Medicine beyond Earth

The next frontier of human health



Carlo Saverio Iorio

Centre for Research and Engineering in Space Technologies CREST, Université libre de Bruxelles

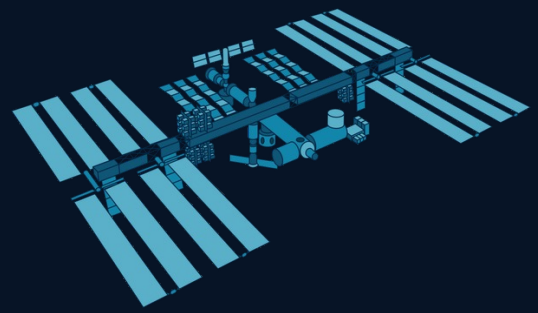
18 November 2026

OUR JOURNEY

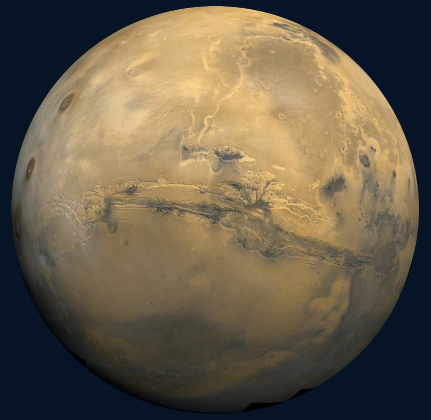
Earth, orbit, the Moon and Mars

Possible human missions









Earth

1 g

Our physiological reference

ISS

Microgravity

Observe adaptation in orbit

Moon

≈ 1/6 g

Deliver care on the surface

Mars

≈ 0.38 g

Sustain care far from Earth

Courtesy of NASA Johnson Space Center (Earth); NASA (ISS illustration); NASA / JPL / USGS (Moon); NASA / USGS (Mars).

Schematic route through the talk. Sizes and distances are not to scale.

Five hazards, one patient

Altered gravity	Changes in loading, fluids and movement
Radiation	Exposure depends on particles, shielding and time
Isolation and confinement	Sleep, stress and team performance
Distance from Earth	Delayed help and restricted evacuation
A closed habitat	Air, water, microbes and contamination

The medical effects interact.

NASA Human Research Program: five hazards of human spaceflight



Courtesy of NASA (public domain)

Gravity changes the way fluids move

Headward redistribution

The usual hydrostatic gradient is greatly reduced.

Eye changes on long missions

SANS (*Spaceflight-associated Neuro-ocular Syndrome)* can involve the optic nerve, retina and eye shape.

Return to gravity

Some astronauts become dizzy on standing.



Eye ultrasound aboard the ISS

Courtesy of NASA Johnson Space Center (public domain)

NASA SANS risk summary; Gew et al., Eye (2026)

Would a tear fall in orbit?



Source video

Your eyes still make tears.

Liquid can cling around the eye.

Surface tension and wetting

Free drops stay cohesive.
Liquids can adhere to surfaces.

Water sphere with an effervescent tablet

Courtesy of NASA — excerpt, audio removed

Canadian Space Agency: Tears in space (2013); NASA: floating-water demonstration (2015)

Exercise becomes a medical countermeasure

9 of 17

astronauts had not fully recovered tibia bone density 12 months after return

Exercise supplies deliberate mechanical loading.



Source video

Courtesy of ESA/NASA — © ESA

Gabel et al. (2022); NASA exercise overview; ESA/NASA video

Sixteen sunrises, one body clock

~16

sunrises per day aboard the ISS

Lighting and schedules help preserve a 24-hour rhythm.

Sleep loss can affect safety and performance.



Kjell Lindgren in a crew sleeping bag

Courtesy of NASA / Bob Hines (public domain)

NASA: Risk from inadequate sleep and irregular schedules

A blood clot, treated in orbit

The finding

An internal-jugular-vein thrombosis was detected during an ISS mission.

