Space : A Promising Frontier

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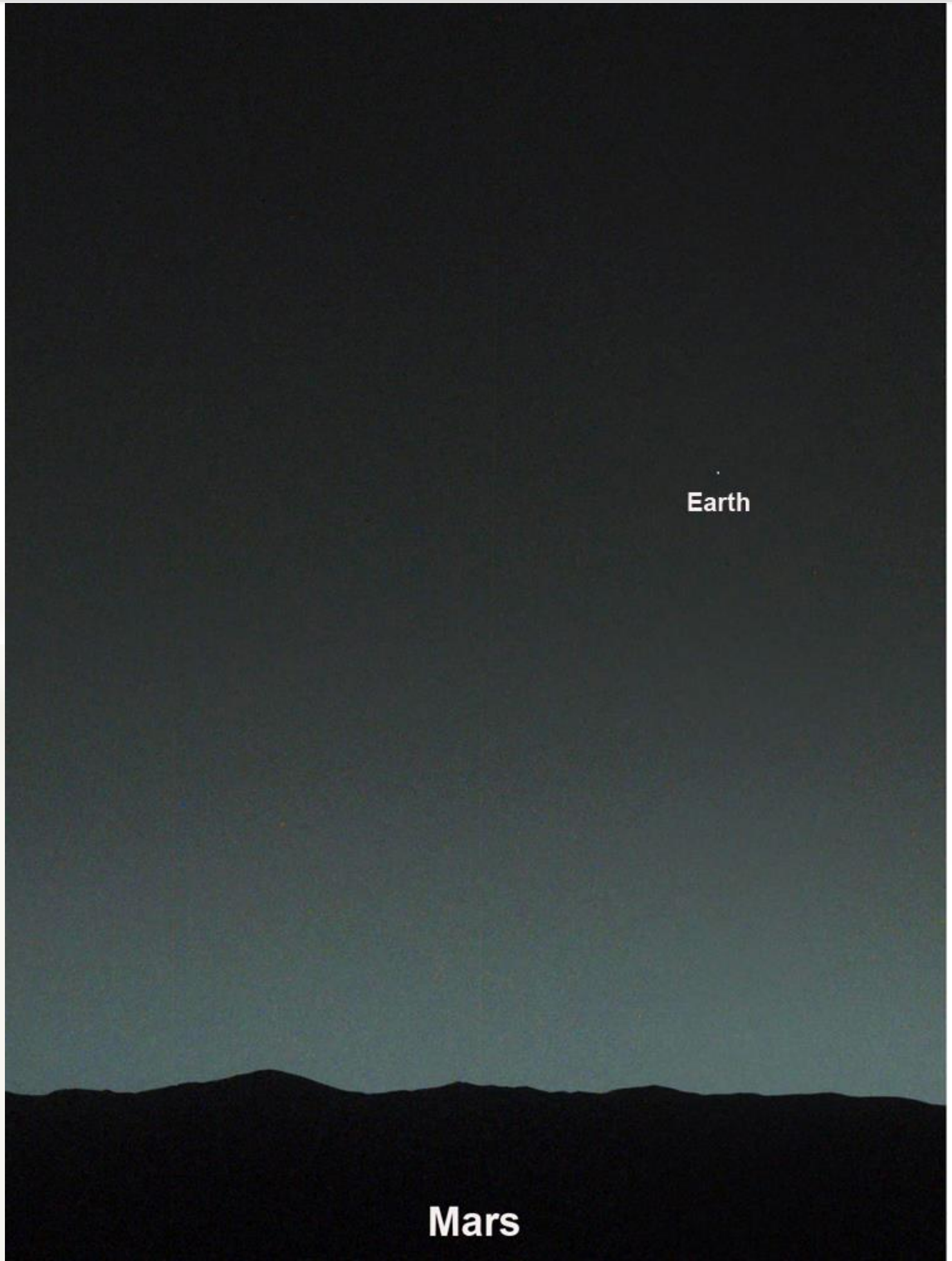
Outline

- Where are we in the Universe?
- Technology Evolution during Human Space Exploration Missions
- Challenges and Opportunities

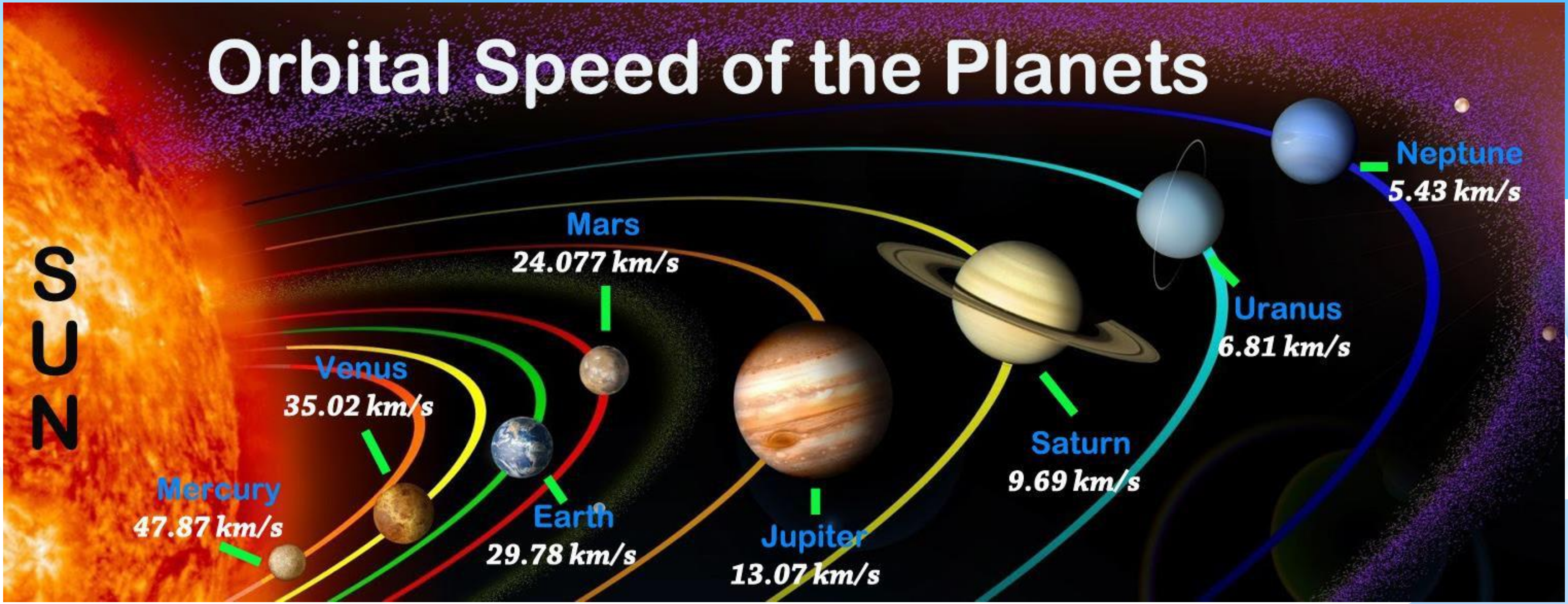
Our Habitation at Night

Beautiful Fragile Blue Planet (~400,000 km)

Mars – Earth Mutual View (~400,000,000 km)

