Loyola Alumni Webinar

Human Space Exploration : A Chemist's Perspective

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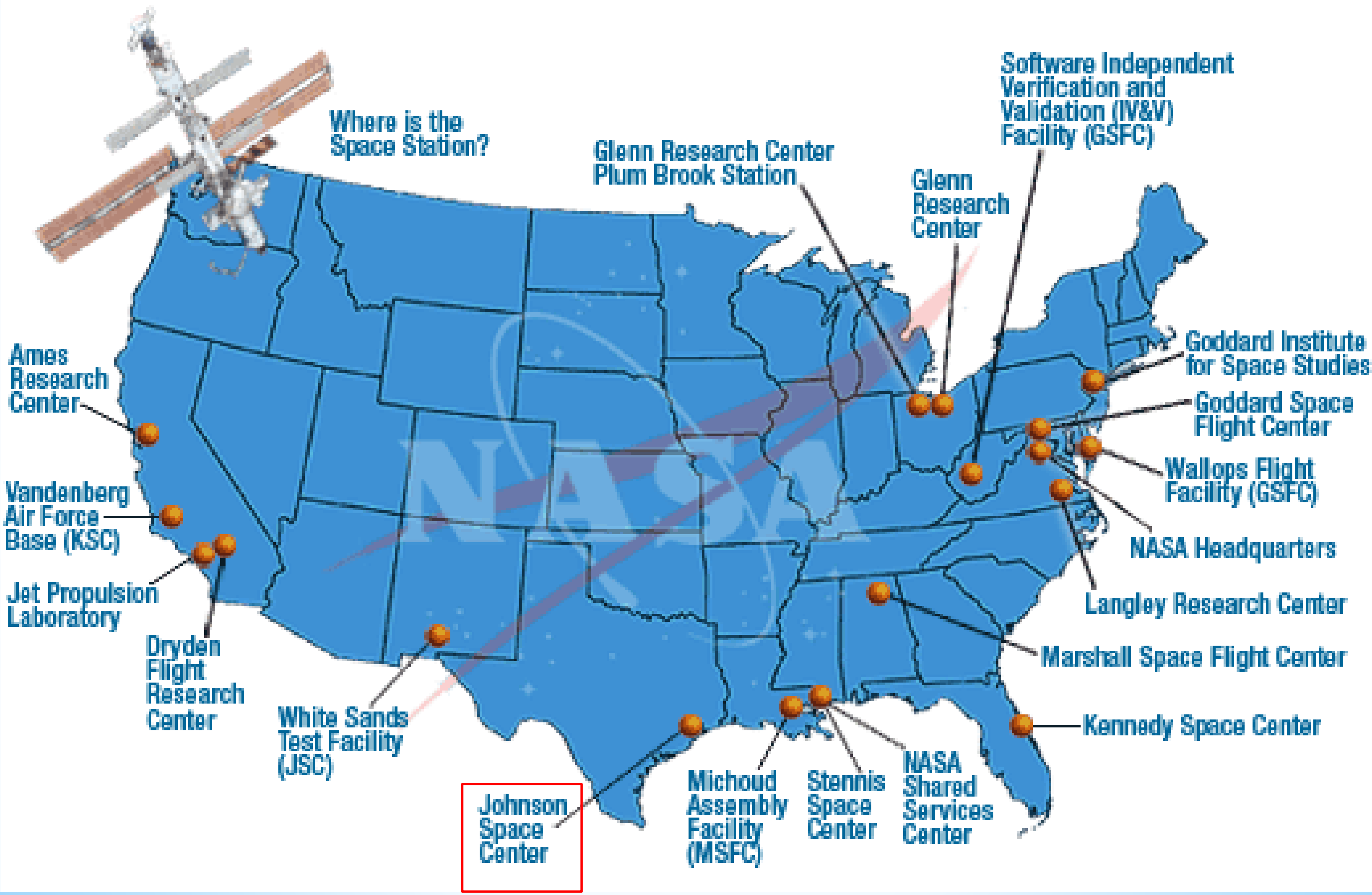
Dedicated to
the
Teachers

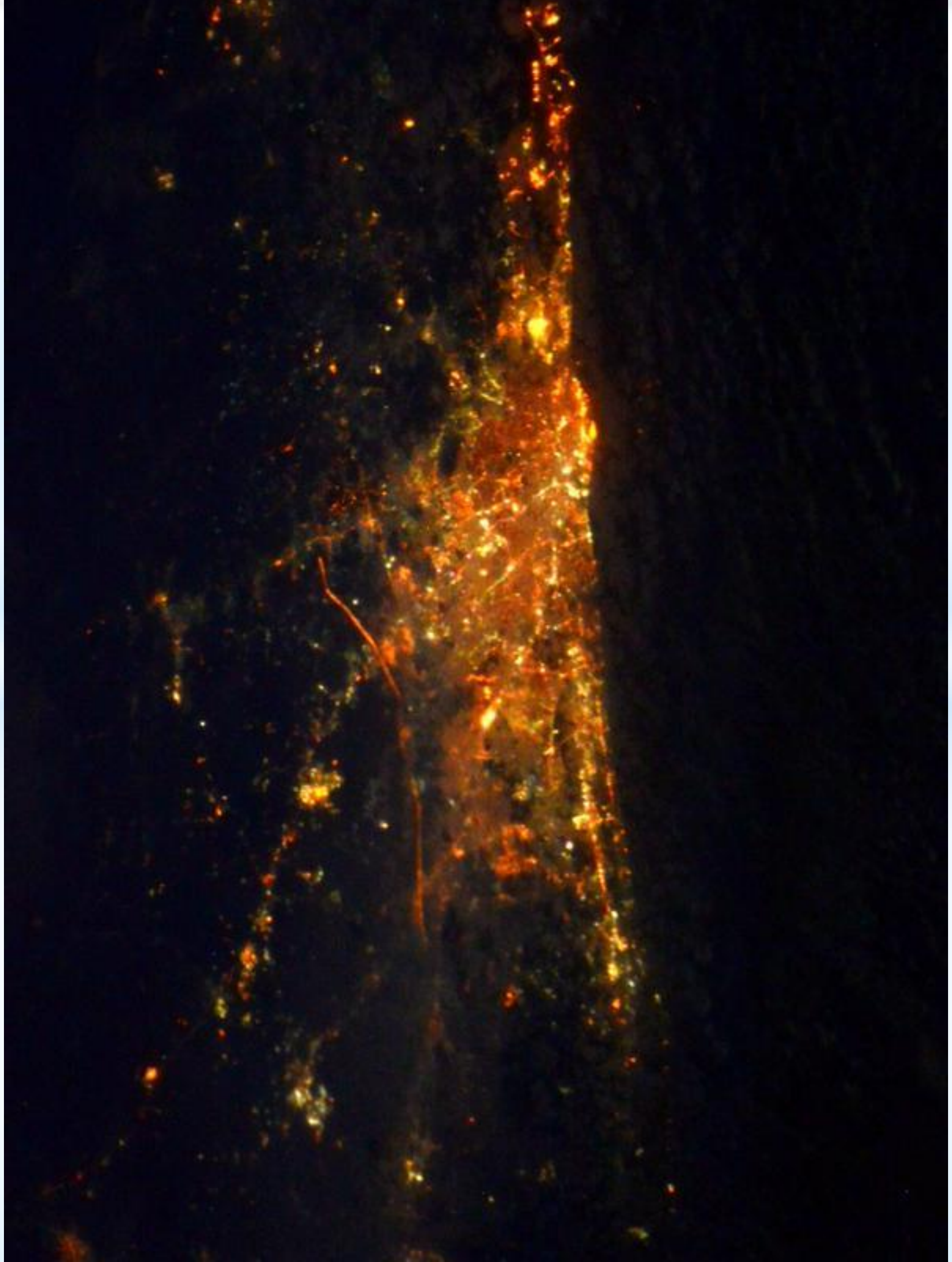
Objectives

- Where are we in the Universe?
- What does it take for humans to go to Mars?
- Role of Chemists/Chemical Engineers
- More importantly, an attempt to answer all of your questions

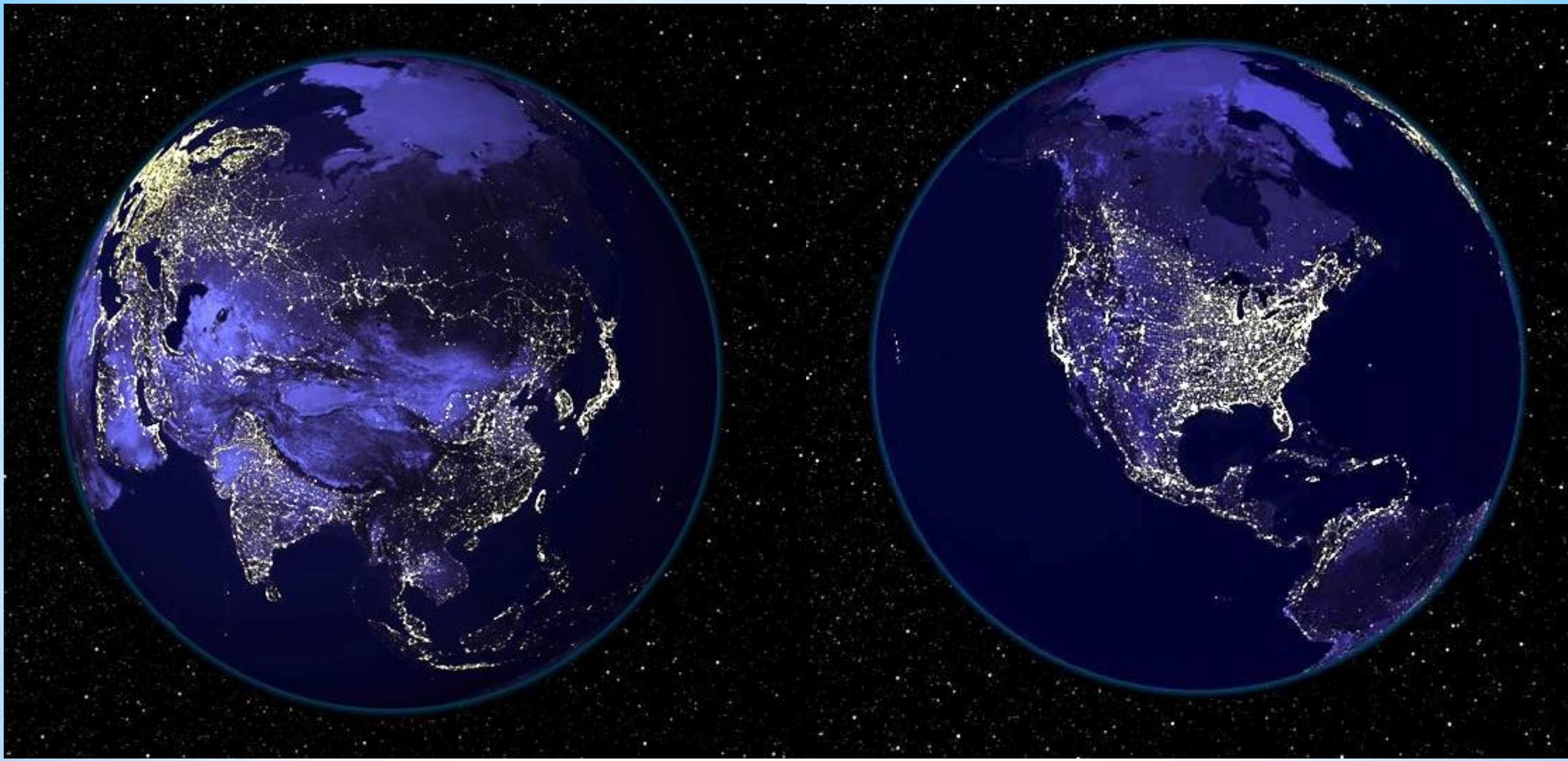
NASA Centers



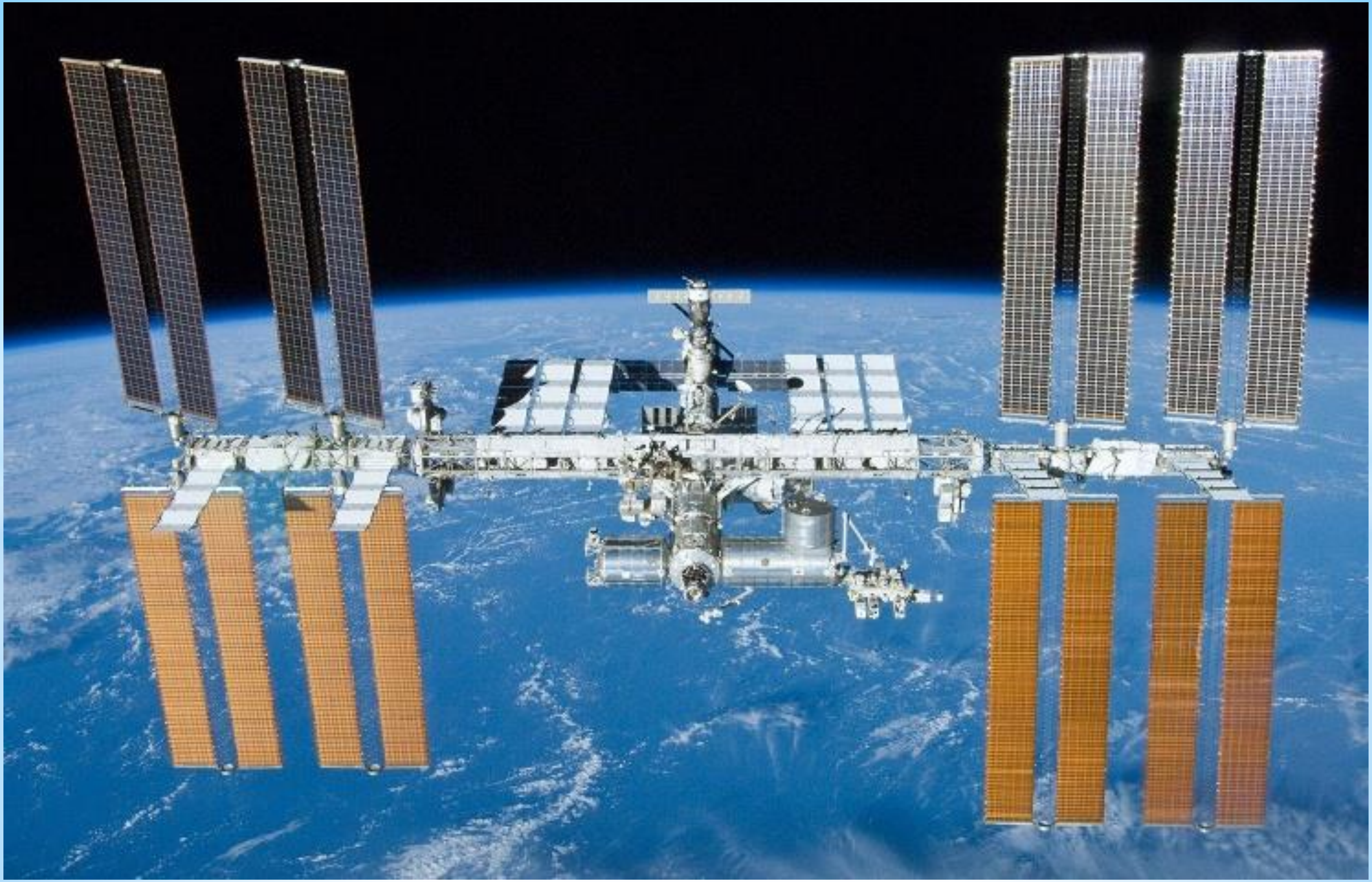
Loyola College Chennai



Our Habitation at Night



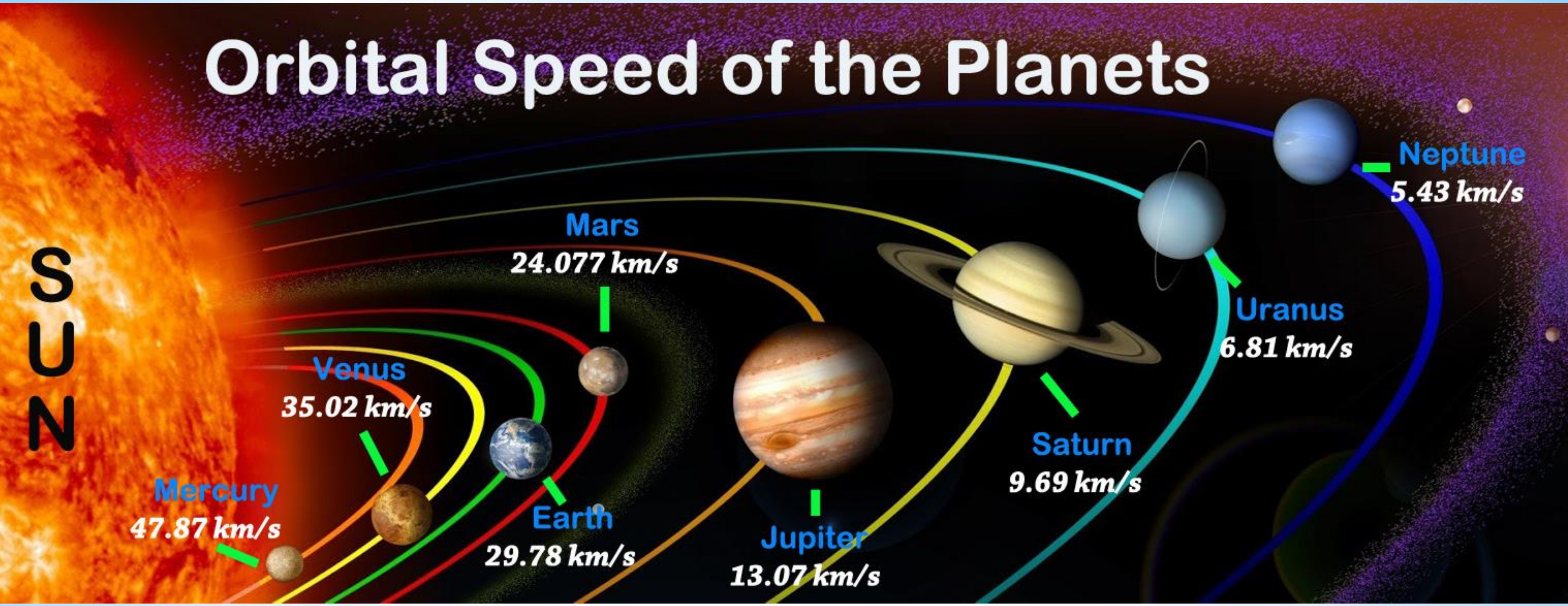
Our Planet from ISS (~250 miles)



