

Human and Robotic Exploration

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On behalf of David Parker
ESA Director of Human and
Robotic Exploration
ESSC Plenary

28 May 2021

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- First elements of Exploration programme at CM22
- Programme and science progress for the exploration programme cornerstones
- Overview of the HRE Research Strategy development
- Status of the SciSpacE Science Roadmaps

Agenda 2025

On ESA website

http://www.esa.int/About_Us/Introducing_ESA_Agenda_2025

Executive Summary

https://esamultimedia.esa.int/docs/ESA_Agenda_2025_Executive_Summary.pdf

Full document:

https://download.esa.int/docs/ESA_Agenda_2025_final.pdf



Terrae Novae: E3P Period 3 overview



Top Priority: meet international commitments

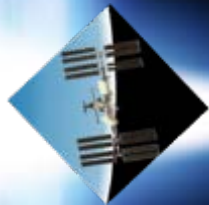
Continue Implementation of Projects, Science, & Operations agreed at Space19+

Autonomous Capabilities and European boots on the Moon by 2030 (additional investment)

Implement new robotic lunar projects

Grow LEO Economy

Prepare activities to implement in Period 4/5+



**CM16
E3P created**

**Space19+
Cornerstones
established**



**CM22
Moon surface +
LEO economy**



Towards a more autonomous exploration programme



2000 → 2015
Non-critical partner

ISS

Only 8.3% utilisation share

Contributions:

- Columbus
- US Nodes 2 & 3, Cupola, and MPLM, made in Europe
- ATVs

Used to building up industrial competences (incl. Spacelab)

2015 → 2030
Mutual interdependence

Gateway

> 50% modules

Orion

European Service Modules

All critical elements

MSR

> 20% of the partnership

ExoMars 2016

Trace Gas Orbiter

ExoMars 2022

Rosalind Franklin Rover

2030 → 2045
ESA led capabilities

E3P Period 3 – new options

- European Large Lunar Lander ?
- Cis-Lunar Transfer Vehicle ?
- Moonlight?
- Lunar science and space resources ?



- European identity
- Strategic autonomy
- Evolved cooperation
- Thematic leadership
- Transversal programmes
- New international partnerships

Agenda 2025 Mapping

Lead delivery of this challenge



ADDRESS PROGRAMME CHALLENGES

We will strive to have the first European on the Moon's surface by the end of this decade, define our role for human Mars exploration and prepare for a renewed presence in low Earth orbit.

TOP ACTIONS

SciSpaceE:
Drives applied science and technology for life on Earth

ESA will help create markets for space technologies serving the green and digital agendas by acting as technical partner for interaction with investors such as venture capital funds and business angels. Further, ESA will boost commercialisation by:

- opening up access to its unique technical facilities
- sharing responsibility and risk with industry
- simplifying access to ESA programmes and activities
- updating ESA procurement and technology strategy
- reducing the average time-to-contract significantly for contracts below €1 million by the end of 2022
- boosting the Technology Strategy to achieve 30% faster development and adoption of innovative technologies
- doubling spending on game-changing technologies

Continue to be a pathfinder for new cooperation and procurement models

Drive LEO and Moon commercialisation

Expand innovation actions in exploration: Spaceships + Luna facility

Use ExPeRT to help deliver this

ESA will negotiate with NASA to land the first European on the surface of the Moon

Wow factor

E3P following Space19+

4 Cornerstone campaigns + 2 transversal activities



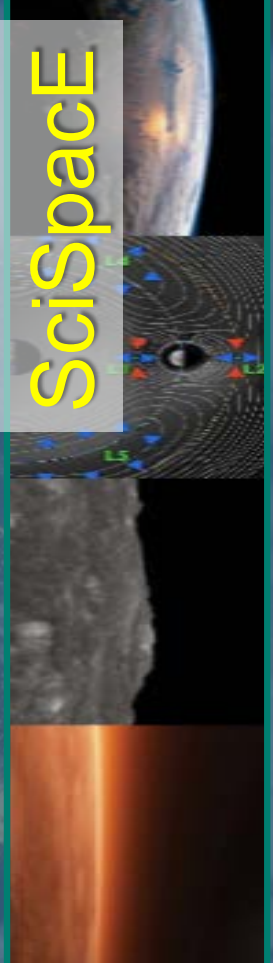
CS#1:
Humans in LEO



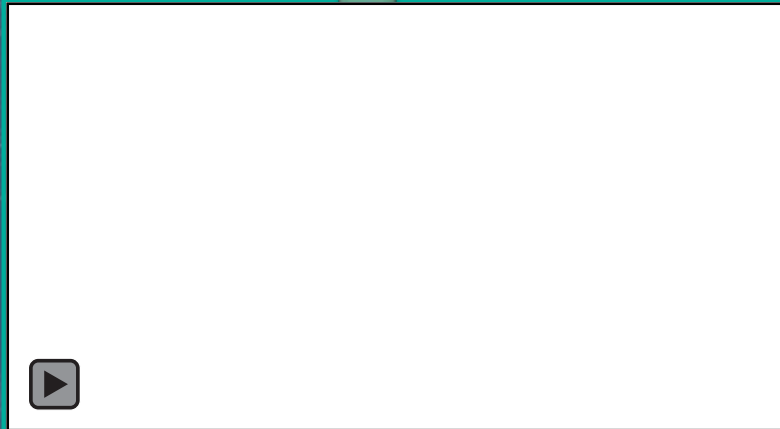
CS#4:
Mars Robotic



SciSpace



CS#3:
Moon robotic



Col-KA

Bartolomeo
commissioning

Preparing Artemis
1 Launch

ESM-2 Delivery

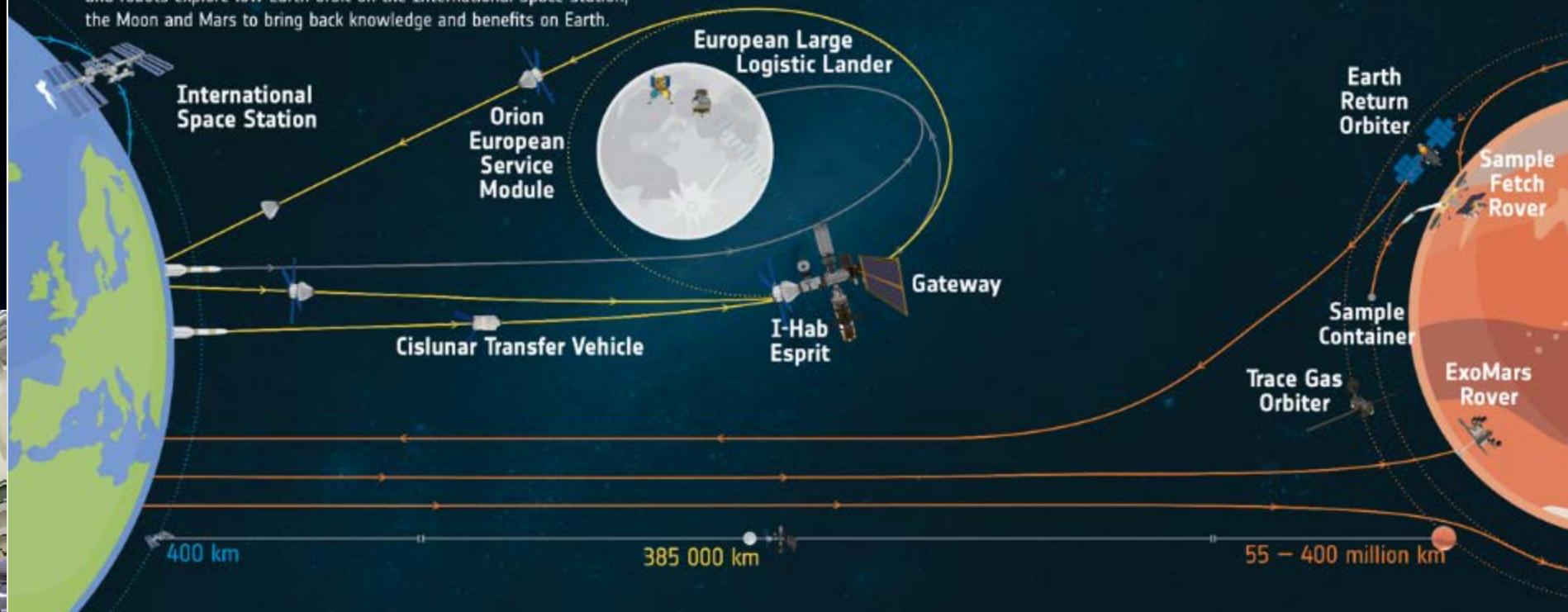
EL3 PRR

Rosalind Franklin
Rover Qualified

ERO PDR

ESA'S HUMAN AND ROBOTIC EXPLORATION DESTINATIONS

ESA's Human and Robotic Exploration programme will see astronauts and robots explore low Earth orbit on the International Space Station, the Moon and Mars to bring back knowledge and benefits on Earth.



