

# The Moon: the next step towards sustainable expansion into space?

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Lecture organized by RAeS Hamburg Branch  
Hamburg Aerospace Lecture Series  
(DGLR, RAeS, VDI, ZAL, HAW Hamburg)  
07.11.2019,  
Hamburg University of Applied Sciences



RAeS Hamburg in cooperation with the DGLR, VDI, ZAL & HAW invites you to a lecture

# The Moon: The Next Step towards Sustainable Expansion into Space?

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**Date: Thursday 07 November 2019, 18:00**

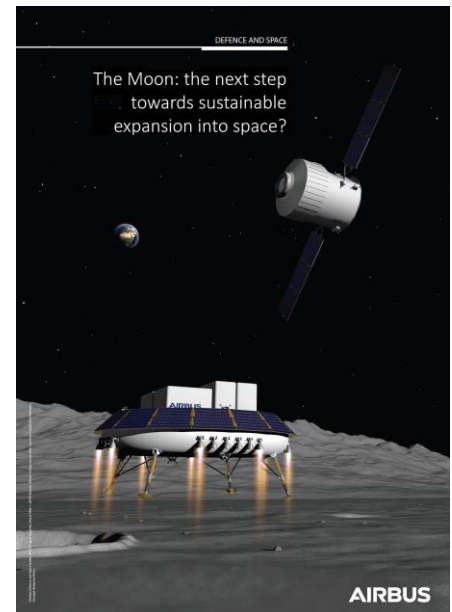
**Location: HAW Hamburg Berliner Tor 5, (Neubau), Hörsaal 01.11**

Lecture followed by discussion  
No registration required!  
Entry free!

Although humans have not travelled beyond the Moon (or even back to the Moon, yet), global space business (excluding the downstream services) exceeds nowadays €80bn a year. This figure depends on a business model in which every kilogram of required hardware or resource is brought from Earth, which raises questions about its sustainability and growth potential.

It is in this context that all major space powers are heading back to the Moon. The possibility of extracting raw materials, resources and – above all – rocket propellant, is what drives the US, Russia, China and others to prospect and settle around the lunar south pole. The presentation will outline the lunar programme of NASA and ESA, and introduce a few thoughts about Europe's options for projecting influence and protecting its stake in a quest shaped by both co-operation and competition.

*Silvio leads the Advanced Projects and Products business, creating programmes and technologies to make human expansion into space possible and sustainable. Until 2017 he was in charge of strategic industrial partnerships at Ariane Group (Paris area). Between 2009 and 2014 he led the development of new launch vehicles programmes and business for Airbus Defence and Space – among which Ariane 6, ADELINe and Liberty. He joined the Airbus Group in 2005 to manage Astrium Space Transportation relations with the European Space Agency. He also spent three years in Arianespace Launch Operations Team in French Guiana, participating in 28 consecutive Ariane 4 successful launches during that period.*



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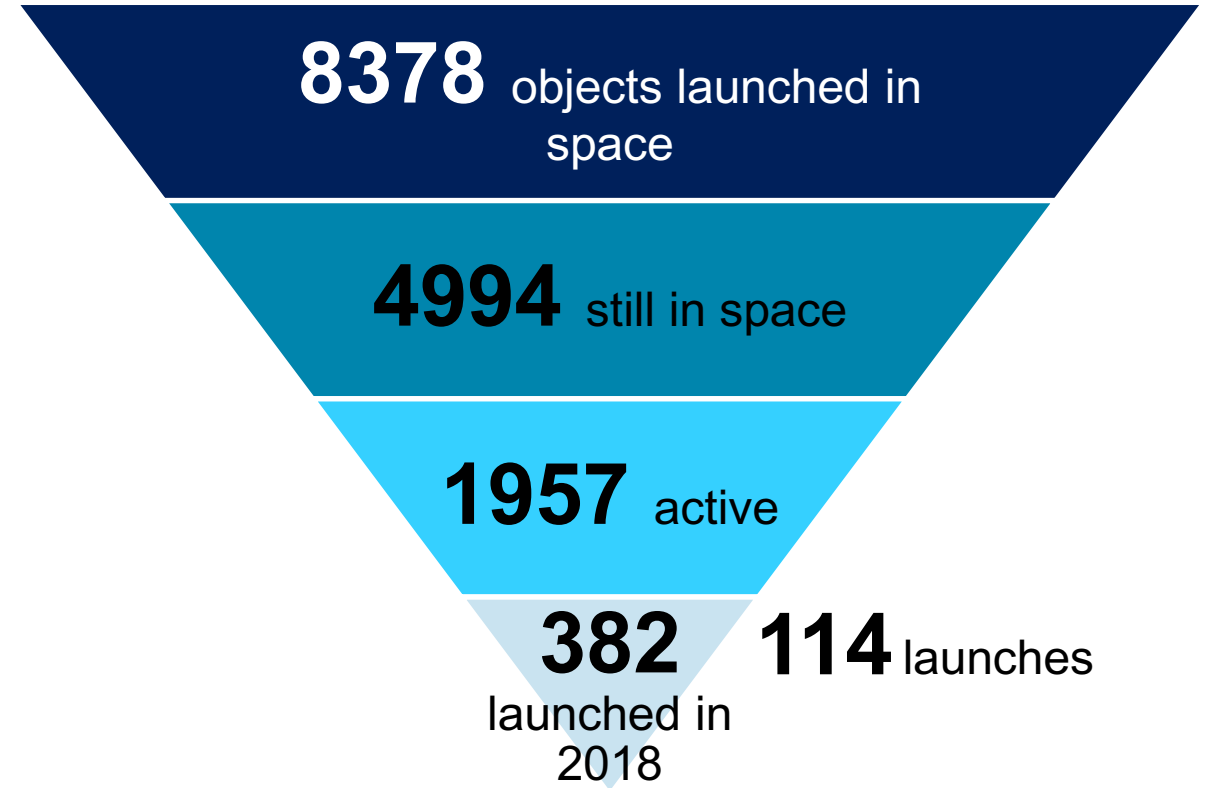
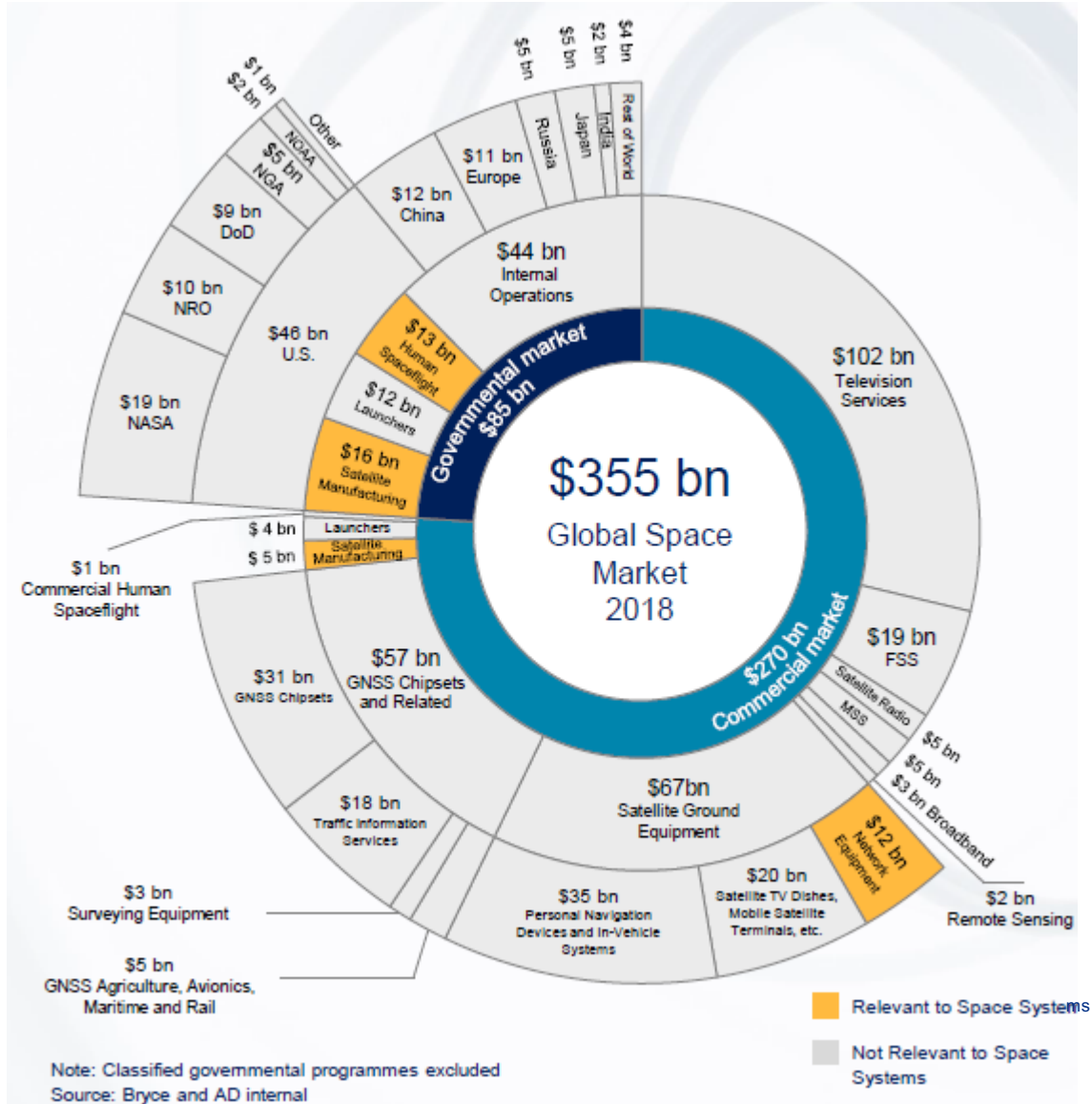