The response

Ground specialists helped manage treatment and repeated ultrasound monitoring.

The lesson

Medical capability depends on equipment, training and supplies.



Illustrative ISS spinal ultrasound, a different examination

Courtesy of NASA (public domain)

Auñón-Chancellor et al., New England Journal of Medicine (2020)

One-sixth gravity, a large evidence gap

1/6 g

at the lunar surface

How much loading is enough to protect a human body for years?

ISS evidence comes mainly from microgravity.

Apollo surface visits were brief.

We cannot scale medical risk directly from the fraction of Earth’s gravity.

NASA: Biological systems on the Moon; Jones, ICES (2021)

Moon dust had an unexpected smell

Apollo astronauts compared it to spent gunpowder.

Fine dust entered the cabin on suits and equipment.

Eye and airway irritation followed exposure.

Long-term exposure remains a research question.



Harrison Schmitt inside the Apollo 17 lunar module

Courtesy of NASA / Eugene Cernan (public domain)

NASA: What hazards are caused by lunar regolith?; Dust in the Wind

Radiation requires protection over time

Galactic cosmic rays

A persistent background of energetic particles

Solar particle events

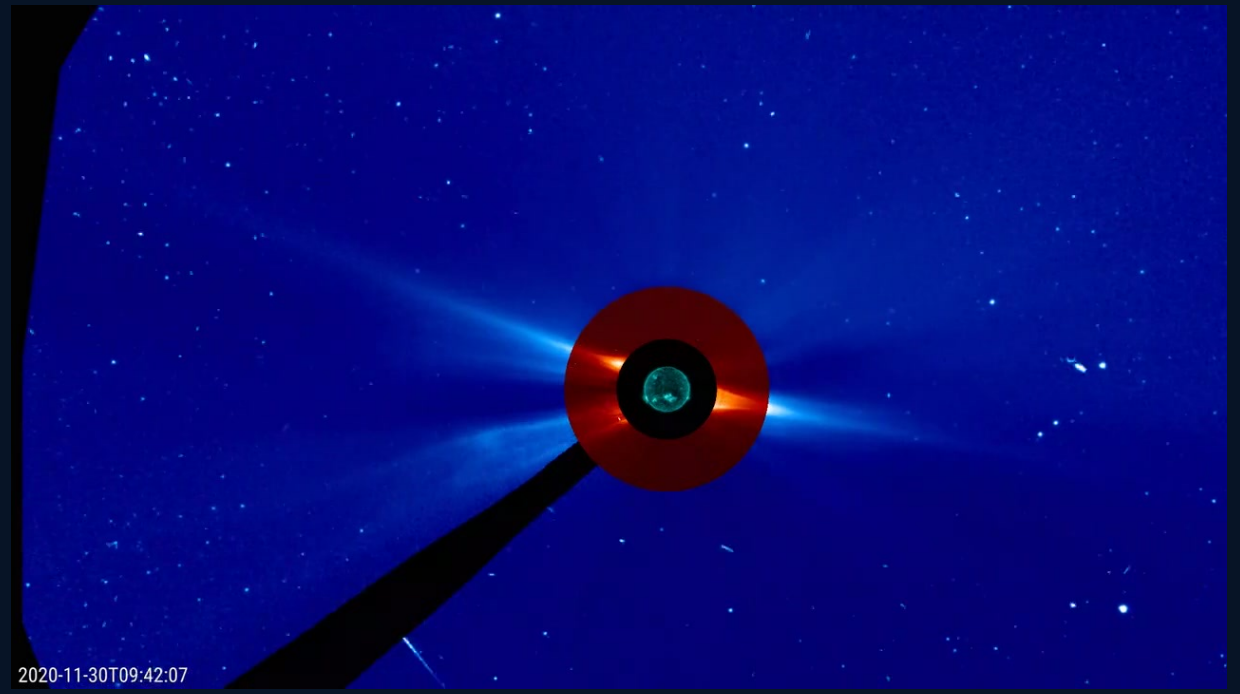
Episodic exposure that can demand shelter

Design response

Dosimetry, shielding, shelter access and mission planning

Risk depends on exposure, shielding and mission duration.

