

Report from ILEWG Task Groups: Science, Technology, human aspects, roadmaps, socio-economics, young lunar explorers, MoonVillage, MoonMars synergies, EuroMoonMars, ArtMoonMars



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SMART-1 Project scientist, Co-I Mars Express & ExoMars

PI ExoGeoLab, EuroMoonMars, Prof VU Amsterdam & Leiden U, ISAE, ISU,

Bernard:Foing@esa.int SMART-1 & EuroMoonMars Team (2009-2020)

2020 Anna, Liza, Jolanda, Henk, Marc, Michaela, Anouk, Jamal, Eibhlin, Ugo, Thomas, Geoffrey, Heloise, Isabella, Victoria, Arlene, Amanda, Robert, Stijn, Zebro & EMMIHS 2-4 teams

2019 Henk, Michaela, Nity, Sebastian, Annelotte, Josh, Ben, Paul, Andrew, Dan & EMMIHS1

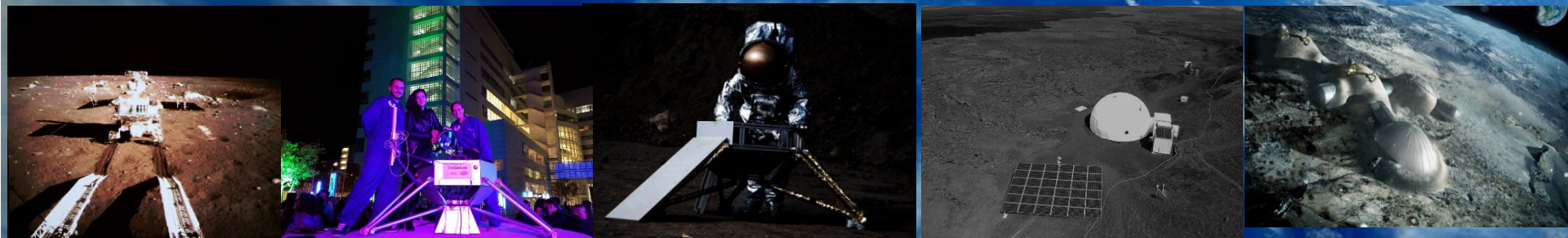
2018-19 Bram, Marc, Dieke, Marjolein, Bram, Isaac, Guido & VU Igluna

Anna S, Marius, Benjamin, Germaine, Yolanda, Carmen, Yvette & ILEWG,

2018 Elise C, Louis D, Sandro P, Pierre E. Anna, Anastasia I, Alexander Z ,

2017 Arthur L, Heleen V, Agata K, Matt H, Matteus K, Maria G, Andjela T, Pierre E, Lorene A, Axel B, Cynthia C. , Tibor P. , Angeliki, Yolanda et al

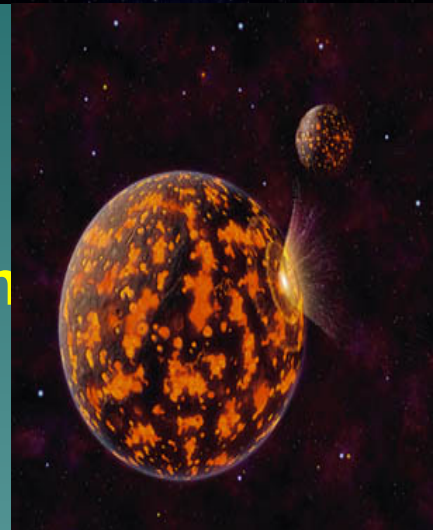
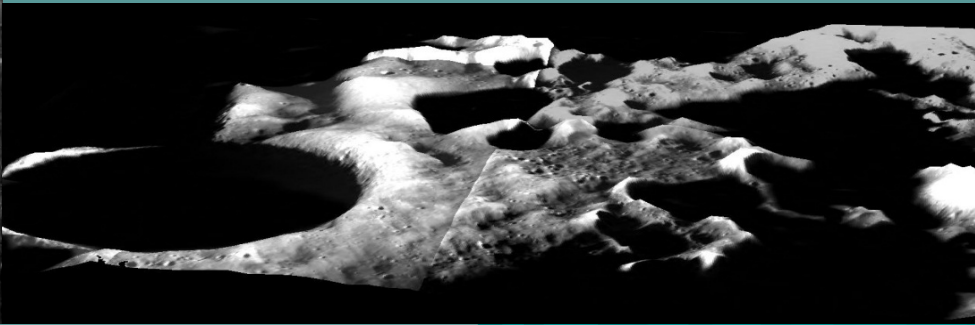
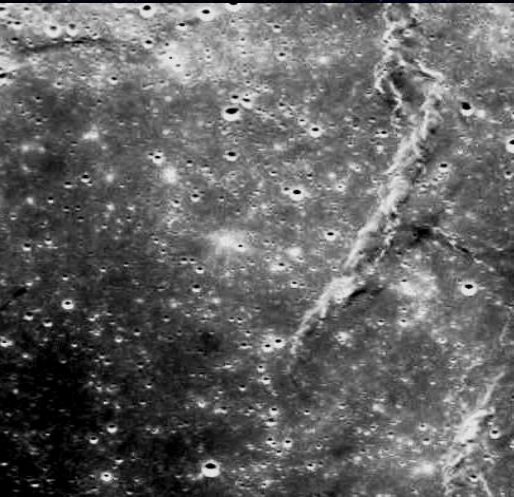
2016 Clément J, Oscar K, Valentin G, Manon M, Irene S, Christiane H



Science:

Destination Moon: a part of Earth.....

