TRANSPORTATION AND PLATFORMS PERSPECTIVE

Gary L. Bennett
National Aeronautics and Space Administration
Washington, DC

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ADMINSISTRATOR
DEPUTY ADMINISTRATOR
ASSOCIATE DEPUTY ADMINISTRATOR
ASSISTANT DEPUTY ADMINISTRATOR
EXECUTIVE OFFICER

INSPECTOR GENERAL

DEPARTMENT OF SMALL AND IMMEDIATELY USER
DEFENSE UTILIZATION

CHIEF FINANCIAL OFFICER
COMPTROLLER

GENERAL COUNSEL

EQUAL OPPORTUNITY PROGRAMS

POLICY COORDINATION & INTERNATIONAL RELATIONS

LEGISLATIVE AFFAIRS

HUMAN RESOURCES & EDUCATION

COMMERCIAL PROGRAMS

PROCUREMENT

PUBLIC AFFAIRS

MANAGEMENT SYSTEMS & FACILITIES

SAFETY & MISSION QUALITY

EXPLORATION

SPACE SYSTEMS DEVELOPMENT

SPACE SCIENCE & APPLICATIONS

SPACE FLIGHT

AERONAUTICS & SPACE TECHNOLOGY

SPACE COMMUNICATIONS

GOODRICH SPACE FLIGHT CENTER

JET PROPULSION LABORATORY

LYNDON B. JOHNSON SPACE CENTER

JOHN F. KENNEDY SPACE CENTER

JAMES E. MARSHALL SPACE FLIGHT CENTER

JAMES E. ESKIN SPACE CENTER

AMES RESEARCH CENTER

LAHOOT RESEARCH CENTER

LEWRE RESEARCH CENTER

Signed by Richard H. Truly
October 26, 1991
SPACE R&T MISSION STATEMENT

OAST 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
INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

RESEARCH & TECHNOLOGY STRATEGY

• 5-YEAR FORECAST INCLUDES
  '93 THRU '97:
  COMPLETION OF INITIAL SSF
  LIMITED SOME SHUTTLE IMPROVEMENTS
  NEW STARTS INITIAL EOS & ESOIDS
  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 FINAL SHUTTLE ENHANCEMENTS
  ADVANCED LEO EOS PLATFORMS/FULL EOSDIS
  SPACE SCIENCE STARTS
  ENS
  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:
  OPTIONS FOR NEW
  STARTS TO BE LAUNCHED IN 2009 THRU 2020
  SSF-MARS EVOLUTION
  MARS EVOLUTION (OPTICAL COMM)
  MULTIPLE SPACE SCIENCE STARTS
  DSN EVOLUTION (OPTICAL COMM)
  EVOLVING LUNAR SYSTEMS
  MARS SEI ARCHITECTURE CHOSEN
  LARGE GEO COMMABSATS
  NEW COMMERCIAL ELVS

SPACE RESEARCH & TECHNOLOGY PROGRAM

TRANSPORTATION 14 %
SPACE SCIENCE 5 %
SPACE PLATFORMS
PLANETARY SURFACE 11 %
R&T BASE 45 %
OPERATIONS 10 %
EXPERIMENTS 11 %

FY 1992
$309.3M

TRANSPORTATION 13 %
SPACE SCIENCE 11 %
SPACE PLATFORMS 7 %
PLANETARY SURFACE 7 %
R&T BASE 45 %
OPERATIONS 9 %
EXPERIMENTS 10 %

FY 1993
$332.0M
### OSSA TECHNOLOGY NEEDS

Grouped According to Urgency & Commonality

<table>
<thead>
<tr>
<th>Near Term</th>
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<td><strong>Cryogenic Systems</strong></td>
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<td><strong>Salmon &amp; Microwave Tech:</strong></td>
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<td>- LTD 127 MHz Monopole</td>
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### NUCLEAR ELECTRIC PERFORMANCE CHARACTERISTICS

- **Mission Performance Factors**
  - Specific Impulse (Isp): Determines propellant mass
  - Power Level (Pe): Affects trip time
  - System Specific Mass (a): Determines trip time limits
  - Thruster Efficiency (η): Affects trip time, vehicle mass

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<tr>
<th>Parameter</th>
<th>Desired Range</th>
<th>Mission Impact</th>
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<td>Isp</td>
<td>High (&gt;5000s)</td>
<td>Low initial mass, Resupply mass</td>
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<td>Pe</td>
<td>High (MWe)</td>
<td>Reduced trip time</td>
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<tr>
<td>a</td>
<td>Low (&lt;10 kg/kWe)</td>
<td>Reduced Mass, trip time</td>
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<tr>
<td>η</td>
<td>High (&gt;50%)</td>
<td>Improved mass, trip time</td>
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</table>
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 ELV'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 TECHNOLOGY

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

91-8048

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### TRANSPORTATION TECHNOLOGY MISSION MODEL

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<tr>
<td><strong>SHUTTLE</strong></td>
<td><strong>EVOLUTION</strong></td>
<td><strong>NEW MANNED SYSTEMS</strong></td>
<td><strong>PERSONNEL LAUNCH SYSTEM</strong></td>
<td><strong>ADVANCED MANNED LAUNCH SYSTEM</strong></td>
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<td><strong>HEAVY LIFT LAUNCH VEHICLES (HLLV)</strong></td>
<td><strong>EVOLUTION</strong></td>
<td><strong>INITIAL CAPABILITY</strong></td>
<td><strong>LUNAR</strong></td>
<td><strong>LAUNCH VEHICLES</strong></td>
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<td><strong>COMMERCIAL LAUNCH VEHICLES &amp; UPPER STAGES</strong></td>
<td><strong>UPGRADES</strong></td>
<td><strong>NEW LAUNCH VEHICLES</strong></td>
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<td><strong>SPACE TRANSFER VEHICLE/LANDERS</strong></td>
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### TRANSPORTATION MILESTONES

