



Future Space

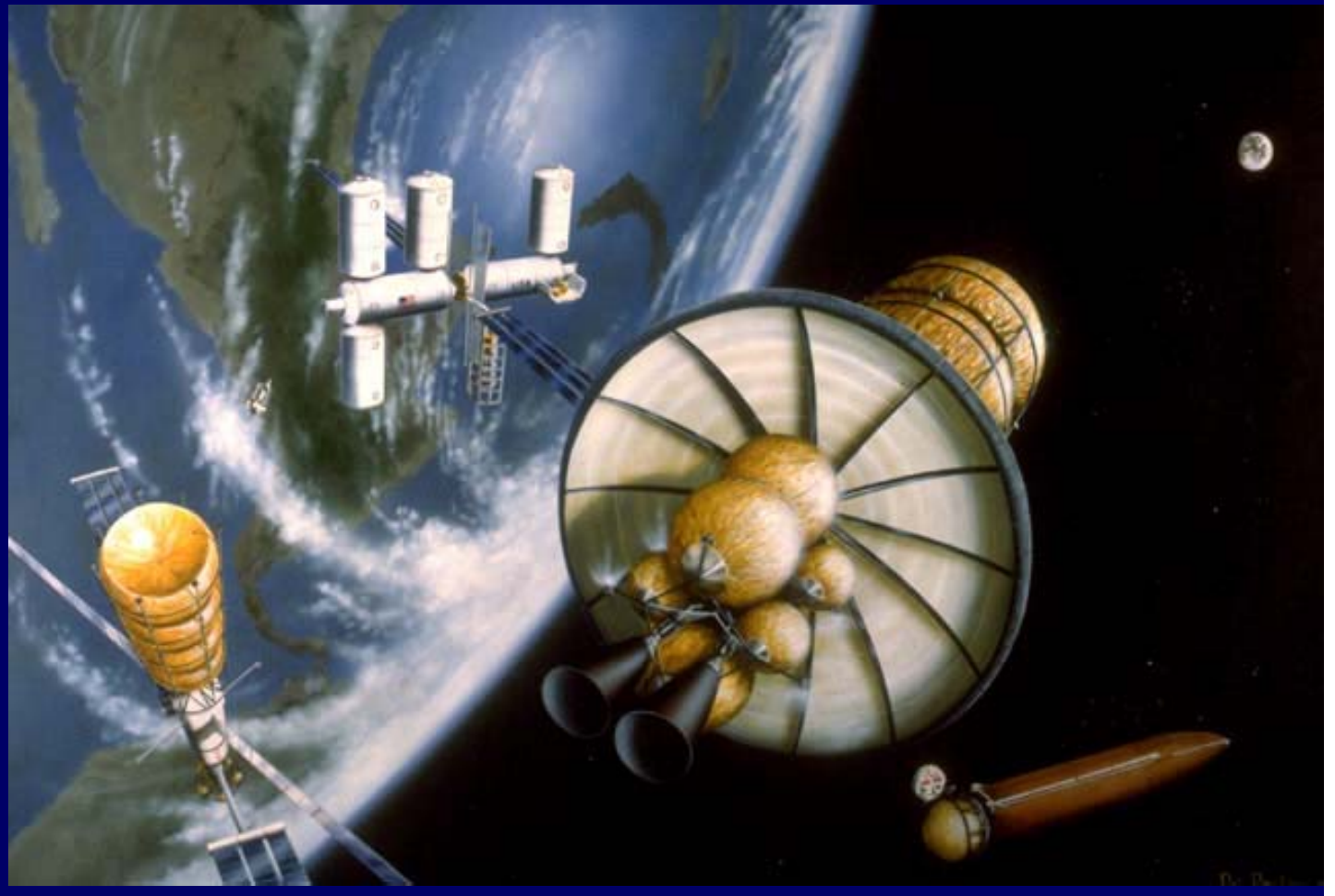
Where are we going?

Philip Stooke

What can we expect to see next in space?

Pat Rawlings

Apollo went to the Moon, then we built a space station, but where are we going now?



Will we go anywhere?

**Space is
expensive.**

**Can we afford
to do
anything?**

**Especially
today?**



Will we go anywhere?

**Space is
expensive.**

**Can we afford
to do
anything?**

**But in fact
space is
not so
expensive.**



Will we go anywhere?

**Space is
expensive.**

**Can we afford
to do
anything?**

**Less than
1% of the
US Federal
budget.**



Space in the economy

**We can't do
without space.**

Communication

Navigation (GPS)

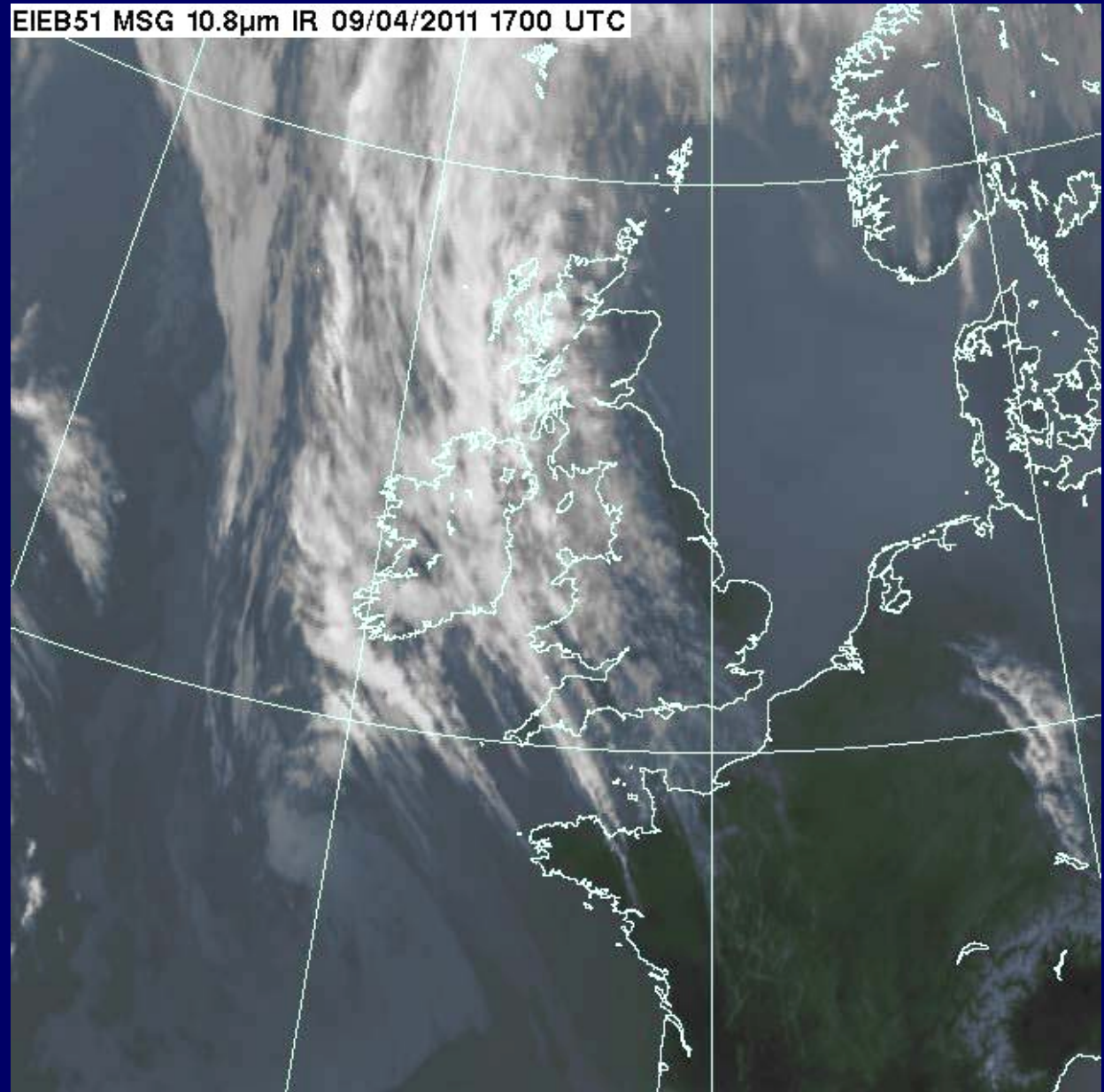
Weather forecasting

**Environmental
monitoring**

National Security

**... all depend on
satellites today.**

Weather satellite image



© Copyright EUMETSAT/Met Office

Space in the economy

**For satellites we
need rockets...**

**Up to 80 launches
happen every year
around the world.**

**We can afford to
use a few for space
exploration!**

**Space is not going
to go away.**

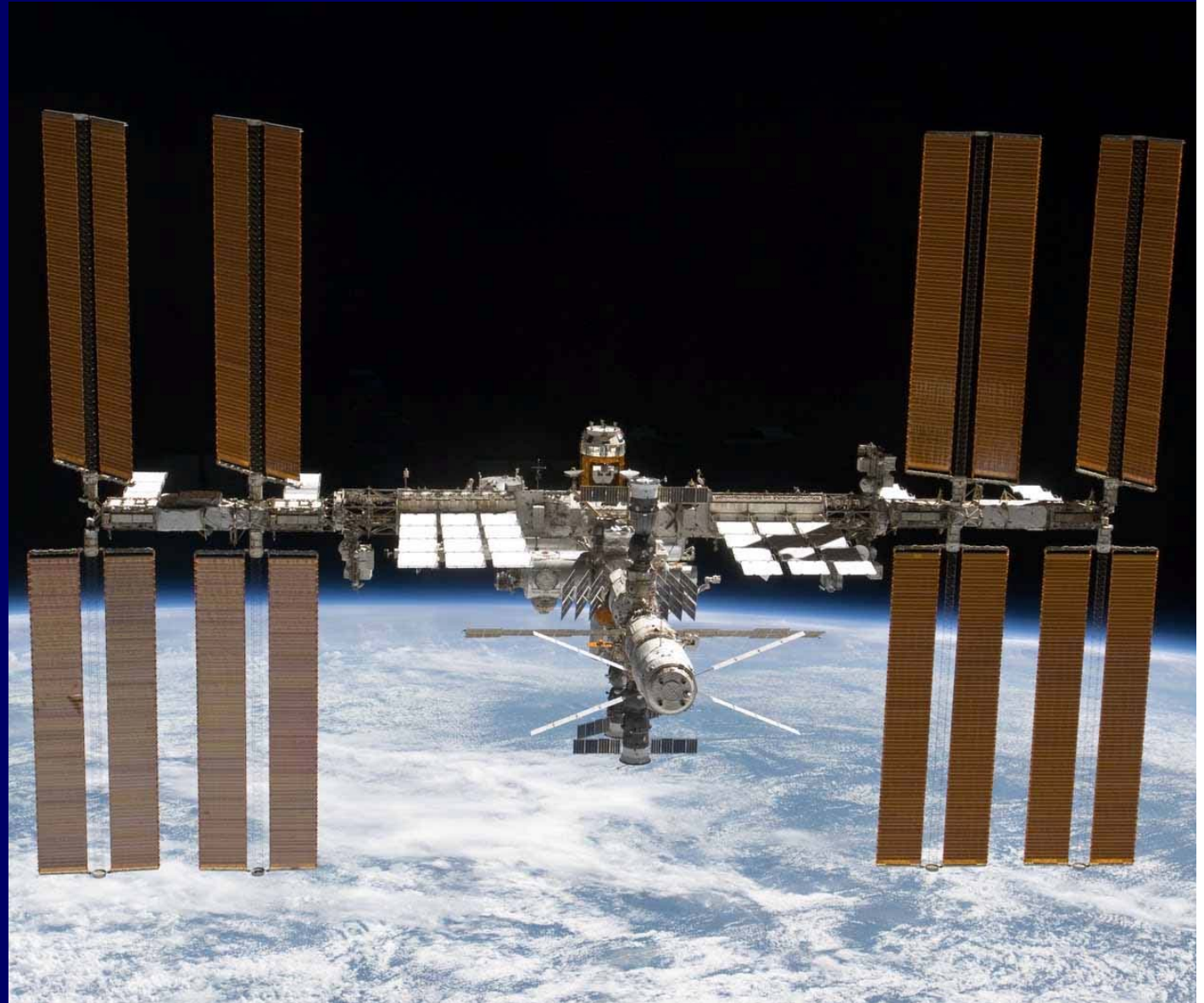


Current situation

**International
Space Station.**

**Operated and
supplied by
Russia, Europe,
Japan and USA
until 2020 or later.**

**A big research
laboratory.**



NASA

Current situation

Space Shuttle.

**Retired! Last flight
was in June 2011**

**What will replace
it? Several
options...**



NASA

Future US crew launch vehicles

Space launch System (SLS):

a big new NASA rocket, still being designed.

Falcon rockets:
developed privately
by Space-X.

Existing Atlas and
Delta rockets,
modified to carry
people?

SLS and Falcon 9



Future space activities?

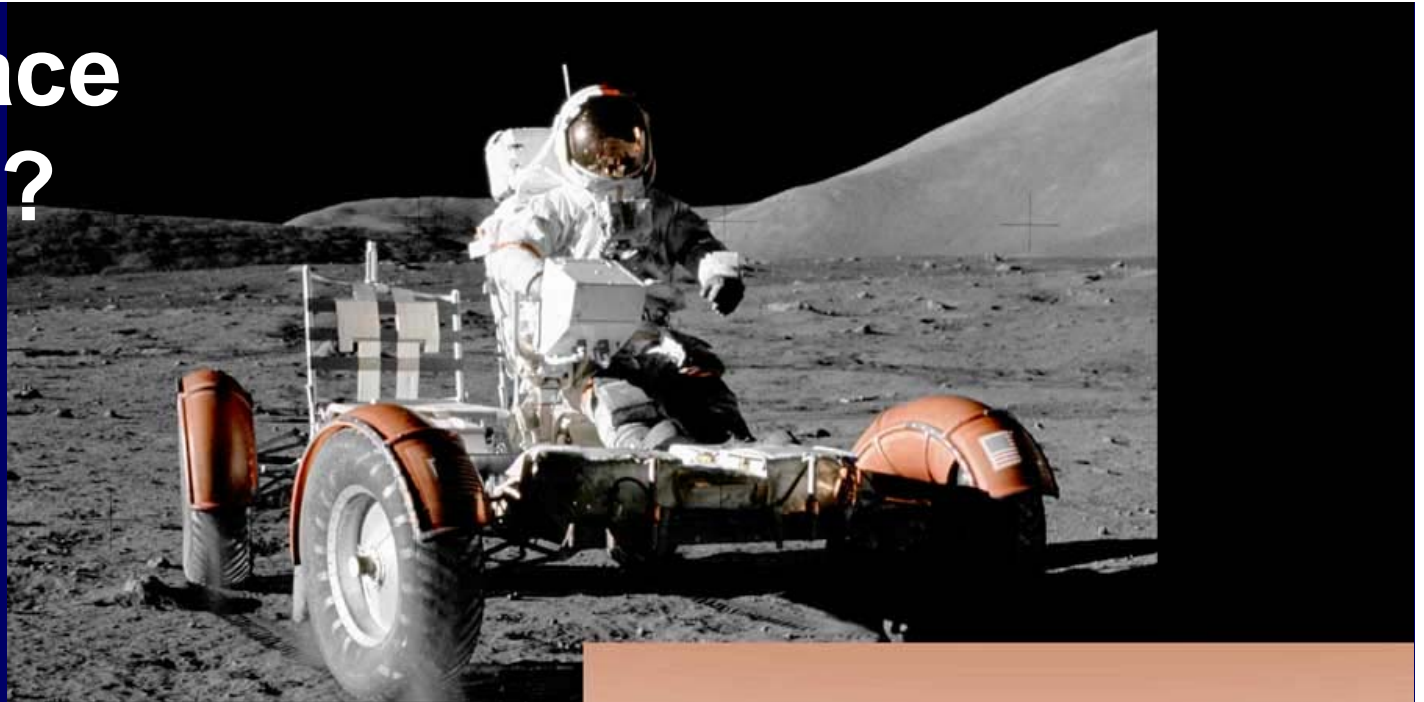
Which way will we go?

