MOON VILLAGE #Space4.0 : In Situ Resource Utilisation & Manufacturing Habitats

Bernard Foing & Jan Wörner

European Space Agency

(with thanks to Claudie Haigneré & Moon Villagers group, Ugo Laffont, Advenit Makaya & Young Lunar Explorers)

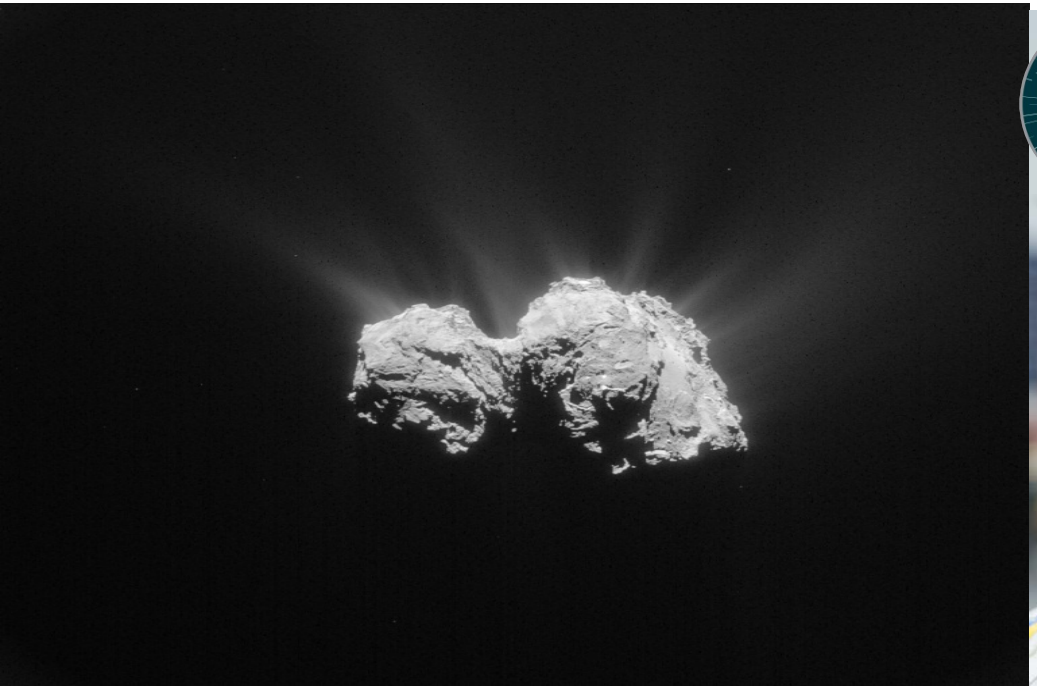
(European) heritage

- democracy, human rights....
- diversity of cultures
- philosophy and arts
- science and development
- **pioneering and exploration**

Space:

→ Fascination…Inspiration…Motivation

The Rosetta mission



The proxima mission

→ What‘s next?

Post ISS

Minimum requirements

- human and robotic
- microgravity-lab
- fundamental research possibilities
- international activities
- inspiring and useful
- science and development
- springboard for future (deep) space travels
- independent access for different actors
- more than a single mission
- multi purpose / space 4.0

1) frequent LEO – activities
2) international exploration activity

AURORA Programme 2001

Proposal: sustainable moon surface operations

Proposal: sustainable moon surface operations

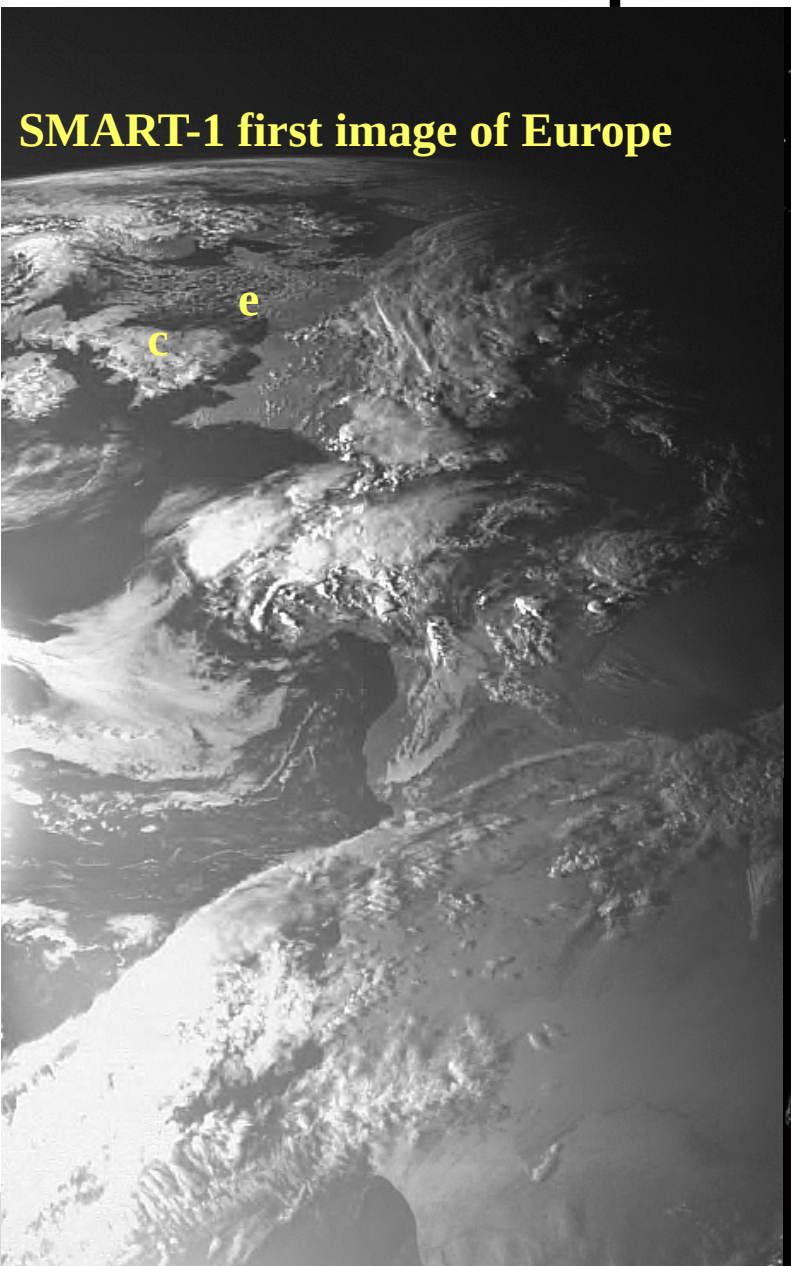
esa

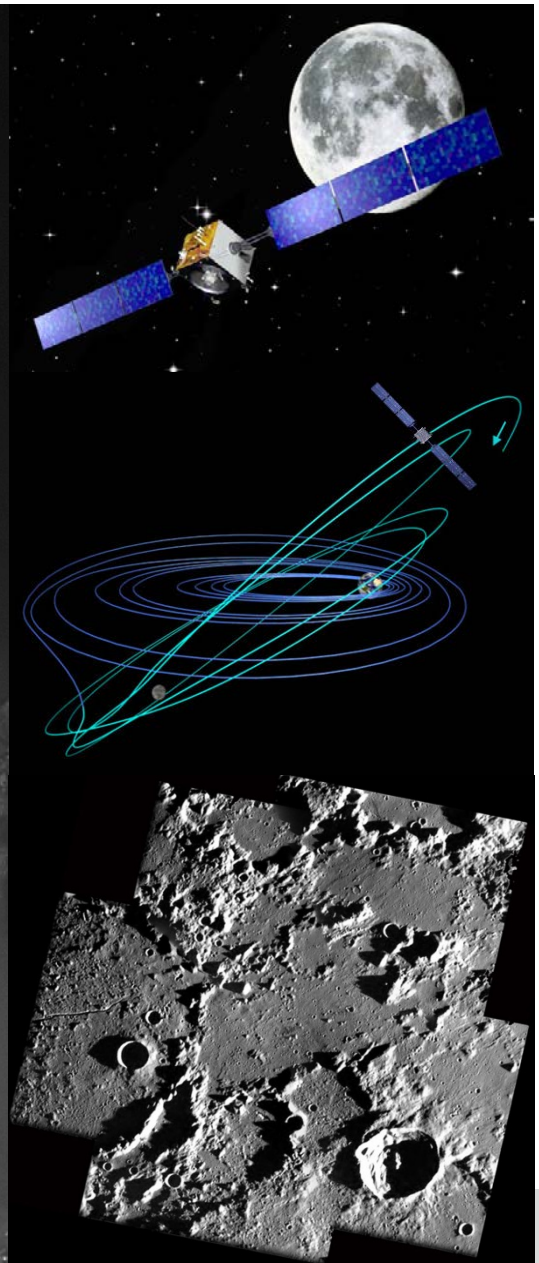
Exploration
Human & robotic
Public & commercial
Moon Science
Cosmology / astronomy
Fundamental research
Transportation
Resource management
Mining & Manufacturing
Communication
Technology
Pioneering
Stepping stone...
Tourism
Outreach /STEM

Free and open access, multiple uses and multiple users

10 years ago, SMART-1 touched down the Moon

http://sci.esa.int/smart-1/





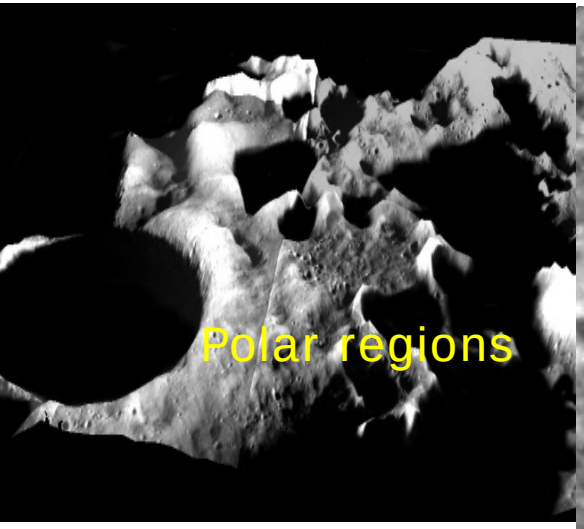
First European lunar orbiter
Test new technologies
- Solar Electric Propulsion
- instrument miniaturisation
- Faster, cheaper, smarter

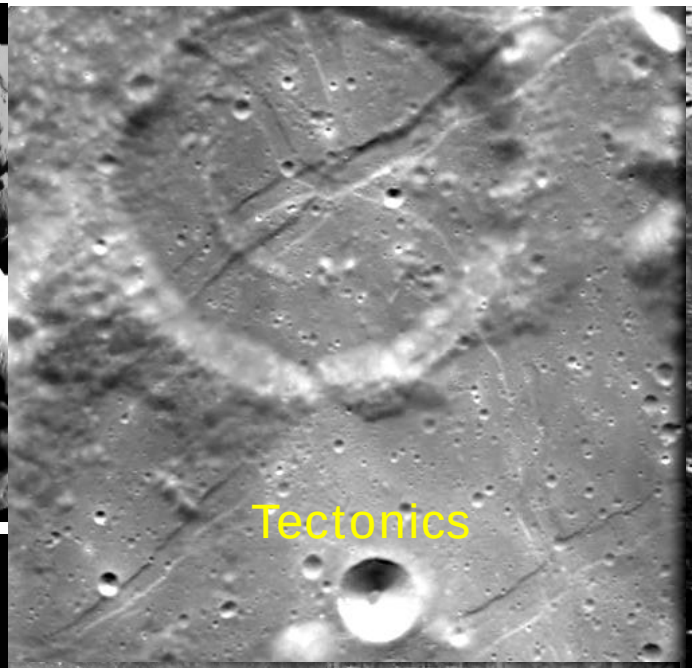
Launch mass: **370 kg**
Payload: 19 kg

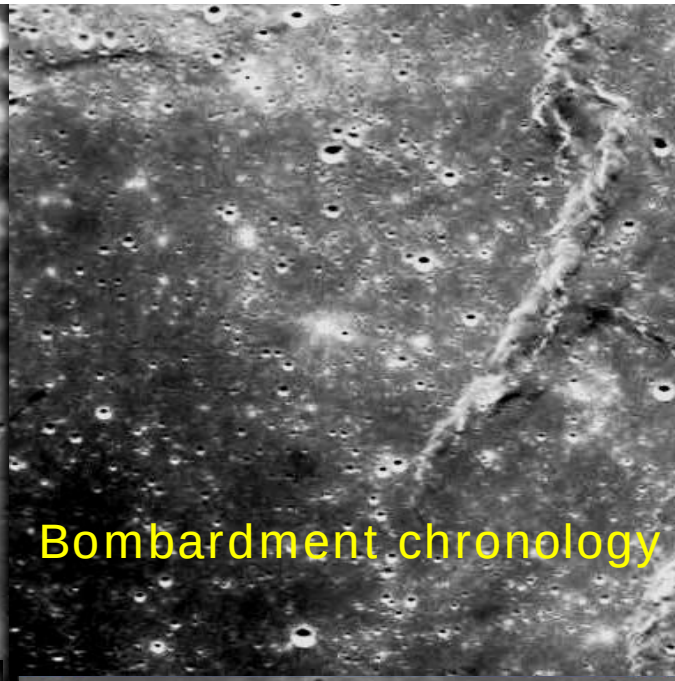
Launch date: **27 Sept 2003, Ariane 5**
Lunar capture: 15 Nov. 2004
Science orbit 15 March 2005
Mission: **6 + 12 months nominal lunar orbit operations until Impact 3 Sept 2006**

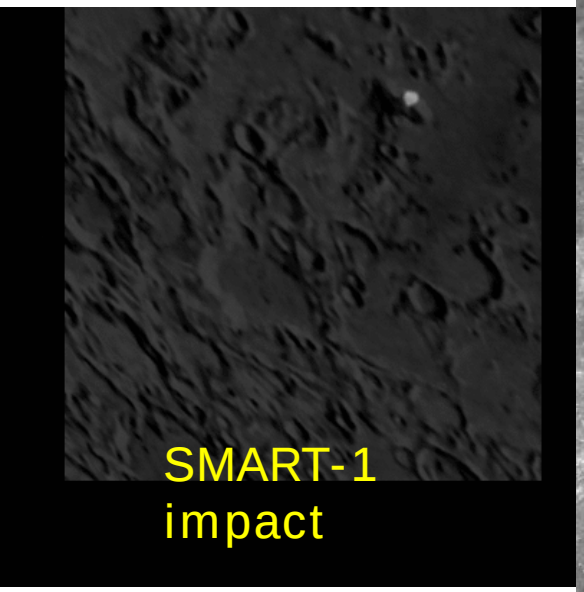
Data on PDS archives,
80 refereed publis

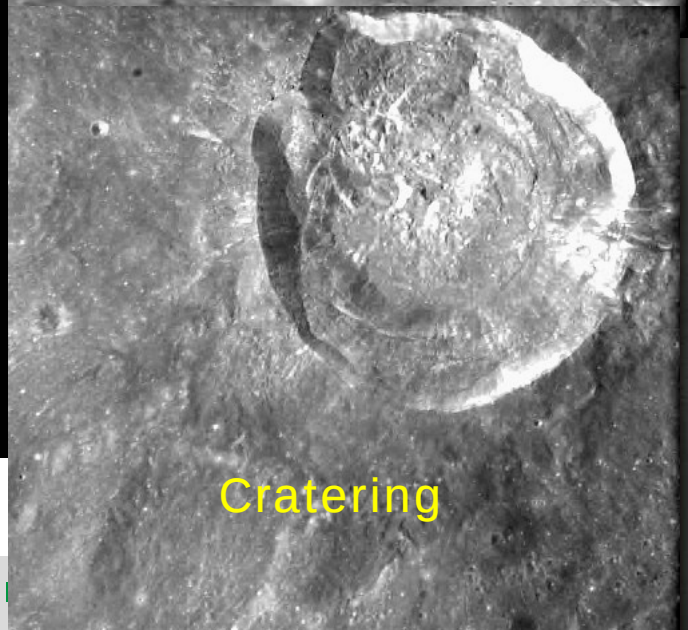
What shapes rocky planets?

