



Human Space Exploration : Challenges and Opportunities

Antony Jeevarajan, Ph.D.
Johnson Space Center
National Aeronautics and Space Administration
Houston, TX 77058
Email: antony.s.jeevarajan@nasa.gov



DEDICATED TO THE TEACHERS OF LOYOLA COLLEGE



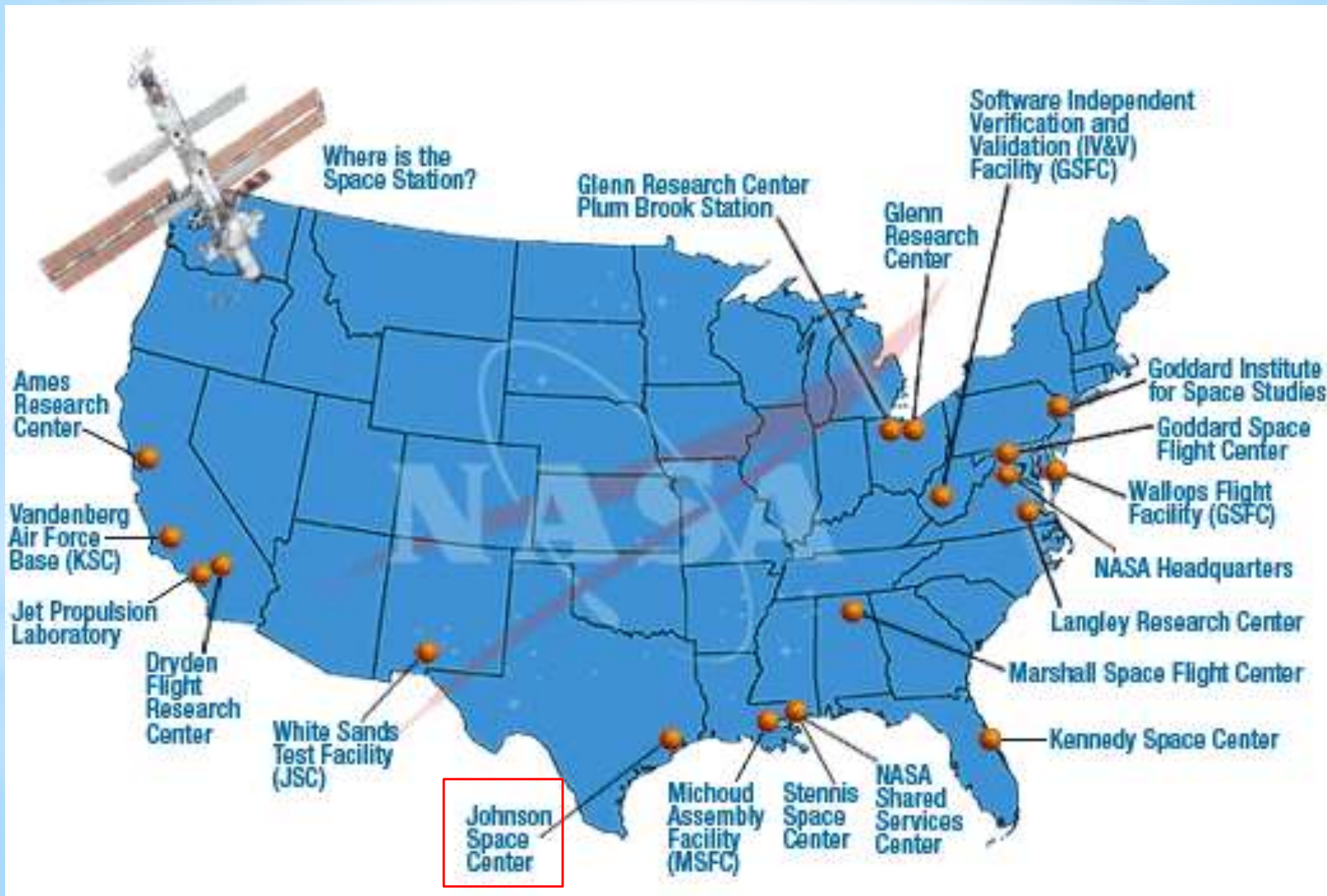
Objectives



- ❖ **Where are we in the Universe?**
- ❖ **What does it take for humans to go to Mars?**
- ❖ **What happens to Human Body during this Journey**
- ❖ **More importantly, to answer your questions**



NASA Centers





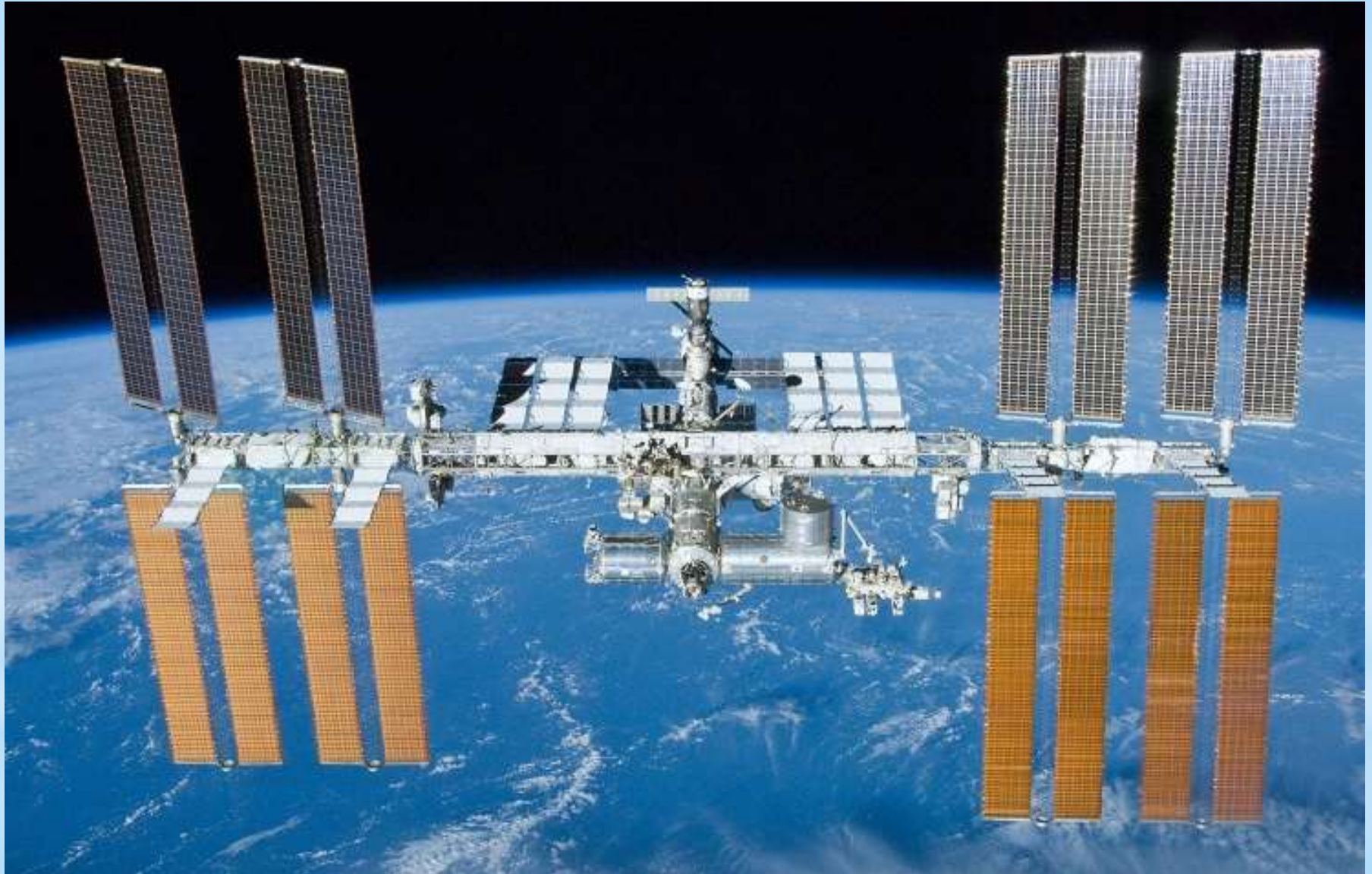
Loyola College Chennai



Our Habitation at Night



International Space Station (~250 miles)





Beautiful Fragile Blue Planet (~250,000 miles)

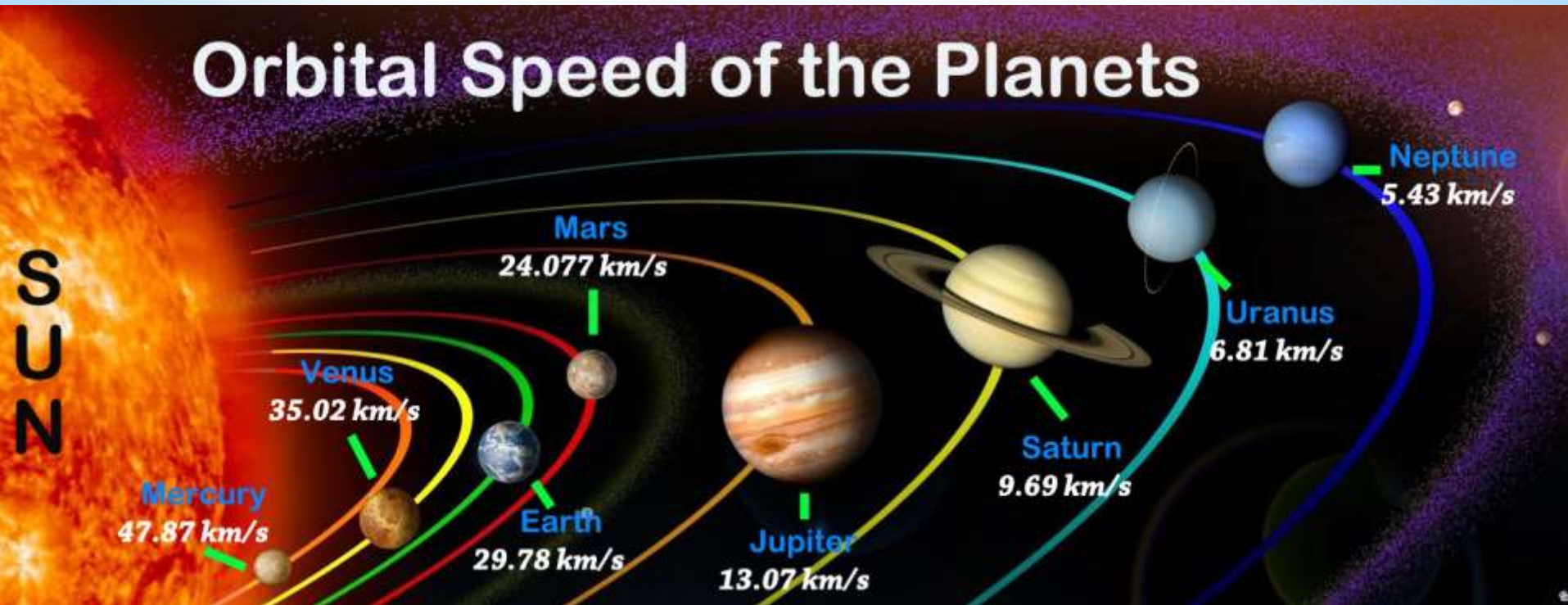


Mars - Earth Mutual View (~250,000,000 miles)



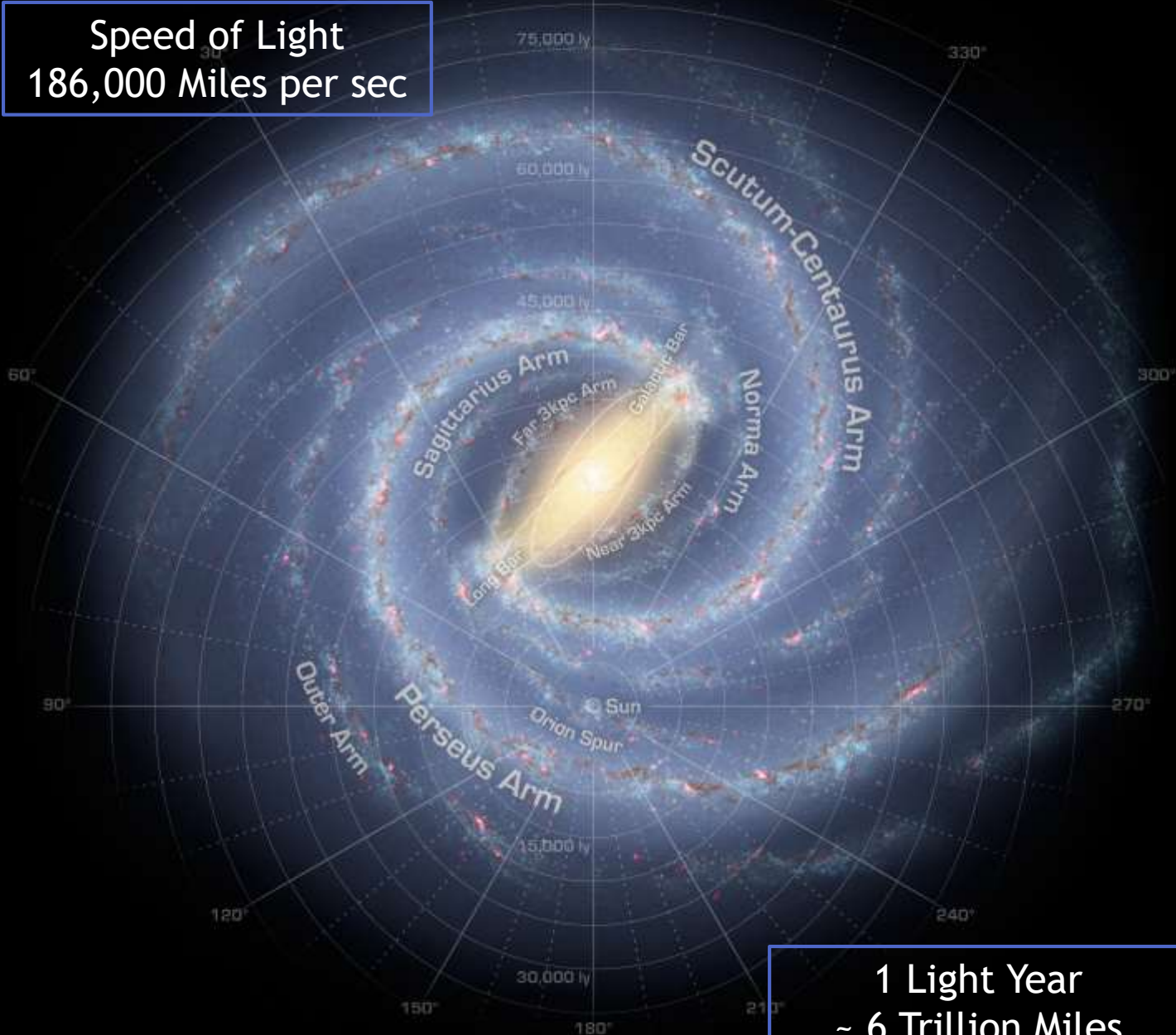
Solar System

Orbital Speed of the Planets



Milky Way Galaxy

Speed of Light
186,000 Miles per sec



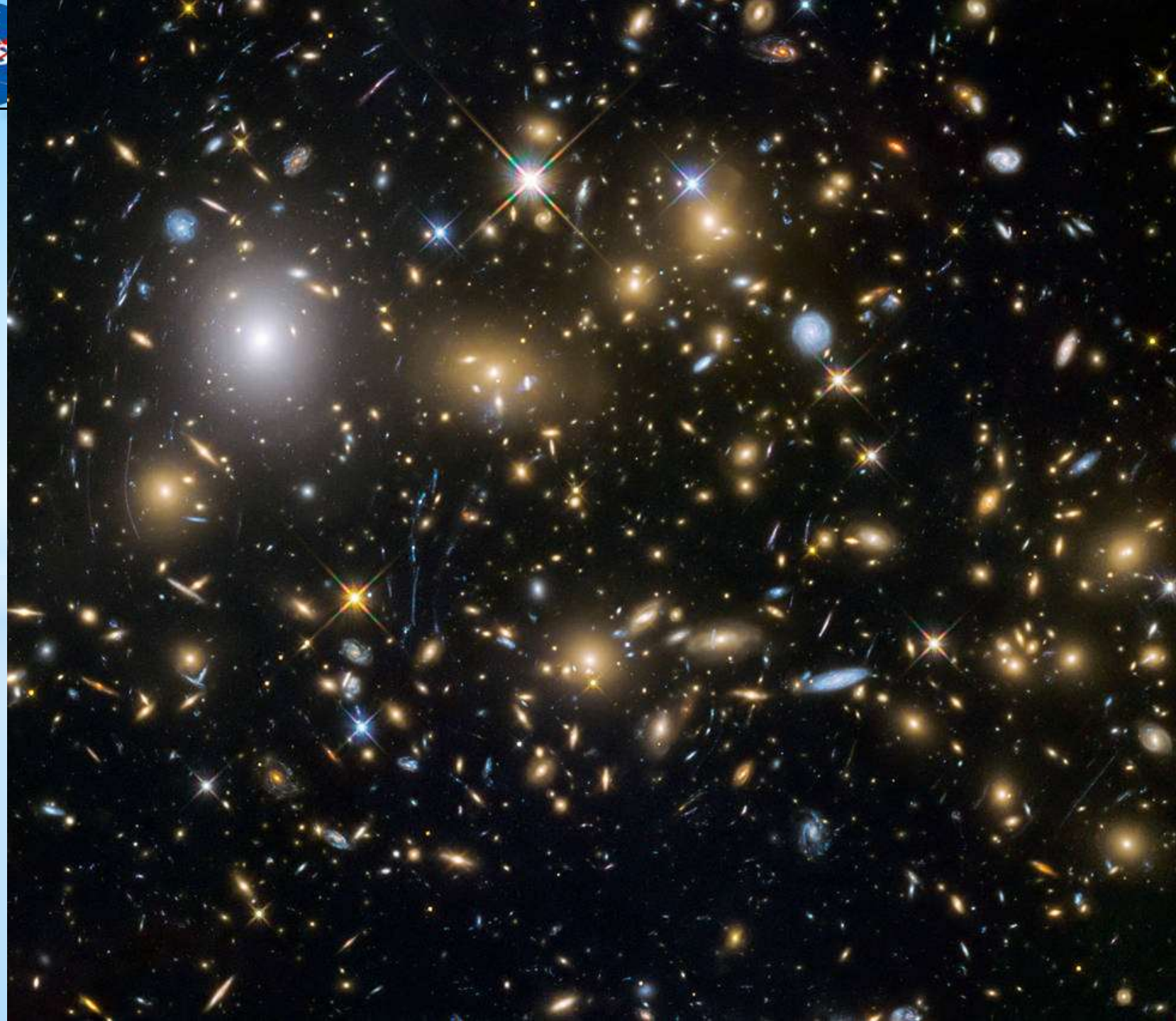
1 Light Year
~ 6 Trillion Miles

Milky Way (Top from Lebanon and Bottom from Chile)



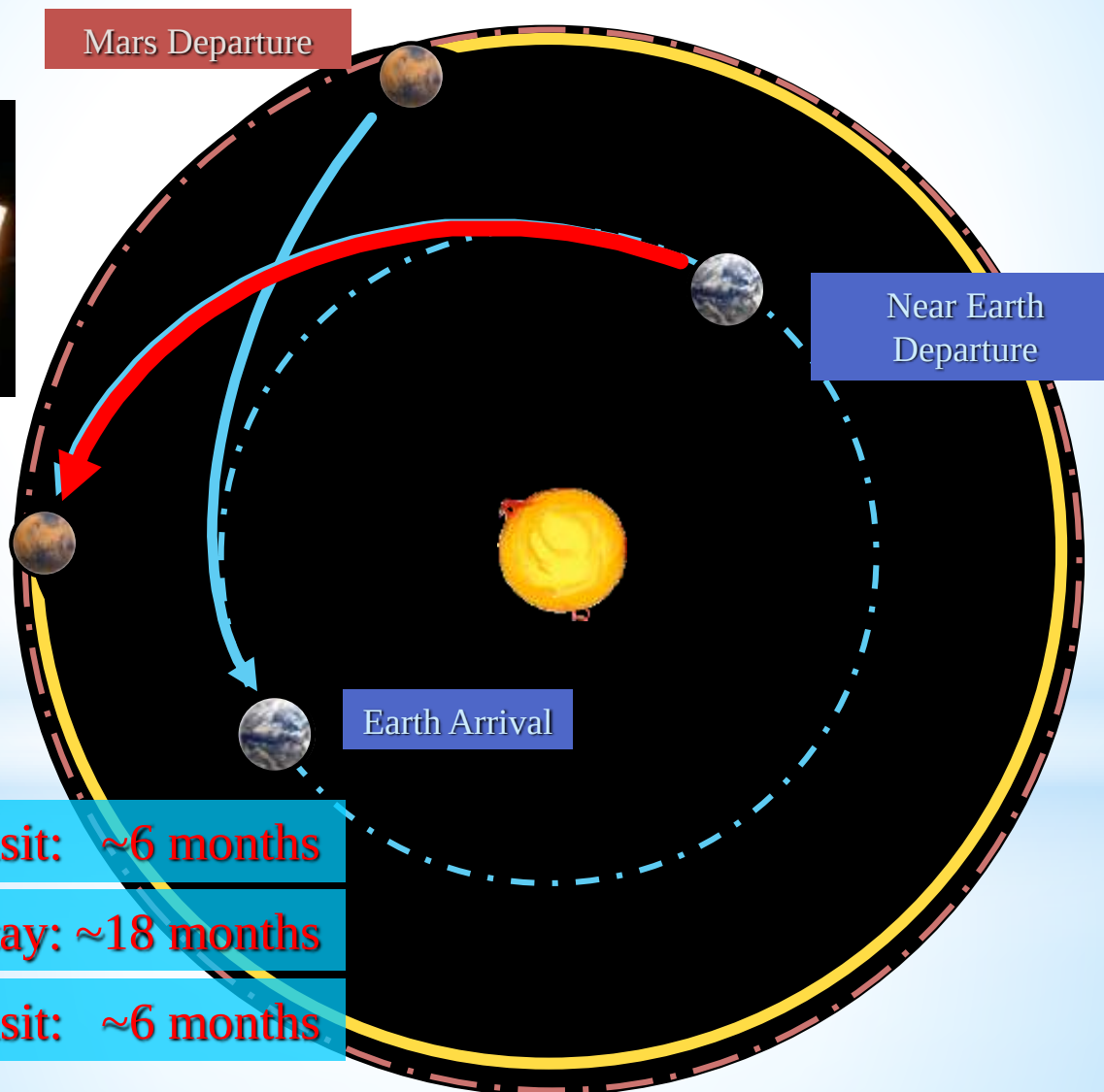








Overview of Notional Mars Expedition



Mars Arrival

Mars Departure

Near Earth
Departure

Earth Arrival

Earth-to-Mars transit: ~6 months

Mars surface stay: ~18 months

Mars-to-Earth transit: ~6 months



<https://www.smithsonianmag.com/videos/category/science/curiositys-seven-minutes-of-terror/>



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 CO₂), 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