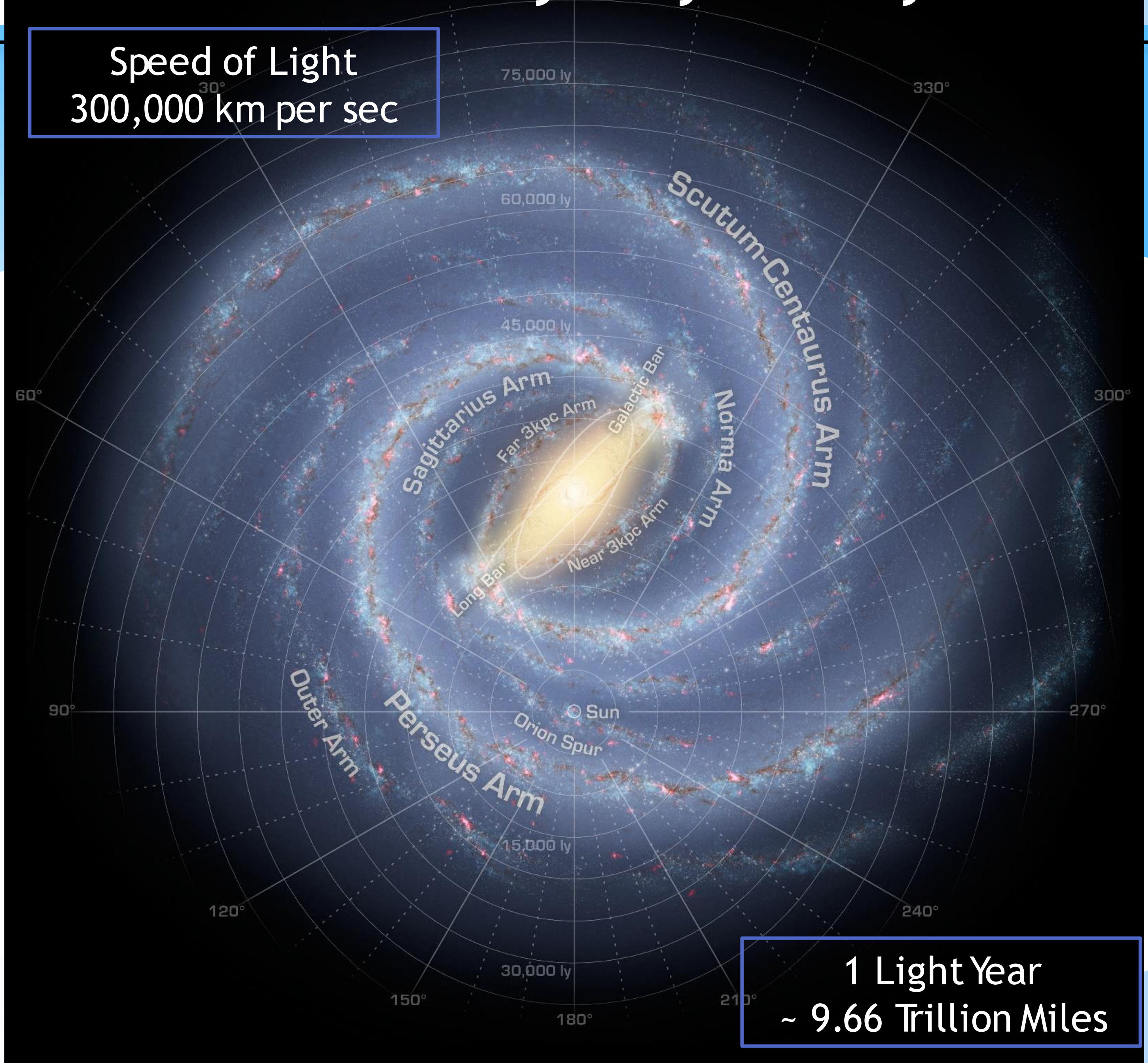


Solar System

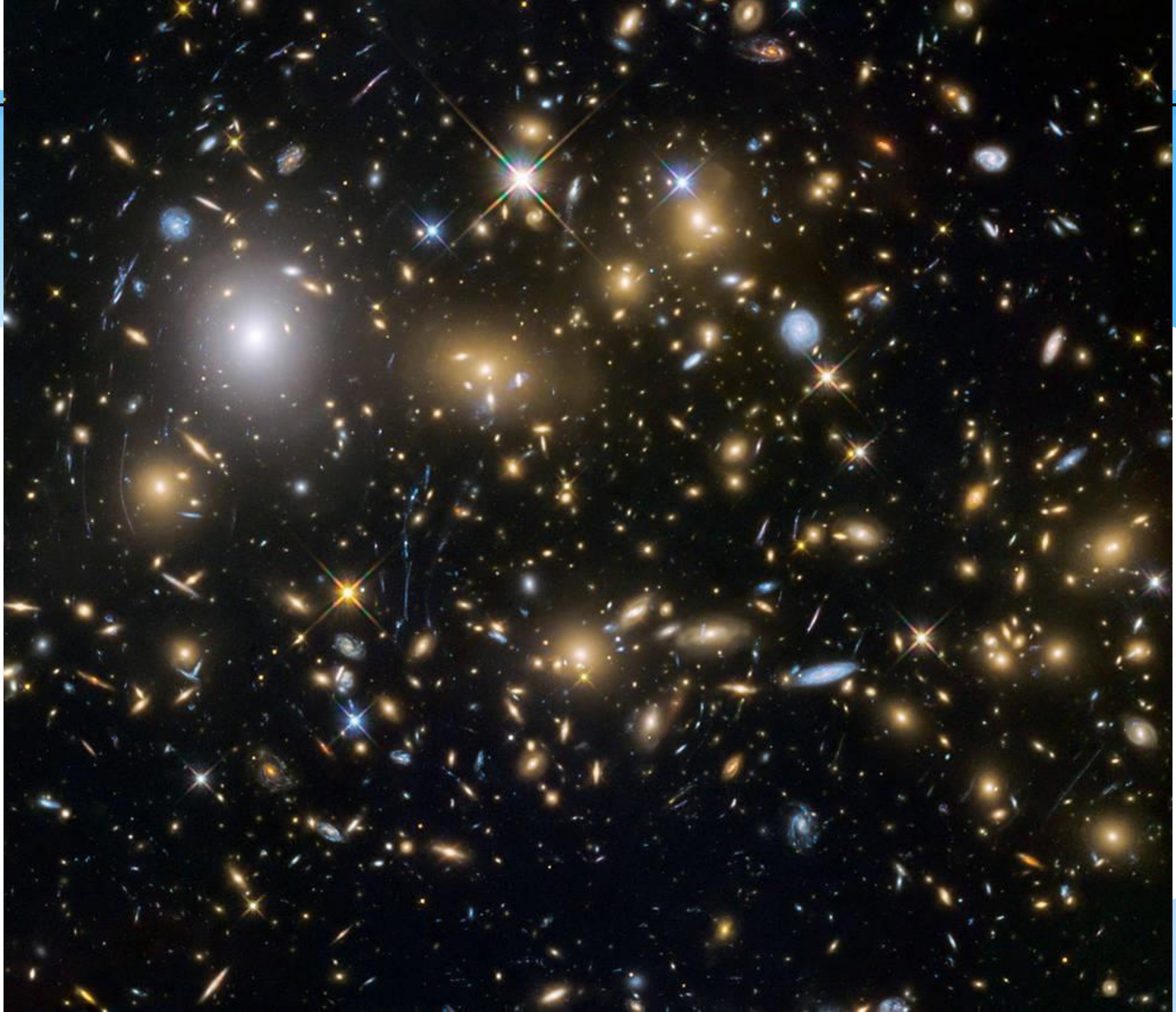


Milky Way Galaxy

Speed of Light
300,000 km per sec



1 Light Year
~ 9.66 Trillion Miles



Our Neighbors

Venus

Atmosphere : 94.5 % CO_2 and 4.5% N_2, SO_2

Temp : 470 deg Celsius

Pressure : 100 atm

Sun rises in West sets in East

Earth

Atmosphere : 80% N_2 and 20% O_2

Temp : -89 to 57 deg Celsius

Pressure : 1 atm

Sun rises in East sets in West

Mars

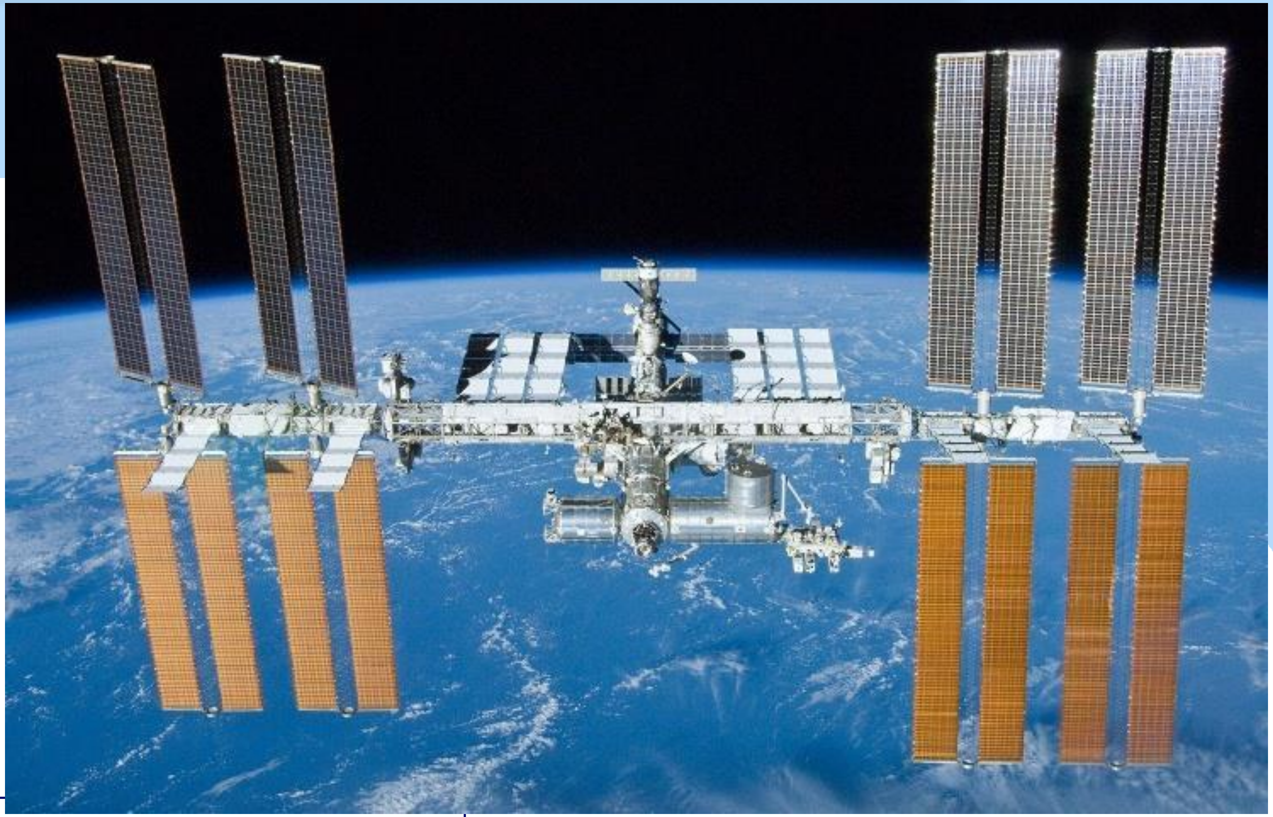
Atmosphere : 95% CO_2 and 5% N_2 and Ar

Temp : -140 to 20 deg Celsius

Pressure : 0.006 atm

Sun rises in East sets in West

Living in a Closed System



Recycling

- Water Regeneration Reactors
- Air Revitalization Reactors
- Environmental Sensors
- Microbial Monitors

Today's Coffee – Yesterday's Coffee

Carbon Dioxide Removal

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

- 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

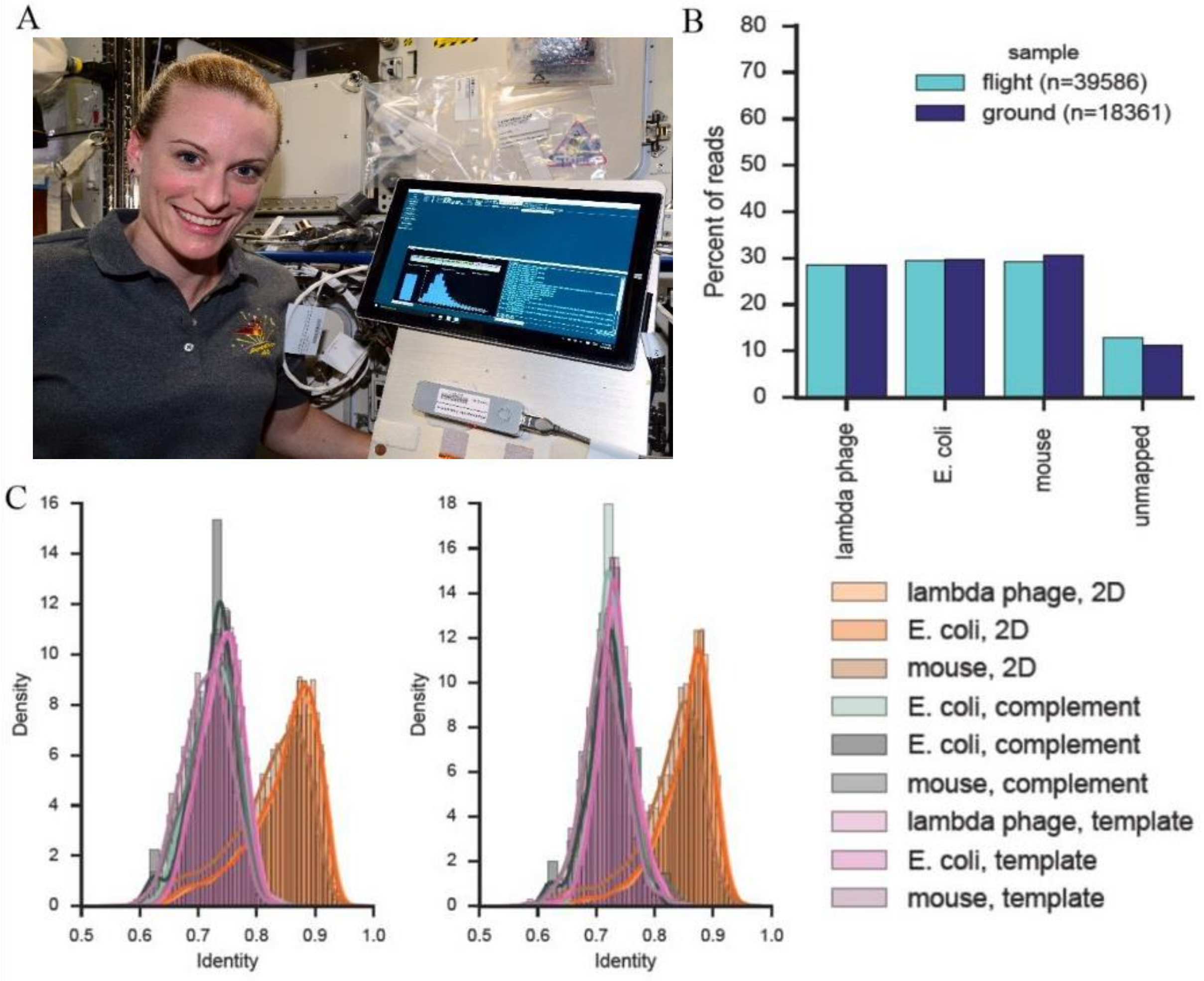
D. Gazda
T. Limero

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
Decamethylcyclopentasil oxane	o-xylene
Acrolein	Octamethylcyclotetrasiloxane
Isopropanol	Decamethylcyclopentasiloxane
Benzene	

DNA Sequencing in Space!

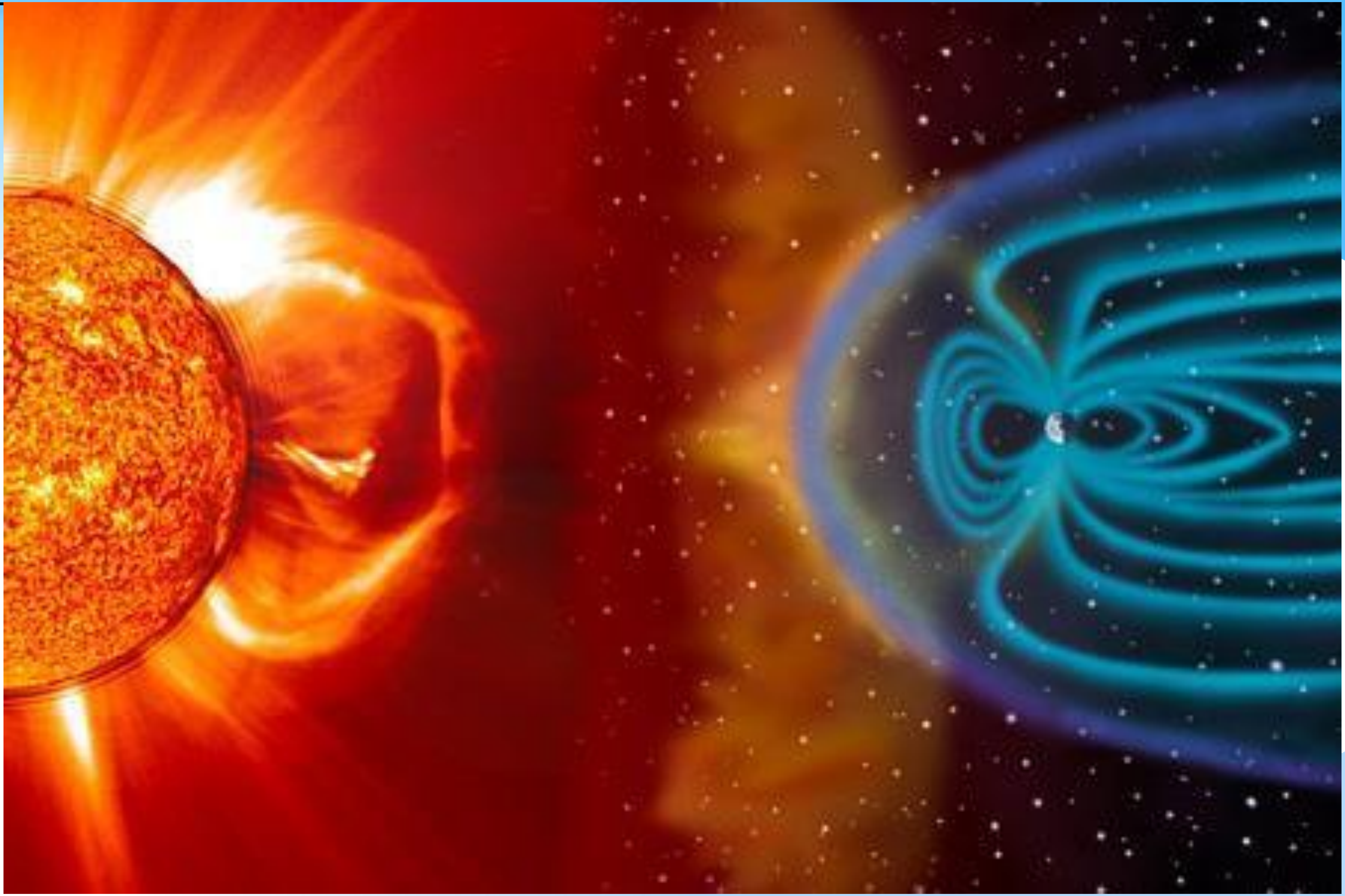
MinION (Oxford Nanopore Technologies)

Biomolecule Sequencer Payload

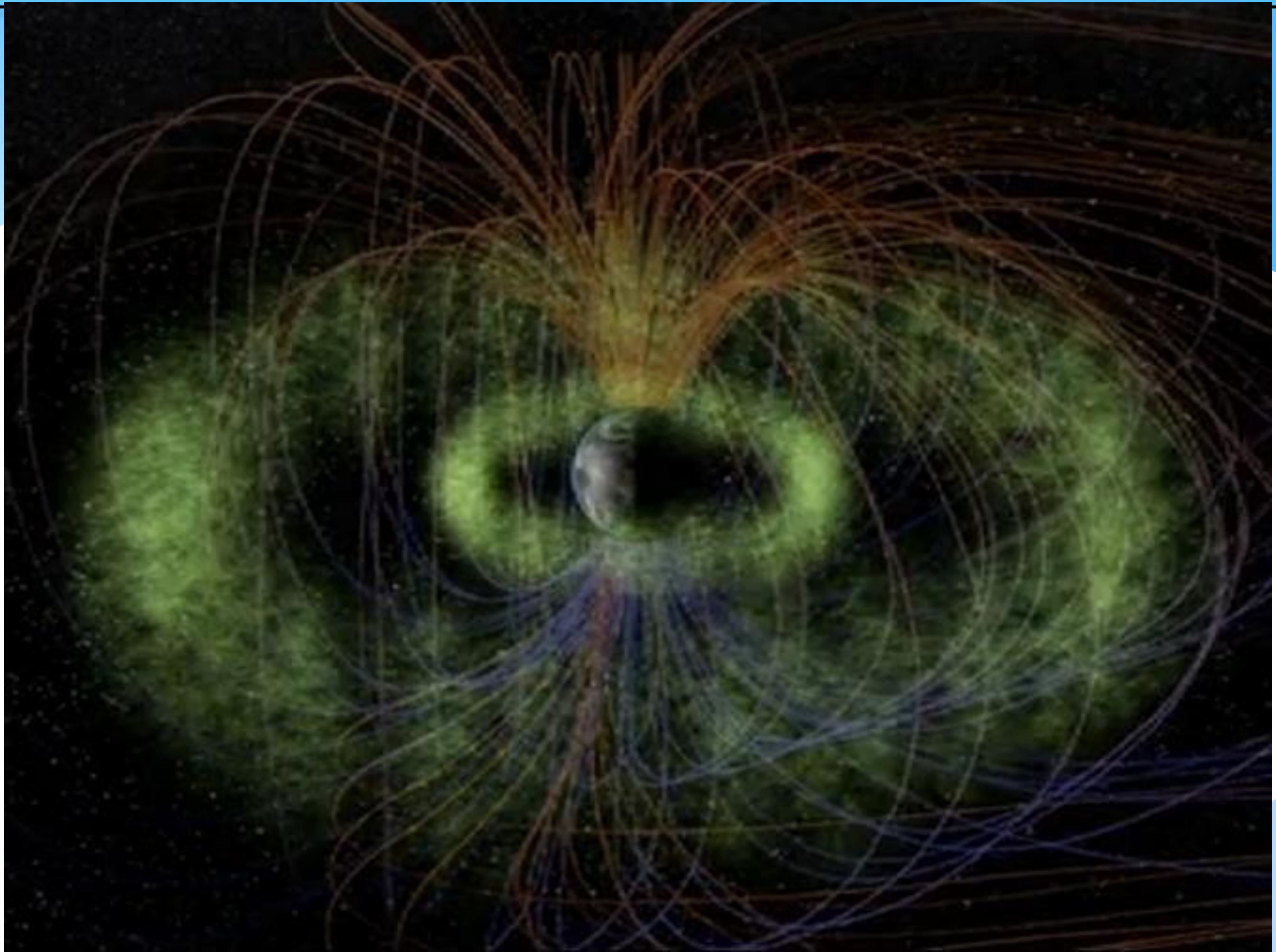


Castro-Wallace et al. [*https://www.nature.com/articles/s41598-017-18364-0*](https://www.nature.com/articles/s41598-017-18364-0)

