meteorite collection on the lunar surface

darick baker, luke erikson, william rance, erik spahr
angel abbud-madrid, michael heeley
 COLORADO SCHOOL OF MINES
 college of william and mary

photo credit: NASA image exchange
the story so far...

• 4 physics PhD students from Colorado School of Mines and the College of William and Mary

• competed in the 2007 lunar ventures business plan competition

• resolved: aggressive meteorite detection and collection on earth and the moon would produce scientific and financial rewards

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“the gift that keeps on giving”

- the words of Dr. Squyres regarding samples taken from outside the earth’s atmosphere
- many current missions directly measure the composition of foreign bodies (Cassini-Huygens, Deep Impact, Hayabusa, Stardust)
- as our presence in space increases so will the relevance of these samples
retrieval missions are expensive

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<tr>
<th>mission</th>
<th>approximate cost</th>
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<tr>
<td>apollo</td>
<td>$135,000,000,000,000</td>
<td>382kg</td>
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samples must be important!

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how about delivery?

- ~10 million sizable meteorites have hit earth during the last 250 years
- only ~3000 have been found
- most of these have been found by farmers
- meteorites have already been found to originate from mars
- many more impacts occur on the moon
meteorites are samples

- huge scientific interest (almost 14,000 published scientific articles)
- huge collector interest (a number of meteorite markets already exist)
- this is the only way to receive some samples
- the lunar surface is a treasure trove and may be the best place for meteorite collection in the entire solar system
scientific interest

Dr. Squyres (principal scientist on Mars rover missions) discussing the importance of retrieving off-world samples.

Dr. Russell holds a tiny fragment of a Martian meteorite.

This recently found meteorite suggests new meteorite types await discovery.

Opportunity finds an iron meteorite on the Martian surface.

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lunar projections

- NASA payed $~350,000/gram for Apollo’s samples -- and no meteorites were found!
- efficient collection of samples from the moon will reduce more costly retrieval missions elsewhere
- space agencies will want to exploit the meteorite resources of the moon because it is cost/time/effort efficient
A scientist's gloved hand holds one of the numerous rock samples brought back to Earth from the Apollo 12 lunar landing mission. This sample is a highly shattered basaltic rock with a thin black-glass coating on five of its six sides. Glass fills fractures and cements the rock together. The rock appears to have been shattered and thrown out by a meteorite impact explosion and coated with molten rock material before the rock fell to the surface.
state of the art?

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state of the art?

recovery on the moon calls for a better approach

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more retrieval with better technology

- seismic, ultrasound, satellite, visual, magnetic sensors are well established technologies
- plus all have detected meteorite impacts
- the cost of these technologies have decreased dramatically in the last 20 years (USGS seismic waveforms are free!)
- many tools and techniques developed on earth would work even better on the moon

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enhance detectors and algorithms

candidate signal detected

sell and lease meteorite samples

locate meteorite

deploy SID and custom sensors

gauge software performance

gauge hardware performance

characterize meteorite find

reduce search area (~200m²)

impact data calibration

establish initial search area

exclude human activity

prepare for next deployment

protect new technologies

field work

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impact waveform

21/12/88
19:03:30 GMT

ECK z 0.71 μm/s

1 Second

P S Surface

seismic wave types

photo credit: Matthews 1990

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earthquake waveform

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photo credit: USGS
Apollo 11 Lunar Module Pilot Edwin E. Aldrin Jr. deploys the Passive Seismic Experiment Package on the Moon's surface near Tranquility Base.
A seismic reading taken from instruments at the Manned Spacecraft Center (MSC) recording impact of the Apollo 13 S-IVB/Instrument Unit with lunar surface. The expended Saturn third stage and instrument unit impacted the lunar surface at 7:09 p.m., April 14, 1970. The location of the impact was 2.4 degrees south latitude and 27.9 degrees west longitude, about 76 nautical miles west-northwest of the Apollo 12 Lunar Surface Experiment package deployment site. The S-IVB/IU impact was picked up by the Passive Seismic Experiment, a component of the package and transmitted to instruments at the Mission Control Center.
summary

• meteorite recovery helps to accomplish one of the key goals of space exploration – knowledge of material composition of the solar system and universe as a whole

• innovative uses of proven technology can make this process cost/time effective

• this approach is suitable for initial deployment on earth with a natural progression to moon
Earth crescent over lunar horizon

taken by Apollo 15: NASA image exchange
reinforcements
improved retrieval

• combination of passive (impact) and active (Simulated Impact Device) seismic techniques
• perform high-resolution geologic survey
• reduced search area and impact uncertainty
• characterization by type, mass, velocity prior to retrieval
• successful retrievals can enhance technology
apollo sample processing

- Subdivide, repackage in ultra high vacuum, ship to principal investigators
- Opening and preliminary examination
- Opening and preliminary examination
- Various biological tests, search for lunar pathogens
- Aseptically collected samples
- Apollo sample processing
- Storage for permanent retention and 2nd generation experiments
- Gas analysis
- Gas analysis samples (2)
- General samples (in sealed bags) (~200)
- Low level radiation counting
- Biological tests
- Ultra high vacuum samples (2) (~10^-11 Torr)
- Temporary storage (~10^-6 Torr)
- Biological tests
- Geochemical and mineralogical tests
- 2 boxes, ~50 pounds of samples

Photo credit: NASA image exchange

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lunar projections

samples returned (kg)

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close-up of astronaut’s foot and footprint during Apollo 11 EVA on lunar surface
Earth on the horizon, taken from the command module of Apollo 11 moments before separation for the first lunar landing.