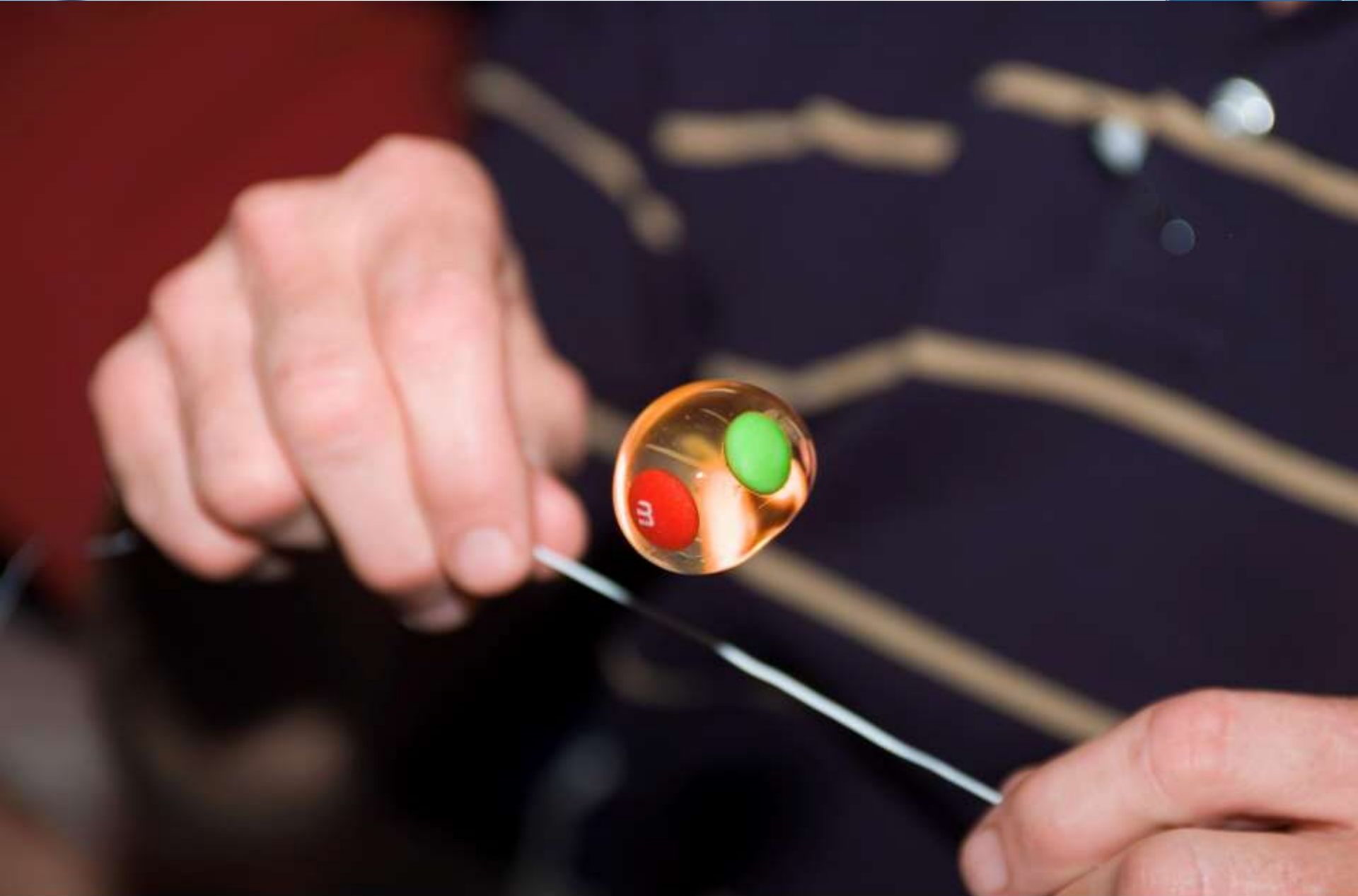
Hair-do







Candies in water bubble



Dinner at his Lap



Salt and Pepper





One of the Favorite Foods





Yummy Dinner





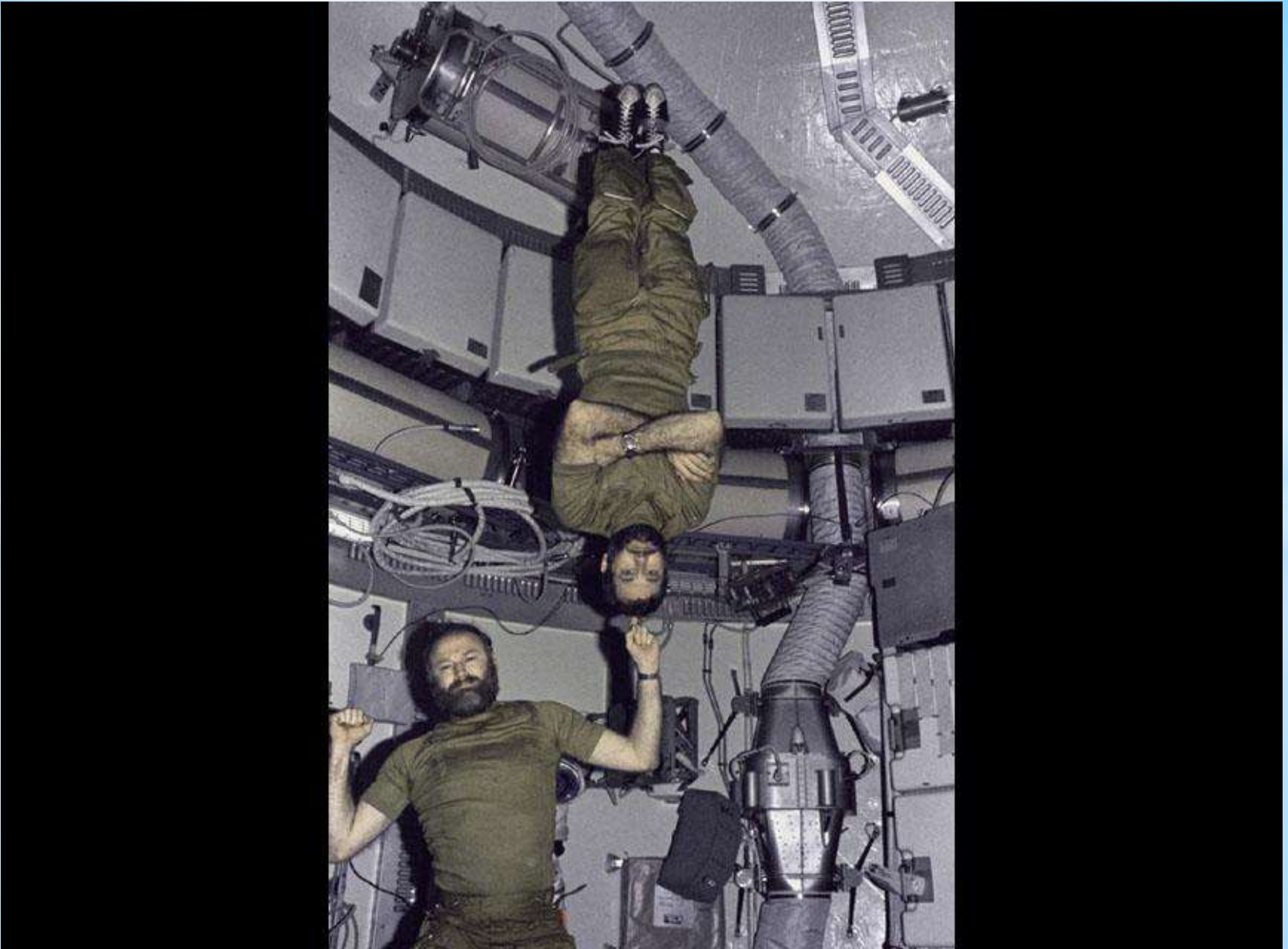
Scott Kelly (1 Year Mission) Twin Studies



Refrigerators and freezers not available to maintain food safety and quality



Weightlessness







Super-Woman

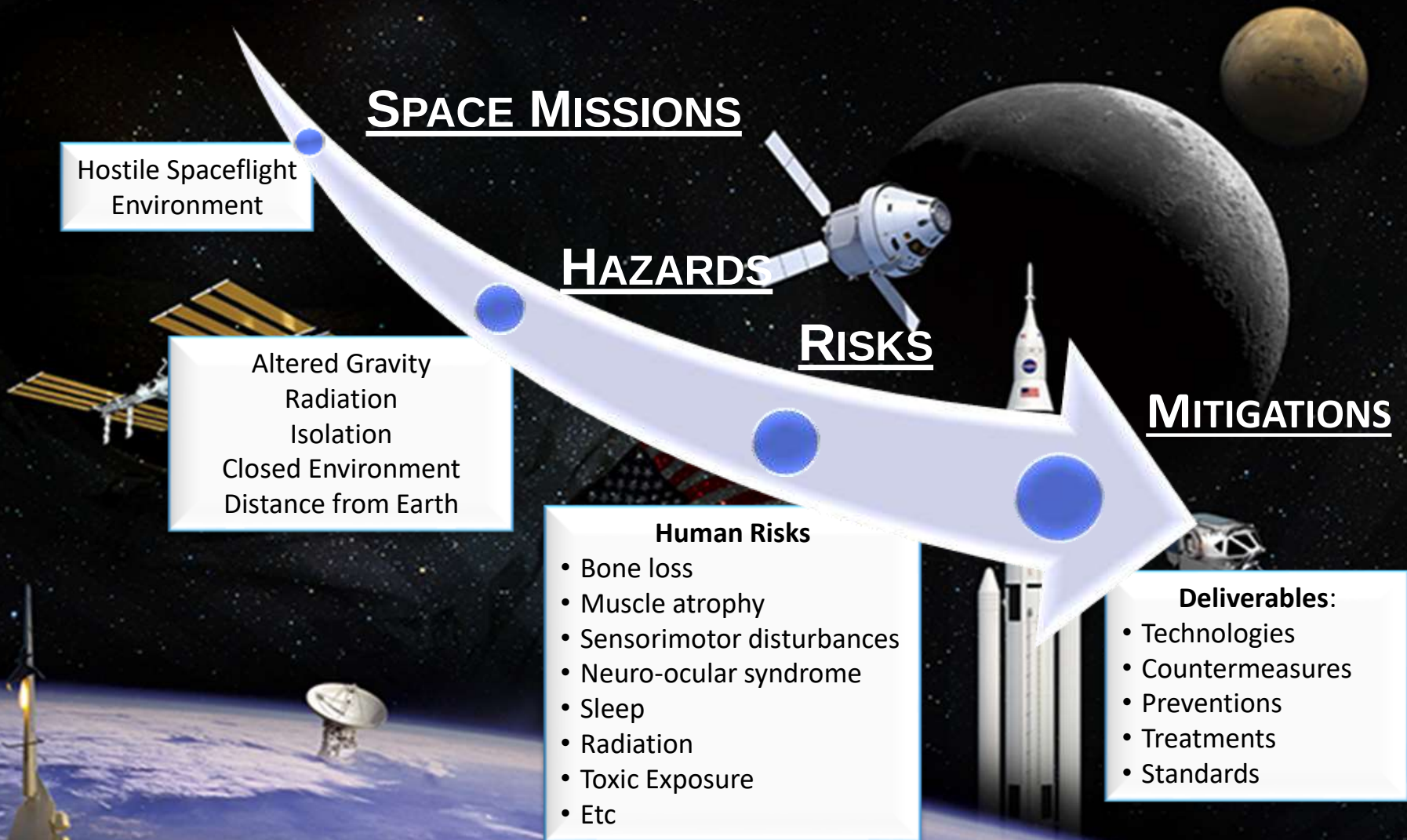


Sleep



NASA Human Health & Performance

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



Hazards of Spaceflight

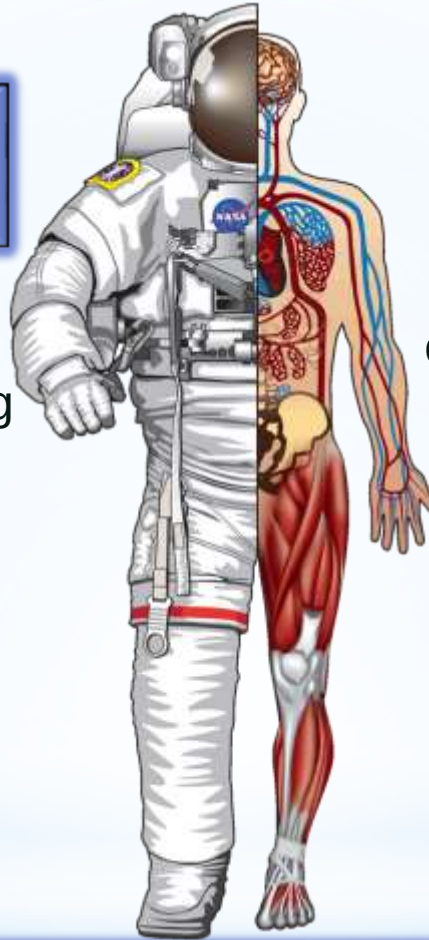
Hazards Drive Human Spaceflight Risks

Altered Gravity - Physiological Changes

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

Space Radiation

Acute In-flight effects
Long term cancer risk



Distance from earth

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

Hostile/ Closed Environment

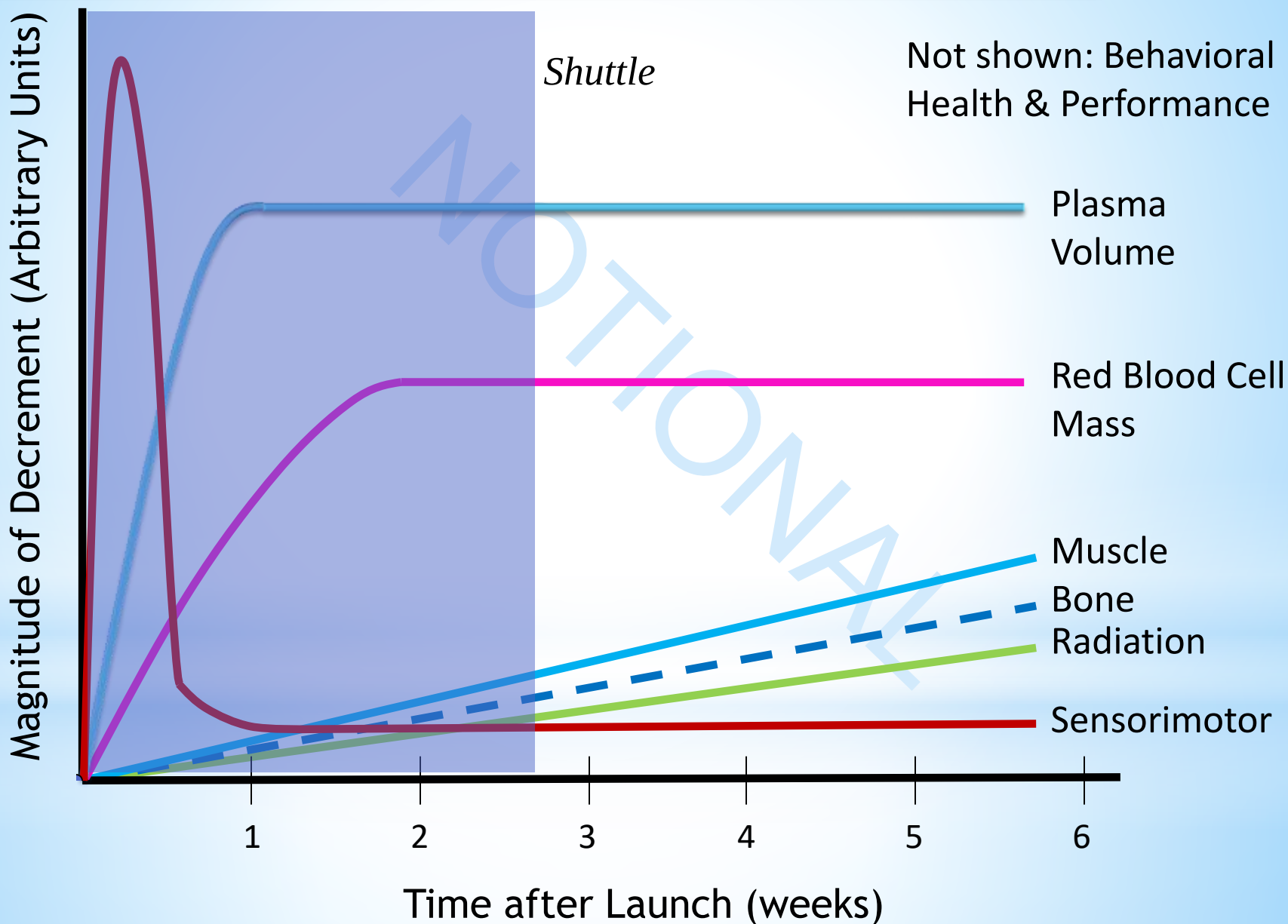
Vehicle Design
Environmental – CO₂ Levels,
Toxic Exposures, Water, Food

Isolation & Confinement

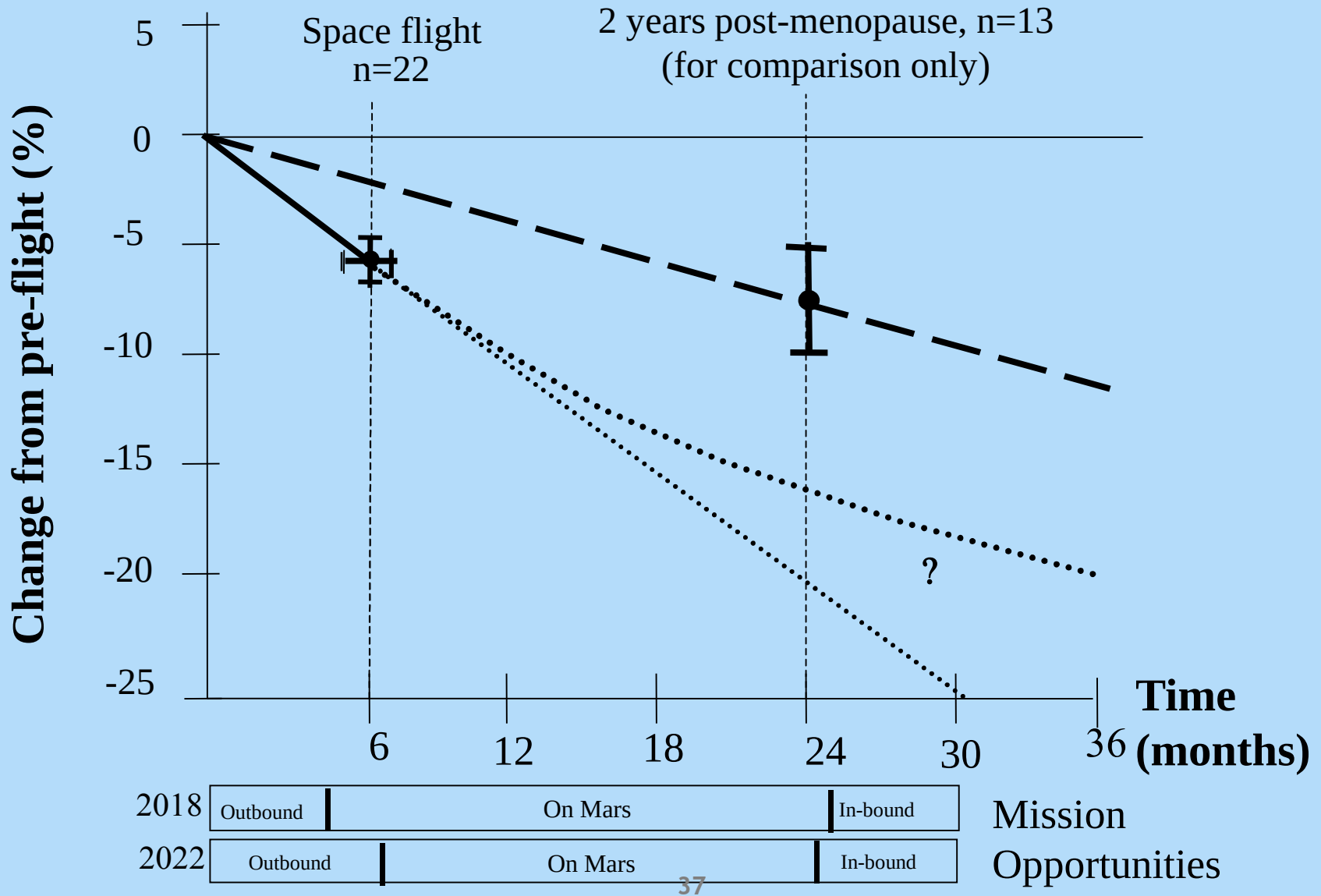
Behavioral aspect of isolation
Sleep disorders