CS#1: Humans in LEO

Research in Low Earth Orbit benefiting Earth



Mission Alpha - SpaceX Crew-2 Mission

Credit: NASA

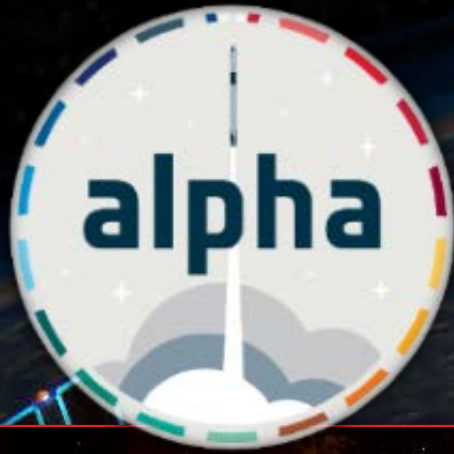


SpaceX's Crew-2 with NASA astronauts Megan McArthur and Shane Kimbrough, JAXA astronaut Akihiko Hoshide and ESA's Thomas Pesquet, launched on April 23rd



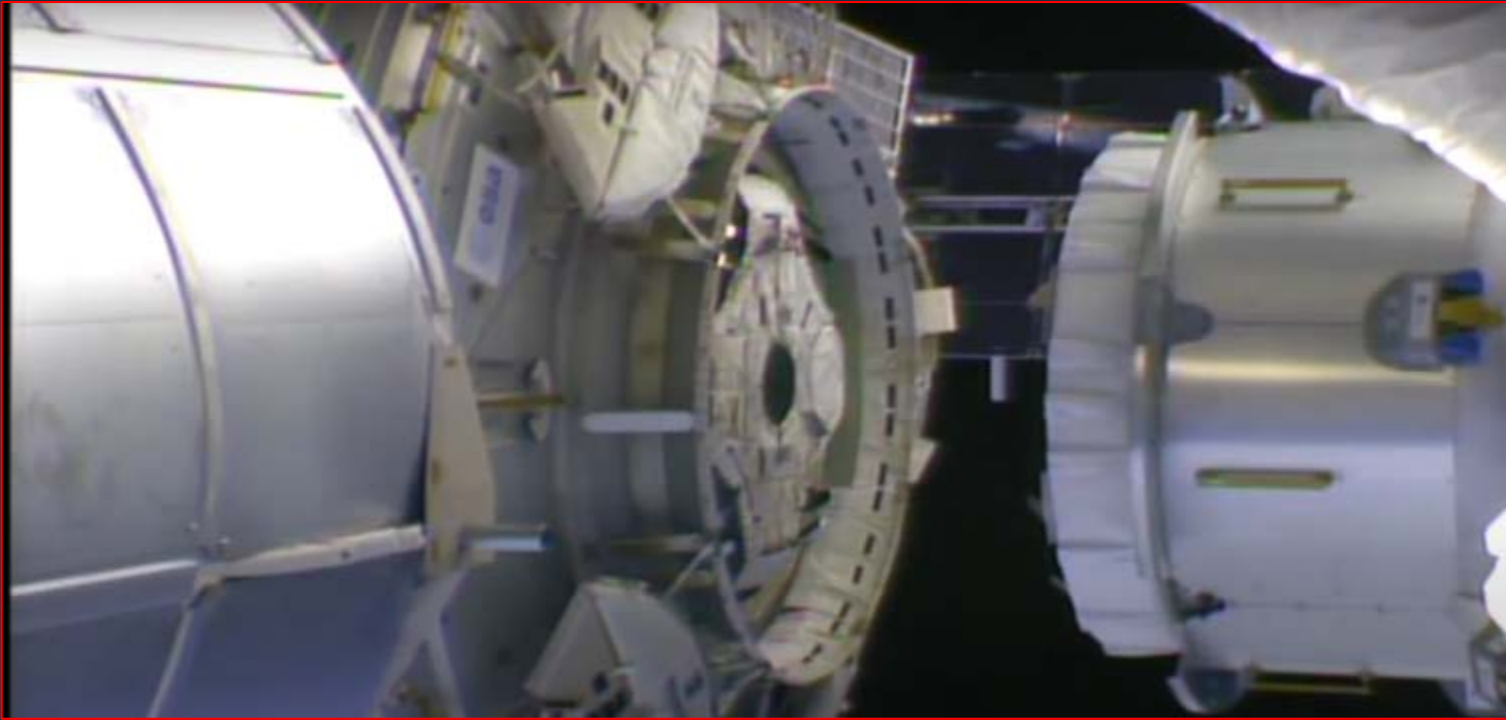
Credit: ESA

Mission Alpha – Thomas Pesquet



Nanoracks Bishop Airlock

Credit: NASA



Nanoracks Bishop Airlock launched on SpX-21 and was attached to the Tranquility module

It will enable more payload deployments outside the ISS



Credit: NASA₁₂

Bartolomeo EVA

A second EVA performed by NASA's Victor Glover and Michael Hopkins on 13 March to troubleshoot Bartolomeo power connectors

P1, P3 & P4 power connectors mated, however, P2 could not be mated and was capped.

Bartolomeo commissioning activities nearly complete

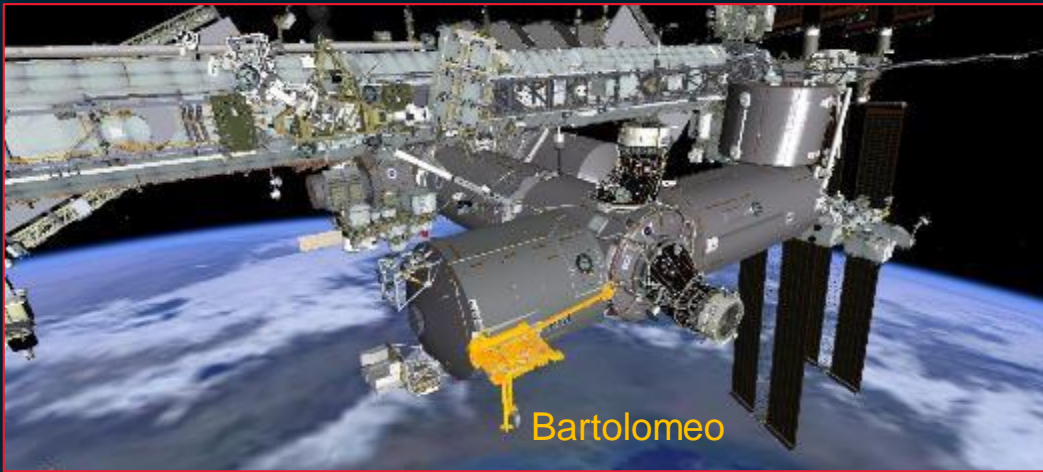


Credit: NASA

ISS – Bartolomeo Commissioning

Credit: NASA

End of March, the commissioning of the Bartolomeo (Columbus external payload facility) was completed successfully