Solar Flare and Earth's Magnetic Field



Van Allen Belt



Food for Space Missions

Natural Form Foods

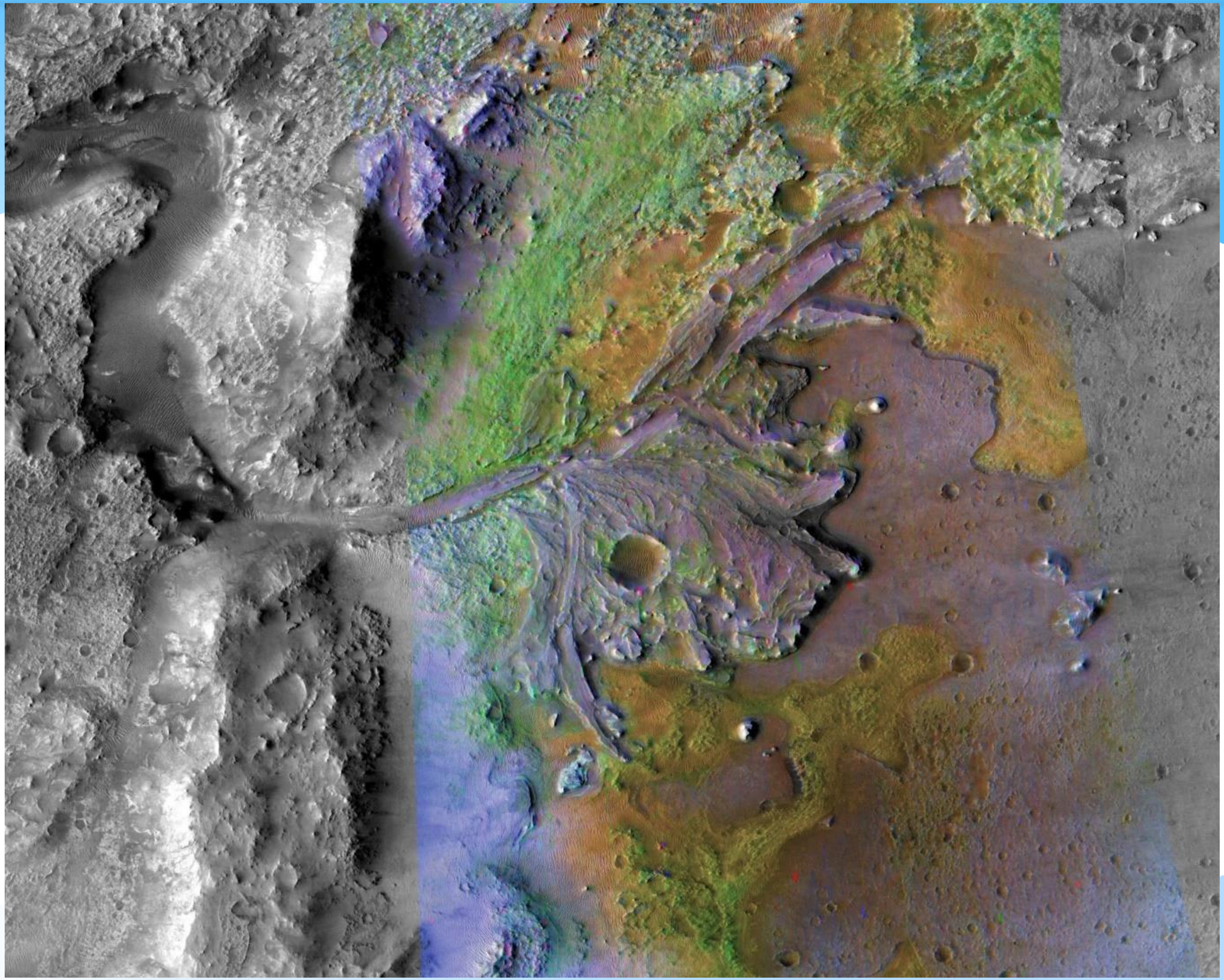
Rehydratable Foods

Intermediate Moisture Foods

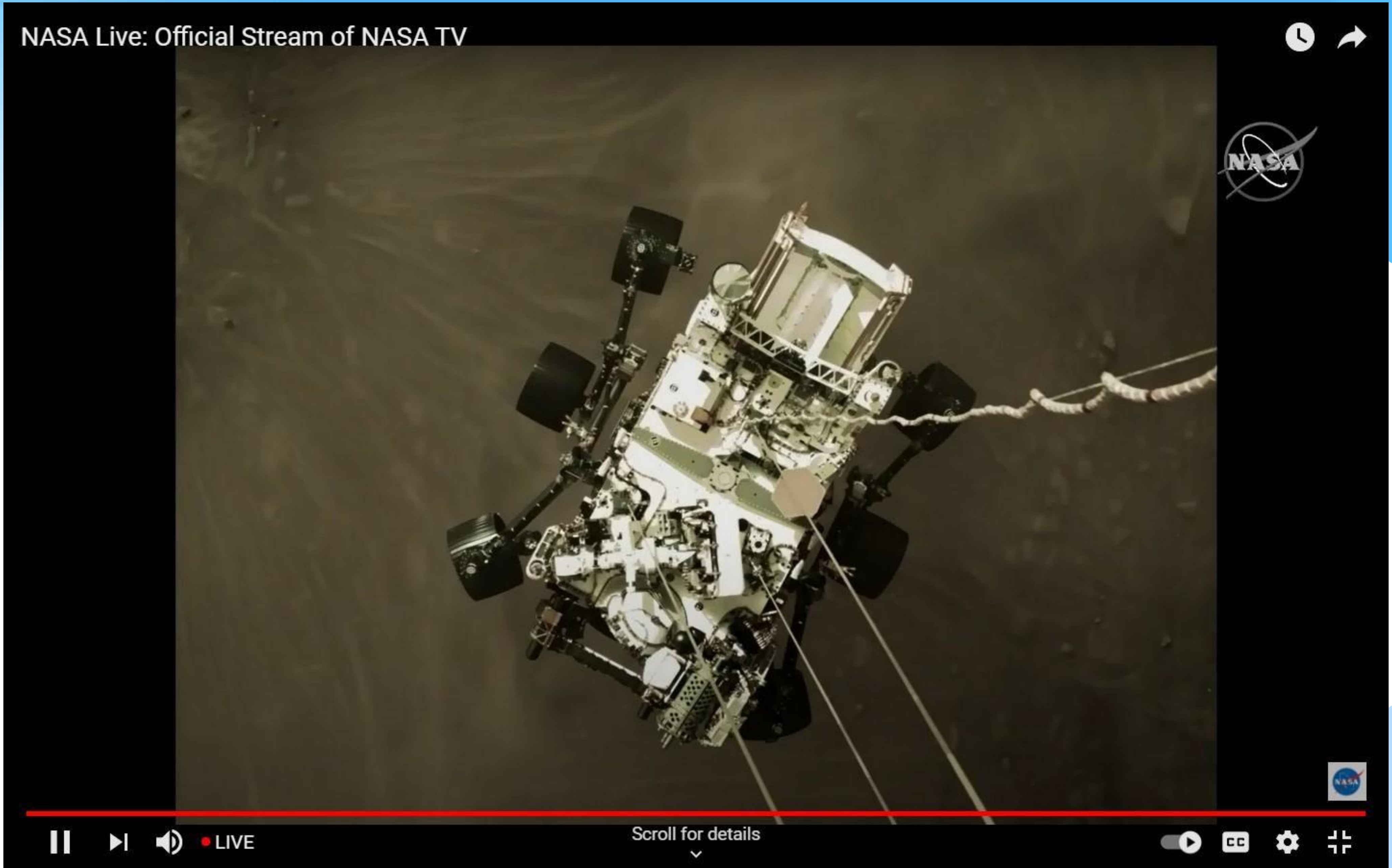
Beverages

Irradiated & Thermo-stabilized Foods

Mars 2020 : Jezero Crater

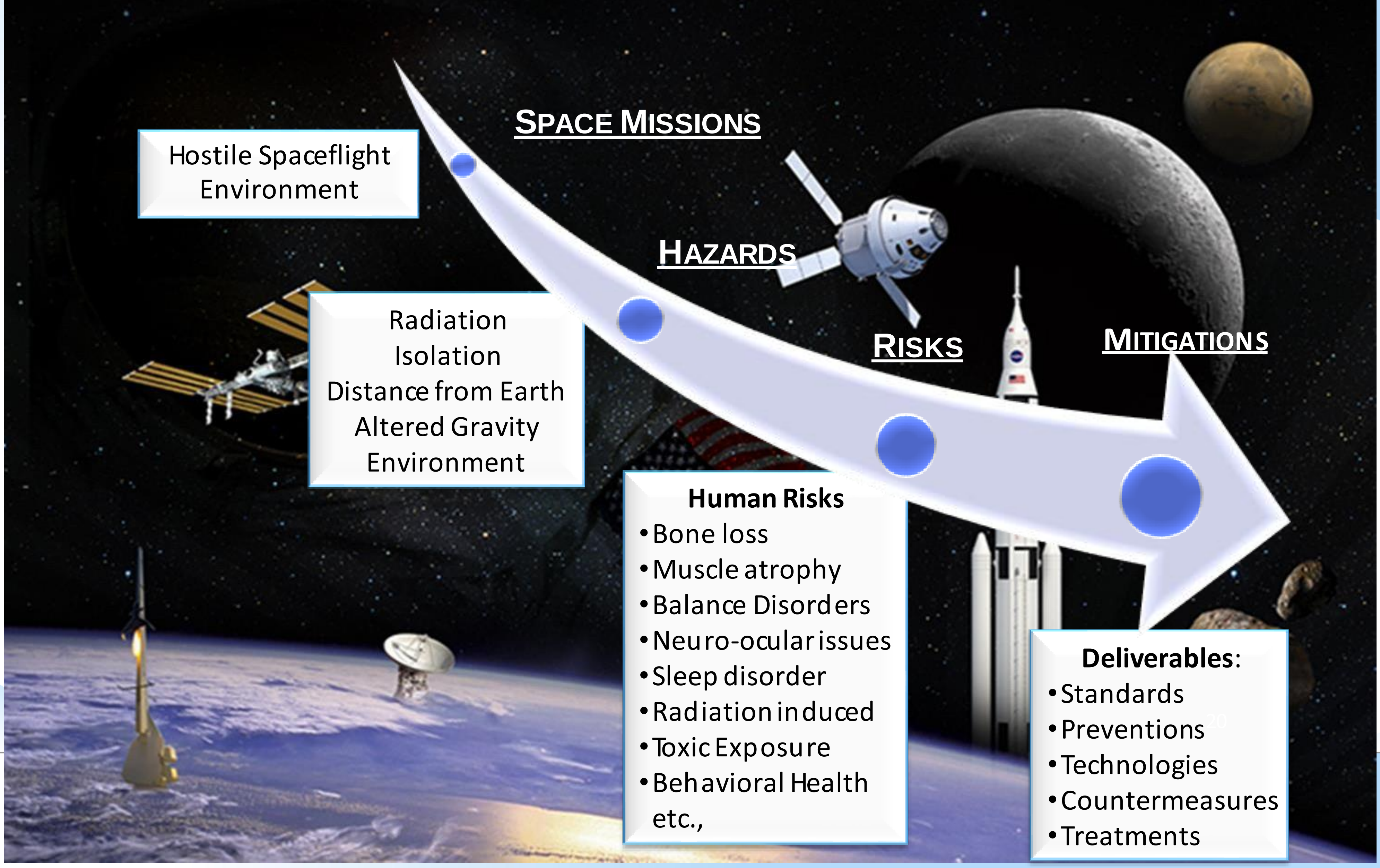


Perseverance Landing



Human Health & Performance

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



Hazards of Spaceflight (RIDGE)
Hazards Drive Human Spaceflight Risks

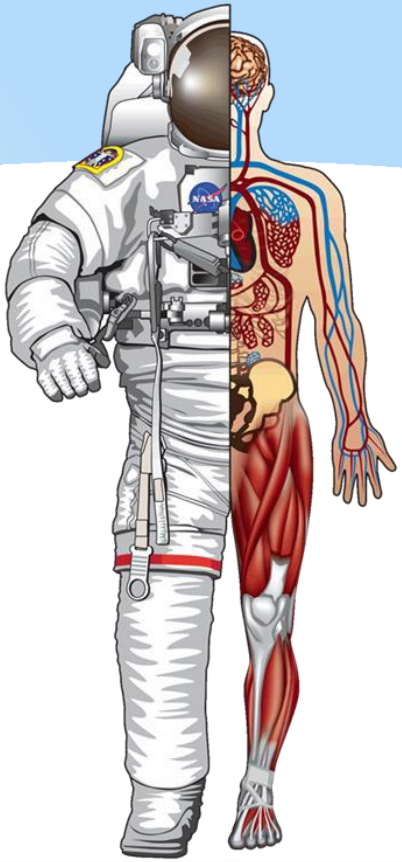
Human Health and Performance
NASA Johnson Space Center
Exploring Space | Enhancing Life

