THE ROBOTIC ARCHITECTURE OF MOON EXPRESS

EXPLORATION, RESOURCES AND DELIVERY

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Outline

New Moon Express spacecraft design – MX-1

Modular design permits several different configurations for different missions

Initial Moon Express missions emphasize science, resources

A robotic architecture for lunar return using the MX-1 building block

Synergy with other lunar missions and surface elements

MX-1 Scout Class Explorer

High performance, smart and robust for demanding or long duration expeditions

High performance. Smart. Lowest cost planetary spacecraft ever.

~5.8km/s ΔV
250kg fully fueled
30kg payload capability
200W power
RS485/422
28v, 12v, 5v, 3.3v

A breakthrough in low cost space exploration the single stage MX-1 can deliver up to 30kg to the lunar surface.

Designed for Scout Class exploration capabilities starting from low Earth orbit, MX-1 delivers flexibility and performance to revolutionize access to the Moon and cislunar space.

MX-1 is environmentally green, using eco-friendly fuels, advanced carbon composites and silicates, powered by the Moon Express PECO rocket engine, for an unparalleled capability in space robotics.

Available in orbiter, lander and deep space probe configurations.

MX-2 Scout Class Explorer

Extended reach. Dual stage flexibility. Deep space ready.

Staged for unparalleled lunar and deep space access.

~7.4km/s ΔV
500kg fully fueled
30kg payload capability
200W power
RS485/422
28v, 12v, 5v, 3.3v

The MX-2 doubles the capability of the MX-1 in cislunar space and brings the inner solar system within reach.

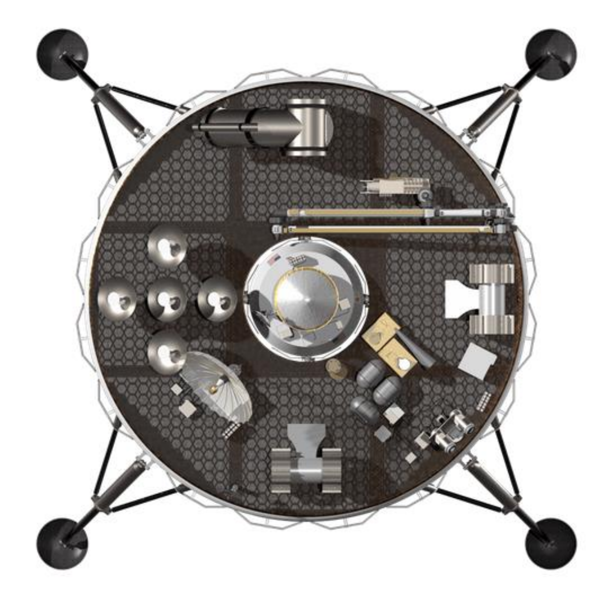
A spectacularly capable dual stage robotic explorer with enough punch to reach Venus or the moons of Mars from low Earth orbit.

Dual stage flexibility drives more payload to the lunar surface or extends reach to deep space. Compatible with existing and emergent launch vehicles, the MX-2 delivers exhilarating Scout Class possibilities for exploration and commerce at low cost.

Available in orbiter, lander, deep space and dual-probe configurations.

MX-5 Discovery Class Explorer

A workhorse for robotic lunar and deep space exploration



Cis-lunar workhorse. Multi-purpose platform lander.
Solar system adrenaline.

~6.9 - 9.8km/s ΔV
1,300kg fully fueled
150kg payload capability
200W power
RS485/422
28v, 12v, 5v, 3.3v

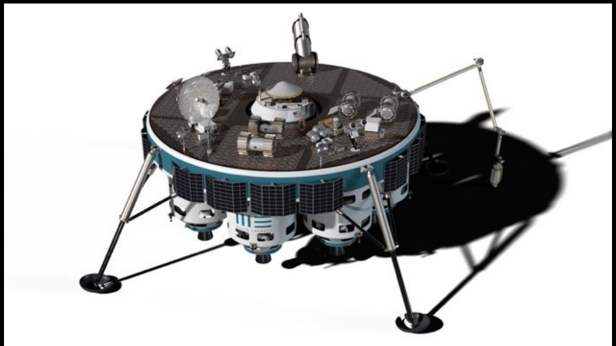
Designed as a workhorse that can deliver 150kg to low lunar orbit from low Earth orbit, with a range of configurations to support lunar landing and cis-lunar operations, the MX-5 can also be outfitted with MX-1 or MX-2 staged systems that can bring the entire solar system within reach.

