EXPLORATION: THE VISION

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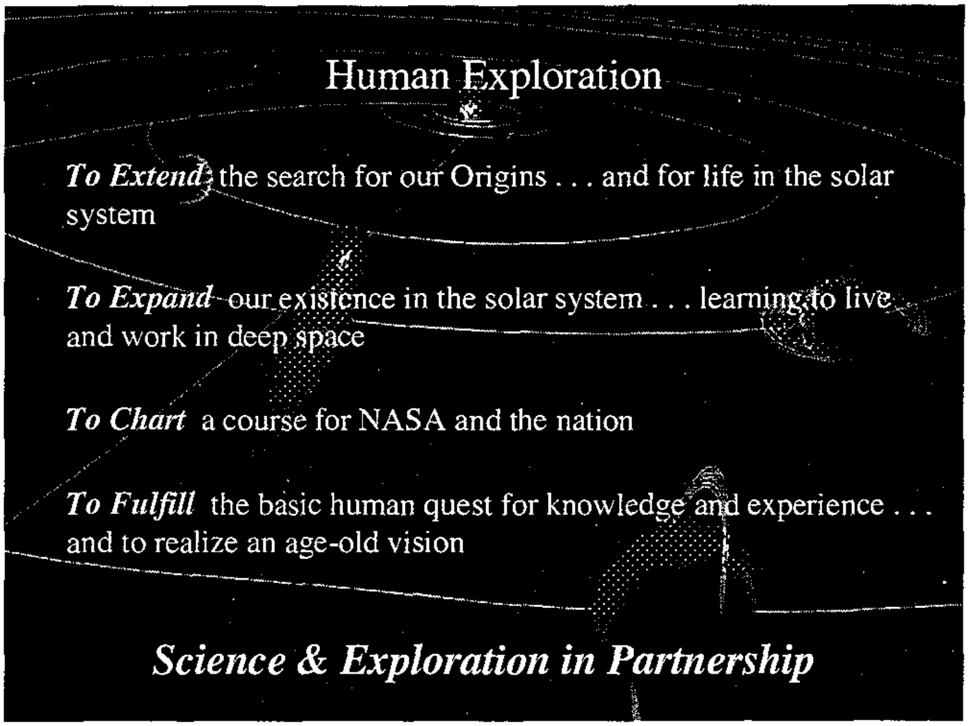
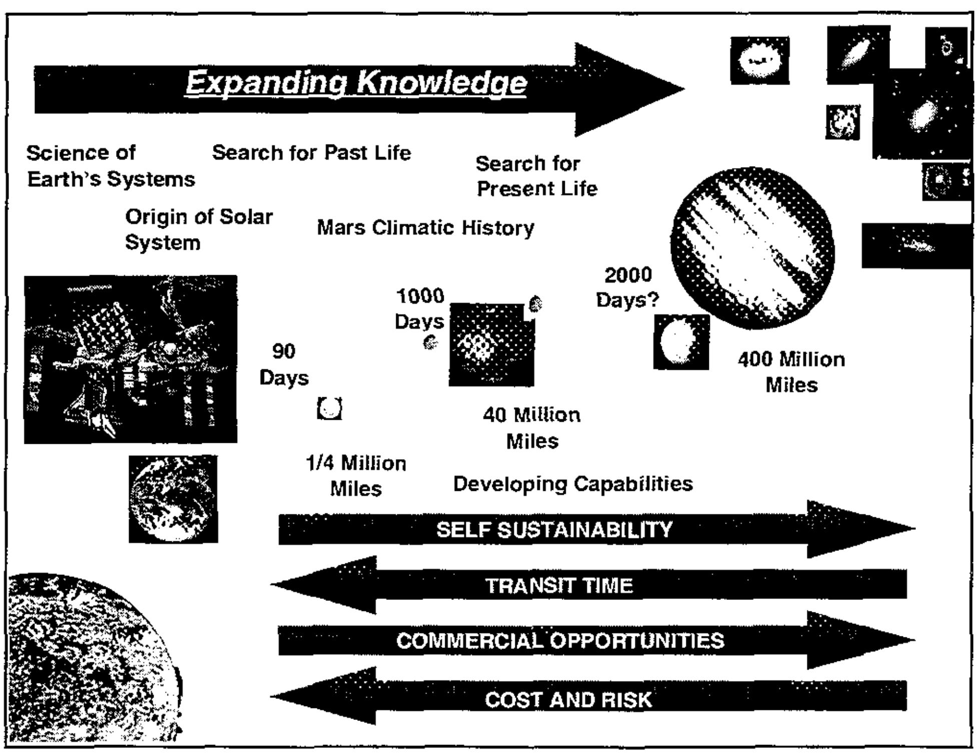




