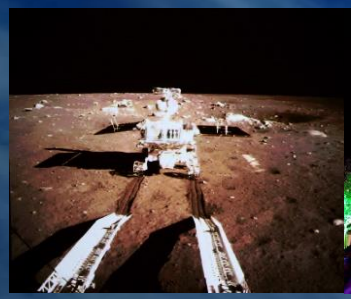
MoonVillage Perspectives for Science, Missions,, Technologies, Infrastructures, Human-Machine Settlements and Society

Prof. Bernard Foing (Executive Director, ILEWG & EuroMoonMars , IMA)
Prof VU Amsterdam &Leiden U, ISAE, ISU; Co-I Mars Express & ExoMars; PI ExoGeoLab, ExoHab,
Former Chief Scientist ESA ESTEC, Chair of RESTEC Staff (2012-2017)
SMART-1 Project scientist, Bernard:Foing@gmail.com , SMART-1 & EuroMoonMars Team (2009-2020)

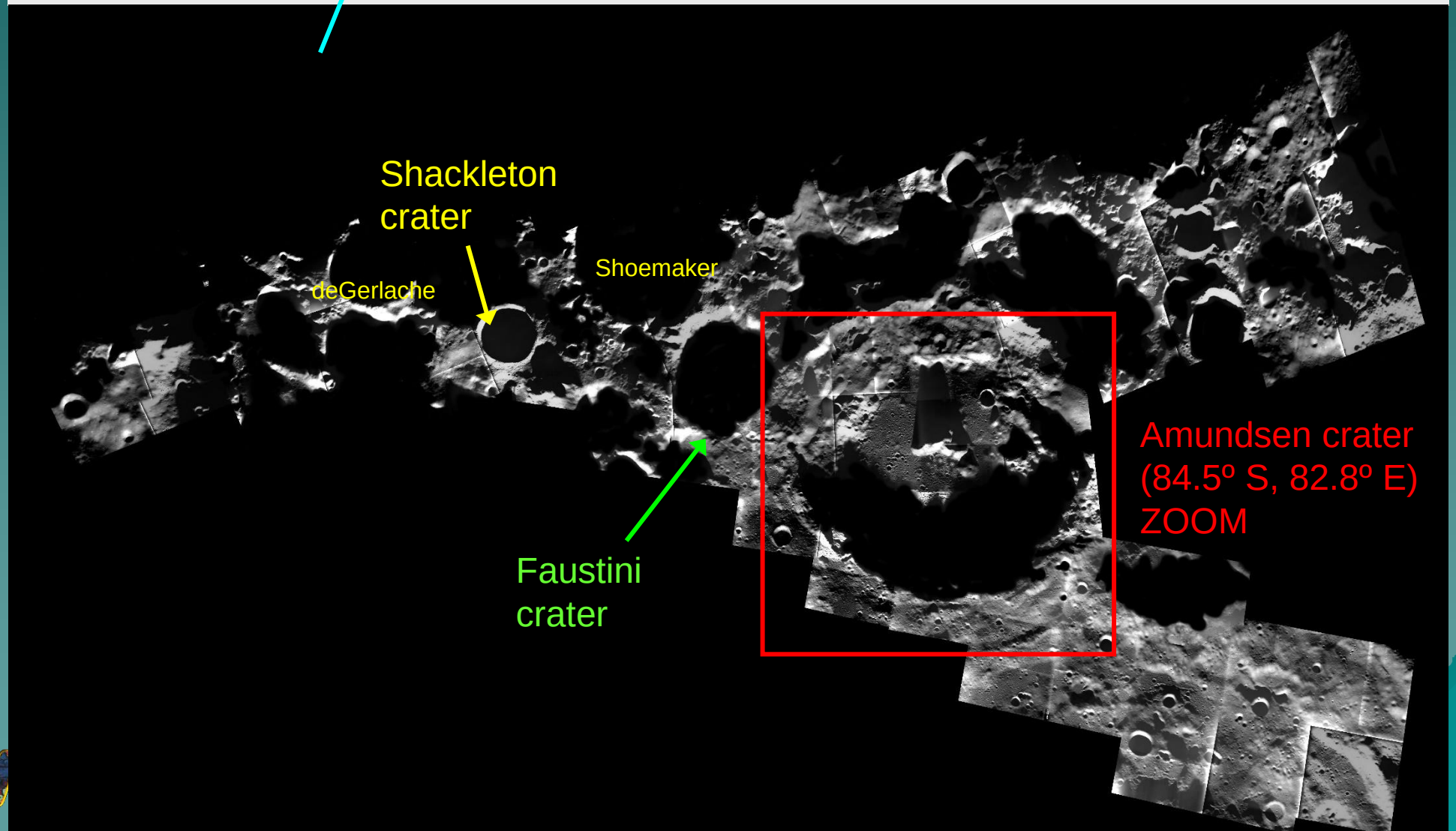
2021 Ao Jiang, Adrien & ChileMoonMars, Kevin, Hannah, Chiaru, Gary &TU Dublin, EMMPOL 3-6 team,
Anna, Liza , Mary, Ronald, Charlotte, Fabian & ArtMoonMars
2021Yke, Christoph, Iris, Johanna, Daniel, Jourdain & Space Data Analysis, Alexis, Samir, Amanda, Hans, Thijs, Shaodi AI4EO
2020-21 Henk, Sabrina, Roxana & IPSA, Nancy, Julien, TaiSik, Eibhlin,Yo, Marc, Michaela, Anouk & EMMIHS 3-4, EMMPOL1-2
2019 Henk, Michaela, Nity, Sebastian, Annelotte, Josh, Ben, Paul, Andrew, Dan & EMMIHS1-2, IgLuna team
2018-19 Bram, Marc, Dieke, Marjolein, Bram, Isaac, Guido & VU Igluna, Anna S, Marius, Benjamin, Germaine, Yolanda, Yvette et
2018 Elise C, Louis D, Sandro P, Anna, Anastasia I, Alexander ,
2017 Arthur L, Heleen V, Agata K, Matt H, Matteus K, Maria G, Andjela T, Pierre E, Lorene, Axel , Cynthia C. , Tibor P. , Angeliki,
2016 Clément J, Oscar K, Valentin G, Manon M, Irene S, Christiane H et al

