Human Space Exploration : Challenges and Opportunities

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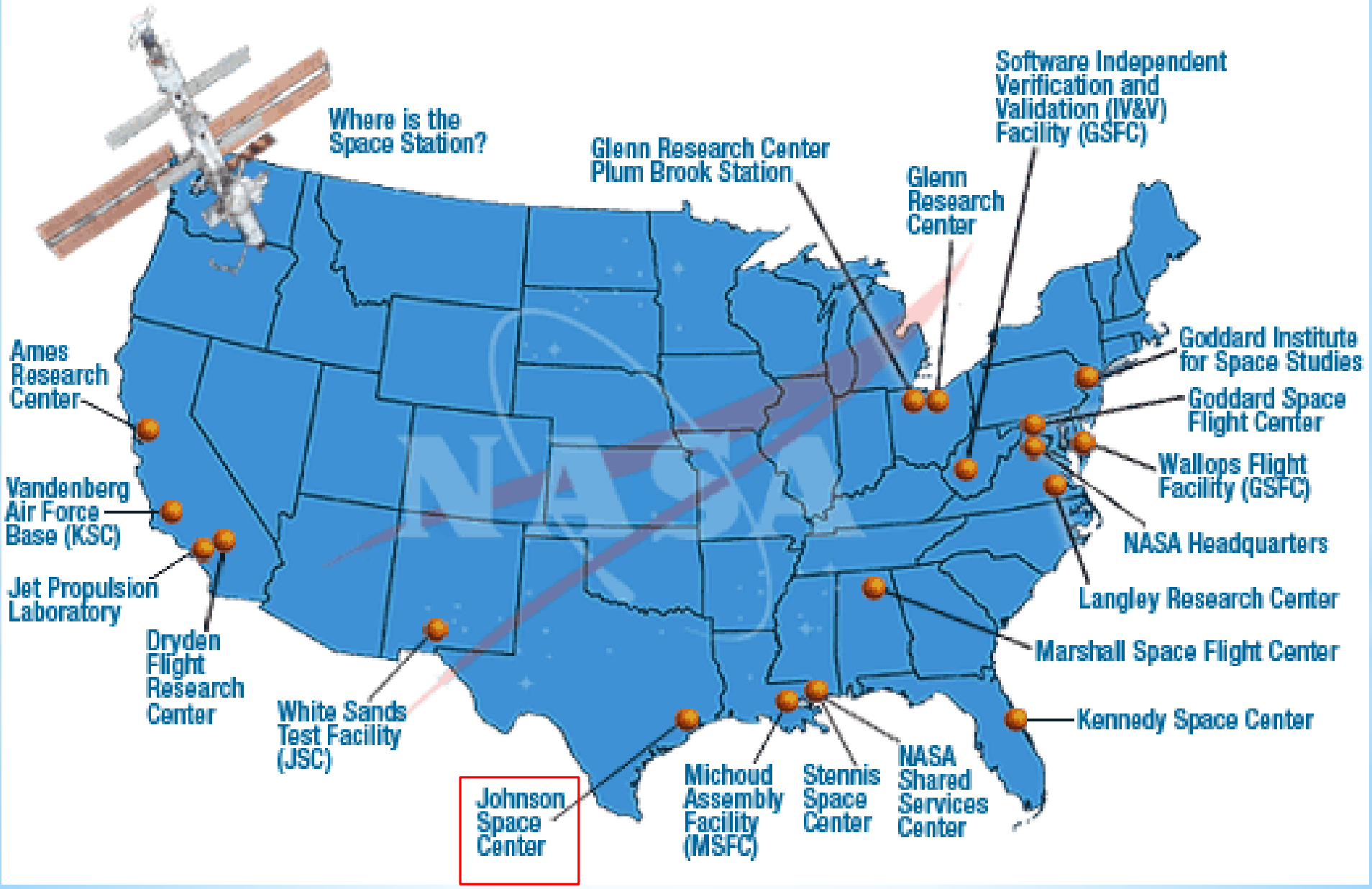
Objectives

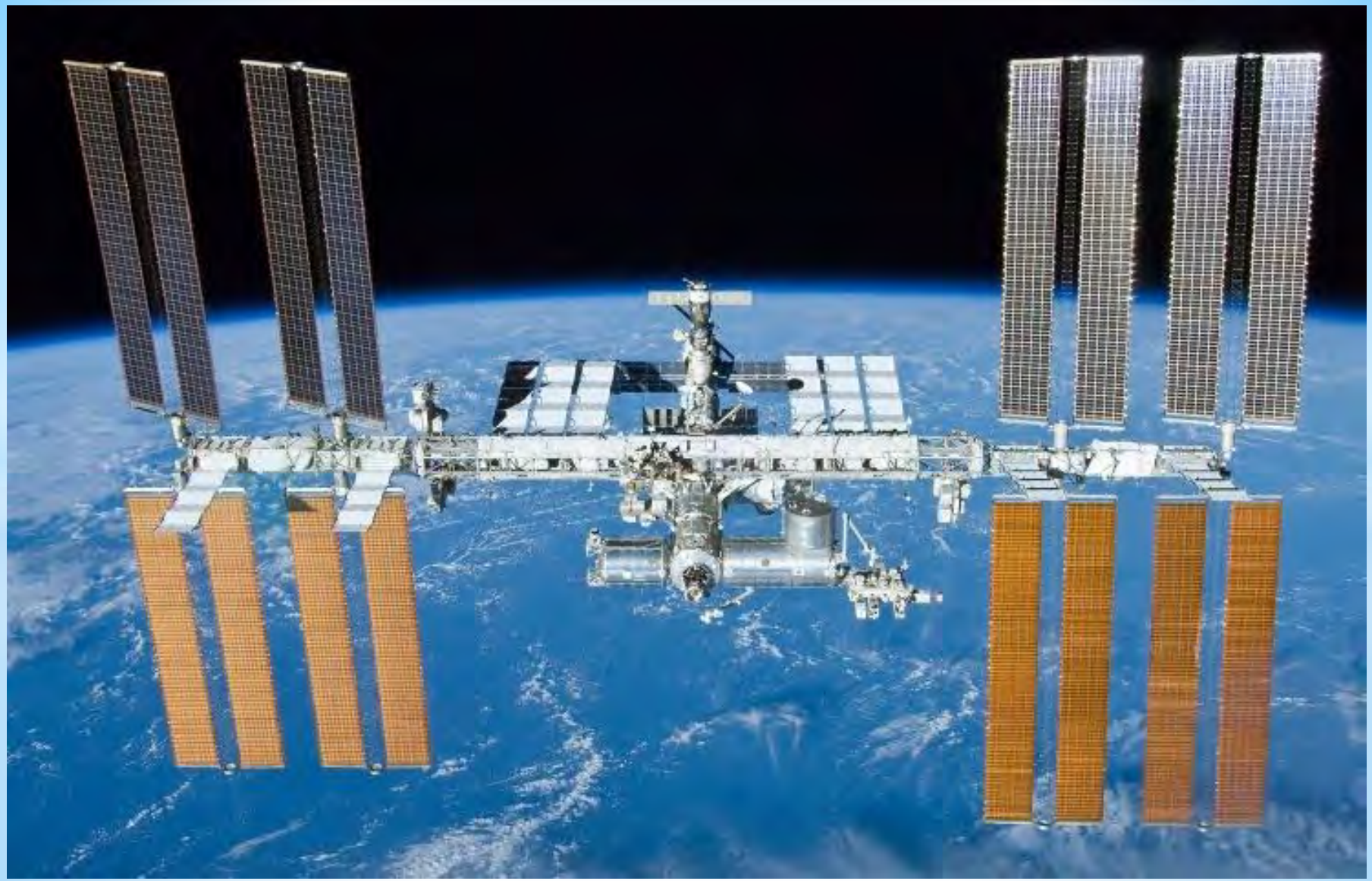
- Where are we in the Universe?
- What does it take for humans to go to Mars?
- Challenges and Opportunities
- More importantly, an attempt to answer all of your questions

NASA Centers



Our Habitation at Night

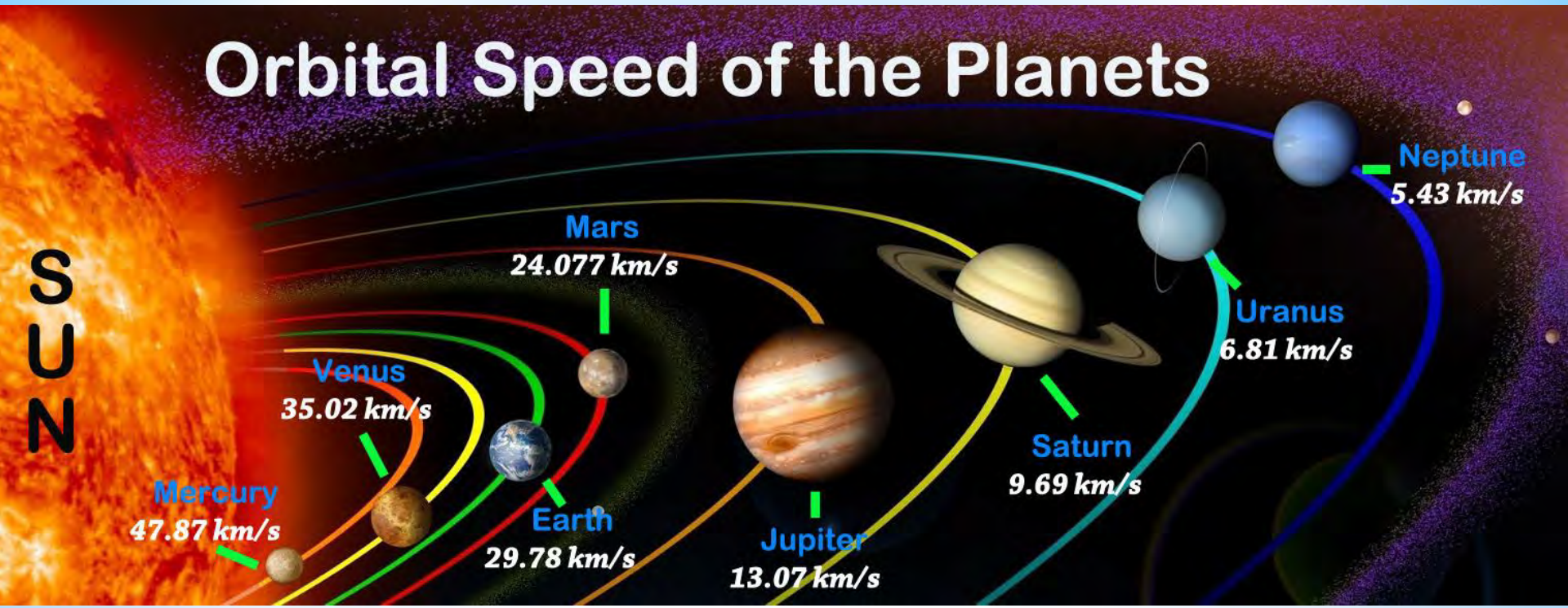
Our Planet from ISS (~250 miles)



Beautiful Fragile Blue Planet (~250,000 miles)

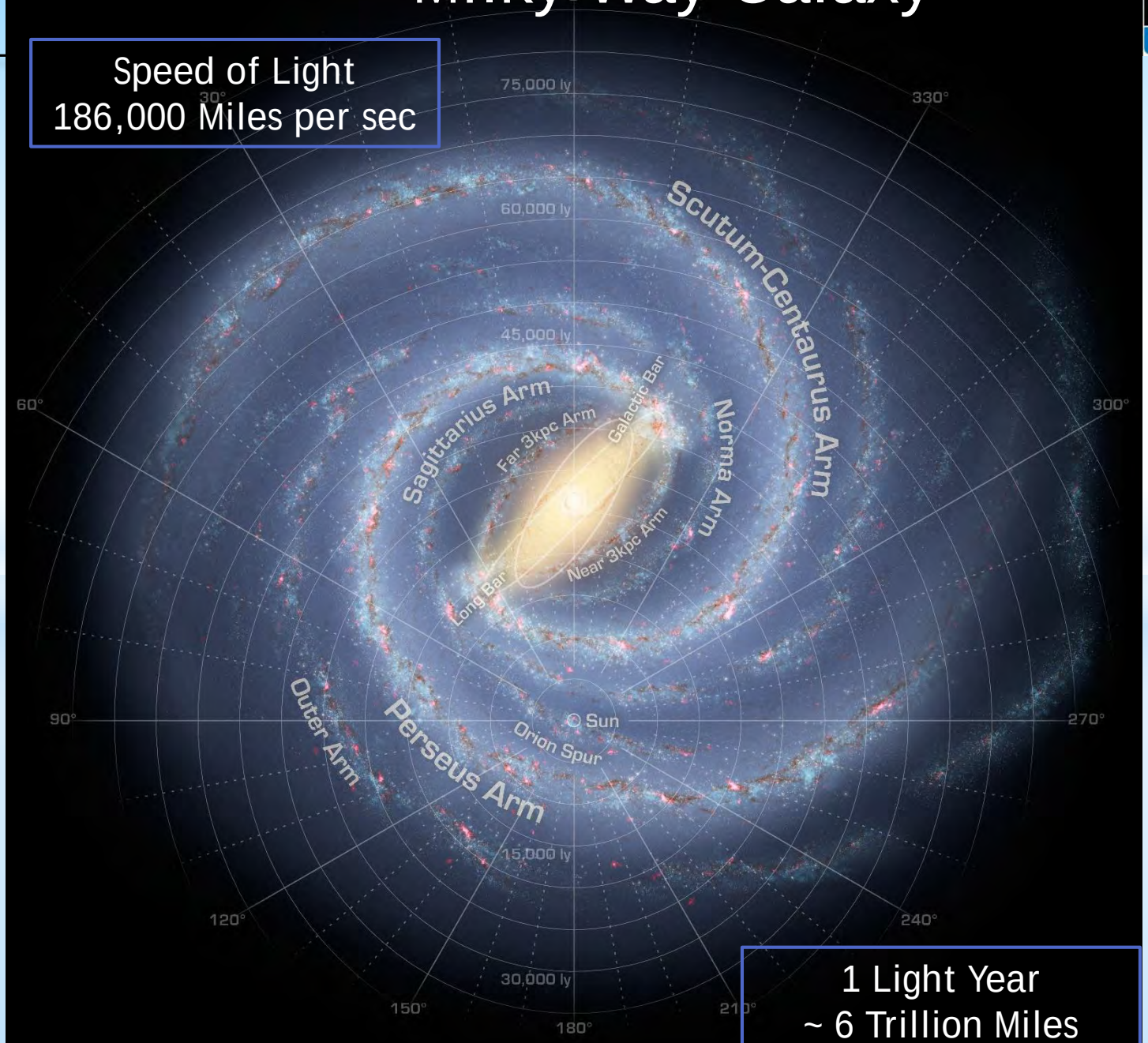
Mars - Earth Mutual View (~250,000,000 miles)

Solar System



Milky Way Galaxy

Speed of Light
186,000 Miles per sec



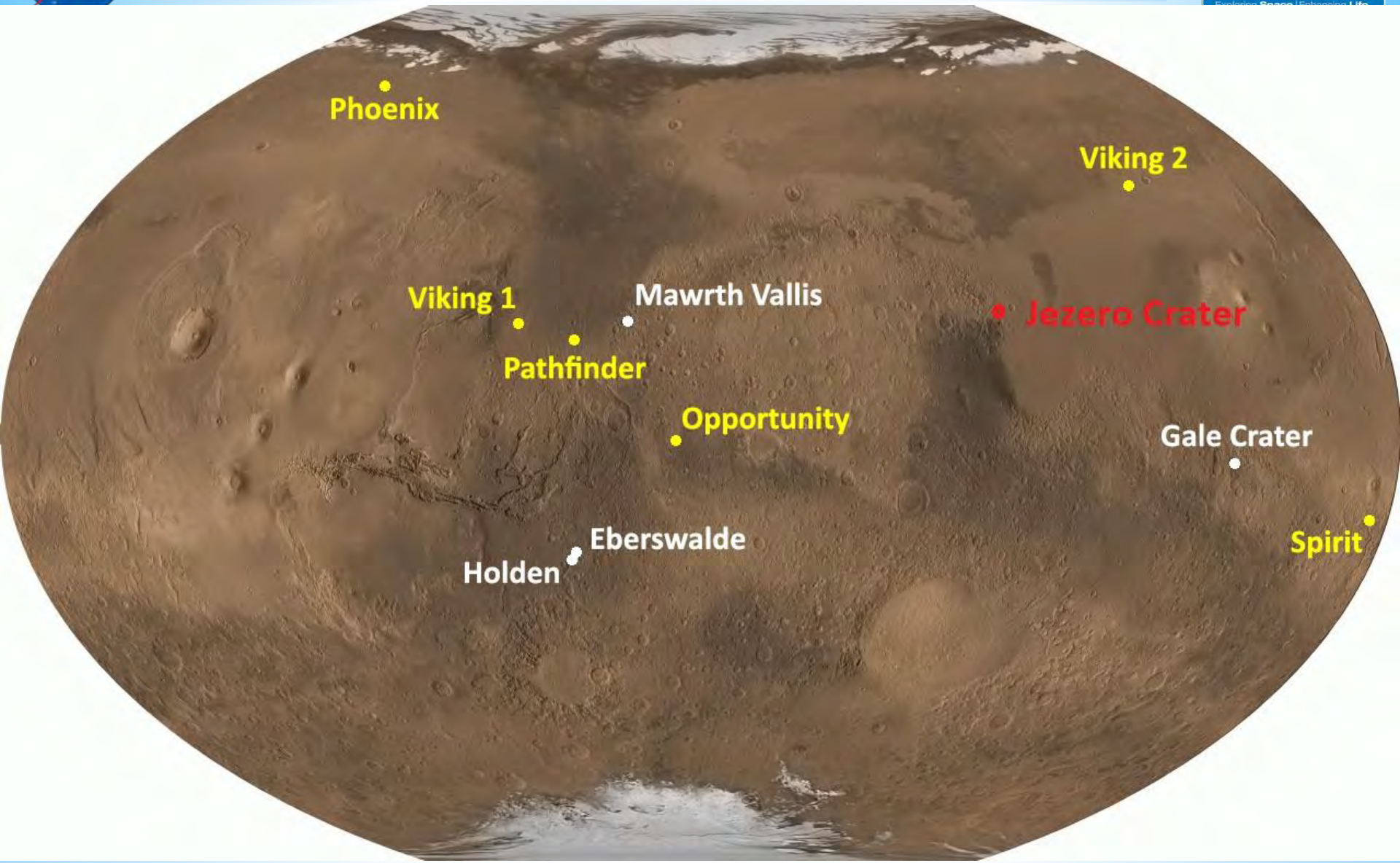
1 Light Year
~ 6 Trillion Miles

Milky Way from Earth
Top from Lebanon and Bottom from Chile

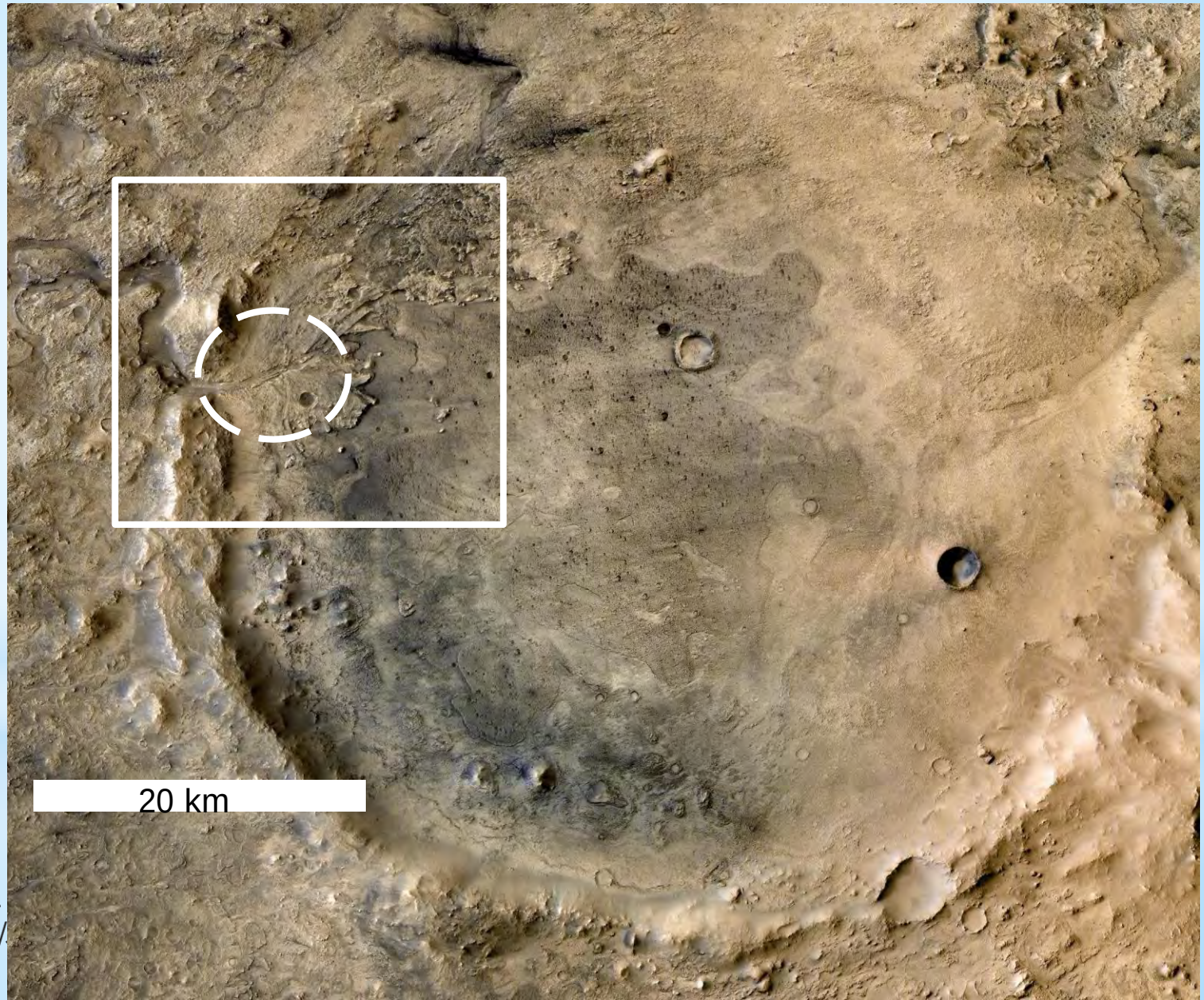
Hubble Telescope Repair Mission Crew (STS-125)