- Early Earth-Moon System
- Terrestrial Planet Differentiation and Evolution
- Solar System Impact Record
- Lunar Environment

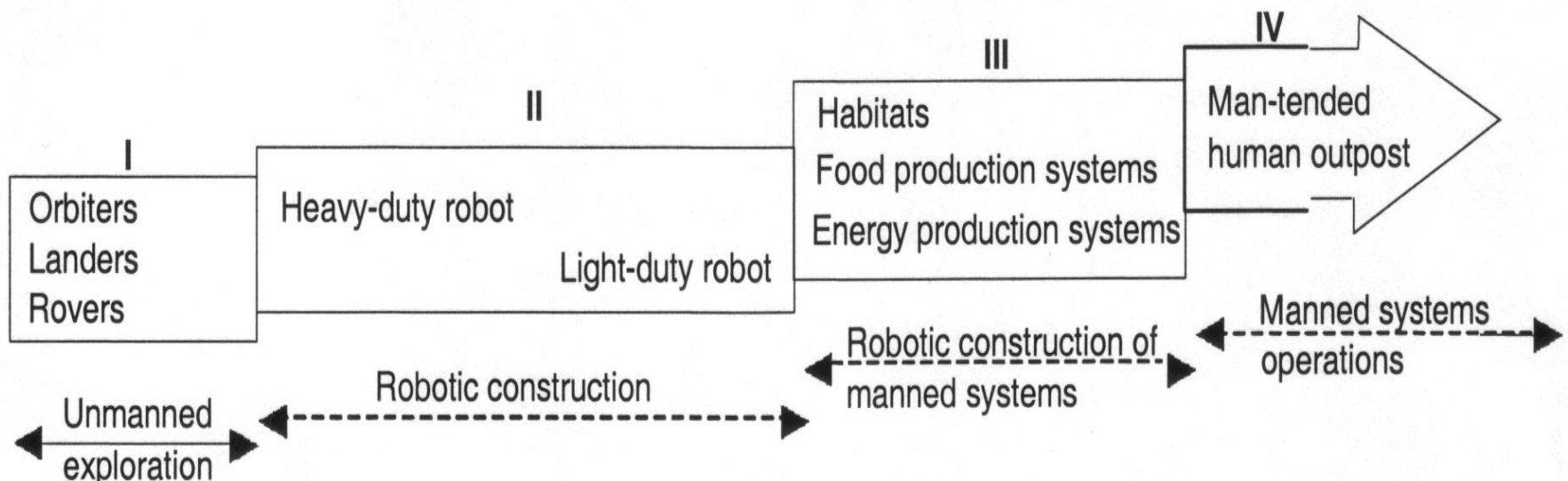
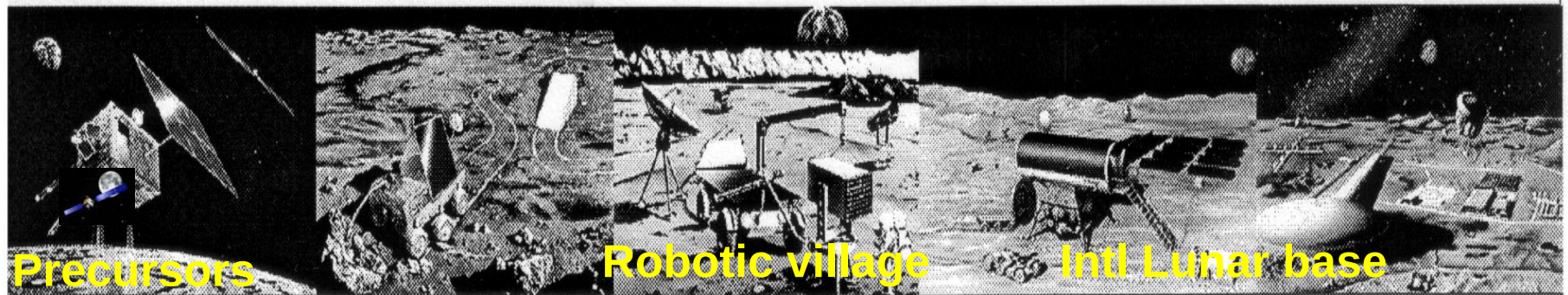
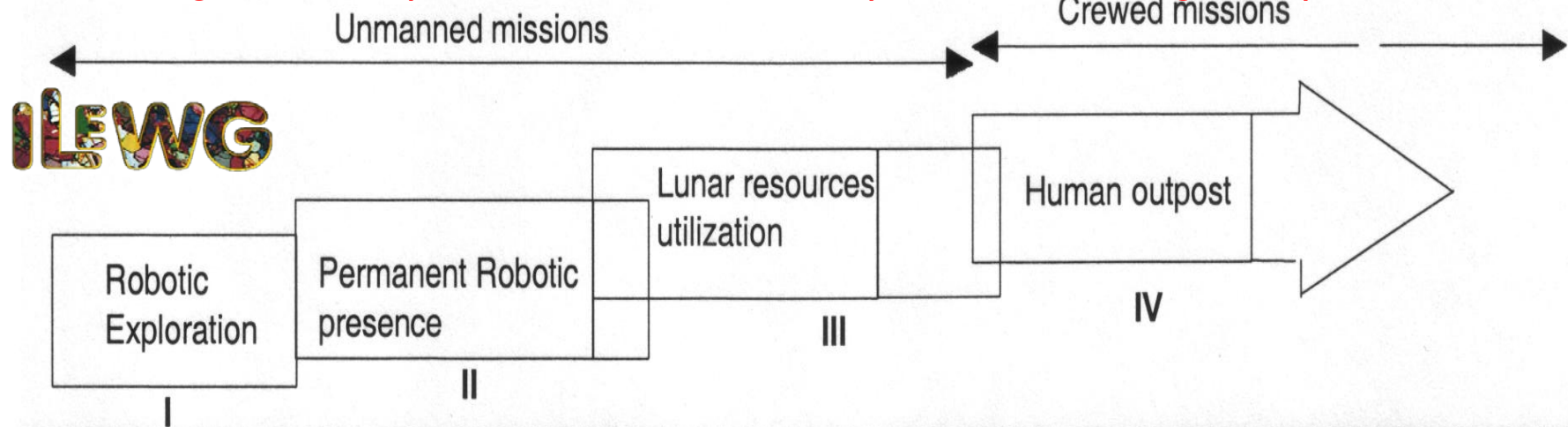


