

RELATIVE ROLES OF ROBOTS AND HUMANS IN THE EXPLORATION OF MARS

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DPT EXPERIENCE

MARS - AGGRESSIVELY INTEGRATE ROBOTIC AND HUMAN MISSIONS

NRC Space Studies Board

3 Part Study

- 1) Scientific Prerequisites for the Human Exploration of Space (1993)
- 2) Scientific Opportunities in the Human Exploration of Space (1994)
- 3) Science Management in the Human Exploration of Space (1997)

“The ultimate decision to undertake further voyages of human exploration and to begin the process of expanding human activities into the solar system must be based on non-technical factors”

National Academy Report

“Science is the fulcrum of the entire space program.”

Augustine Report

CHEX REPORT

Role Robots and Humans

Robotic Probes Provide Enough Information to:

- 1) Optimize Site Chosen for Human Exploration
- 2) Define Set Scientifically Important Tasks that can be WELL
Performed by Humans In Situ

SCIENCE BY HUMANS

Planetary Science

Geologic Field Work (although other field work also applies)

Mapping Distribution of Rocks in the Field

Measuring Parameters (e.g., bedding attitude, thickness) that can only be made in the field

Two Types of Field Work

Reconnaissance - broad characterization or
answer a specific question

can be done by robots or humans

Field Study - requires human intelligence and experience

Geologic materials are complex and subtle

Requires extraordinary combination of observation,
pattern recognition, synthesis of broad experience base

Robotic Missions - Should do most Reconnaissance Field Work

Human Missions - Should concentrate on Field Study

Requires Robust Robotic Program to Identify Places where Humans can Optimize their study

Spudis, P.D., and Taylor, G.J. (1992) The roles of humans and robots as field geologists on the Moon: Lunar Bases and Space Activities of 21st Century, 2nd Symposium Proceedings (W. Mendell, ed.), NASA Conference Publ. 3166, vol. 1, p. 307-313.

Spudis, P.D., 1992, An argument for human exploration of the Moon and Mars: American Scientist, vol. 80, p. 269-277, May-June 1992.

Spudis, P.D., Robots vs. humans, Who should explore space, in The Future of Space Exploration, A Guide to the Voyages Unveiling the Cosmos, Scientific American Presents, v. 10, p. 24-31, Spring 1999. (see also counterpoint by F. Slakey in the same pages.

MARS - AGGRESSIVELY INTEGRATE ROBOTIC AND HUMAN MISSIONS

RATIONALE

Use Robots to Perform Reconnaissance

CHEX

Broad Characterization or Answer a Specific Question

Use Humans to Perform Detailed Field Work

Map Distribution and Parameters of Rocks in the Field

Requires Human Intelligence, Knowledge and Experience

PHASING

Robots

Define Scientifically Important Tasks WELL Performed by Humans

Define Environment & Hazards, Identify Resources &

Technologies to Extract/Use; Emplace Infrastructure

Start Broad Characterization to More Detailed Study at Finer Scale

Global Remote Sensing

In Situ Investigations of 40 Geologic Units on Mars

Network-Simultaneous Meteorology & Seismology Measurements

Surface Rovers - Characterize Selected Areas km Scale

Sample Returns - Definitive Analyses

Balloons, Hoppers, Airplanes;

Send Humans to Robotically Emplaced Outpost

DEVELOP A SCENARIO OPTION THAT AGGRESSIVELY INTEGRATES ROBOTICS AND HUMANS FOR MARS

M. Golombek, P. Curreri, J. Kramer

THE PROBLEM:

Mars Surveyor Yearly Budget has been ~100M/yr

Missions were FBC (Budget - New Start to Launch + 30 days)

MPF ~200M

MPL, MCO ~150M

MS Now Ramped up to ~200M/yr to Accomplish '03 & '05

Includes Sample Return - Major Engineering Effort

But Reference/Other Human Mission Tens of B!!!

MS Cost Cap Pervades Engineering and Management Decisions

[Outside of Launch Vehicle Cost]

SO HOW INTEGRATE THESE TWO EFFORTS?

MUST RAMP UP SCALE OF ROBOTIC MISSIONS

e.g., Current Reference Mission Include Nuclear Reactor
Solar Power Insufficient

Surveyor Program Cannot Use RTG - Political & Cost (Lawyers, EIS)

Huge Effect of Where Can Go on Mars

Solar Power on Surface Marginal

Land Near SubSolar Latitude $\pm 25^\circ$ Maximize Power and Data

Last Few Months [Viking Landers w/RTGs Lasted Years]

Human Missions/Outpost Also Driven by Resources

Expect Volatiles Stable at Higher Latitudes

Trade btw Latitude and Equatorial Launch Assist

Not Enough Landers to Risk Them at Potentially Hazardous Sites

HOW ATTACK PROBLEM?