SOHO / LASCO · event beginning 29 November 2020



Source video

Courtesy of ESA, NASA SOHO/LASCO team — © ESA

Zhang et al. (2020); NASA HRP; ESA / NASA SOHO/LASCO team video

On the Moon, the nearest hospital is still Earth

Let’s now imagine:
A crew member develops severe abdominal pain on the Moon.

Teleconsultation can help. Diagnosis and initial care must happen locally.

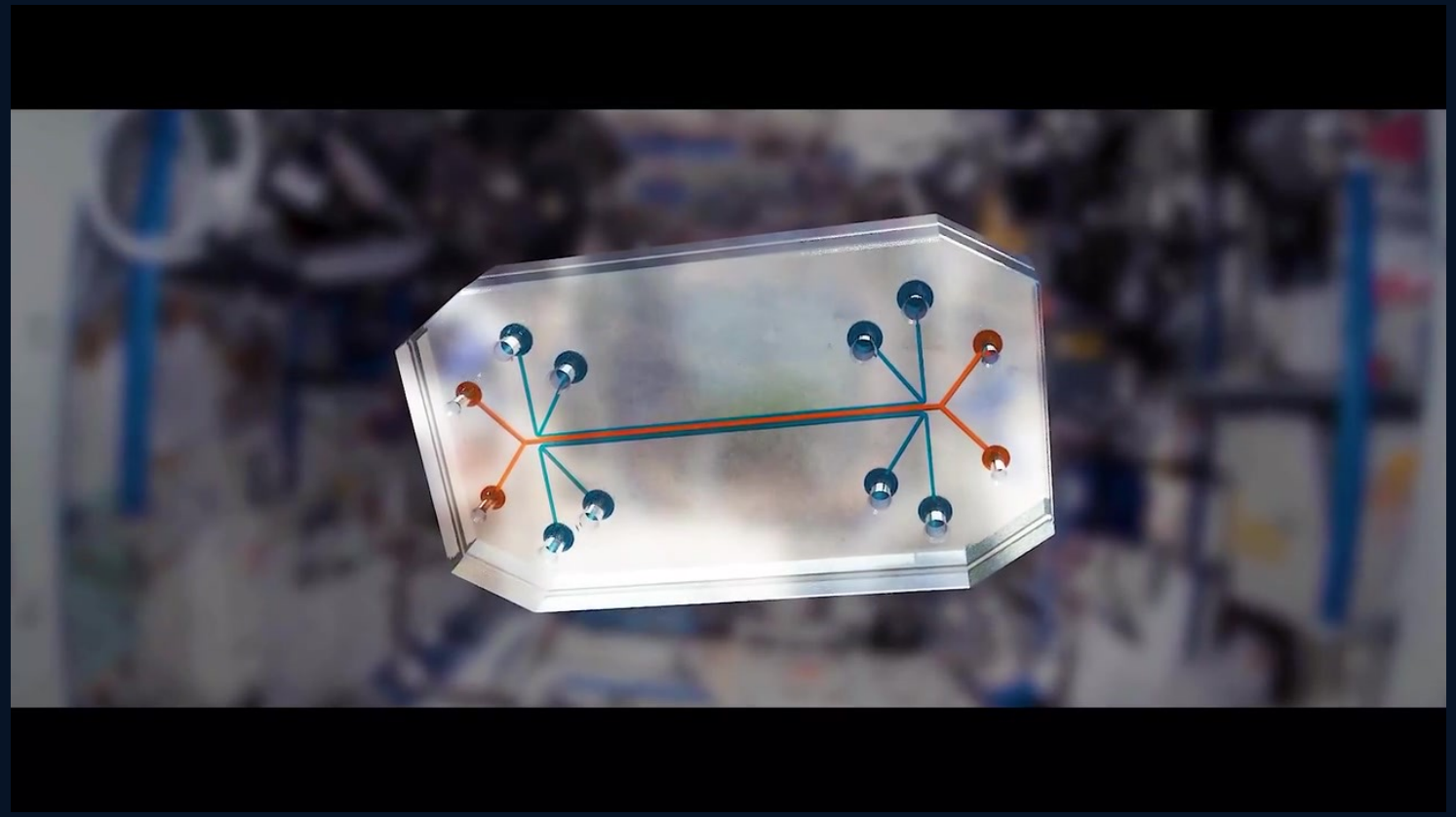
Illustrative scenario informed by NASA mission constraints and the ISS clinical case