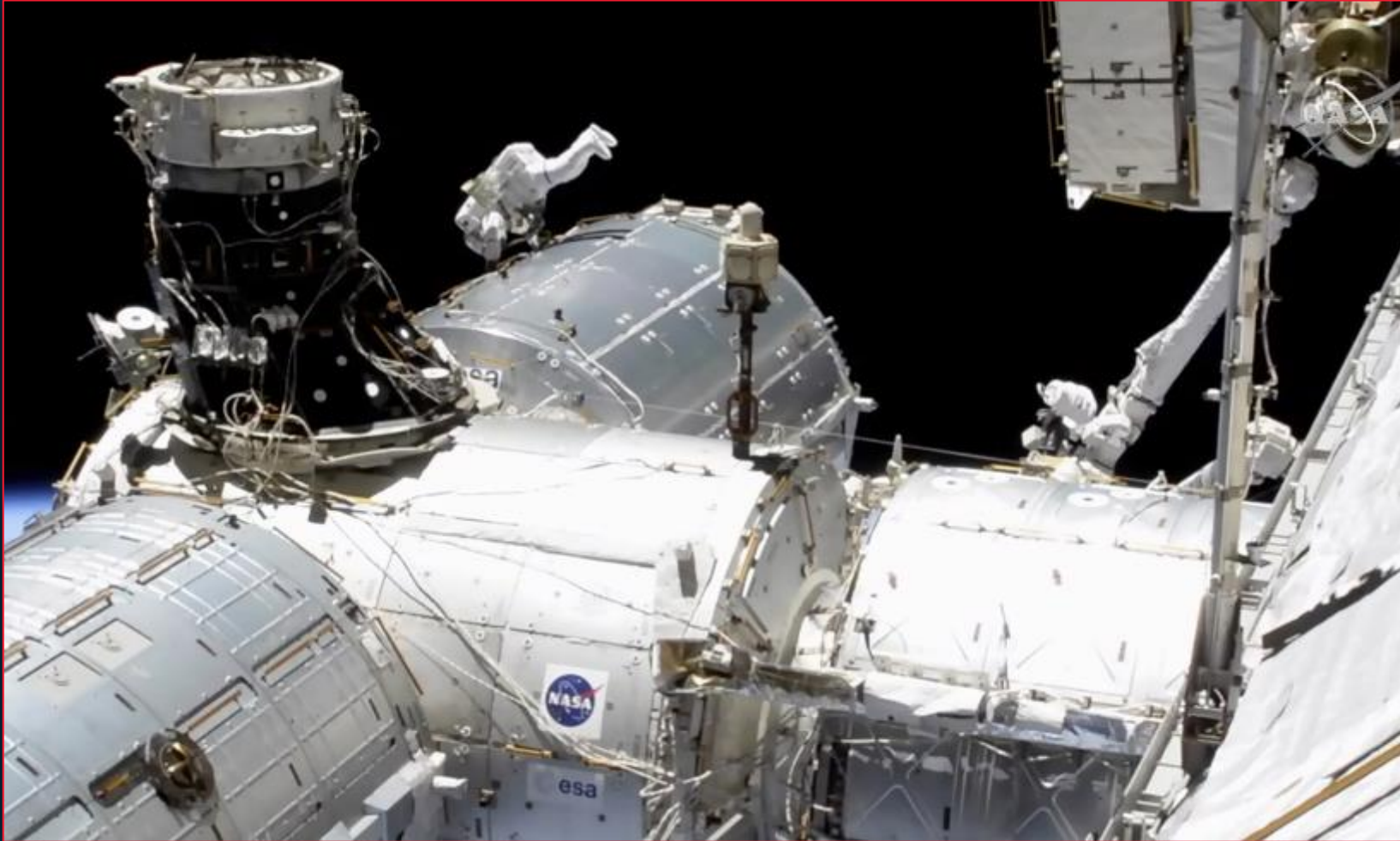


Credit: ForumAstronautico



The Col-Ka & Bartolomeo facilities outside Columbus taken during their installation spacewalk on 27 January 2021

ISS – Col-Ka Installation & Commissioning

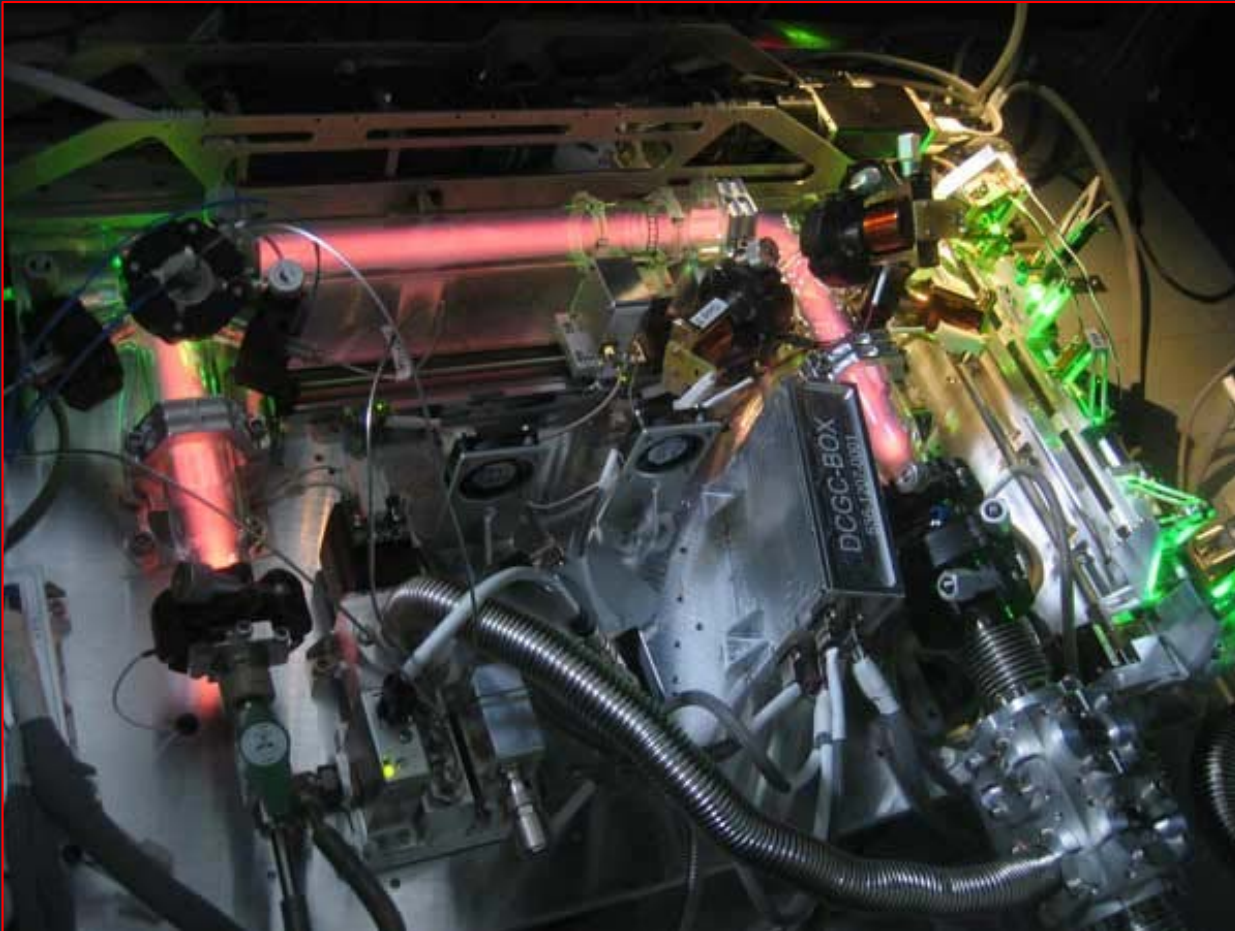


Credit: NASA

End of January, the installation of the Columbus Ka-band antenna (Col-Ka) was performed during Extra Vehicular Activity

Col-Ka commissioning (Phase A1) on-going

Plasma Kristall-4 Session #11



Credit: DLR

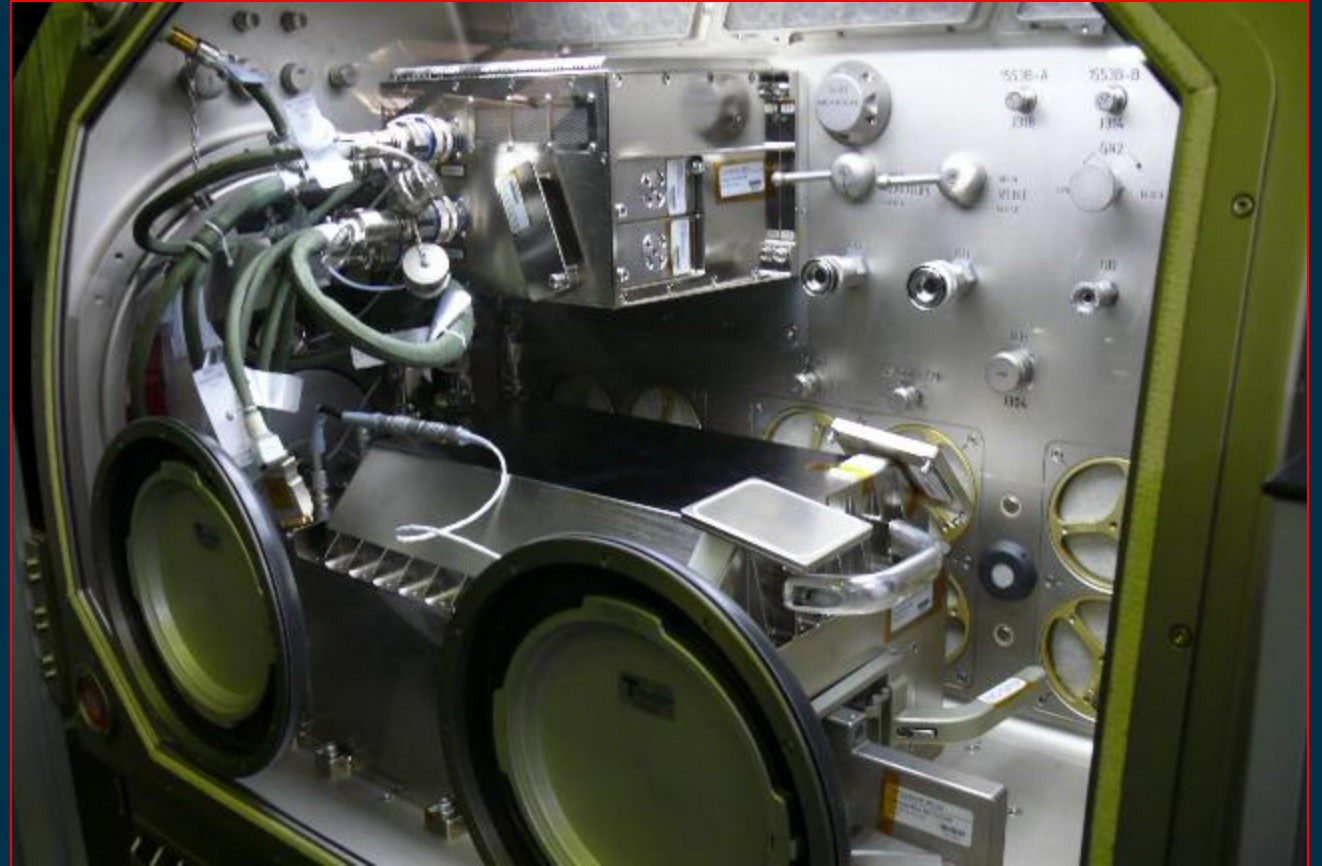
The European Physiology Module was upgraded on 26 February, with support from JAXA astronaut Soichi Noguchi, by replacing the Science Module Support Computer

