PATHFINDER
SURFACE EXPLORATION, IN-SPACE OPERATIONS, AND
SPACE TRANSFER

Technology for NASA Future Missions
an AIAA/NASA OAST Conference

September 12-13, 1988
The Capital Hilton
Washington, DC

JOHN MANKINS
PATHFINDER PROGRAM MANAGER
PATHFINDER PROGRAM AREA
SURFACE EXPLORATION

TECHNOLOGY NEEDS

- PILOTED AND AUTOMATED SURFACE MOBILITY
  AND MANIPULATION SYSTEMS

- MOBILE AND STATIONARY SURFACE POWER
  SYSTEMS (SOURCES AND STORAGE)

- ADVANCED SPACE COMPUTING, WITH GROUND &
  ON-BOARD AUTONOMOUS SYSTEMS

- MULTIPLE SENSORS (REMOTE AND LOCAL)

- SURFACE MATERIALS, STRUCTURES, AND
  MECHANISMS

- TECHNOLOGIES FOR SURFACE SCIENCES
  (E.G., SAMPLING AND IN SITU ANALYSIS)
PATHFINDER PROGRAM AREA
SURFACE EXPLORATION

ELEMENT PROGRAMS

• PLANETARY ROVER
• SAMPLE ACQUISITION, ANALYSIS, & PRESERVATION
• AUTONOMOUS LANDER
• SURFACE POWER
• PHOTONICS
<table>
<thead>
<tr>
<th>TECHNOLOGIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOBILITY</td>
</tr>
<tr>
<td>AUTONOMOUS GUIDANCE</td>
</tr>
<tr>
<td>SAMPLING ROBOTICS</td>
</tr>
<tr>
<td>ROVER POWER</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MISSION APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUNAR ROVERS (Piloted &amp; Robotic)</td>
</tr>
<tr>
<td>MARS ROVERS (Piloted &amp; Robotic)</td>
</tr>
<tr>
<td>OTHER ROBOTIC EXPLORATION AND SAMPLE RETURN MISSIONS (e.g., CNSR)</td>
</tr>
</tbody>
</table>
PATHFINDER
PLANETARY ROVER

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Information Sciences And Human Factors Division

- LEAD NASA FIELD CENTER:
  Jet Propulsion Laboratory

- PARTICIPATING CENTERS:
  Ames Research Center
  Langley Research Center
  Lewis Research Center

- FY 1989 BUDGET: $ 5 MILLION
### TECHNOLOGIES

- SAMPLING TOOLS & SYSTEMS
- CHEMICAL/PHYSICAL ANALYSIS SENSORS
- PRESERVATION (e.g., Materials, Seals)

### MISSION APPLICATIONS

- LUNAR ROVERS (Piloted & Robotic)
- MARS ROVERS (Piloted & Robotic)
- OTHER SAMPLE RETURN MISSIONS (CNSR)
PATHFINDER
SAMPLE ACQUISITION, ANALYSIS, & PRESERVATION

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Materials and Structures Division

- LEAD NASA FIELD CENTER:
  Jet Propulsion Laboratory

- PARTICIPATING CENTERS:
  Ames Research Center
  Johnson Space Center

- FY 1989 BUDGET: $ 1 MILLION
# PATHFINDER
## AUTONOMOUS LANDER

### TECHNOLOGIES

- GN&C (Terminal Descent)
- SENSORS
- SYSTEMS AUTONOMY
- MECHANIZATION/MECHANICAL SYSTEMS

### MISSION APPLICATIONS

- LUNAR OUTPOST OPERATIONS VEHICLES
- ROBOTIC SOLAR SYSTEM EXPLORATION
- PILOTED MARS EXPEDITION
PATHFINDER
AUTONOMOUS LANDER

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Information Sciences & Human Factors Division