What a lunar clinic must be able to do

Detect a problem early	Track meaningful changes rather than collect every possible signal.
Resolve uncertainty locally	Combine examination, imaging and targeted tests.
Treat with finite resources	Plan medicines, consumables, skills and waste handling together.
Support a human decision	Validate decision support under realistic conditions.

Design synthesis informed by the ISS clinical case and NASA mission constraints

An astronaut’s cells can travel alongside them



Source video

Courtesy of NASA Headquarters (excerpt)

NASA AVATAR investigation; NASA Headquarters animation excerpt (2026)

AVATAR / ARTEMIS II

Astronaut-derived bone-marrow chips

Compared with ground controls and crew samples

Returned samples under analysis

Circumlunar flight; no lunar surface gravity exposure.

Medical support changes with distance

Setting	One-way signal time	Medical implication
Low Earth orbit	Near real time	Ground guidance and possible return
Moon	About 1.3 seconds	Useful teleconsultation; return depends on the mission
Mars	Roughly 4–24 minutes	Local decisions during delay or outages

A fast conversation does not provide a fast evacuation.

NASA Deep Space Communications; Mars communications delay analysis (2024)

Mars adds a new gravity transition

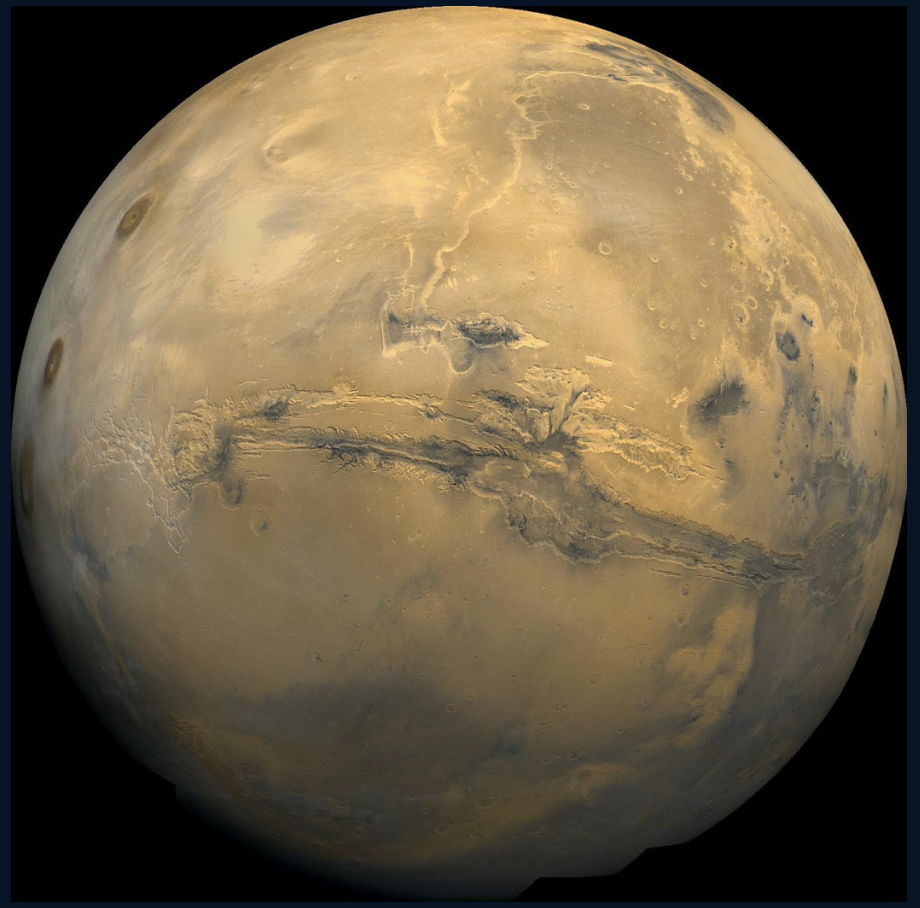
0.38 g

at the surface of Mars

After microgravity
A new demand on balance, movement and circulation

Surface operations
Landing and field work require a functioning crew

Evidence gap
Long-term physiological protection remains unproven



Mars, Viking 1 mosaic

Courtesy of NASA / USGS (public domain)

NASA: Humans to Mars; Gravity Fields; Jones, ICES (2021)