Science questions & knowledge gaps

- ◆ What are the conditions for planetary formation?
(bombardment chronology, isotopic dating) -> **craters/tecto detection**
- ◆ How does the Solar System work?
(Impact basins, accretion, collision) -> **morphologies**
- ◆ Comparative planetology **3D multispectral maps**
(volcanics, tectonics, cratering, erosion, interior & subsurface)
- ◆ What are the conditions for life?
(Search for extraterrestrial ice/organics on Moon) -> **dark maps**
- ◆ Validation of extreme organics and life detection technologies
(organics and ice) **where to bring them ?**
- ◆ Habitability of Moon (**planning, travel, maps, autonomous, remote action**)
(survival and return, life sciences , ecosystems, mini biospheres)
- ◆ Search for Early Earth samples **Trenching, subsurface layers, multispectral**
- ◆ Science from the Moon (Earth, solar system, astronomy, cosmology, SETI)



MoonVillage Roadmap: International Lunar Exploration Working Group 1998

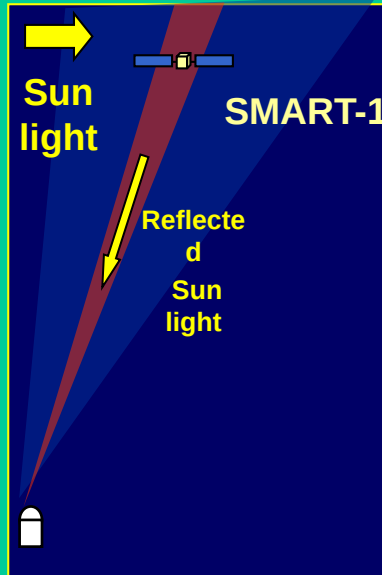


ILEWG Community events

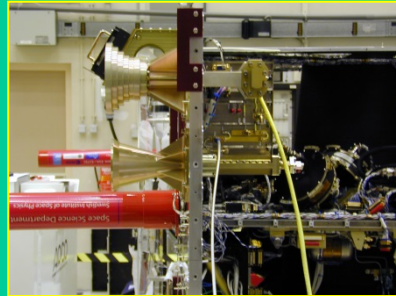
- ◆ **ICEUM ILEWG Int'l Conferences on Exploration & Utilisation of the Moon**
 - Beatenberg 1994 (founding conference co-chaired by Prof H. Curien),
 - Kyoto 1996, Moscow 1998, ESTEC 2000, Hawaii Nov 2003,
 - Udaipur Nov 2004, Toronto Sept 2005, Beijing Jul 2006, Sorrento Oct 2007,
 - ICEUM10/NASA LEAG/Space Resources Roundtable, Port Canaveral 27-31 Oct 2008,
 - GLUC/ICEUM11 Beijing 2010 (with IAF & CSA),
 - ICEUM13 Pasadena/COSPAR 2018, ICEUM14 Geneva EPSC/DPS 2019
- ◆ **COSPAR:** Washington92, Hamburg94, Nagoya98, Warsaw00, Houston02, Paris04, Beijing06, Montreal08, Bremen10, Mysore12, Moscow14, Pasadena18, Sydney20->21
- ◆ **IAF/IAC:** Houston 02, Bremen 03, Vancouver 04, Fukuoka 05, Valencia 06, Hyderabad 07, Glasgow 08, Daejeon 09, Global Lunar Beijing 10, Prag 10, Cape 2011, Naples 2012, Toronto 2014, Jerusalem 2015, Guadalajara 16, Adelaide 2017, Bremen 2018, Washington 2019, Cyber 2020, Dubai 2021, Paris 20212
- ◆ **EGS/EGU/ lunar sessions:** Hamburg 95, Vienna 97, Nice 98, The Hague 99, Nice 00 – 04, Vienna 2005-2019 yearly
- ◆ **Europlanet EPSC:** Berlin7 Muenster8, Potsdam9, Rome10 (yearly) Riga17, Berlin18, Geneva19
- ◆ **ILEWG meetings at International Conferences LPSC, IAC, ESLAB**
- ◆ **Website: ICEUM declarations online**
- ◆ **Publications:** 10 ICEUM proceedings + 7 books (Adv. Space Res.)
- ◆ **Outreach:** 18000 Google quotes