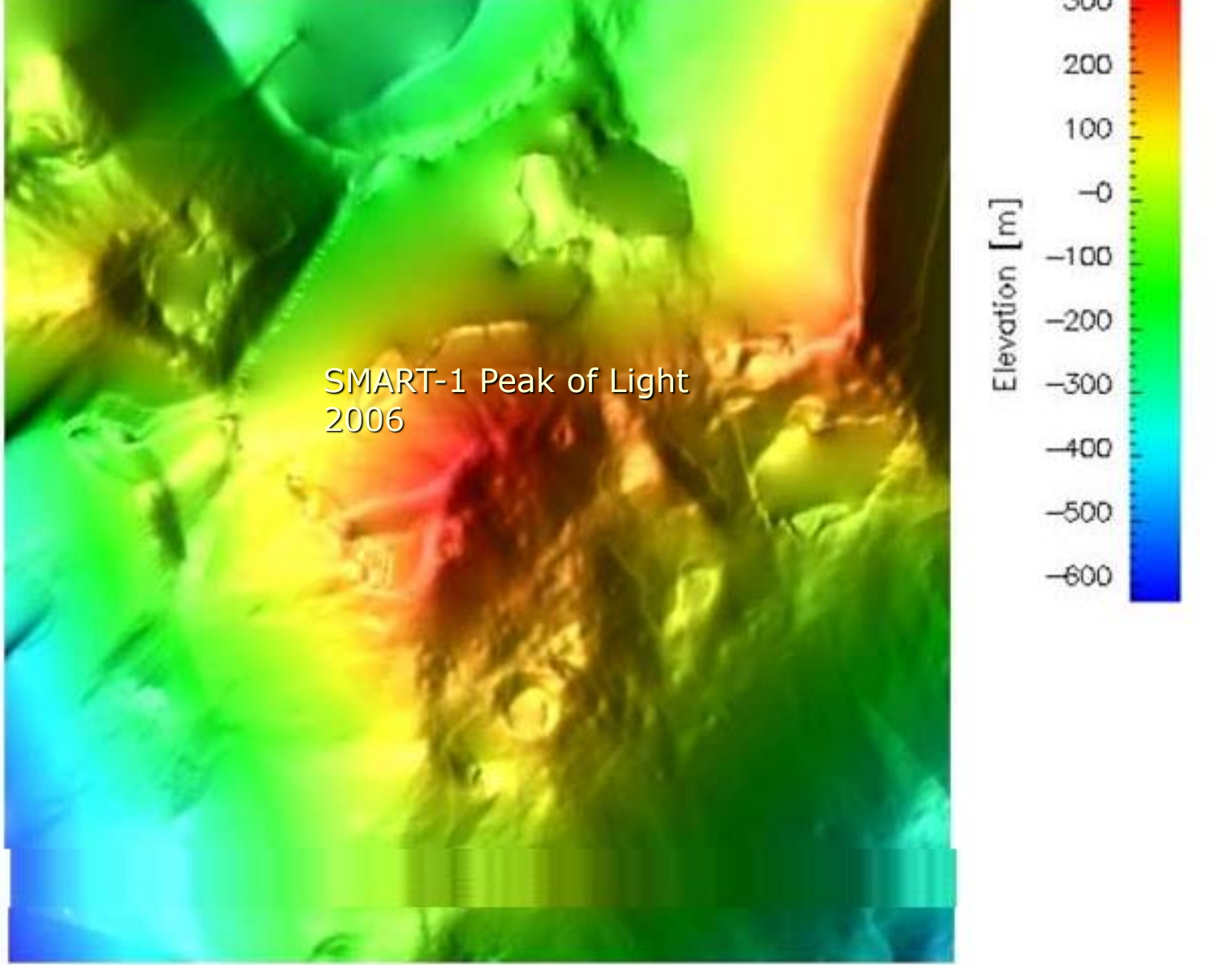




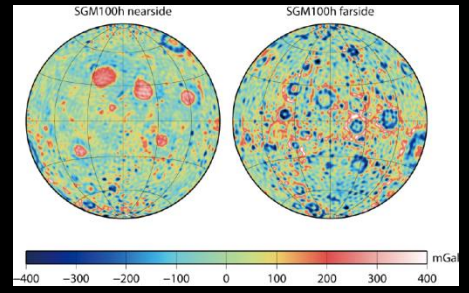
European Space Agency

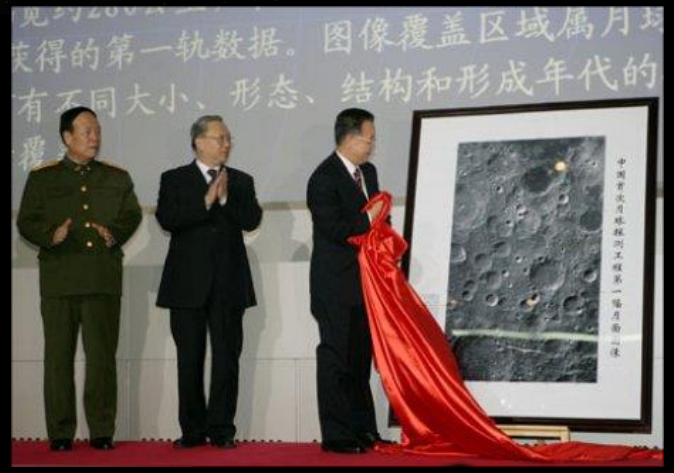
SMART travel maps to Lunar South Pole (Ellouzi, Foing et al 2006)

