minor improvements ... are still the mainstay of space structure design..."
- "Materials and structures technology needs encompass space durable materials, dimensionally stable materials; advanced thermal protection system (TPS) concepts; advanced coatings; stiff light-weight, high-strength structural composites; advanced space structural concepts; and development of an adequate data base for advanced concepts that will allow for confident design."

Technology Drivers:

Lightweight
Large Size
High Temperature
High Precision and Dimensional Stability
Space Durability
Hot/warm Structures versus Insulating TPS
Ground Testing and NDE/NDI

Conclusion: 1970's technology is not adequate for the 1990's and beyond

STAFFORD REPORT

SUPPORTING TECHNOLOGIES

Technology will provide the tools for safe cost effective exploration of the Moon and Mars. Technology development is required in the following areas:

- Heavy lift launch with a minimum capability of 150 metric tons with designed growth to 250 metric tons
- Nuclear thermal propulsion
- Nuclear surface power to megawatt levels
- Extravehicular activity suit
- Cryogenic transfer and long term storage
- Automated rendezvous and docking of large masses
- Zero gravity countermeasures

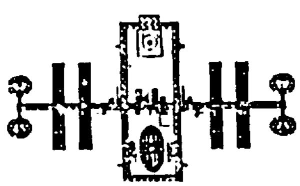
- Radiation effects and shielding
- Telerobotics
- Closed loop life support systems
- Human factors for long duration space missions
- Lightweight structural materials and fabrication
- Nuclear electric propulsion for follow-on cargo missions
- In-situ resource evaluation and processing

MATERIALS AND STRUCTURES BASE R&T FUNDING

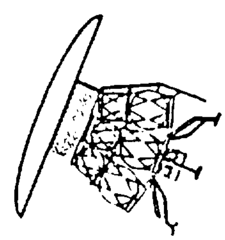
OAET

FY 1991 TOTAL: $19400 K NET: $11350 K (INCLUDES $2540 K IN GENERIC HYPERSONICS)	PERCENT OF FY 1991 NET	FY 1992 TOTAL: $20930 K NET: $11350 K (INCLUDES $2640 K IN GENERIC HYPERSONICS)	PERCENT OF FY 1992 NET
MATERIAL SCIENCE $1940 K	17.1	MATERIAL SCIENCE $2160 K	19.0
SPACE ENVIRONMENTAL EFFECTS $2220 K	19.6	SPACE ENVIRONMENTAL EFFECTS $1330 K	11.7
AEROTHERMAL STRUCTURES AND MATERIALS $3110 K	27.4	AEROTHERMAL STRUCTURES AND MATERIALS $3110K	27.4
SPACE STRUCTURES $1190 K	10.5	SPACE STRUCTURES $1790 K	15.8
DYNAMICS OF FLEXIBLE STRUCTURES $350 K	3.1	DYNAMICS OF FLEXIBLE STRUCTURES $320 K	2.8

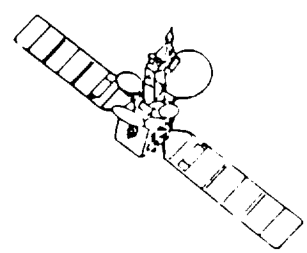
MISSIONS PROVIDING SPACE MATERIALS TECHNOLOGY FOCUS



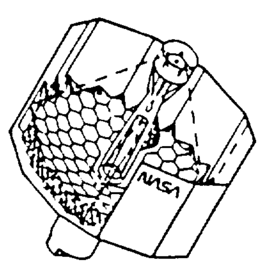
Space Station



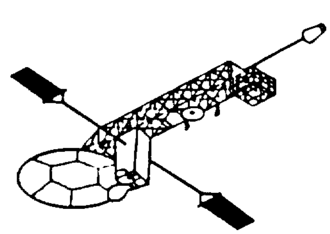
Lunar and Mars transfer vehicles



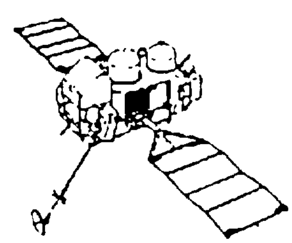
Communications satellites



Astrophysics missions



Mission to planet earth



Science missions

TECHNOLOGY PERSPECTIVE SPACE MATERIALS

1980's

- Composites
  - Application of aircraft composites
    - Microcracking
    - Moisture expansion
    - Thermal hysterisis
    - Residual stresses
- Structures
  - Large erectable/deployable truss structures
  - Low precision reflectors
- Films and coatings
  - Screening for AO resistance
  - Transparent polyimide films
  - Large area anodizing of Al

1990's And Beyond

- Composites
  - Development of new space tailored composites
    - New resins (cyanates)
    - Ultra-high modulus fibers
    - Innovative processing (low residual stress)
    - Smart materials
- Structures
  - High precision optical benches
  - Large lightweight high precision reflectors
  - Deployable/rigidable materials and structures
- Films and coatings
  - Space tailored polymers
  - Inorganic composites/coatings

TECHNOLOGY PERSPECTIVE SPACE MATERIALS (CONT.)

1980's

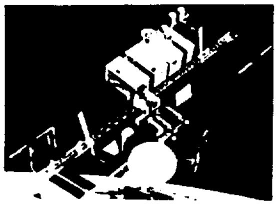
- Space env. exposure/simulation
  - Single parameter simulation or sequential exposure
  - Characterization/fundamental understanding
  - Radiation effects on materials
  - Single parameter environment/ materials modeling
  - 1st generation flight experiments
    - STS-3, 5, 8
    - LDEF

1990's And Beyond

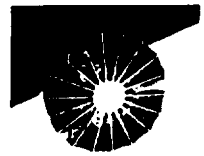
- Space env. exposure/simulation
  - Combined exposures
    - e^+, p^+, UV, ΔT
    - AO, UV, ΔT
    - AO, micrometeoroids, ΔT
  - Materials certification test methodology
  - Radiation shielding for humans
  - Life prediction modeling
  - Next generation flight experiments
    - EOIM 3
    - TDMX-2011
    - "Benchmark"

SPACE MATERIALS AND STRUCTURES

SPACE STATION



SPACE TRANSPORTATION SYSTEMS

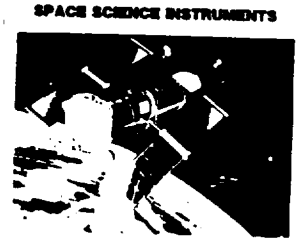


CANDIDATE MATERIALS

- LIGHT ALLOYS
- METAL-MATRIX COMPOSITES
- C-C COMPOSITES
- CERAMIC-MATRIX COMP.
- COATINGS
- POLYMER FILMS
- RESIN-MATRIX COMP.

COMMUNICATION SATELLITES

SPACE SCIENCE INSTRUMENTS



RM 500.0

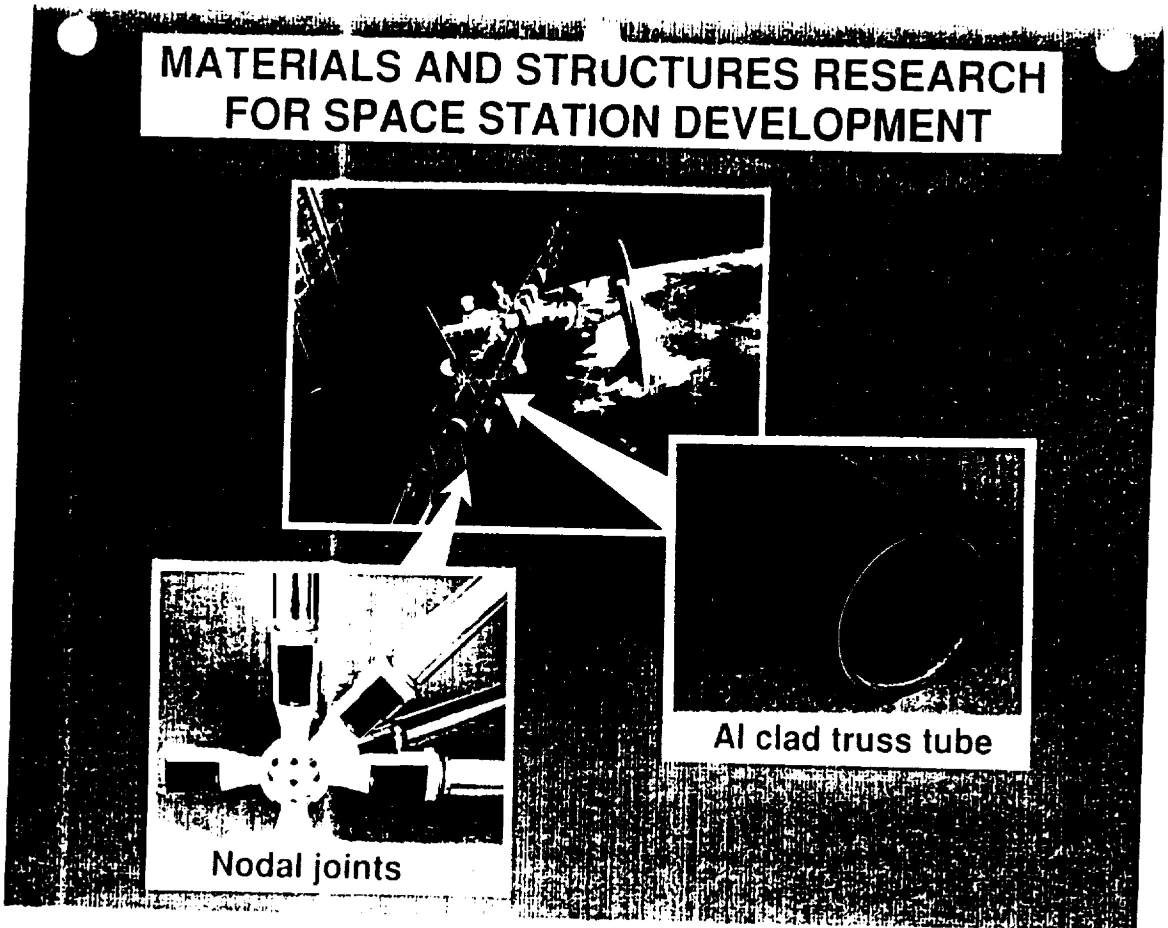
TECHNICAL PERSPECTIVE SPACE STRUCTURES

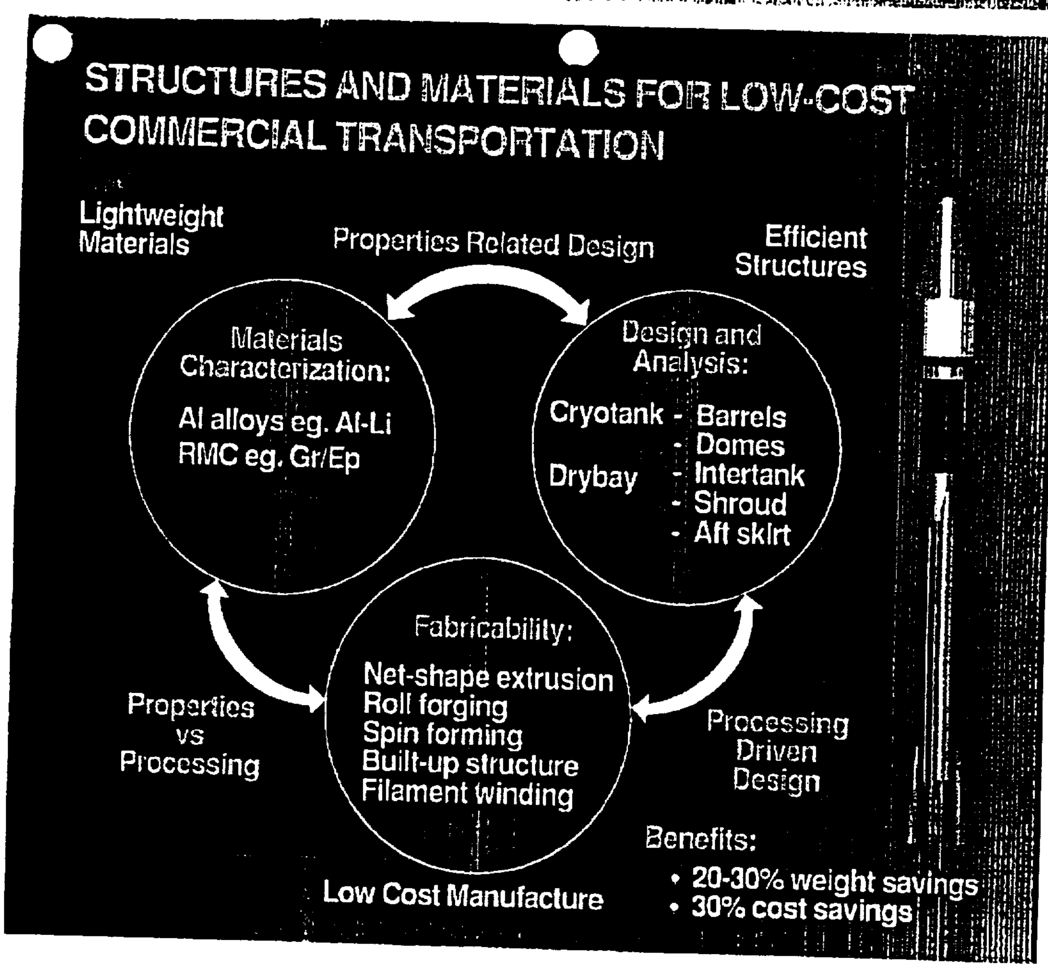
1980's
"ERA OF SPACE STATION'

- Flat Trusses/Equal Length Struts
- Design Methodology for Near-Earth Environment (LEO, GEO)
- Erectable Space Station Truss Structure
- Space Station Pressure Vessel Structures
- Conventional Aluminum Design Concepts - Conventional Manufacturing
- EVA Manual Assembly - Low Mass Components and Ease of Construction
- Large Antennae - Deployable Concepts, Low Frequency (<30 GHz) and Lightweight Submillimeter Telescopes

1990's And Beyond
"ERA OF SPACE SCIENCE AND EXPLORATION"

- Doubly- Curved Trusses/Unequal Strut Lengths, High Precision
- Design Methodology for Deep Space Environment (GEO, Lunar and Mars)
- Complex Modular Structures, Joining/Welding and Precision Erectable/Deployable
- Lightweight Lunar Habitats and Construction Methods
- Advanced Alloys and Composites for Low-Cost Fabrication, e. g., Gr/Ep Shells, Superplastic Forming, etc.
- Robotic Assembly - Precision Structures and Large Mass Manipulation, Integrated Utilities
- Large Precision Antennae (30-100GHz) and Telescopes (RF Thru UV/Visible) - Complex Shape Control

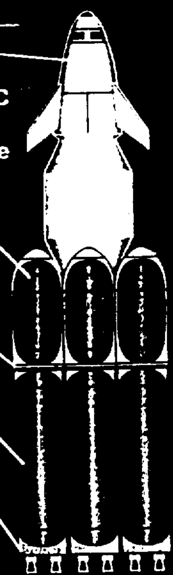

MATERIALS AND STRUCTURES RESEARCH FOR SPACE STATION DEVELOPMENT
Al clad truss tube
Nodal joints


STRUCTURES AND MATERIALS FOR LOW-COST COMMERCIAL TRANSPORTATION
Lightweight Materials
Properties Related Design
Efficient Structures
Materials Characterization:
Al alloys eg. Al-Li
RMC eg. Gr/Ep
Design and Analysis:
Cryotank - Barrels
- Domes
Drybay - Intertank
- Shroud
- Aft skirt
Fabricability:
Net-shape extrusion
Roll forging
Spin forming
Built-up structure
Filament winding
Properties vs Processing
Processing Driven Design
Low Cost Manufacture
Benefits:
• 20-30% weight savings
• 30% cost savings

VEHICLE STRUCTURES AND CRYOTANKS FOR EARTH TO ORBIT TRANSPORTATION

Materials

- PLS
  - Advanced C-C & TPS
  - Al-Li structure
- LOX tank
  - Al-Li
- Intertank
  - Gr/E
- LH_2 tank
  - Al-Li
- Aft skirt
  - Al-Li



Structures

- PLS
  - Improved design codes & aerothermal analysis
- Cryotanks
  - Design of net section and built-up Al-Li components
- Intertank
  - Design of Gr/E structure
  - Structural analysis of Al-Li, Gr/E interface

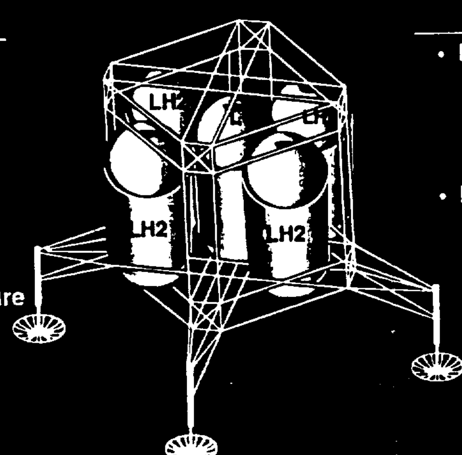
Benefits

- Advanced materials: 20-30% weight savings
  Improved durability & lighter weight TPS
  Increased payload capability
  Lower systems cost ($/lb to orbit)
- Low cost processing: 30% cost saving
  Reduced manufacturing time
- Advanced structural design & aerothermal analysis: Improved structural efficiency - lower weight
  Increased reliability

MATERIALS AND STRUCTURES TECHNOLOGY FOR SPACE TRANSFER VEHICLES

Cryotank

- Materials
  - Al-Li
  - SiCp/Al MMC
  - Ti
  - RMC
- Low cost fabrication
  - Spun formed domes
  - SPF, Built-up structure
  - Filament wound RMC tanks
  - Explosively formed components



Core primary structure

- Materials
  - Al-Li
  - B/Al MMC
  - Gr/E
- NDE/durable materials
  - Real time radiography
  - Advanced ultrasonics
  - Space hardened materials
  - Protective coatings/platings

Benefits

- Advanced materials: 20-30% weight savings
  Increased payload
  Greater range
- Low cost fabrication: 30% cost savings
  Reduced assembly time
- NDE/durable materials: Increased reliability and vehicle life

TECHNOLOGY PERSPECTIVE
SPACE STRUCTURAL DYNAMICS

1980's

- Structural Dynamics - Uncoupled Rigid Body Dynamics and Linear Control
- Conventional Aerospace Material Systems Used for Tailoring Spacecraft Structural Dynamics
  - Metals Design Data Base
  - Uniform Properties
- Ground-Based System ID Methodology for Structural Verification
- Capability for Linear, Small Deflection Dynamics of Space Structures
- Analysis and Ground-Based Testing Methodology for Spacecraft Qualification
  - Component Level Testing
  - Scale Model Tests
  - Full-Scale Behavior From Sub-Component Analysis and Synthesis

1990's And Beyond

- Integrated Controls/Structures Interaction - Nonlinear Coupled Behavior
- "Smart" Material Systems Integrated Into Optimized Structural Dynamics and Control
  - Active Members
  - Embedded Sensors/Actuators
- On-Orbit System ID for Final Verification of Large Flexible Structures
- Capability to Predict Behavior & Performance for Large Motions of Complex Articulating Structures
- New Qualification Methodology for Large Complex Space Structures
  - Reliable Full-Scale Analysis and Design Optimization Methods
  - Adaptive Structures
  - Full-Scale On-Orbit Testing

TECHNOLOGY PERSPECTIV E
AEROTHERMAL MATERIALS AND STRUCTURES

1980's

- Uncoupled Fluid, Thermal, Structural Vehicle Analysis and Design
- Combined Thermal and Mechanical Load Testing Capability
- High Temperature, Flow Test Facilities for Shuttle Re-entry (1000-25,000 BTU/lb)
- Rigid and Flexible Shuttle TPS Insulation Systems (1000-2500°F)
- Insulated Aluminum Structural Concepts
- Carbon-Carbon Material System with Limited-Use Coatings for Nonstructural Applications
- Applications Using Isotroptic, Monolithic Metallics and Refractory Material Systems (Superalloys, Ti, Intermetallics)

1990's And Beyond

- Integrated Fluid-Thermal-Structural Vehicle Analysis and Design Optimization
- Integrated Thermal, Mechanical and Cryogenic Complex Load Environment Simulation Test Capability
- High Temperature, Flow Facilities for High Enthalpy Earth Re-Entry (Aerobrake - 20,000-50,000 BTU/lb)
- Advanced Composite TPS Material Concepts (3000-5000°F)
- Integrated Insulated and Hot Structures Design Concepts
- Carbon-Carbon Material and Tailored Coating Systems for Primary Load-Carrying Structures
- Applications Using Fiber Reinforced Metal Matrix Composites and Refractory Composites (Gr/MMC, Advanced Intermetallic Composites)

BASE R&T AUGMENTATION PROCESS

OAET — MATERIALS & STRUCTURES

RESPONSE TO AUGUSTINE REPORT RECOMMENDATION #8

- CENTER INPUT REVIEWED FOR RELEVANCE, CONTENT AND BUDGET
- PROPOSED AUGMENTATION FORMULATED BY RM RESPONSIVE TO CURRENTLY PERCEIVED AGENCY NEEDS AND BUDGET GUIDELINES
- CANDIATE AUGMENTATION PACKAGES FORMULATED AT PROGRAM ELEMENT/SUB-ELEMENT LEVEL INCORPORATING
  - OBJECTIVE
  - RATIONALE
  - PAYOFF
  - BUDGET AUGMENTATION RUNOUT
  - PRODUCTS
  - CENTERS
- CENTER PERSONNEL CONSULTED AT PROGRAM ELEMENT AND SUB-ELEMENT LEVEL
- DRAFT DISTRIBUTED TO CENTERS FOR REVIEW
- FINAL PROGRAM UNDER DEVELOPMENT

BASE R&T AUGMENTATION PROCESS

OAET — MATERIALS & STRUCTURES

PROGRAM IMPLEMENTATION STRATEGY FOR X2 TO X3 BUDGET

- COMPOSITION OF TOTAL BASE R&T PROGRAM:

  ON-GOING:
  - FUNDAMENTAL IN-HOUSE CAPABILITY
  - SUPPORTING GRANTS AND CONTRACTS

  NEW ACTIVITY:
  - "RESEARCH PROJECTS"
    - GOAL ORIENTED, DIRECTED RESEARCH
    - DEFINED RESOURCES AND SCHEDULE OF ACCOMPLISHMENTS
    - FUNDED AT MODEST LEVELS (< $1000 K/YR) FOR 2 TO 4 YEARS
    - TRANSITION TO FOCUSED PROGRAM, CONTINUE AT LOW LEVEL OR TERMINATE
- "RESEARCH PROJECTS" CAN BE IN-HOUSE, GRANTS, OR CONTRACTS
- GRANTS , CONTRACTS AND "RESEARCH PROJECTS" PROVIDE MECHANISM FOR PROGRAM ROLLOVER FOR NEW INNOVATIVE IDEAS
- X3 BUDGET SUBSTANTIALLY INCREASE INDUSTRY AND UNIVERSITY INVOLVEMENT (>60%)

FOCUSED PROGRAMS - BASE R&T

OAET — MATERIALS & STRUCTURES

FOCUSED PROGRAMS

CSI, TELESCOPE TECHNOLOGY, RADIATION PROTECTION, ETC.

BASE R&T - "RESEARCH PROJECTS"

EXAMPLE: DEVELOP LONG-LIFE BEARING FOR 1000 TO 5000 RPM BY FY 1995

EXAMPLE: COMPUTATIONALLY PREDICT STRUCTURAL PROPERTIES OF POLYIMIDE POLYMER CHAIN BY FY 1995

EXAMPLE: DEVELOP LIGHTWEIGHT COMPOSITE JOINT FOR ERECTABLE STRUCTURES BY FY 1994

BASE R&T - FUNDAMENTAL

IN-HOUSE, GRANTS, CONTRACTS

BASE R&T AUGMENTATION PROCESS

OAET — MATERIALS & STRUCTURES

"RESEARCH PROJECT" IMPLEMENTATION APPROACH

- ANNUAL IDENTIFICATION OF PRIORITY RESEARCH AREAS AND ALLOCATION OF AVAILABLE FUNDS
  - NASA HEADQUARTERS
  - NASA CENTERS
  - REVIEW COMMITTEES

→

- PROPOSED RESEACH PROJECTS SOLICITED THROUGH NASACENTERS
  - IN-HOUSE
  - OUT-OF-HOUSE

→

- INITIAL EVALUATION MADE BY EACH CENTER
- PRELIMINARY SELECTION MADE BY HEADQUARTERS

→

- HEADQUARTERS SELECTION REVIEWED BY INDEPENDENT COMMITTEE (E.G. ARTS)

BASE R&T

OAET — MATERIALS & STRUCTURES

PROGRAM REVIEW

- ANNUAL REVIEWS BY OUTSIDE COMMITTEE
  - STANDING ARTS COMMITTEE
  - INVITED SPECIALISTS
  - REVIEWS AT NASA HQ
- EMPHASIS ON NEW ACTIVITIES AND "MATURE" ACTIVITIES
  - GENERAL REVIEW OF THE ENTIRE PROGRAM
  - DETAILED REVIEW OF NEW ACTIVITIES BEFORE INITIATION
  - DETAILED BI-ANNUAL REVIEW OF "RESEARCH PROJECTS" AND CRITICAL ON-GOING PROGRAMS
- PURPOSE OF REVIEW
  - INDEPENDENT EVAUATION OF QUALITY AND RELEVANCE OF BASE R&T
  - ASSURE POTENTIAL USERS AWARE OF PROGRAMS AND ACCOMPLISHMENTS

BASE AUGMENTATION PROCESS

OAET — MATERIALS & STRUCTURES

FY 1992 NET FUNDING BY AREAS IDENTIFIED FOR AUGMENTATION

(UNDERLINE IDENTIFIES NEW AREA)

TOTAL: $20930 K
NET: $11350 K

(INCLUDING $2640 K IN GENERIC HYPERSONICS *EXCLUDS $1700 K OF "BASE R&T" IN CSI)

MATERIAL SCIENCE **$2160 K**	COMPUTATIONAL CHEMISTRY - $290 K *COMPUTATION L MATERIALS*	MATERIAL SYNTHESIS $1170 K	*OPTICS* -	POWER & PROPULSION MATLS $700 K
SPACE ENVIRONMENTAL EFFECTS **$1330 K**	DEBRIS PROTECTION $50 K	SPACE ENVIRONMENT EFFECTS $1000 K	SPACECRAFT MATERIALS $280 K	
AEROTHERMAL STRUCTURES AND MATERIALS **$3110K**	THERMAL PROTECTION SYSTEMS $310 K	*ARCJET RESEARCH* *$100 K*	*HEAVY LIFT LAUNCH SYSTEMS* -	HOT STRUCTURES/ INTEGRATED DESIGN $2700 K
SPACE STRUCTURES **$1790 K**	STRUCTURAL CONCEPTS & SPACE CONST. $1790 K	*SPACE MECHANISMS* *($500 K)*	*SPACE WELDING AND BONDING* *$100 K*	*NDE/NDI* -
DYNAMICS OF FLEXIBLE STRUCTURES* **$320 K**	ADVANCED TEST TECHNIQUES $70 K	ADAPTIVE STRUCTURES $250 K	*SPACECRAFT DYNAMIC ANALYSIS* -	*VIBRATION AND ACOUSTIC ISOLATION* -

BASE R&T AUGMENTATION PROCESS

OAET — MATERIALS & STRUCTURES

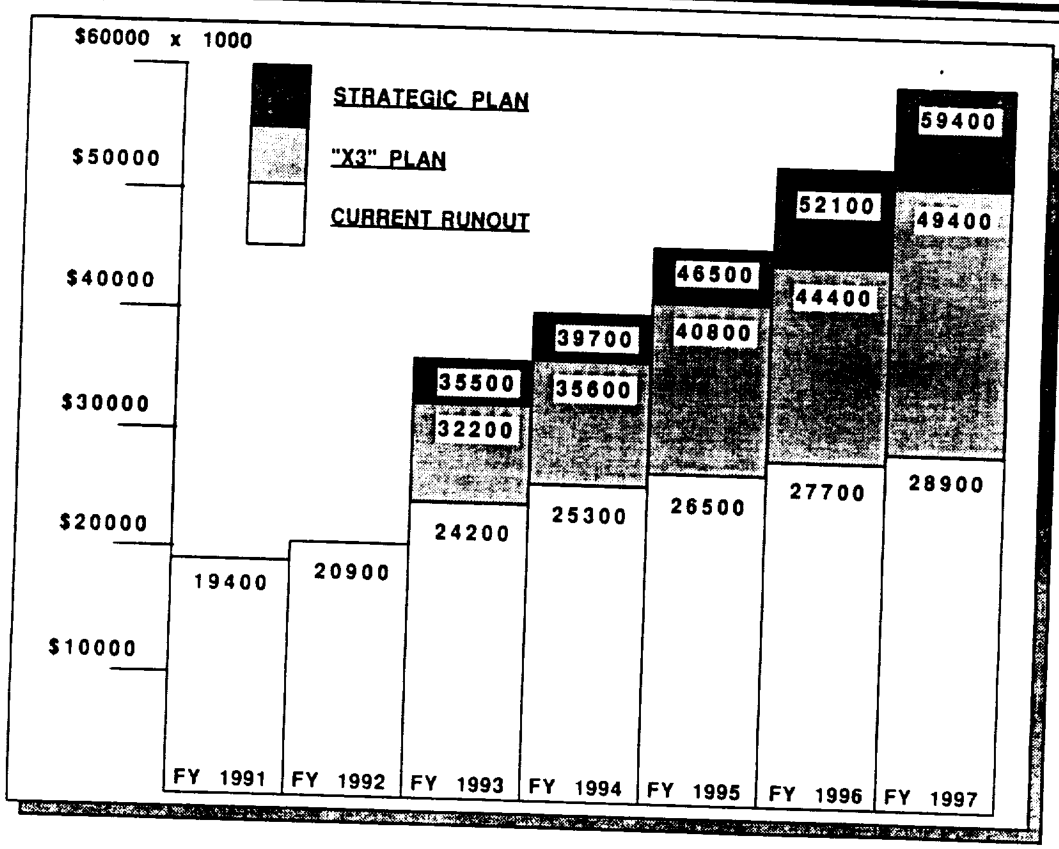
AREAS IDENTIFIED FOR FY 1993 AUGMENTATION

(UNDERLINE IIDENTIFIES NEW AREA)

MATERIAL SCIENCE	*COMPUTATIONAL MATERIALS*		*OPTICS*	
SPACE ENVIRONMENTAL EFFECTS	DEBRIS PROTECTION	SPACE ENVIRONMENT EFFECTS	SPACECRAFT MATERIALS (INCLUDES MATERIAL SYNTHESIS AND SPACE DURABLE MAT.)	
AEROTHERMAL STRUCTURES AND MATERIALS	THERMAL PROTECTION SYSTEMS	*ARCJET RESEARCH*		
SPACE STRUCTURES	STRUCTURAL CONCEPTS & SPACE CONSTRUCTION	*SPACE MECHANISMS*	*SPACE WELDING AND BONDING*	*NDE/NDI*
DYNAMICS OF FLEXIBLE STRUCTURES		ADAPTIVE STRUCTURES		*VIBRATION AND ACOUSTIC ISOLATION*

MATERIALS AND STRUCTURES BASE R&T FUNDING

OAET



PROPULSION AND POWER RESEARCH AND TECHNOLOGY BASE

Presentation to

THE ITP EXTERNAL EXPERT REVIEW TEAM

Earl E. VanLandingham
Director
Propulsion, Power and Energy Division

June 25, 1991

OAET

BASE RESEARCH AND TECHNOLOGY PROGRAM

PROPULSION TECHNOLOGY

OAET

PROPULSION TECHNOLOGY

R&T BASE ELEMENTS

- LOW THRUST PROPULSION (PRIMARY & AUXILIARY)
- ADVANCED PROPULSION CONCEPTS
- HIGH THRUST CHEMICAL PROPULSION
- CRYOGENIC FLUID MANAGEMENT

"TECHNOLOGY PUSH"

FOCUSED TECHNOLOGY PROGRAMS

- ETO PROPULSION
- LOW COST COMMERCIAL TRANSPORT PROPULSION
- AUXILIARY PROPULSION
- ADVANCED CRYO ENGINE
- CRYO FLUID SYSTEMS & EXPERIMENTS
- NUCLEAR THERMAL PROPULSION
- NUCLEAR ELECTRIC PROPULSION
- STATION-KEEPING PROPULSION
- SPACECRAFT ON-BOARD PROPULSION

"MISSION PULL"

PROPULSION, POWER AND ENERGY DIVISION

OBJECTIVES

PROGRAMMATIC

Provide a technology base and maintain an institutional capability for continued advances in the development of advanced space propulsion systems to enable challenging future NASA missions.