- LEAD NASA FIELD CENTER:
  Johnson Space Center

- PARTICIPATING CENTERS:
  Ames Research Center
  Jet Propulsion Laboratory

- FY 1989 BUDGET: $1 MILLION
### PATHFINDER
**SURFACE POWER**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>- ADVANCED PHOTOVOLTAICS</td>
</tr>
<tr>
<td>- POWER STORAGE (e.g., Fuel Cells)</td>
</tr>
<tr>
<td>- ENVIRONMENTAL COUNTERMEASURES</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
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</tr>
</thead>
<tbody>
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<td>- LUNAR OUTPOST START-UP</td>
</tr>
<tr>
<td>- PILOTED MARS EXPEDITIONS</td>
</tr>
<tr>
<td>- OTHER SPACECRAFT (Earth-orbit, Transfer)</td>
</tr>
</tbody>
</table>
PATHFINDER
SURFACE POWER

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Propulsion, Power, and Energy Division

- LEAD NASA FIELD CENTER:
  Lewis Research Center

- PARTICIPATING CENTERS:
  Jet Propulsion Laboratory
  (Not funded in FY'89)

- FY 1989 BUDGET: $1.5 MILLION
# PATHFINDER PHOTONICS

## TECHNOLOGIES

- **FAULT-TOLERANT ELECTRONICS/PHOTONICS SYSTEM ARCHITECTURES**
- **PHOTONICS COMPONENTS**
  (Sensors, Memories, Input/Output Components, Image Processing)

## MISSION APPLICATIONS

- **LUNAR OUTPOST SYSTEMS** (e.g., Observatories)
- **PILOTED PHOBOS/MARS EXPEDITIONS**
- **ROBOTIC SOLAR SYSTEM EXPLORATION**
  (e.g., Autonomous Landers, Planetary Rovers)
- **ADVANCED EARTH-ORBITING OPERATIONS**
PATHFINDER
PHOTONICS

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Information Sciences & Human Factors Division

- PARTICIPATING CENTERS:
  Ames Research Center
  Jet Propulsion Laboratory
  Johnson Space Center
  Langley Research Center

- INITIATION DEFERRED TO 1990
PATHFINDER PROGRAM AREA
IN-SPACE OPERATIONS

TECHNOLOGY NEEDS

- AUTOMATED AND SEMI-AUTONOMOUS OPERATIONS (E.G., RENDEZVOUS & DOCKING)
- ASSEMBLY, CONSTRUCTION, AND TESTING OF LARGE SPACE SYSTEMS (IN ORBIT AND ON SURFACES)
- MANAGEMENT AND LONG-TERM STORAGE OF CRYOGENIC FLUIDS
- HIGH-CAPACITY POWER SYSTEMS (E.G., NUCLEAR)
- HIGH-RATE SPACE COMMUNICATIONS SYSTEMS
- IN SITU RESOURCE UTILIZATION TECHNIQUES AND HARDWARE (E.G., FUEL PRODUCTION AND MINING)
PATHFINDER PROGRAM AREA
IN-SPACE OPERATIONS

ELEMENT PROGRAMS

- AUTONOMOUS RENDEZVOUS & DOCKING
- IN-SPACE ASSEMBLY AND CONSTRUCTION
- CRYOGENIC FLUID DEPOT
- SPACE NUCLEAR POWER (SP-100)
- RESOURCE PROCESSING PILOT PLANT
- OPTICAL COMMUNICATIONS
### TECHNOLOGIES

- SENSORS (e.g., Laser Ranging, Radars)
- GN&C (Fault-Tolerant, On-Board)
- SYSTEM AUTONOMY

### MISSION APPLICATIONS

- SPACE TRANSFER VEHICLES (Earth & Lunar)
- PILOTED MARS EXPEDITION
- ROBOTIC SAMPLE RETURN MISSIONS (MRSR)
PATHFINDER
AUTONOMOUS RENDEZVOUS & DOCKING

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Information Sciences & Human Factors Division

- LEAD NASA FIELD CENTER:
  Johnson Space Center

- PARTICIPATING CENTERS:
  Jet Propulsion Laboratory
  Marshall Space Flight Center

- FY 1989 BUDGET: $1 MILLION
### TECHNOLOGIES

- LARGE-SCALE MANIPULATION SYSTEMS (Including highly flexible manipulators)
- JOINING TECHNIQUES (e.g., Welding)
- PRECISION STRUCTURE ALIGNMENT/ADJUSTMENT