Changes during short-duration space flight



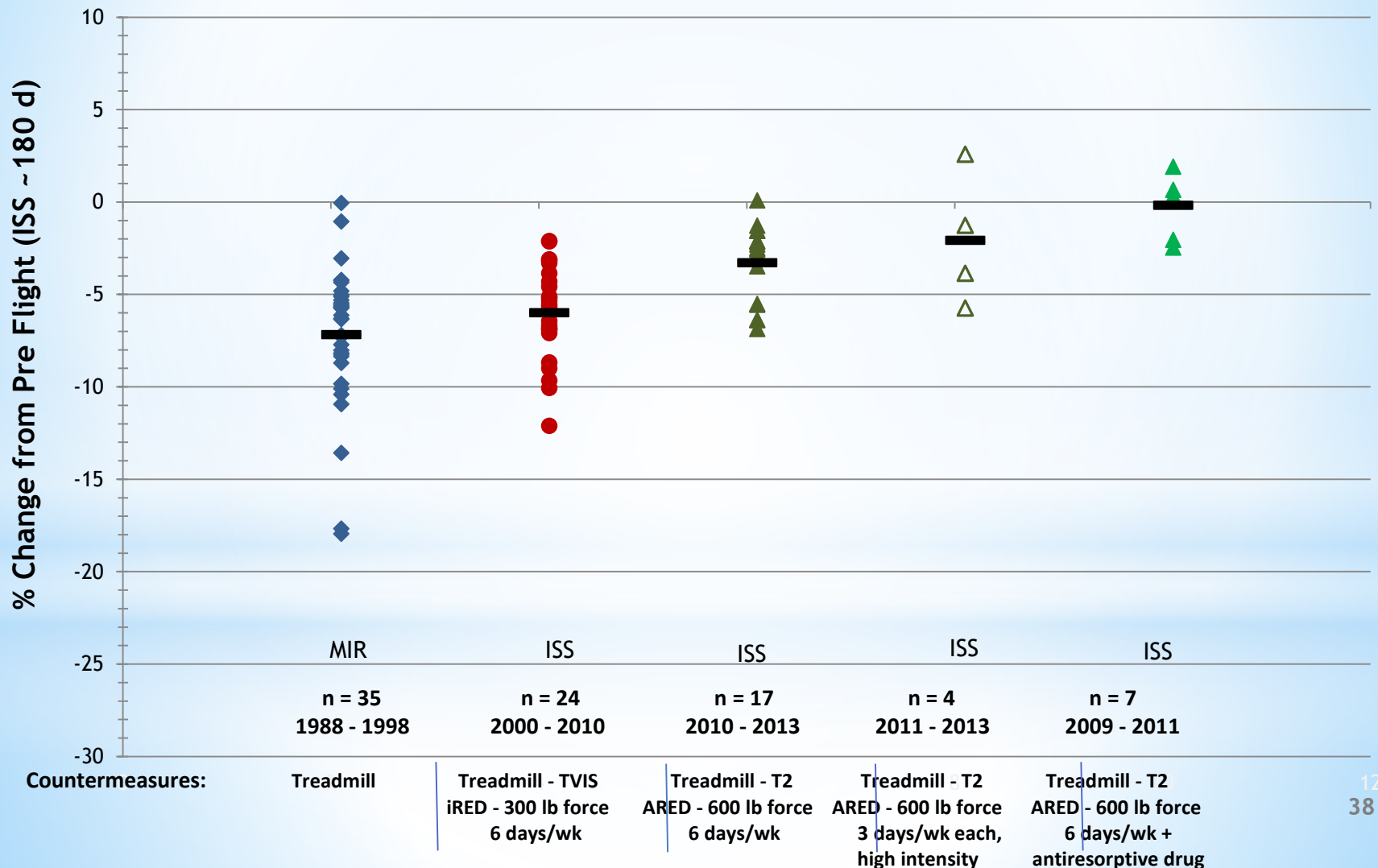
Bone Loss During Space Missions



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

Mean % Change in Total Hip DXA BMD

1371B - January 2014 Bone & Mineral Lab Data Analysis





Resistive Exercise Device



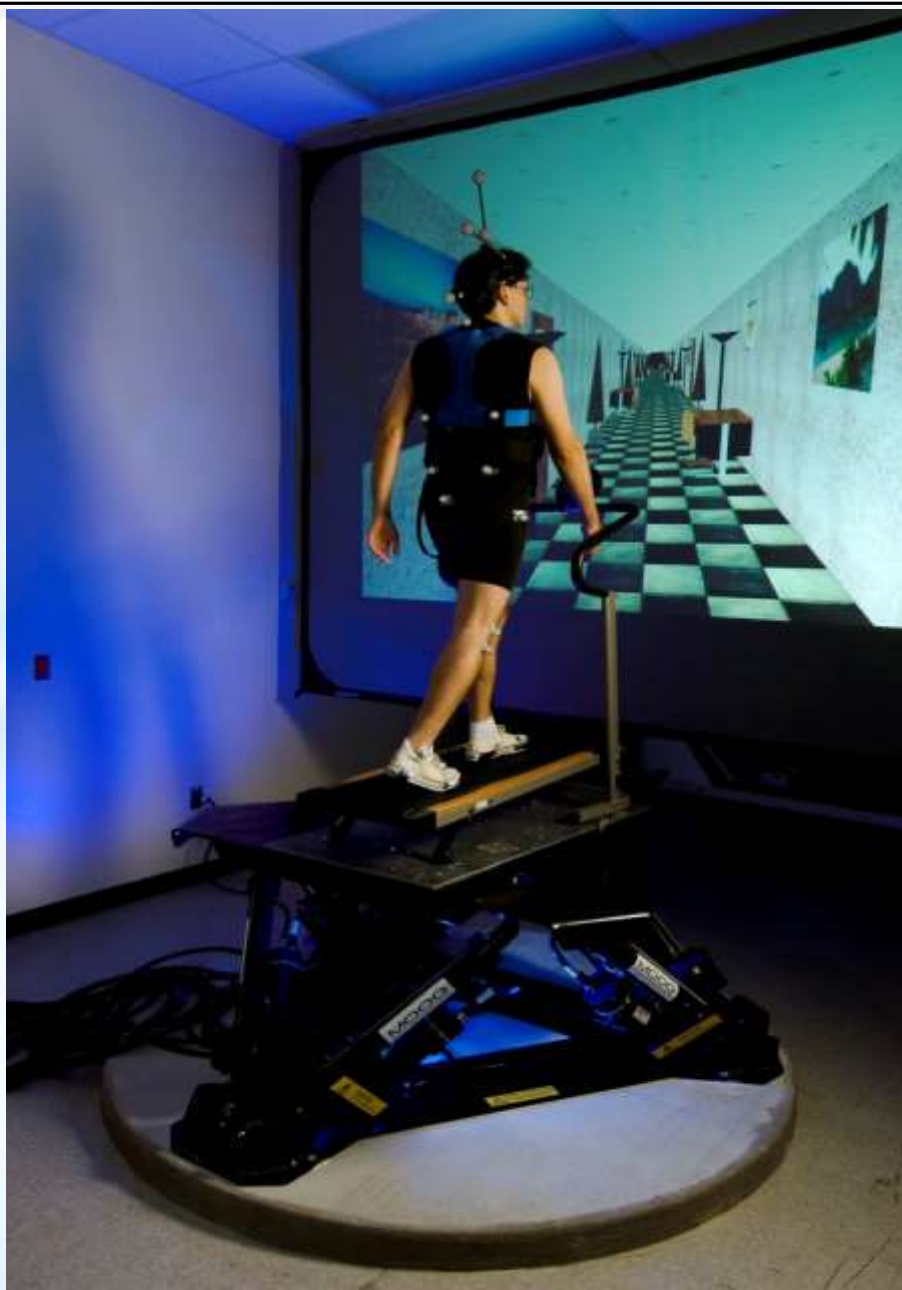


Treadmill in International Space Station





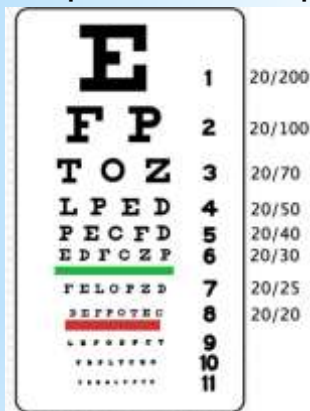
Treadmill in a six-degree of freedom Platform



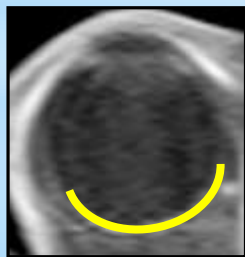


•Hyperopic Shifts

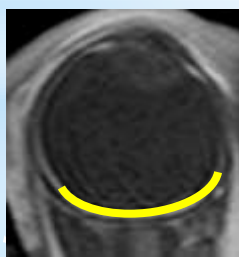
-Up to +1.75 diopters



•Globe Flattening

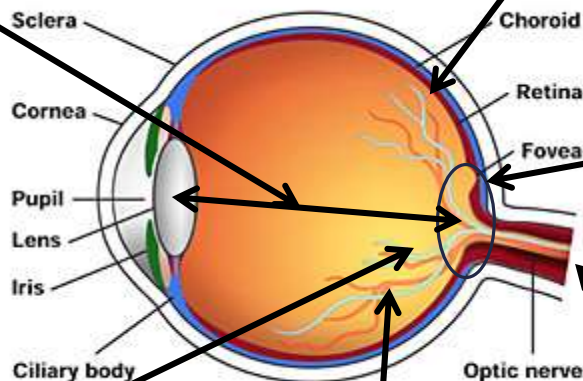


Normal Globe



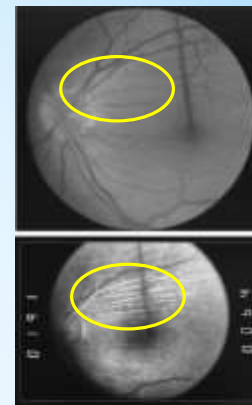
Flatten Globe

MRI Orbital Image showing globe flattening



•Choroidal Folds

- parallel grooves in the posterior pole



•Optic Disc Edema (swelling)

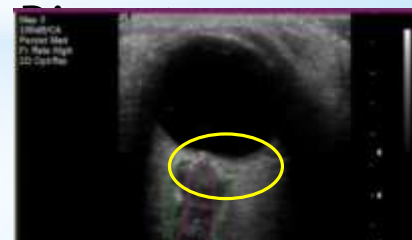


•Altered Blood flow

•“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.



SpaceX Crew Return from ISS - Two Months Stay



<https://twitter.com/i/status/860139550231863296>

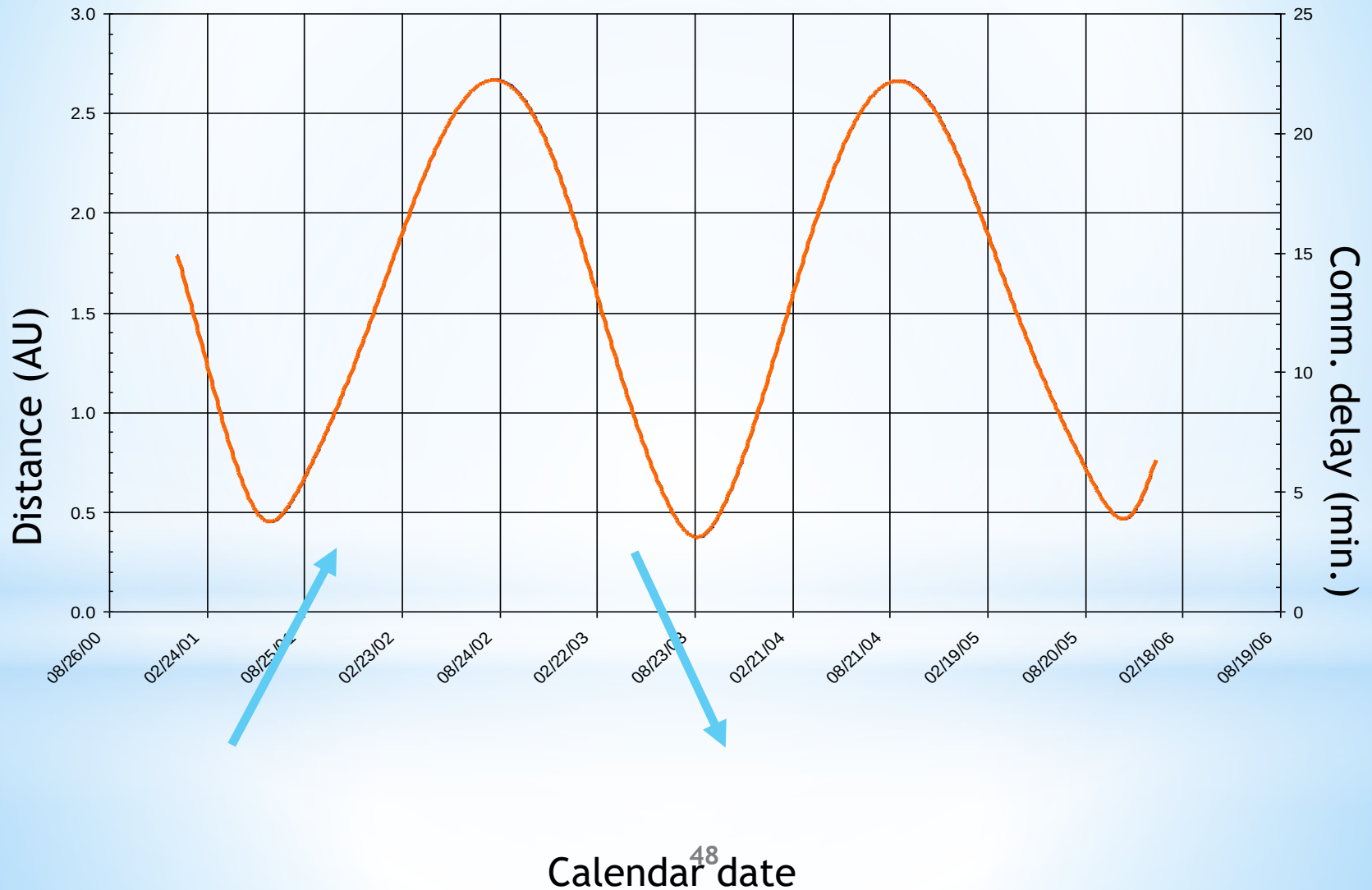
<https://twitter.com/i/status/860139550231863296>

<https://twitter.com/i/status/1075889929119547393>





Variation in Distance and Communications Delay Between Earth and Mars



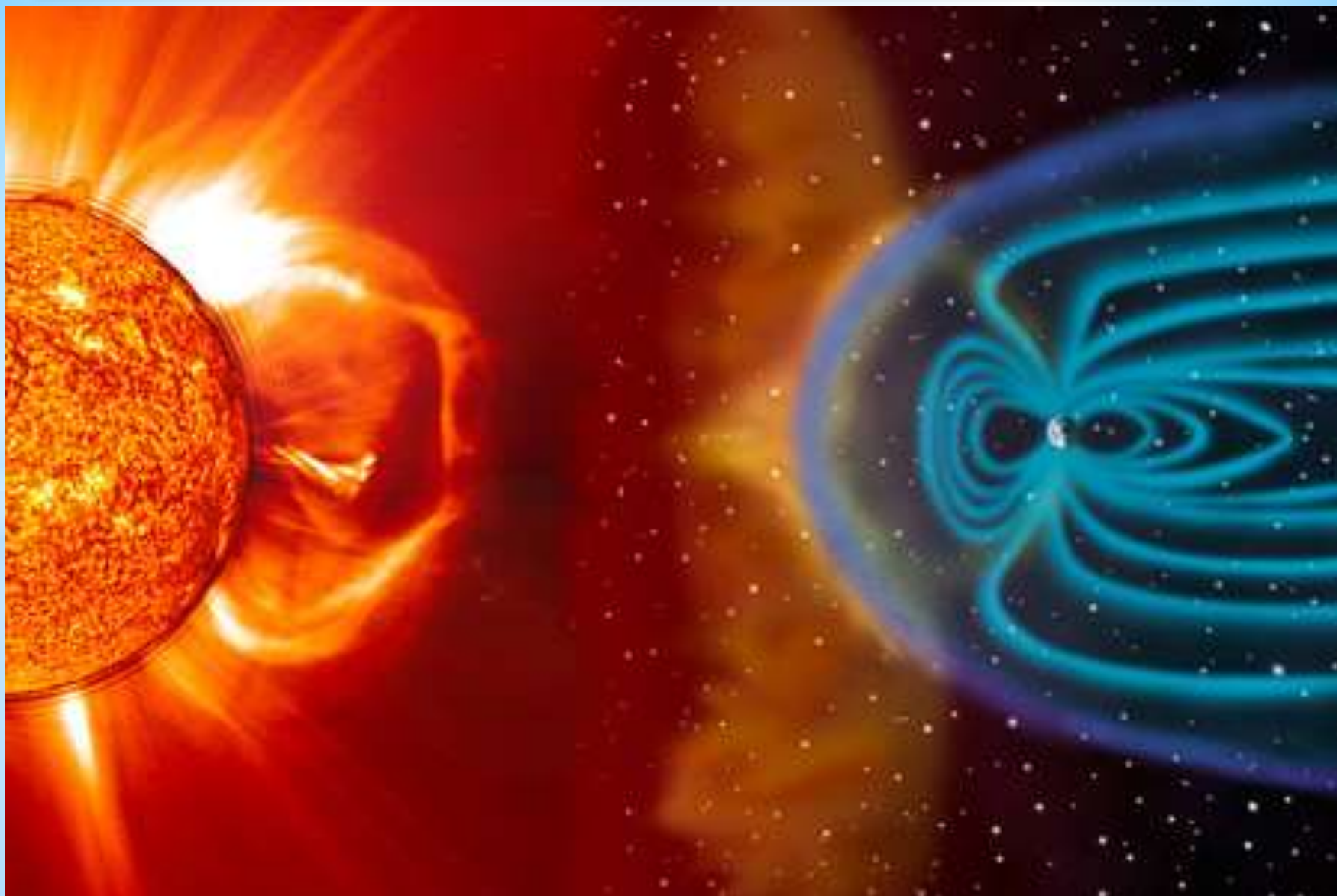
Mars-Earth Mutual View





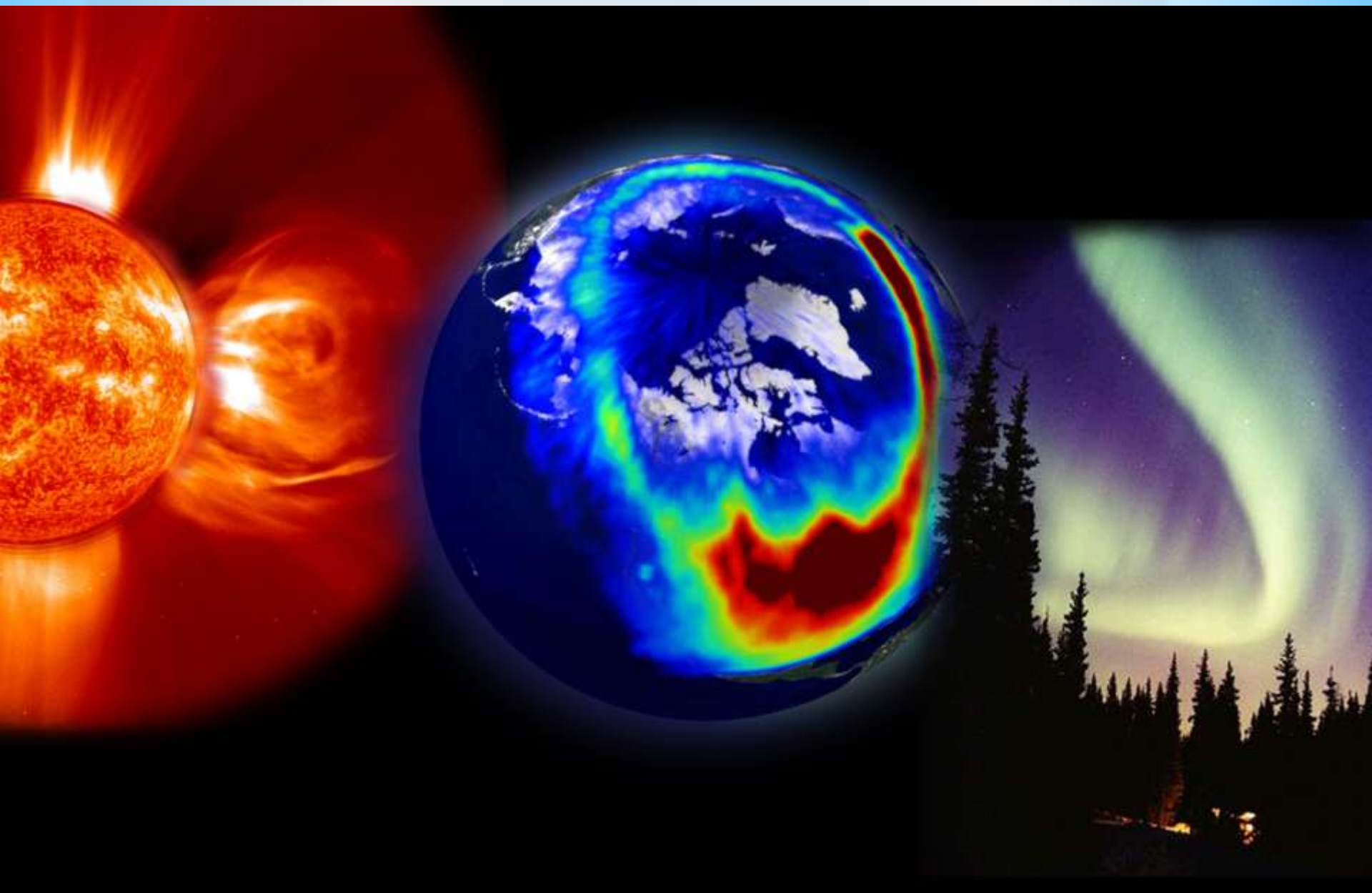
Solar Flare







Solar Flare/Aurora from Space/Earth



Auroras from ISS

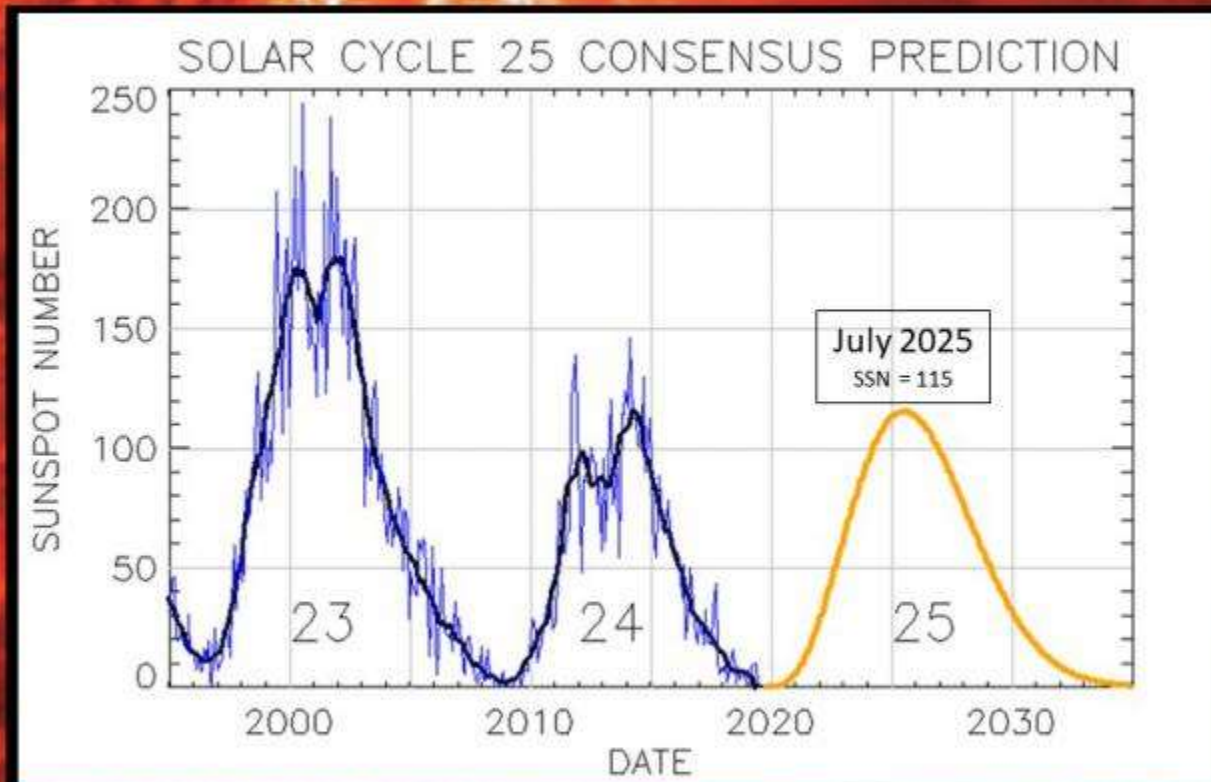


Aurora from Northern Hemisphere



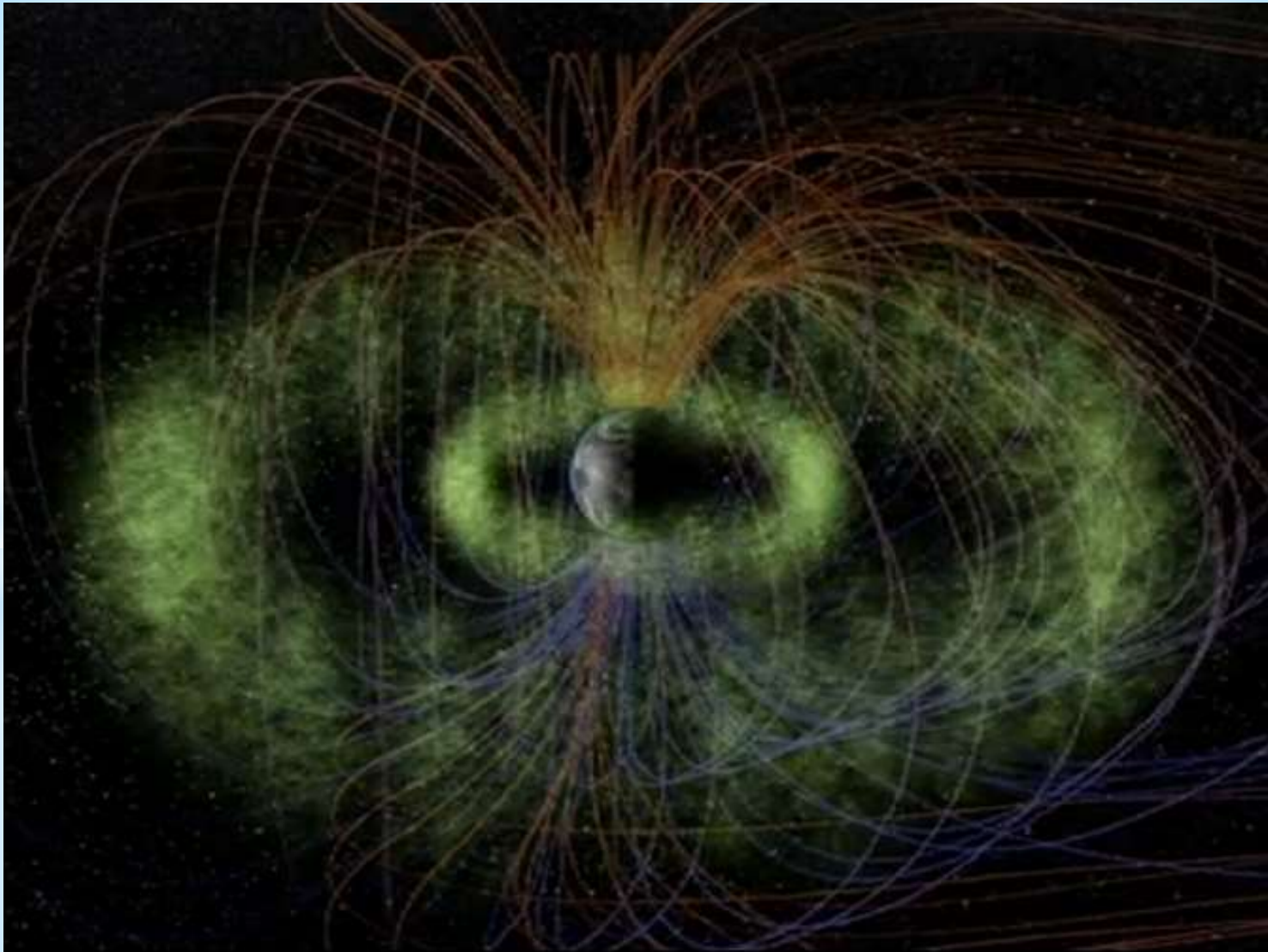
Solar Cycle 25 Forecast Update

- 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



van Allen Belt Particles

Components:

Protons: ~ 0.04 to 500 MeV

Electrons: ~ 0.04 to 7 MeV

Heavier Ions: Low Energies

Location of peak levels is energy dependent

Location of populations shifts with time

Average counts vary slowly with solar cycle

Counts may increase by orders of magnitude with magnetic storms

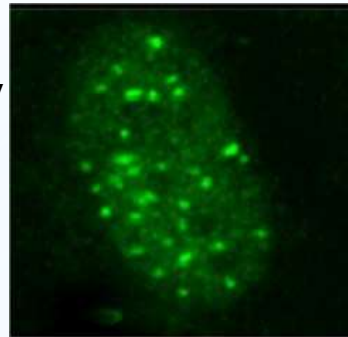
The Space Radiation Problem

National Aeronautics and Space Administration

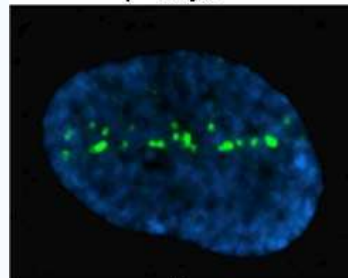


Space radiation is comprised of high-energy protons and heavy ions (HZE's) and secondary protons, neutrons, and heavy ions produced in shielding

- Unique damage to biomolecules, cells, and tissues occurs from HZE ions
- No human data to estimate risk
- Animal models must be applied or developed to estimate cancer, and other risks
- Shielding has excessive costs and will not eliminate galactic cosmic rays (GCR)