DGLR Bezirksgruppe Hamburg  
RAeS Hamburg Branch  
VDI, Arbeitskreis L&R Hamburg  
ZAL TechCenter

http://hamburg.dglr.de  
http://www.raes-hamburg.de  
<http://www.vdi.de/>  
<http://www.zal.aero/veranstaltungen>

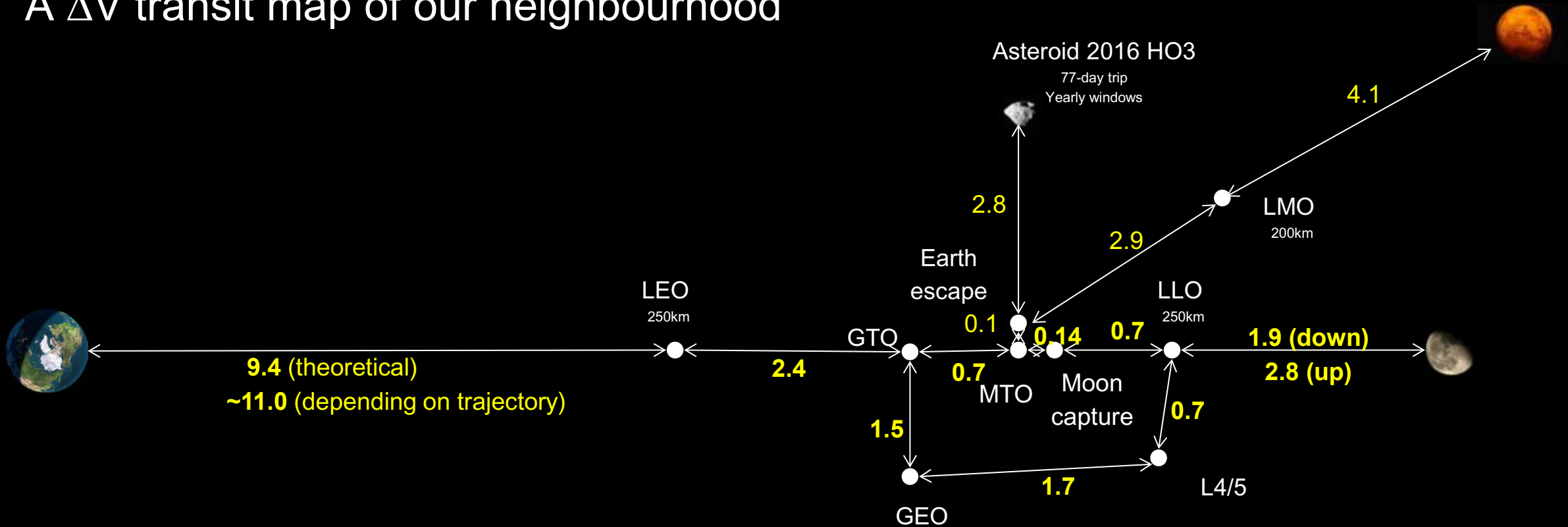


# The worldwide space economy



Source: UN OOSA and Concerned Scientists

# A $\Delta V$ transit map of our neighbourhood



## A few notable approximate $\Delta V$

Earth to GEO: 14.9 km/s	Moon to GEO: 5.2 km/s
Earth to LEO: 9.4-11 km/s	Moon to LEO: 6.8 km/s
Earth to GTO: 13.4 km/s	Moon to GTO: 4.4 km/s
Earth to LLO: 15 km/s	Moon to LLO: 2.8 km/s