TECHNICAL

30-40 sec. Increase in Chemical Rocket Isp
10 x Increase in Storable Arcjet Power
6 x Throttling of H2 Arcjet
5000 sec. Isp, 75% Efficient Ion Propulsion
Reduced Operations Cost, Increased Life
High Energy Density/Power Electric Propulsion
High Energy Density Propellants

MILESTONES

FY-92: Demonstrate 100 LBF Ir-Re Rocket
FY-92: Demonstrate 10kHr Ion Engine Life
FY-93: Verify 3D CFD Model for Small Rockets.
FY-94: Complete 3D Plume Code Development
FY-94: 10 KWe Ion Engine Life & Perf Demo.
FY-94: Complete H/O Stability Model
FY-95: Demonstate Flight Weight Ir-Re Rocket
FY-96: Complete Atomic Hydrogen Engine/Feed System Fabrication
FY-97: Establish MPD Electrode Erosion/life Model
FY-99: Demonstate Basic Principles of Microwave Heating and Plasma Containment.

RESOURCES ($M)

	CURRENT	"3X"	STRATEGIC
FY91	14.8	14.8	14.8
FY92	16.7	16.7	16.7
FY93	17.2	20.4	23.0
FY94	18.0	26.2	28.7
FY95	18.8	30.1	33.7
FY96	19.7	32.9	38.0
FY97	20.6	36.9	43.9

PARTICIPANTS

LEWIS RESEARCH CENTER
- Auxiliary Chemical & Electric Propulsion
- Electric Primary Propulsion
- Advanced Concepts
- High Thrust Chemical
- Cryogenic Fluid Management
- Use of In-situ Propellants

JET PROPULSION LABORATORY
- Advanced Propulsion Concepts
- Electric Propulsion for Planetary Missions

MARSHALL SPACE FLIGHT CENTER
- High Thrust Chemical

BASE RESEARCH AND TECHNOLOGY PROGRAM

SPACE PROPULSION R&T

SPACE PROPULSION SYSTEMS

- *MISSION RELATED TECHNOLOGY DRIVERS*

- REDUCED LAUNCH COSTS
- INCREASED TRANSFER VEHICLE PERFORMANCE AND LIFE
- PROVIDE REUSE, SPACE BASING FOR SPACE PROPULSION SYSTEMS
- REDUCED PLANETARY AND CARGO VEHICLE TRIP TIMES
- REDUCED SATELLITE/VEHICLE MASS - INCREASED LIFE
- REDUCED NUMBER OF VEHICLE PROPELLANT SYSTEMS
- INCREASED PERFORMANCE & RELIABILITY OF UPPER STAGES
- INCREASED THROTTLING FOR ASCENT/DESCENT ENGINES
- ADVANCED PROPULSION SYSTEMS FOR FUTURE HIGH ENERGY MISSIONS

BASE RESEARCH AND TECHNOLOGY PROGRAM

SPACE PROPULSION R&T

SPACE PROPULSION SYSTEMS

MISSION SPECIFIC

HIGH PERFORMANCE ORBIT RAISING PROPULSION
INTEGRATED H/O PROPULSION
FLUID FILM BEARINGS/SEALS
NO VENT FILL CRYOGENIC SYSTEMS
PROPULSION SYSTEM HEALTH MANAGEMENT
MMW MPD THRUSTERS
H2 ARCJETS
WATER RESISTOJETS

BREAKTHROUGH

ELECTRODELESS THRUSTERS (ECR, MICROWAVE)
HIGH-ENERGY DENSITY PROPELLANTS
BEAMED ENERGY/LASER ROCKETS
FISSION/FUSION PROPULSION
SUPER CONDUCTING MAGNETIC BEARINGS

CAPABILITY

INTERNAL PUMP FLOW CFD
EXPERT SYSTEM ENGINE ANALYSIS
COMBUSTION DIAGNOSTICS
COMBUSTION PERFORMANCE/STABILITY MODELS
CRYO FLUID MGMT. ANAL. MODELS

BASE RESEARCH AND TECHNOLOGY PROGRAM

SPACE PROPULSION R&T

ELEMENT	CURRENT PROGRAM	STRATEGIC PROGRAM
ADVANCED CONCEPTS	Feasibility studies and limited laboratory experiments in the following areas: - Atomic hydrogen - MMW plasma rockets - Fusion; alternate energy states - Electrodless rockets	In-depth evaluations and experiments of more concepts with broader participation, including universities
ELECTRIC PROPULSION	Proof-of-concept demonstrations of: - 2-5 kW storable arcjet - 5 kW ion - 200 - 1000 kW MPD - 5-30 kW H2 arcjet	More extensive R&T of current program areas plus the following: - Water resistojets - SEP-class ion thrusters - Laser rocket demo - Antimatter, fusion and other advanced concepts
CHEMICAL PROPULSION	- Code development and validation for turbomachinery, combustion, and heat transfer - Engine system analyses - Advanced materials and fab. techniques - Adv. sensors/instrumentation, health monitoring, and diagnostics	Same content as current program applied to full-scale components and integrated system demonstrations, plus: - Alternate/parallel approaches, subcomp. - System-level code validations - Broadened applications - Alt. comp. nozzles, high mixture ratio

BASE RESEARCH AND TECHNOLOGY PROGRAM

PROPULSION TECHNOLOGY

OAET

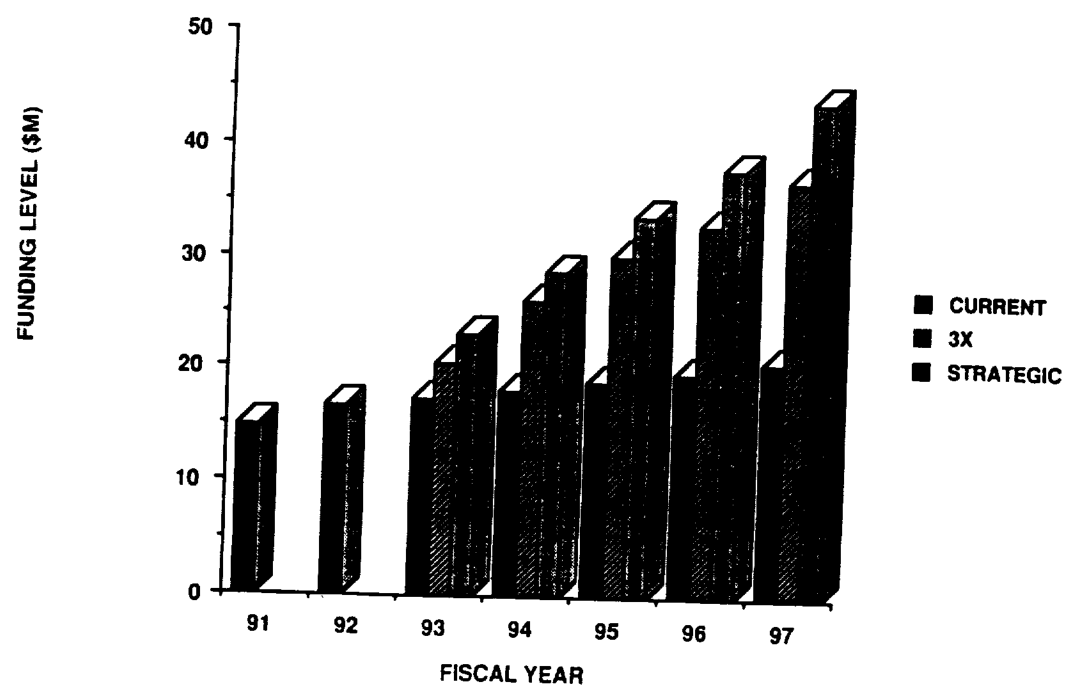
AUGMENTATION STRATEGY

- HIGH-RISK, INNOVATIVE, PROPULSION TECHNOLOGIES THAT HAVE THE POTENTIAL OF HIGH PAYOFF FOR FUTURE MISSIONS
  - LOW THRUST PROPULSION
  - ADVANCED PROPULSION CONCEPTS
- SPECIFIC ACTIVITIES TO COMPLEMENT FOCUSED TECHNOLOGY PROGRAMS
  - HIGH THRUST CHEMICAL PROPULSION (ETO PROPULSION, ADV. CRYO ENGINE)
  - CRYO FLUID MANAGEMENT (FOCUSED CRYO PROGRAM & FLIGHT EXPERIMENTS)
- SPECIFIC ACTIVITIES TO MAINTAIN OR ENHANCE NASA'S CAPABILITY TO RESPOND TO TECHNOLOGY NEEDS
  - CFD
  - PROPULSION SYSTEM ANALYSIS CODES
  - TECHNOLOGY TEST FACILITIES

BASE RESEARCH AND TECHNOLOGY PROGRAM

PROPULSION TECHNOLOGY

OAET



WBS No. 506-42 (CURRENT BUDGET)

REVISED 6/11/91

TECHNOLOGY ELEMENT:	PROPULSION R&T			WBS 506-42				CODE RP				
Sub-Element Resources: ($M)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
-31 Low Thrust (P&A)	5.8	5.2	5.4	5.6	5.8	6.1	6.3					
-41 Advanced Concepts	1.2	1.4	1.5	1.5	1.6	1.6	1.7					
-72 High Thrust Chemical	3.5	3.5	3.6	3.8	3.9	4.1	4.3					
-73 Cryogenic Fluid Management	1.5	2.6	2.0	2.1	2.2	2.2	2.3					
-74 Lunar/Planet Propellant	==	==	==	==	==	==	==					
Sub-Element Totals: ($M)	12.0	12.7	12.5	13.0	13.5	14.0	14.6					
CoF:												
CoF Totals:												
Resources Requirements: ($M)	12.0	12.7	12.5	13.0	13.5	14.0	14.6					
Program Support: ($M)	2.4	2.5	2.6	2.7	2.8	2.9	3.0					
Special Requirements: ($M)	0.4	1.5	2.1	2.3	2.5	2.8	3.0					
TOTAL ($M):	14.8	16.7	17.2	18.0	18.8	19.7	20.6					

Basis for Resource Estimates:

- Maintain current funding levels; adjust for inflation.

WBS No. 506-42 ("3X" BUDGET)

REVISED 6/11/91

TECHNOLOGY ELEMENT:	PROPULSION R&T			WBS 506-42				CODE RP				
Sub-Element Resources: ($M)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
-31 Low Thrust (P&A)	5.8	5.2	7.0	9.8	11.0	12.5	14.5					
-41 Advanced Concepts	1.2	1.4	3.2	4.0	4.7	5.0	6.0					
-72 High Thrust Chemical	3.5	3.5	4.0	5.5	6.6	7.1	7.4					
-73 Cryogenic Fluid Management	1.5	2.6	2.1	2.2	2.3	2.4	2.5					
Sub-Element Totals: ($M)	12.0	12.7	16.3	21.5	24.6	27.0	30.4					
CoF:												
CoF Totals:												
Resources Requirements: ($M)	12.0	12.7	16.3	21.5	24.6	27.0	30.4					
Program Support: ($M)	2.4	2.5	2.3	2.6	3.0	3.2	3.6					
Special Requirements: ($M)	0.4	1.5	1.8	2.1	2.5	2.7	2.9					
TOTAL ($M):	14.8	16.7	20.4	26.2	30.1	32.9	36.9					

Basis for Resource Estimates:

- Grow Low Thrust Propulsion to enable revolutionary reductions in spacecraft weight allocated to propulsion and to enable missions with very high total energy requirements.
- Increase Advanced Concepts Program to permit broader participation, study of additional concepts, and an increase transition from study activities to experimental efforts.
- Maintain a supporting base activity in High Thrust Chemical Propulsion and Cryogenic Fluid Management.
- Inadequate fun[illegible] start activity in Lunar/Planet In-Situ Propellants.

WBS No. 506-42 (STRATEGIC BUDGET)

REVISED 6/11/91

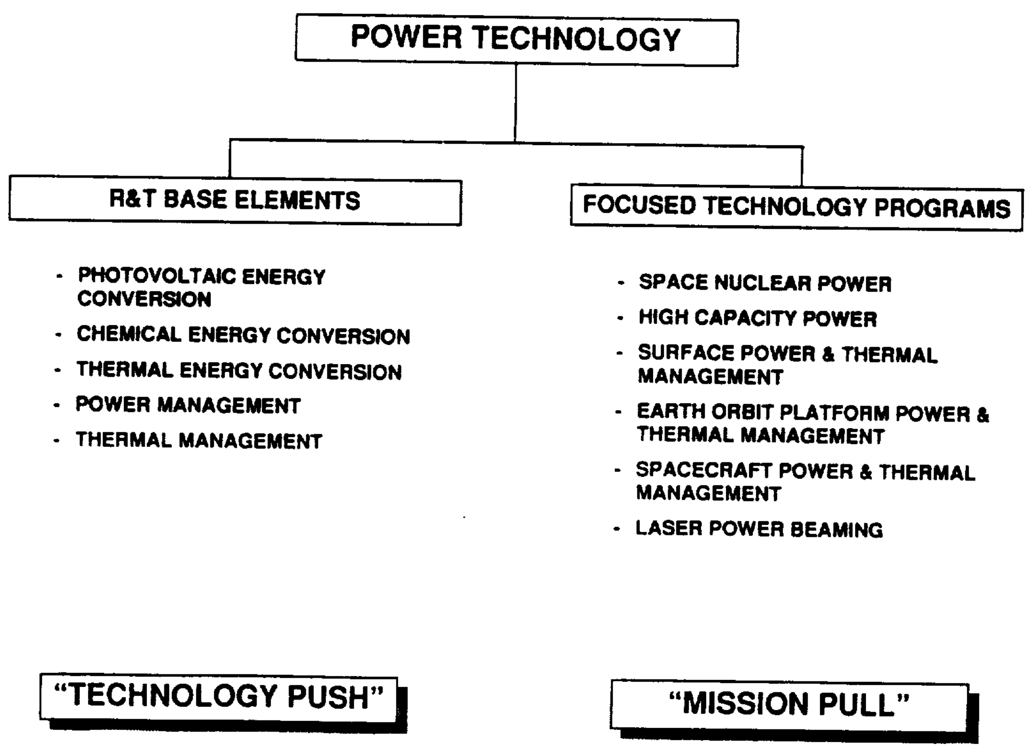
TECHNOLOGY ELEMENT:	PROPULSION R&T				WBS 506-42				CODE RP			
Sub-Element Resources: ($M)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
-31 Low Thrust (P&A)	5.8	5.2	8.0	11.0	11.0	12.5	14.5					
-41 Advanced Concepts	1.2	1.4	3.5	4.0	4.7	5.0	6.0					
-72 High Thrust Chemical	3.5	3.5	4.8	6.1	7.4	8.2	9.2					
-73 Cryogenic Fluid Management	1.5	2.6	2.1	2.2	2.3	2.4	2.5					
-74 Lunar/Planet Propellant	==	==	==	==	2.0	3.1	4.0					
Sub-Element Totals: ($M)	12.0	12.7	18.4	23.3	27.4	31.2	36.2					
CoF:												
CoF Totals:												
Resources Requirements: ($M)	12.0	12.7	18.4	23.3	27.4	31.2	36.2					
Program Support: ($M)	2.4	2.5	2.3	2.9	3.4	3.8	4.4					
Special Requirements: ($M)	0.4	1.5	2.3	2.5	2.9	3.0	3.3					
TOTAL ($M):	14.8	16.7	23.0	28.7	33.7	38.0	43.9					

Basis for Resource Estimates:

- Grow Low Thrust Propulsion to enable revolutionary reductions in spacecraft weight allocated to propulsion and to enable missions with very high total energy requirements.
- Increase Advanced Concepts Program to permit broader participation, study of additional concepts, and an increase transition from study activities to experimental efforts.
- Maintain a supporting base activity in High Thrust Chemical Propulsion and Cryogenic Fluid Management.
- Start, when appropri. tivity related to the use of in-situ resources.

BASE RESEARCH AND TECHNOLOGY PROGRAM

SPACE ENERGY CONVERSION TECHNOLOGY



BASE R&T PROGRAM
SPACE ENERGY CONVERSION R&T

OBJECTIVES

- **Programmatic**
  Provide the technology base to meet power system requirements for future space missions, including growth Space Station, Earth orbiting spacecraft, lunar and planetary bases, and solar system exploration

- **Technical**
  ≥300 W/kg Planar Array Technology
  100 - 200 Wh/kg Batteries
  ≥20% System Efficiency (Thermal-to Electric)
  >0.6 W/cm3 and >20 W/kg PMAD
  1 - 4 kg/m2 Radiator Specific Mass

SCHEDULE

- 1992 12-panel APSA
  Complete critical technology experiments for liquid sheet radiator (LSR)
- 1993 5-Ah Li-TiS2 Engineering Model Demo
  Solar Dynamic Heat Receiver Tech Demo
  Prototype Smart Pole (PMAD)
- 1994 Demonstrate thin 20% InP Cell
  Deliver Bipolar Flight Battery
  15% Efficient, 3000-Hour AMTEC
- 1995 Complete 100 Wh/kg Nickel Hydrogen Battery
- 1996 Demo 600 K PMAD Test Bed
- 1997 Complete integrated thermal and electrical test of power electronics orbital replacement unit
- 1998 Demonstrate 2nd generation APSA (>200 W/kg)
- 1999 Ground test 330 W/m2, 1 kW Concentrator Array

RESOURCES ($M)

	CURRENT	"3X"	STRATEGIC
FY91	12.5	12.5	12.5
FY92	12.8	12.8	12.8
FY93	13.3	15.8	17.7
FY94	13.8	20.1	21.5
FY95	14.6	23.4	25.8
FY96	15.3	25.6	29.7
FY97	16.0	28.6	33.9

PARTICIPANTS

- **Lewis Research Center**
  Responsibility includes advanced solar cells, nickel hydrogen & sodium sulfur batteries; dynamic conversion systems; fault-tolerant/high-temperature PMAD; thermal management
- **Jet Propulsion Laboratory**
  Responsibility includes advanced arrays, lithium & advanced batteries; AMTEC; advanced thermoelectrics; power integrated circuits
- **Langley Research Center**
  Space-based laser power technology
- **Goddard Space Flight Center**
  Thermal management for space experiments

BASE RESEARCH AND TECHNOLOGY PROGRAM
SPACE ENERGY CONVERSION R&T

SPACE POWER SYSTEMS

- **MISSION RELATED TECHNOLOGY DRIVERS**
  - REDUCED POWER SYSTEM WEIGHT FOR GEO AND PLANETARY APPLICATIONS
  - LOW-AREA, HIGH ENERGY DENSITY RIGID ARRAYS FOR LEO
  - HIGH CYCLE LIFE BATTERIES FOR LEO
  - HIGH ENERGY DENSITY, LONG-LIVED ENERGY STORAGE SYSTEMS
  - LIGHTWEIGHT, HIGH TEMPERATURE, COMPACT POWER MANAGEMENT FOR ALL APPLICATIONS
  - LONG-LIVED POWER SYSTEMS IN ALL RELEVANT ENVIRONMENTS - LEO, GEO, INTER PLANETARY, LUNAR/MARS SURFACE
  - LOW MASS RADIATORS FOR ORBITAL, SURFACE APPLICATIONS

BASE RESEARCH AND TECHNOLOGY PROGRAM

SPACE ENERGY CONVERSION R&T

SPACE POWER SYSTEMS

MISSION SPECIFIC

300 W/m2 CONCENTRATORS, 300 W/kg SOLAR ARRAYS
100 W-hr/kg BATTERIES
600K POWER ELECTRONICS AND THERMAL CONTROL
HIGH FREQUENCY POWER
ATOMIC OXYGEN PROTECTIVE COATINGS/ARC PROOF SOLAR ARRAYS
ORBITAL AND PLANETARY SURFACE ENVIRONMENTAL DESIGN GUIDELINES

BREAKTHROUGH

Li/CO2 FUEL CELLS
BEAMED POWER SYSTEMS
LUNAR REGOLITH STORAGE
1-2 kg/m2 RADIATORS/ADVANCED HEAT PIPES
DIAMOND FILM POWER ELECTRONICS

CAPABILITY

PV PERFORMANCE VERIFICATION/FUNDAMENTALS
ELECTROCHEMICAL ADVANCED DIAGNOSTICS/MODELLING
SOLAR DYNAMIC DESIGN/ANALYSIS
HEAT PIPE CODE VALIDATION
SPACE ENVIRONMENTAL SIMULATION FACILITIES

RJS91-00

BASE RESEARCH AND TECHNOLOGY PROGRAM

SPACE ENERGY CONVERSION R&T

SUB-ELEMENT	STATE-OF-THE-ART	OBJECTIVE
PHOTOVOLTAICS	Comm: 20 W/kg (rigid) to 66 W/kg (flex.) Demo: 100 W/kg (rigid) to 130 W/kg (flex.) 240 W/m2	> 300 W/kg (flex.) 1000 W/kg (blanket) >300 W/m2 (concentrator)
CHEMICAL ENERGY CONVERSION	Comm: 10 Wh/kg Demo: >20 Wh/kg	150 Wh/kg (75 % DOD)
THERMAL ENERGY CONVERSION	< 7 % efficiency	> 10 % efficiency
POWER MANAGEMENT	< 0.03 W/cm3 <15 W/kg	> 0.6 W/cm3 > 20 W/kg
THERMAL MANAGEMENT	10 kg/m2	1-4 kg/m2

BASE RESEARCH AND TECHNOLOGY PROGRAM

SPACE ENERGY CONVERSION TECHNOLOGY

OAET

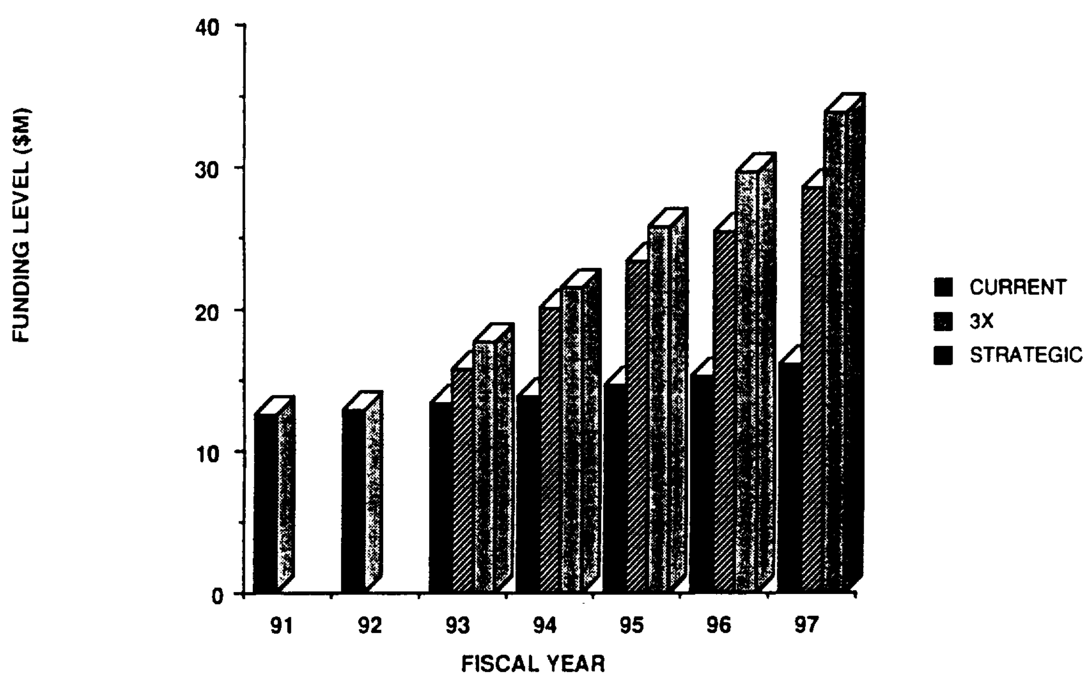
AUGMENTATION STRATEGY

- HIGH-RISK, INNOVATIVE POWER TECHNOLOGIES THAT HAVE THE POTENTIAL OF HIGH PAYOFF FOR FUTURE MISSIONS
  - DIAMOND FILM POWER ELECTRONICS
  - Li/CO_2 FUEL CELLS
- MAINTAIN A BALANCE BETWEEN TECHNOLOGY ELEMENTS TO SUPPORT EVOLUTIONARY SPACECRAFT POWER SYSTEM NEEDS
  - PHOTOVOLTAIC ENERGY CONVERSION
  - CHEMICAL/THERMAL ENERGY CONVERSION
  - POWER/THERMAL MANAGEMENT
- MAINTAIN SPECIFIC ACTIVITIES TO ENHANCE NASA'S CAPABILITY TO RESPOND TO TECHNOLOGY NEEDS
  - ADVANCED DIAGNOSTICS/MODELLING
  - SPACE ENVIRONMENTAL SIMULATION FACILITIES

BASE RESEARCH AND TECHNOLOGY PROGRAM

SPACE ENERGY CONVERSION TECHNOLOGY

OAET



WBS No. 506-41 (CURRENT BUDGET)

REVISED [illegible]

TECHNOLOGY ELEMENT:	POWER R&T				WBS 506-41				CODE RP			
Sub-Element Resources: ($M)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
-11 Photovoltaic Energy Conversion	2.4*	2.3	2.4	2.5	2.6	2.7	2.8					
-21 Chemical Energy Conversion	1.8	2.0	2.1	2.2	2.3	2.4	2.5					
-31 Thermal Energy Conversion	1.7	1.4	1.5	1.6	1.7	1.8	1.9					
-41 Power Management	2.0	1.8	1.9	2.0	2.1	2.2	2.3					
-51 Thermal Management	0.7	1.0	1.0	1.1	1.1	1.2	1.2					
Sub-Element Totals: ($M)	8.6	8.5	8.9	9.4	9.8	10.3	10.7					
CoF:												
CoF Totals:												
Resources Requirements: ($M)	8.6	8.5	8.9	9.4	9.8	10.3	10.7					
Program Support: ($M)	1.7	1.8	2.0	2.1	2.3	2.4	2.6					
Special Requirements: ($M)	2.2	2.5	2.4	2.3	2.5	2.6	2.7					
TOTAL ($M):	12.5*	12.8	13.3	13.8	14.6	15.3	16.0					

Basis for Resource Estimates:

- Maintain current funding levels; adjust for inflation.

* *Includes $1M carried over from FY90*

WBS No. 506-41 ("3X" BUDGET)

REVISED [illegible]

TECHNOLOGY ELEMENT:	POWER R&T				WBS 506-41				CODE RP			
Sub-Element Resources: ($M)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
-11 Photovoltaic Energy Conversion	2.4*	2.3	3.4	5.8	7.2	7.5	8.3					
-21 Chemical Energy Conversion	1.8	2.0	2.9	3.5	3.9	4.4	5.0					
-31 Thermal Energy Conversion	1.7	1.4	1.9	2.1	2.4	2.7	3.0					
-41 Power Management	2.0	1.8	2.9	3.3	3.7	4.1	4.6					
-51 Thermal Management	0.7	1.0	1.1	1.4	1.7	1.9	2.3					
Sub-Element Totals: ($M)	8.6	8.5	12.2	16.1	18.9	20.6	23.2					
CoF:												
CoF Totals:												
Resources Requirements: ($M)	8.6	8.5	12.2	16.1	18.9	20.6	23.2					
Program Support: ($M)	1.7	1.8	1.8	2.0	2.3	2.6	2.8					
Special Requirements: ($M)	2.2	2.5	1.8	2.0	2.2	2.4	2.6					
TOTAL ($M):	12.5*	12.8	15.8	20.1	23.4	25.6	28.6					

Basis for Resource Estimates:

- Grow photovoltaic and associated chemical energy storage and power management technologies to make dramatic reductions in spacecraft mass allocated to power.
- Maintain a supporting base activity in thermal energy conversion and thermal management.
- Insufficient resources to develop an advanced concepts technology program as a separate sub-element program. Advanced concepts will be worked in the existing sub-elements.