Business and space services

Human exploration

Robotic exploration

All of the above?

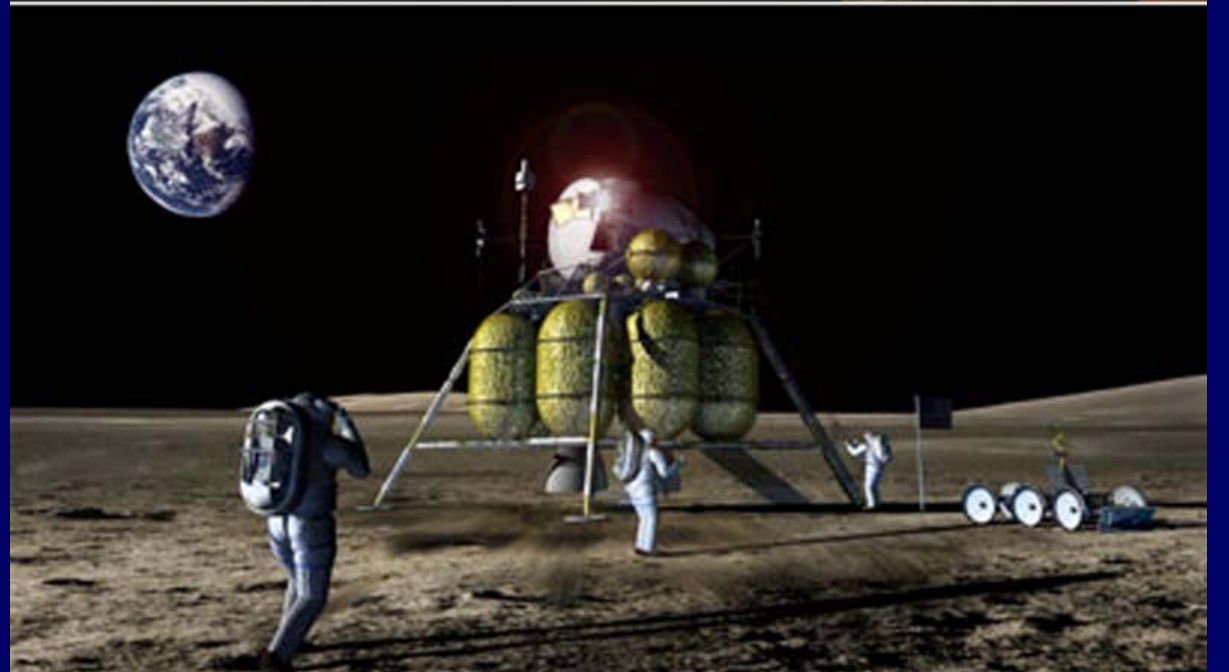


Future space activities

Return to the Moon?

President Bush's
'Vision for Space Exploration'

NASA's Project Constellation



Constellation lunar outpost

**South pole
of the Moon.**

**Near-
permanent
sunlight for
solar energy.**

**“Peaks of
eternal light”
(not quite
eternal)**

JAXA/NHK

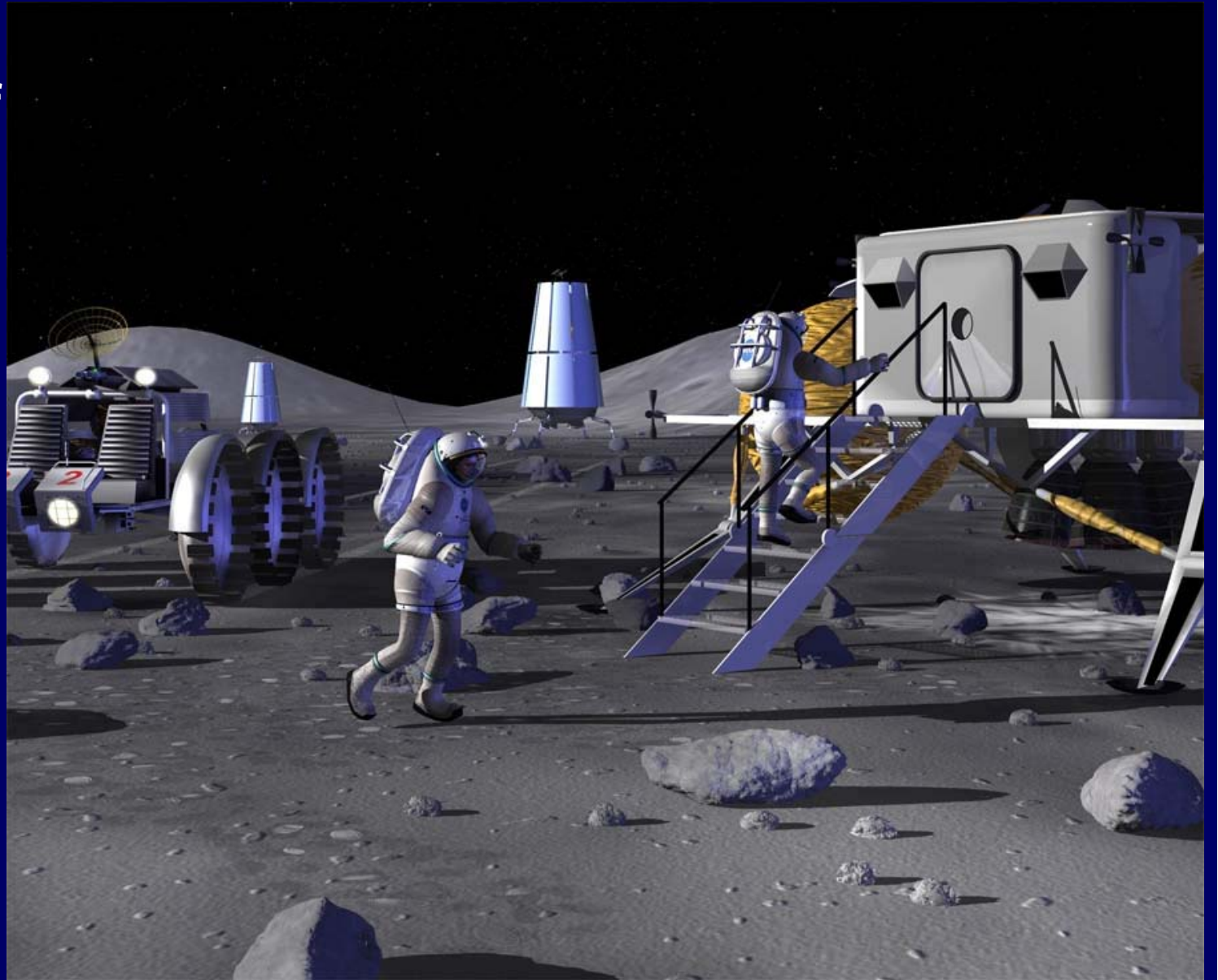


Constellation lunar outpost

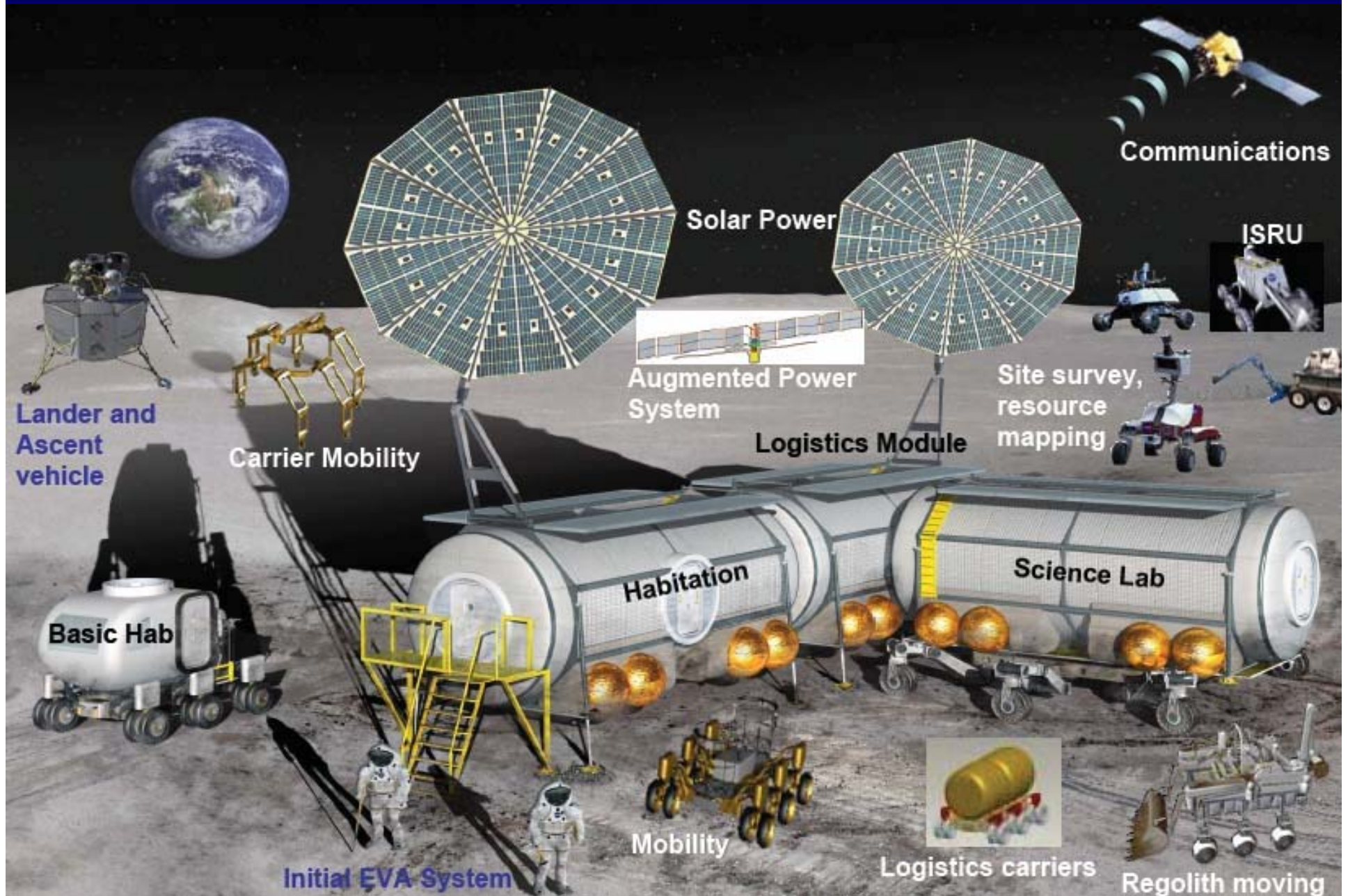
**South pole of
the Moon.**

**Water (as ice) in
permanent
polar shadows.**

**Resources for
astronauts and
for rocket fuel.**



Constellation lunar outpost

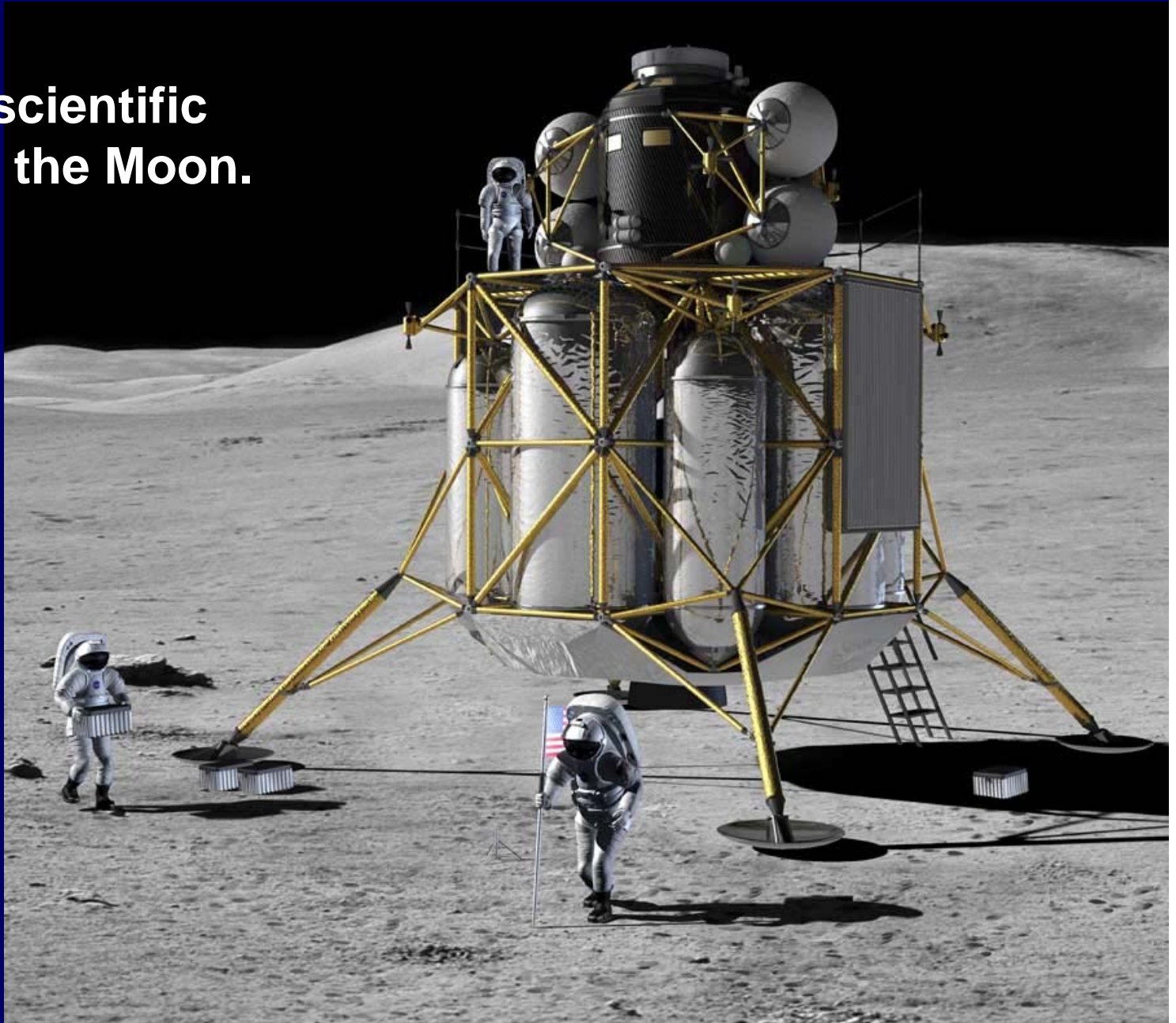


Constellation science sorties

Continue the scientific exploration of the Moon.

Youngest volcanic rocks, oldest impact basins, unusual features.

Apollo only scratched the surface.