Webb Telescope

Mars Landing Sites

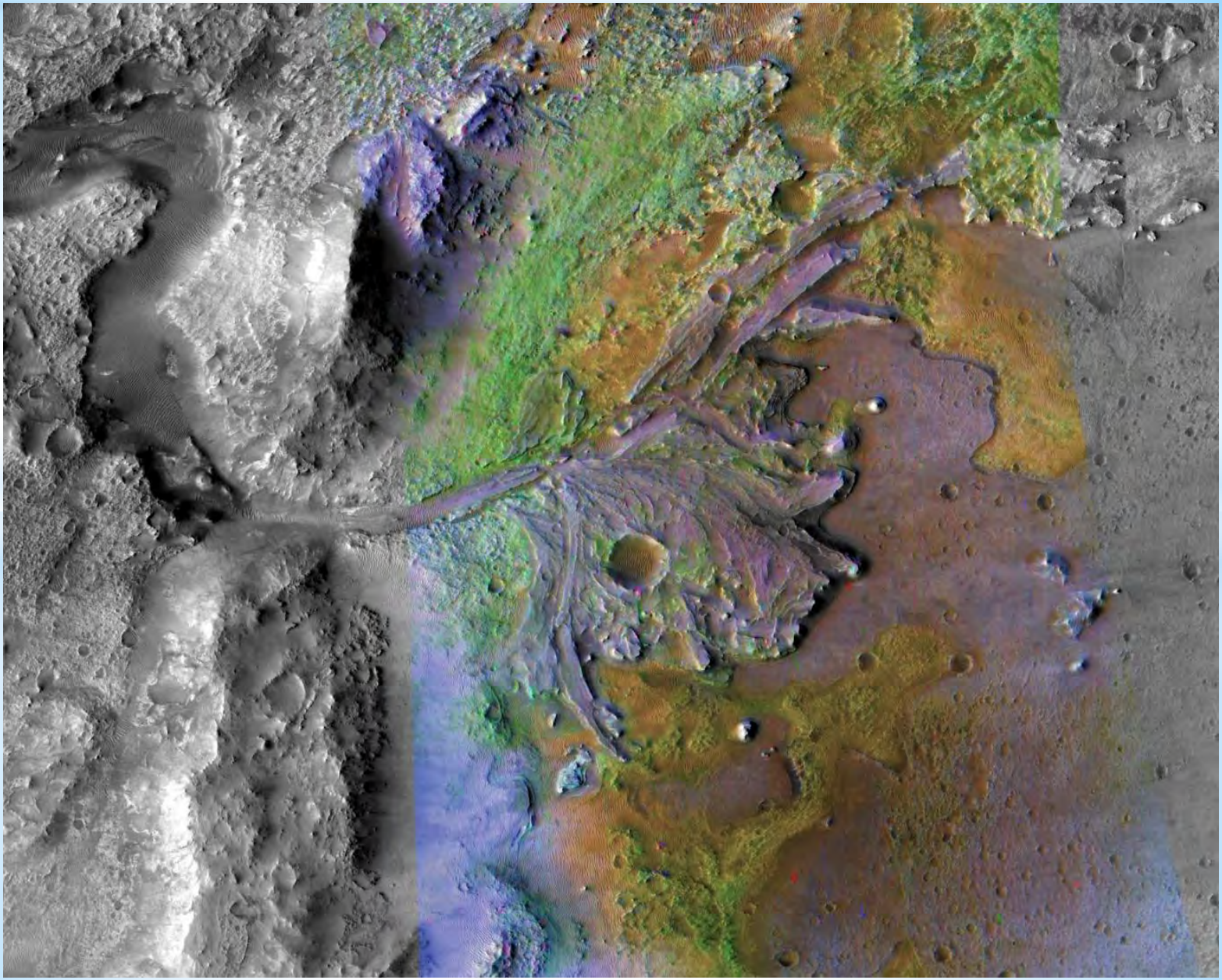


Mars 2020 : Jezero Crater

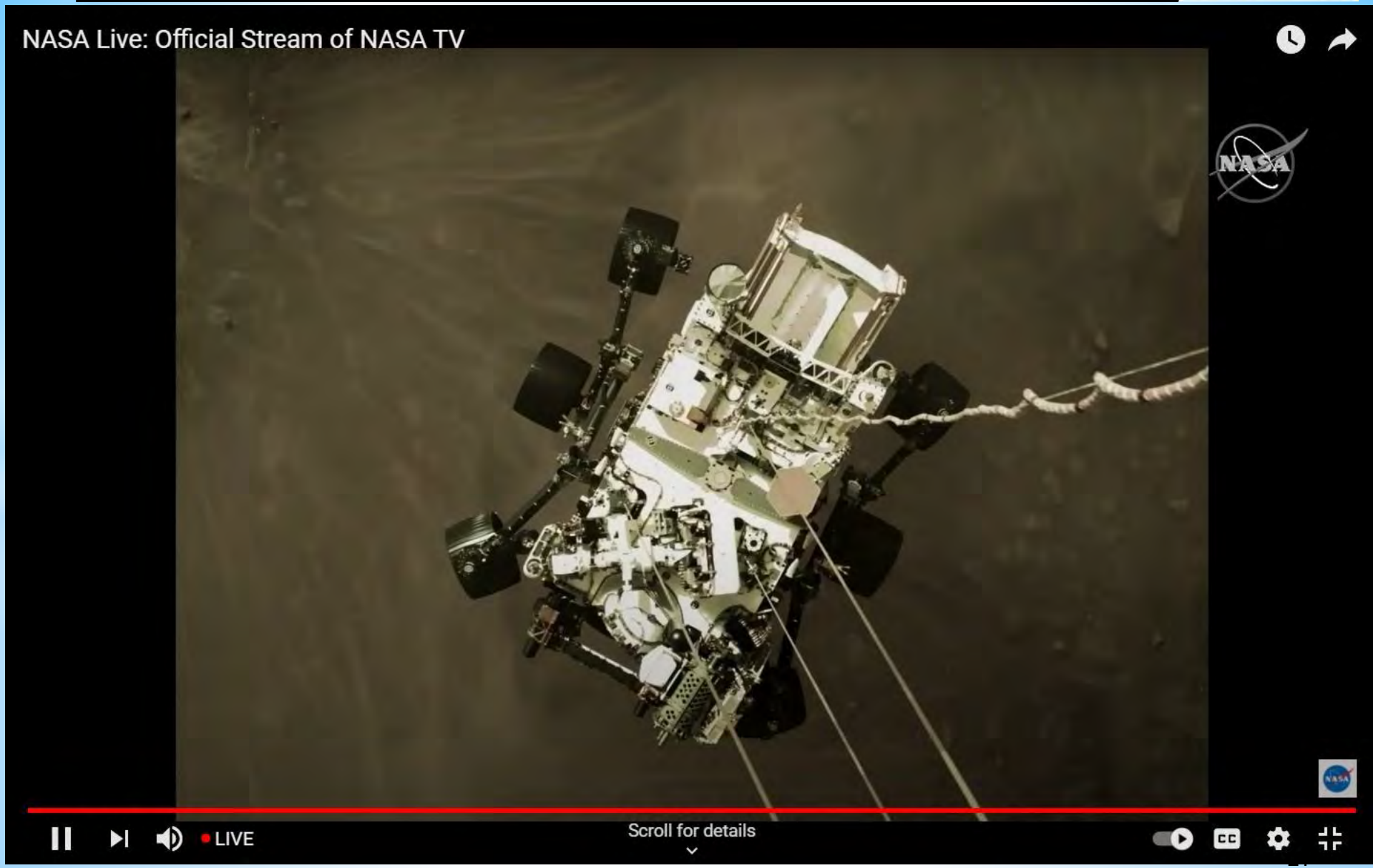


Credit: NASA / JPL
DLR / FU Berlin /

Mars 2020 : Jezero Crater

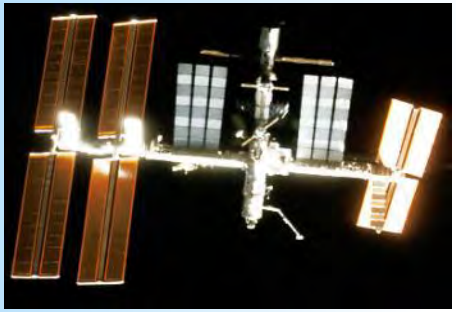


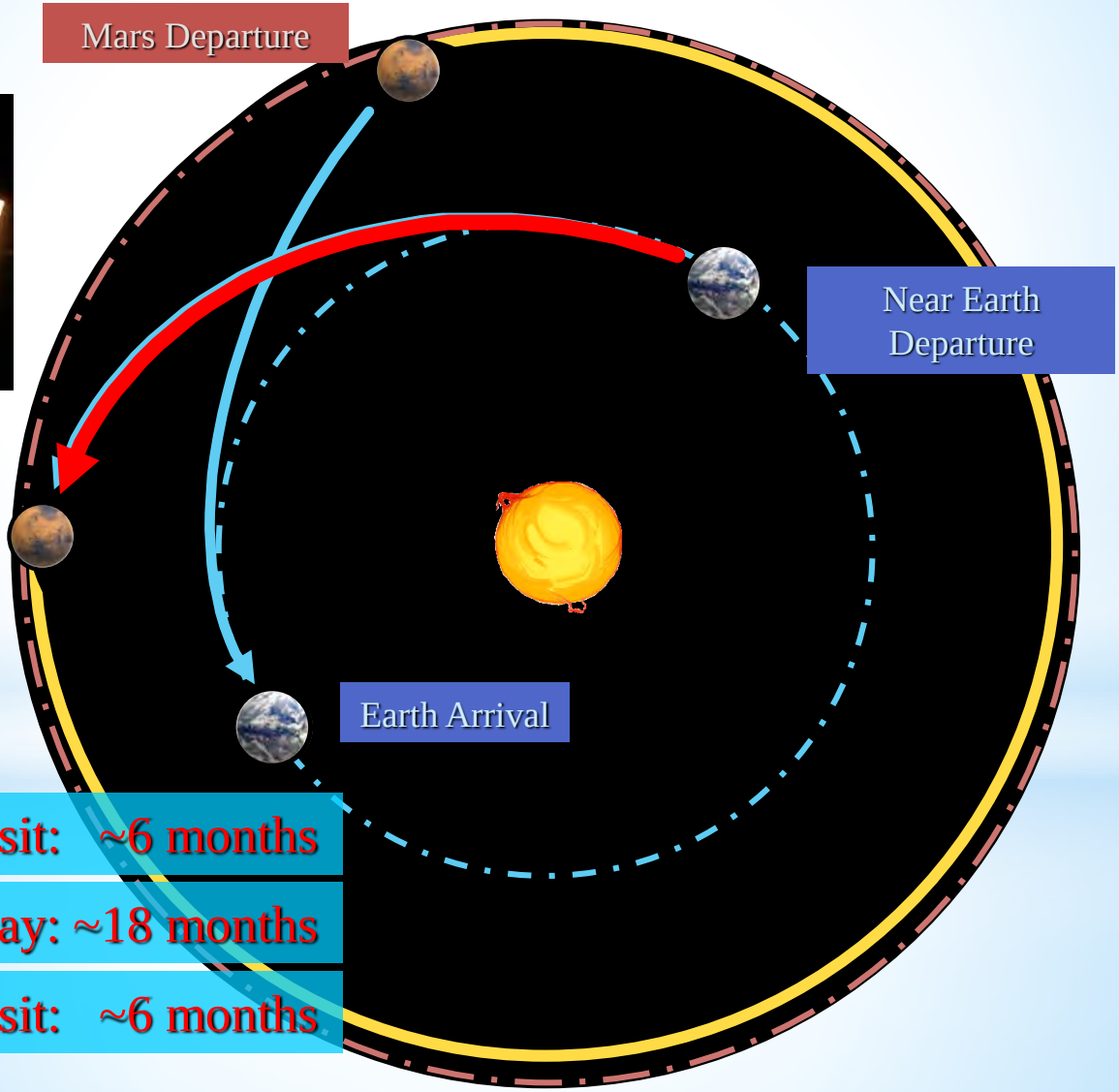
Perseverance Landing



minutes-of-terror/

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 462ºC (864ºF) 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 20ºC (70ºF) 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

Resources and Recycling

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

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

Today's Coffee - Yesterday's Coffee

Carbon Dioxide Removal

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

- Oxygen Generation System (Electrolysis)