Expand Knowledge

- **Science**
  - Origin of Life
    - Search for life beyond Earth
    - Environmental conditions promoting life
  - Solar System Formation and Evolution
    - What is the history recorded at the Moon?
    - What caused climatic changes on Mars?
    - What can asteroids tell us about the formation and evolution of the solar system?
    - What is in store for Earth?

- **Life Science**
  - Understand how to live and work effectively in space
  - Understand key physical, chemical, and biological processes
- **Exploration - A basic human quest for knowledge and first hand experience**
  - To dream of great discoveries
  - To venture beyond normal everyday life
  - To find great treasures
  - To see the wonders of the planets, the solar system, the universe
  - To overcome great odds

Developing Capabilities

- **Developing Self-sustainability**
  - **The ability to reduce or break the chain of supply into Earth; to live off resources discovered at other destinations as we explore out in to the Solar System**
  - **Decrease Transit Times**
  - **Develop efficient propulsion and related space transportation capabilities that reduce human exposure to the space environment for long trips**
  - **To effectively shrink the size of our solar system, making planets more accessible**
- **Provide Commercial Opportunities**
  - **Develop capabilities that commercial enterprises can take advantage of**
  - **Buy services where possible rather than develop independent capabilities**
  - **Privatize space assets**
  - **Develop technologies with commercial potential**
- **Reduce Cost**
  - **Develop revolutionary technologies and innovative mission approaches that make exploration affordable**

Develop Capabilities

- Technology Development & Testing
- Preliminary Knowledge Return: Robotic Missions
- Space Infrastructure Evolution

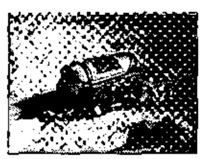
Enable Opportunities

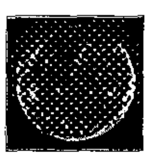
- Commercial Opportunities
- Opportunities For Human Experience & Presence Through Exploration
- Opportunities For Scientific Knowledge Return

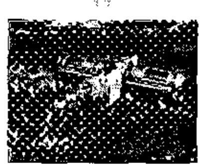
Potential Objectives for Returning to the Moon

Mars Risk Reduction

- Systems testbeds
- Operational approaches to be developed
- Advanced technologies to be proven
- Test human health and safety approaches







Science

- Astronomy
- Solar system history
- Resource characterization
- etc.

Identify Commercial Opportunities

- Lunar Oxygen or Water Production
- Regolith Materials Processing
- He_3

- Current vision does not include permanent NASA funded base

"Conditions for Human Exploration"

- **Compelling Scientific or Exploration Rationale**
- **Strong Commercial Potential for High Return...**
- **Public support**
- **Credible cost estimate**

Exploration & Commercialization

'NASA must undertake the difficult tasks that companies simply can't do...' Dan Goldin

As the space horizon is advanced, behind it are opened opportunities for commercial activity at acceptable levels of risk

As this occurs, NASA's research funds can then be redeployed toward ever-advancing that horizon.

NASA's role: Exploration of the solar system, outer space and the universe beyond

1. Answer fundamental questions about the solar system
   --history of the solar system and planets
   --origin of life
   --relevance to life on earth
2. Develop low cost access to space and planetary surfaces. Transition to commercial ventures as early as possible
3. Make choices that enable future commercialization - including elimination of barriers to commercialization

Industry's role (Aerospace & Non-Aerospace)

1. Identify commercial goals and promising opportunities
2. Help guide and partner with NASA to define technology investments that:
   --support commercial needs
   --open up commercial opportunities
3. Seek and acquire investment capital to exploit these opportunities

Potential Commercial Roles
vs
NASA Roles: Near Term

Low Earth Orbit:
NASA's Role
Shuttle operations
ISS development
Begin privatization of shuttle, International Space Station
Develop/enable low cost access to space

Industry's Role
Expendable & reusable launch vehicles
Communications satellites
Privatization of shuttle, plan for privatization of ISS

Joint venture: X-33 Research

Moon, Mars, Asteroids:
NASA's Role
Basic Research: Fly Robotic Missions to:
- answer fundamental questions about composition, environment for humans and machines
- test environment dependent technologies (ISRU, etc)

Initiate development systems to enable low cost human and robotic access to to orbit and for surface operations

Industry's Role
Explore potential concepts for development of resources, tourism, space transportation, services and others for the moon and asteroids, etc.