γ - rays

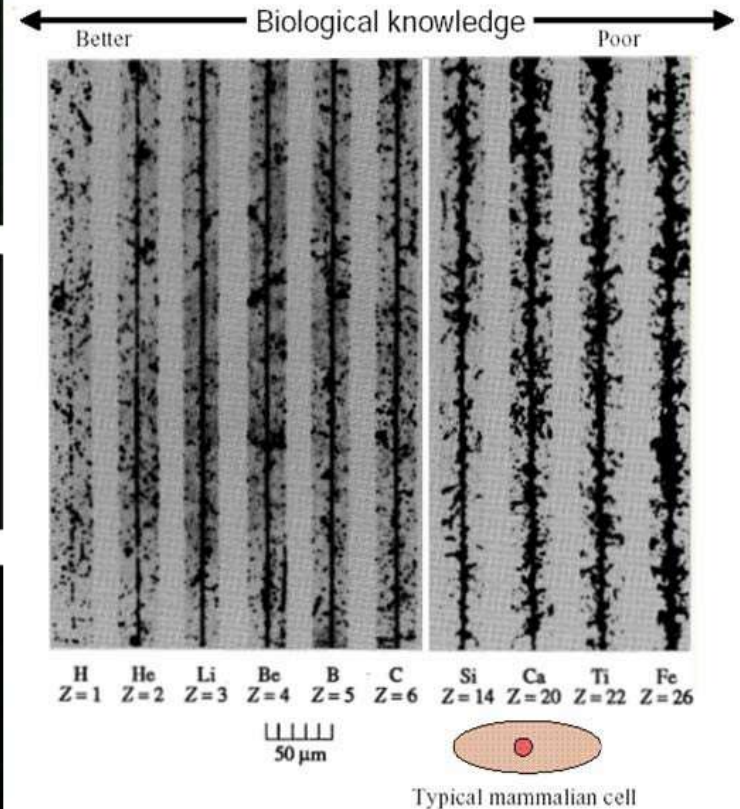


silicon

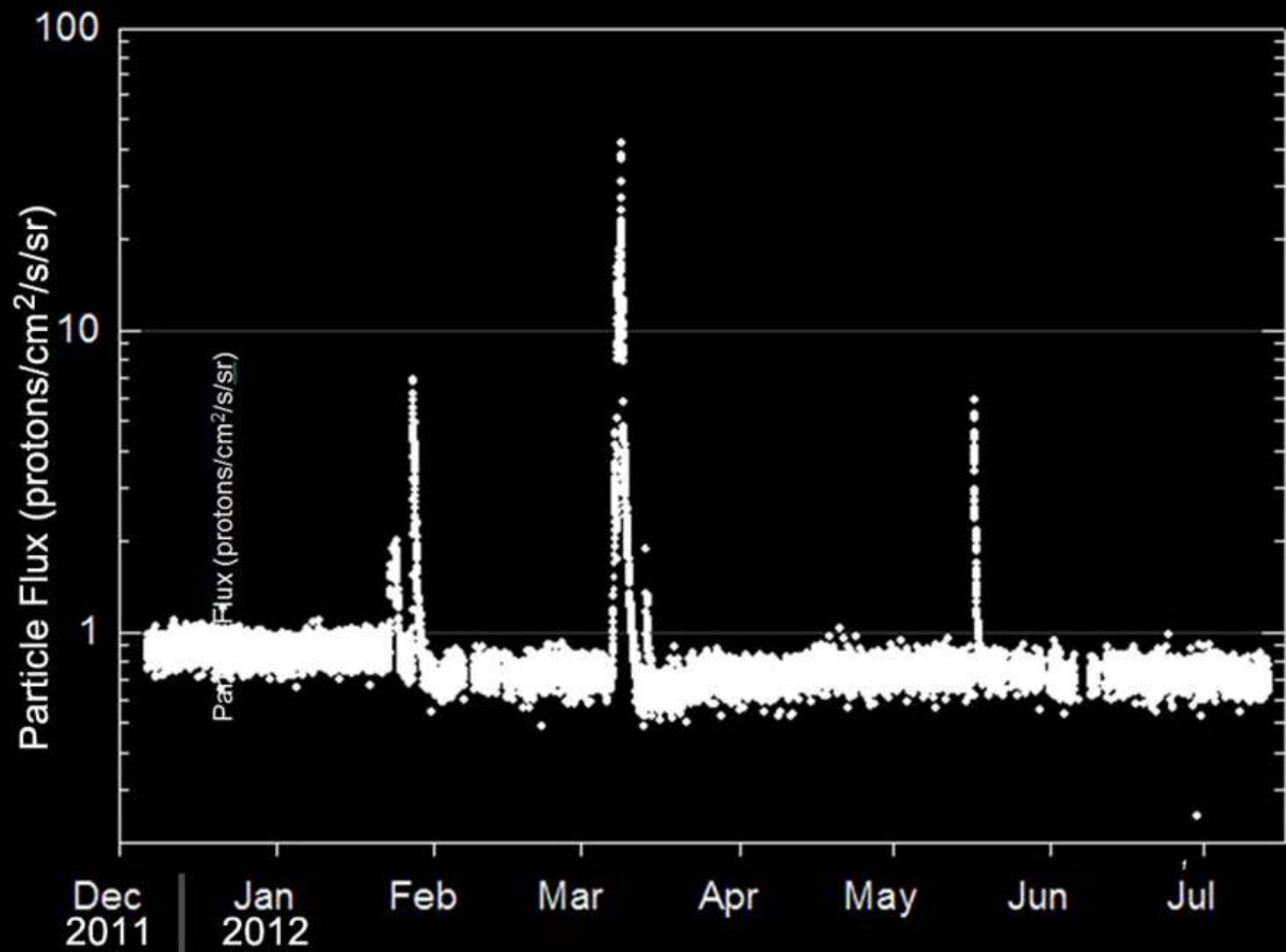


iron

Single HZE ions in cells
And DNA breaks



Single HZE ions in photo-emulsions
Leaving visible images

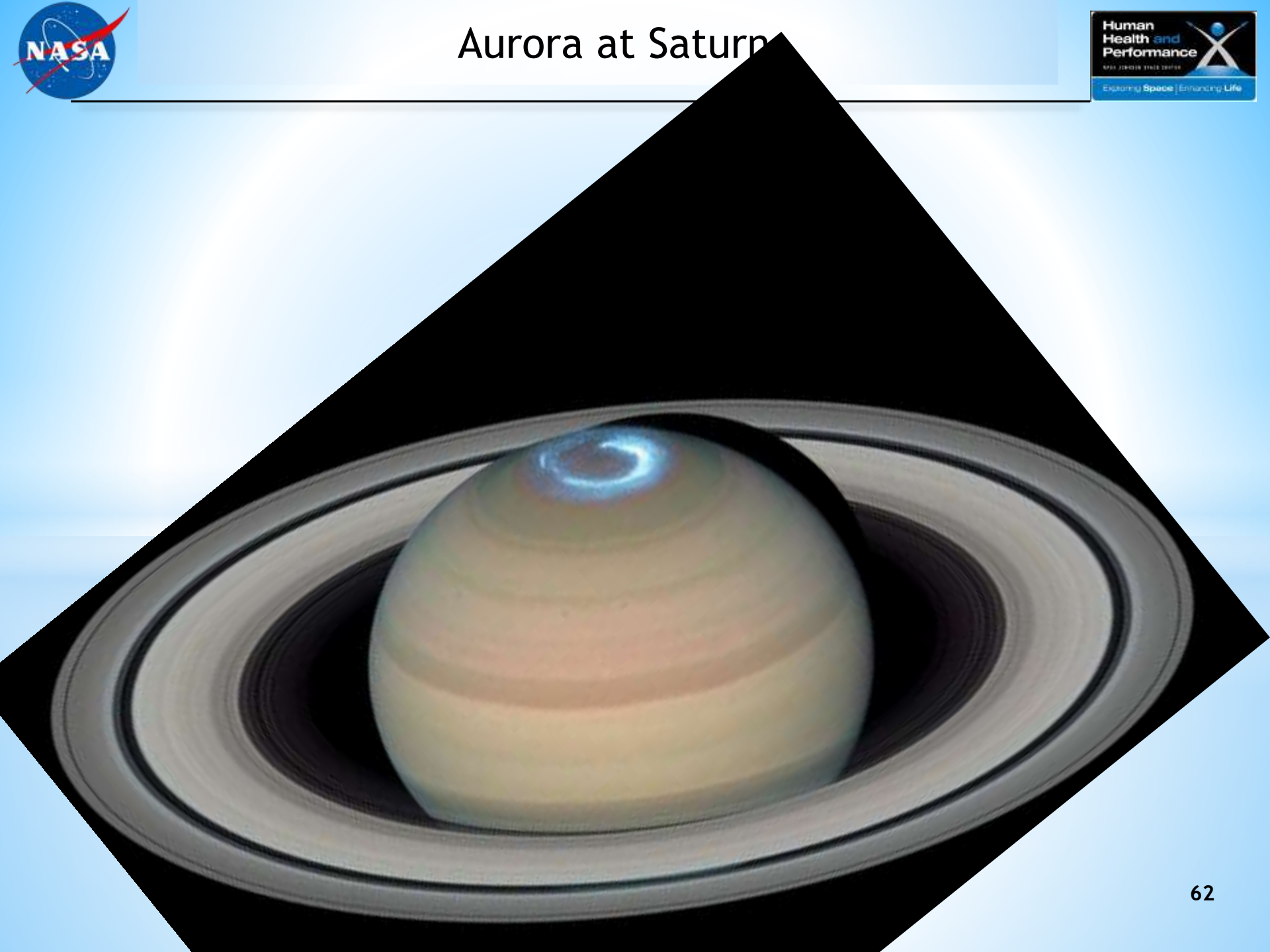


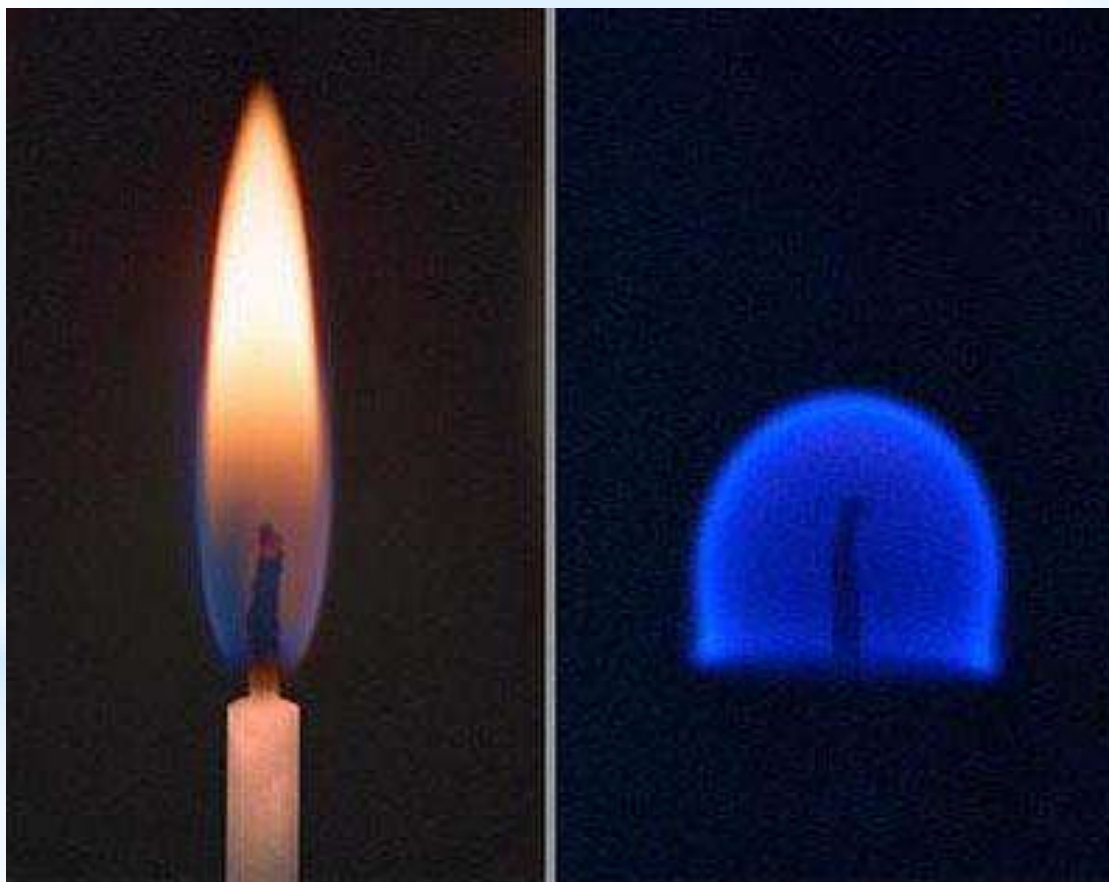
Aurora at Jupiter





Aurora at Saturn

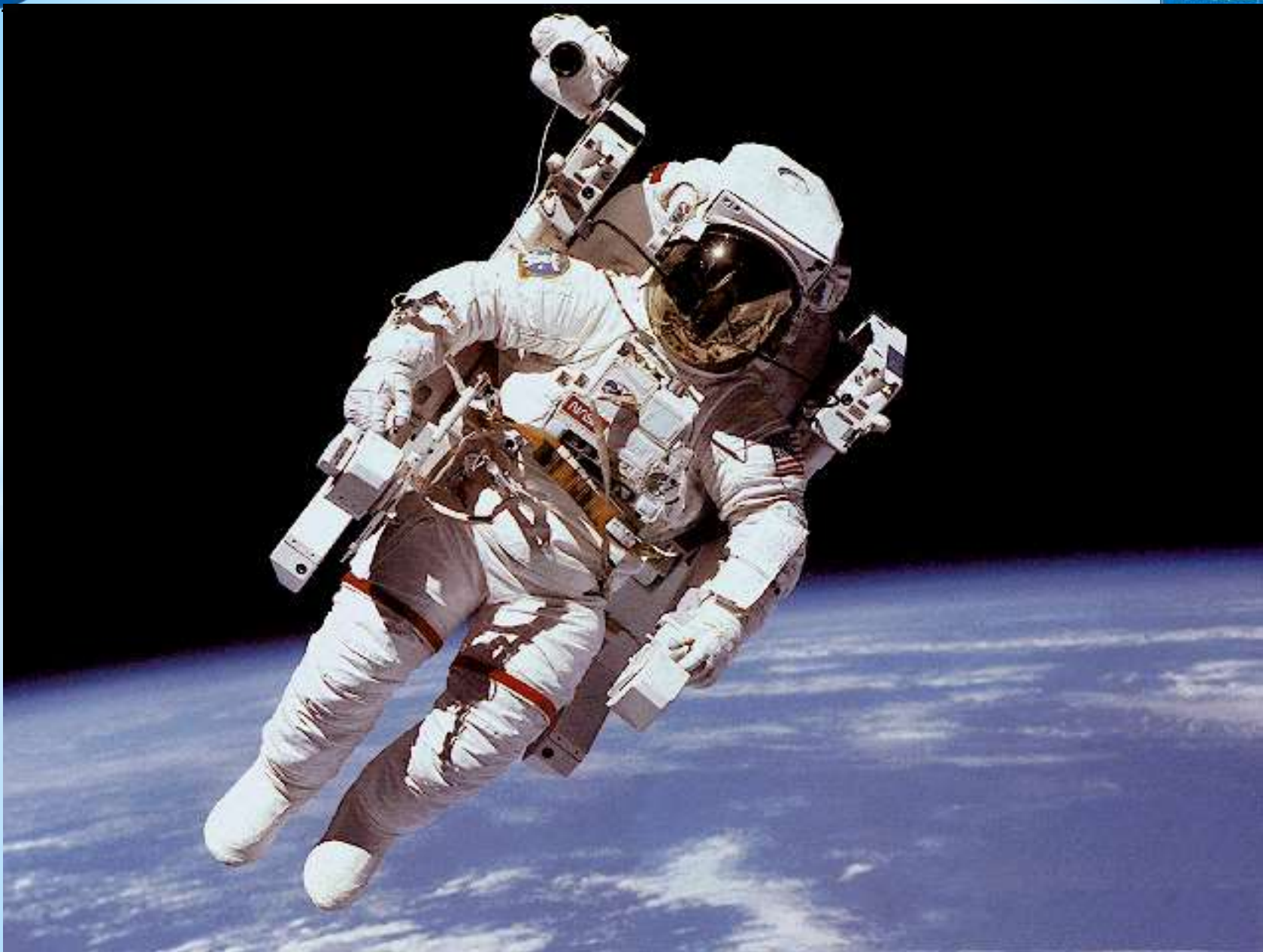






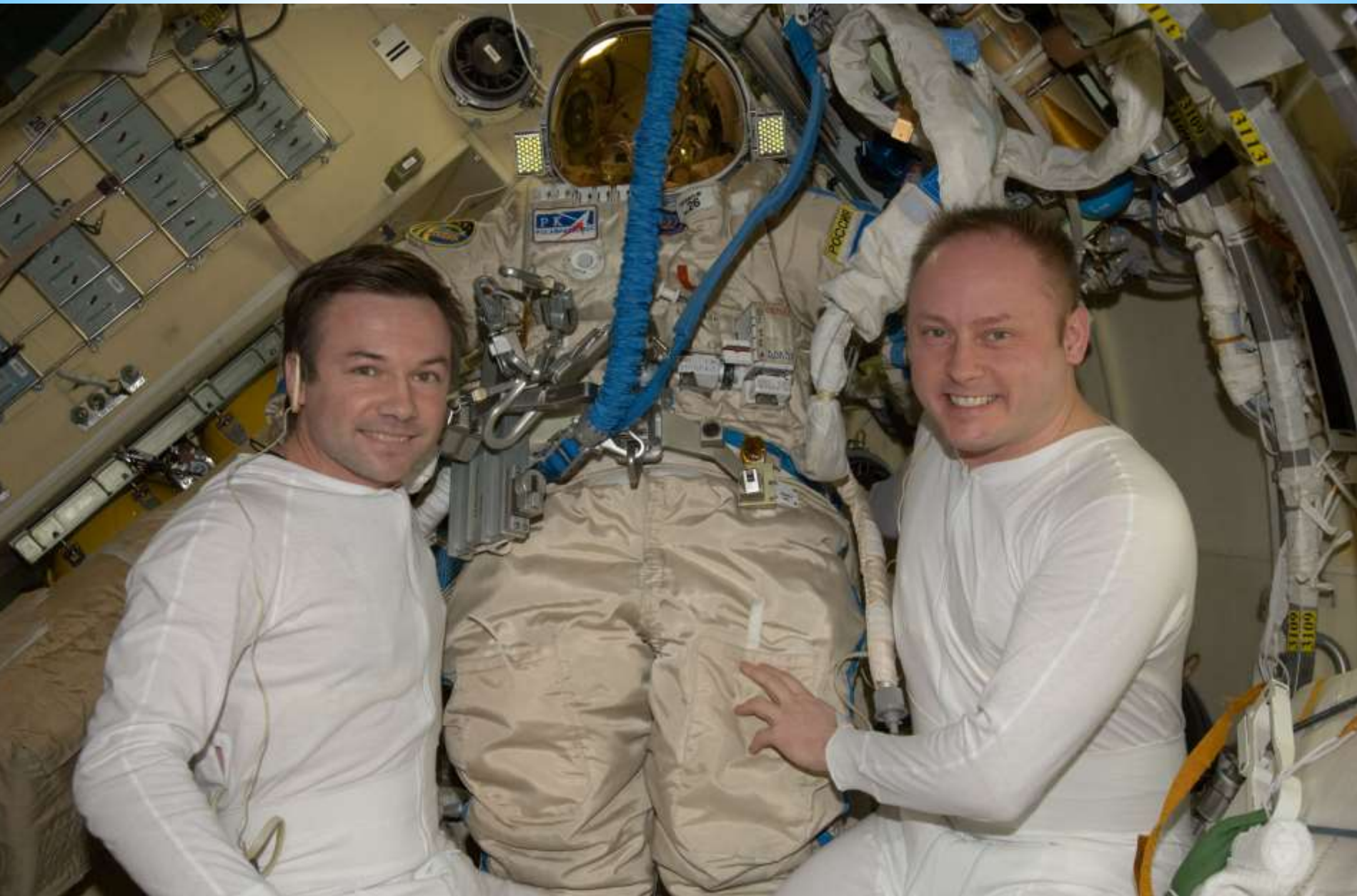


Human Stay in Outer Space



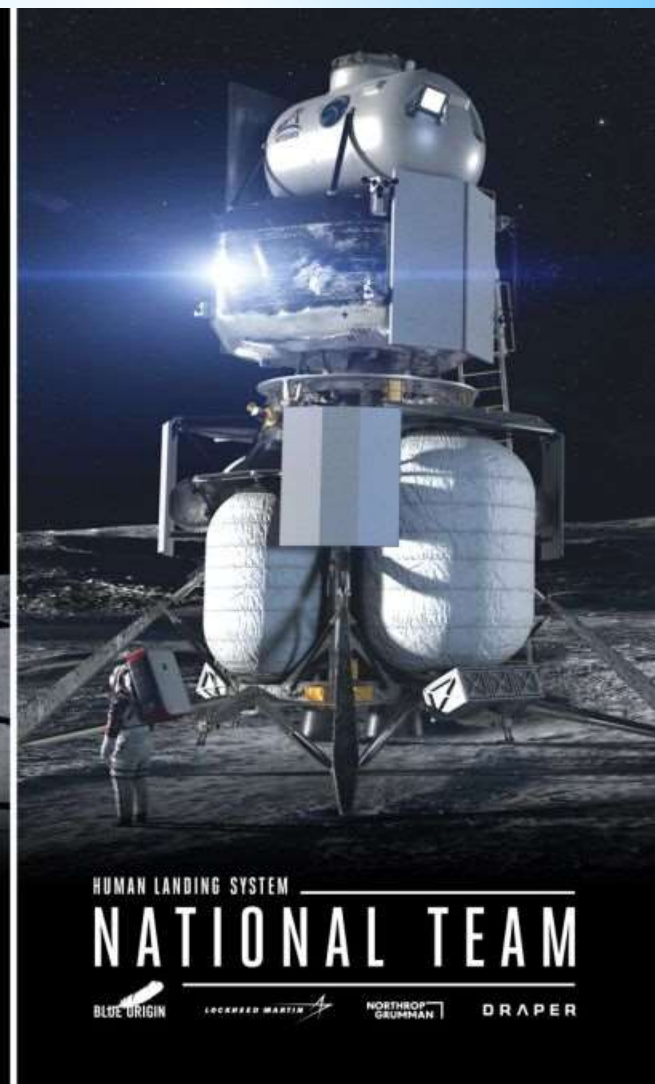
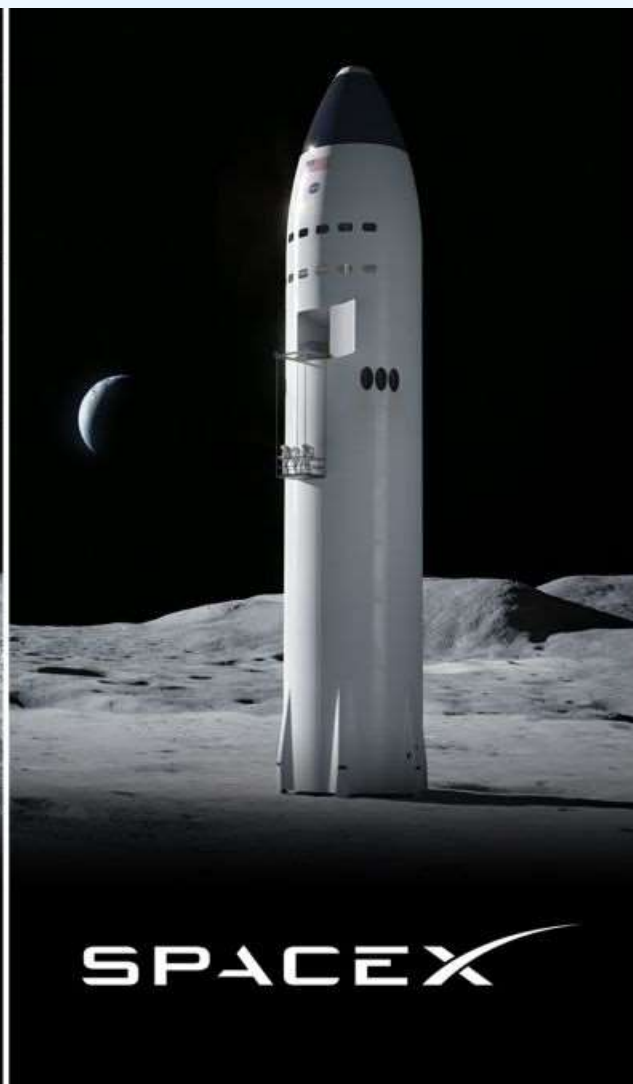
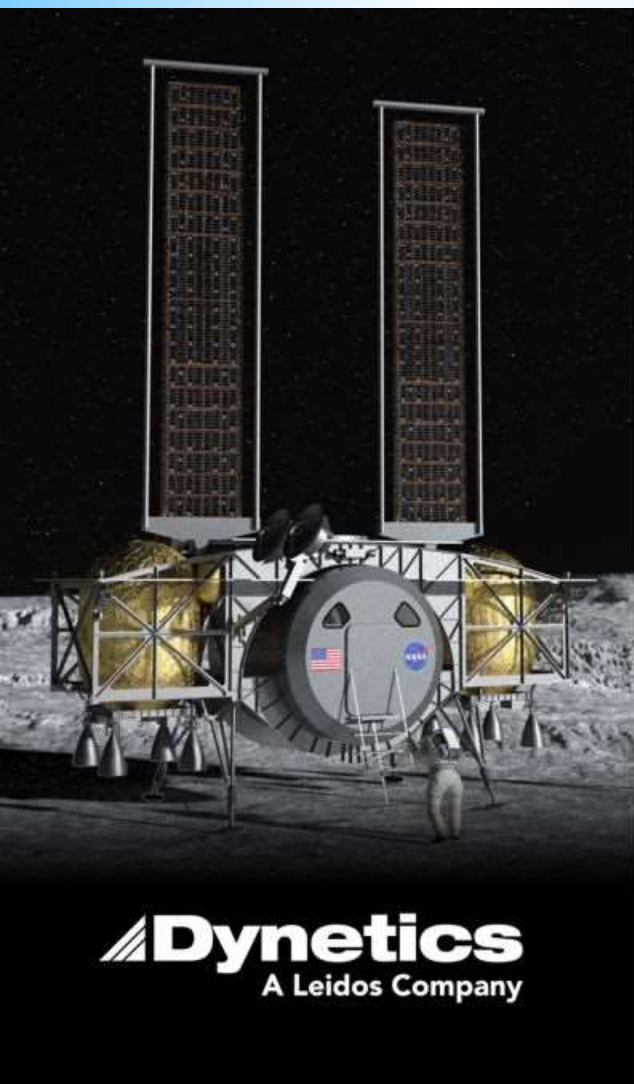


EVA suit Cooling Garment



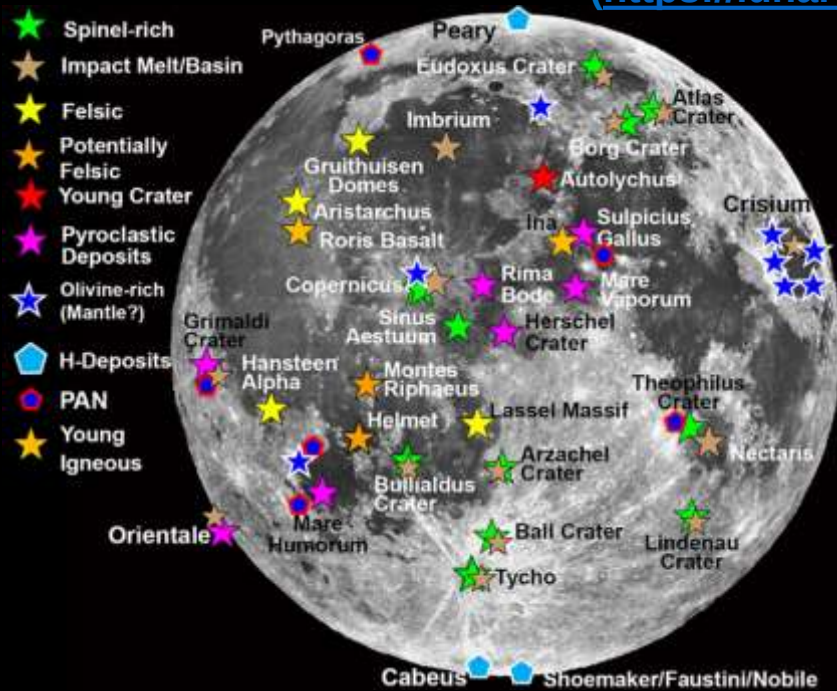


Moon Landing : 2024

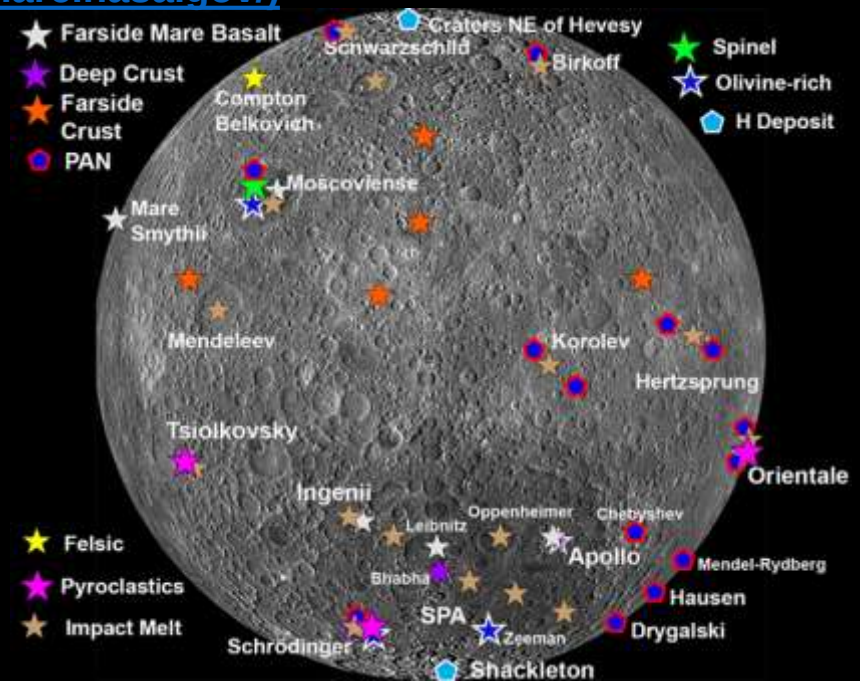


Lunar Scientists have a lot of places they would like to go!

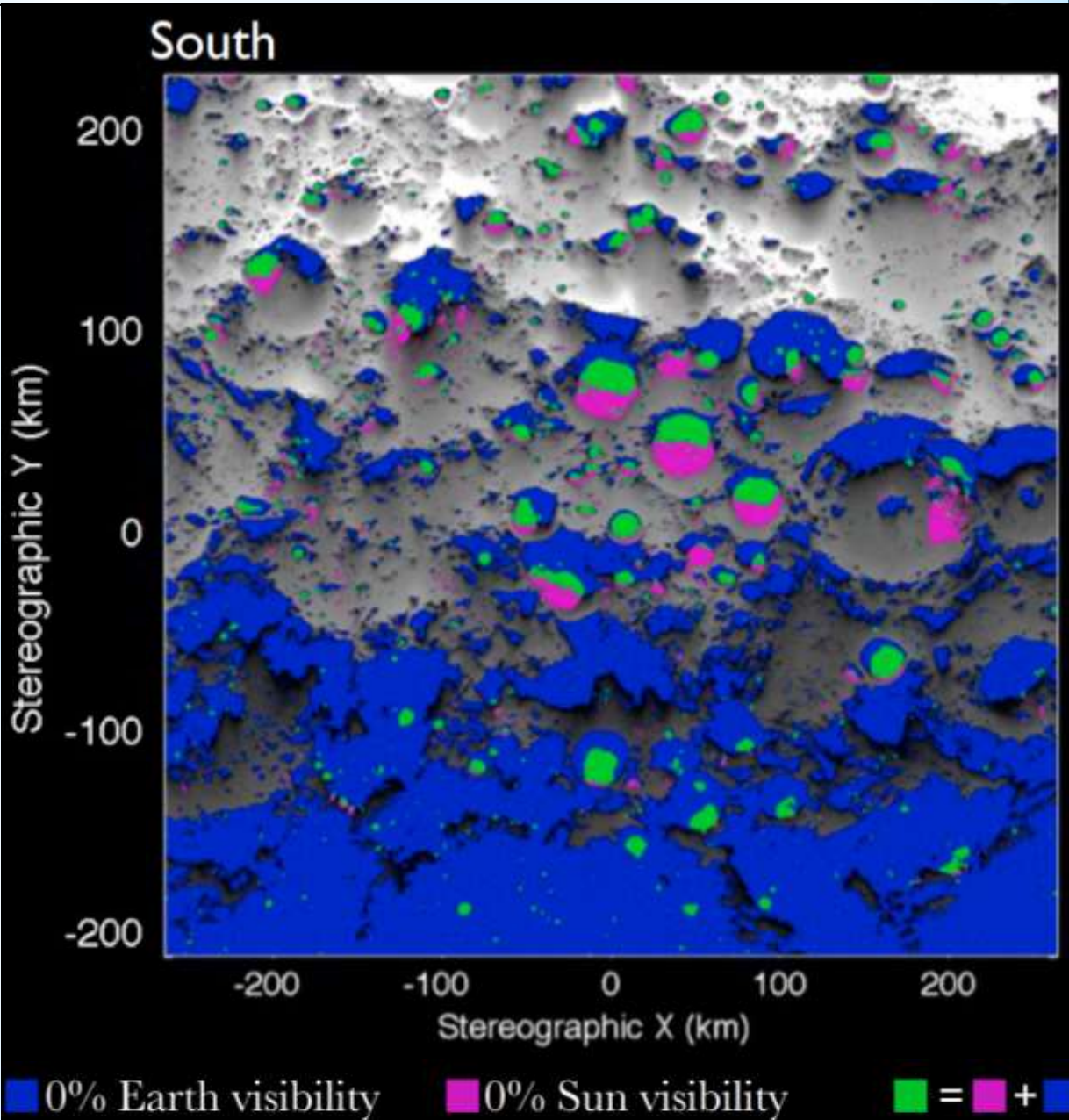
(<https://lunar-landing.arc.nasa.gov/>)



Near Side

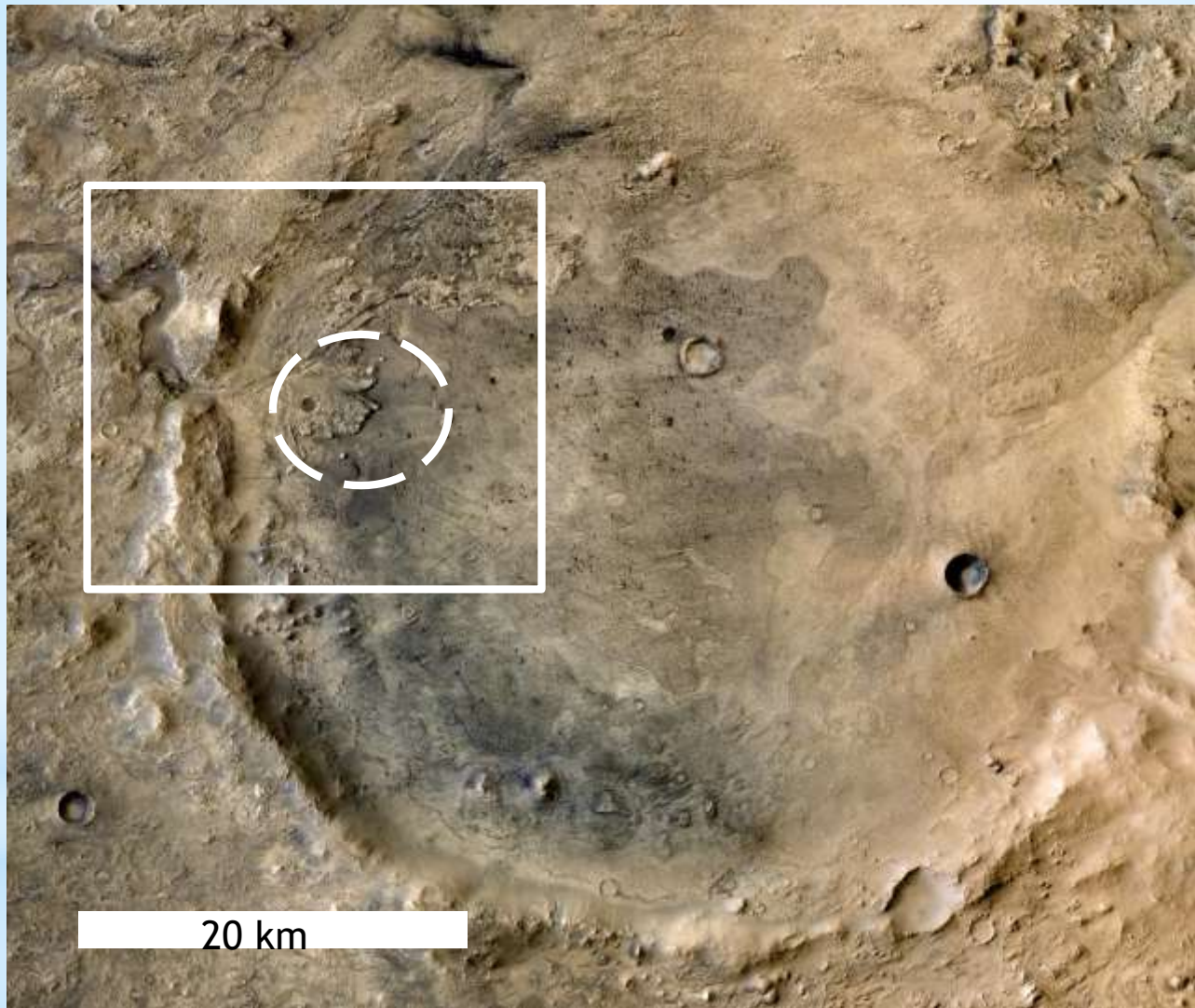


Far Side



Mazarico, LEAG 2013

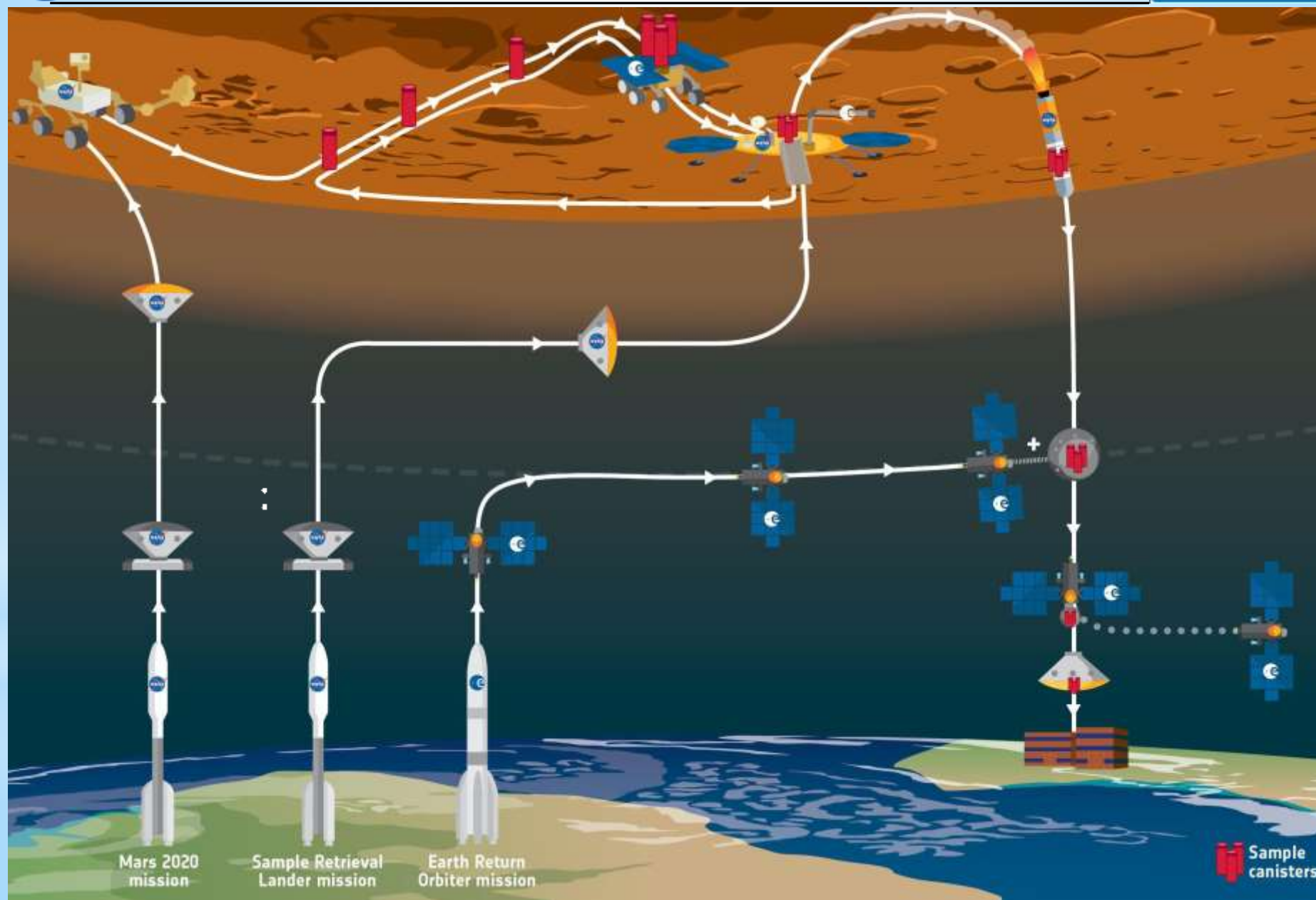
Mars 2020 : Jezero Crater



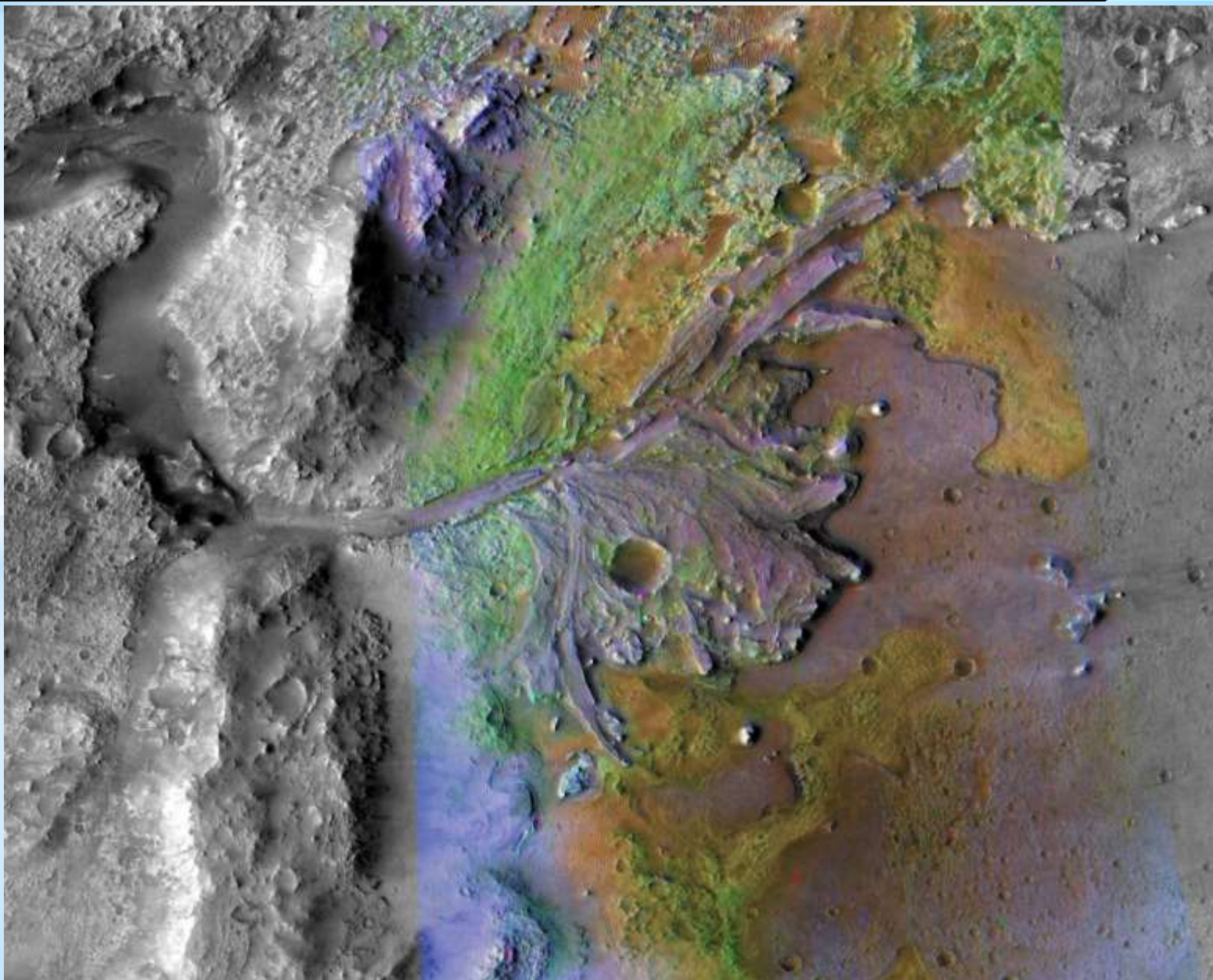
Credit: NASA / JPL / MSSS / ESA / DLR / FU Berlin / J. Cowart



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



Mars 2020 : Jezero Crater





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 Skills

Who is at Your Window?