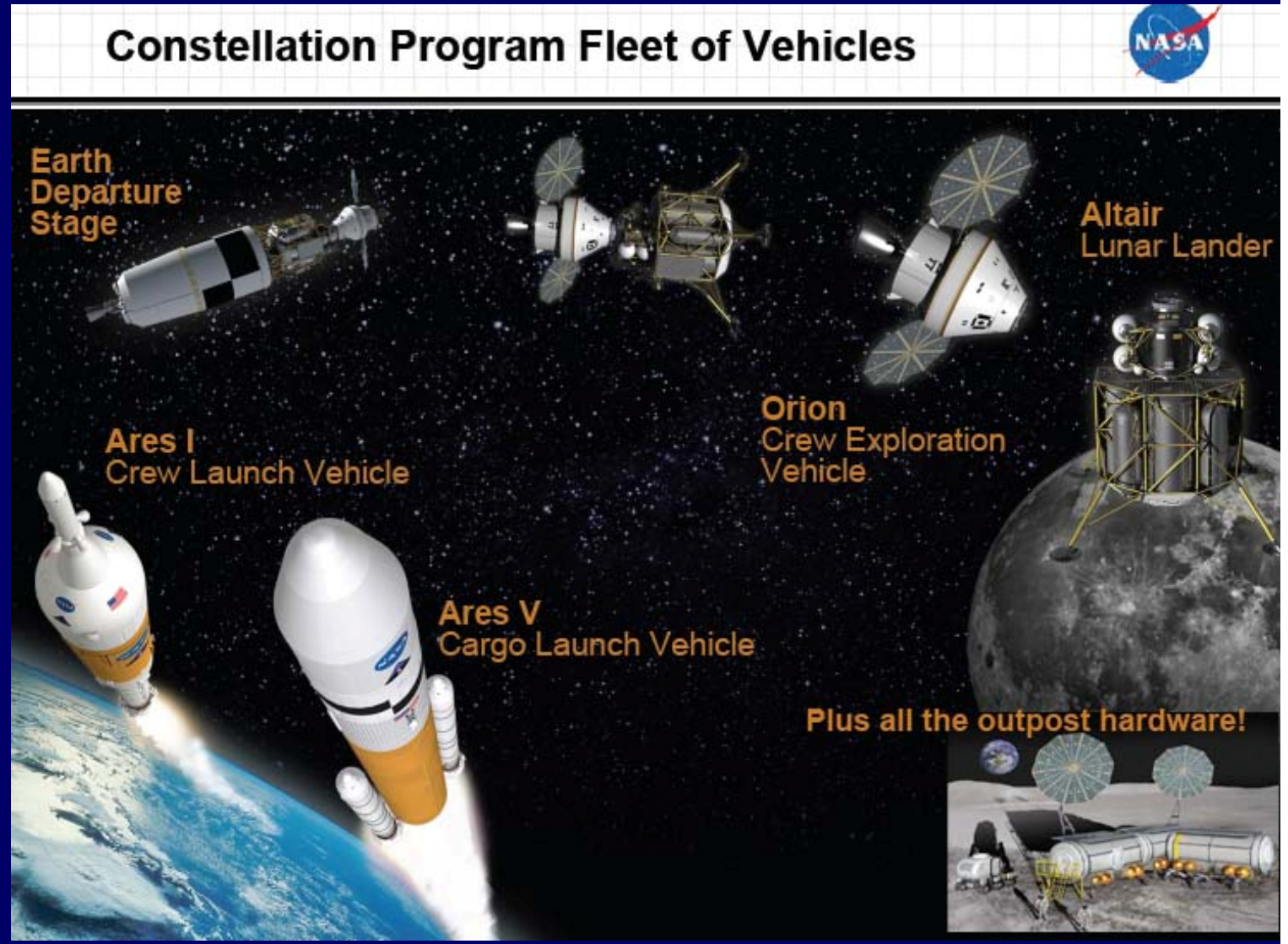


Constellation cancelled

Difficult economic times: lunar missions are too expensive.

Constellation needed rockets, a crew vehicle, a lunar lander and outpost hardware.

That's a lot of hardware!



Constellation cancelled

What if we only develop the rockets and crew vehicle?

Can we do anything with them?

Asteroids and the moons of Mars!

Stepping Stones

Exploring a series of increasingly challenging destinations on the way to Mars...



Lockheed Martin

Asteroid missions

Some small asteroids come close to Earth.

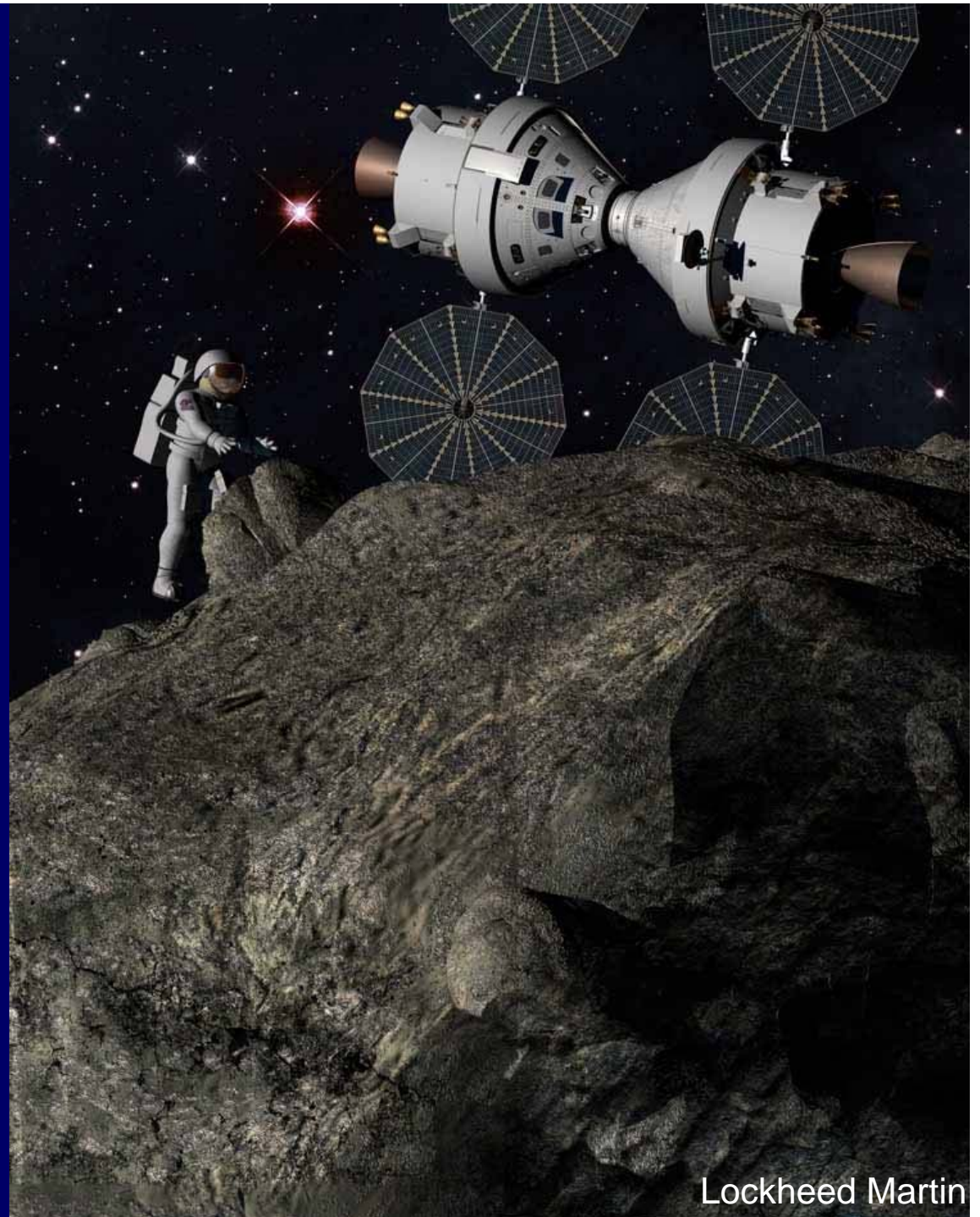
So small that no
lander is needed.

A round trip might
take several months.



Asteroid missions

Imagine just floating over to the asteroid to collect rock samples...

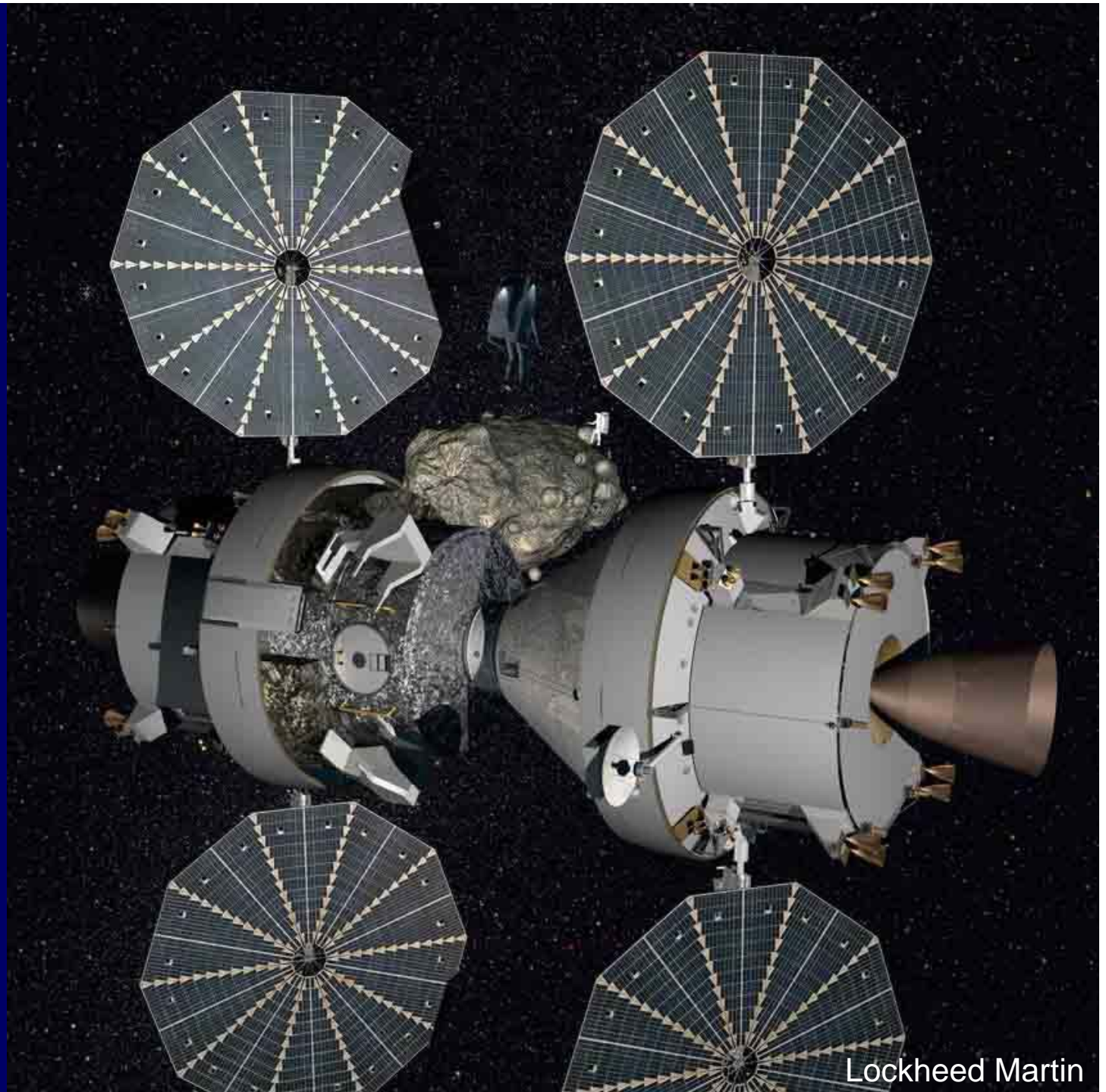


Dual Orions

Extra cargo
space for
months-long
trips.

Some backup
capability.

Eventually you
could go as
far as Mars...

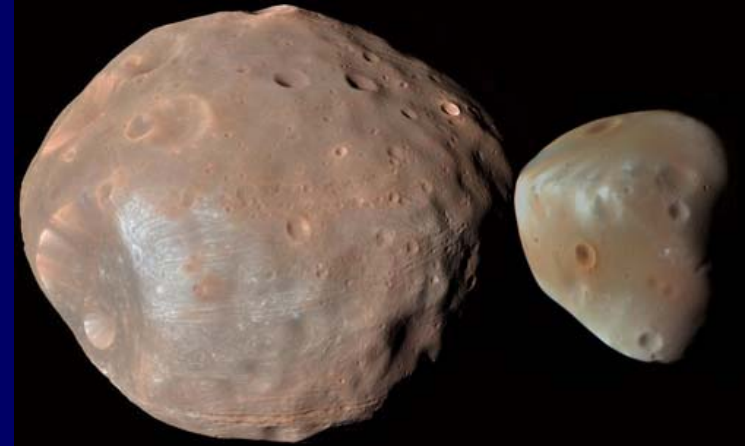


Lockheed Martin

Mars missions

So we get to Mars, but we didn't build a lander...

No problem! Mars has two little moons, like asteroids about 15 and 25 km across.



Phobos

Deimos



Pat Rawlings

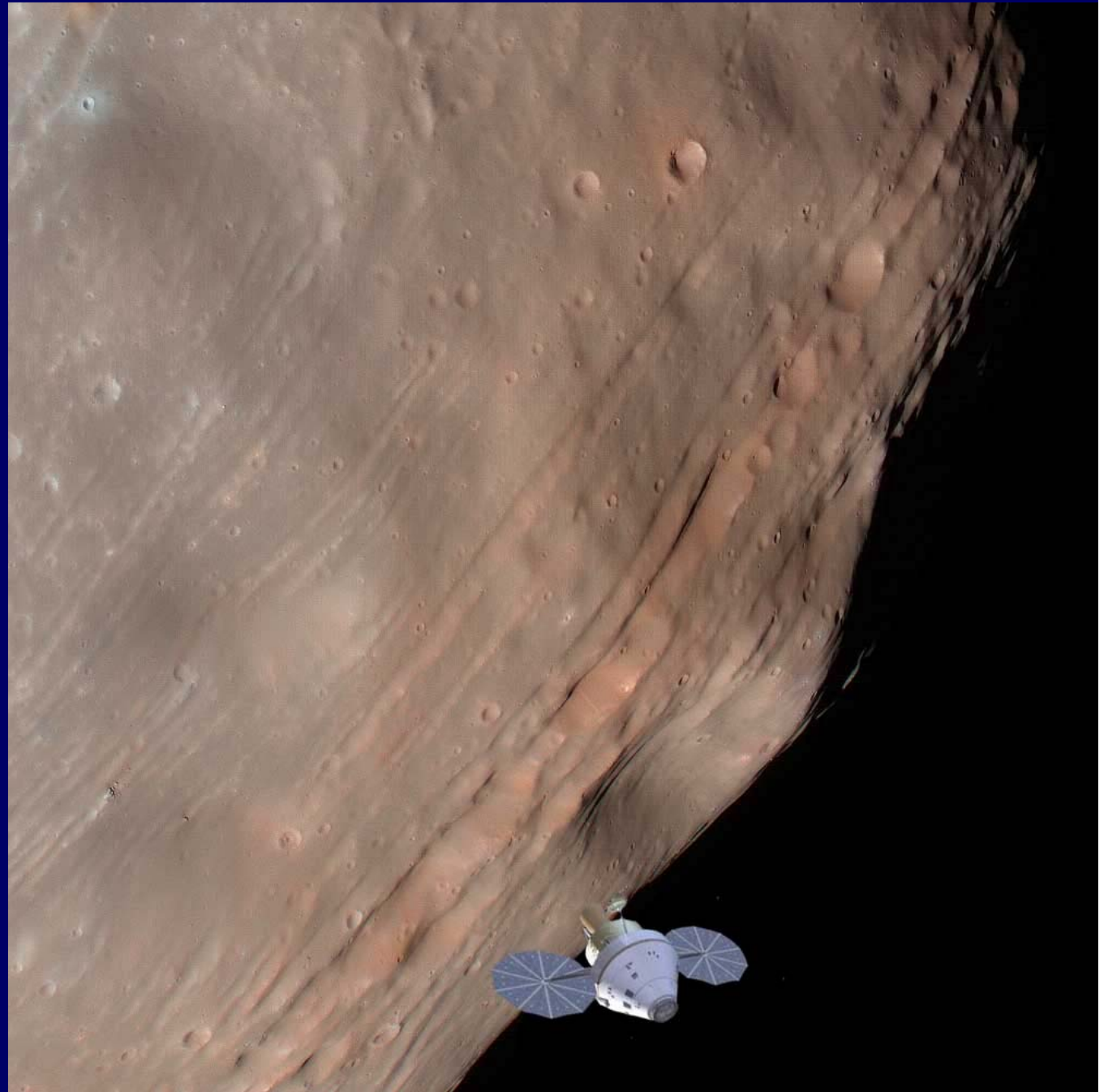
Phobos and Deimos

Cache supplies before crews arrive.