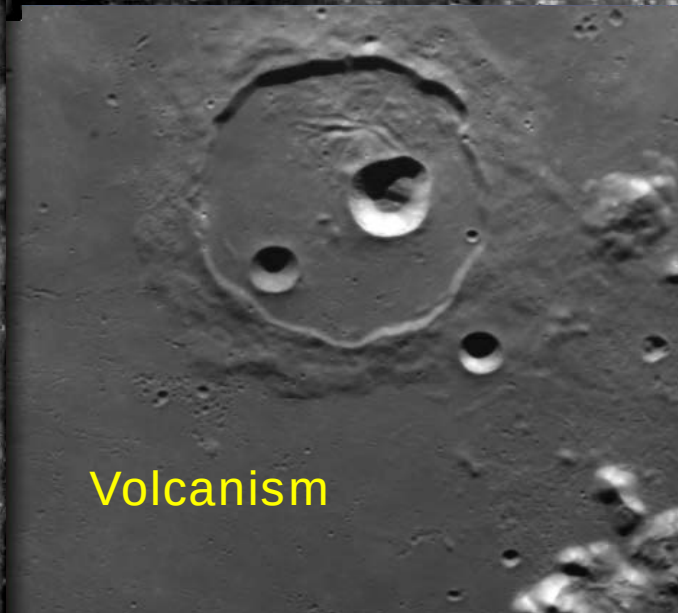




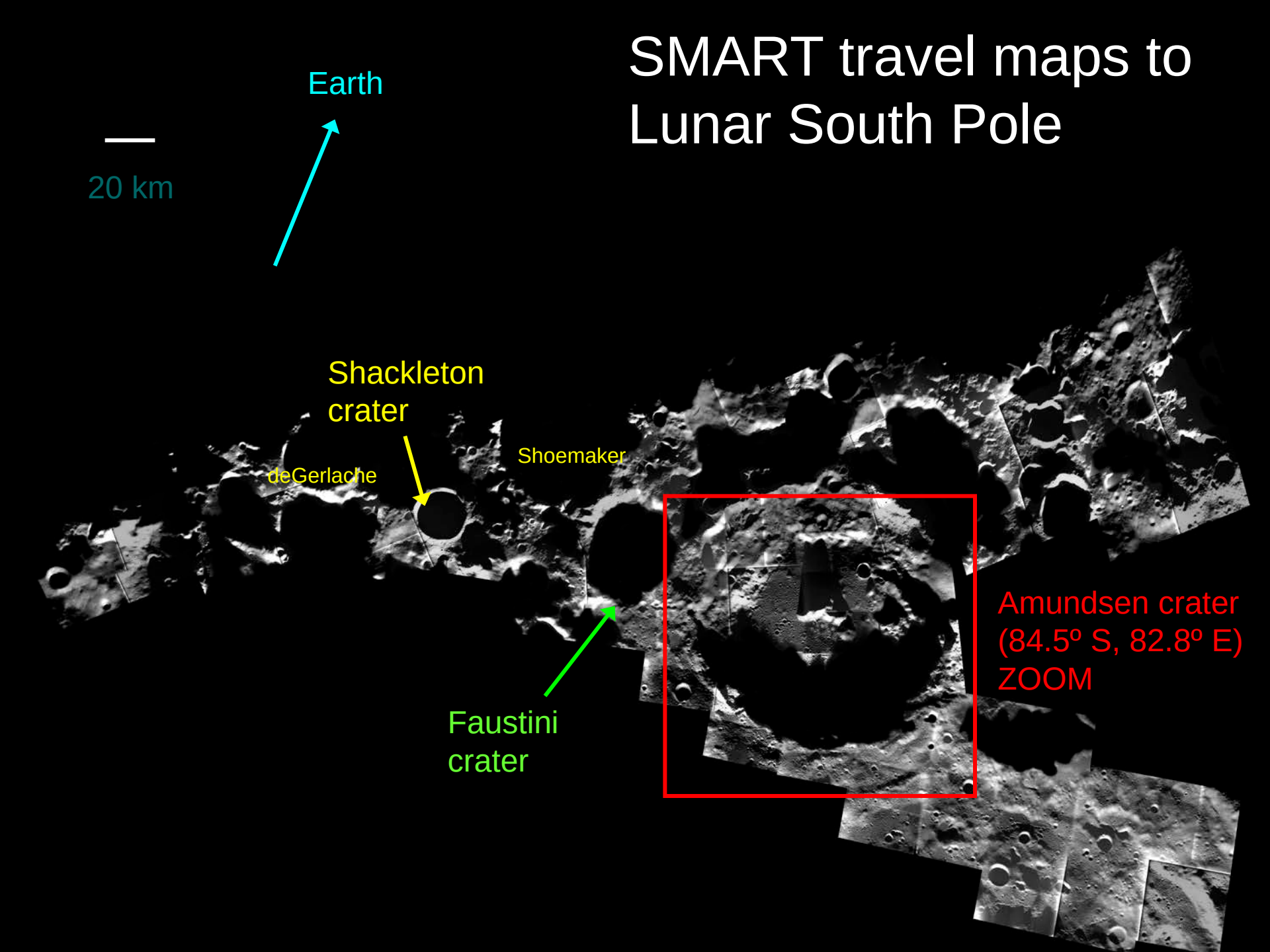


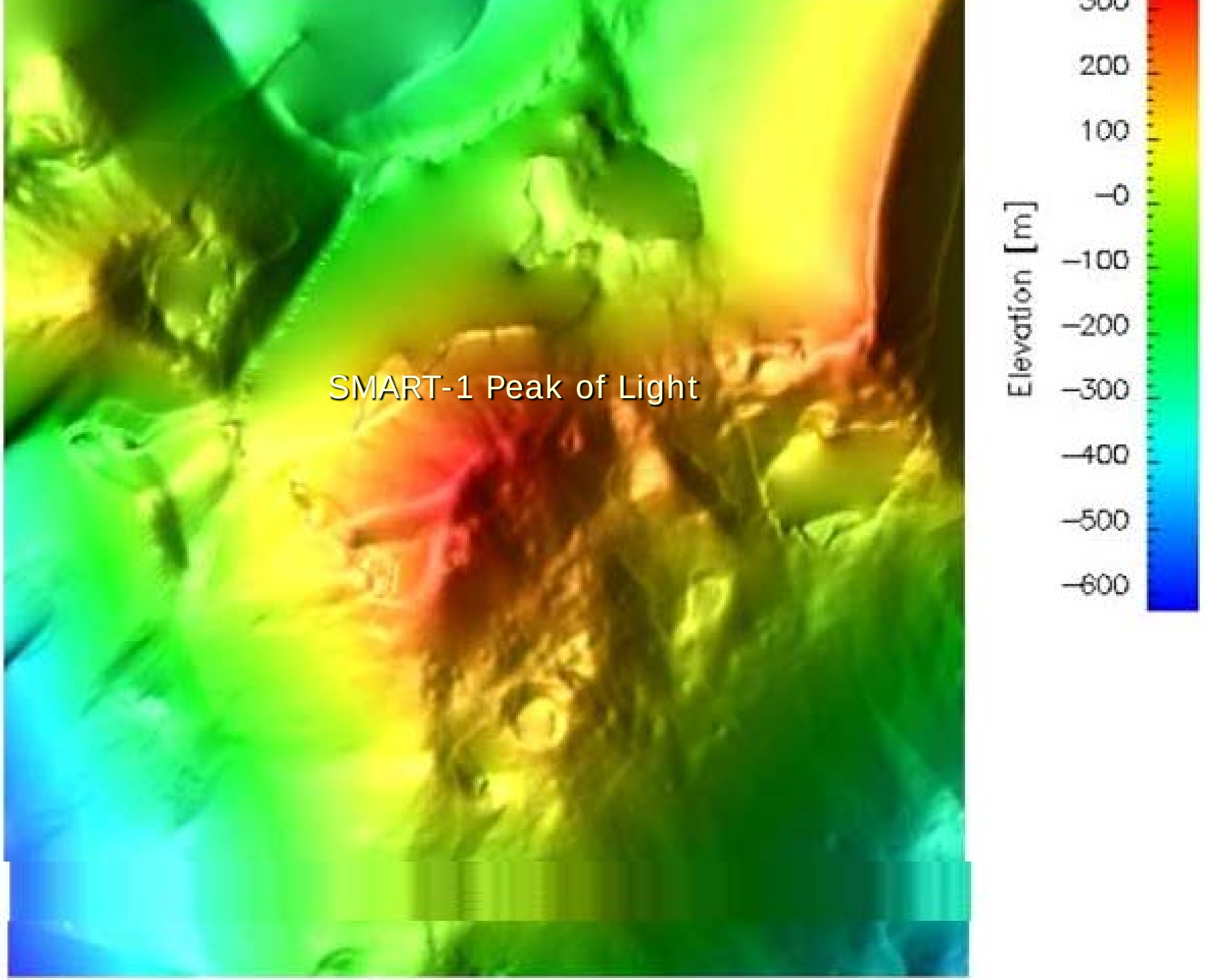






SMART travel maps to Lunar South Pole




SMART-1 Peak of Light
Elevation [m]
200
100
0
−100
−200
−300
−400
−500
−600

ILEWG International Lunar Exploration Working Group

ICEUM Int'l Conferences on Exploration & Utilisation of the Moon:

- **ICEUM1 Beatenberg 94 (chair Prof H. Curien)**
- **ICEUM2 Kyoto 96 (chair Prof H. Mizutanu)**
- **ICEUM3 Moscow 98 (chair Acad. E. Galimov)**
- **ICEUM4 ESTEC 2000 (300 participants, Chair BH Foing)**
- **ICEUM5 US Hawaii Nov 2003,**
- **ICEUM6 Udaipur, India, 22-26 Nov 2004, co-Chair N. Bhandari)**
- **ICEUM7 Toronto 2005 Canada co-Chairs B. Richards, C. Sallaberger)**
- **ICEUM8 Beijing 06 after COSPAR (co-Chair Prof Wu Ji)**
- **ICEUM9 Sorrento 2007 (300 participants) (co-chair ESA/ASI/ILEWG)**
- **ICEUM10 Cape Canaveral (co-chairs Drs M. Wargo, C.Neal)**
- **ICEUM11 Global Lunar Conference Beijing (co-chair Dr Li Ming)**

(500 participants + 400 local students)

ILEWG sponsored lunar sessions

COSPAR: Washington 92, Hamburg 94, Nagoya 98, Warsaw 00, Houston 02, Paris 04, Beijing 06, Montreal 08, Bremen 10, Mysore 12, Moscow 14

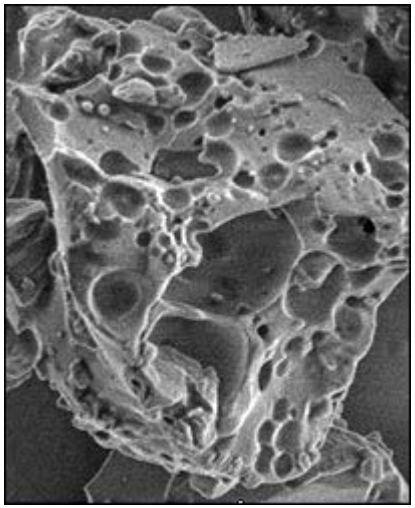
EGS/EGU lunar sessions: Vienna 97, Nice 98, The Hague 99, Nice 2000 – 2004, Vienna 2005 - 2017

Publications, Information exchange: lunar register database

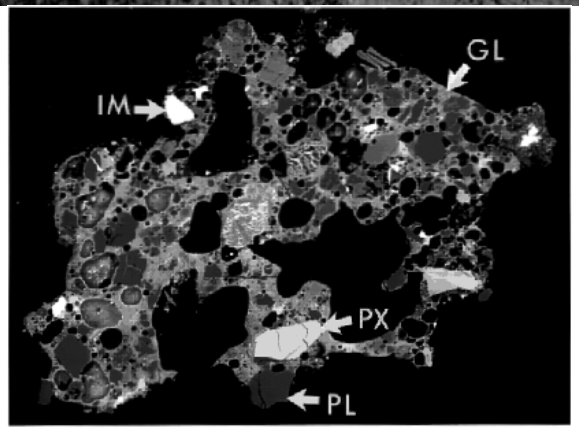
Public outreach, lunar explorers, web, ILEWG calendar

