TRANSPORTATION AND PLATFORMS PERSPECTIVE

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Deputy Associate Administrator
Robert Rosen
Deputy Associate Administrator (Policy)
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Leonard A. Harris

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Glenn C. Fuller

High Performance Computing and Communications
Lee S. Halcomb

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Cecil C. Rosen, III
Subsonic Transportation
Robert E. Whitehead
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High Performance Aircraft and Flight Projects
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NASP Inter-Agency Office
Ming H. Tang
NASP Joint Program Office
James P. Arlingtion
Plana
TBD

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

CIVIL SPACE TECHNOLOGY INITIATIVE

SPACE RESEARCH & TECHNOLOGY

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

UNIVERSITY PROGRAMS

SPACE FLIGHT R&T

SYSTEMS ANALYSIS

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

PLANETARY SURFACE TECHNOLOGY
Surface Systems
Human Support
Technology Flight Expts.

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

OPERATIONS TECHNOLOGY
Automation & Robotics
Infrastructure Operations
Info, & Communications
Technology Flight Expts.

TRANSPORTATION TECHNOLOGY
ETO Transportation
Space Transportation
Technology Flight Expts.
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
SPACE R&T PROGRAM DEVELOPMENT

20-YEAR VISION OF FUTURE FLIGHT PROGRAM STARTS

SPACE R&T PROGRAM STRATEGIES AND DECISION RULES

INTEGRATED TECHNOLOGY PLAN BASE R&T, FOCUSED R&T, FACILITIES, R&PM
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 & 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 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
- OPTIONS FOR NEW MULTIPLE
- SSF-MARS EVOLUTION OPTIONS FOR NEW MULTIPLE SPACE SCIENCE STARTS
- BEGINNING OF AMIS/PILLS DEVELOPMENT DSN EVOLUTION (OPTICAL COMM)
- MULTIPLE SPACE SCIENCE STARTS INITIAL MARS HLLV DEVELOPMENT
- EVOLVING LUNAR SYSTEMS DSN EVOLUTION (OPTICAL COMM)
- MARS SEI ARCHITECTURE CHosen EVOLVING LUNAR SYSTEMS
- LARGE GEO COMMSATS MARS SEI ARCHITECTURE CHosen
- NEW COMMERCIAL ELVS LARGE GEO COMMSATS
- NEW COMMERCIAL ELVS

SPACE RESEARCH & TECHNOLOGY PROGRAM

<table>
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<tr>
<th>Year</th>
<th>Experiments</th>
<th>Transportation</th>
<th>Space Science</th>
<th>Space Platforms</th>
<th>Planetary Surface</th>
<th>R&amp;T Base</th>
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</table>
### Nuclear Electric Performance Characteristics

**Mission Performance Factors**
- Specific Impulse (Isp): Determines propellant mass
- Power Level (Pe): Affects trip time
- System Specific Mass (α): Determines trip time limits

**Mission Impact**
- High (>50%)
- Low (<10 kg/kW)

**Desired Range**
- High (>5000s)
- Low initial mass, reduced trip time

**Mission Technology Needs**
- Portable Advanced 3-D packaging
- Rapid Subject
- Thermal Spectral

**Controlled Environment**
- High Volume, High Dill
- Subtle

**Analysis and Development**
- Methane
- Air

---

**Grouped According to Urgency & Commonality**

<table>
<thead>
<tr>
<th>Near Term</th>
<th>Far Term</th>
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<td>High Time</td>
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<td>Medium Time</td>
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<tr>
<td>Low Time</td>
<td>Low Time</td>
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**Technology Needs**
- Solar Electric Propulsion
- Electric Propulsion
- Nuclear Electric Propulsion

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**Technology Development**
- Power Systems
- Electrical Systems
- Propulsion Systems

---

**Technology Maturation**
- Transportation
- Propulsion
- Power Systems

---

**Technology Readiness**
- Low
- Medium
- High

---

**Technology Transition**
- Rocket Propulsion
- Electrical Power Systems
- Nuclear Electric Propulsion

---

**Technology Enabling**
- Advanced Materials
- Advanced Controls
- Advanced Propulsion Systems

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**Technology Readiness Level**
- R&D
- Development
- Application

---

**Technology Readiness Stage**
- Initial
- Development
- Demonstration

---

**Technology Readiness Phase**
- Conceptual
- Technology Development
- Technology Validation

---

**Technology Readiness Objectives**
- Reduced Mass
- Reduced Trip Time
- Improved Mass

---

**Technology Readiness Milestones**
- Initial Mass
- Reduced Trip Time
- Improved Mass

---

**Technology Readiness Challenges**
- Advanced Power Systems
- Advanced Controls
- Advanced Propulsion Systems

---

**Technology Readiness Opportunities**
- Solar Electric Propulsion
- Electric Propulsion
- Nuclear Electric Propulsion

---

**Technology Readiness Solutions**
- Power Systems
- Electrical Systems
- Propulsion 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 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
- Systems & Components for Electric Actuators
- On-Vehicle Adaptive Guidance & Control
- 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
### TRANSPORTATION TECHNOLOGY MISSION MODEL