Remote operation of robots on Mars to collect rocks.

Rocks from Mars on these moons?

Meteorites from Mars are found on Earth. They passed the moons on the way here.

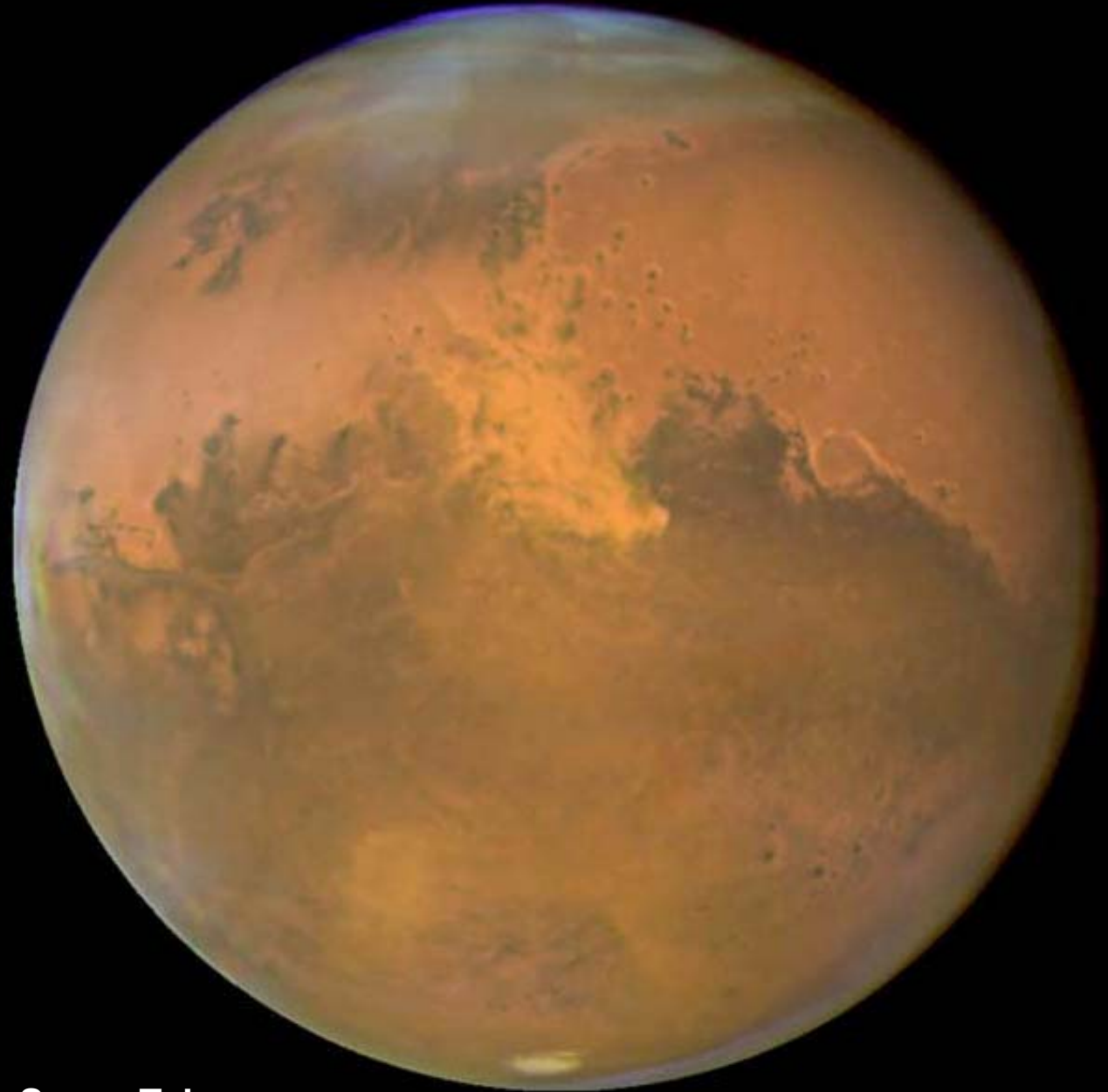


Mars

Mars is a more difficult goal.

When budgets allow it, a big lander could be built.

NASA has studied human missions to Mars.



NASA – Hubble Space Telescope

HEM-SAG

**The Human
Exploration of
Mars - Science
Analysis Group**

**Their report is
online: search for
“MEPAG HEM-
SAG 2008”.**



HEM-SAG

Long or short?

Because of the way the planets move, visits to Mars have to be short (a few weeks) or very long (500 days)

(not including the travel time).

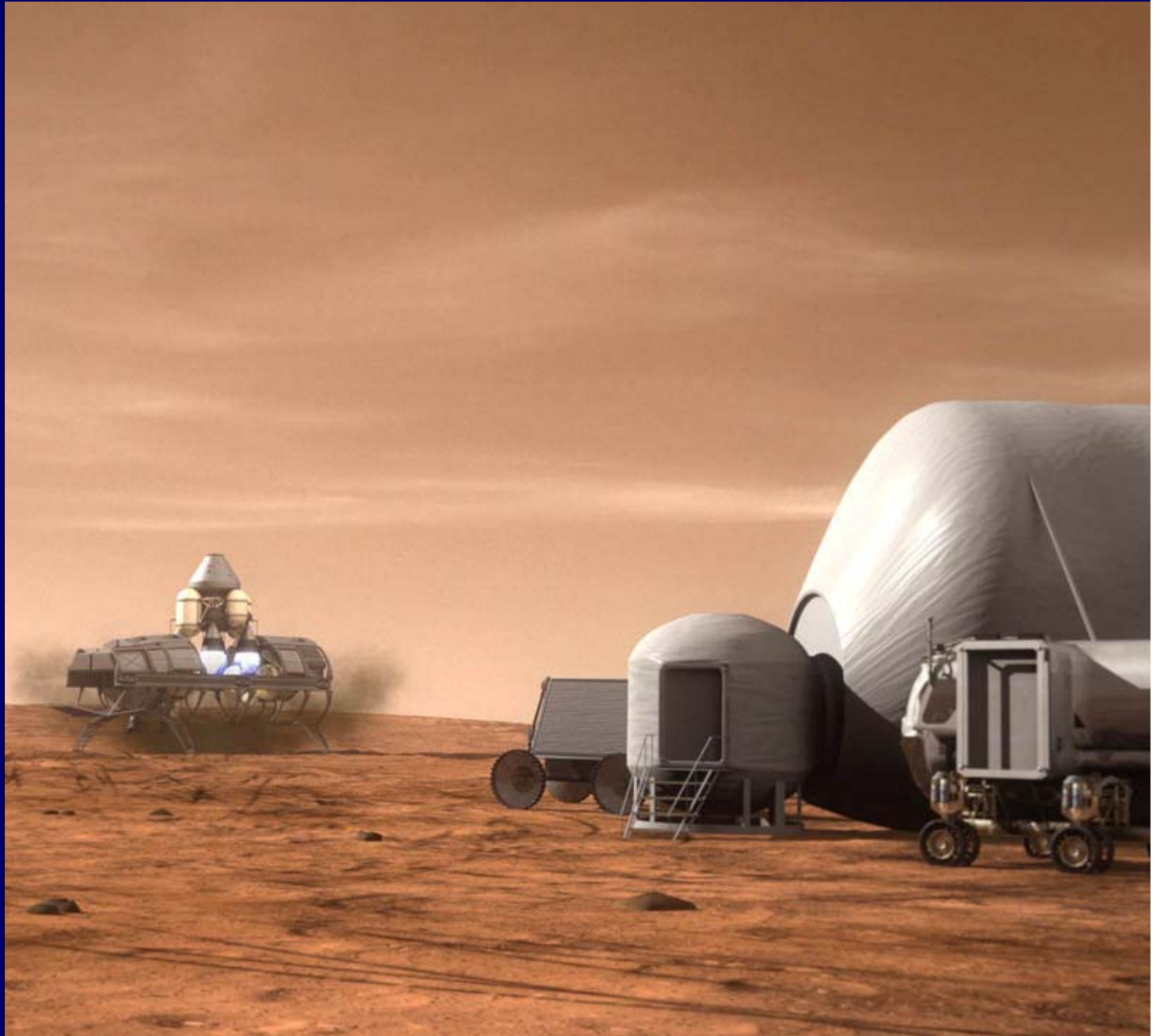


HEM-SAG

**HEM-SAG
decided short
trips were not
worth the
cost.**

**A Mars voyage
would take three
years:**

**8 months to get
there, 18
months there, 8
months back.**

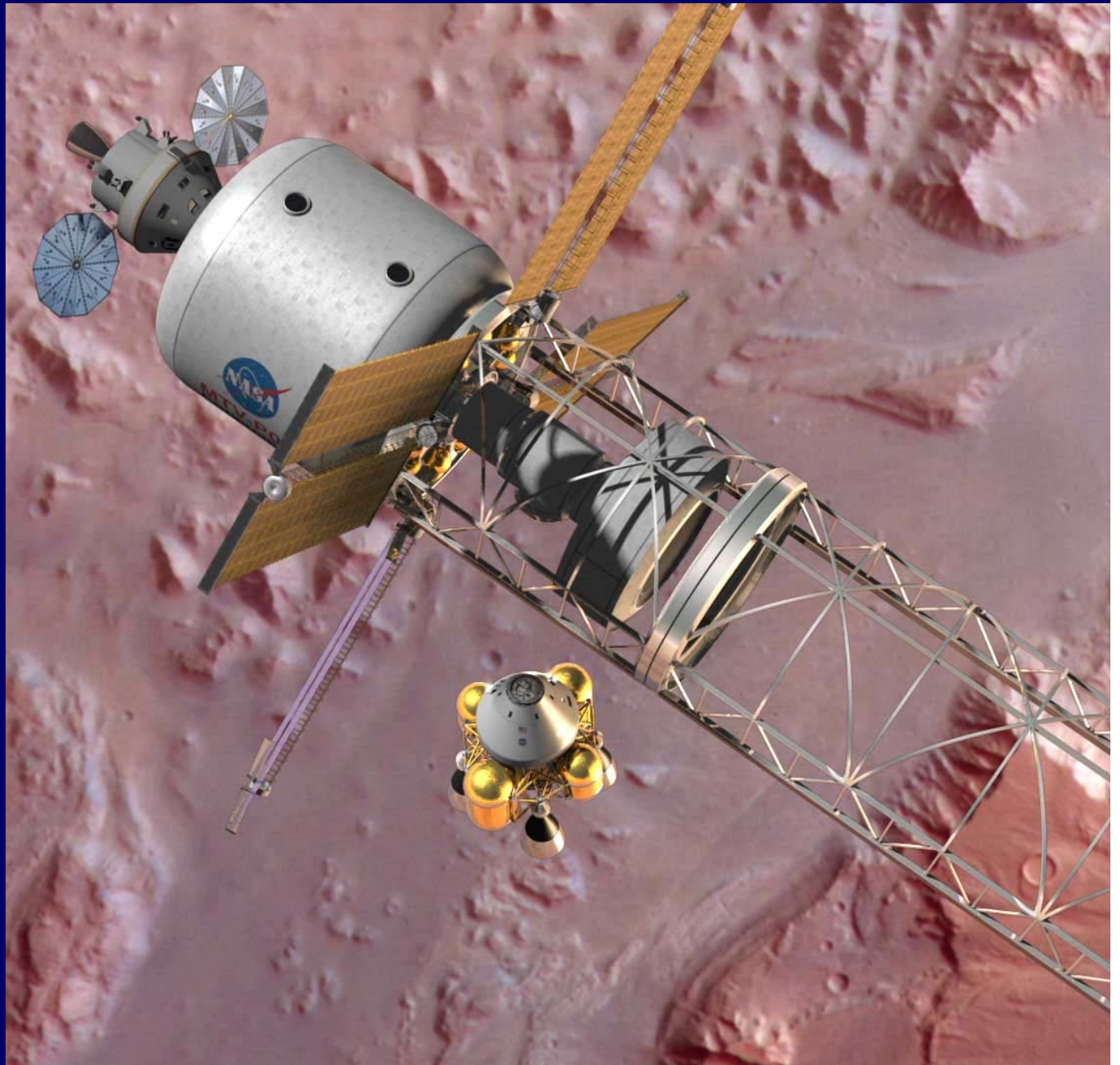


HEM-SAG

Send supplies first.

When safely landed on Mars, send the crew and spare supplies.

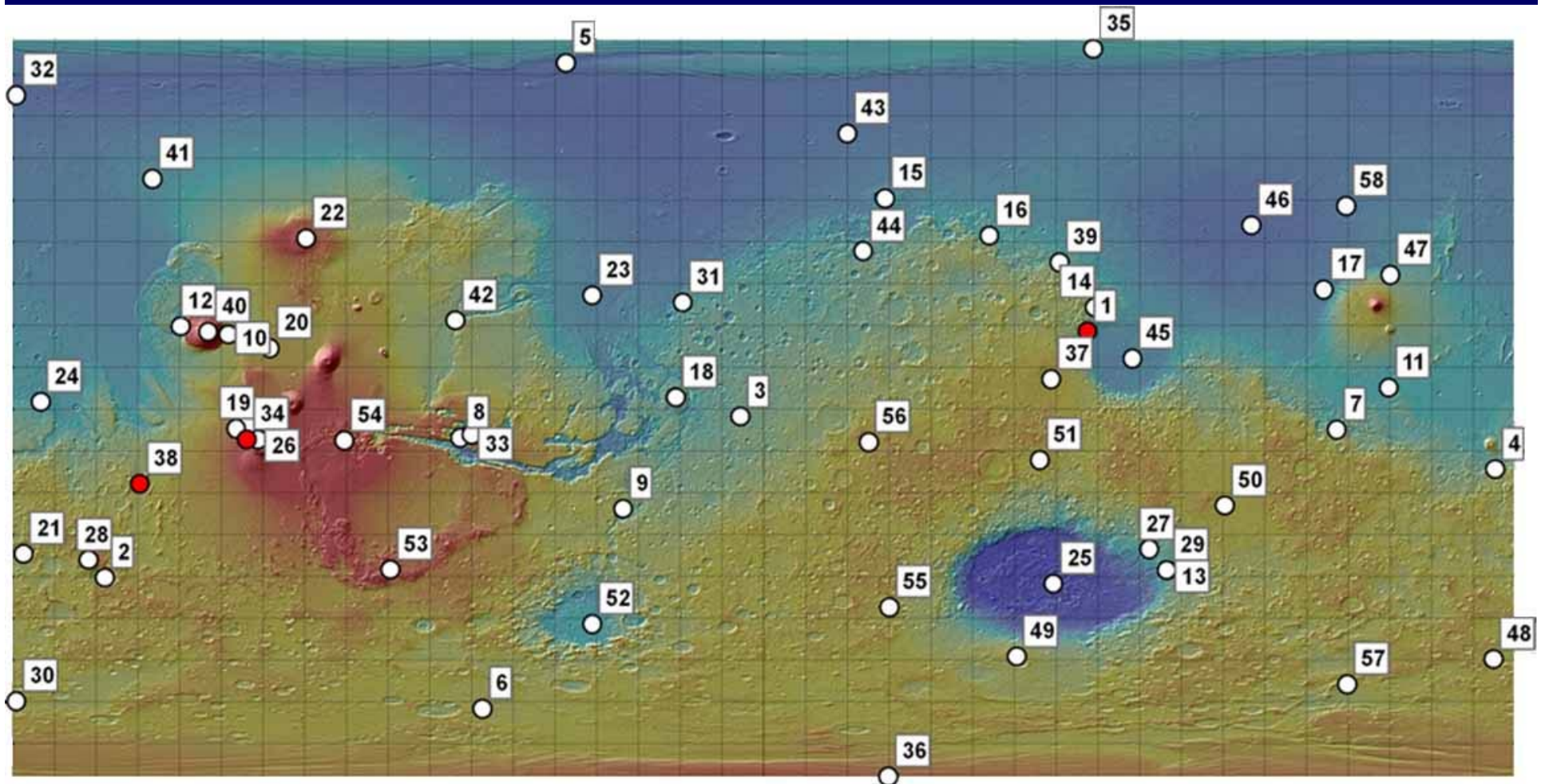
Problems? Use the spares as needed. But if all is well, those supplies support the next crew.