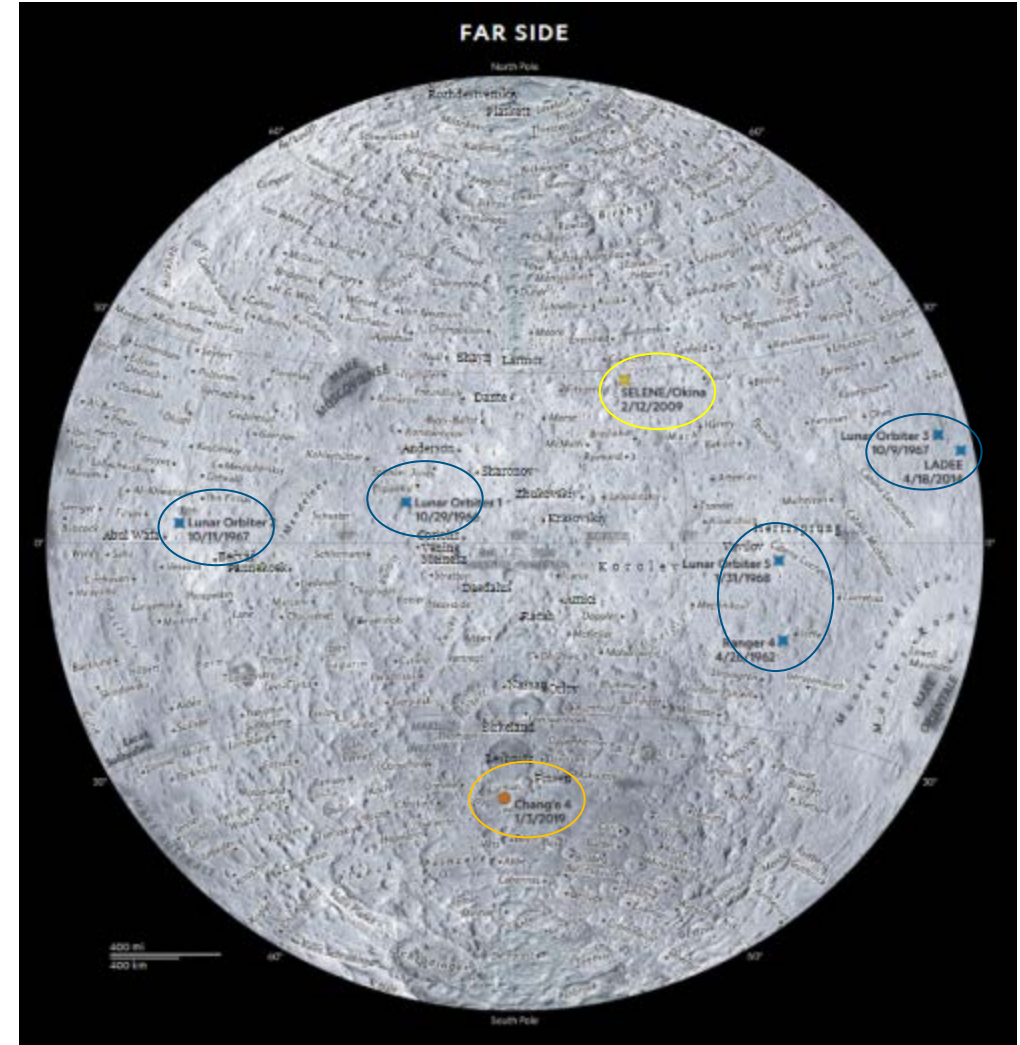
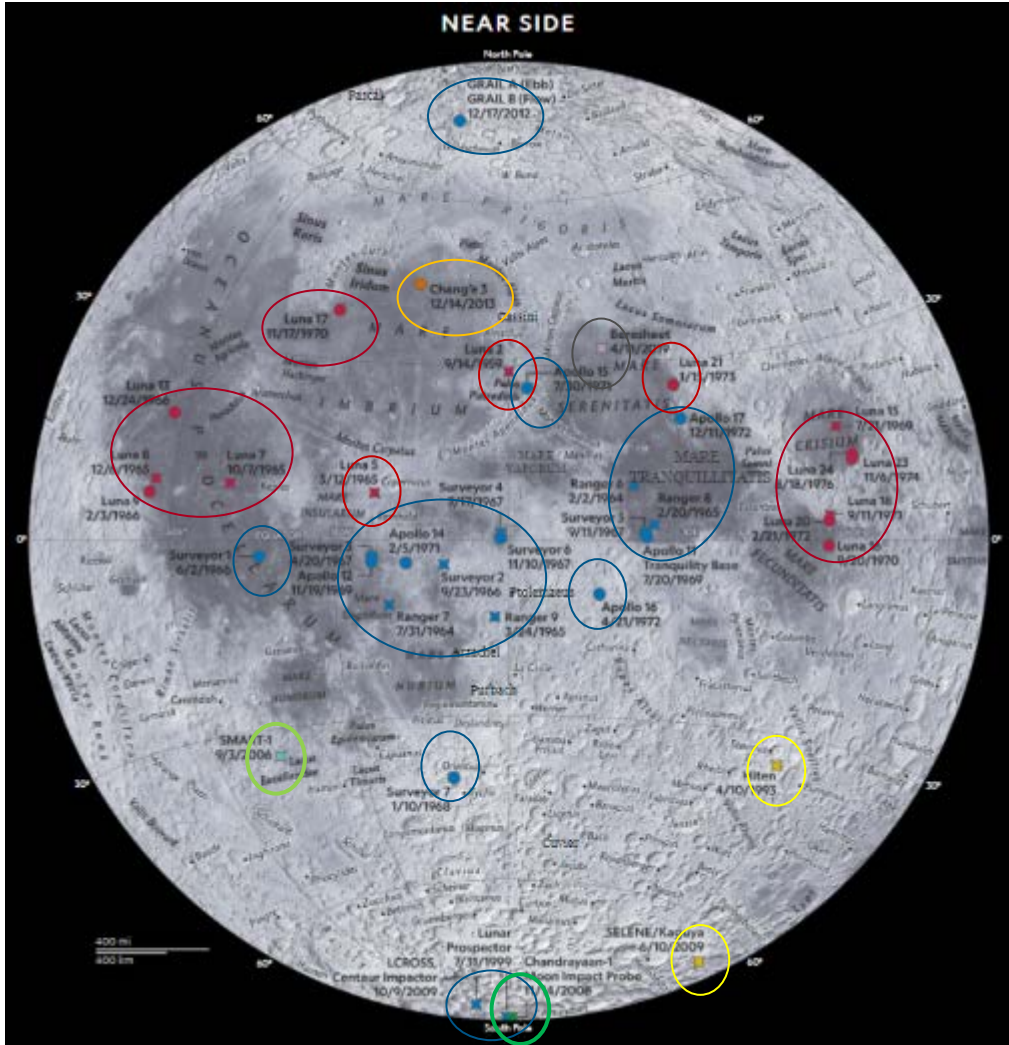
Each figure is  $\Delta V$  between two points in km/s  
Diagram roughly to scale

Sources

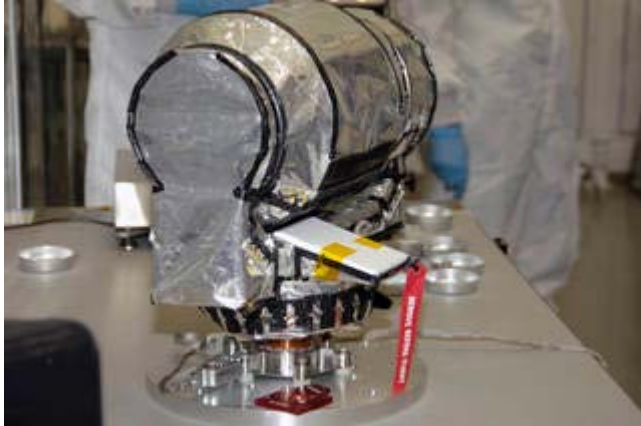
- Wikipedia (en)
- TU Delft website
- Stackexchange.com
- Aerospace America, September 2016

# Implemented lunar missions

- US
- Russia
- China
- Israel
- Japan
- Europe
- India



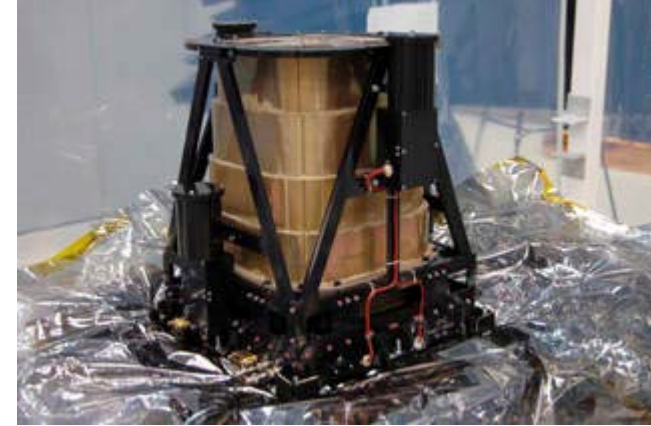
# Lunar Reconnaissance Orbiter – LRO (2009)



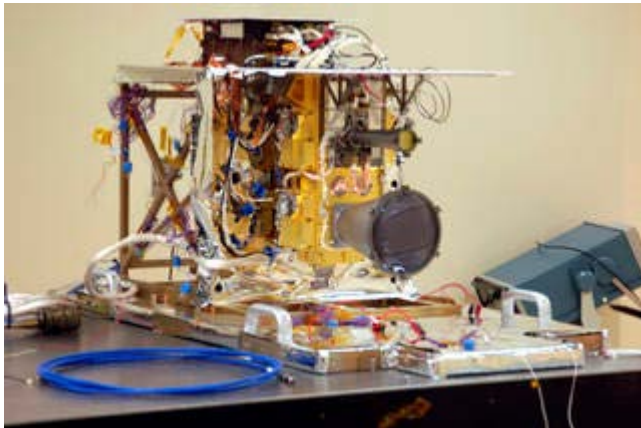
**Diviner Lunar Radiometer Exp.**  
Identify cold traps