With 5 PECO engines delivering solar system level ΔV, the MX-5 is a categorical improvement on conventional approaches to spacecraft, with embedded cost reduction through common systems and efficient adaptability to a multitude of jobs at a transformer level.

Available in orbiter, lander and deep space probe and sample return configurations.

MX-9 Frontier Class Explorer

Solar System Conquering ΔV with Robust Sample Return Capacity



Lunar Prospector. Harvester. Solar System Class Performance

~6.5 - 10.9km/s ΔV
2,350kg fully fueled
500kg payload capability
200W power
RS485/422
28v, 12v, 5v, 3.3v

Designed for Frontier Class exploration capabilities, MX-9 will support robust lunar sample return operations. Like it's MX-5 little brother, the MX-9 can also be outfitted with MX-1 or MX-2 staged systems that can deliver over 10kms ΔV and extend its reach to span the solar system, and beyond.

With 9 PECO engines churning out solar system conquering ΔV, the MX-9 can deliver up to 500kg to the lunar surface from GTO. Available in orbiter, lander, deep space probe and sample return configurations.

Available in orbiter, lander and deep space probe and sample return configurations.

Initial Missions

MX-1 Orbiter

Full systems validation in cislunar space, low lunar orbit

Possible orbital measurements: 3 μm water band, bistatic radar, neutron mapping of H_2 at high resolution

MX-1 Lander – Rima Bode pyroclastics

Hydrogen resources of a regional, high-Ti pyroclastic deposit

Bulk H_2 of regolith, major elements, maturity

Multiple data points from ballistic hops

MX-1 Lander - South polar fixed station

ILOA optical telescope to image galactic center

Bulk H_2 of polar regolith

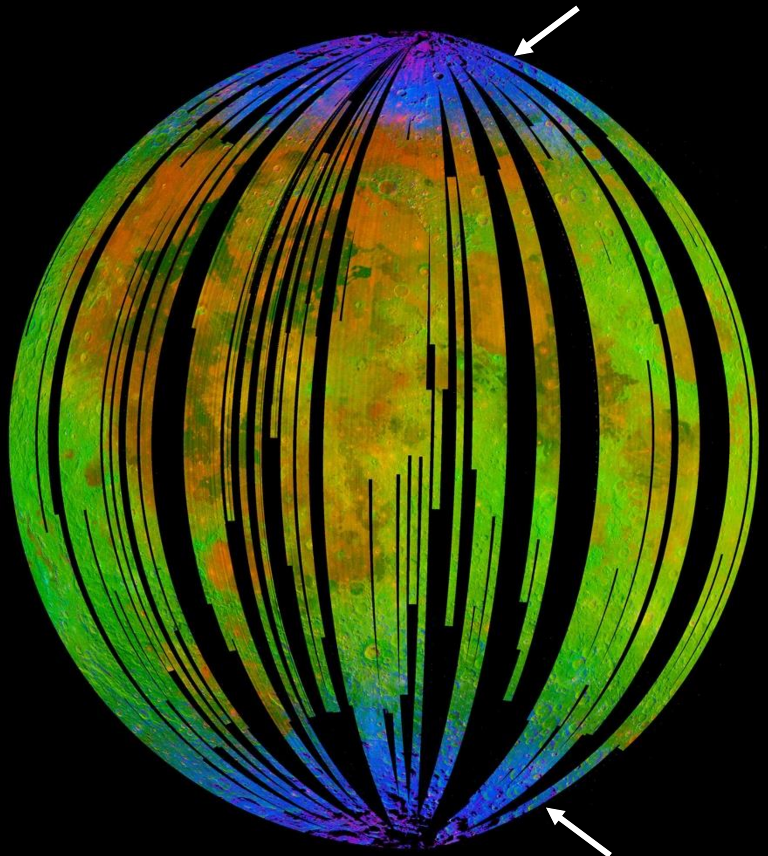
Electrical and physical properties of polar regolith