### MISSION APPLICATIONS

- LUNAR OUTPOST STAGING
- MARS MISSION STAGING (Robotic, Piloted)
- ADVANCED SPACE STATION OPERATIONS
- EARTH-ORBIT OBSERVATORY STAGING
PATHFINDER
IN-SPACE ASSEMBLY & CONSTRUCTION

PROGRAM MANAGEMENT

- **LEAD OAST DIVISION:**
  Materials and Structures Division

- **LEAD NASA FIELD CENTER:**
  Langley Research Center

- **PARTICIPATING CENTERS:**
  Jet Propulsion Laboratory
  Johnson Space Center
  Marshall Space Flight Center

- **FY 1989 BUDGET:** $1 MILLION
# PATHFINDER CRYOGENIC FLUID DEPOT

## TECHNOLOGIES

- **LONG-TERM CRYOGEN CONTAINMENT & MANAGEMENT**
- **REFRIGERATION COMPONENTS/SYSTEMS**
- **FLUID TRANSFER COMPONENTS/SYSTEMS**

## MISSION APPLICATIONS

- **LUNAR OUTPOST STAGING/OPERATIONS**
- **MARS MISSION STAGING (Robotic, Piloted)**
- **ADVANCED SPACE STATION OPERATIONS**
- **ASTROPHYSICS OBSERVATORY SERVICING**
PATHFINDER
CRYOGENIC FLUID DEPOT

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Propulsion, Power, and Energy Division

- LEAD NASA FIELD CENTER:
  Lewis Research Center

- PARTICIPATING CENTERS:
  Johnson Space Center
  Marshall Space Flight Center

- FY 1989 BUDGET: $3 MILLION
# PATHFINDER
## SPACE NUCLEAR POWER (SP-100)

### TECHNOLOGIES
- Refractory Metal Reactor
- Fuel Pins
- High-Temperature Control System
- Liquid-Metal Thermoelectric Magnetic Pump
- Thermal-To-Electric Conversion
- Heat-Pipe Heat-Rejection Systems

### MISSION APPLICATIONS
- Lunar/Mars Outposts
- Piloted Mars Expedition
- Advanced Earth-Orbit Operations
- Robotic Solar System Exploration (Nuclear Electric Propulsion/Power)
# PATHFINDER RESOURCE PROCESSING PILOT PLANT

## TECHNOLOGIES

- MATERIALS ANALYSIS SENSORS
- MECHANICAL SEPARATION/EXTRACTION
- ELECTRO-CHEMICAL SEPARATION/EXTRACTION
- ROBOTIC MATERIALS COLLECTION/HANDLING

## MISSION APPLICATIONS

- LUNAR OUTPOST RESOURCE PLANT
- MARS RESOURCE PLANT
- OTHER SOLAR SYSTEM RESOURCE UTILIZATION
PATHFINDER
RESOURCE PROCESSING PILOT PLANT

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Materials and Structures Division

- LEAD NASA FIELD CENTER:
  Johnson Space Center

- PARTICIPATING CENTERS:
  Jet Propulsion Laboratory

- INITIATION DEFERRED TO 1990
# PATHFINDER

**OPTICAL COMMUNICATIONS**

## TECHNOLOGIES

- Acquisition & Tracking Systems
- Control Systems
- Telescope/Laser Systems

## MISSION APPLICATIONS

- Lunar Outpost
- Piloted Mars Expeditions
- Robotic Solar System Exploration
PATHFINDER
OPTICAL COMMUNICATIONS

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Information Sciences & Human Factors Division

- PARTICIPATING CENTERS:
  Goddard Space Flight Center
  Jet Propulsion Laboratory

- INITIATION DEFERRED TO 1990
PATHFINDER PROGRAM AREA
SPACE TRANSFER

TECHNOLOGY NEEDS

- ADVANCED CHEMICAL PROPULSION SYSTEMS (DESIGNED FOR SPACE-BASING/MAINTENANCE)