With the new SMSC, PK-4 operations could resume and session #11 was completed at the end of March

Transparent Alloys – METCOMP

Astronaut Kate Rubins set up experiment hardware for Transparent Alloys

The investigation focuses on microstructure evolution by comparing the effects of Earth's gravity to microgravity, pinpointing the correlation in particle size, growth dynamics, and fluid flow



Credit: NASA

Astronaut Flight Opportunities

3 ISS missions assigned in Period 2

- ✓ *Alpha*: Thomas Pesquet (ongoing)
- ✓ *Cosmic Kiss*: Matthias Maurer (October 2021 - additional opportunity)



- ✓ *Minerva*: Samantha Cristoforetti (Spring 2022)

ESA New Astronaut Selection Campaign ▶



CS#2: Humans beyond LEO

- Launch of NASA and ESA elements on SLS B1B confirmed
- SpaceX selected for HLS demonstration mission

Europe's new era of lunar exploration



✓ ESM4/5/6 contract agreed

Orion European Service Module

Cis-Lunar Transfer Vehicle

✓ Design work underway

Gateway

✓ I-HAB and ESPRIT in development

Lunar Comm/Nav Services

✓ Design work in 2021

✓ PILOT precision landing system
✓ PROSPECT ice-drill

Luna-27

European Large Logistic Lander

✓ Design work underway

CS#3: Lunar robotic exploration



The *next* place where humans will live and work



Status of Moon Research Activities



Science Topical
Teams in place

Mission of
Opportunity
Payloads in
development for
partner led
missions

Mission pre-
Phase A studies
on going or in
preparation to
prepare future
selection

Payload studies
to prepare future
selection

Human surface
exploration
discussions
ongoing with NASA
regarding possible
contributions to
Artemis human
missions

Lunar Topical Teams now in place



Team	Coordinator
Lunar Polar Explorer Science Topical Team: Fundamental and exploration science at the lunar poles	Nicole Schmitz Institute of Planetary Research, DLR, Germany
Lunar Geological Explorer Science Topical Team: Fundamental and exploration science	M. Cristina De Sanctis Istituto di Astrofisica e Planetologia Spaziali-INAF, Italy
Physics of plasma–surface–exosphere–dust coupling at the lunar surface for future exploration programmes	Yoshifumi Futaana Swedish Institute of Space Physics (IRF), Sweden
Astronomical Lunar Observatory – ALO	Marc Klein Wolt Radboud University Nijmegen, Netherlands
Lunar BioMission	Charles Cockell, University of Edinburgh, UK
Space radiation research for the lunar missions	Marco Durante GSI, Germany
A complete resource production flowsheet for lunar materials	Kathryn Hadler Imperial College London, UK

Additional proposals received and under review for geophysics, and Aristarchus exploration

Payloads in development for partner led missions



All payloads address objectives in the Strategy for Space Resources and Strategy for Science at the Moon
Payloads prepare for future missions in preparation

Payload	Topic	Status
EMS-CLPS	Exosphere and volatiles	Testing for flight December 2021
EMS-LUPEX	Resource exploration and volatiles	In preparation for mission in 2024
PROSPECT-Luna	Resource exploration and volatiles	Phase CD for flight 2025
PROSPECT-CLPS	Resource exploration and volatiles	Manifest for CLPS delivery 2024
Laser reflector	Geophysics and relativity	Manifest CLPS delivery 2023

Mission concepts are being advanced with CDF and early industrial study activities

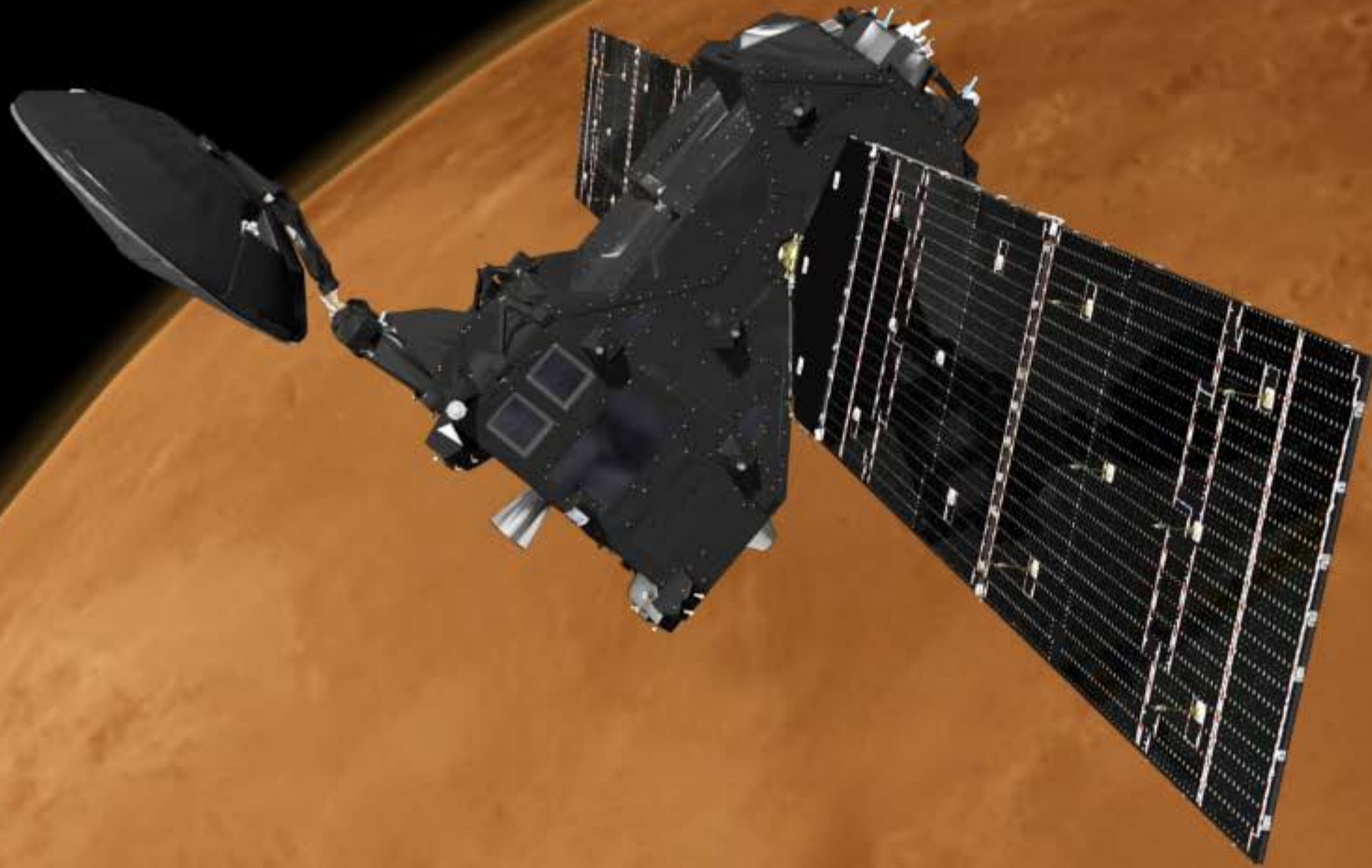
Mission Concept Theme	CDF Study	Pre-Phase A Industrial Study
Polar Explorer: Water, ice & volatile prospecting	Completed Q4, 2020	KO: April 2021
Astrophysical observatory	In preparation June, 2021	Q4, 2021
European rover for science & exploration	-	In preparation: NLT Q3/Q4, 2021 (TBC)
Biosciences mission exposing diverse biological samples	In preparation: Q4, 2021/2022 (TBC)	2022 (TBC)
Geological exploration of new terrains and lithologies	In preparation: Q4, 2021/2022 (TBC)	2022 (TBC)