Beautiful Fragile Blue Planet (~250,000 miles)

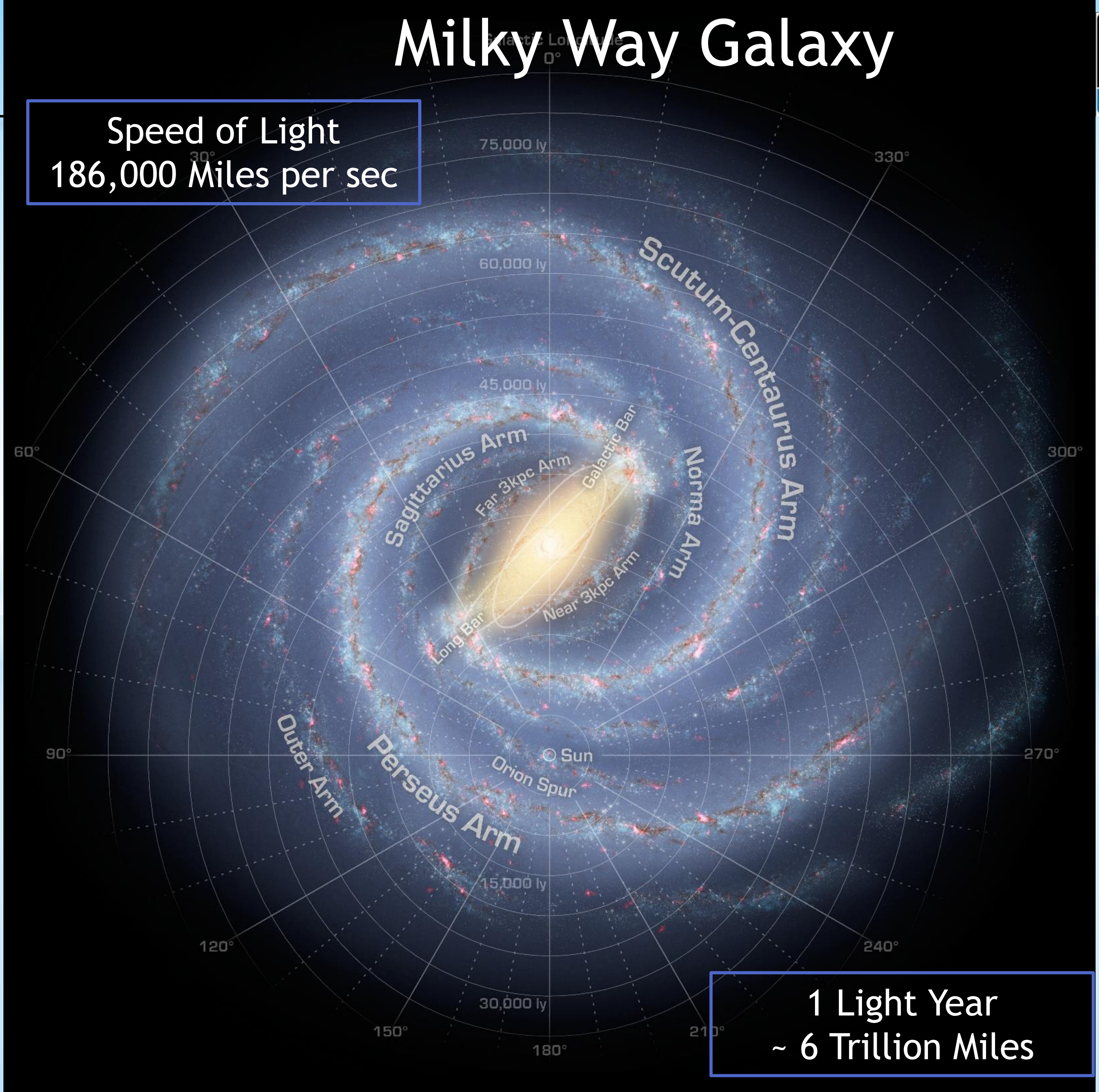
Mars – Earth Mutual View (~250,000,000 miles)

Solar System



Milky Way Galaxy

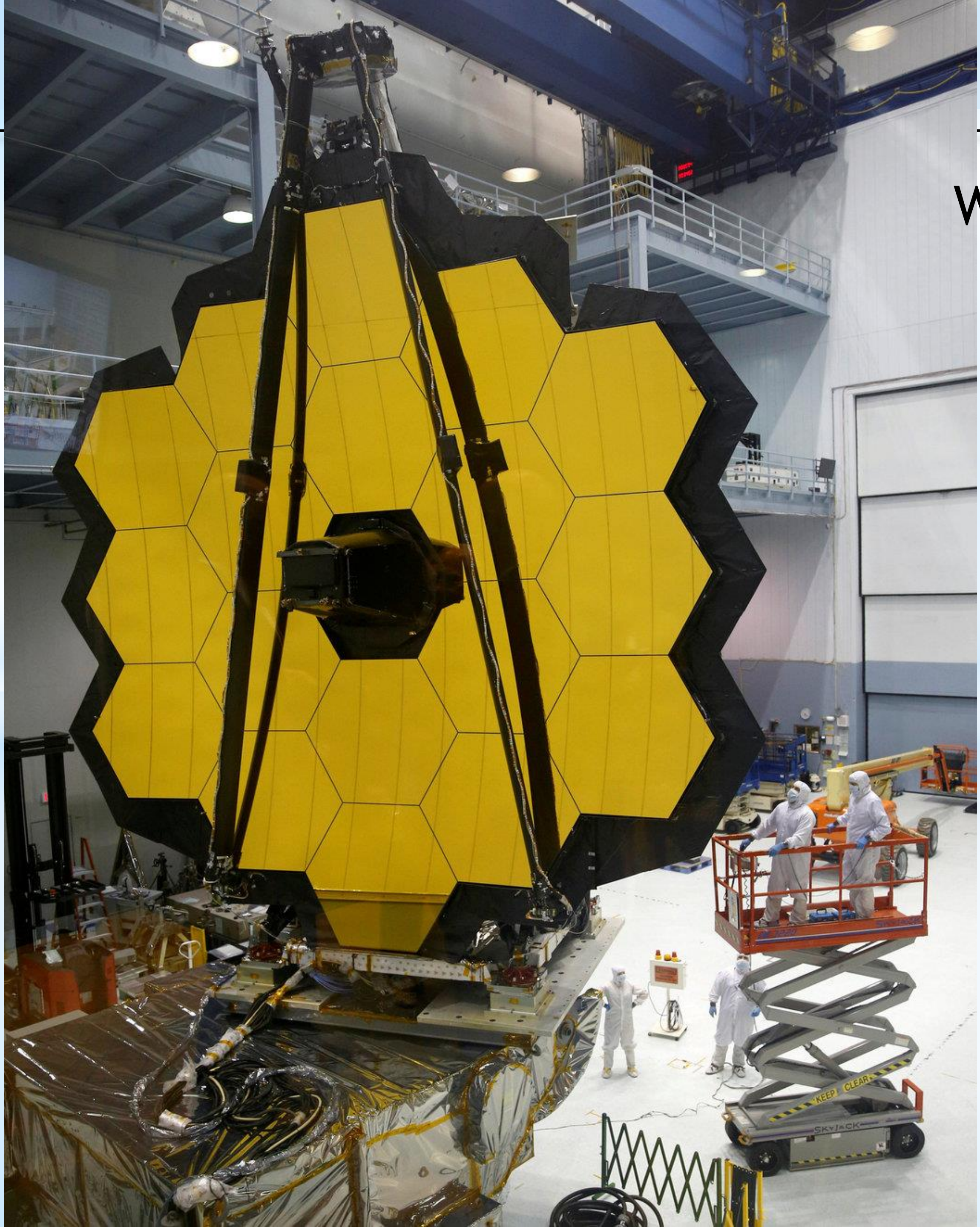
Speed of Light
186,000 Miles per sec



1 Light Year
~ 6 Trillion Miles

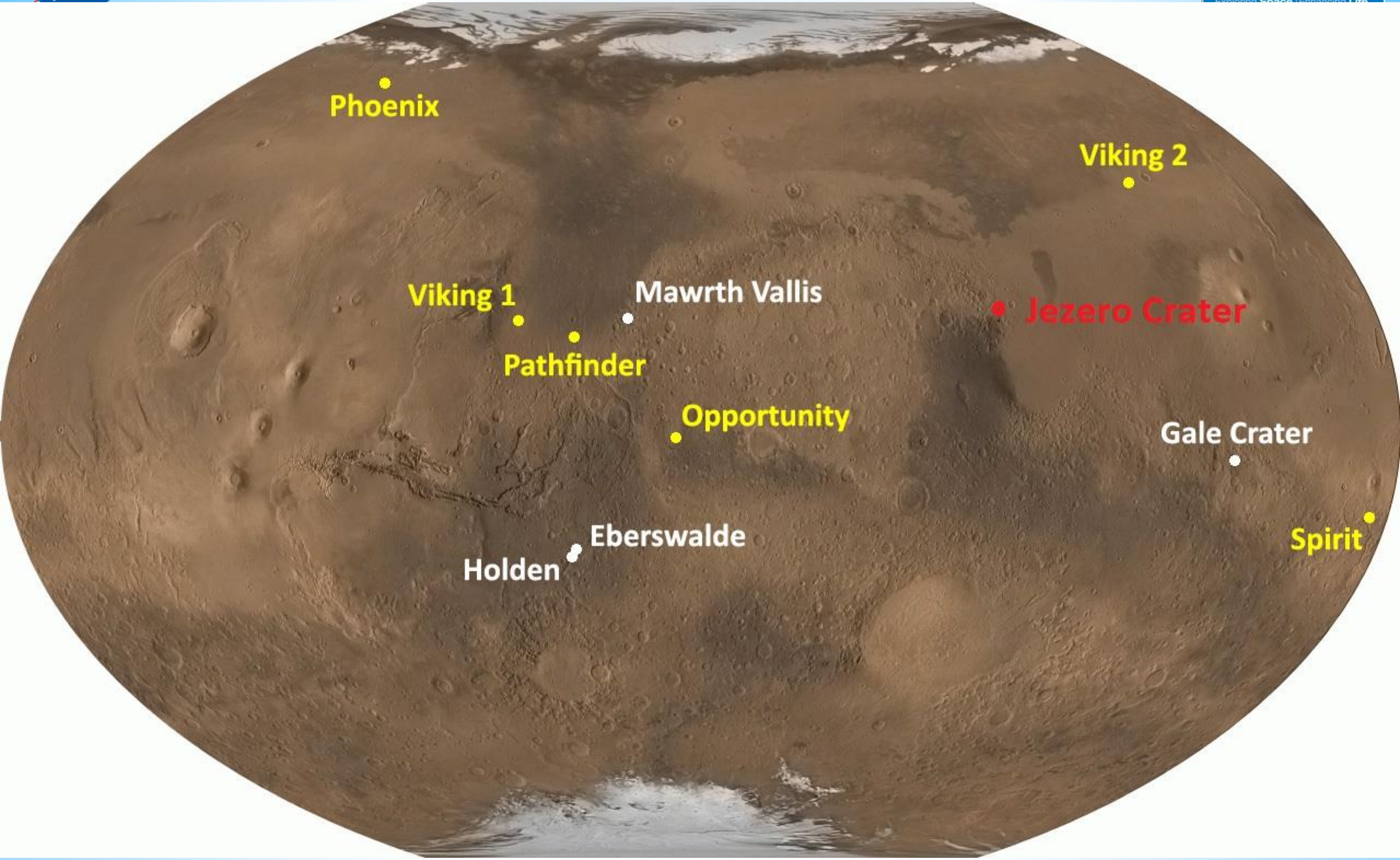
Milky Way from Earth
Top from Lebanon and Bottom from Chile

Hubble Telescope Repair Mission Crew (STS-125)