* *Includes $1M carried over from FY90*

WBS No. 506-41 (STRATEGIC BUDGET)

REVISED 6/11/91

TECHNOLOGY ELEMENT:	POWER R&T			WBS 506-41				CODE RP				
Sub-Element Resources: ($M)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
-11 Photovoltaic Energy Conversion	2.4*	2.3	3.3	4.6	5.9	7.2	8.5					
-21 Chemical Energy Conversion	1.8	2.0	2.8	3.4	3.9	4.4	5.0					
-31 Thermal Energy Conversion	1.7	1.4	1.8	2.1	2.4	2.7	3.0					
-41 Power Management	2.0	1.8	2.8	3.2	3.7	4.1	4.6					
-51 Thermal Management	0.7	1.0	1.1	1.4	1.7	1.9	2.3					
-91 Advanced Concepts	0.0	0.0	2.1	2.4	3.2	3.8	4.3					
Sub-Element Totals: ($M)	8.6	8.5	13.9	17.1	20.8	24.1	27.7					
CoF:												
CoF Totals:												
Resources Requirements: ($M)	8.6	8.5	13.9	17.1	20.8	24.1	27.7					
Program Support: ($M)	1.7	1.8	1.8	2.2	2.6	3.0	3.4					
Special Requirements: ($M)	2.2	2.5	2.0	2.2	2.4	2.6	2.8					
TOTAL ($M):	12.5*	12.8	17.7	21.5	25.8	29.7	33.9					

Basis for Resource Estimates:

- Grow photovoltaic and associated chemical energy storage and power management technologies to make dramatic reductions in spacecraft mass allocated to power.
- Develop advanced concepts program to permit development of innovative technologies that promise revolutionary improvements in performance.
- Maintain a supporting base activity in thermal energy conversion and thermal management.
- *Includes $1M carried over from FY90*

OAET ITP REV1

INTEGRATED TECHNOLOGY PLAN REVIEW MEETING

PRESENTATION ON

IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM

BY
JON PYLE
ACTING DEPUTY DIRECTOR, FLIGHT PROJECTS DIVISION, OAET
JUNE 24, 1991

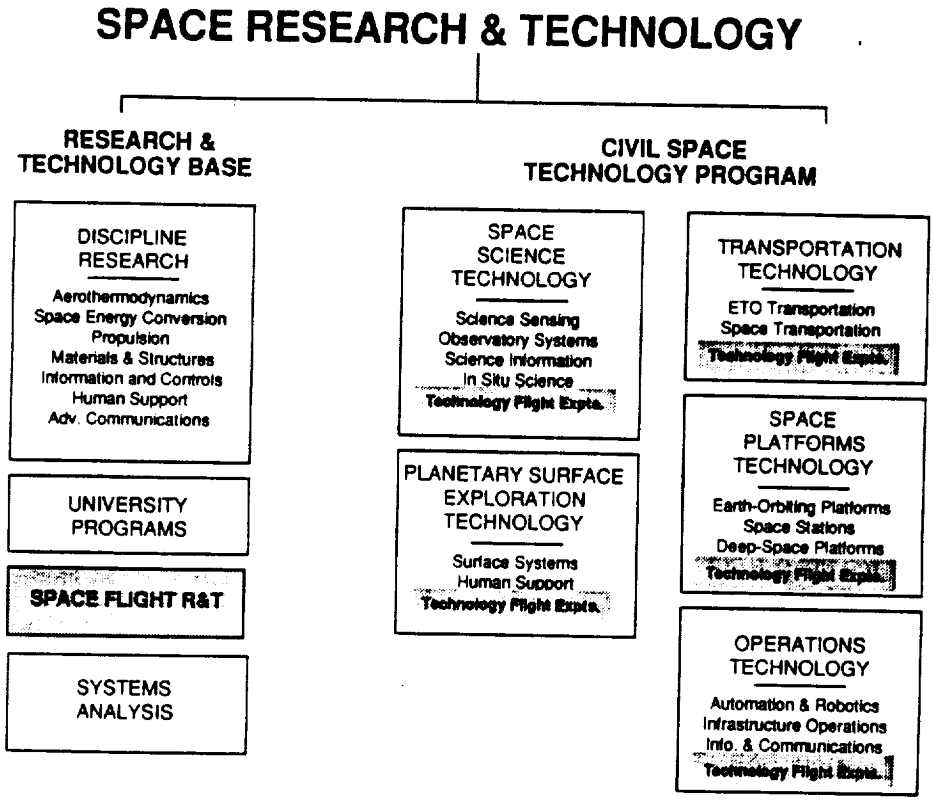
BRIEFING PURPOSE

OAET ITP REV2

- PROVIDE OVERVIEW OF IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM (IN-STEP)
  - BACKGROUND
  - IDENTIFICATION AND SELECTION PROCESS
  - IMPLEMENTATION PROCESS
  - CURRENT EXPERIMENTS
  - RESOURCES
- DESCRIBE CURRENT FLIGHT EXPERIMENTS AND FUTURE PLANS

SPACE WORK BREAKDOWN STRUCTURE

OAET — ITP REV4



IN-STEP PROGRAM

OAET — ITP REV4

PURPOSE

- PROVIDE FLIGHT OPPORTUNITIES FOR THE EVALUATION OF ADVANCED SPACE TECHNOLOGIES IN THE SPACE ENVIRONMENT OR SUBJECTED TO MICRO-GRAVITY CONDITIONS

JUSTIFICATION

- REQUIRES SPACE FLIGHT TO OBTAIN LONG-TERM MICRO-GRAVITY CONDITIONS & EFFECTS OF SPACE ENVIRONMENT

PAYOFF

- FLIGHT DATABASE OF MICRO-GRAVITY & SPACE ENVIRONMENTAL EFFECTS FOR DESIGN OF ADVANCED SPACE SYSTEMS
- ADVANCED PREDICTION TECHNIQUES & ANALYTICAL MODELS VALIDATED WITH SPACE MEASUREMENTS
- IMPROVED EFFICIENCY & EFFECTIVENESS OF CURRENT SENSORS & SUBSYSTEMS (REDUCED INTERFERENCE OF OPTICAL SENSORS)

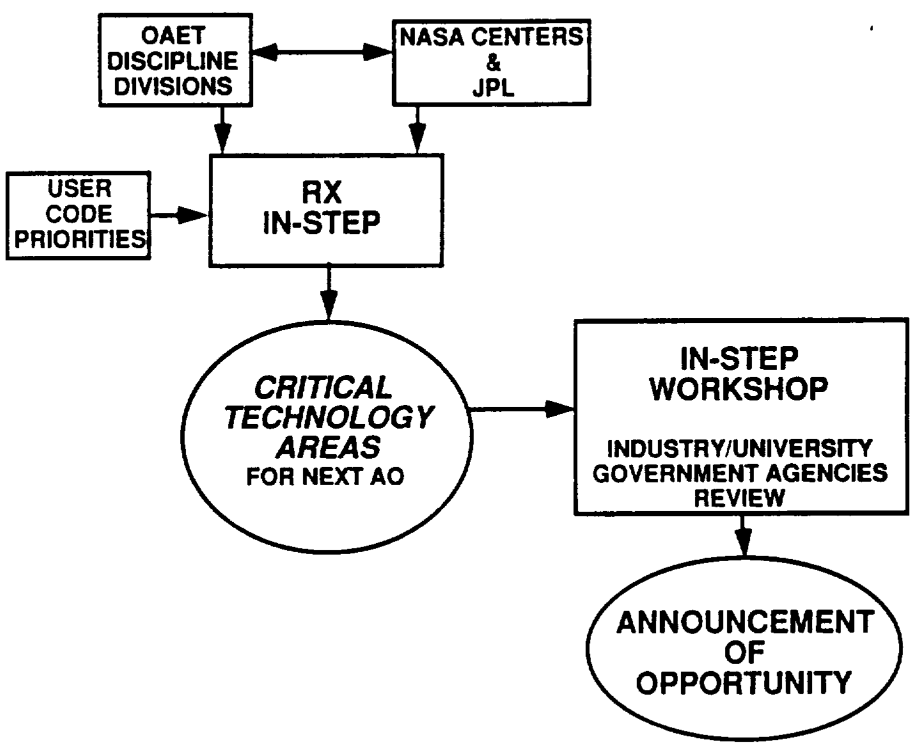
IN-STEP PROCESS

OAET ITP REV5

- IDENTIFICATION OF CRITICAL TECHNOLOGIES
- PROPOSALS OBTAINED THROUGH ANNOUNCEMENT OF OPPORTUNITY (AO) PROCESS
  - EXPERIMENT DEVELOPMENT COST LESS THAN $5M
  - 60% OF PROGRAM FUNDING FOR INDUSTRY/UNIVERSITY
  - CLASS D MODIFIED EXPERIMENTS
- SELECTION OF FLIGHT EXPERIMENTS FOR DEVELOPMENT
- LAUNCH/CARRIER OPPORTUNITIES IDENTIFIED
- FLIGHT EXPERIMENTS IMPLEMENTATION (HARDWARE DEVELOPMENT)
- FLIGHT EVALUATION
- DATA ANALYSIS AND REPORTING (TECHNOLOGY TRANSFER)

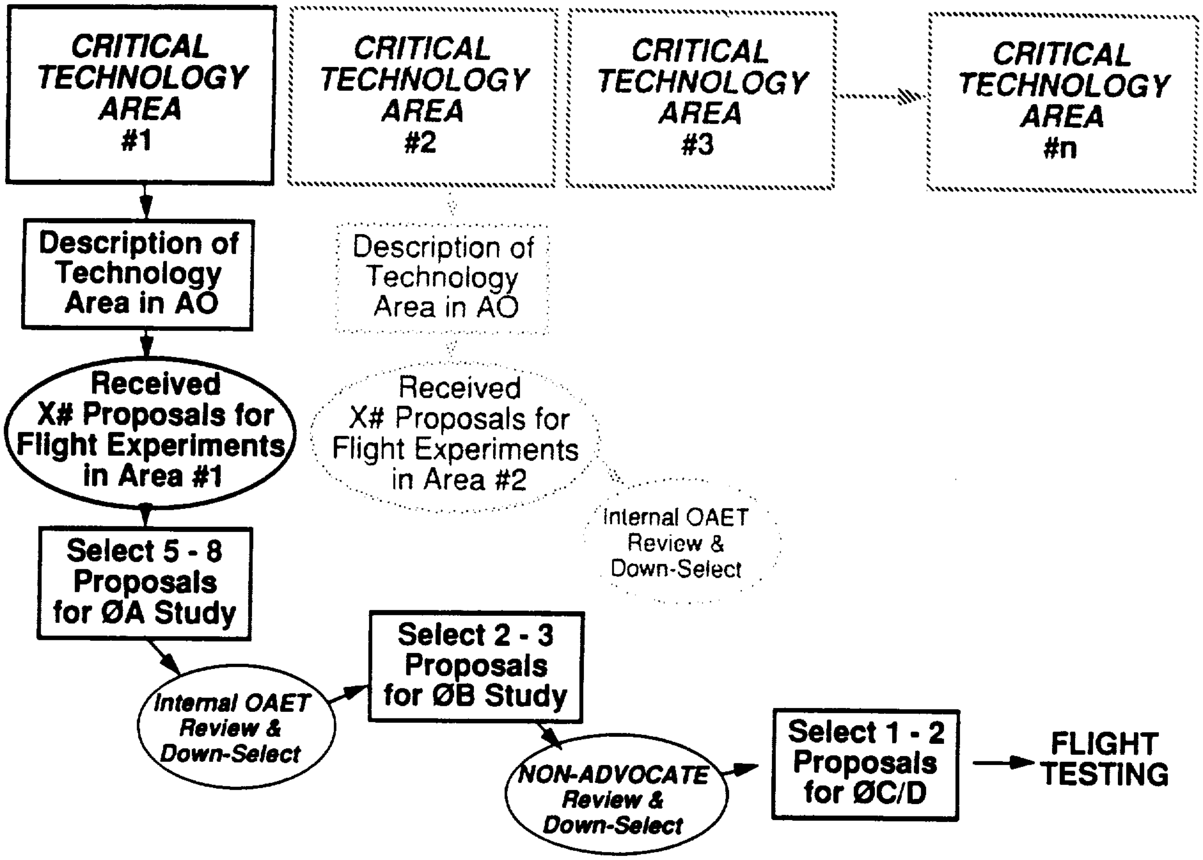
TECHNOLOGY IDENTIFICATION

OAET ITP REV6



ANNOUNCEMENT OF OPPORTUNITY

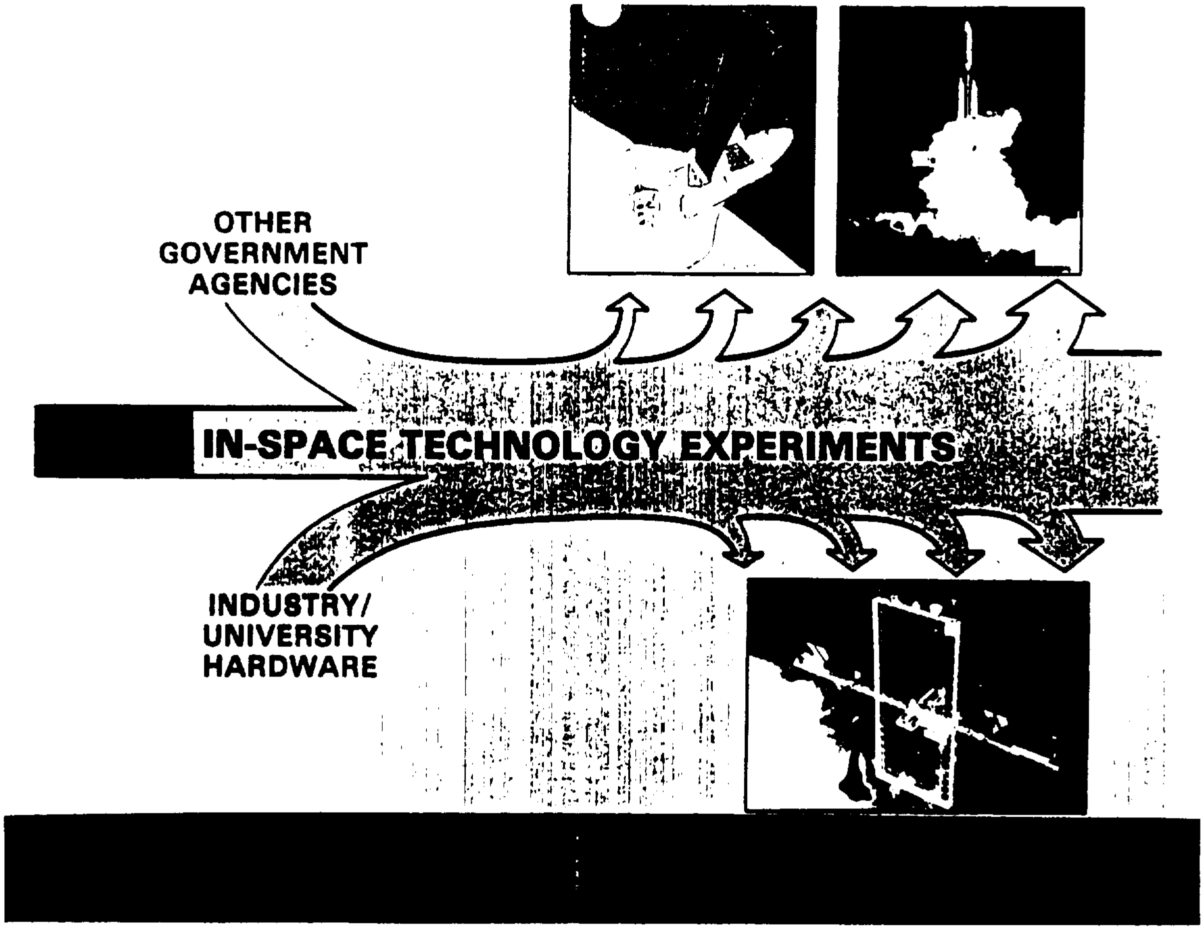
OAET ITP REV7



FLIGHT OPPORTUNITY IDENTIFICATION

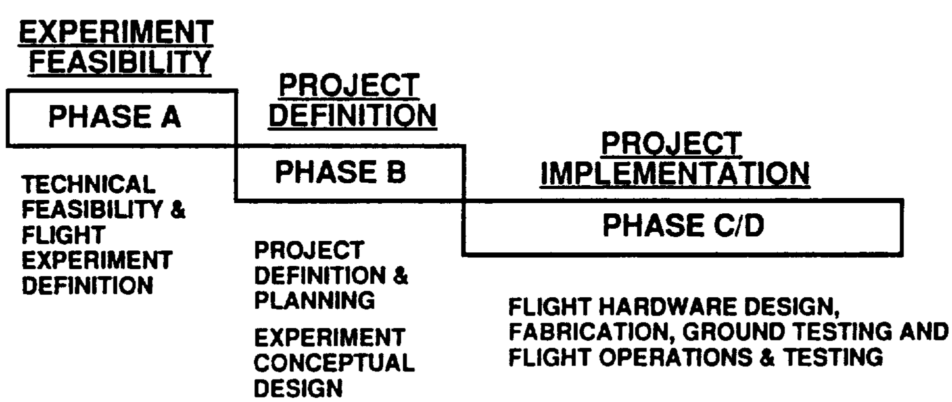
OAET ITP REV9

- DETERMINE OPTIMUM APPROACH FOR FLIGHT EVALUATION
  - SPACE SHUTTLE (MIDDECK, GAS, HH-M OR G, SPARTAN, OTHER)
  - EXPENDABLE LAUNCH VEHICLE
  - SPACE STATION FREEDOM
  - OTHER
- SELECTION OF OPPORTUNITY CONSISTENT WITH AVAILABILITY OF PAYLOAD & LAUNCH SYSTEM



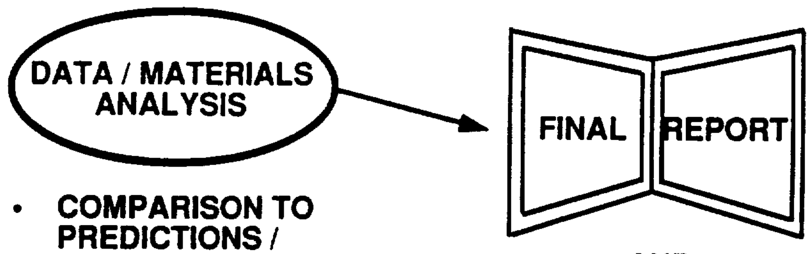
IMPLEMENTATION PROCESS

OAET ITP REV10



TECHNOLOGY TRANSFER

OAET ITP REV11



- COMPARISON TO PREDICTIONS / MODELS
- UPGRADE ANALYTICAL METHODOLOGIES
- IMPROVE TECHNIQUE OR TECHNOLOGY

AND

PRESENTATION TO IN-STEP WORKSHOP

CURRENT FLIGHT EXPERIMENTS

OAET ITP REV12

PRE - IN-STEP EXPERIMENTS (3)

- LIDAR IN-SPACE TECHNOLOGY EXPERIMENT
- ORBITER EXPERIMENTS
- LONG DURATION EXPOSURE FACILITY

FY 87 I/U EXPERIMENTS (5)

- TANK PRESSURE CONTROL EXPERIMENT
- MIDDDECK 0-GRAVITY DYNAMICS EXPERIMENT
- HEAT PIPE PERFORMANCE EXPERIMENT
- EMULSION CHAMBER TECHNOLOGY EXPERIMENT
- INVESTIGATION OF SPACECRAFT GLOW

FY 87 NASA EXPERIMENTS (7)

- THERMAL ENERGY STORAGE MATERIALS
- THIN FOIL MIRRORS
- SOLAR ARRAY MODULE PLASMA INTERACTION
- RETURN FLUX EXPERIMENT
- DEBRIS COLLISION WARNING SENSOR
- LASER OSCILLATOR
- MODAL IDENTIFICATION EXPERIMENT

FY 90 I/U EXPERIMENTS (15)

- ELECTROLYSIS EXPERIMENT
- LIQUID MOTION IN A ROTATING TANK
- TANK VENTING
- LARGE INFLATABLE PARABOLOID
- HYDROGEN-MASER CLOCK
- TWO-PHASE FLOW
- SPACE CRYOGENIC SYSTEM EXPERIMENT
- JITTER SUPPRESSION
- JOINT DAMPING IN SPACE
- PERMEABLE MEMBRANE EXPERIMENT
- MIDDECK ACTIVE CONTROL EXPERIMENT
- SODIUM SULFUR BATTERY
- OPTICAL PROPERTIES MONITOR
- RISK BASED FIRE SAFETY
- ACCELERATION MEASUREMENT

IN-STEP PARTICIPANTS

OAET ITP REV13

INDUSTRY

LIFE SYSTEMS
MARTIN MARIETTA
ROCKWELL
KMS FUSION
SPECTRON
PAYLOAD SYSTEMS INCORPORATED
LORAL
L'GARDE
SMITHSONIAN ASTROPHYSICS OBSERVATORY
TRW
HUGHES
AZ TECHNOLOGY
MCDONNELL DOUGLAS CORPORATION
BOEING AIRCRAFT CO
LOCKHEED MISSILE & SPACE
WYLE LABORATORIES
AMERICAN SPACE TECHNOLOGY
SOUTHWEST RESEARCH INSTITUTE

UNIVERSITY

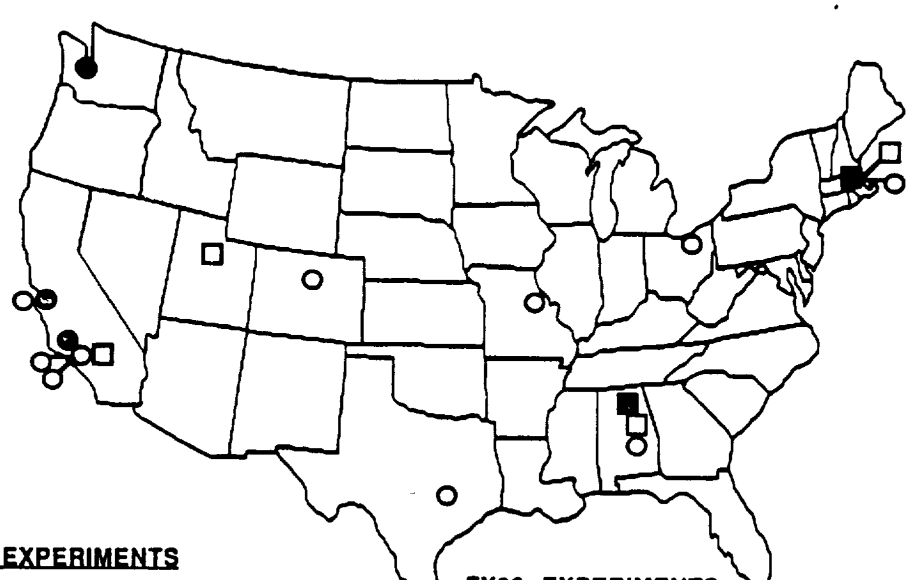
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
UNIVERSITY OF CALIFORNIA - LOS ANGELES
UNIVERSITY OF ALABAMA, HUNTSVILLE
UTAH STATE UNIVERSITY

NASA

AMES RESEARCH CENTER
GODDARD SPACE FLIGHT CENTER
JET PROPULSION LABORATORY
JOHNSON SPACE CENTER
KENNEDY SPACE CENTER
LANGLEY RESEARCH CENTER
LEWIS RESEARCH CENTER
MARSHALL SPACE FLIGHT CENTER

IN-STEP INDUSTRY/UNIVERSITY LOCATIONS

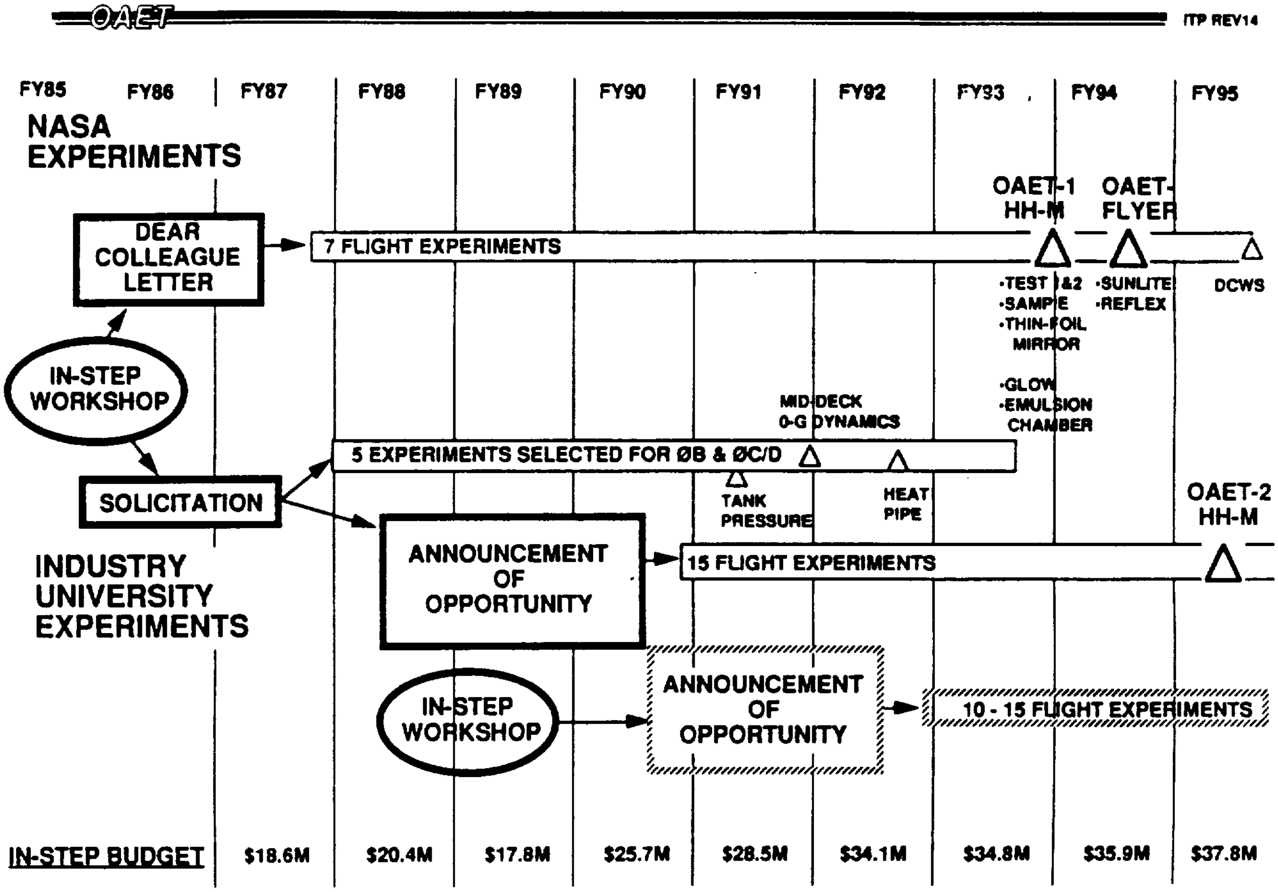
OAET



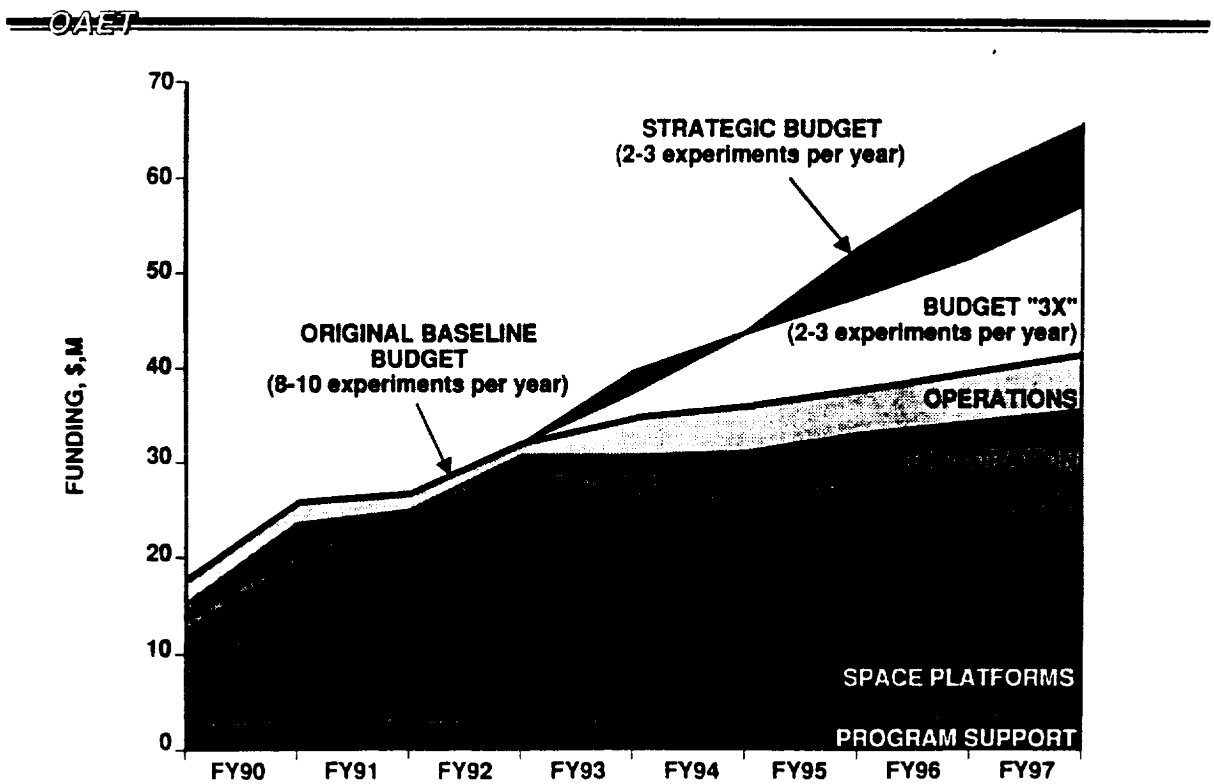
FY87 EXPERIMENTS
(5 IN PHASE C/D)
● 3 INDUSTRY EXPERIMENTS
■ 2 UNIVERSITY EXPERIMENTS

