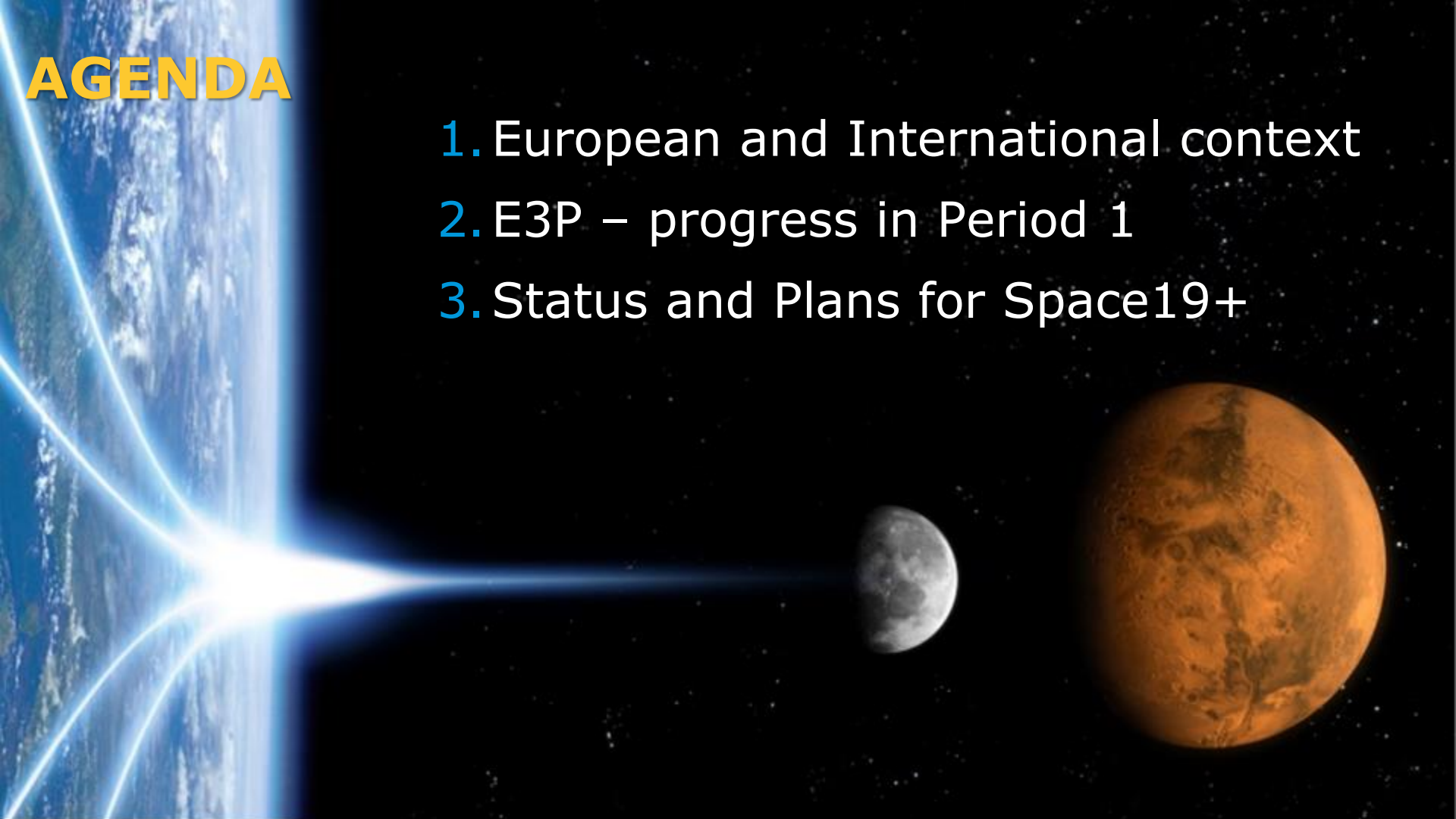
Once Explorers, Always Explorers
Update on E3P status and plans

The European Space Exploration Envelope Programme

David Parker
Director - Human and Robotic Exploration

AGENDA

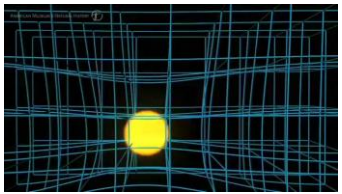
1. European and International context
2. E3P – progress in Period 1
3. Status and Plans for Space19+



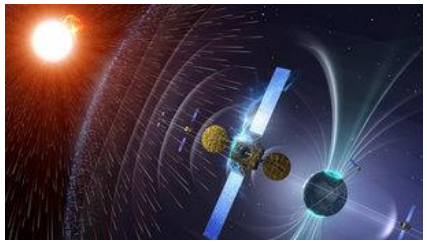
EUROPEAN AND INTERNATIONAL CONTEXT

Four Programmatic Pillars

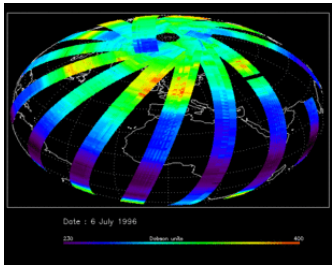
Science and Exploration

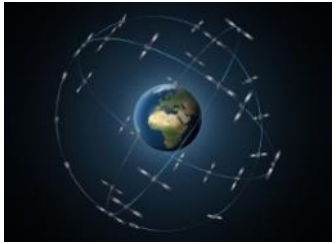


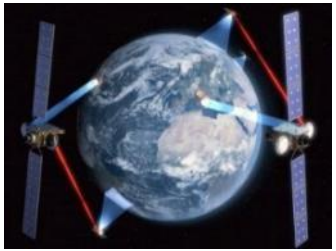
Safety and Security



Applications

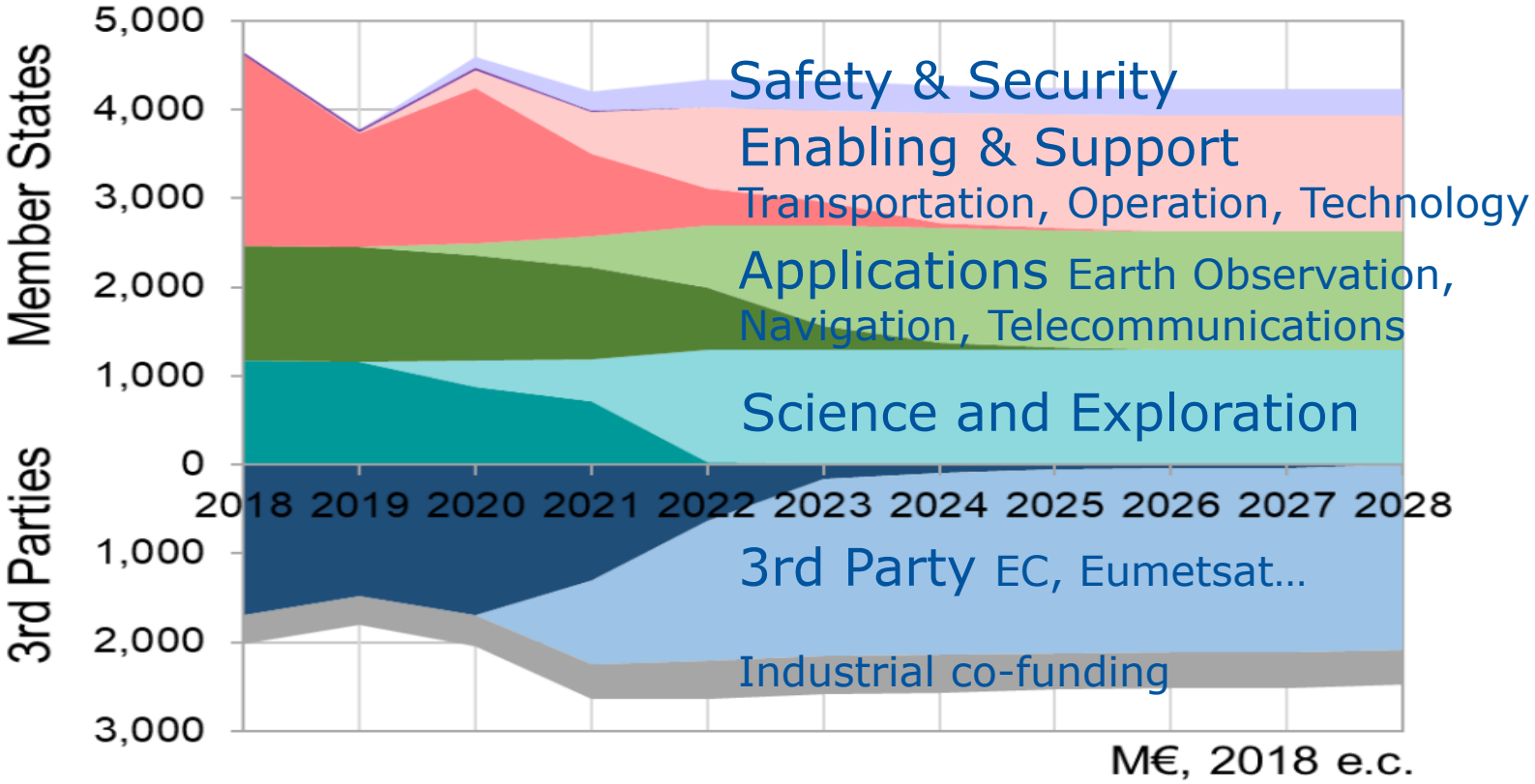




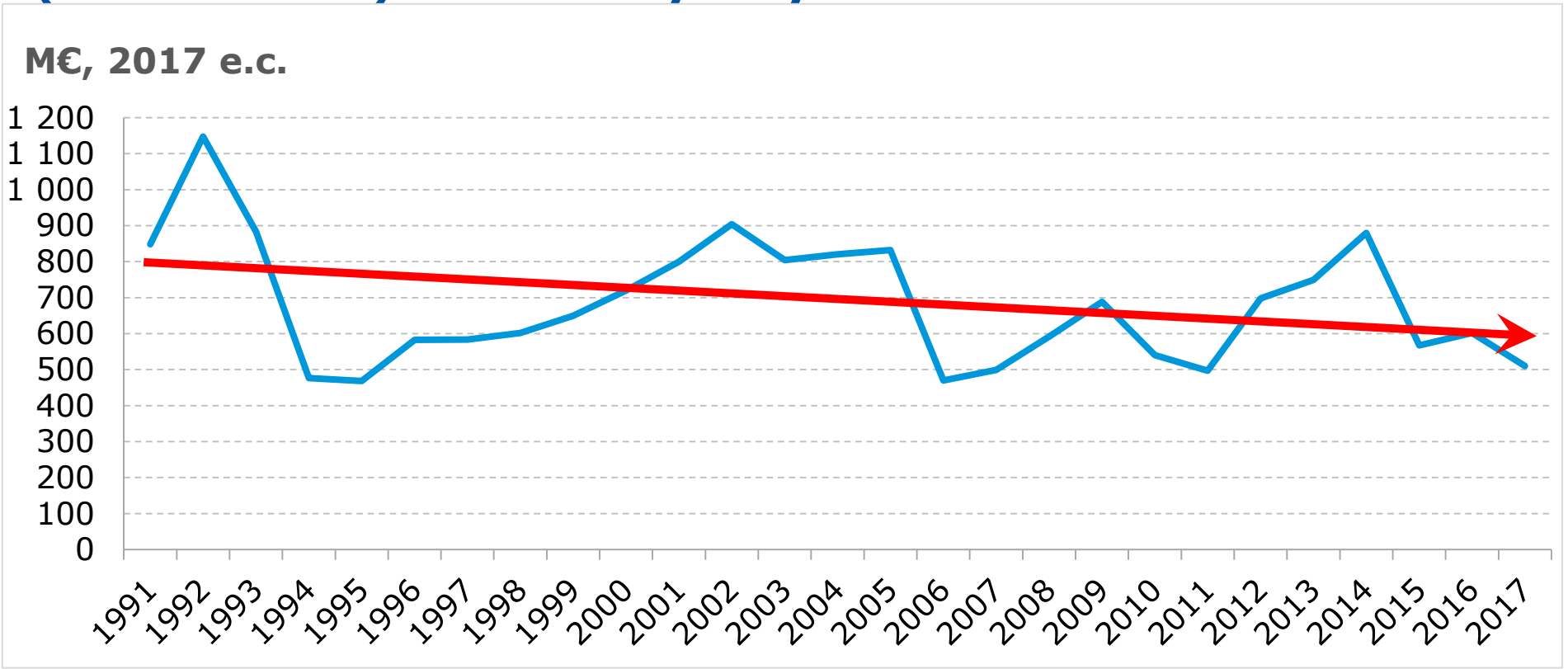


Enabling & Support (transportation, tech, & ops)

Funding - ESA draft Long Term Plan



ESA space exploration average cost 675 M€/yr (1991 – 2017) – but today only 500M€



Exploration @ESA is Strategy-Driven

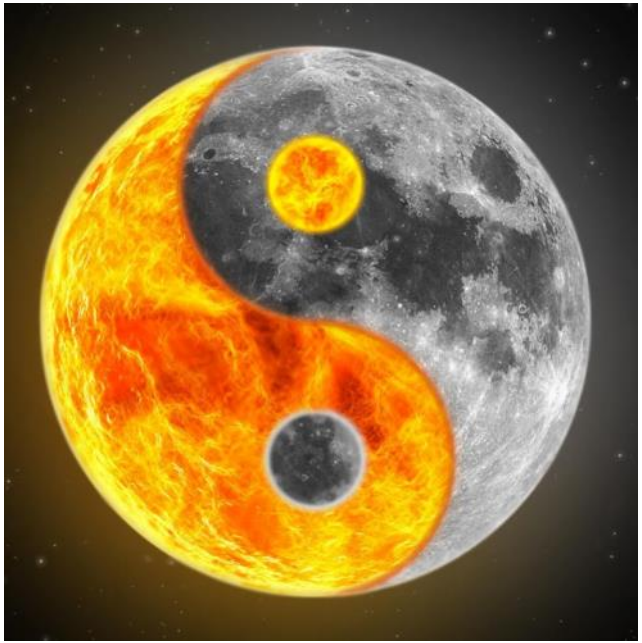
"focused on solar system destinations where humans will someday live and work."

Global Exploration Strategy Framework Document, 2007

ESA Scientific Programme

'bottom-up' + mandatory

➢ **competitive mission selection** among proposals from science community

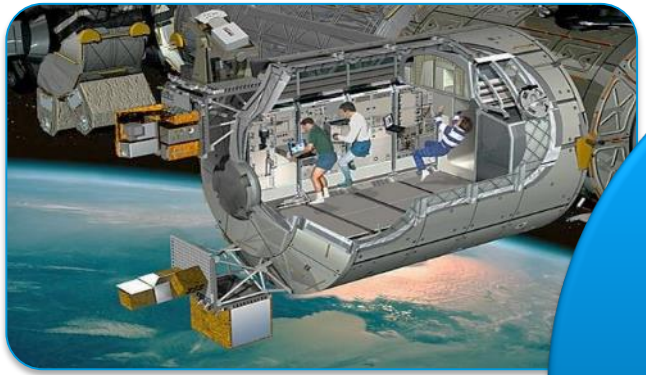


ESA Exploration Programme

'top-down' + optional

➢ **step-wise** with goal of extending human reach to Mars surface

Why Explore ?