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<td><strong>LOW-COST COMMERCIAL TRANSPORT</strong></td>
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47
DEVELOP TECHNOLOGIES TO INCREASE ON-ORBIT MISSION EFFICIENCY AND DECREASE LIFE CYCLE COSTS FOR FUTURE MANNED AND UNMANNED SCIENCE, EXPLORATION & COMMERCIAL MISSIONS.

- 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

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
### SPACE PLATFORMS TECHNOLOGY MISSION MODEL

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<td>EARTH OBSERVING SYSTEM</td>
<td>EOSAR</td>
<td>EOS POLAR</td>
<td>EOS GEO</td>
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<td>SPACE STATION FREEDOM</td>
<td>MTC</td>
<td>FOLLOW-ON PHASES USER OPERATIONS</td>
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<td>SPACE SCIENCE</td>
<td>LUNAR OBSERVER</td>
<td>MARS NETWORK</td>
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<td>COMMUNICATIONS</td>
<td>ADRSS</td>
<td>GEO PLATFORMS</td>
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#### SPACE PLATFORMS MILESTONES

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<tr>
<td>EARTH ORBITING PLATFORMS</td>
<td>Complete Testing &amp; e-0 Evolutionary Model</td>
<td>CSI Ground TestBed Operational</td>
<td>Launch Mid-deck Airwave Control (MACS) Experiment</td>
<td>Demo 100 Wtph Concentrator Solar Array</td>
<td>Conduct CSI Benefits Studies for Multip-PL Platforms &amp; Attached P/L</td>
<td>Laboratory Test &amp; Selection of On-Orbit NDI Technologies</td>
<td>Complete Advanced LEO Masscool &amp; DAB Model</td>
<td>Demo Advanced Control Technologies</td>
<td>Advanced Portable Life Support Methodology Selected</td>
<td>Begin ECLS Hardware Testing on Ground Based TestBed</td>
<td>On-Orbit Demo of MultilPropellant Resealctes</td>
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<tr>
<td>SPACE STATION</td>
<td>Acquire Hybrid-Scale Model of SS Freedom MB-15 (AC) Configuration</td>
<td>Advanced Displays Tested</td>
<td>Complete Advanced EMU Prototype</td>
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<tr>
<td>DEEP SPACE PLATFORMS</td>
<td>Heat Rebal Design</td>
<td>Demo 300-Wtph Planar PV Blanket</td>
<td>Demo Advanced Tolerant PMAD Breakout</td>
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SPACE TECHNOLOGY PLANNING CYCLE

Winter
- Integrated NASA Space Technology Plan - Baseline
- SSTAC Preliminary Review of Planning

Fall
- SSTAC ARTS Detailed Review
- Technology Opportunities
- OAST Guidelines for Program Planning
- Administrator Budget Decisions
- Final Integrated Annual Plan and Budget To Code A

Spring
- SSTAC Review of Integrated Space Tech. Plan

Summer
- Non-Advocate Tech. Project Reviews
- Spring Preview Technology Budget To Code A
- Integrated NASA Space Technology Annual Plan - Revised
- Program Office Tech. Needs Coordination

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

TECHNOLOGY READINESS LEVELS

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<th>LEVEL</th>
<th>Description</th>
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<tr>
<td>1</td>
<td>Basic Principles Observed and Reported</td>
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<tr>
<td>2</td>
<td>Technology Concept and/or Application Formulated</td>
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<tr>
<td>3</td>
<td>Analytical &amp; Experimental Critical Function and/or Characteristic Proof-of-Concept</td>
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<tr>
<td>4</td>
<td>Component and/or Breadboard Validation in Laboratory Environment</td>
</tr>
<tr>
<td>5</td>
<td>Component and/or Breadboard Validation in Relevant Environment</td>
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<tr>
<td>6</td>
<td>System/Subsystem Model or Prototype Demonstration in a Relevant Environment (Ground or Space)</td>
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<tr>
<td>7</td>
<td>System Prototype Demonstration in a Space Environment</td>
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<tr>
<td>8</td>
<td>Actual System Completed and &quot;Flight Qualified&quot; through Test and Demonstration (Ground or Flight)</td>
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<tr>
<td>9</td>
<td>Actual System &quot;Flight Proven&quot; through Successful Mission Operations</td>
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March 25, 1991
JCM-7207b

MARCH 17, 1991
JCM-7410

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### TECHNOLOGY MATURATION STRATEGY

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<td>Basic Technology Research</td>
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Flight Readiness Levels:
- Level 9: Potential Flight Program
- Level 8: Flight Project Joint Office
- Level 7: Flight Project Office

**Flight Readiness Level 9**
- Capabilities Demonstrated
- Selected Higher-Risk, New-Mission Enabling Subsystems (e.g., Science Instruments)

**Flight Readiness Level 8**
- Transition Project
- Evaluation/Transition Project
- Flight Project Full-Scale Development, Launch & Operations