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

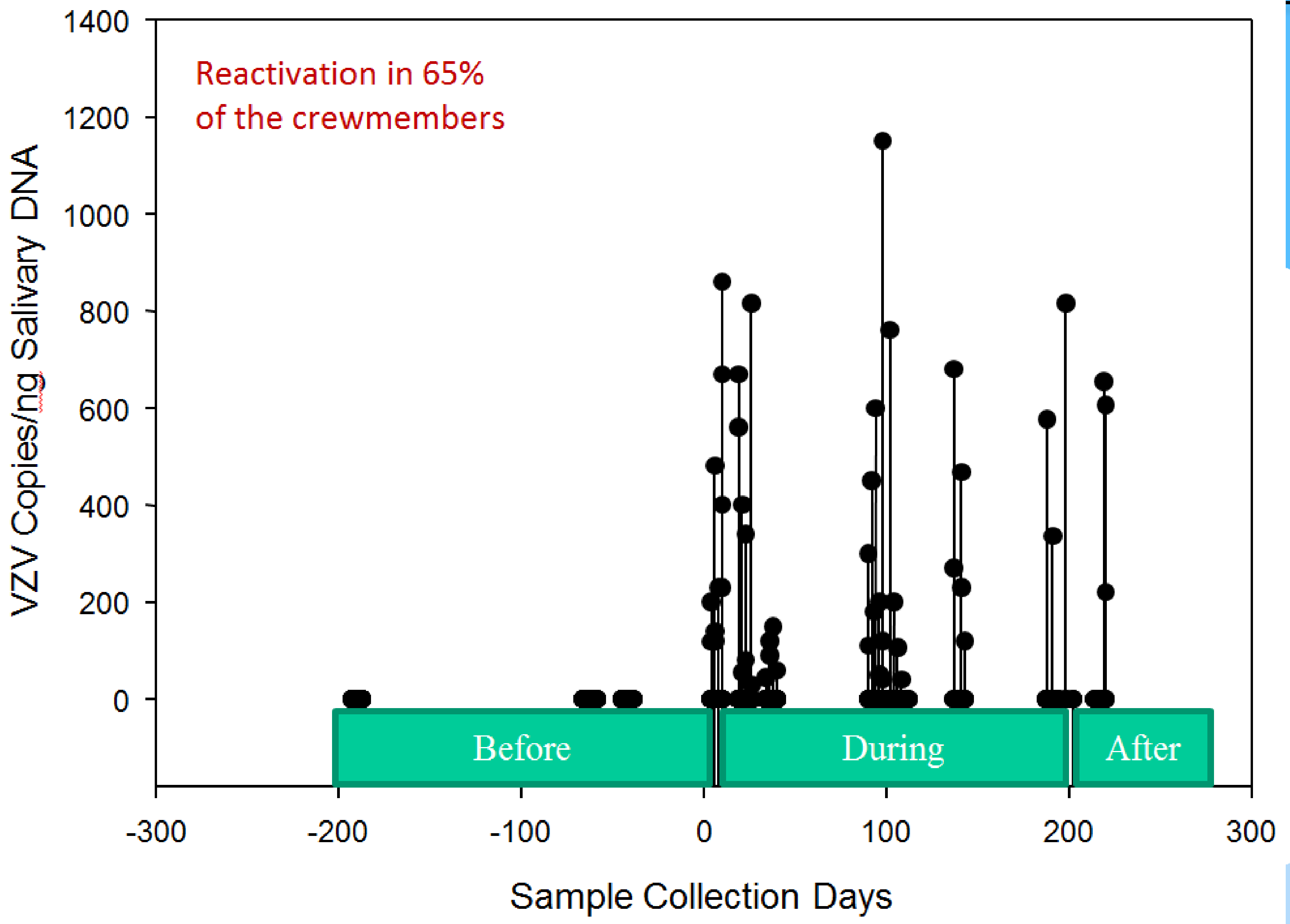
Altered Gravity - Physiological Changes

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

Reactivation of VZV Virus in Astronauts



Kunz et al, Life Sciences in Space Research, **125** (2020) 119-128

Immune Dysregulation and Countermeasures

Crucian *et al*., Frontiers in Immunology, Vol 9, 1437, **2018**

Potential Immunologic Countermeasures for Deep Space Missions

Precision Countermeasures

Pre-Mission Immunological Screen

Pre-mission immunological screen may include:
Personal history of allergy/hypersensitivity, etc.
Medication history (antihistamines, etc.)
Leukocyte distribution (NK cell subsets)
Cytokine concentration: Th1/Th2, etc.
Allergy screen, patch testing
Latent herpesvirus sero-positivity

Pathogen-Specific Mitigations

Antiviral (VZV) vaccination

General Countermeasures

Already in Place/Will be Optimized

Pre-flight medical operations screening of crewmembers
Pre-flight quarantine
Microbial screening of vehicle/payloads/foods
Environmental control
Optimized exercise equipment
Radiation shielding

Multisystem Countermeasures

Optimized exercise regimen
Adequate sleep schedules
Psychological support - family communication
Stress relieving techniques

Pharmacological Intervention

Beta blockers
Anti-cortisol
Antibiotics
Antiviral
Anti-inflammatory
Cytokine therapy

Specific Countermeasures

Nutritional Countermeasures

Diet optimized to reduce nutrient deficiency
Functional foods/bioactive compounds
Nutritional supplements:

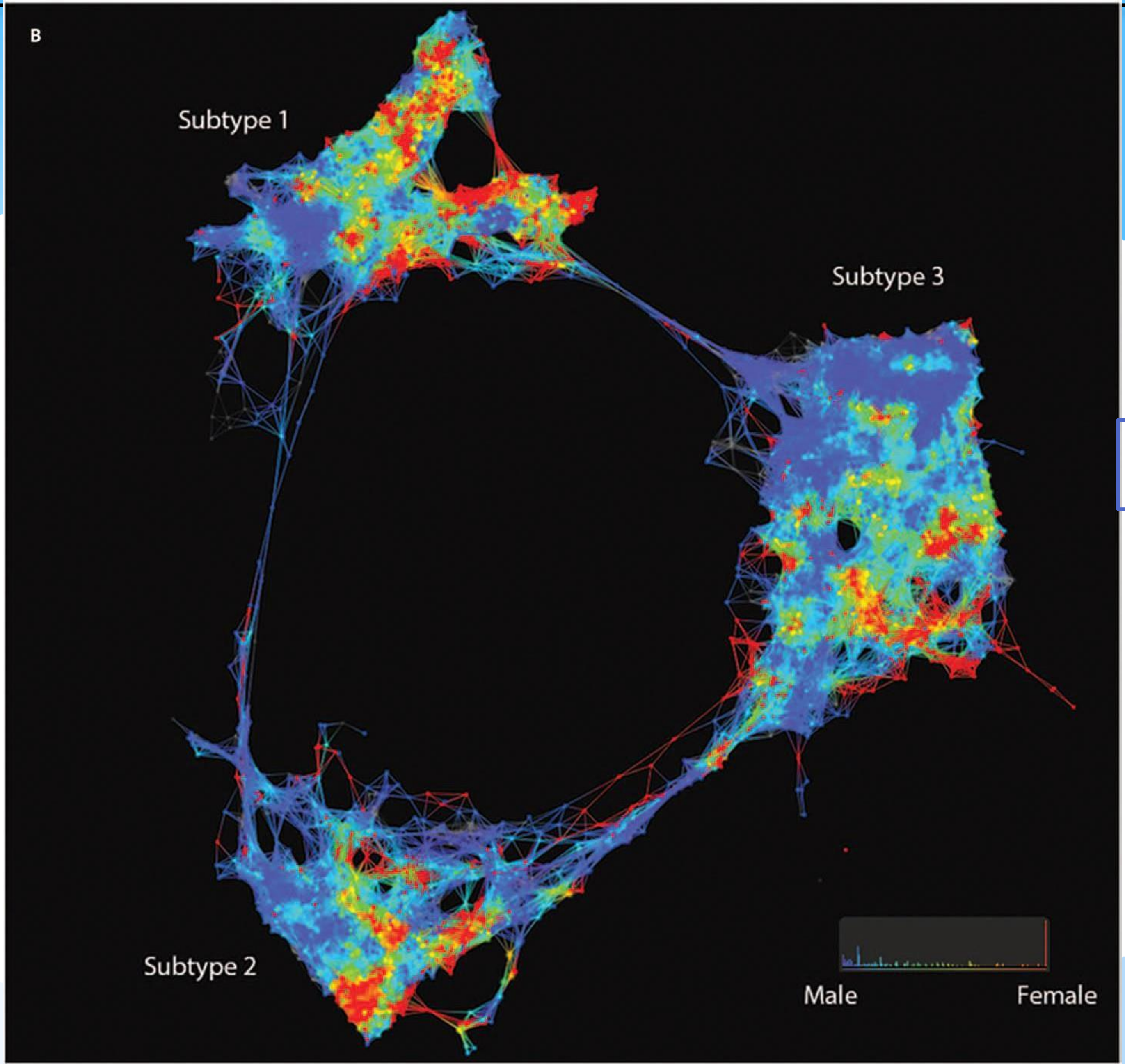
- Antioxidants
- Probiotics
- Omega 3 fatty acids
- Supplemental nucleotides
- AHCC
- Pegylated-IL-2

In-flight Monitoring of Immune Parameters?

Data Analytics in Healthcare

Li *et al.*, Science Trans Medicine, Vol 7, 311, 2015

Type 2 Diabetic Patients
N = 1184



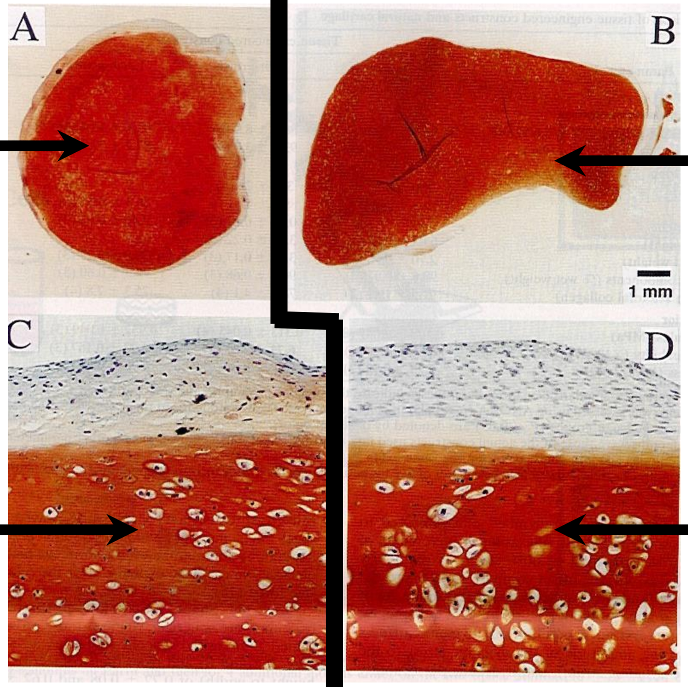
System Biology

Subtype 1 : Kidney and Eye
Subtype 2 : Heart and cancer
Subtype 3 : Heart and Neuro