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

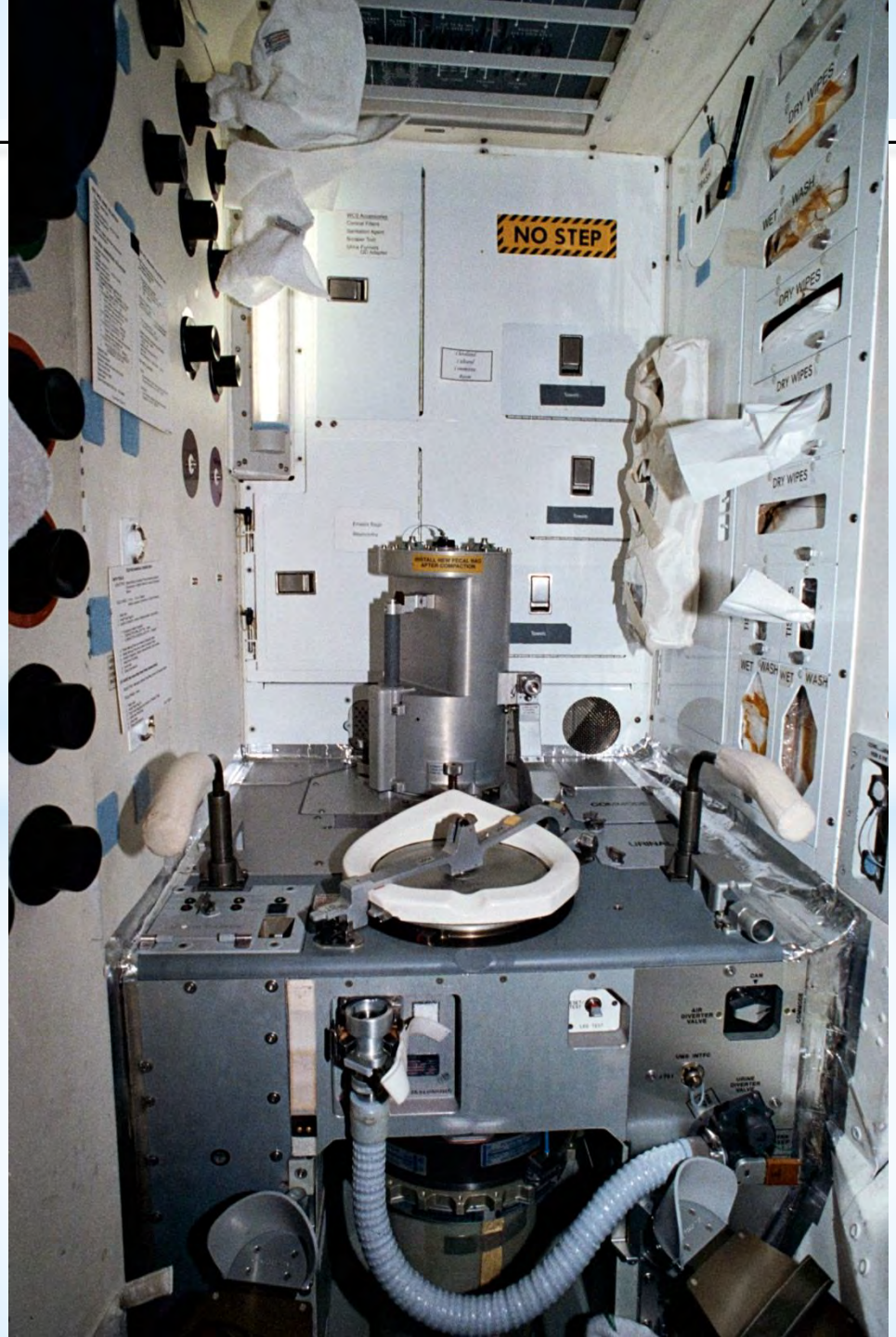
- Sabatier Reaction

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

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

Hygiene

Hair-do


NO STEP
DRY WIPES
WET WASH

Dinner at his Lap

Salt and Pepper

One of the Favorite Foods

Yummy Dinner

Scott Kelly (1 Year Mission) Twin Studies

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

Weightlessness

Weightlessness

Super-Woman

Sleep

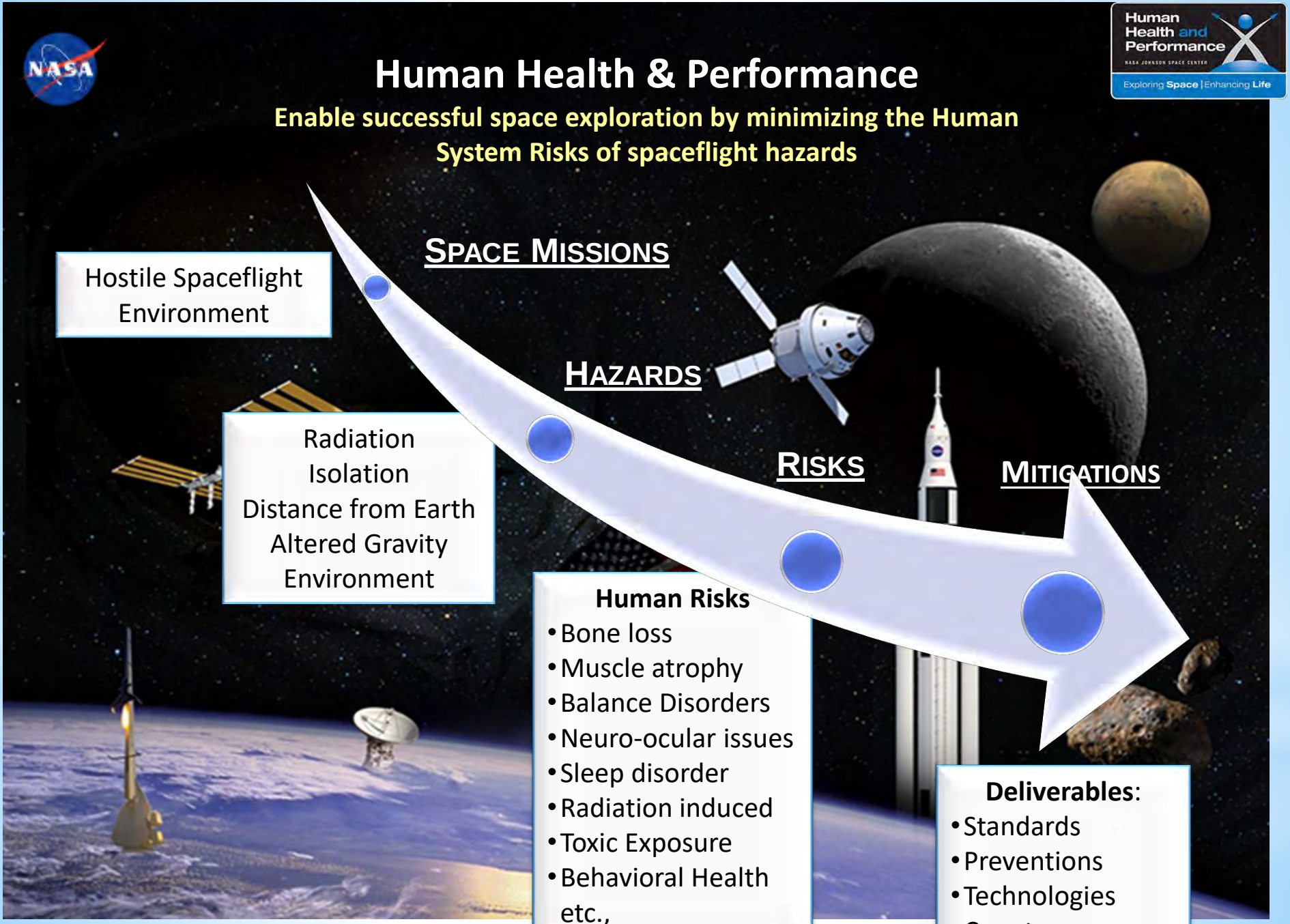
Air Quality Monitoring

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

Human Health & Performance

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



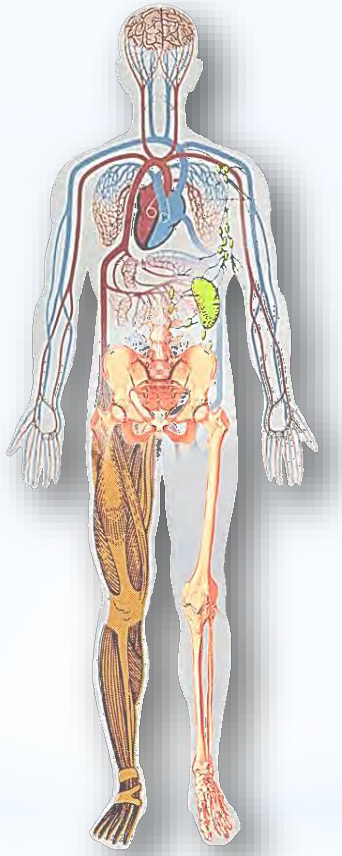
Hazards of Spaceflight (RIDGE)
Hazards Drive Human Spaceflight Risks

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

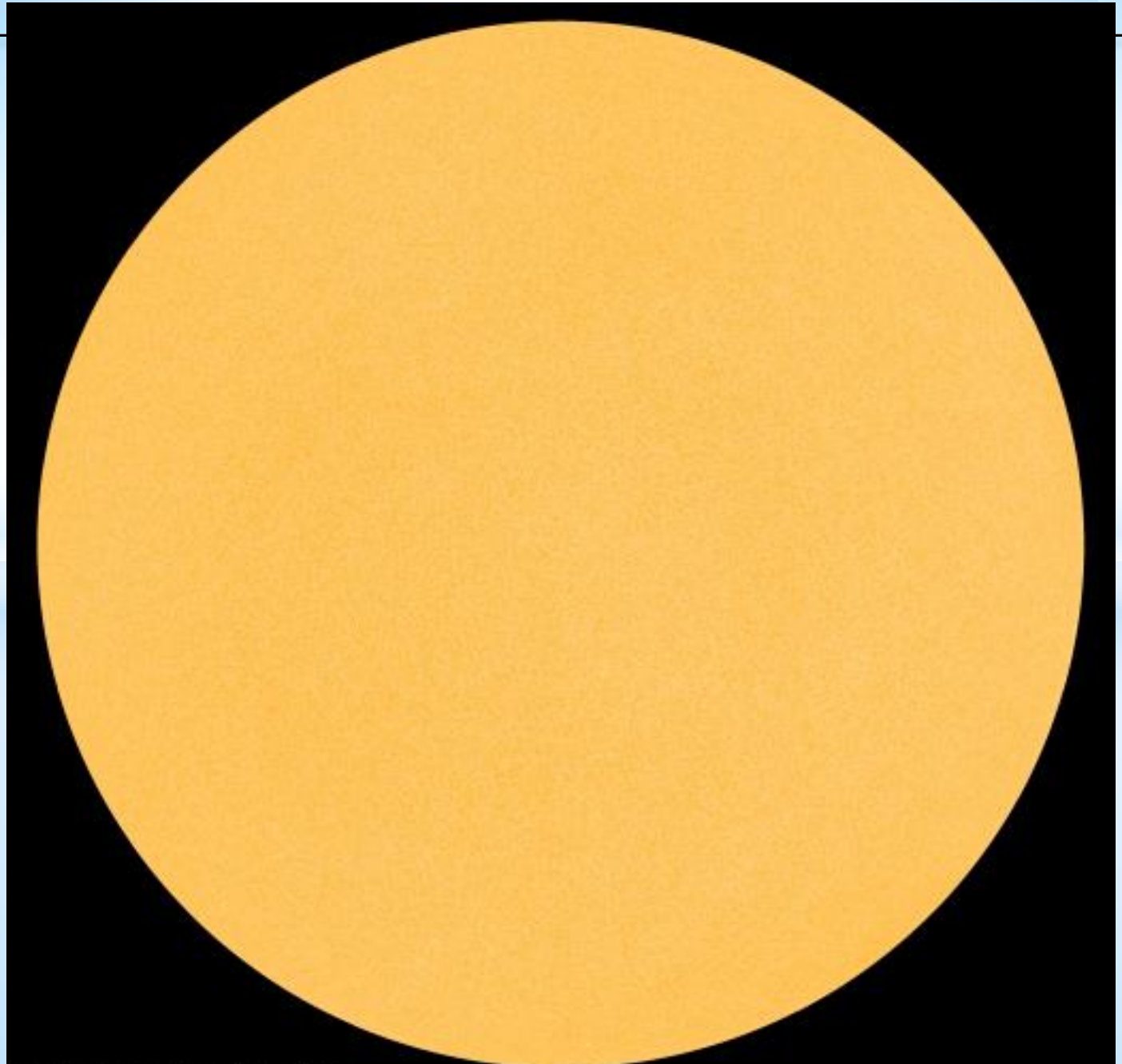
Altered Gravity - Physiological Changes

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

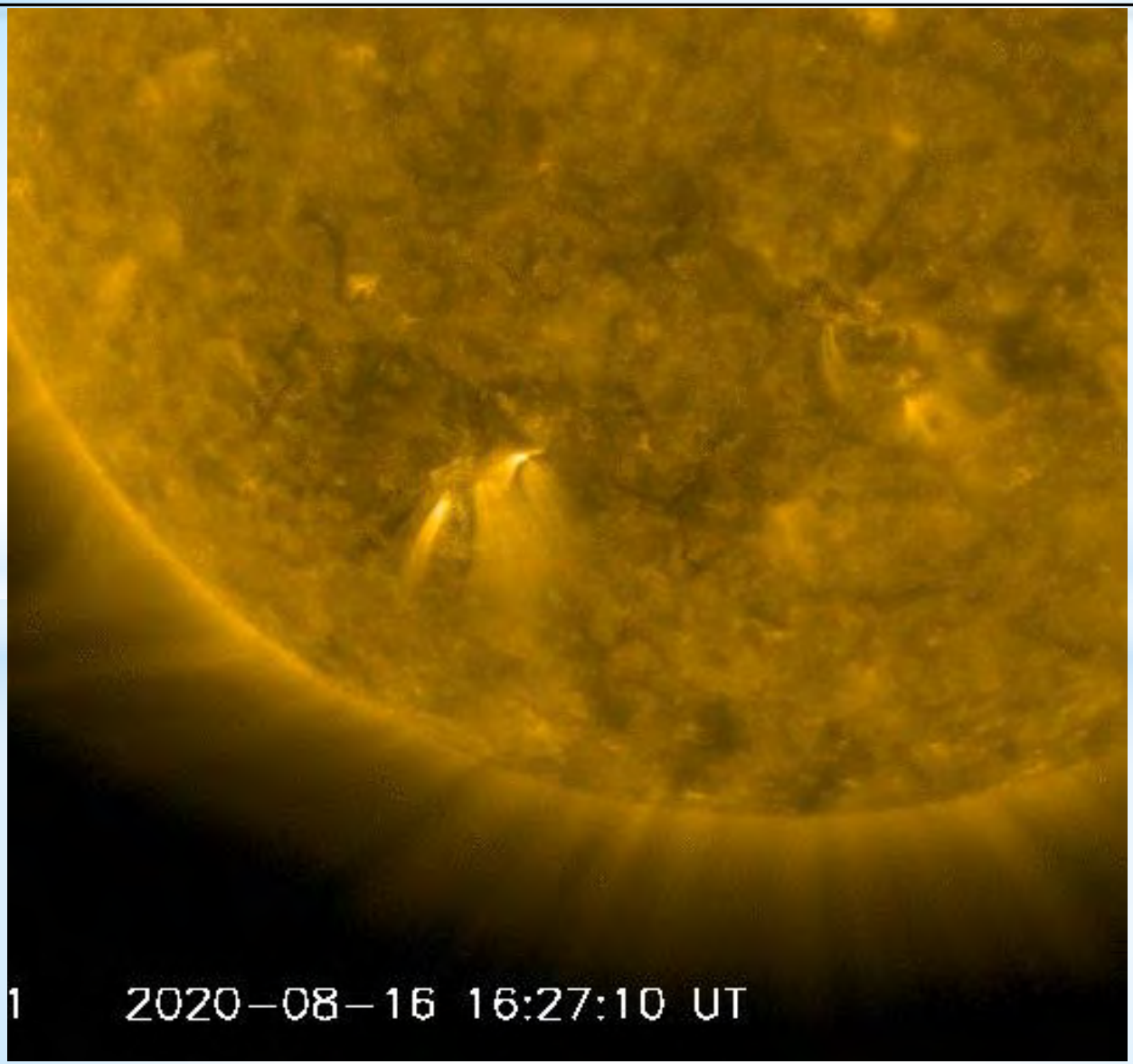
Environment (Closed/Hostile)

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

Spotless Sun 2019

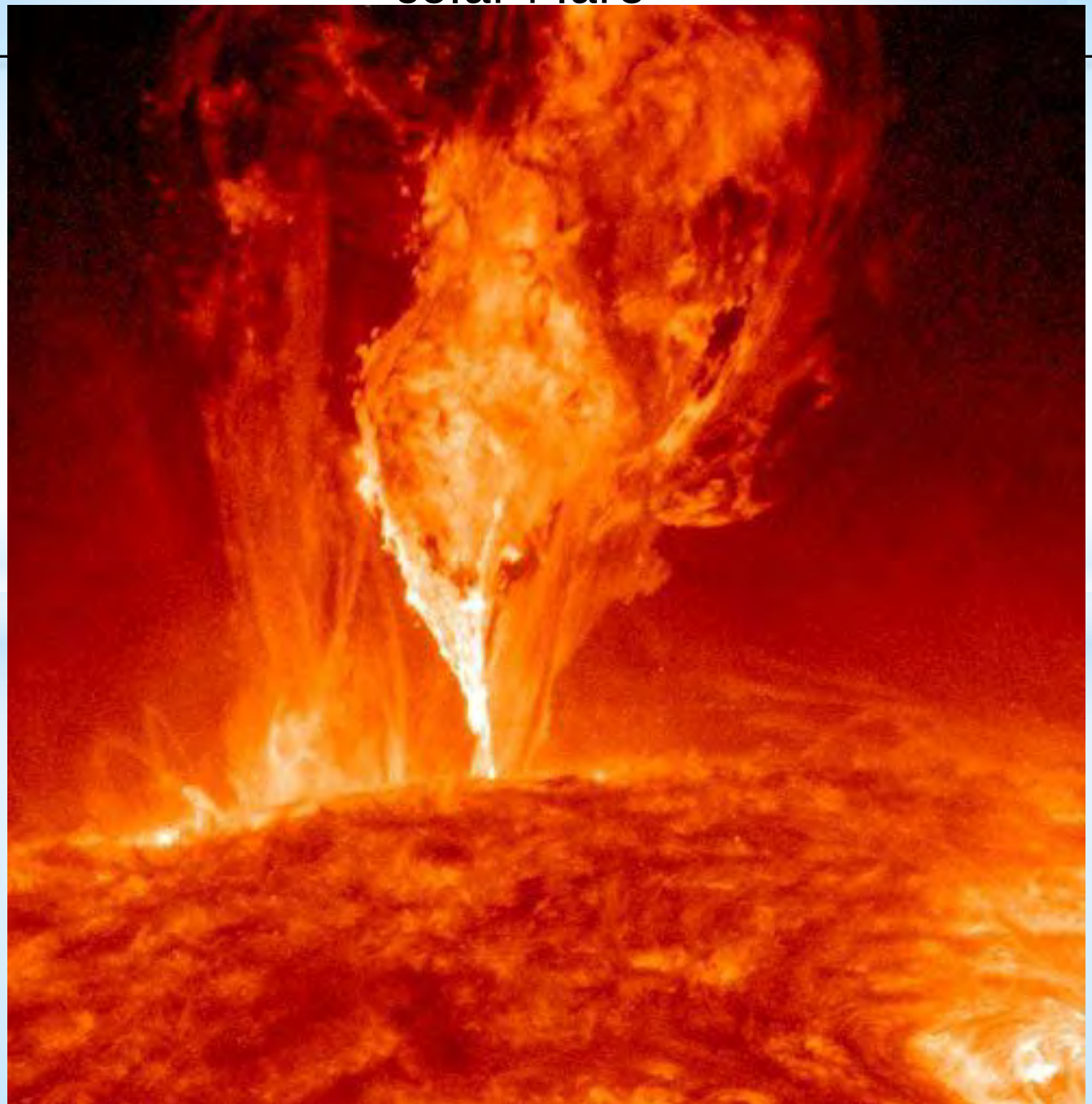


Solar Flare Aug 16, 2020



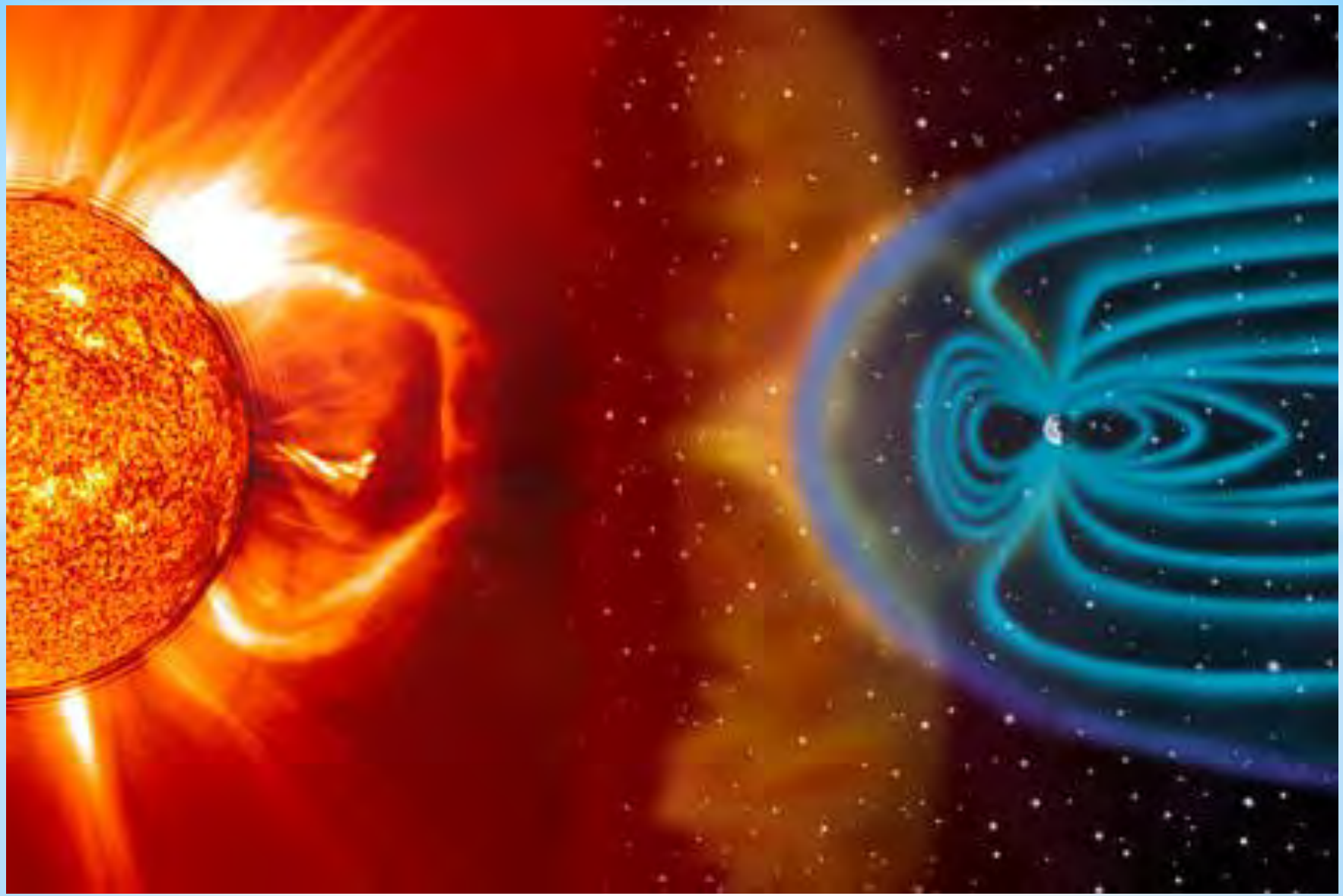
https://spaceweather.com/

Solar Flare



Solar Flare and Earth (Size Comparison)