**LAMP**  
Surface ice and frost



**Lunar Exploration Neutron Detector**  
Hydrogen distribution

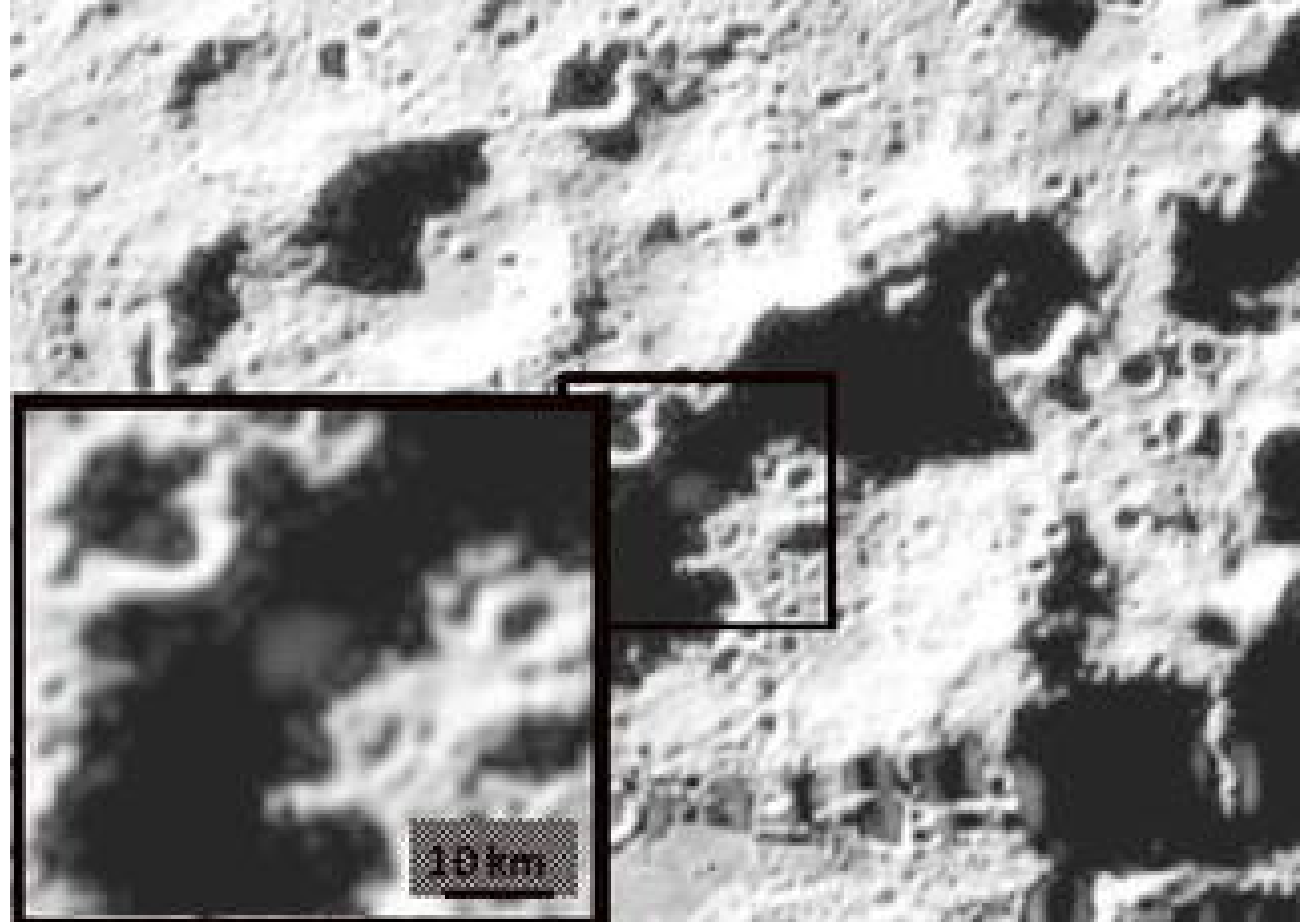


**Lunar Orbiter Laser Altimeter**  
Determine illuminated/shaded areas

# LCROSS – digging for water (2009)

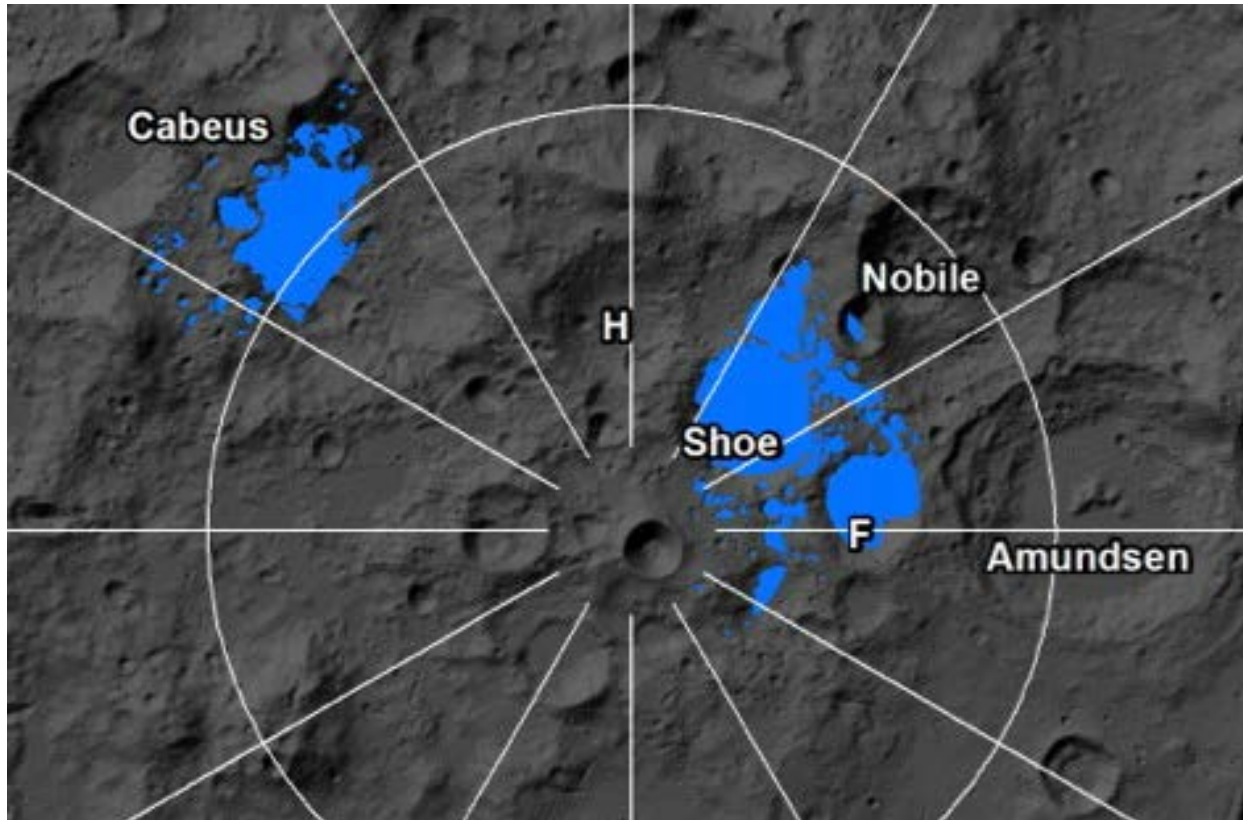