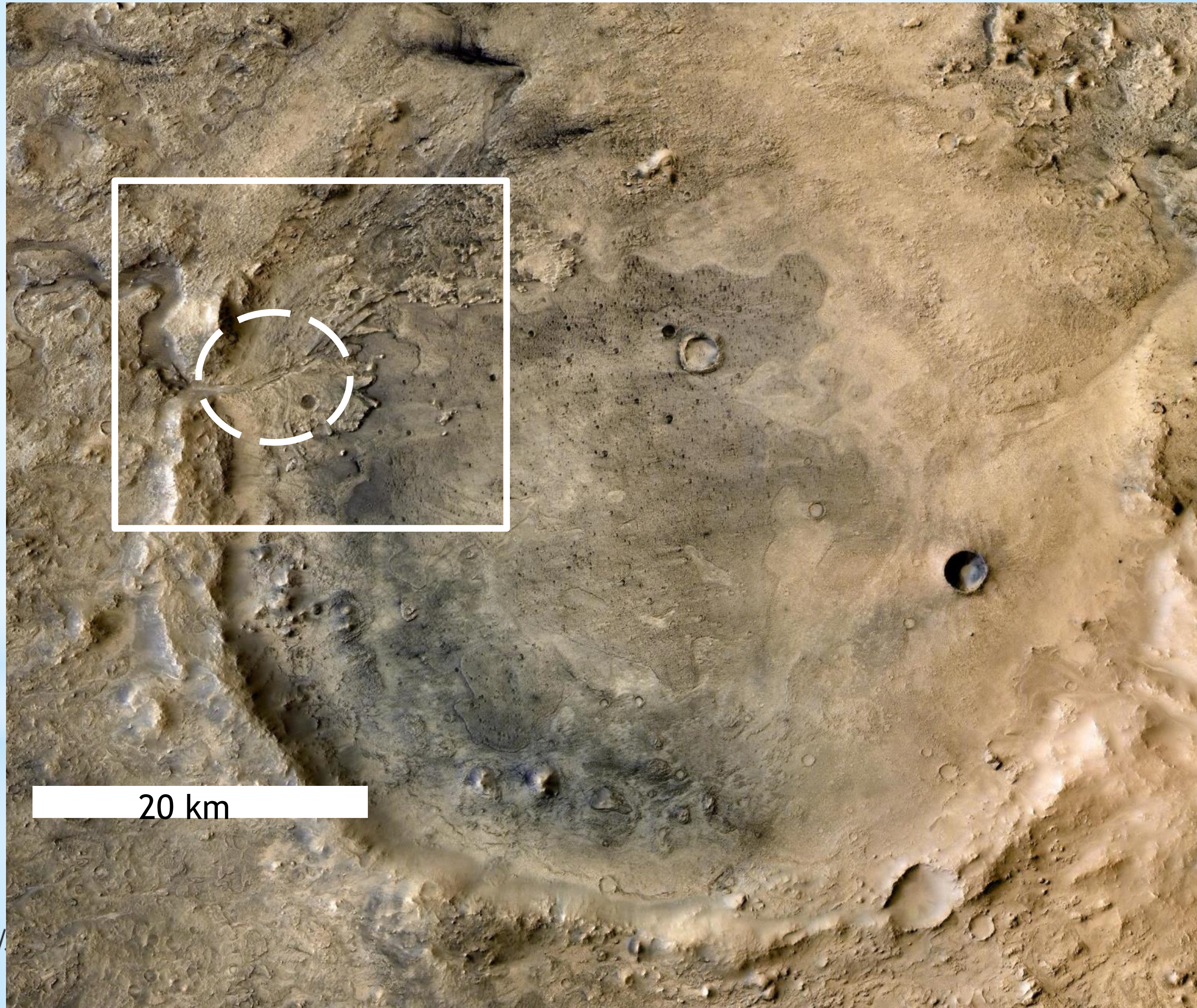


Webb Telescope

Mars Landing Sites

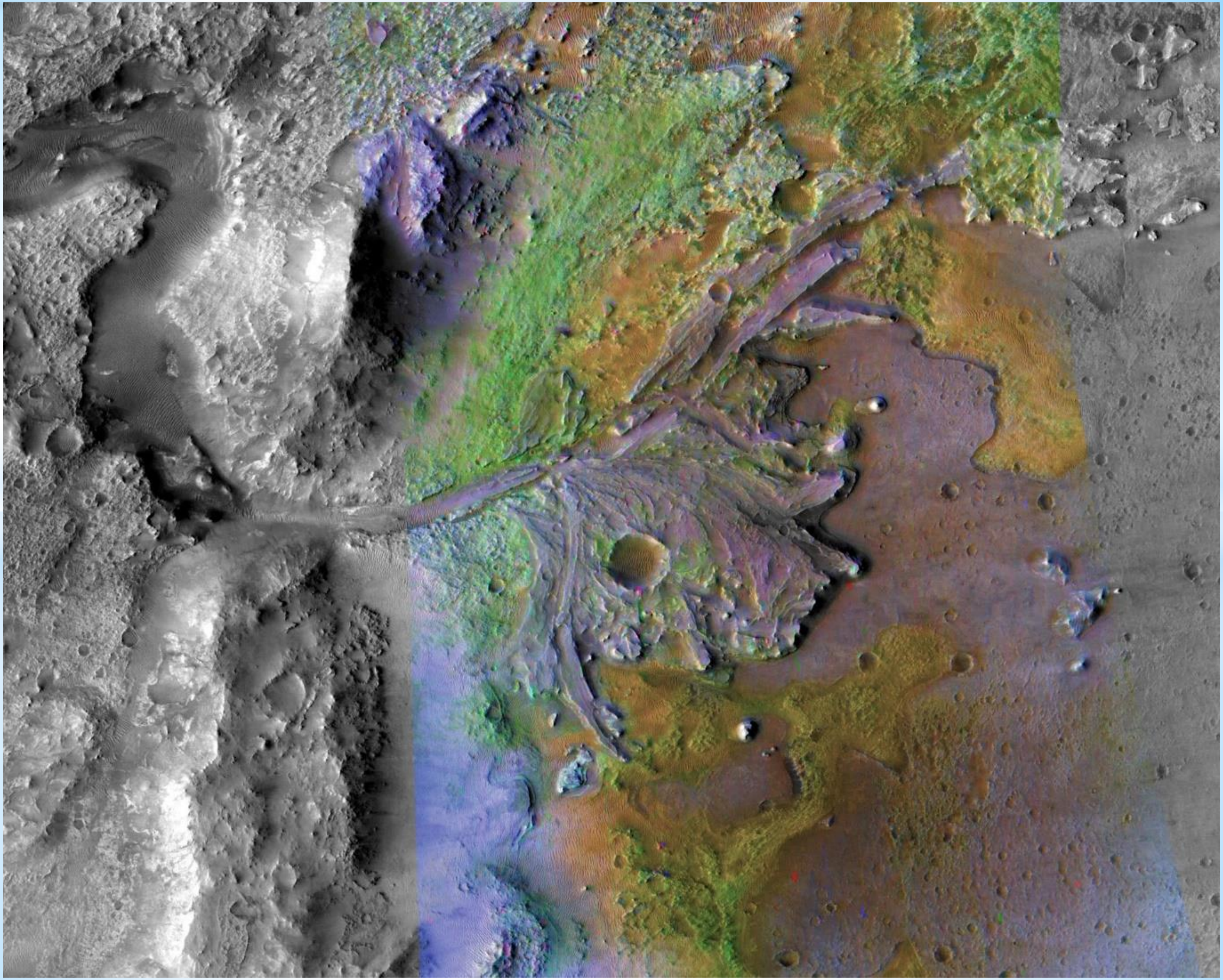


Mars 2020 : Jezero Crater

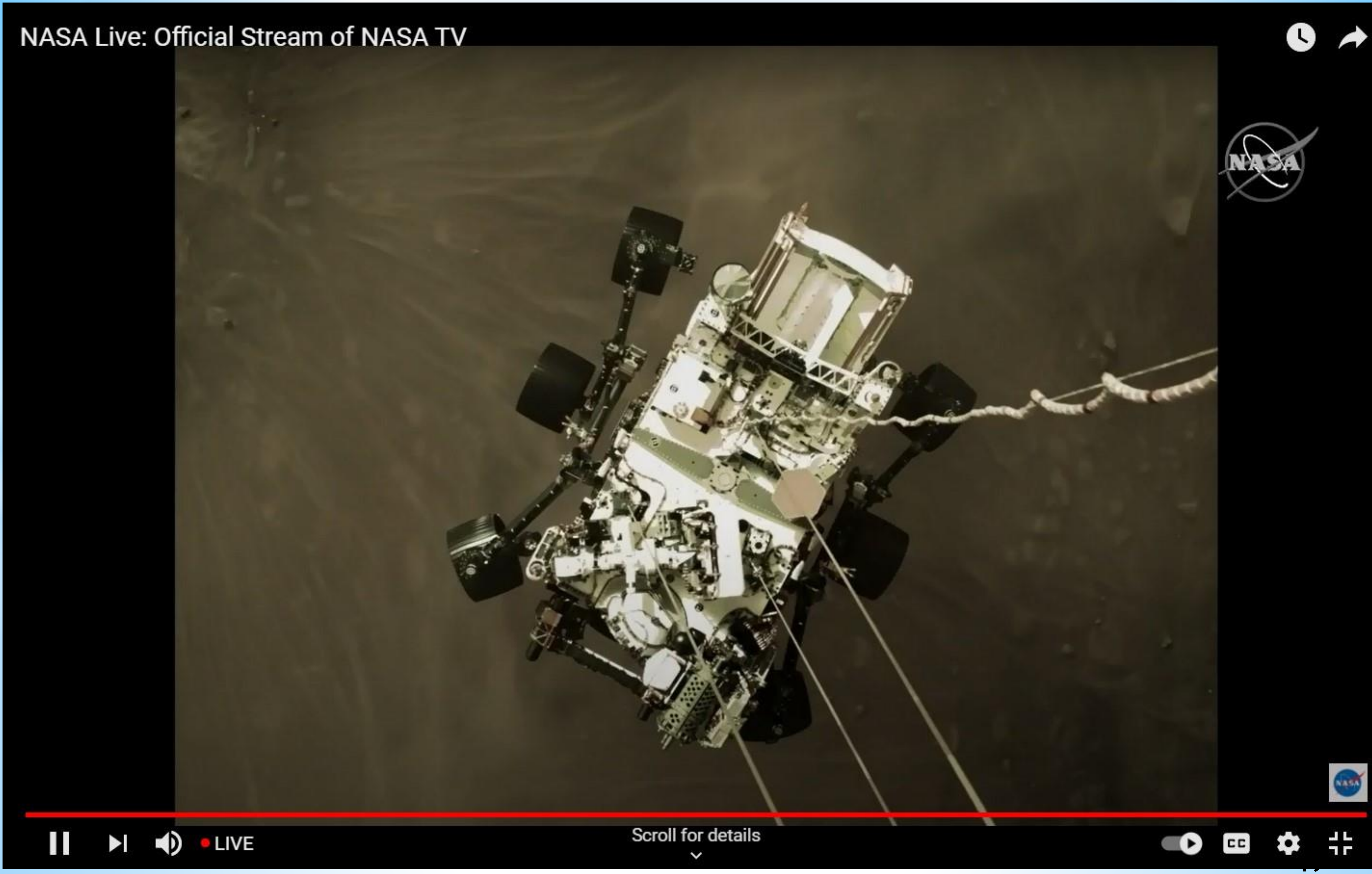


Credit: NASA / JPL
DLR / FU Berlin /

Mars 2020 : Jezero Crater

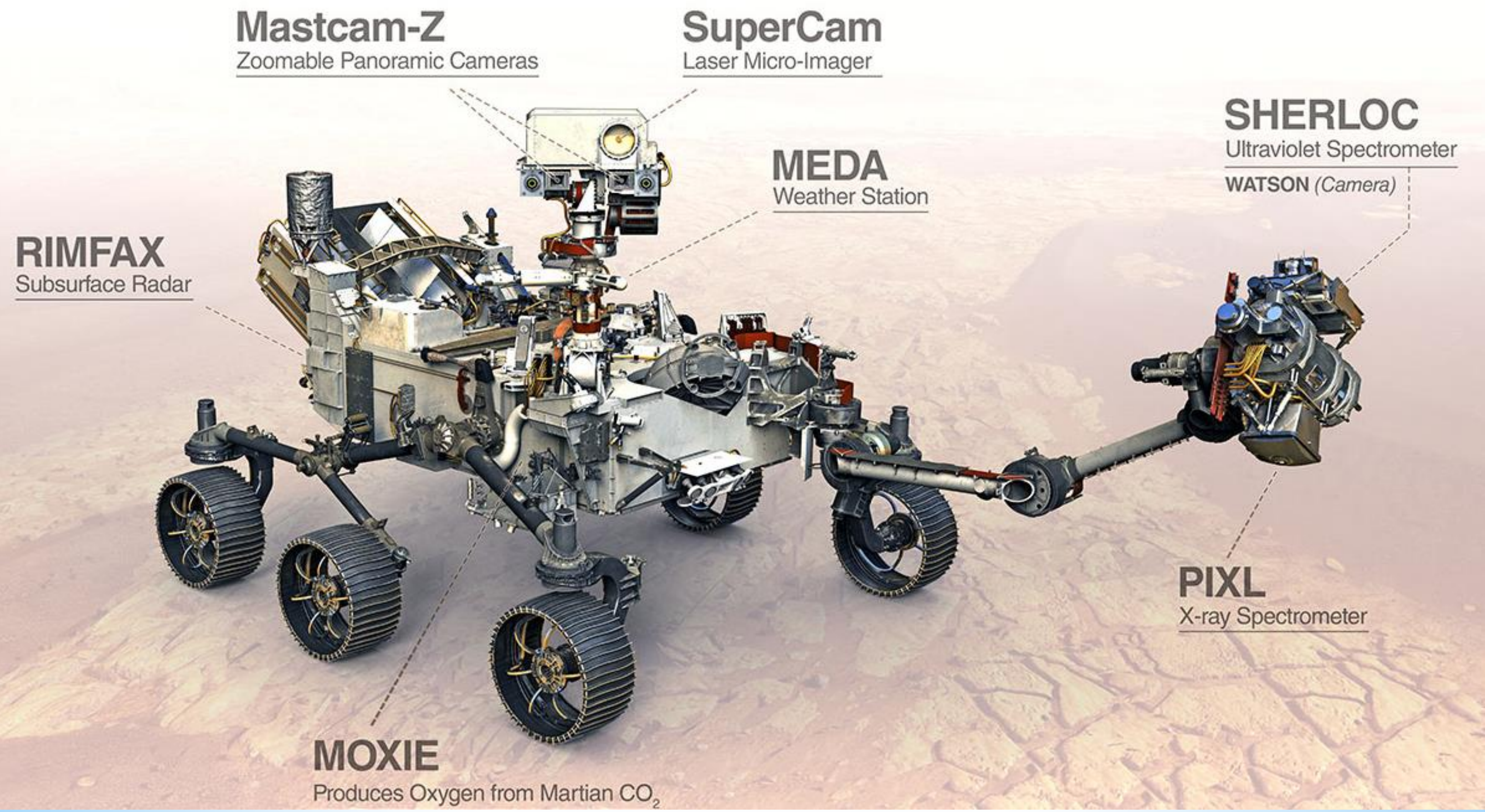


Perseverance Landing

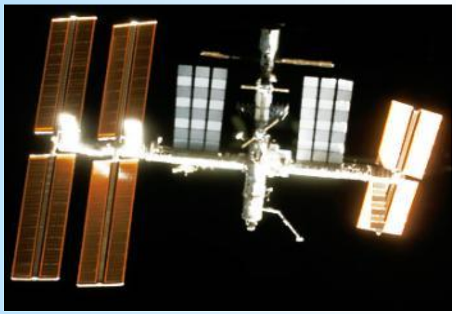


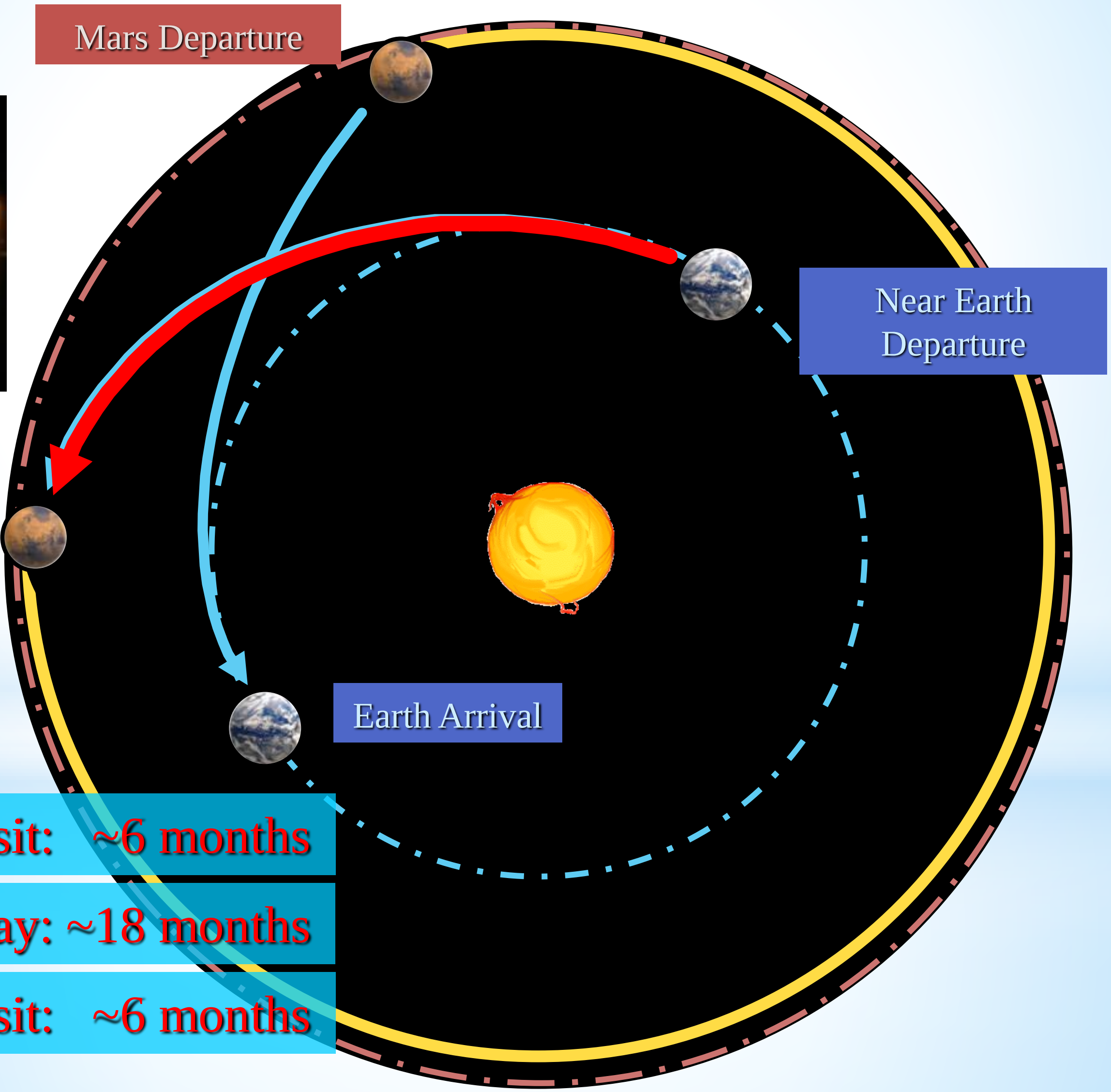
minutes-of-terror/

Mars 2020 : Perseverance



Overview of Notional Mars Expedition





Earth-to-Mars transit: ~6 months

Mars surface stay: ~18 months

Mars-to-Earth transit: ~6 months

Why Mars?

- Mars is our most hospitable planetary neighbor
  - Venus is closer, but its average temperature of 462°C (864°F) and the sulfuric acid atmosphere—90 times higher pressure than Earth—would crush our spaceships
- Mars will feel like home in many ways:
  - Approximately the same day/night cycle as Earth
  - 4 seasons: cold winters, but as warm as 20°C (70°F) on a summer day
  - Vistas similar to Earth's deserts: mountains, cliffs, valleys, dunes, dust devils
  - Abundant natural resources: oxygen (from ice or CO_2), water, iron, sunlight
  - Enough atmosphere to provide some radiation protection
- Mars is also exotic:
  - 0.64 of Earth's gravity and 2 moons that cross each other traveling different directions
  - May have once supported life
  - We don't know what may be underground--our rovers have only explored a fraction of Mars' surface

Life Support Requirements Mass Breakdown

5.02 - 30.74 kg per person-day

11.3 Metric Tons Per Person-Year

DAILY INPUTS - NOMINAL

	kg
Oxygen	0.84
Food Solids	0.62
Water in Food	1.15
Food Prep Water	0.79
Drink	1.62
Hand/Face Wash Water	1.82
Shower Water	5.45
Clothes Wash Water	12.50
Dish Wash Water	5.45
Flush Water	0.50
TOTAL	30.74