HEM-SAG

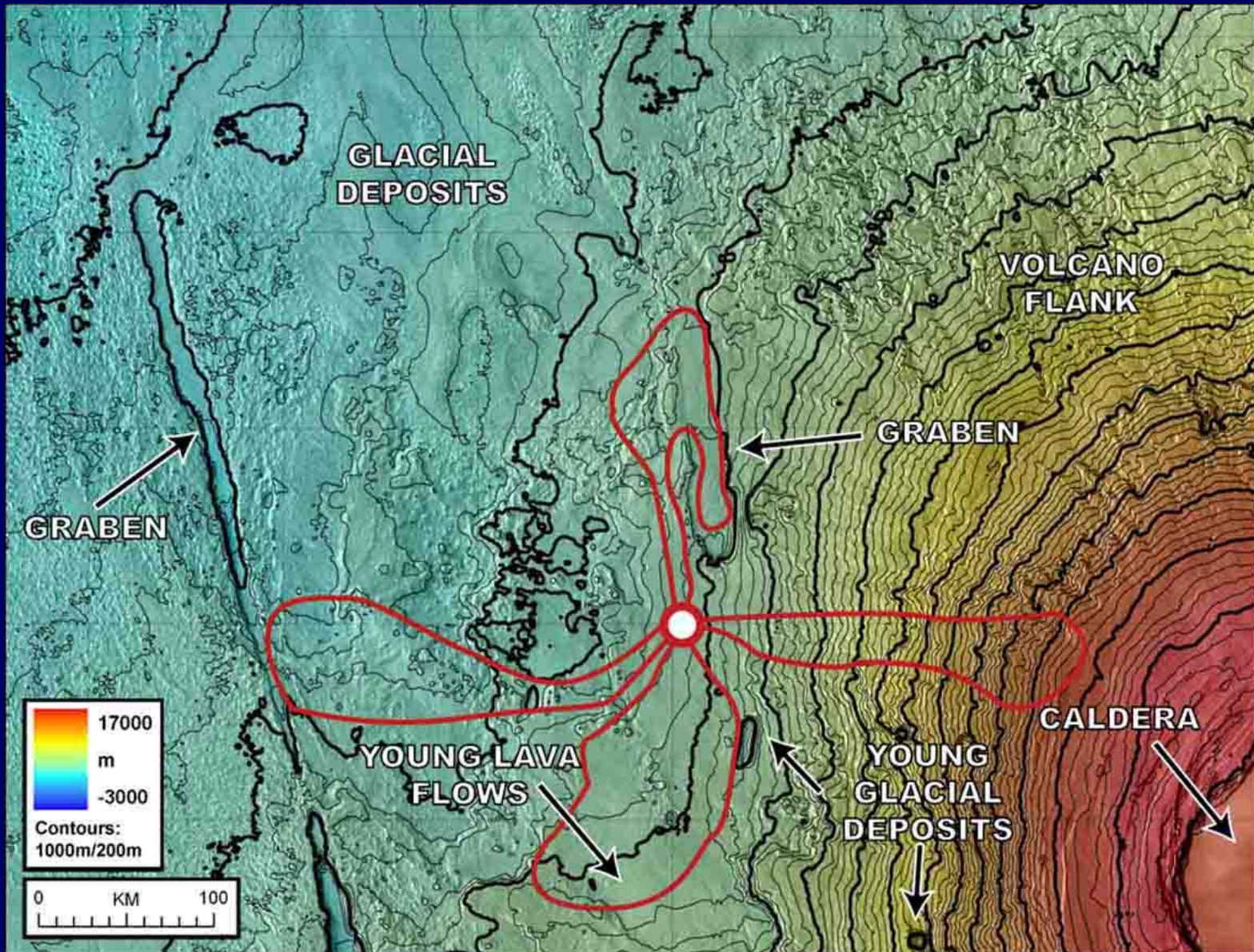
Surface operations: lots of targets!

Land in areas with maximum science value. Pressurized rovers allow long exploration traverses during the 500 days on Mars.



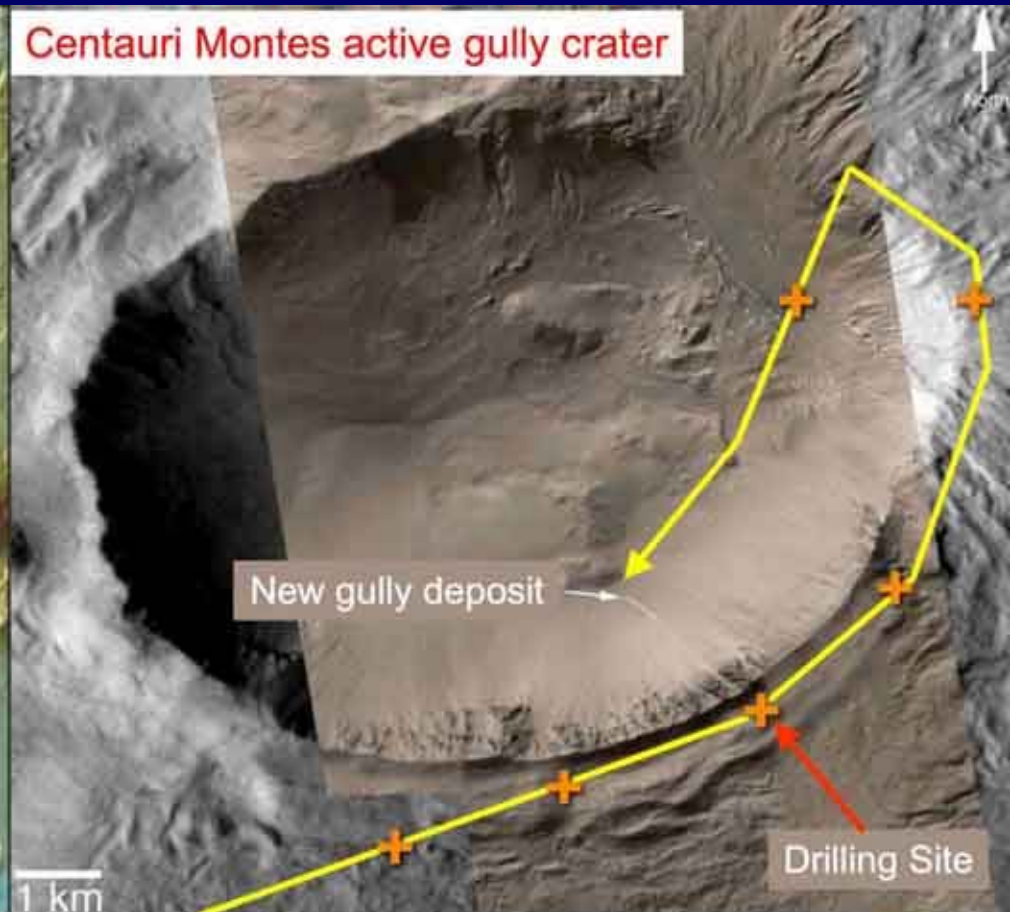
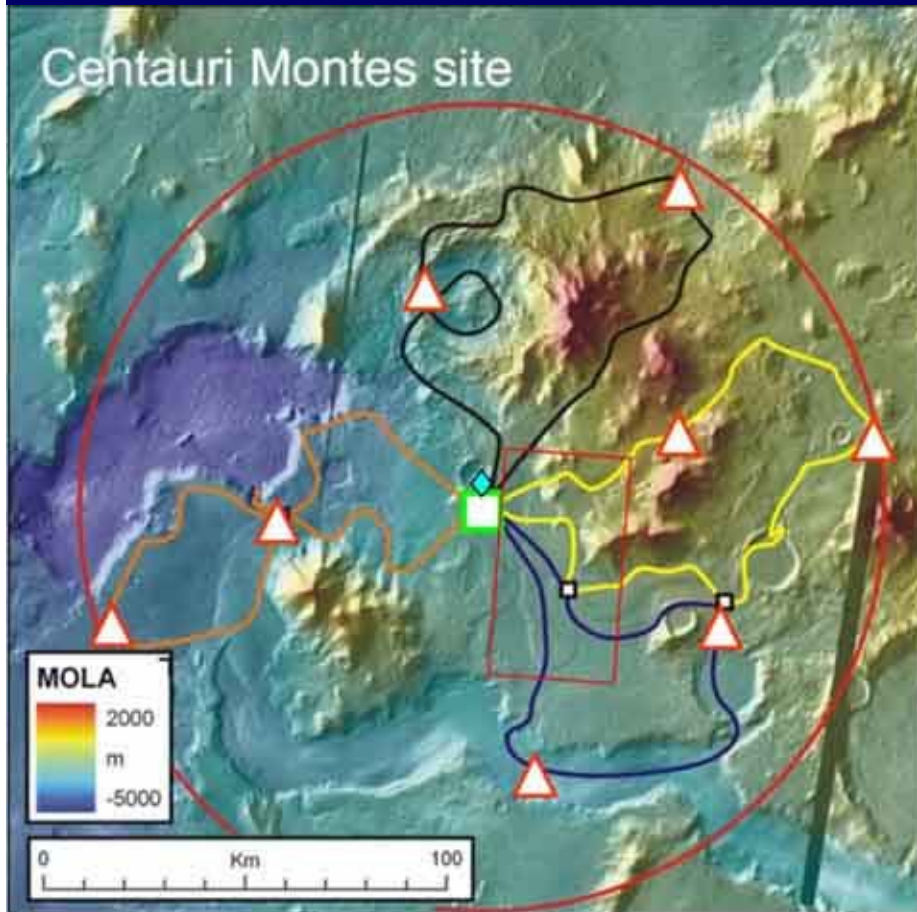
HEM-SAG

One target: glaciers on the side of a volcano



HEM-SAG

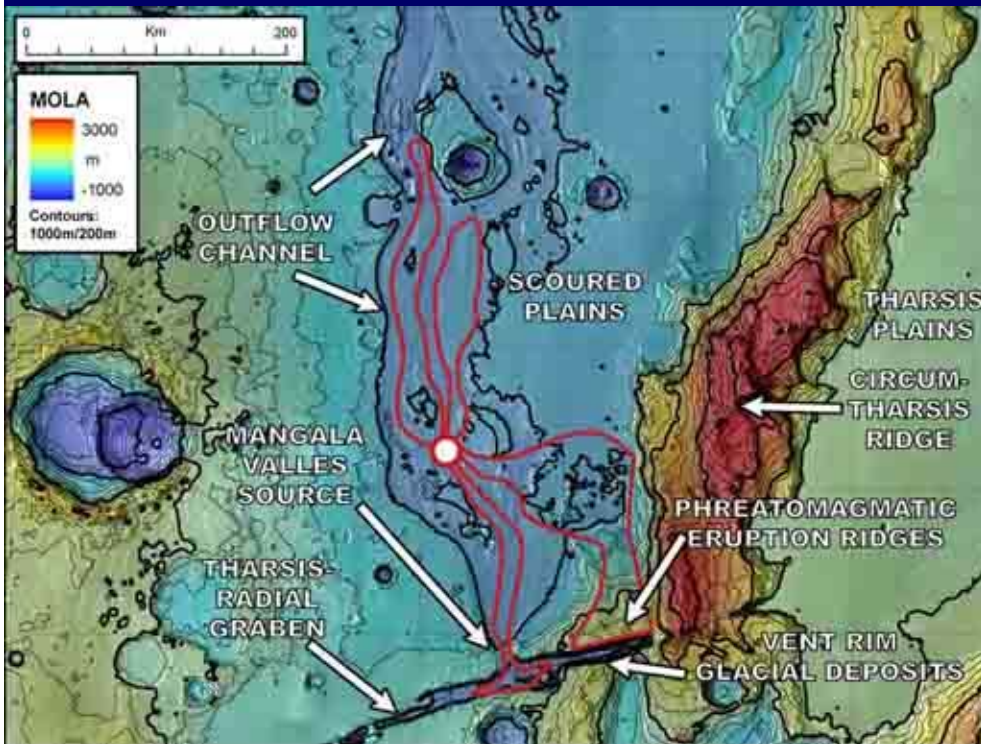
This gully may have had flowing water in the last decade. Astronauts will drill into the source region.



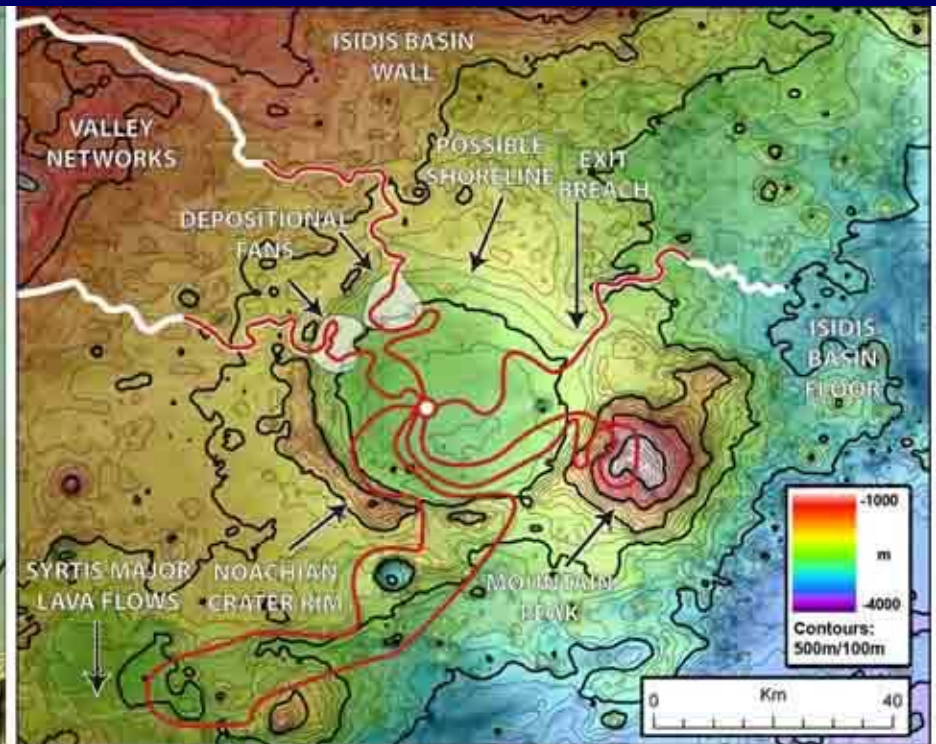
HEM-SAG

At Mangala and Jezero the astronauts will explore old river valleys and lake beds, now dried up.