I feel responsible - Collins

APOLLO AND OUR FUTURE

A panel discussion with:

Apollo 11 Astronaut Mike Collins
JSC Director Mark Geyer
NASA Astronaut Anne McClain



Acknowledgment

Engineers, Scientists
and Physicians

Thanks

Science Capabilities Evolution: Emplacing a Far Side Radio Telescope

The Challenge

There is an observational gap in our understanding of the Universe's history, during the cosmological "Dark Ages". The signals from this epoch are sufficiently faint that they may be detectable only from the radio-quiet lunar farside. (from NASA SSERVI Lunar University Network for Astrophysical Research node, <http://lunar.colorado.edu/lowfreq/>)

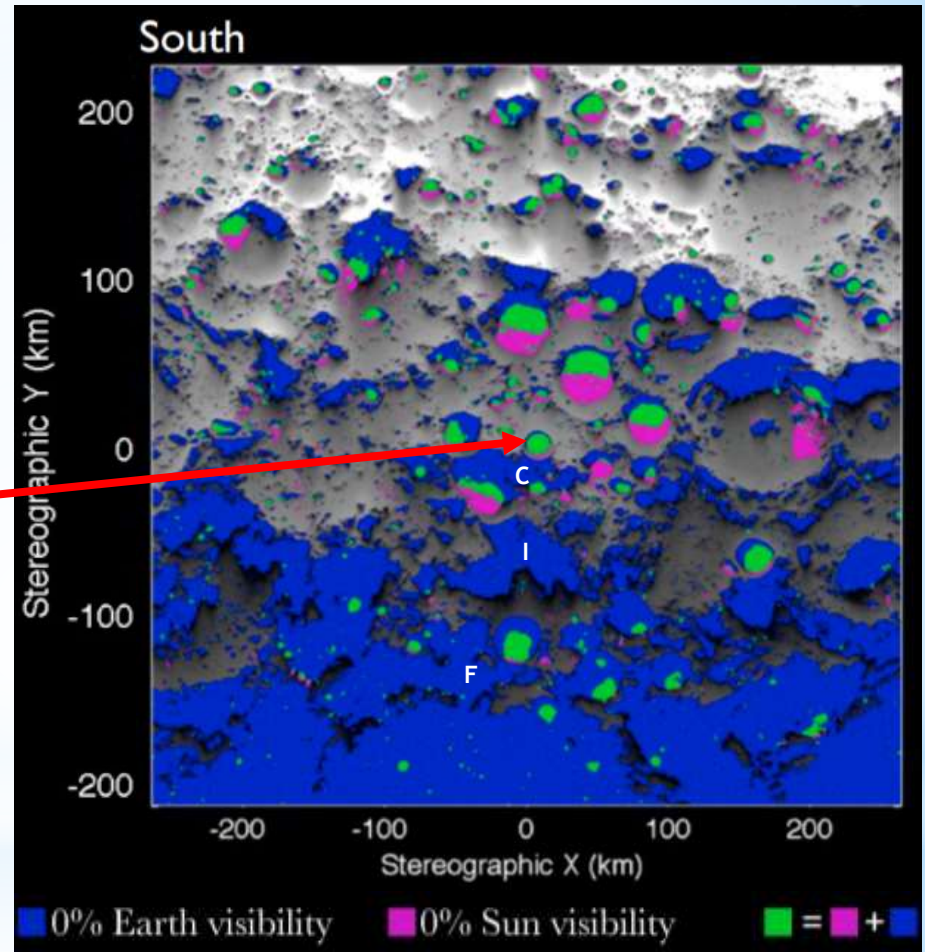
Exploration Approach

Determine feasibility of close location (~ a few 10s km from landing zone) for radio astronomy (see 'C' on image).

Determine feasibility of intermediate location (~ 50-100 km distant) for radio astronomy (see 'I' on image).

If needed, emplace radio telescope at far location (~ 150-200 km distant), see 'F' on image.

Shackleton
Crater

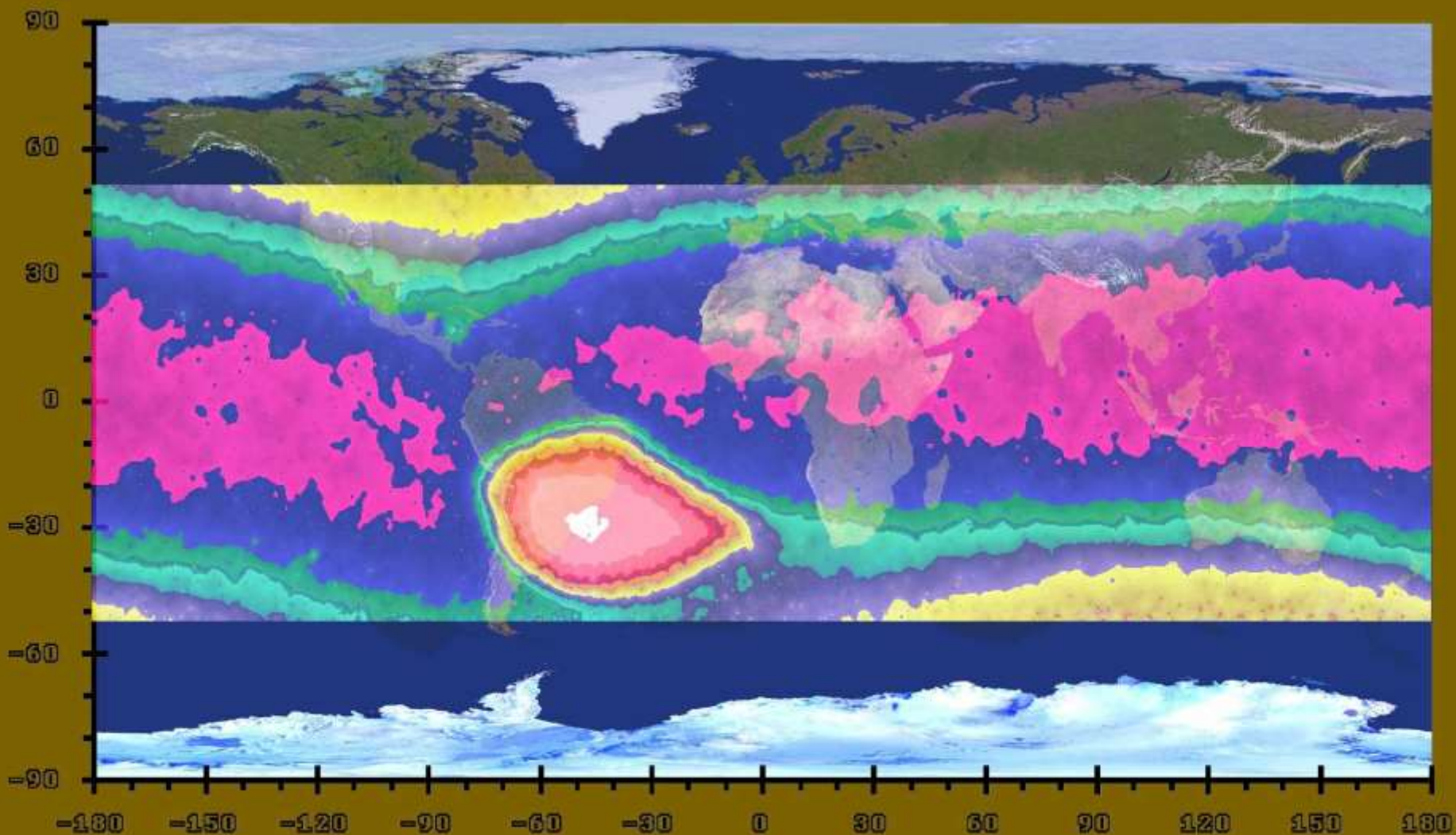


Mazarico, LEAG
2013



Mars Rover from China in 2020





Inclination = 51.6 deg.
Altitude ~ 385 km.
November 2, 1997 -
November 4, 1997

NASA-MIR 6 - Radiation Dosage TEPC- ⁷⁹PRIRODA

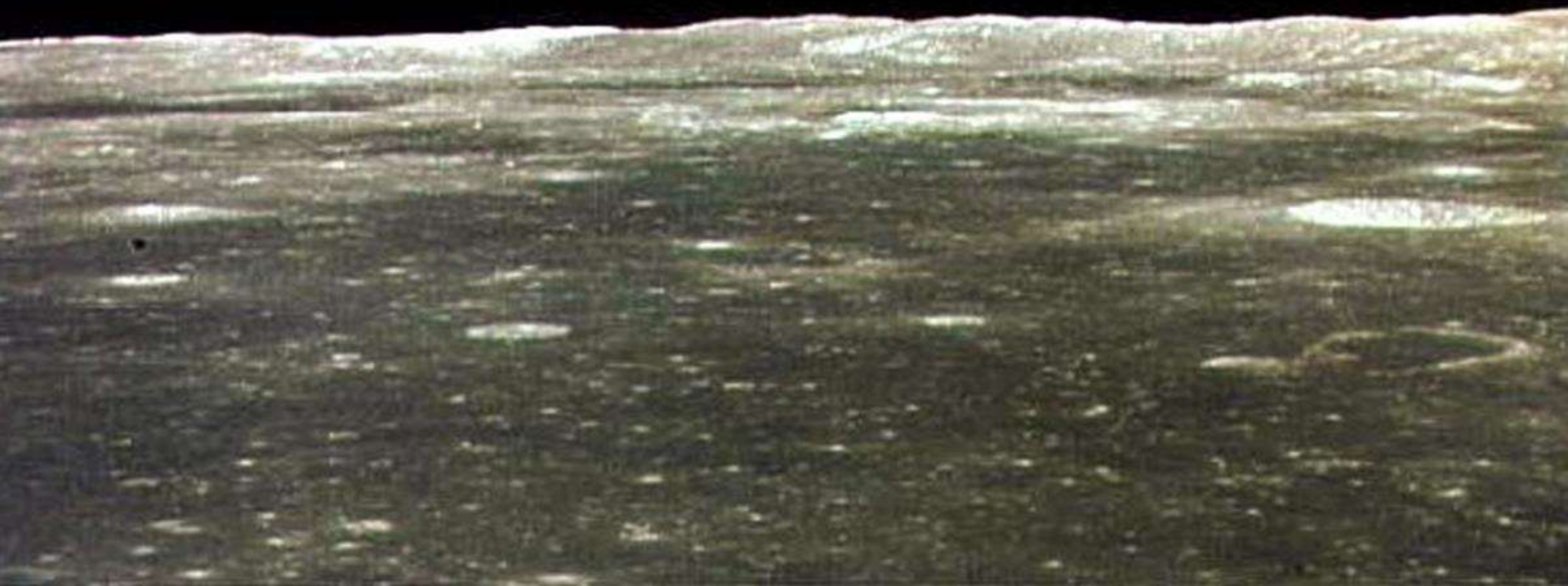
0 nGy/min 6500



Beautiful Fragile Blue Planet



With God's grace, Make a difference



Biomedical & Environmental Analytical (10) : South Wing

- Clinical Laboratory
- Core Analytics
- Immunology
- Nutritional Biochemistry
- Toxicology & Environmental Chemistry
- Pharmacotherapeutics
- Radiation Biology
- Space Cell Biology
- Microbiology
- Animal Care Facility



Human Performance (7) : North Wing

- Bone & Mineral
- Cardiovascular Physiology
- Anthropometry & Biomechanics
- Behavior Health and Performance
- EVA Physiology
- Exercise Physiology
- Neurosciences



Projects & Services : Anchor Wing

- Biostatistics
- Medical Library
- HRP Element Management
- Administrative Management

Infrastructure

- Machine Shop and Laboratory Support Services (LSS)



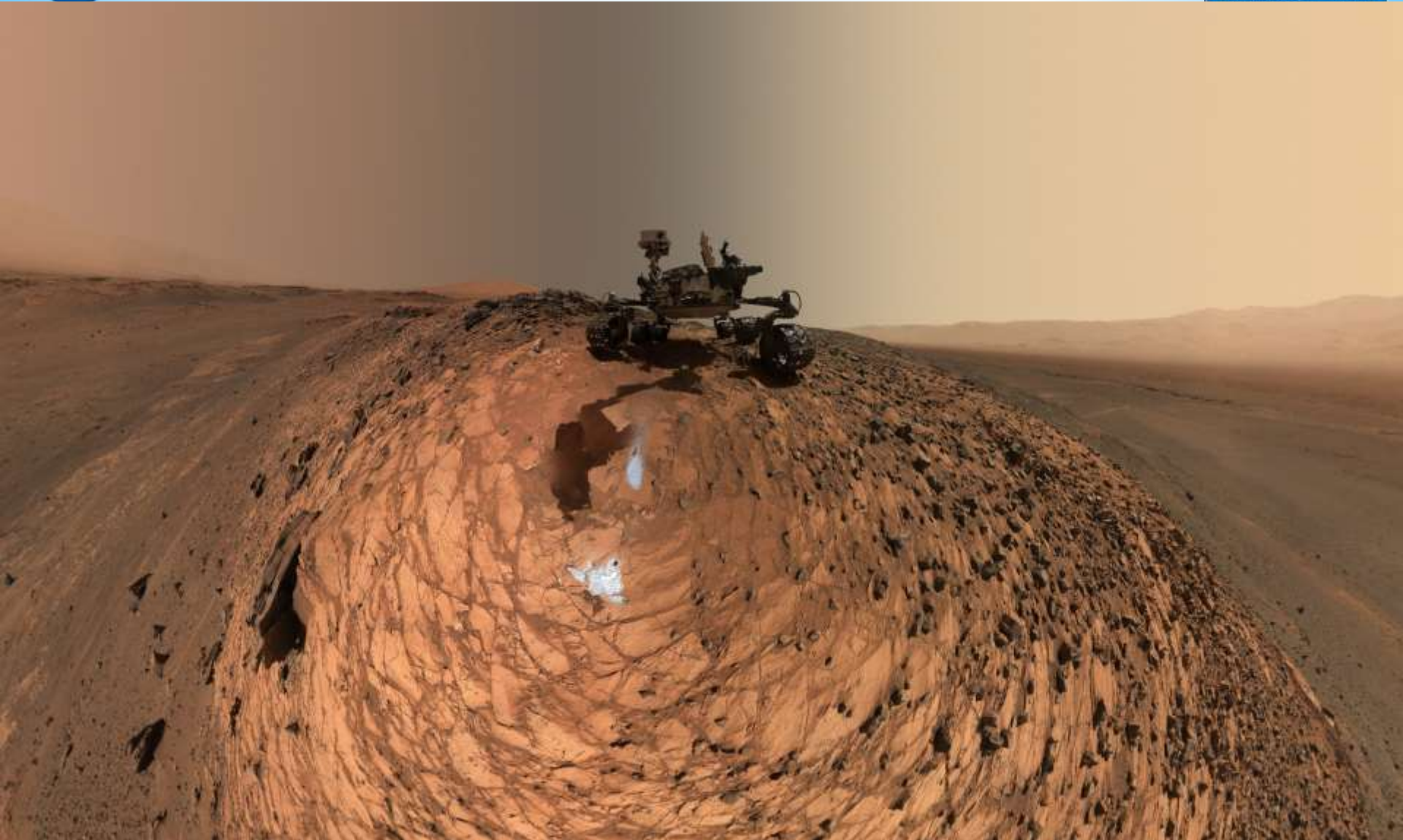


Thanks

Let us Collaborate



Mars 20ft Mount









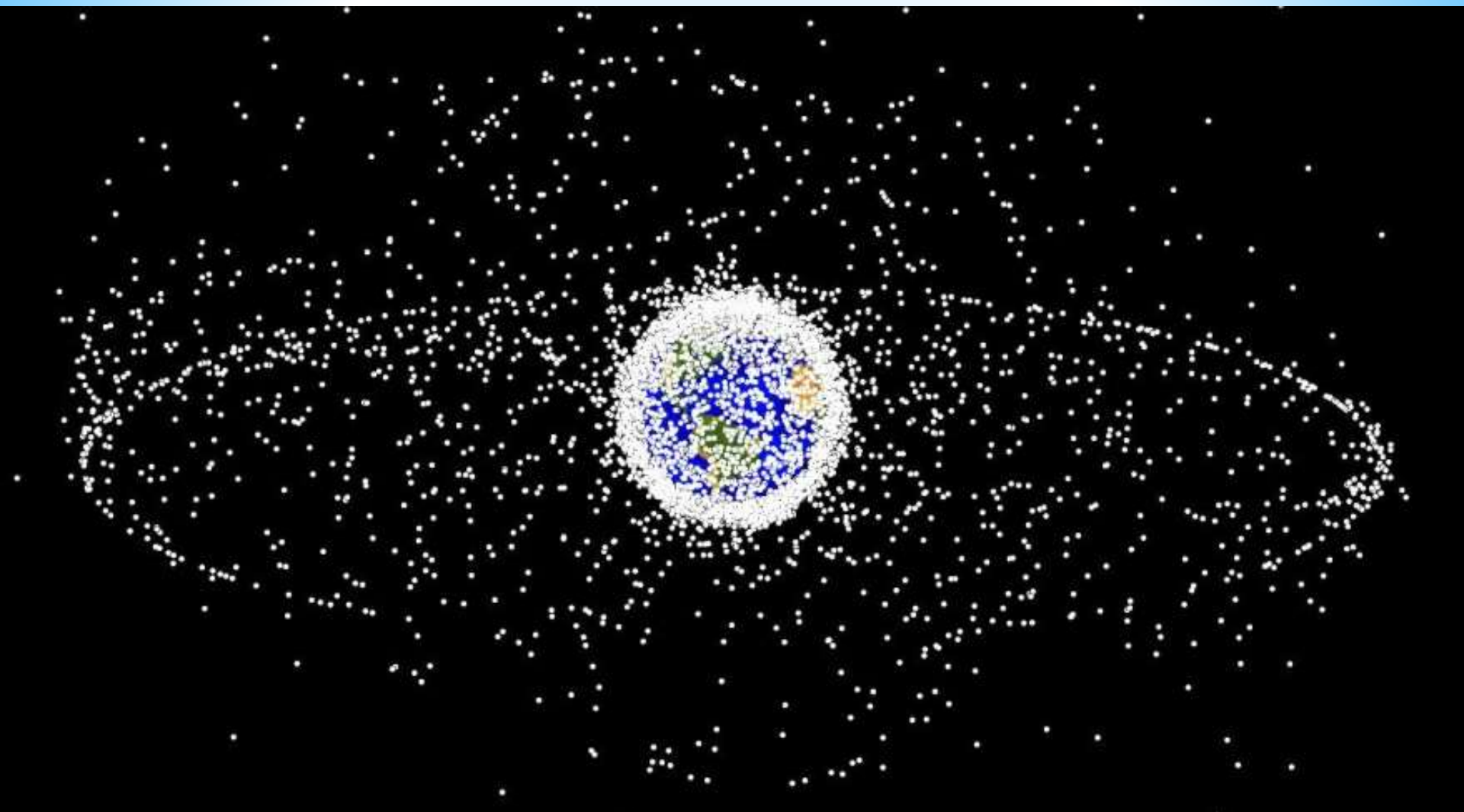


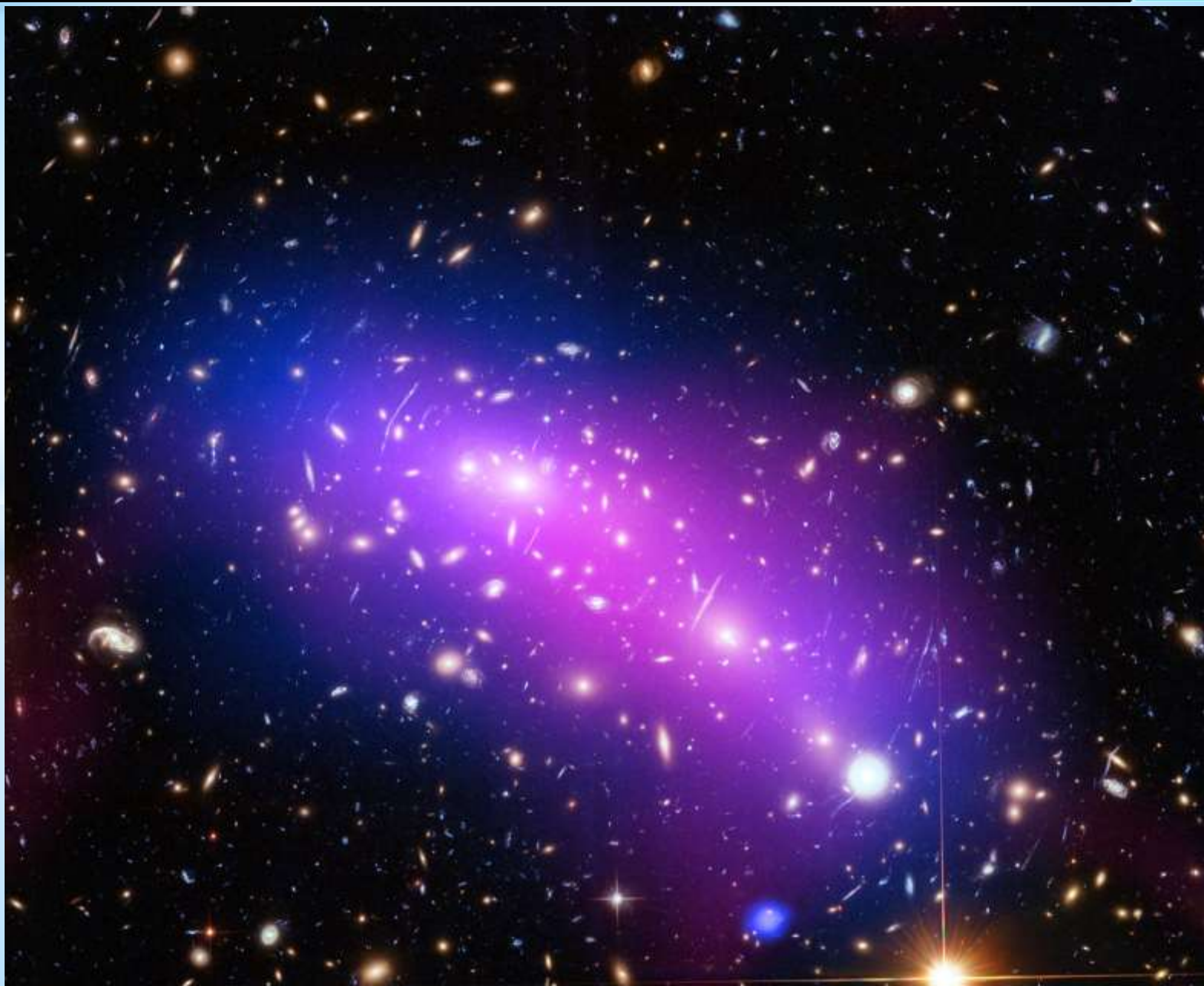
View from Sudan



Zuma Pilot Picture









X-37B Space Plane



Pluto





Gross Lift-off weight : 2 Million tons

Thrust : 33,327 kilonewtons

SRB Separation : 45 km

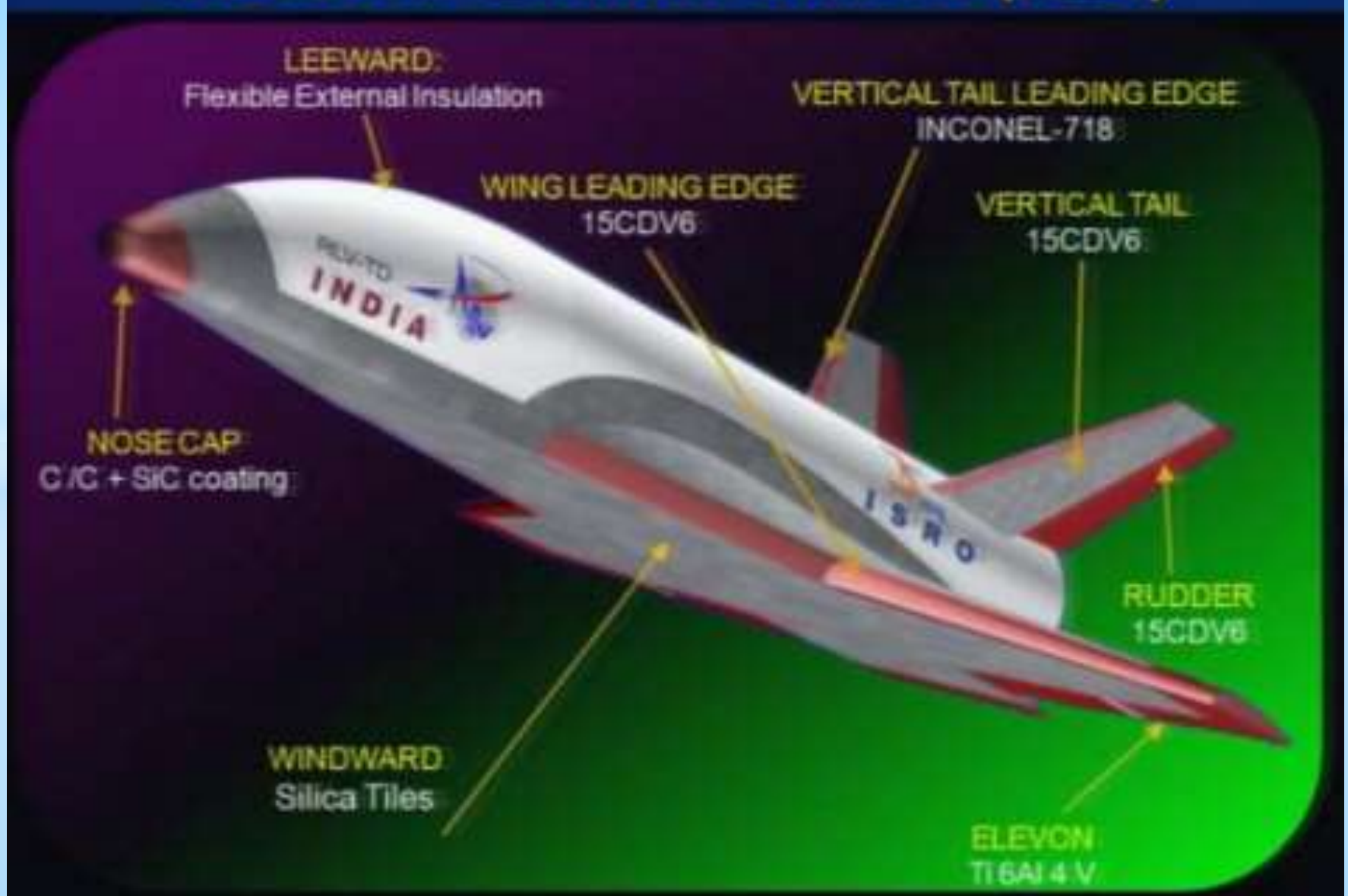
External Tank Separation : 111 km

Orbital velocity : 27,869 km/hour

Payload weight : 25 tons

Shuttle weight : 78 tons

Reusable Launch Vehicle (RLV)



Biological samples will be taken from the lunar receiving lab and then sent to the rest of the station. At upper left, lunar samples arrive and are taken by vacuum system and vacuum lab by elevator. Other resources indicated are for air, food and laundry. Lines at far right show where all personnel come and go through allocated airlocks (space).