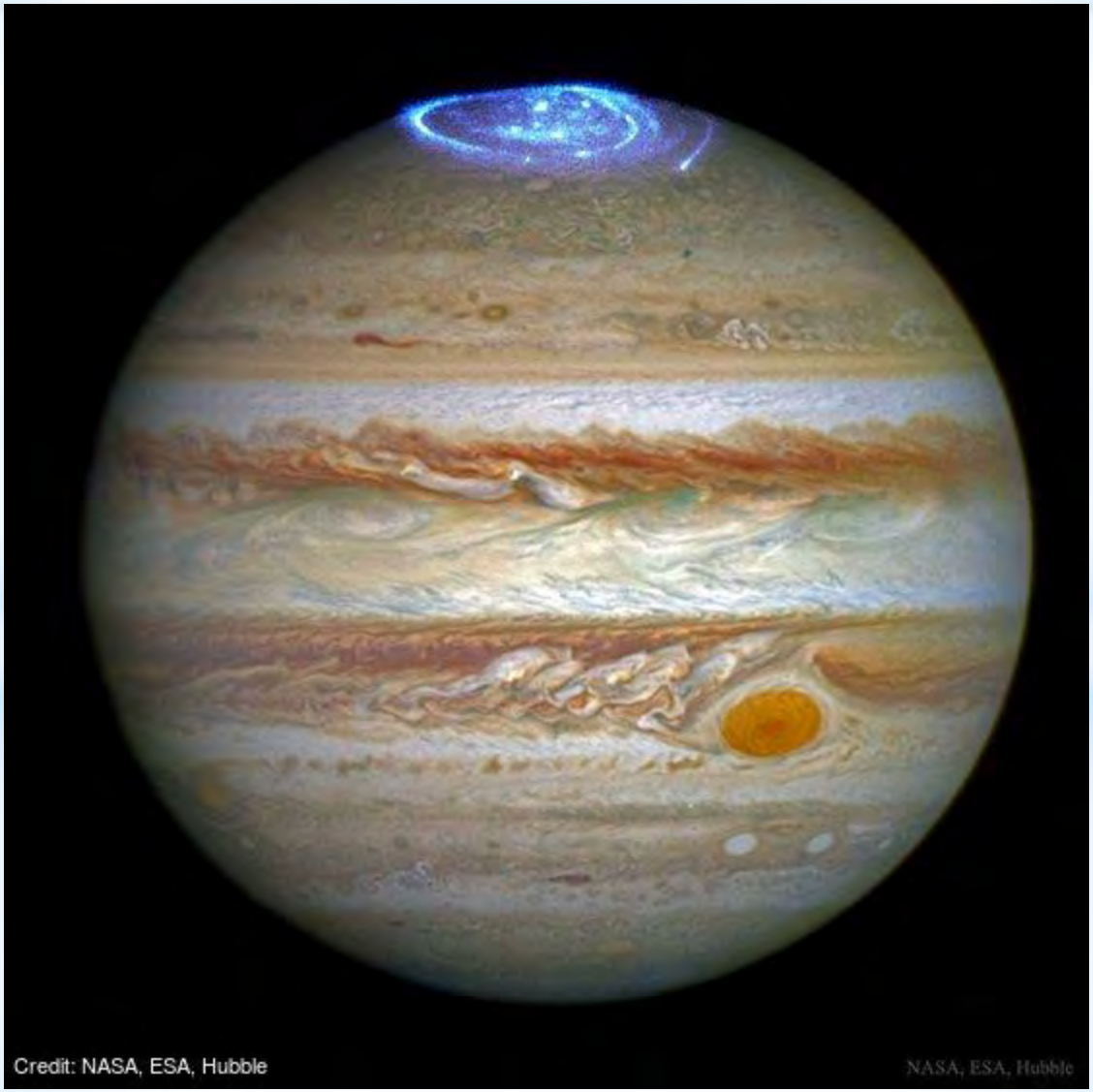
Solar Flare and Earth's Magnetic Field



Aurora from Northern Hemisphere

Auroras from ISS

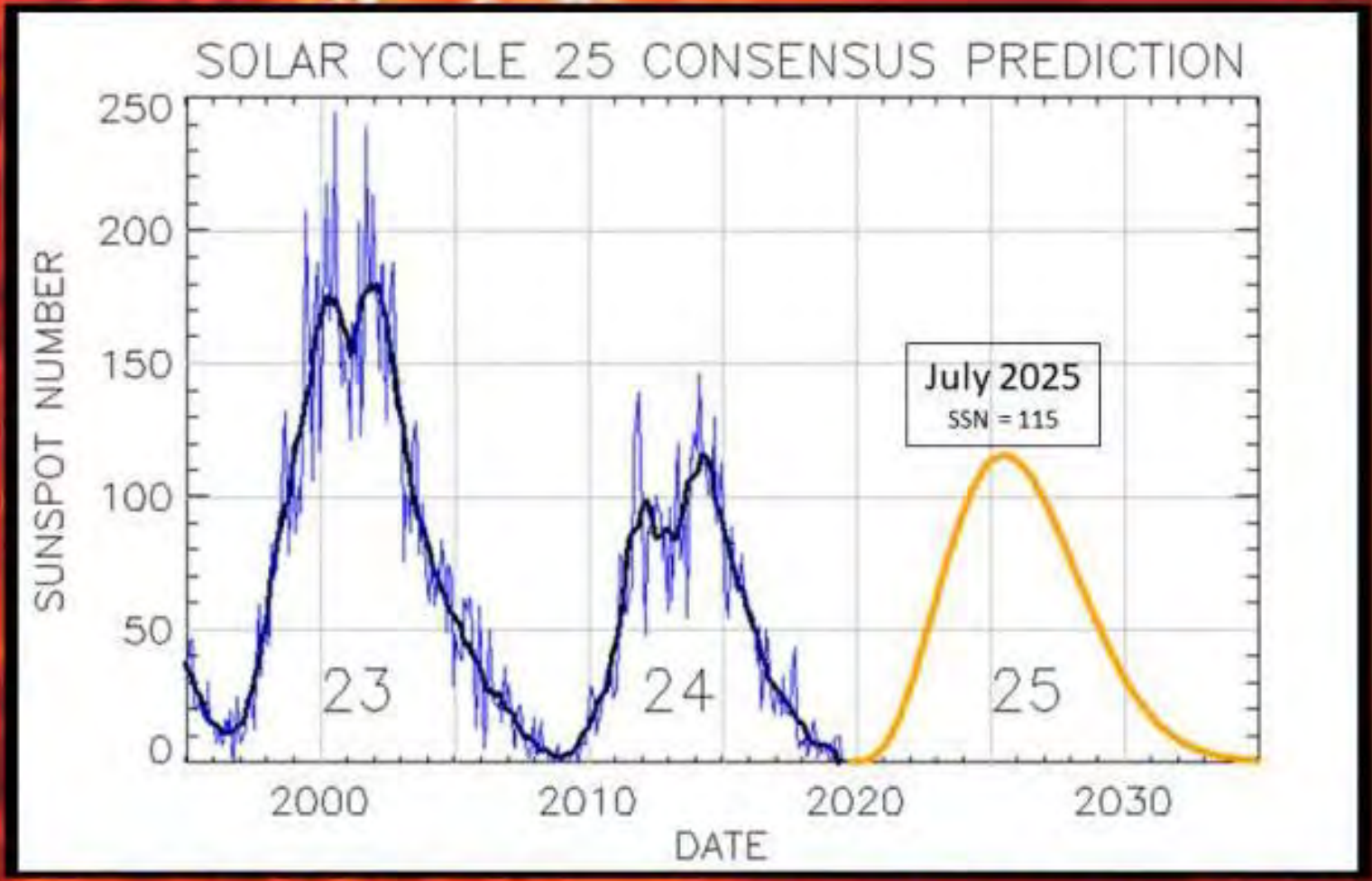
Aurora at Jupiter



Aurora at Saturn

Solar Cycle 25 Forecast Update

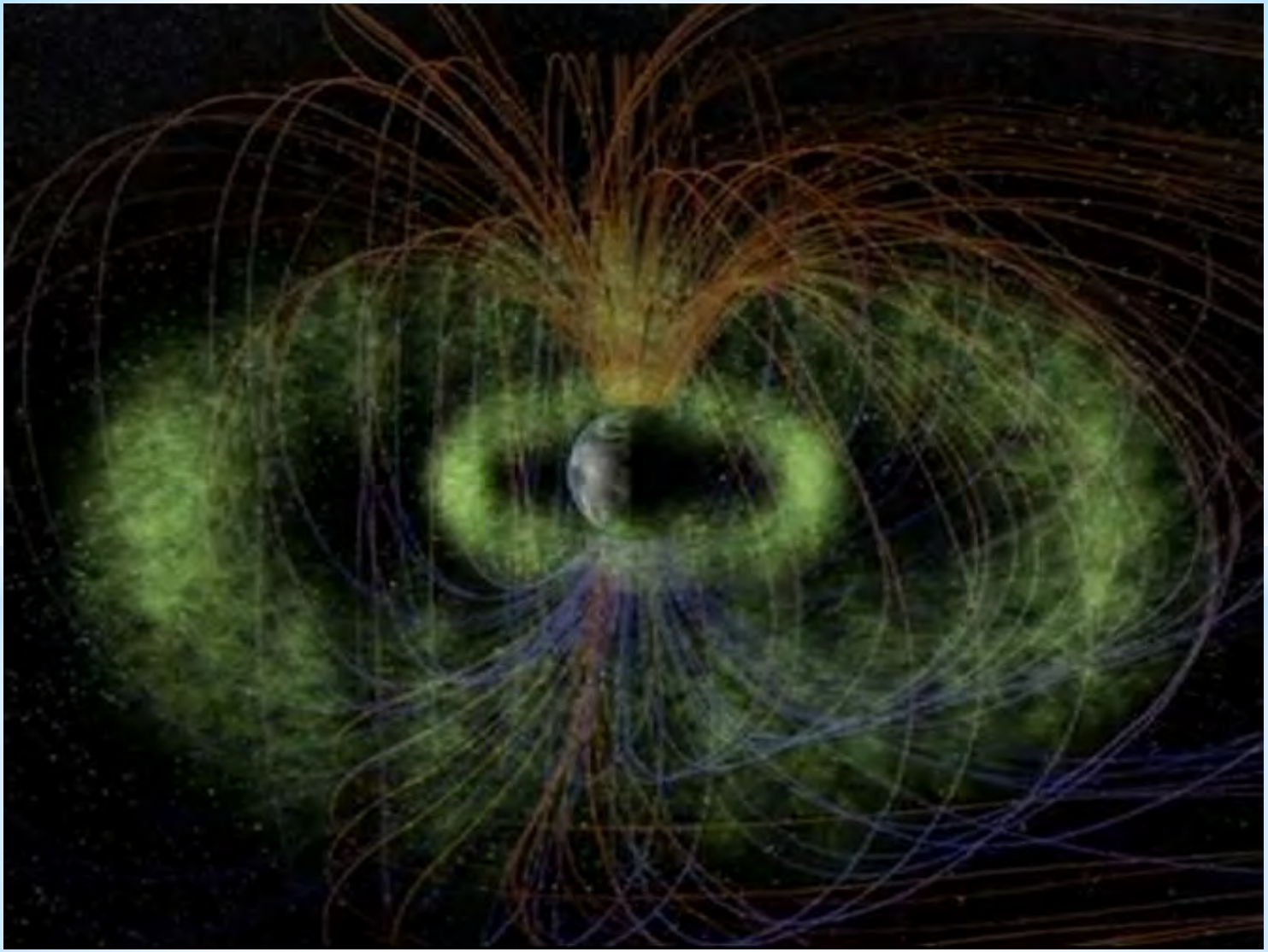
- Released December 9th, 2019 -



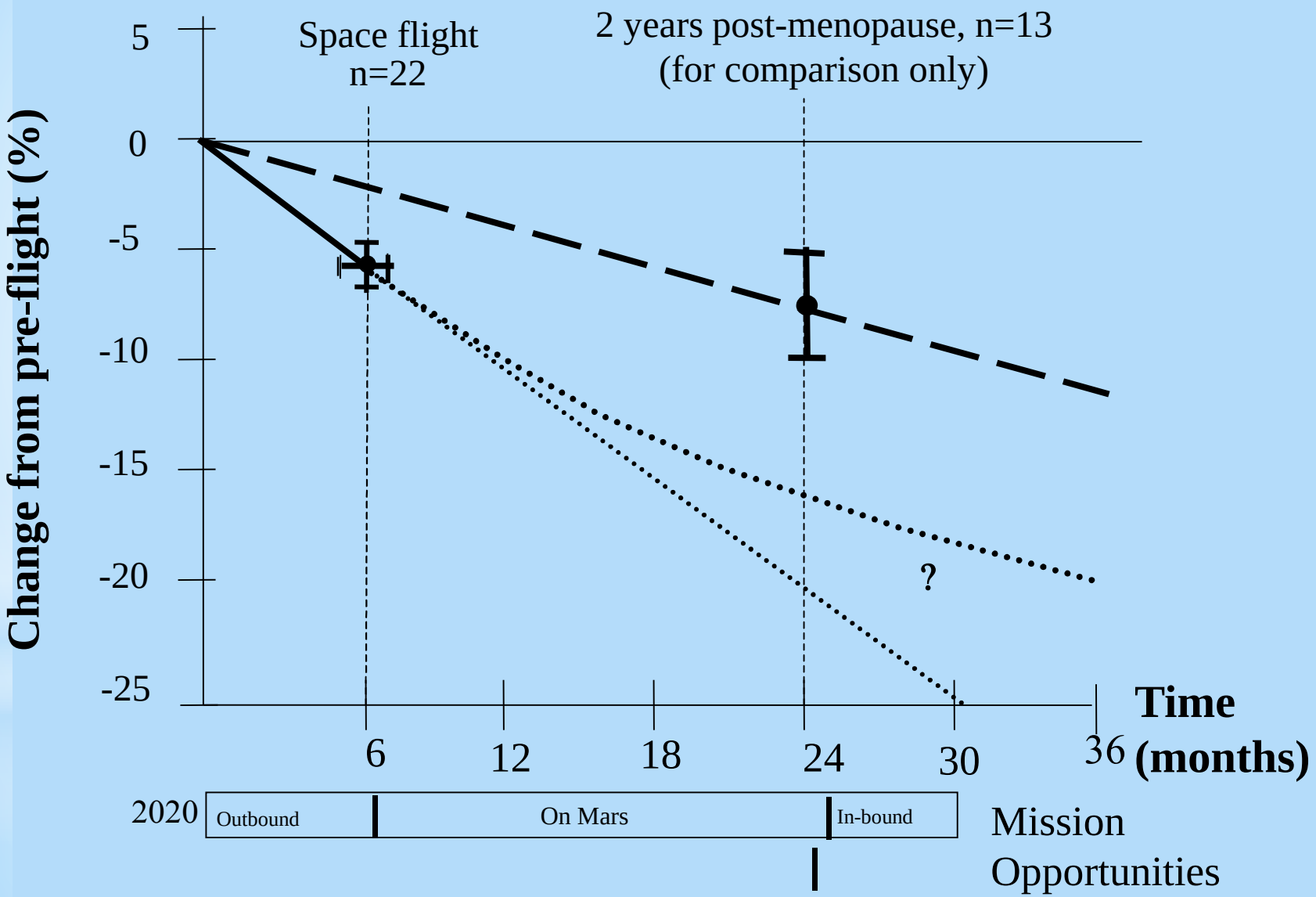
Solar Cycle 25 will have a peak SSN of 115 (± 10) in July 2025

Solar Cycle 24/25 minimum will occur in April, 2020 (± 6 months)

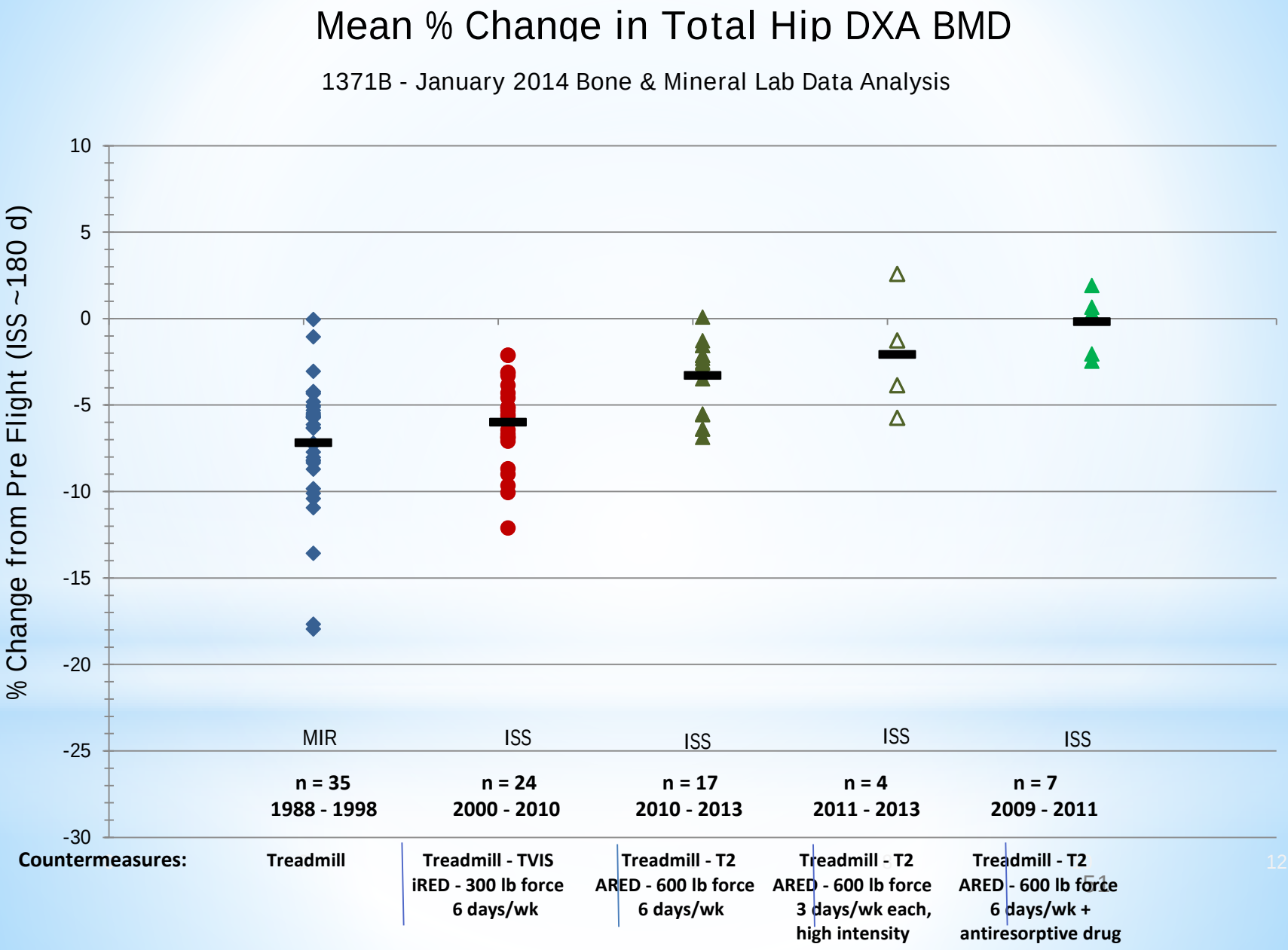
Van Allen Belt



Bone Loss During Space Missions



Risk of Bone Fracture due to Spaceflight-induced Changes to Bone



ISS026E018823

Resistive Exercise Device

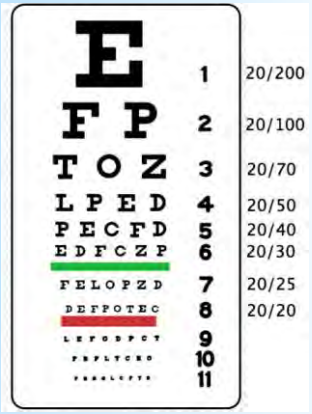
Treadmill in International Space Station