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<tr>
<td><strong>SHUTTLE</strong></td>
<td><strong>EVI</strong>LUTION</td>
<td><strong>PERSONNEL LAUNCH SYSTEM</strong></td>
<td><strong>ADVANCED MANNED LAUNCH SYSTEM</strong></td>
<td><strong>NASP/N-30</strong></td>
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<td><strong>NEW MANNED SYSTEMS</strong></td>
<td><strong>STME INITIAL CAPABILITY</strong></td>
<td><strong>LUNAR</strong></td>
<td><strong>NEW LAUNCH VEHICLES</strong></td>
<td><strong>CHEMICAL</strong></td>
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<tr>
<td><strong>HEAVY LIFT LAUNCH VEHICLES (HLLV)</strong></td>
<td><strong>EVOLUTION UPGRADES</strong></td>
<td><strong>NEW LAUNCH VEHICLES</strong></td>
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<td><strong>NUCLEAR THERMAL/ELECTRIC</strong></td>
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<td><strong>NUCLEAR THERMAL/ELECTRIC</strong></td>
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### TRANSPORTATION MILESTONES

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<td>OEX Flight Data Analysis Complete</td>
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<td>Right Canopy TFI Test</td>
<td>Vacuum Plasma Spray Treat Chamber Demo in TPS</td>
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<td><strong>NEXT GENERATION MANNED TRANSPORTS</strong></td>
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<td>Developing Optimized HL-20 Data Base</td>
<td>Identity Preferred Propulsion Concepts</td>
<td>Complete Aero-Aerodynamic Config. Analysis</td>
<td>Select Candidate Concept</td>
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<td>SSTO Assessment Complete</td>
<td>Identity Preferred Vehicle Concepts</td>
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<td><strong>HEAVY LIFT CAPABILITY</strong></td>
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<td>Integrated ACHIC, CASE, AIPS Demo</td>
<td>Cryogenic Fluid Film Bearing Tech.</td>
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<td>OXe4B Expander Cycle Verification</td>
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<td><strong>SPACE TRANSFER VEHICLE/LANDERS</strong></td>
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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
• Power Systems
• On-Orbit Non-Destructive Evaluation Techniques
• Thermal Management
• Space Environmental Effects
• Advanced Information Systems

SPACE STATIONS

• Regenerative Life Support
• Extravehicular Mobility
• Integrated Propulsion and Fluid Systems Architecture
• Telerobotics
• Space Environmental Effects
• 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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## SPACE PLATFORMS MILESTONES

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<td>Complete Testing &amp; e-0 Evolutionary Model</td>
<td>Conduct CSI Beretta Studies for Multi-P/L Platforms &amp; Attached P/L</td>
<td>CBI Ground Test Bed Operational</td>
<td>Laboratory Test &amp; Selection of On-Orbit NDI Technologies</td>
<td>Complete Advanced LEO Mars and Solar Array</td>
<td>Demo Advanced Control Technologies</td>
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<td>Demo Fault Tolerant PM/B</td>
<td>Demo 500 W/kg Planar PV Module</td>
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<td>Demo Advanced Inertial Power Conversion Unit</td>
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|  | Demo Advanced Ambiguity Reduction Methodology | Demo Advanced Inertial Power Conversion Unit |

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SPACE TECHNOLOGY PLANNING CYCLE

Winter

Integrated NASA Space Technology Plan - Baseline

R&T Base & Focused R&T Program Revisions

SSTAC Preliminary Review of Planning

Spring

Integrated NASA Space Technology Annual Plan - Revised

Final Integrated Annual Plan and Budget To Code A

Summer

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

TECHNOLOGY READINESS LEVELS

LEVEL 1 BASIC PRINCIPLES OBSERVED AND REPORTED
LEVEL 2 TECHNOLOGY CONCEPT AND/OR APPLICATION FORMULATED
LEVEL 3 ANALYTICAL & EXPERIMENTAL CRITICAL FUNCTION AND/OR CHARACTERISTIC PROOF-OF-CONCEPT
LEVEL 4 COMPONENT AND/OR BREADBOARD VALIDATION IN LABORATORY ENVIRONMENT
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)
LEVEL 7 SYSTEM PROTOTYPE DEMONSTRATION IN A SPACE ENVIRONMENT
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

March 29, 1991

JCM 7207b