- HIGH-THRUST IN-SPACE PROPULSION FOR HUMAN MISSION STAGING

- LUNAR-LEO AND INTERPLANETARY AERO-BRAKING (TPS, GN&C, AEROTHERMODYNAMICS)

- DESCENT/ASCENT PROPULSION FOR MOON/MARS APPLICATIONS

- HIGH-EFFICIENCY ELECTRIC PROPULSION FOR CARGO TRANSFER
ELEMENT PROGRAMS

- CHEMICAL TRANSFER PROPULSION
- HIGH-ENERGY AEROBRACING
- CARGO VEHICLE PROPULSION
# Pathfinder Chemical Transfer Propulsion

## Technologies

- Liquid Oxygen/Hydrogen Engines
- High-Heat Combusters
- High-Pressure Turbo-Machinery
- Integrated Diagnostics/Controls

## Mission Applications

- Lunar Outpost Operations Vehicles
- Robotic Solar System Exploration
- Piloted Mars Expedition
- Advanced Earth-Orbit Operations
PATHFINDER CHEMICAL TRANSFER PROPULSION

PROGRAM MANAGEMENT

- LEAD OAST DIVISION: Propulsion, Power, and Energy Division
- LEAD NASA FIELD CENTER: Lewis Research Center
- PARTICIPATING CENTERS: Marshall Space Flight Center (Not funded in FY'89)
- FY 1989 BUDGET: $4 MILLION
# PATHFINDER
## HIGH-ENERGY AEROBRAKING

### TECHNOLOGIES

- Aerobrake Configurations
- Aerothermodynamics
- GN&C (On-Board, Autonomous, Adaptive)
- Thermal Protection Systems

### MISSION APPLICATIONS

- Lunar Outpost Operations
- Robotic/Piloted Mars Expedition
- Robotic Solar System Exploration
PATHFINDER
HIGH-ENERGY AEROBRAKING

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Aerodynamics Division

- LEAD NASA FIELD CENTER:
  Langley Research Center

- PARTICIPATING CENTERS:
  Ames Research Center
  Johnson Space Center
  Jet Propulsion Laboratory

- FY 1989 BUDGET: $1.5 MILLION
# PATHFINDER CARGO VEHICLE PROPULSION

## TECHNOLOGIES

- **MAGNETOPLASMA DYNAMIC THRUSTERS (MPD)**  
  (e.g., Cathodes, Controls, Magnetic Fields, High Power Level Systems)
- **ION ENGINES** (Testing)
- **LONG-LIFE TESTING**

## MISSION APPLICATIONS

- **LUNAR OUTPOST OPERATIONS (OTV/Ion)**
- **PILOTED MARS EXPEDITION (Cargo Vehicle)**
- **ROBOTIC SOLAR SYSTEM EXPLORATION (Ion)**
PATHFINDER
CARGO VEHICLE PROPULSION

PROGRAM MANAGEMENT

- LEAD OAST DIVISION:
  Propulsion, Power, and Energy Division

- LEAD NASA FIELD CENTER:
  Lewis Research Center

- PARTICIPATING CENTERS:
  Jet Propulsion Laboratory

- INITIATION DEFERRED TO 1990
PATHFINDER THRUSTS AND ELEMENTS

MISSION STUDIES

EXPLORATION
- PLANETARY ROVER
- SAMPLE ACQUISITION, ANALYSIS & PRESERVATION
- SURFACE POWER
- OPTICAL COMMUNICATIONS

HUMANS-IN-SPACE
- EVA/SUIT
- HUMAN PERFORMANCE
- CLOSED-LOOP LIFE SUPPORT

TRANSFER VEHICLES
- CHEMICAL TRANSFER PROPULSION
- CARGO VEHICLE PROPULSION
- HIGH ENERGY AEROBRACING
- AUTONOMOUS LANDER
- FAULT-TOLERANT SYSTEMS

OPERATIONS
- AUTONOMOUS RENDEZVOUS AND DOCKING
- RESOURCE PROCESSING PILOT PLANT
- IN-SPACE ASSEMBLY & CONSTRUCTION
- CRYOGENIC FLUID DEPOT
- SPACE NUCLEAR POWER (SP100)