Some of the Innovative Technologies on Smart-1



Communication



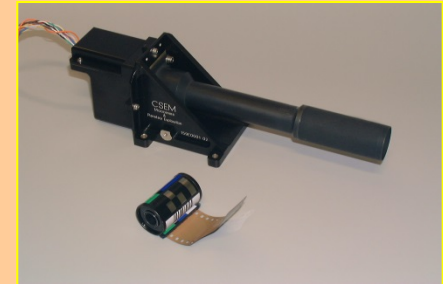
KA-band antenna



Triple junction solar cells



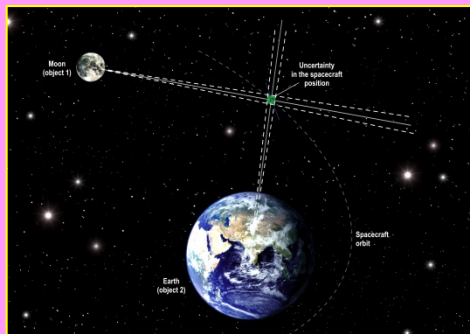
On-board computer



Multicolor microcamera

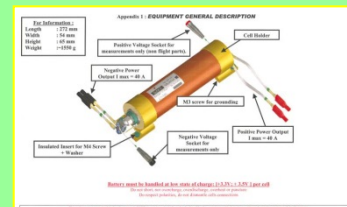


X-Ray Spectrometer



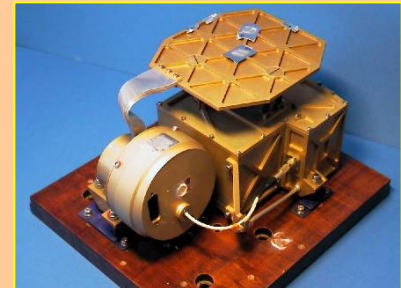
OBAN

Autonomy



Lithium ion batteries

Platform Technologies



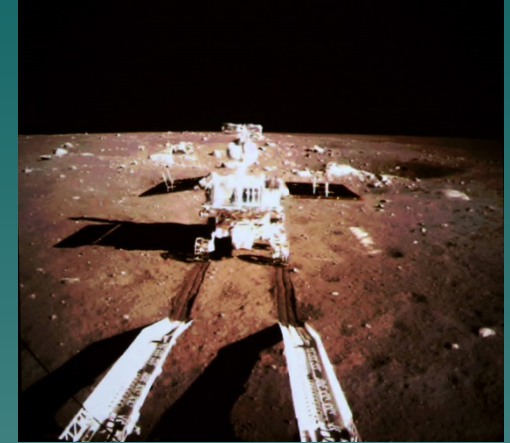
Infrared Spectrometer

Miniaturisation

Lunar village: next steps

