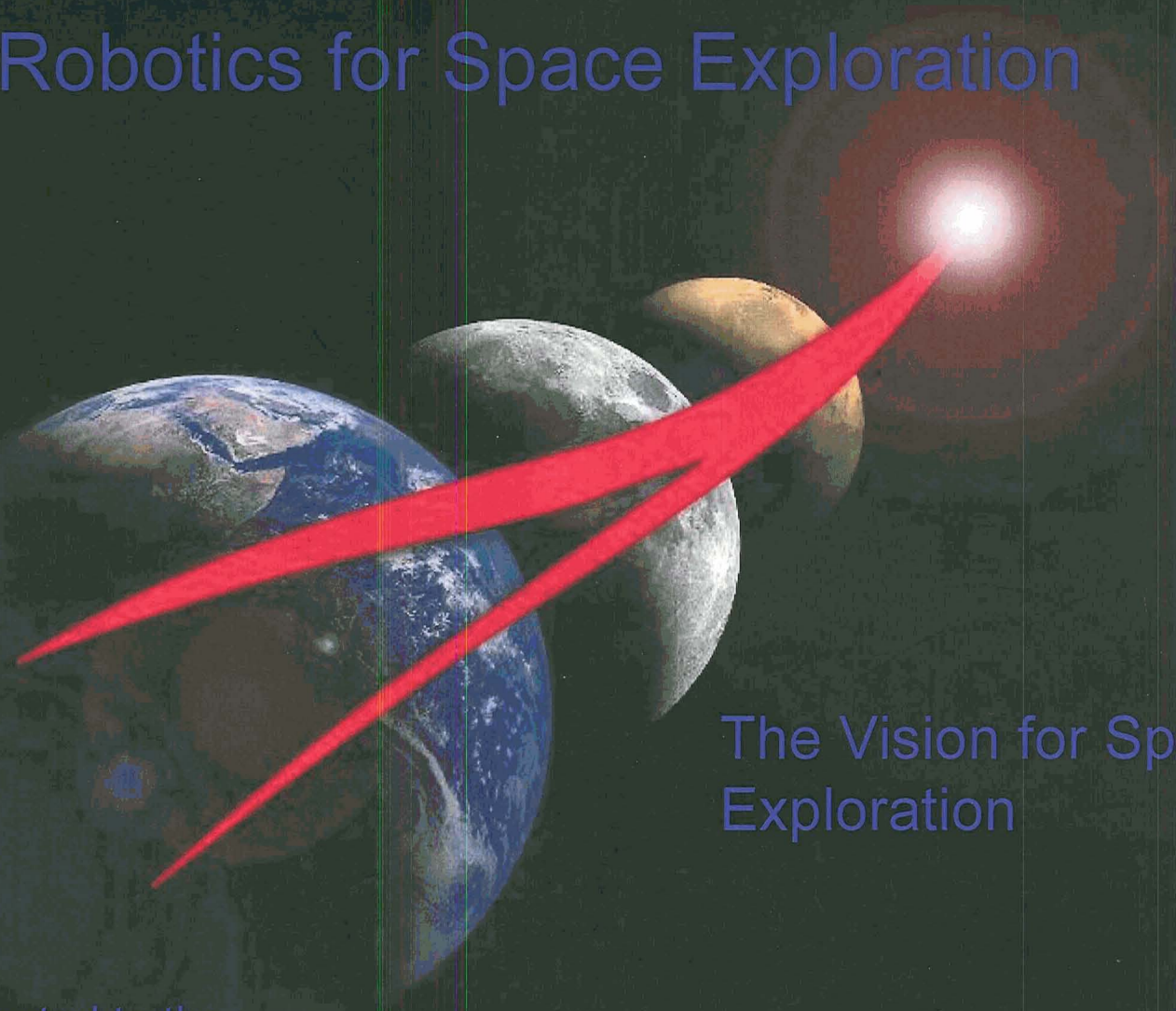
"NASA Robotics for Space Exploration"
presented by
Richard Fischer, NASA Marshall Space Flight Center

This presentation focuses on NASA's use of robotics in support of space exploration. The content was taken from public available websites in an effort to minimize any ITAR or EAR issues. The agenda starts with an introduction to NASA and the "Vision for Space Exploration" followed by NASA's major areas of robotic use: Robotic Explorers, Astronaut Assistants, Space Vehicle, Processing, and In-Space Workhorse (space infrastructure). Pictorials and movies of NASA robots in use by the major NASA programs: Space Shuttle, International Space Station, current Solar Systems Exploration and Mars Exploration, and future Lunar Exploration are throughout the presentation.

NASA Robotics for Space Exploration

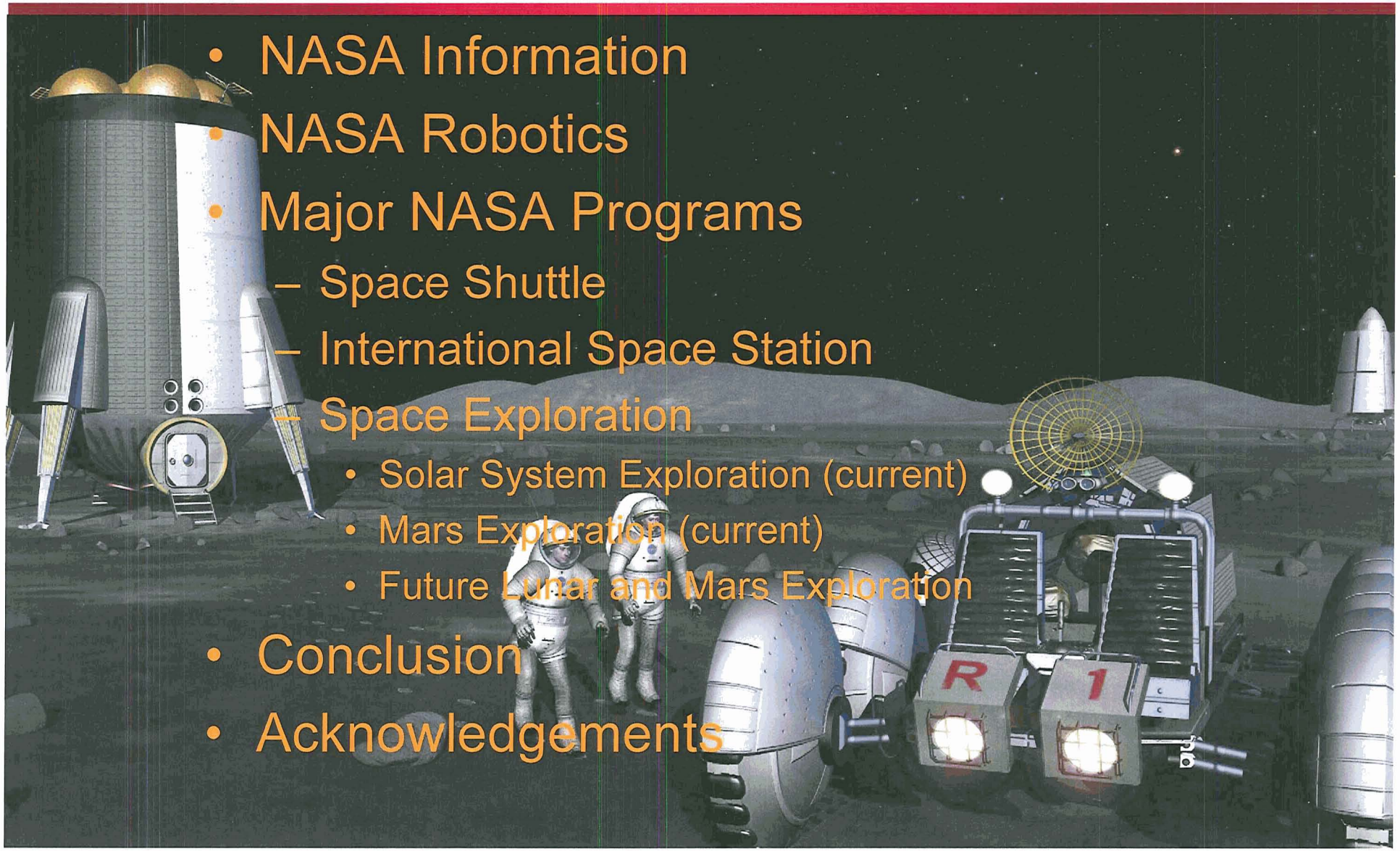


The Vision for Space Exploration

Presented to the
Third Technological Age Congress
Morelia, Michoacán, Mexico
March 2007

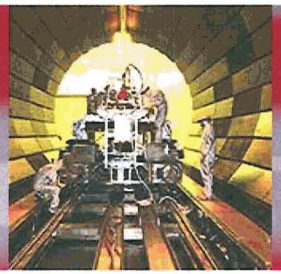
Richard T. Fischer
Exploration Advanced Capabilities Office
NASA Marshall Space Flight Center

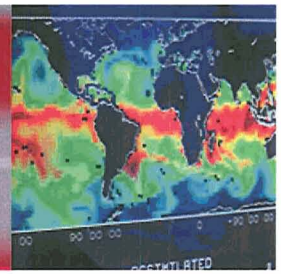
AGENDA

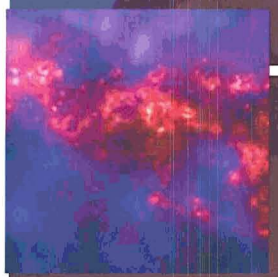


- NASA Information
- NASA Robotics
- Major NASA Programs
  - Space Shuttle
  - International Space Station
  - Space Exploration
    - Solar System Exploration (current)
    - Mars Exploration (current)
    - Future Lunar and Mars Exploration
- Conclusion
- Acknowledgements

National Vision for Space Exploration



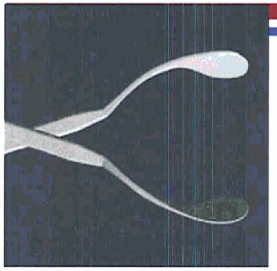


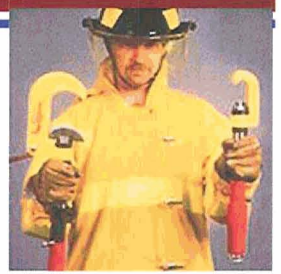


NASA's strategic goals

- Fly the space shuttle as safely as possible until its retirement.
- Complete the International Space Station, accommodating international partner commitments and human exploration.
- Develop a balanced overall program of science, exploration, and aeronautics consistent with the new focus on human exploration.
- Bring a new Crew Exploration Vehicle into service.
- Encourage partnerships with the emerging commercial space sector.
- Return to the moon and make it a base for later missions to Mars and beyond.