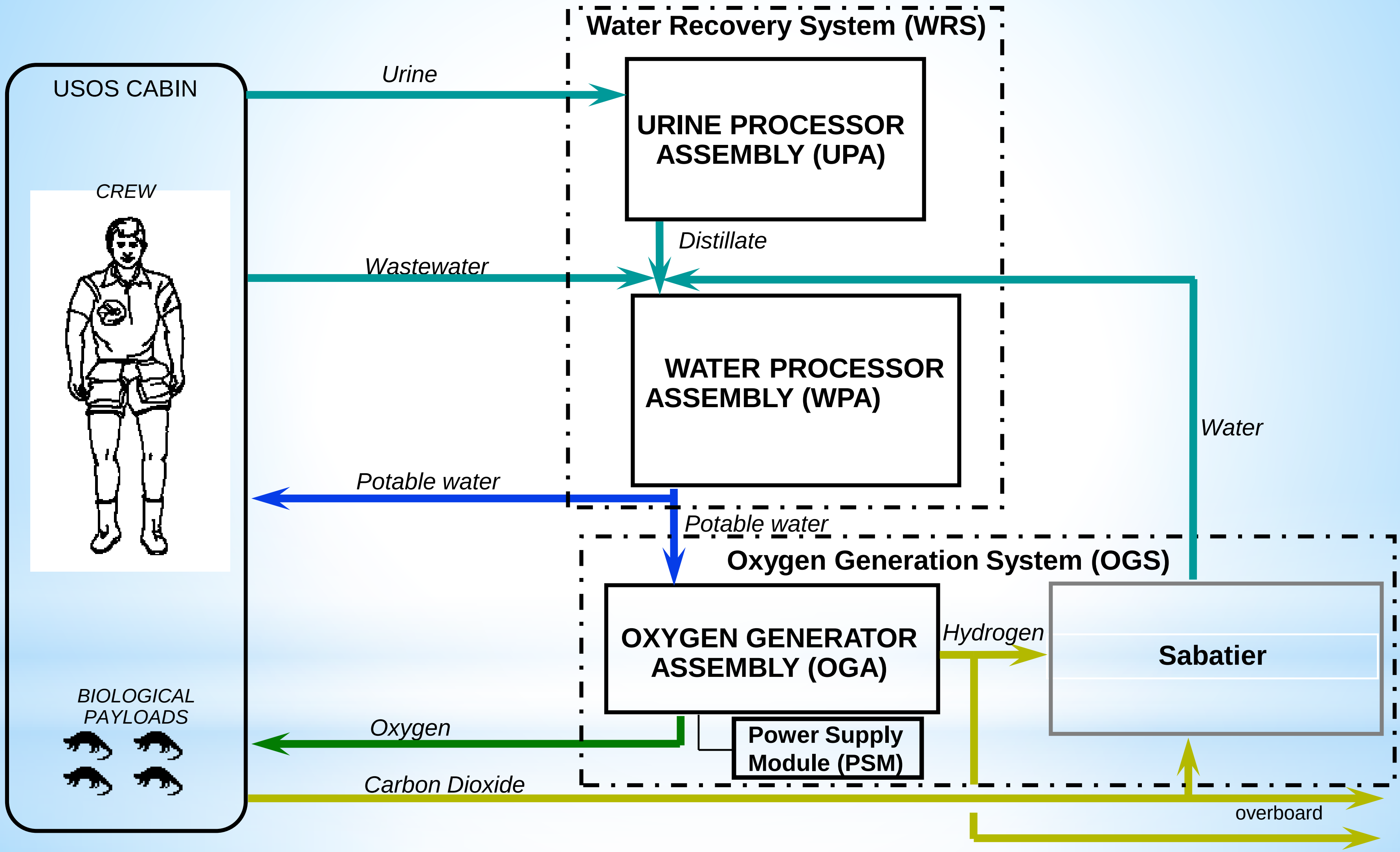
DAILY OUTPUTS - NOMINAL

	kg
Carbon Dioxide	1.00
Respiration and Perspiration Water	2.28
Urine	1.50
Feces Water	0.09
Sweat Solids	0.02
Urine Solids	0.06
Feces Solids	0.03
Hygiene Water	6.68
Clothes Wash Water	11.90
Clothes Wash Latent Water	0.60
Other Latent Water	0.65
Dish Wash Water	5.43
Flush Water	0.50
TOTAL	30.74

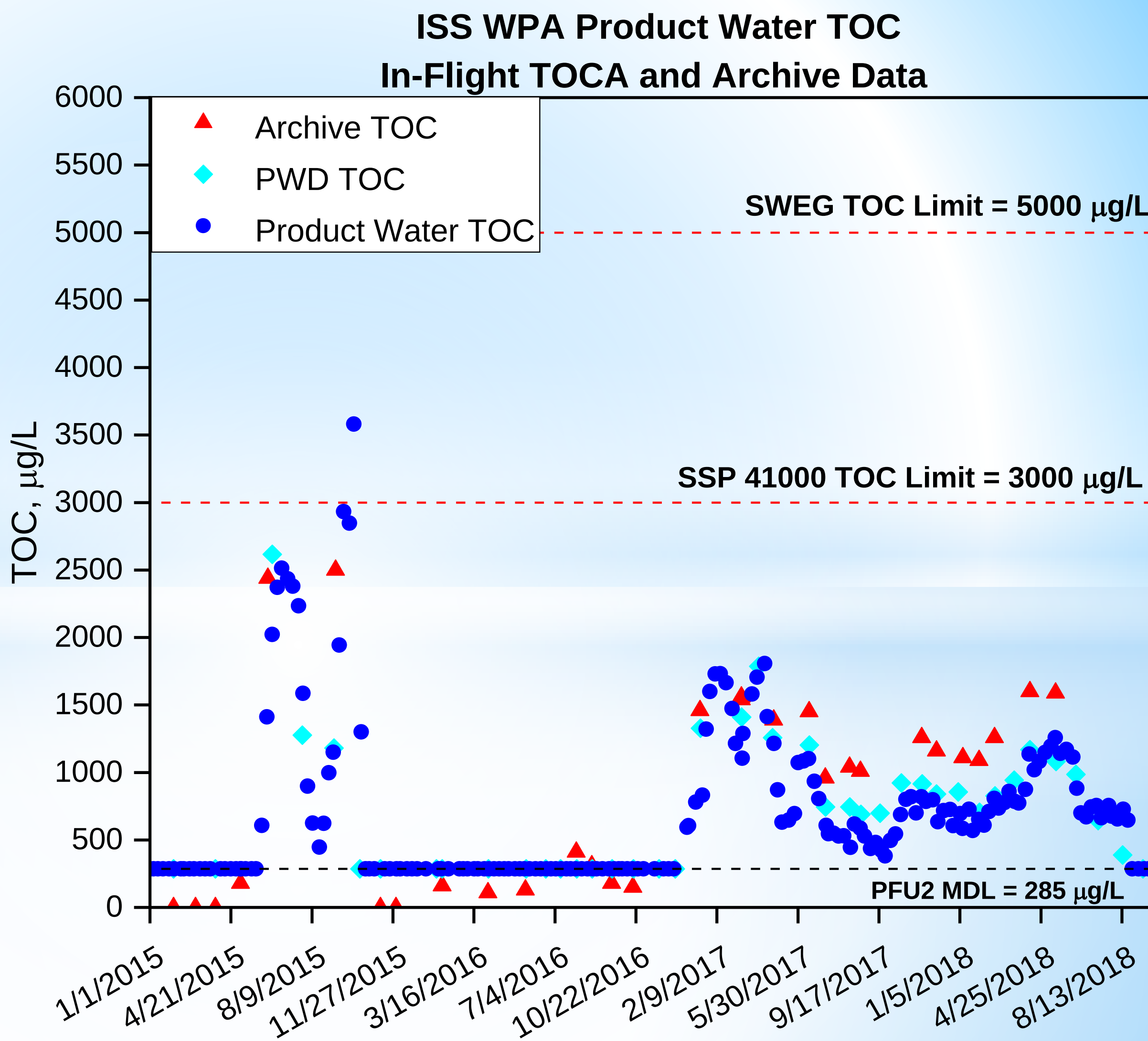
Resources and Recycling

- Water Regeneration Reactors
- Air Revitalization Reactors
- Environmental Sensors (Chemical)
- Microbial Monitors

Water and CO2 Recycling



Total Organic Carbon Analyzer



D. Gazda

Today's Coffee – Yesterday's Coffee

“Pea Brittle”

Carbon Dioxide Removal

- Lithium Hydroxide
- Zeolite
- Amine Bed
- Anchored Amine Bed
- Sabatier Reaction

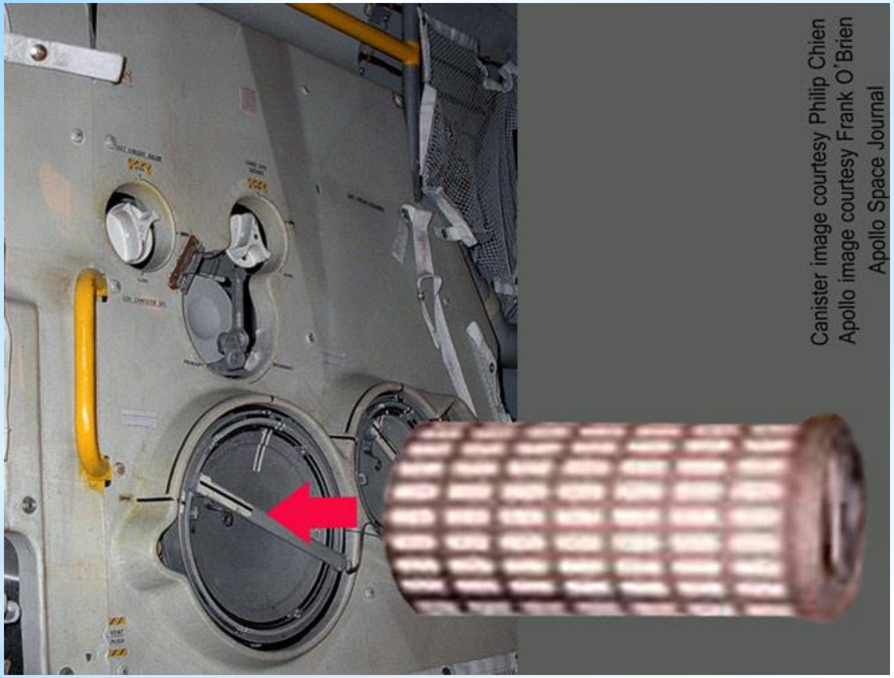
<u>Lithium Hydroxide (Single Use)</u>

- Apollo Missions
- Apollo 13 Hardships
- Extra Vehicular Activity (EVA) Suit

<u>Zeolite (Reusable)</u>

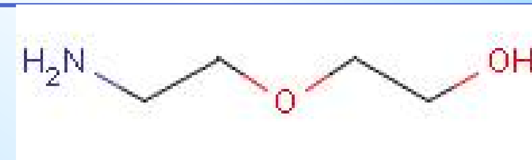
- Removal of water
- Physisorption of CO2
- Removal by exposing to Vacuum

Apollo-13 LiOH Cannisters



- Fatigue
- Difficulty concentrating
- Irritability
- Performance decrements
- Headache / Death

Carbon Dioxide Removal



Swing Amine Bed Reactor

- Soluble in water
- Low vapor pressure (<0.01 mmHg) – (MEA is 20 times greater)
- High capacity (~40%)
- Low regeneration temperature (80 °C)
- Low viscosity (40 cP *pure* @ room temperature)
- Working Viscosity (50 cP with loaded CO_2)
- Primary amine (fast reaction rate)
- Favorable mass flux
- Health effects
  - Safe for trace off-gassing and Skin irritant (strong base)

T. Rogers

- Oxygen Generation System (Electrolysis)

$$2\,H_2O \rightarrow 2\,H_2(g) + O_2(g)$$

- Sabatier Reaction

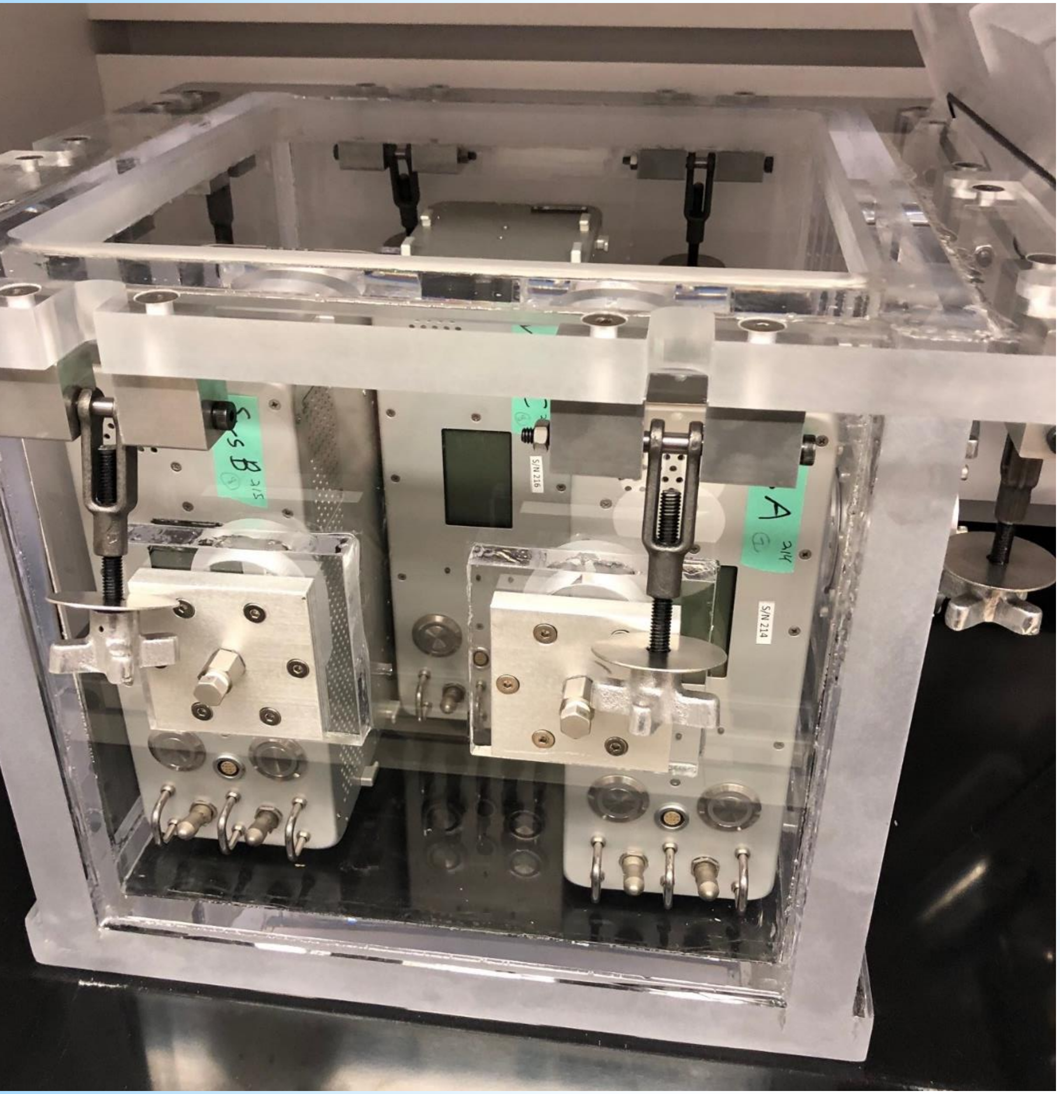
$$CO_2 + 2\,H_2(g) \rightarrow CH_4(g) + O_2(g)$$

Air Quality Monitoring

AQM 1 (624 column)	AQM 2 (DB5 column)
Acetone	Ethanol
Hexane	Dichloromethane
1,2-dichloroethane	Trimethysilanol
Toluene	2-butanone
Hexamethylcyclotrisiloxane	Ethyl acetate
Hexanal	N-butanol
m,p-xylene	Toluene
o-xylene	Hexamethylcyclotrisiloxane
Octamethylcyclotetrasiloxane	m,p-xylene
Decamethylcyclopentasiloxane	o-xylene
Acrolein	Octamethylcyclotetrasiloxane
Isopropanol	Decamethylcyclopentasiloxane
Benzene	

D. Gazda
T. Limero

Anomaly Gas Analyzer



Uses combination of Tunable Diode Laser Spectroscopy and Photoacoustic Spectroscopy

Analytes :
O_2, CO_2, CO, H_2O, HF, HCl, HCN, and NH_3.

P. Mudgett and T. Limero

Anomaly Gas Analyzer

Gas	Wavelength (um)	Spectroscopy	Concentration Range
O2	0.8	Direct absorption	14-50%
CO2	2.0	Direct absorption	0.3-21 mmHg
NH3	1.5	Direct absorption	10-30,000 ppm
H2O	1.4	Direct absorption	2-20 mmHg
CO low	4.6	Photoacoustic	10-200 ppm
CO high	2.3	Direction absorption	200-1000 ppm
HCN	3.0	Photoacoustic	2-50 ppm
HF	1.3	Direct absorption	2-50 ppm
HCl	1.7	Direct absorption	2-50 ppm

P. Mudgett and T. Limero

Human Health & Performance

Enable successful space exploration by minimizing the Human System Risks of spaceflight hazards

Human Health and Performance
NASA Johnson Space Center
Exploring Space | Enhancing Life

SPACE MISSIONS

HAZARDS

RISKS

MITIGATIONS

Hostile Spaceflight Environment

Radiation
Isolation
Distance from Earth
Altered Gravity
Environment

Human Risks
- Bone loss
- Muscle atrophy
- Balance Disorders
- Neuro-ocular issues
- Sleep disorder
- Radiation induced
- Toxic Exposure
- Behavioral Health

etc.,

Deliverables:
- Standards
- Preventions
- Technologies
- Countermeasures
- Treatments

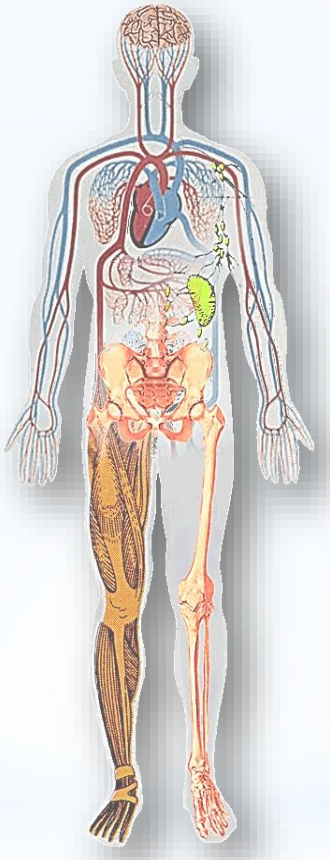
Hazards of Spaceflight (RIDGE)
Hazards Drive Human Spaceflight Risks