Laser reflector

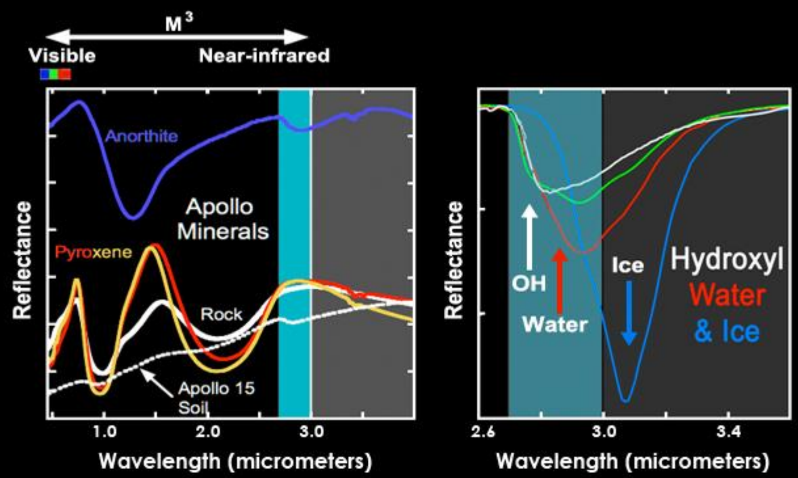
Water on the Moon

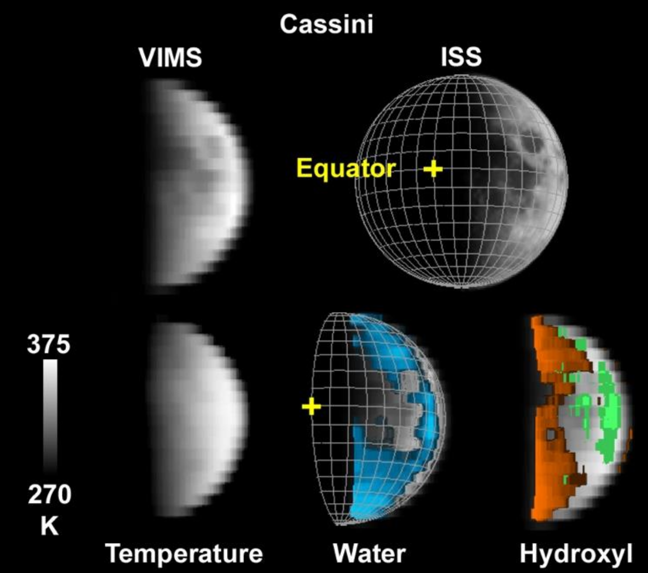
New Evidence from Remote Sensing

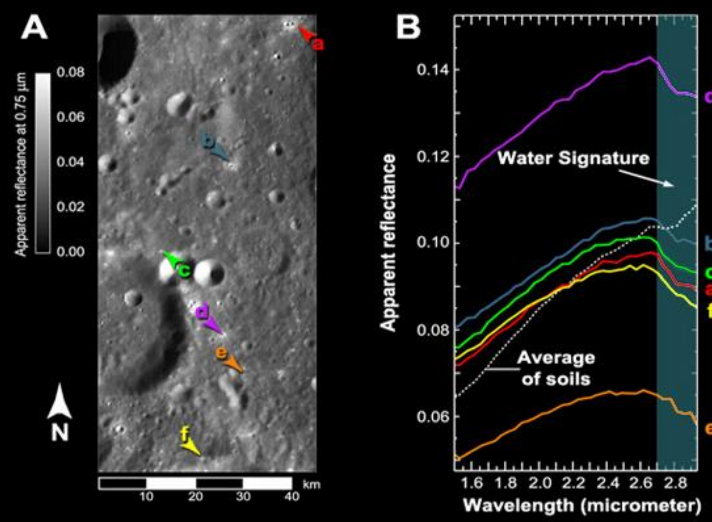
- Spectral evidence from M^3 for widespread hydration (2.8 μm absorption band)
- Seems correlated with latitude (most evident at latitudes > 65°)
- Created how?
  - Solar wind reduction of oxides in rock and soil
  - Water residue from comet impacts
  - Outgassed water vapor from lunar interior
- A possible source reservoir for polar ice
  - Migration to polar cold traps by ballistic hopping