FY90 EXPERIMENTS
(15 IN PHASE C/D)
○ 11 INDUSTRY EXPERIMENTS
□ 4 UNIVERSITY EXPERIMENTS

CURRENT FLIG..IT PROGRAM



IN-STEP FUNDING



CONCLUDING REMARKS

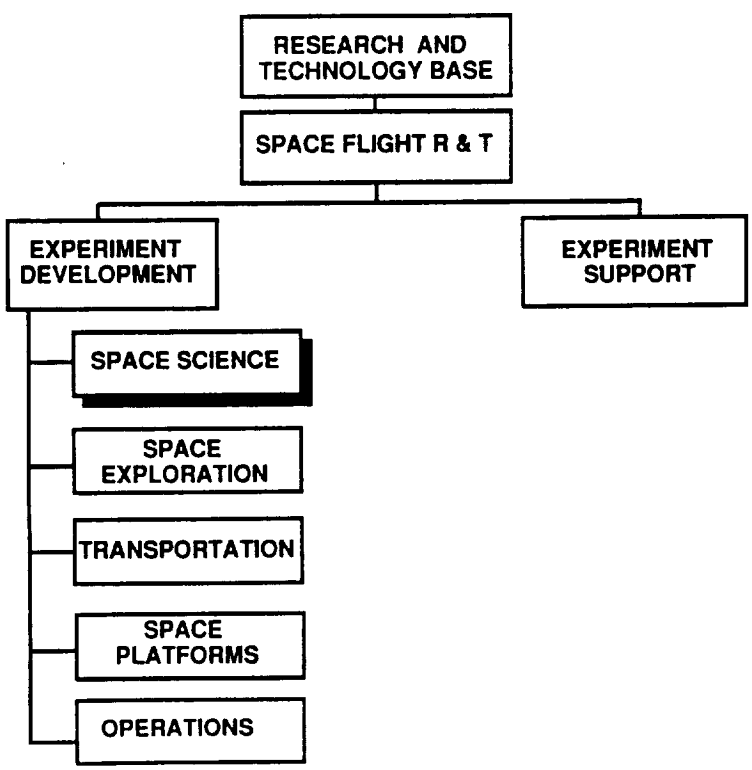
OAET ITP REV22

- IN-STEP FLIGHT EXPERIMENT CAPABILITIES
  - IN-STEP WORKSHOP EVERY OTHER YEAR
    - REVIEW COMPLETED EXPERIMENT RESULTS
    - REVIEW ON-GOING EXPERIMENTS
    - IDENTIFY CRITICAL TECHNOLOGY NEEDS
  - ANNOUNCEMENT OF OPPORTUNITY EVERY TWO YEARS
    - 8 - 12 CRITICAL TECHNOLOGY AREAS
    - INITIATE ~ 50 NEW PHASE A STUDIES
    - CREATE STEADY OUTPUT OF 8 - 10 FLIGHT EXPERIMENTS PER YEAR
  - OAET EXPECTS 20-25% ALLOCATION OF SPACE STATION FREEDOM (SSF) EXPERIMENT SPACE WHEN IT BECOMES AVAILABLE
    - IN-STEP WILL UTILIZE SSF AS A FLIGHT EVALUATION OPPORTUNITY FOR THOSE EXPERIMENTS REQUIRING LONG-TERM EXPOSURE OR ASTRONAUT PARTICIPATION
    - EXPERIMENTS BEYOND THE FUNDING SCOPE OF IN-STEP WILL BE IDENTIFIED & FUNDED THROUGH FOCUSSED THRUSTS

TECHNOLOGY FLIGHT EXPERIMENTS

OAET ITP REV14

WORK BREAKDOWN STRUCTURE



SPACE SCIENCE
TECHNOLOGY FLIGHT EXPERIMENTS

INDUSTRY/UNIVERSITY EXPERIMENTS

- INVESTIGATIONS OF SPACECRAFT GLOW
- SPACE CRYOGENIC SYSTEM EXPERIMENT
- LARGE INFLATABLE PARABOLOID
- HYDROGEN-MASER CLOCK
- SODIUM SULFUR BATTERY
- ACCELERATION MEASUREMENT

NASA/JPL DEVELOPED EXPERIMENTS

- RETURN FLUX EXPERIMENT
- THIN FOIL MIRRORS
- LASER OSCILLATOR EXPERIMENT
- ORBITAL ACCELERATION RESEARCH EXPERIMENT
- LIDAR IN-SPACE TECHNOLOGY EXPERIMENT

EXPERIMENTAL INVESTIGATION OF SPACECRAFT GLOW (EISG)

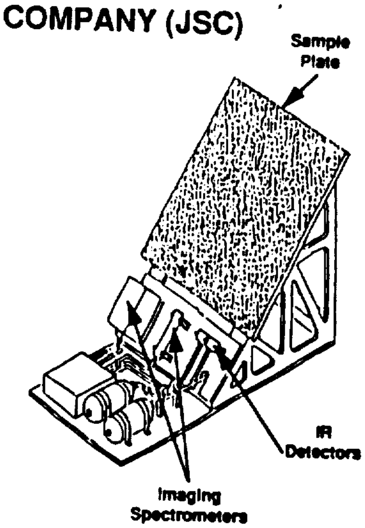
LOCKHEED MISSILE AND SPACE COMPANY (JSC)

OBJECTIVE:

- DETERMINE THE MECHANISM CAUSING FORMATION OF GLOW PRODUCING MOLECULES & ASSESS THE EFFECTS OF TEMPERATURE ON GLOW EMISSION

APPROACH:

- MEASURE THE INTENSITY OF ENERGY RELEASED IN THE ULTRAVIOLET, INFRARED & VISIBLE SPECTRUM FROM GLOW PRODUCING MATERIALS SUBJECTED TO ATOMIC OXYGEN PARTICLE ABSORPTION AT VARIOUS TEMPERATURES



- EXPERIMENT COST: $4.2M FLIGHT DATA: 5/93 (STS-62) OAET-1 (HH-M)

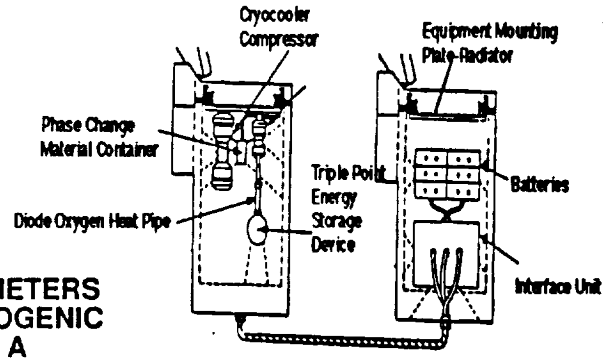
APPLICATION:

- RESULTS WILL ENABLE THE DEVELOPMENT OF NON-GLOWING SURFACE COATINGS FOR REDUCING SPECTRAL INTERFERENCE IN OPTICAL SENSORS

35.12N7-4 9/90

SPACE CRYOGENIC SYSTEMS EXPERIMENT

HUGHES AIRCRAFT COMPANY (JPL)



OBJECTIVE:

- DEMONSTRATE MICROGRAVITY OPERATION OF AN ACTIVE CRYOGENIC (65°K) THERMAL CONTROL SYSTEM

APPROACH:

- MEASURE PERFORMANCE PARAMETERS FOR OXYGEN HEAT PIPES, A CRYOGENIC THERMAL STORAGE DEVICE, AND A LONG-LIFE STIRLING CYCLE CRYOGENIC COOLER IN MICROGRAVITY
- EXPERIMENT COST: $7.5M   FLIGHT DATA: 6/95, CAP

APPLICATION:

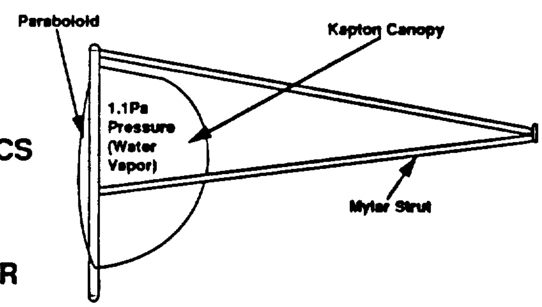
- VERIFICATION OF ANALYTICAL MODELS FOR CRYOGENIC SYSTEM DESIGN
- PROVIDES FLIGHT DATA FOR INFRARED SENSOR COOLERS FOR EARTH OBSERVING SATELLITES (EOS) AND ORBITING X-RAY OBSERVATORIES

35.12N.8.7 9/90

OAST IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM

INFLATABLE PARABOLOID

L'GARDE, INC. (JPL)



OBJECTIVE:

- VALIDATE ERECTION OF A PACKAGED 28 METER PARABOLOID
- DETERMINE THE STRUCTURAL DYNAMICS & SURFACE ACCURACY

APPROACH:

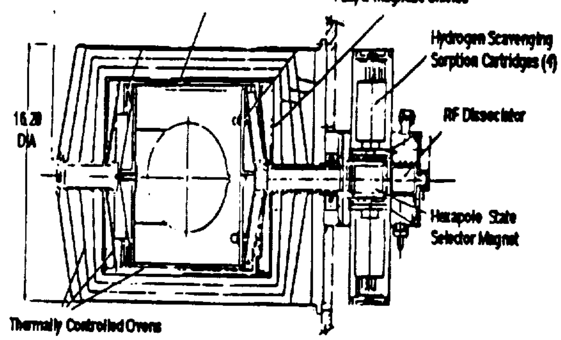
- INFLATE STRUCTURE & ANTENNA AFTER INSERTION IN LOW EARTH ORBIT
- MEASURE PARABOLOID ACCURACY AT VARIOUS PRESSURES & SUN ANGLES WITH SURFACE IMAGER
- PERTURB ANTENNA WITH REACTION JETS & GATHER RESPONSE WITH SURFACE IMAGER
- EXPERIMENT COST: $9.0M   FLIGHT DATA: TBD, NSTS OR ELV

APPLICATION:

- ULTRA LIGHTWEIGHT, LOW COST APPROACH FOR LARGE MODERATE ACCURACY REFLECTORS
- POSSIBLE BREAKTHROUGH TECHNOLOGY FOR EXPLORATION INITIATIVE OR EVOLUTIONARY SPACE STATION

35.12N.8.4 9/90

HYDROGEN MASER CLOCK
SMITHSONIAN ASTROPHYSICAL OBSERVATORY (MSFC)



OBJECTIVE:

- DETERMINE LONG-TERM FREQUENCY STABILITY OF HYDROGEN MASER CLOCK AND ITS SENSITIVITY TO THE SPACE ENVIRONMENT

APPROACH:

- SPACE HYDROGEN-MASER COMPARED WITH GROUND MASER USING S-BAND TRANSPONDER & TRANSMITTER TO DETERMINE RELATIVISTIC FREQUENCY CORRECTIONS
- EXPERIMENT COST: $9.6M

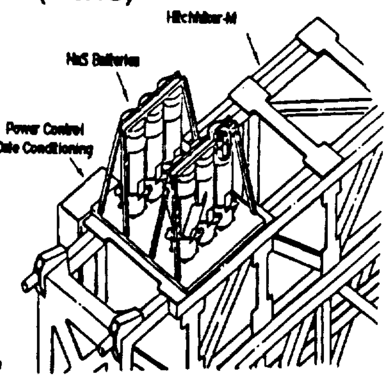
FLIGHT DATA: PLANNED FOR FLIGHT ON EUREKA (1996)

APPLICATION:

- PROVIDES MEASUREMENT TOOLS TO CONDUCT RADIOASTRONOMY, RELATIVITY & GRAVITATIONAL RESEARCH
- INCREASED TIMING PRECISION WILL IMPROVE EARTH & SPACE NAVIGATION
- WILL INCREASE ACCURACY OF GLOBAL POSITIONING SYSTEM

35.12N.8.5 8/90

SODIUM-SULFUR BATTERY
FORD AEROSPACE CORPORATION (LERC)



OBJECTIVE:

- DETERMINE PERFORMANCE CHARACTERISTICS OF SODIUM-SULFUR (NaS) BATTERIES IN THE MICROGRAVITY ENVIRONMENT

APPROACH:

- MEASURE THE CHARGE/DISCHARGE CHARACTERISTICS, FLUID REACTANT DISTRIBUTION, FREEZE-THAW CHARACTERISTICS, DURABILITY & PERFORMANCE OF NaS CELLS UNDER MICROGRAVITY CONDITIONS MOUNTED IN THE BAY OF THE SPACE SHUTTLE
- EXPERIMENT COST: $6.0M FLIGHT DATA: 10/95

APPLICATION:

- LOWER WEIGHT & HIGHER EFFICIENCY (2 X SPECIFIC ENERGY) OVER CURRENT SPACE BATTERIES WILL PROVIDE LONGER LIFE SPACECRAFT WITH GREATER PAYLOAD CAPACITY

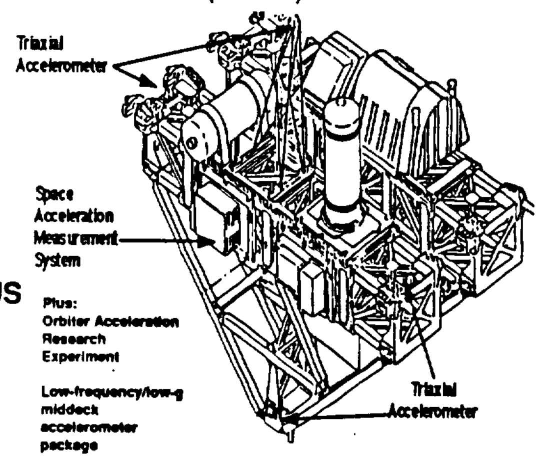
ACCELERATION MEASUREMENT
UNIVERSITY OF ALABAMA - HUNTSVILLE (LARC)

OBJECTIVE:

- DETERMINE MICROGRAVITY ENVIRONMENT IN SHUTTLE BAY

APPROACH:

- UTILIZE SHUTTLE SYSTEM WITH DISTRIBUTED, CALIBRATED ACCELEROMETERS TO CHARACTERIZE MICROGRAVITY CONDITIONS AT VARIOUS LOCATIONS IN SPACE SHUTTLE BAY
- EXPERIMENT COST: TBD
  FLIGHT DATA: 6/95



APPLICATION:

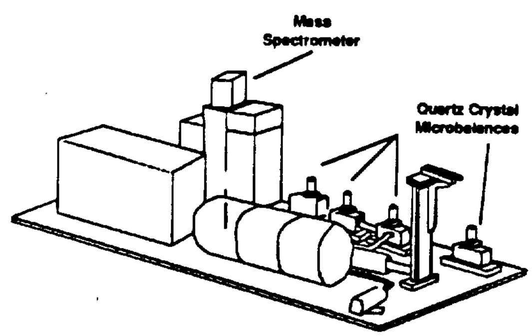
- PROVIDE FLIGHT DATA TO VALIDATE & UPGRADE SPATIAL ACCELERATION DISTRIBUTION MODELS
- ACCURATE KNOWLEDGE OF MICROGRAVITY ENVIRONMENT REQUIRED TO CONDUCT MATERIALS & BIOLOGICAL PROCESSING EXPERIMENTS IN SPACE SHUTTLE & SPACE STATION

OAET IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM

RETURN FLUX EXPERIMENT (REFLEX)
GODDARD SPACE FLIGHT CENTER

OBJECTIVE:

- DETERMINE SPECIE ACCRETION, VELOCITY, DIRECTION & CHEMISTRY OF SPACECRAFT CONTAMINATION



APPROACH:

- USE QUARTZ CRYSTAL MICROBALANCES & A MASS SPECTROMETER TO MEASURE MOLECULAR CONSTITUTENTS OF ENVIRONMENT AROUND A SPACECRAFT
- RELEASE KNOWN GAS AND CHARACTERIZE RESULTING CONTAMINATION
- EXPERIMENT COST: $5.1M FLIGHT DATA: 7/94, OAET-FLYER (SPARTAN)

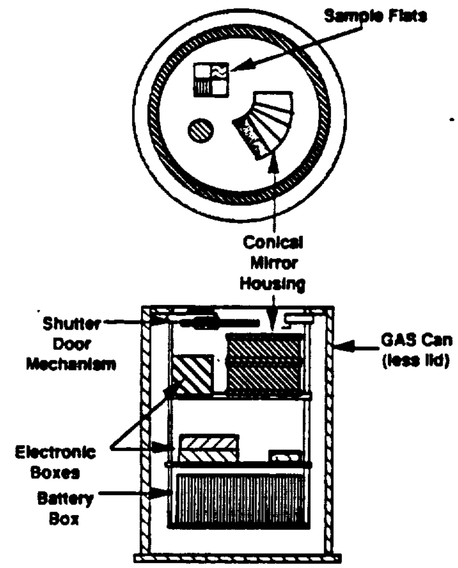
APPLICATION:

- FLIGHT RESULTS WILL BE USED TO IMPROVE CONTAMINATION MODELING TECHNIQUES & PREDICTION CODES (INCREASES EFFECTIVENESS OF OPTICAL SENSORS, THERMAL RADIATORS & SOLAR ARRAYS)

THIN FOIL MIRROR (TFM)
GODDARD SPACE FLIGHT CENTER

OBJECTIVE:

- MEASURE DEGRADATION OF X-RAY REFLECTION EFFICIENCY DUE TO INTERACTION WITH ATOMIC OXYGEN FOR CANDIDATE MIRROR SURFACES
- DETERMINE EFFECTIVENESS OF PROTECTIVE COATINGS TO MINIMIZE SURFACE DEGRADATION



APPROACH:

- SERIES OF LACQUER-COATED, HIGH REFLECTIVITY ALUMINUM FOILS WITH 500 ANGSTROM GOLD LAYER AND MIRRORS WITH VARIOUS PROTECTIVE COATINGS SUBJECTED TO INCIDENCE BY ATOMIC OXYGEN PARTICLES

- EXPERIMENT COST: $2.0M
- FLIGHT DATA: 5/93 (STS-62), OAET-1 (CAP)

APPLICATION:

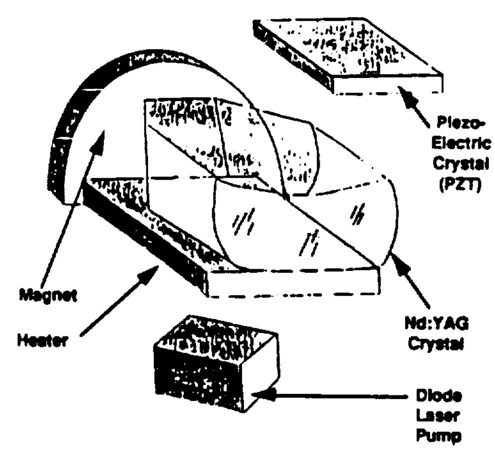
- PROVIDES FLIGHT DATA TO IMPROVE DESIGN AND REDUCE COST OF ADVANCED X-RAY MIRROR SURFACES (i.e., ASTRO-D, SPECTRUM-X, & SPEKTROSAT)

35.12N7-8 9/90

LASER OSCILLATOR SENSOR
LANGLEY RESEARCH CENTER

OBJECTIVE:

- VALIDATE ULTRA-STABLE, SOLID STATE LASER OSCILLATOR
- INVESTIGATE LASER LINEWIDTH AND FREQUENCY STABILITY LIMITS



APPROACH:

- DEVELOP A SELF-CONTAINED, AUTOMATED LASER OSCILLATOR
- MEASURE THE LASER LINEWIDTH & FREQUENCY STABILITY IN A MICROGRAVITY, ACOUSTICALLY QUIET ENVIRONMENT
- COMPARE WITH GROUND BASED TESTING AND ANALYTICAL PREDICTIONS
- EXPERIMENT COST: $6.7M FLIGHT DATE: 7/94, OAET-FLYER (SPARTAN)

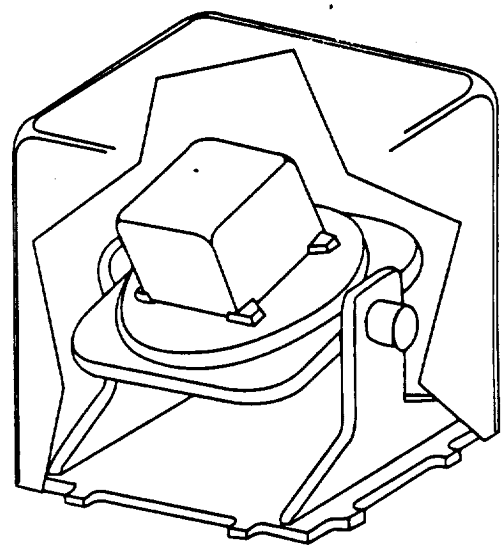
APPLICATION:

- IMPROVED FREQUENCY AND TIME STANDARDS FOR GLOBAL POSITIONING SYSTEM, ADVANCED COMMUNICATIONS, & VERY LONG BASE INTERFEROMETRY (VLBI)
- SOURCE OF STABLE, COHERENT LIGHT FOR REMOTE SENSORS

35.12N7-12- 9/90

ORBITAL ACCELERATION RESEARCH EXPERIMENT (OARE)

LANGLEY RESEARCH CENTER



OBJECTIVE:

- ACCURATE MEASUREMENT OF AERODYNAMIC ACCELERATION ALONG THE ORBITER'S PRINCIPAL AXES IN THE FREE MOLECULAR FLOW REGIME AND THROUGH THE TRANSITIONAL FLOW REGIME DURING REENTRY

APPROACH:

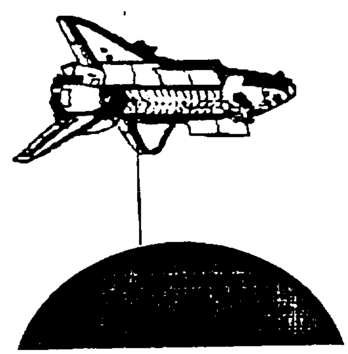
- MEASURES LINEAR ACCELERATIONS (10-9g) IN THE PRESENCE OF ORBITER STRUCTURAL VIBRATION NOISE
- UTILIZES THREE AXIS ELECTROSTATICALLY SUSPENDED PROFF-MASS WITH ON-ORBIT CALIBRATION CAPABILITY
- INSTALLED ON THE KEEL BRIDGE FITTING IN THE PAYLOAD BAY
- OPERATIONAL ON OV-102 FLIGHTS

APPLICATION:

- DETERMINATION OF ORBITAL DRAG WHICH PROVIDES DESIGN SPECIFICATIONS FOR ORBIT MANAGEMENT AND MAINTENANCE SYSTEM FOR THE SSF
- PROVIDES AERODYNAMIC DESIGN DATA FOR ADVANCED AEROMANEUVERING SPACE TRANSFER VEHICLES
- EXPAND KNOWLEDGE OF MICROGRAVITY ENVIRONMENT NEEDED FOR THE CONDUCT OF MICROGRAVITY EXPERIMENTS

LIDAR IN-SPACE TECHNOLOGY EXPERIMENT (LITE)

LANGLEY RESEARCH CENTER



OBJECTIVE:

- EVALUATE CRITICAL ATMOSPHERIC PARAMETERS & VALIDATE OPERATION OF A SOLID-STATE LIDAR SYSTEM FROM A SPACEBORNE PLATFORM MEASURING:
  - CLOUD DECK ALTITUDES
  - PLANETARY BOUNDARY-LAYER HEIGHTS
  - STRATOSPHERIC & TROPOSPHERIC AEROSOL
  - ATMOSPHERIC TEMPERATURE & DENSITY (10km to 40km)

APPROACH:

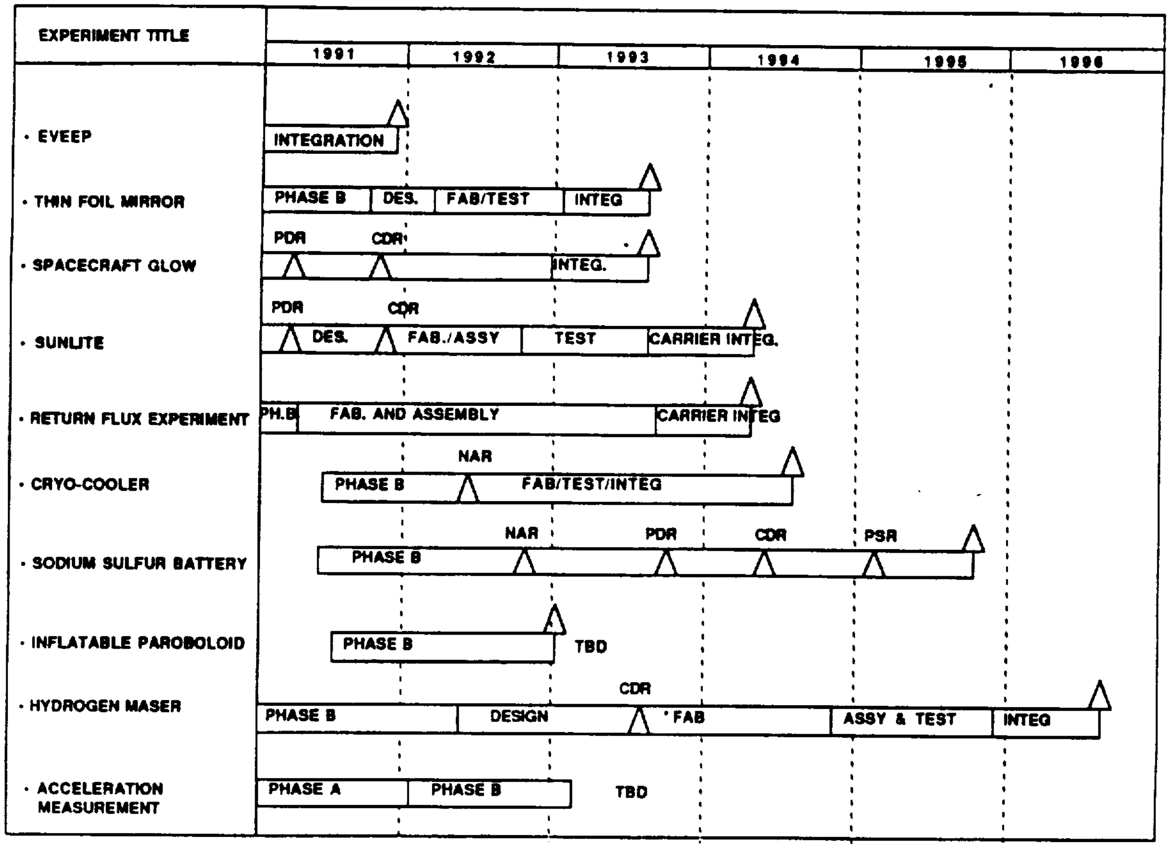
- DESIGNED AS A SHUTTLE-BORNE EXPERIMENT WITH MULTI-MISSION CAPABILITIES
- MEASUREMENTS OVER CHANGING ATMOSPHERIC BACKSCATTER CONDITIONS (DAYTIME AND NIGHTTIME)
- EXPERIMENT COST: $18.3M FLIGHT DATE: MID 1993

APPLICATION:

- GENERALLY APPLICABLE TO A CLASS OF INSTRUMENTS INCORPORATING HIGH POWER LASERS, OPTICAL SYSTEMS AND LARGE TELESCOPES
- SPECIFICALLY APPLICABLE TO THE EARTH OBSERVING SYSTEM (EOS) AND THE LIDAR ATMOSPHERIC SOUNDER AND ALTIMETER (LASA) FACILITY

SPACE SCIENCE

FLIGHT PROJEC..S DIVISION
TECHNOLOGY FLIGHT EXPERIMENTS PROGRAM

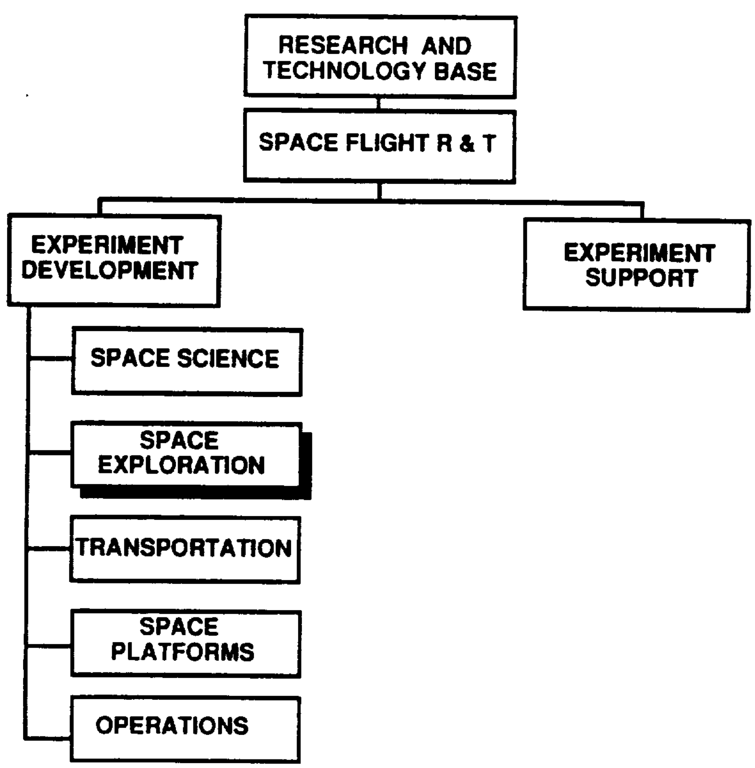


TECHNOLOGY FL.GHT EXPERIMENTS

OAET

ITP REV15

WORK BREAKDOWN STRUCTURE



EXPLORATION
TECHNOLOGY FLIGHT EXPERIMENTS

INDUSTRY/UNIVERSITY EXPERIMENTS

- ELECTROLYSIS EXPERIMENT
- PERMEABLE MEMBRANE EXPERIMENT

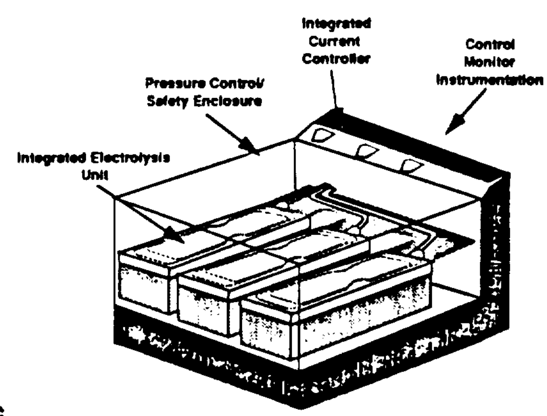
NASA/JPL DEVELOPED EXPERIMENTS

(NONE IDENTIFIED)