Grants for Students, Field research, Moon Village workshops

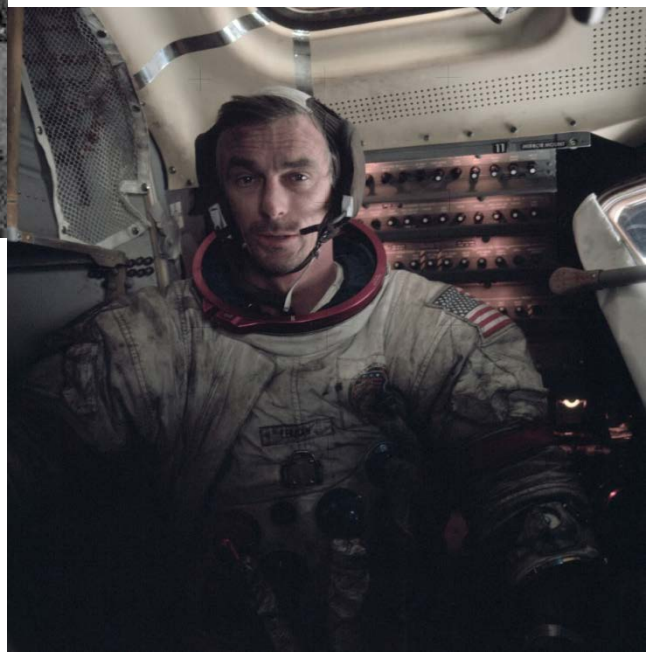
Lunar Environment Soil



- Abrasive
- Charged
- Irritant
- Slow settling down

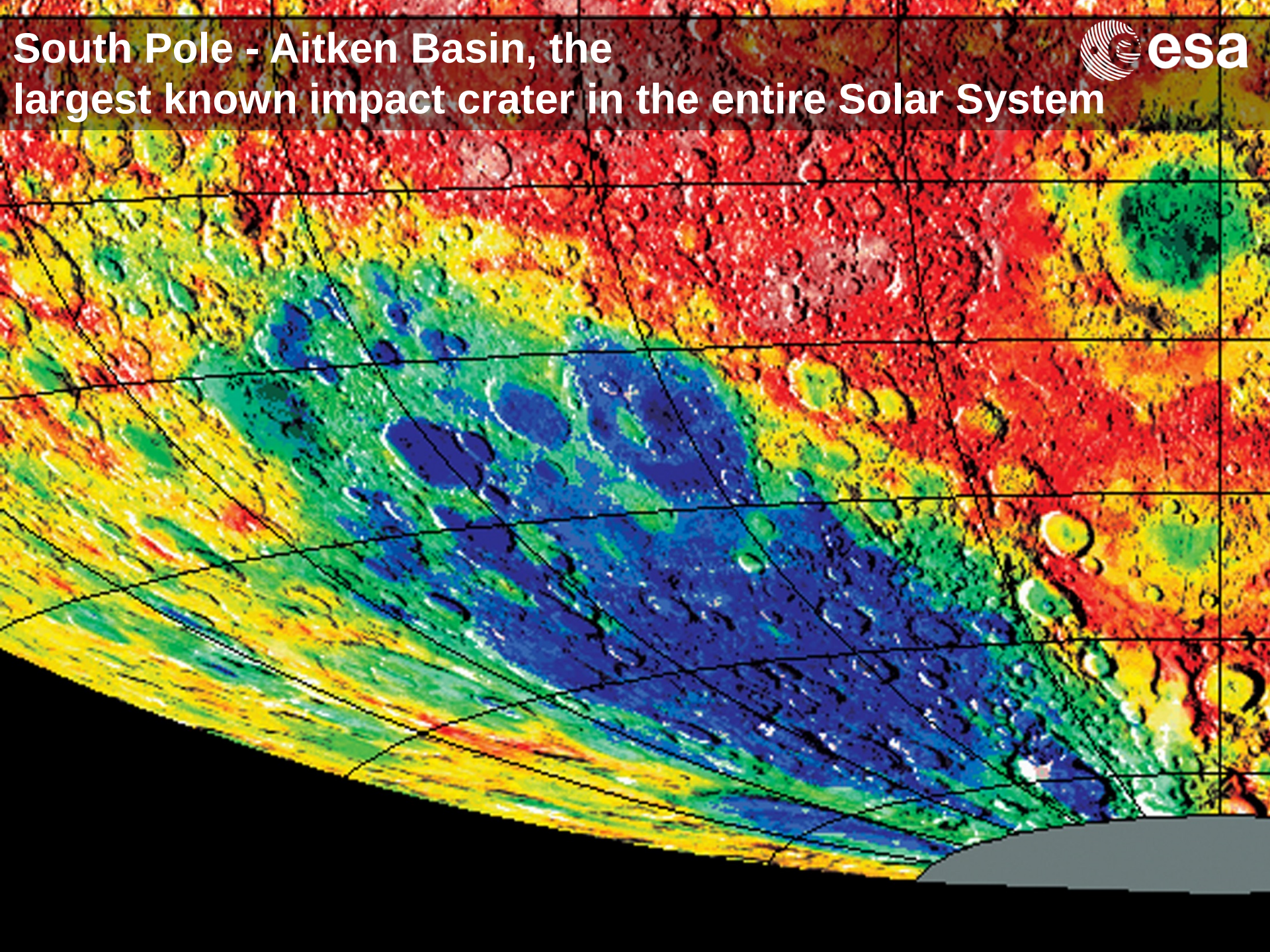


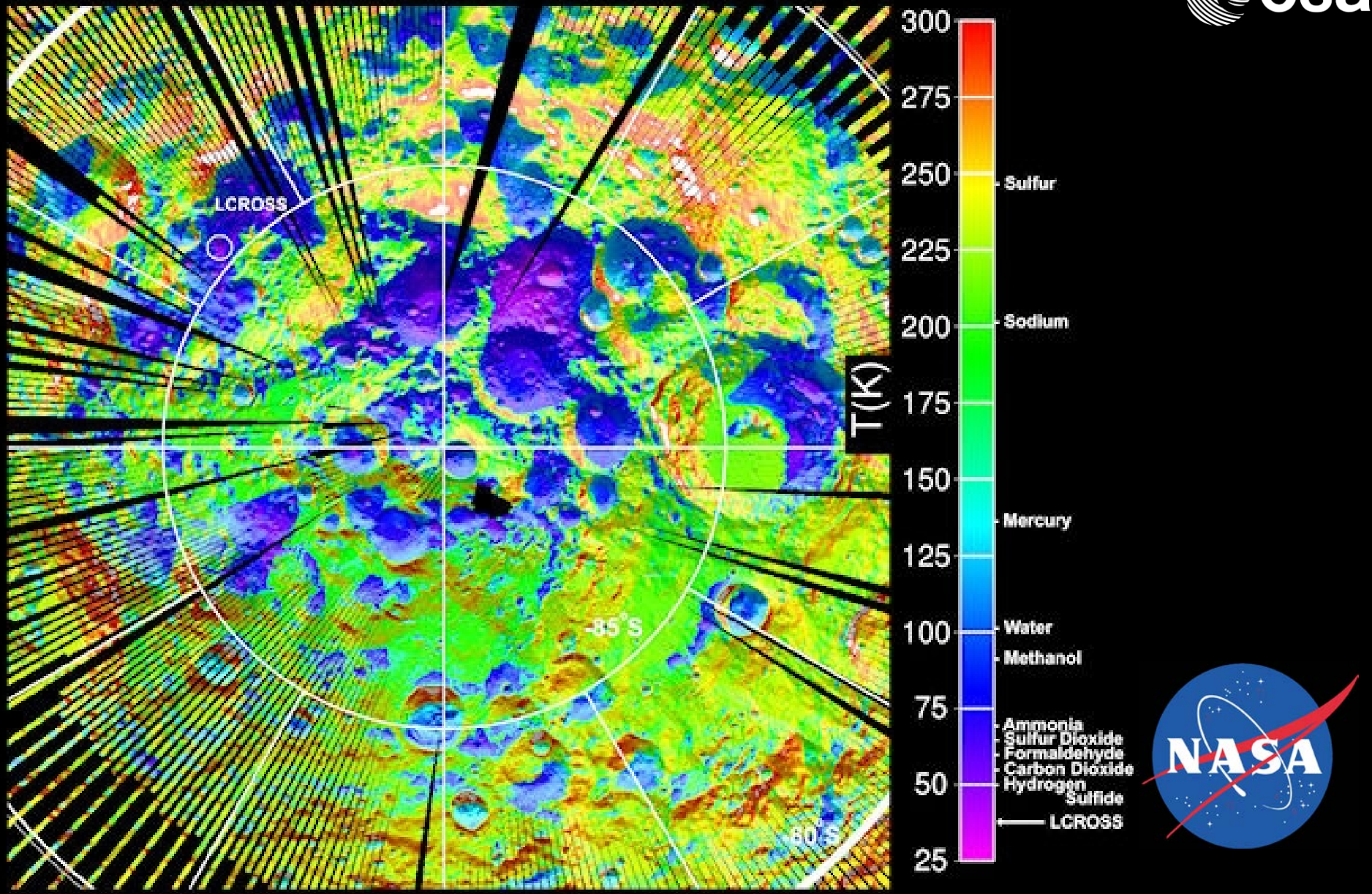
Apollo 17



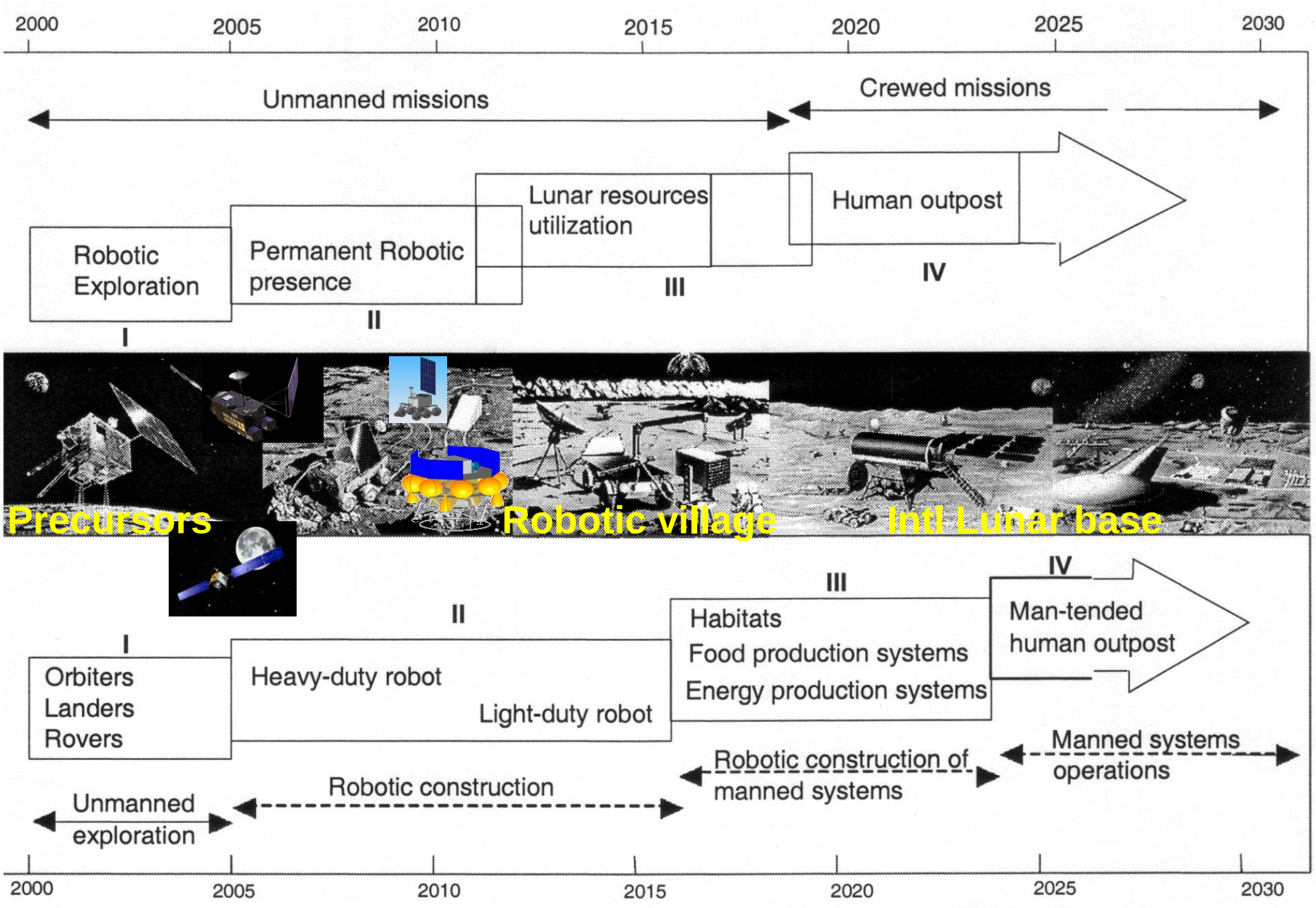
Eugene A. Cernan

South Pole - Aitken Basin, the largest known impact crater in the entire Solar System



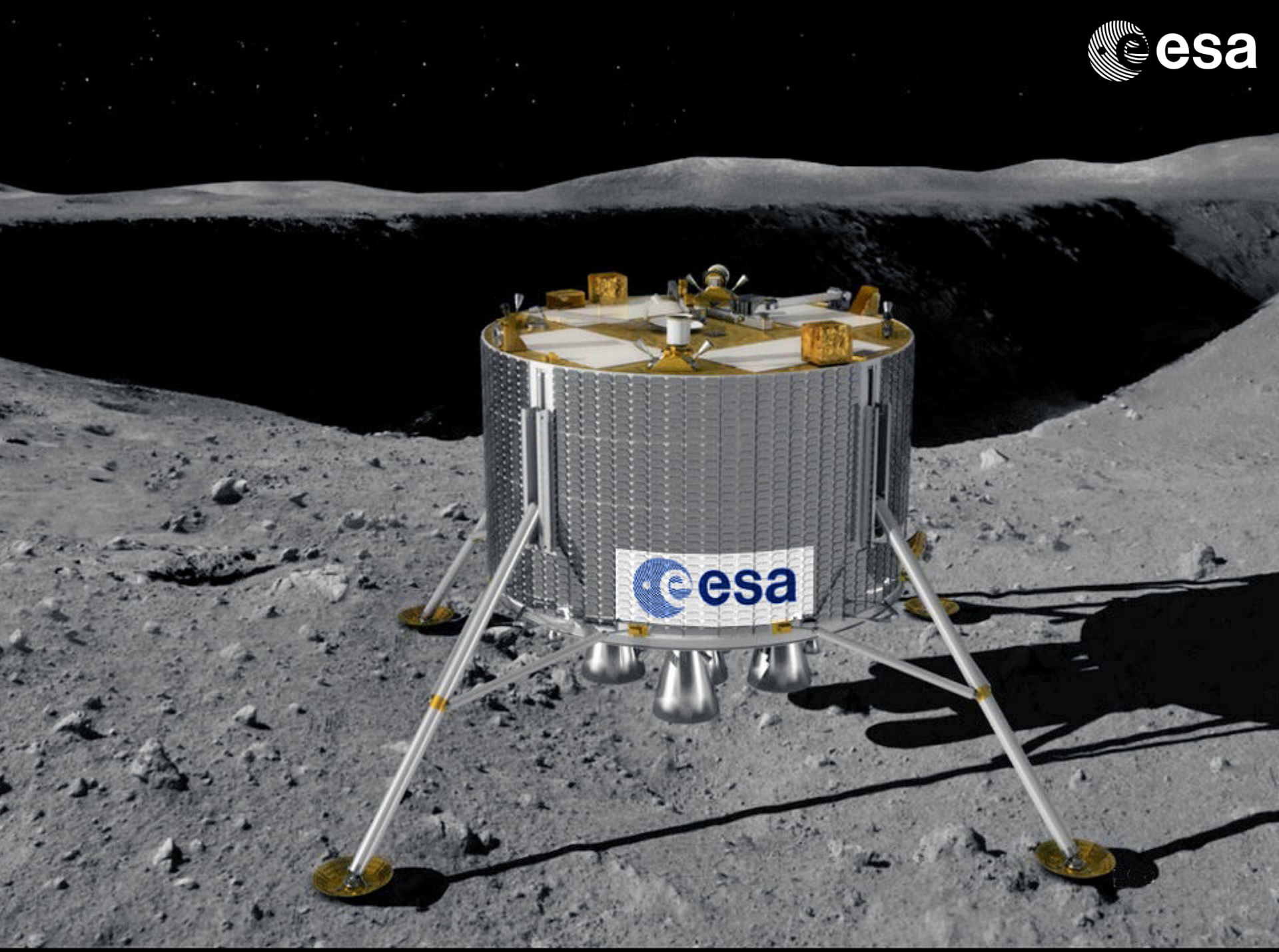

LCROSS
-85°S
80°S
T(K)
300
275
250
225
200
175
150
125
100
75
50
25
Sulfur
Sodium
Mercury
Water
Methanol
Ammonia
Sulfur Dioxide
Formaldehyde
Carbon Dioxide
Hydrogen Sulfide
LCROSS

Roadmap: International Lunar Exploration Working Group (sci.esa.int/ilewg)



ESA Human Exploration Destinations: LEO, Moon, Mars

- LEO destination confirmed with continuation of ISS station operations
- Start of human exploration beyond LEO with cooperation with NASA on Orion Multi Purpose Crew Vehicle – European Service Module (2018 Lunar fly-by)
- MPCV Exploration Missions 2&3: from 2022, 4 crew to Moon, beyond and back


esa
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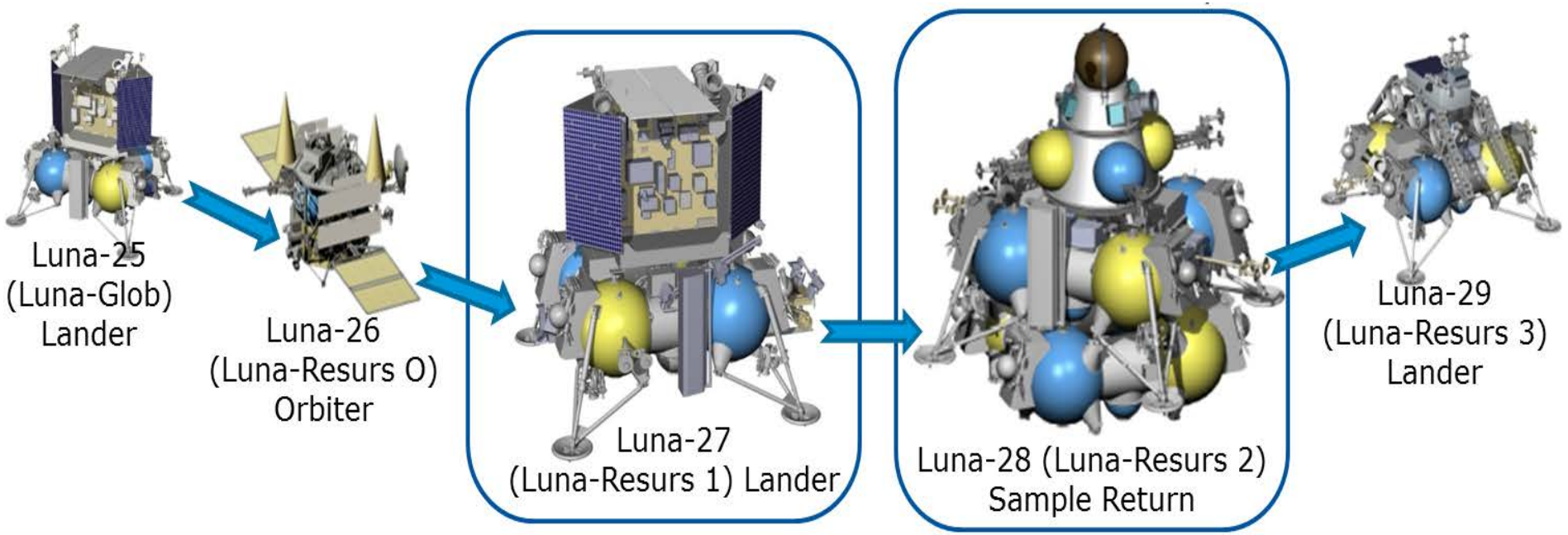
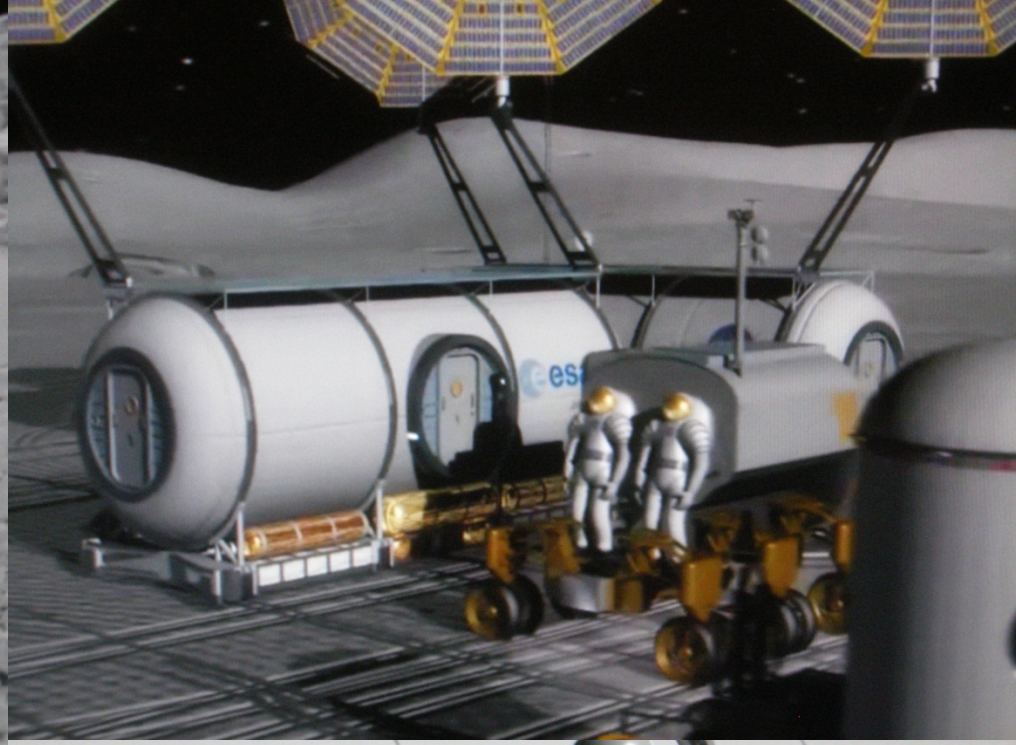
ROSCOSMOS/ESA Cooperation on Lunar Exploration