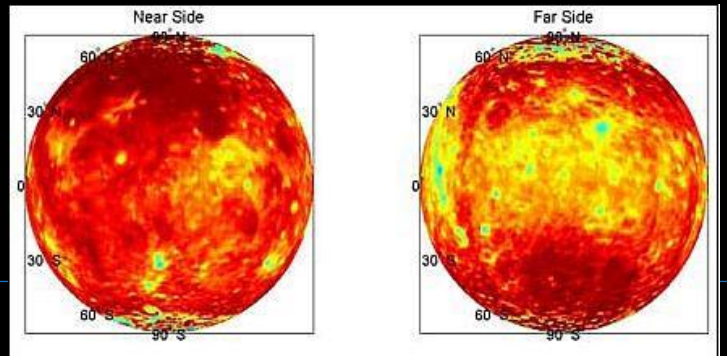


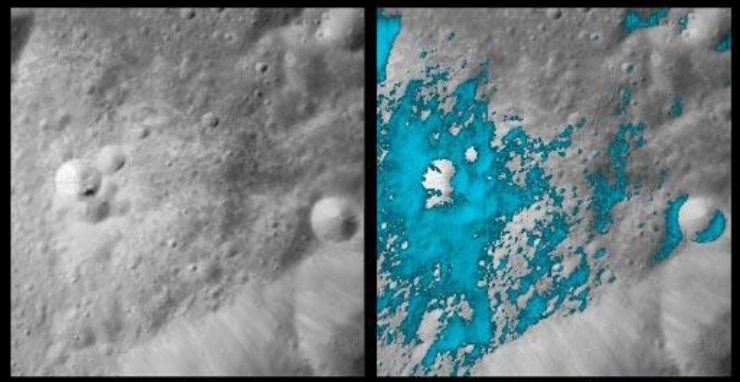

SMART-1 Peak of Light
2006
Elevation [m]
200
100
0
−100
−200
−300
−400
−500
−600

Moon village orbital fleet 2003-2020: SMART-1, Kaguya, Chang'E 1 & 2 , Chandrayaan1, GRAIL, Ladee
LRO, Chandrayaan-2 orbiter (still in operations in 2020)