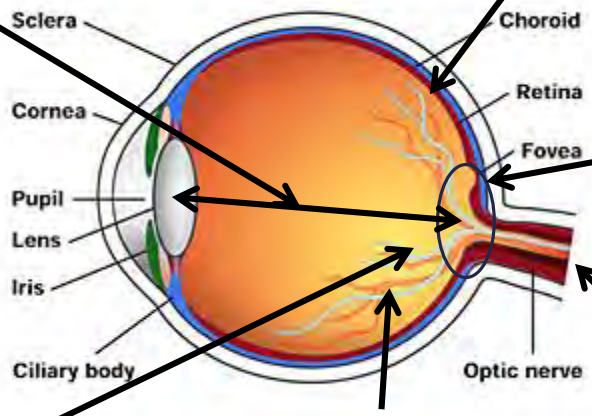
Fluid Shift Induced Puffiness

Integrated Visual Impairment/Intracranial Pressure

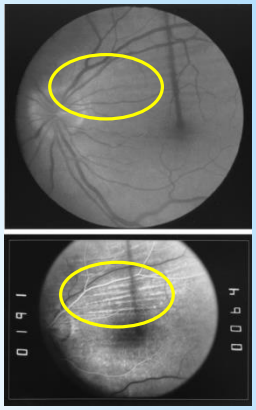
Macias, JAMA Opthalmology, 2020

- Hyperopic Shifts
  - Up to +1.75 diopters

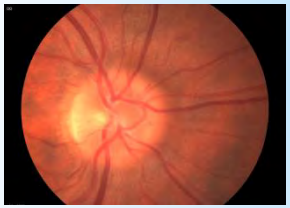




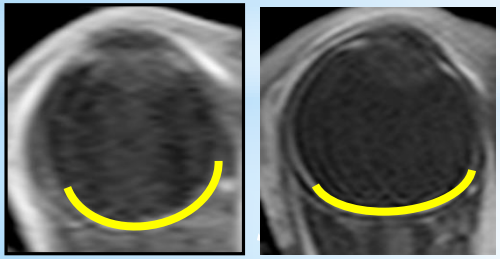
- Choroidal Folds - parallel grooves in the posterior pole



- Optic Disc Edema (swelling)



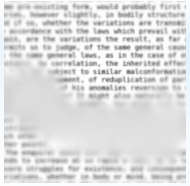
- Globe Flattening



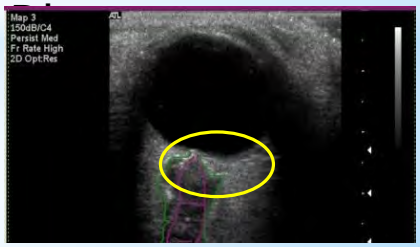
Normal Globe | Flatten Globe

MRI Orbital Image showing globe flattening

- Altered Blood flow
  - "cotton wool" spots

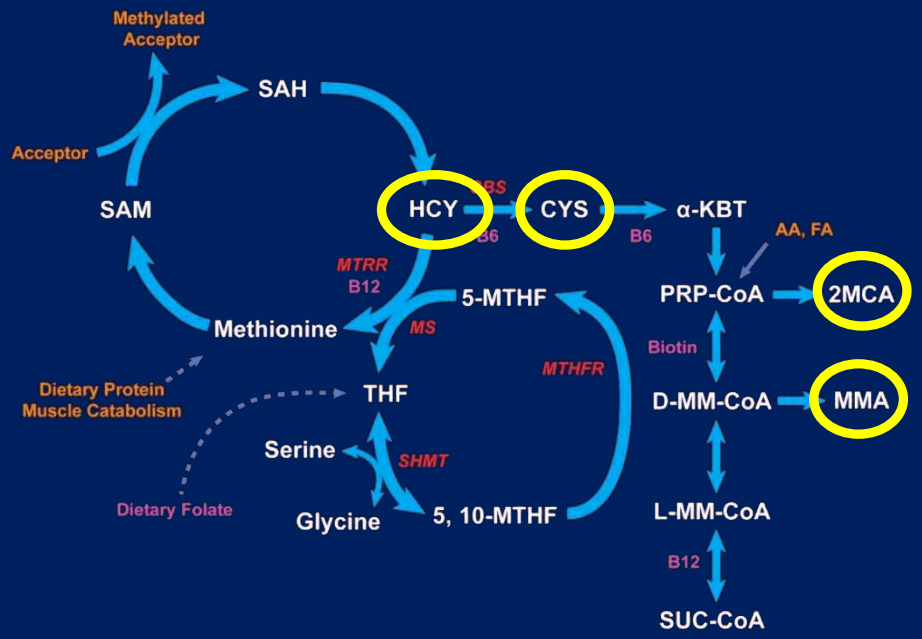


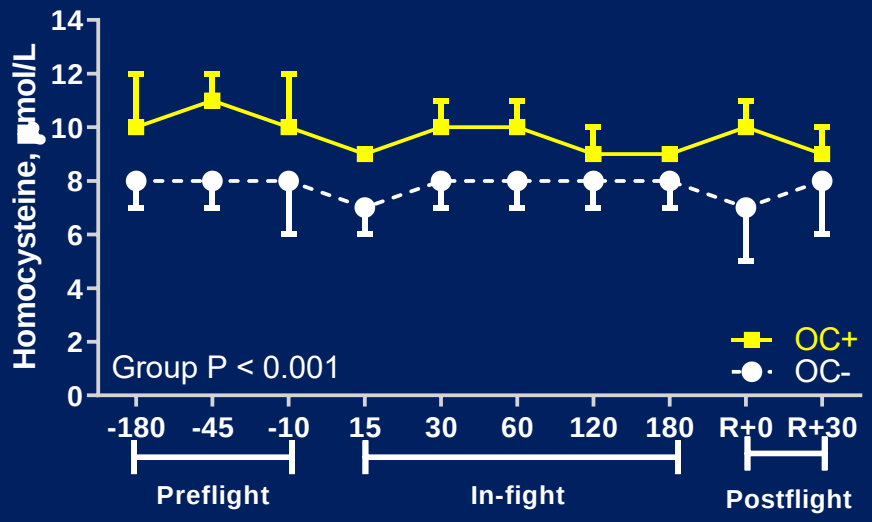
- Increased Optic Nerve Sheath



Addressing Critical Health Issues for Exploration- ISS research is necessary to address a recently discovered health issue related to long duration space exposure. As a result of elevated intracranial pressure in space, visual acuity changes are occurring in over 76% of astronauts.

Vision Issues During Long-term Space flight
Homocysteine



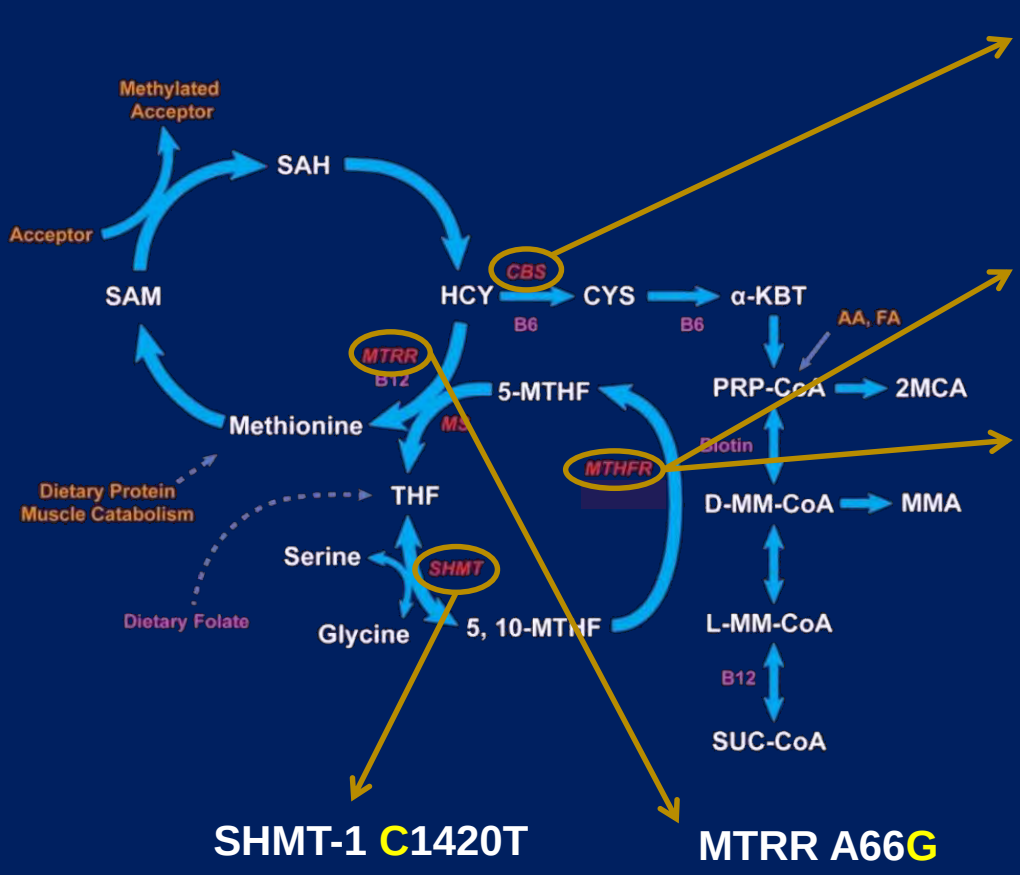


Astronauts with ocular changes had higher serum homocysteine concentration than astronauts without ocular changes. *Before* flight.

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



CBS 844ins68 (with T833C)

MTHFR C677T

MTHFR A1298C

SHMT-1 C1420T

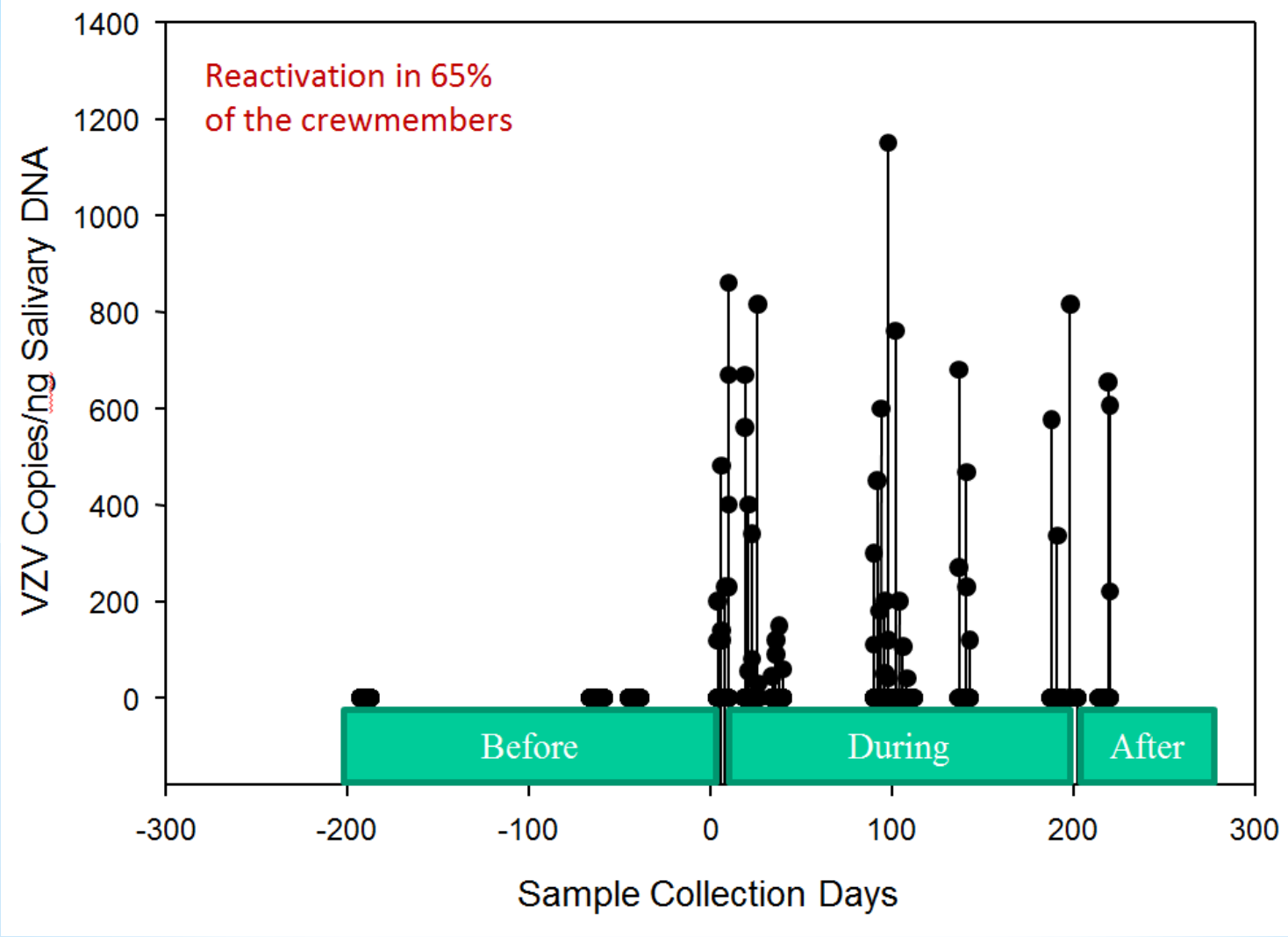
MTRR A66G

ENZYMES

VITAMINS

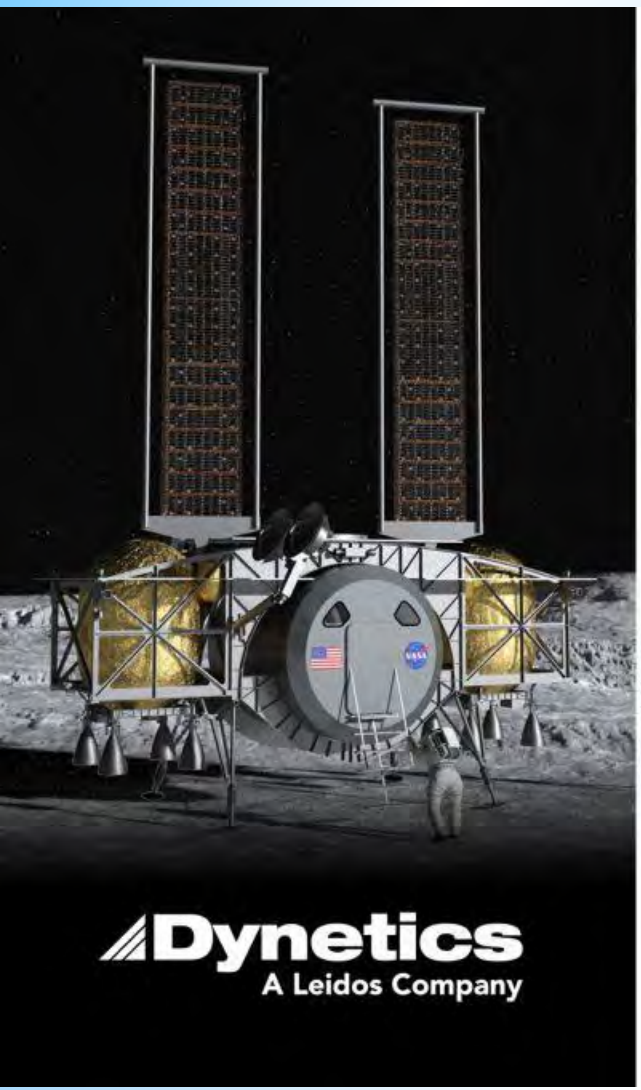
Zwart et al., *FASEB J*, 2016

Reactivation of VZV Virus in Astronauts



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

Moon Landing : 2024



Apollo Landing Sites

Apollo 11 JUL 69
Mare Tranquillitatis
0.67416°N 23.47314°E
LM: 21.6 hours EVA: 2.5 hours

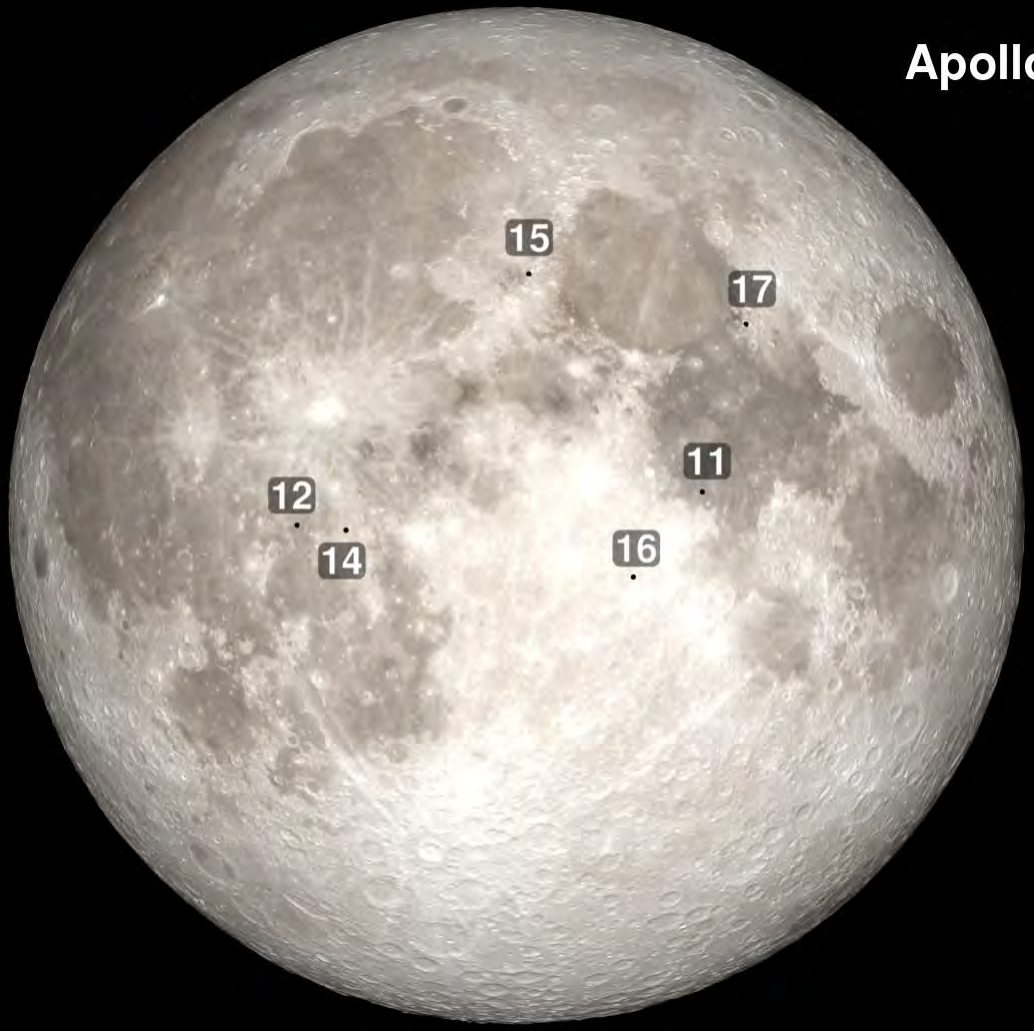
Apollo 12 NOV 69
Oceanus Procellarum
3.0128°S 23.4219°W
LM: 31.5 hours EVA: 7.8 hours

Apollo 14 FEB 71
Fra Mauro Highlands
3.64589°S 17.47194°W
LM: 33.5 hours EVA: 9.4 hours

Apollo 15 AUG 71
Hadley Rille
26.13239°N 3.63330°E
LM: 66.9 hours EVA: 19.1 hours