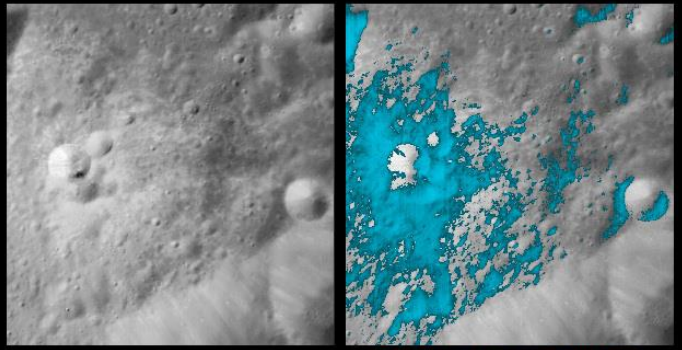


Finding water with spectra









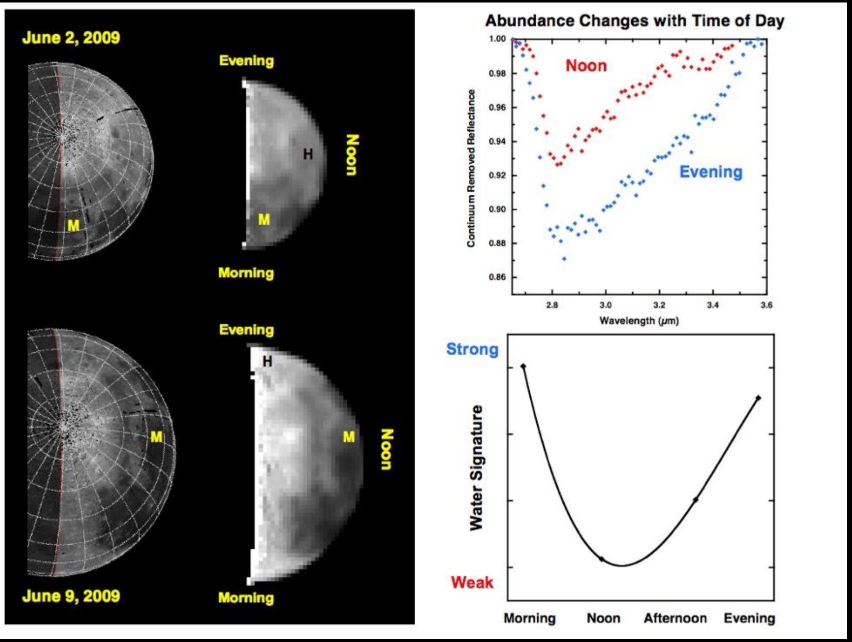
Infrared Reflectance

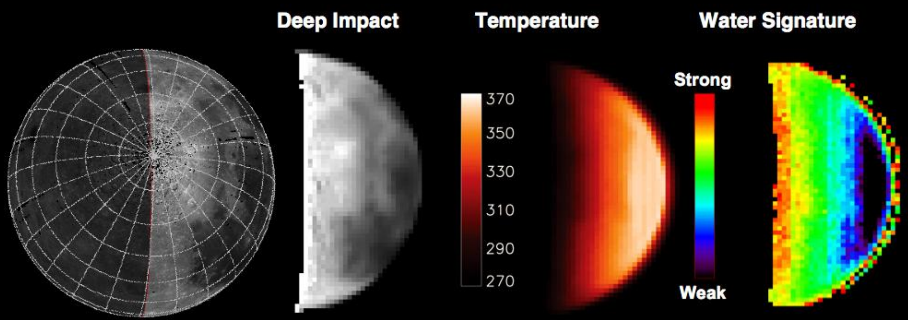
Blue = water absorption strength on Infrared Reflectance

Chandrayaan-1 Moon Mineralogy Mapper

Water abundance varies

with space, time and temperature





MX-1 Class Orbiter

Initial mission to test system performance and durability

- MX-1 configured as an orbiter and injected into low lunar orbit
- Map global distribution of 2.8 μm absorption bands (OH and H_2O)
- Determine distribution and concentration of surface OH and water
- Monitor variations in concentration with time
- Determine geological controls on water distribution