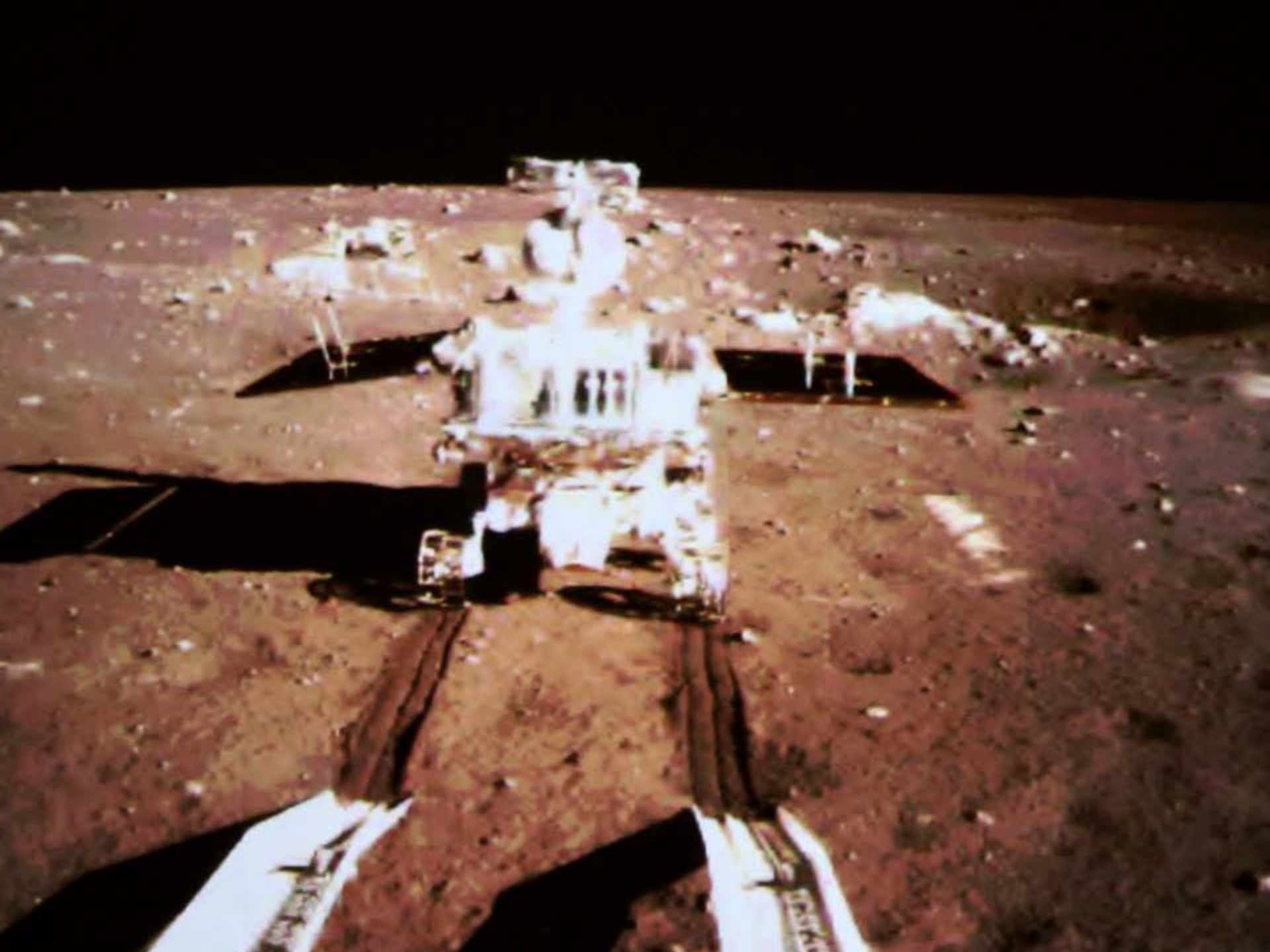
Surface Robotic Village

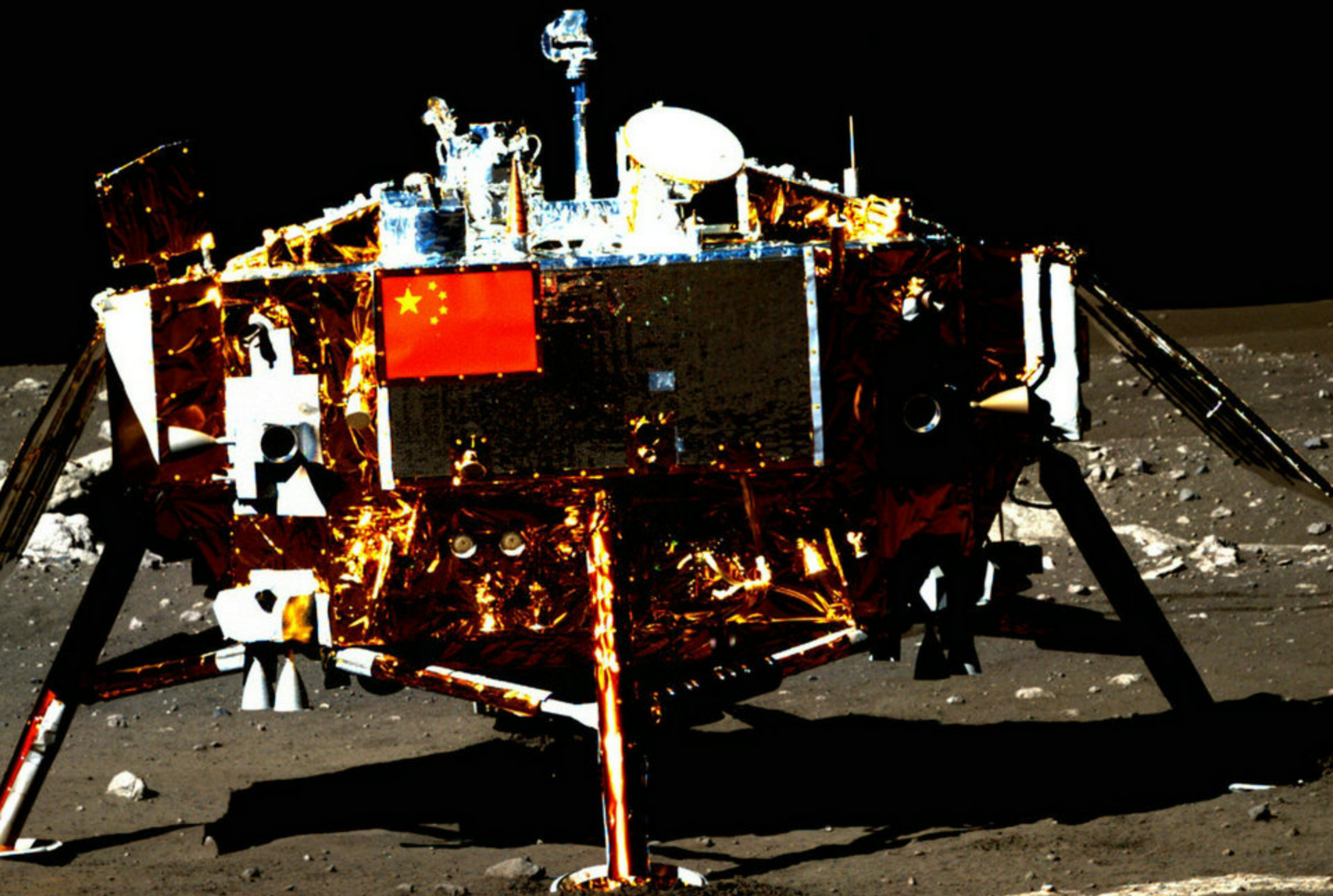
- ◆ 2013/Q4 Chang'E 3 lander & rover
- ◆ 2018/Q3-4 Chang'E 4 far side relay & lander
- ◆ 2019 Space IL Beresheet & Chandrayaan 2
- ◆ 2020/Q2 Chandrayaan 3 lander & rover
- ◆ 2020/Q4 Chang'E 5 sample return
- ◆ 2020/Q4 commercial GLXP follow on
- ◆ 2020 US Commercial Lunar Payload CLPS
- ◆ 2022+ Kari, Chang'E 6 pole sample return
- ◆ 2024+ J SLIM, Luna 25, 26 KARI lander
- ◆ 2025 Luna 27 Polar lander RU/ESA
- ◆ 2026 ESA technology resource lander