Improving Life on Earth

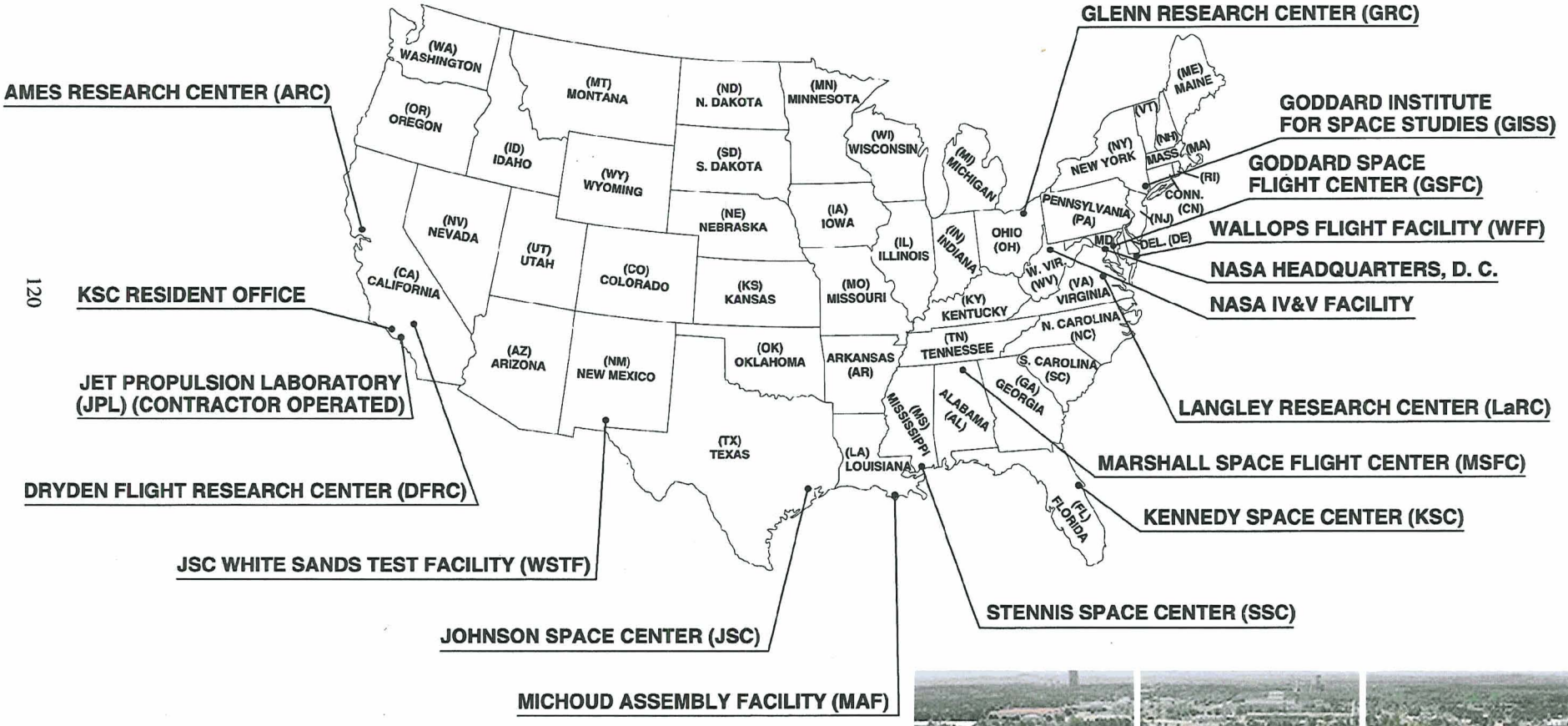




More than 1,000 consumer products and services are built on NASA-developed technologies

- Smoke detectors
- Solar water heaters
- Cordless tools
- Satellite-based telephone, TV, and GPS
- Video enhancement system for law enforcement
- Selectively lockable knee brace
- "Smart" obstetrical forceps
- Compact rescue shears
- Eye health screening system
- Powerful medical X-ray lens system
- Many, many more ...

NASA LOCATIONS



MSFC

NASA Robotics

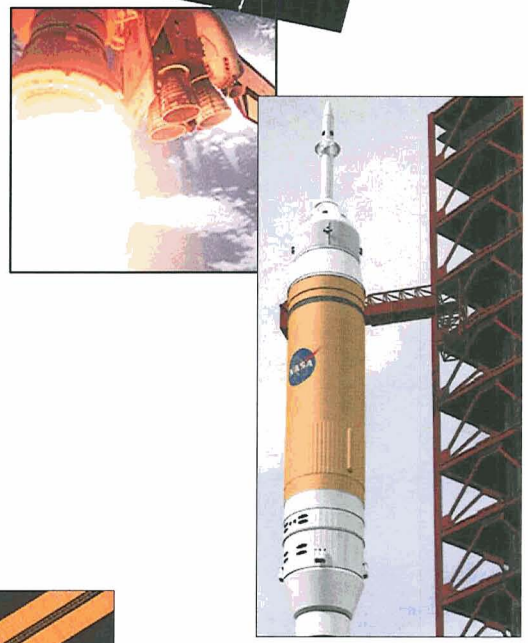
- **NASA's major areas of robotic use:**
  - **Robotic Explorers**
  - **Astronaut Assistants**
  - **Space Vehicle Processing**
  - **In-Space Workhorse** (space infrastructure)

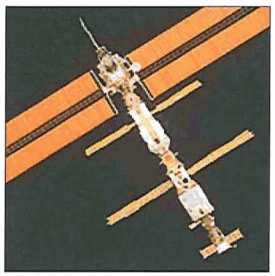
Presentation Methodology

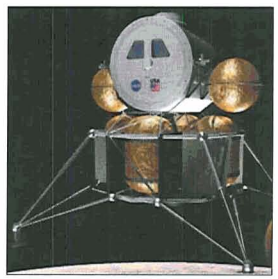
- I will show video clips that depict either actual events or simulated events that illustrate various robotic related activities on Space Shuttle, International Space Station and the future Exploration missions.
- Obviously, you can imagine a great deal of simulation activities must have taken place to enable these events to occur.
- Use your imagination and see how many applications you can see that are not point out.

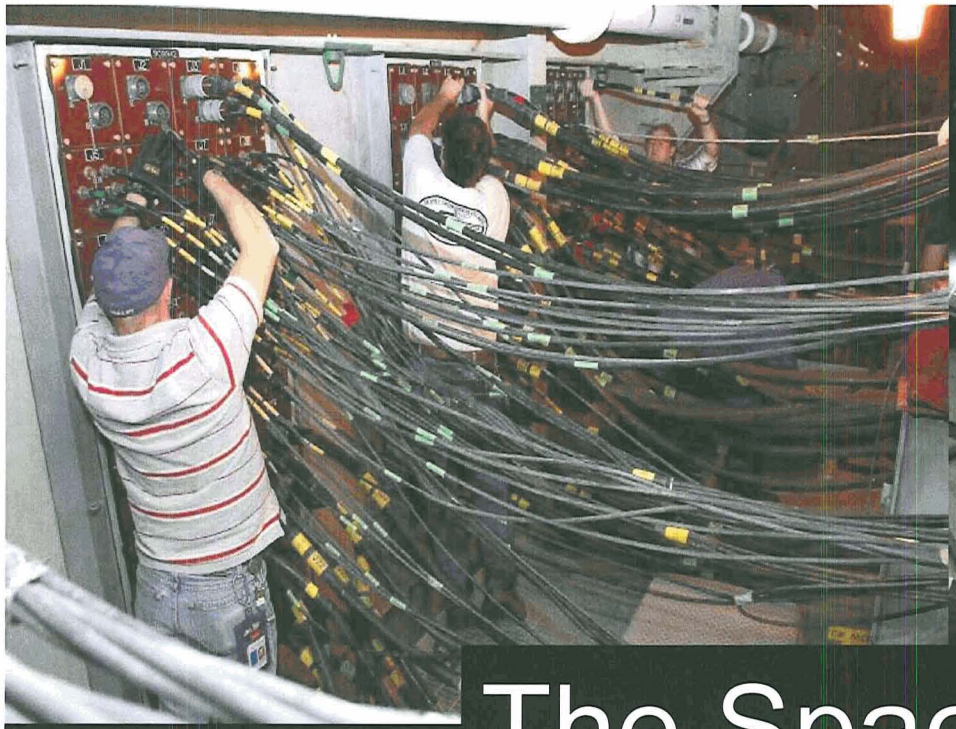
MAJOR NASA PROGRAMS

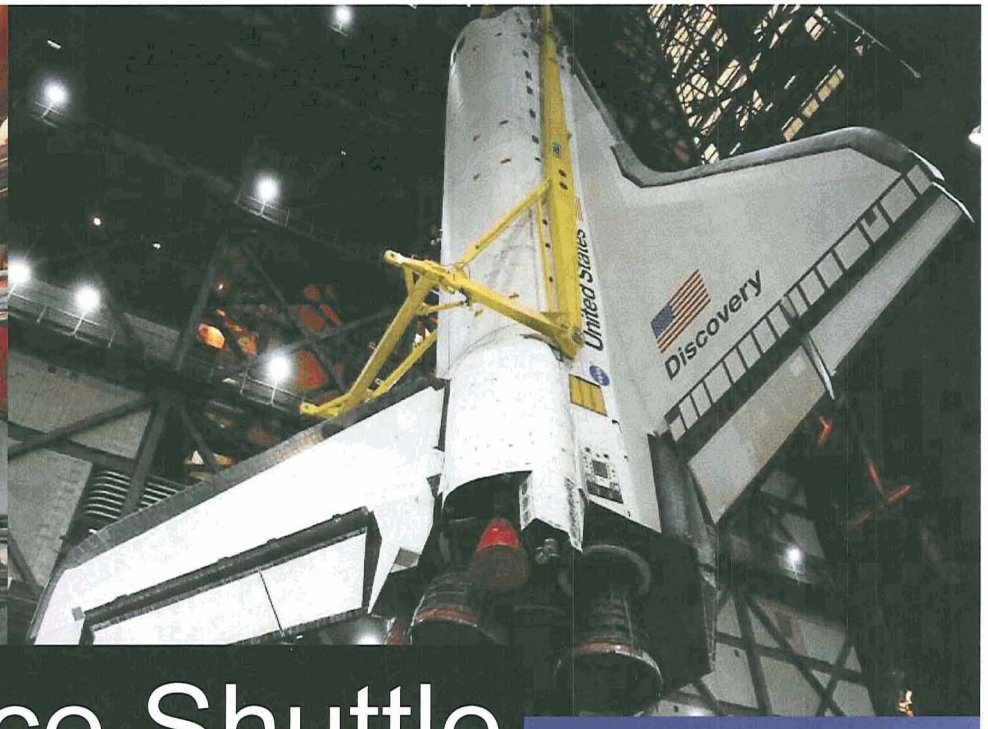
- Space Shuttle
- International Space Station
- Solar System Exploration Program
- Mars Exploration Program
- Future Lunar Exploration
  - Constellation
  - Lunar Precursor Robotics Program