New knowledge

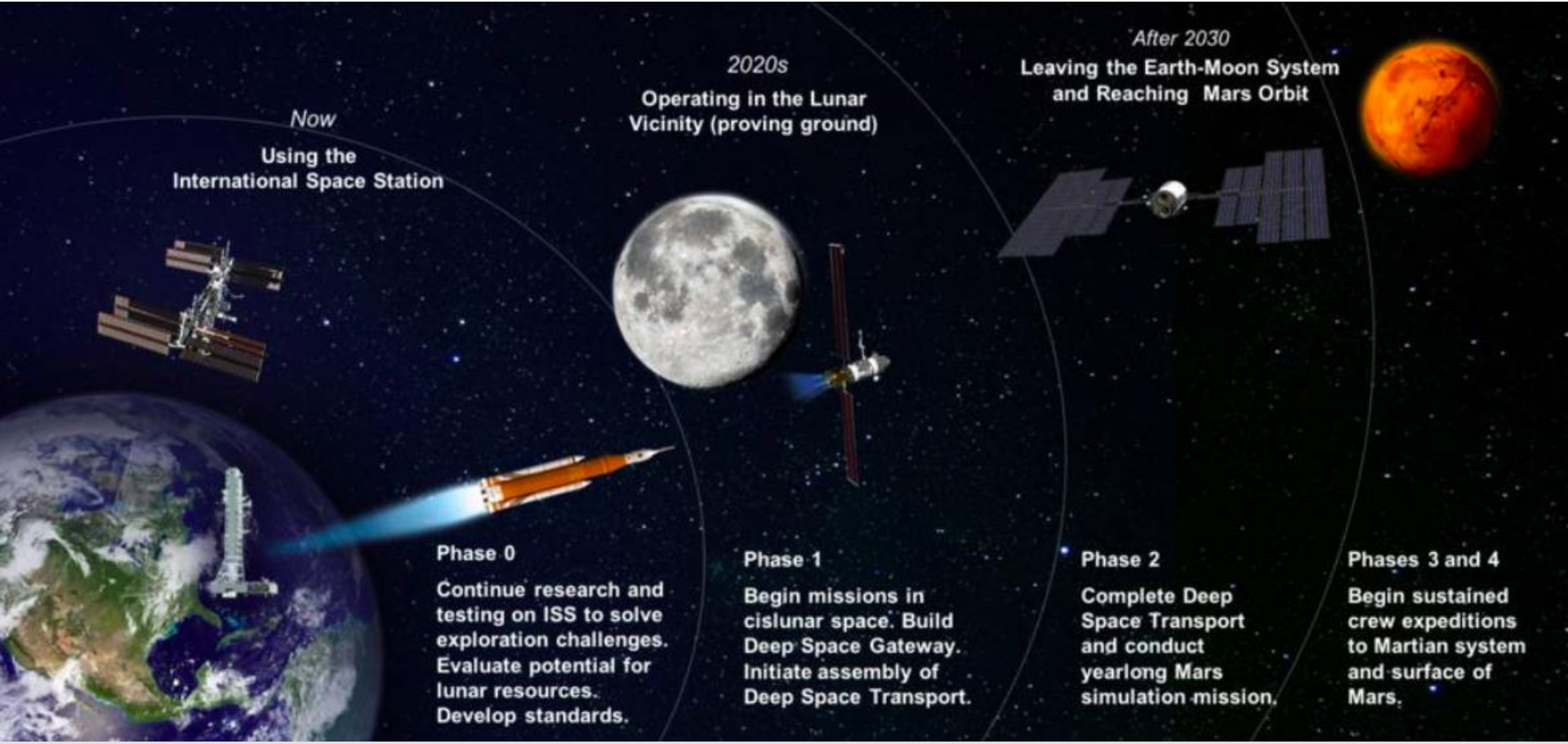
Challenge driven innovation

Inspiration Motivation Education

Global partners

- **The Global Exploration Roadmap, *January 2018***

The Global Exploration Roadmap



2019 ESA Ministerial Meeting – *Space 19+*

- Global context for exploration clearer than for many years
- What role for Europe ?

E3P – TODAY AND TOMORROW

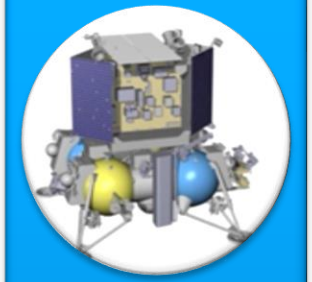
E3P Period 1 (2017-20)

Europe aboard the ISS

World-class science in space

Propulsion & power for first 2 Orion missions

First Mars life-search rover



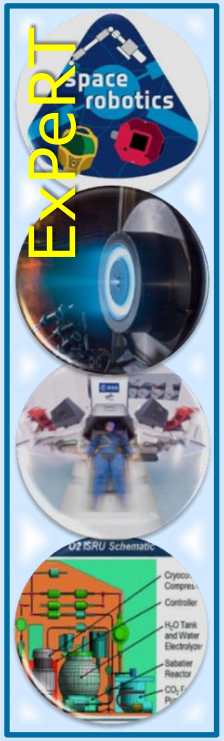
Taking Europe to lunar surface

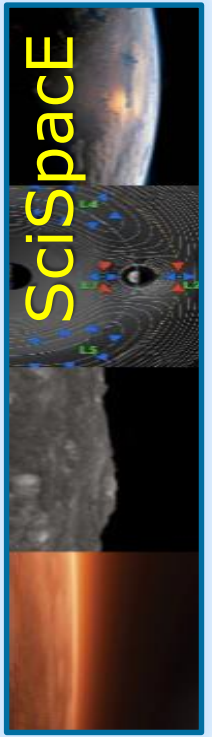
Preparing tomorrow's missions

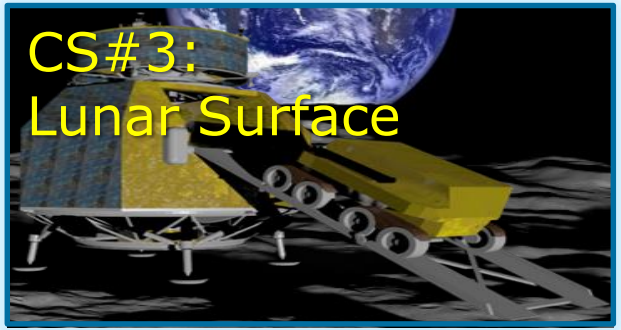
Increased synergy between robotic and human exploration

E3P Period 2 and Beyond:

Once Explorers, Always Explorers







E3P Cornerstone #1 – ISS and beyond

CONTEXT

- Extension to 2030 discussed by US Senate
- Formal decision in 2019?
- More industrialisation and commercialisation
- Transition 1 → 3 crew vehicles

ESA ACTIONS

- Integrate and grow ESA + national + commercial utilisation
- Operations Modernisation → more cost reduction
- Market stimulation → link to ESA Downstream Gateway

Astronaut Missions

"**Horizons**" mission ongoing

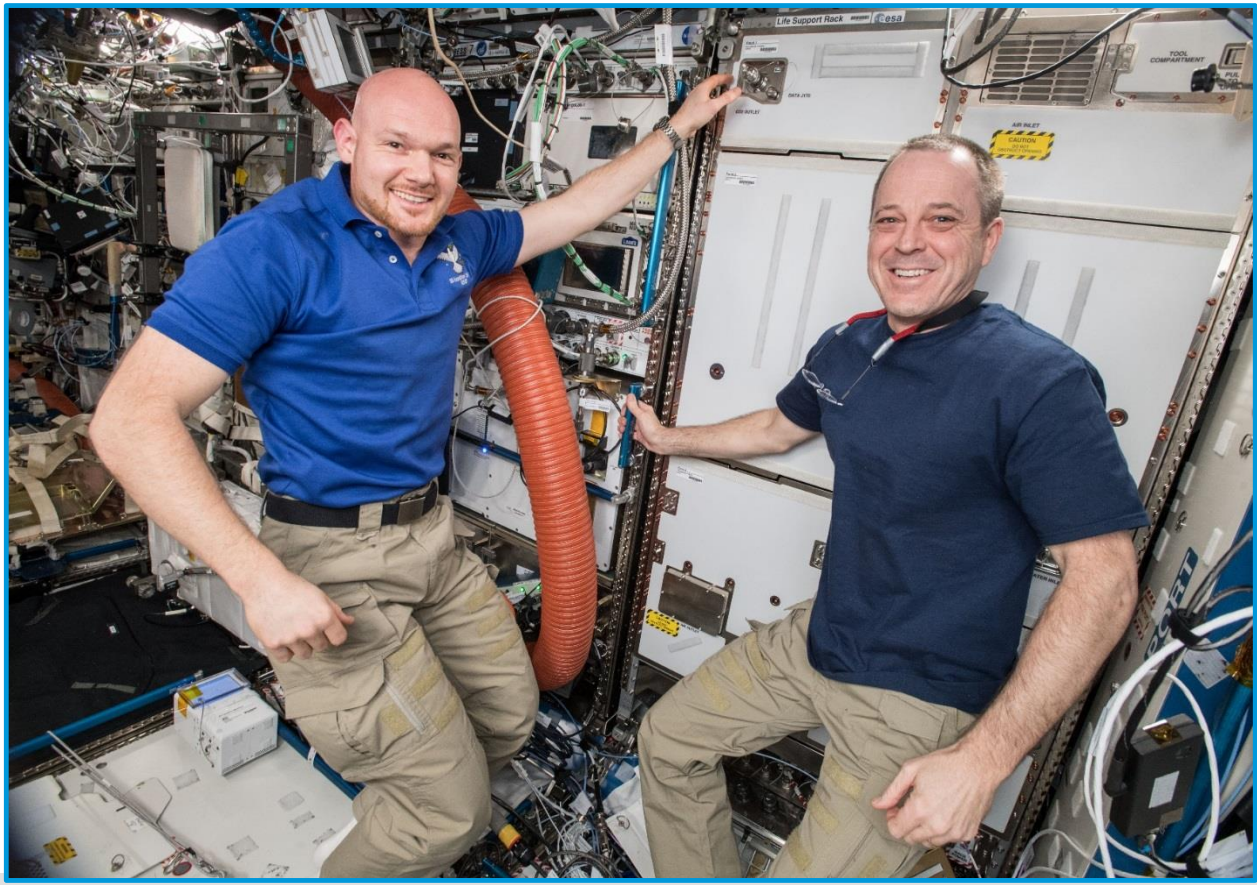
- 200% of planned science implemented in recent increments

2019 Mission of **Luca Parmitano**: Mission name and logo released on 27 Sept.

E3P Supports UN Sustainable Development Goals

- **AstroPlant**: Contributing to e.g. quality education and fighting the habits of consumption
- **EML**: Development of improved industrial alloys
- **MELiSSA**: Waste water treatment technology

ACLS has arrived at ISS!



→ INTERNATIONAL SPACE STATION BENEFITS FOR EUROPE

esa

BETTER TOGETHER

1998: ESA meets International Space Station

esa

strong partnership and international cooperation

PROFITABLE SPACE

each euro spent on the Space Station produces €1.8 added value to European economies

1€ = 1€ 1€

€7B government revenues from ESA spending

90% spent in ESA participating countries

every 100 jobs in the space sector linked to the Space Station creates 90 additional jobs

INSPIRATION

educational kits for schools

university lectures

student nano-satellites

1.9M friends **Facebook**

3M followers **Twitter**

14.5M views **YouTube**

KNOWLEDGE FOR SOCIETY

400 scientific papers

800+ experiments

COMPETITIVE INDUSTRY

the partnership established Europe as a reliable international partner

Source: Pricewaterhouse Coopers

European Space Agency

SciSpace

WITH ACKNOWLEDEGMENTS TO MARC HEPPENER

Human Research

The Human body under space conditions: adaptations and countermeasures

- *Understanding human physiological processes.*
- *Exploration –related health risks and their prevention.*
- *Health and ageing issues on Earth.*

Psychological and neurosensory adaptations to reduced gravity, isolation and confinement

- *Impact of spaceflight on psychological, sensorimotor and neuro-behavioural performance.*
- *Selection, training and support methodologies for crew on long-duration missions.*

Biology

Astrobiology

- *Chemical and biological effects of exposure to space radiation and vacuum.*
- *Origins, limits and signs of life in the Universe.*

Biology under non-Earth gravity conditions

- *Understanding gravity-dependent processes in cells and organisms.*
- *Biochemistry and health-related phenomena.*

Supporting life in hostile environments

- *Understanding the effects of space factors on microorganisms and plants.*
- *Integrated closed-loop life support systems for exploration.*

Physical Sciences

Ultra-precise cold atom sensors, quantum information and high energy particles

- *Boundaries of relativity and quantum physics.*
- *Advanced navigation and communication.*

Soft or Complex matter

- *Interactions and self-organisation in foams, emulsions, granular matter, atmospheric dust and colloids.*
- *Food and (petro)chemical industry, physics of biological processes.*

Boiling, evaporation and heat transfer

- *Multi-scale modelling of fluid physics including phase change.*
- *Efficient cooling of micro-electronics, industrial boilers and power plants.*

Advanced material processing

- *Microstructure formation and materials properties.*
- *Casting, automotive and aerospace industry.*

Cosmic radiation risks for Human Exploration of the Solar System

Excellent curiosity-driven research

Energy storage, fire safety, cardiovascular fluid physics, hibernation and torpor

ESA Research On-Board the ISS

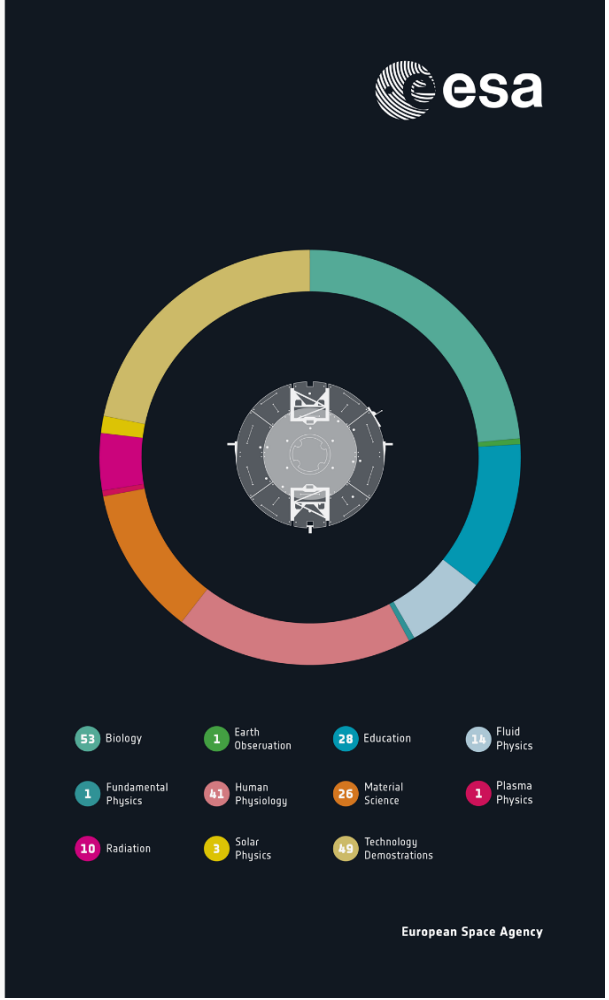
S122E008916

→ COLUMBUS

Experiments

227

EXPERIMENTS
HAVE RUN
IN COLUMBUS
SINCE LAUNCH



ESA's Human Research Programme On-Board the ISS

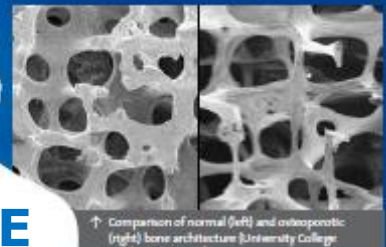
- ✓ Ageing
- ✓ Cardiovascular
- ✓ Immunology
- ✓ Muscle and bone
- ✓ Neurophysiology
- ✓ Nutrition
- ✓ Respiratory system
- ✓ Thermoregulation