Mangala



Jezero

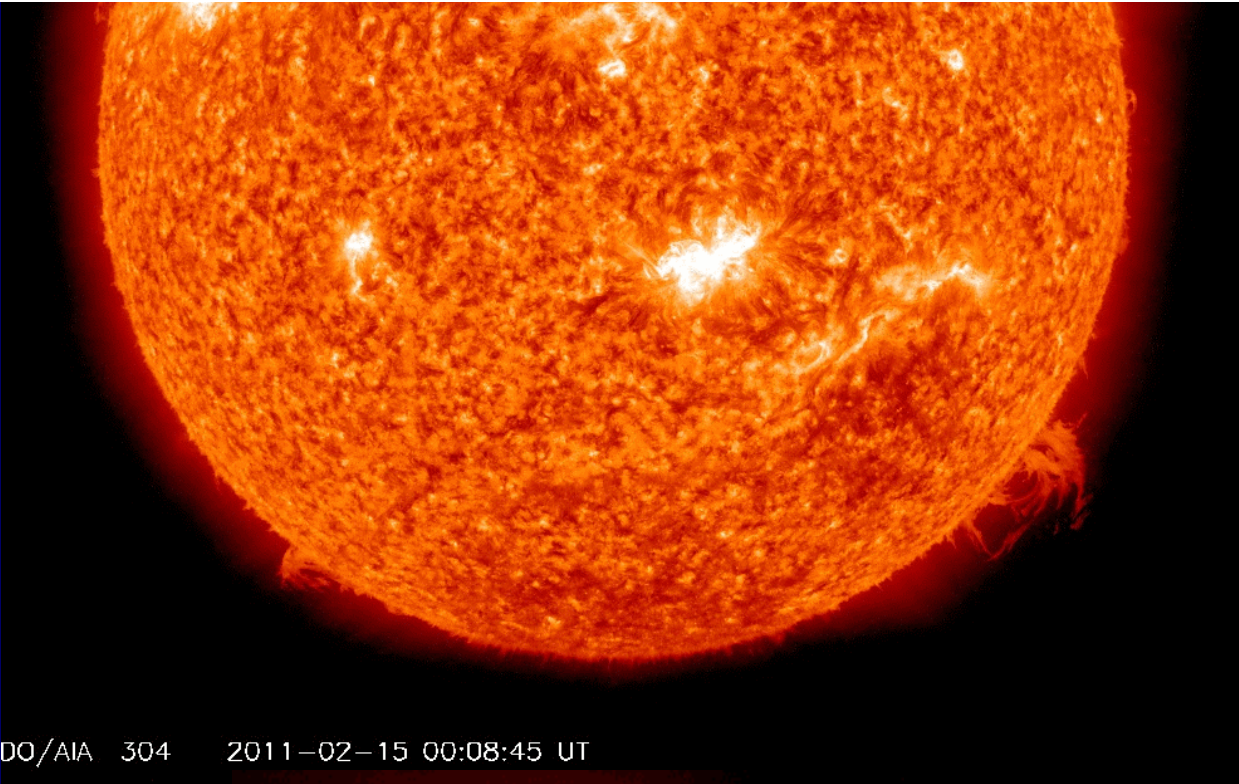


HEM-SAG

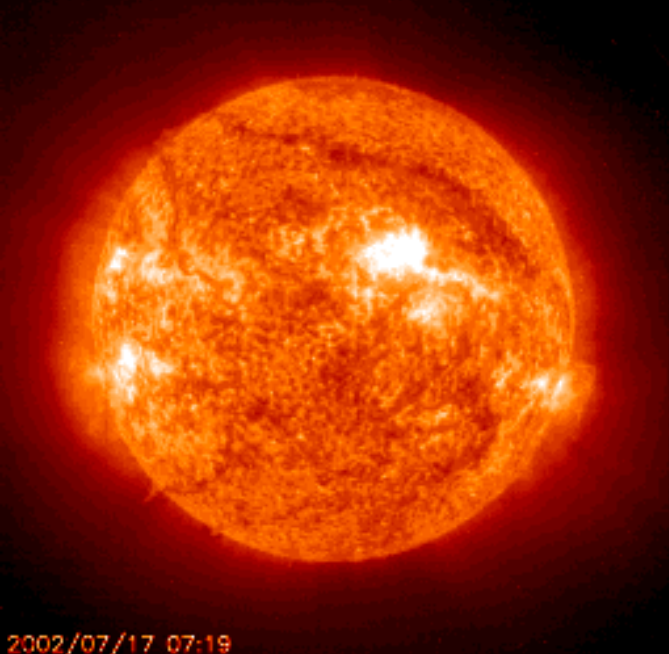
**Biggest
problem for
deep space
operations:**

**Radiation,
especially high
energy particles
from solar storms.**

**Special shielding
will be essential.
We can't do it yet.**



DO/AIA 304 2011-02-15 00:08:45 UT



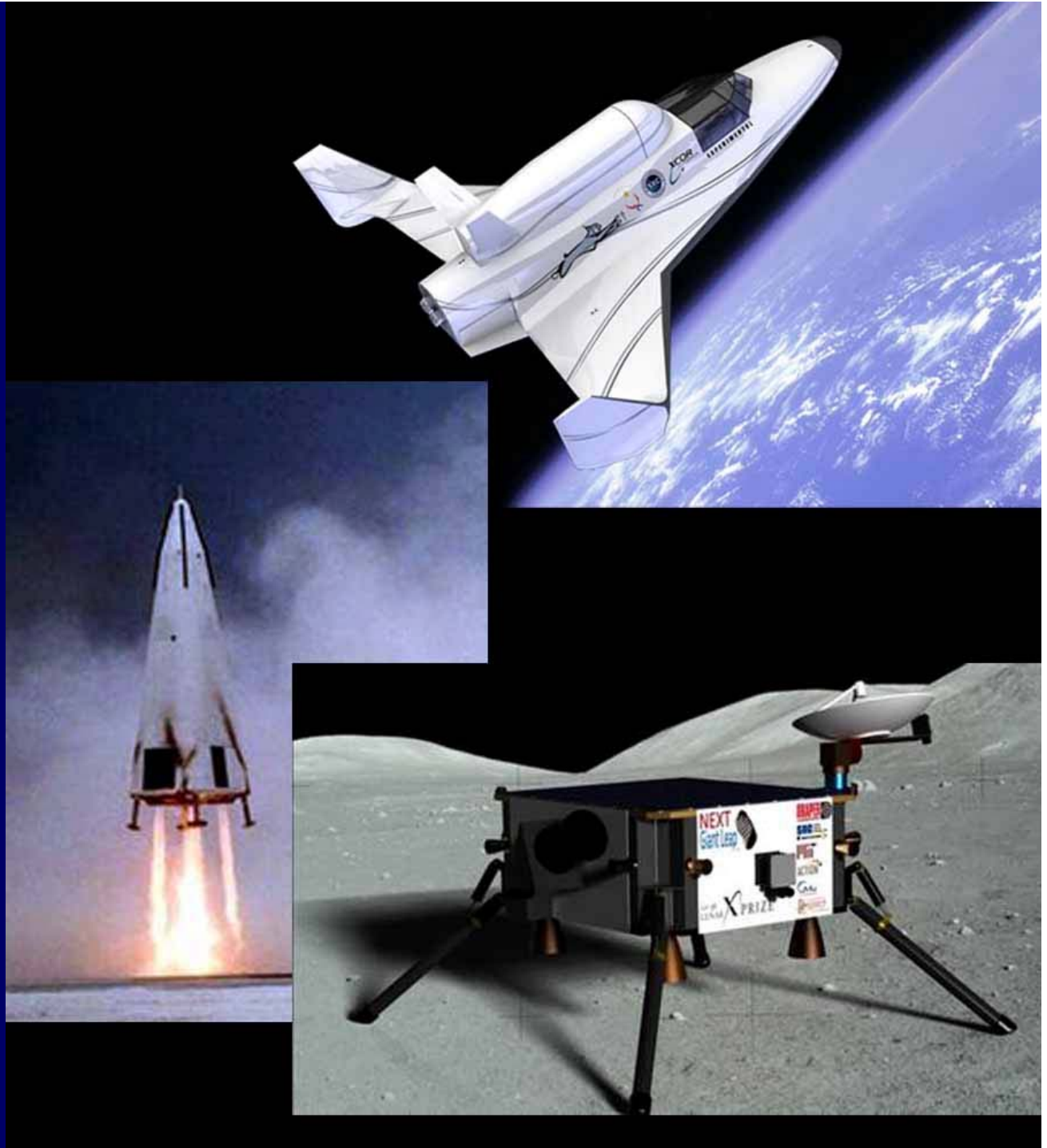
2002/07/17 07:19

Private space?

Some people want to go into space privately.

Space tourism, private rockets and space stations, robotic explorers.

Lots of ideas.

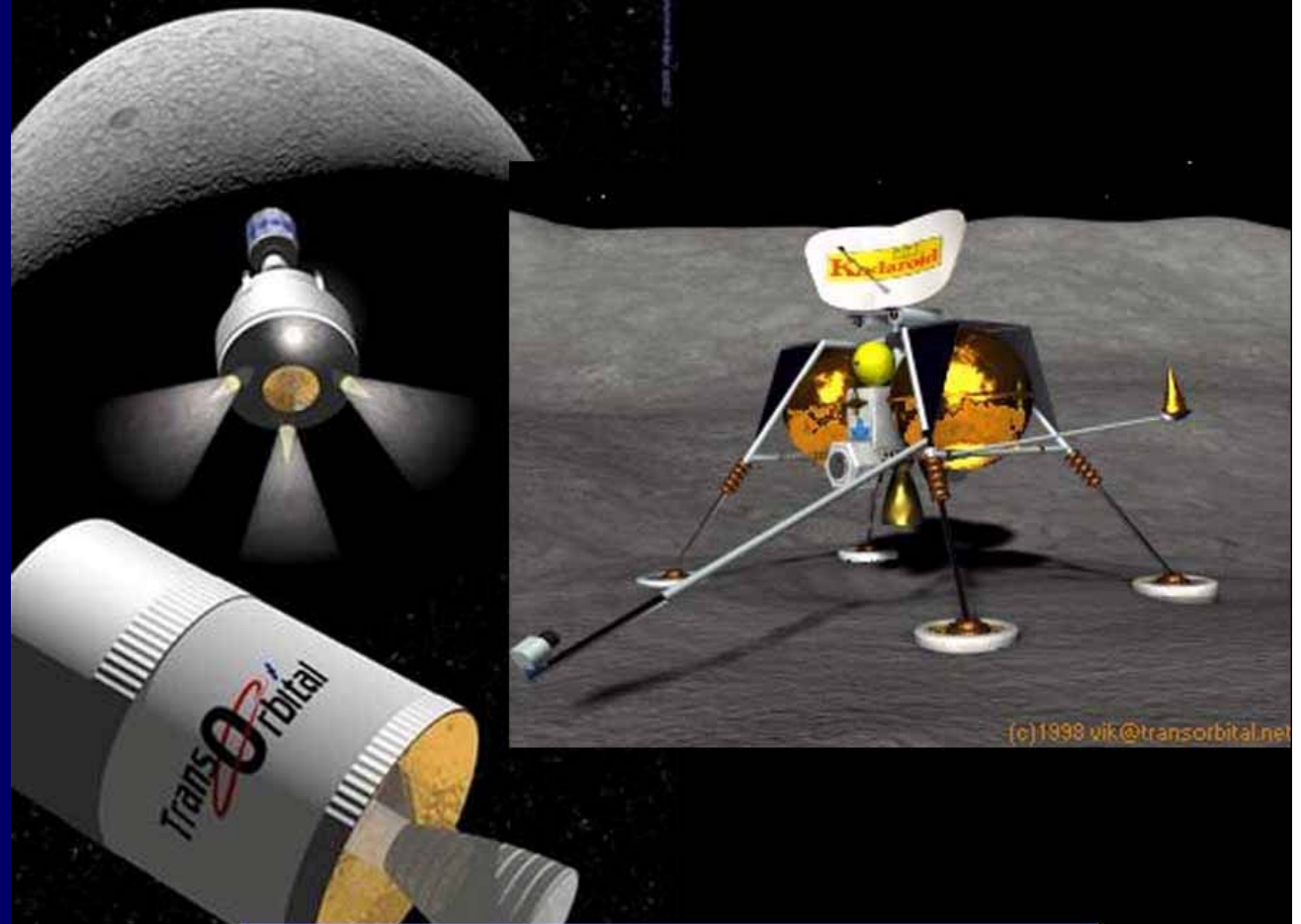


Private space?

In the 1990s there were several plans for private lunar missions...

Transorbital - lunar orbiter and lander, selling images and data.

Applied Space Resources - sample return, selling lunar rock and soil.



TRANSORBITAL

Applied Space Resources



The Lunar Retriever I Mission



Private space?

Most ambitious:

Lunacorp - rovers linked to theme parks and entertainment.

Ride in a simulator run by video and motion data from a rover on the Moon. Pay to drive the rover yourself.

Companies could not raise funds.



LunaCorp



Ansari X Prize

1996 - X Prize Foundation, prize for human sub-orbital space flight.

Fly up to 100 km altitude in a reusable vehicle.

Part of the \$10 million prize came from the Ansari family.



Scaled Composites, Google Inc.

Ansari X Prize

Won in 2004 by Burt Rutan's company *Scaled Composites* of Mojave, CA.

Technology licensed by Sir Richard Branson for *Virgin Galactic* - space tourism.



Scaled Composites

Virgin Galactic

Branson's new company sells tickets for \$200,000.

Three days: training and flight up to 100 km, five minutes weightless, 6 passengers.

Vehicle now in test phase, flights maybe next year.

Spaceport in New Mexico (Dubai and Scotland later).



Virgin Galactic

Other Space Tourism companies

Other companies are aiming at this market.

XCOR – Lynx vehicle, 1 passenger, \$100,000.

Blue Origin (Jeff Bezos, founder of Amazon.com) – plans include orbital vehicles. Launch failure in 2011.



Google Lunar X Prize

New X Prize competition, prize funded by Google, Inc.

\$30 million in prizes for landing on the Moon, moving around, sending pictures.

Deadline December 2015, first attempt in about 2013.

The screenshot shows the Google Lunar X Prize website. At the top, there is a navigation bar with the XPRIZE FOUNDATION logo on the left and icons for a car, a DNA helix, and a star on the right. Below the navigation bar is a large banner featuring the Google Lunar XPRIZE logo and a close-up image of the moon's surface. Underneath the banner is a horizontal menu with the following items: About the Prize, The Teams, Education, Store, and Get Involved.

The main content area is divided into several sections:

- JOIN THE REVOLUTION:** A section for email sign-ups. It includes the text "Get email updates about the Google Lunar X PRIZE, teams and upcoming events." followed by an "Email Address" input field and a "Subscribe" button.
- Follow Us:** A section with social media icons for YouTube, Google+, Facebook, Twitter, LinkedIn, and Tumblr, along with a "Google Gadget" button.
- Most Recent Team Stories, Videos, and Photos:** A list of team updates:
 - Penn State Lunar Lion Team:** April 10, 2011. [Penn State Students are learning what it takes to land on the Moon and win the Prize!](#)
 - Astrobotic:** April 08, 2011. [Field Test Preparations](#)
 - Rocket City Space Pioneers:** April 08, 2011. [Rocket City Space Pioneers Discuss Lander](#)
 - Part Time Scientists:** April 08, 2011. [PTS goes HMI](#)
- Featured Articles:** A section with the article **Final Team Roster Announced!**. The text reads: "PLAYA VISTA, CA (February 17, 2011) – Today, the X PRIZE Foundation announced the official roster of 29 registered teams competing for the \$30 million Google Lunar X PRIZE, an unprecedented competition to send a robot to the Moon that travels at least 500 meters and transmit video, images, and data back to the Earth. This group of teams signifies this new era of exploration's diverse and participatory nature as it includes a huge variety of groups ranging from non-profits to university consortia to billion dollar businesses representing 17 nations on four continents. The global competition, the largest in history, was announced in September 2007, with a winner projected by 2015."
- YouTube Videos:** A section with a video player showing a lunar lander on the moon's surface.