Source: NASA

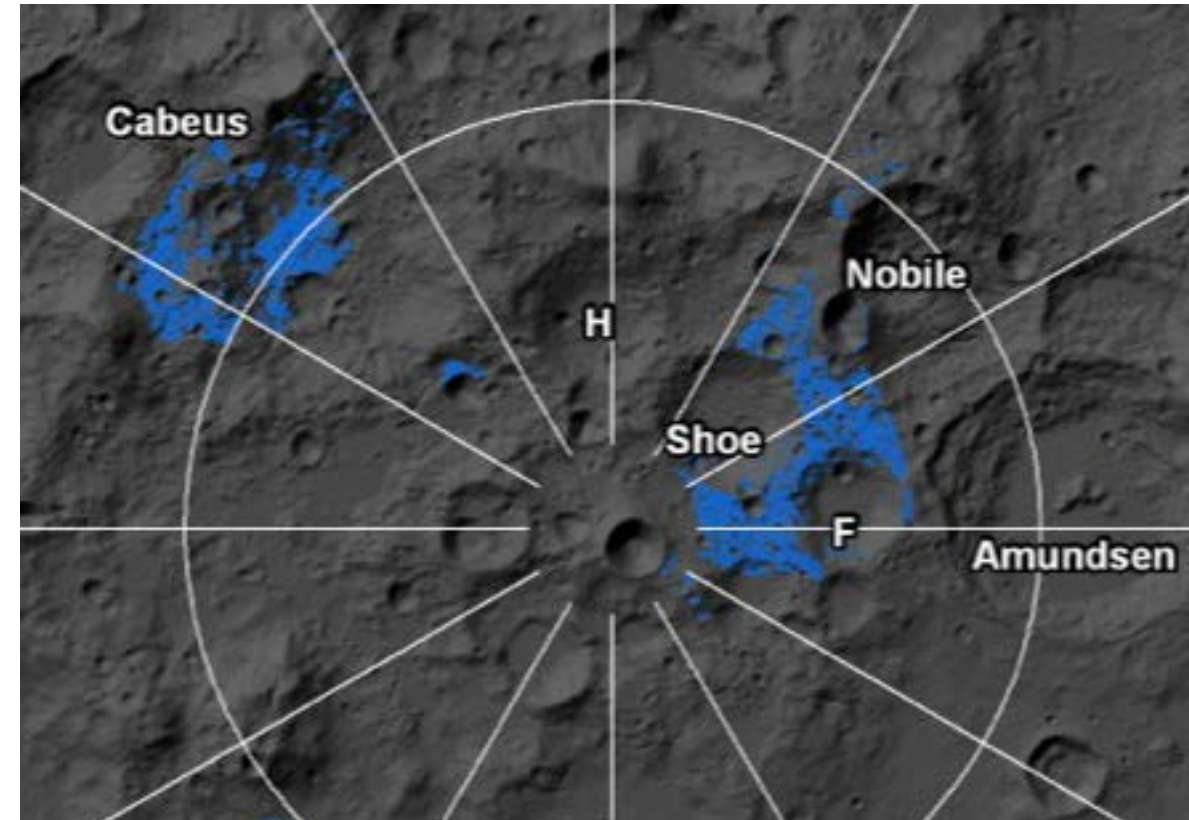


Source: NASA

## The South Pole example



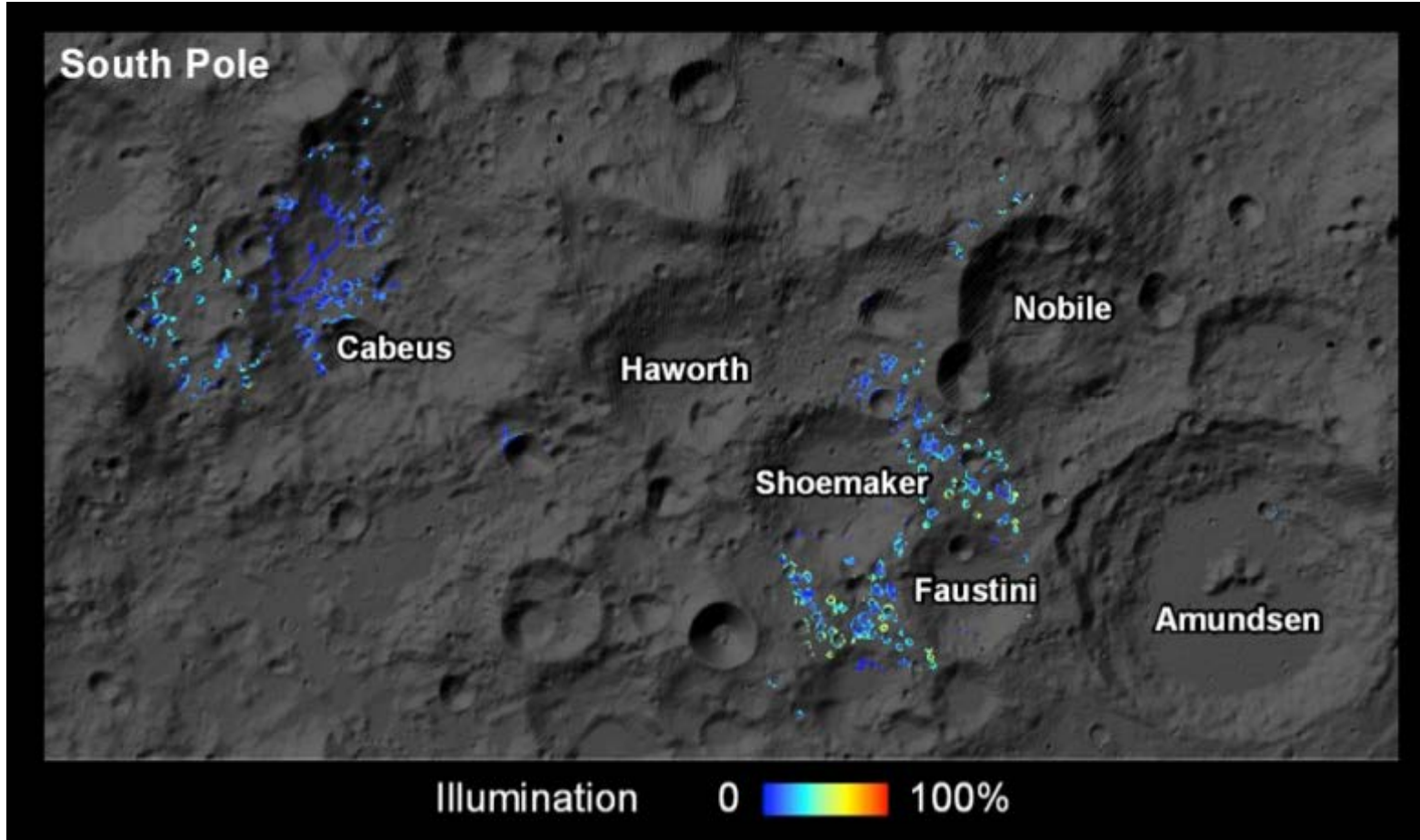
Close to LCROSS site in T and H concentration



H concentration > 150ppm  
Average T < 110K  
Slope < 10°  
Outside but adjacent to PSR