- ISRU research objectives are addressed through ISRU DM Phase B1 and through measurements made on the above missions
- Cave exploration CDF study also planned

- ✓ Can be deployed on one or more EL3 missions
- ✓ Can be re-scoped for missions of opportunity
- ✓ Can be adapted for human mission scenarios
- ✓ Prepare the basis for a future payload selection

Payload Package	Pre-Phase A Study Status
Biosciences exposure facility	Open ITT: released April 2021
Exosphere & environment “weather station”	Open ITT: released April 2021
Low frequency radio antenna	Open ITT: released April 2021
Geophysical station	Open ITT: released April 2021
Geological analytical package	In preparation: ITT release due end Q2, 2021
Water, ice and volatiles prospecting package	In preparation: ITT release due end Q2, 2021

CS#4: Robotic Mars Exploration



European science and technology at the Red Planet



Ambitious decade of Mars exploration

Trace Gas
Orbiter

- TGO science continuing
- Data relay for Perseverance

- ERO System Preliminary Design review complete

Carrier
module

- Spacecraft environmental testing complete

Earth
Return
Orbiter

Descent
module

- Rover transferring to Italy for operations centre testing this week

Rover

Sample
Fetch
Rover

Sample
Transfer
Arm

- Industrial contracts about to be negotiated

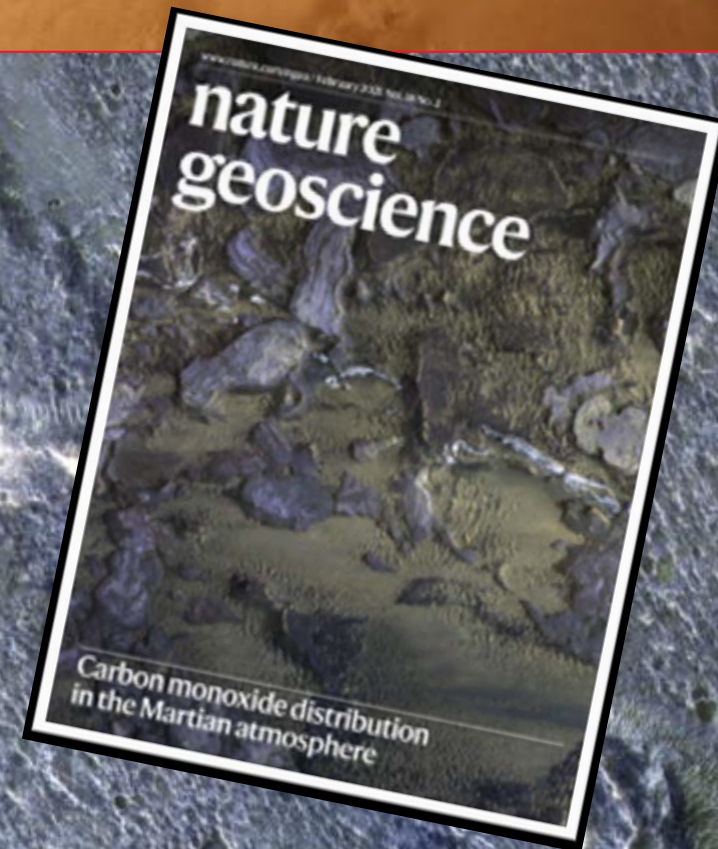
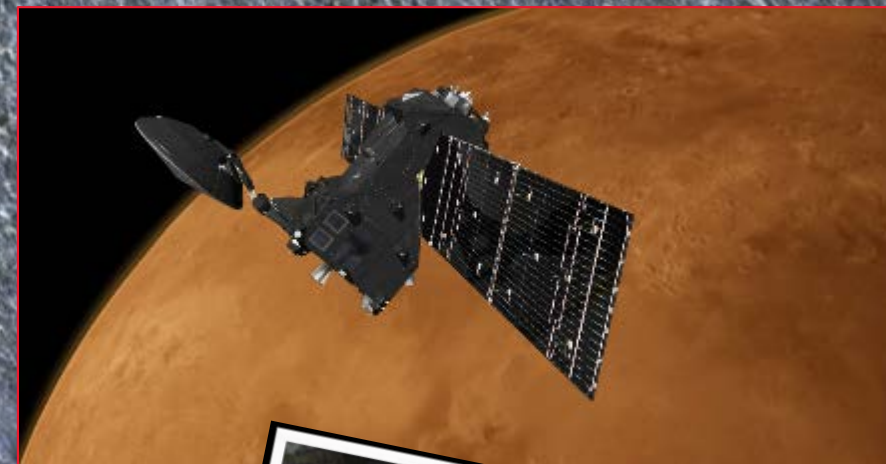
ExoMars
Mars Sample Return
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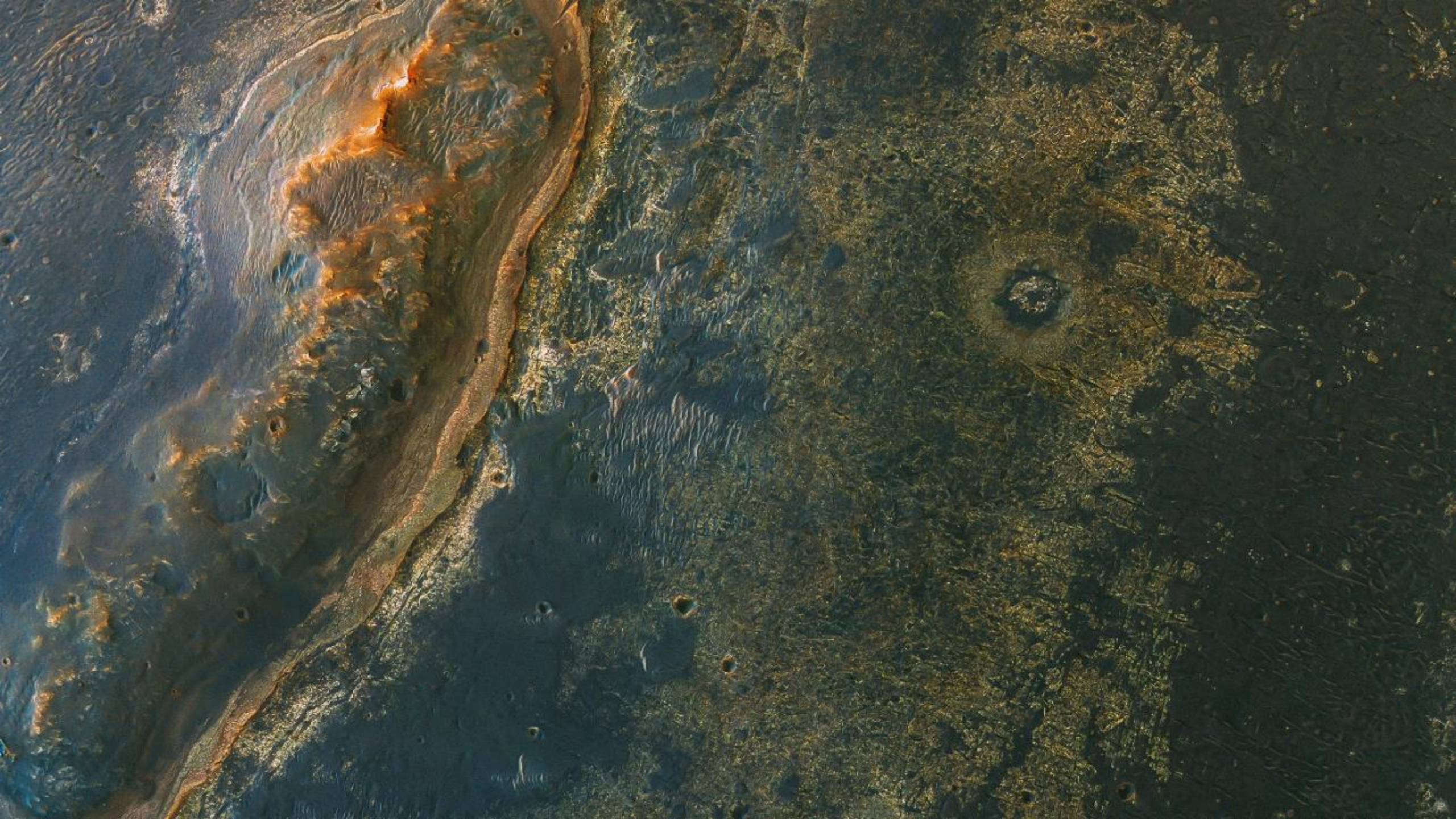
ExoMars Trace Gas Orbiter is five years old