Global maps of OH and H_2O, spatial and temporal distribution

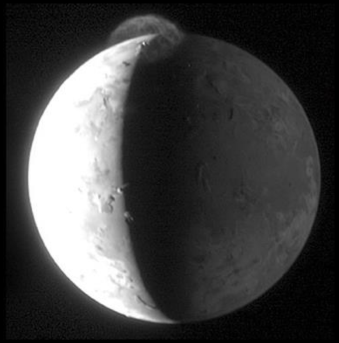
Value of Lunar Pyroclastics

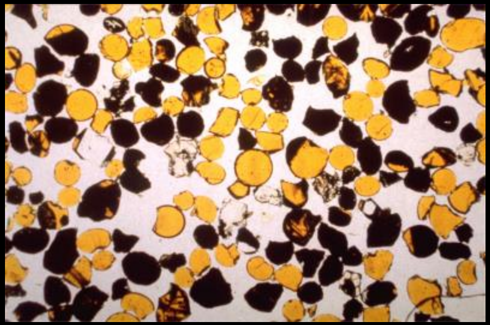
Scientific value

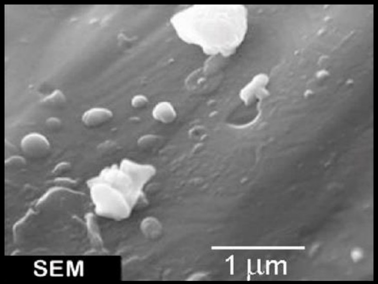
- Primitive, unmodified magmas from the deep mantle
- Source regions contain volatiles
- Eruption mechanisms, dynamics - source of deep-seated rock fragments?

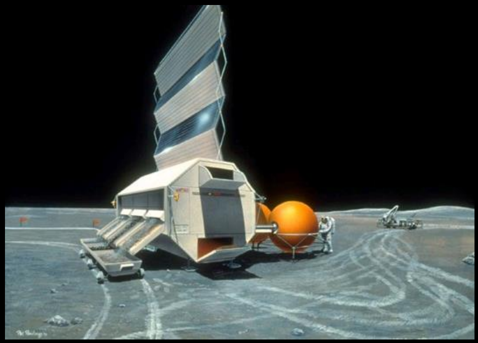
Resource value

- Uniform, fine-grained deposits - easy feedstock for resource processing
- Solar wind gas content may be enhanced in pyroclastics; if so, a potential “ore” deposit for H_2 recovery