ELECTROLYSIS EXPERIMENT
LIFE SYSTEMS, INC. (LARC)

OBJECTIVE:

- DETERMINE EFFECTS OF MICROGRAVITY ON WATER ELECTROLYSIS CELL PERFORMANCE



APPROACH:

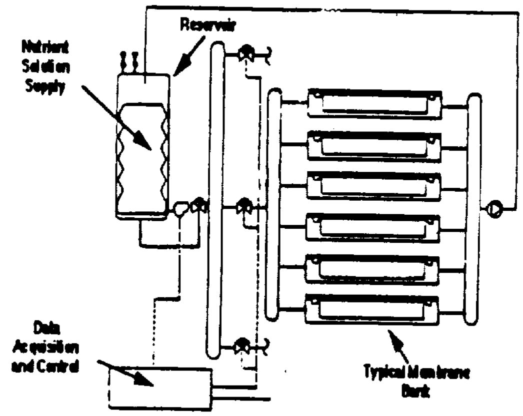
- THREE ELECTROLYSIS UNITS PACKAGED IN A SINGLE MIDDECK LOCKER
- INDIVIDUAL UNITS USE DIFFERENT ELECTRODES EACH WITH VARYING THICKNESS, PORE SIZE AND POROSITY

- EXPERIMENT COST: $1.9M FLIGHT DATA: 2/94, MIDDECK

APPLICATION:

- EFFICIENT PRODUCTION OF HYDROGEN AND OXYGEN IN SPACE FOR FUTURE MISSIONS REQUIRING LONG-TERM LIFE SUPPORT

PERMEABLE MEMBRANE TECHNOLOGY EXPERIMENT
BOEING AEROSPACE AND ELECTRONICS (ARC)



OBJECTIVE:

- VERIFY MEMBRANE TRANSPORT PERFORMANCE IN LOW GRAVITY

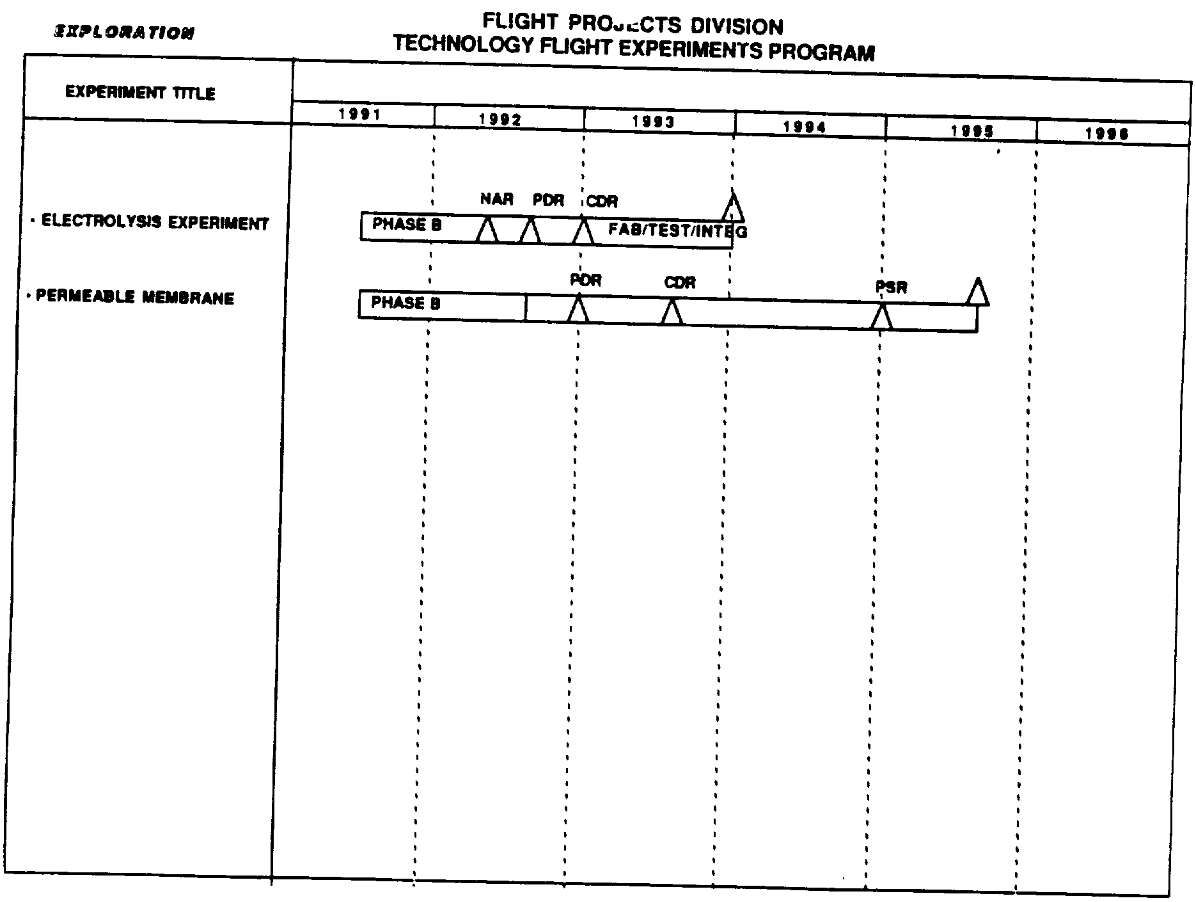
APPROACH:

- EXPOSE A VARIETY OF MEMBRANES TO A SUPPLY SOLUTION IN MICROGRAVITY
- PHOTOGRAPH FLUID TRANSPORT BEHAVIOR
- COLLECT FLUID SAMPLES TO DETERMINE TRANSFER RATES

- EXPERIMENT COST: $4.5M   FLIGHT DATE: 1/94, CAP

APPLICATION:

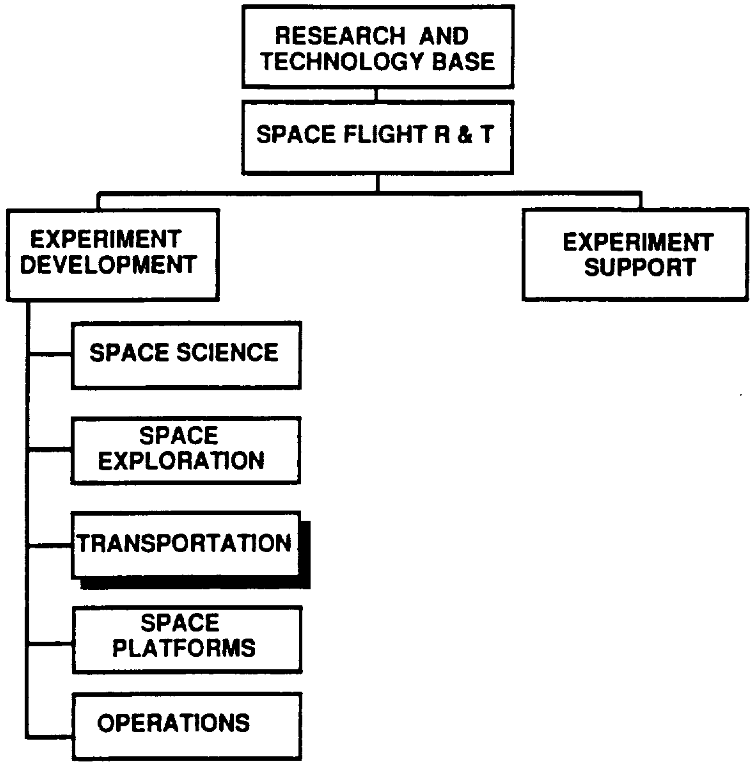
- VALIDATION OF MEMBRANE TECHNOLOGY TO BE USED IN SPACE STATION FREEDOM ENVIRONMENTAL CONTROL LIFE SUPPORT SYSTEM
- SUPPORTS PERMEABLE MEMBRANE-BASED TECHNOLOGIES FOR SPACE-BASED MATERIALS PROCESSING AND LABORATORY TECHNIQUES



TECHNOLOGY FLIGHT EXPERIMENTS

OAET ITP REV16

WORK BREAKDOWN STRUCTURE



TRANSPORTATION TECHNOLOGY FLIGHT EXPERIMENTS

FLIGHT PROJECTS DIVISION

TRANSPORTATION TECHNOLOGY FLIGHT EXPERIMENTS

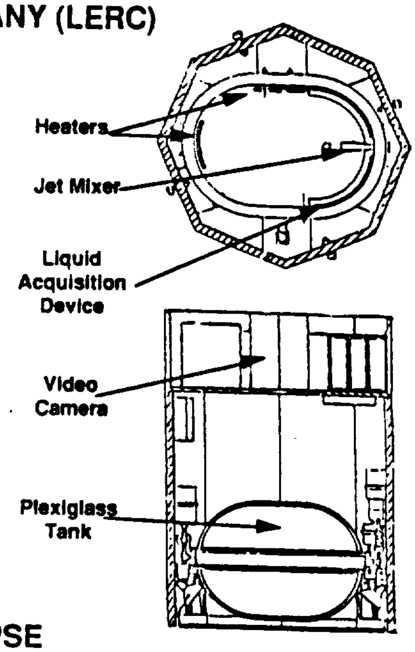
INDUSTRY/UNIVERSITY EXPERIMENTS

- TANK PRESSURE CONTROL EXPERIMENT
- TANK VENTING EXPERIMENT

NASA/JPL DEVELOPED EXPERIMENTS

- NONE IDENTIFIED

TANK PRESSURE CONTROL EXPERIMENT
BOEING AEROSPACE COMPANY (LERC)



OBJECTIVE:

- REDUCE PRESSURE BUILD-UP OF CRYOGENIC TANKS CAUSED BY 0-G THERMAL STRATIFICATION

APPROACH:

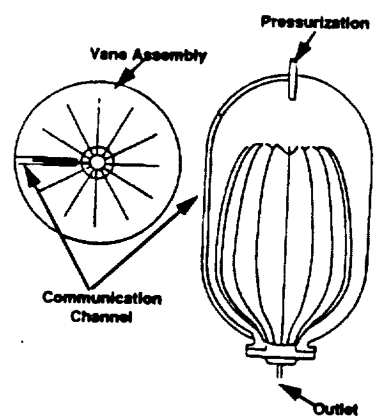
- CHARACTERIZE THE FLUID DYNAMICS OF JET-INDUCED MIXING OF A CRYOGENIC FLUID SUBJECTED TO MICROGRAVITY CONDITIONS
- EXPERIMENT COST: $1.7M
  FLIGHT DATA: 7/91, STS-43
  (GAS HARDWARE)

APPLICATION:

- FLIGHT RESULTS WILL UPGRADE THE ECLIPSE (ENERGY CALCULATIONS FOR LIQUID PROPELLANTS IN A SPACE ENVIRONMENT) COMPUTER CODE
- ENABLES USE OF LIGHTER WEIGHT CRYOGENIC FLUIDS FOR SPACE STATION & ADVANCED TRANSPORTATION SYSTEMS

35.12N7-8- 9/90

TANK VENTING
BOEING AEROSPACE COMPANY (LERC)



OBJECTIVE:

- DEVELOP VENTING CONCEPTS TO PROVIDE TANK FILL WHILE VENTING TO 90% FULL CAPACITY

APPROACH:

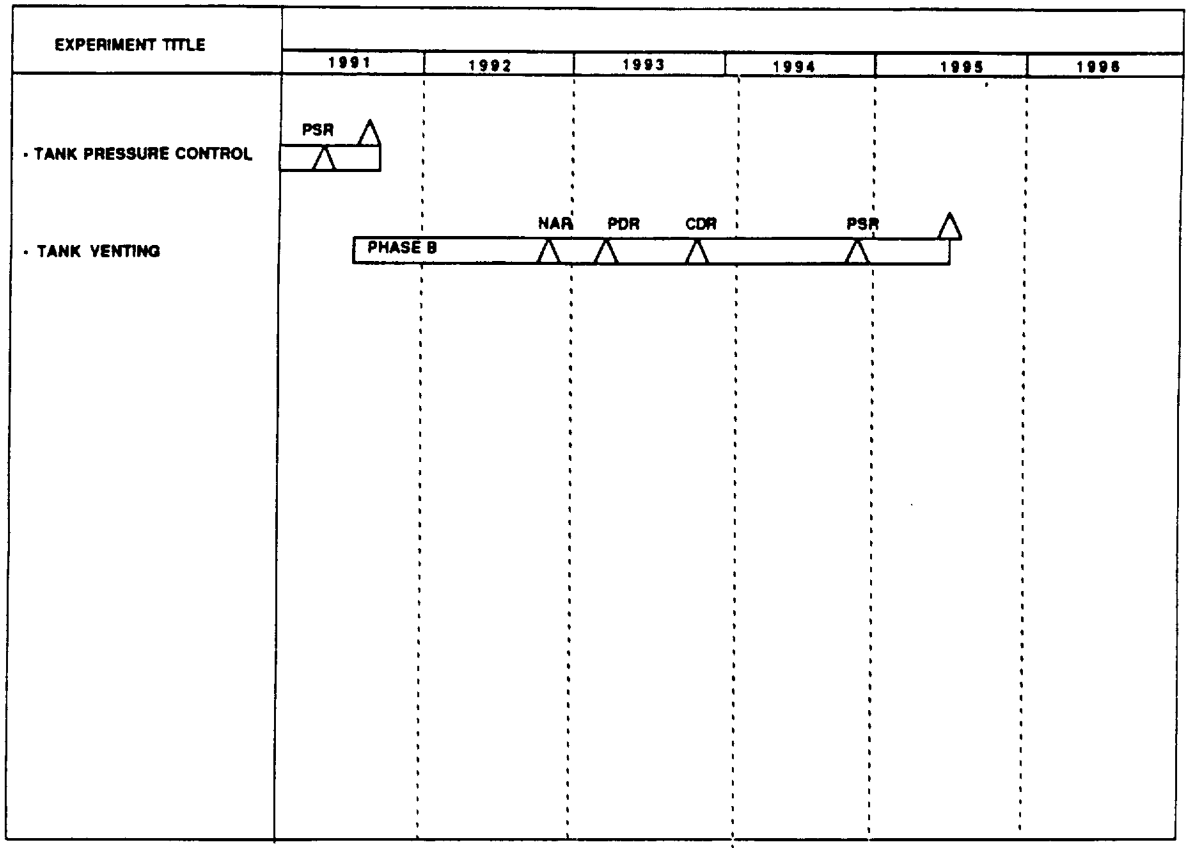
- FLUIDS WILL BE TRANSFERRED BETWEEN TRANSPARENT TANKS OF DIFFERENT CONFIGURATION
- GAS ULLAGE TO BE CONTROLLED BY CAPILLARY DEVICE & VENTED TO SPACE
- EXPERIMENT COST: $4.2M FLIGHT DATA: 1/95, (HH-G)

APPLICATION:

- RESUPPLY OF FLUIDS IN SPACE IS A CRITICAL TECHNOLOGY FOR EXTENDED DURATION MISSIONS (i.e., EXPLORATION & SPACE STATION)
- VENTING IS ESSENTIAL TO ALLOW MAXIMUM USE OF TANK VOLUME

TRANSPORTATION

FLIGHT PRO..CTS DIVISION
TECHNOLOGY FLIGHT EXPERIMENTS PROGRAM

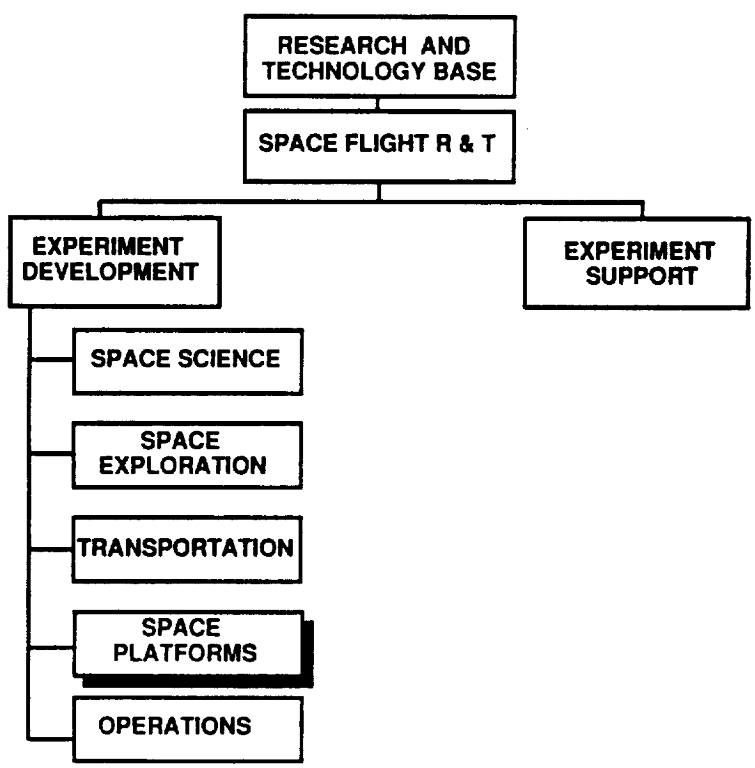


TECHNOLOGY FL.GHT EXPERIMENTS

OAET

ITP REV17

WORK BREAKDOWN STRUCTURE



INDUSTRY/UNIVERSITY EXPERIMENTS

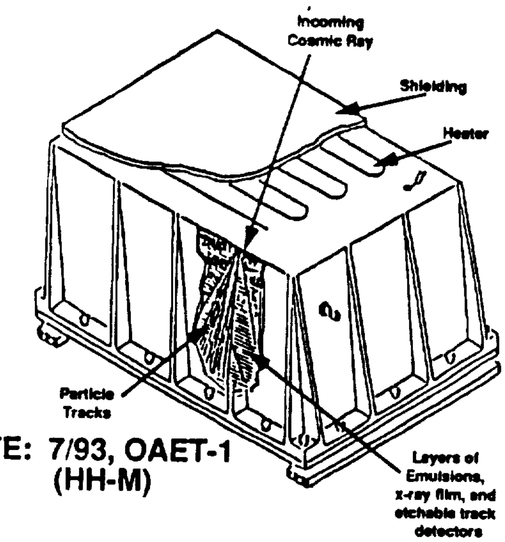
- EMULSION CHAMBER TECHNOLOGY
- MIDDECK ACTIVE CONTROL EXPERIMENT
- MODELING AND MEASUREMENT OF JOINT DAMPING
- MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT
- JITTER SUPPRESSION
- HEAT PIPE PERFORMANCE
- LIQUID MOTION IN A ROTATING TANK
- OPTICAL PROPERTIES MONITOR
- TWO PHASE FLOW
- FIRE SAFETY

NASA/JPL DEVELOPED EXPERIMENTS

- SOLAR ARRAY MODULE PLASMA INTERACTION EXPERIMENT
- THERMAL ENERGY STORAGE

EMULSION CHAMBER TECHNOLOGY (ECT)

UNIVERSITY OF ALABAMA, HUNTSVILLE (MSFC)



OBJECTIVE:

- CHARACTERIZE THE SPACE RADIATION ENVIRONMENT
- DEVELOP NEW DETECTOR TECHNIQUES TO MEASURE SECONDARY PARTICLE PRODUCTION

APPROACH:

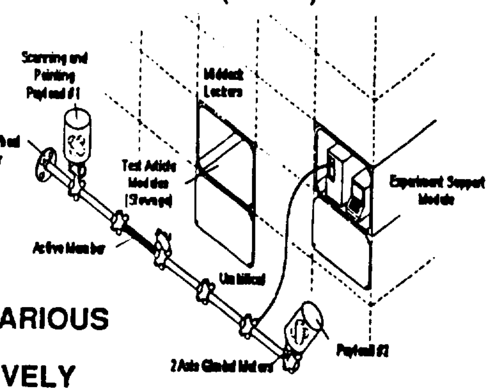
- MEASURE DOSE RATES, SPECTRA OF COSMIC RAYS, TRAPPED & SECONDARY PARTICLES AS A FUNCTION OF SHIELDING IN A LARGE EMULSION CHAMBER
- EXPERIMENT COST: $3.9M FLIGHT DATE: 7/93, OAET-1 (HH-M)

APPLICATION:

- FLIGHT DATA FOR PASSIVE DOSIMETERS SELECTED FOR USE ON SPACE STATION FREEDOM
- MEASUREMENTS WILL VERIFY DOSAGE & PARTICLE RATE COMPUTER CODES
- UNDERSTANDING OF THE RADIATION ENVIRONMENT WILL LEAD TO IMPROVED PERFORMANCE OF ADVANCED SENSORS & MICROCIRCUITS

35.12N7-10- 9/90

MIDDECK ACTIVE CONTROL EXPERIMENT (MACE)
MASSACHUSETTS INSTITUTE OF TECHNOLOGY (LARC)



OBJECTIVE:

- INVESTIGATE THE CONTROL/ STRUCTURES INTERACTION (CSI) OF AN ACTIVELY CONTROLLED, FLEXIBLE, ARTICULATING, MULTIBODY PLATFORM IN MICROGRAVITY

APPROACH:

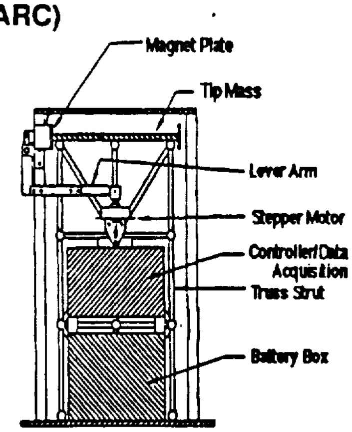
- EXCITE THE MULTIBODY PLATFORM WITH VARIOUS INPUT DEVICES
- MEASURE DYNAMIC RESPONSE WHILE ACTIVELY CONTROLLING STRUCTURE
- CORRELATE RESULTS WITH ANALYTICAL MODELS & GROUND TEST RESULTS
- EXPERIMENT COST: $7.8M FLIGHT DATA: 6/94, MIDDECK

APPLICATION:

- FLIGHT DATA PROVIDES FUNDAMENTAL UNDERSTANDING OF THE EFFECTS OF MICROGRAVITY ON THE INTERACTION BETWEEN THE DYNAMICS OF THE STRUCTURE AND CONTROL OF STRUCTURE
- ENABLES THE CONTROL OF FUTURE LARGE SPACE STRUCTURES (SUCH AS PRECISION SEGMENTED REFLECTORS)

35.12N.8.11 9/90

MEASUREMENTS & MODELING of JOINT DAMPING in SPACE
UTAH STATE UNIVERSITY (LARC)



OBJECTIVE:

- DETERMINE DAMPING BEHAVIOR OF JOINT DOMINATED TRUSS STRUCTURE IN MICROGRAVITY
- UPGRADE PREDICTION TECHNIQUES TO ELIMINATE GRAVITY EFFECTS ON SPACE STRUCTURES

APPROACH:

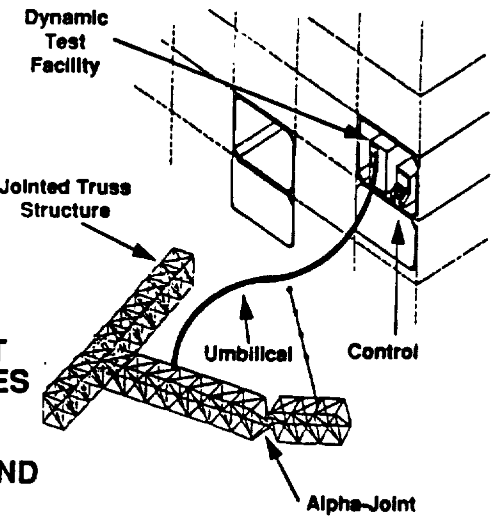
- EXCITE TRUSS STRUCTURE IN MICROGRAVITY
- MEASURE DYNAMIC RESPONSE OF STRUCTURE
- CORRELATE RESULTS WITH ANALYTICAL MODELS, GROUND AND KC-135 FLIGHT TEST RESULTS

- EXPERIMENT COST: $1.5M FLIGHT DATA: 2/94, CAP

APPLICATION:

- IMPROVE CAPABILITY OF PREDICTING DYNAMIC BEHAVIOR OF JOINT DOMINATED, TRUSS STRUCTURES IN SPACE (i.e., SPACE STATION)
- IMPROVED ANALYTICAL PREDICTIONS WILL REDUCE WEIGHT OF ADVANCED SPACE STRUCTURES

MIDDECK O-GRAVITY DYNAMICS EXPERIMENT (MODE)
MASSACHUSETTS INSTITUTE OF TECHNOLOGY (LaRC)



OBJECTIVE:

- MEASURE EFFECTS OF MICROGRAVITY ON THE DYNAMIC CHARACTERISTICS OF JOINTED-TRUSS STRUCTURES (SUCH AS SPACE STATION ALPHA-JOINT)
- INVESTIGATE THE DYNAMICS OF FLUID-SPACECRAFT INTERACTION IN 0-G

APPROACH:

- DEVELOP A MICROGRAVITY, DYNAMIC TEST FACILITY TO INDUCE KNOWN DISTURBANCES IN TEST ARTICLES, MEASURE DYNAMIC RESPONSES & DETERMINE METHODS OF PREDICTING DYNAMICS OF STRUCTURES AND FLUIDS IN THE 0-G ENVIRONMENT

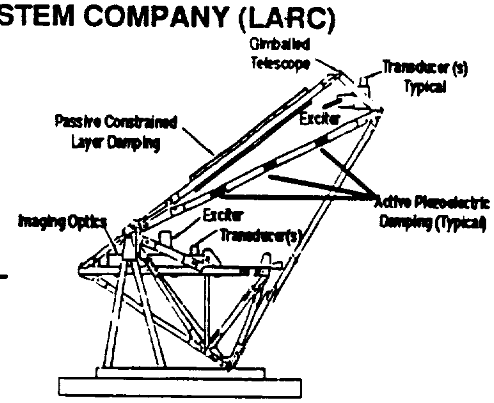
- EXPERIMENT COST: $1.9M   FLIGHT DATA: 9/91 (STS-48)
  MIDDECK (2 1/2 LOCKERS)

APPLICATION:

- VALIDATED PREDICTION & ANALYTICAL MODELING TECHNIQUES WILL PROVIDE ABILITY TO DESIGN & CONTROL LARGE SPACE STRUCTURES (i.e., SPACE STATION)

35.12N7-2 9/90

JITTER SUPPRESSION
MCDONNELL DOUGLAS MISSLE SYSTEM COMPANY (LARC)



OBJECTIVE:

- IN-SPACE EVALUATION OF PASSIVE AND ACTIVE DAMPING
- DEMONSTRATE TECHNIQUES APPLICABLE TO SUPPRESSION OF VIBRATORY JITTER
- ESTABLISH GROUND/FLIGHT EXPERIMENTAL DATABASE ON JITTER SUPPRESSION TECHNIQUES

APPROACH:

- EXPERIMENT BASED ON USE OF EXISTING PRECISION STRUCTURAL ASSEMBLY
- EXCITE STRUCTURE & RECORD STRUCTURAL DYNAMIC RESPONSE

- EXPERIMENT COST: $3.0M   FLIGHT DATA: 6/95, OAET-2 (HH-M)

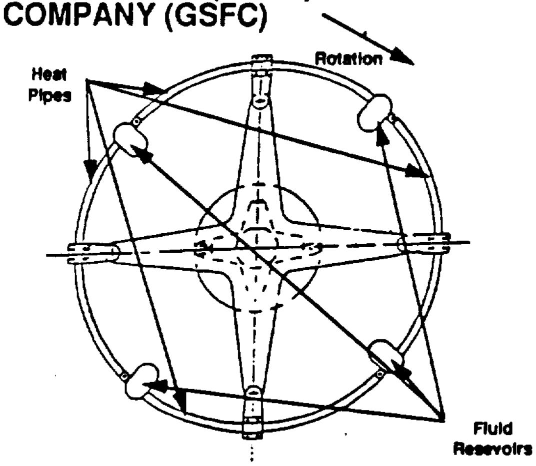
APPLICATION:

- IMPROVED CONTROL OF OPTICAL SENSORS AND LASER COMMUNICATION DEVICES
- PASSIVE & ACTIVE DAMPING TECHNOLOGIES WILL REDUCE WEIGHT OF LARGE SPACE STRUCTURES

35.12N.8.8 9/90

HEAT PIPE PERFORMANCE (HPP)

HUGHES AIRCRAFT COMPANY (GSFC)



OBJECTIVE:

- EVALUATE EFFECTS OF MICROGRAVITY ON HEAT PIPE PERFORMANCE
- TEST METHODS OF RECOVERY FROM HEAT PIPE DEPRIME CONDITIONS
- INVESTIGATE NUTATION DYNAMICS

APPROACH:

- 4 HEAT PIPES MOUNTED ON ROTATING STRUCTURE
- VARIABLE-G APPLIED TO HEAT PIPES BY CONTROLLED SPINNING
- DEPRIME AND REPRIME IN LOW GRAVITY CONDITIONS
- MEASURE HEAT PROPAGATION THROUGH HEAT PIPES AT VARIOUS G LEVELS

- EXPERIMENT COST: $2.6M   FLIGHT DATA: 9/92, MIDDECK

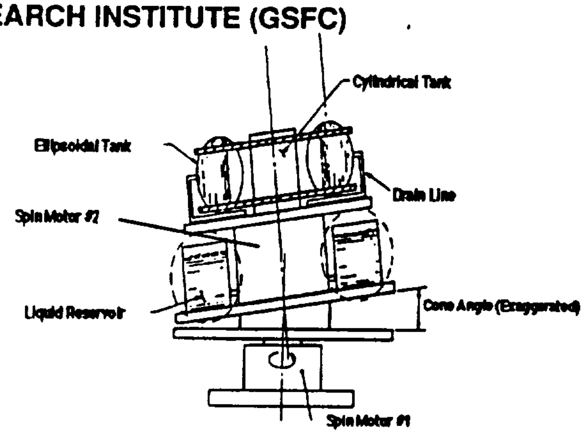
APPLICATION:

- IMPROVE THERMAL EFFICIENCY OF SPACECRAFT POWER SYSTEMS
- ENABLING TECHNOLOGY FOR APPLICATION OF HEAT PIPES TO ADVANCED SPACECRAFT

35.12N7-11- 9/90

LIQUID MOTION in a ROTATING TANK

SOUTHWEST RESEARCH INSTITUTE (GSFC)