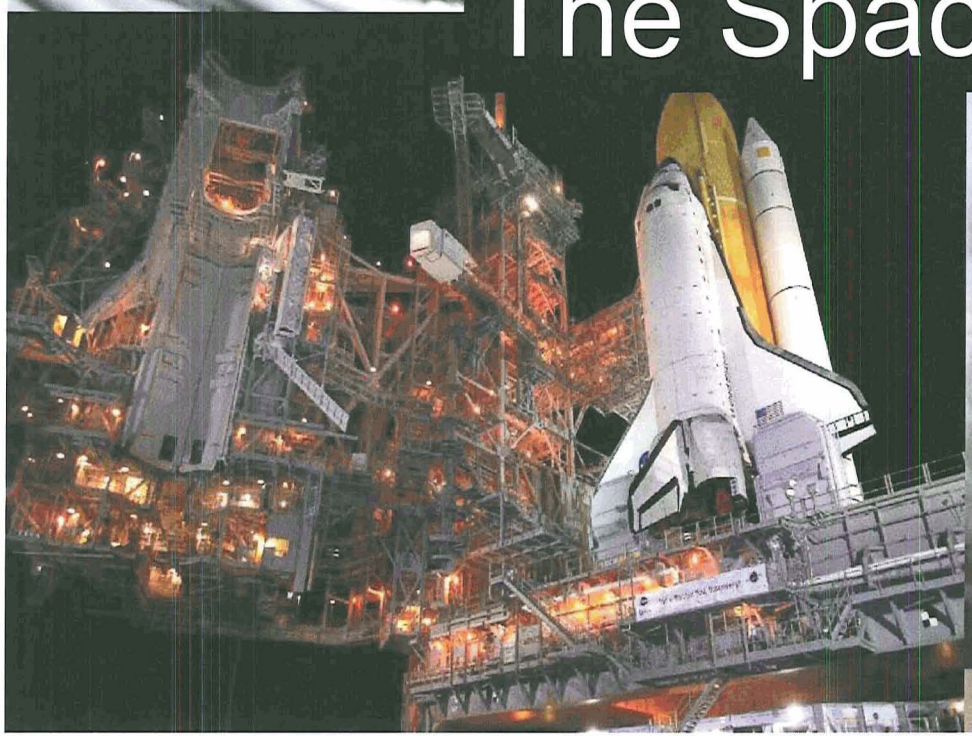






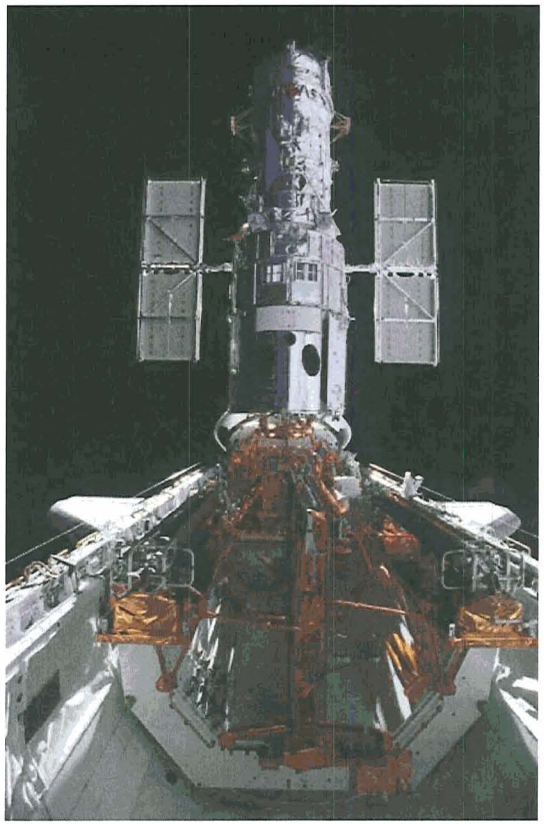


The Space Shuttle



Space Shuttle - Hubble Mission

- These Hubble Servicing Mission - STS 109 videos illustrate some Space Shuttle activities that involve astronauts and robotic arm (Remote Manipulator System RMS) activities
  - Use of Shuttle
    - launch sts109
  - Approach and tile inspection
    - sts 109 approach hubble
  - Retrieve of Hubble Space Telescope
    - RMS capture
  - Astronaut Servicing
    - Astronaut on end of robotic arm
  - Release of Hubble Space Telescope
    - Cargo Bay shot

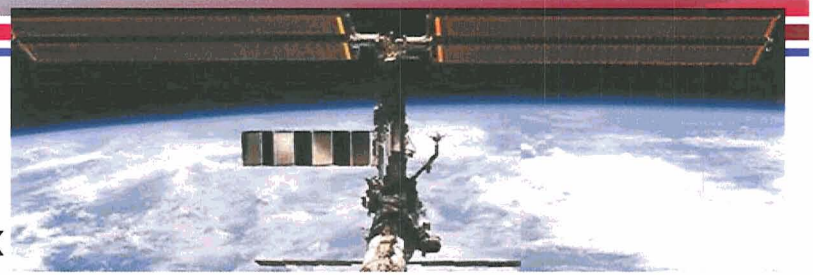


Space Shuttle - other applications

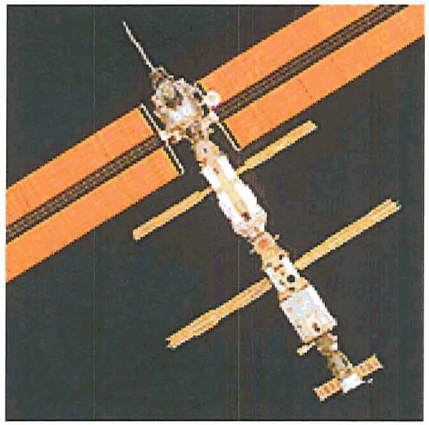
- Servicing the systems of the Space Shuttle
  - Movie of robotic processing of the SRB
- Modeling and Simulation of extended robotic arm for in-flight shuttle tile inspection.
  - Alabama A&M RoboSim movie


The International Space Station

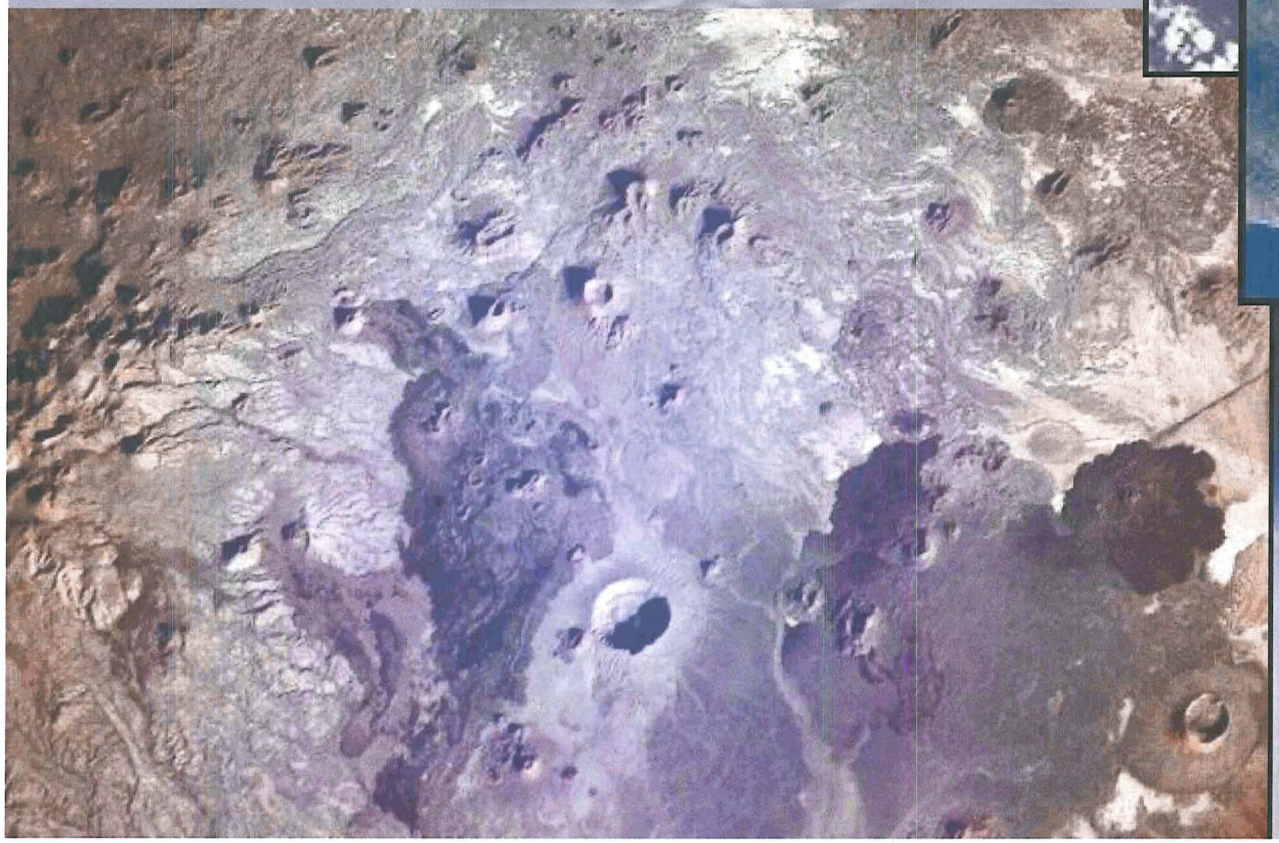
International Space Station Applications

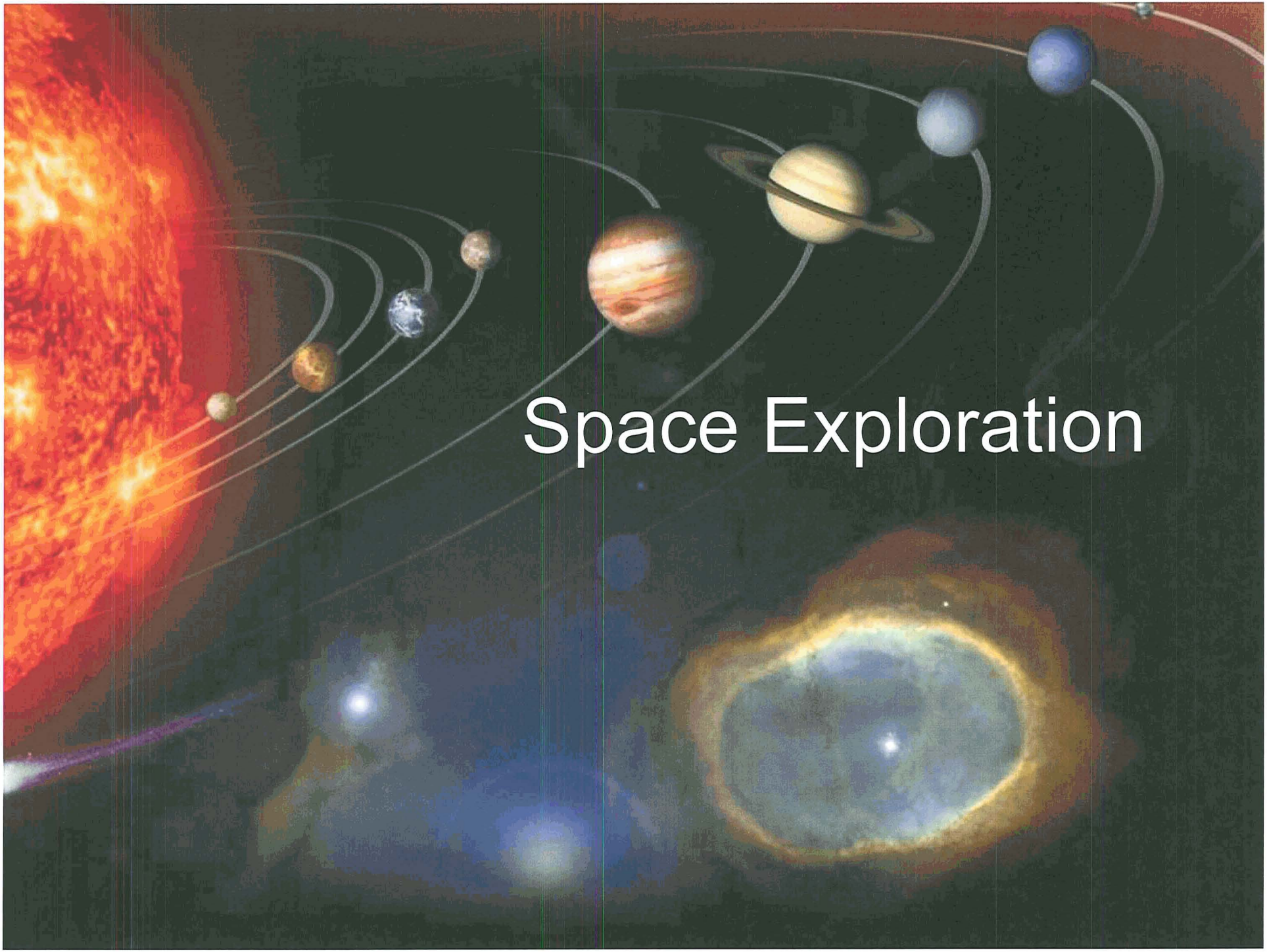


- ISS Assembly
  - ISS_Assembly_Sequence.asx
  - truss segment sts 115 P3 P4 video.asx
- ISS maintenance
  - HRF install 114_fdh06_clip3_56.asx
- ISS Science and Capabilities R&D
  - Inside Destiny 114fd06fdh_1_56.asx
- Logistics
  - Attaching MPLM to Unity
    - mplm to unity sts121_fdh04_01_56.asx
- Spacewalk over BAJA
  - spacewalk baja 114_fdh05_clip3_56.asx
- Other
  - Spheres