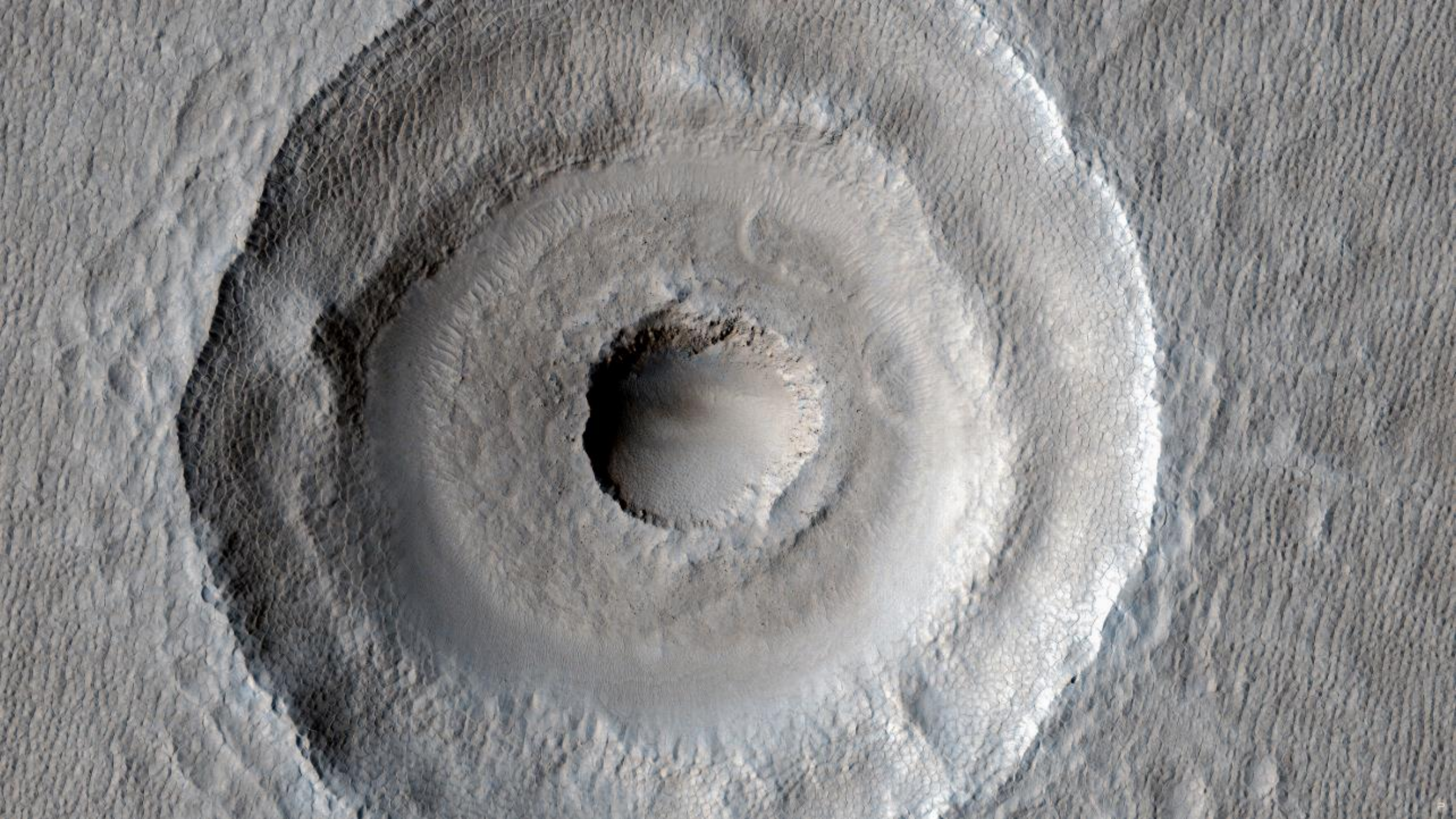
14 March
2016



20 000th image of Mars by the
CaSSIS stereo camera



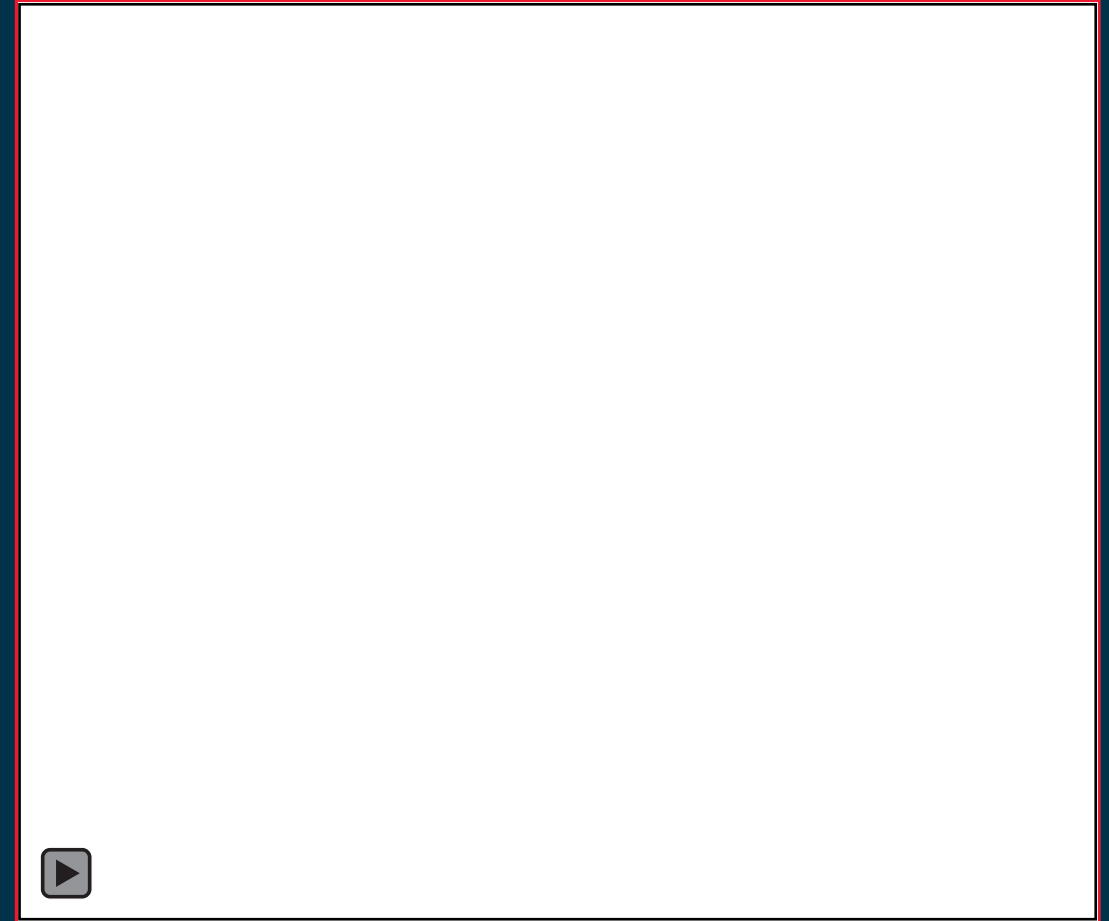






ExoMars and Mars Sample Return (MSR)

- **ExoMars 2022**: Schedule contingencies 41 days
- Top 3 risks:
 1. Completion of parachute qualification
 2. Correction of the propulsion command electronics by Lavochkin
 3. Contractual coverage by ROSCOSMOS of the AIT work at TAS in 2021/2022
- NASA/JPL working on **MSR** Phase-A since January 2021:
 - Evolution of system solution under study
 - Earth Return Orbiter in full development
 - Sample Fetch Rover and Sample Transfer Arm industrial proposals evaluation