Main focus of ROSCOSMOS/ESA Lunar Cooperation

Extended Deep Space Habitat to prove ground for Moon & Mars

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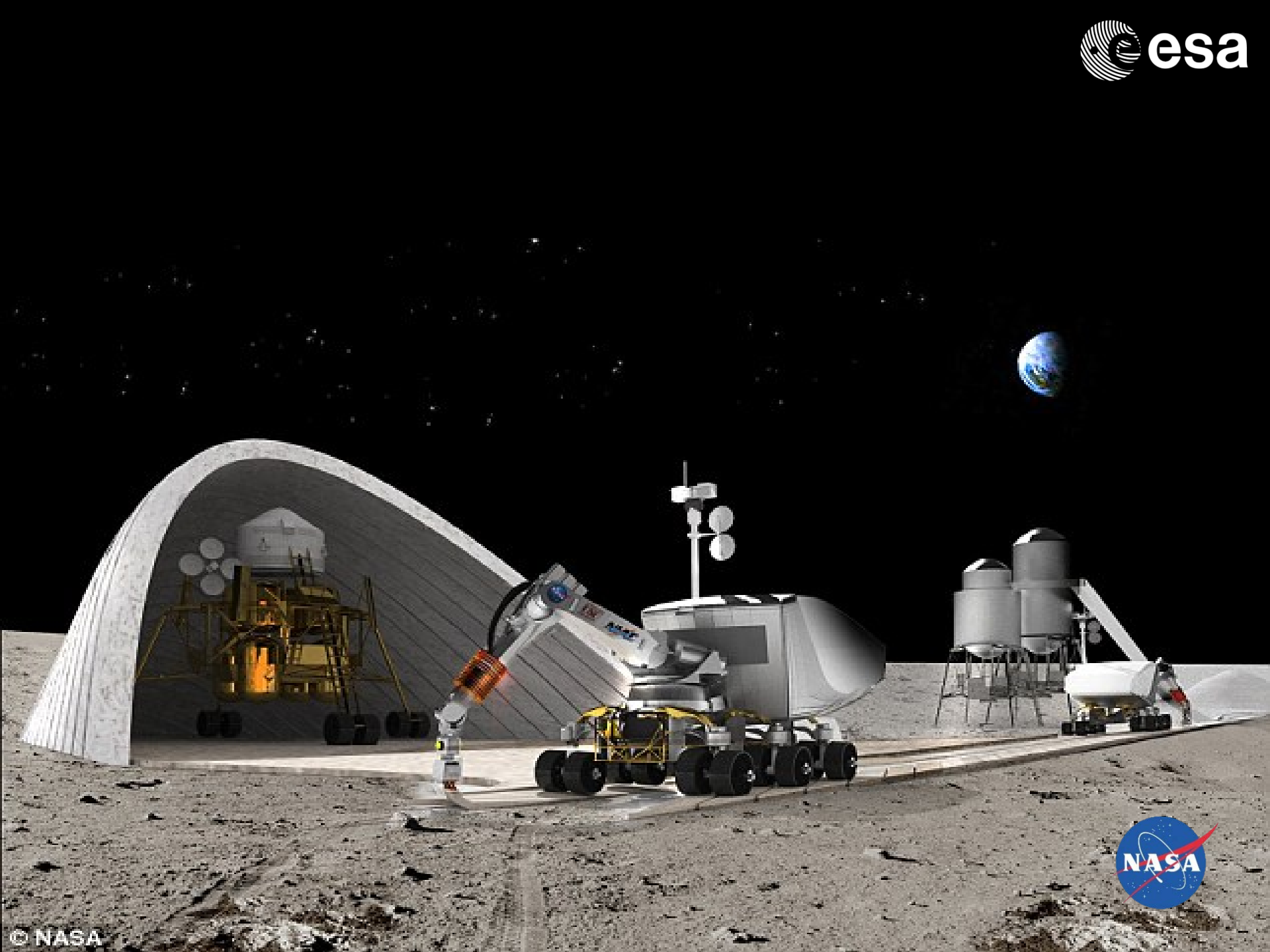
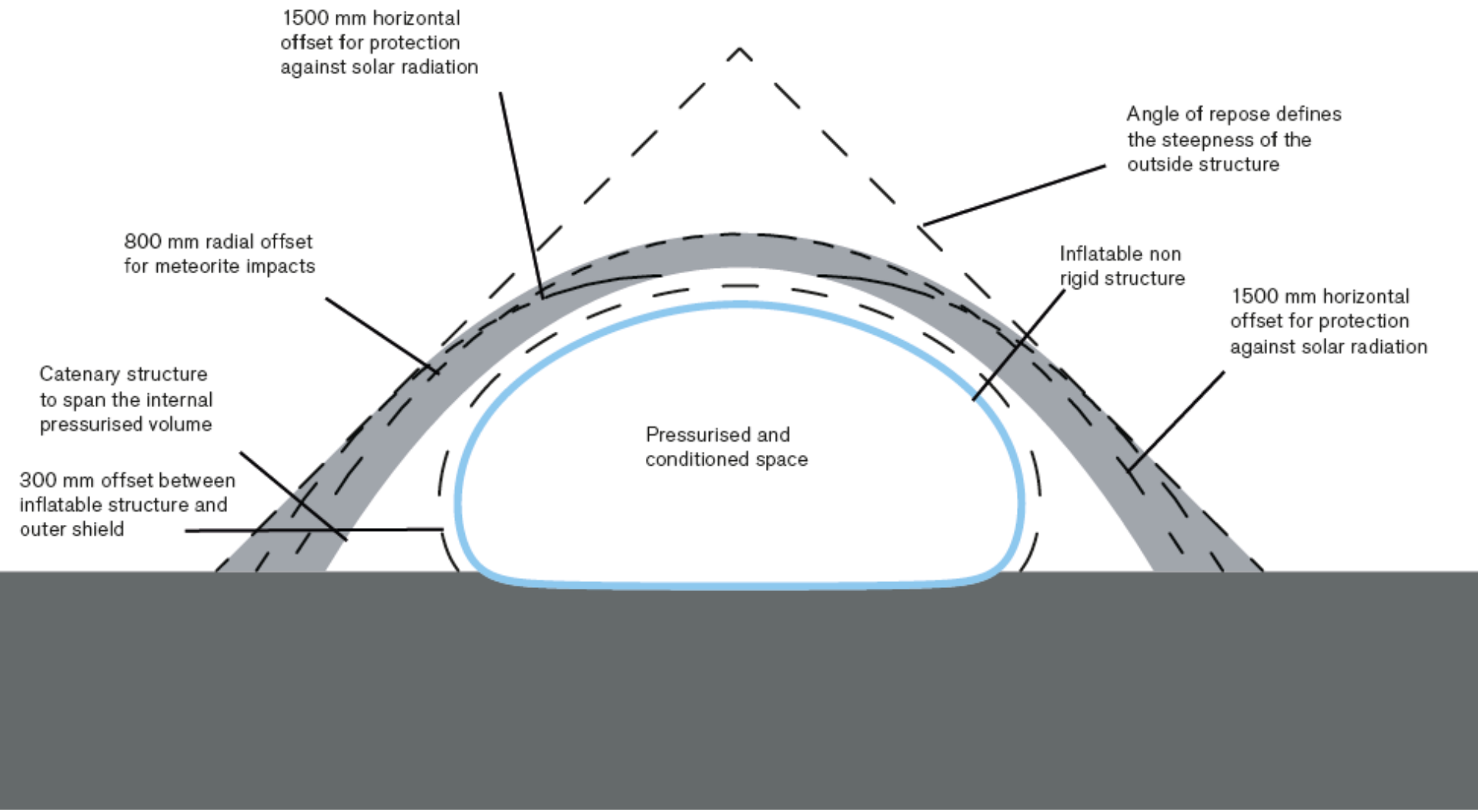
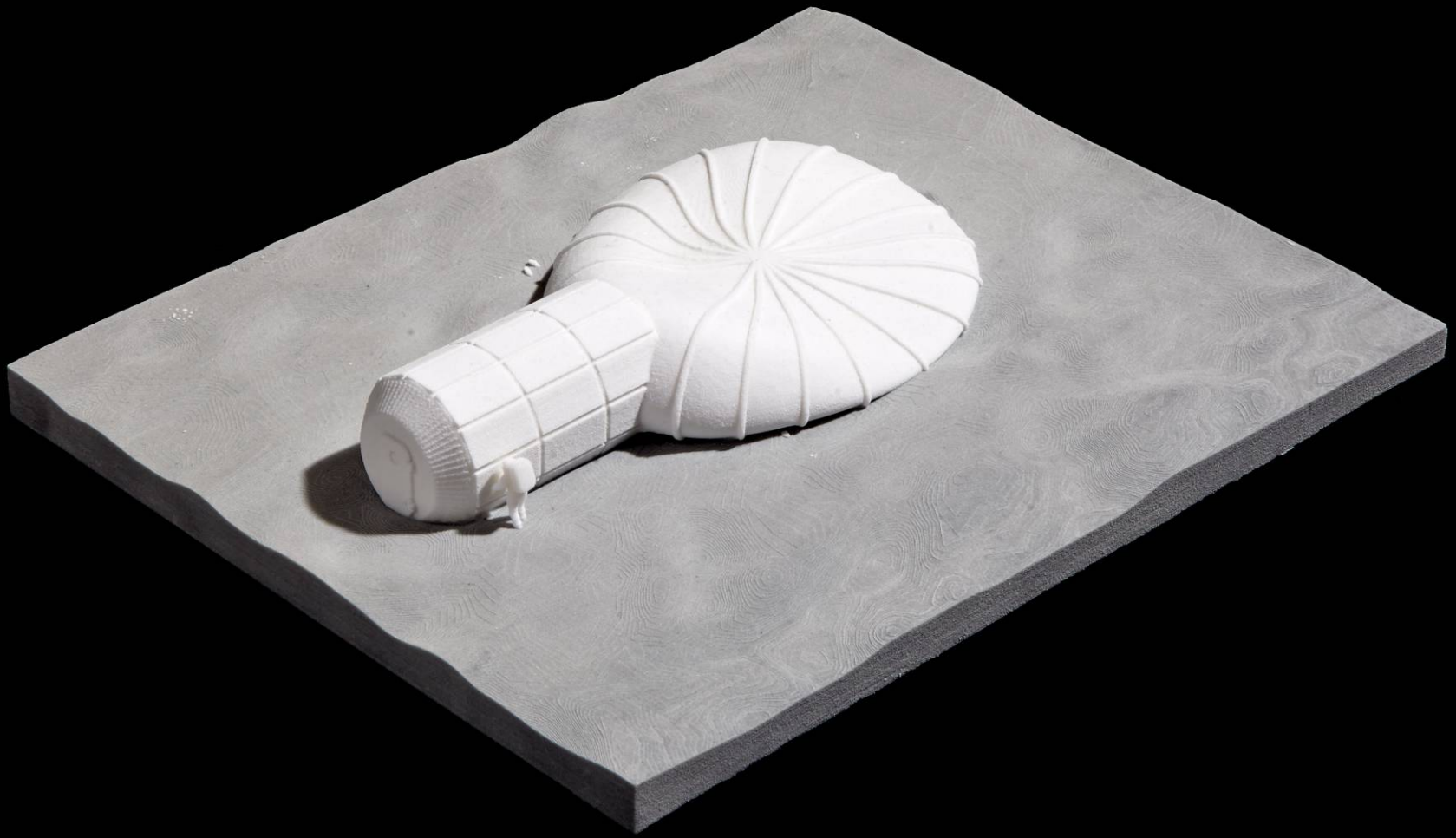
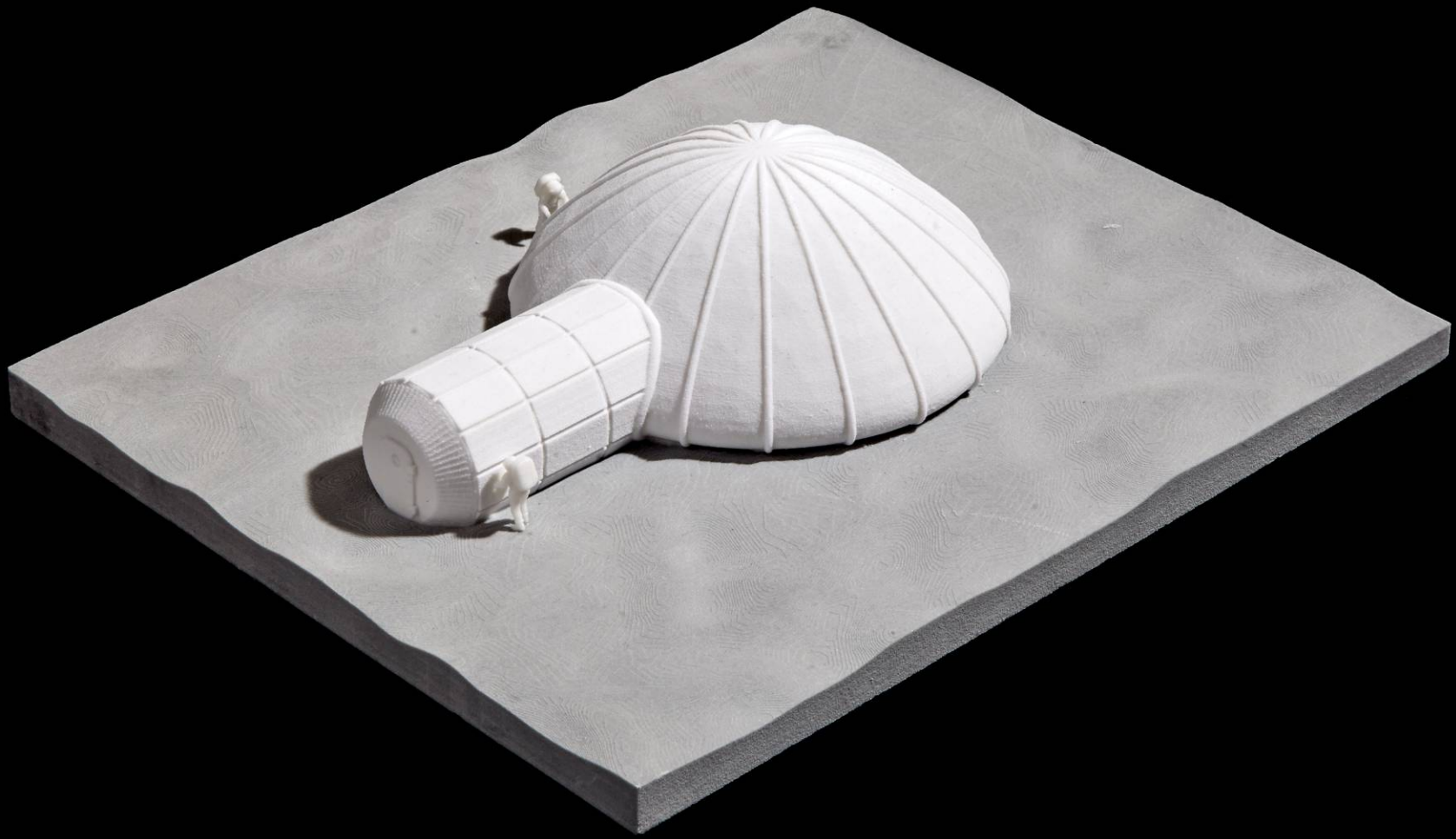
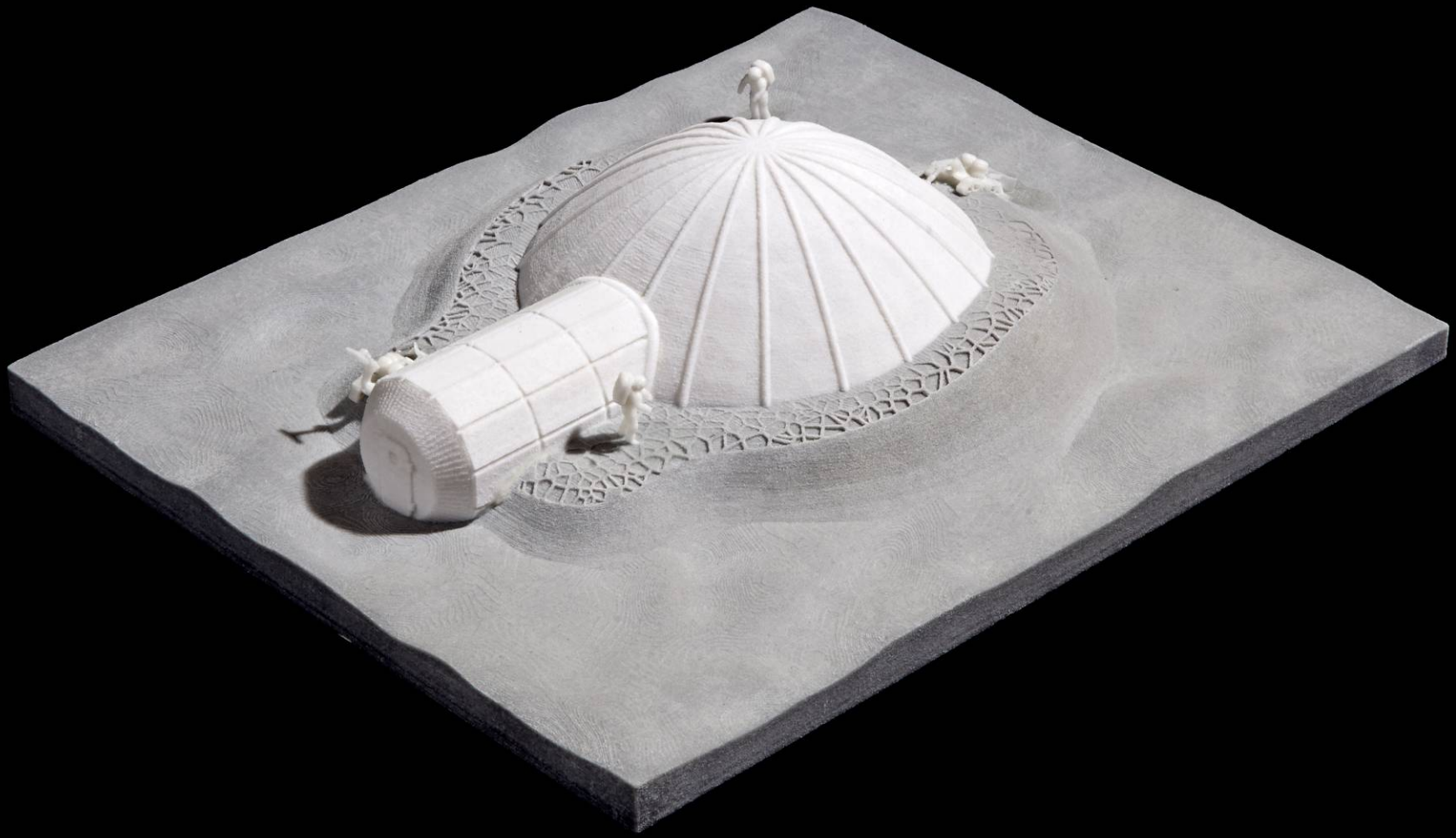