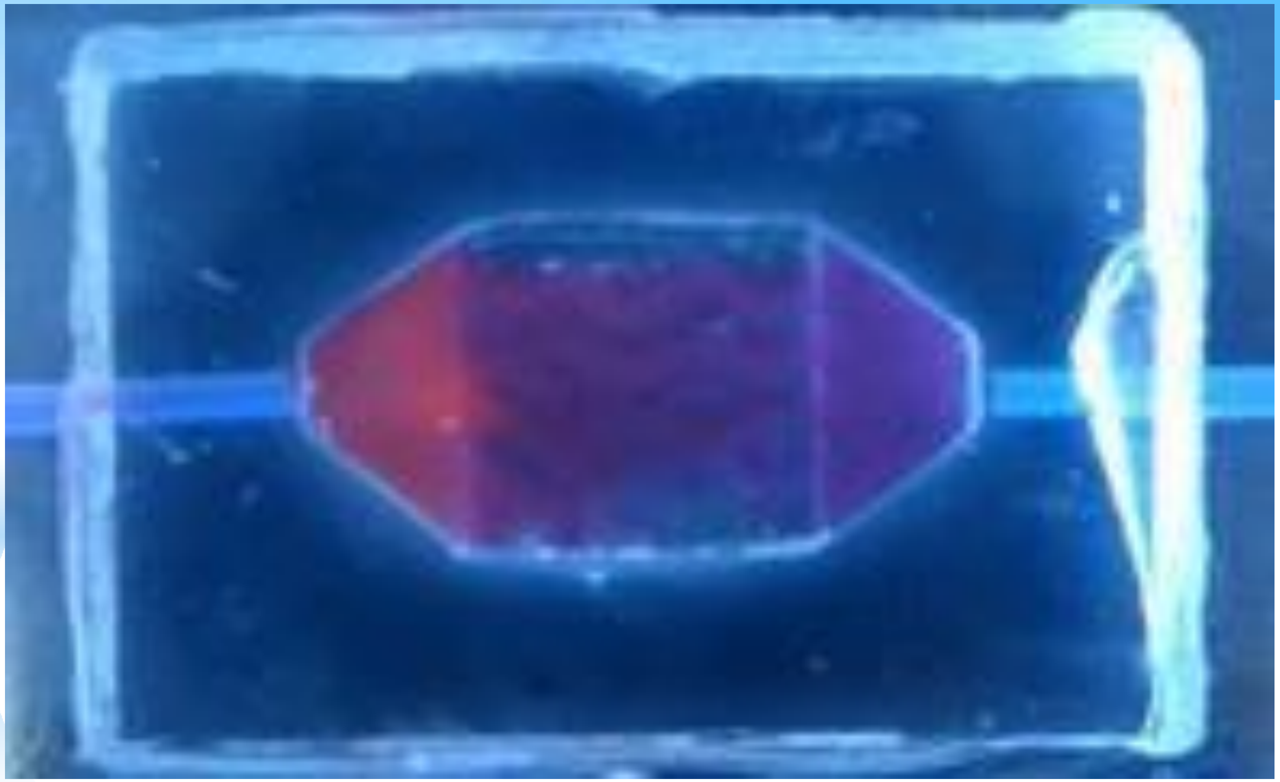
The Cellular Biotechnology Program

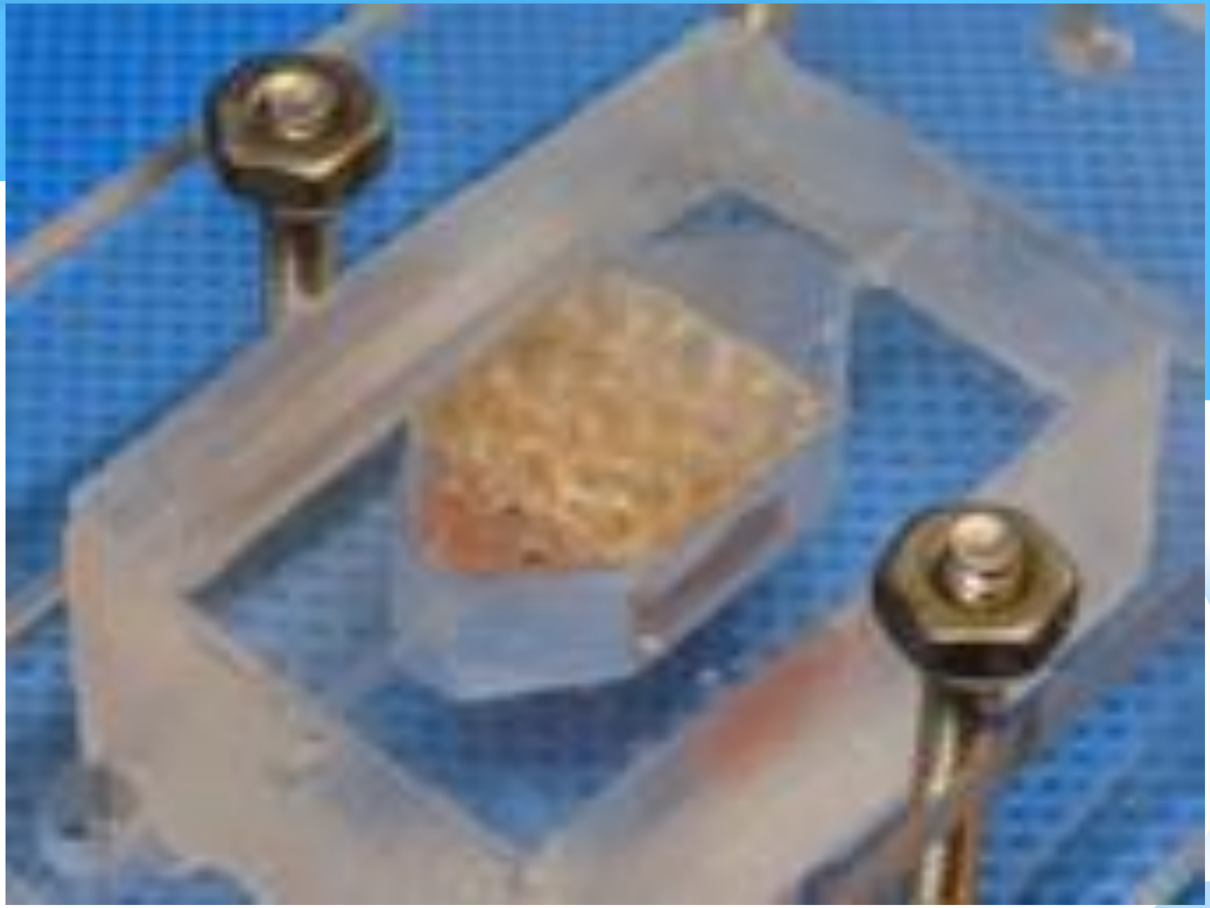
Johnson Space Center Houston, Texas

NASA-Mir Bioreactor	Ground Based Bioreactor
Spherical Less Dense Immature Cartilage	Disk shaped More rigid Cartilage
Mechanically weak but compressable	Mechanically stronger and less compressable



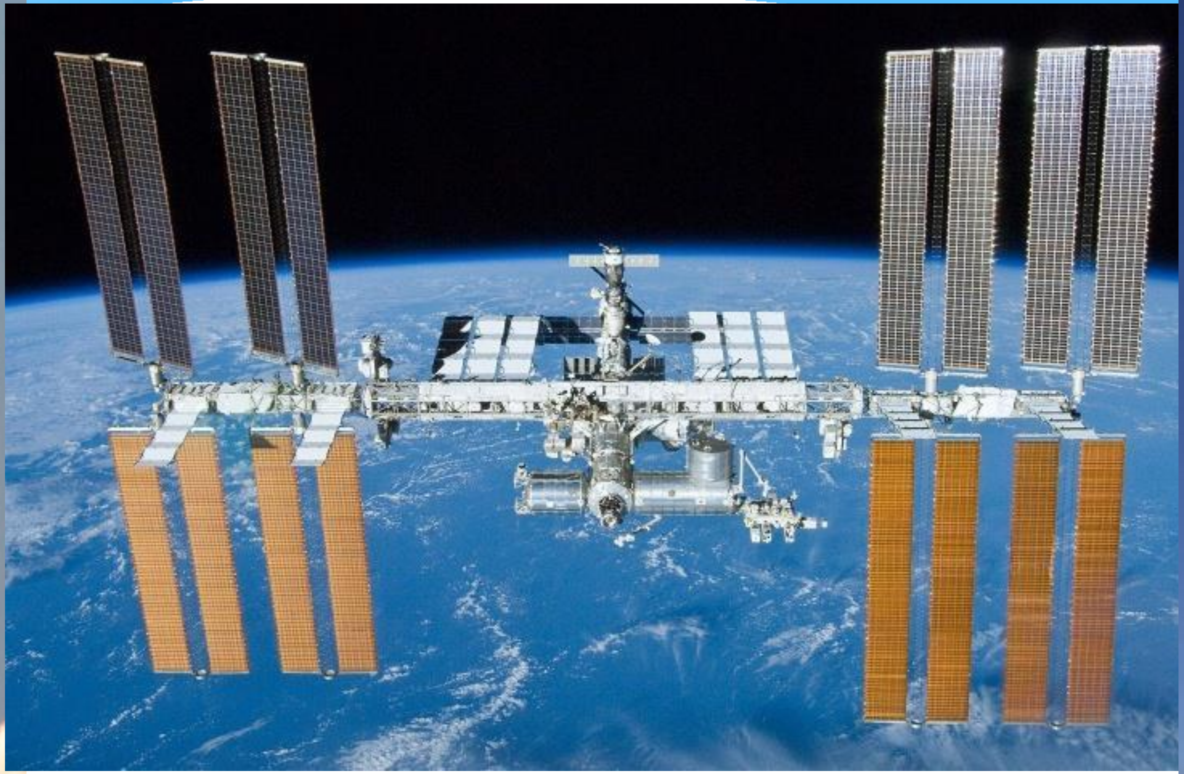
PI : Dr. Lisa Freed, MIT, *Proc. Natl. Acad. Sci. 94*, (1997) pp 1385-1389.

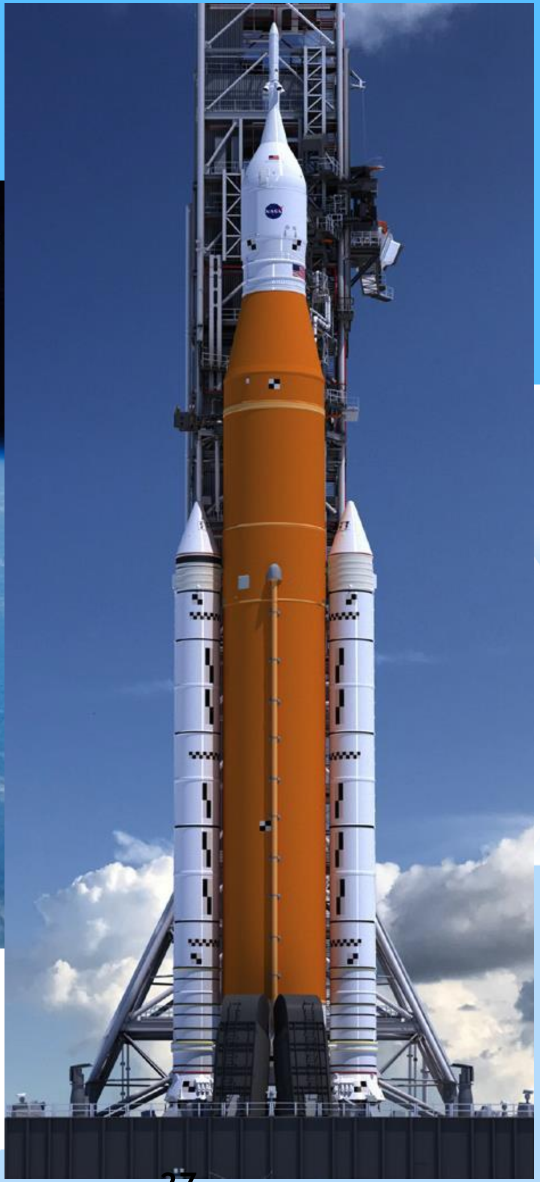




Vascularized Human Liver Tissue (1 cm3; 30 day Survival)
Wake Forest Institute for Regenerative Medicine, NC

System Engineering (Past, Present and Future





To become an Astronaut?

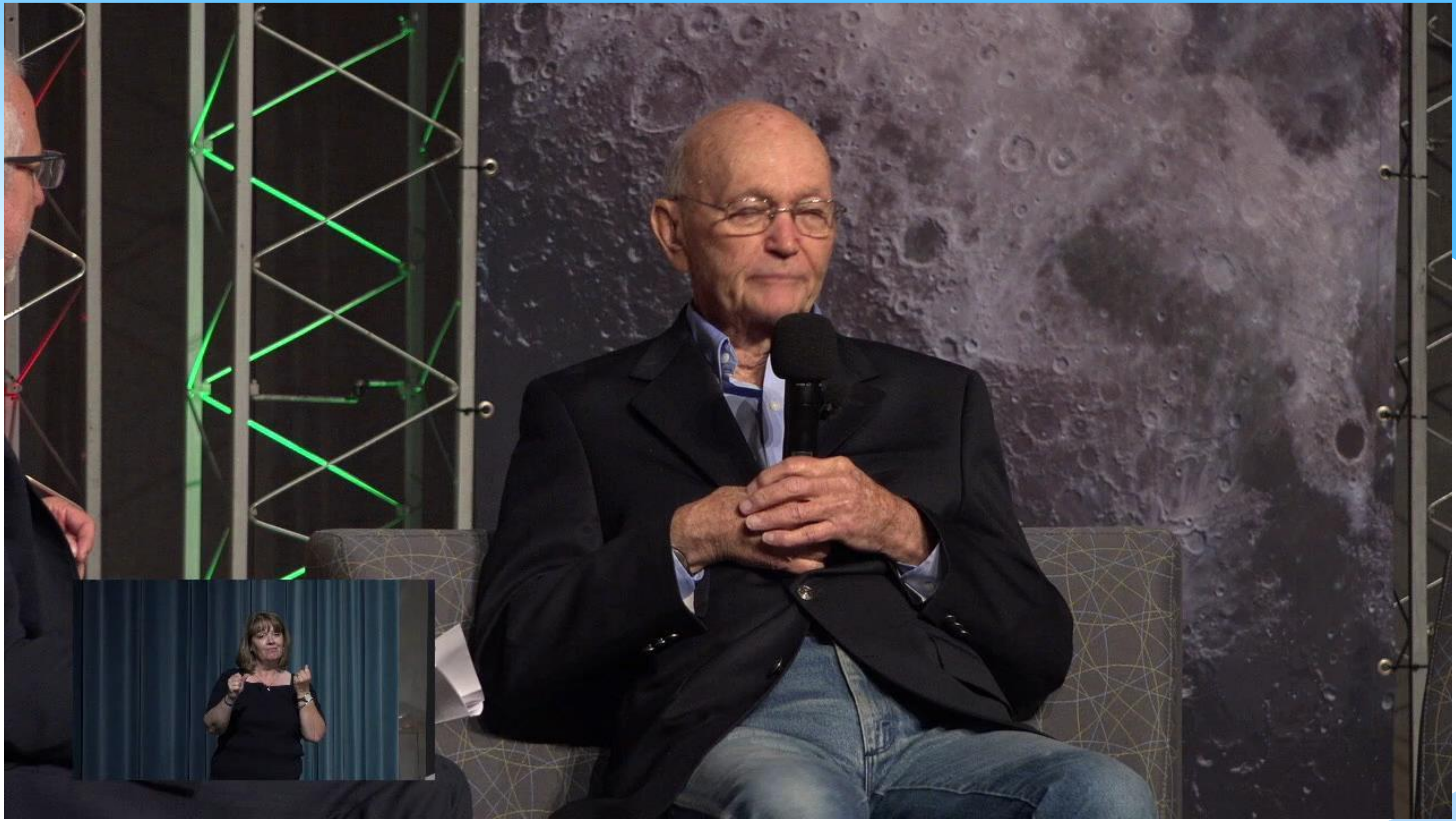
- Training in one of the STEM (Science, Technology, Engineering and Mathematics) disciplines
- Diverse Experience
- Team Player

- 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, Raj Chari, Loral O' Hara and Jessica Watkins.

Who is at Your Window?



I feel responsible - Collins

Acknowledgment

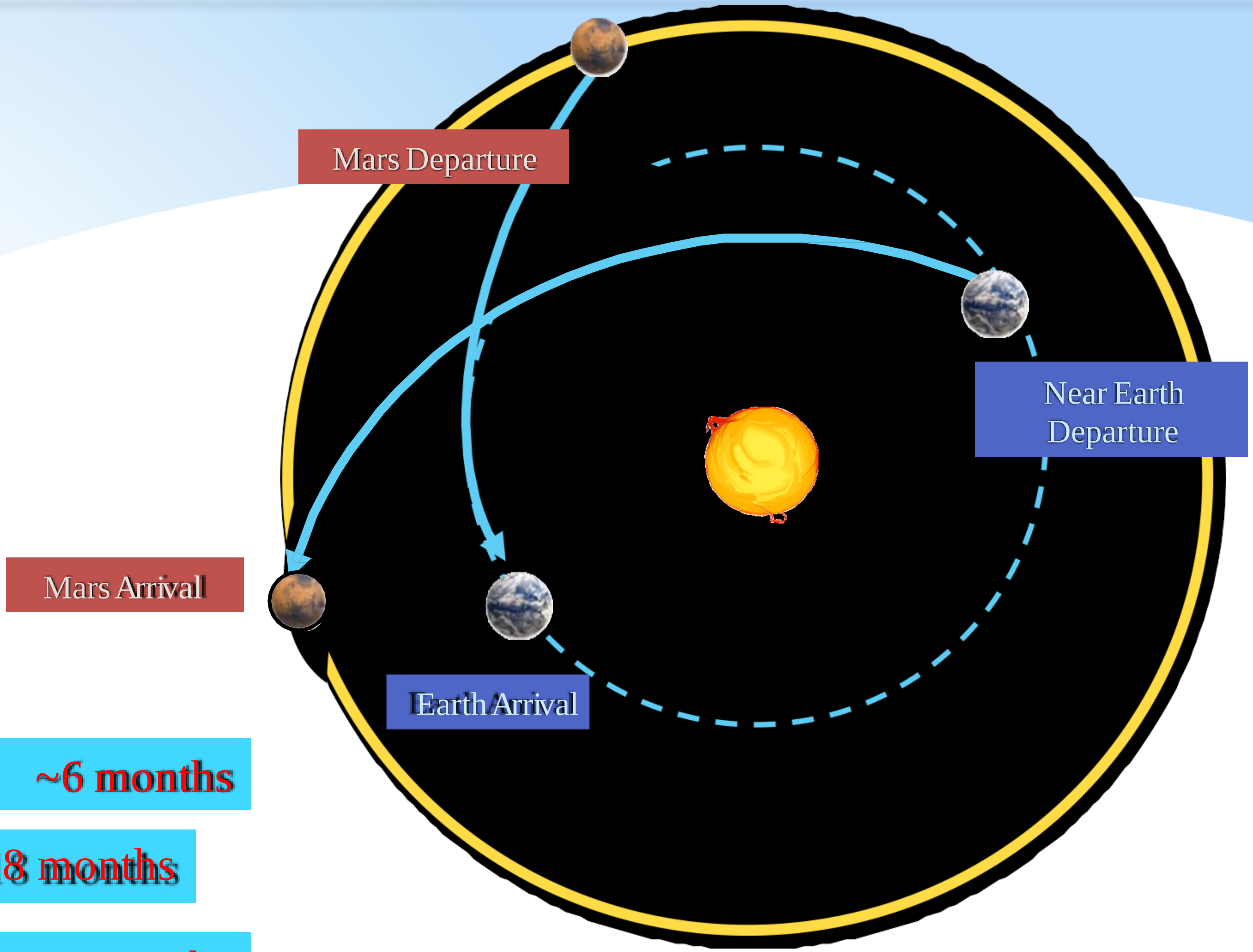
Engineers, Scientists
Physicians and Astronauts