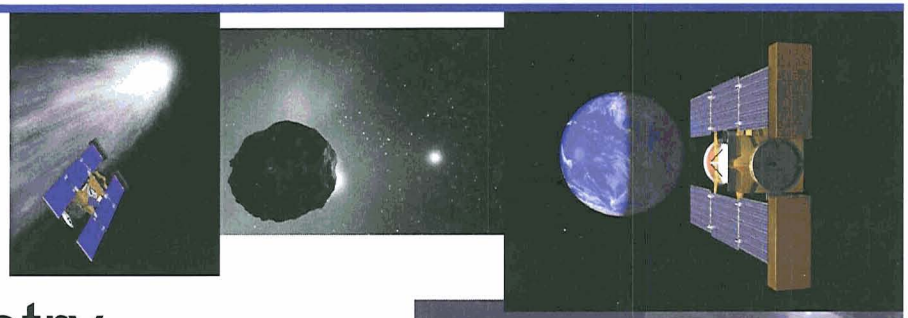
ISS Pictures of Mexico

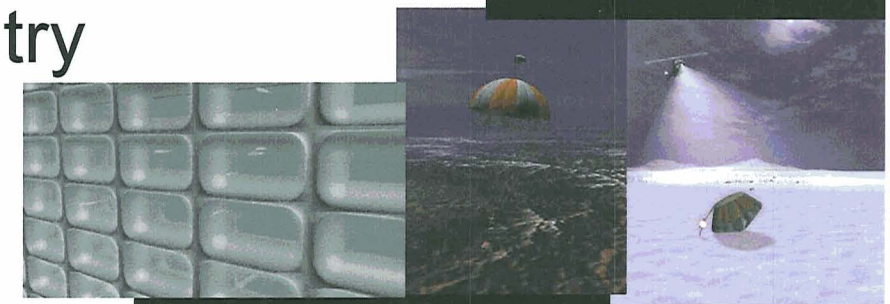


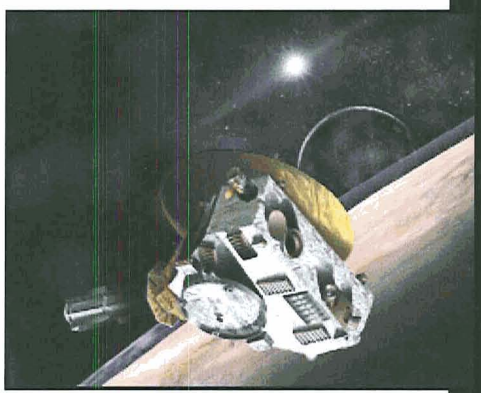

Space Exploration

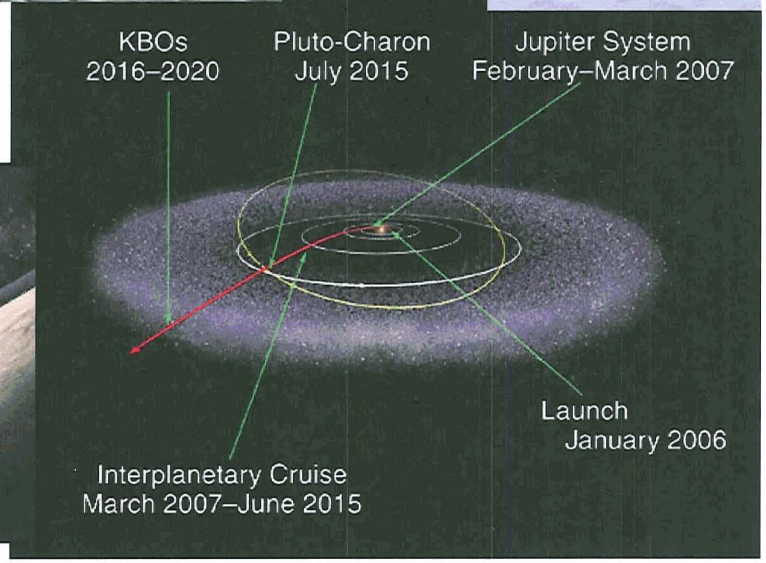
Solar System Exploration

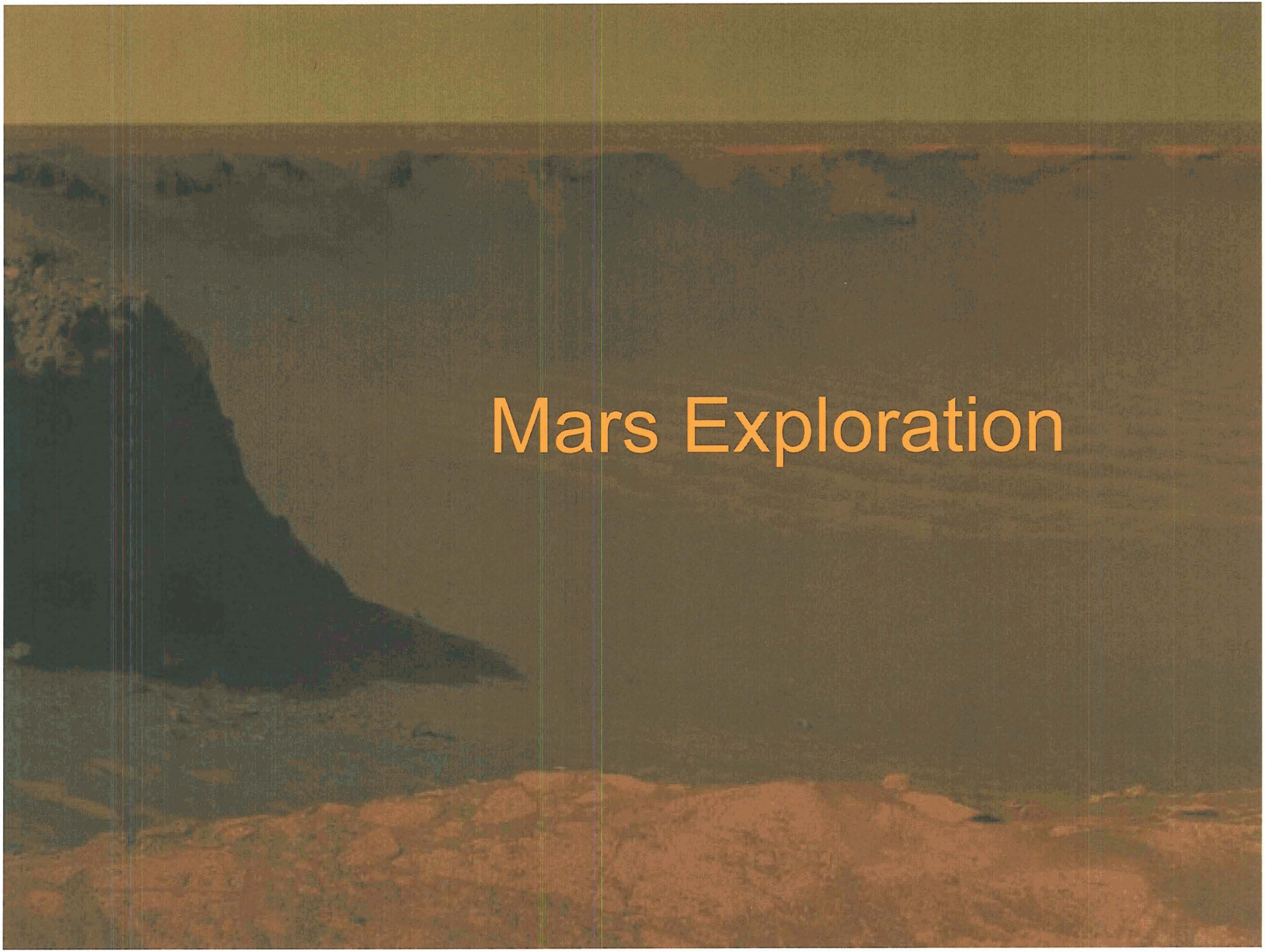
- Stardust
  - Picture of stardust
  - Movie of stardust re-entry
- New Horizons
  - Movie PKB
  - Picture of timeline





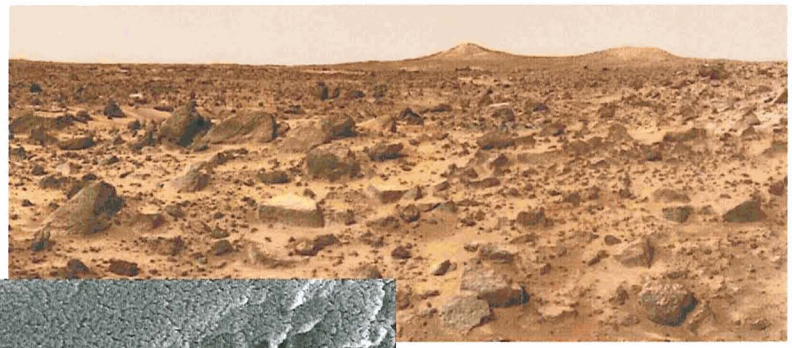


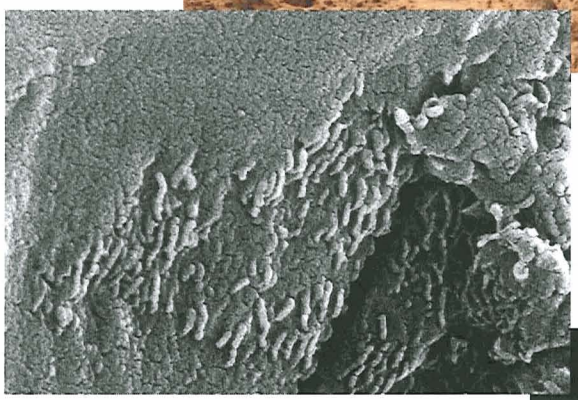


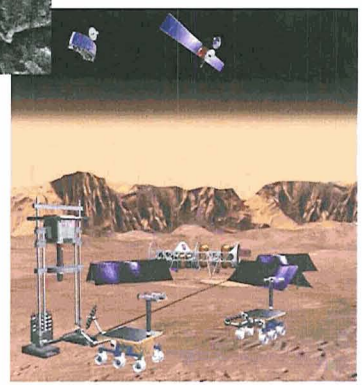

Mars Exploration

Mars Exploration Program

- First close-up pictures 1965
- Defining Question for Mars Exploration:
  - Life on Mars?
- NASA's Strategy
  - Follow the Water!
  - 3 Phases
    - Flyby
    - Orbiter
    - Landers and Rovers
- Missions
  - Current
  - Future



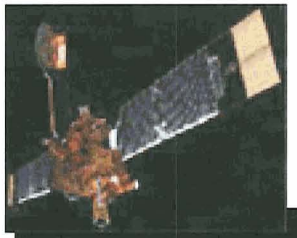


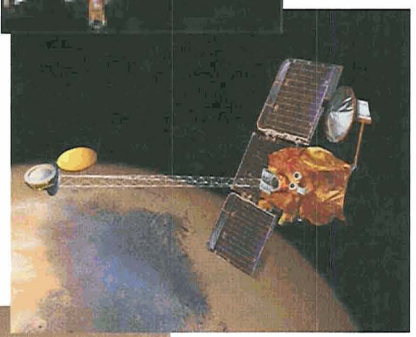


http://mars.jpl.nasa.gov/

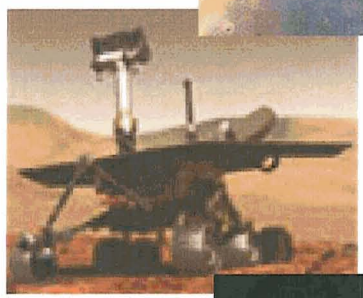
Current

- Mars Global Surveyor (1996-Nov 2006?)
  - Animation from data collected by MGS
- Mars Odyssey (2001 -)