Radiation

Acute In-flight effects
Long term cancer risk

Isolation & Confinement

Behavioral aspect of isolation
Sleep disorders



Distance from earth

Autonomous Medical Care and Operations; Communication Delay

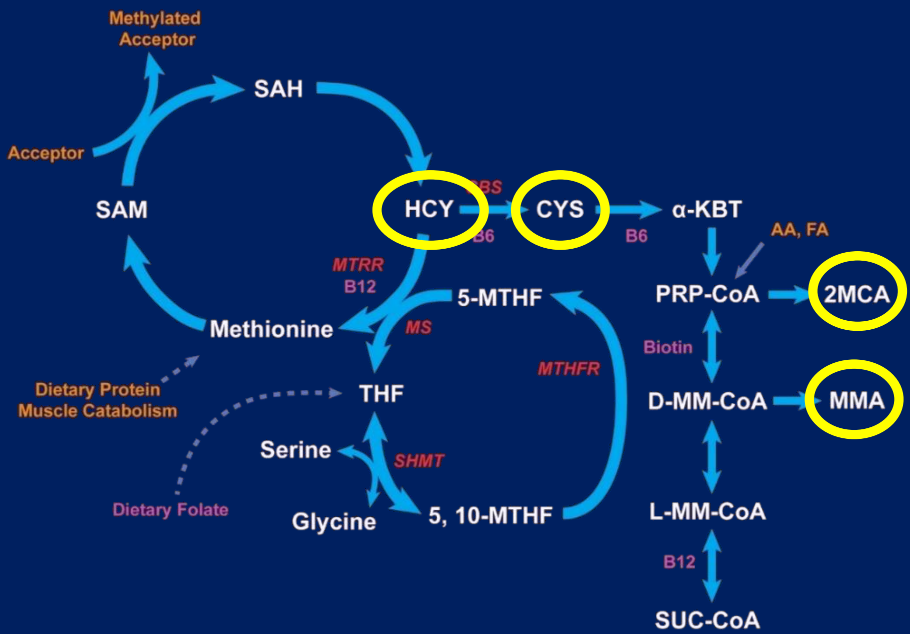
Altered Gravity - Physiological Changes

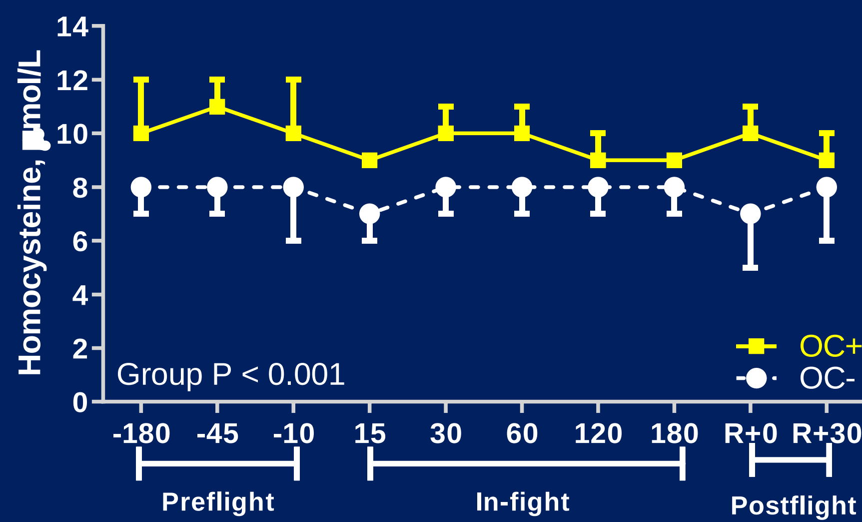
Balance Disorders
Fluid Shifts
Cardiovascular Deconditioning
Decreased Immune Function
Muscle Atrophy
Bone Loss

Environment (Closed/Hostile)

Vehicle Design
Environmental – CO_2 Levels, Toxic Exposures, Water, Food

Vision Issues During Long-term Space flight
Homocysteine



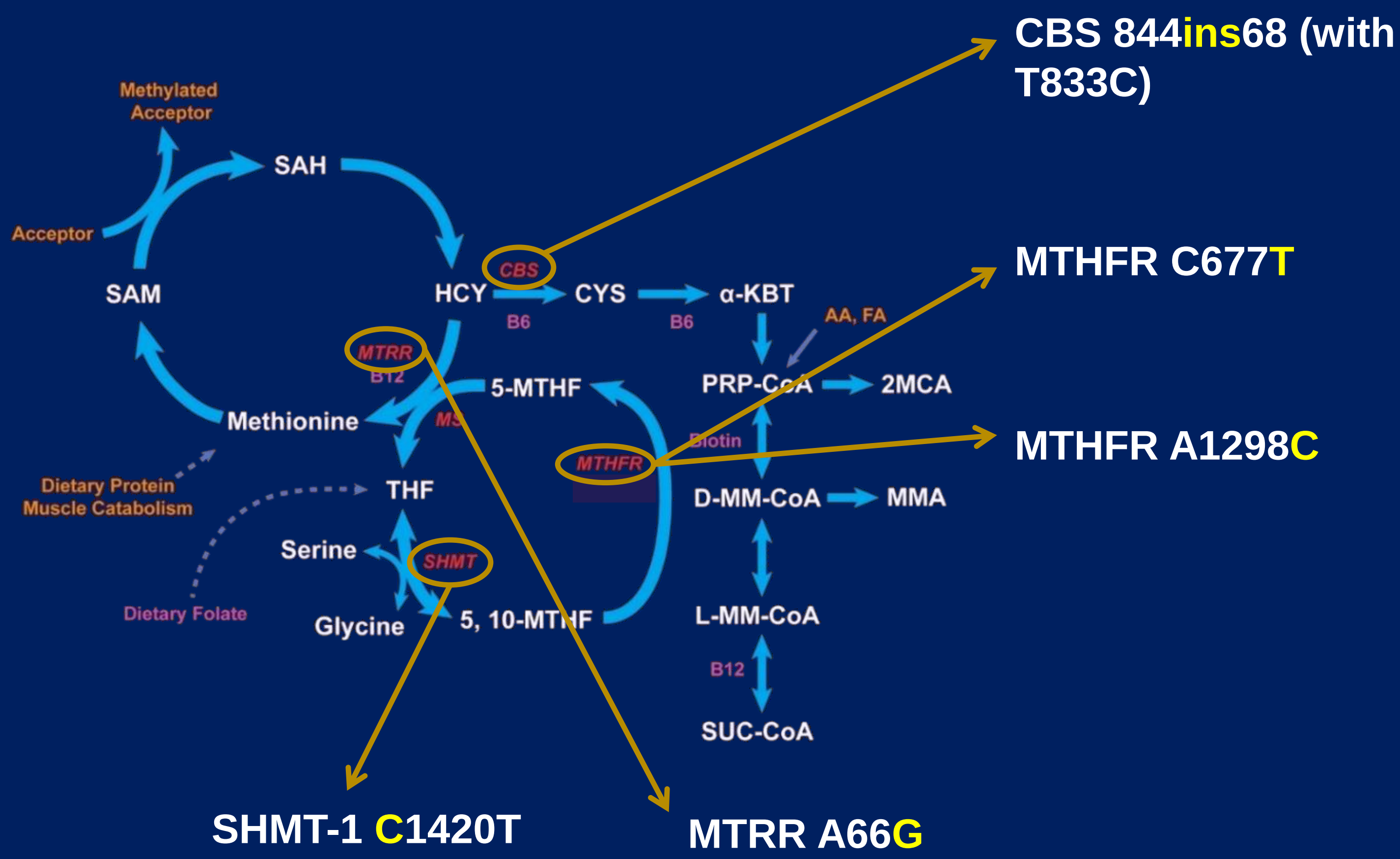


Astronauts with ocular changes had higher serum homocysteine concentration than astronauts without ocular changes. *Before* flight.

Zwart et al., Vision changes after spaceflight are related to alterations in folate- and vitamin B-12-dependent one-carbon metabolism.. *J Nutrition*, 2012

Enzyme Polymorphisms Studied

"Risk" alleles

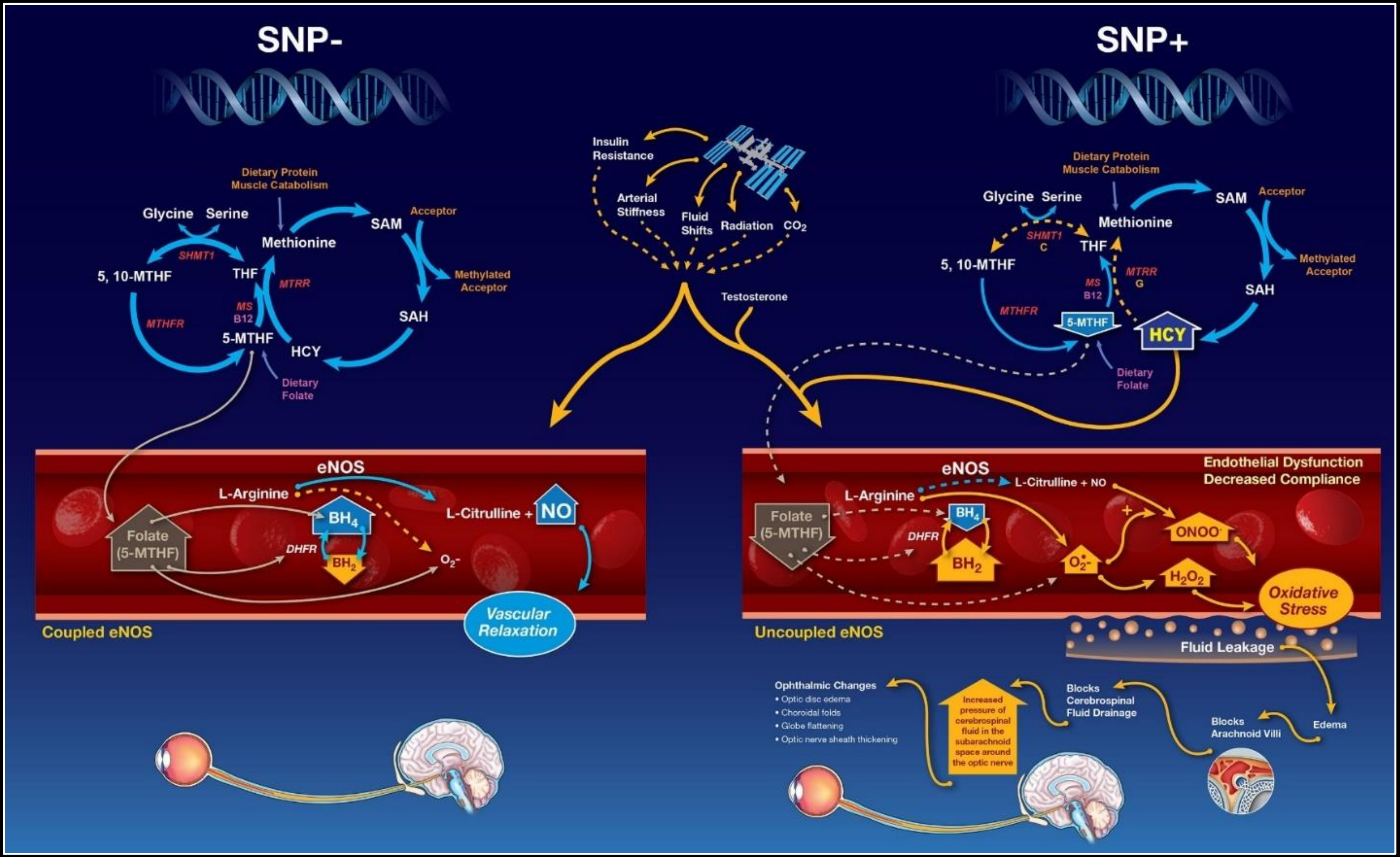


ENZYMES

VITAMINS

Zwart et al., *FASEB J*, 2016

How Could Genetics Affect Astronaut Eyes?



Multiple-hit hypothesis shows how genetics of the enzymes of the 1-carbon metabolic pathway are proposed to be associated with astronaut ophthalmic syndrome.

Zwart, S. R., et al. "Astronaut ophthalmic syndrome." *FASEB Journal* 31(9): 3746-3756, 2017.
Smith, Zwart. Spaceflight-related ocular changes: the potential role of genetics, and the potential of B vitamins as a countermeasure." *Curr Opin Clin Nutr Metab Care* 21:481-8, 2018.

