

# Human-Robotic Combined Activities on the Moon

**Paul D. Spudis**  
*Applied Physics Laboratory*

***Workshop on Science Associated with the  
Lunar Exploration Architecture***

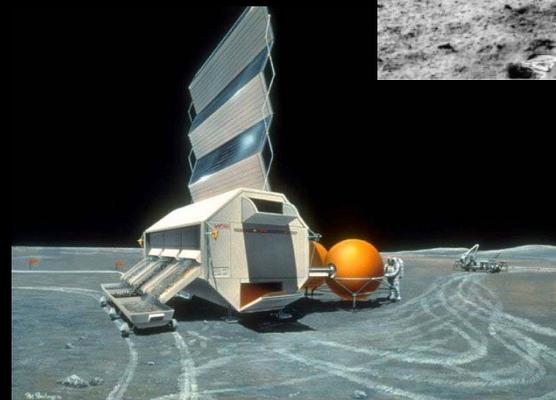
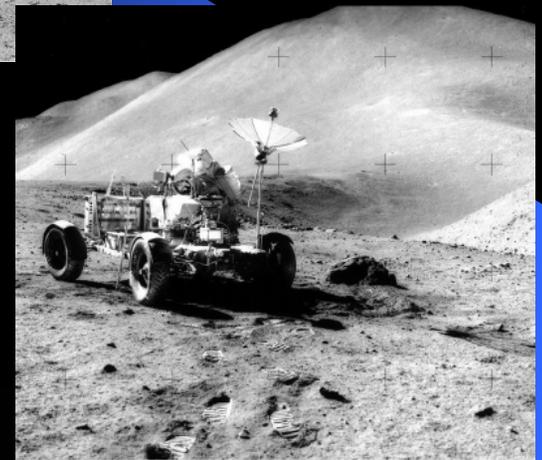
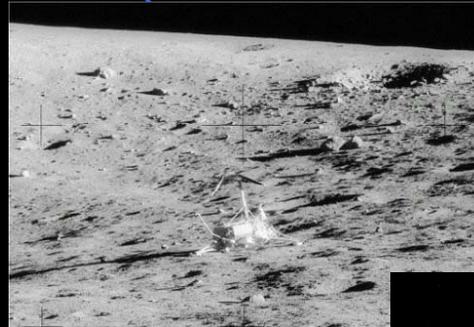
February 28, 2007

# The Human-Robotic “Partnership”

Traditionally in space,  
machines lead and  
people follow

Limited use of robotic  
missions (e.g., strategic  
knowledge gathering) in  
part because of their  
technical limitations

Can people and machines  
work together  
synergistically? (Is the  
whole greater than sum  
of the parts?)



# Humans and Robots

What is the current robotic exploration architecture?  
What should it be?

Which tasks are appropriate for people? Which tasks for machines?

How can humans and robots work together to explore planetary surfaces?

What is the role (if any) of teleoperations and telepresence in planetary surface exploration?



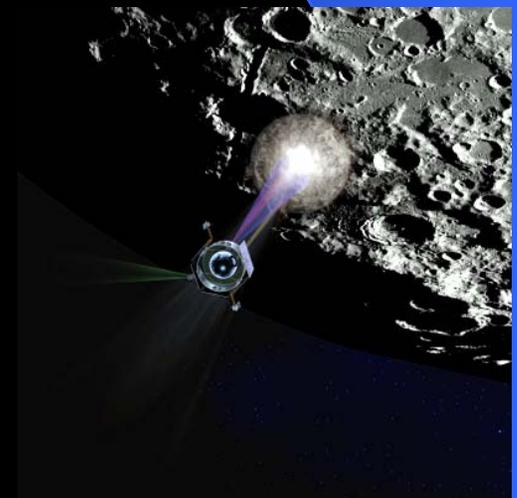
# Lunar Precursor Robotic Program

Currently, only LRO and LCROSS are funded

LAT plan for landers, rovers, ISRU demos on hold

Small (micro) satellites may fly orbital missions (what will they do?)

What are the missing pieces of lunar return architecture?