Try to work Backwards - From Reference Mission

Subject to Uncertainties/Changes in Reference Mission

What Capabilities (Instr., Labs) and Mobility Humans Have?

Try to Work Forwards - From Surveyor Program

Subject to Uncertainties in Timing and Approach

Try to Work From - What Want to Know Before Send Humans

Avoids Problems Above, but Assumes Rationale

RATIONALE

AGGRESSIVELY INTEGRATE ROBOTIC AND HUMAN MISSIONS

Optimize Sites for Humans

Understand Environments and Hazards

Define Scientifically Important Tasks WELL Performed by Humans

Not Reconnaissance but Field Work

Define Environment and Resources Available for Human Exploration

T, P, Wind, Dust (Elect.), Quakes, Water, Soil Reactivity, Materials

Define Technologies Needed for Human Presence

ISRU, Extraction of Water, Oxygen, Power

HOW DO DO THIS? - Need to Know/Learn About Mars

APPROACH START BROAD SCALE - GENERAL CHARACTERIZATION

To More Detailed Characterization at Finer and Finer Scale

Global Remote Sensing

Many Small Surface Landers

Surface Reconnaissance at Many Locations

More Detailed Study by Surface Rovers

Find Location Where Humans can Perform Important Field Work

Find Location with Resources

HOW DO WE EXPLORE MARS?

SMALL LANDERS/ROVERS [ORDER 10]

Network Science - Distributed Sites Meteorology/Seismology [>10]

Enough Landers to "Risk" Some at Potentially Hazardous but

Scientifically Interesting Sites, Send Beyond Equatorial Latitudes

CAPABLE ROVERS/SAMPLE RETURNS - Thorough Reconnaissance

ADDITIONAL REMOTE SENSING

Orbiting Instruments, Balloons, Planes

AFTER THIS - IN POSITION TO SELECT SITE FOR ROBOTIC OUTPOST

Example: Look for Evidence of Past Life

What was environment on Mars? Was Liquid water stable?

Land in Ancient Cratered Terrain - analyze rocks

Did life start on Mars?

Land at Lake Bed - analyze sediments deposited, organics?

Ancient Hydrothermal Systems - ancient volcano w/fluvial activity

Find Resources

Demonstrate ISRU and Develop Them for use

ROBOTIC OUTPOST

BEGIN PERMANENT PRESENCE

Robotically First

MORE DETAILED AND ADVANCED SCIENCE INVESTIGATIONS

(Including Sample Return?)

EXPLORE AREA TO BE VISITED BY HUMANS FROM SITE

Over Scale that Humans will Investigate

BEGIN EMPLACEMENT OF INFRASTRUCTURE FOR HUMANS

DEMONSTRATE AND DEVELOP ISRU

Robotically First, Then on Scale Needed for Humans

LOCATE RESOURCES

Find Water, Extract Water

Find Other Resources of Importance

DEVELOP MATERIALS FOR HABITAT LOCALLY

Martian Adobe, Soil for Greenhouses, etc.

EVOLUTION OF MARS EXPLORATION STRATEGIES AND MISSIONS

- 1978 COMPLEX** [Strategy for Exploration of the Inner Planets, 1977-1987]
Stressed Local Scale Investigations, Extensive Mobility (Rover)
or Multiple Surface Landers, Sample Return
- 1988 SSEC** [Planetary Exploration through Year 2000]
Big Questions; Mars Observer, MRSR, Multiple MRSR
- 1988 SSB, NRC** [Space Science in the 21st Century]
Mars Focus, Global Mapping, Surface Stations
Mars Observer, MRSR, Network
- 1990 COMPLEX** [Update to Strategy for Exploration of the Inner Planets]
Global Processes Stressed over
Local Scale Investigations and Sample Return
[Result of Viking Analysis, Dynamic Planet, Early-Warm Wet]
- SSED Strategic Plan, 1991**
Mars Observer, Mars Network-Recommended, MRSR Candidate

EVOLUTION OF MARS EXPLORATION STRATEGIES AND MISSIONS (cont.)

1994 COMPLEX [An Integrated Strategy for the Planetary Sciences: 1995-2010]
Global Processes, Mars Surveyor, Pathfinder, Network

1994, OSS STRATEGIC PLAN

Mars Surveyor Program, 2 Landers in '01, 4 in '03
Either Network or Sample Return

1997, SPACE SCIENCE ENTERPRISE STRATEGIC PLAN

Mars Surveyor Program, Orbital and Surface Investigations
1st of 3 Sample returns in '05

[Result of Mars Rock, focus on possible life, aka A Discovery]

OBSERVATIONS

Evolution of Thought from Local Investigations & SR to
Global Processes & Network back to Global Processes & SR
Basic Science Questions Have Changed Little
Emphasis and Implementation Linked
Depend on Political Environment (cost, relevance)
and Engineering Feasibility