Develop candidate technologies through IRAD, SBIR's

Help NASA strategize for developing future commercial technologies and opportunities at Mars

Evaluate science data returned for potential return on investments, early concept development

Outer Planets & Moons
NASA's Role
Basic research on planetary composition
Identify compelling destinations for future exploration

Industry's Role
Help NASA plan for technologies and capabilties that allow for future expansion

PUBLIC SUPPORT

WHAT WE KNOW TODAY:

- Extremely Positive Public Support of Pathfinder
- Outstanding Press Coverage of MGS, Prospector, Pathfinder
- Yankelovich Polls Show Broad But Inconsistent Public Support for Space Programs
- TV Network (Non-Scientific) Polls Show Strong Support for Human Space Exploration
- Many Anecdotal Stories of Public Support for Mars Exploration

CHALLENGES:

- Provide More of the Benefits of Space Exploration Directly to People on Earth
- Develop Techniques of Bringing the Excitement of Discovery and Exploration and the Experience of Living in Space to People on Earth
- Implement a Systematic Approach to Measure Public Support

PUBLIC SUPPORT

SPECIFICS OF WHAT WE PROPOSE TO DO:

- Implement a Systematic Approach to Assessing and Developing Public Support
- Undertake Projects Immediately to Increase Public Awareness and Understanding
    - Develop a Business Plan, Including Plans for:
        - Stakeholder Engagement
        - Customer Engagement
        - Communications
        - Outreach
    - Deliberative Poll to Develop Metrics, Targets
    - HEDS-UP Academic Partnerships
    - Partnerships with Specialists in Customer Engagement (Anteon, GSD&M,..)
    - Involvement of NASA Technology Transfer Centers in Commercialization Studies
    - Partnerships with State, Regional Interests
    - International Conferences
    - Policy Analysts' Forum

AFFORDABLE, CREDIBLE COSTS

Today's Facts and Assumptions:

- **Costs Must be Bounded by NASA's Current Funding Levels**
- **Mr. Goldin's Challenge of $20B**
- **Yearly Funding Levels on the Order of Space Station Funding: $2-3B/Year**
- **Costs are Heavily Influenced by Management and Programmatic Approaches**

Status:

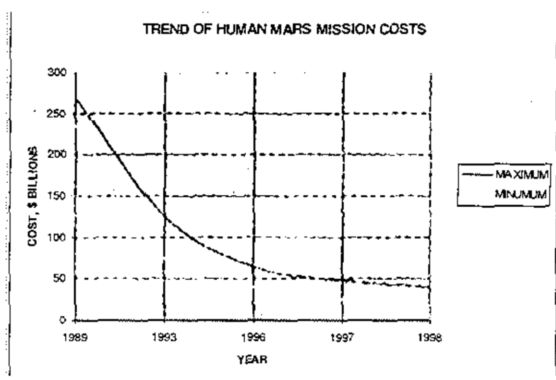
- **Current Estimates Approximate the Affordability Criteria**
- **Credibility of Cost Models are Being Evaluated and Questioned**
- **NASA Management of Programs is Continuously Scrutinized for Improvement**

Challenges:

- **Improvements in NASA and Other Government Processes to Efficiently Manage Large Programs**
- **The Details of Spacecraft and Mission Designs are Needed to Develop High-Fidelity, High-Probability Cost Estimates**
- **Fidelity in Development of Costs Must be Improved**
- **Technologies, Mission and Design Approaches, and Management Approaches Must be Constantly Scrutinized to Maximize Efficiency**
- **Credibility in Costs Must be Earned Through Peer Review, Independent Evaluation**
- **Communication of the Fidelity of Costs**