Humans & robots

- ◆ 2020 EM1 Orion+ ESA ServiceMod (auto), 2022 Space X (7H)
- ◆ 2023 EM2 Orion+ ESA ServiceMod (+4 crew), Space X (+8 H)
- ◆ 2024 Blue Origins, Space X, Dynetics Human lander
- ◆ **LEWNG** 2024 Artemis3 First woman on Moon, 2028 Sustain base





Human Robot partnership in ILEWG/ESTEC/OWF MoonMars field tests at Eifel volcano region





ESTEC/ILEWG ExoHab Lab module EuroMoonMars workshop July 2016



ILEWG EuroMoonMars Field Campaigns 2009-2019

◆ Lab & Field research

- Geology in-situ and samples
- Astrobiology and life sciences

◆ Instruments demo

- Cameras, spectros, comms
- Rovers & drones, Navigation, maps
- Traverses, Sampling, GPR, drills

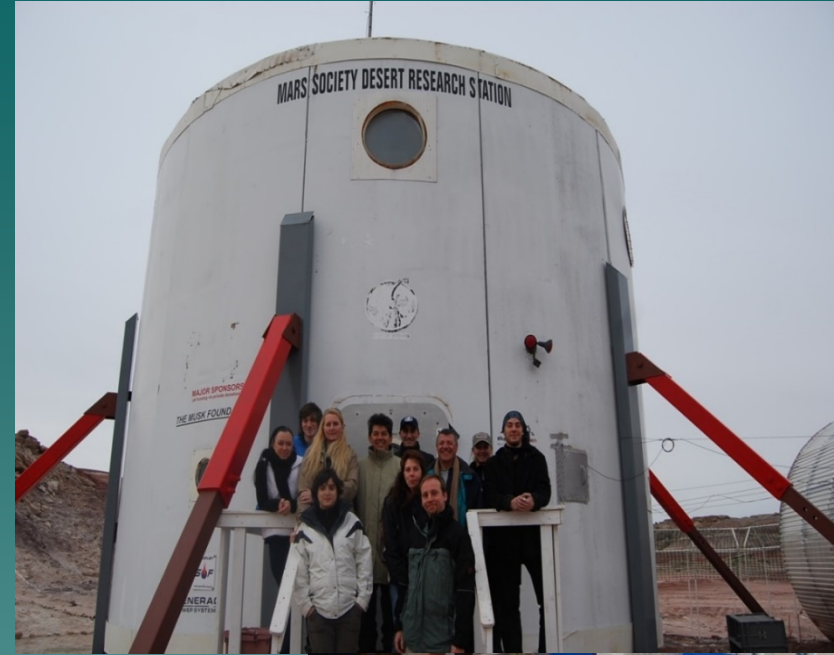
◆ Habitat technologies:

- Hab structure
- Architecture and layout
- Power, comms
- Grey water, Greenhouse
- Laboratory

◆ Human aspects

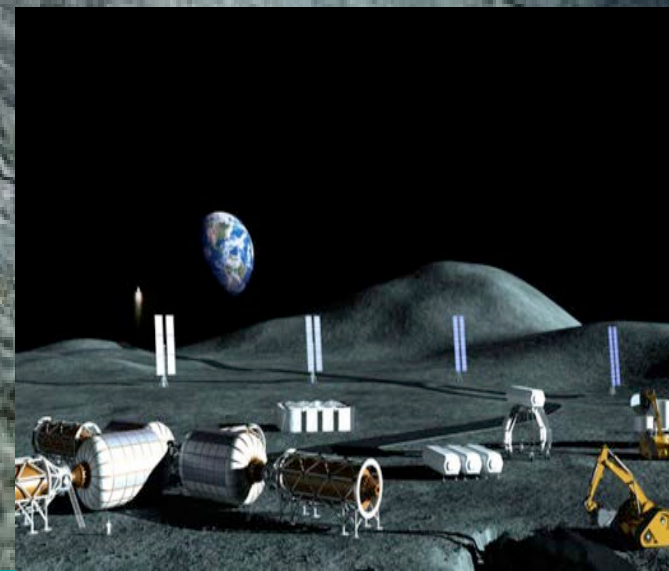
- Time sheets/Performance
- Astronauts & EVAs suits
- Food and medical study