Food for Space Missions

Refrigerators and freezers not available to maintain food safety and quality

Natural Form Foods

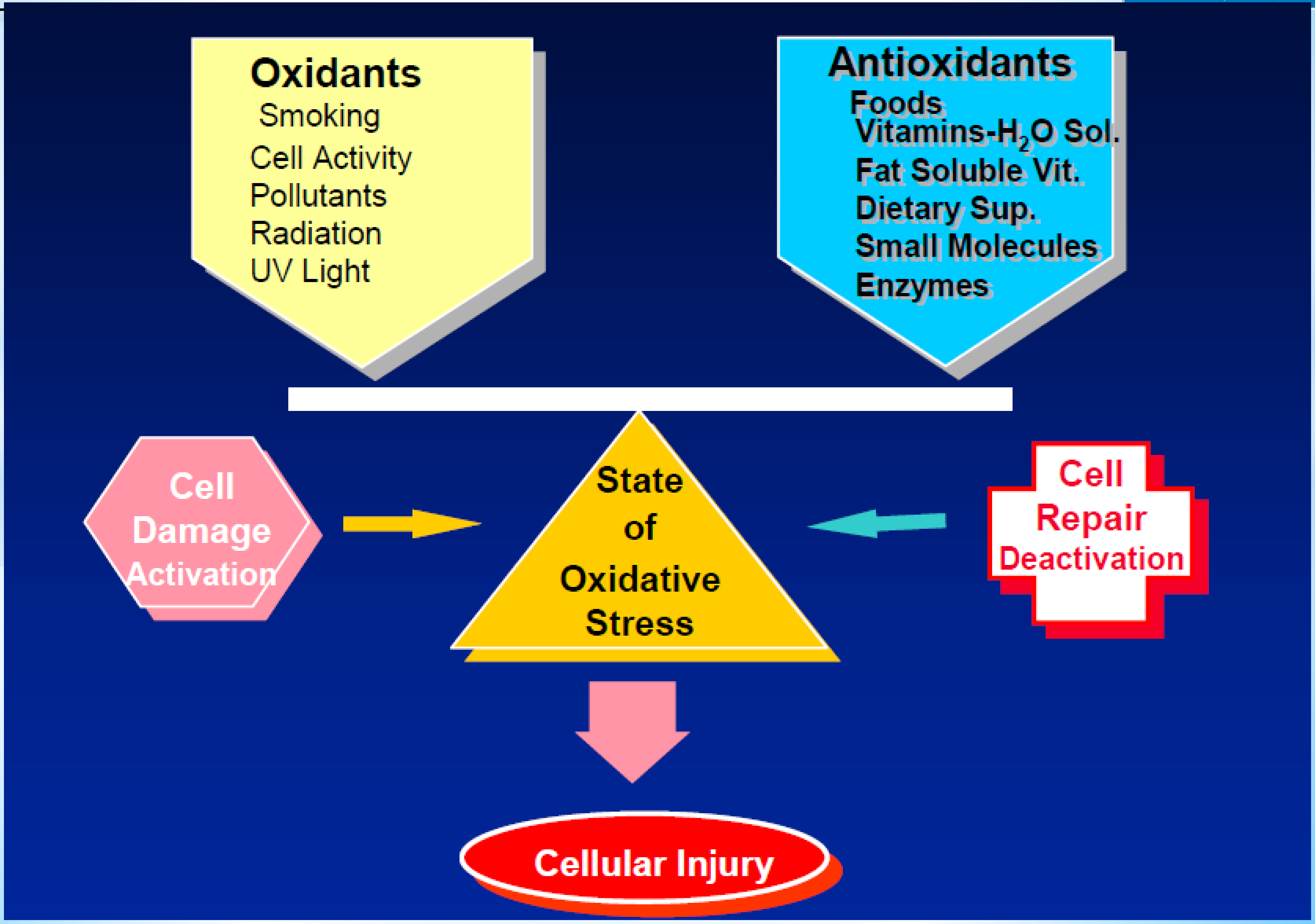
Rehydratable Foods

Intermediate Moisture Foods

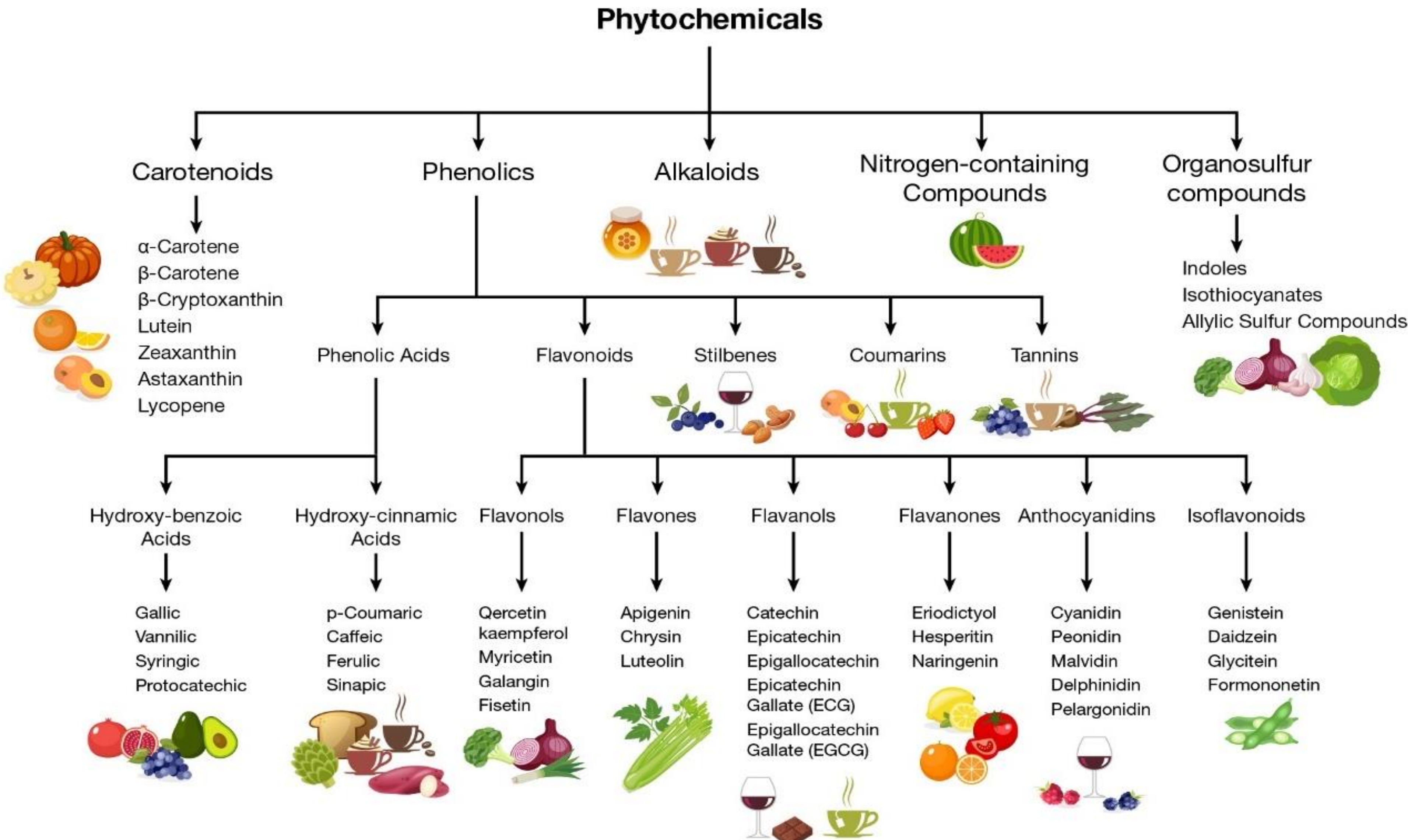
Beverages

Irradiated & Thermo-stabilized Foods

Oxidative Stress

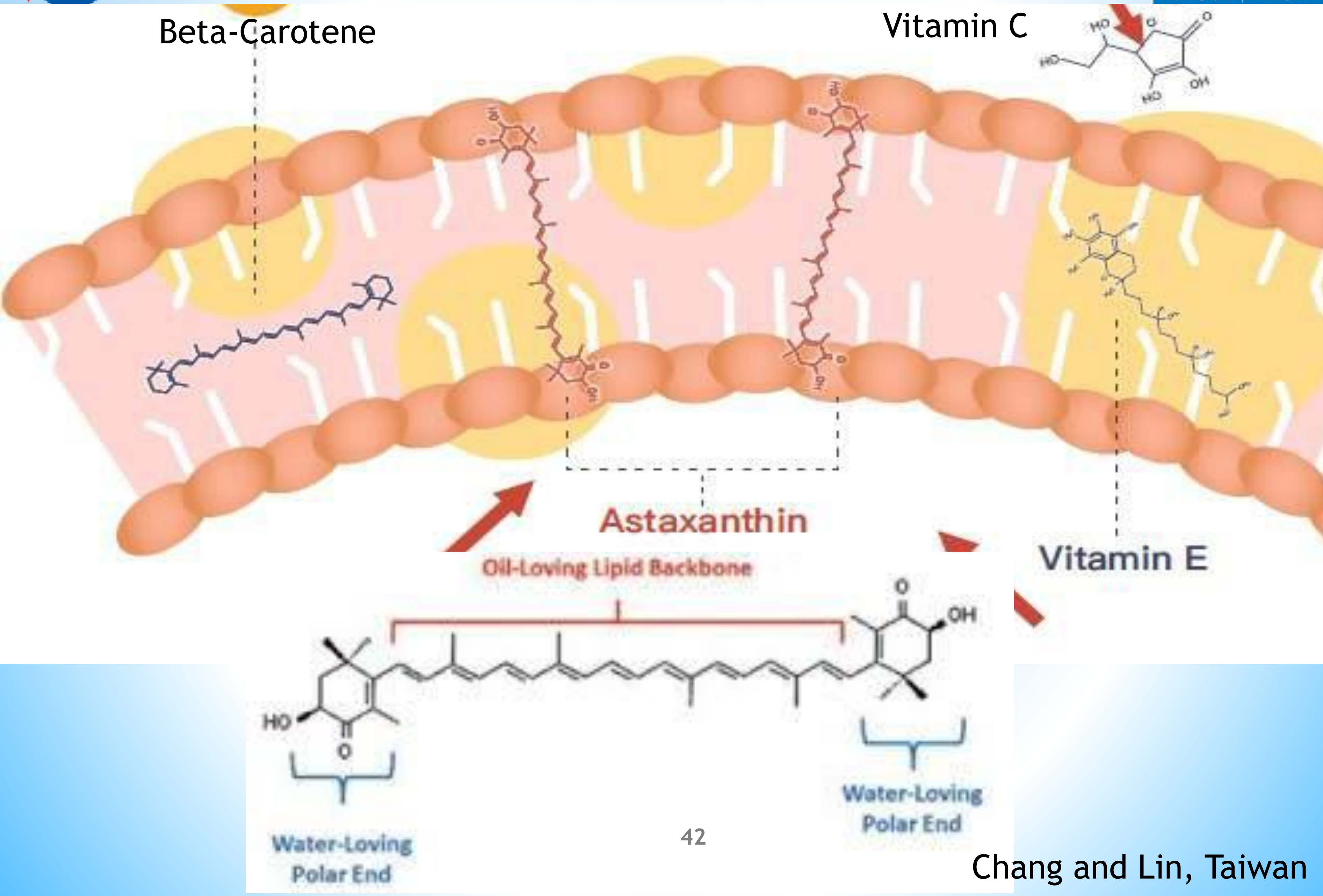


Acworth et al., "The Handbook of Redox Biochemistry", ESA Inc., **2003**, 19.



Scott Smith, NASA/JSC

3S-3S'-Astaxanthin : Blood Brain Barrier



Chang and Lin, Taiwan

Scott Kelly (1 Year Mission) Twin Studies

Acknowledgment

Engineers, Scientists
and Physicians

Thanks

Beautiful Fragile Blue Planet

Back up

Food for Space Missions

Refrigerators and freezers not available to maintain food safety and quality

Natural Form Foods

Beverages

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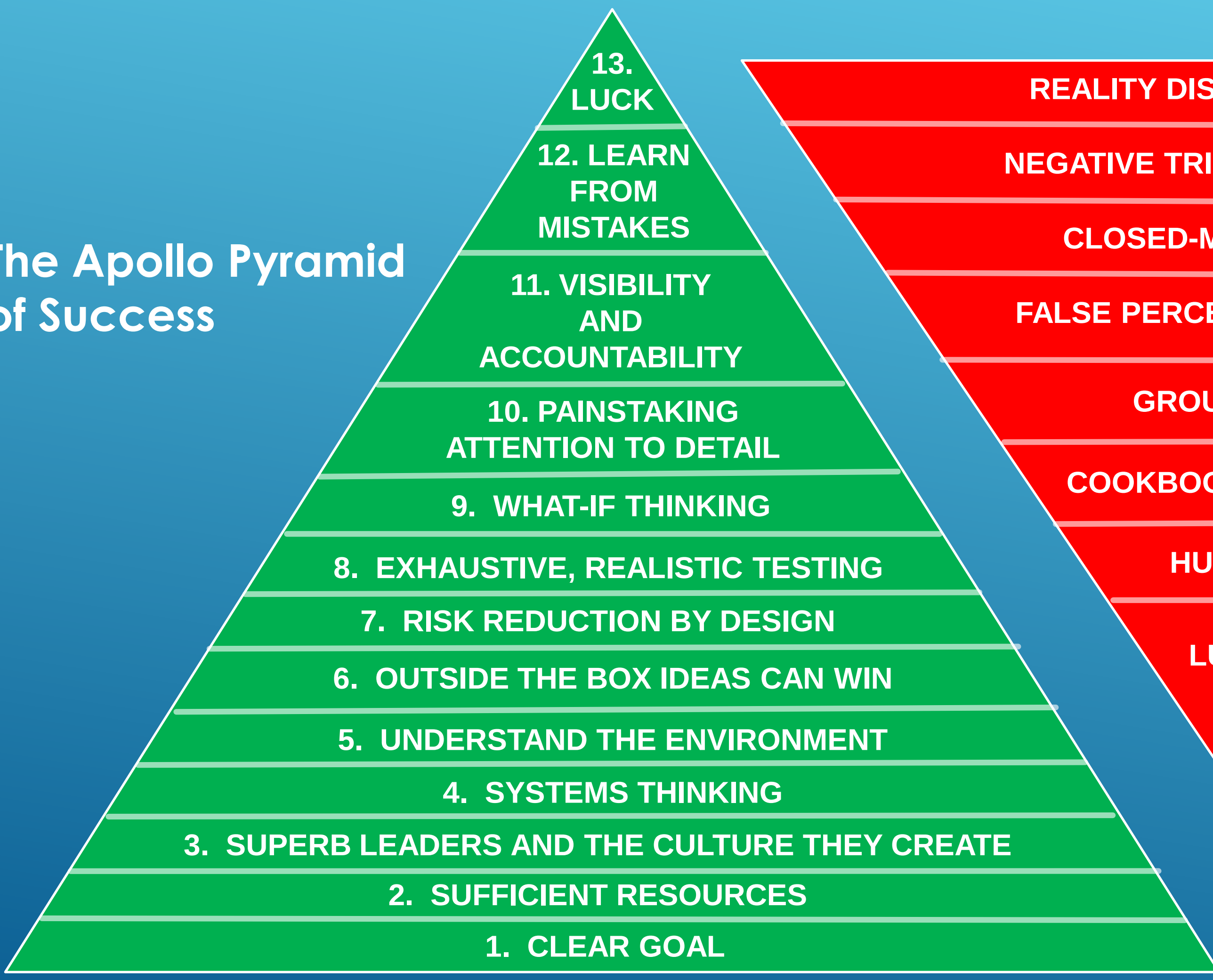
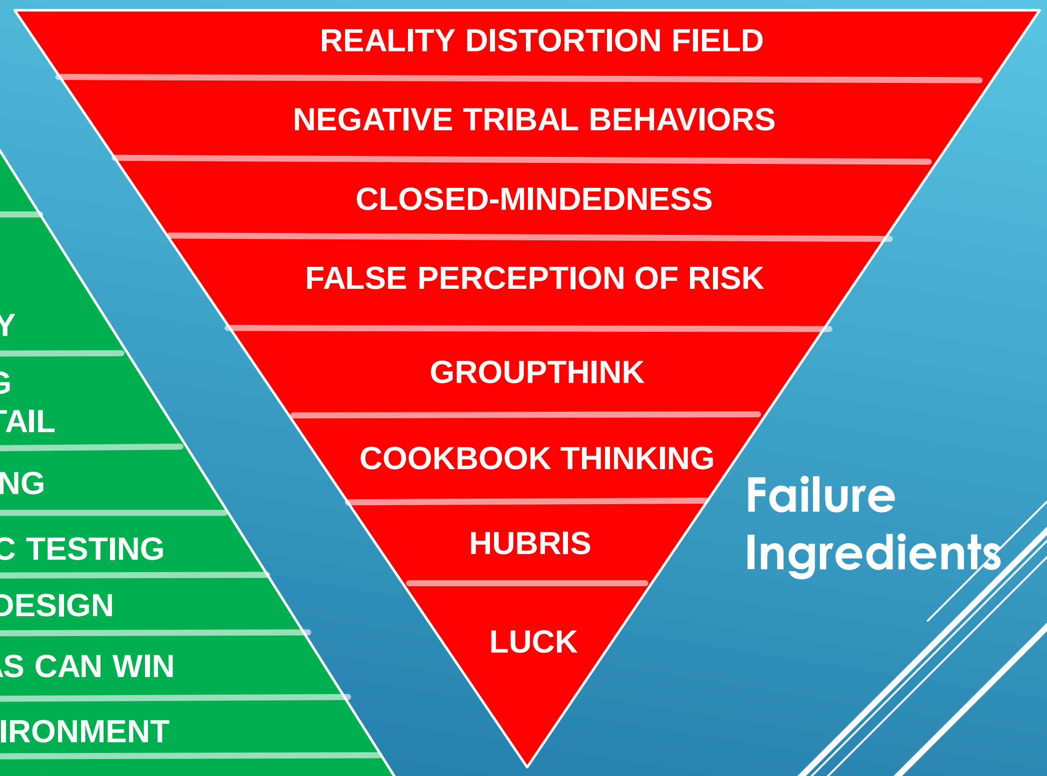
Intermediate Moisture Foods

Irradiated & Thermo-stabilized Foods

THE SUCCESS OF APOLLO

The Apollo Pyramid of Success

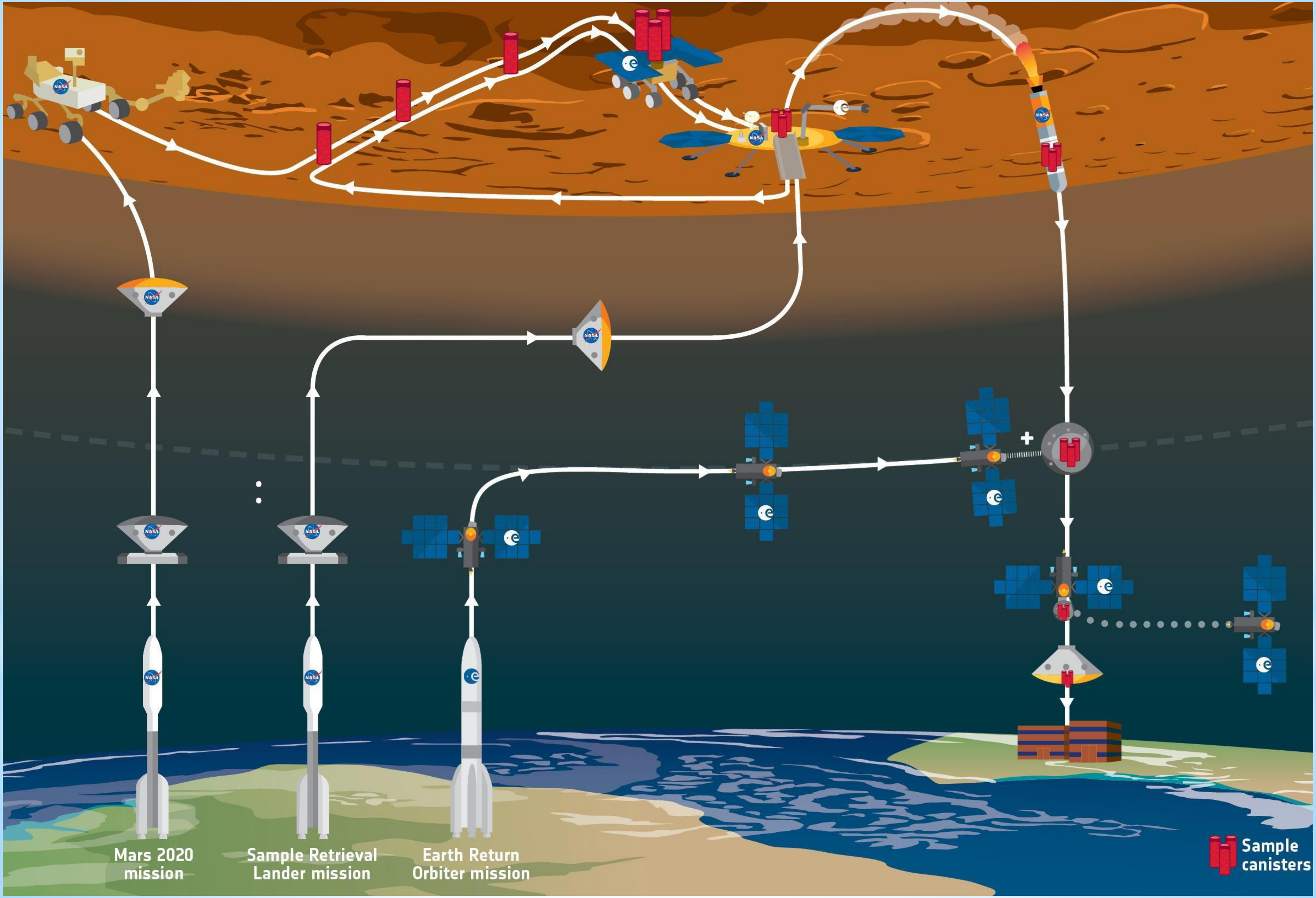




Failure Ingredients

Adapted from Andrew Chaikin

Mars 2020 : Rove, Fly, Persevere, Sample, Return



To become an Astronaut?