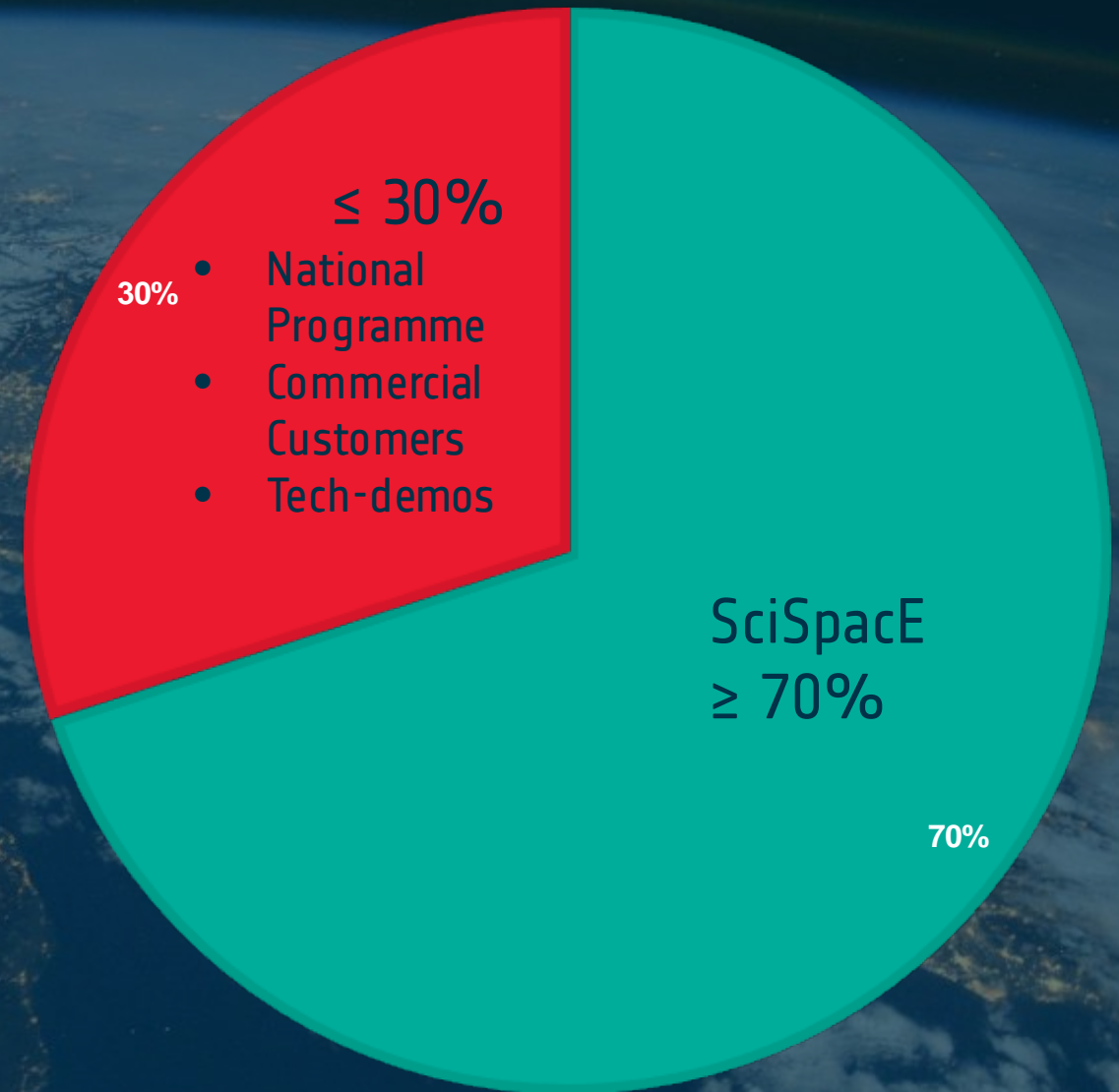
Courtesy Thales Alenia Space

*mass properties
characterisation in
TAS-F Cannes*

ESA HRE Research Strategy: What it is, what has been done, what remains to be done

- Define scope
- Define a vision : long-term and aspirational
- Define a mission: time-set and achievable
- Identify values: characteristics of how we work
- Identify and consult stakeholders
 - Science community
 - Member states
 - International Partners
 - In-house experts in international affairs, technology development, implementation experts, science leads
 - Research organizations
 - Industry
- Set priorities in general terms
- Conduct Strengths, Weaknesses, Opportunities and Threats Assessment against priorities

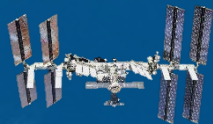
- Exploration – enabled AND enabling
- Health Sciences (formerly human research)
- Life Sciences (formerly space biology)
- Physical Sciences
- Planetary Sciences (formerly exploration sciences - still need a better name)



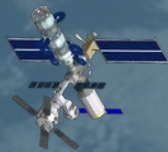
ESA SciSpacE platforms/destinations



Micro-/Partial Gravity	Radiation	Isolation/Confinement	Other
Bedrest Dry Immersion Parabolic Flight Drop Tower Sounding Rockets GBF ISS Gateway - future	Ground-based Radiation GSI Radiation Gateway - future	MARS500 / SIRIUS ESA-led isolation studies - future Concordia Gateway - future	Ground-based facilities

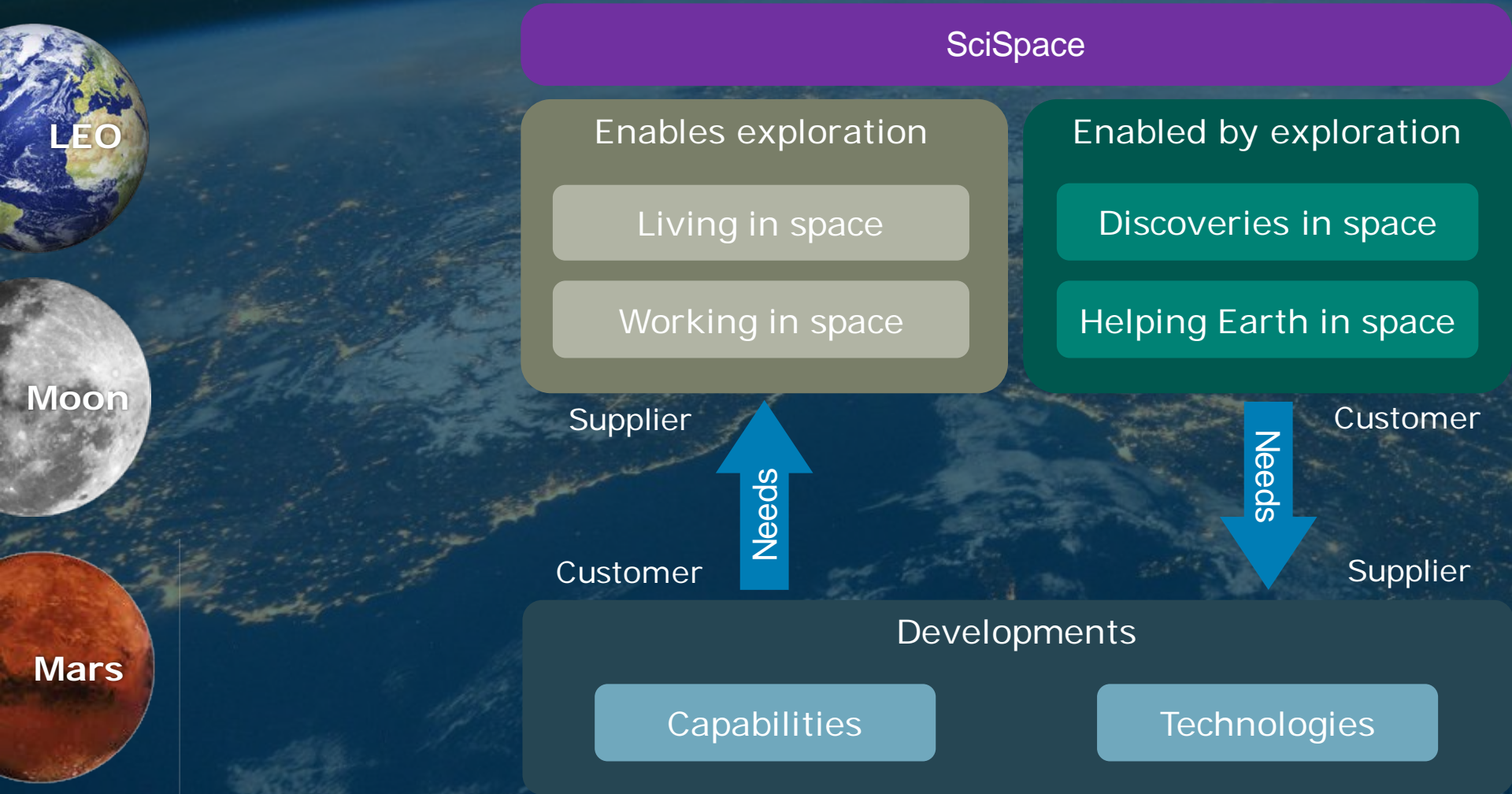


LEO: International Space Station (ISS), others?