# Possible robotic missions

Orbiters to map surface, emplace assets (e.g., communications-navigation network)

Landers and rovers to characterize surface, prospect for resources

Landers/rovers to emplace surface assets (dirt-moving equipment, habitat emplacement, infrastructure creation)



# Robotic Landers

## In situ analyses and sample returns

We've already explored (both robotic and human) and returned samples from six near-equatorial sites (both mare and terra)

Some sites of unusual properties and great practical potential could be characterized by robotic landers (e.g., mature, regional pyroclastics)

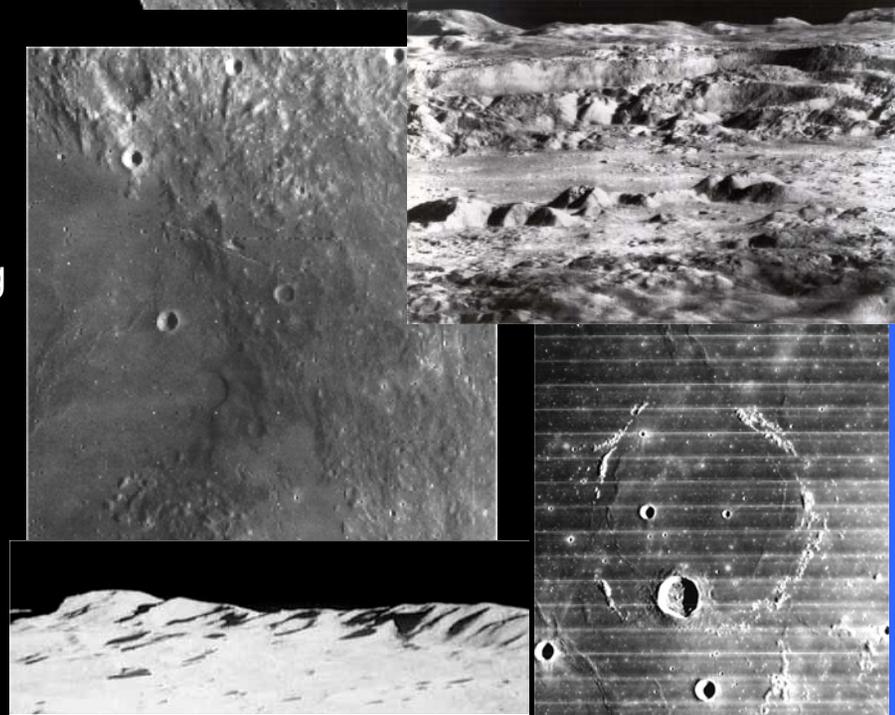
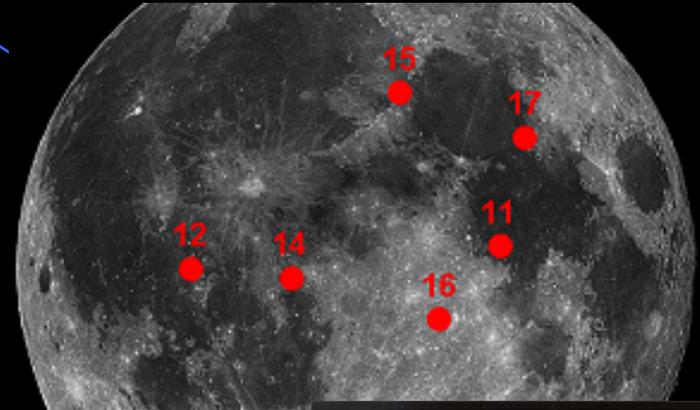
**Scientific targets of great desirability (in situ analyses and sample returns):**

Far side compositional provinces (ancient feldspathic crust, floor of SPA basin, maria)

Youngest mare basalts (Flamsteed ring mare)

Floors of a variety of impact craters for radiometric dating (Copernicus)

Unusual features (Reiner  $\gamma$ , Ina, Airy, young highland ridges)

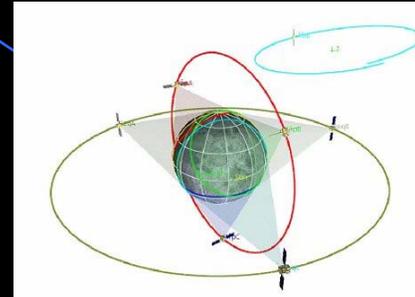




# Other Possible Robotic Missions

## Com-Nav system

Constellation of small lunar satellites to provide communications relay from limbs and far side and navigational guidance on the lunar surface and in cislunar space



## ISRU demo

Experiment with extraction and processing techniques; produce demonstration amounts of materials (e.g., water)