- Training in one of the STEM (Science, Technology, Engineering and
- Mathematics) disciplines
- Diverse Experience
- Team Player

- Group Living Skills
- Teamwork Skills
- Performance under Stress
- Self-regulation
- Motivation
- Judgment/Decision-making
- Conscientiousness
- Communication Skills
- Leadership/Followership Skills

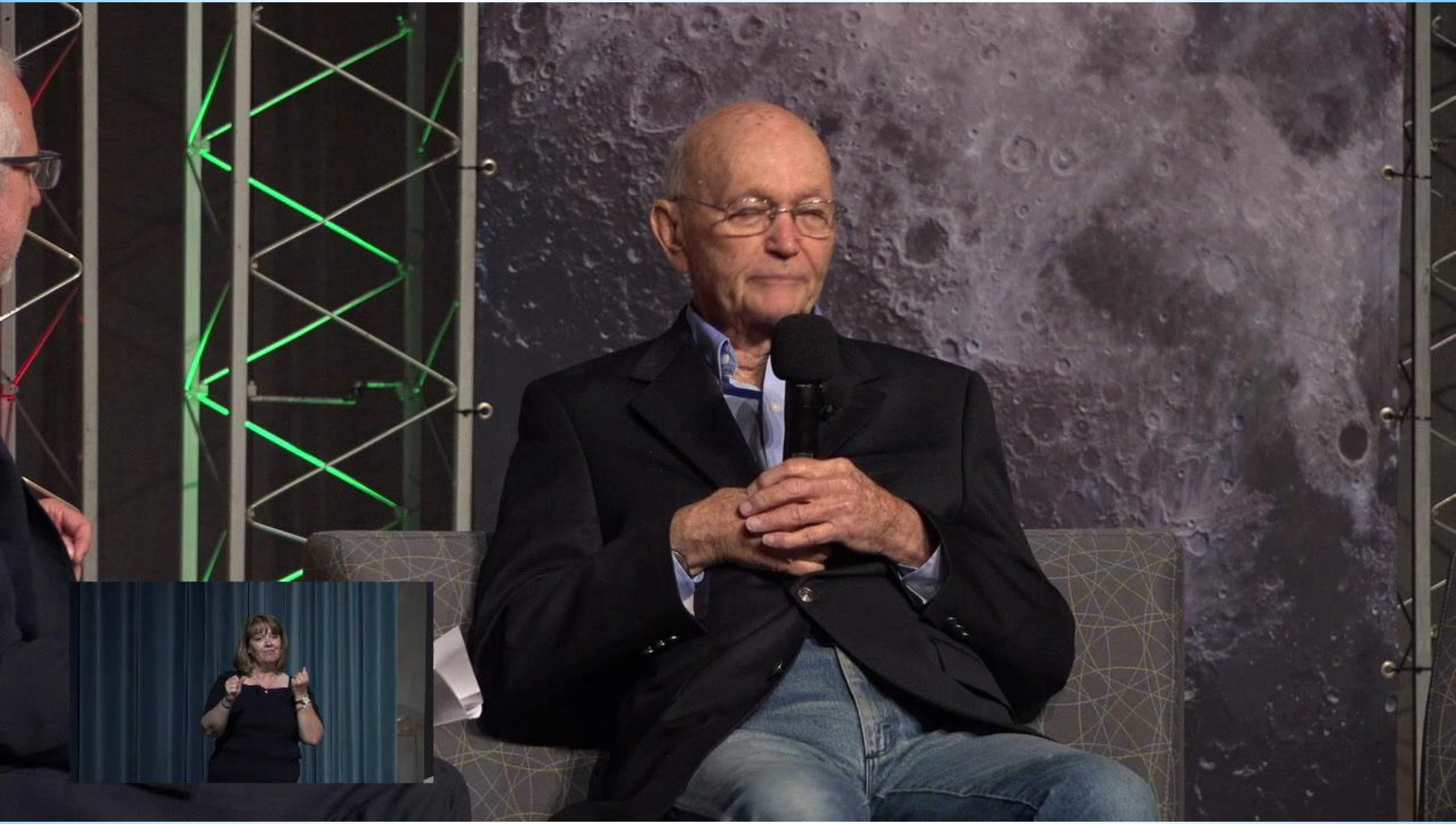
Astronaut Class of 2017

Zena Cardman, Jasmin Moghbeli, Jonny Kim, Frank Rubio, Matthew Dominick, Warren Hoburg, Robb Kulin, Kayla Barron, Bob Hines, Raji Chari, Loral O' Hara and Jessica Watkins.

Who is at Your Window?

I feel responsible - Collins

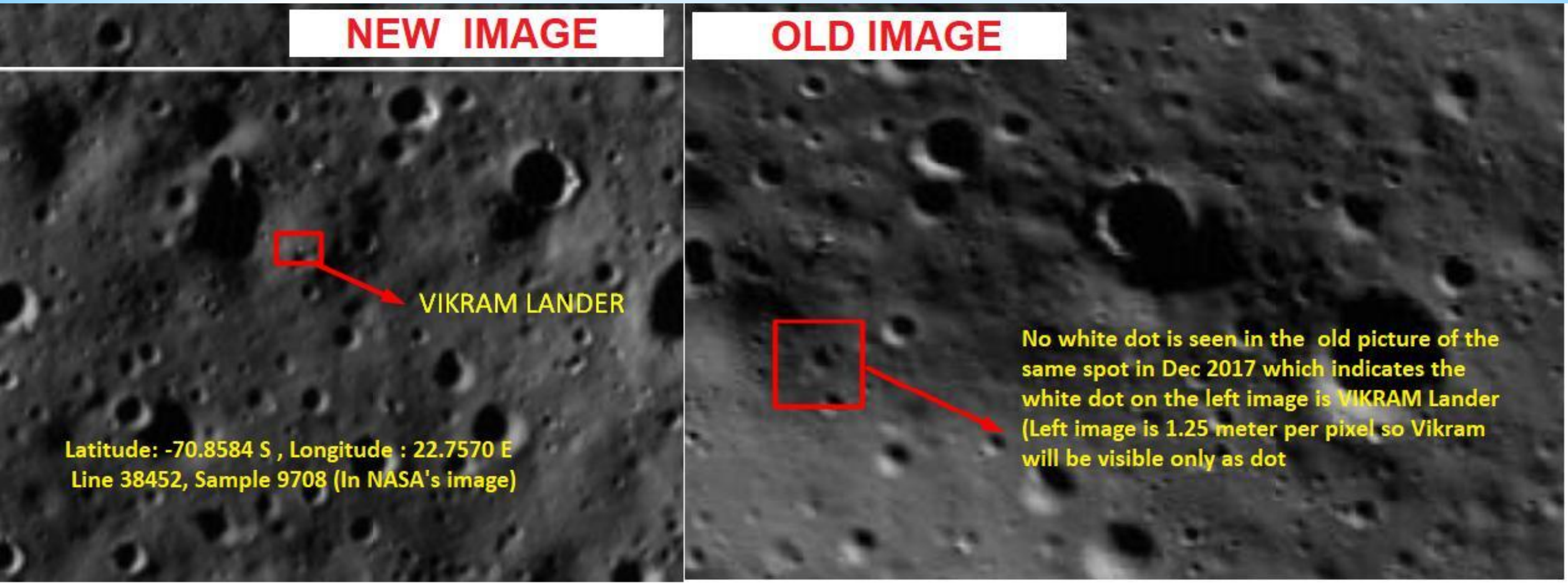
Who is at Your Window?



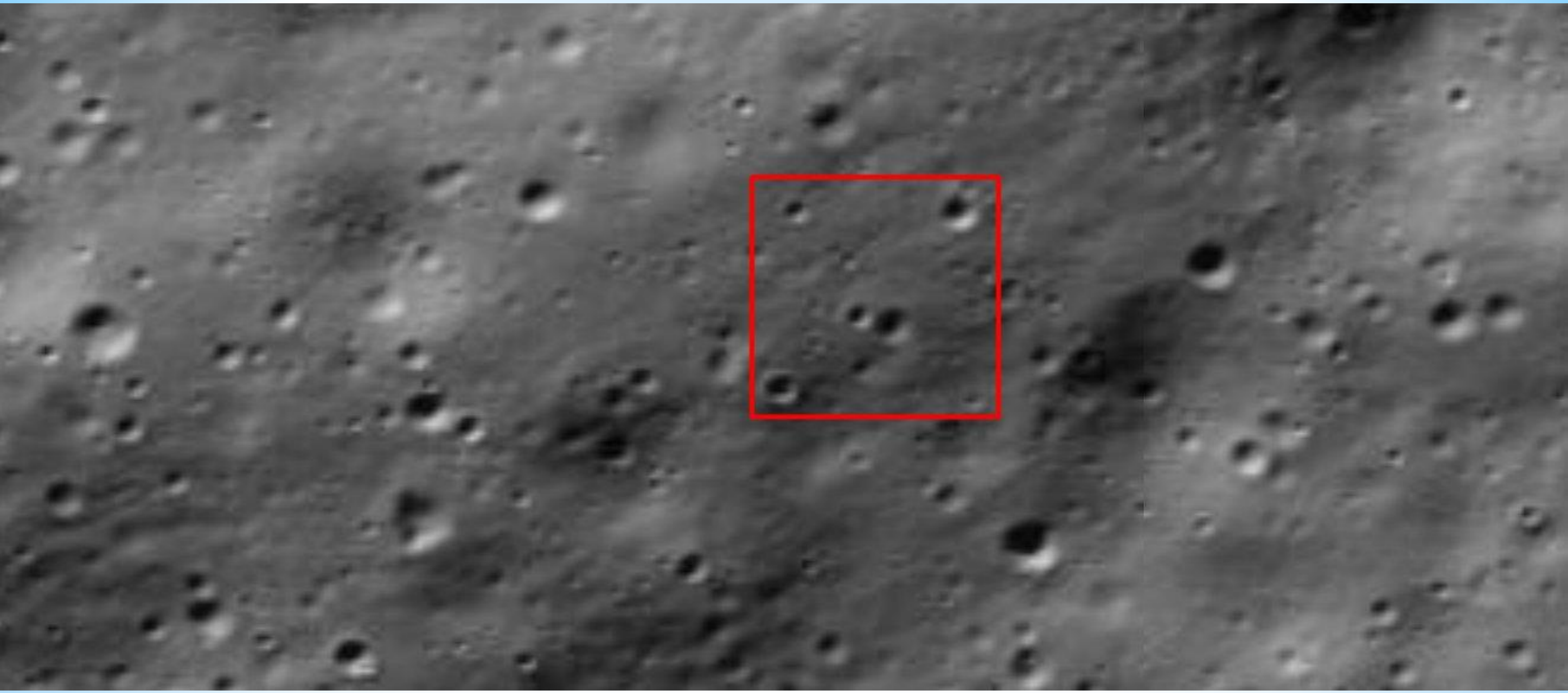
I feel responsible - Collins

Crew Debriefing at Bld 37 (July 27, 1969)

Vikram Lander

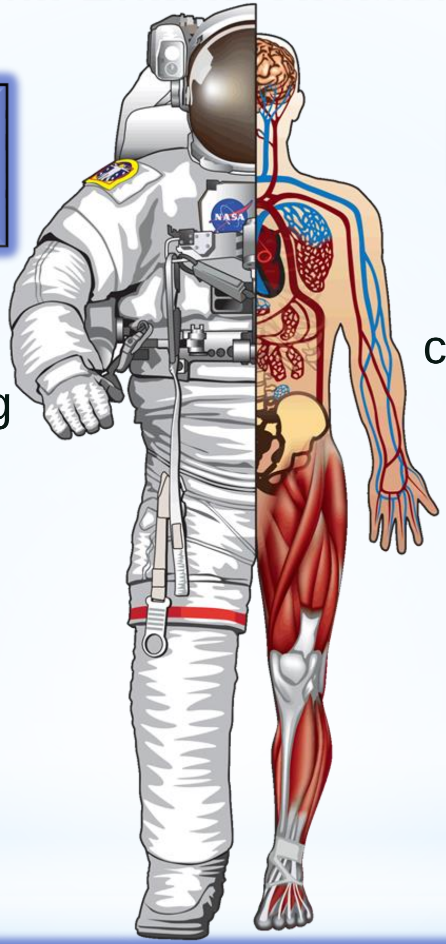


Vikram Lander



Hazards of Spaceflight

Hazards Drive Human Spaceflight Risks



Altered Gravity - Physiological Changes

Bone Loss, Muscle Atrophy
Fluid Shifts
Cardiovascular Deconditioning
Decreased Immune Function
Balance Disorders

Distance from earth

Drives the need for additional "autonomous" medical care capacity – cannot come home for treatment