↑ Brain scan (University of Antwerpen)

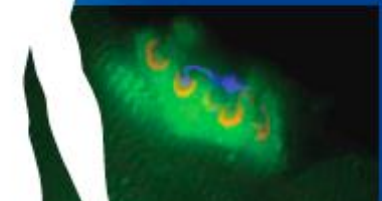
↑ Testing GRIP prototype on weightless parabolic flight

↑ Space food for the Energy experiment

↑ ESA astronaut Alexander Gerst with a thermometer on his forehead to measure his temperature continuously (ESA/NASA)



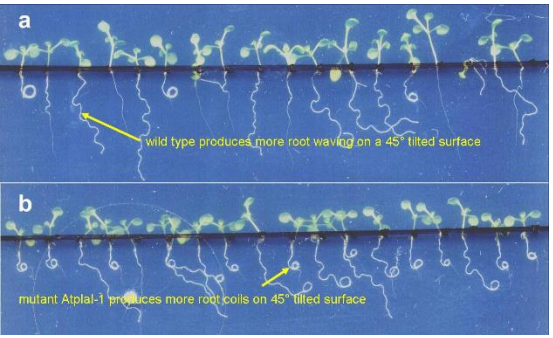
↑ Comparison of normal (left) and osteoporotic (right) bone architecture (University College London – T. Arnett)



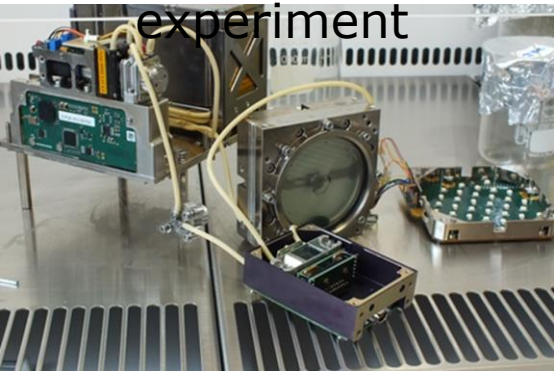
↑ Laser image of a calf muscle (Charité)

↑ ESA astronaut Samantha Cristoforetti running the Skin-B experiment (ESA/NASA)

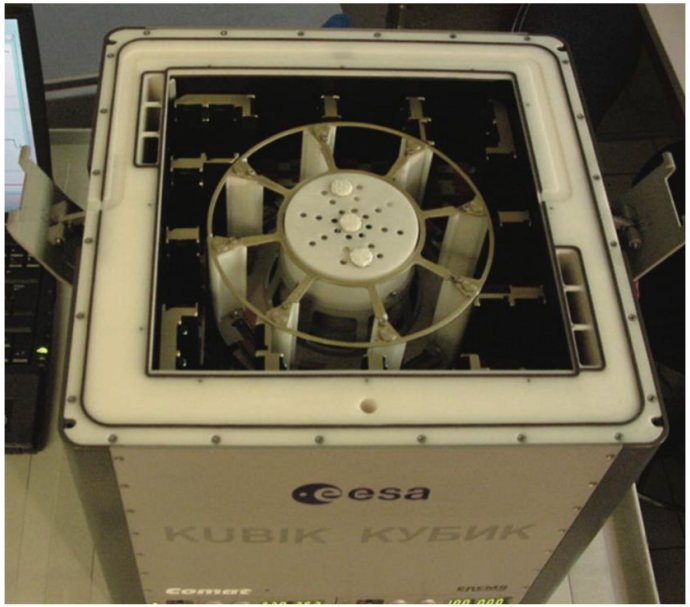
ESA's Biology Programme On-Board the ISS



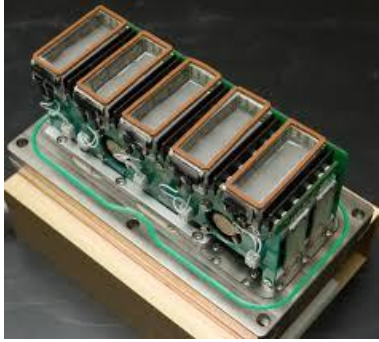
WAICO experiment

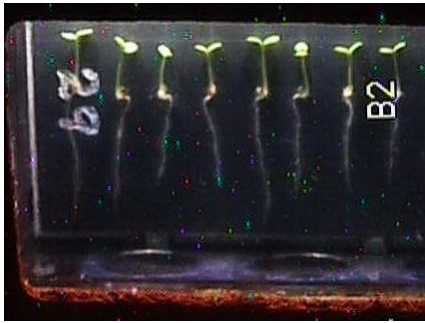


Arthrospira-B experiment



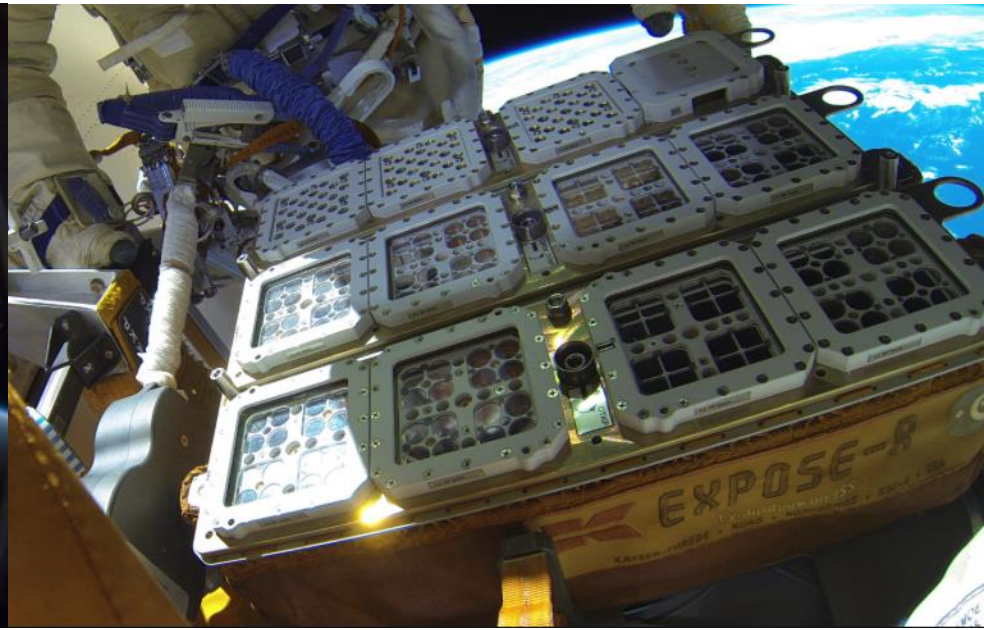
KUBIK container





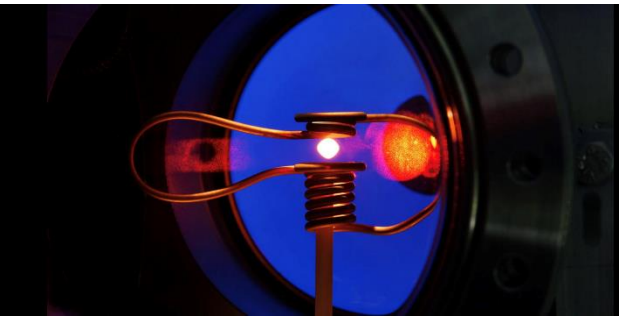
Seedling Growth-3

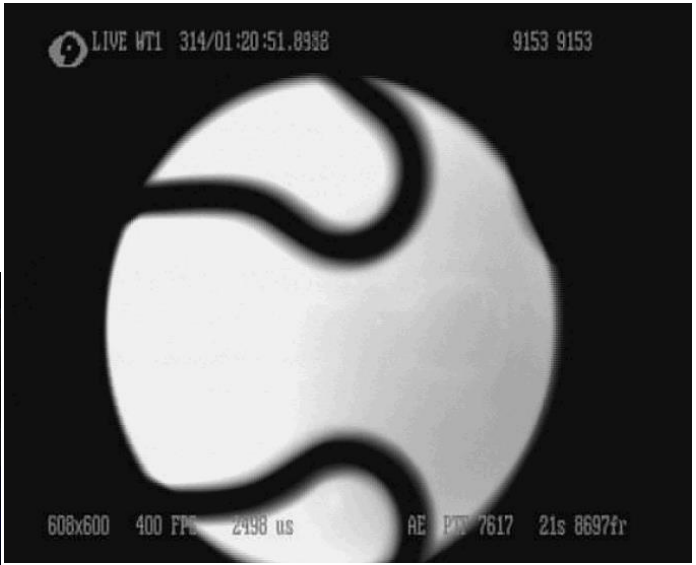
ESA's ExoBiology Programme On-Board the ISS

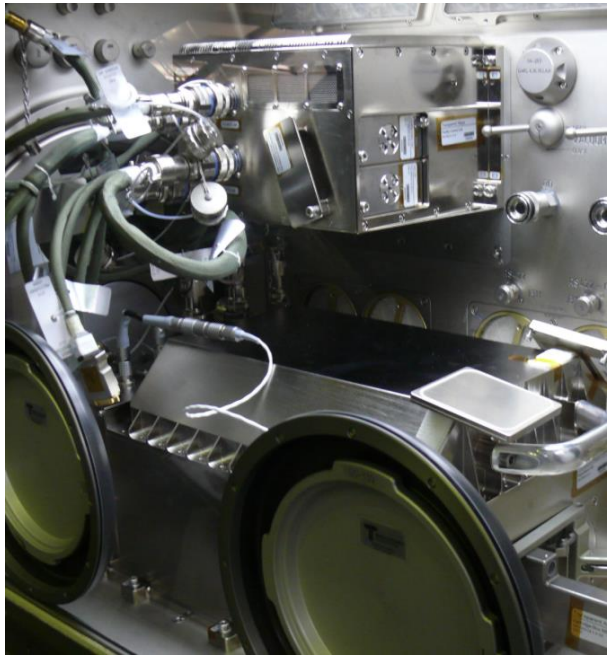


EXPOSE facility

ESA'S PHYSICAL SCIENCES PROGRAMME ON-BOARD THE ISS







ElectroMagnetic Levitator (EML)

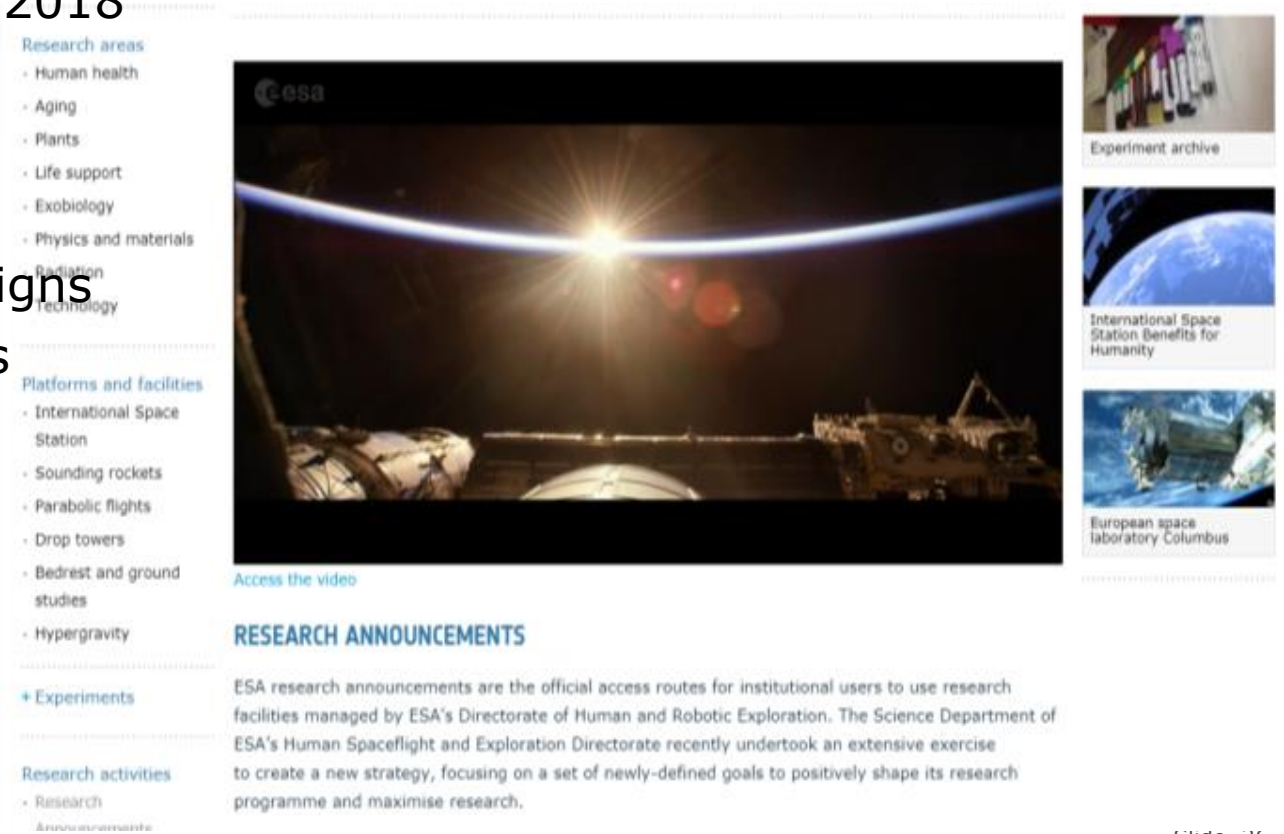
Transparent Alloys instrument

CONTINUOUSLY OPEN RESEARCH ANNOUNCEMENTS

Released on 1 October 2018

Individual CORAs for

- Sounding Rockets
- Drop Towers
- Parabolic Flight Campaigns
- Ground-Based Facilities
- IBER
- MAP programme



Sounding Rockets
Achievements in Period 1

- MAXUS-9:
  GRADECET, EUGRAPHO,
  XRMON-DIFF,
  Perwaves
- *MASER-14 (target launch 2019):*

  XRMON-GF, ARLES
- *Texus-56 (target launch 2019):*
  Perwaves, ICAPS

Planned Activities in SciSpacE Period 2

- Future solicitation and implementation of experiments through dedicated **C**ontinuously **O**pen **R**esearch **A**nnouncement