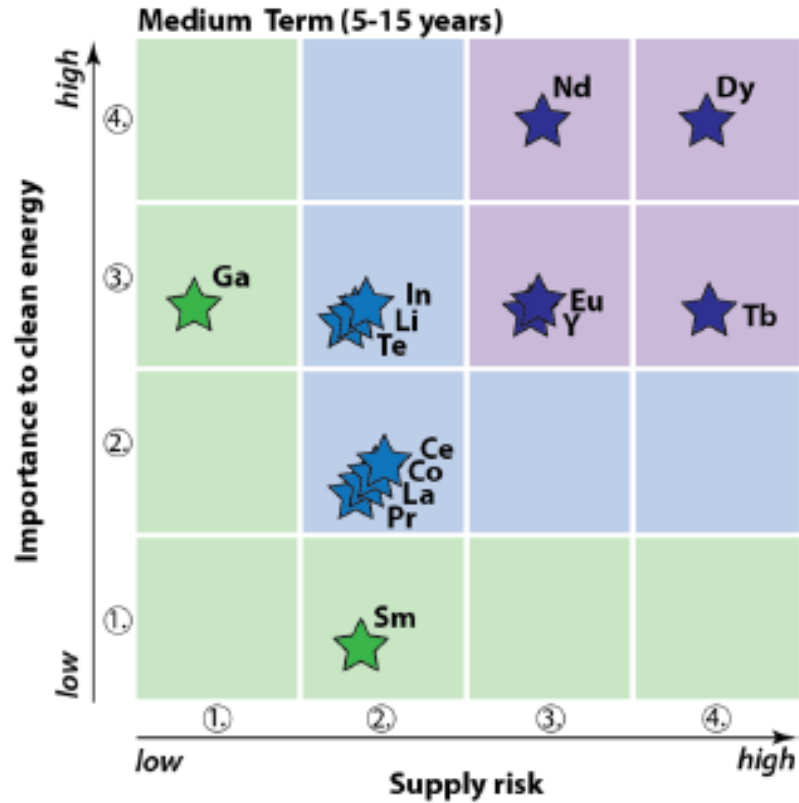


# The South Pole example



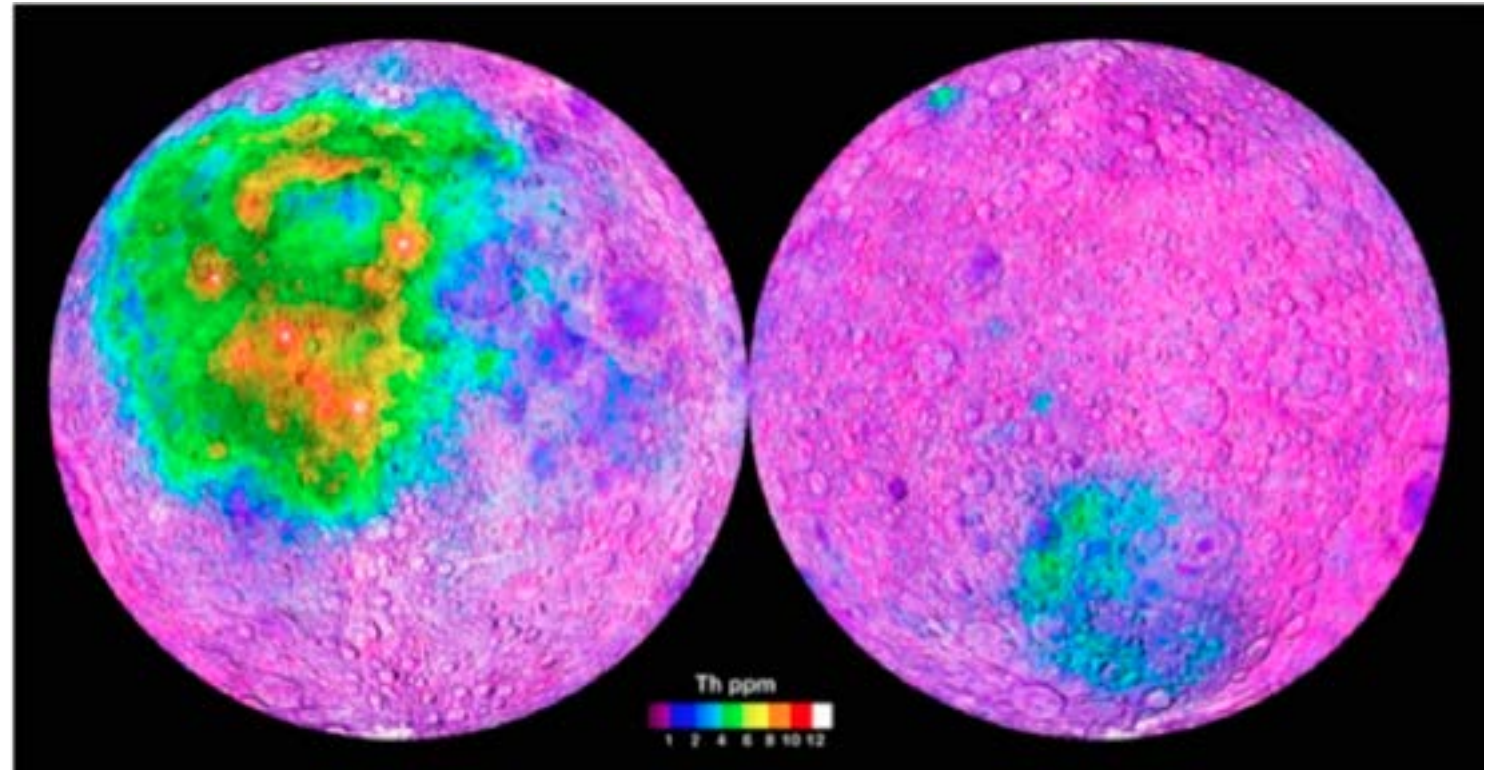
H concentration > 150ppm  
Average T < 110K  
Slope < 10°  
Within 1km of a PSR  
Illumination available

# Beyond water: rare earths?



Supply risk of REE relevant to clean energy

Source: McLeod et al, Florida University, Creative Commons Attribution License



Thorium Distribution Map

Source: NASA

# Artemis Phase 1: To the Lunar Surface by 2024

MARS 2020

ARTEMIS 1: FIRST HUMAN SPACECRAFT  
TO THE MOON IN THE 21st CENTURY

ARTEMIS 2: FIRST HUMANS TO  
THE MOON IN THE 21st CENTURY

FIRST HIGH POWER  
SOLAR ELECTRIC  
PROPULSION (SEP)  
SYSTEM

FIRST PRESSURIZED  
CREW MODULE  
DELIVERED TO  
GATEWAY

ARTEMIS 3: CREWED  
MISSION TO GATEWAY  
AND LUNAR SURFACE

## Commercial Lunar Payload Services

- CLPS delivered science and technology payloads

## Descent Element Test

- First large-scale lander on the Moon

## Early South Pole Crater Rim Mission(s)

- First robotic landing on eventual human lunar return and ISRU site  
- First ground truth of polar crater volatiles