Apollo 16 APR 72
Descartes Highlands
8.9734°S 15.5011°E
LM: 71.0 hours EVA: 20.2 hours

Apollo 17 DEC 72
Taurus-Littrow Valley
20.1911°N 30.7655°E
LM: 75.0 hours EVA: 22.1 hours



Apollo Landing Sites

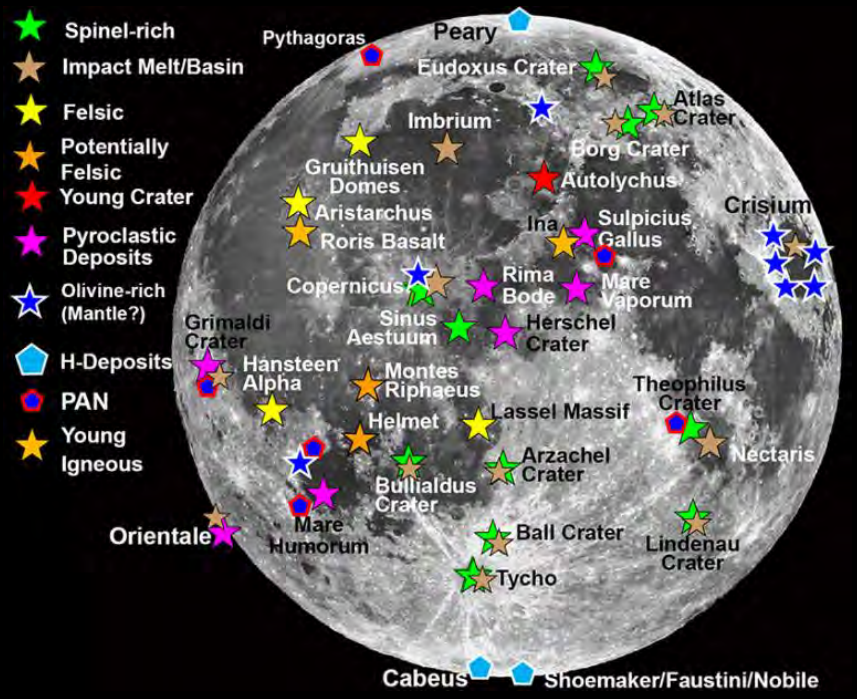
Artemis Program

First woman to land on the Moon
Technology validation on Moon for the Human Space Exploration of Mars

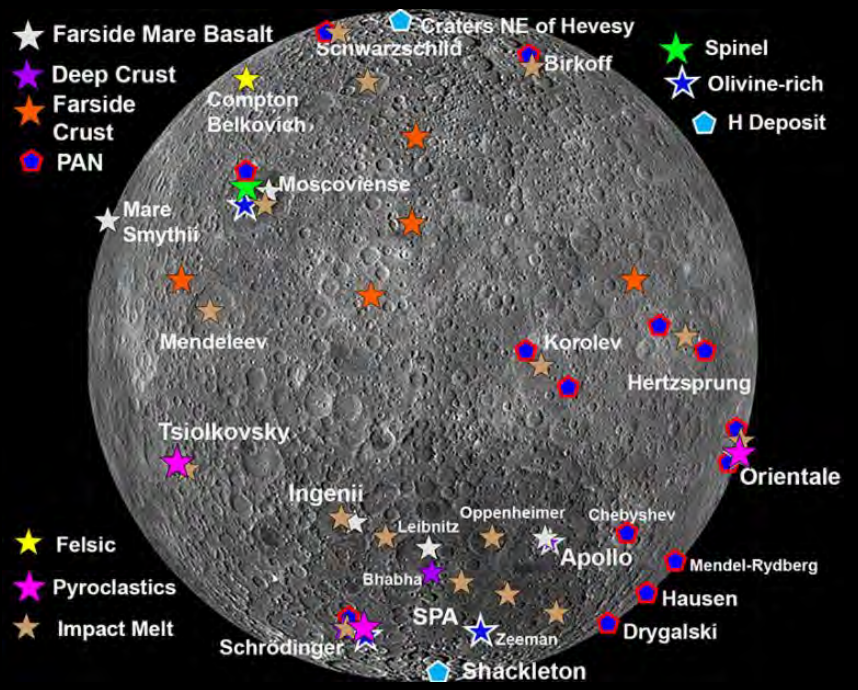
In Greek Mythology, Artemis is the twin sister of Apollo

Lunar Scientists have a lot of places they would like to go!

(https://lunar-landing.arc.nasa.gov/)

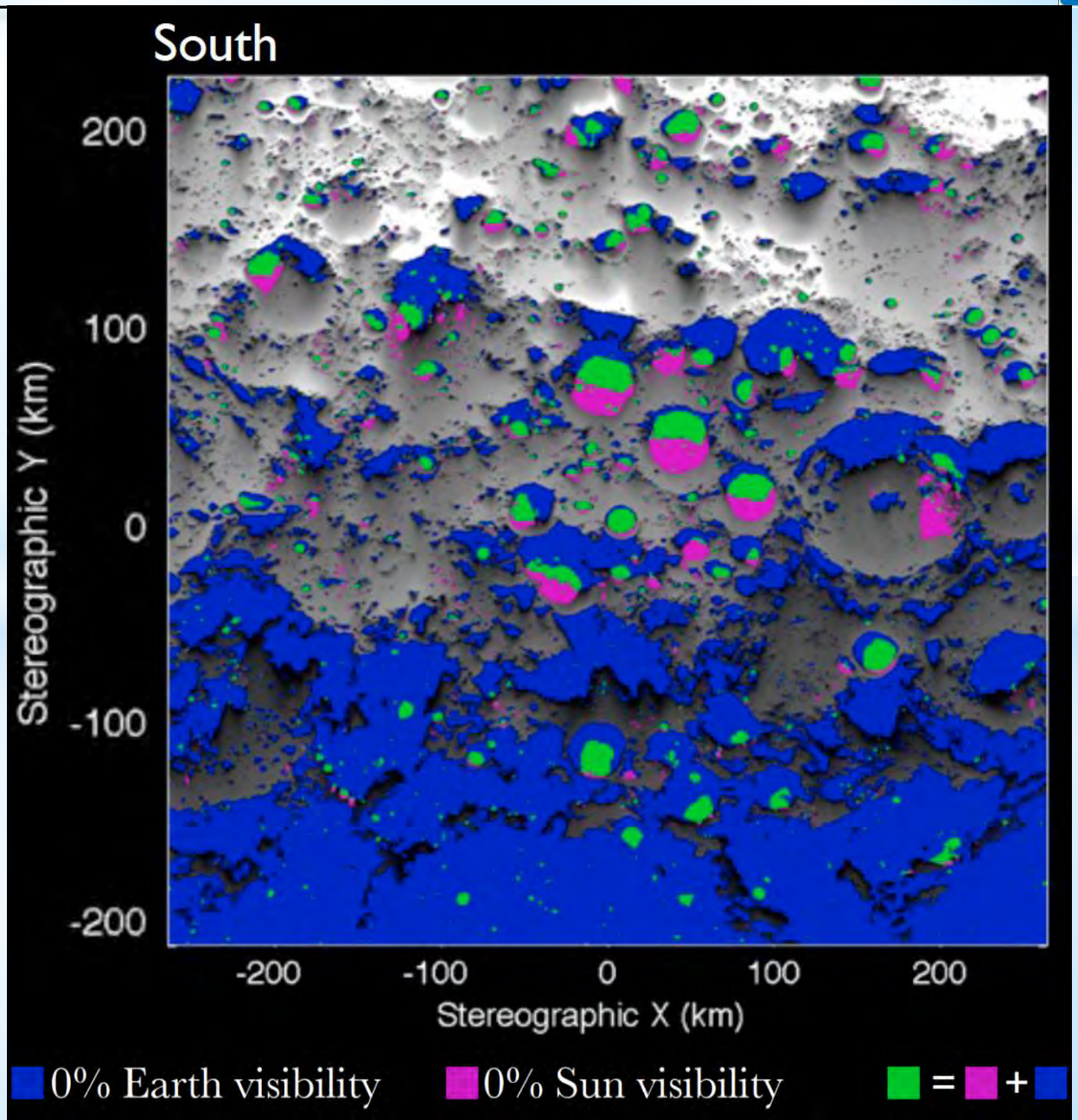


Near Side



Far Side

Moon Landing Potential Sites : 2024



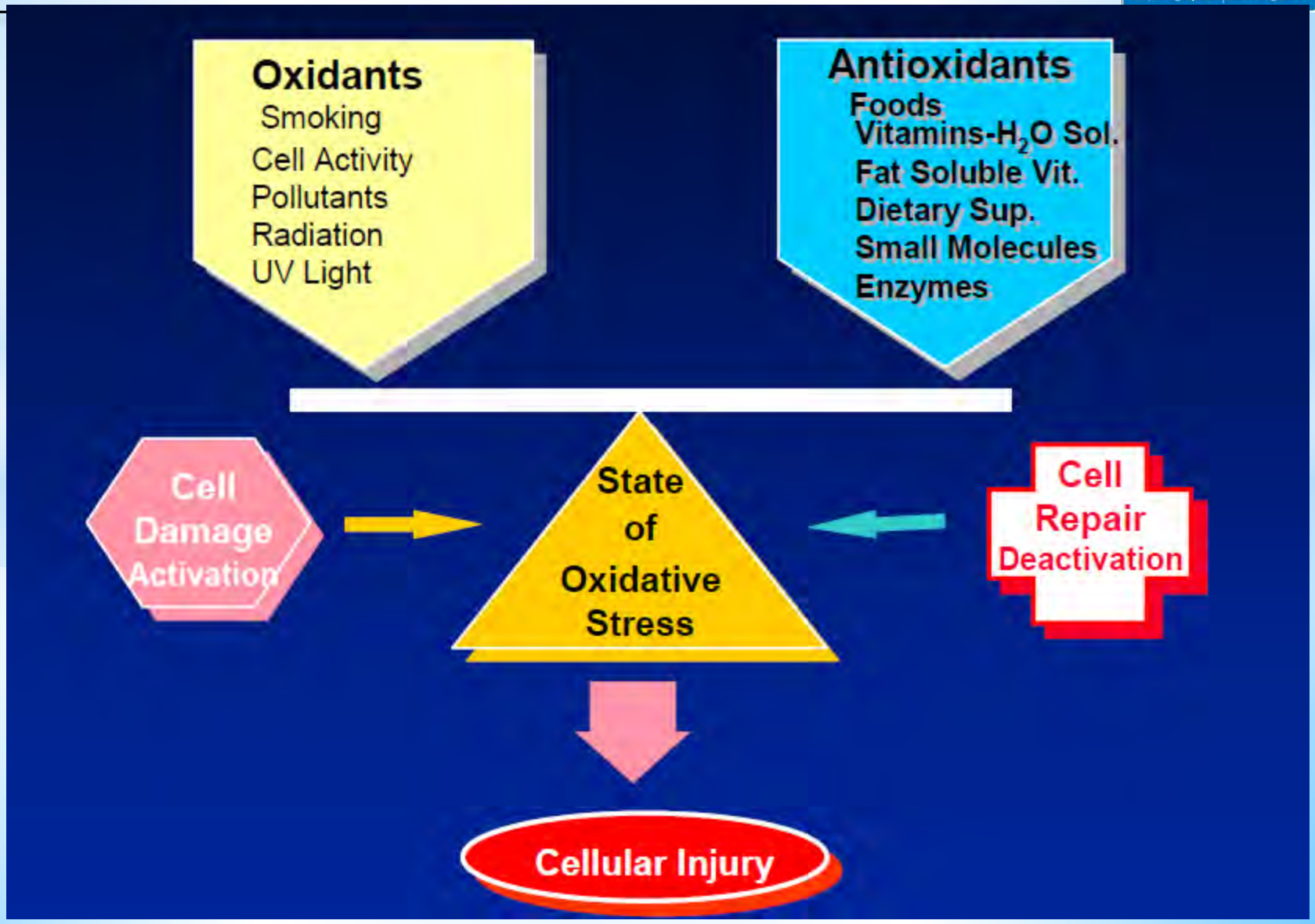
Mazarico, LEAG 2013

Acknowledgment

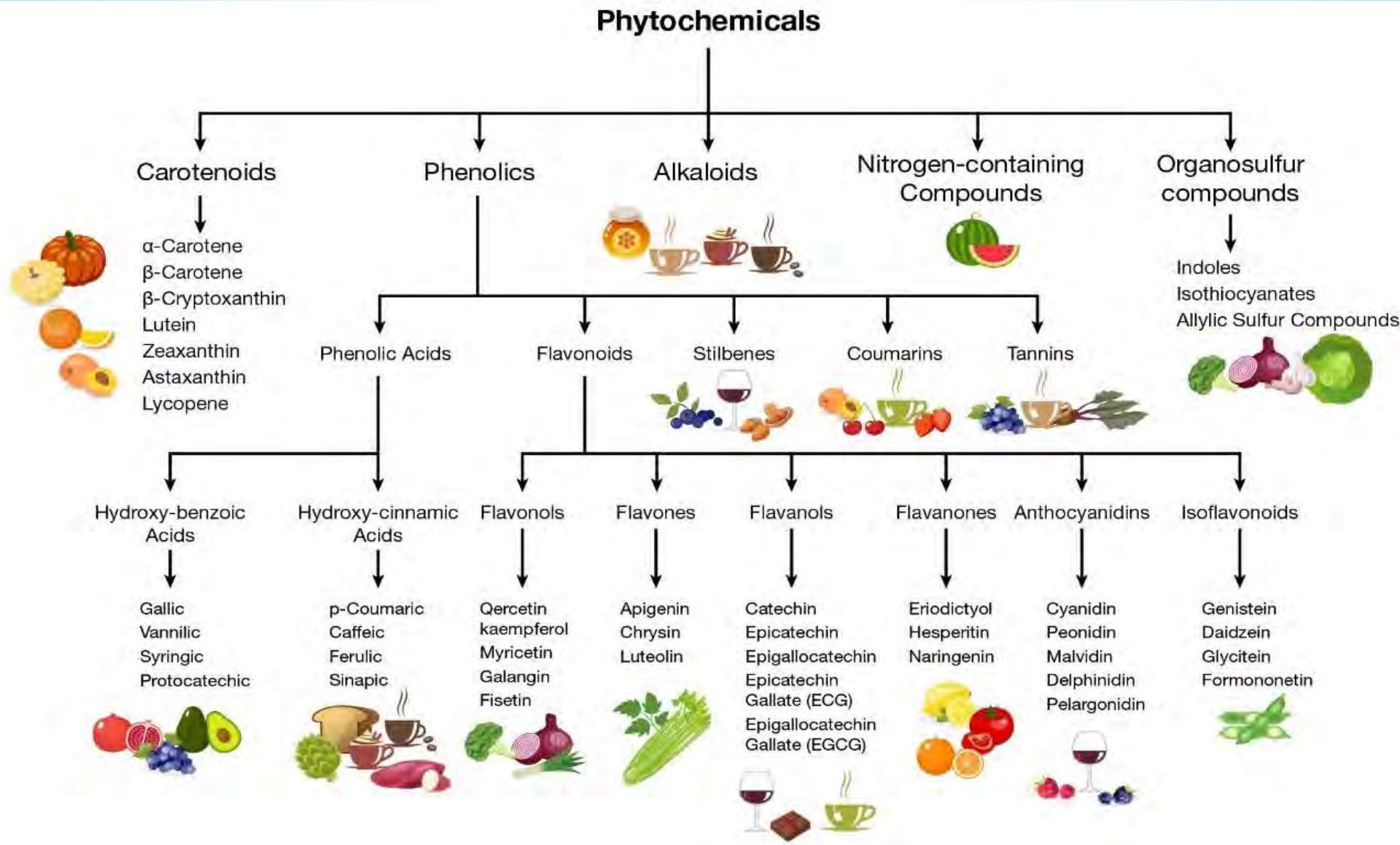
Beautiful Fragile Blue Planet

Back up

Oxidative Stress

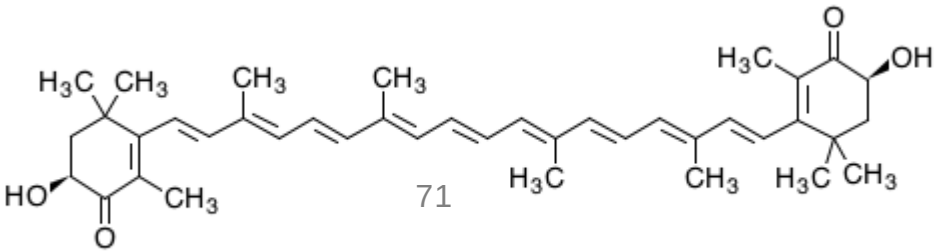


Acworth et al., "The Handbook of Redox Biochemistry", ESA Inc., 2003, 19.



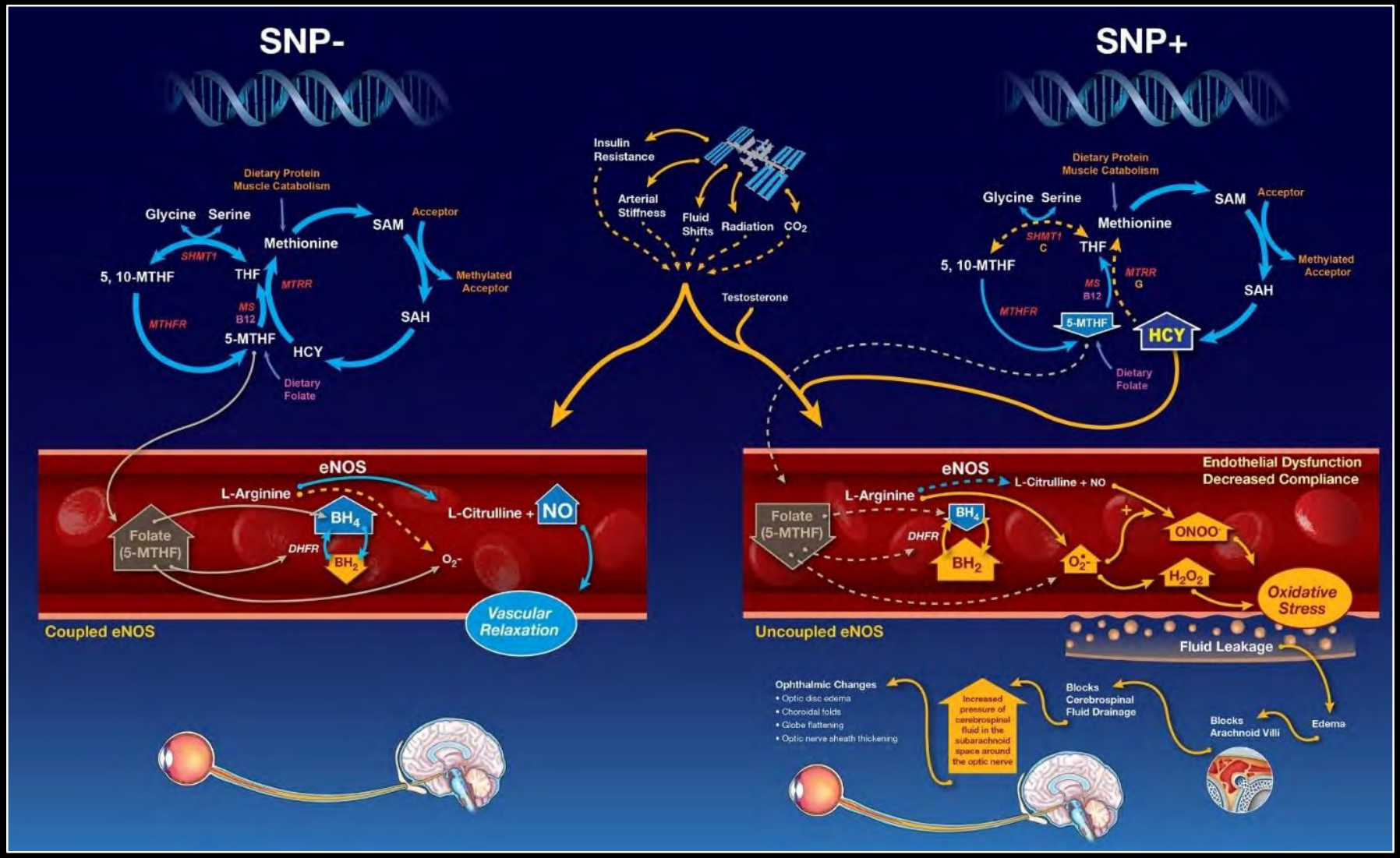
Scott Smith, NASA/JSC

Krill (Astaxanthin) and Whales



C08580

How Could Genetics Affect Astronaut Eyes?