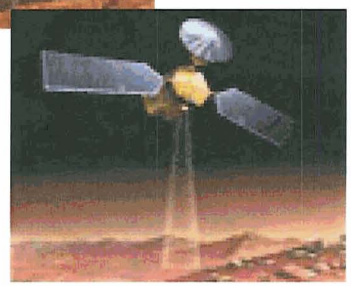




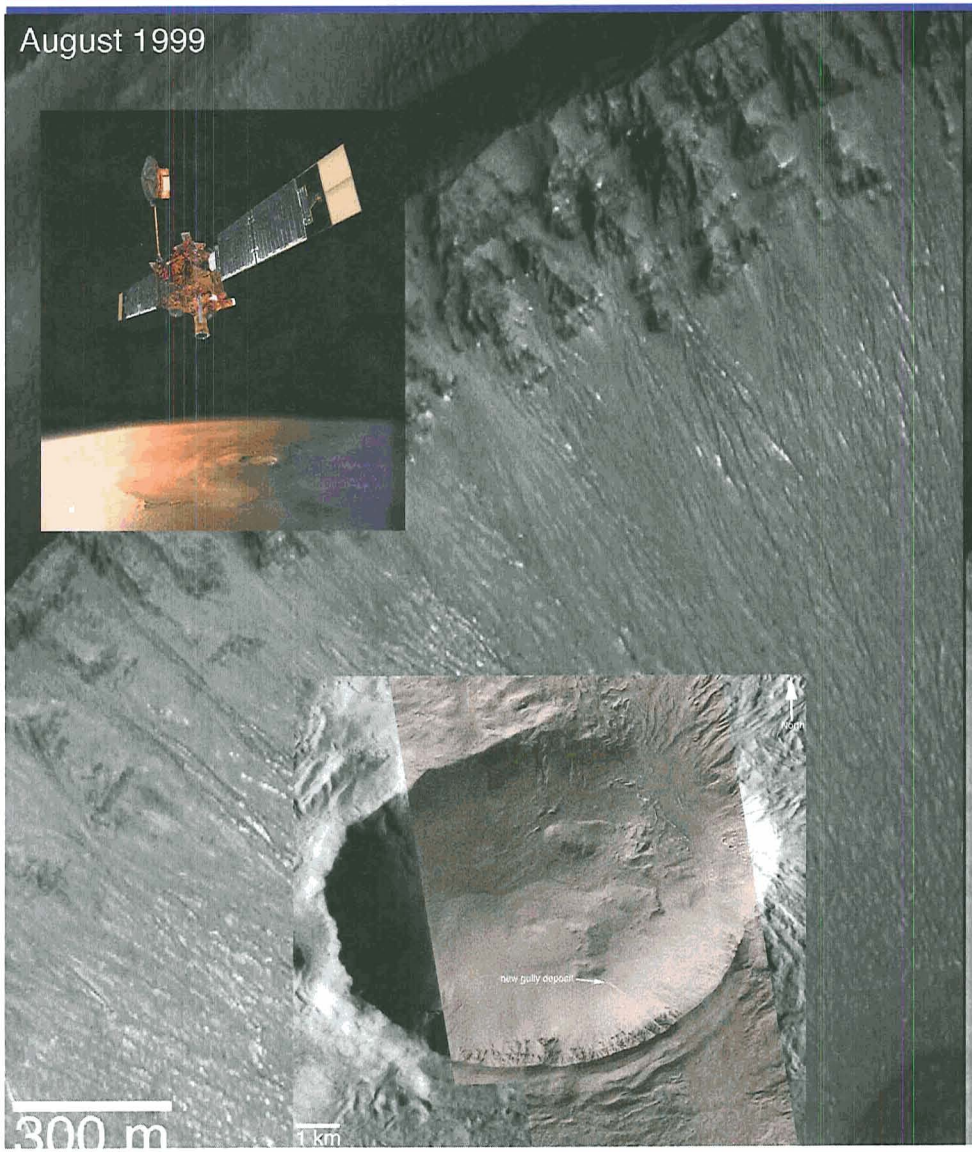
- Mars Exploration Rovers (2003 -)
  - Autonomous Navigation movie
  - Spirit movie
  - Opportunity movie



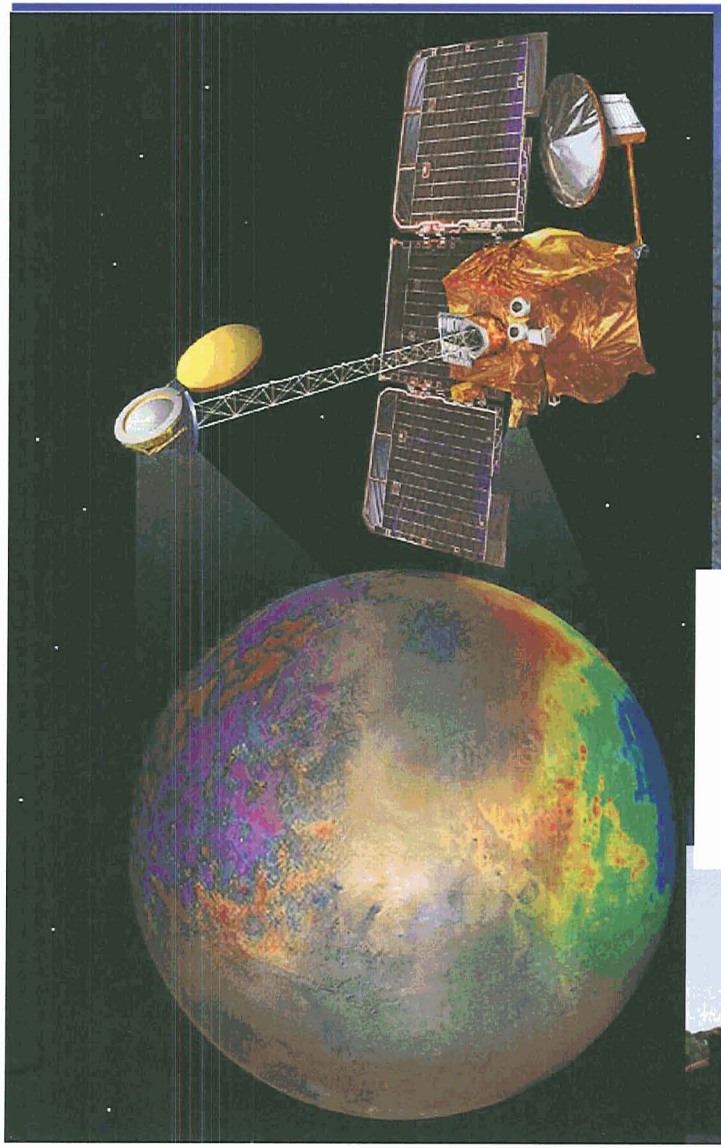
- Mars Reconnaissance Orbiter (2005 -)