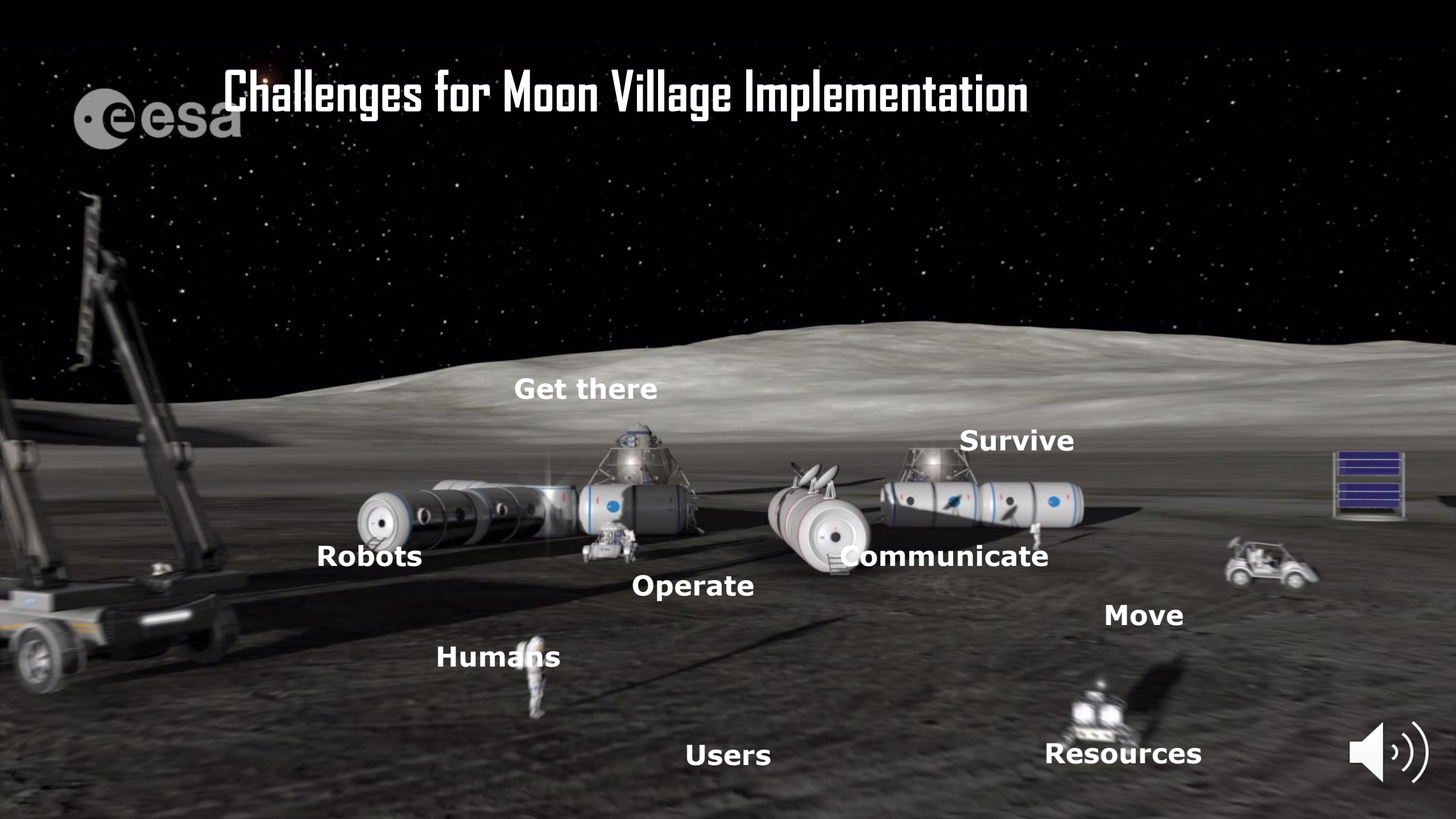








Challenges for Moon Village Implementation

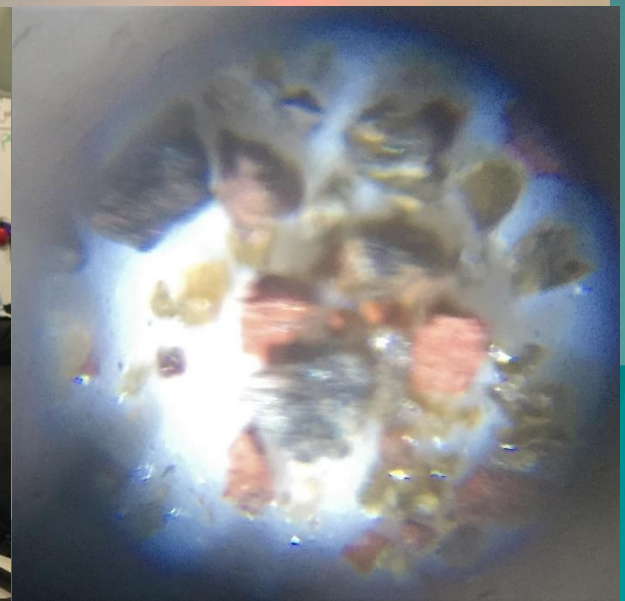


Sustainable Presence on the Moon

Credit: ESA/Foster + Partners

International MoonBase Alliance

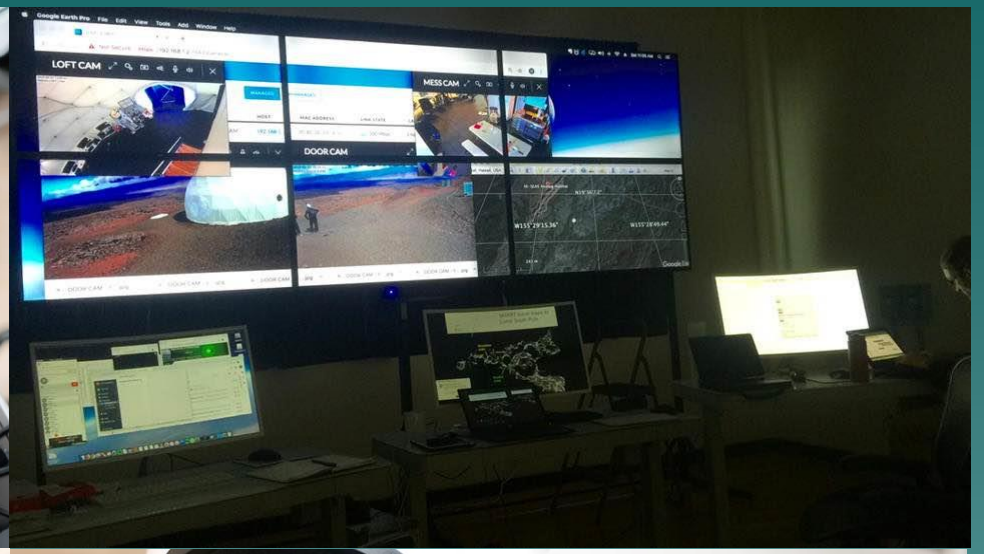
Hawaii EuroMoonMars 2018 instruments