OBJECTIVE:

- MEASURE DYNAMICS OF LIQUIDS IN TANKS ROTATING ABOUT A CENTROID IN SPACE

APPROACH:

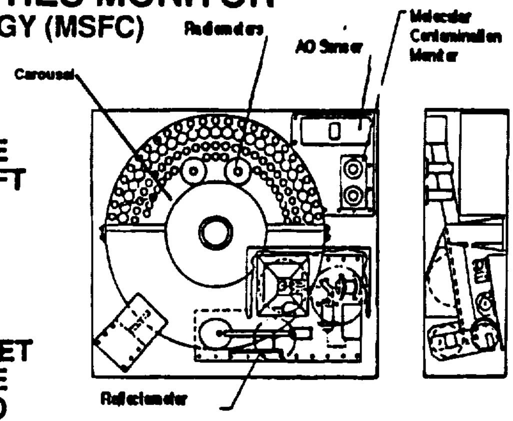
- VARY LIQUID FILL LEVELS, LIQUID PROPERTIES, TANK GEOMETRY, SPIN RATES & NUTATION ANGLES TO OBTAIN FLIGHT DATA
- EXPERIMENT COST: $3.2M
  FLIGHT DATA: 2/94, MIDDECK

APPLICATION:

- FLIGHT DATA TO BE USED TO VALIDATE & UPGRADE ANALYTICAL MODELS
- UNDERSTANDING OF FLUID DYNAMICS IN MICROGRAVITY ALLOWS DESIGN OF LONGER LIFE SPACECRAFT THROUGH REDUCED FUEL CONSUMPTION

OPTICAL PROPERTIES MONITOR

AZ TECHNOLOGY (MSFC)



OBJECTIVE:

- DETERMINE THE EFFECTS OF THE SPACE ENVIRONMENT ON CRITICAL SPACECRAFT AND OPTICAL MATERIALS

APPROACH:

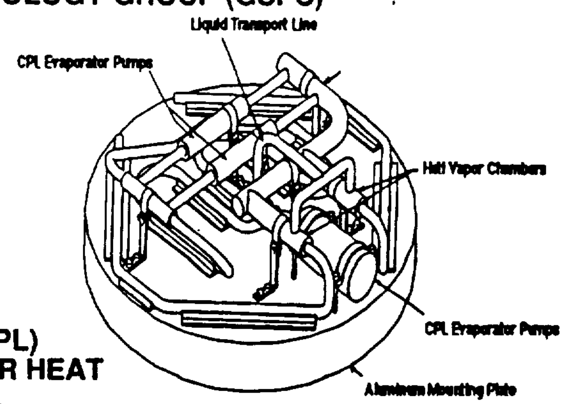
- SPECTRAL REFLECTANCE, TOTAL INTEGRATED SCATTER AND ULTRA-VIOLET REFLECTANCE/TRANSMITTANCE WILL BE MEASURED IN-SITU AND POST-FLIGHT TO DETERMINE OPTICAL, MECHANICAL, ELECTRICAL AND EROSION EFFECTS
- EXPERIMENT COST: TBD FLIGHT DATA: 10/93, EURECA-2

APPLICATION:

- IMPROVE OPTICAL COATINGS FOR ADVANCED SENSORS AND MATERIALS FOR ADVANCED SPACECRAFT
- UPGRADE ABILITY TO PREDICT DEGRADATION OF MATERIALS & COATINGS DUE TO THE SPACE ENVIRONMENT

TWO-PHASE FLOW

TRW SPACE & TECHNOLOGY GROUP (GSFC)



OBJECTIVE:

- EVALUATE MICROGRAVITY OPERATION OF A HIGH EFFICIENCY THERMAL INTERFACE (HETI) IN AN INTEGRATED TWO-PHASE THERMAL CONTROL SYSTEM

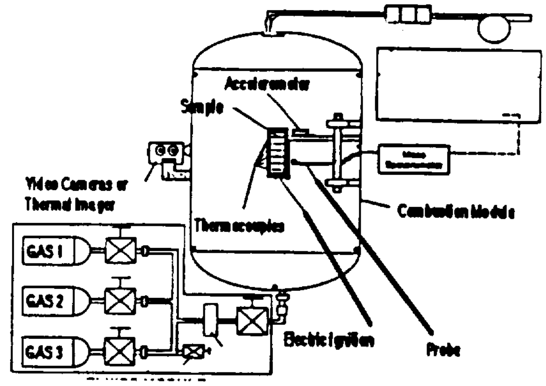
APPROACH:

- UTILIZE CAPILLARY PUMP LOOP (CPL) EVAPORATOR PUMPS TO TRANSFER HEAT THROUGH THE THERMAL CONTROL SYSTEM
- MEASURE PERFORMANCE OF SYSTEM DURING A VARIETY OF START-UP, HEAT LOAD, AND SHUT-DOWN CONDITIONS
- EXPERIMENT COST: $3.5M FLIGHT DATA: 2/95, CAP

APPLICATION:

- WILL PROVIDE RELIABLE, EFFICIENT, INTEGRATED THERMAL CONTROL SYSTEM FOR HIGH POWER SPACECRAFT

RISK BASED FIRE SAFETY
UNIVERSITY of CALIFORNIA, LOS ANGELES (LERC)



OBJECTIVE:

- MEASURE EFFECTS OF MICROGRAVITY ON THE COMBUSTION CHARACTERISTICS OF MATERIALS SUBJECT TO VARIOUS OXYGEN CONCENTRATIONS

APPROACH:

- SHUTTLE BAY MOUNTED COMBUSTION CHAMBER UTILIZED TO MEASURE FIRE PROPAGATION, CHARACTERISTICS & COMBUSTION PRODUCTS

- EXPERIMENT COST: TBD   FLIGHT DATA: TBD

APPLICATION:

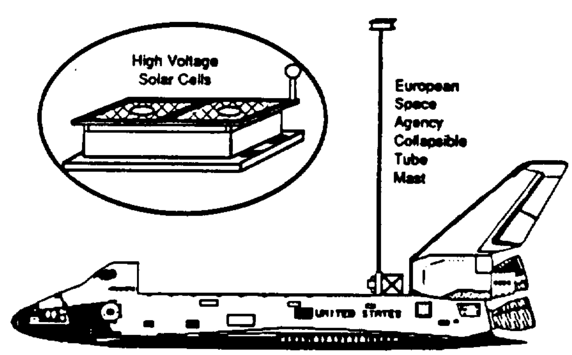
- PROVIDES FUNDAMENTAL FLIGHT DATA TO VALIDATE & IMPROVE FIRE PROPAGATION PREDICTION & MODELING TECHNIQUES
- ESSENTIAL MEASUREMENTS TO PROVIDE SAFE ENVIRONMENT FOR LONG-TERM, MANNED SPACE SYSTEMS

35.12N.8.14 9/90

SOLAR ARRAY MODULE PLASMA INTERACTION EXPERIMENT (SAMPIE)
LEWIS RESEARCH CENTER

OBJECTIVE:

- EVALUATE THE EFFECTS OF LOW EARTH ORBIT PLASMA INTERFERENCE ON HIGH VOLTAGE SOLAR CELLS



APPROACH:

- DETERMINE VOLTAGE THRESHOLD FOR ARCING ACROSS CELLS, ARC RATE, STRENGTH & PLASMA CURRENT COLLECTION CHARACTERISTICS FOR ADVANCED SOLAR CELLS EXTENDED 15 METERS AWAY FROM SHUTTLE BAY

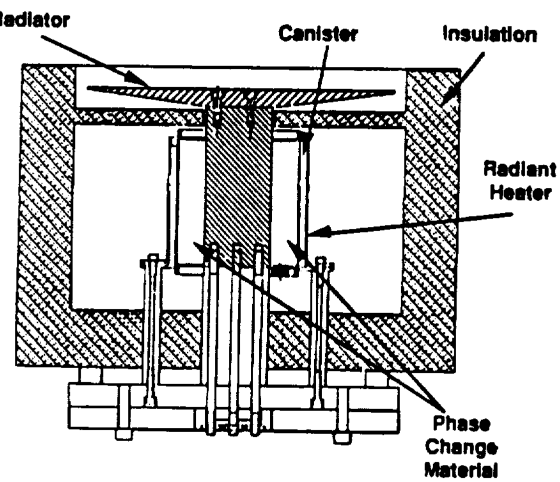
- EXPERIMENT COST: $3.5M   FLIGHT DATE: 7/93, OAET-1 (HH-M)

APPLICATION:

- IMPROVE EFFECTIVENESS & LIFETIME OF ADVANCED HIGH VOLTAGE SOLAR CELLS TO BE USED ON SPACE STATION UPGRADE & ADVANCED SCIENCE SATELLITES

35.12N7-7- 9/90

THERMAL ENERGY STORAGE (TES) MATERIALS
LEWIS RESEARCH CENTER



OBJECTIVE:

- DETERMINE THE BEHAVIOR OF THERMAL ENERGY STORAGE MATERIALS SUBJECTED TO MICROGRAVITY CONDITIONS

APPROACH:

- MEASURE THE TRANSIENT TEMPERATURES, STRESSES, VOID SIZE & VOID LOCATIONS OF PHASE CHANGE SALTS DURING MULTIPLE FREEZING & THAWING CYCLES

- EXPERIMENT COST - $7M FLIGHT DATA: 7/93 (STS-62) OAET-1(HH-M) & 7/95 OAET-2 (HH-M)

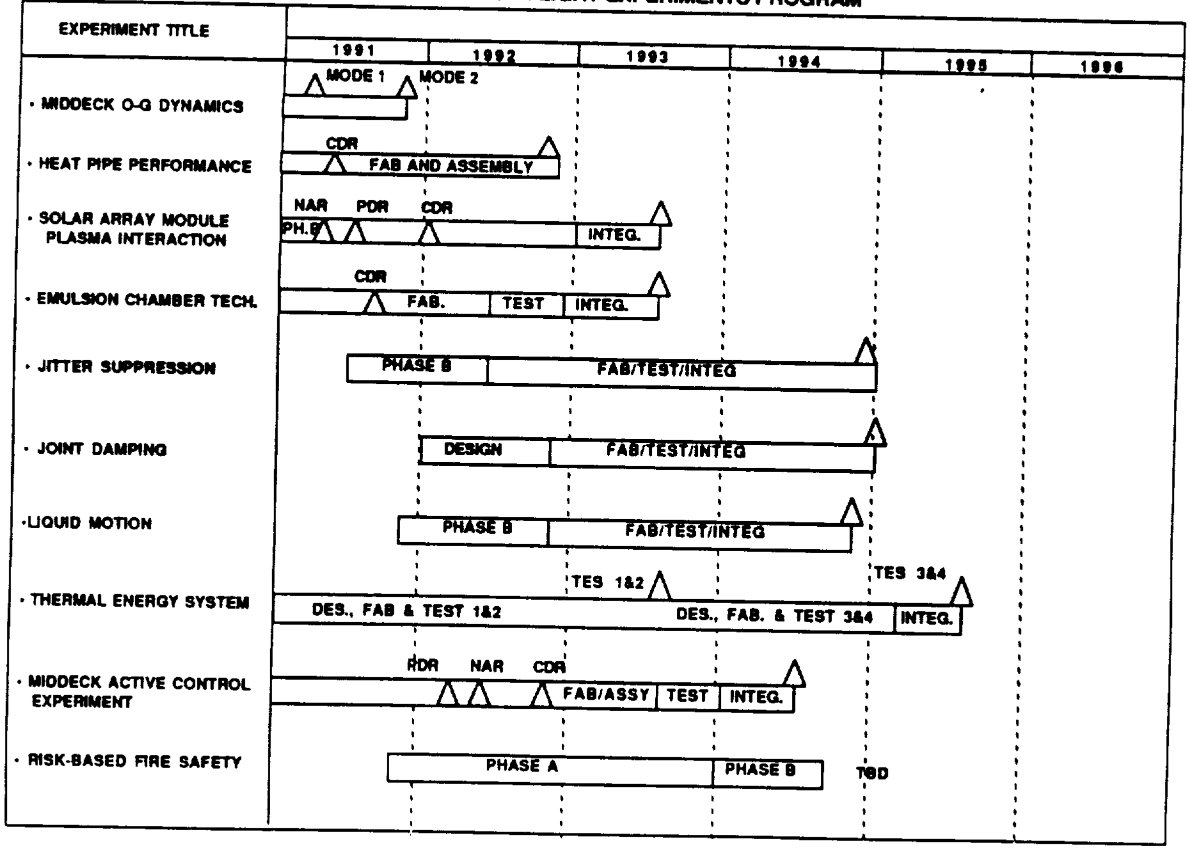
APPLICATION:

- PHASE CHANGE MATERIALS PROVIDE POTENTIAL FOR INCREASED ENERGY STORAGE WITH LOWER WEIGHT & VOLUME PENALTIES (EFFICIENT STORAGE DEVICE FOR ADVANCED SPACE STATION)

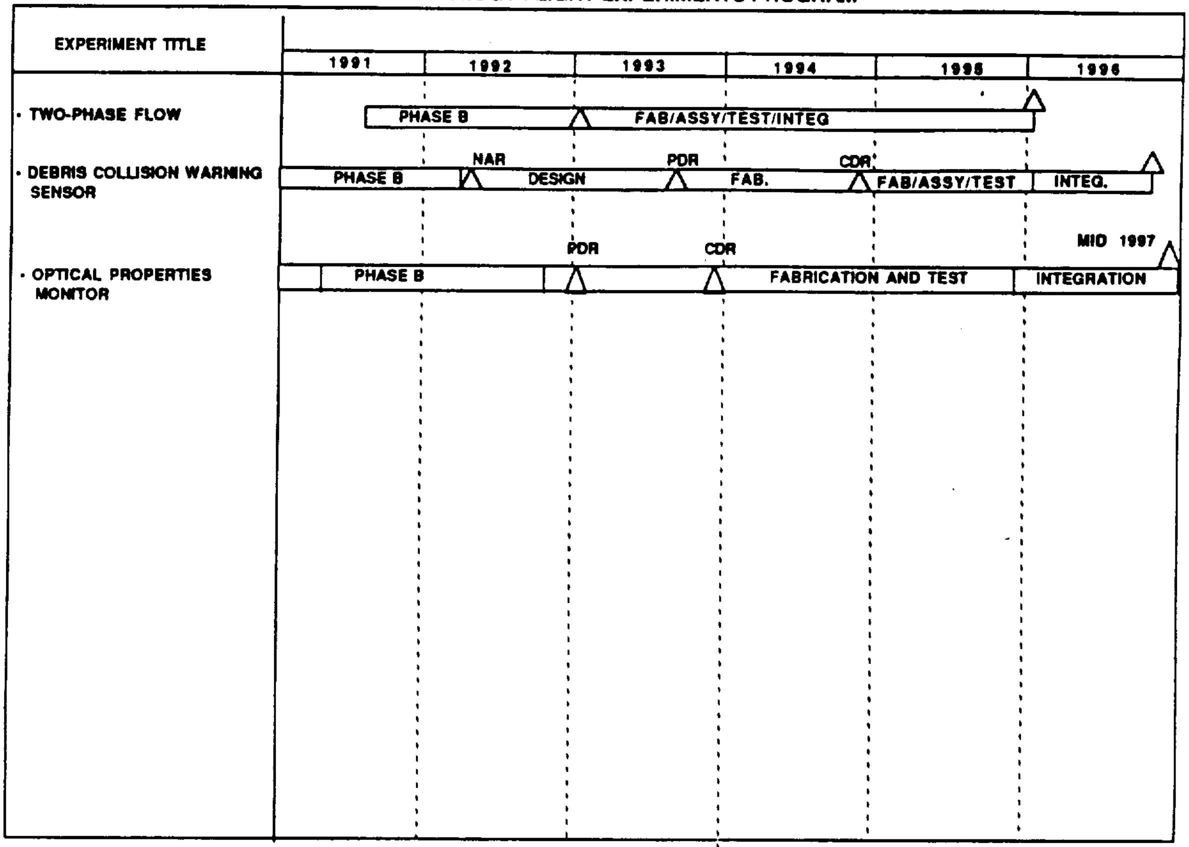
35.12N7-3- 8/90

SPACE PLATFORM

FLIGHT PRO...CTS DIVISION
TECHNOLOGY FLIGHT EXPERIMENTS PROGRAM



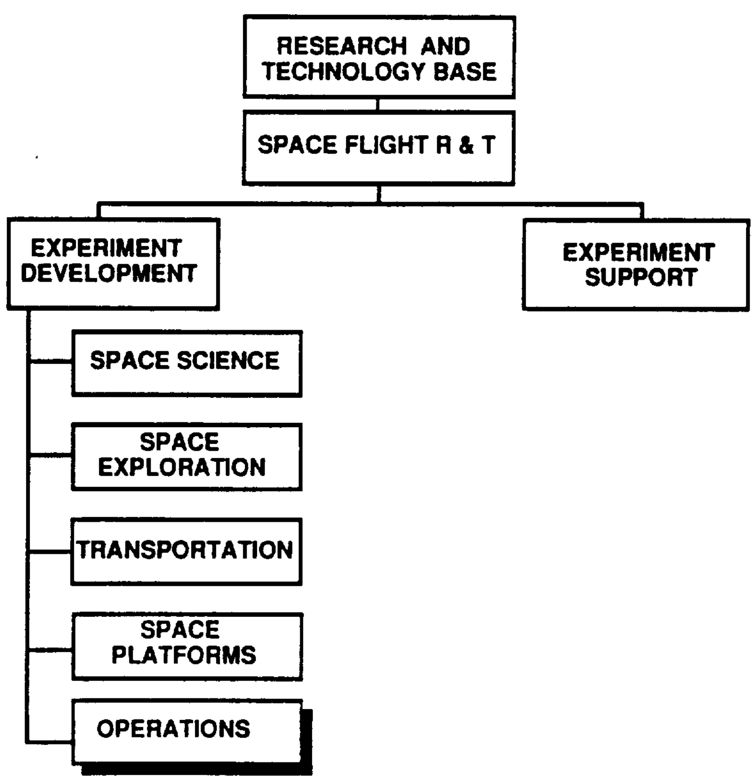
FLIGHT PRC. .CTS DIVISION
TECHNOLOGY FLIGHT EXPERIMENTS PROGRAM



TECHNOLOGY FLıGHT EXPERIMENTS

OAET ITP REV18

WORK BREAKDOWN STRUCTURE



INDUSTRY/UNIVERSITY EXPERIMENTS

(NONE IDENTIFIED)

NASA/JPL DEVELOPED EXPERIMENTS

(NONE IDENTIFIED)

UNIVERSITY PROGRAMS OVERVIEW

Presentation to:

THE ITP EXTERNAL REVIEW TEAM

Gregory M. Reck
Director for Space Technology
Office of Aeronautics, Exploration and Technology

June 25, 1991

OAET

UNIVERSITY PROGRAMS

BROADEN THE CAPABILITIES OF THE NATION'S ENGINEERING COMMUNITY TO PARTICIPATE IN THE U.S. CIVIL SPACE PROGRAM THROUGH UNIVERSITY-BASED RESEARCH AND EDUCATION

- UNIVERSITY SPACE ENGINEERING RESEARCH CENTERS
  - FOSTER CREATIVE AND INNOVATIVE CONCEPTS OF FUTURE SPACE SYSTEMS
  - EXPAND THE NATION'S ENGINEERING TALENT BASE FOR RESEARCH AND DEVELOPMENT
- UNIVERSITY INVESTIGATORS — RESEARCH
  - SPONSOR INDIVIDUAL RESEARCH ON HIGHLY INNOVATIVE SPACE TECHNOLOGY CONCEPTS AND APPROACHES
- UNIVERSITY ADVANCED DESIGN
  - FOSTER INTERDISCIPLINARY ENGINEERING DESIGN EDUCATION

91 2061

Office of Aeronautics, Exploration and Technology

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UNIVERSITY SPACE ENGINEERING RESEARCH PROGRAM

UNIVERSITY-BASED CENTERS

- ATTRACT AND RETAIN STUDENT AND INDUSTRY SUPPORT
- SUPPORT AND EXPAND THE NATION'S ENGINEERING TALENT BASE
- FOSTER INNOVATIVE, MULTI-DISCIPLINARY RESEARCH

- UNIVERSITY OF ARIZONA
  - Planetary Resources
- UNIVERSITY OF CINCINNATI
  - Propulsion Monitoring Systems
- UNIVERSITY OF COLORADO, BOULDER
  - Space Construction
- UNIVERSITY OF IDAHO
  - VLSI hardware
- MASSACHUSETTS INSTITUTE OF TECHNOLOGY
  - Controlled Structures Technology
- UNIVERSITY OF MICHIGAN
  - Space TeraHertz Sensing Technologies
- NORTH CAROLINA STATE AT RALEIGH & NORTH CAROLINA AGRICULTURAL & TECHNICAL STATE UNIVERSITIES
  - Mars Mission Technologies
- PENNSYLVANIA STATE UNIVERSITY
  - Propulsion
- RENSSELAER POLYTECHNIC INSTITUTE
  - Robotics

91-2118

UNIVERSITY SPACE ENGINEERING RESEARCH CENTERS

OAET

- NINE CENTERS SELECTED (4/88) OUT OF 115 PROPOSALS
- PLAN TO INCREASE TO TWENTY CENTERS
- GRANTS OF $1M TO $2M PER YEAR FOR A MINIMUM OF FOUR YEARS
- FLEXIBLE SO THAT UNIVERSITIES ARE FREE TO BE INNOVATIVE
- CENTER CONCEPT FOR MULTI-DISCIPLINARY RESEARCH AND EDUCATION
- COLLABORATIVE ACTIVITY INVOLVING NASA CENTERS AND INDUSTRY
- FUNDING SUPPORT TO U.S. STUDENTS ONLY

UNIVERSITY INVESTIGATORS RESEARCH

OAET

- SPONSORS INDIVIDUAL RESEARCH ON HIGHLY INNOVATIVE SPACE TECHNOLOGY CONCEPTS AND APPROACHES
- GRANTS TO INDIVIDUALS WITH DEMONSTRATED RECORD OF PERFORMANCE
- EFFORT OUTSIDE THE BOUNDS OF RESEARCH TYPICALLY SUPPORTED BY THE OAET TECHNICAL DIVISIONS (i.e. HIGH TECHNICAL RISK / PAY-OFF, MULTI- OR TRANS-DISCIPLINARY, &c.)
- POSITIVE RESEARCH RESULT LIKELY TO LEAD TO FURTHER SUPPORT FROM OTHER NASA SOURCES
- GRANTS ON ORDER OF $100K PER YEAR FOR UP TO THREE YEARS

UNIVERSITY INVESTIGATORS RESEARCH

OAET

- DR. BOCKRIS, TEXAS A&M UNIVERSITY -- THE ELECTROCHEMICAL INCINERATION OF HUMAN WASTES IN CONFINED SPACES
- DR. BYER, STANFORD UNIVERSITY -- SOLID-STATE LASERS FOR COHERENT COMMUNICATION AND REMOTE SENSING
- DR. PETERSON, STANFORD UNIVERSITY -- LOW POWER SIGNAL PROCESSING TECHNOLOGY
- DR. PILKEY, UNIVERSITY OF VIRGINIA -- ADVANCED CONCEPTS FOR METALLIC CRYO-THERMAL SPACE STRUCTURES
- DR. COLDREN, UNIVERSITY OF CALIFORNIA, SANTA BARBARA -- INTEGRABLE, FIELD-INDUCED GUIDES FOR MODULATION / SWITCHING OF LIGHTWAVES
- DR. SADEH, COLORADO STATE UNIVERSITY -- INFLATABLE STRUCTURES FOR A LUNAR BASE
- ADDITIONAL PROPOSALS UNDER REVIEW / EVALUATION

UNIVERSITY ADVANCED DESIGN

OAET

- PROGRAM FOSTERS INTERDISCIPLINARY UNIVERSITY ENGINEERING DESIGN EDUCATION
- SUPPORTS ADVANCED SYSTEM DESIGN COURSES AND PROJECTS AT THE UNDERGRADUATE SENIOR LEVEL
- AWARDS OF APPROXIMATELY $25K / YEAR FOR 3 YEARS
- ~1,000 STUDENTS AT 40 UNIVERSITY ENGINEERING DEPARTMENTS INVOLVED, INCLUDING 2 HBCU's WITH CODE E FUNDING AND 10 AERO DEPARTMENTS
- ADMINISTERED BY USRA UNDER CODE XEU CONTRACT
- UNIVERSITIES ARE TEAMED WITH NASA CENTER MENTORS
- GRADUATE TEACHING ASSISTANT SPENDS SUMMER WORKING WITH MENTOR AT NASA FIELD CENTER
- STUDENTS PRESENT RESULTS AT ANNUAL SUMMER CONFERENCE HELD NEAR A NASA CENTER

UNIVERSITY ADVANCED DESIGN

OAET

- SELECTED EXAMPLES OF CURRENT STUDENT DESIGN PROJECTS
  - GEORGIA INSTITUTE OF TECHNOLOGY -- LUNAR SURFACE VEHICLES AND STRUCTURES MODEL
  - UNIVERSITY OF ALABAMA -- DESIGN OF HIGH TEMPERATURE FURNACE FOR APPLICATIONS IN MICRO-GRAVITY
  - FLORIDA A&M / FLORIDA STATE UNIVERSITY -- LUNAR LANDER GROUND SUPPORT SYSTEM
  - UNIVERSITY OF IDAHO -- EXERCISE FACILITY FOR A SPACE HABITAT
  - UNIVERSITY OF MARYLAND -- WALKING ROBOT
  - OLD DOMINION UNIVERSITY -- MARS / LUNAR RESOURCE UTILIZATION
  - PENNSYLVANIA STATE UNIVERSITY -- MARS SAMPLE RETURN PROJECT
  - PRAIRIE VIEW A&M UNIVERSITY -- MARS HABITAT
  - VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY -- SOLAR ELECTRIC PROPULSION CARGO VEHICLES FOR SPLIT/SPRINT MARS MISSIONS

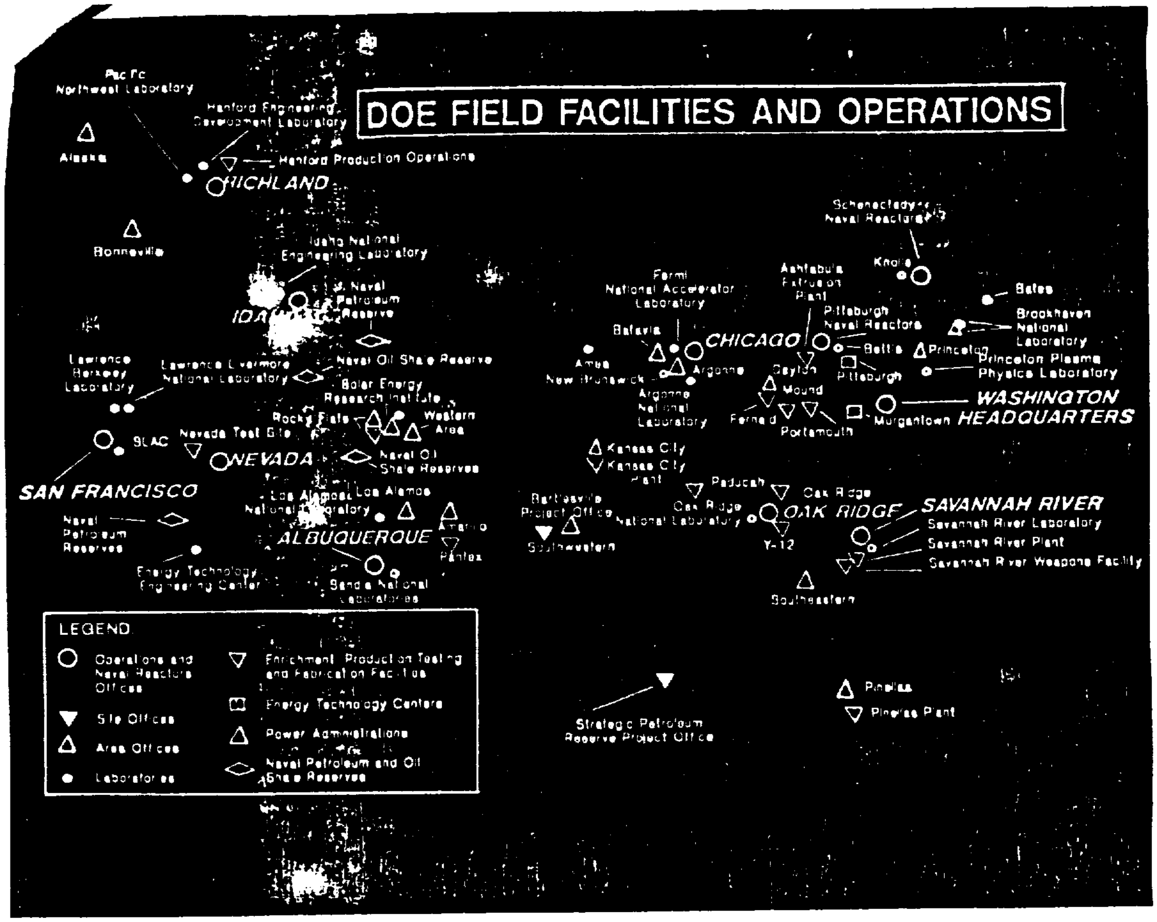
PRESENTATION TO

THE SPACE SYSTEMS AND TECHNOLOGY ADVISORY COMMITTEE (SSTAC)

Dr. Tom Finn
U.S. Department of Energy

DEPARTMENT OF ENERGY MISSION

- o ENERGY
  - ENERGY R&D - OIL, GAS, COAL, CONSERVATION, NUCLEAR, RENEWABLES, FUSION, GLOBAL CLIMATE CHANGE
  - REGULATION
  - ENERGY SECURITY - STRATEGIC PETROLEUM RESERVE
- o NATIONAL SECURITY
  - WEAPONS COMPLEX/CLEANUP
  - NAVAL REACTOR DEVELOPMENT
  - SDI
- o SCIENCE AND TECHNOLOGY
  - SUPERCONDUCTING SUPERCOLLIDER (SSC)
  - SYNCHROTRON LIGHT SOURCES, BEVALAC