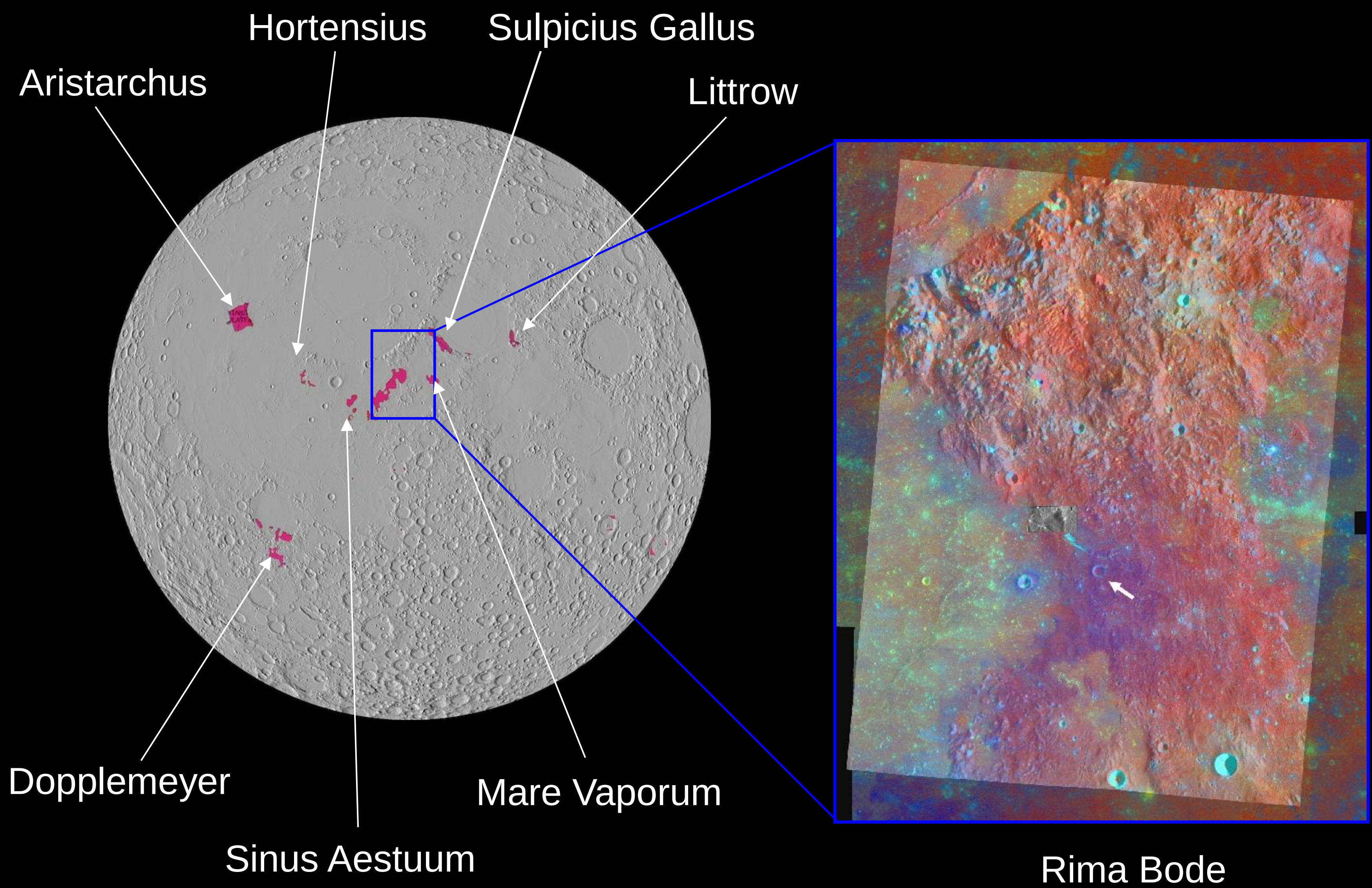








Distribution of Pyroclastics



Rima Bode Pyroclastic Deposits

Vast, regional dark mantling deposit (~7000 km^2)

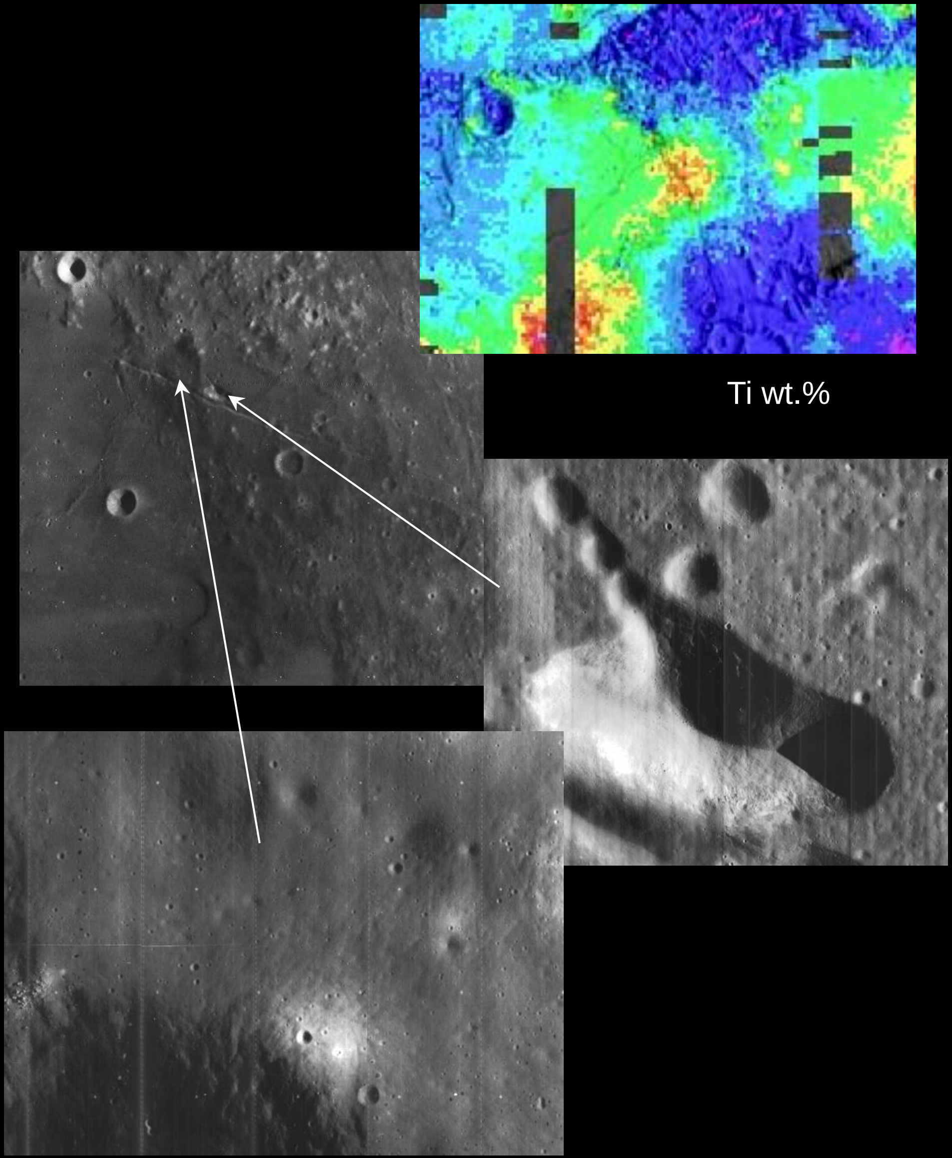
High-Ti content (black glass?)