Drop Tower
Achievements in SciSpacE Period 1

- 118 drops serving 7 experiments

Planned Activities in SciSpacE Period 2

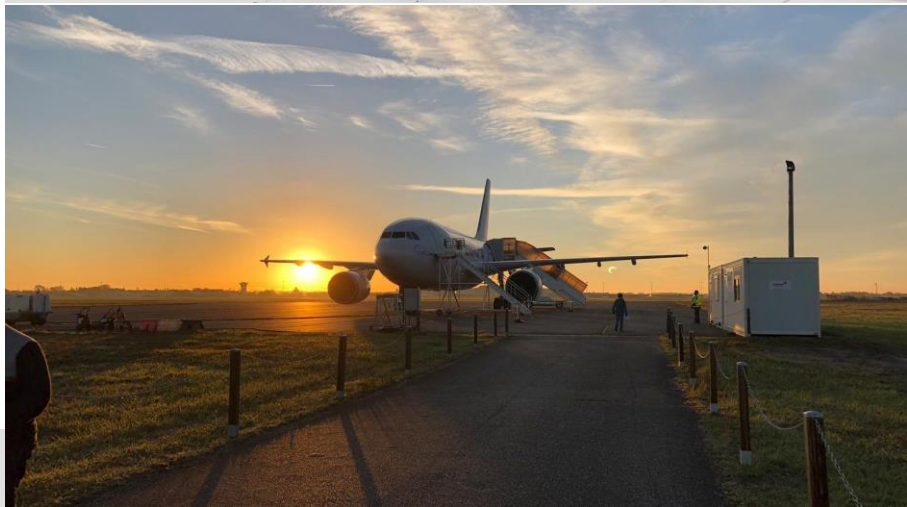
- Future solicitation and implementation of experiments through dedicated **C**ontinuously **O**pen **R**esearch **A**nnouncement

Parabolic Flight Campaigns
Achievements in SciSpacE Period 1

- 3 ESA parabolic flight campaigns in 2017
  18 Physical, 8 Life Sciences experiments
- 2 ESA parabolic flight campaigns in 2018
  12 Physical, 7 Life Sciences experiments
- ISLSWG parabolic flight campaign in 2018
  4 ESA Life Sciences experiments

Planned Activities in SciSpacE Period 2

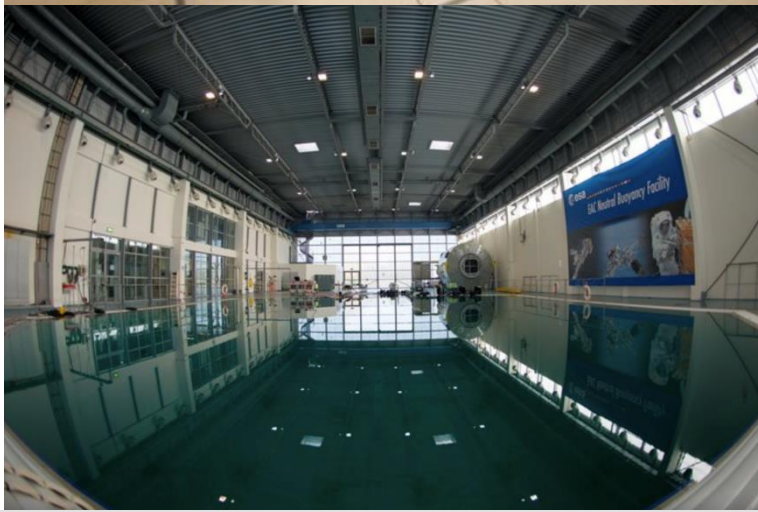
- Future experiments through dedicated **C**ontinuously **O**pen **R**esearch **A**nnouncement
- 2 ESA parabolic flight campaigns per year, not limited to microgravity levels.



Ground-Based Research Facilities

Achievements in SciSpacE Period 1

- Re-start of programme in January 2017 after temporary discontinuation since 2015
- Selection & implementation of 5 proposals



Planned in SciSpacE Period 2

- Future solicitation and implementation of experiments through dedicated **C**ontinuously **O**pen **R**esearch **A**nnouncement

Bedrest Studies:
Achievements in SciSpacE Period 1

- 60d Reactive Jump Study "RSL"
- 60d "Cocktail" Study
- Joint ESA/NASA 60d Bedrest study "AGBRESA"
- ESA Bedrest Call for Ideas 2017
- Database for Bedrest Core Data under preparation

Planned in SciSpacE Period 2

:envihab
AGBRESA +RSL
AGBRESA +RVE

MEDES
AGBRESA +PAP
AGBRESA +PAP+BE

Planica (normobaric hypoxia)
AGBRESA
AGBRESA +RVE

Dry-immersion validation
DI -6° HDT +8.5° HUT

Dry-immersion + AGBRESA

- AO for Bedrest Core Data datamining

Human Research: Antarctic Stations
Achievements in SciSpacE Period 1

- Implementation of experiments solicited from AO-2013-Concordia
- Release of AO-2017-Concordia
- First science results workshop stemming from ESA-selected experiments

Planned Activities: SciSpacE Period 2

- Implementation of experiments solicited from AO-2017-Concordia

Space Radiation studies

Achievements - SciSpacE Period 1

- Resumption of science activities through traditional IBER programme: AO-2017-IBER (11 proposals)
- Release of complementary **C**ontinuously **O**pen **R**esearch **A**nnouncement

Planned Activities - SciSpacE Period 2

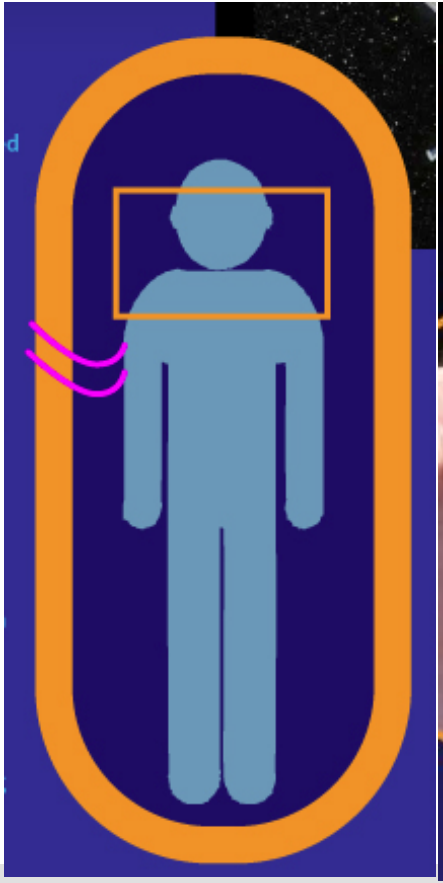
- Science through IBER programme at GSI
- **CORA**
- Preparation for space radiation activities with future FAIR facilities
- *Focussed research opportunities on-board ISS under preparation.*

The Universal Linear Accelerator (Unilac) at GSI

New topic - Moon Dust

Eugene Cernan in the Lunar Module Challenger. (Image credit: NASA)

Hibernation and Torpor



Space trips to the other planets would require months of travel through the vacuum of space. Maintaining the crew's health is a vital concern. If the crew could be induced to hibernate, the problems of survival become easier to solve.

HIBERNATION, NOT FREEZING

Hibernation is a type of torpor, or reduced metabolism caused by hypothermia. Unlike in cryogenics, the body does not actually freeze.

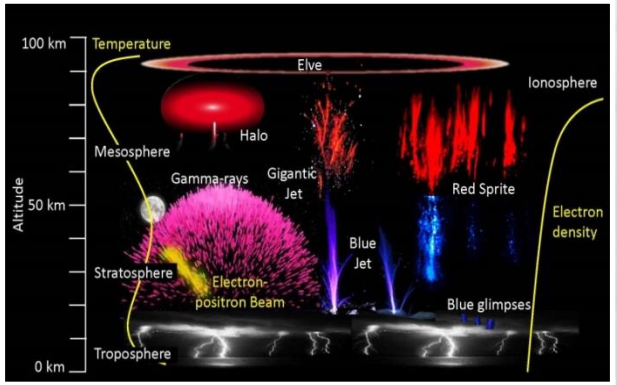
A 10 degree drop in body temperature reduces metabolic rate by 50 to 70 percent.

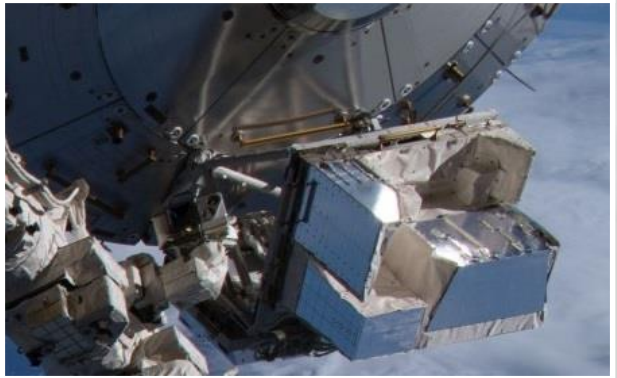
Preble's Mouse hibernates during the colder half of the year. (CREDIT: U.S. Fish and Wildlife Service)

Astronaut Dave Bowman monitors hibernating crew members on the voyage to Jupiter in "2001: A Space Odyssey." (1968)

New EO Science from the ISS

- **ATMOSPHERE SPACE INTERACTION MONITOR (ASIM)**:
  - Studying giant electrical discharges
  - 30-day report:
    - Data quality excellent
    - Extensive observations including TGFs
    - Presentations for AGU