DEPARTMENT OF ENERGY NATIONAL LABORATORIES

MULTI-PROGRAM

ARGONNE NATIONAL LABORATORY
BROOKHAVEN NATIONAL LABORATORY
IDAHO NATIONAL ENGINEERING LABORATORY
LAWRENCE BERKELEY LABORATORY
LAWRENCE LIVERMORE NATIONAL LABORATORY
LOS ALAMOS NATIONAL LABORATORY
OAK RIDGE NATIONAL LABORATORY
PACIFIC NORTHWEST LABORATORY
SANDIA NATIONAL LABORATORY

SINGLE-PROGRAM

AMES LABORATORY
CONTINUOUS ELECTRONIC BEAM ACCELORATOR FACILITY
FERMI LABORATORY
PRINCETON PLASMA PHYSICS LABORATORY
SOLAR ENERGY RESEARCH INSTITUTE
STANFORD LINEAR ACCELERATOR CENTER
SUPER CONDUCTING SUPER COLLIDER

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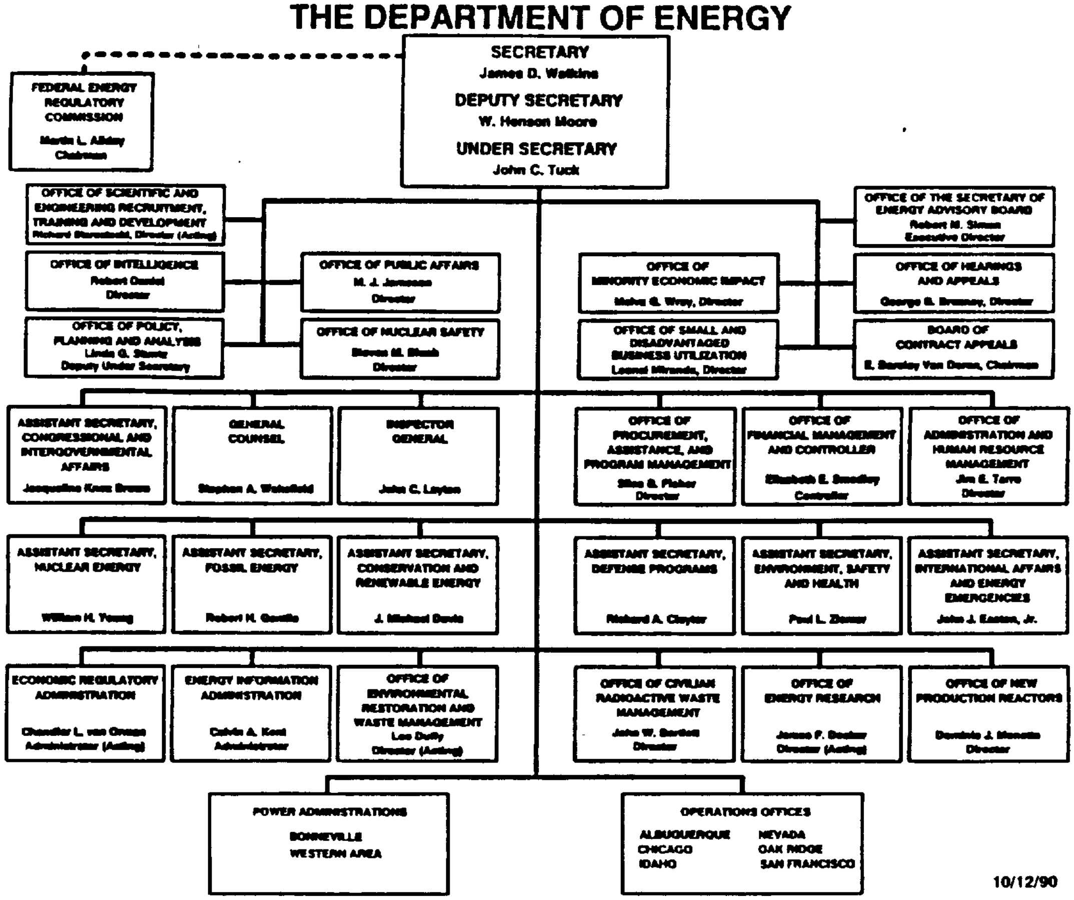
DOE SPACE ACTIVITIES

- o Power and Propulsion
  - SP-100 (Joint NASA/DoD/DOE Program)
  - Radioisotope Thermal Generators (Joint NASA/DOE Program)
  - Thermionic Conversion (DOE/DoD Program)
  - Nuclear Propulsion (DOE/DoD/NASA Program)
  - Supporting Technologies in Space Power (DOE/DoD Program)
- o National Security
  - Treaty Verification
  - Kinetic and Directed Energy Weapons
  - State-of-the-art space qualified computers, sensors and materials
  - Rapid prototype development and flight test
  - Extensive modeling and simulation

THE DEPARTMENT OF ENERGY



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DOE SPACE ORGANIZATIONAL INITIATIVES

- o Special Assistant to the Secretary (Space)
- o Office of Space, by 1 October 1991
  - Policy
  - Long-Range Planning
  - Department-wide Budget Formulation
  - Systems Architecture and Engineering
  - Technical Coordination and Oversight
  - Advanced Technology Development

DEPARTMENT OF ENERGY'S SPACE MISSION

- o Evolving from terrestrial missions
  - Energy
  - National Security
  - Science and Technology
- o Primary focus is to support national objectives:
  - Civil
  - National Security
  - Commercial

DOE FUTURE SPACE ACTIVITIES

- SPACE EXPLORATION INITIATIVE

- U.S. GLOBAL CHANGE RESEARCH AND DEVELOPMENT PROGRAM

- SPACE TECHNOLOGY INITIATIVE

DOE SPACE TECHNOLOGY INITIATIVES

Nuclear Energy Technologies, Concepts and Applications

- o Power
- o Propulsion

Non-nuclear Energy Technologies, Concepts and Applications

- o Sources, including in situ
- o Transmission
- o Storage and management

Environmental Assessment and Monitoring

- o Remote sensing
- o Modeling
- o Optoelectronics

Human Health/Life Sciences

- o Radiation effect
- o Risk management

Manufacturing and Construction

- o Materials
- o Shielding
- o Robotics

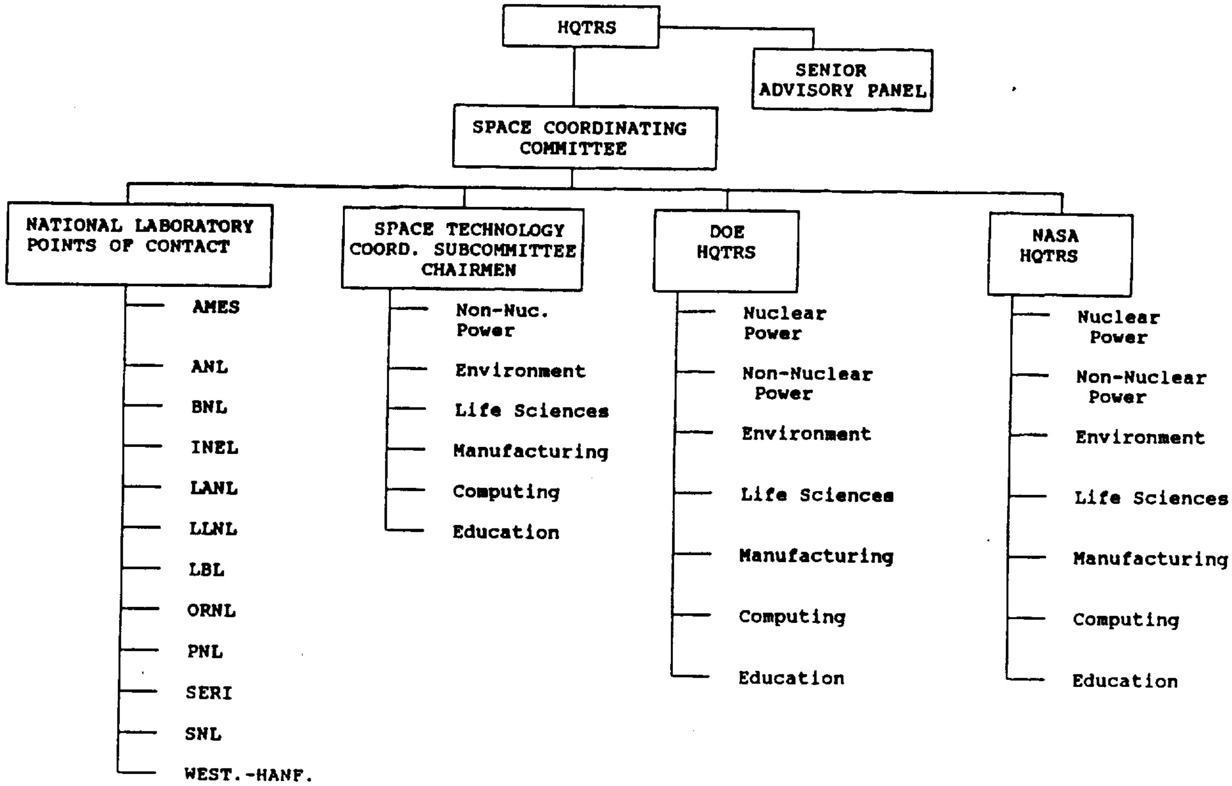
High Performance Computing

Science, Mathematics and Engineering Education

DOE SPACE TECHNICAL COORDINATING SUBCOMMITTEES

NUCLEAR ENERGY TECHNOLOGIES, CONCEPTS AND APPLICATIONS	[NE-50]
- POWER	
- PROPULSION	
NON-NUCLEAR ENERGY TECHNOLOGIES, CONCEPTS AND APPLICATIONS	[PNL]
- SOURCES	LANL
- TRANSMISSION	PNL
- STORAGE	SERI
- ENERGY MANAGEMENT	
ENVIRONMENTAL ASSESSMENT AND MONITORING	[SNL]
- SENSING	SNL
- MODELING	LLNL
- ELECTRONICS	SNL
HEALTH/LIFE SCIENCES	[LANL]
- RADIATION EFFECTS	LBL/BNL
- SHIELDING	
MANUFACTURING AND CONSTRUCTION TECHNIQUES	[ORNL]
- MATERIALS	AMES
- SHIELDING	SNL/LANL
- ROBOTICS	ORNL
HIGH PERFORMANCE COMPUTING	[LLNL]
SCIENCE, MATHEMATICS AND ENGINEERING EDUCATION	[PNL]

[ ] INDICATES PROPOSED COORDINATOR LABORATORY AND CHAIRMAN



DOE SPACE
INTER-AGENCY COORDINATION

- o NASA-DOE MOU ON SEI
- o NASA-DOE-DoD MOU'S
  - SP-100
  - THERMIONICS
- o SPACE COORDINATING COMMITTEE

DOE-NASA SEI MEMORANDUM OF UNDERSTANDING (9 JULY 1990)

OBJECTIVE

- o COORDINATE ACTIVITIES RELATIVE TO SEI
- o DEVELOP PROCESS THAT FOSTERS EXCHANGE OF INFORMATION AND FACILITATES MANAGEMENT OF SEI RESEARCH AND DEVELOPMENT
- o ENABLE EACH AGENCY TO FOCUS RESEARCH AND DEVELOPMENT OF RESPECTIVE LABORATORIES AND PROGRAMS

Synergy Group Symposium
June 24, 1991

Technology Development for America's Future Competitiveness

The National Center for Advanced Technologies

Aerospace Industries Association

Some Historical Precedents

KEY TECHNOLOGIES FOR THE YEAR

2000

- 1970 - The Smoke Stacks
- 1975 - Appliances
- 1980 - Automotive Industry
- 1985 - Consumer Electronics
- ? - Aerospace Technology

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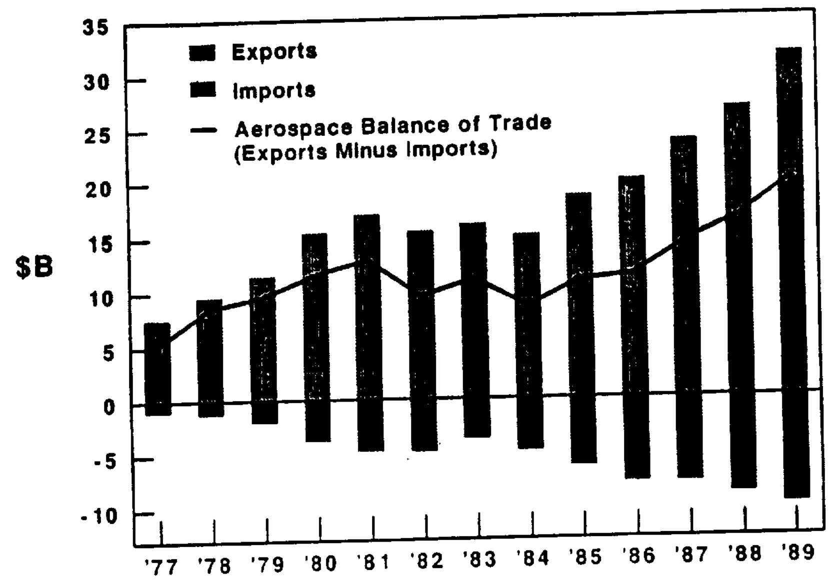
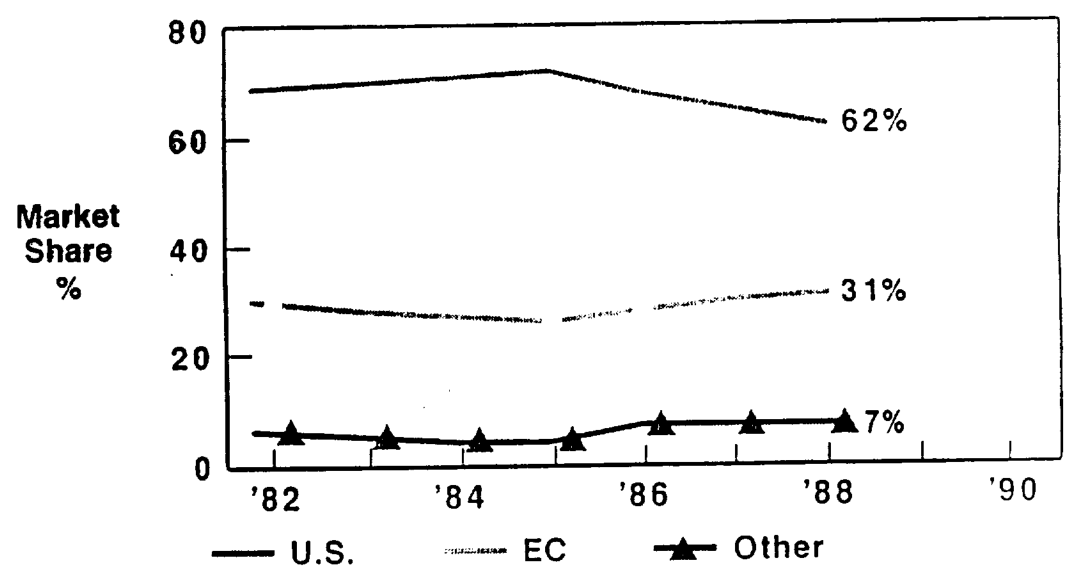
Aerospace Exports, Imports, and Trade Balance

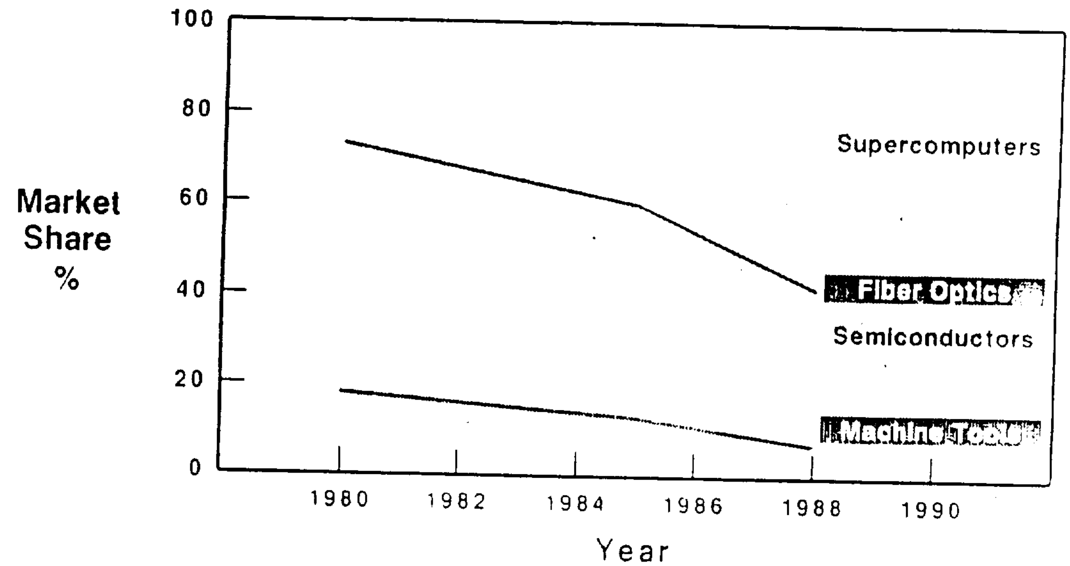


KEY TECHNOLOGIES FOR THE YEAR 2000

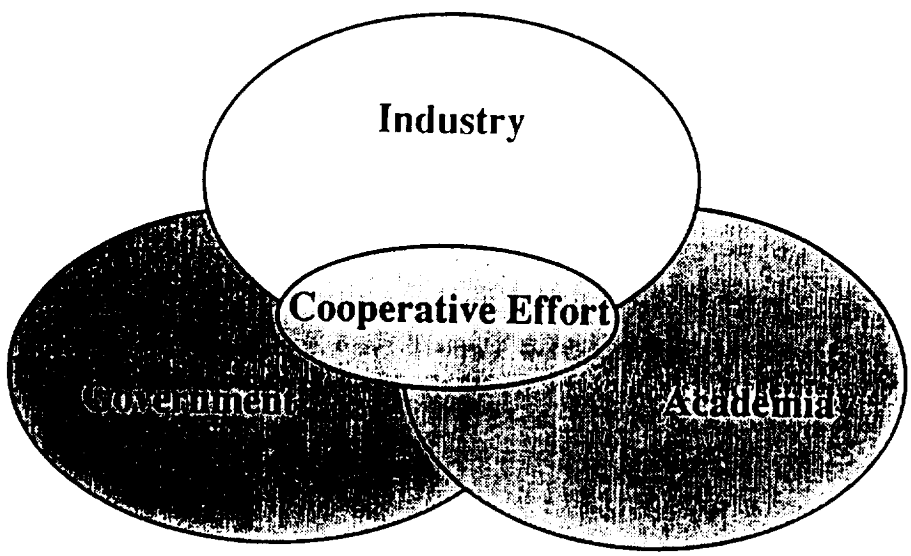
World Aerospace Market Share



World Market Share



Key Technologies for the Year 2000

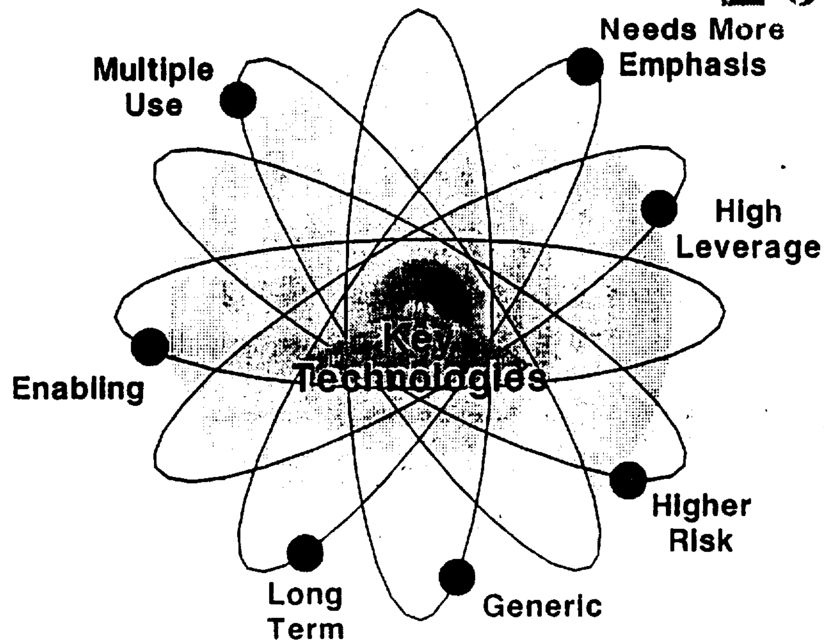


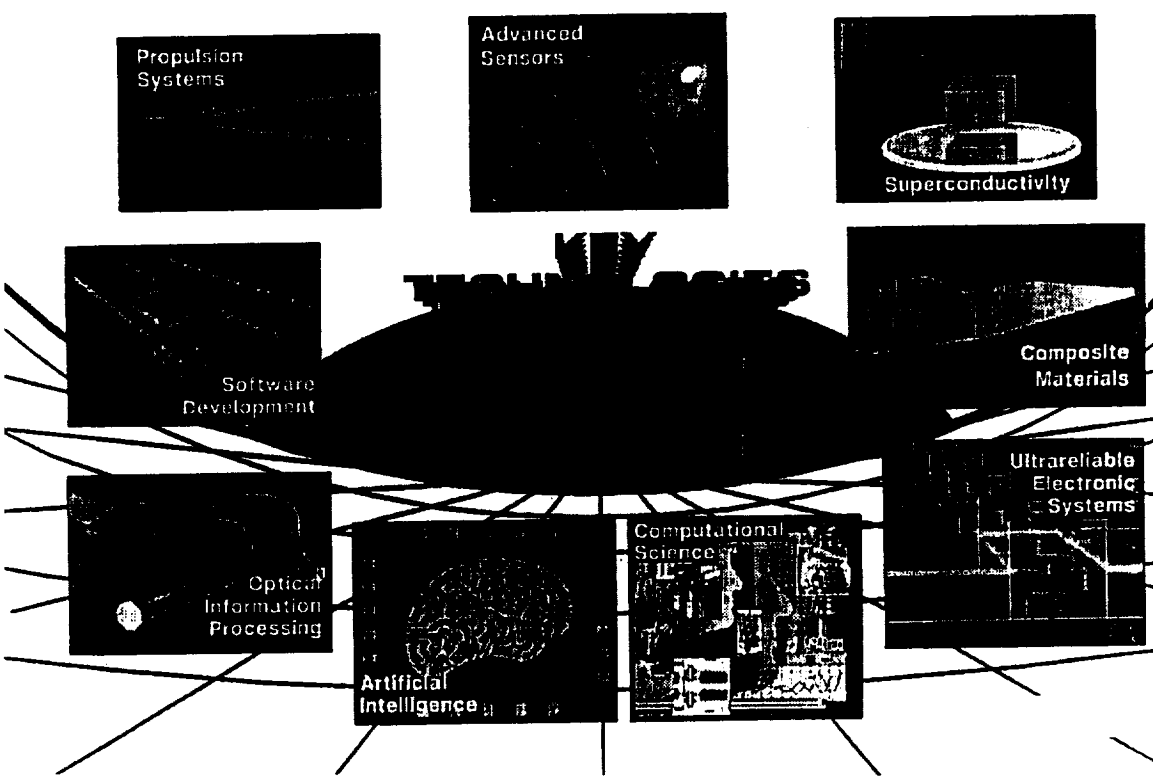
To Identify, Nurture and Insure Benefits from a Focused Set of Essential Enabling Technologies

Technologies Selection Criteria

KEY TECHNOLOGIES FOR THE YEAR

2000





Company Involvement

KEY TECHNOLOGIES FOR THE YEAR 2000

Technology	Sponsor	Company
Advanced Sensors	R.N. Longuemare	Westinghouse
Airbreathing Propulsion	F.E. Pickering	General Electric
Artificial Intelligence	R.P. Caren	Lockheed
Advanced Composites	F.W. Fenter	LTV
Computational Science	A.N. Chester	GM / Hughes
Optical Information Processing	R.G. Anderson	Grumman
Rocket Propulsion	H.W. Campen	Aerojet
Software Development	J.R. Burnett	TRW
Superconductivity	R.P. Caren	Lockheed
Ultra-Reliable Electronic Systems	L. Giuliano	ITT
Advanced Metallic Structures	W.S. Cebulak	Alcoa

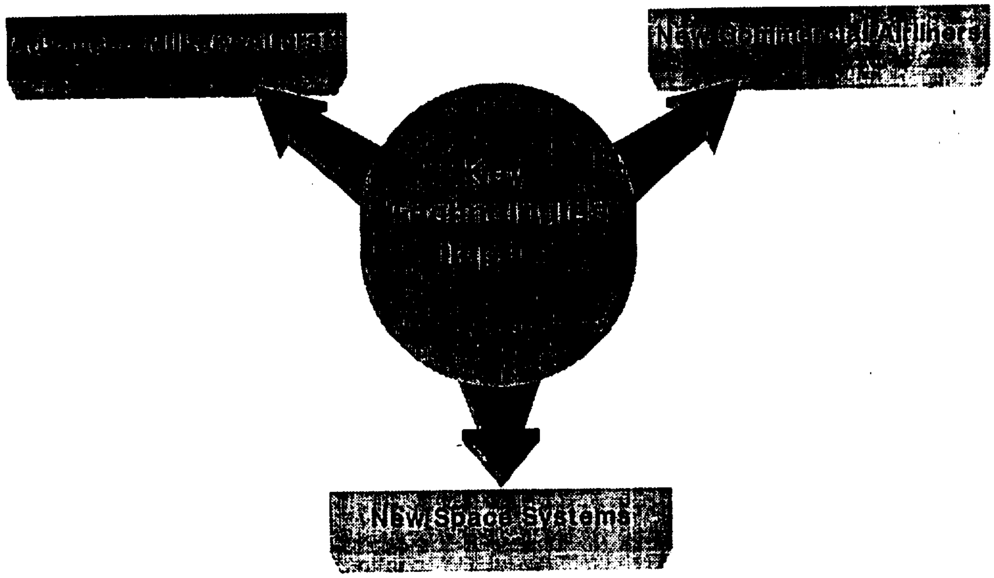
Consensus Building for National Strategic Plans

KEY TECHNOLOGIES FOR THE YEAR 2000

Rocket Propulsion		Advanced Composites
200	Participants	150
+ 500	Reviewers	+ (600)
+ 200	Symposium Attendees	+ (350)
+ 100	Personnel Briefed	+ (200)
1,000	Interested Parties	(1,300)

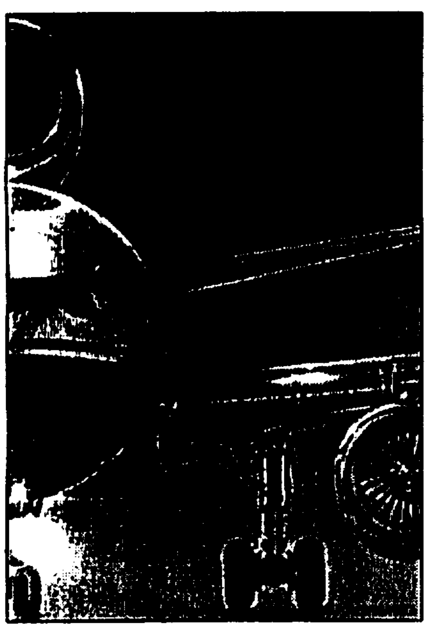
New Systems Development

KEY TECHNOLOGIES FOR THE YEAR 2000



Very Low-Cost Commercial Aircraft

KEY TECHNOLOGIES FOR THE YEAR 2000

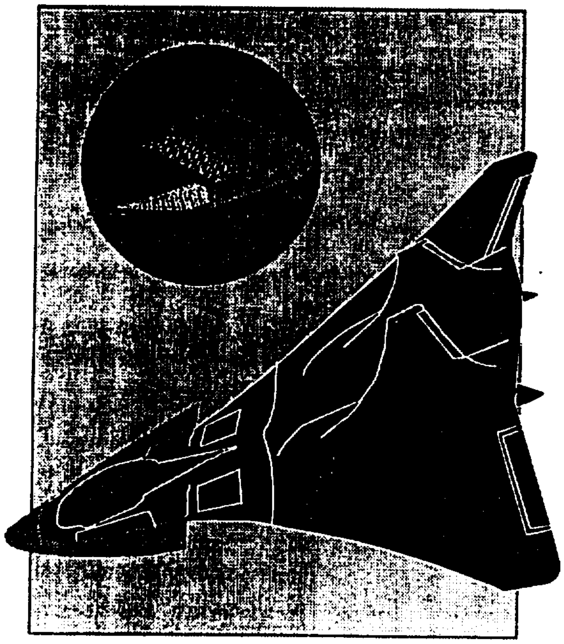


- 33% Lower Cost Than Foreign Competition
- Low Maintenance - Long Life
- Mature CAD/CAM and Business Systems
- 10:1 Thrust-to-Weight Ratio Engine
- Electronics and Fiber Optics Replace Cables and Hydraulics
- Turbulence (Microburst) Detection With Radar
- Pilot Associate (AI), Ultrareliable Electronics and Advanced Sensors Provide Increased Safety

Ultrasurvivable Aircraft

KEY TECHNOLOGIES FOR THE YEAR

2000

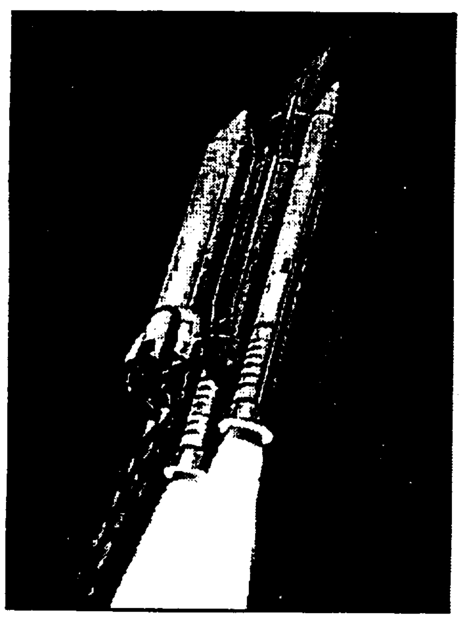


- Smart Skins for Superstealth
- Ultrareliability - Never Fail
- Autonomous Operation With Pilot's Associate (AI)
- Improved Fault Tolerance Through Reconfigurability
- Integrated RF and EO Operations - 10:1 Improvement
- Multisensor Fusion
- 25% Cost Reduction Through Computer Integrated Business (CIB)