esa
NASA
© NASA

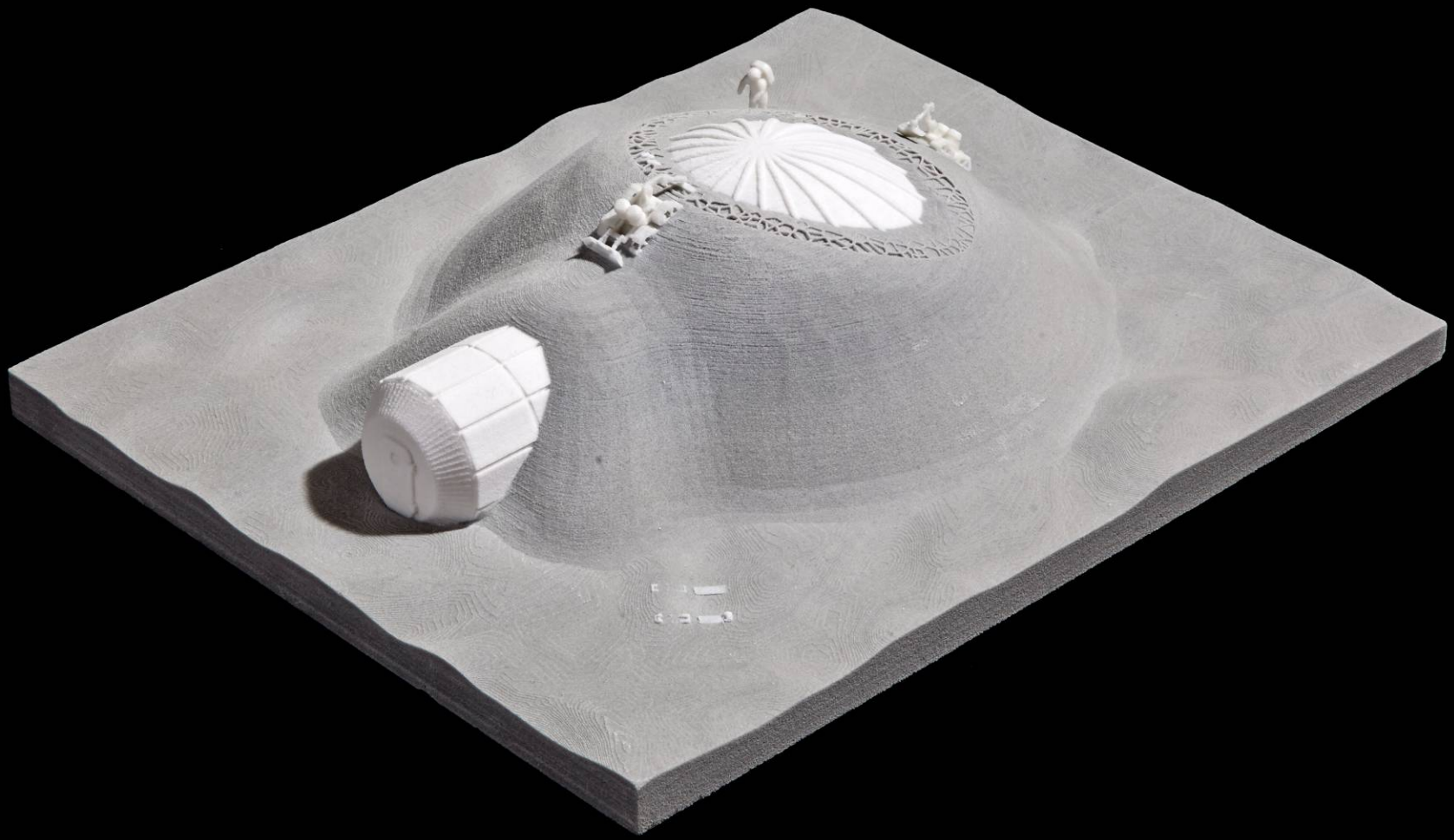
Lunar base conception

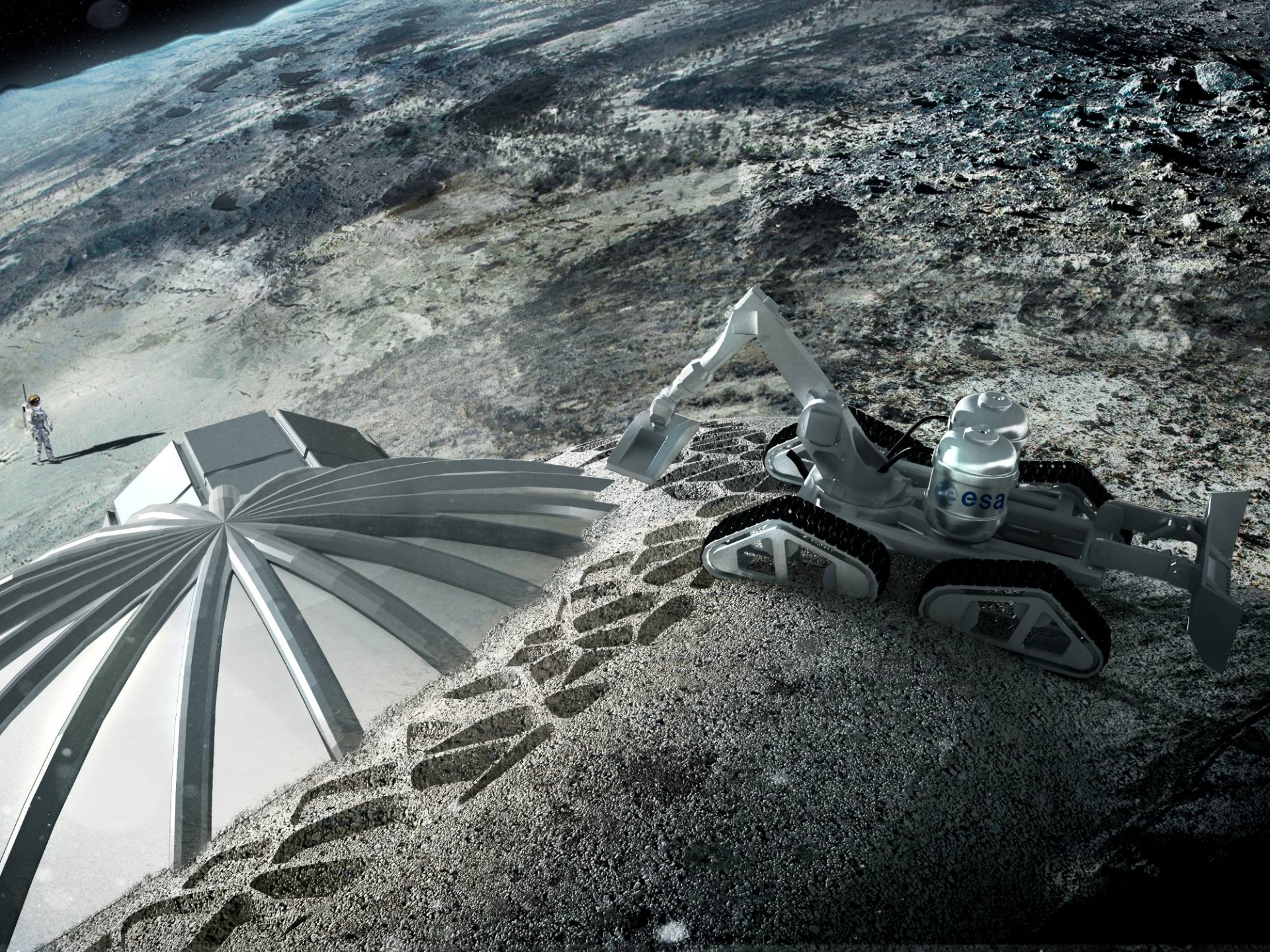











esa


esa

Challenges to Moon Manufacturing

Materials and bulk glasses, volatiles, organics

Robotic production

Telerobotic exploration, utilisation, construction

In situ manufacturing of solar arrays

Technologies

Manufacturing research

Industrial evolution, legislation, regulation

Global Earth-Moon economy

MOTIVATION - Living with Limited resources

FROM CLOSE SYSTEM

DEPENDENCE ON CARGO

TRANSPORTATION COST

HABITAT MAINTENANCE

TO EXPANDING SYSTEM

- INCREASE AUTONOMY
- MINIMIZE LOGISTIC NEEDS
- DIFFERENT CONCEPTS

HUMAN EXPLORATION / SETTELMENT / EXPANSION

MOTIVATION - MANUFACTURING NEEDS

NEED FOR MULTI PURPOSE MANUFACTURING TOOL

GENERAL MAINTENANCE CONCEPT

- Less exchange with spare parts from ground
- Enable versatile in-situ repair

MANUFACTURING FOR EXPANSION

ADDITIVE MANUFACTURING / 3D PRINTING

NEED FOR RAW MATERIALS

- MINIMIZE MATERIAL SCARCITY
  - Use of local resources / Harvesting technologies
- OPTIMIZE USE OF IMPORTED RESOURCE
  - Packing density / High functionality
  - Full recycling / Zero waste