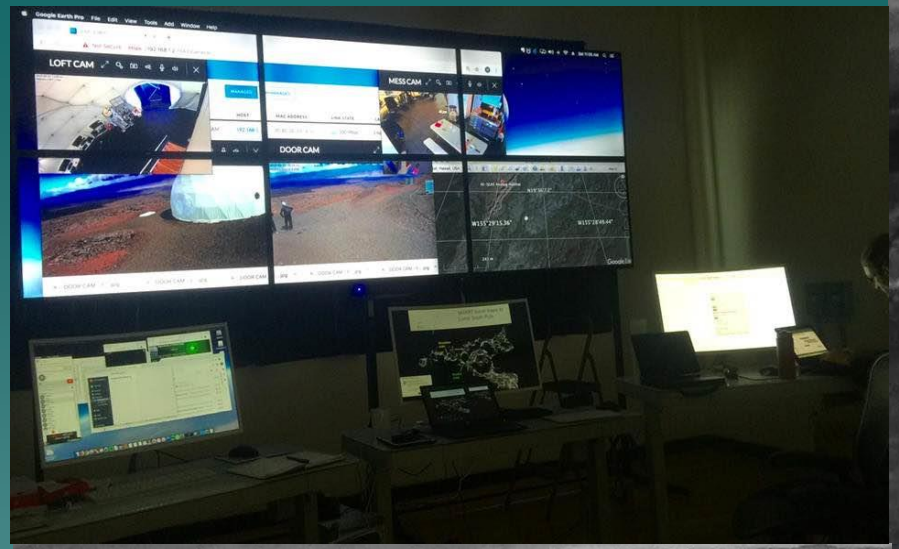
Hawaii EuroMoonMars 2018 EVAs

Hawaii EuroMoonMars 2018 lavatube

MoonBase day 3 preparation



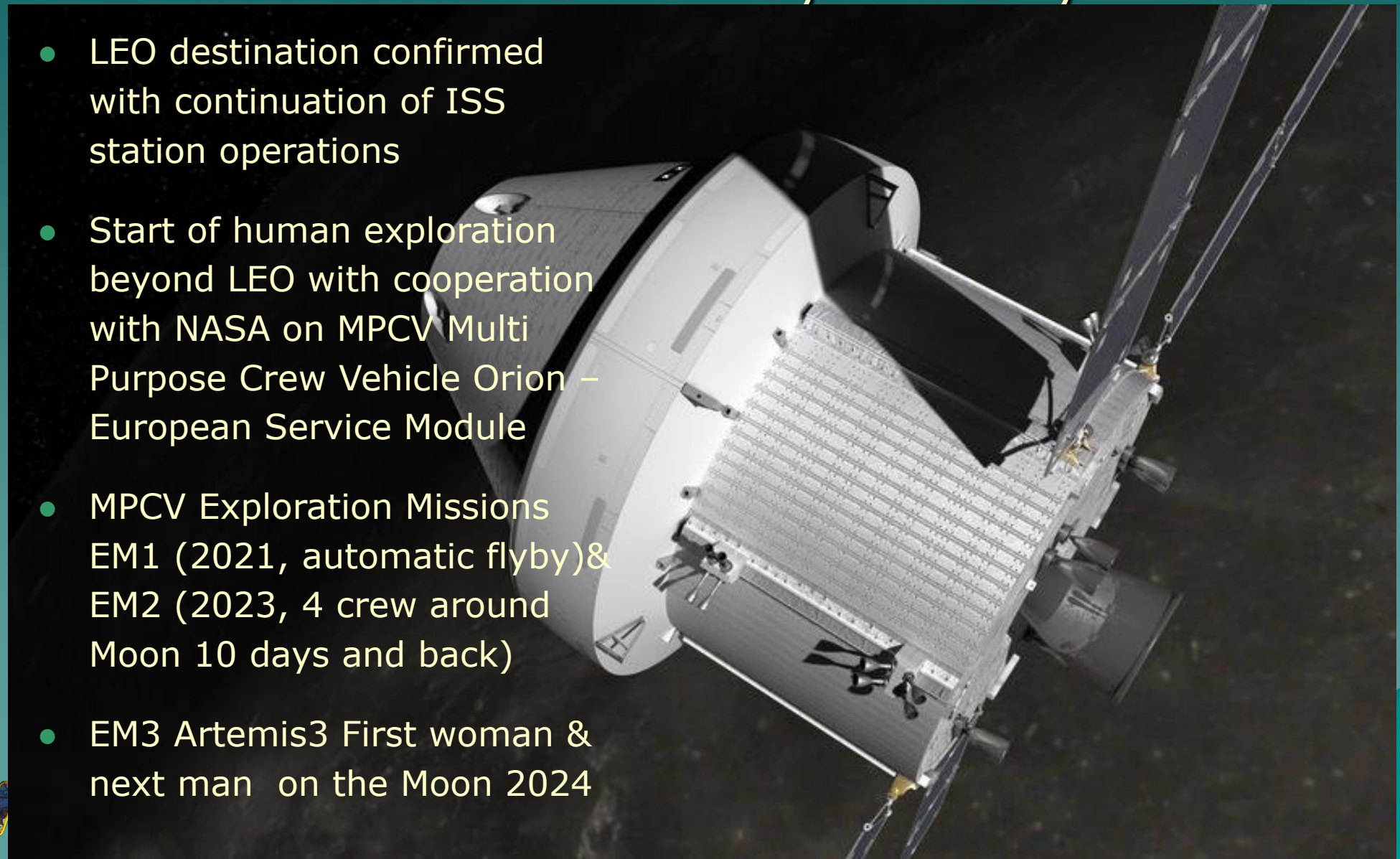
Day 3 at MoonBase



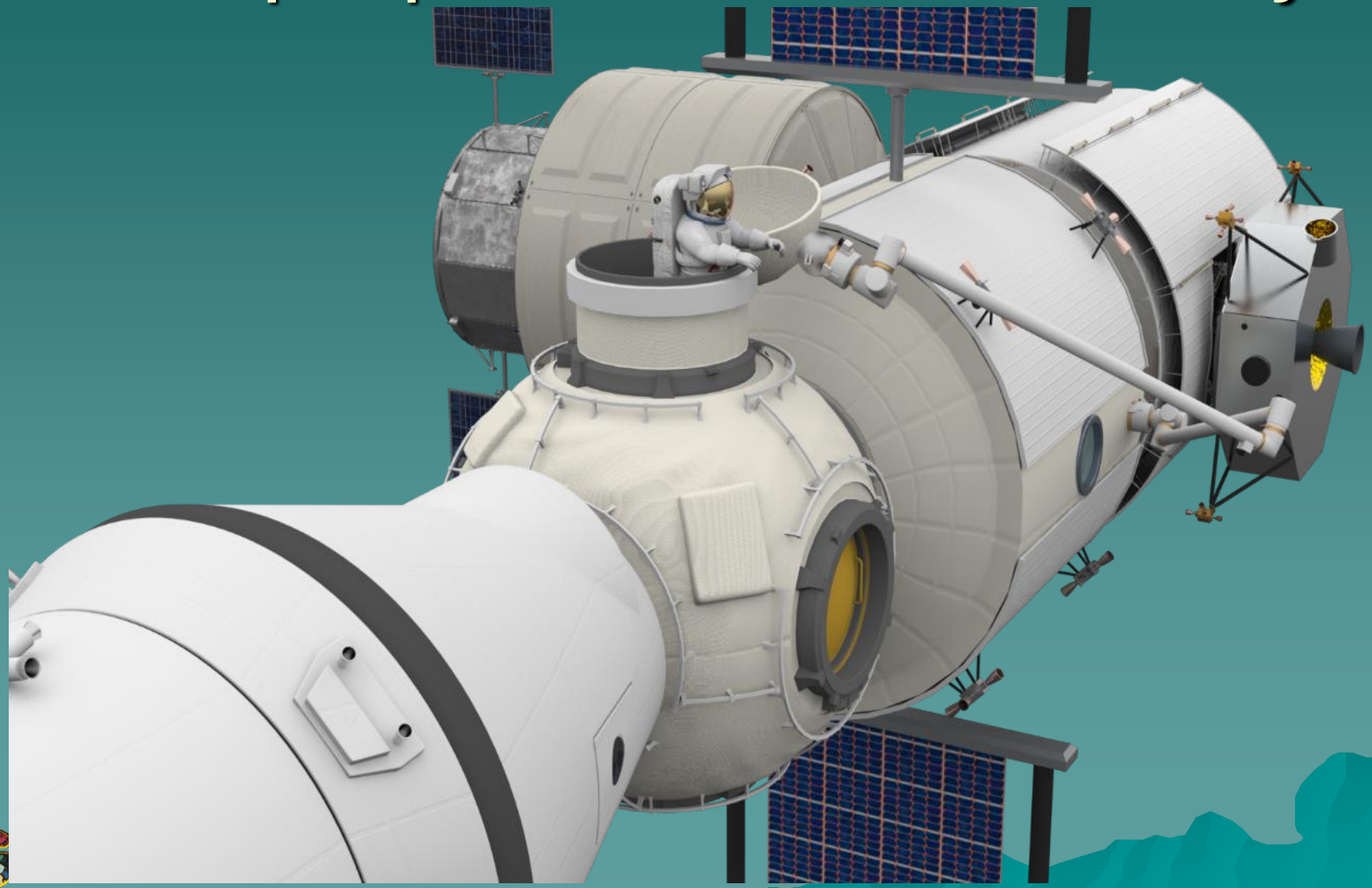
MoonBase day 3 EVA survey of basalts and tube skylights