Space Systems

KEY TECHNOLOGIES FOR THE YEAR

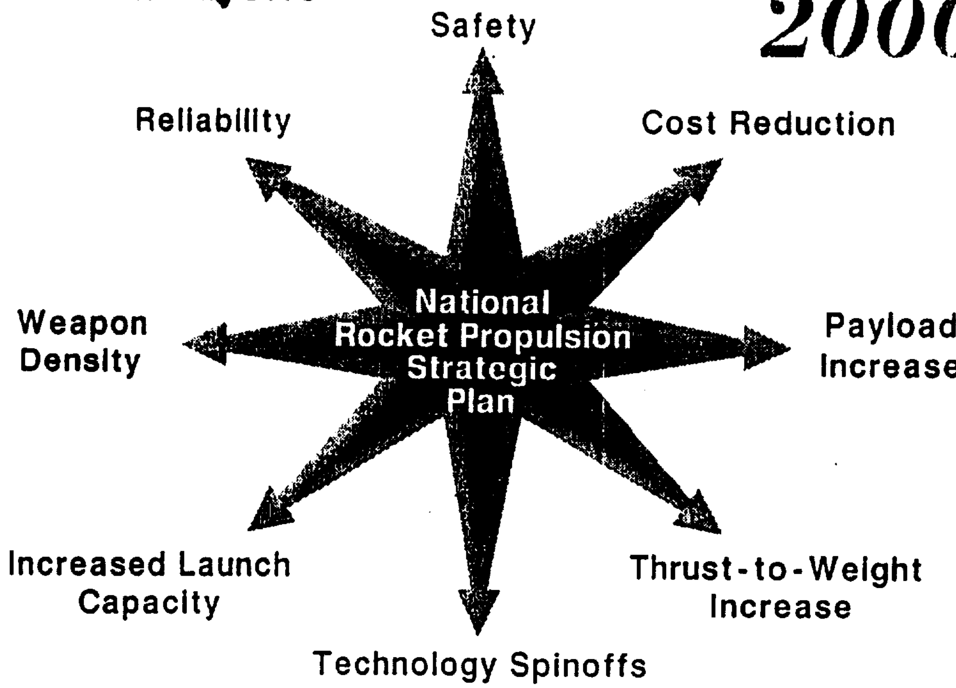
2000



- Semi-Independent Operation Through Onboard Robotic Elements
- Advanced Launch and Transportation
- Autonomous Ground Sites
- Multisensor Platforms
- Low-Power and High-Density Electronics
- Design for Manufacturing (DFM) Will Enable 25-Year Lifespans
- Expect Cost Reduction From 3 to 10:1

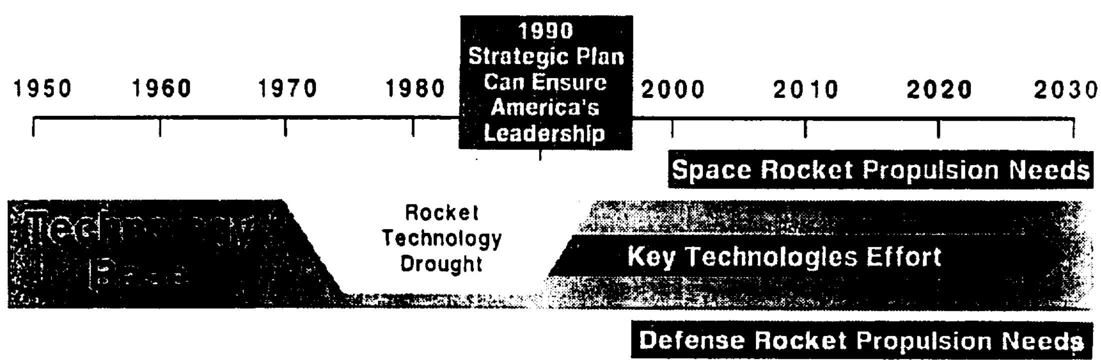
Technical Payoffs

KEY TECHNOLOGIES FOR THE YEAR
2000

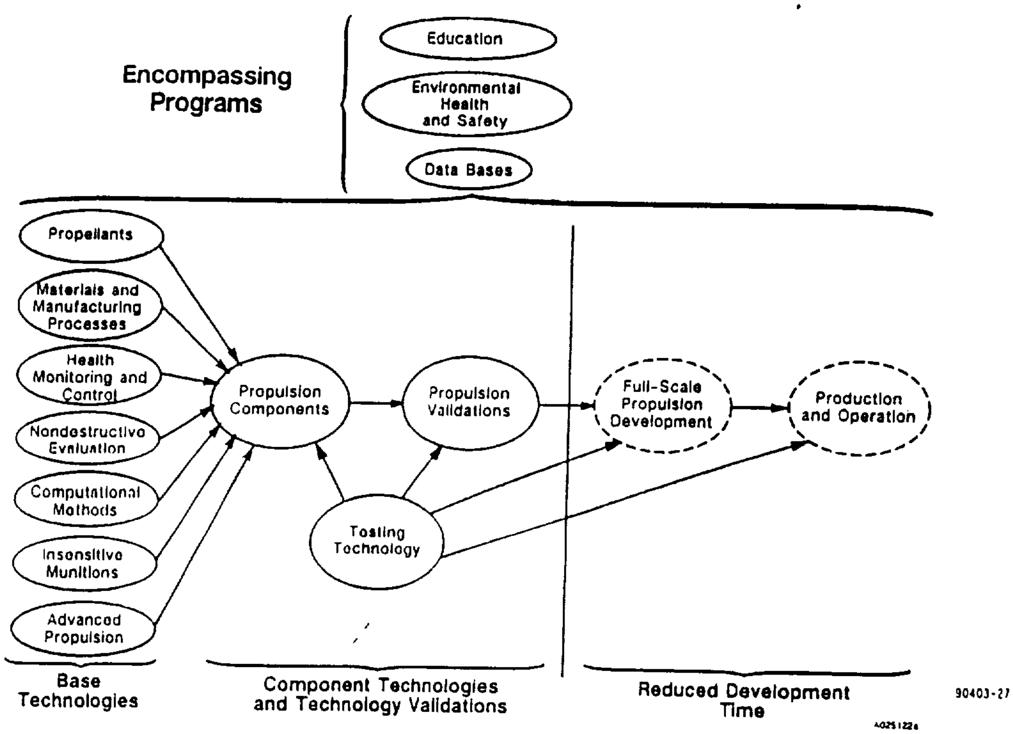


The Facts

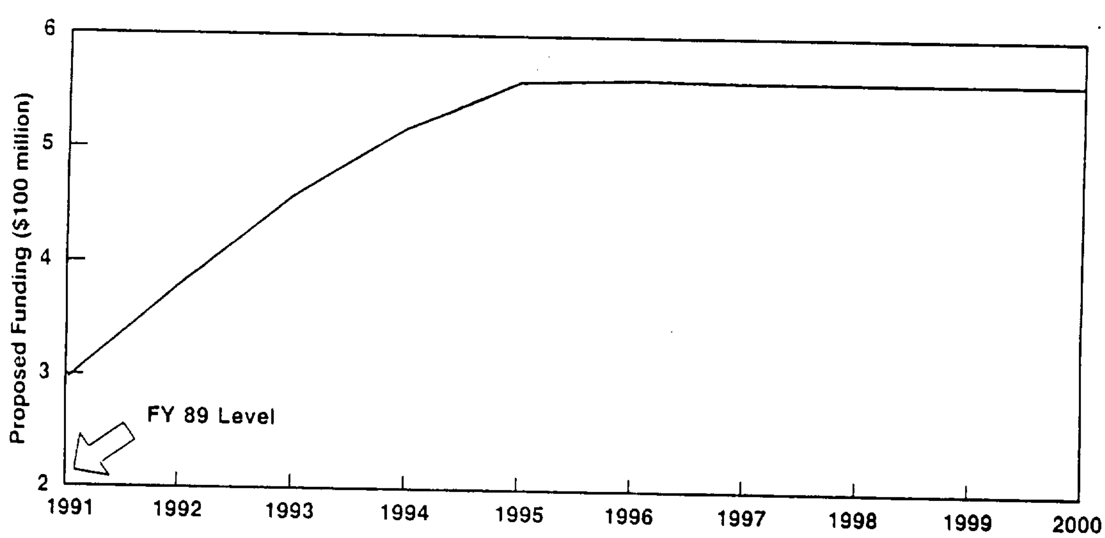
KEY TECHNOLOGIES FOR THE YEAR
2000



The Plan Addresses the Key Areas in Rocket Propulsion Technology



The Plan Proposes a Ramping Up of Funding for R&D to a Steady Plateau of $550 Million per Year



Objectives

Hypersonic Propulsion Technology

- Retain U.S. Leadership
- Demonstrate That Airbreathing Propulsion Operates in the Mach 4 to Mach 25 Flight Speed Range
- Demonstrate Technology in a "Building Block" Manner

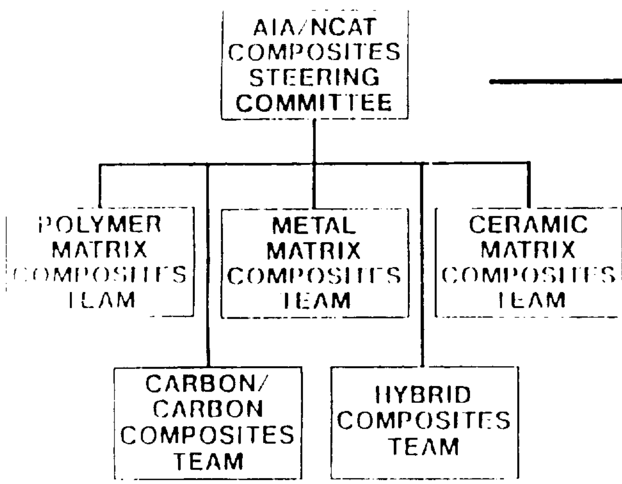
Benefits

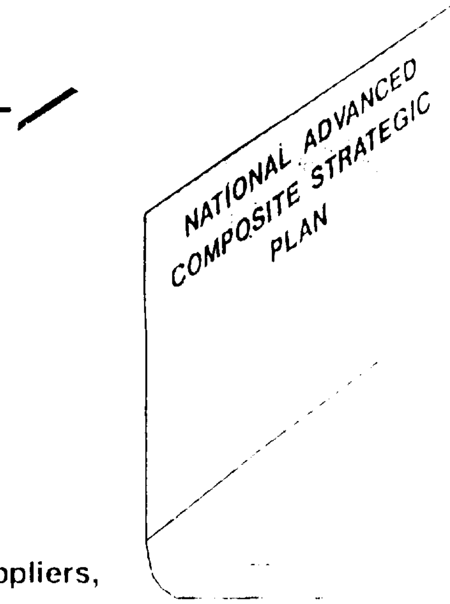
KEY TECHNOLOGIES FOR THE YEAR 2000

Hypersonic Propulsion Technology

- Reduced Cost of Payload-to-Orbit
- Extended Cruise Range
- Improved Performance
- Increased Military Superiority Against a Growing Hypersonic Threat
- Continued Civil Dominance of U.S. Aircraft Engines

The National Strategic Plan Is Being Developed Under AIA/NCAT Leadership

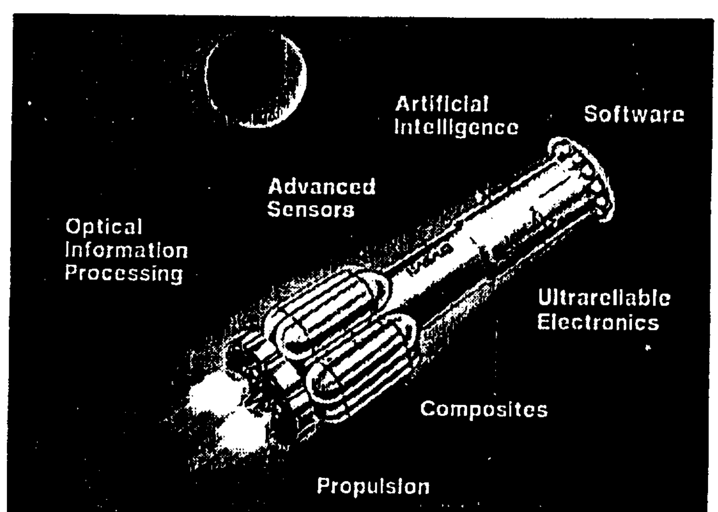




- Participants:
  - Aerospace companies, material suppliers, DoD, NASA, universities, etc.

Synergism of Key Technologies

KEY TECHNOLOGIES FOR THE YEAR 2000

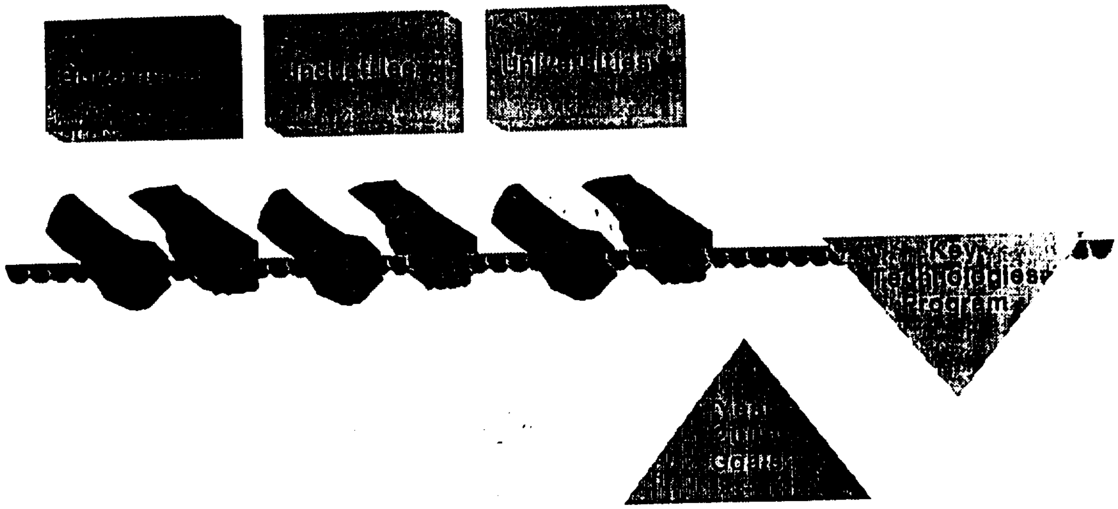


All Lead to Lower Cost for Payload Delivered, Higher Reliability, and Shortened Development Time

Pulling Together

KEY TECHNOLOGIES FOR THE YEAR

2000

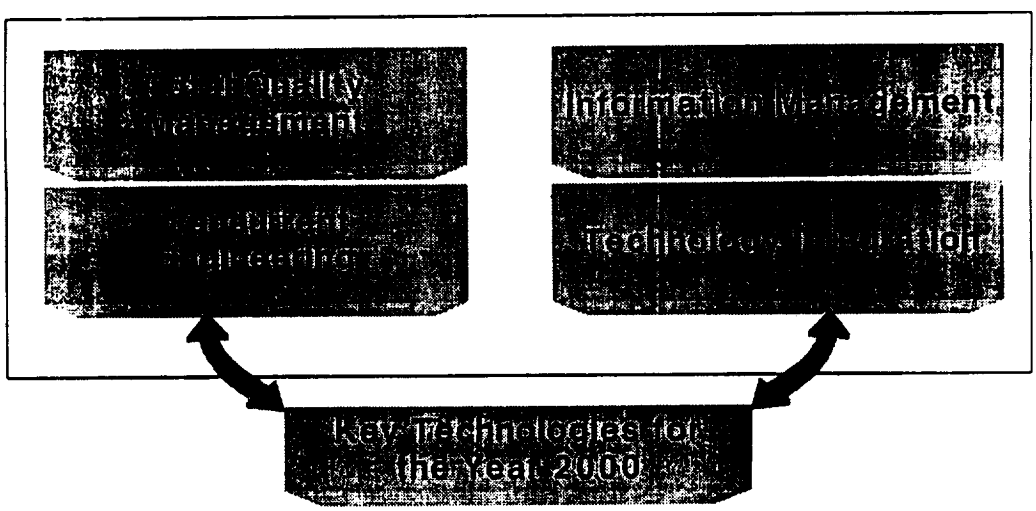


Key Technologies for the Year 2000

KEY TECHNOLOGIES FOR THE YEAR

2000

Combined Thrusts To Improve U.S. Competitiveness



Nation-Wide Thrust

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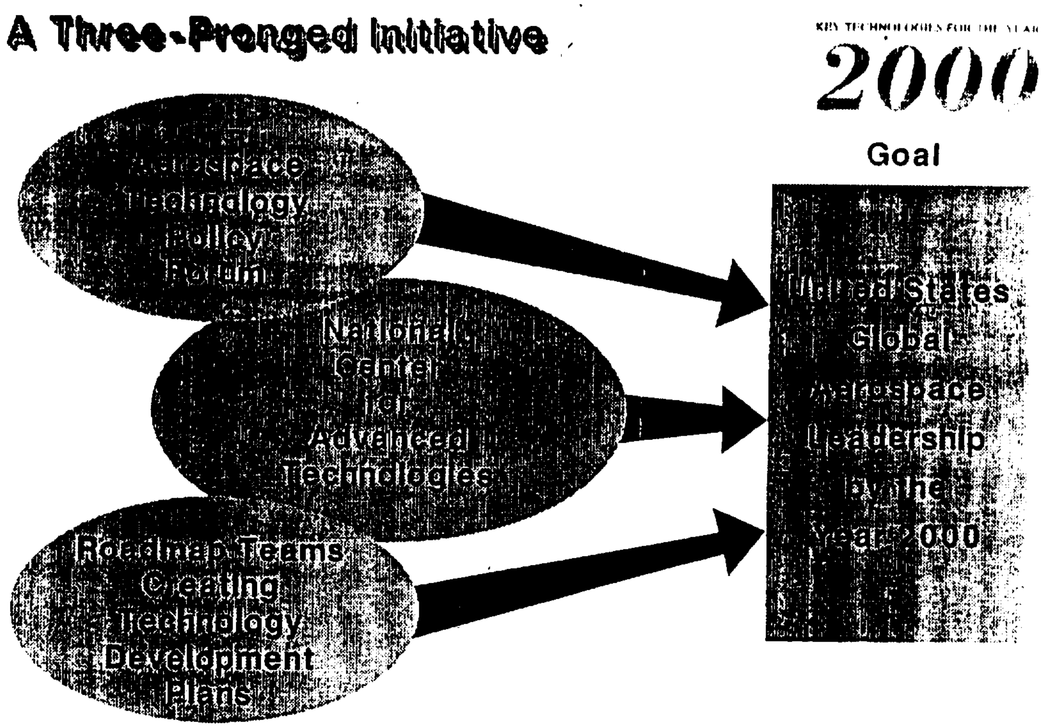
A Three-Pronged Initiative



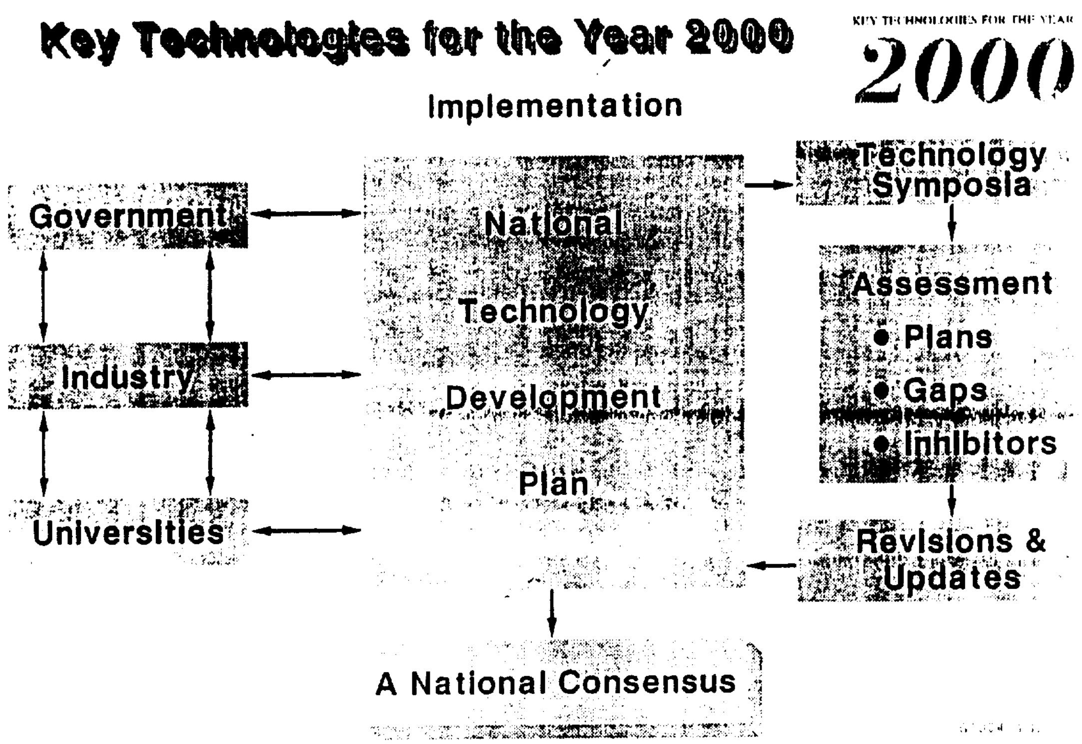
KEY TECHNOLOGIES COMPARISON

NCAT/AIA	DOD	DOC	OSTP
ADVANCED COMPOSITES	✓	✓	✓
ADVANCED SENSORS	✓	✓	✓
OPTICAL INFORMATION PROCESSING	✓	✓	✓
ARTIFICIAL INTELLIGENCE	✓	✓	✓
COMPUTATIONAL SCIENCE	✓	✓	✓

KEY TECHNOLOGIES COMPARISON (CONTINUED)

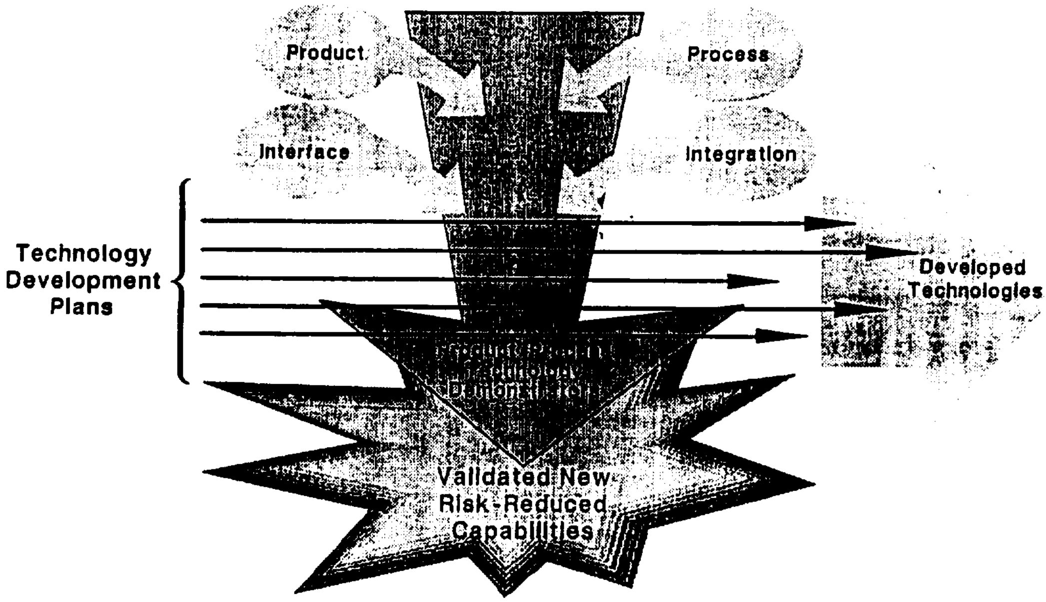
NCAT/AIA	DOD	DOC	OSTP
ULTRARELIABLE ELECTRONIC SYSTEMS	✓	✓	
SOFTWARE DEVELOPMENT	✓		✓
SUPERCONDUCTIVITY	✓	✓	
ADVANCED METALLIC STRUCTURES			✓
AIRBREATHING PROPULSION	✓		
ROCKET PROPULSION			

Key Technologies for the Year 2000



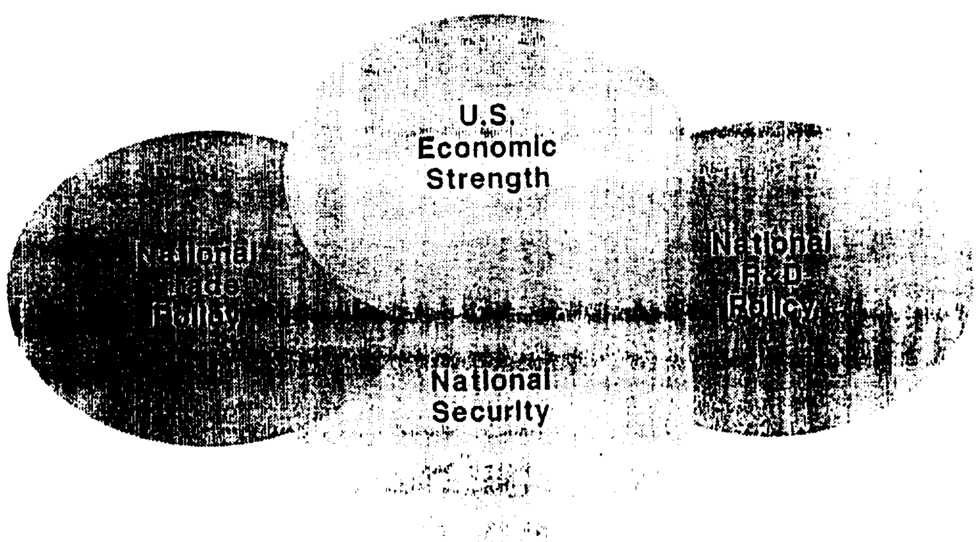
Tech Demonstrators Provide Technology Focus

KEY TECHNOLOGIES FOR THE YEAR 2000



Forging a New National Consensus-International Competitiveness

KEY TECHNOLOGIES FOR THE YEAR 2000



NAME	CO/AGENCY/UNIV.
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DeVall, O.R.	NASA Johnson Space Center
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Dorsey, John	NASA Langley Research Center
Doughman, Pamela	NASA Goddard Space Flight Center
Dula, Alex	NASA Johnson Space Center
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Fanson, James L.	Jet Propulsion Laboratory
Fedricks, John P.	McDonnell Dougles
Fehr, Austin E.	Martin Marietta Denver Aerospace
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Finn, Tom	Department of Energy
Fitzmaurice, Michael	NASA Goddard Space Flight Center
Flood, D.	NASA Lewis Research Center
Fosque, Hugh S.	NASA Headquarters
Fossum, Eric R.	Jet Propulsion Laboratory
Frerking, Margaret A.	Jet Propulsion Laboratory
Friedlan, Peter	NASA Ames Research Center
Friedman, Robert	NASA Lewis Research Center

NAME	CO/AGENCY/UNIV.
Fuller, Paul	Propulsion Systems
Gamota, George	University of Michigan
Garcia, Roberto	NASA Marshall Space Flight Center
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Gernand, Joseph J.	Rockwell International
Giffin, Geoffrey A.	NASA Headquarters
Gilland, Jim	NASA Lewis Research Center
Glaze, Stuart	NASA Headquarters
Glazer, Stu	NASA Headquarters
Glover, Dennis C.	SWL, Inc.
Golding, Lenard S.	Hughs Networking Systems
Gorland, Sol	NASA Lewis Research Center
Granajo, D.	Department of Defense
Gross, Anthony R.	NASA Ames Research Center
Gualdoni, Richard A.	NASA Headquarters
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Hadaegh, Fred Y.	Jet Propulsion Laboratory
Hanby, Walter	NASA Johnson Space Center
Harr, S.C	Xsirius
Harris, Leonard A.	NASA Headquarters
Harrison, Ph.D., Steven D.	Department of Defense
Hart, Richard	National Academy of Science
Hartke, Dick	Aerospace Industries Association
Hartman, Steve C.	NASA Headquarters
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Hirschbein, Murray S.	NASA Headquarters
Hoffman, William F.	University of Arizona
Hoggatt, John T.	Boeing Aerospace Company
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Holloway, Paul F.	NASA Langley Research Center
Hook, W. Ray	NASA Langley Research Center
Howard, Edward	NASA Headquarters
Hubbarth, William F.	IBM
Huffaker, C.F.	NASA Marshall Space Flight Center
Hunter, Paul	NASA Headquarters
Huseonica, William	NASA Stennis Space Center
Janni, Joseph	Air Force Space Technology Center
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Johnson, Benjamin	Sandia National Labs
Johnston, Allen R.	Jet Propulsion Laboratory
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Kaplin, Mike	NASA Headquarters
Karas, John C.	General Dynamics Corporation
Karim, R	SAIC
Katti, Romney	Jet Propulsion Laboratory
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Lawson, Denise	NASA Headquarters
Lesh, James R.	Jet Propulsion Laboratory
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Masica, William J.	NASA Lewis Research Center
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Meadow, W.E.	NASA Langley Research Center
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Miller, W.E.	NASA Langley Research Center
Mohler, Stanley	Wright State University
Montemerlo, Melvin D.	NASA Headquarters
Moore, Franklin K.	Cornell University
Moran, Steve	NASA Headquarters
Morgan, Jamie	TRW
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Mosier, Stanley A.	United Technologies Corporation
Moss, James N.	NASA Langley Research Center
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Mullin, Jorome P.	Sunstrand
Musles, James L.	NASA Marshall Space Flight Center
Neilson, Jr., A. Edward	W.J. Schafer Associates, Inc.
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Null, Cynthia	NASA Ames Research Center
O'Neal, Adrain P.	
Obal, Michael W.	SDIO/TNK/SL
Overmyer, Robert F.	McDonnell Douglas
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Sercel, Joel	Jet Propulsion Laboratory
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Statler, I.C.	NASA Ames Research Center
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Swint, M. Shayne	NASA Marshall Space Flight Center
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Taylor, Glenn	NASA Langley Research Center
Teeter, Ron	Boeing Company
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Voecks, Gerald	Jet Propulsion Laboratory
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Weber, III, William J.	Jet Propulsion Laboratory
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