Lunar Sample Laboratory

Over 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. Corridor for storage and transfer of lunar material
3. Controls for vacuum system
4. Support room for purified and sterilized
5. Can 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 lab
11. Physical effects of test lab—microbiology, pathology, 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 tissue
14. Holding lab for growth from tissue
15. Holding lab for conventional tests
16. Lunar microbiology lab to isolate, identify and possibly grow lunar microorganisms
17. Spectrographic lab and detection (connected to 11)
18. Rest, lab and maintenance lab where sleeping, food, vacuum, systems and other resources are engaged to lunar material
19. Microbiology lab for test collection of lunar and personnel material
20. Egg and tissue culture lab (support and additional facilities for 11)
21. Core ecology lab for postflight ecological analysis of atmosphere
22. Plant lab where greenhouse algae, mosses, seeds and seedlings will be exposed to lunar material
23. Entrance to lunar sample operations area. Shows and facilities for all personnel passing in and out to change clothing
24. Airlock for venting all material entering or leaving area
25. Bio-safety lab to handle all systems
26. Support office
27. Entrance to radiation counting lab

Anatomy of a Lunar Receiving Lab

Astronaut Reception Area

Quarantine area where personnel will live and be maintained in shaded yellow. In an emergency, lunar lab work area could also be quarantined there.

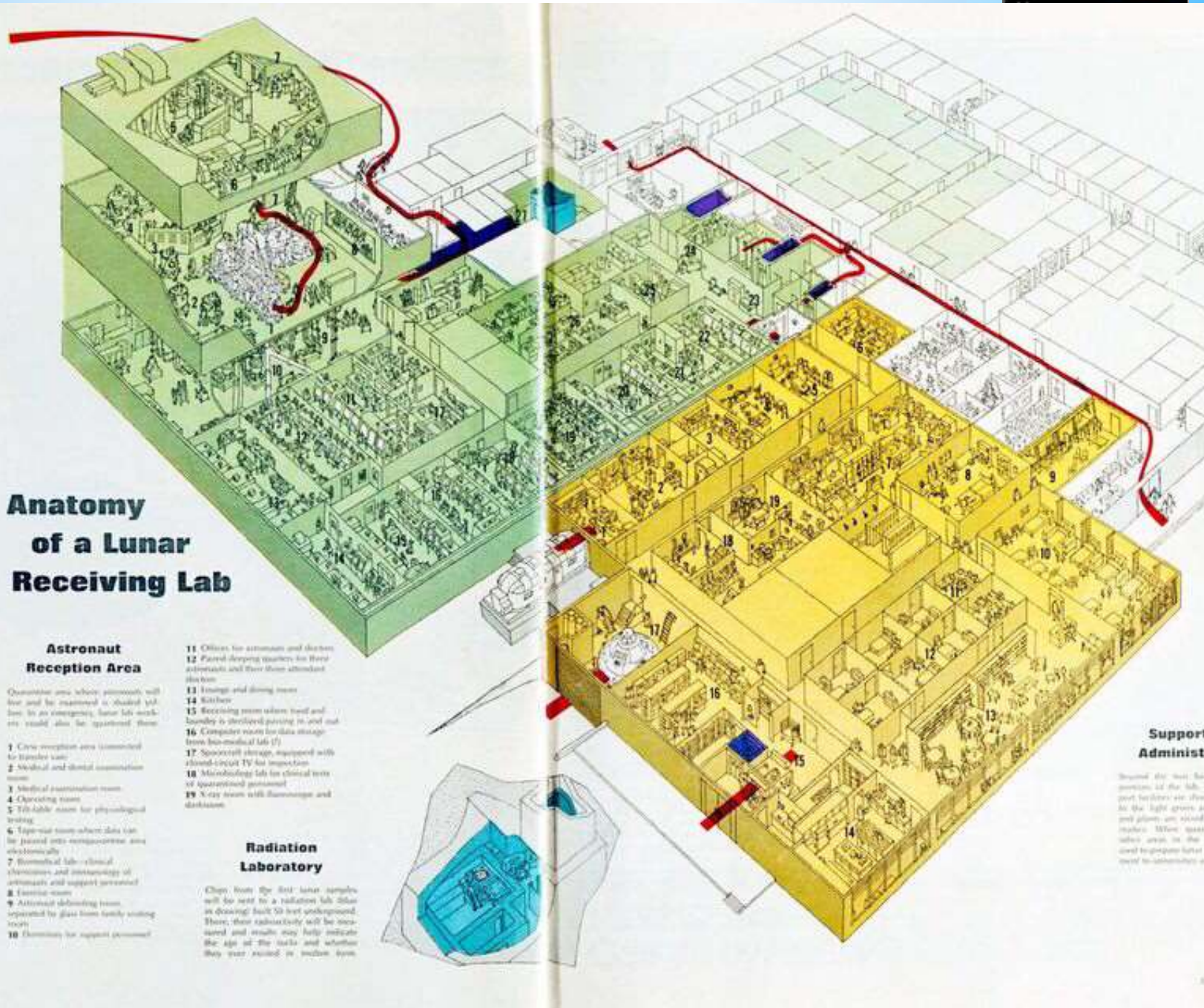
1. Crew reception area (connected to transfer van)
2. Medical and dental examination room
3. Medical examination room
4. Operating room
5. Triage room for physiological testing
6. Support room where data can be passed into microprocessor area electronically
7. Biomedical lab—clinical chemistry and immunology of astronauts and support personnel
8. Exercise room
9. Astronaut debriefing room (separated by glass from family visiting room)
10. Chemistry for support personnel

Radiation Laboratory

Clips 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 were formed in volcanic form.

Support Administration

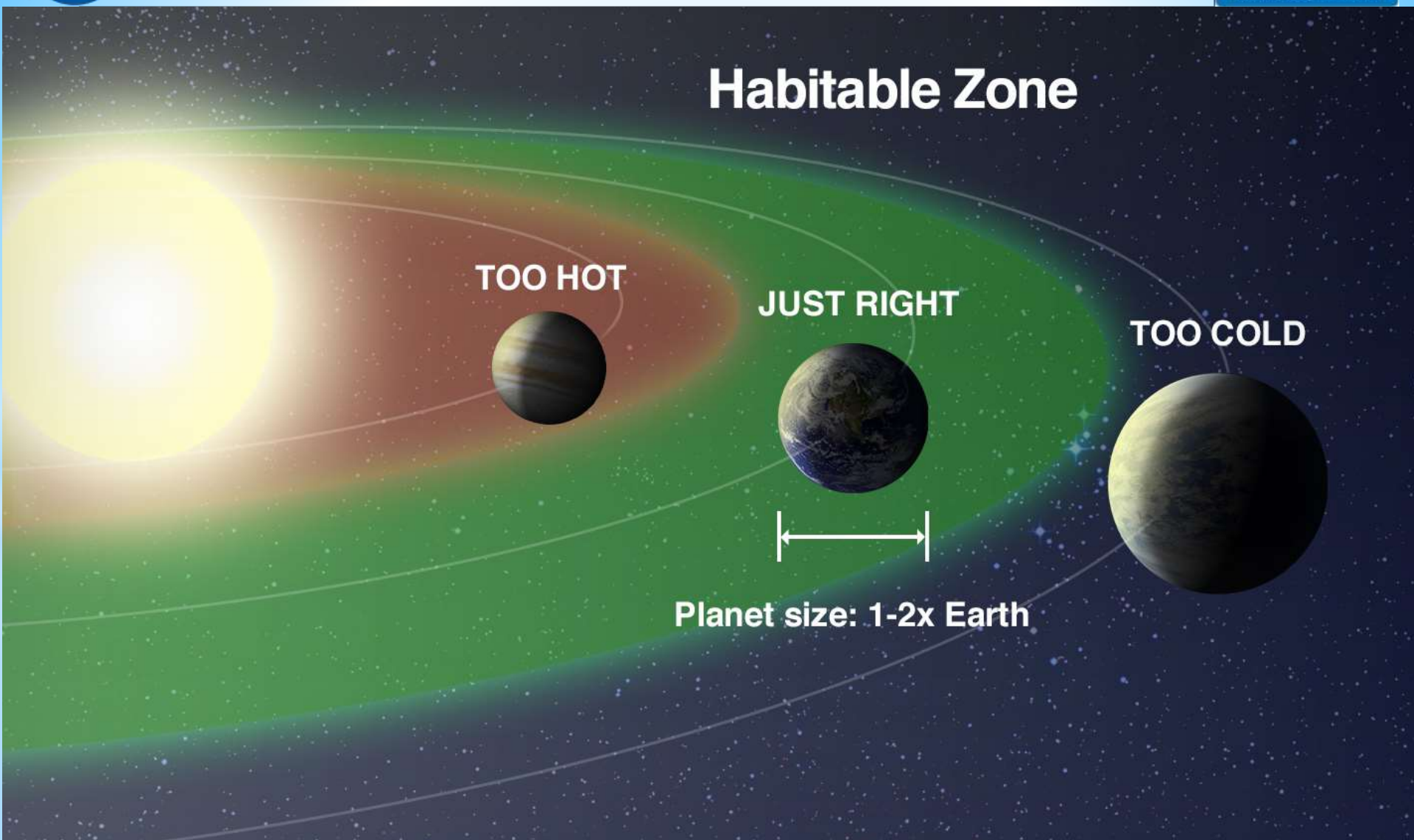
Support area for the lab, support facilities are shown in the light green area. Support area is used to prepare lunar material for laboratory work.





T-38 and Space Shuttle Transfer





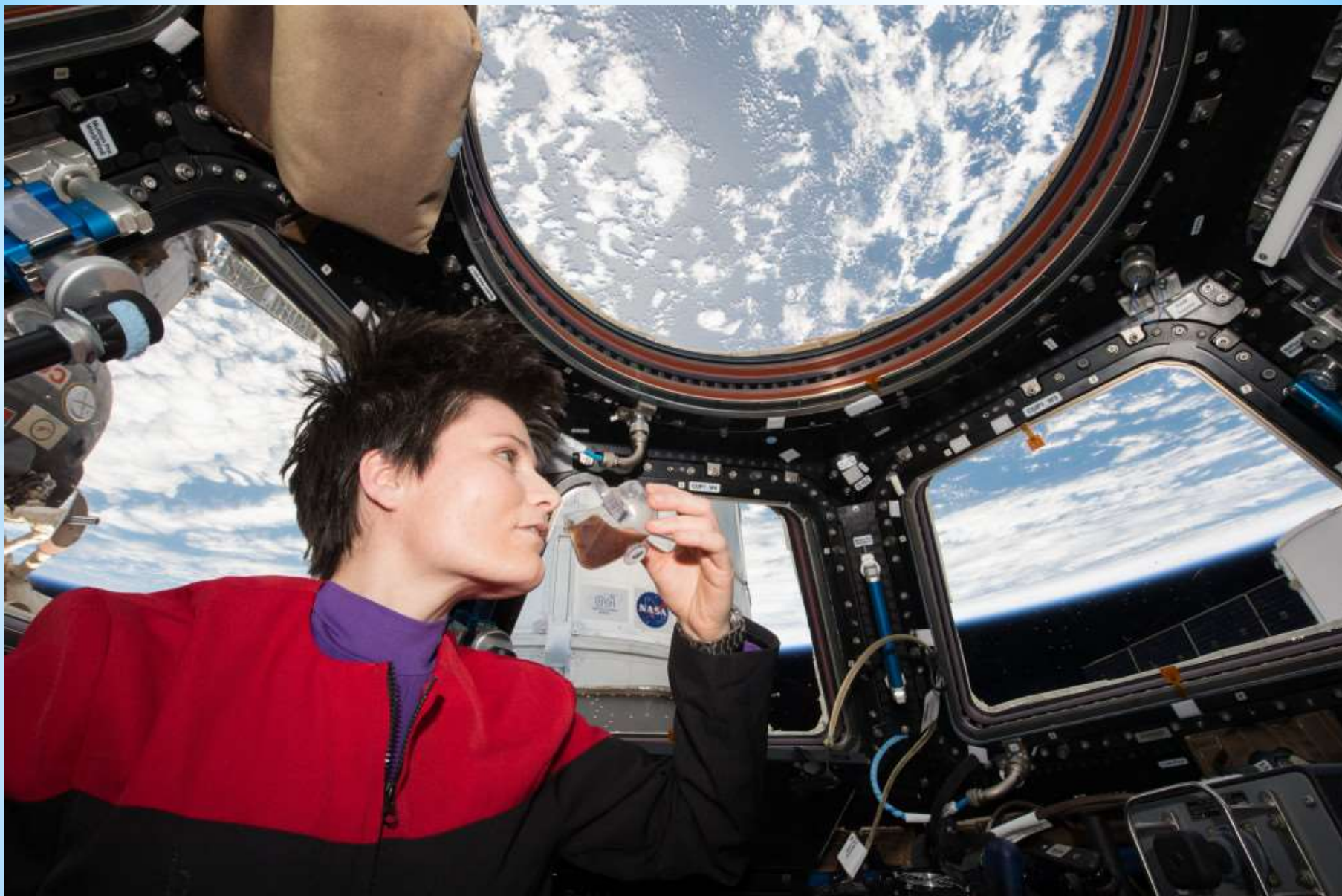


Veggie at ISS





Samantha- Espresso - Capillary flow



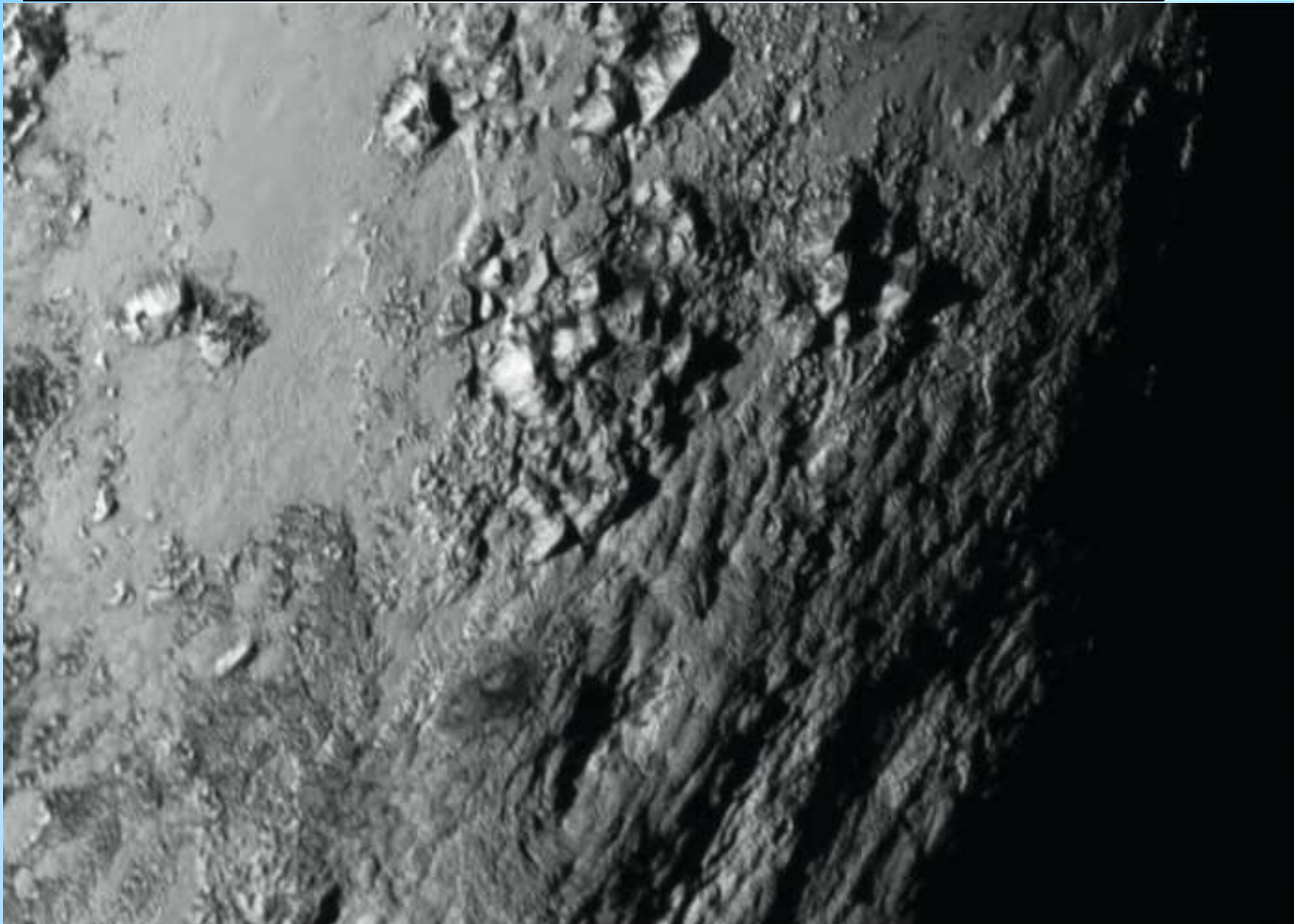


Exo Planet





Pluto





Zebra Larvae

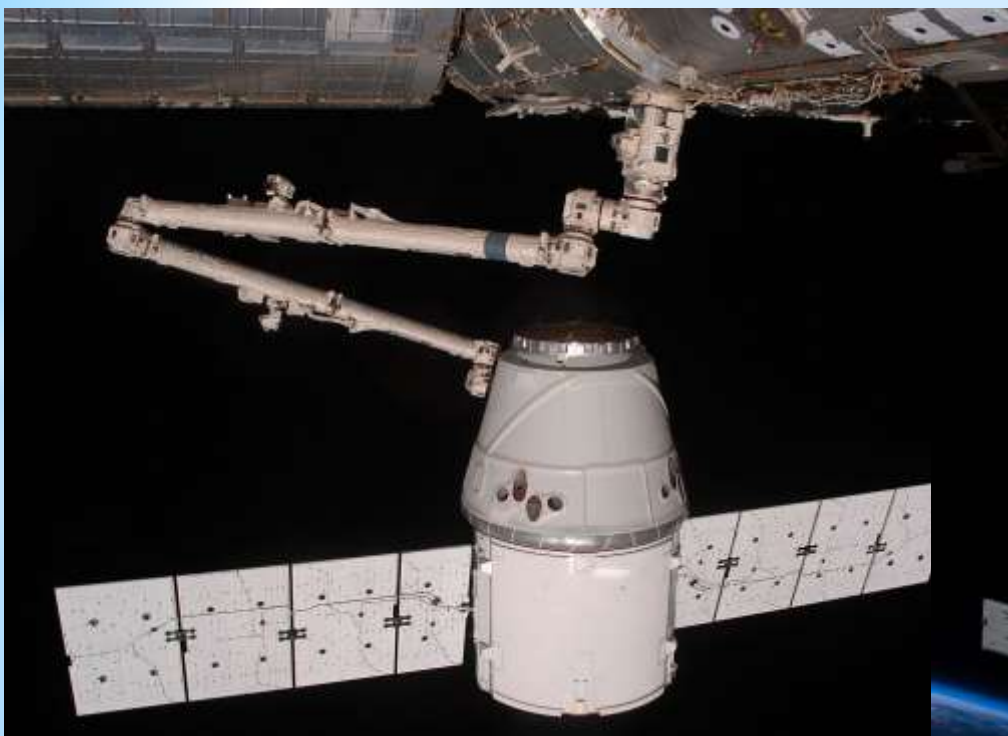




Commercial Space Companies



Space-X
Orbital Sciences
Blue Origin
Bigelow
Virgin Galactic

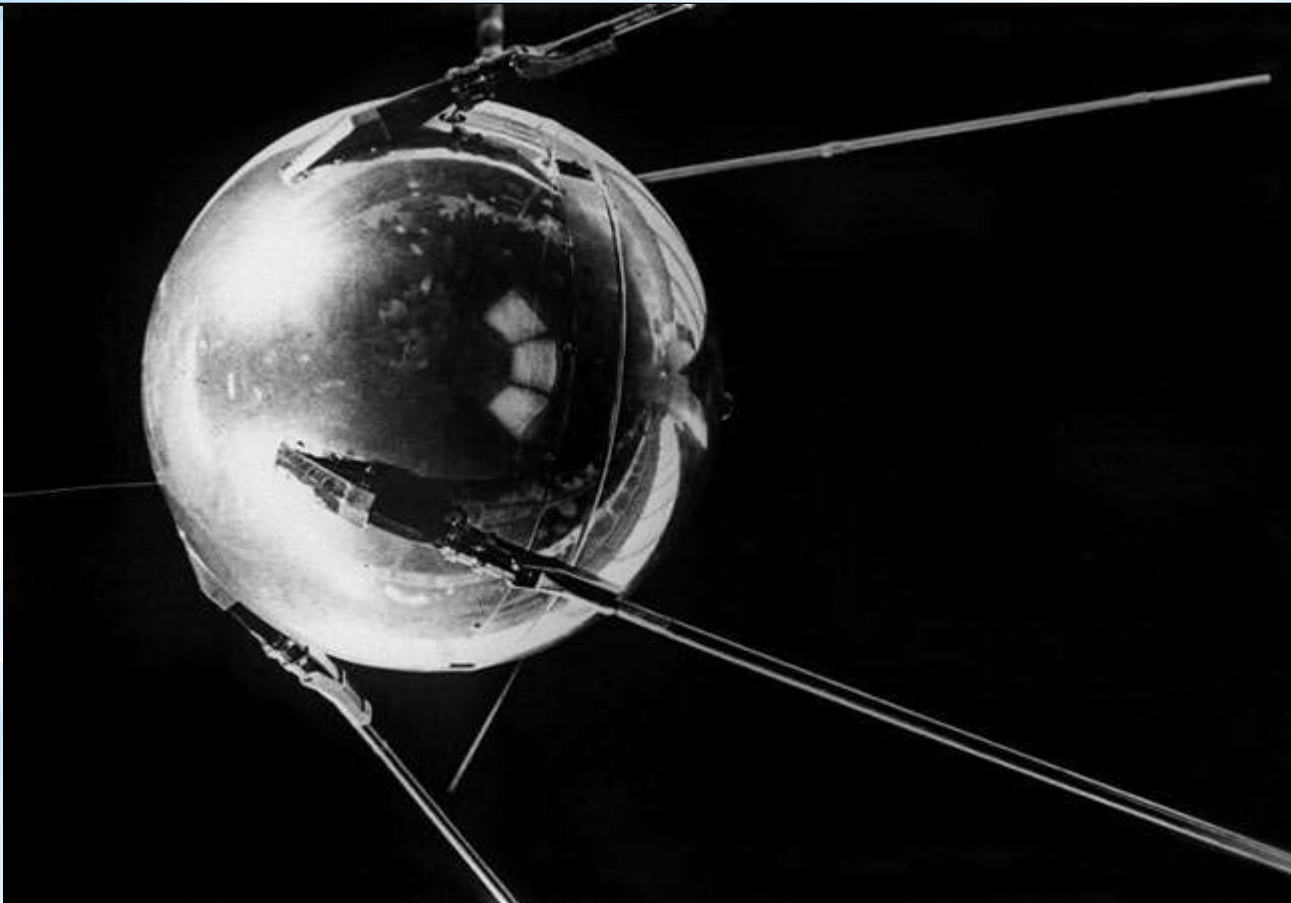


Dragon

Cygnus



Remote Sensing Satellite : Sputnik (1957)



- History changed on October 4, 1957, when the Soviet Union successfully launched Sputnik I
- The world's first artificial satellite was about the size of a beach ball (58 cm. or 22.8 inches in diameter), weighed only 83.6 kg. or 183.9 pounds,
- Took about 98 minutes to orbit the Earth on its elliptical path.