At the bottom of the page, there is a dark banner with the text "Peter Congratulates Google Lunar X PRIZE Regis".

Google Lunar X Prize

A few teams:

Astrobotic (USA)

Odyssey Moon (Isle of Man)

Moon Express (USA)

Euroluna (Europe)

Selenokhod (Russia)

29 teams signed up, 25 left now.



Odyssey Moon



Astrobotic



Team Italia



Next Giant Leap



FREDNET



ARCA



Moon Express



STELLAR



JURBAN



Independence-X



Omega Envoy



SYNERGY MOON



Euroluna



SELENE



White Label Space



Part-Time-Scientists



SELENOKHOD



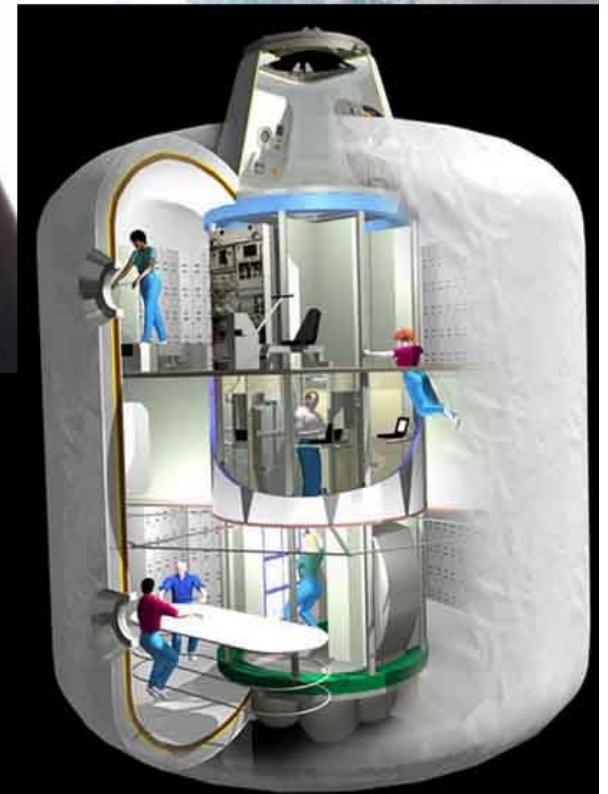
Bigelow Aerospace

Founded by
Robert Bigelow.

Genesis: inflatable
space modules
licensed from NASA.

Two are in orbit now
for testing.

Private space
stations, ISS add-on,
Lunar outpost etc.



Space-X

Space Exploration Technologies

Founded by Elon Musk. Private rockets, several successful launches to orbit with the Dragon capsule.

Will supply the Space Station, and later carry crews to orbit.

NASA would buy tickets to space, not build rockets.



Space Adventures

Only company to organize private flights to orbit.

Every seat purchased from Russia.

Dennis Tito in 2001, seven others since.

More to come - costs \$35 million per trip.

or... \$150 million for a trip around the Moon!

2012 – UK firm Excalibur-Almaz offers similar lunar trips in Russian vehicles.

Space Adventures - Internet Explorer provided by Dell

http://www.spaceadventures.com/

File Edit View Favorites Tools Help

Space Adventures

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SPACE ADVENTURES

DELIVERING SPACEFLIGHT EXPERIENCES

Our Vision
Lunar Mission
Orbital Spaceflight
Suborbital Spaceflight
Zero Gravity Flights
More Spaceflight Experiences
Corporate Promotions and Incentives

Space Adventures - the only company to have sent private citizens to space, [Read more »](#)

LUNAR MISSION
Be the world's first private lunar explorer, see the far side of the moon and witness the Earth rise.

ORBITAL SPACEFLIGHT
Rocket to space, orbit Earth 200 miles above its surface and live in weightlessness.

SUBORBITAL SPACEFLIGHT
Soar into suborbital space to

ZERO GRAVITY FLIGHTS
Experience true weightlessness

In what way can private spaceflight make the most significant contribution to society?

Help humanity expand into space.

Contribute to the

Planetary Resources

New company hoping to find valuable resources in asteroids.

(1) discover many small asteroids that pass near Earth.

(2) explore them for valuable minerals.

(3) move into lunar orbit and extract resources.

Big names backing the idea, so it may happen.



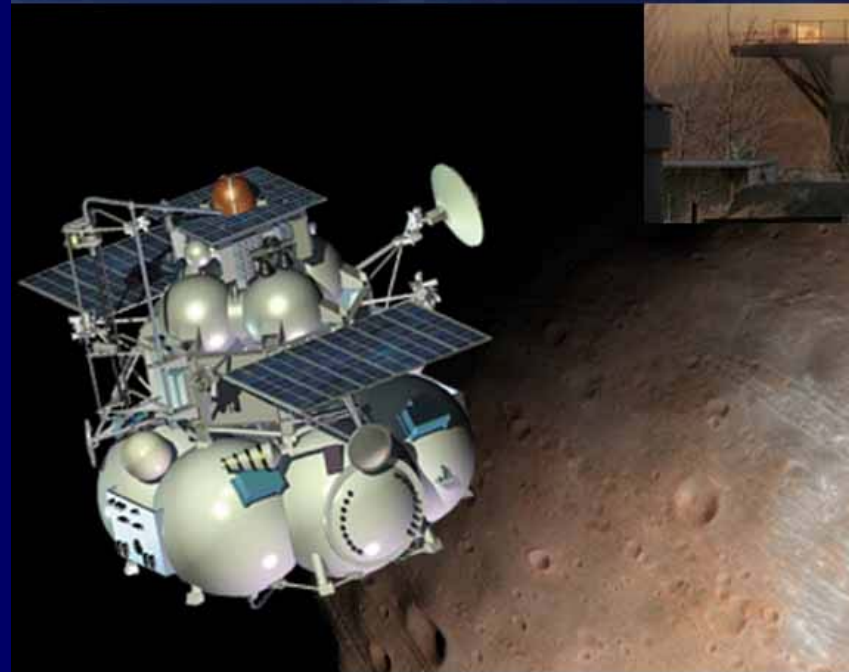
Other nations? Russia

Russia's economy has held it back, but it's still big in space.

More rocket launches than any other nation each year.

The only crew access to the Space Station for much of this decade.

Planning missions to the Moon and Mars.



Roscosmos, IKI RAN

China

China is only the third nation to orbit its own crews.

First astronaut in 2003, small space station tested in 2012, big station in 2020.

Slow but steady progress.

CNSA



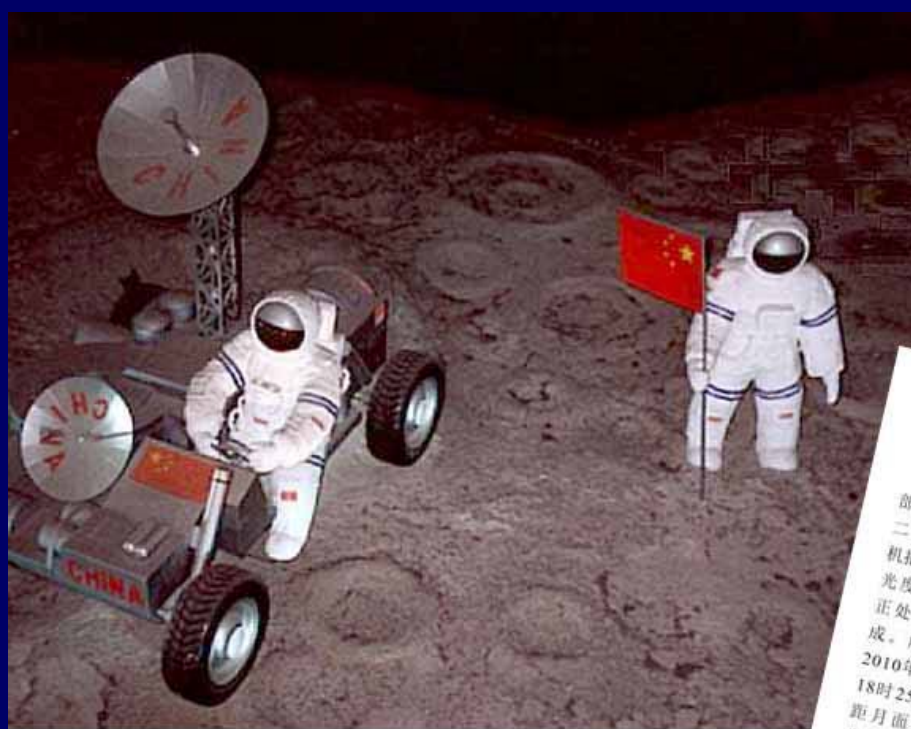
China to the Moon

Lunar orbiters (Chang-E) now, and landers, rovers, sample return soon.

May send an orbiter to Mars soon.

People to the Moon? Maybe, in about 2025.

CNSA



嫦娥二号虹湾局部

月球虹湾局部影像图由嫦娥二号卫星CCD相机拍摄，经辐射、光度、几何等校正处理后制作而成。成像时间为2010年10月28日18时25分，卫星距月面约18.7千米，像元分辨率约1.3米。影像图中心位置为西经31°3'、北纬43°4'，对应月面东西宽约8.0千米，南北长约15.9千米。该区域表面较平坦，由玄武岩质的月壤覆盖，分布有不同大小的环形坑和石块，其中最大的环形坑直径约2.0千米。

影像位置示意图

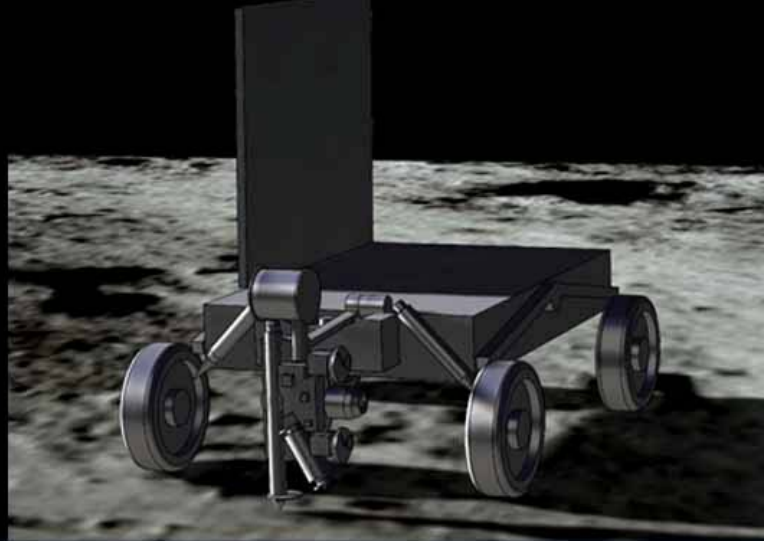
India

Rockets and satellites form a robust base to build on.

Lunar orbiter in 2008, rover in 2014, Mars orbiter soon.

Human space flight developing slowly, first flight after 2020.

A new 'space race' with China?

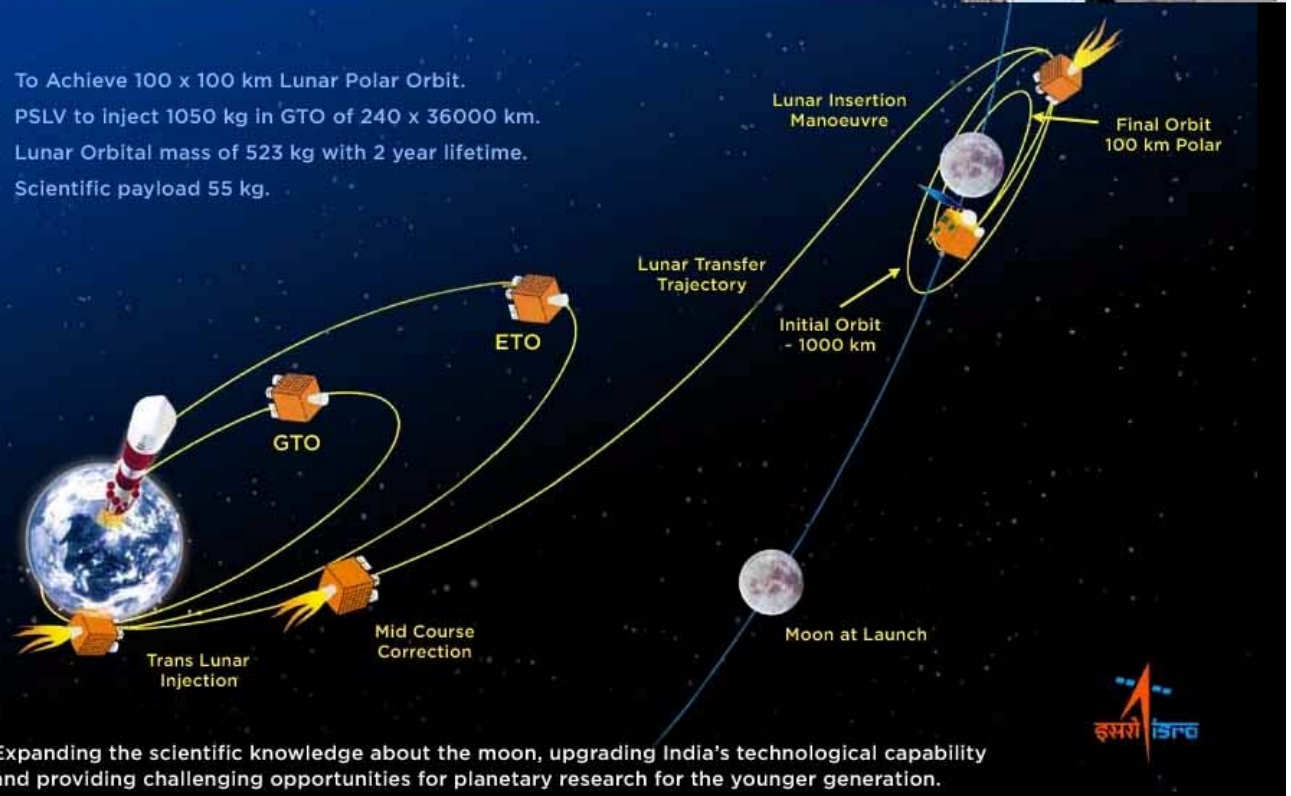


Chandrayaan - 1

INDIA'S FIRST MISSION TO THE MOON



- To Achieve 100 x 100 km Lunar Polar Orbit.
- PSLV to inject 1050 kg in GTO of 240 x 36000 km.
- Lunar Orbital mass of 523 kg with 2 year lifetime.
- Scientific payload 55 kg.



ISRO

Expanding the scientific knowledge about the moon, upgrading India's technological capability and providing challenging opportunities for planetary research for the younger generation.