NASA

EXPLORATION OFFICE



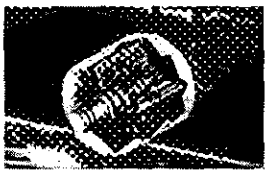
NOTE: 90 DAY STUDY COSTS IN 1989 ASSUME MOON/MARS COSTS EQUAL

Innovation Enables Human Exploration

A lynchpin to the planning of viable and affordable human exploration missions is innovative ideas

Working with new partners

- Pan-enterprise partnership between HEDS and Space Science for Mars robotic missions
- Internationals
- Industries
- Universities



Evolving capabilities through applying new technologies such as:

- Inflatable structures
- Micro and Nano technologies
- In-situ Resource Utilization

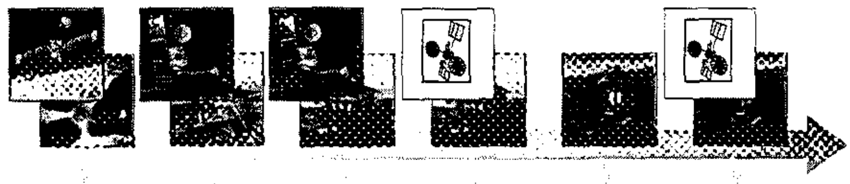
Testing in new places

- The International Space Station
- Technology demonstrations on asteroids, the Moon, and Mars

Exploration Activities

- **Human Exploration and Robotics Team**
  - **–Integrated human and robotic mission planning**
  - **–Technology planning**
  - **–Science strategy development**
  - **–Human Health and Performance planning and development**
  - **–Management and Customer Engagement**
- **HEDS technology planning**
  - **–Test and Demonstration identification and implementation**
- **Mission design and design concept development**
- **Participation in HEDS strategic planning**

Robotic Mission Strategy



Science	✦Mars Global Surveyor ✦Mars Pathfinder	✦'98 Polar Orbiter ✦'98 Polar Lander	✦Surface Mineralogical Orbiter ✦'01 Sample Caching Rover	✦High-Bandwidth Com. Orbiter ✦'03 Sample Caching Rover	✦'05 Mars Sample Return	✦High-Bandwidth Com. Orbiter ✦'07 Mars Sample Return
Exploration			✦Oxygen production ✦Radiation ✦Soil & Dust ✦Aerocapture ✦Precision Landing	✦End-to-End ISRU demo. ✦Surface engineering characteristic ✦Biconic entry and landing ✦Life science data	✦Sample return using in-situ type propellants ✦Mars orbit rendezvous ✦Surface cryogenic storage ✦Life science data	✦Sample return using in-situ propellants ✦Kw-class power system demonstration

Note: Refinement of mission objectives is currently underway

Exploration Critical Factors

Maintain Low Levels of Risk in Human Space Travel

Basic Performance

☆ *Affordable & Safe Planetary Exploration*

Human Health & Safety

☆ *Safe and Reliable Exploration Strategy*

Reduced Cost (Mass)

☆ *Reduced Launch Costs*

☆ *Jucicious Reduction of Mass:*

Every pound to Mars and back = 40 pounds launched to Low-Earth-Orbit

Exploration Critical Factors

Basic Performance

☆ **Affordable & Safe Planetary Exploration**

Human Support

- Advanced, light-weight, space suit and surface mobility for routine, robust exploration
- Advanced life support

Space Transportation

- Lift Capability ~ 80 metric tons for large payload volumes
- Efficient transportation to and from planetary surfaces

Advanced Space Power

- High continuous power (110 kWe) for robust exploration (In-Situ resource utilization, food closure)

Information & Automation

- Advanced operations in remote environments
- Science and mission data storage / computation / transfer

Sensors & Instruments

- Science data
- Medical & hardware health monitoring
- Advanced scientific field laboratories and capabilities

Exploration Critical Factors

Reduced Cost (Mass)

☆ **Every pound to Mars and back = 40 pounds launched to Low-Earth-Orbit**

Human Support

- Closed-loop life support reduces mass (25%)
- Advanced EVA Suit minimizes expendables and maintenance
- Advanced inflatable structures = reduced mass (25%)