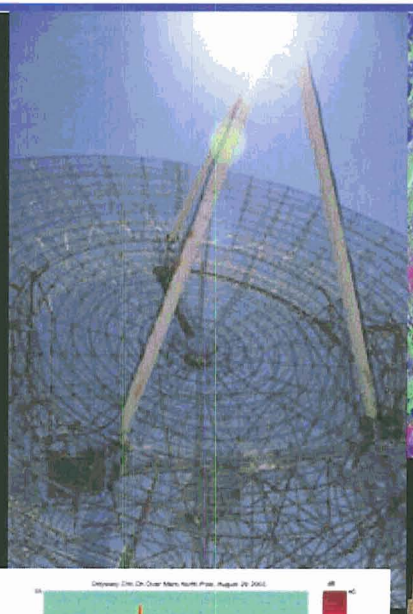


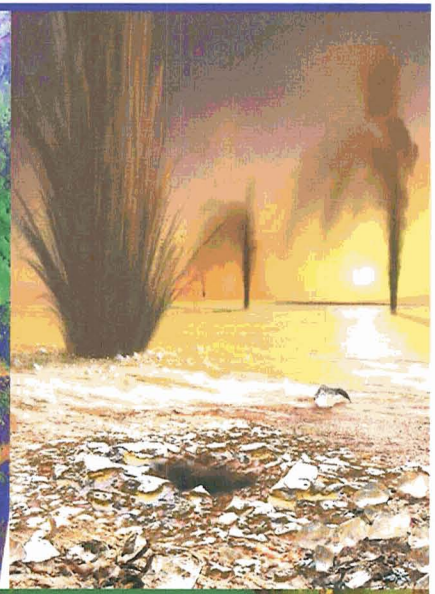
Mars Global Surveyor

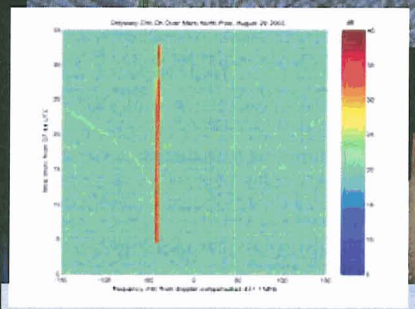


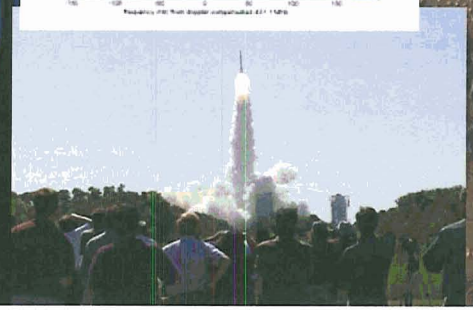
Mars Odyssey

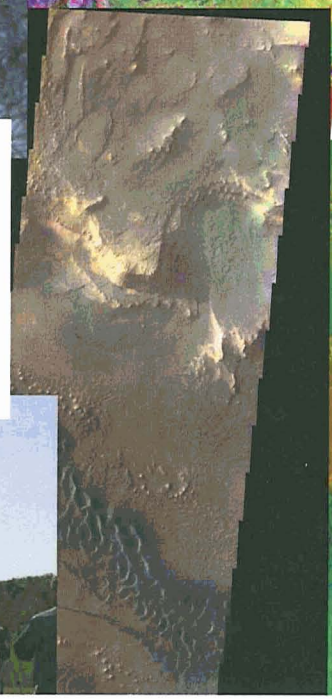


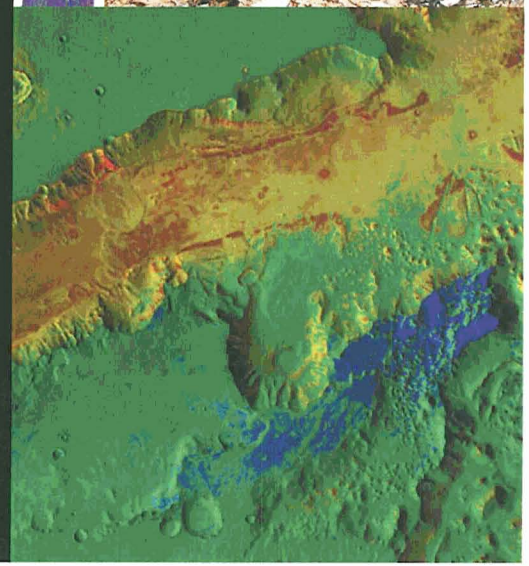




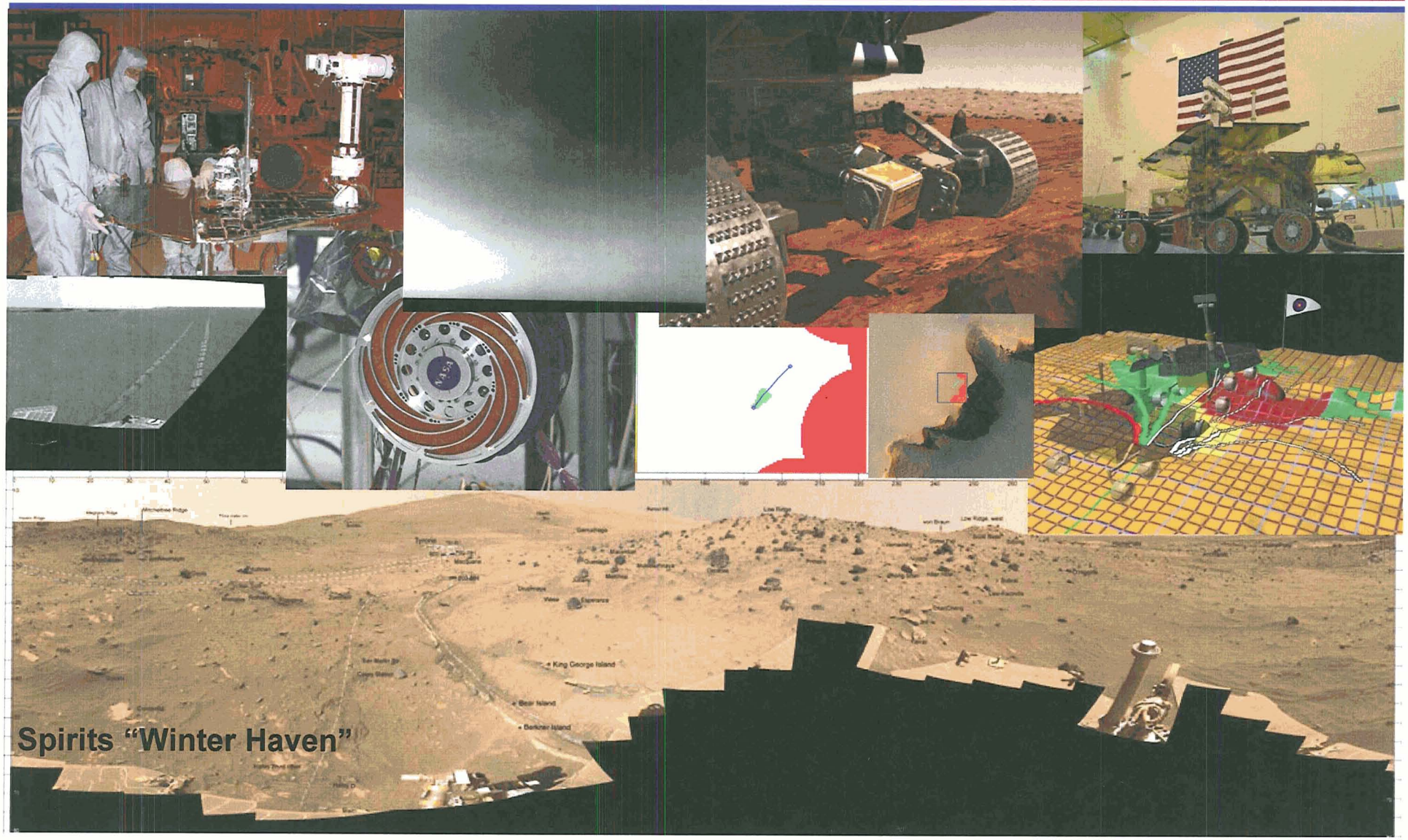




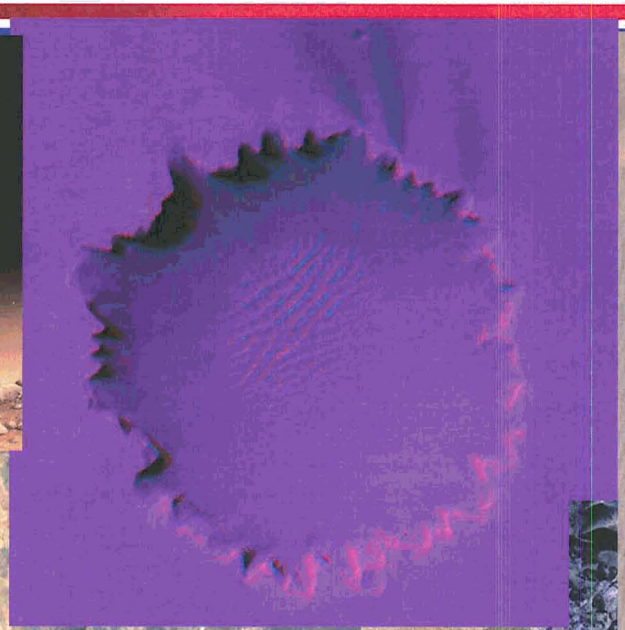


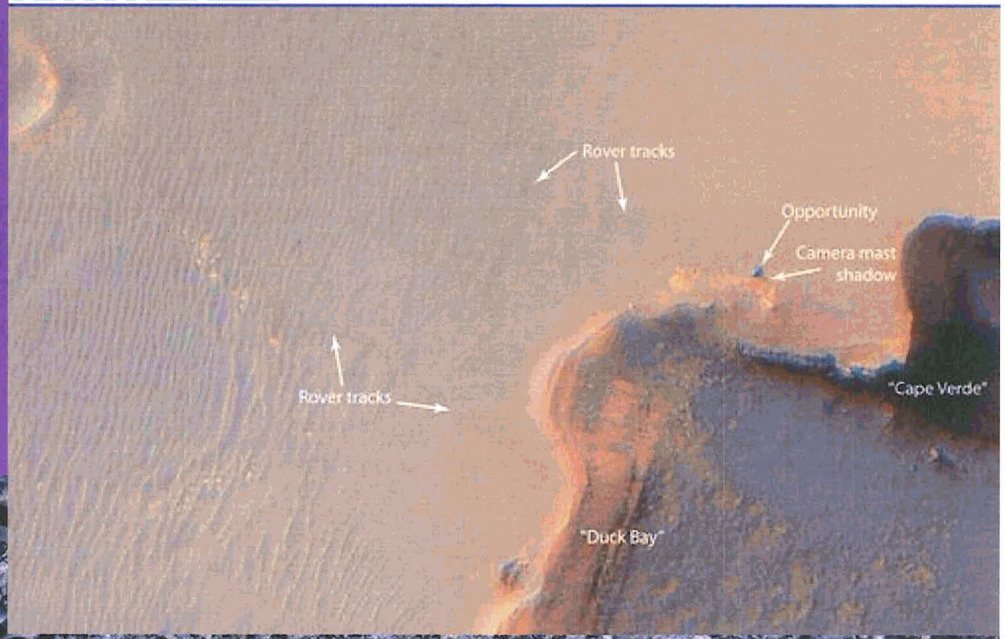


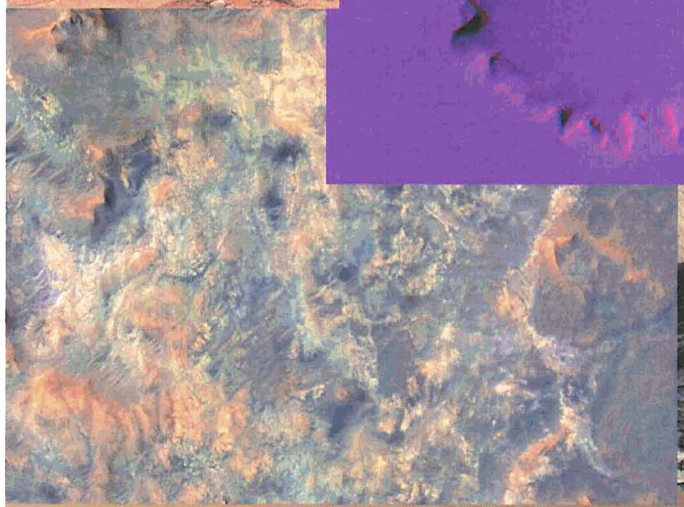
Mars Exploration Rovers (MER)

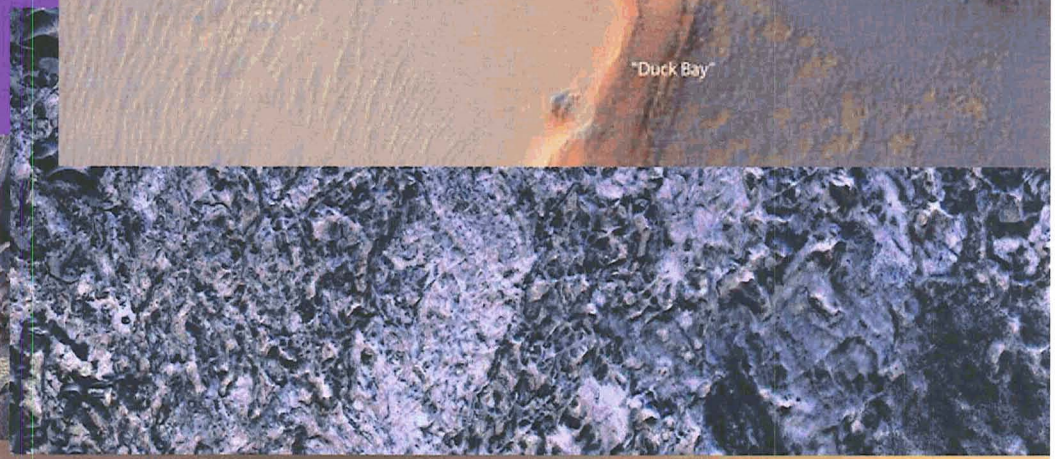


Mars Reconnaissance Orbiter

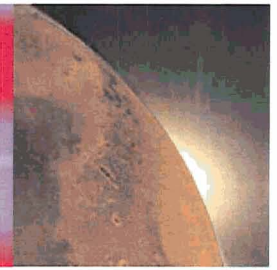




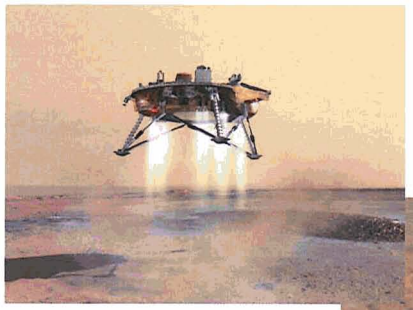


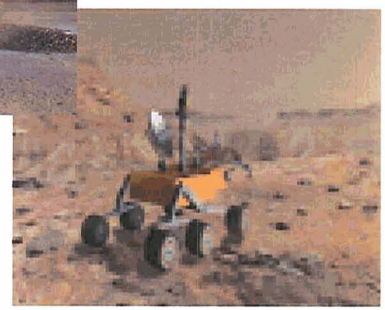


Future



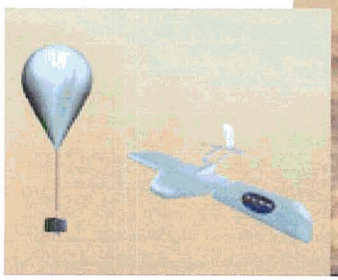
- Phoenix
  - (launch 2007)