◆ Training of young/advanced , outreach



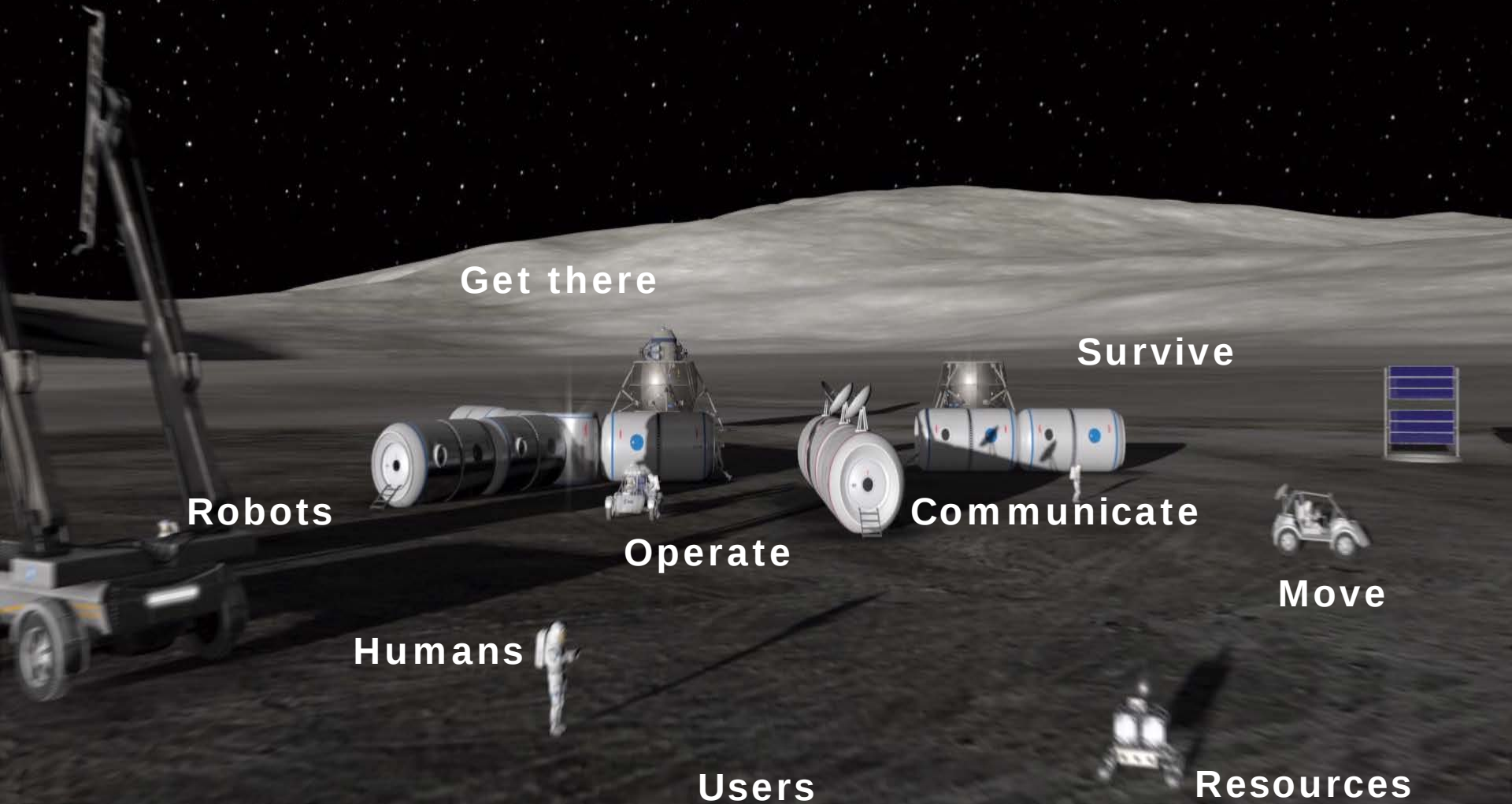
Sustainable Presence on the Moon

Credit: ESA/Foster + Partners

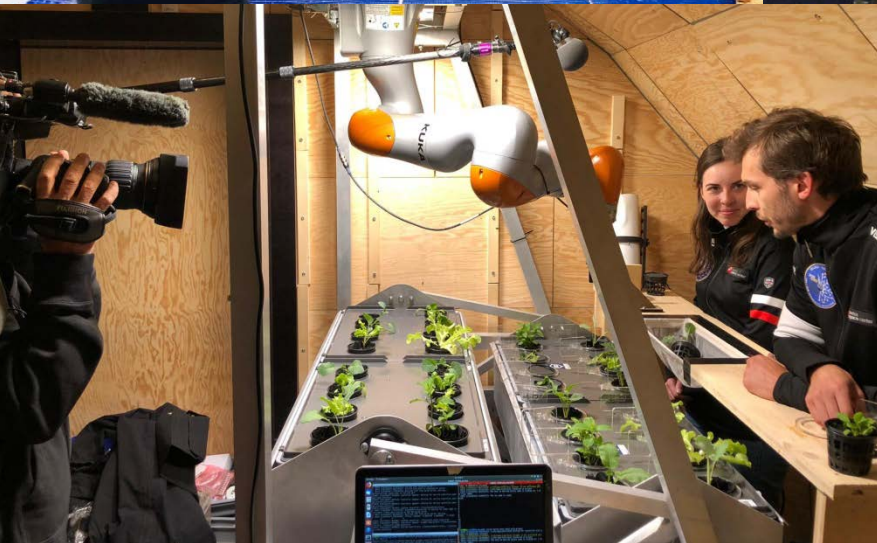




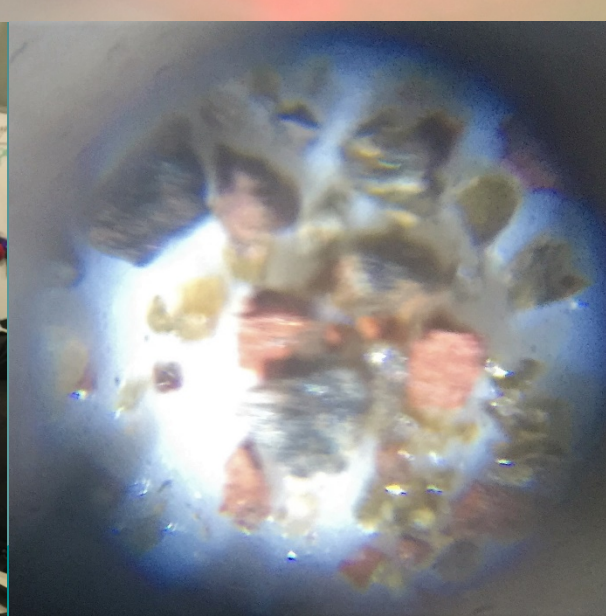
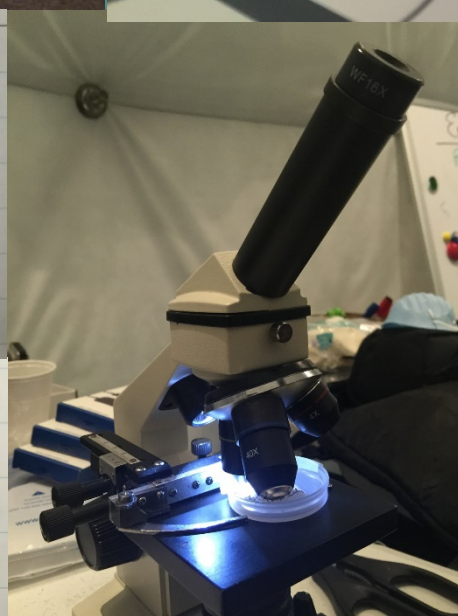
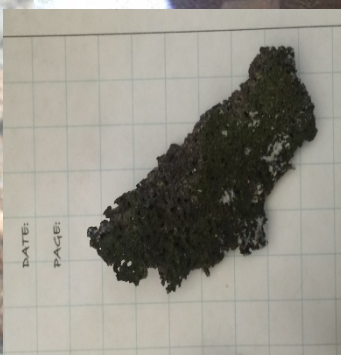
Challenges for Moon Village Implementation



IgLuna Ice Moon Habitat 2019

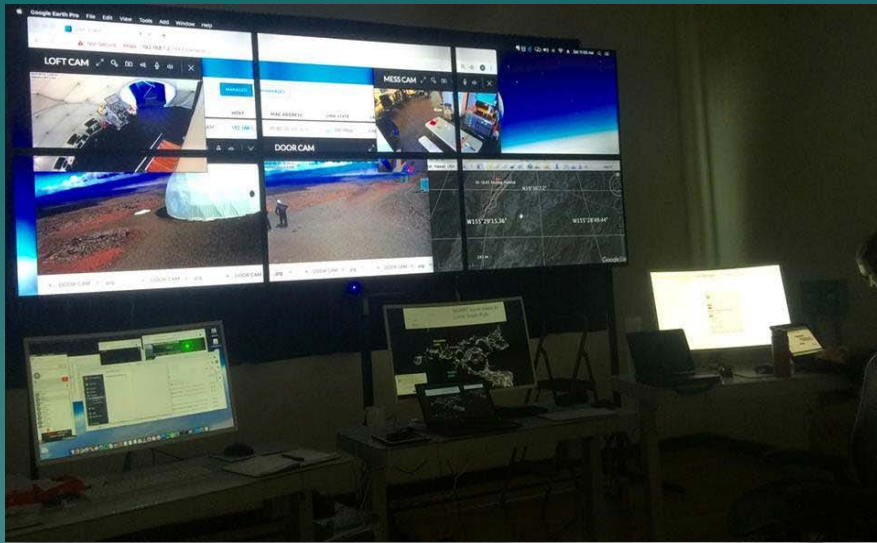


Hawaii EuroMoonMars 2018 instruments





Day 3 at MoonBase



Preparing MoonMars Village on Earth