A Mars medical system must work locally

Capability	Mission requirement
Diagnose	Portable imaging and selected point-of-care tests
Treat	Practised skills, usable medicines and consumables
Support decisions	Local records and validated offline guidance
Continue care	Follow-up and recovery during communication gaps

NASA’s Earth-Independent Medical Operations concept is a development framework.

NASA Earth-Independent Medical Operations concept (2025); Medical-701

Medicines need evidence for long missions

Inside the package

Shelf life, formulation, temperature, radiation and packaging can influence stability.

Inside the patient

Spaceflight may change drug handling; useful human data remain drug specific and sparse.

On-demand production is a research direction with quality-control demands.

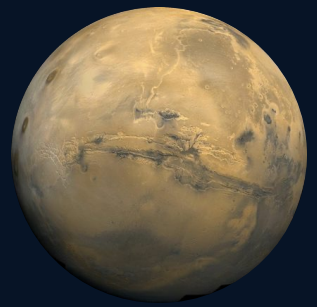
Du et al., AAPS Journal (2011); Blue et al., npj Microgravity (2019)

Living farther from Earth raises human questions

Who can participate?	Design and evidence for a broader range of bodies and needs
Who controls health information?	Privacy within a closely monitored workplace and home
Who accepts the risk?	Clear responsibilities when evacuation is difficult

Discussion questions informed by NASA human-research and medical-capability constraints

Now, let’s go back to Earth



Mars



Earth

What can space research bring back to medicine on Earth?

Images courtesy of NASA Johnson Space Center (Earth) and NASA / USGS (Mars).

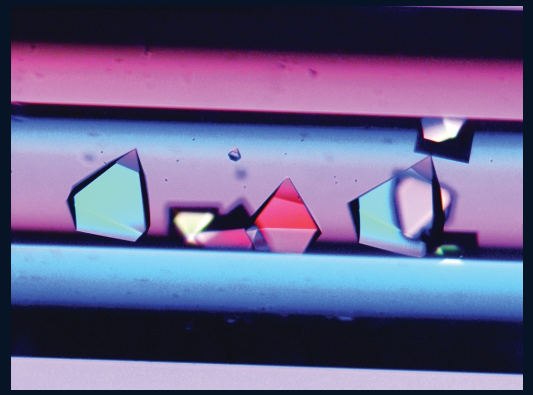
A pharmaceutical example: protein crystals

ISS study: pembrolizumab

More uniform particles and useful suspension properties in one study.