Thanks

Beautiful Fragile Blue Planet

Back up

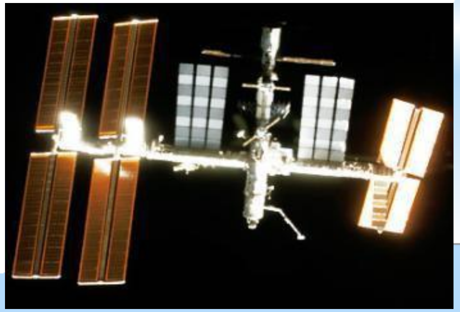
Overview of Notional Mars Expedition



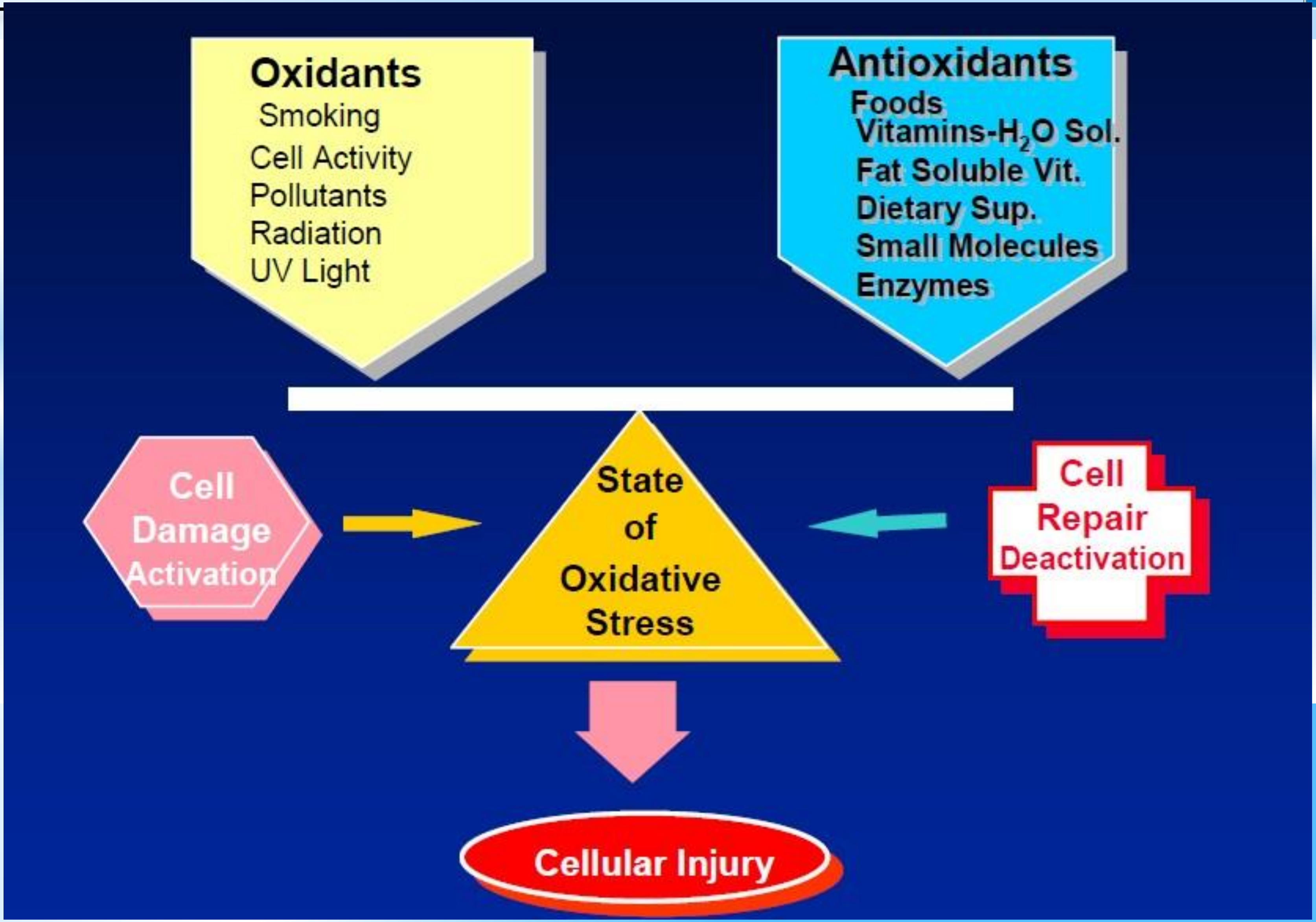
Earth-to-Mars transit: ~6 months

Mars surface stay: ~18 months

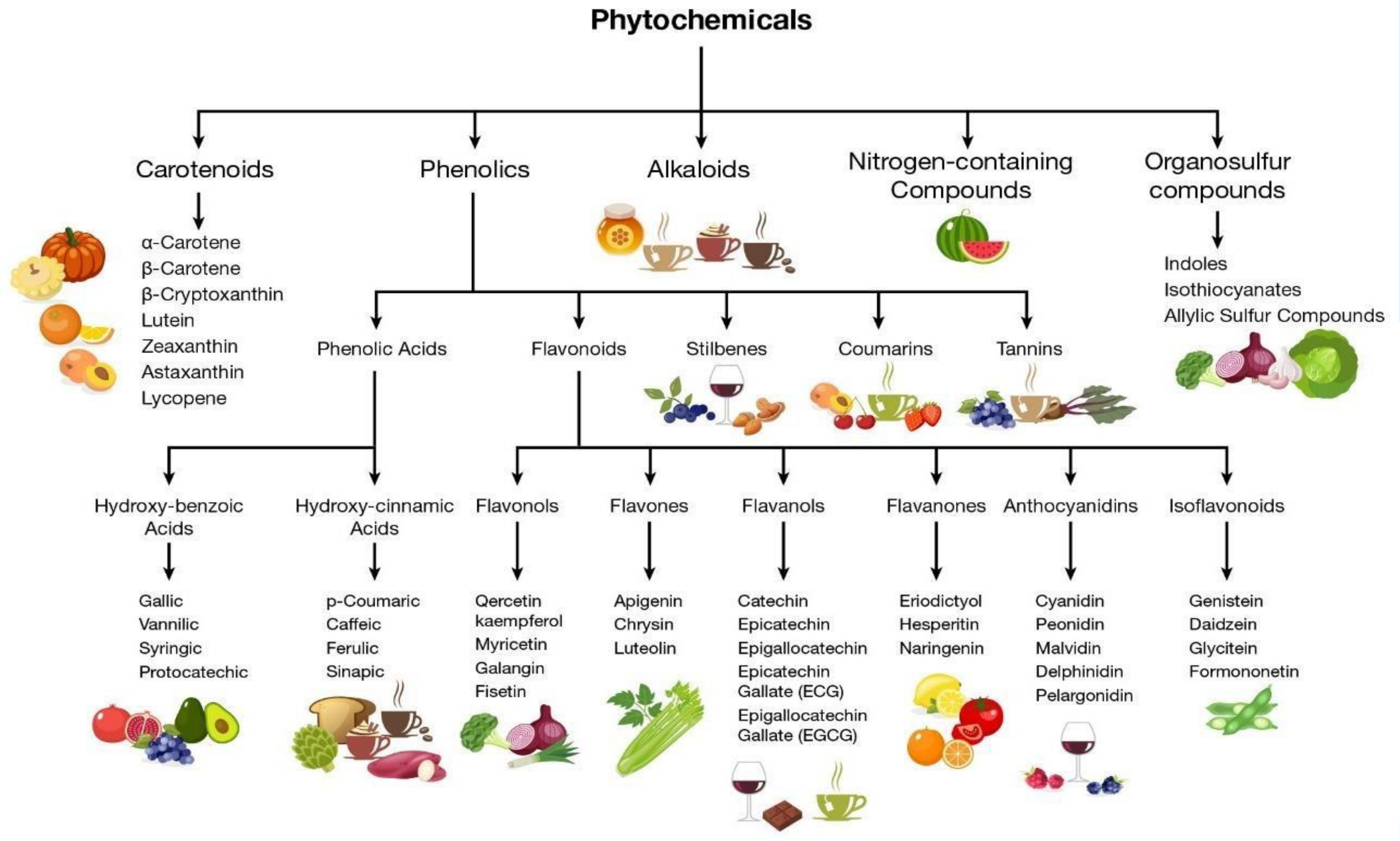
Mars-to-Earth transit: ~6 months



Oxidative Stress

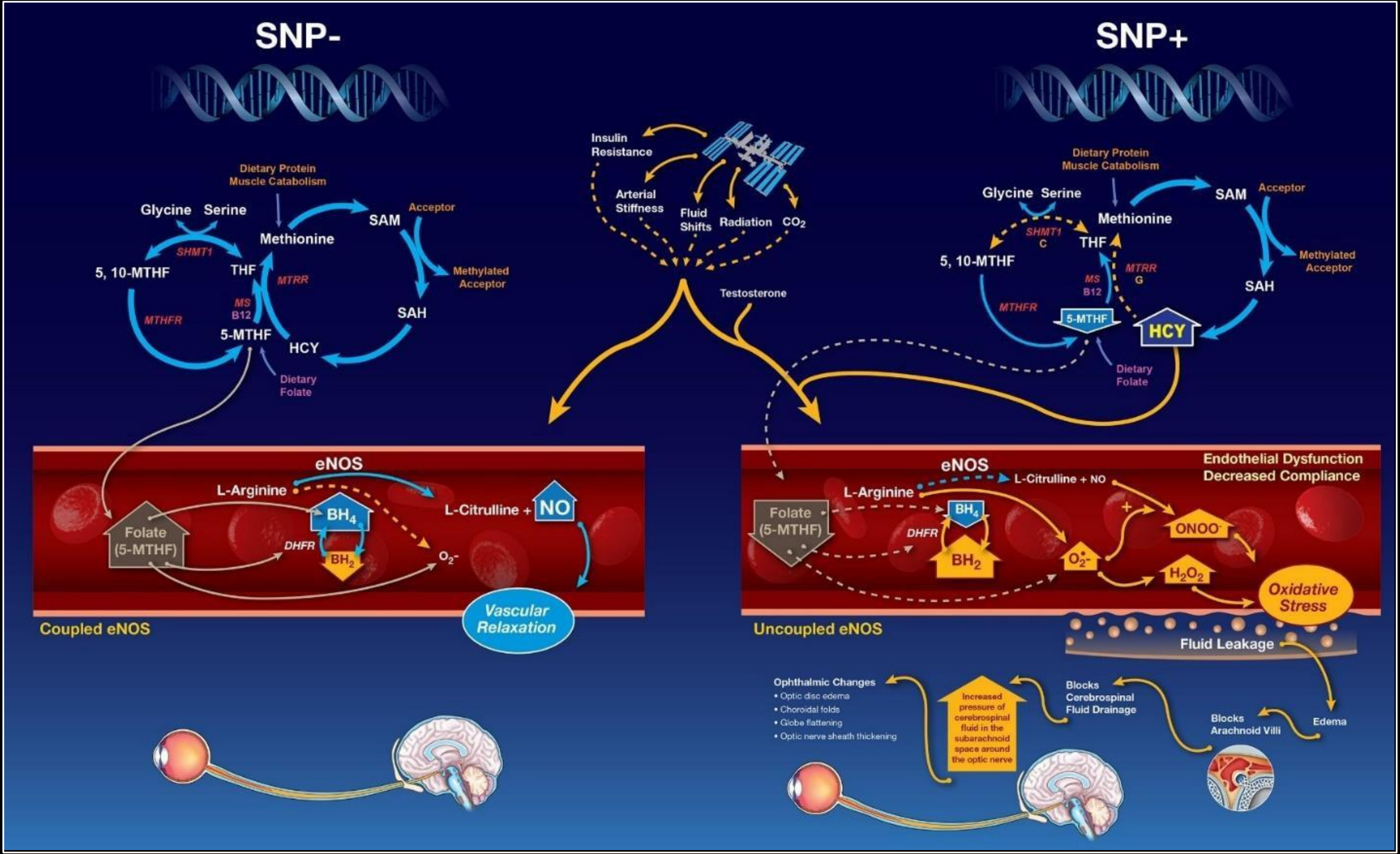


Acworth et al., "The Handbook of Redox Biochemistry", ESA Inc., **2003**, 19.



Scott Smith, NASA/JSC

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.