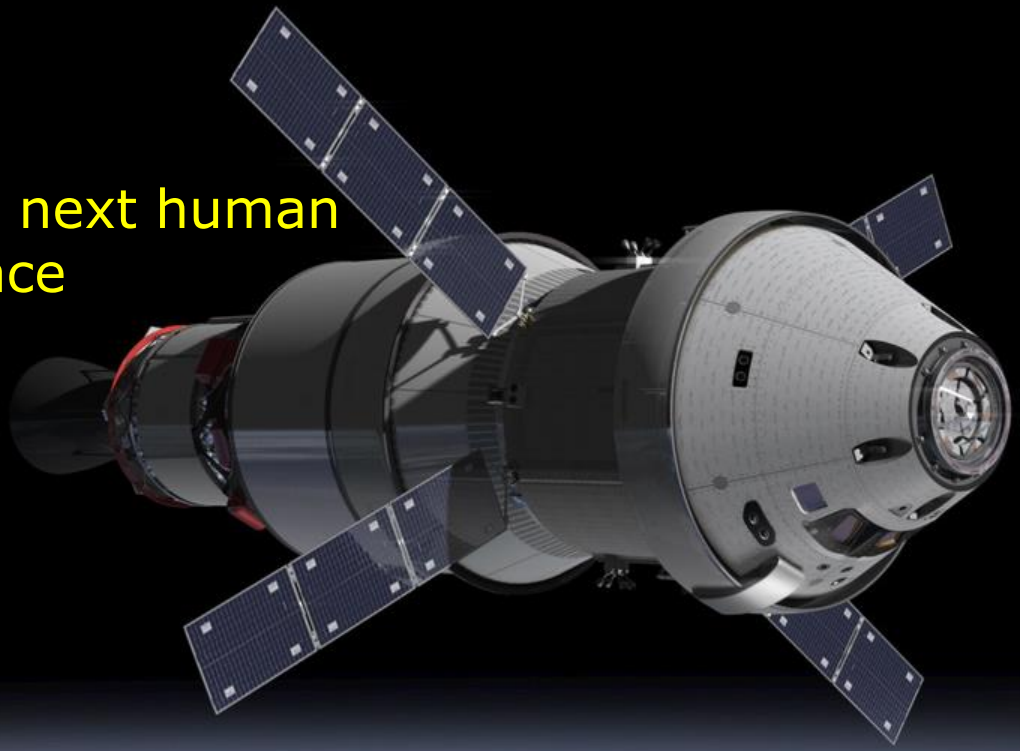




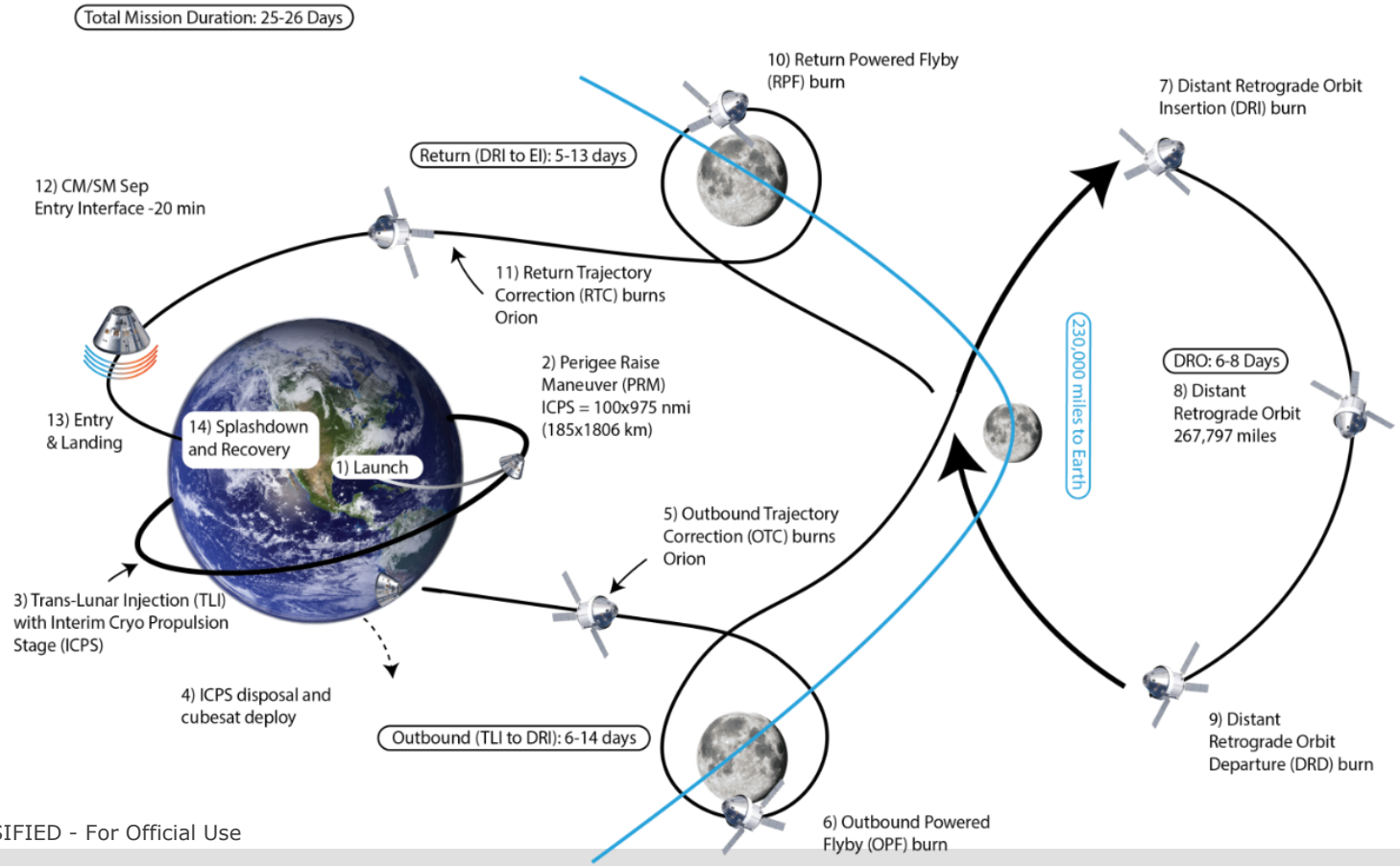
Cornerstone #2:
Forward to the Moon

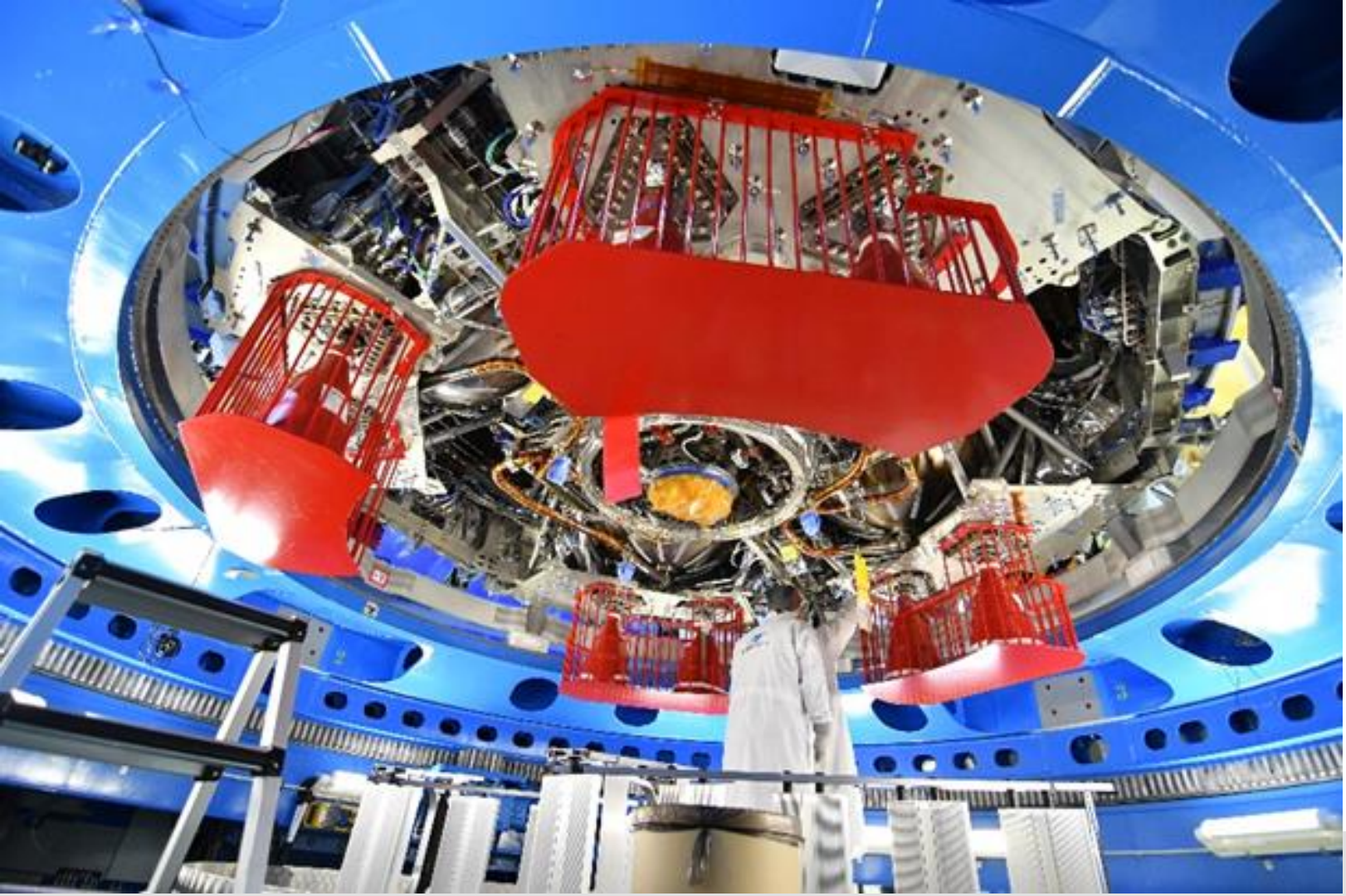
Orion

Europe powering the next human missions to deep space



EXPLORATION MISSION 1





European Service Module for Orion

ESM-1 Event at KSC

The Lunar Gateway

By 2025, humanity’s most remote research base

Near rectinlinear halo orbit around the Moon

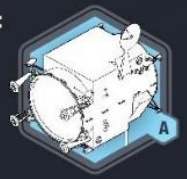
Unique new science opportunities in a unique environment e.g. for space radiation, space plasma physics, human research

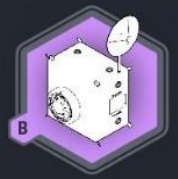
GATEWAY

An exploration and science outpost in orbit around the Moon

esa

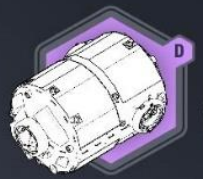
Power and Propulsion Element:
Power, communications, attitude control, and orbit control and transfer capabilities for the Gateway.

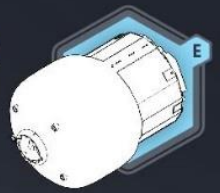




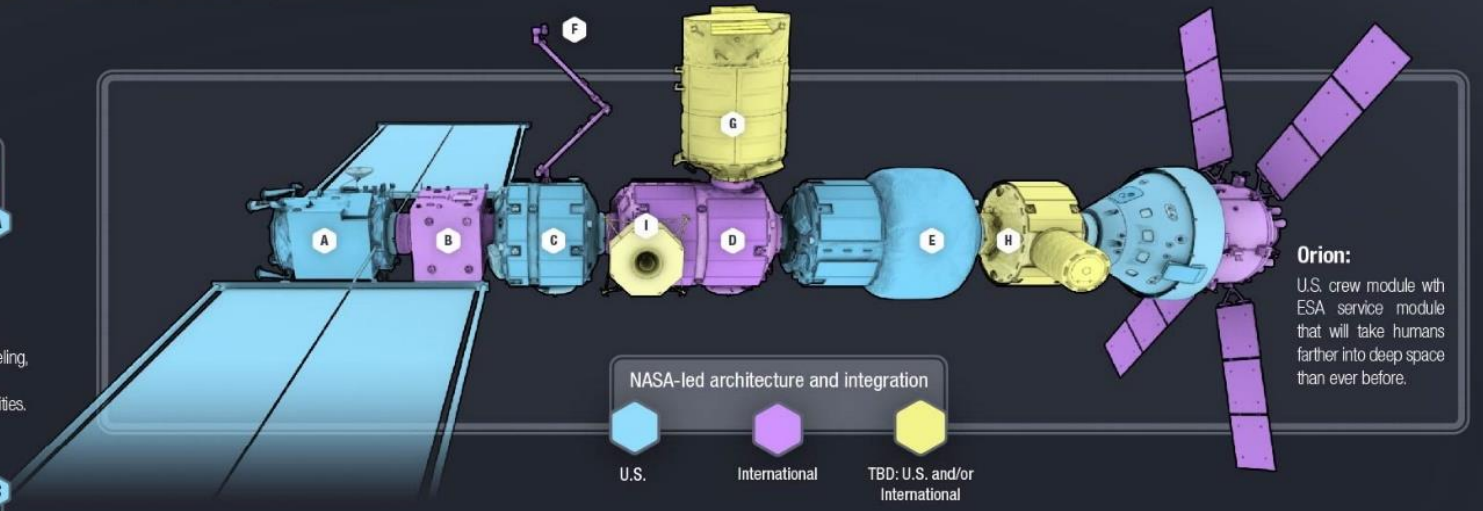
ESPRIT:
Science airlock, additional propellant storage with refueling, and advanced lunar telecommunications capabilities.

Utilization Element:
Small pressurized volume for additional habitation capability.





Habitation Modules: Pressurized volumes with environmental control and life support, fire detection and suppression, water storage and distribution.



Orion:
U.S. crew module wth ESA service module that will take humans farther into deep space than ever before.

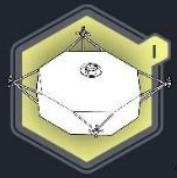
NASA-led architecture and integration

U.S. | International | TBD: U.S. and/or International

Robotic Arm:
Mechanical arm to berth and inspect vehicles, install science payloads.

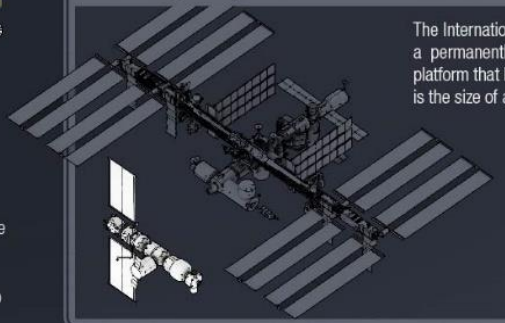
Logistics and Utilization:
Cargo deliveries of consumables and equipment. Modules may double as additional utilization volume.

Airlock:
Enables spacewalks, potential to accommodate docking elements.



Sample Return Vehicle:
A robotic vehicle capable of delivering small samples or payloads from the lunar surface to the Gateway.

Gateway Compared to the International Space Station

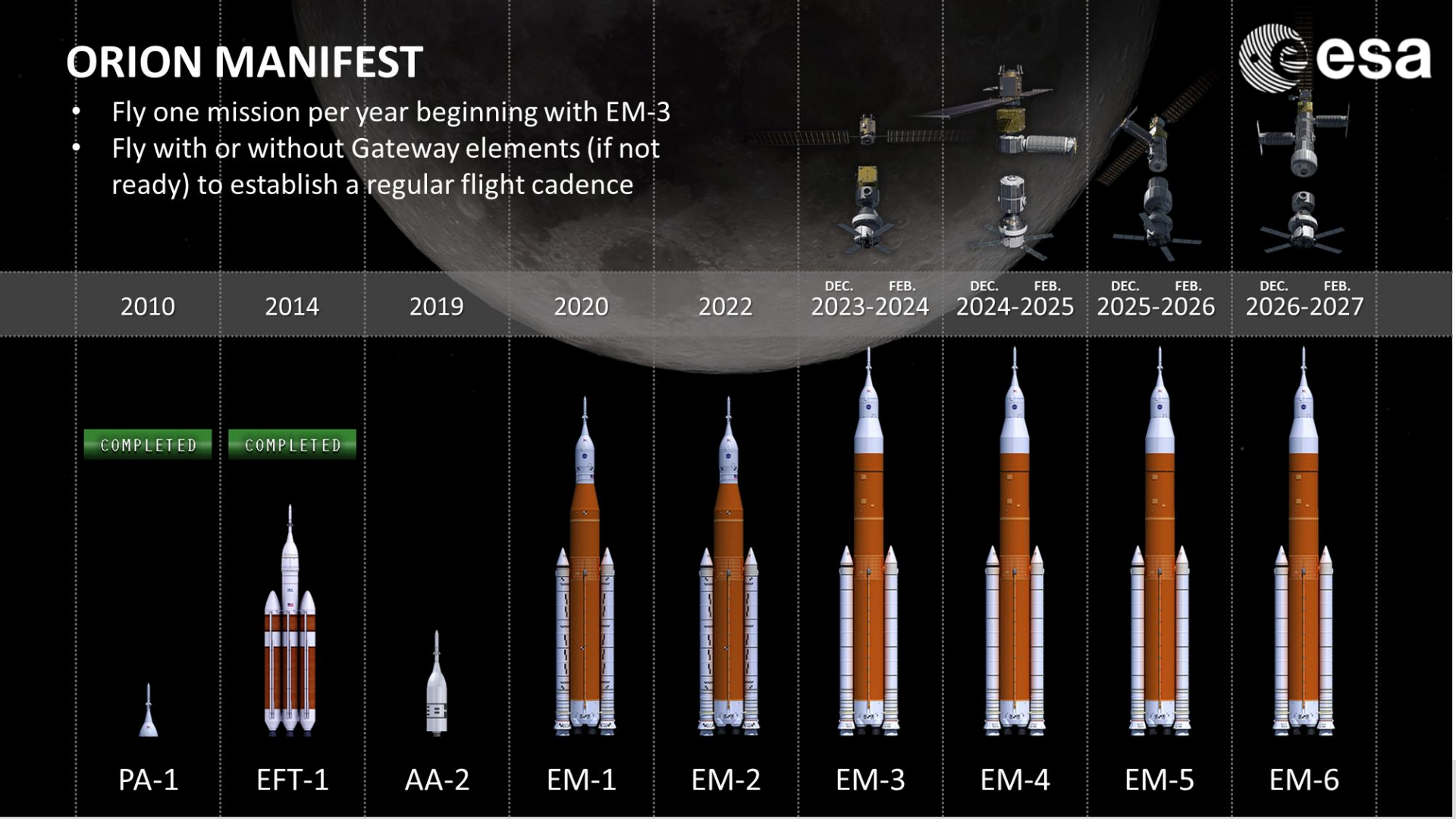


The International Space Station is a permanently crewed research platform that has 11 modules and is the size of a football field.

The Gateway is a much smaller, more focused platform for extending initial human activities into the area around the Moon.