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 MPCV Multi Purpose Crew Vehicle Orion – European Service Module
- MPCV Exploration Missions EM1 (2021, automatic flyby)& EM2 (2023, 4 crew around Moon 10 days and back)
- EM3 Artemis3 First woman & next man on the Moon 2024



Cis-Lunar Extended Deep Space Habitat/Gateway



PREPARATION OF HUMAN-TELEROBOTICS OPERATIONS USING EAC & ESTEC FACILITIES

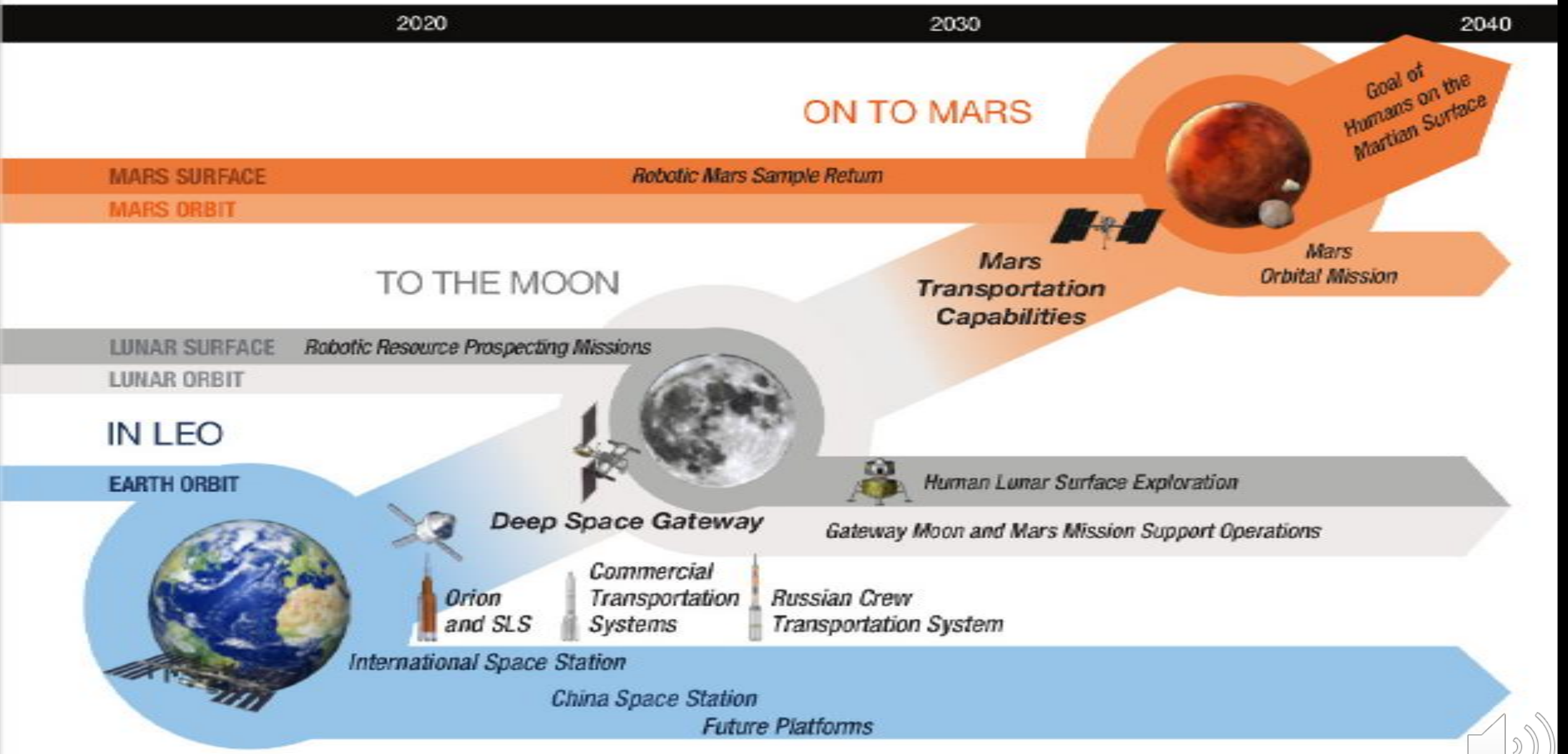
V. Guinet[1,3], M. Monnerie[1,3], B. Jehannin[1,3], A. Cowley[1], C. Jonglez[2,3], B. H. Foing[2], [1]ESA/EAC, Köln, Germany, [2]ESA/ESTEC, Noordwijk, The Netherlands, [3]ISAE-SUPAERO, Toulouse, France.