BLEO: Gateway, Moon and Mars





Living in Space

- Effects of exploration environments on physiology, biology, pharmaceuticals; establishing countermeasures
- Biological processes underpinning sustainable life support

Working in Space

- Effects of exploration environments on technologies and mitigating approaches
- Finding and using space resources
- Addressing knowledge gaps underpinning transformative technologies for space
- Human performance in space environments

Discoveries in space

- The history and fundamental laws of the universe
- The nature and behaviour of matter
- The history and processes of the Solar System
- The emergence and distribution of life
- The fundamentals of biological systems

Helping Earth from Space

- Food, water and sanitation
- Energy and climate
- Health and wellbeing
- Economically driven research

- Roadmaps
- Topical Teams
- Advisory/Working Groups
- Destination –specific science strategies
- Consultations

What should we do

- Resources
- Feasibility
- Capability
- Risks

- Member States
- International partners
- Industry
- Trends

What can we do best

What can we do



Timeline for Science Strategy Creation



SciSpacE Roadmaps Status

SciSpacE Research Roadmaps in the E3P Programme

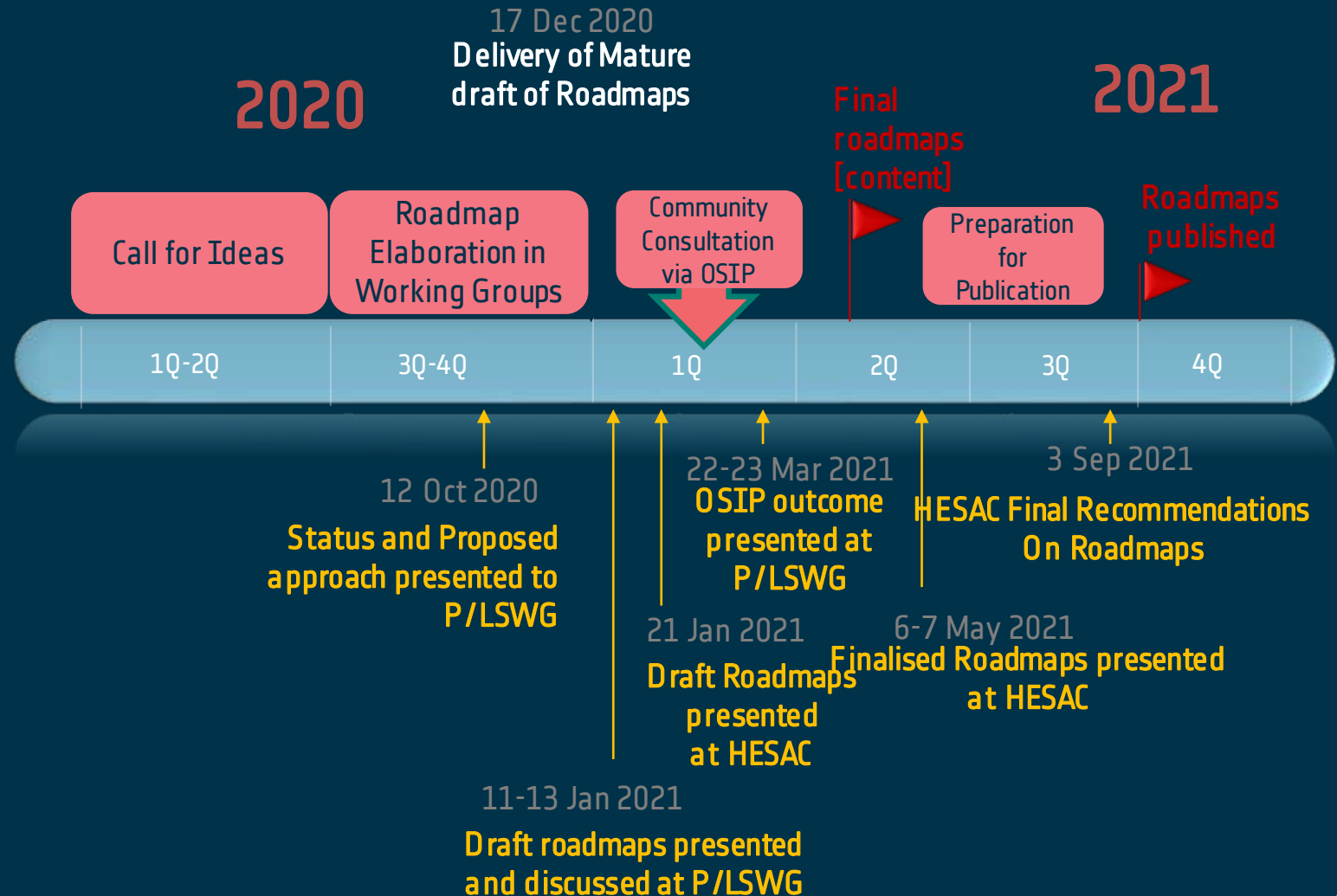
- The 2016 roadmaps were created with the research community during the preparation of the first E3P period and focused on optimal utilisation ISS and ground-based platforms.
- The current roadmap exercise was undertaken to update the previous work to identify key questions for the broader range of platforms available with the addition of Gateway, Moon and Mars to ISS and other LEO platforms in the future E3P programme periods.
- The SciSpacE Roadmaps represent the research community's recommendations on scientific goals and focus for research within the E3P programme.
- The Roadmaps are an important input to the definition of the overall E3P Science Strategy, alongside with Exploration Enabling Research

- Consulted the science community as represented by:
 - Science teams with projects in SciSpacE research pool
 - Topical Teams
 - Call for Ideas (CFI) posted on HRE Research Portal, with thematic workshops where applicable
- Roadmaps written by working groups consisting of representatives from the research community, coordinating with the broader community
- In some cases new roadmaps were added to address identified gap
- Public comment consultation of draft roadmaps on OSIP platform (February 2021)
 - 20 comments received, mainly in life science area. None of the submissions warranted major changes. Some minor updates implemented in roadmaps
- PSWG & LSWG involvement in process
 - P/LSWG involved as observers in Roadmap WG's and provided comments on drafts at January P/LSWG meetings.
 - OSIP consultations comments reviewed by P/LSWG

SciSpacE Roadmap Update status and forward plan

- Roadmaps elaborated by working groups consisting of representatives from the research community, coordinating with the broader community for inputs, comments and review
- ESA Science Advisory groups (P/LSWG, HESAC) consulted on approach and reviewed draft roadmaps
- Draft Roadmaps published on ESA OSIP platform for 4 weeks for public comments, these were assessed with the support of P/LSWG and minor updates where needed
- Presentation of updated roadmaps to HESAC for further comments and recommendations as well as consultation with AWG & SSEWG foreseen ahead of publication of final roadmaps.

SciSpacE Roadmap Timeline



2021 SciSpacE ROADMAP STRUCTURE

Biology

- Biology in Space and Analogue Environments
- Astrobiology
- Regenerative Life Support Systems in Space

Physical Sciences

- Fundamental Physics
- **Astrophysics**
- **Planetary Science**
- **Applied Space Sciences**
- **Earth Observation**
- Materials Science
- Two-Phase Heat Transfer
- Soft Matter Physics

Pharmacology

Human Research

- Human Physiology
- Behavioural Health and Performance
- **Countermeasures and Integrative Approach**

Cross Linking
between Roadmaps

Radiation

Note: New topics compared to 2016 Roadmaps highlighted in yellow.

E3P includes missions to LEO, Moon and Mars permitting a broader range of topics to be addressed compared to previous periods.

- The opportunities offered by E3P LEO, Moon and Mars platforms enables a broader range of science topics to be addressed in the programme than in the past. This is reflected in the expanded number of SciSpacE roadmaps addressing aspects such as Astrophysics, Planetary Sciences and Earth Observation.
- Close strategic coordination between HRE, SCI and EOP required to ensure a common vision for science within ESA and that research activities and projects are complimentary



Terrae Novae

KNOWLEDGE — ECONOMY — INSPIRATION — COOPERATION