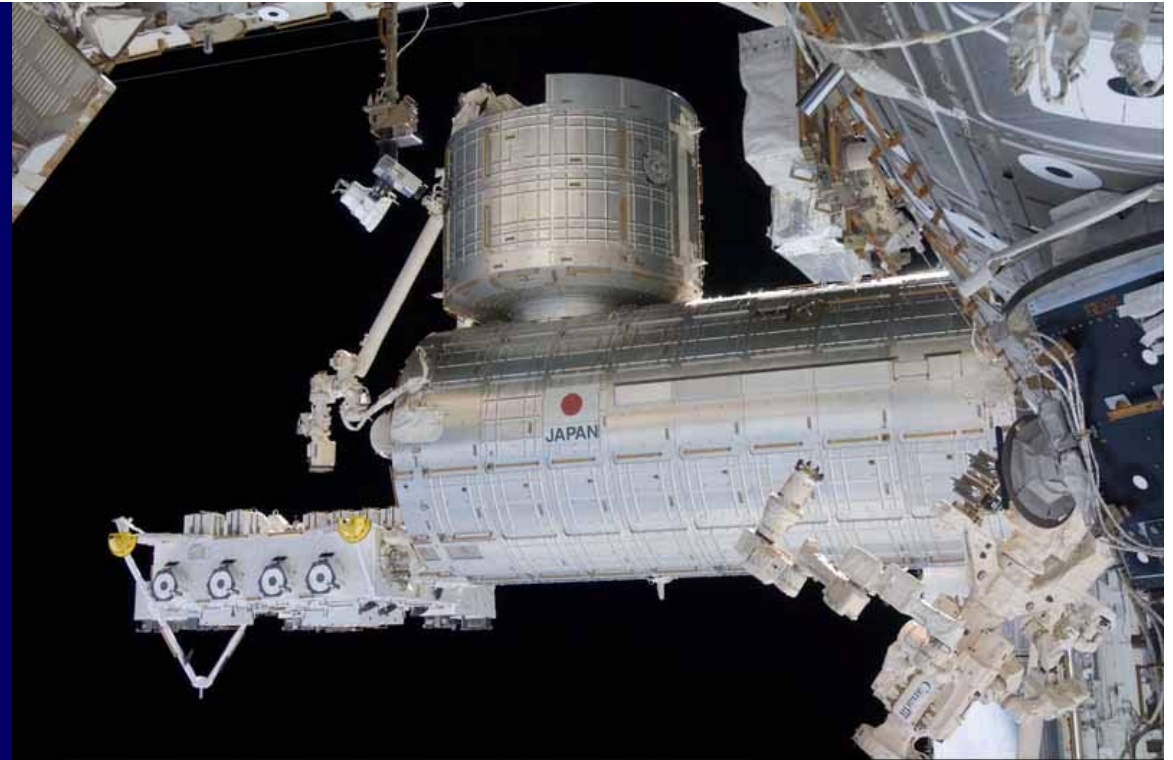
Japan

Rockets and satellites well established.

Part of the Space Station program, but plans for human space flight cancelled.

Kaguya lunar orbiter, planned future moon lander, *Hayabusa* asteroid sample return mission.

JAXA

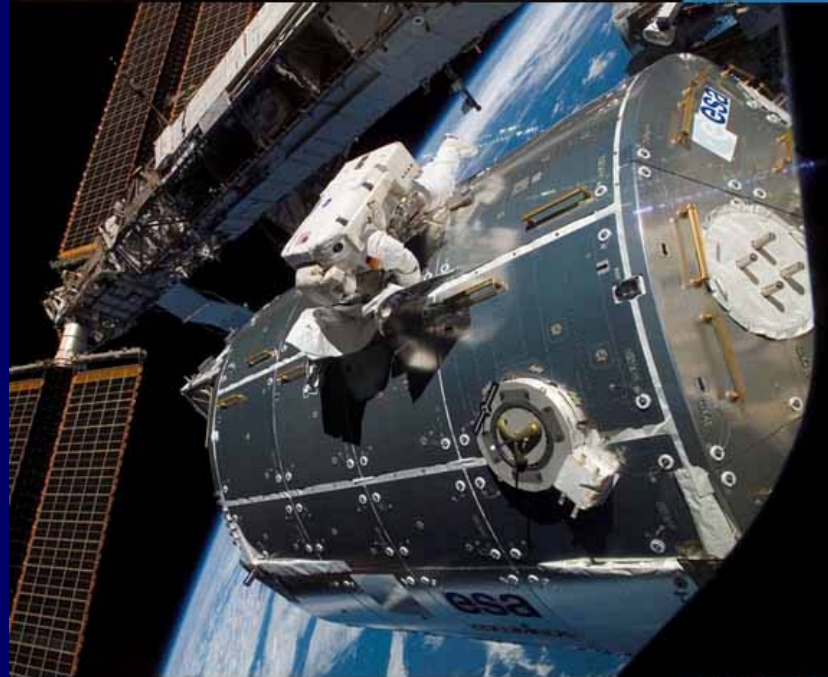
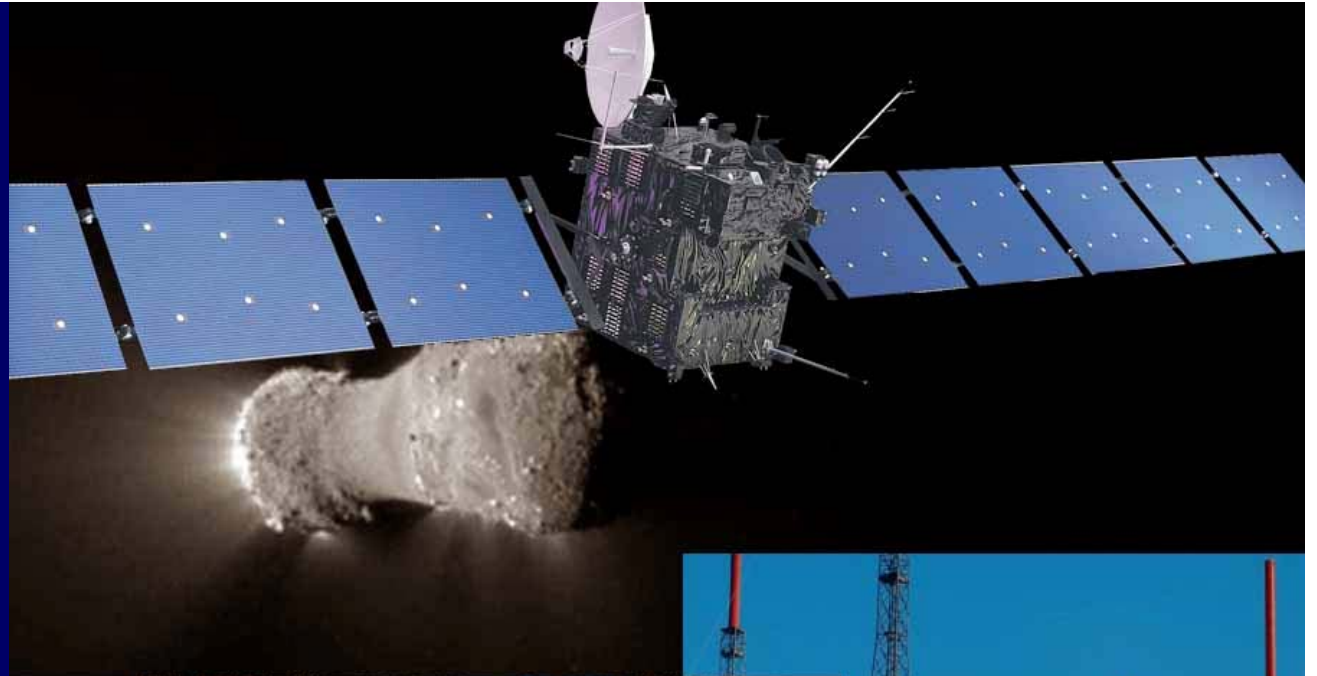


Europe (ESA)

Rockets and satellites well established.

Part of the Space Station program, and their astronauts may go further when finances improve.

Spacecraft to the Moon, Mars, Venus and asteroids. Mercury and a comet coming up.



ESA

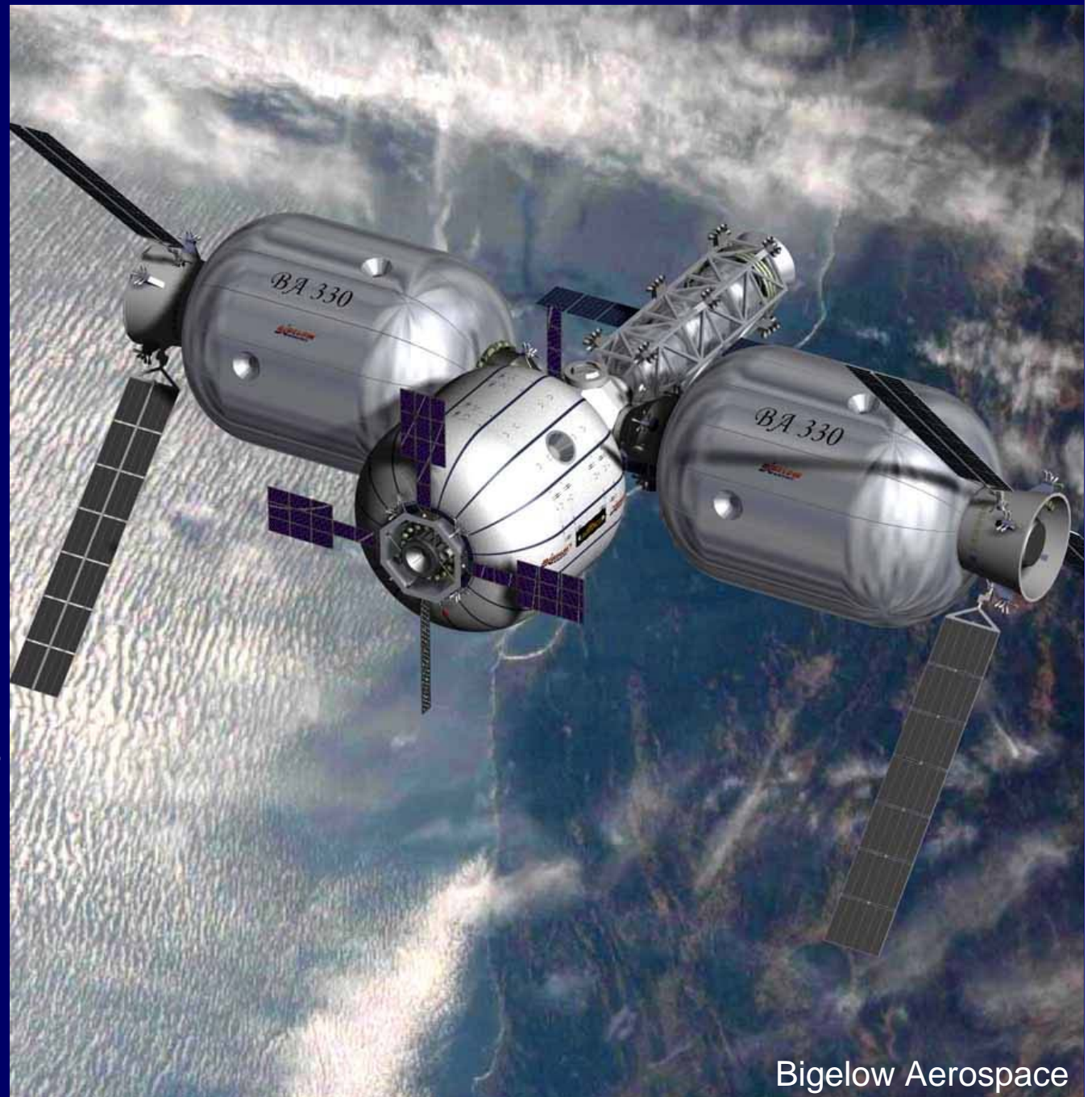
Future of space?

Not colonies on Mars, but we're not giving up.

Routine operations run by private companies like Space-X and Bigelow.

Astronauts prepare to move beyond Earth orbit.

Robots continue to explore the planets.



Bigelow Aerospace

Future of space?

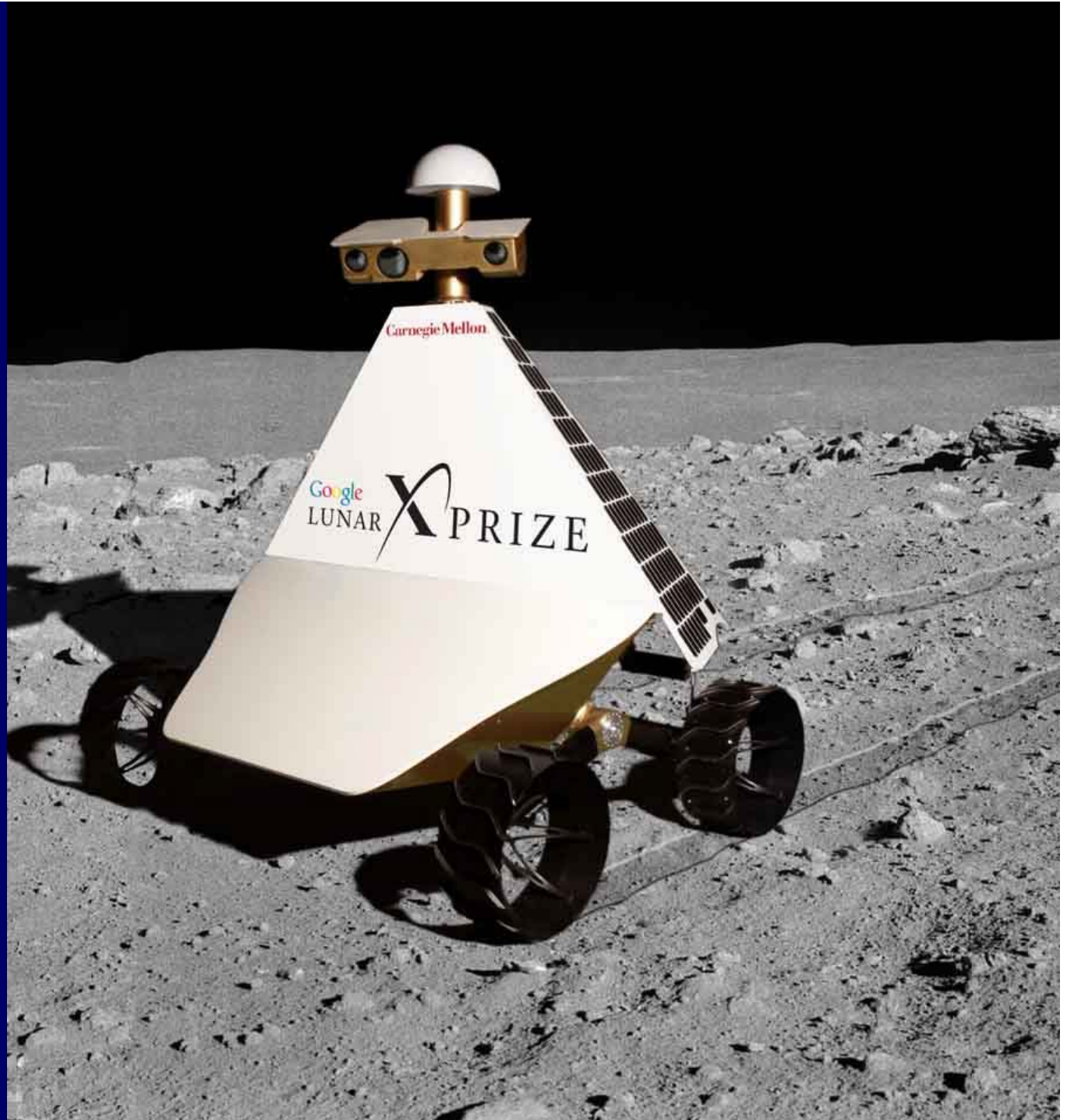
Space will be a busy place in the 21st Century.

International scope.

Private investment.

Not the old Cold War space race any more!

Astrobotic Inc.



End

Thanks for your interest in the future of space.

Philip Stooke