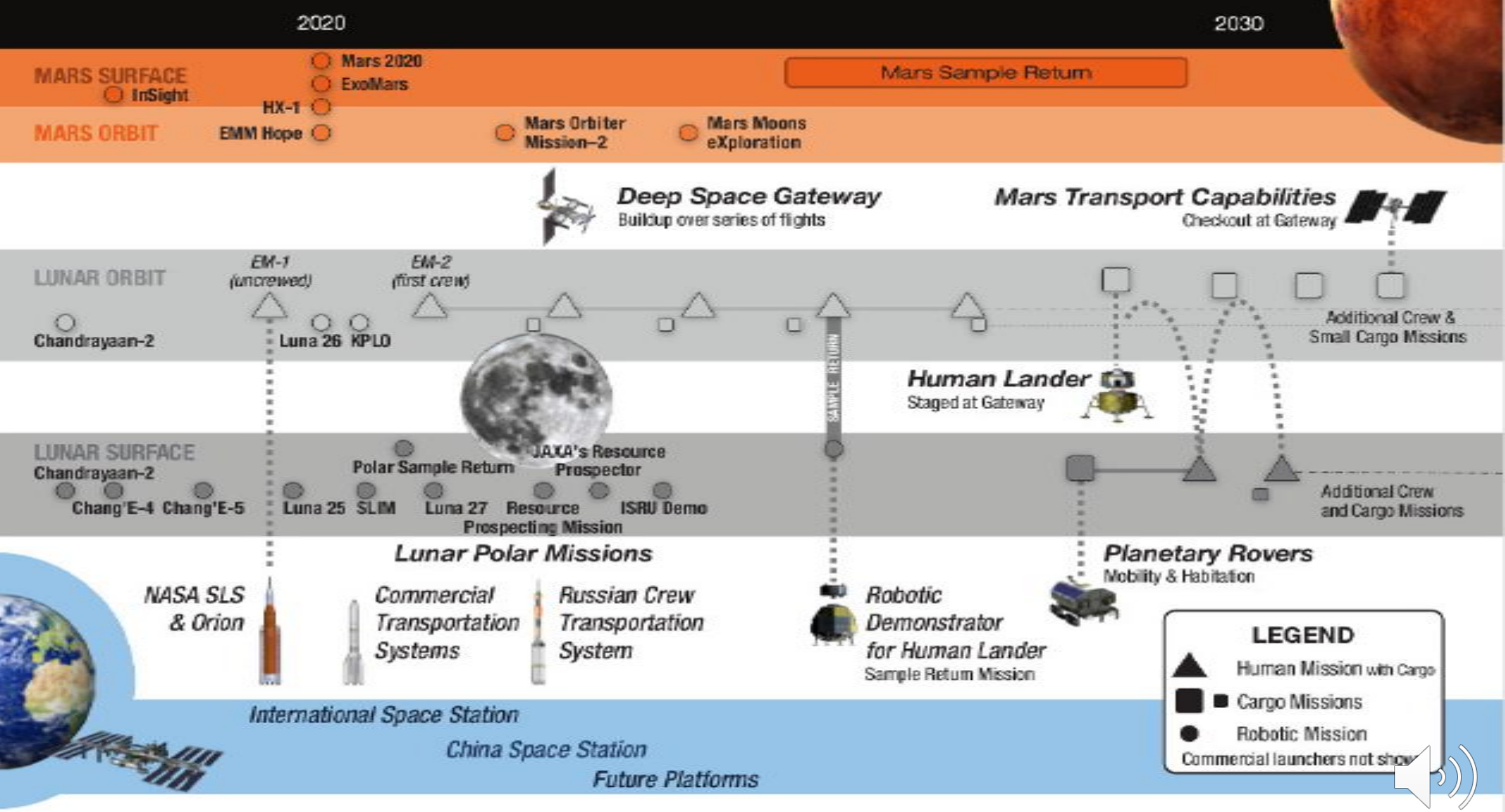
Figure 1. **ATV mockup in the Training Hall at EAC**

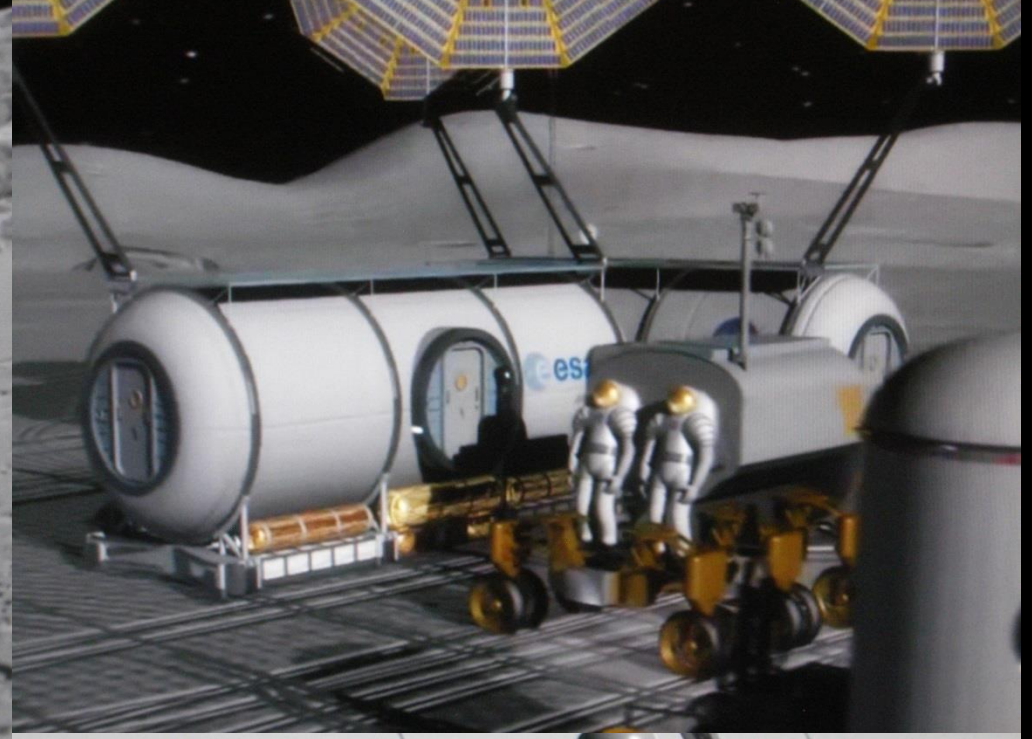
Figure 2. **Soyuz mockup in opened configuration**


FH
SPACEX

The Global Exploration Roadmap




2020
2030
MARS SURFACE
InSight
Mars 2020
ExoMars
HX-1
MARS ORBIT
EMM Hope
Mars Orbiter Mission–2
Mars Moons eXploration
Mars Sample Return
Deep Space Gateway
Buildup over series of flights
Mars Transport Capabilities
Checkout at Gateway
LUNAR ORBIT
EM-1 (uncrewed)
EM-2 (first crew)
Chandrayaan-2
Luna 26
KPLO
Additional Crew & Small Cargo Missions
SAMPLE RETURN
Human Lander
Staged at Gateway
LUNAR SURFACE
Chandrayaan-2
Polar Sample Return
JAXA's Resource Prospector
Chang'E-4
Chang'E-5
Luna 25
SLIM
Luna 27
Resource Prospecting Mission
ISRU Demo
Additional Crew and Cargo Missions
Lunar Polar Missions
Planetary Rovers
Mobility & Habitation
NASA SLS & Orion
Commercial Transportation Systems
Russian Crew Transportation System
Robotic Demonstrator for Human Lander
Sample Return Mission
LEGEND
Human Mission with Cargo
Cargo Missions
Robotic Mission
Commercial launchers not shown
International Space Station
China Space Station
Future Platforms