ORION MANIFEST

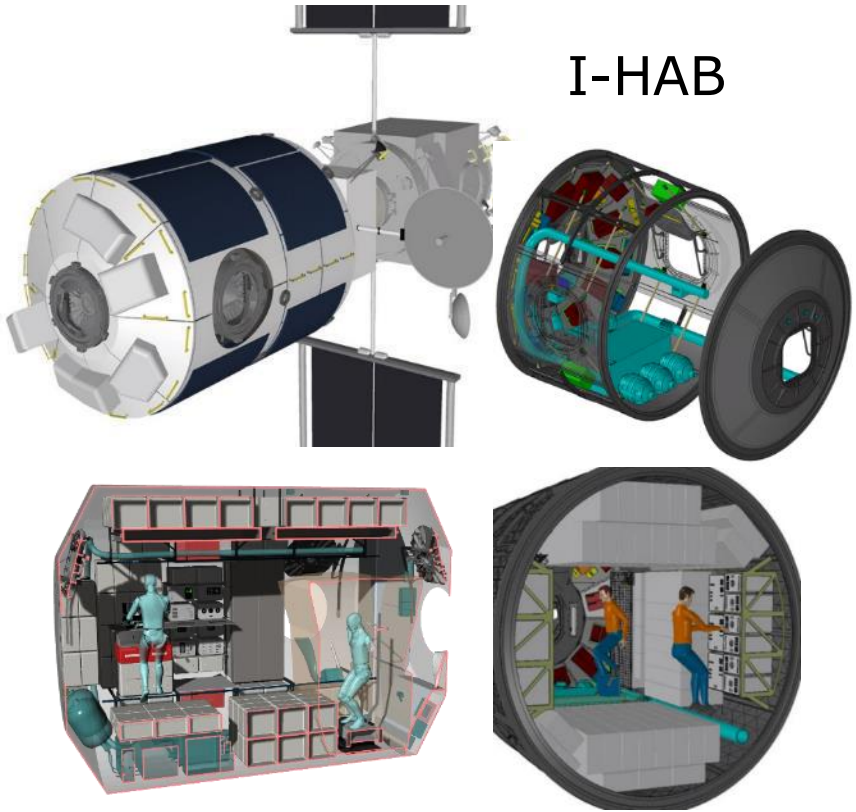
- Fly one mission per year beginning with EM-3
- Fly with or without Gateway elements (if not ready) to establish a regular flight cadence



ESA Roles in the Gateway

NASA-ESA 'Umbrella Understanding' signed 12 April 2018

I-HAB



→ RESEARCH OPPORTUNITIES ON THE DEEP SPACE GATEWAY

- Decision on ESA participation expected in 2019
- Identification of high-importance research areas benefitting from the Deep Space / Lunar Orbital Platform Gateway which cannot be performed in Low Earth Orbit, e.g.:
  - Radioprotection research
  - Radiation risk models
  - Exobiology
  - Space plasma physics
  - Cosmic dust sample collection
  - Support to robotic surface missions

3-4 ESA "model payload" feasibility studies in 2019

Lunar Exploration - Cornerstone #3

A science-driven robotic lunar exploration campaign

and

A step towards human lunar exploration

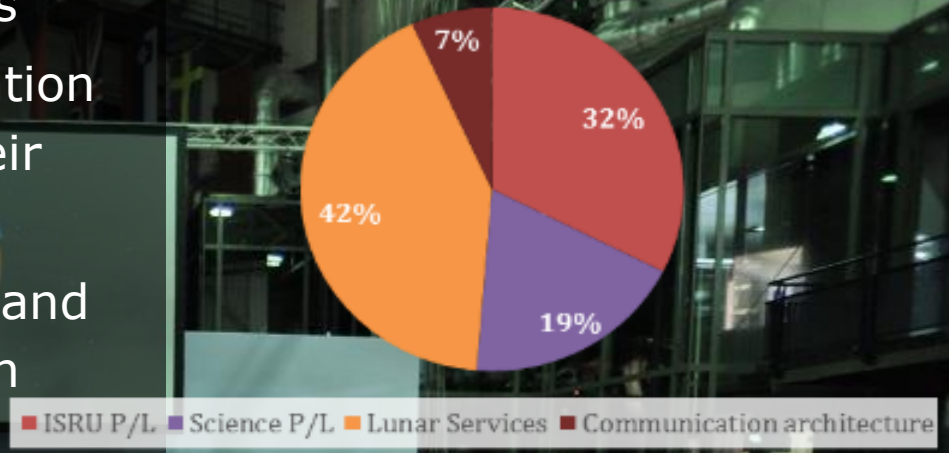
- achieve strong scientific return
- advance key exploration technology
- exploit the Gateway when available
- prepare for human exploration

Science identified by the community

- The bombardment history of the inner solar system
- The structure and composition of the lunar interior
- The diversity of lunar crustal rocks
- Volatiles at the lunar poles
- Volcanism
- Impact processes and Regolith processes
- Atmospheric and dust environment
- Life sciences and astrobiology
- Fundamental physics
- Low frequency Radio Astronomy
- Space resource utilisation

“Towards the Use of Lunar Resources” 3-5 July

- 270 participants from diverse sectors
- Space Resources strategy in preparation focussing on lunar resources and their role in the future programme
- RFI on Mission Services, technology and science payloads for an ISRU mission closed in early July
- 117 submissions, 68 entities, 24 countries
- Informing ISRU mission preparation



International Lunar Missions planned 2018-2025

Actor	Landers	Orbiters
Russia	Luna-25, Luna-27	Luna-26
USA	NASA & private missions (Moon Express, Astrobotic, Blue Origin, Masten etc.)	Private missions
China	Chang'e 4 & 5, Polar missions	Chang'e 4 relay (in flight)
India	Chandrayaan-2	
Japan	JAXA - SLIM, Selene 2 (TBC) iSpace Japan (private)	
Israel	SpaceIL (private)	
South Korea	Lander (tentative)	KPLO
Europe	Private - Part Time Scientists, iSpace Europe	Private (Lunar Pathfinder)

Lunar Resource Lander (ESA+Russia)

Permanently shadowed regions at the Moon's South pole, perhaps hosting water ice stored at low temperatures

false colour !!

CS#3: Lunar Exploration Campaign

Gradually increasing opportunities for science & applied research

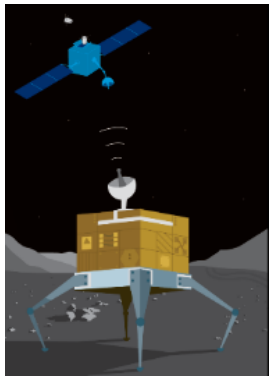
Luna Resource

Precision Landing

Lunar Pathfinder

Cube Delivery
Com/ Nav Services

ISRU Demo



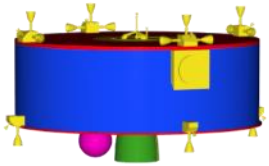
ISRU
Commercial Mission

HERACLES

Sample Return
Extended Mobility

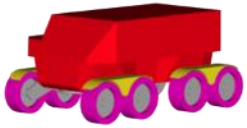
Human Lunar Precursor – A prototype for the human return to the Moon

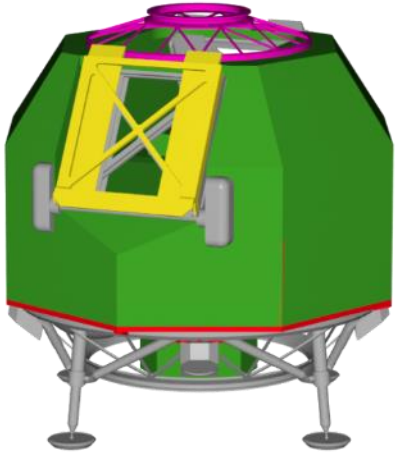
Sample Container



Ascender (LAE)

Long Range Rover





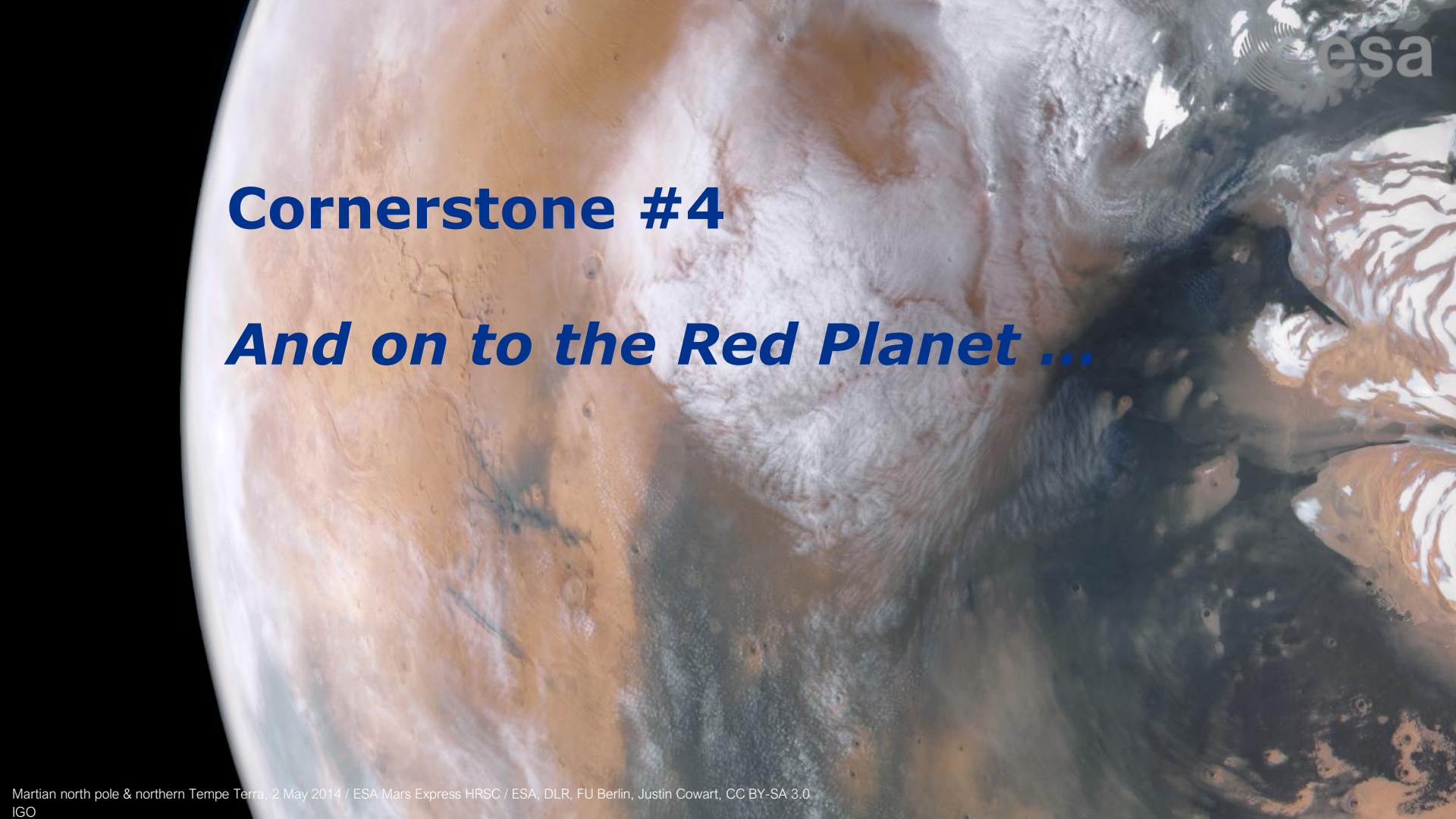
Descender (LDE)

Gateway + robotic missions

= sustainable human exploration

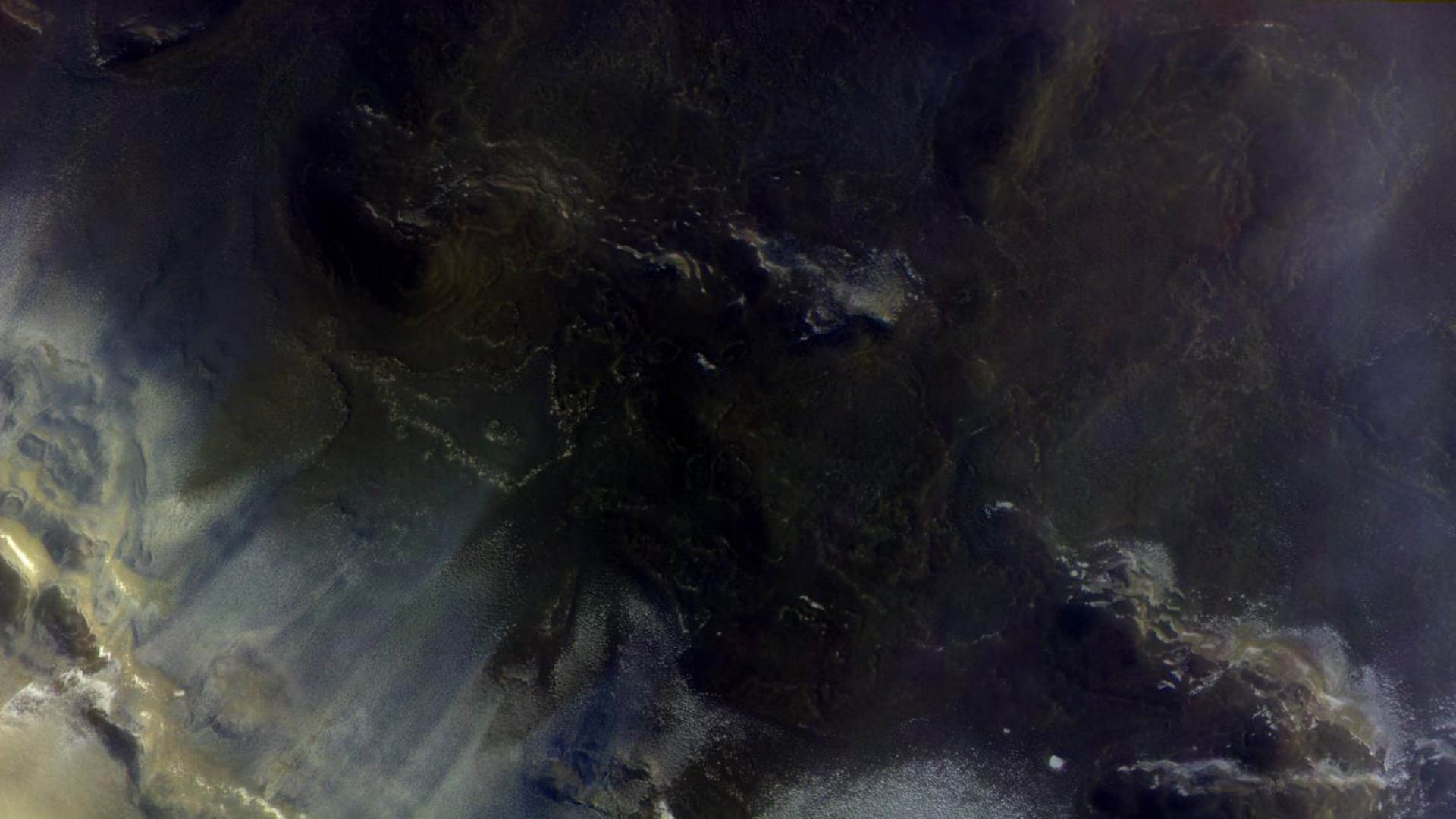
Cornerstone #4

And on to the Red Planet …



Martian north pole & northern Tempe Terra, 2 May 2014 / ESA Mars Express HRSC / ESA, DLR, FU Berlin, Justin Cowart, CC BY-SA 3.0 IGO

ExoMars 2016 Trace Gas Orbiter Mars orbit insertion, 19 October 2016 / ESA, Roscosmos