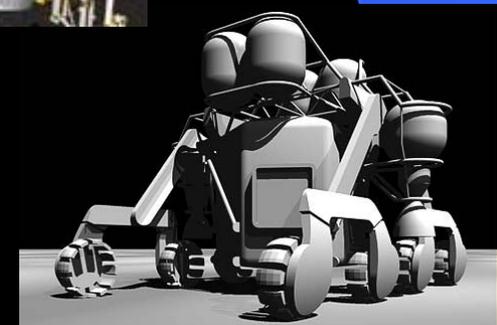
## Teleoperated Explorer

Reconnoiter landing site, map and catalog units, physical properties, identify interesting sites



## Construction rover and outpost pre-deployment

Prepare site for habitats, earth-moving, berm construction, road paving, emplace solar arrays



# Human surface activities

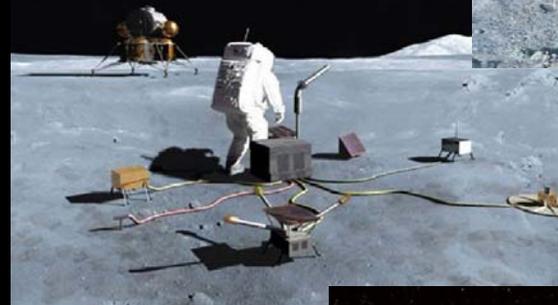
Scientific exploration

Equipment deployment  
and installation

Resource prospecting  
and mapping

Habitat and outpost site  
construction

Outpost maintenance



# Robots interacting with humans

## Autonomous robots

Construction robots, pavers, diggers

## Robotic assistants

Field assistant, habitat assembly

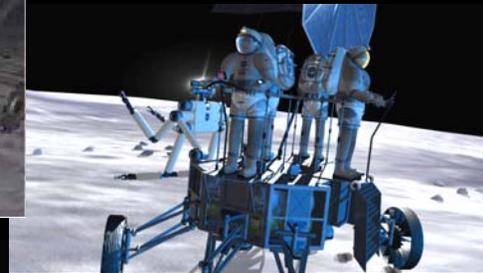
## Human-controlled robots

Remote-controlled from Earth or locally

## Telepresence robots

Used by crews on Moon and scientists on Earth; pre-reconnaissance of geological targets

Use to conduct real field work?  
Will TP robots replace human geologists?



# Telepresence Issues

## What's really required?

- Stereo HD vision
- Tactile feedback
- Mobility
- Dexterity

## Anthropomorphism

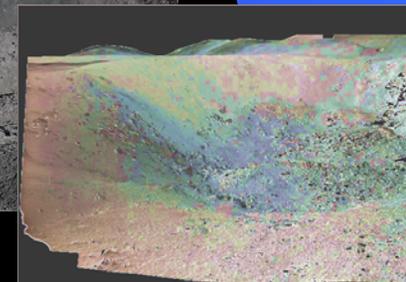
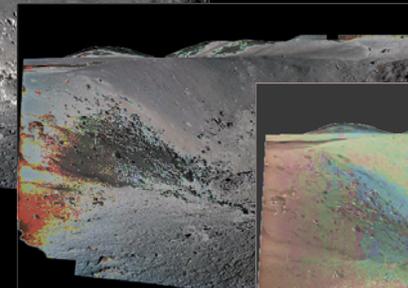
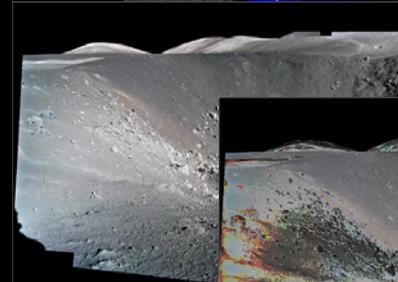
- How significant is the “presence” effect?
- Multiple limbs, eyes, end-effectors
- Single- or multi-operator control?

## Augmented sensory capability

- Multi-spectral vision
- In situ analysis: what and how much?

## Control time lags

- Maximum permissible
- How does “presence” effect degrade with increasing time lag? Does it matter?



# A suggested paradigm

Have robots to do what they can do  
Use robots to conduct  
reconnaissance at exploratory  
sites

Let people do follow-up field study

Make equipment that deploys  
automatically (no ALSEP)

However, design systems to allow  
people to intervene when things  
get hung-up or broken

The actual mix of activities and  
development of an operational  
paradigm is in itself a research  
topic