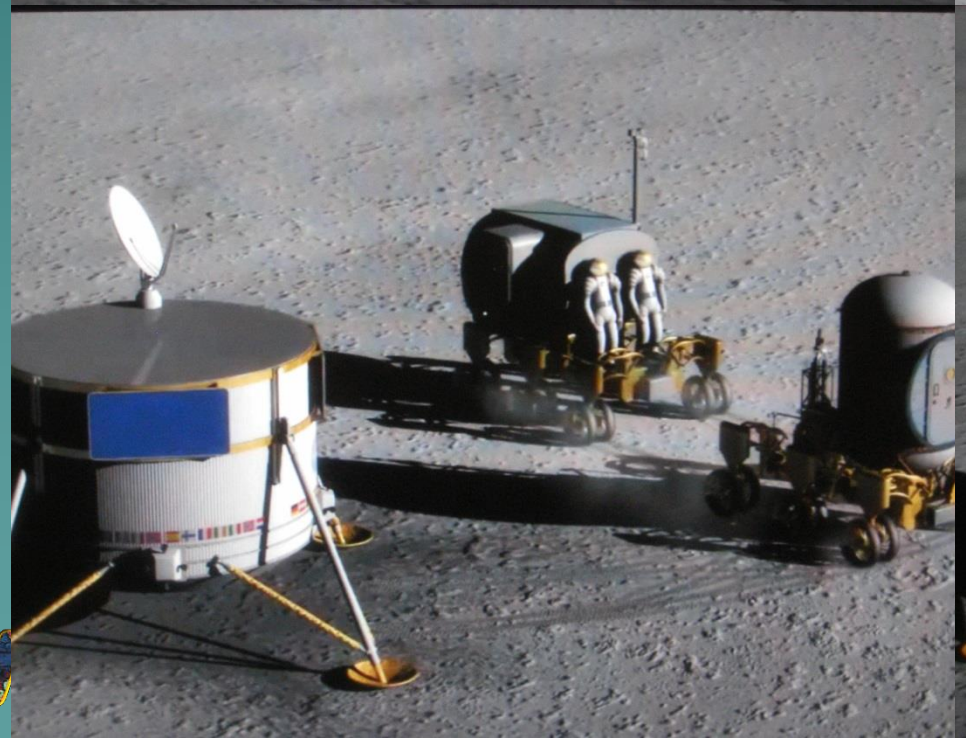


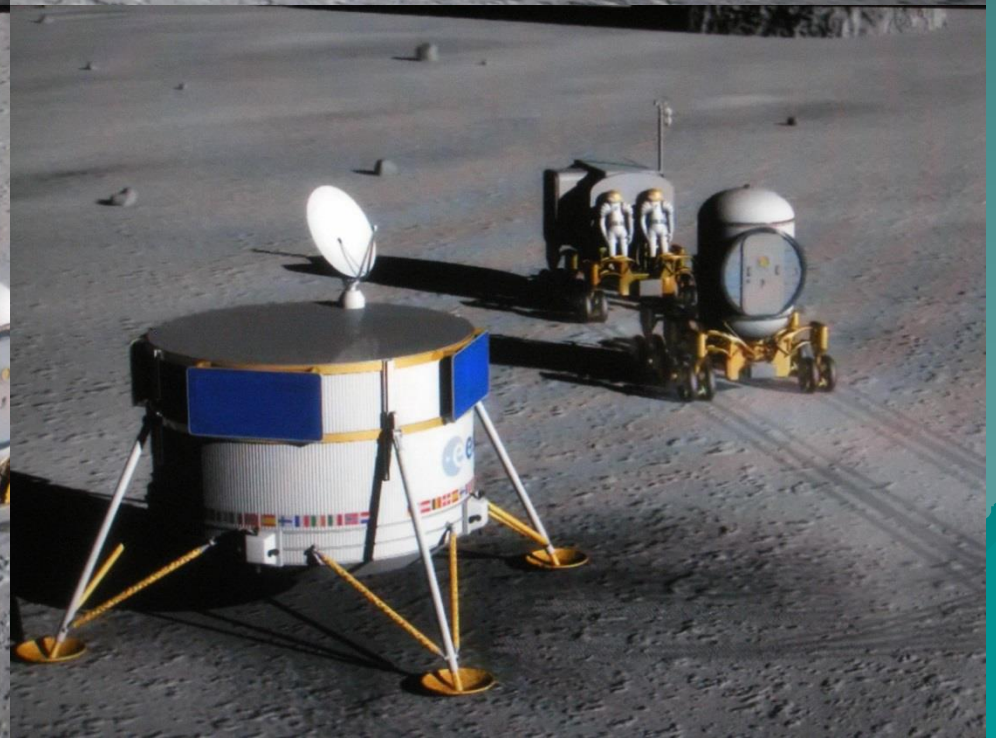

esa


esa


esa


esa





MoonVillage Roadmap to 2061

2003-13	Orbital Lunar Decade (ESA SMART1,China Chang‘E, J Kaguya , India, US LRO,Grail)
2013-24	Robotic village (ChangÉ3-4-5, India, Luna, LRP Viper, CLPS, commercial, ISRU)
2022/24	Humans in lunar orbit/ on surface (Orion, space X)
2030	10xHumans in permanent sustainable ops, H2O market
2040	100H spaceport, energy, Moon born humans
2050	1000H humans , Noah‘s Ark, interplanetary
2057	production , manufacturing, economy
2061	10000H Moon Cities
2069	Moon Republic Independence