Advanced Space Power

- Reduced mass/kw = reduced cost

Sensors & Instruments

- Micro/Nano Technology = reduced mass

Space Transportation

- Space Transportation Efficiencies (IMLEO Reduction) Compared to Chemical Propulsion Scenario:
  - Aerobraking: 40-45% reduction
  - In-Situ Resource Utilization: 21-25% reduction
  - High Efficiency In-Space Propulsion: 55% reduction
  - Combined: 68% reduction

Human Health & Safety

☆ **Safe and Reliable Exploration Strategy**

Human Health & Safety (Human Support)

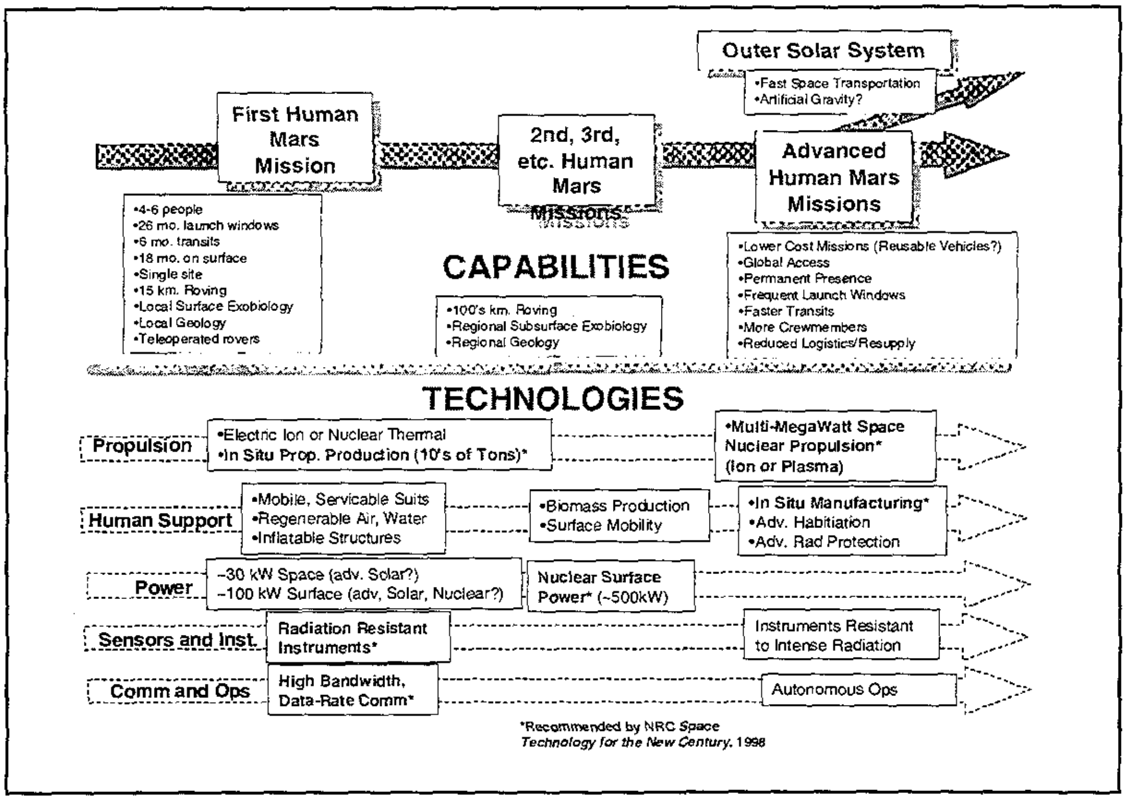
- Radiation research
- Zero and partial gravity research
- Medical care

Space Transportation

- Quick trips to and from planetary destinations

Sensors & Instruments

- Environmental & medical monitoring



Human Support

Health & Human Performance

☆ Radiation protection research

• *Countermeasure development*

• *Medical care & environmental health*

• *Human factors*

Advanced Life Support

• *Air and water loop closure*

• *Solid waste processing*

• *Thermal control*

• *Food production*

Advanced Habitation Systems

• Habitat concepts and emplacement methods

• Advanced light-weight structures (inflatable vs "hard")

• Integrated radiation protection

EVA & Surface Mobility

• Enable routine surface exploration

• *Highly reusable, light-weight, high-mobility suit and portable life support system*