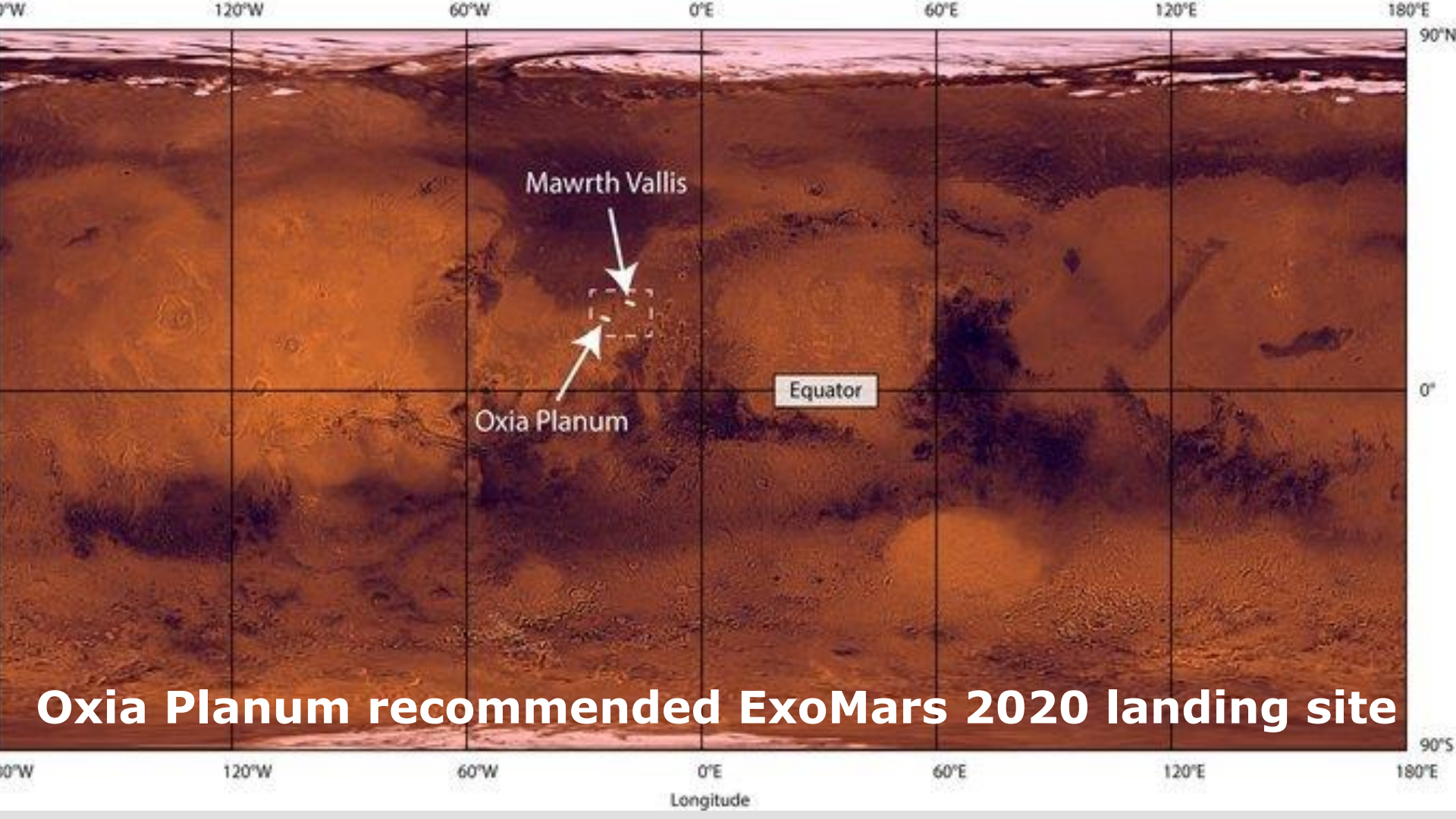


ExoMars 2020

A Robot Astro-biologist

ExoMars 2020 rover / ESA, Roscosmos

ESA, Roscosmos



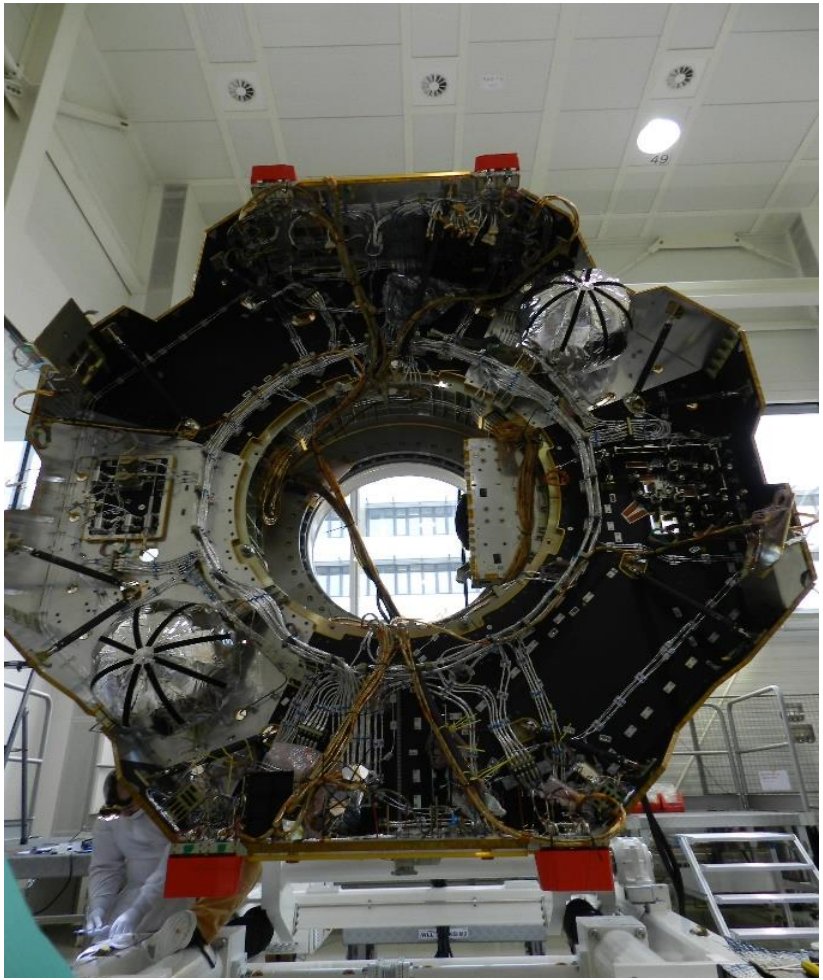
Oxia Planum recommended ExoMars 2020 landing site

ExoMars 2020 UPDATE

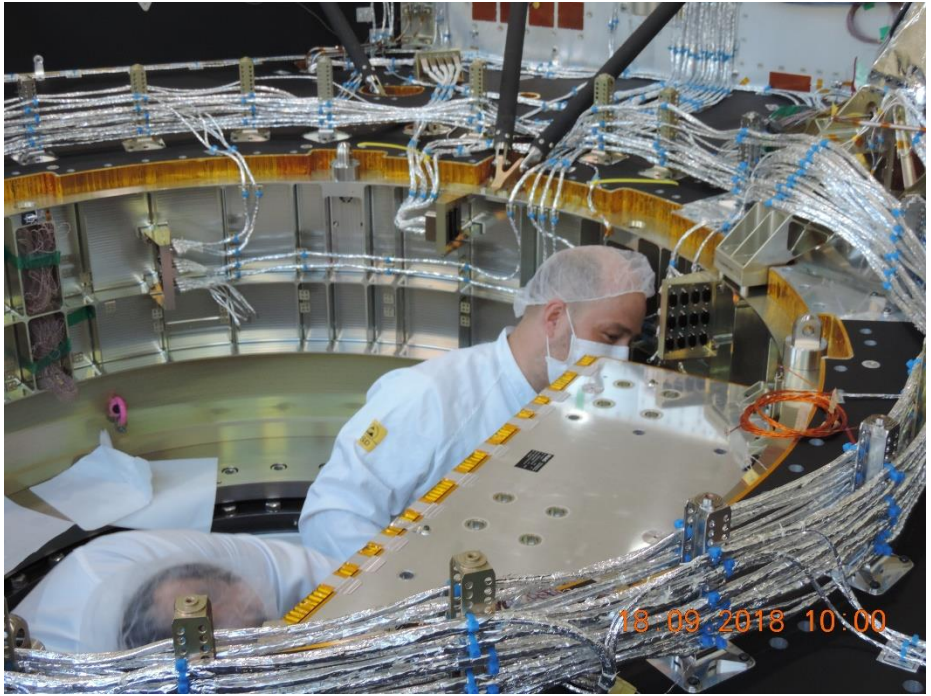
- Rover environmental test programme completed, PFM integration started
- Russian Decent Module and Landing Platform FM parts delivery delay - schedule crash action at DG level
- avionics test bench under integration
- HADT anomaly: drop system did not separate from balloon, root cause identified, new test date TBD
- Financial contingency increase decision approved at PB-HME 09/2018.

Status of Carrier Module

Protoflight Model of the Carrier Module PFM Integration at OHB-D



Status of the Carrier Module

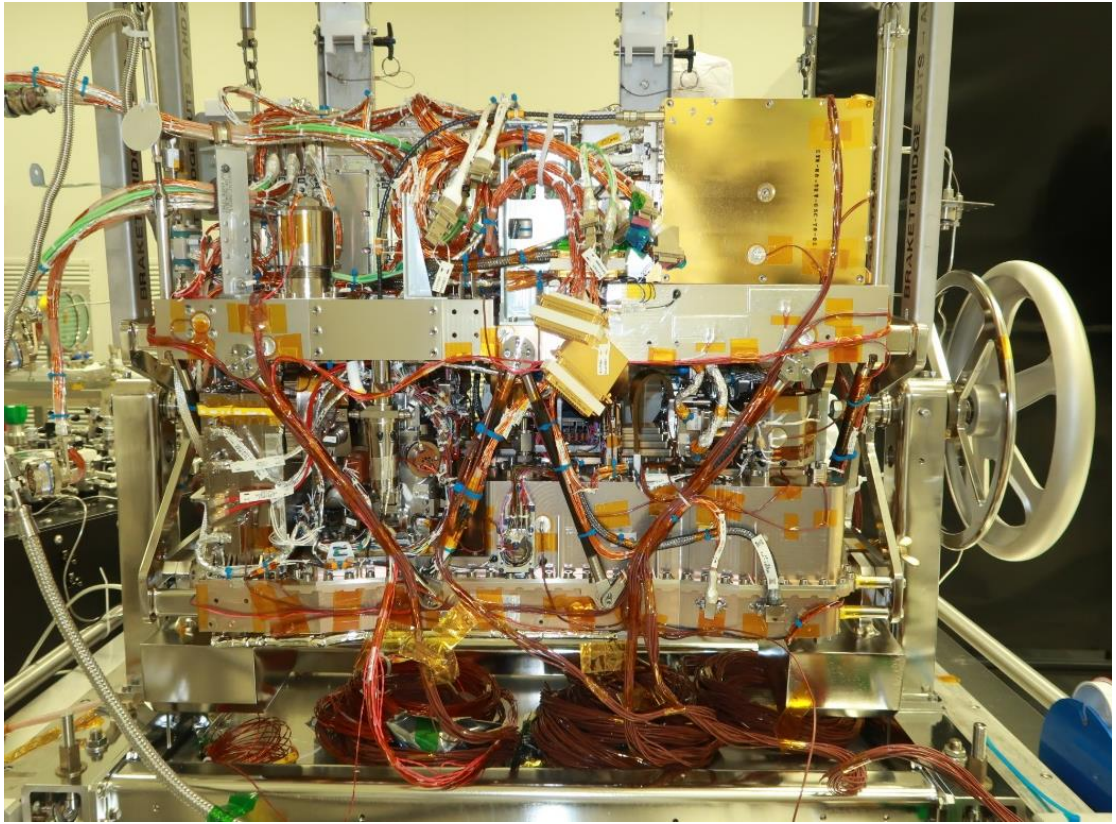


Flight harness integration

ExoMars 2020 Landing Module at Lavochkin

ExoMars 2020 Spacecraft Composite Structural Model

Status of ALD and Rover Module



ALD QM integration and preparation for thermal test at TASinI

Status of ALD and Rover Module

Rover LVM at RUAG-CH facilities

Rover Module STM at Airbus DS F facilities

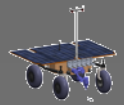
The First Round Trip to Mars ?

Robotic Mars Sample Return

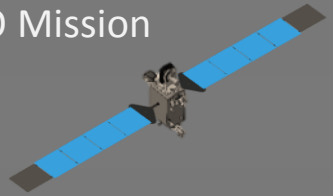
Notional MSR Campaign Architecture

M2020 Rover

SRL Mission



ERO Mission



MRSH Facility(ies)

Launch from Earth/Land on Mars → Select Samples → Acquire/Cache Samples

Retrieve/Package Samples on Mars → Launch Samples to Mars Orbit

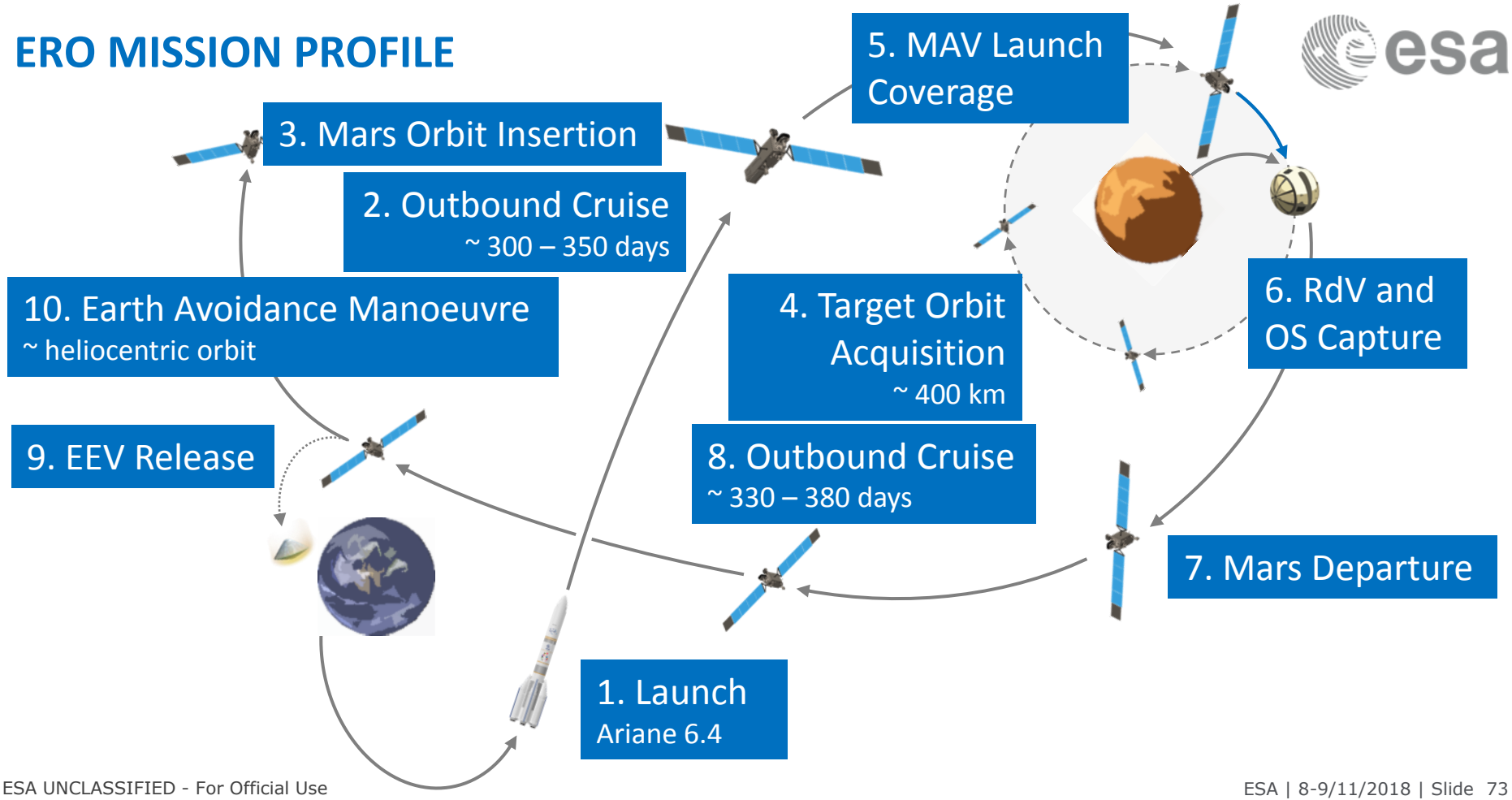
Capture and Isolate Sample Container → Return to Earth → Land on Earth