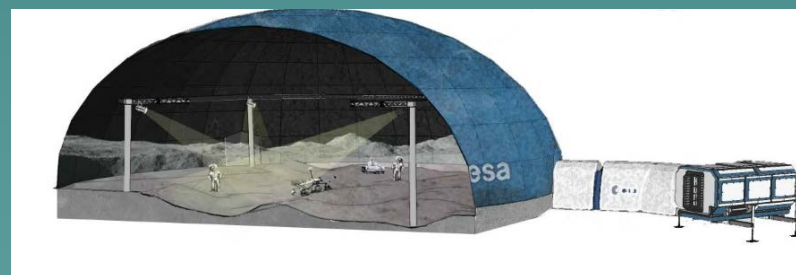
Robotic Village

- ◆ Landers and rovers , telerobotics
- ◆ Instruments
- ◆ Field tests in MoonMars analogues
- ◆ ISRU & life sciences
- ◆ Dusty Vacuum facilities



Human Bases

- ◆ Habitats & pressurised vehicles
- ◆ Laboratories (geo, astro, bio)
- ◆ Infrastructures (transport, power, ISRU)
- ◆ Human facilities
 - ESTEC ExoHab/EXoLab , EAC Luna
 - LunAres isolation studies
 - ESA Lab & Ice Habitat (CH)
- ◆ MoonMars analogue bases
 - MDRS, HiSeas, Intl MoonBase Alliance



Young Lunar Explorers brainstorming and recommendations