THERMOPLASTIC / METAL / REGOLITH

FUTURE TECHNOLOGIES

ROBOTISATION – FULL AUTOMATION – UP SCALING

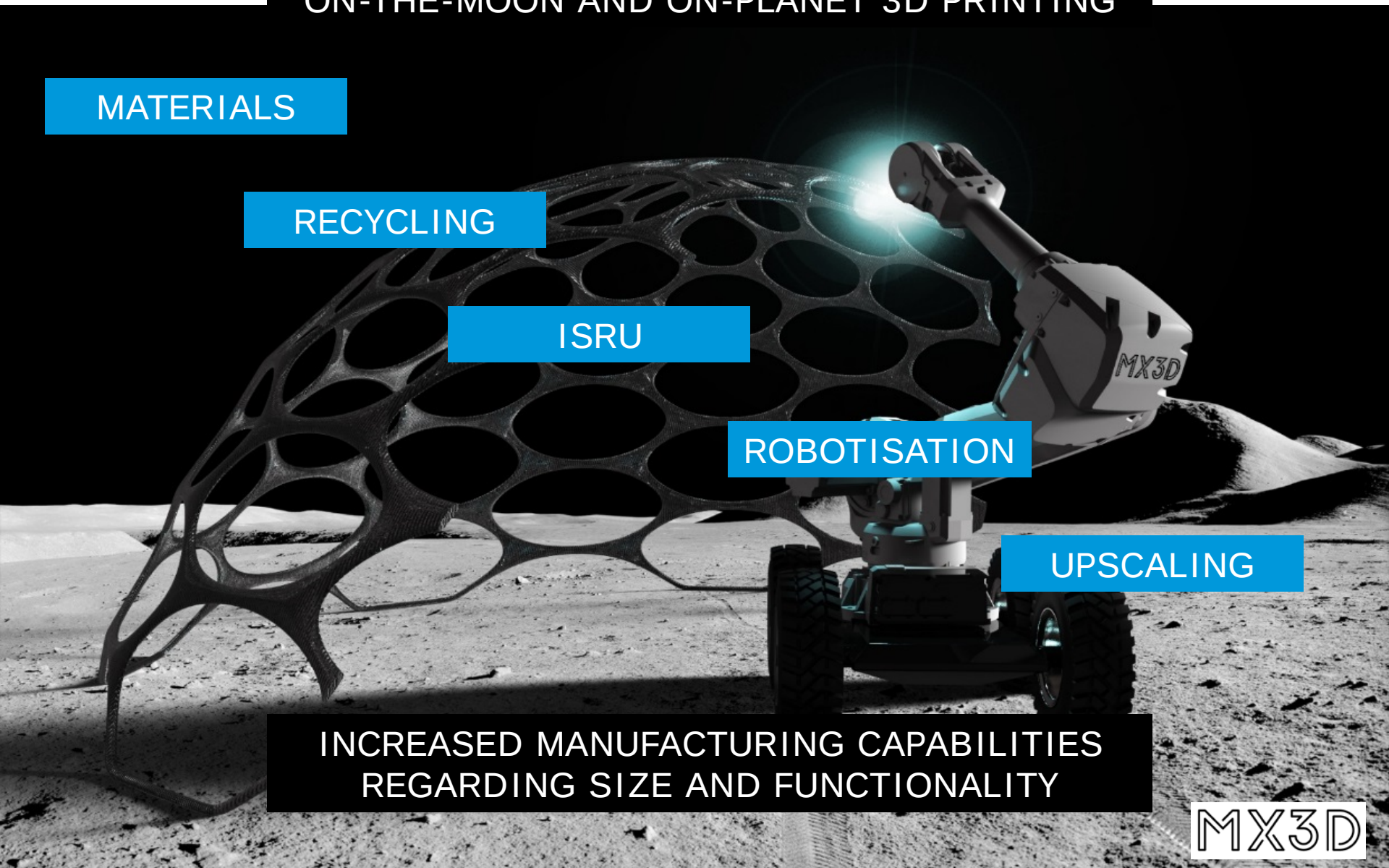
- BIG STRUCTURE
- INTELLIGENT DESIGN

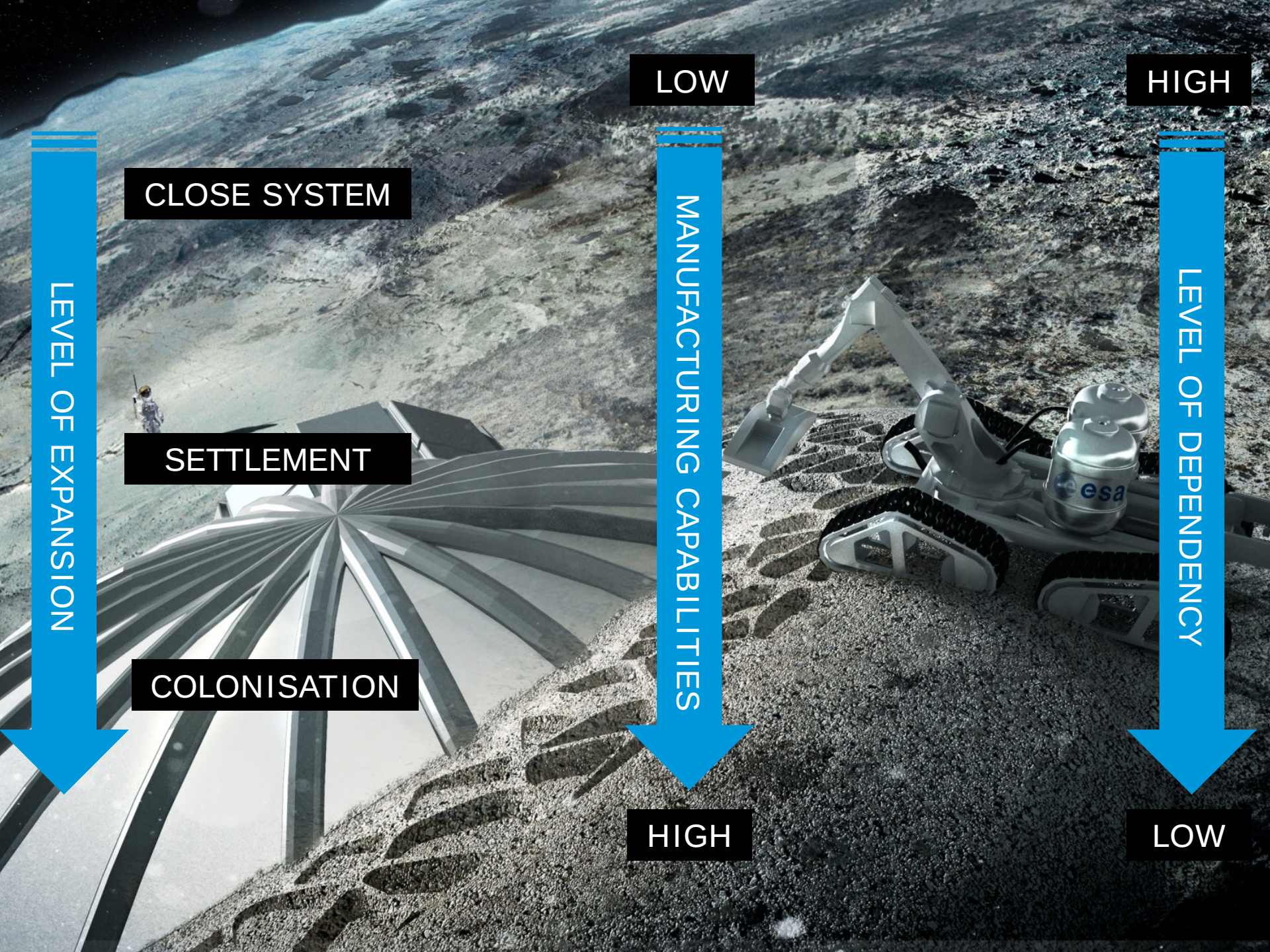
SETTLEMENT AND EXPANSION

MX3D

FUTURE ?

ON-THE-MOON AND ON-PLANET 3D PRINTING

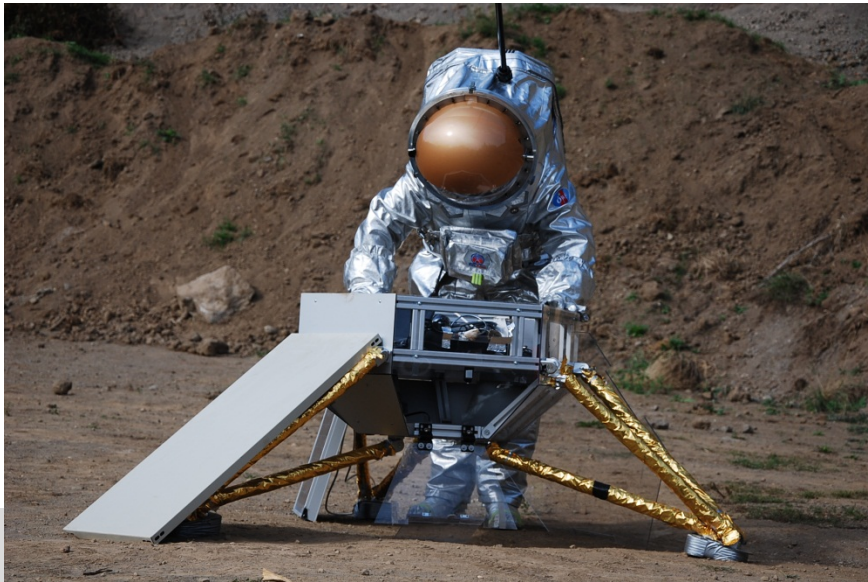



LOW
HIGH
CLOSE SYSTEM
LEVEL OF EXPANSION
MANUFACTURING CAPABILITIES
LEVEL OF DEPENDENCY
SETTLEMENT
COLONISATION
esa
HIGH
LOW

Inspiring and motivating

Moon Academy Workshop

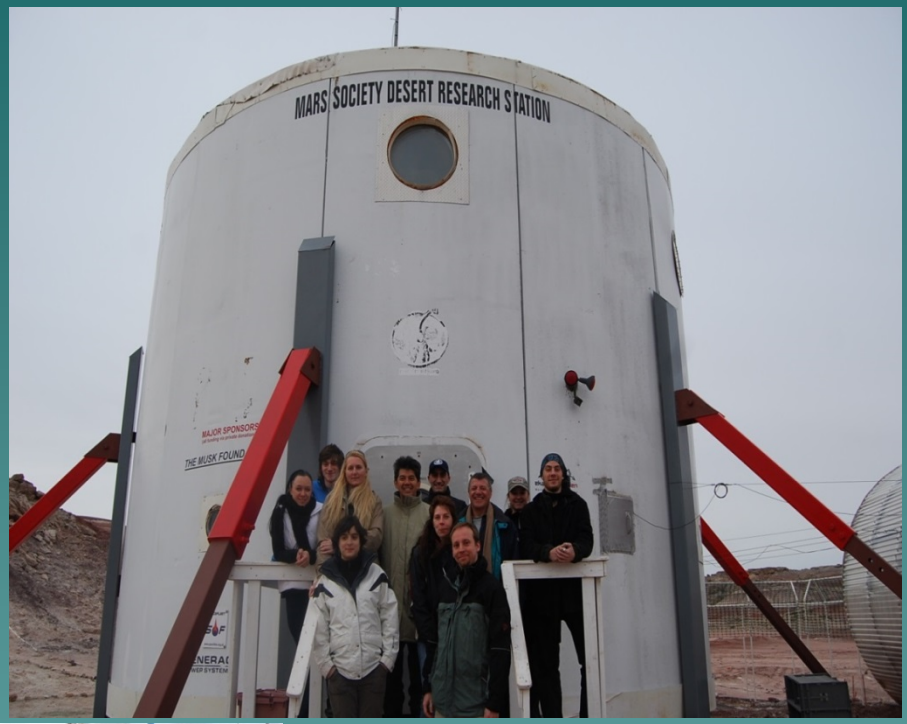
Human Robot partnership in MoonMars field tests at Eifel volcanoregion



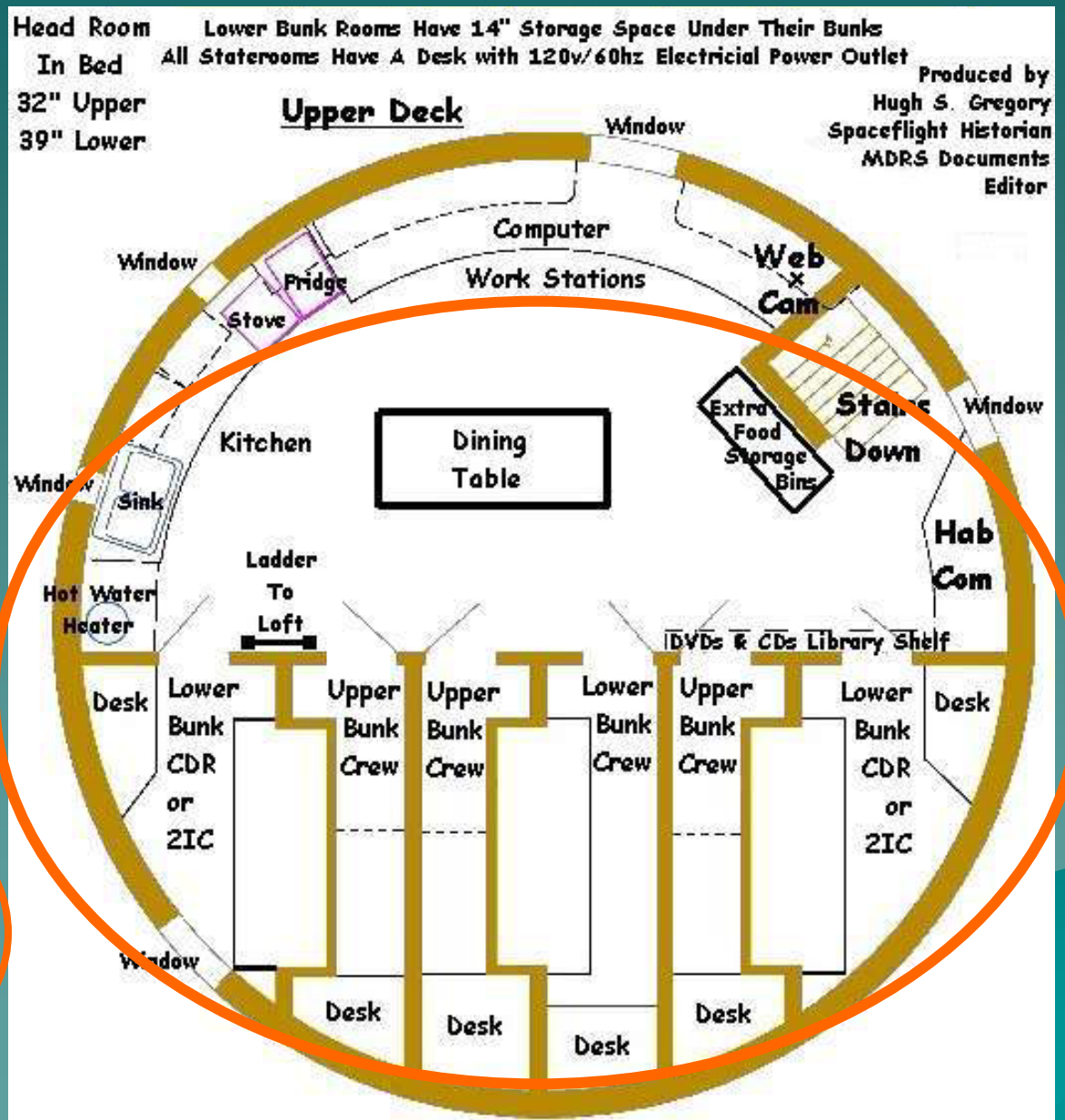
EuroMoonMars-DOMMEX 2009-2016
MDRS habitat and human factors

ILEWG FIELD TESTS: EuroGeoMoonMars Human aspects

- Habitat technologies:
  - Hab structure
  - architecture and layout
  - power,
  - grey water,
  - Greenhouse
  - Laboratory
- Human aspects
  - Time sheets
  - Performance
  - EVAs suits
  - Food study



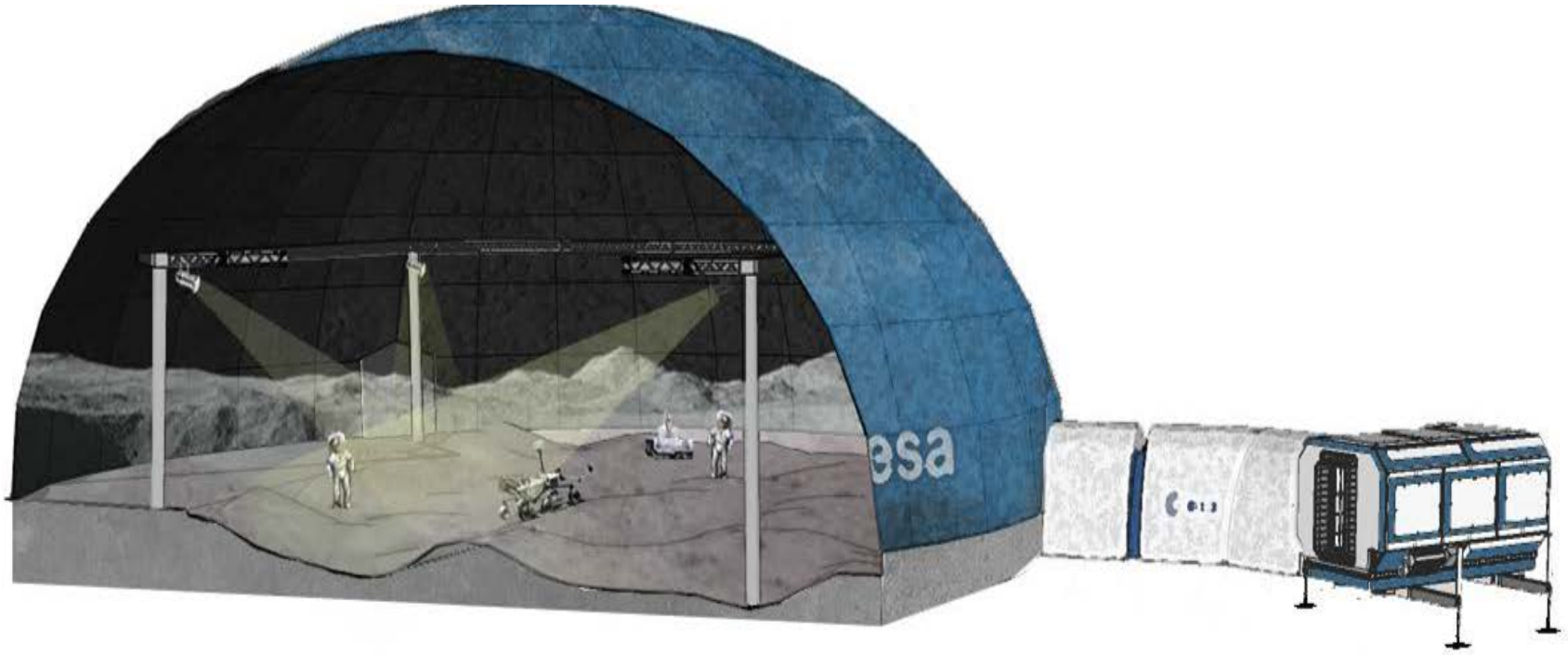
HabitatLab


Head Room
In Bed
32" Upper
39" Lower
Lower Bunk Rooms Have 14" Storage Space Under Their Bunks
All Staterooms Have A Desk with 120v/60hz Electricial Power Outlet
Produced by
Hugh S. Gregory
Spaceflight Historian
MDRS Documents
Editor
Upper Deck
Window
Computer
Work Stations
Web
Cam
Window
Pridge
Stove
Kitchen
Dining
Table
Extra
Food
Storage
Bins
Down
Window
Sink
Hab
Com
Ladder
To
Loft
Hot Water
Heater
DVDs & CDs Library Shelf
Desk
Lower
Bunk
CDR
or
2IC
Upper
Bunk
Crew
Upper
Bunk
Crew
Lower
Bunk
Crew
Upper
Bunk
Crew
Lower
Bunk
CDR
or
2IC
Desk
Desk
Desk
Desk
Desk