Quarantine and Preserve Samples on Earth → Assess Hazards → Sample Science & Curation

ESA's PREPARATION FOR MSR

- Exploring MSR mission concepts for over 10 years
  - **Mars Robotic Exploration Preparation** (MREP) programme since CM08
  - Focus on Sample Return Orbiter
- Strong heritage from **ATV**, **ExoMars TGO** and **BepiColombo**
  - Autonomous orbital rendezvous
  - Mars Orbit Insertion and Aerobraking
  - Multi-stage spacecraft and hybrid propulsion system (Chemical + Highly efficient solar electric propulsion)

ERO MISSION PROFILE



→ Mission Firsts

First return from surface of another planet

Round-trip to Mars

First rendezvous around Mars

Rendezvous and Capture in Mars orbit

First bio-contained Sample Return

Bio-sealing of unsterilized Mars material

→ Design Challenges

Critical launch mass

Full capacity of Ariane 64

Need for high-efficiency electric propulsion

Autonomous rendezvous

Mars light-time delay (~20min)

Autonomous operation (<few km)

Planetary Protection

Restricted category V mission

HYBRID ORBITER CONCEPT (dual-stage)

Parameter	Value
Wet Mass at Launch	~ 6000 *kg*
Launch excess velocity	2.52 *km/s*
Wet Mass in LMO	~ 3200 *kg*
Mass jettisoned in LMO	~ 1200 *kg*
Mass returned to Earth	~ 1500 *kg*
Total CP delta-v	3.7 *km/s*
Total EP delta-v	9.0 *km/s*

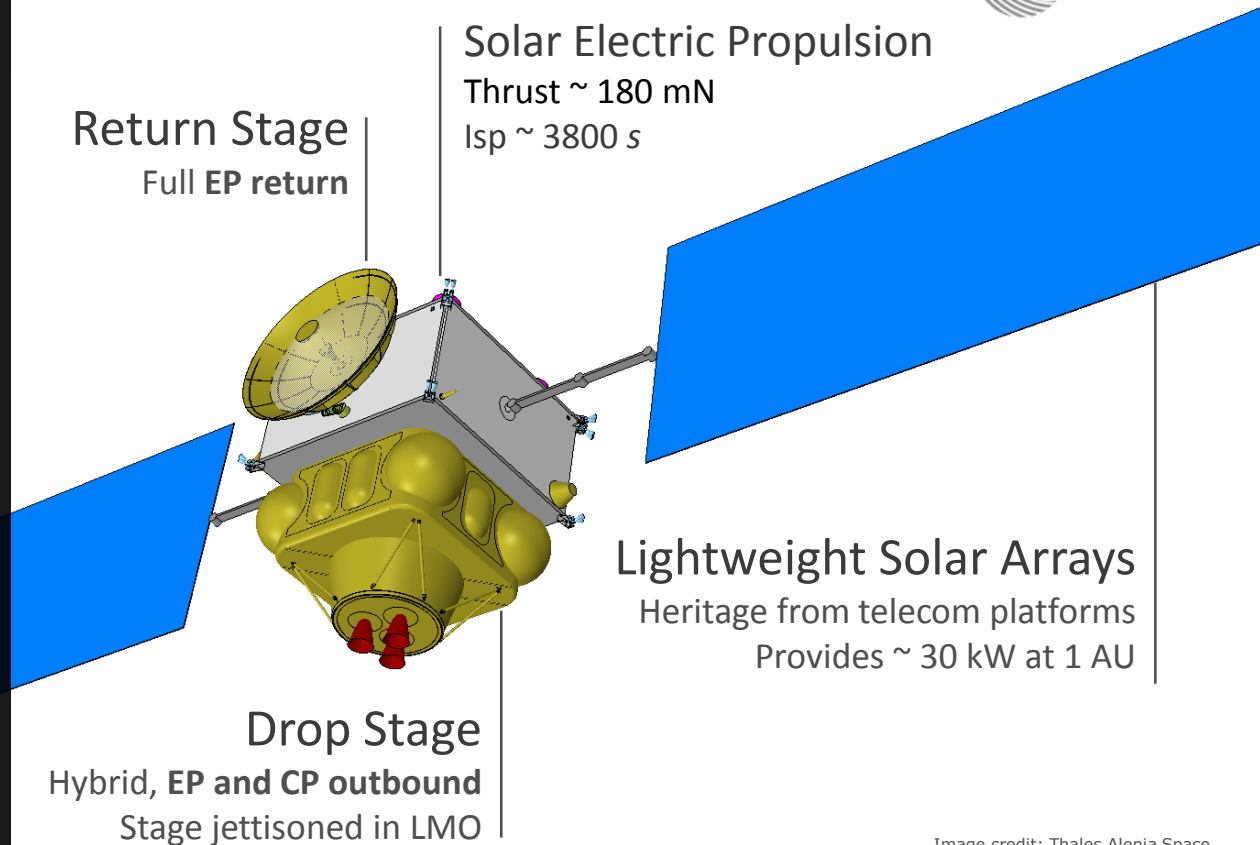


Image credit: Thales Alenia Space

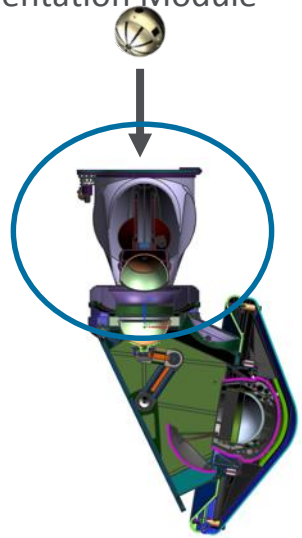
The Capture, Containment, and Return System

JPL payload ensuring bio-containment and safe return to Earth

Breaking the chain of contact of unsterilized Mars material with Earth

OS Capture

Capture and Orientation Module

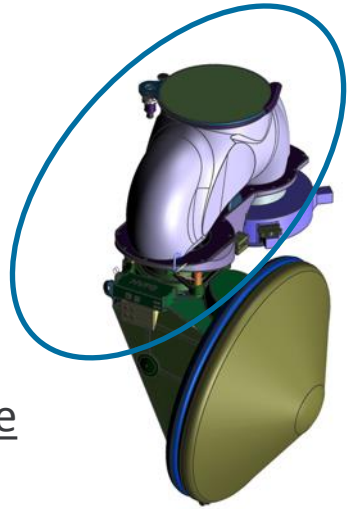


Break-the-Chain

Containment Module

Jettison of non-return elements in LMO

Mass saving for return journey



EEV Protection and Release

Earth Return Module

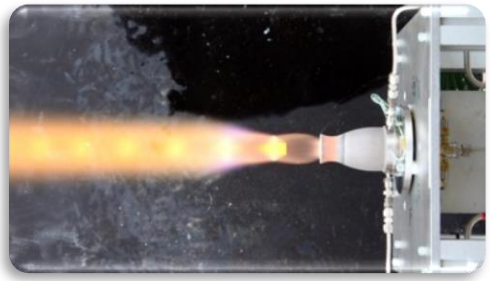
Image credit: NASA/JPL

ESA closing technology gaps

Technology readiness is key to lowering mission development risk

On-going European technology developments aim to buy down risk

De-risking

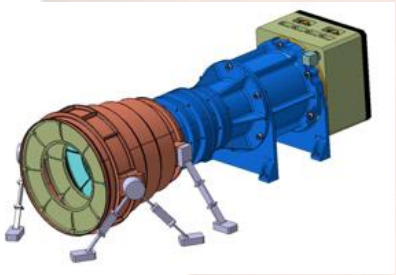


Credit: NAMMO

High Thrust Apogee Engine Qualification

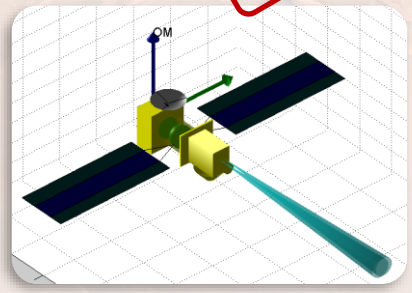
Credit: Ariane Group

EP Engine Delta-Qualification



Credit: Airbus Group (Sodern)

Narrow Angle Camera EM



Credit: GMV

Autonomous Mars Rendezvous System Validation

→ TRL 6 by end 2019 is targeted before ERO mission adoption

Notional Timeline

2019

Implementation decision on MSR

ERO Support to surface missions from LMO

MAV launch coverage by ERO and OS rendezvous

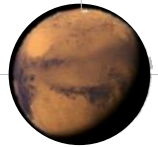
2018

2020

2026

2028

2030



ERO Phase A/B1

ERO Phase B2/C/D

2029

2031

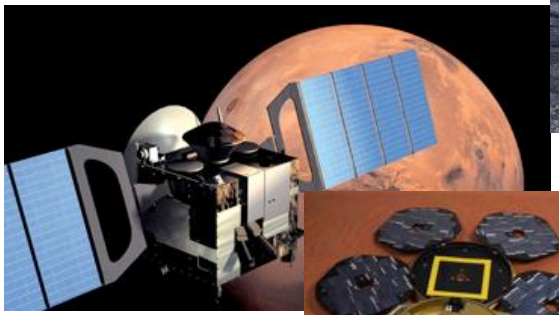
Ariane 6.4

ESA SFR Industrial activities

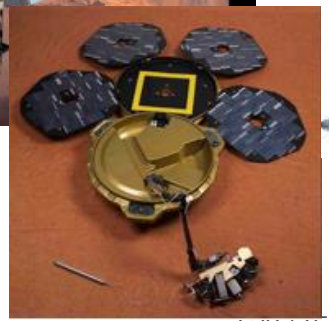
- Two main streams
  - Phase A/B1 to support MSR campaign
  - Technology development
- Building on
  - Heritage of ExoMars and past ESA mission to Mars
  - MREP (Mars Robotic Exploration Programme)

2016: TGO & Schiarapelli lander

Exomars



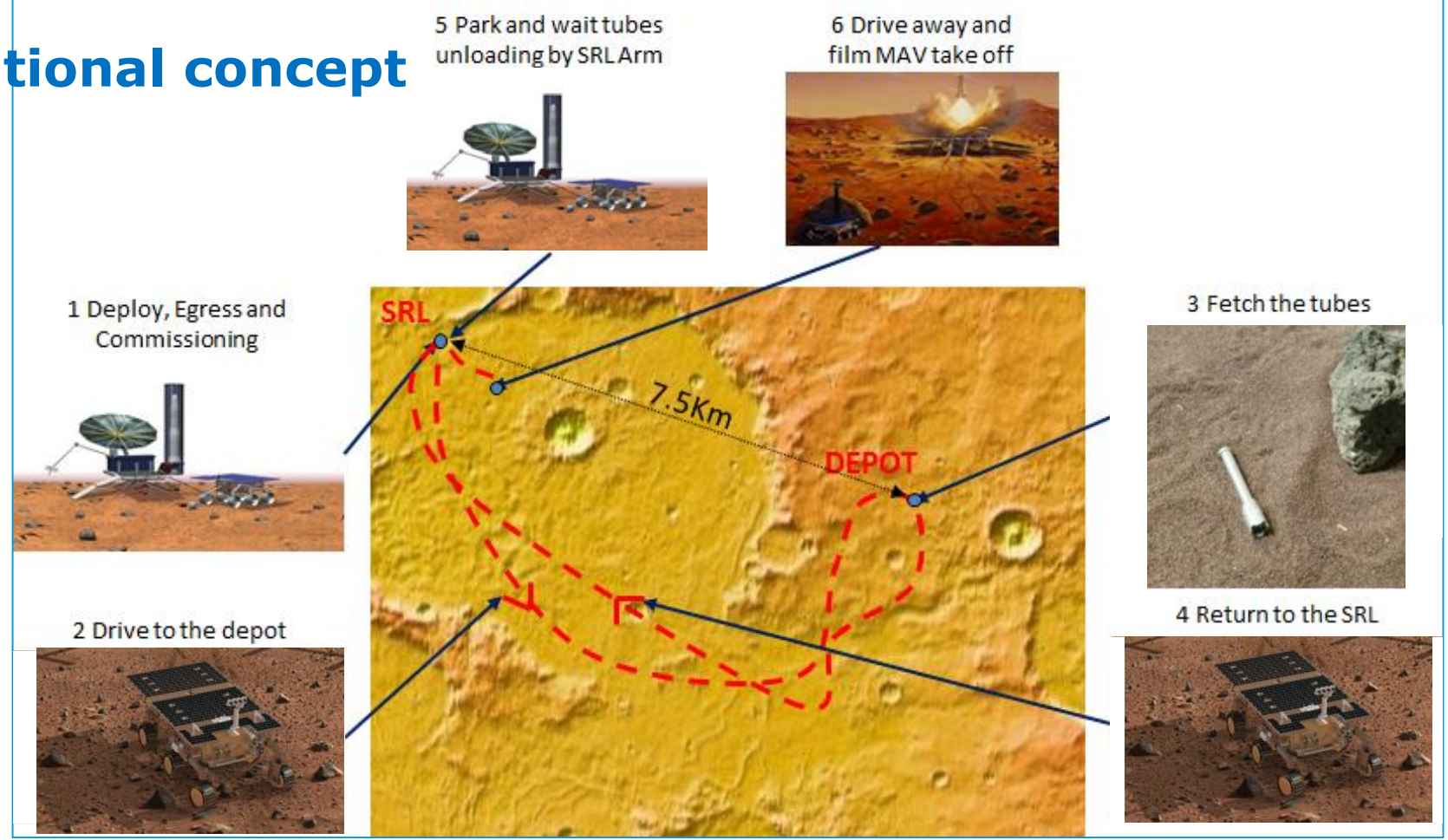
Mars Express



BEAGLE 2

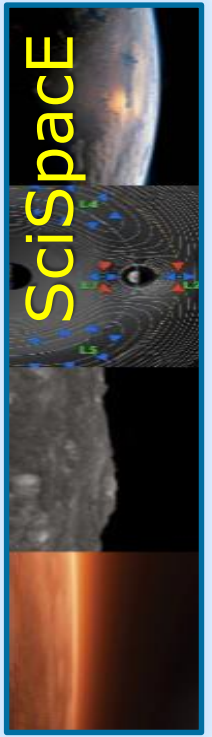
Exomars landing platform

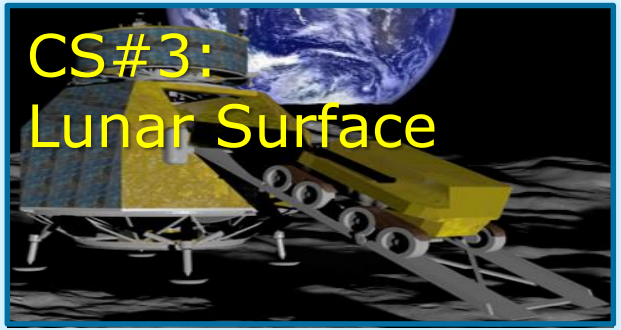
Operational concept




2030’s and beyond
human Mars explorers
MARS / Robert Viglasky, National Geographic Channels

E3P Period 2 and Beyond:
Once Explorers, Always Explorers





Tomorrow's headlines ?

… First European scientist now working aboard the Lunar Gateway …

… First commercial lunar internet service now operational …

… First proof that explorers can 'live off the land' using off-world resources …

… First round-trip mission to surface of Mars is underway …