## Humans on the Moon - 21st Century

First crew leverages infrastructure left behind by previous missions

**LUNAR SOUTH POLE CRATER TARGET SITE**

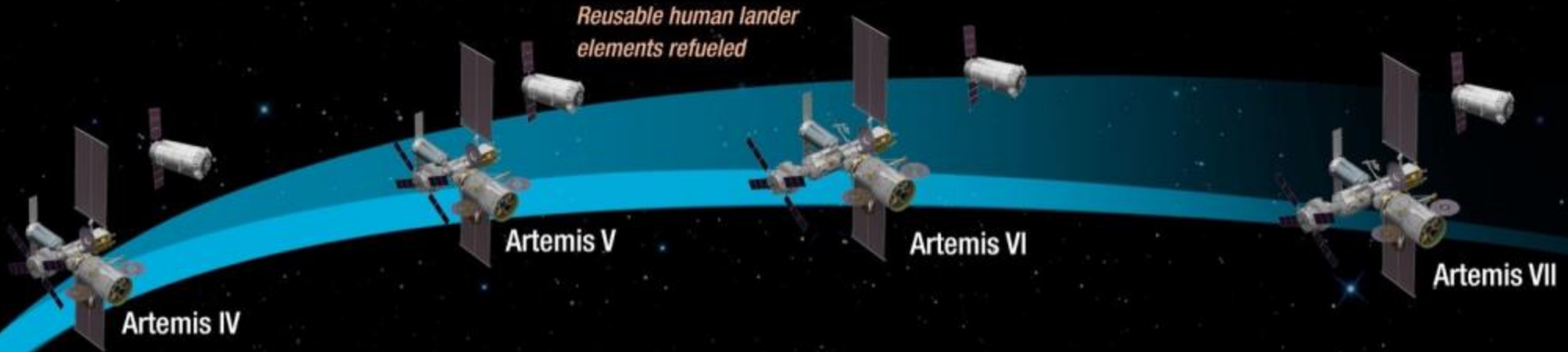
2019

2024

# Artemis Phase 2: Building Capabilities For Mars Missions



*Reusable human lander elements refueled*



Artemis IV

Artemis V

Artemis VI

Artemis VII

**Artemis Support Mission**  
*Lunar surface asset deployment for longer surface expeditions*

CLPS opportunities



## **SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION**

MULTIPLE SCIENCE AND CARGO PAYLOADS

INTERNATIONAL PARTNERSHIP OPPORTUNITIES

TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS

2025

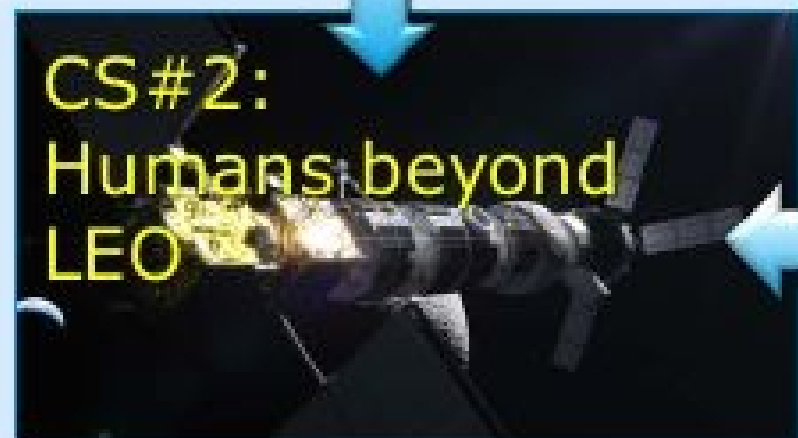
2029

# 6 Activities; 4 Cornerstone campaigns; 1 Programme

**EXPERT** space robotics



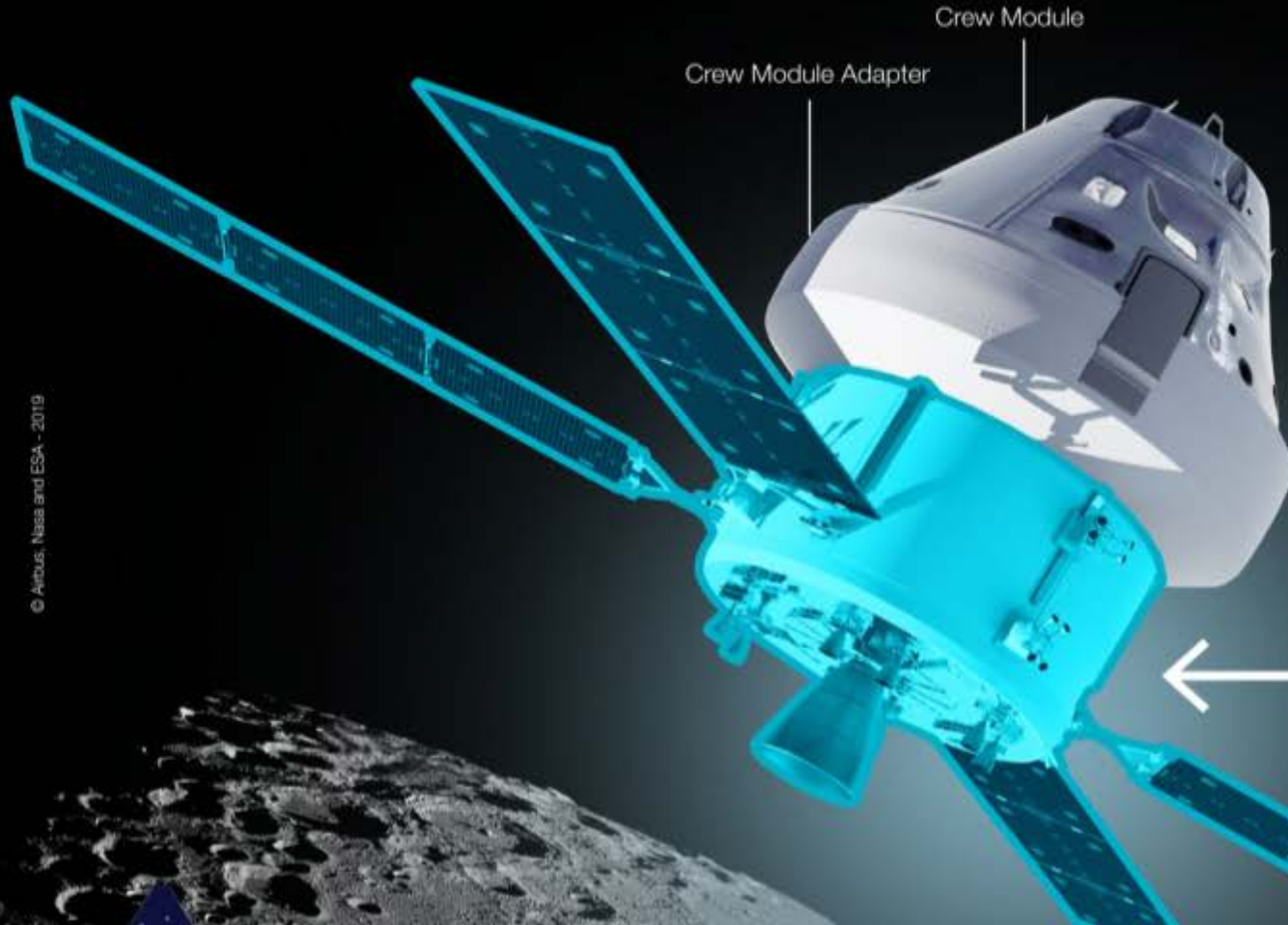

**SciSpace**

TO THE MOON  
AND BEYOND  
WITH THE

# ORION

EUROPEAN SERVICE MODULE ESM  
- BUILT BY AIRBUS



1ST SUPPLY OF CRITICAL FUNCTIONS  
FOR A NASA SPACE MISSION



Spacecraft  
**PROPULSION**



**CONSUMABLES**  
(air and water)



**ELECTRICAL  
POWER** supply



**THERMAL**  
control

**PRESSURE  
CONTROL**  
assembly (2x)

**HELIUM  
pressurant  
tanks** (2x)

**PROPELLANT  
tanks** (4x)

**REACTION  
CONTROL  
thrusters**  
(24x)

**GAS  
tanks**  
(4x)

**RADIATOR  
PANELS**  
(6 in total)

**WATER  
tanks**  
(4x)

**SOLAR ARRAY  
panels** (4x)

**Main  
ENGINE**

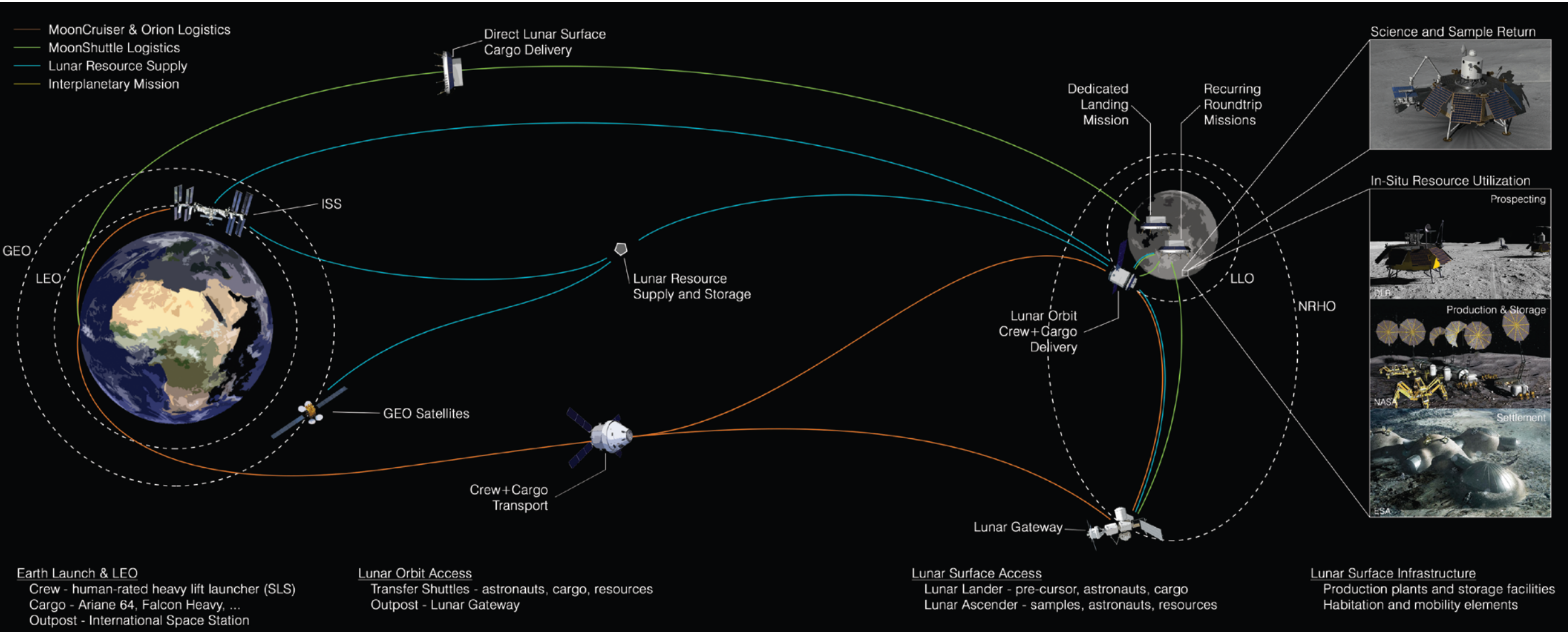