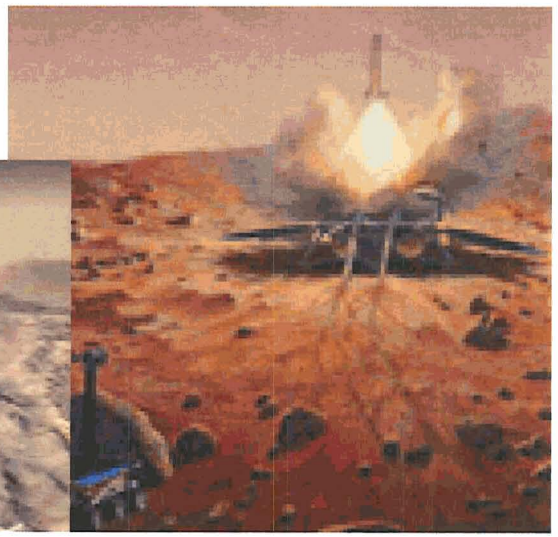


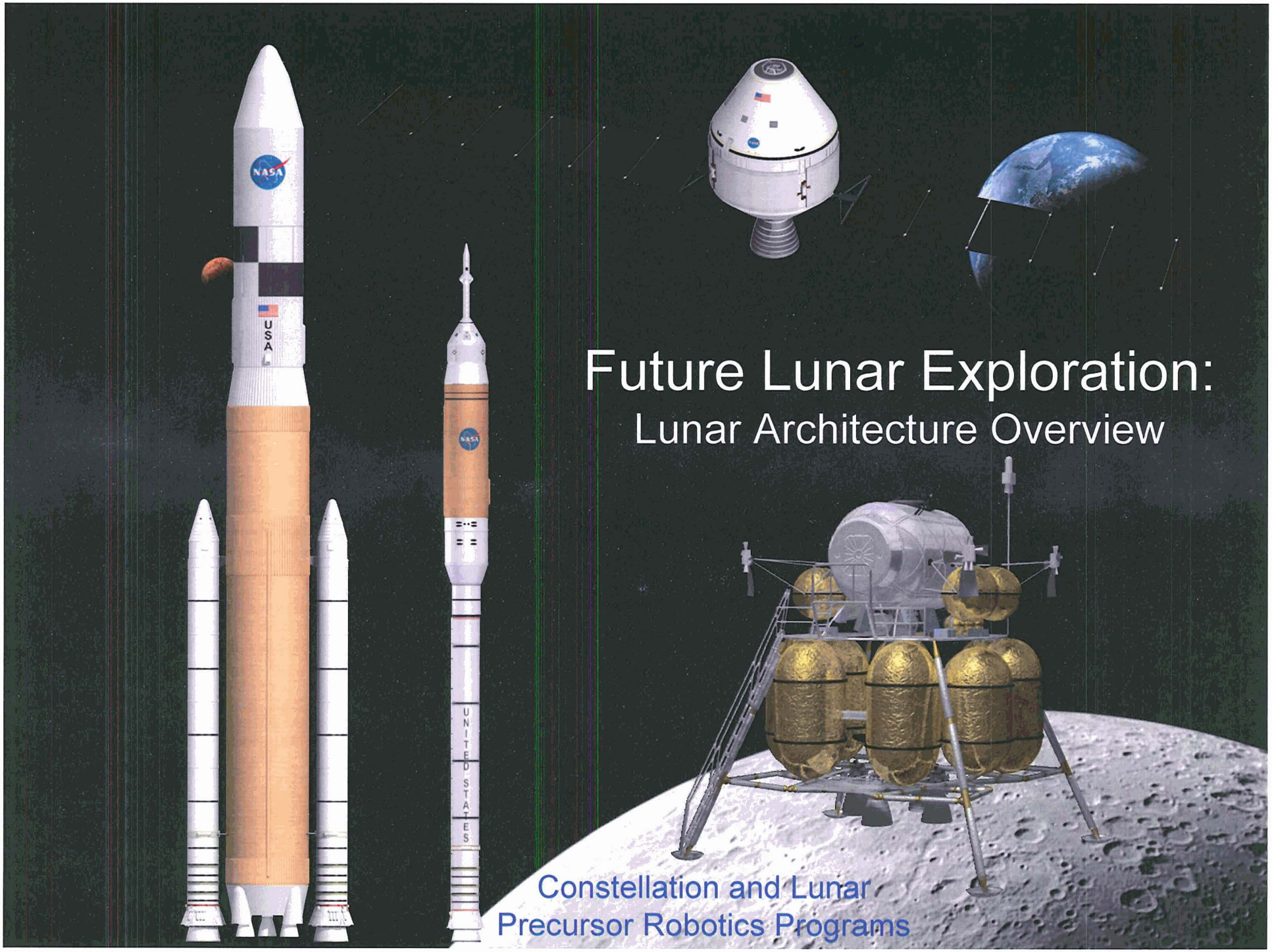


- Mars Science Laboratory
  - (launch 2009)

- Beyond 2009
  - Scout missions
  - Mars Sample Return
  - Astrobiology Field Laboratory
  - Deep Drilling etc.







Future Lunar Exploration:

Lunar Architecture Overview

Constellation and Lunar
Precursor Robotics Programs

- Lavoie movie

First Steps

Return of human beings to the Moon

The Moon as a stepping stone for future exploration missions

Explore Mars and beyond

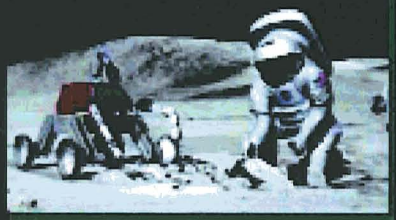
Robotic missions will come first but, eventually, crewed vessels could routinely cross the Solar System

Lunar Architecture Overview

Global Lunar Themes

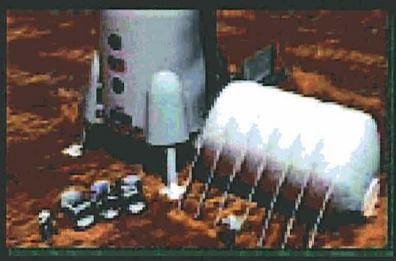
Human Civilization

Global Partnerships



Scientific Knowledge

Economic Expansion

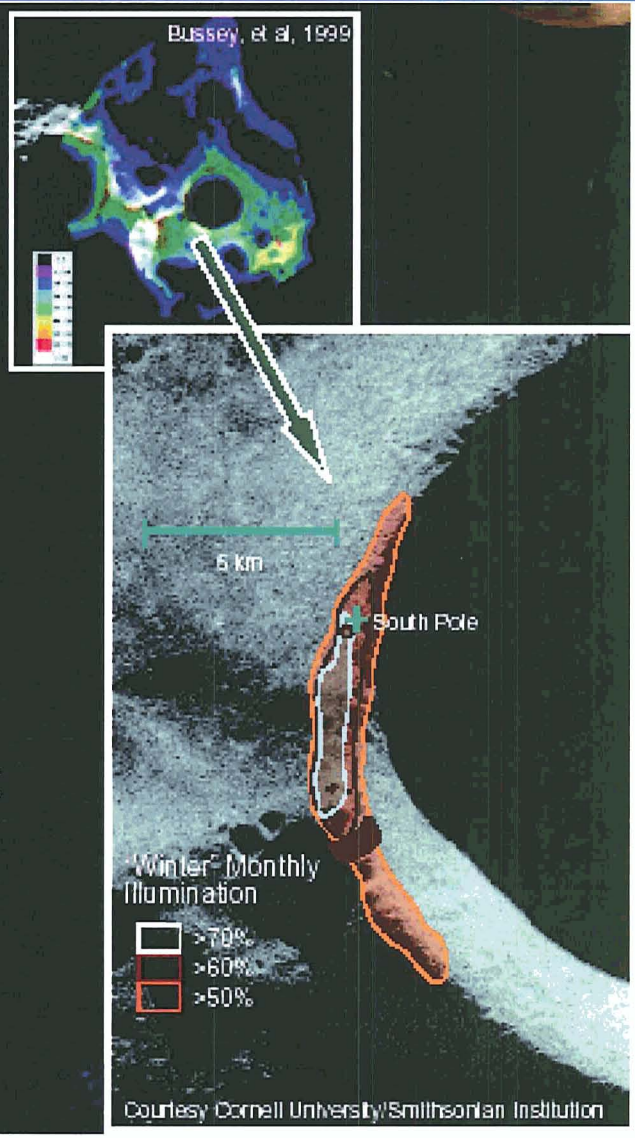


Exploration Preparation

Public Engagement

Key Decisions: Sortie vs. Outpost

- First: What is the fundamental lunar approach?
- LAT concluded outpost first is best approach
- Top 2 Themes – "Exploration Preparation" and "Human Civilization" drive to outpost
- Enables global partnerships
- Allows development and maturation of ISRU
- Results in quickest path toward other destinations
- Many science objectives can be satisfied at an outpost

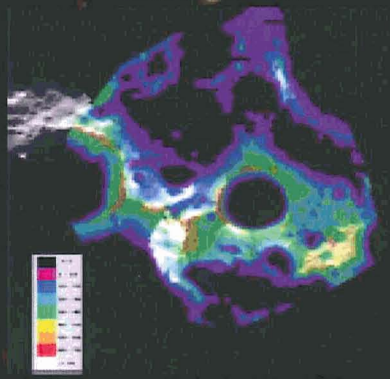


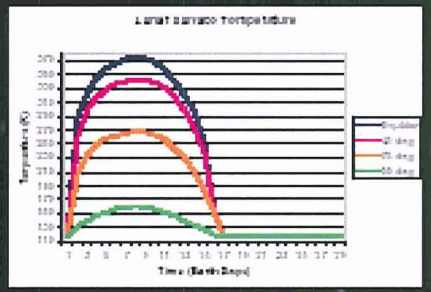
Outpost Site Location

Outpost Site: Polar

- **Safe**
  - Thermally Moderate
- **Cost Effective**
  - High percentage of sunlight
  - Allows use of solar power
  - Least Delta V required
- **Resources**
  - Enhanced hydrogen (possibly water)
  - Potentially other volatiles
  - Oxygen
- **Flexibility**
  - Allows incremental buildup using solar power
  - Enhanced surface daylight ops
  - One communication asset (with backup)
  - More opportunities to launch
- **Exciting**
  - Not as well knows as other areas
  - Offer unique, cold, dark craters

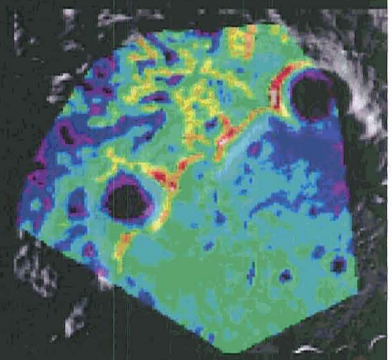
South Pole





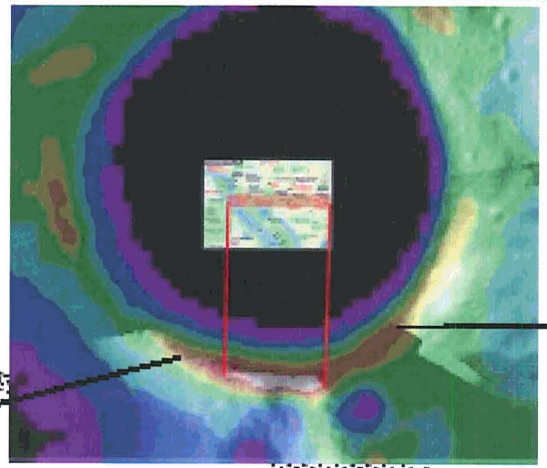
Data obtained during southern winter (maximum darkness)

North Pole



Data obtained during northern summer (maximum sunlight)

Shackleton Crater Rim with Notional Activity Zones



Potential Landing Approach

Resource Zone
(100 Football Fields Shown)

South Pole (Approx.)