THE SUCCESS OF APOLLO

The Apollo Pyramid of Success

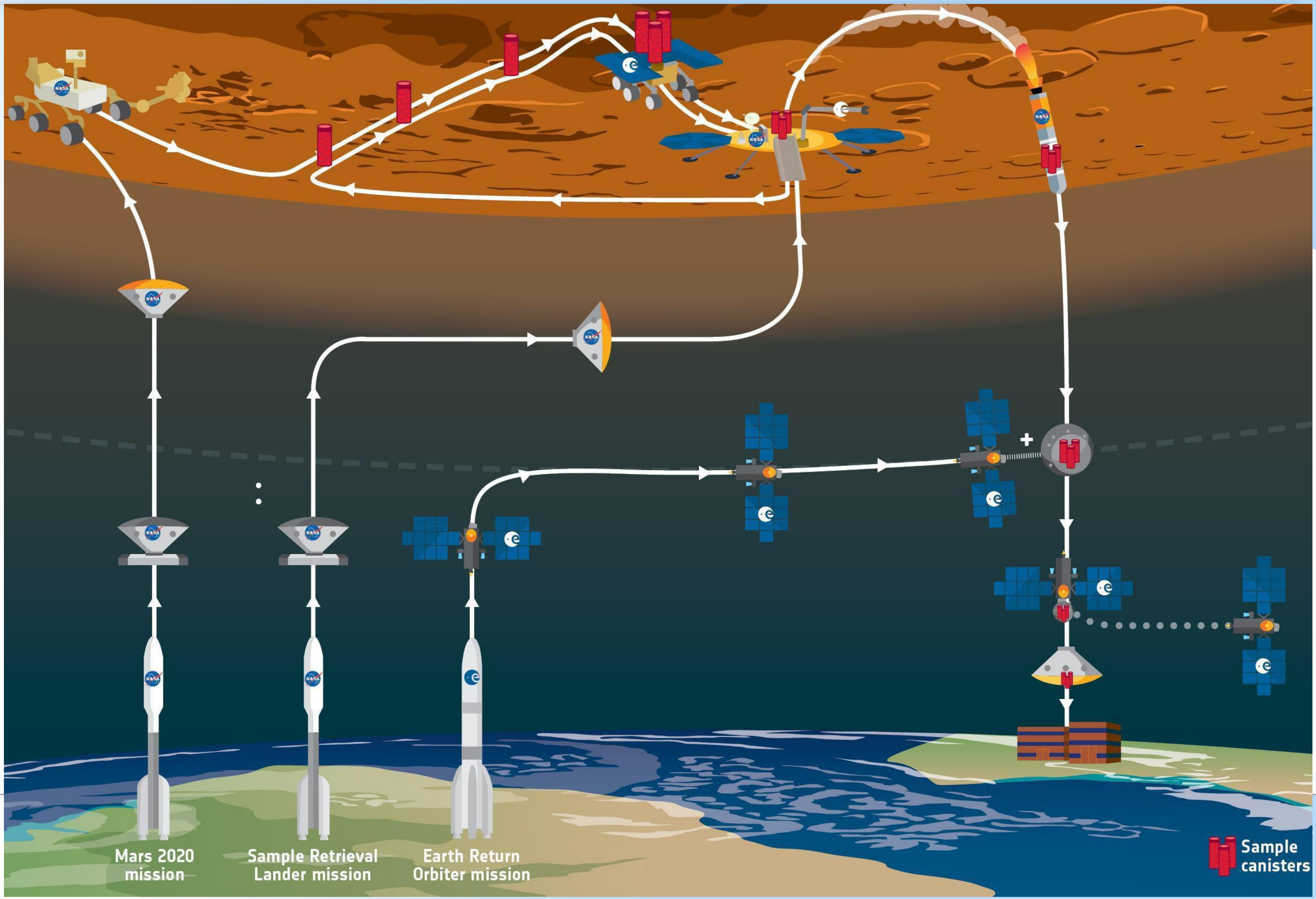
13. LUCK
12. LEARN FROM MISTAKES
11. VISIBILITY AND ACCOUNTABILITY
10. PAINSTAKING ATTENTION TO DETAIL
9. WHAT-IF THINKING
8. EXHAUSTIVE, REALISTIC TESTING
7. RISK REDUCTION BY DESIGN
6. OUTSIDE THE BOX IDEAS CAN WIN
5. UNDERSTAND THE ENVIRONMENT
4. SYSTEMS THINKING
3. SUPERB LEADERS AND THE CULTURE THEY CREATE
2. SUFFICIENT RESOURCES
1. CLEAR GOAL

Failure Ingredients

- REALITY DISTORTION FIELD
- NEGATIVE TRIBAL BEHAVIORS
- CLOSED-MINDEDNESS
- FALSE PERCEPTION OF RISK
- GROUPTHINK
- COOKBOOK THINKING
- HUBRIS
- LUCK

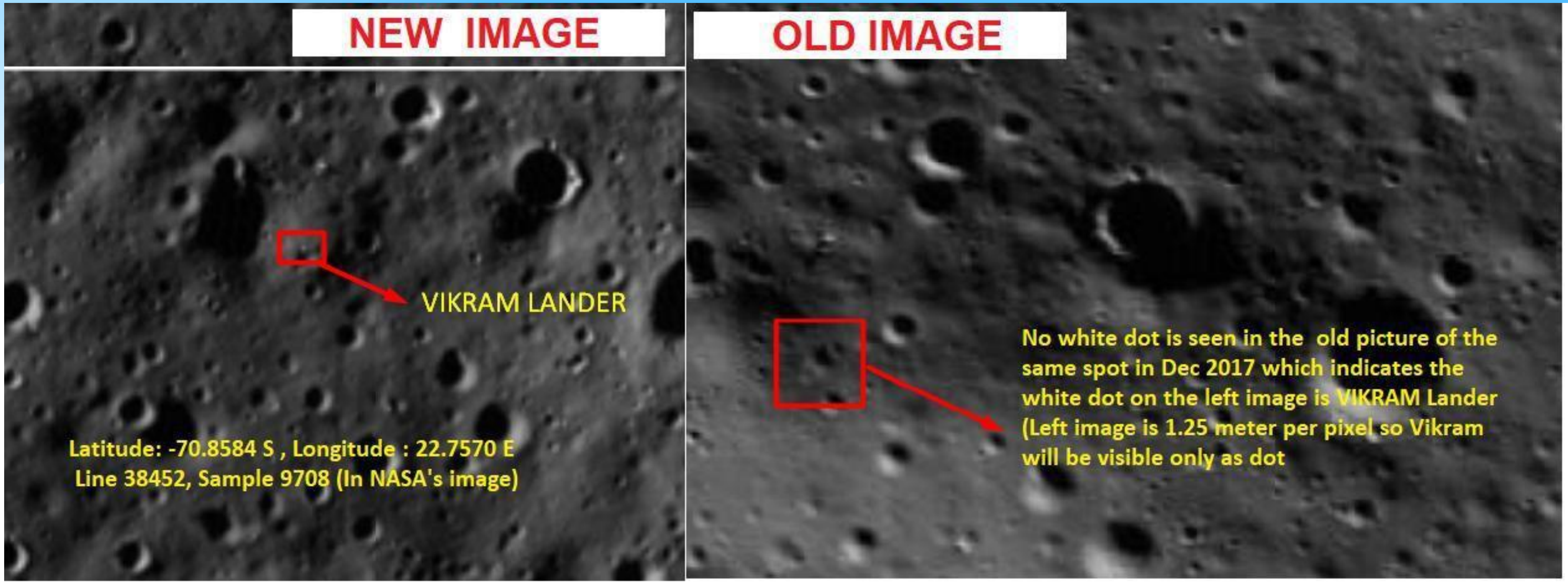
Adapted from Andrew Chaikin

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

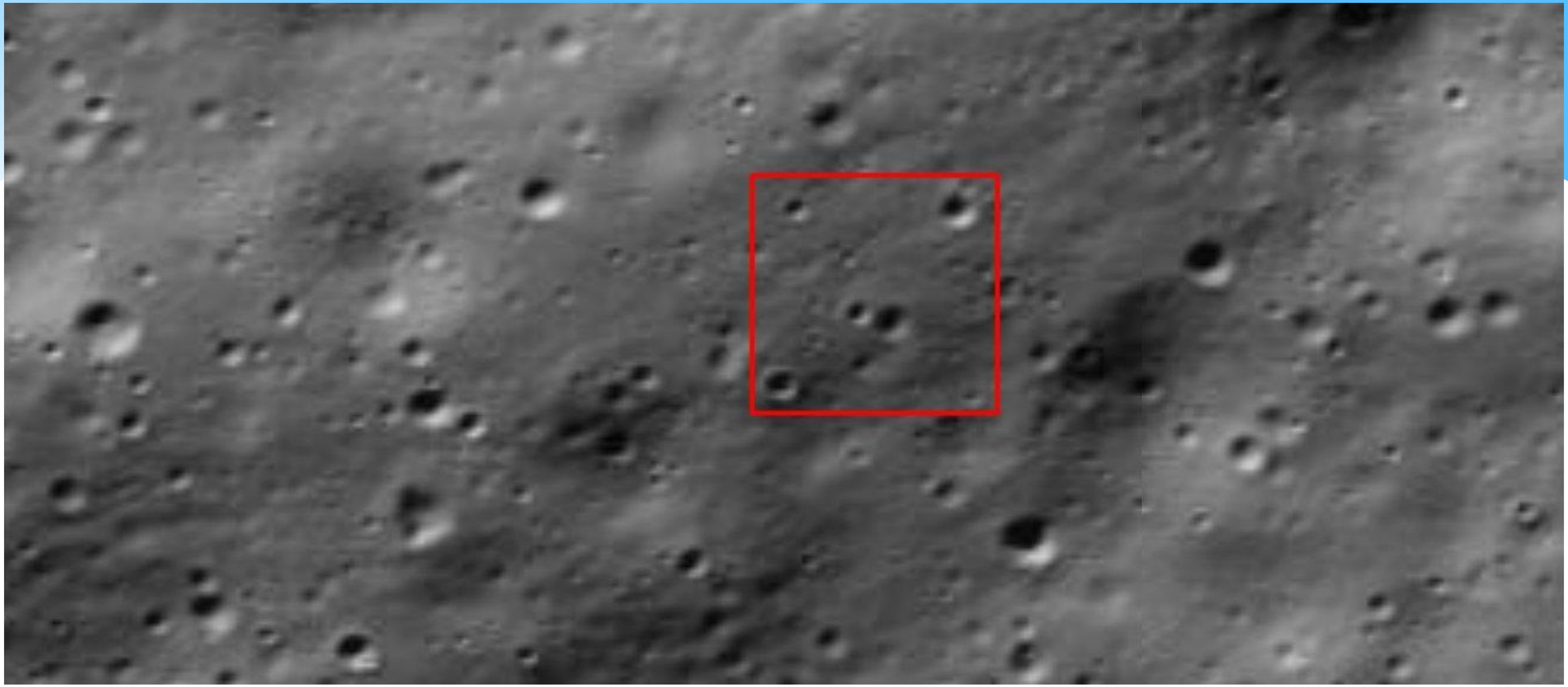


Crew Debriefing at Bld 37 (July 27, 1969)