ESTEC/ILEWG ExoHab Lab module EuroMoonMars workshop July 2016

MoonMars Simulation base Poland

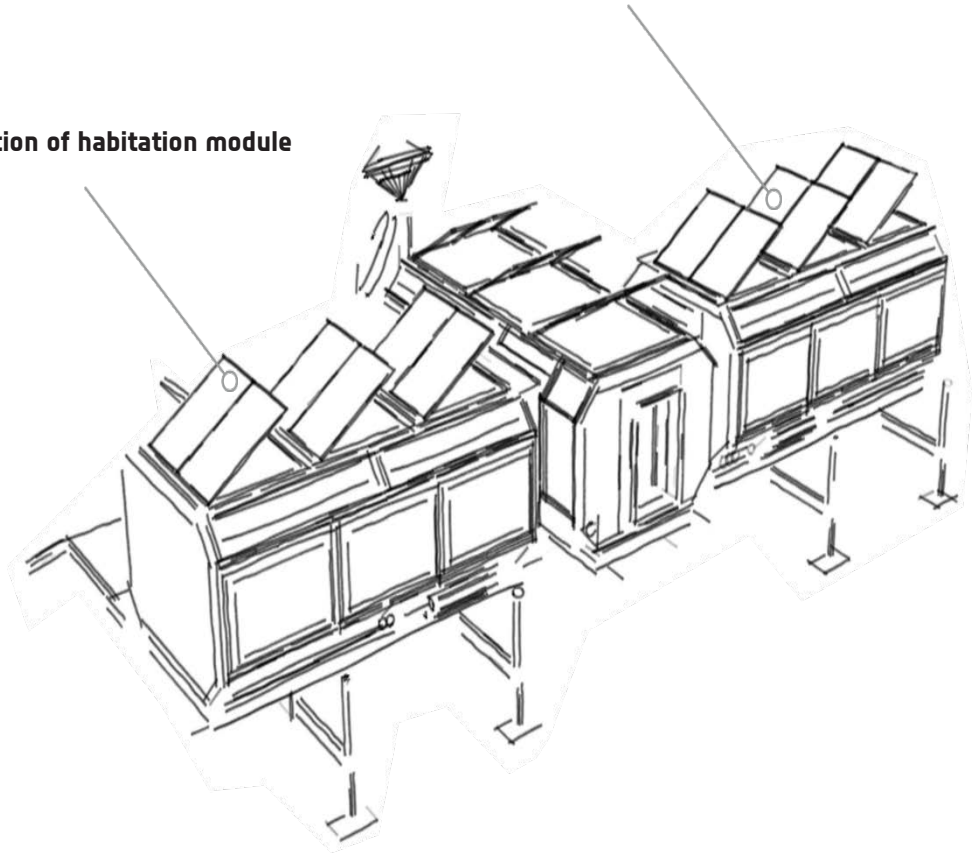
Flex Habitat and training at EAC European Astronaut Centre & DLR Cologne