To Earth

Monthly Illumination
(Southern Winter)

50-60%
60-70%
>70%

Observation Zone

Landing Zone
(40 Landings Shown)

Power Production Zone

Habitation Zone
(ISS Modules Shown)

0

5 km

Potential Landing Approach

Lander Basic Architecture

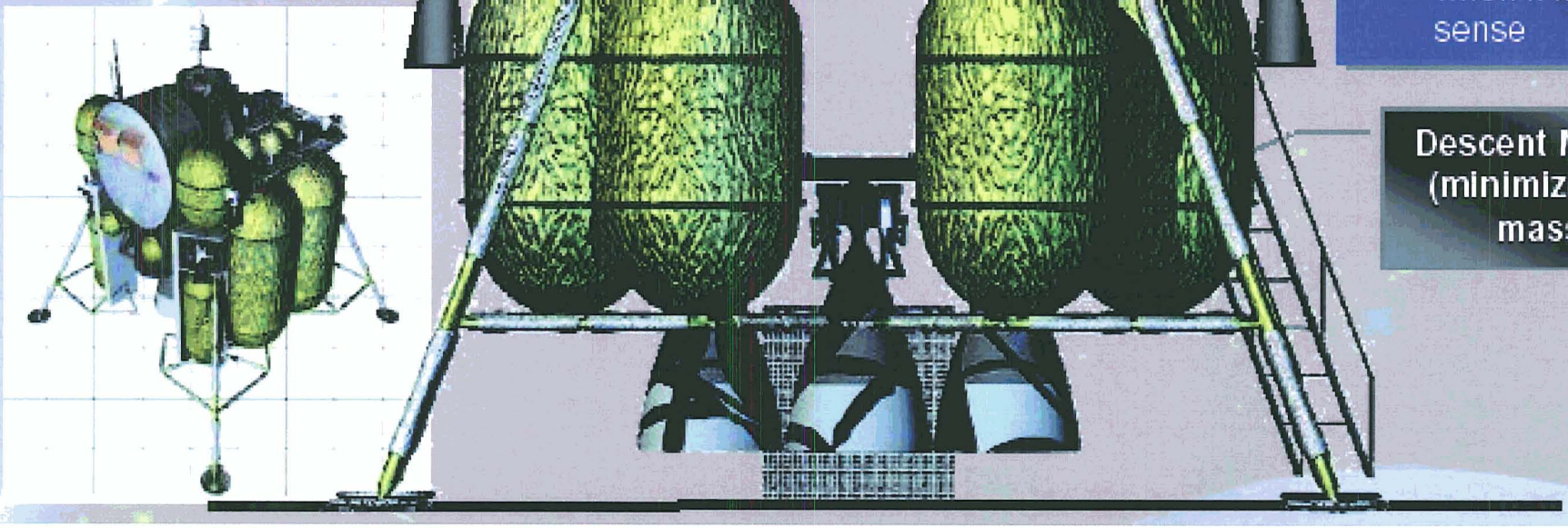
Point of Departure Only

Ascent Module (minimized for mass)

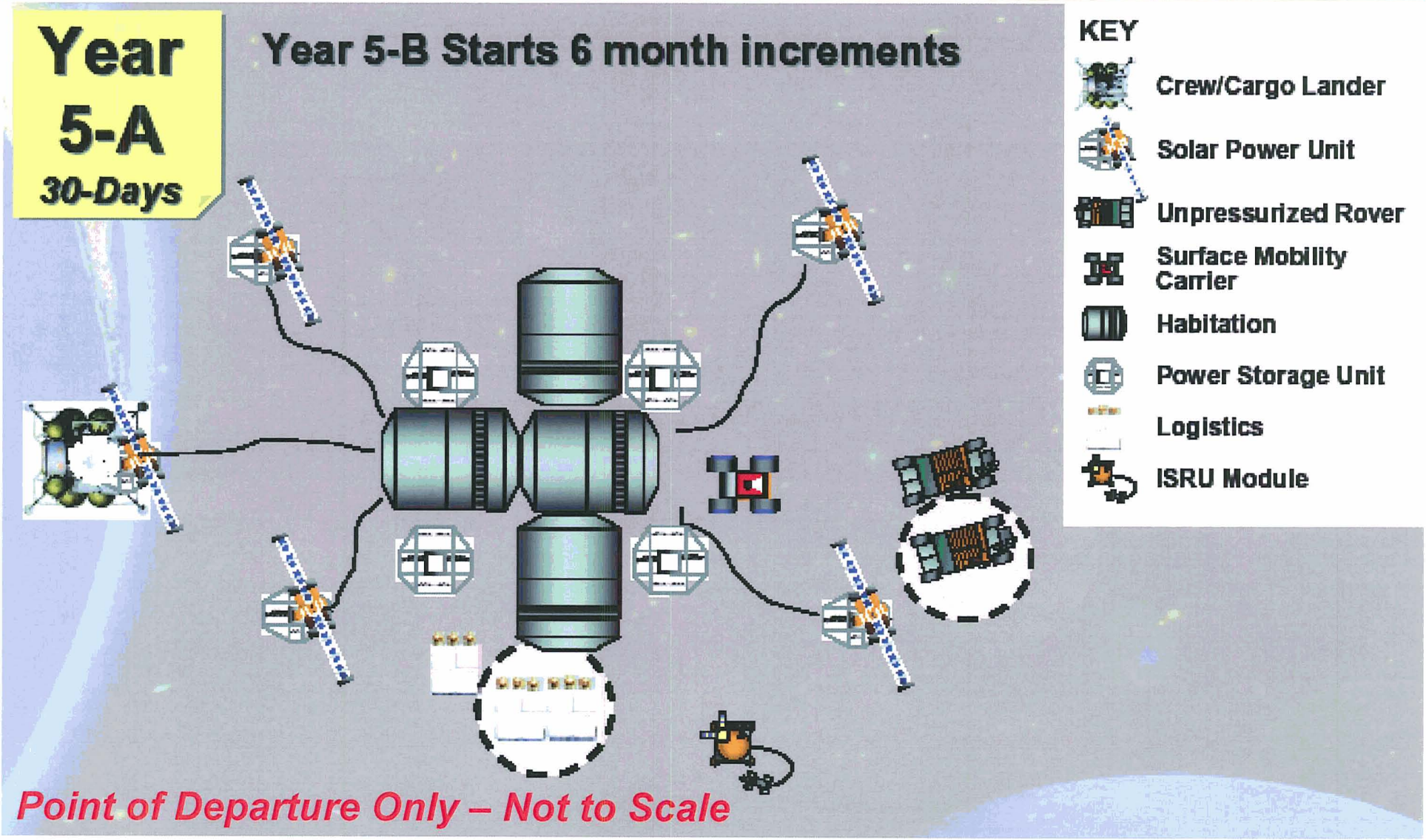
Landed Mass (Cargo, Habitat, Mobility, etc – Maximized for Mass)

- **Design Goals**
  - Minimize Ascent Module mass
  - Minimize Descent Module mass
  - Maximize landed "payload" mass
  - Simplify interfaces
  - Move functions across interfaces when it makes sense

Descent Module (minimized for mass)

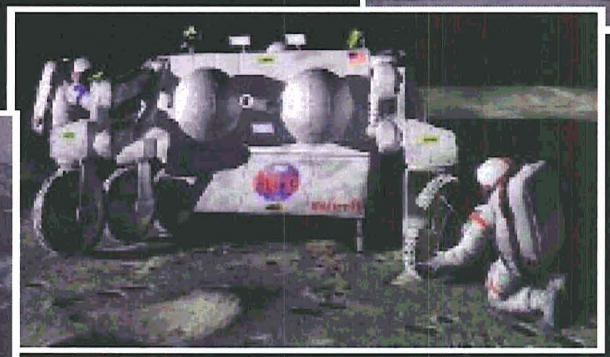


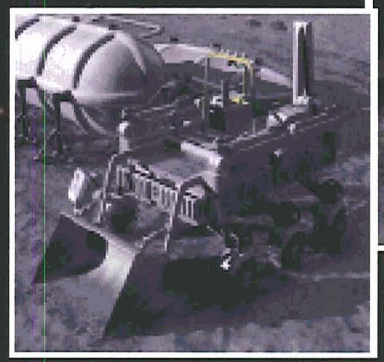
Outpost Build Up



In-Situ Resources Utilization (ISRU)

- ISRU is a critical capability and key implementation of the VSE
- ISRU is also unproven
- Therefore, ISRU is manifested to take incremental steps toward the desired endstate
- Architecture takes advantage of ISRU from: LSAM residuals, ECLSS by-products, Lunar ISRU





Point of Departure Only

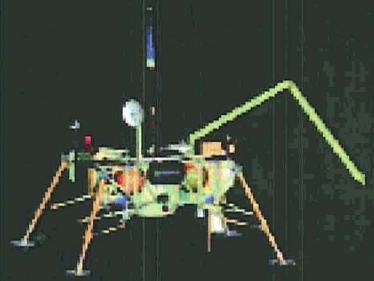
Lunar Robotic Exploration Architecture

Robotic Precursor Missions

- Landing Site Recon
- Reduce the risk for human missions
- Potential for ISRU demonstrations
- Scientific Exploration
- Early and sustained public engagement

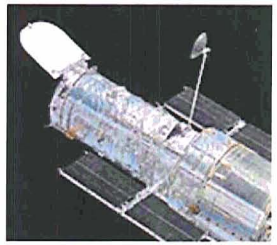
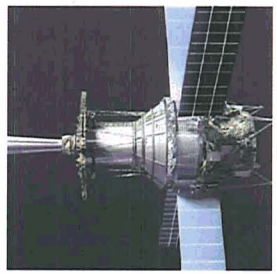
Implementation

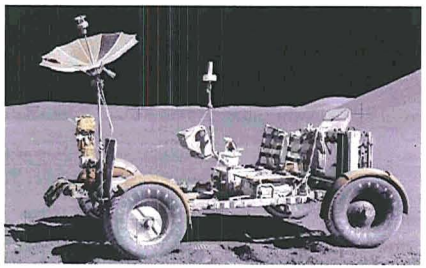
- LRO/LCROSS (launching in 2008)
- Medium Lander at potential Outpost site (Launching in 2011 or 2012)
- SmallSat for communications demo (Launching in 2011 or 2012)
- Other mission opportunities afterwards for:
  - Human Mission Risk reduction
  - Resource determination (especially Hydrogen and other volatiles)
  - ISRU proof of concept/risk reduction (O2, H2, H2O, N2, structure fabrication, etc)
  - Science

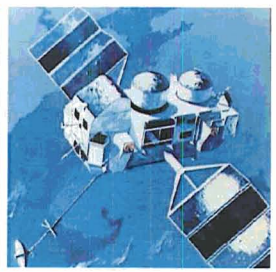


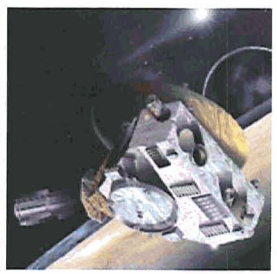
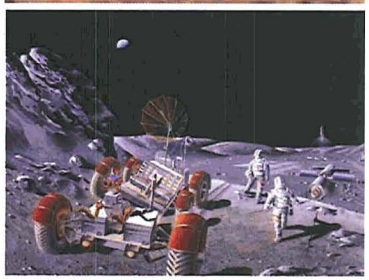
Conclusion

- Using current lunar architecture, robotic missions will:
  - Characterize critical environmental parameters and lunar resources.
  - Test technical capabilities to enhance future human and robotic exploration.
- Early robotic precursor missions will update and refine baseline requirements
- NASA will coordinate lunar exploration plans among international partners
- Lunar exploration supports development of Mars reference missions





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