Space Radiation

Acute In-flight effects
Long term cancer risk

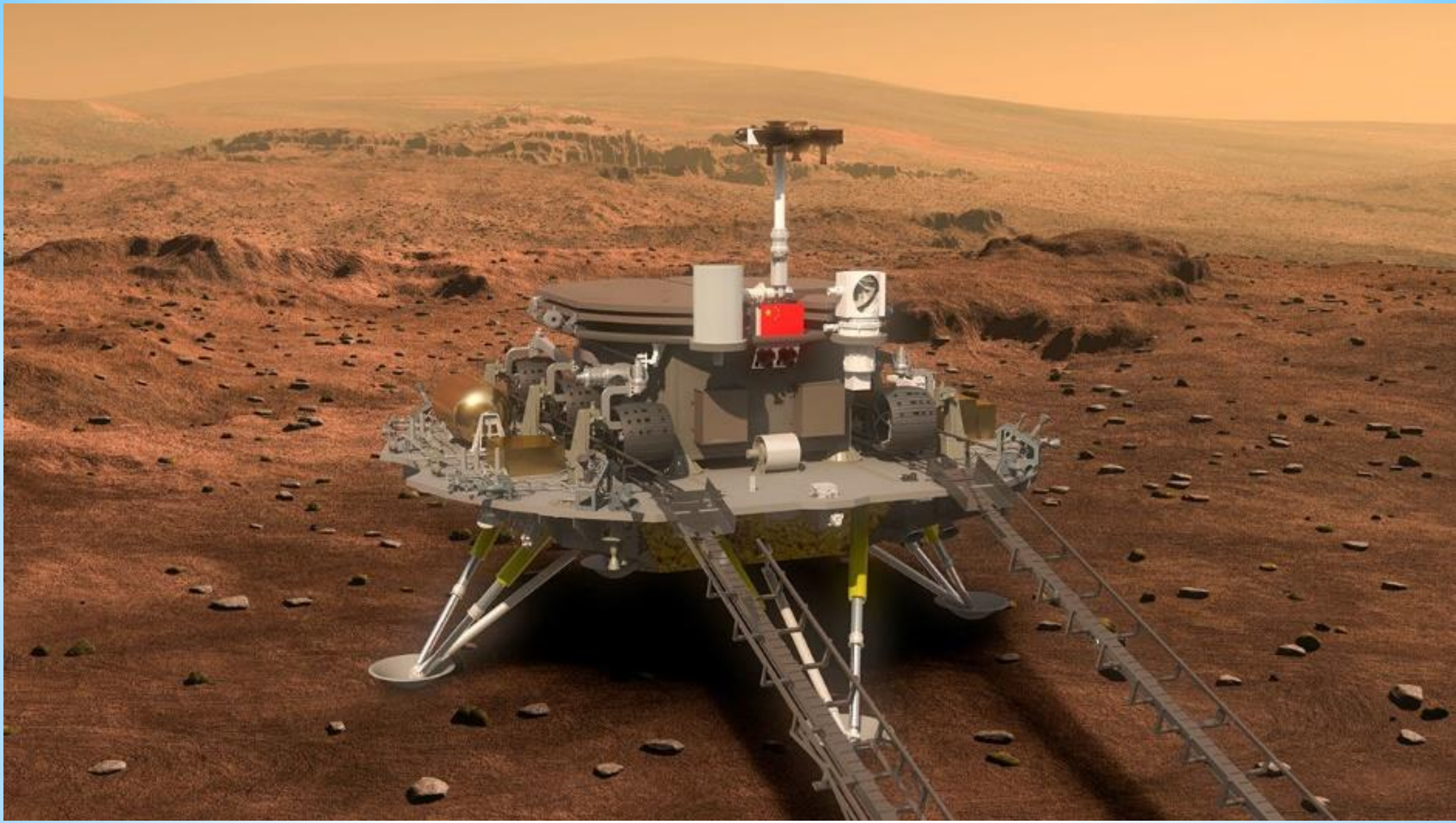
Hostile/ Closed Environment

Vehicle Design
Environmental – CO_2 Levels, Toxic Exposures, Water, Food

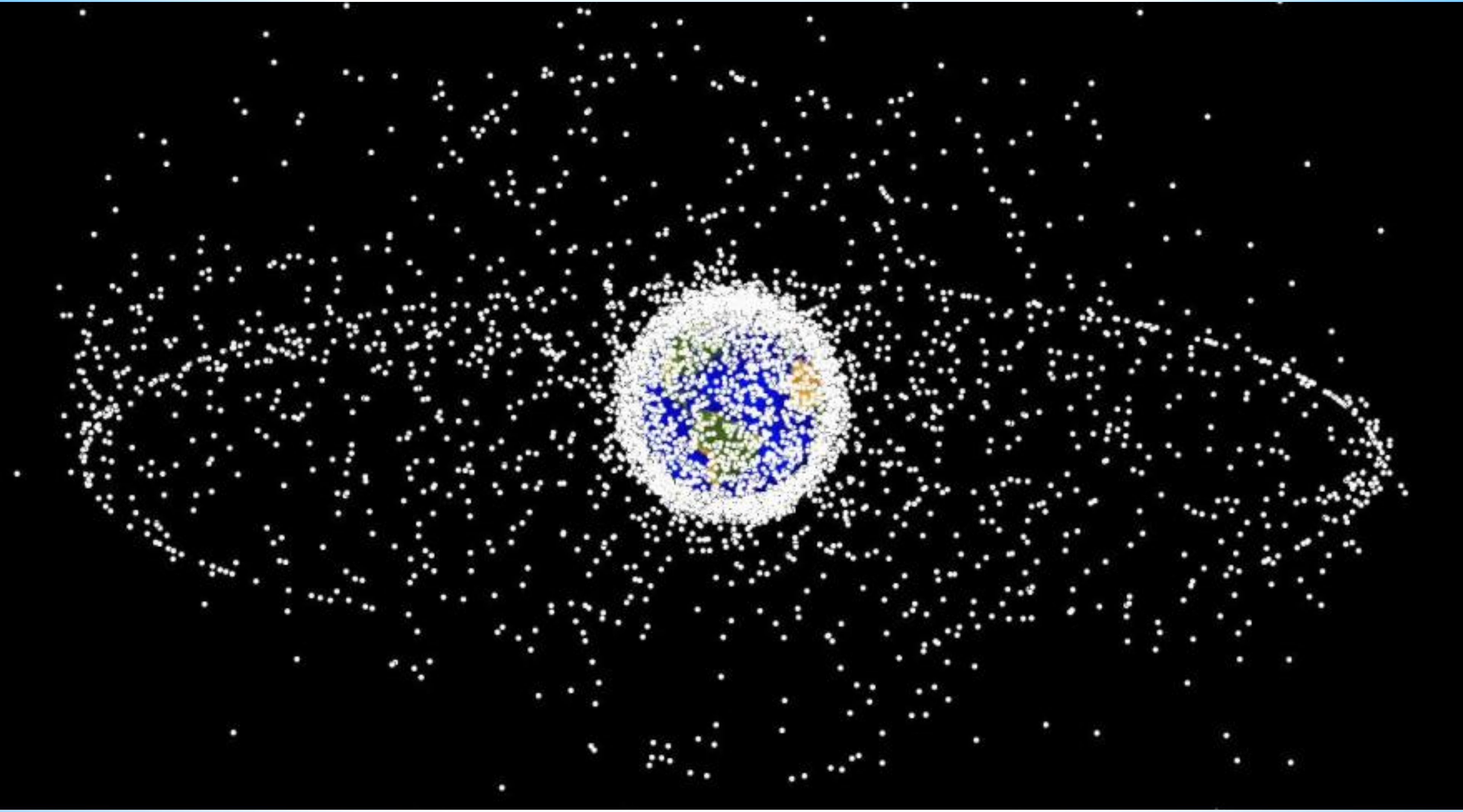
Isolation & Confinement

Behavioral aspect of isolation
Sleep disorders

Mars Rover from China in 2020

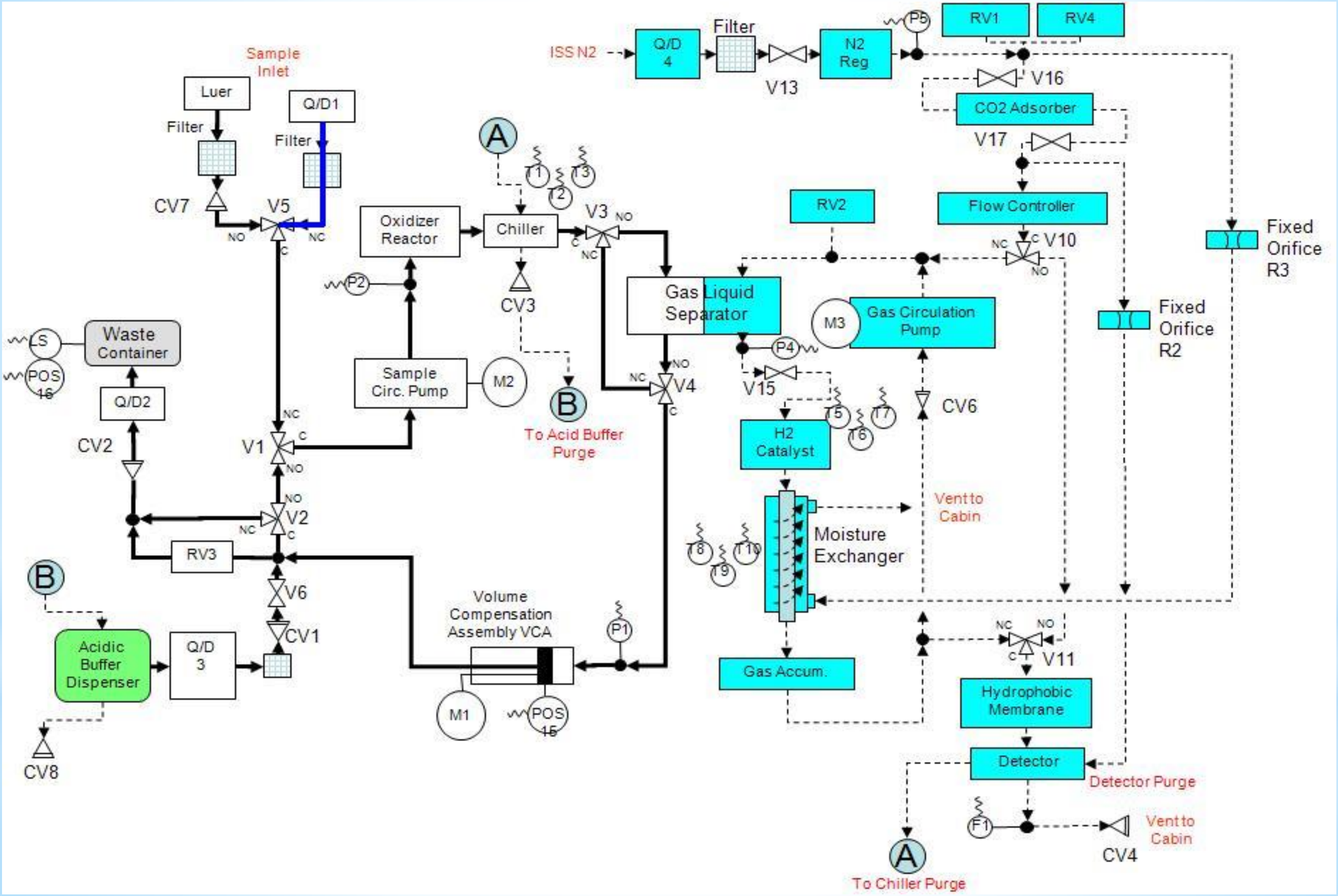


Space Debris



Zuma Pilot Picture

Total Organic Carbon Analyzer



View from Sudan

Zero-Gravity Aircraft

Magnitude of the Universe

Number of Atoms in the Universe $<10^{80}$

Atoms in the earth = 6×10^{27} g/12 g)x $6 \times 10^{23} = 3 \times 10^{50}$

Atoms in the solar system = $3 \times 10^{50} \times 1000 = 3 \times 10^{53}$

Atoms in the Milkyway Galaxy = $3 \times 10^{53} \times 10^{9} = 3 \times 10^{62}$

Atoms in the Universe = $3 \times 10^{62} \times 10^{9} = = 3 \times 10^{71}$

One Day in other planets

Planet	Day Length
Mercury	1,408 hours
Venus	5,832 hours
Earth	24 hours
Mars	25 hours
Jupiter	10 hours
Saturn	11 hours
Uranus	17 hours
Neptune	16 hours

X-37B Space Plane

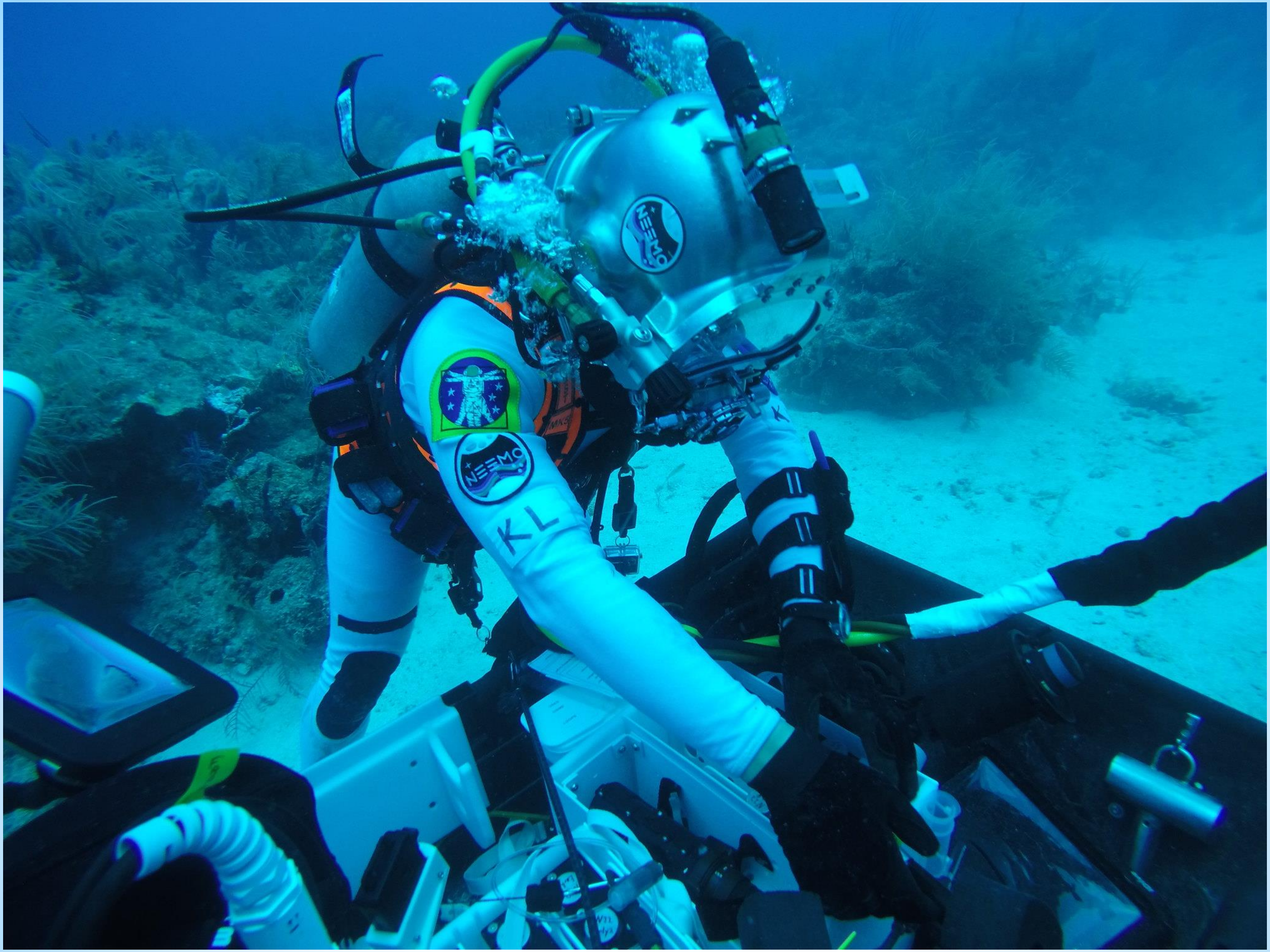

Still daylight in California.
Chicago
Cities of Boston, New York, Philadelphia and Washington.
Dallas
Houston
Miami
Puerto Rico


NASA
ZVEZ
CHALLENGER

EVA at Neutral Buoyancy Lab (NBL)

Bed Rest Studies :envihab

Under Water NEEMO



Mars 500 Analog

Rover : Desert Rat

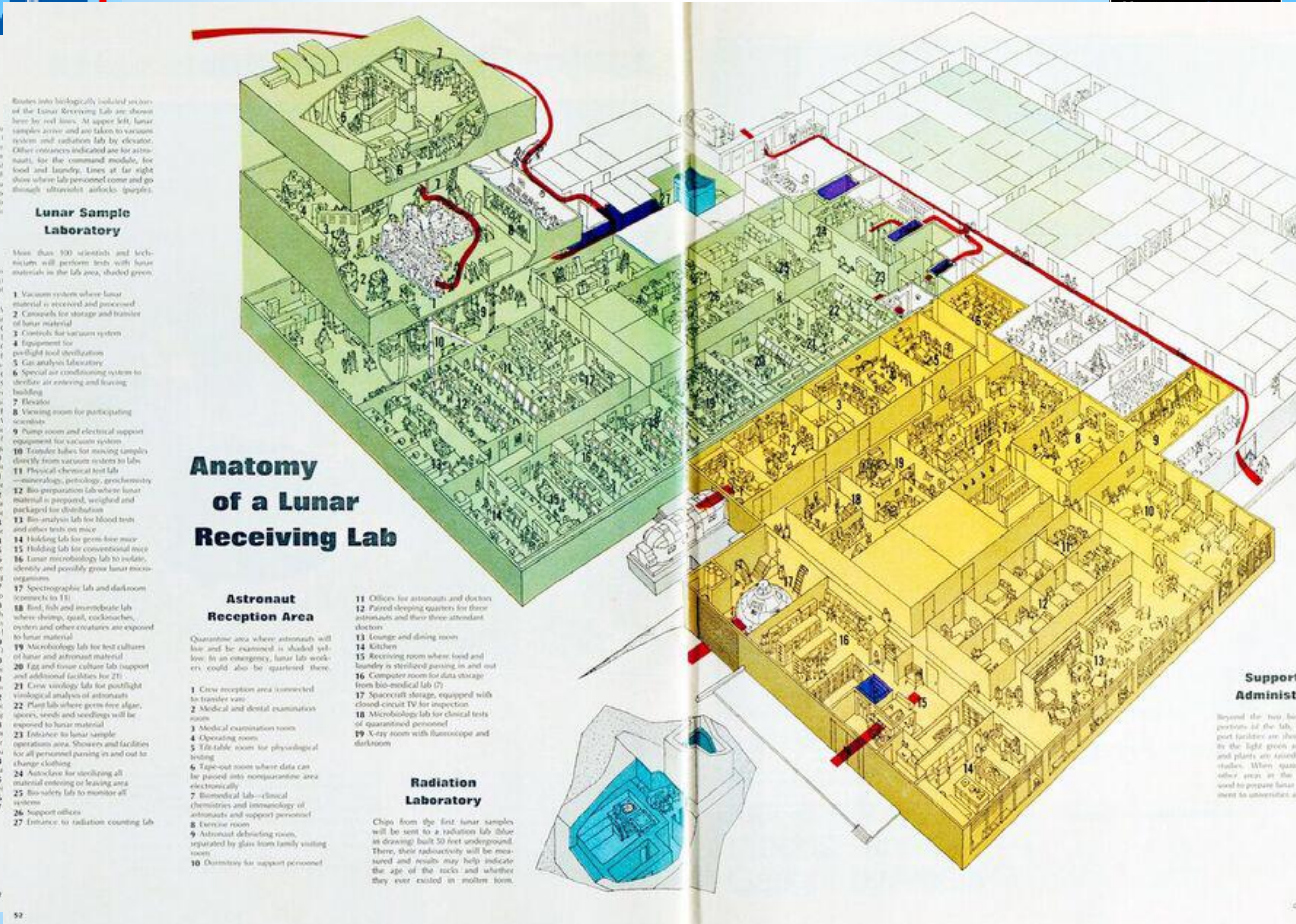
Deep Space Habitat : Isolation and Confinement

Shuttle Launch : Speed of Rocket

Gross Lift-off weight : 2 Million tons
Thrust : 33,327 kilonewtons
SRB Separation : 45 km
External Tank Separation : 111 km

Orbital velocity : 27,869 km/hour

Payload weight : 25 tons
Shuttle weight : 78 tons



Routes into biologically isolated sections of the Lunar Receiving Lab are shown here by red lines. At upper left, lunar samples arrive and are taken to vacuum system and radiation lab by elevator. Other entrances indicated are for astronauts, for the command module, for food and laundry. Lines at far right show where lab personnel come and go through ultraviolet airlocks (purple).

Anatomy of a Lunar Receiving Lab

Lunar Sample Laboratory

More than 100 scientists and technicians will perform tests with lunar materials in the lab area, shaded green.

1 Vacuum system where lunar material is received and processed
2 Canisters for storage and transfer of lunar material
3 Controls for vacuum system
4 Equipment for preflight tool sterilization
5 Gas analysis laboratory
6 Special air conditioning system to sterilize air entering and leaving building
7 Elevator
8 Viewing room for participating scientists
9 Pump room and electrical support equipment for vacuum system
10 Transfer tubes for moving samples directly from vacuum system to labs
11 Physical-chemical test lab —mineralogy, petrology, geochemistry
12 Bio-preparation lab where lunar material is prepared, weighed and packaged for distribution
13 Bio-analysis lab for blood tests and other tests on mice
14 Holding lab for germ-free mice
15 Holding lab for conventional mice
16 Lunar microbiology lab to isolate, identify and possibly grow lunar microorganisms
17 Spectrographic lab and darkroom (connects to 11)
18 Bird, fish and invertebrate lab where shrimp, quail, cockroaches, oysters and other creatures are exposed to lunar material
19 Microbiology lab for test cultures of lunar and astronaut material
20 Egg and tissue culture lab (support and additional facilities for 21)
21 Crew virology lab for postflight virological analysis of astronauts
22 Plant lab where germ-free algae, spores, seeds and seedlings will be exposed to lunar material
23 Entrance to lunar sample operations area. Showers and facilities for all personnel passing in and out to change clothing
24 Autoclave for sterilizing all material entering or leaving area
25 Bio-safety lab to monitor all systems
26 Support offices
27 Entrance to radiation counting lab

Astronaut Reception Area

Quarantine area where astronauts will live and be examined is shaded yellow. In an emergency, lunar lab workers could also be quartered there.

1 Crew reception area (connected to transfer van)
2 Medical and dental examination room
3 Medical examination room
4 Operating room
5 Tilt-table room for physiological testing
6 Tape-out room where data can be passed into nonquarantine area electronically
7 Biomedical lab—clinical chemistries and immunology of astronauts and support personnel
8 Exercise room
9 Astronaut debriefing room, separated by glass from family visiting room
10 Dormitory for support personnel
11 Offices for astronauts and doctors
12 Paired sleeping quarters for three astronauts and their three attendant doctors
13 Lounge and dining room
14 Kitchen
15 Receiving room where food and laundry is sterilized passing in and out
16 Computer room for data storage from bio-medical lab (7)
17 Spacecraft storage, equipped with closed-circuit TV for inspection
18 Microbiology lab for clinical tests of quarantined personnel
19 X-ray room with fluoroscope and darkroom

Radiation Laboratory

Chips from the first lunar samples will be sent to a radiation lab (blue in drawing) built 50 feet underground. There, their radioactivity will be measured and results may help indicate the age of the rocks and whether they ever existed in molten form.

Support

Can we hear sound in space?
How do astronauts communicate in space?

- In empty space, there is no air, and what we call "sound" is actually vibrations in the air.
- There are indeed light waves and radio waves in space, but these waves are not sound, but light.
- Light does not need air to travel, but then you don't hear it; you see it, or it is interpreted by your radio set and then translated into sound.

- Astronauts in space do talk to each other. In the spacecraft, there is plenty of air, so they just talk normally.
- When they are spacewalking, they talk by means of radios in their helmets.
- The radio waves, again, have no problem in space, but they're not sound. They're radio waves (electromagenetic radiation), which has to be converted into sound by the astronauts' headsets.