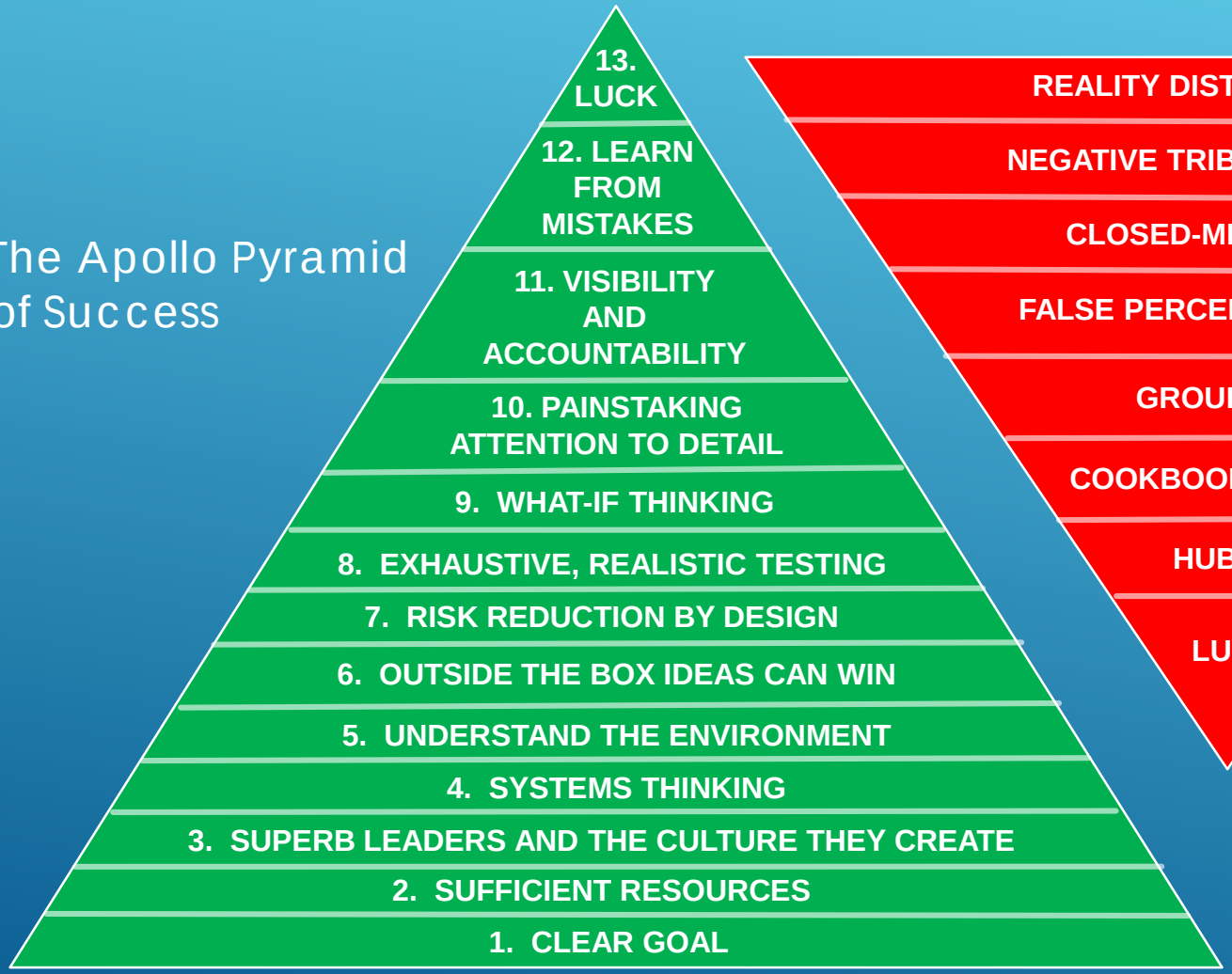


Multiple-hit hypothesis shows how genetics of the enzymes of the 1-carbon metabolic pathway are proposed to be associated with astronaut ophthalmic syndrome.

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

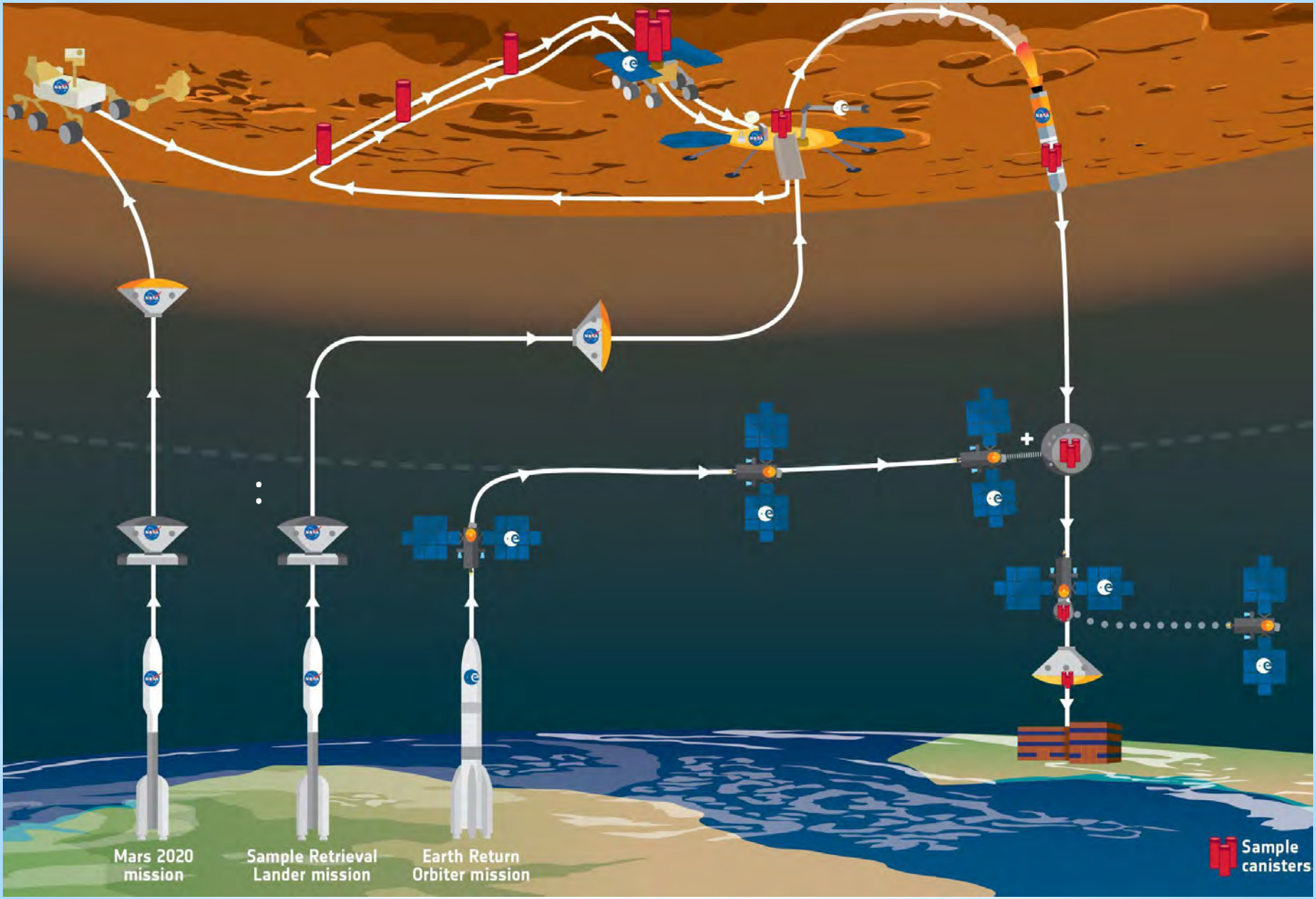
The Apollo Pyramid of Success



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

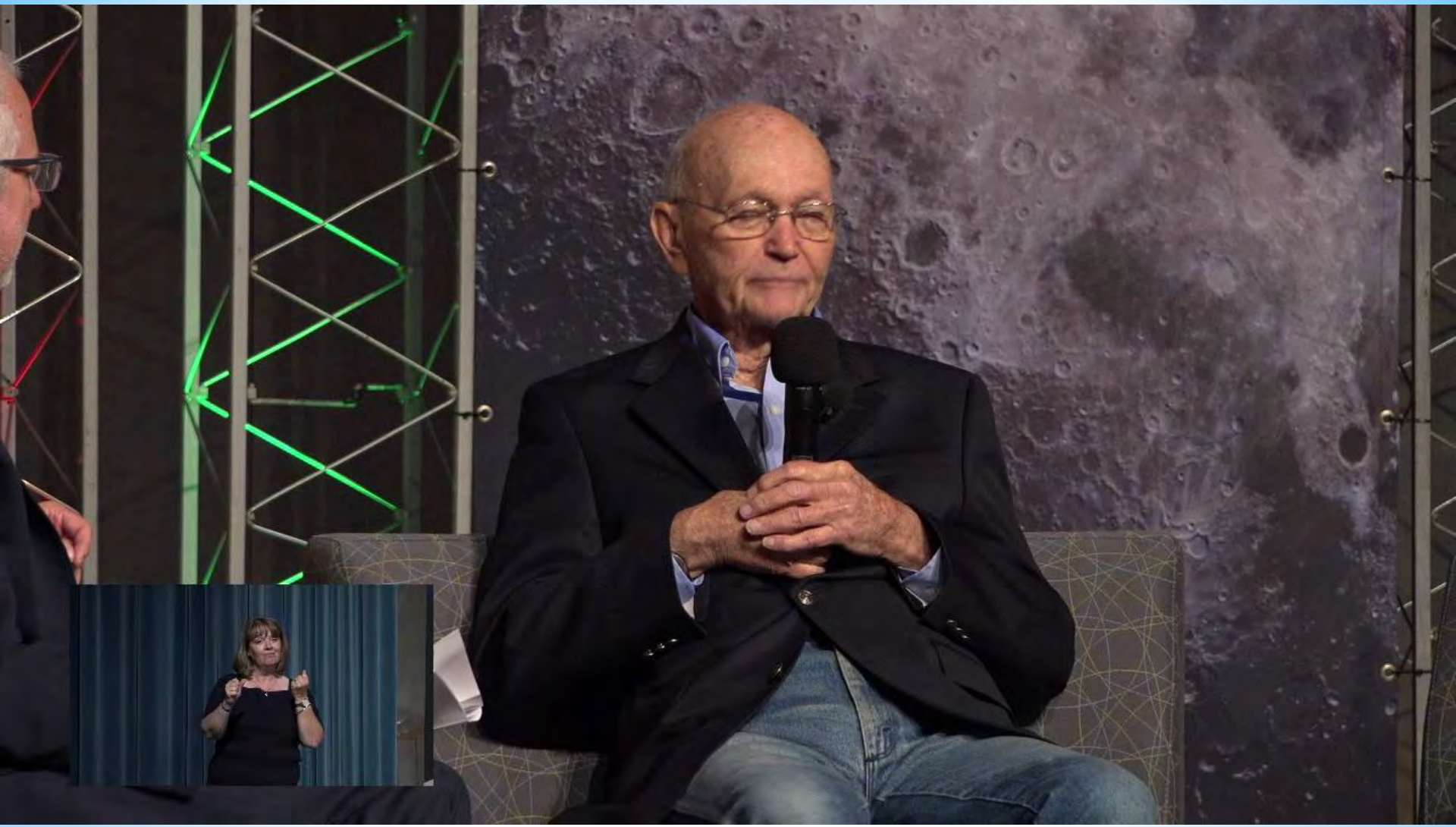
Astronaut Class of 2017

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

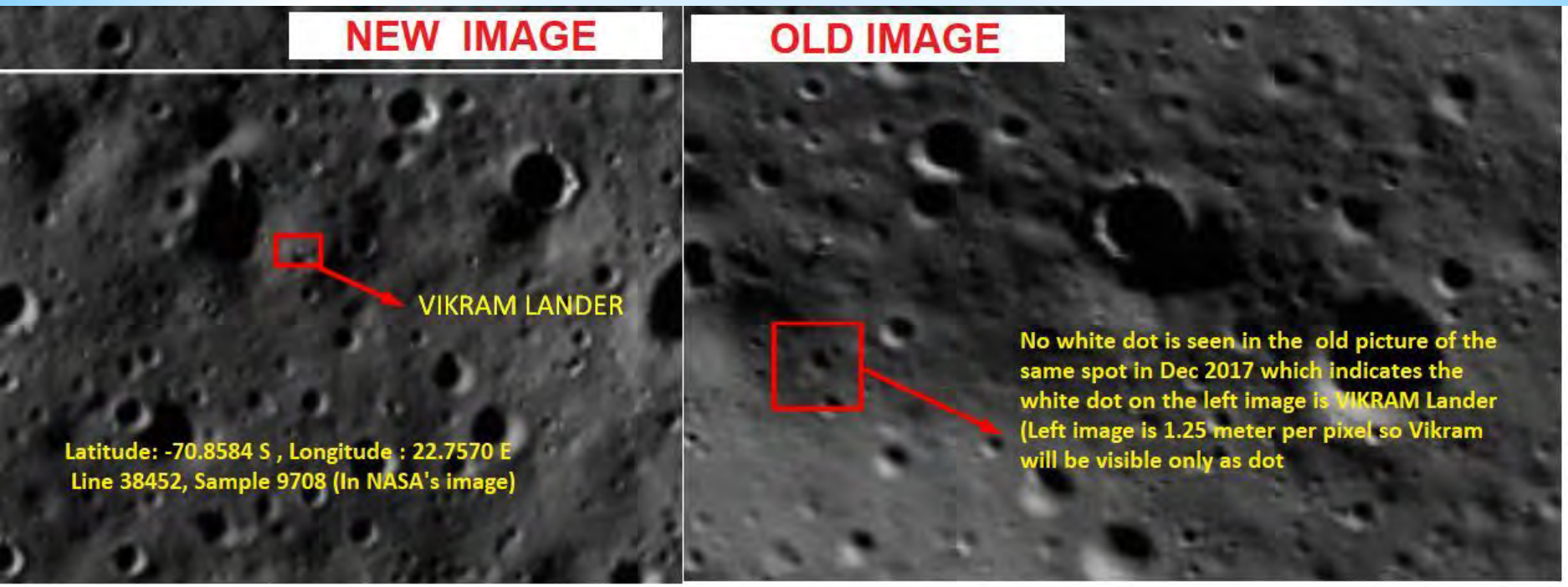
Who is at Your Window?



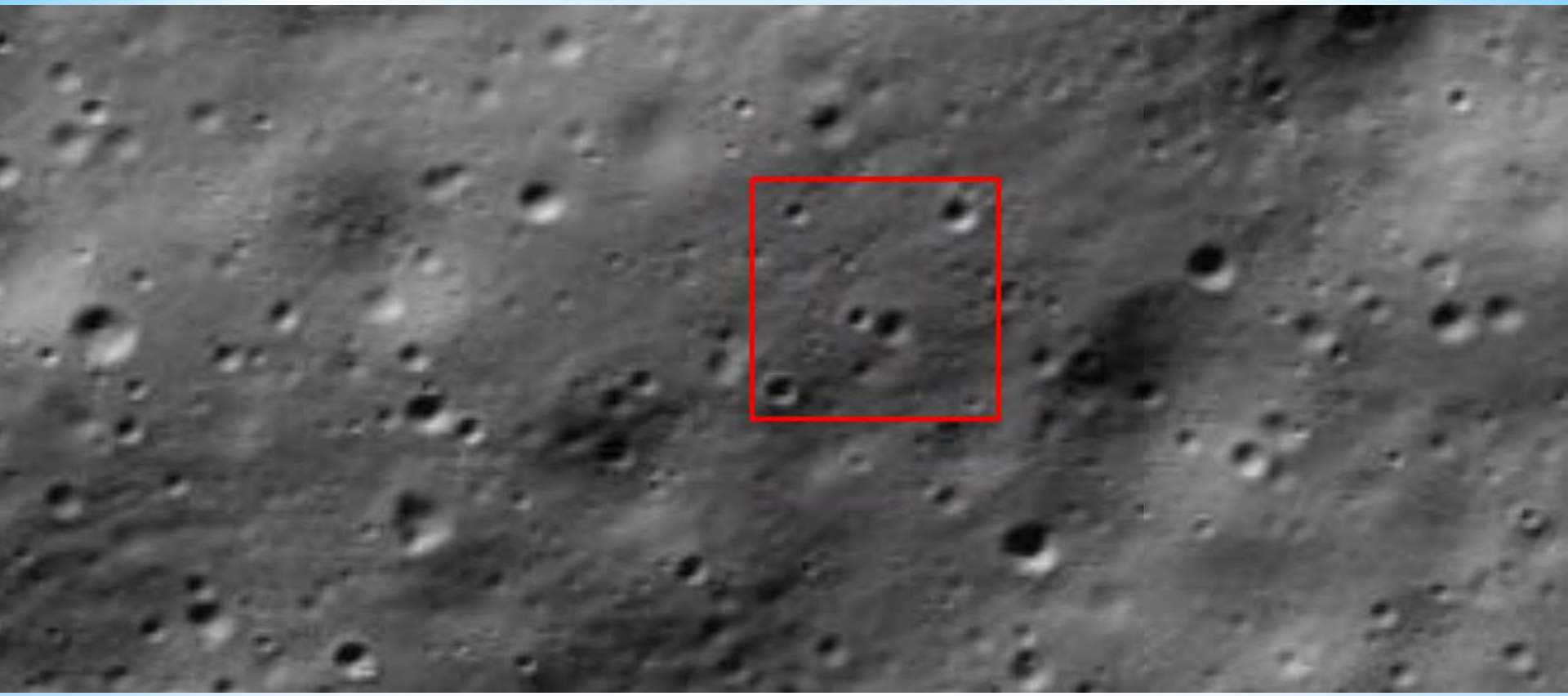
I feel responsible - Collins

Crew Debriefing at Bld 37 (July 27, 1969)