**Auxiliary  
THRUSTERS** (8x)

Airbus is prime contractor to ESA



# Lunar Logistics – Moon Shuttle and Moon Cruiser

## Utilization of Lunar Resources by a Cis-Lunar Economy





# CLTV

Europe's own Earth-Moon transport and contribution to Gateway logistics



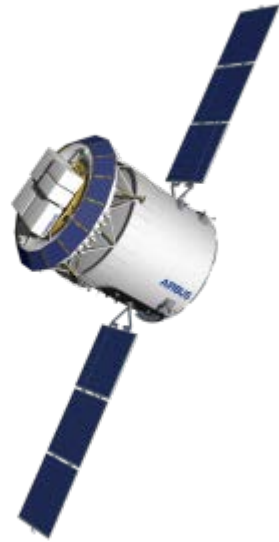
## Missions linked to the Gateway



Cargo delivery



Module delivery



GTO/LTO to LLO tugging of EL3 lander



NRHO to LLO tugging



Orbital propellant depot

## FEATURES

- Enabler for EL3 extended missions
- Participates in Gateway logistics
- Valuable contribution for international co-operation
- Designed for Ariane 6, but in principle compatible with others

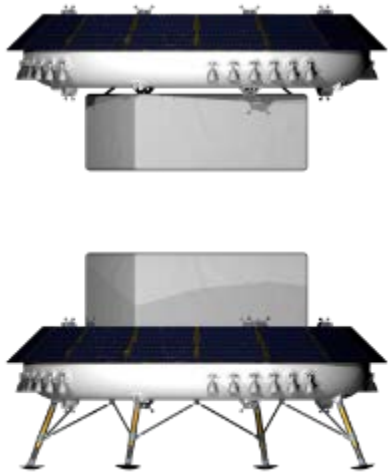
## Missions compatible with Ariane 6

# EL3

And Airbus' concept for the world's first reusable lander/ascender

## Single Shot Mission

Moon Shuttle on Ariane 64

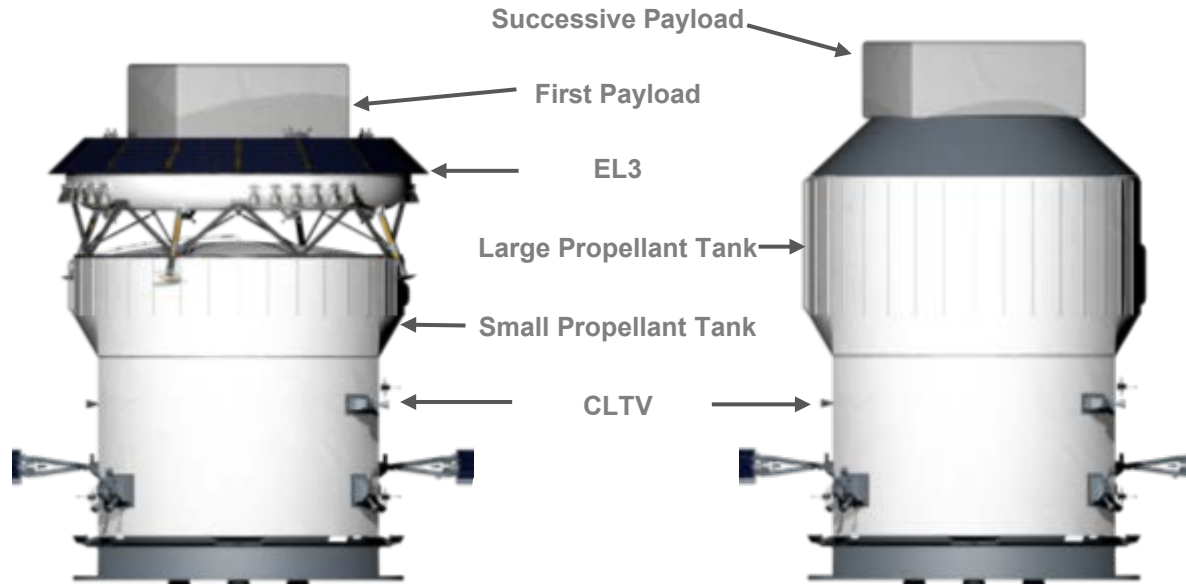


## Round Trip Mission

Moon Shuttle and Moon Cruiser

### First Round Trip

### Recurring Round Trip



## AUTONOMOUS MISSIONS

- Goal EL3: >1.5t cargo to the lunar surface on Ariane 64
- Independent of Gateway and US capabilities
- Significantly extends first US crewed surface missions

## SYNERGIES WITH CLTV

- Same vehicle returns to orbit (no debris left on Moon)
- Return payload from surface
- Refueling in LLO and resupply by CLTV
- Recurring cargo capacity depending on launcher GTO/TLI performance



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THANK YOU