Earth follow-up

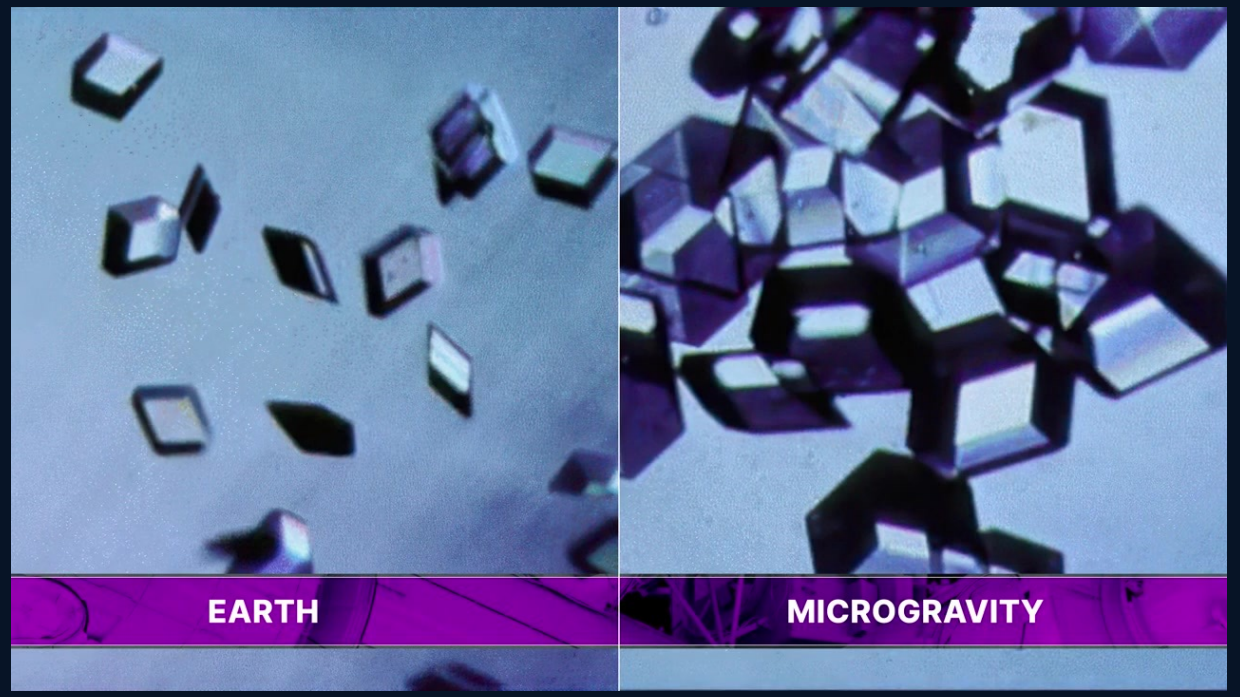
Rotational mixing and temperature control informed terrestrial processing.



Protein crystals grown in Kibo

Courtesy of JAXA

Human insulin — comparison of still micrographs



Source video

Courtesy of NASA — excerpt, audio removed

Protein and conditions matter.
Clinical benefit requires separate evidence.

Reichert et al., npj Microgravity (2019); NASA: human insulin comparison; JAXA

What could return to patients on Earth?

Research pathway	Terrestrial use	Evidence still needed
Guided portable imaging	Care in remote settings	Training, reliability and clinical outcomes
Tissue and physiology models	Mechanism and drug research	How well the model predicts patient responses
Compact monitoring and production	Care with limited infrastructure	Quality, cost and dependable operation

The benefit comes through a validated transfer to a real clinical need.

Fincke et al. (2005); tissue and pharmaceutical studies cited in notes

There is work here for many disciplines

Biology and medicine	Connect a measurable change with a meaningful health outcome.
Physics and engineering	Control loading, fluids, transport and diagnostic reliability.
Materials science	Design surfaces, shielding, packaging and tissue interfaces.
Data and human factors	Test prediction, uncertainty and decisions in realistic workflows.

A useful research question includes the measurement and the validation.

BACK TO EARTH

Medicine beyond Earth

To thrive beyond Earth, we must understand how deeply Earth has shaped us.



Courtesy of NASA (educational reuse)

CRESTLAB

an official ESA ground-based facility

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