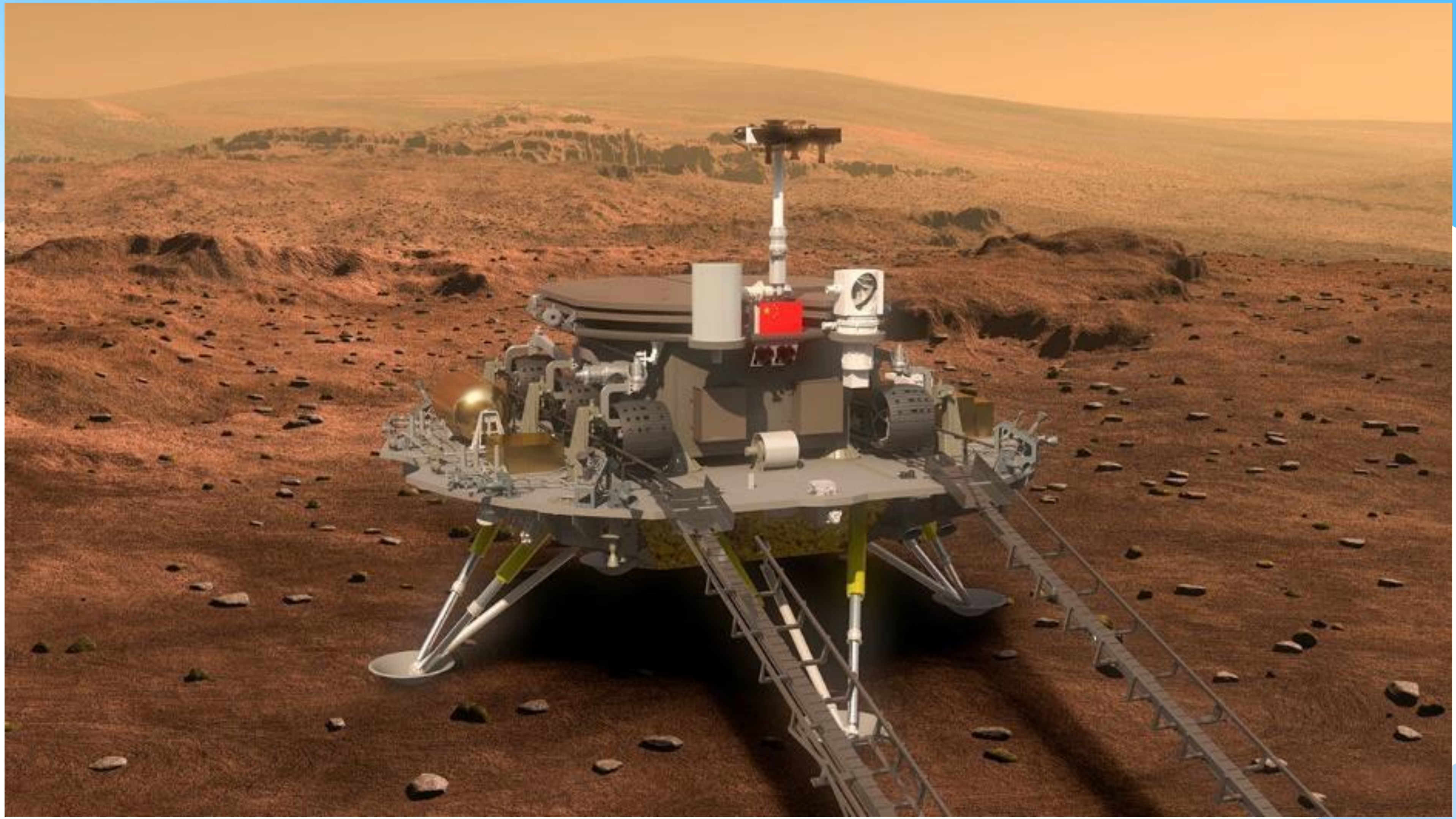
Vikram Lander



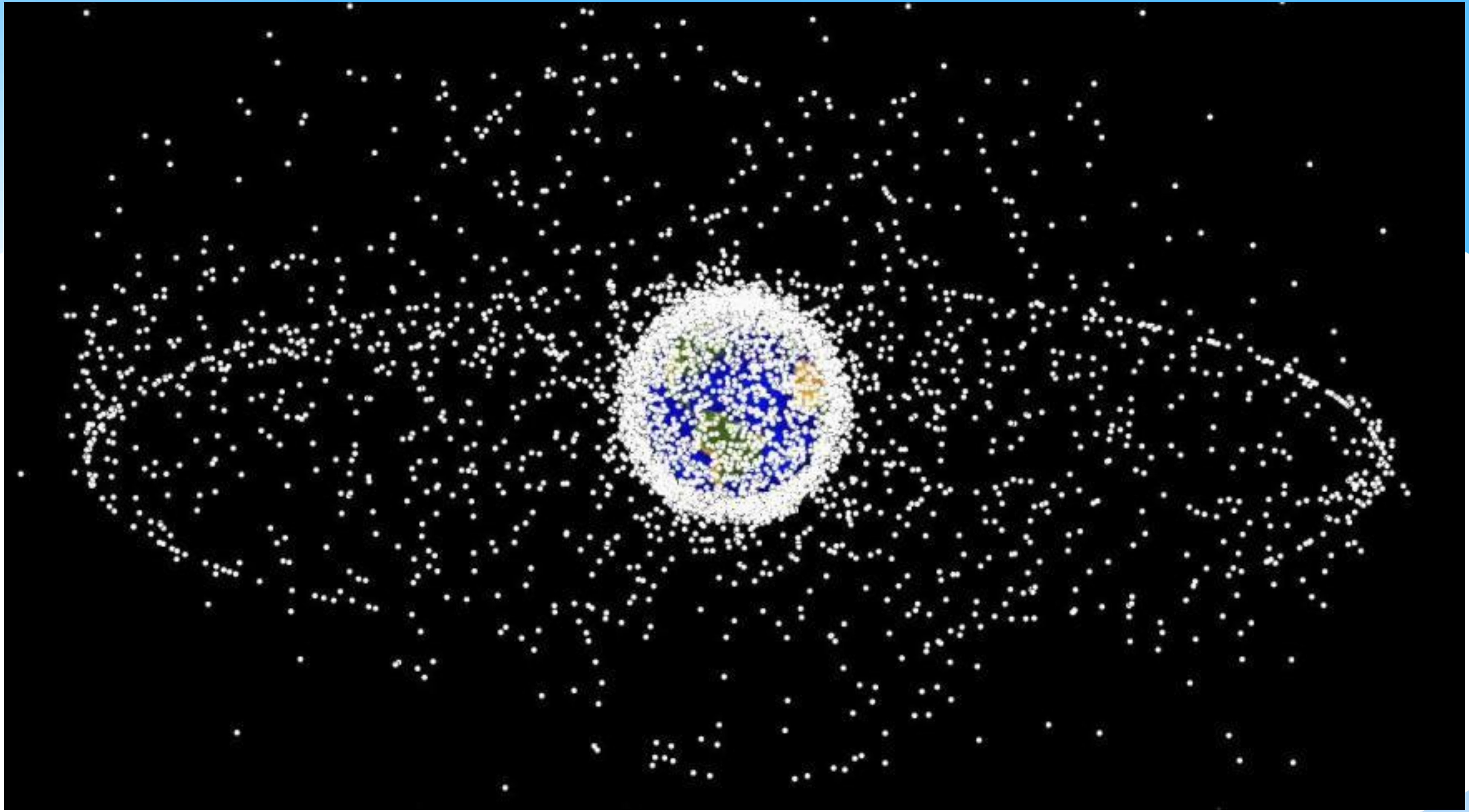
Vikram Lander



Mars Rover from China in 2020



Space Debris



Zuma Pilot Picture

View from Sudan

Zero-Gravity Aircraft

Magnitude of the Universe

Number of Atoms in the Universe <10^80

Atoms in the earth = 6 x 10^27 g/12 g)x 6 x 10^23 = 3 x 10^50

Atoms in the solar system = 3 x 10^50 x 1000 = 3 x 10^53

Atoms in the Milkyway Galaxy = 3 x 10^53 x 10^9 = 3 x 10^62

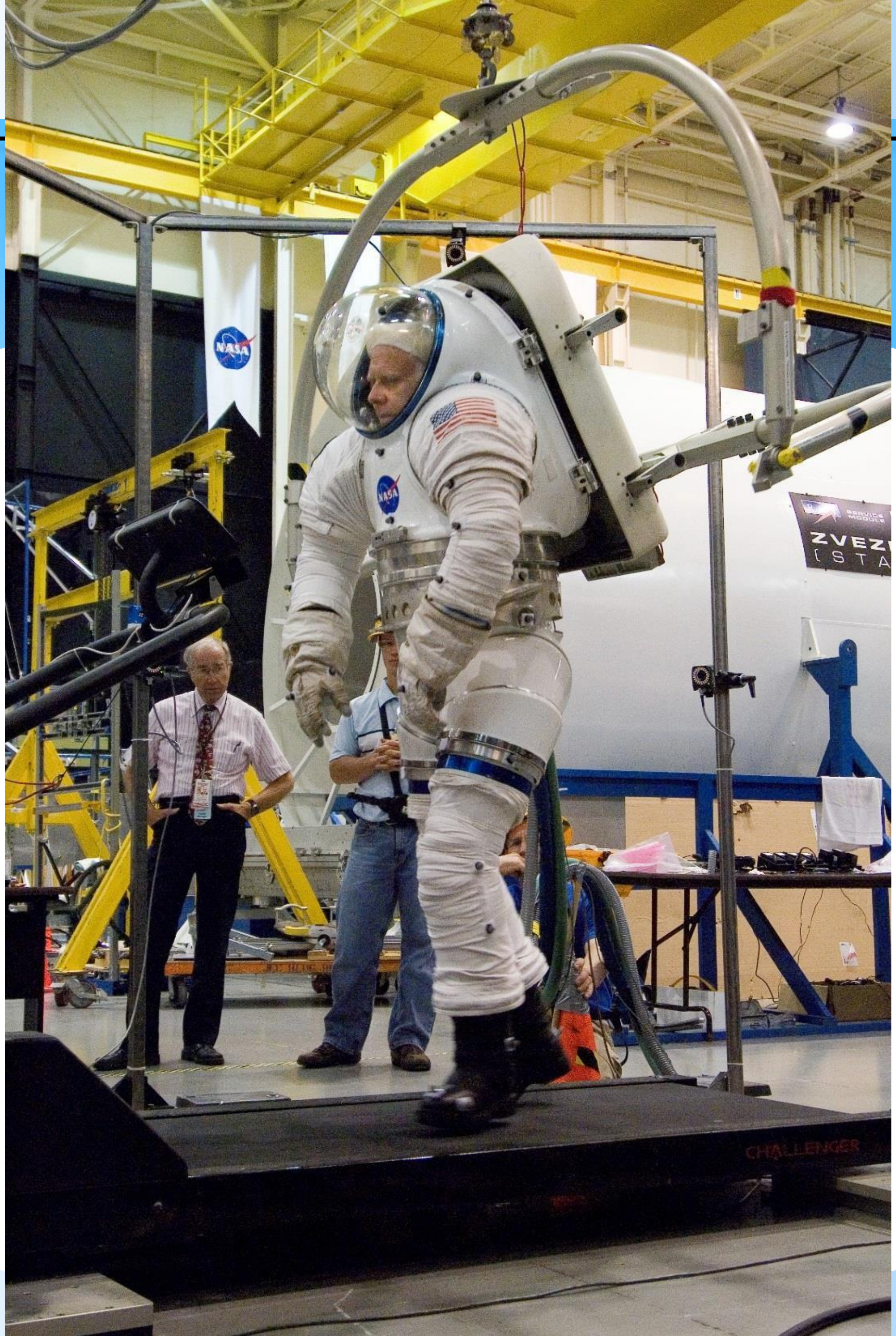
Atoms in the Universe = 3 x 10^62 x 10^ 9 = = 3 x 10^71

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

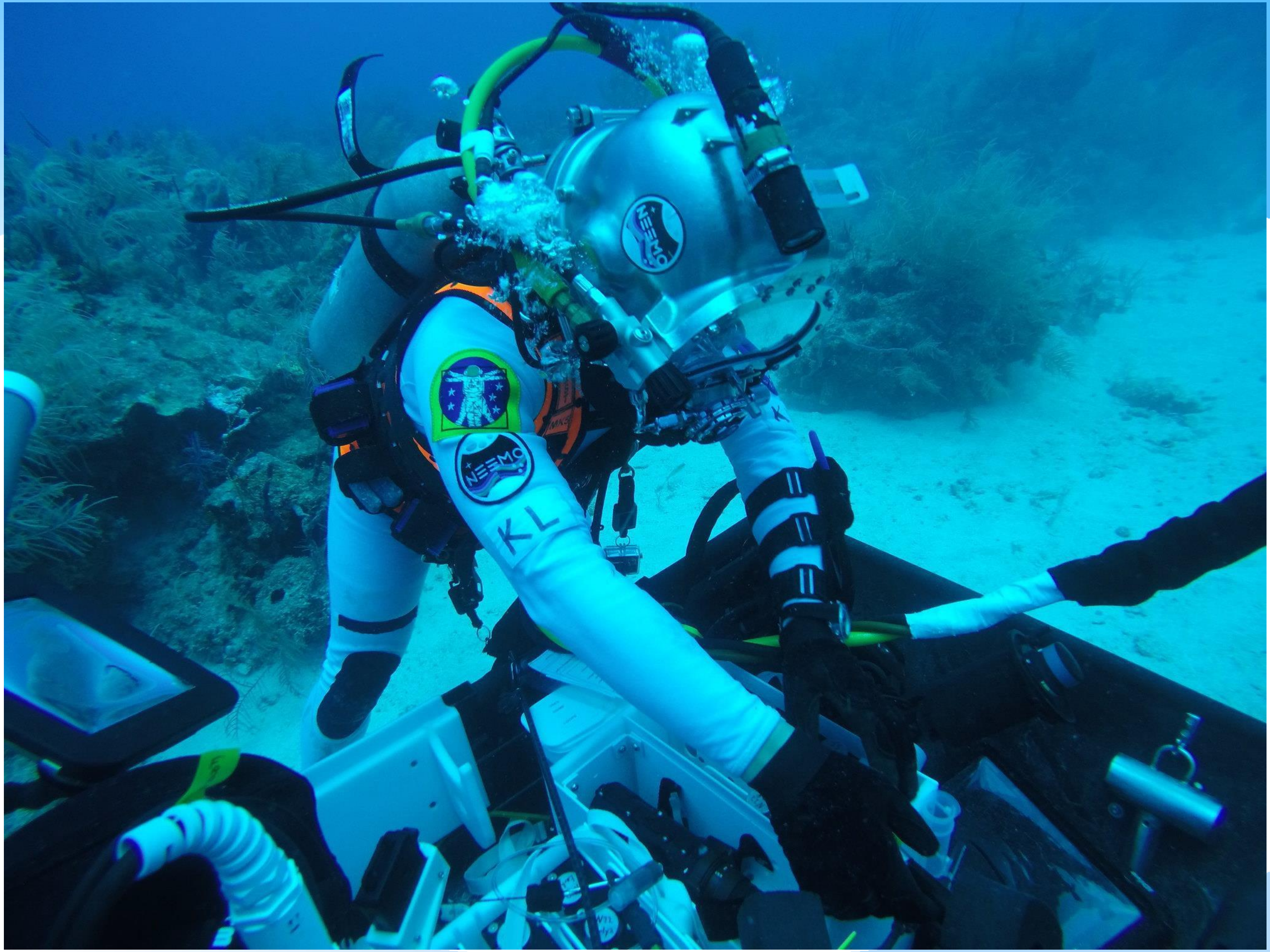

Still daylight in California.
Chicago
Cities of Boston, New York, Philadelphia and Washington.
Dallas
Houston
Miami
Puerto Rico


NASA
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

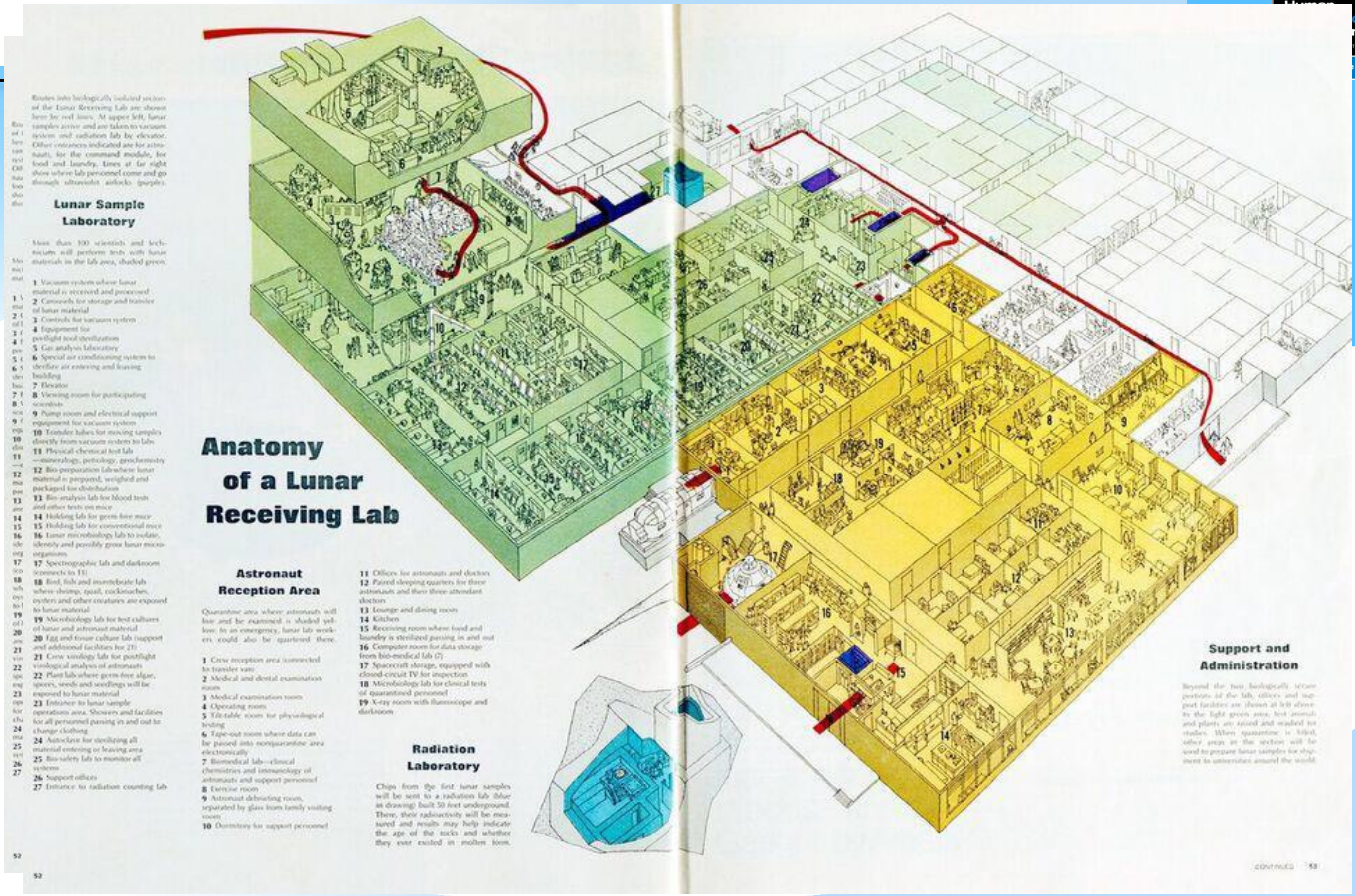
Shuttle Launch : Speed of Rocket

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).

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 Carousels for storage and transfer of lunar material
3 Controls for vacuum system
4 Equipment for postflight 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

Anatomy of a Lunar Receiving 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 and Administration

Beyond the two biologically secure portions of the lab, offices and support facilities are shown at left above. In the light green area, test animals and plants are raised and readied for studies. When quarantine is lifted, other areas in the section will be used to prepare lunar samples for shipment to universities around the world.

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CONTINUED 53

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.