Embayed by (older than) maria 3.5 billion years old

Complex vent and rille system associated with eruption

Near center of near side (12º N, 3º W); smoothed terrain of lunar ash beds

Xenoliths from deep in the Moon may be found near vent



MX-1 Lander

Mission to a Regional Pyroclastic Deposit

First lander could be outfitted with only two instruments

- APX - determine chemical composition of pyroclastic deposit
- NS - measure bulk H_2 in upper meter of regolith

Instruments mounted underneath spacecraft (close contact with lunar surface desired)

Measurements (2) complete within ~ 1 hour

Second point measurements (after hop) desired but not critical

First direct measurement of the composition of a mature high-Ti pyroclastic deposit

Possible Instruments

Instrument	Information	Mass (kg)	Power (W)	Volume (cm)	Comments/Heritage
APX	Major and minor elements	0.5	3	5 x 5 x 5	Low data rate, analysis time; MER
MS imager	Mineralogy	2	2	7 x 7 x 2	5 bands @ 410, 750, 900, 950, 1000 nm, high rate; Clementine, LROC
EGA	Solar wind gas content	4	8	10 x 10 x 8	Need soil sampler (surface only), low rate; Mars Phoenix lander
Neutron spectrometer	Total hydrogen	0.5	2	20 x 5 x 5	Passive; ~10 min. integration time, low rate; Lunar Prospector, Mars Odyssey
Imaging lidar	Topography	4	10	50 x 30 x 30	Navigate and topographic mapping, high data rate; terrestrial models
Magnets	Magnetic properties	< 0.5	--	5 x 5 x 2	Study magnetic properties of dust, resource and utilization properties; Viking, MER

MX-1 Lander

Mission to South Polar Region

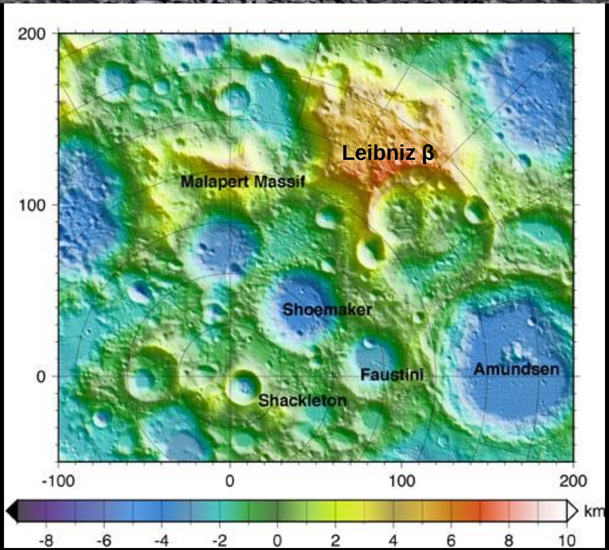
Landing site on either Malapert peak or Leibniz β

- Constant Earth view, sunlight > 80% of lunar day

ILOA steerable telescope to image and study galactic center from south polar region of Moon

Measure bulk hydrogen of polar regolith and other physical properties

Determine environment of landing site (electrical charging, thermal cycles, lighting)



Conclusions

The Moon Express MX series of spacecraft can be combined in a modular fashion to execute many different kinds of missions in cislunar space, lunar orbit and the lunar surface

We have developed an architecture that addresses key problems in lunar strategic knowledge gaps on the distribution and origin of lunar water and other volatiles

The mission sequence consists of orbital and landed elements, global surveys and site studies and offers the lunar science community an opportunity to address major lunar scientific questions

Later missions can be configured to conduct additional orbital surveys and measurements, deliver rovers and network packages, and return samples from a variety of landing sites