• Short and long-range surface mobility for advanced surface exploration capabilities

• *Minimize resupply, repair, and maintenance*

Human Support

	Self Sustain-ability	Reduce Transit Time	Commer-cial Oppor-tunities	Reduce Cost	Increase Know-ledge	Reduce Risk	Near Term Candidate Projects
Health & Human Performance	☒	☐	☑	☐	☒	☒	Mars 2001 Tissue Equivalent Proportional Counter. Radiation Test & Demonstration Mission; ISS Micro-g Countermeasures
Advanced Life Support	☒	☐	☑	☒	☐	☐	ISS Node III ALS Implementation
Advanced Habitation Systems	☒	☐	☑	☑	☐	☑	ISS TransHab Implementation
EVA & Surface Mobility	☒	☐	☑	☑	☑	☑	Mark III Technology Demonstrator Field Test; ISS Advanced Gloves

☒ Highly Applicable
☑ Somewhat Applicable
☐ Limited Applicability

Space Transportation

Affordable Earth-to-Orbit Transportation

- ☆ Low Cost Technologies Scaled to Large Launcher
  - *Tanks & Structures*
  - *Propulsion Systems*
  - Shrouds
  - Upper Stages
- Accommodate large-volume payload requirements
- *Minimum on-orbit assembly costs*
- Minimum impact to launch facilities

Advanced Interplanetary Propulsion

- All Chemical Propulsion Option
- ☆ *Solar-Electric Propulsion Option*
- Nuclear-Electric Propulsion Option
- ☆ Nuclear-Thermal Option
- Ascent & Descent Propulsion

Cryogenic Fluids Management

- ☆ Long-Term (1700 days) Cryogenic Fluid Storage
- ☆ Cryogenic Liquefaction of In-Situ Propellants
- Cryogenic Refrigeration
- *Zero-G Fluid Management*

Aeroassist

- Earth/Mars Orbital Insertion & Direct Entry
- ☆ Advanced Thermal Protection Systems
- Mars Atmospheric Modeling
- ☆ Guidance & Navigation for Precision Landing & Aerocapture

In-Situ Resource Utilization

- ☆ *Propellant Production from Mars Atmosphere*
- Human Mars Ascent Propellant
- ☆ Mars Sample Return Using In-Situ Resources
- *Lunar Demonstration from Soil*

Space Transportation

	Self Sustain-ability	Reduce Transit Time	Commer-cial Oppor-tunities	Reduce Cost	Increase Know-ledge	Reduce Risk	Near Term Candidate Projects
Affordable Earth-to-Orbit Transportation	☐	☐	☒	☒	☐	☐	NASA/TRW Ultra Low-Cost Engine Demo
Advanced Interplanetary Propulsion	☐	☒	☒	☒	☐	☒	50kW Hall Thruster Static Test; Bimodal Fuels Evaluation; Radiation Test & Demonstration Mission
Cryogenic Fluid Management	☒	☒	☑	☒	☐	☐	Cryogenic Liquid Acquisition, Storage & Supply Exp.
Aeroassist	☐	☒	☐	☒	☐	☐	Mars 2001 Aerocapture; Advanced Ablative Materials Testing
In Situ Resource Utilization	☒	☐	☒	☒	☐	☑	Mars 2001 In Situ Propellant Production

☒ Highly Applicable
☑ Somewhat Applicable
☐ Limited Applicability

Advanced Space Power

☆Advanced Power Generation

- Lightweight, high reliability, high efficiency systems for multi-year missions
  - Megawatt-class systems for efficient spacecraft propulsion
  - 100 KW-class fixed surface power systems
  - 10 KW-class mobile systems
  - 1 KW-class human-portable systems
- *Advanced PV systems for 1-100 KW*
- Solar Dynamic options for 10-1000's KW
- Potential Nuclear options for 100 - Multi-MW

Energy Storage

- High capacity regenerative fuel cell and lightweight battery options for long-term storage and fixed surface operations
- *Compact, mobile systems (batteries, fuelcells or flywheel systems)*

Power Management

- *Very lightweight, high efficiency systems (10-100X better than state-of-the-art)*
- Broad power range: KW to MW
- Reconfigurable, fault tolerant power networks

