

## Future Low-Cost Lunar and Planetary Missions Enabled by Commercial Space Companies

**Alain Berinstain** and Robert D. Richards

Moon Express Inc., 100 Spaceport Way, Cape Canaveral, Florida 32920, alainberinstain@moonexpress.com

### Abstract

Science missions to the Moon need not be seen as rare and expensive opportunities. Affordable, repeated access to lunar orbit and/or the lunar surface is being made possible by innovations by commercial space companies.

Moon Express' vision is to open the lunar frontier with turn-key payload, data and services for missions to the Moon for a wide range of customers globally, including governments, NGO's, commercial enterprises, universities, and consumers.

Like the Earth, the Moon has been enriched with vast resources through billions of years of bombardment by asteroids and comets. Unlike the Earth, these resources are largely on or near the lunar surface, and therefore relatively accessible. Moon Express is blazing a trail to the Moon to seek and harvest these resources to support a new space renaissance, where economic trade between countries will eventually become trade between worlds. All Moon Express expeditions will prospect for materials on the Moon as candidates for economic development and in-situ resource utilization.

One of the greatest practical space discoveries of our generation is the presence of vast quantities of water on the Moon. Water not only supports life but its constituents, hydrogen and oxygen, are energetic and clean rocket fuel. The discovery of water on the Moon is a game changer, not just for the economic viability of lunar resources, but

for the economics of humans reaching Mars and other deep space destinations. Water is the oil of the solar system, and the Moon can become a gas station in the sky to fuel human space exploration, development and settlement of the solar system. Moon Express will begin prospecting for water resources on the Moon with its very first expedition.

### 1. The MX family of spacecraft

Moon Express has developed a family of flexible, scalable robotic explorers that can reach the Moon and other solar system destinations from Earth orbit. The MX spacecraft architecture supports multiple applications, including delivery of scientific and commercial payloads to the Moon at low cost using a rideshare model, or charter science or commercial expeditions to distant worlds.

The MX robotic explorer spacecraft are optimized for launch on existing and emergent rocket systems. The payload masses quoted below assume no launcher constraints.

MX-1: A single stage spacecraft capable of delivering up to 30kg to the lunar surface.

MX-2: A dual-stage spacecraft that doubles the capability of the MX-1 and can reach the moons of Mars.

MX-5: A cis-lunar workhorse spacecraft that can deliver up to 150kg to lunar orbit or 50kg to the surface.

MX-9: A lunar prospector/harvester that can deliver up to 500kg to the lunar surface, including an embedded MX-1R spacecraft that can launch from the lunar surface and return lunar samples to Earth.

The MX spacecraft architecture supports multiple applications, including delivery of scientific and commercial payloads to the Moon at low cost using a rideshare model, or charter science expeditions to distant worlds.

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



Figure 1: MX-1 Spacecraft

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



Figure 2: MX-2 Spacecraft

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



Figure 3: MX-5 Spacecraft

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



Figure 4: MX-9 Spacecraft

## 2. Currently-Planned Lunar Missions

Our first expedition will utilize our MX-1E robotic explorer to deliver a diverse manifest of scientific and commercial payloads to the lunar surface. Our customers for this mission include the International Lunar Observatory Association, the University of Maryland, The National Laboratories of Frascati, Celestis and Google.

Following our initial “Lunar Scout” expedition next year, we will offer payload accommodations on future voyages, planned at the rate of one per year. But we can also scale up and increase the frequency of our lunar flights to meet market demand and opportunity.

Our second expedition in 2020, “Lunar Outpost”, will enable the first commercial presence and exploration of the lunar South Pole. It may in fact be the first-ever soft-landing at a lunar pole. The primary goals of this mission are to set up the first lunar research outpost at a “peak of eternal light”, prospect for water and useful minerals, and accommodate a variety of research instruments for our expedition partners.

Our third expedition, “Harvest Moon”, will take place by 2021 and includes the first commercial sample return, beginning our business phase of lunar resource prospecting and harvesting. The

samples brought back will be the only privately obtained lunar materials on Earth, and will be used to benefit science as well as commercial purposes.

## 3. Collapsing the cost of lunar missions

The paradigm of what it takes to fly a lunar mission has begun to shift. Launch costs are rapidly decreasing with emerging commercial launch providers. Commercial operators can reduce the cost of orbiters and landers by re-using designs and by innovating in ways that national space agencies are not mandated to do.

Although the current architectures for Moon Express missions involve going from Low Earth Orbit directly to Lunar orbit, then Lunar surface, or to other destinations in the solar system, integrating the MX family spacecraft into an architecture that involves the Lunar Orbital Platform (LOP) presents new and exciting opportunities for science and for cis-lunar operations in general.

Mission concepts that assume that the LOP is available as a hub of operations in Lunar orbit can enable much larger landed masses on the lunar surface and/or continuous shuttle service for assets on the surface or for returned samples to LOP.

Moon Express has been able to collapse the cost of Lunar missions, and the incorporation of LOP into mission scenarios enable even lower mission costs with a workhorse for small payloads to and from the surface of the Moon, and from the Lunar Orbital Platform itself.