Vikram Lander

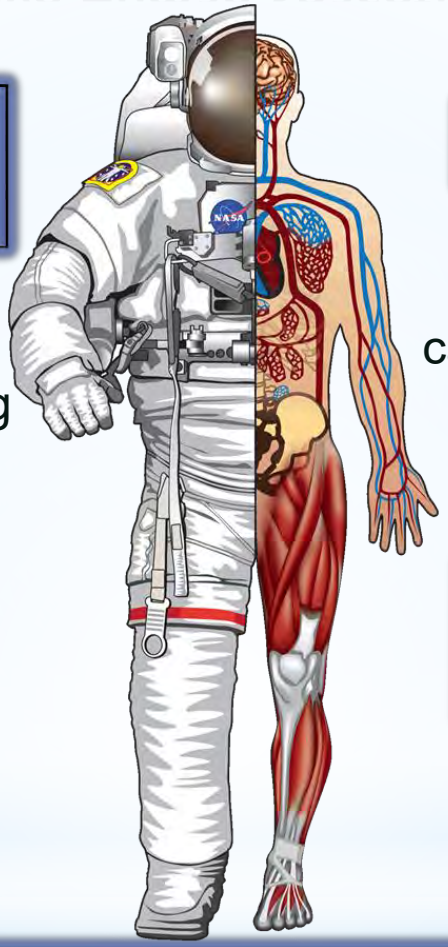


Vikram Lander



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

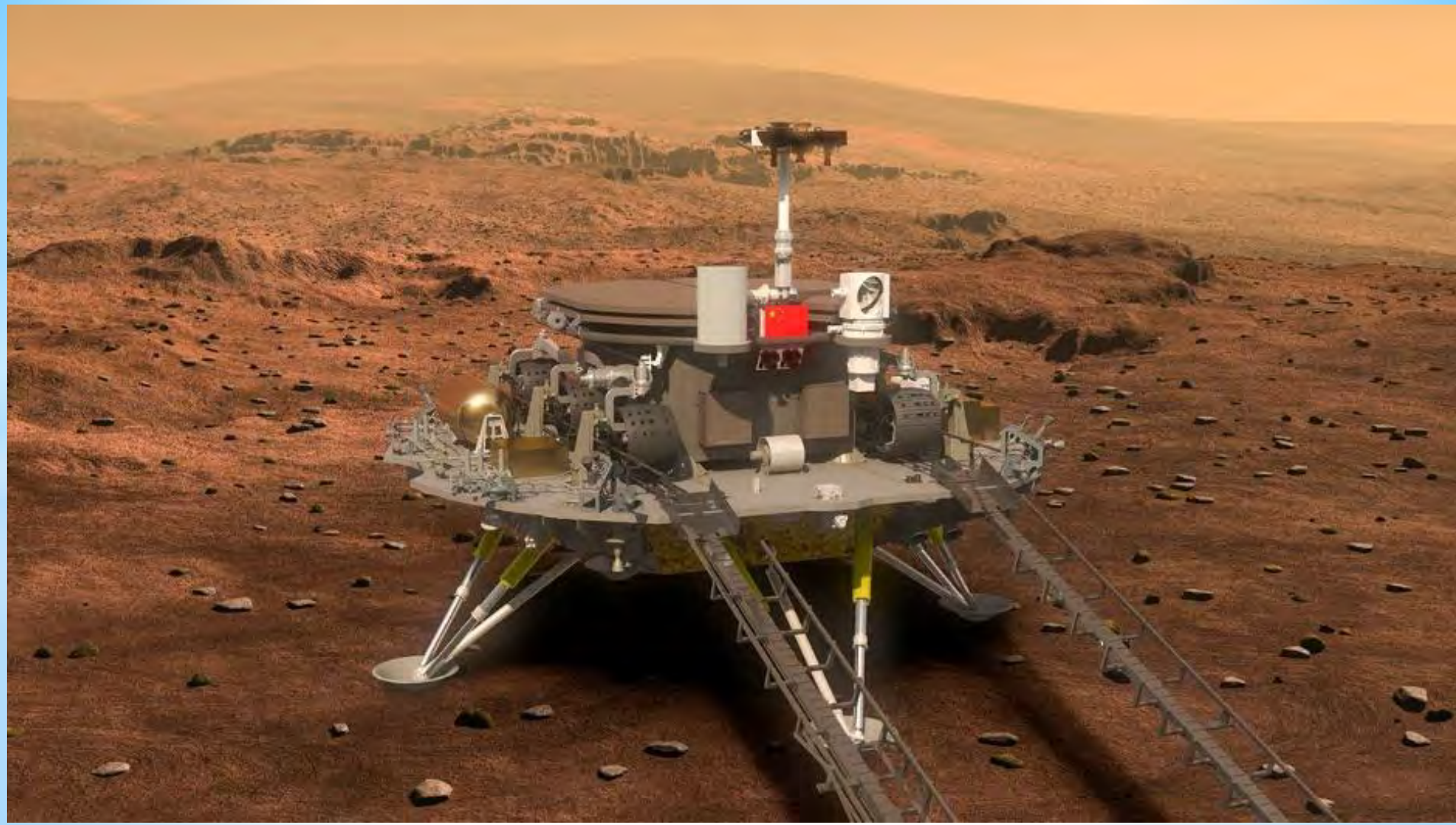
Hostile/ Closed Environment

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

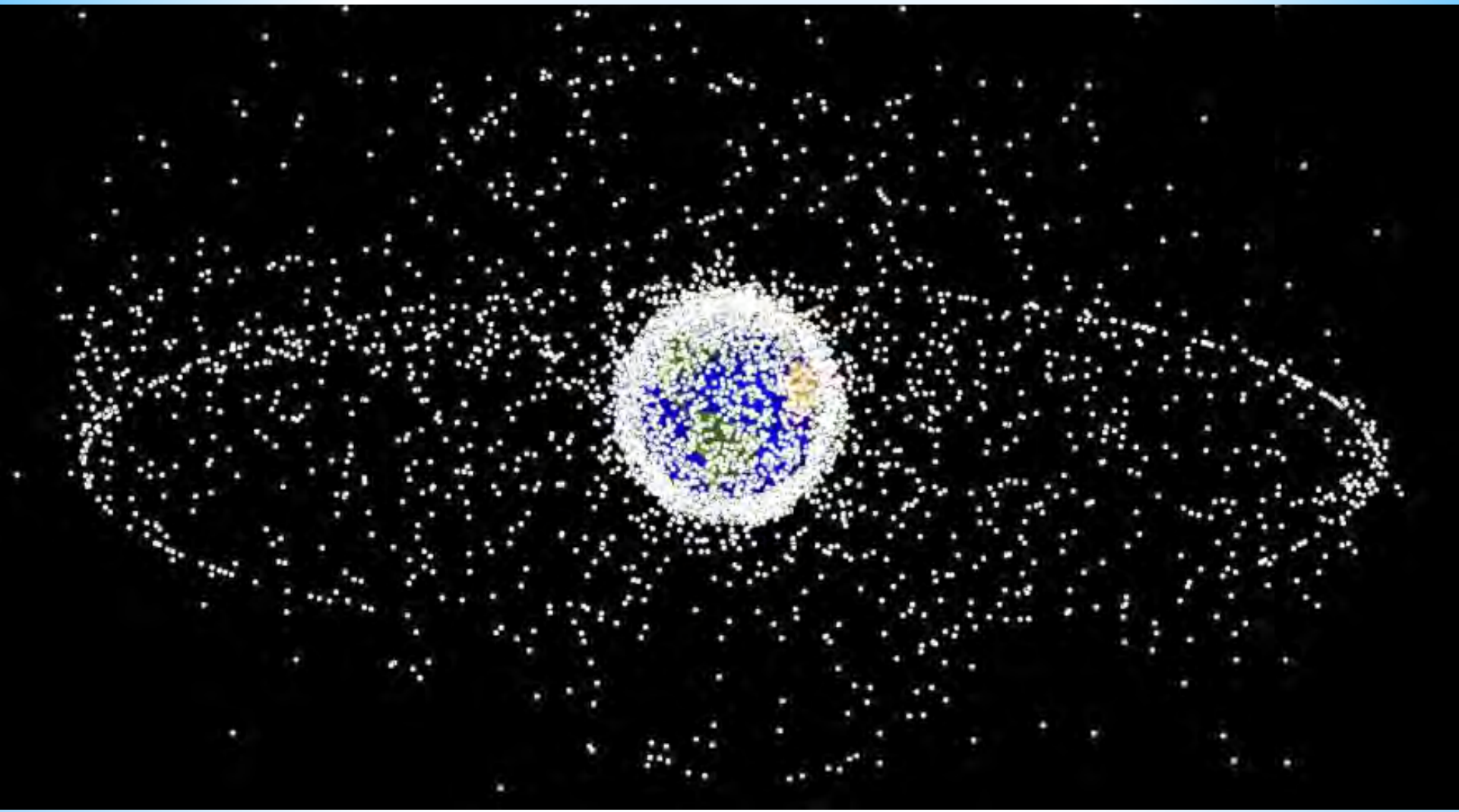
Isolation & Confinement

Behavioral aspect of isolation
Sleep disorders

Mars Rover from China in 2020

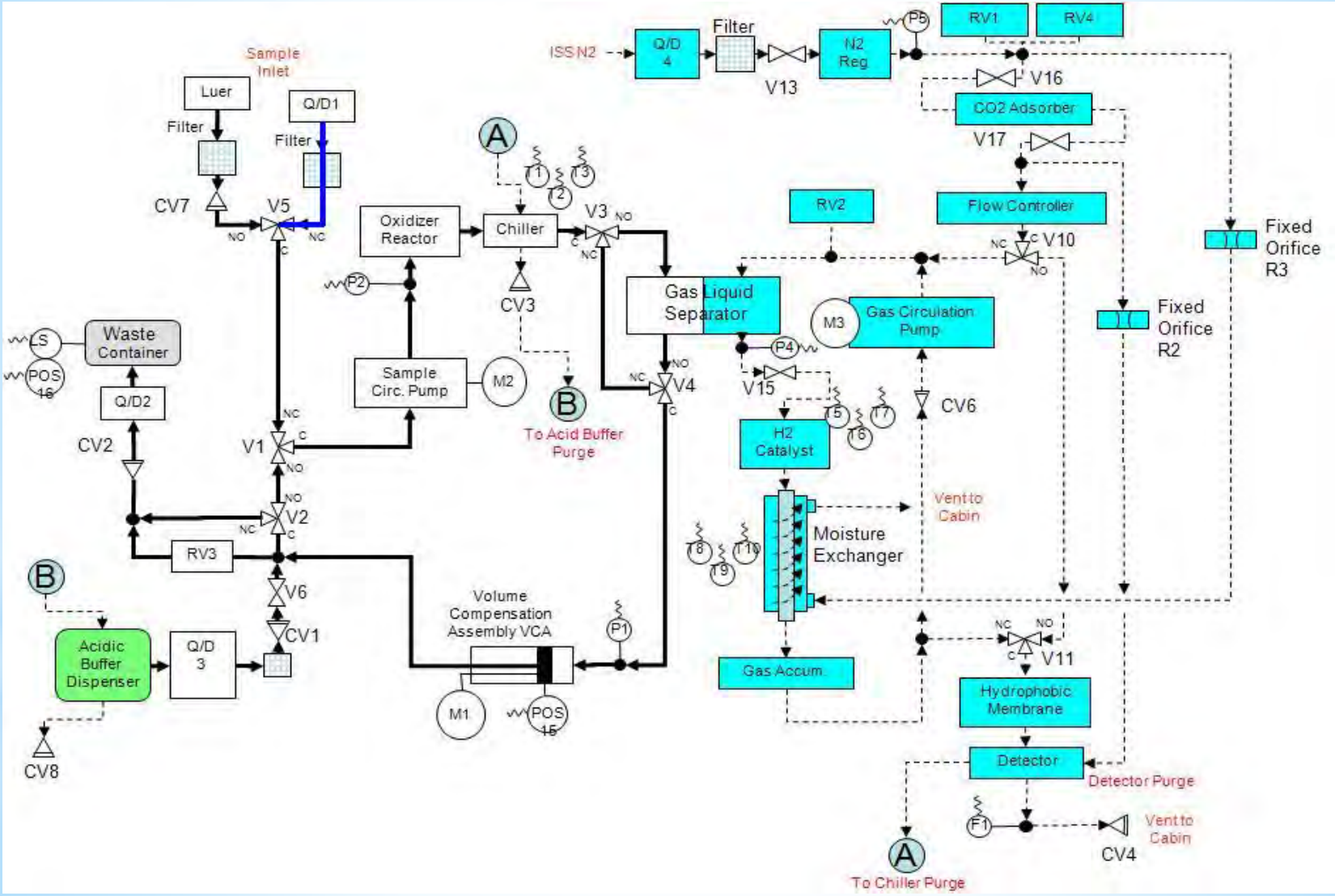


Space Debris



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 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

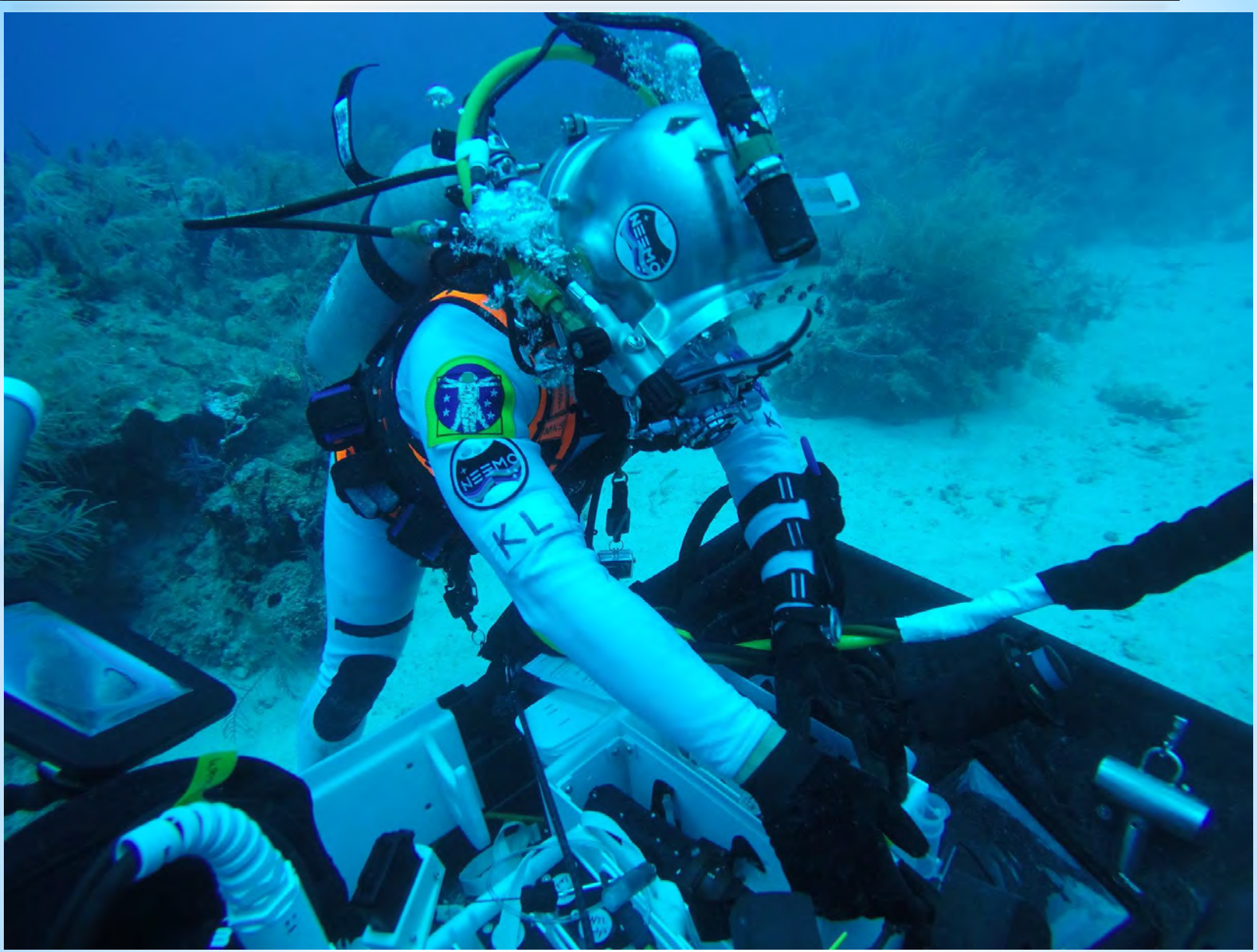

Still daylight in California.
Chicago
Cities of Boston, New York, Philadelphia and Washington.
Dallas
Houston
Miami
Puerto Rico


CHALLENGER

EVA at Neutral Buoyancy Lab (NBL)

Bed Rest Studies :envihab

Under Water NEEMO



Mars 500 Analog

Rover : Desert Rat

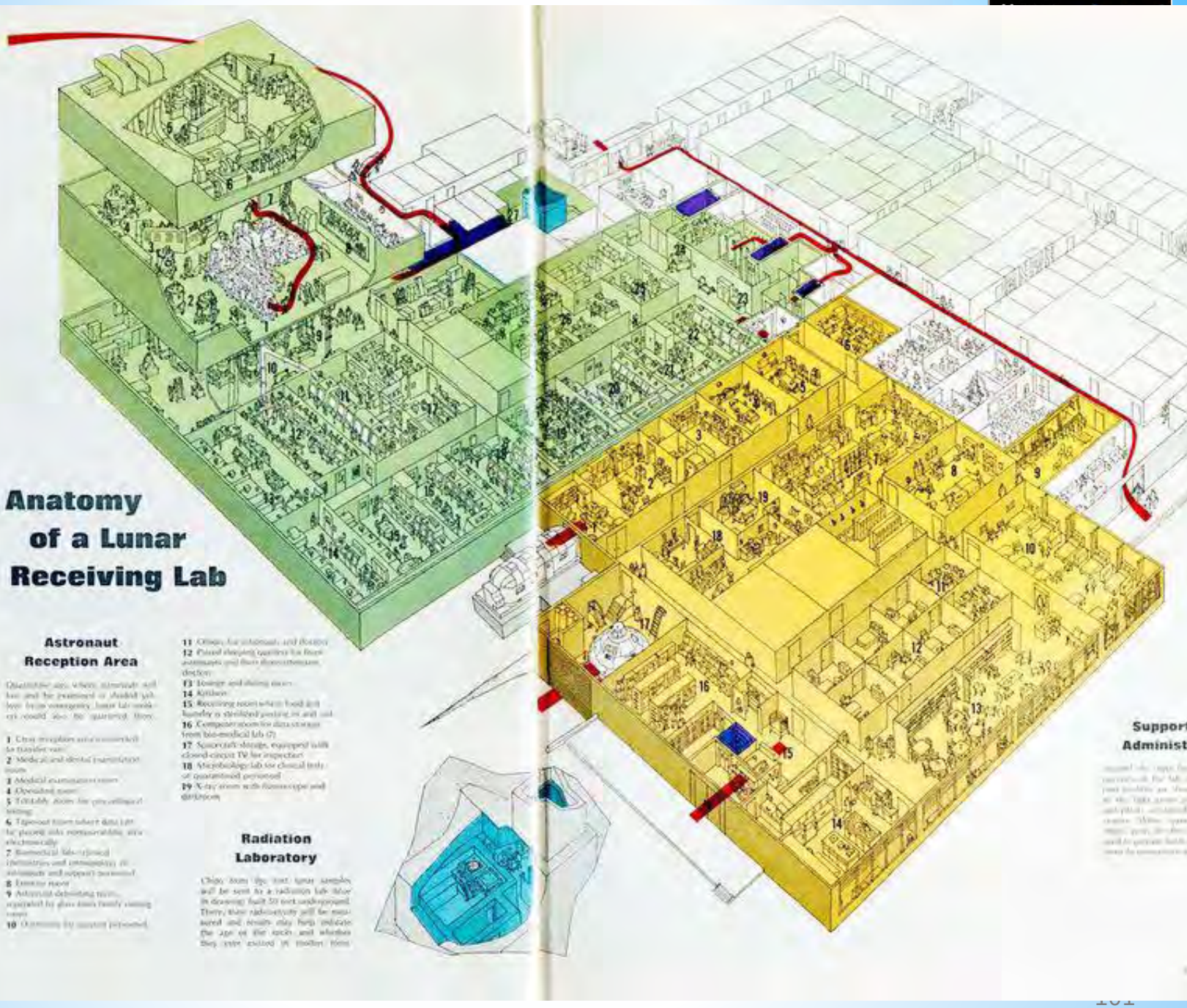
Deep Space Habitat : Isolation and Confinement

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


Anatomy of a Lunar Receiving Lab
Lunar Sample Laboratory
Astronaut Reception Area
Radiation Laboratory
Support
Administ

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.