Advanced Space Power

	Self Sustain-ability	Reduce Transit Time	Commer-cial Oppor-tunities	Reduce Cost	Increase Know-ledge	Reduce Risk	Near Term Candidate Projects
Advanced Power Generation	☒	☐	☑	☑	☐	☒	Thin Film PV Array Manufacturing & Performance Testing
Power Management	☒	☐	☑	☑	☐	☒	
Power Storage	☒	☐	☑	☑	☐	☒	Proton Exchange Membrane Fuel Cell Flight Exp.: ISS Flywheels

☒ Highly Applicable
☑ Somewhat Applicable
☐ Limited Applicability

Information & Automation

Communications & Networks

- High Bandwidth communications
- Robust communications capability at exploration destinations
- Fast and reliable data acquisition, transmission, and delivery to remote operations sites

☆Intelligent Synthesis Environment

- State-of-the-art simulation based system engineering & analysis environment for all phases of development and execution
- Integrates remote teams in virtual environments: scientists, technology developers, project engineers
- Provides for rapid and efficient systems analysis and integration

Intelligent Systems & Advanced Operations

- *Autonomous system operation for remote operations independent of direct earth-based control*
- Systems health management
- Performance Support Systems for both astronauts and ground operations personnel
- Integration of robotic and human interfaces

Information and Automation

	Self Sustain-ability	Reduce Transit Time	Commer-cial Oppor-tunities	Reduce Cost	Increase Know-ledge	Reduce Risk	Near Term Candidate Projects
Communications & Network	☑	☐	☒	☐	☑	☒	Miniaturized Optical Com System
Advanced Operations	☒	☐	☒	☒	☐	☒	Mars Mission Simulation Project, SSE/HEDS Collaboration
Intelligent Systems	☒	☐	☒	☒	☑	☒	On-Board Automation Architecture Tests
Intelligent Synthesis Environment	☑	☐	☒	☒	☐	☒	Integrated Design Environment Development

☒ Highly Applicable
☑ Somewhat Applicable
☐ Limited Applicability

Science & Engineering Field Labs

- In-situ sample analysis
  - Organic chemistry and age dating
  - Electron microscopy
  - Sample preparation
- Remote geologist
  - Sample context visualization
  - Chemical and mineral analysis
  - Interior and weather
- Virtual presence
  - Imaging and remote sensing

Planetary Prospecting

- Sample acquisition
  - on-site analysis
  - sample screening and selection
  - cross-sample contamination control
- Site safety and selection
- Resource identification and mapping

☆ *Environmental & Medical Monitoring*

- Alarm monitors (fire, toxics, radiation, etc.)
- Environmental monitors (food, water, air)
- Human health monitors (suit/EVA, IVA, routine check-ups)
- Emergency medical systems/telemedicine
  - Care provider virtual presence
- Global monitoring and hazard avoidance (e.g. dust storms)

Sample Curation

- Long-term packaging/preservation and "witness-plate" monitoring
- Hazards/contamination analysis
- On-site caching and archival

Crosscutting Technologies

☆ *Micro/Nano Technologies*

Sensors & Instruments

	Self Sustain-ability	Reduce Transit Time	Commer-cial Oppor-tunities	Reduce Cost	Increase Know-ledge	Reduce Risk	Near term Candidate Projects
Science and Engineering Field Labs	☒	☐	☒	☐	☒	☑	University Surface Science Studies
Planetary Prospecting	☒	☐	☒	☐	☒	☑	Devon Island Field Site Invstigation
Sample Curation	☒	☐	☒	☐	☒	☑	MSR 2001 Soil & Dust Characterization Instrument
Environmental and Medical Monitoring	☒	☐	☒	☐	☒	☒	Enhanced Catalyst Trace Contaminant Control System Test

☒ Highly Applicable
☑ Somewhat Applicable
☐ Limited Applicability

Test Beds and Flight Demonstrations

Leveraging and Evolving Current Capabilities

Developing Relevant Capabilities Early

Test Beds

- Ground Test Facilities
  - BIOPLEX
  - MIST
  - Others
- KC135
- Space Shuttle as a test bed
- Space Station as a test bed
- Robotic Missions
  - Partnering on Mars robotic missions
  - Partnering on other robotic missions
    - Earth orbit
    - Lunar
    - Beyond