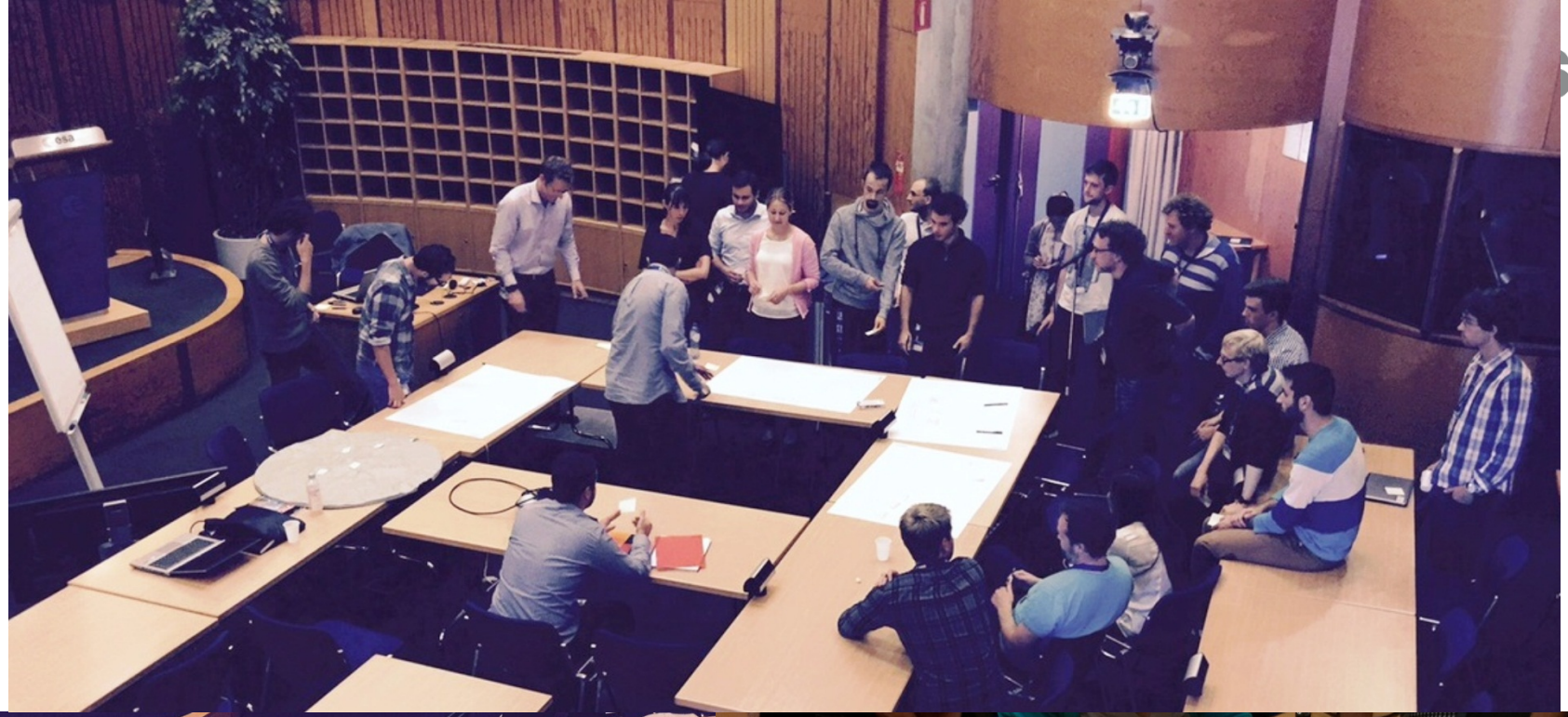


FLEXhab

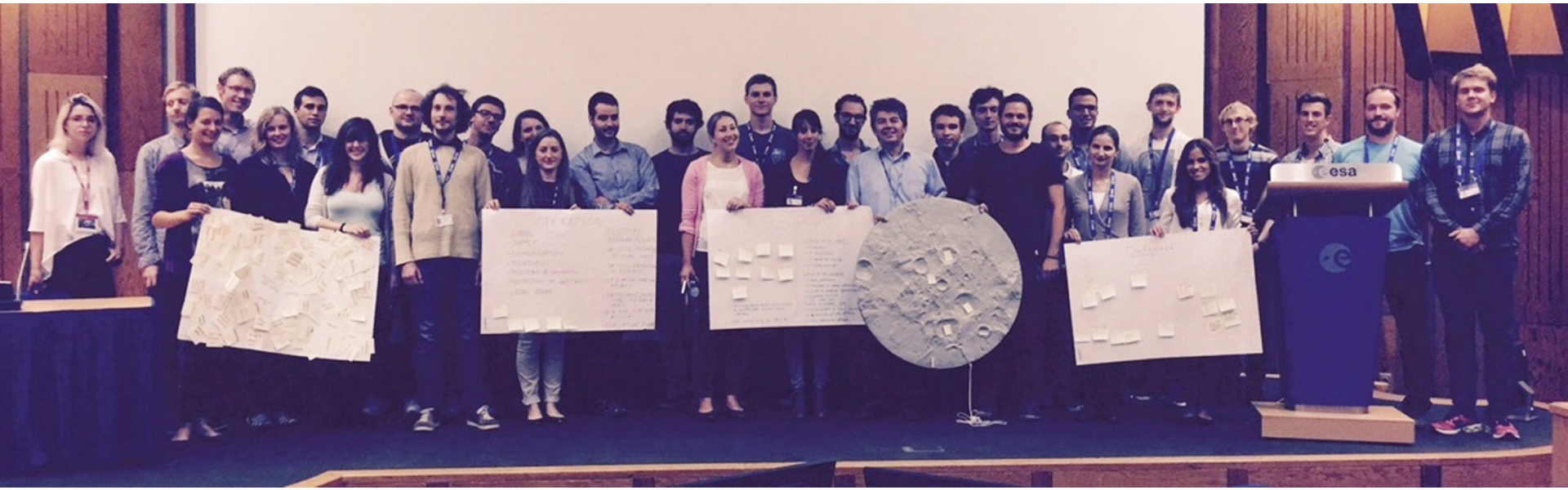
Addition of habitation module

Addition of habitation module





Moon Village Jam sessions & Workshops



ESTEC trainees, Aug 2015

DLR/ Spaceship EAC 2015-2016

MV workshop ESTEC Dec 2015

EGU Vienna April 2016

Moon Village Jam sessions with DG

Moon V. & Finance Rotterdam June

Lunar commercialisation , SF July 2016

MoonMars Hands-on Workshop July 2016

MoonMars workshop TodaysArt Hague

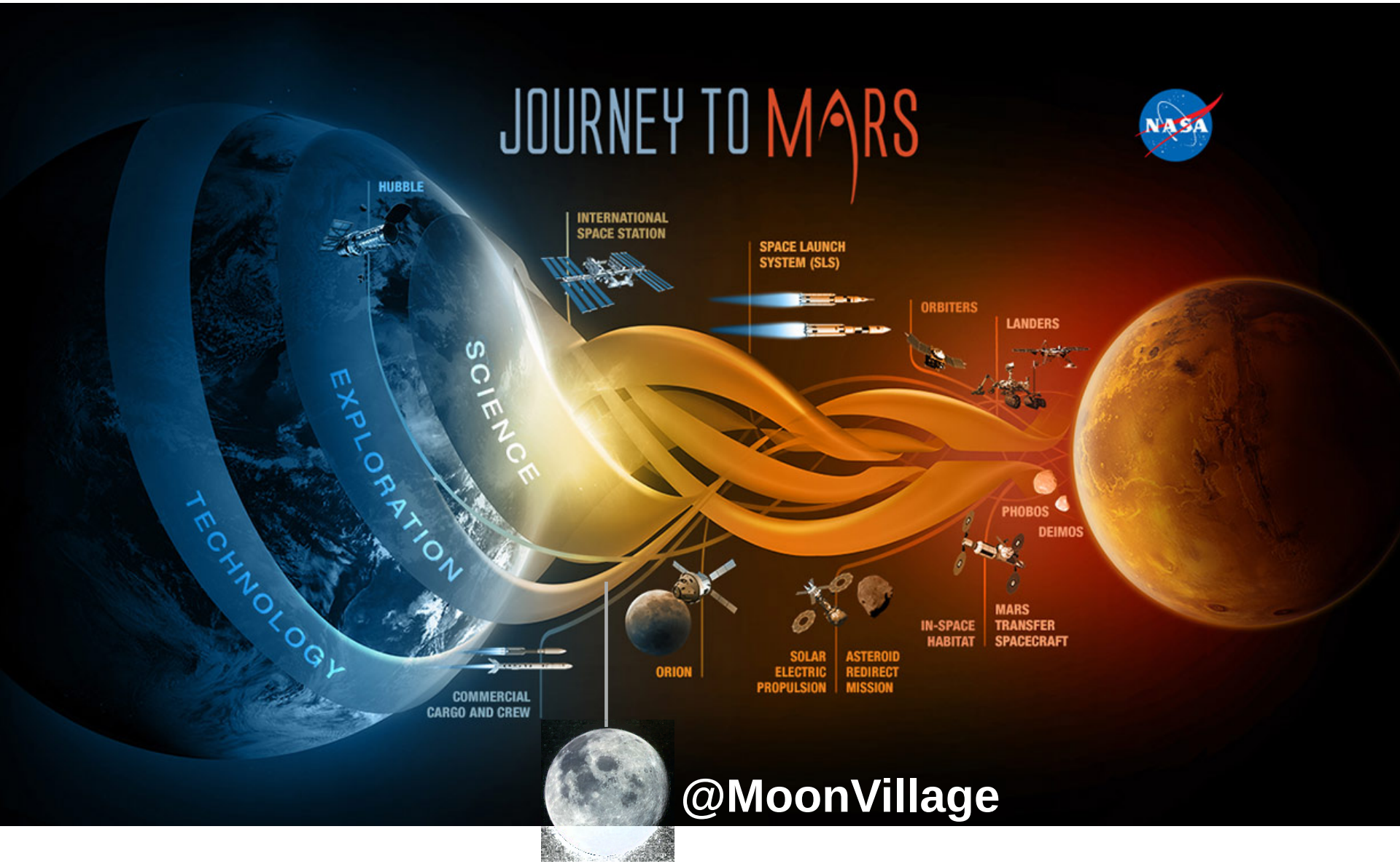
MoonMars Pannel at IAC 2016 Mexico

Moon Village sessions at VU Amsterdam

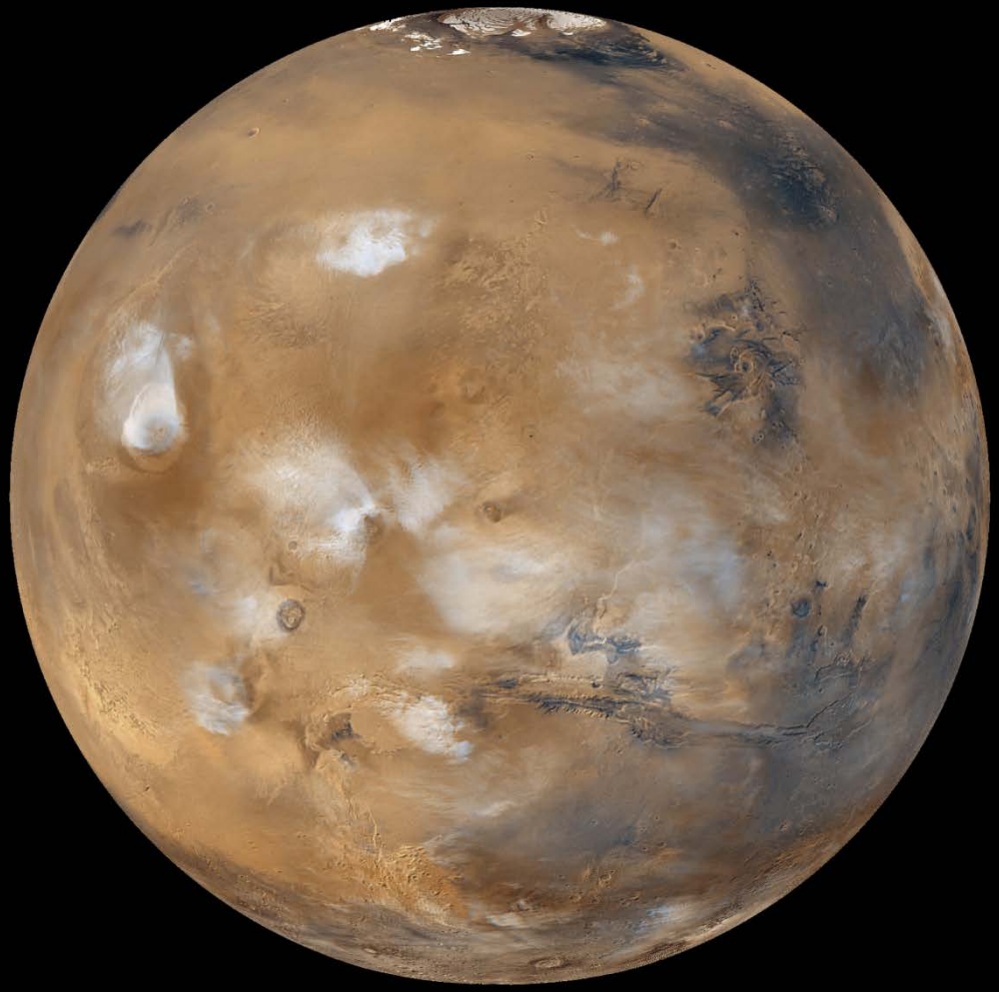
Moon Village session at LEAG 1 Nov

MV sessions with artists & designers

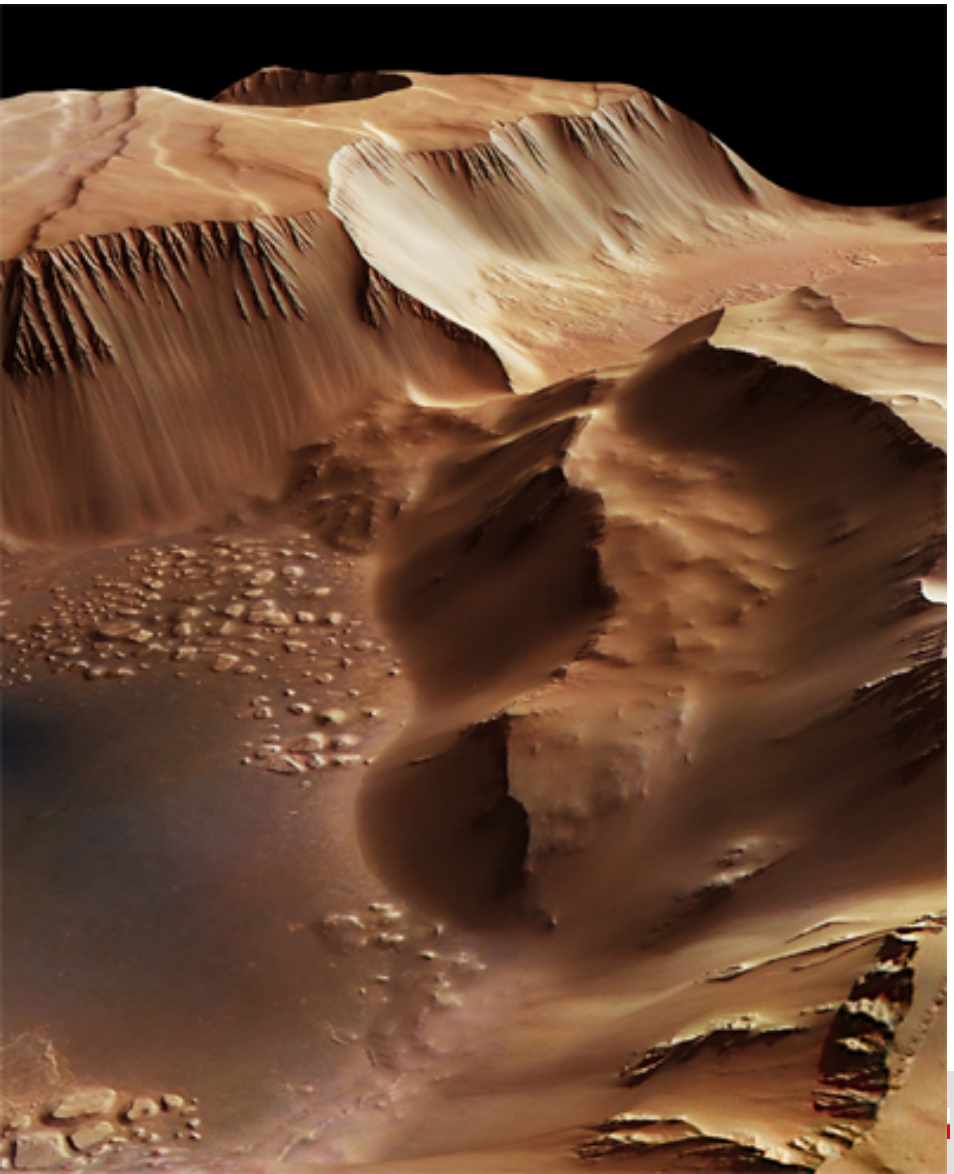
Many Moon Village Workshops 2017


JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
COMMERCIAL CARGO AND CREW
@MoonVillage

Mars
next destination?



Mars Express, 2003-
Global view of the Red Planet



First European ESA mission to Mars

Breathtaking, **high-resolution** images of **the surface in 3D and in colour**

First **sub-surface sounding**,

Discovery of water-ice deposits

Mineralogical evidence for liquid water throughout Martian history

Evidence for **recent volcanism**

First detection of **night-glow and mid-latitude aurorae** and possibly of **methane**

Estimation of **atmospheric escape** rate

In-depth studies of Martian moon **Phobos**

Launch: 2 Jun 2003, Soyuz-Fregat

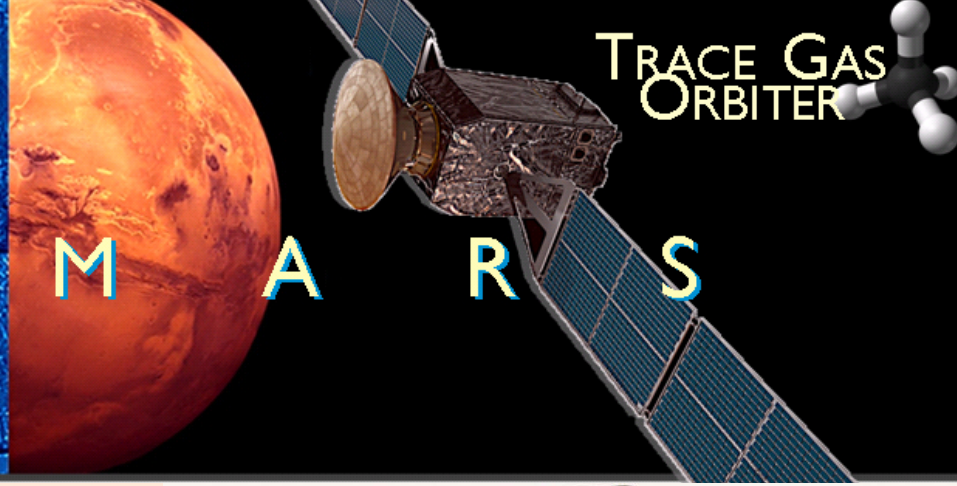
Arrival at Mars: 25 Dec 2003

Orbit: polar, elliptical

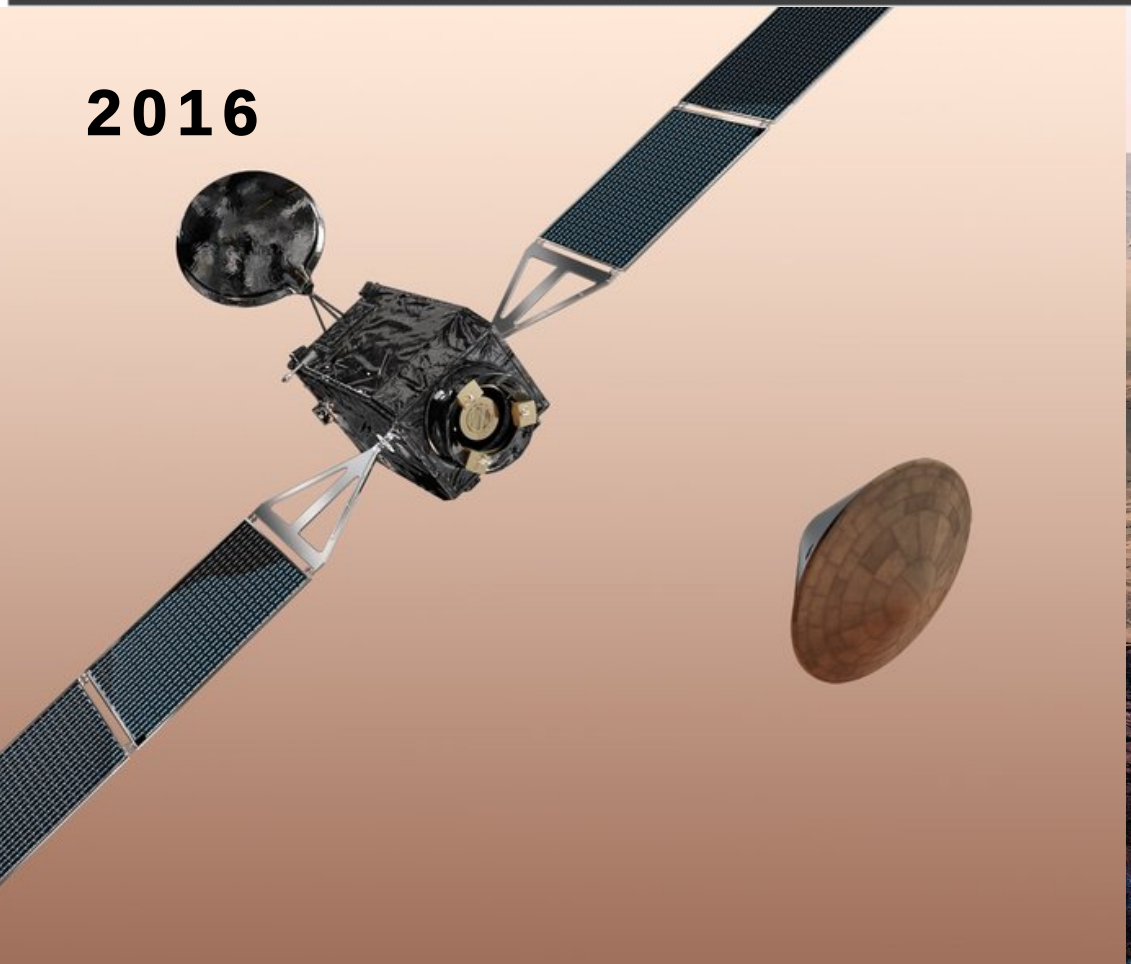
Status: operational

EXOMARS

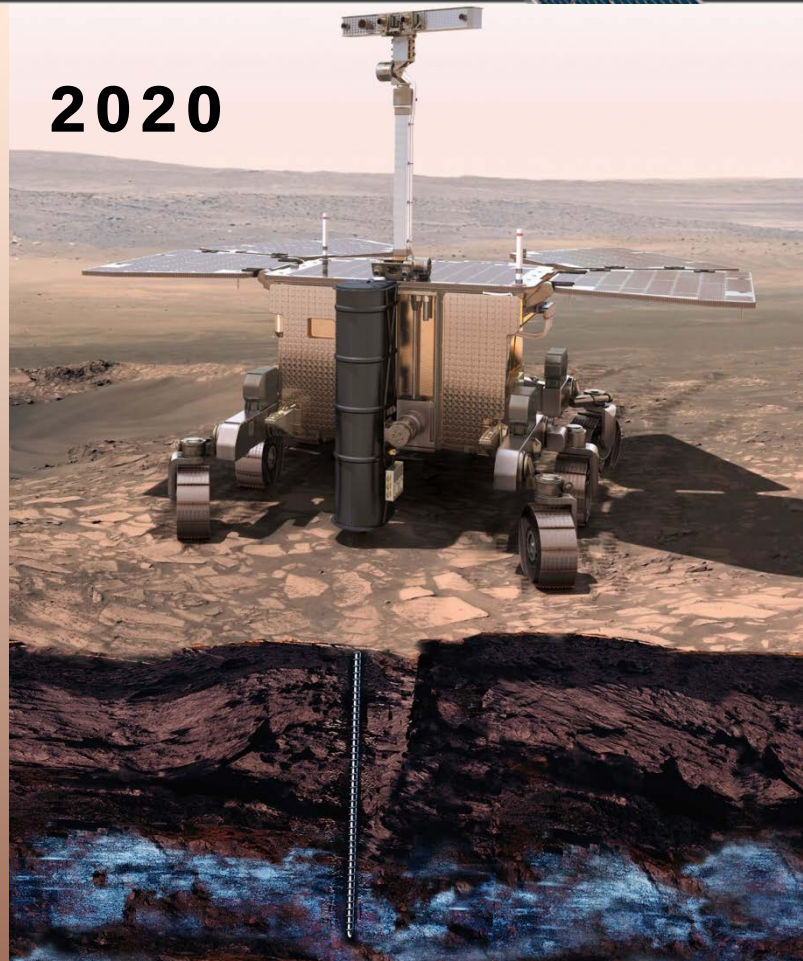
esa NASA РОСКОСМОС

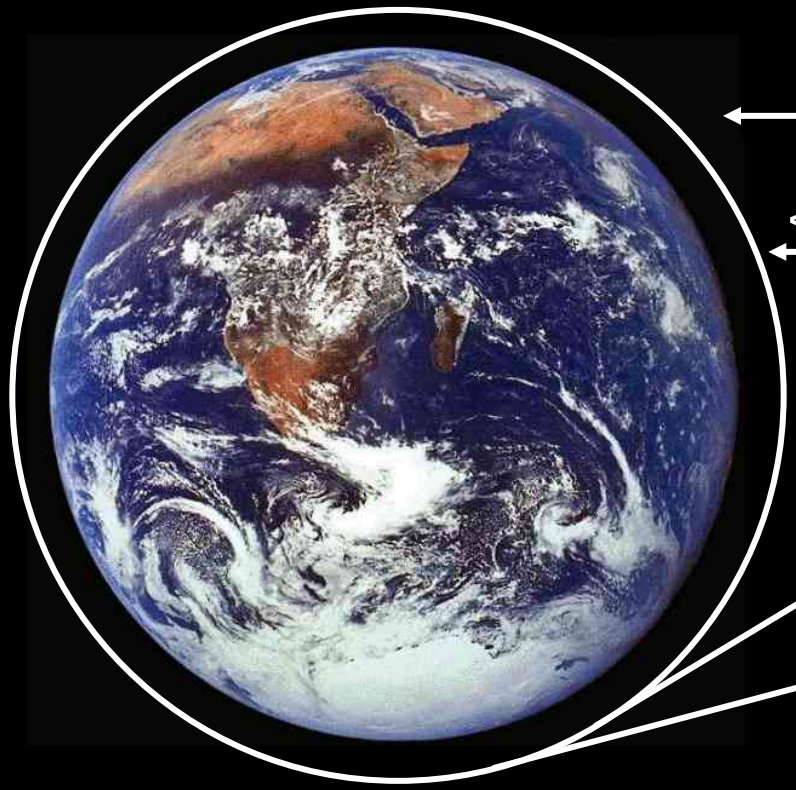


2016



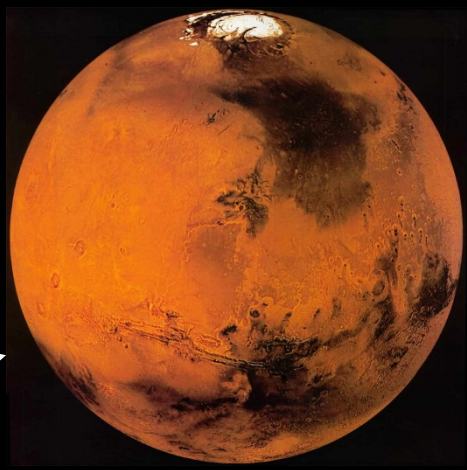
2020





> 2 years

< 1 week



Mars:

- propulsion
- safety/security
- health
- psychology
- radiation
- communication
- …

FAA Advisory Group Endorses “Moon Village” Concept

by **Jeff Foust** — December 15, 2015

ESA Director-General Johann-Dietrich Woerner discussed his concept of an international "Moon Village" at the International Astronautical Congress in Jerusalem in October. Credit: ESA/C. Diener


EUROPEAN SPACE AGENCY EYES FUTURE "MOON VILLAGE"
LIVE
CNN
11:25 PM GMT
@AmaraCNN

Stephen Hawking Says Humanity Won't Survive Without Leaving Earth

By Clara Moskowitz, SPACE.com Assistant Managing Editor | August 10, 2010 06:14pm ET

Cosmologist Stephen Hawking says humans should settle on other planets

Credit: NASA/Arrow Media

Long distance flight...

Roadmap to MoonVillage 2075

2003-2013 Inter Lunar Decade ILD1: ReconOrbiters

2013-2024 ILD2 Robotic village, pre deploy, ISRU,

2022/26 Humans in lunar orbit/ on surface

2030 10xHumans permanent sustainable operations

2040 100H spaceport, energy, Moon born humans

2050 1000H humans , Noah‘s Ark, interplanetary

2057 10000H Moon Cities, production , economy

2069 100000H Moon Republics Independence

2075 1000000H Moon continent

Next destinations?


esa
Carlsberg
Carlsberg

esa

Do you support Moon Village concept & initiative ?

Why the Moon Village ? (pick top 3 & vote)

- Science: research of , from (astro) & on (biology) the Moon
- Technology, resource utilisation & development
- Global international cooperation & peace
- Economical benefits and commercial partnerships
- Inspiration & education for public and next generation
- Philosophical and humanistic renaissance off the Earth ground


esa
©themoonhouse

additive manufacturing and polymers

for implementation of new Life support / Maintenance Support for settling and expansion.

Polymers and Plastics

scarcity (they are made on earth),

recyclibility. low density (good regarding mass budget)

multi functionality (Radiation resistant, Structural, biocompatible, optical, electromagnetic, electrical conduction, thermal stability, energy generation / harvesting, self-healing)

design of certain spacecraft or other module

regrading the additive manufacturing process itself,

upscaling and automation

to enable expansion and settlement perspective.