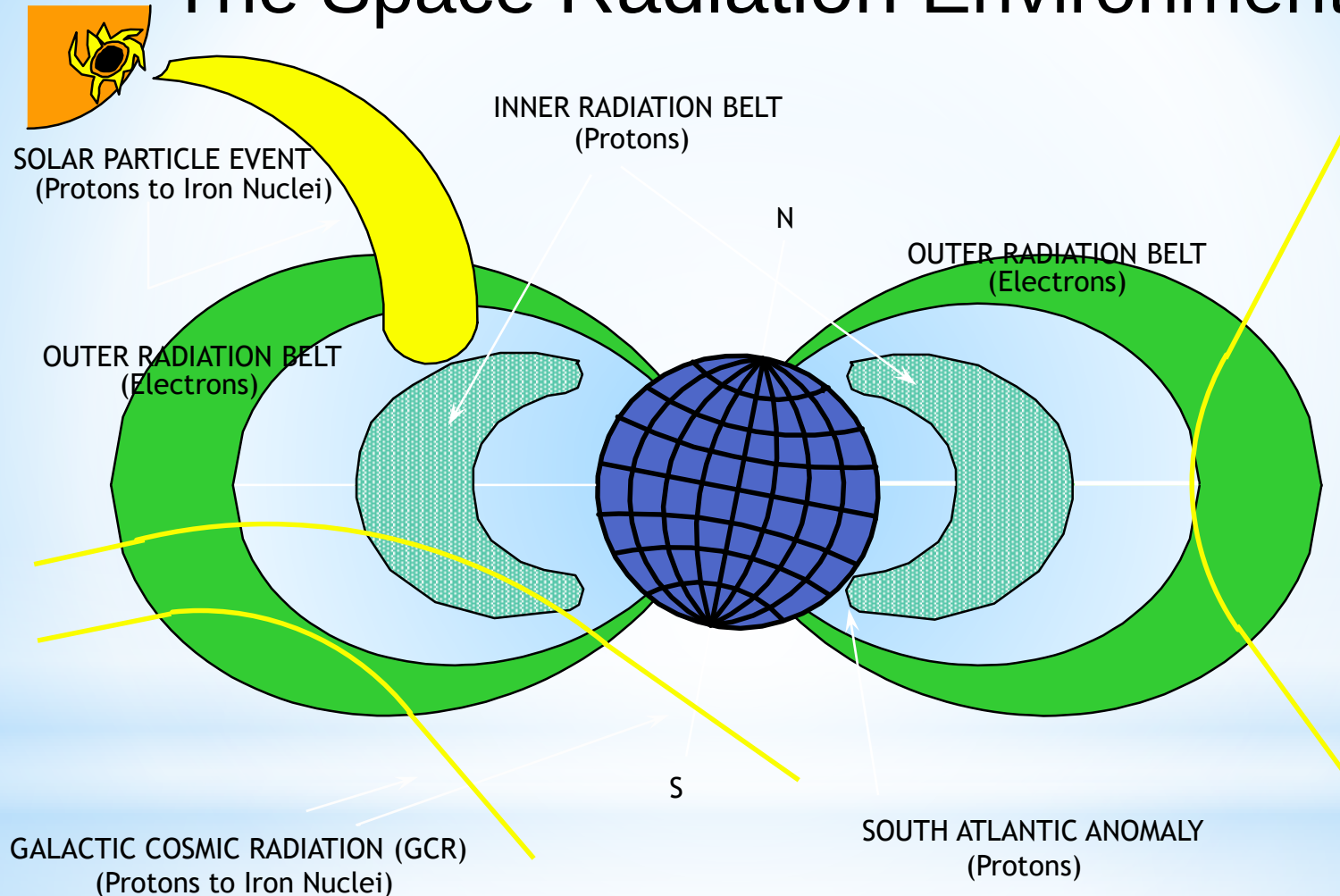




Two Shuttles in the Launch Pad

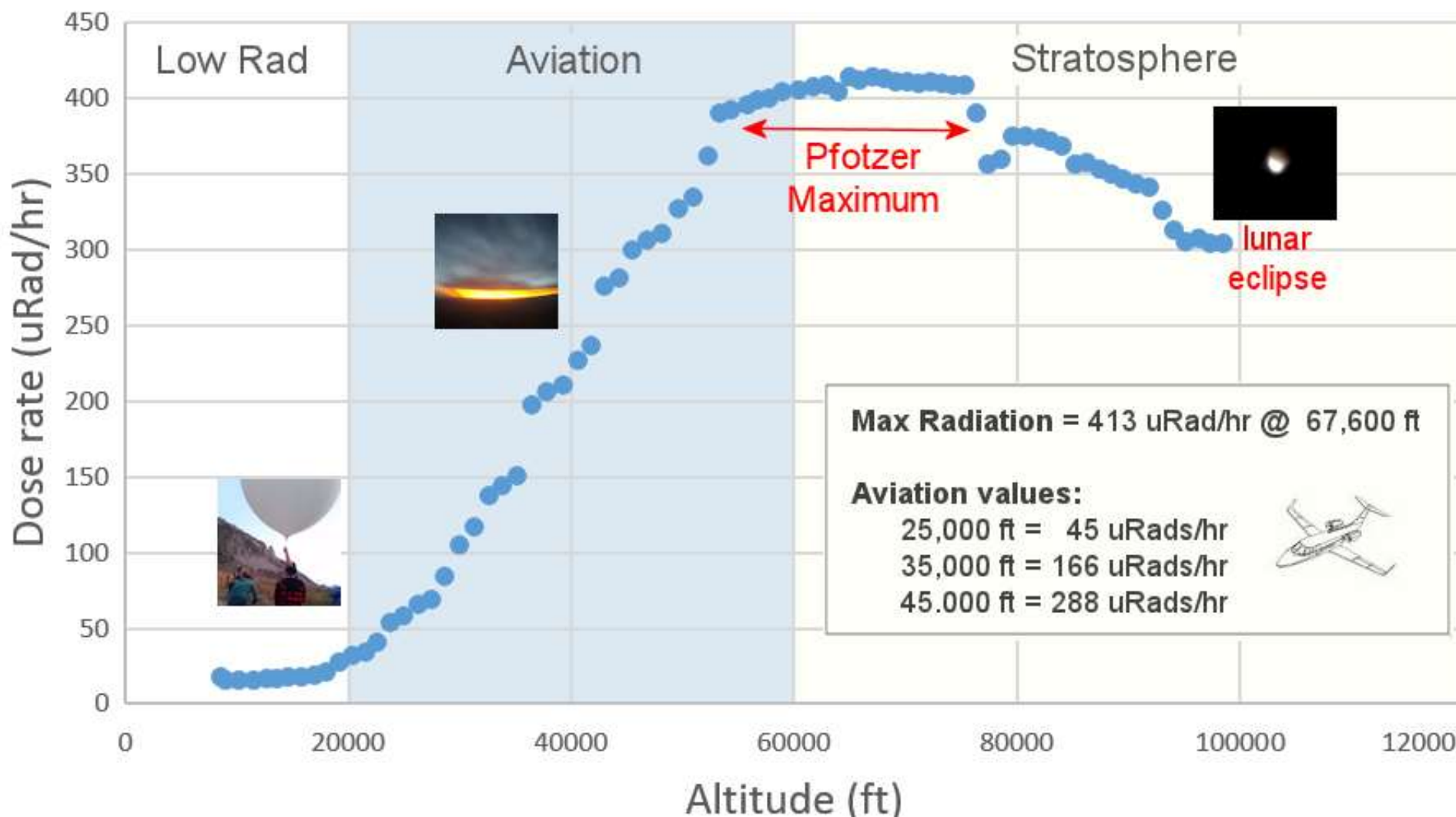


The Space Radiation Environment



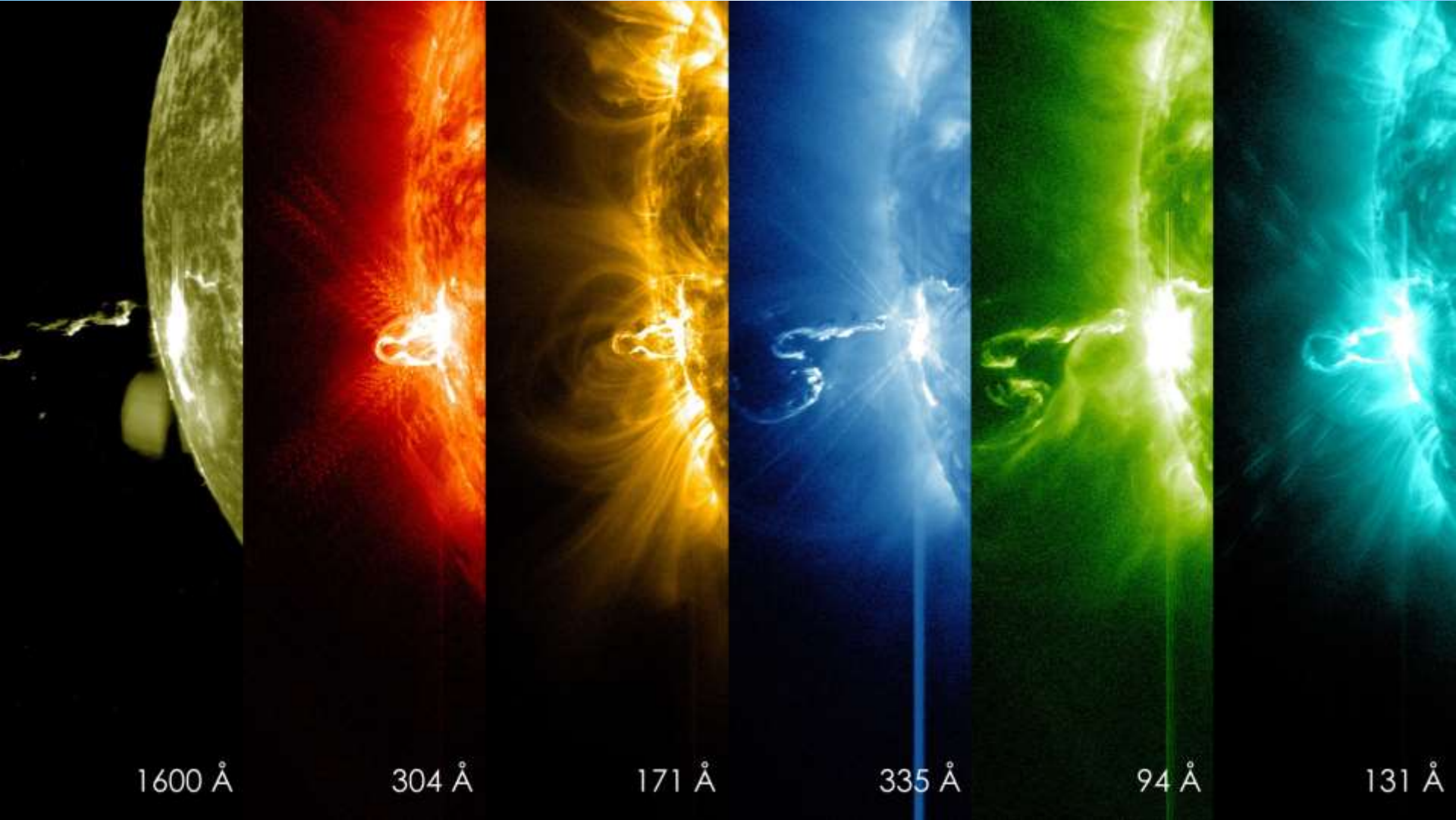
Space radiation : Energetic charged particles, high-LET (linear energy transfer)

Radiation vs. Altitude -- September 27, 2015



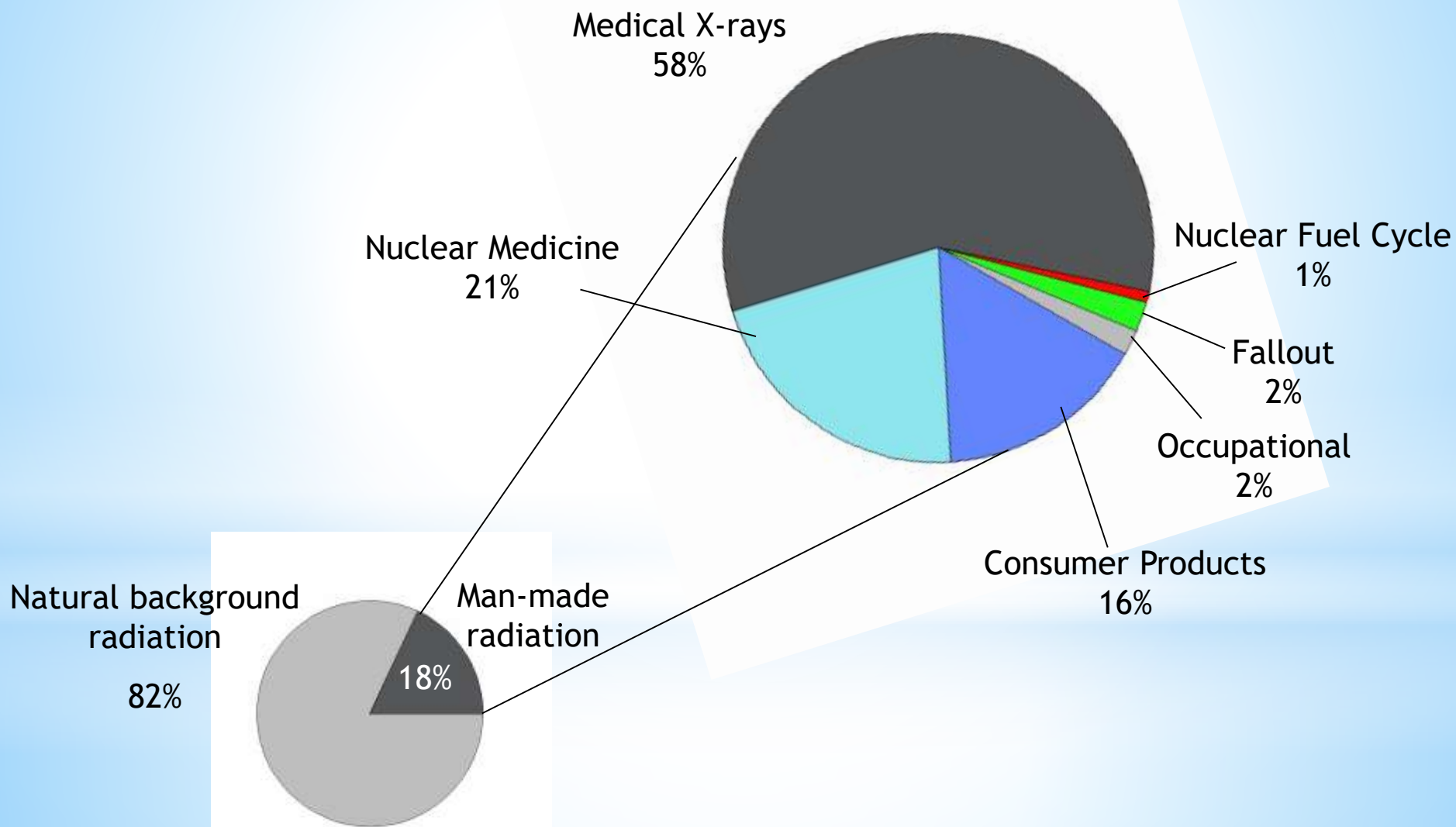


Solar Flare Observed at Various Wavelengths



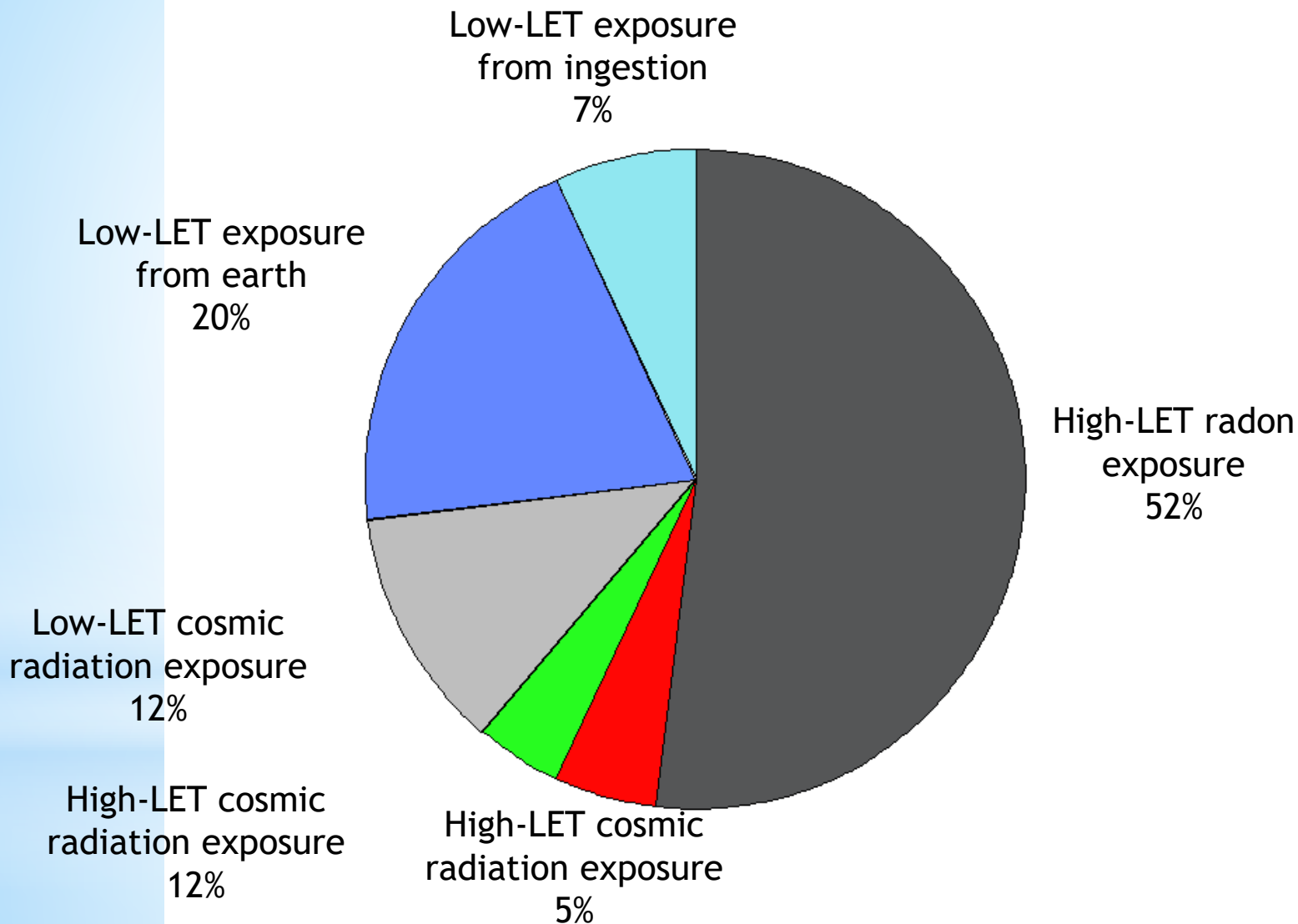


Contribution to exposure from man-made Radiation sources in USA





Environmental exposure to natural background radiations: 2.4 mSv/year





Approximate Response of a single Mammalian Cell to 1Gy of Radiation



<i>Radiation</i>	<i>Low- LET</i>	<i>High- LET</i>
Tracks in nucleus	10^3	4
total SSB	10^3	10^3
total DSB	~ 40	< 40
Complex DSB	20%	70%
DSB per lethal lesion	87	22
Chrom. Aberration	1	3
Dicentric per cell	0.1	0.4
Cell Inactivation	30%	85%

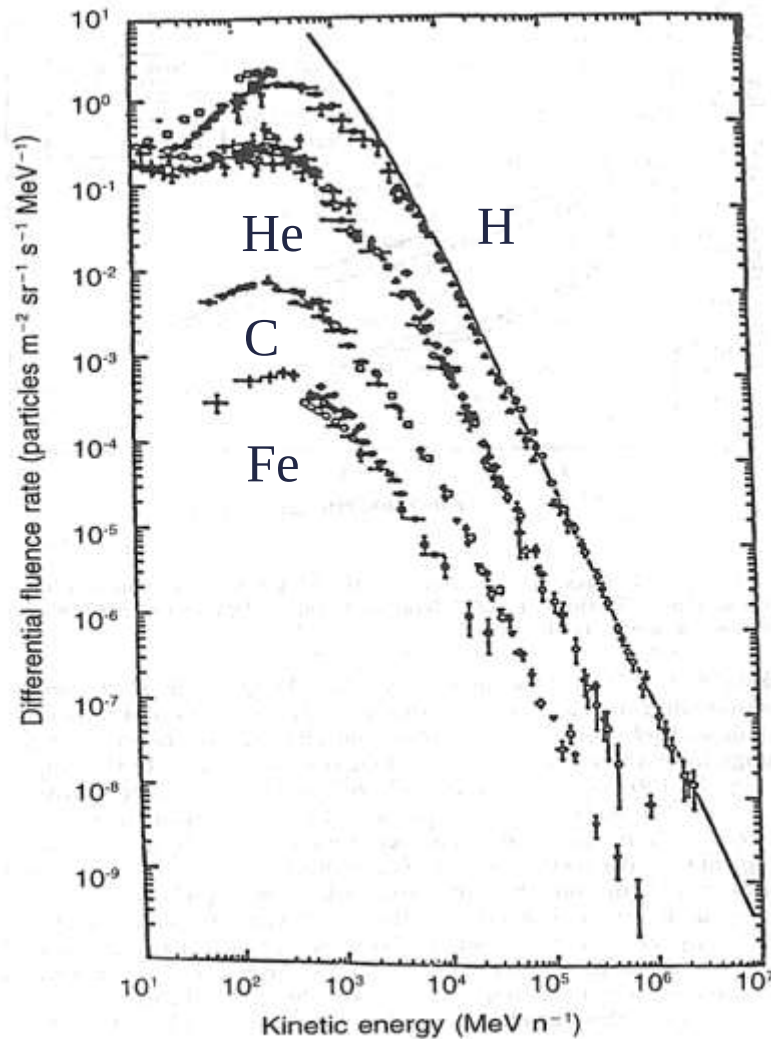
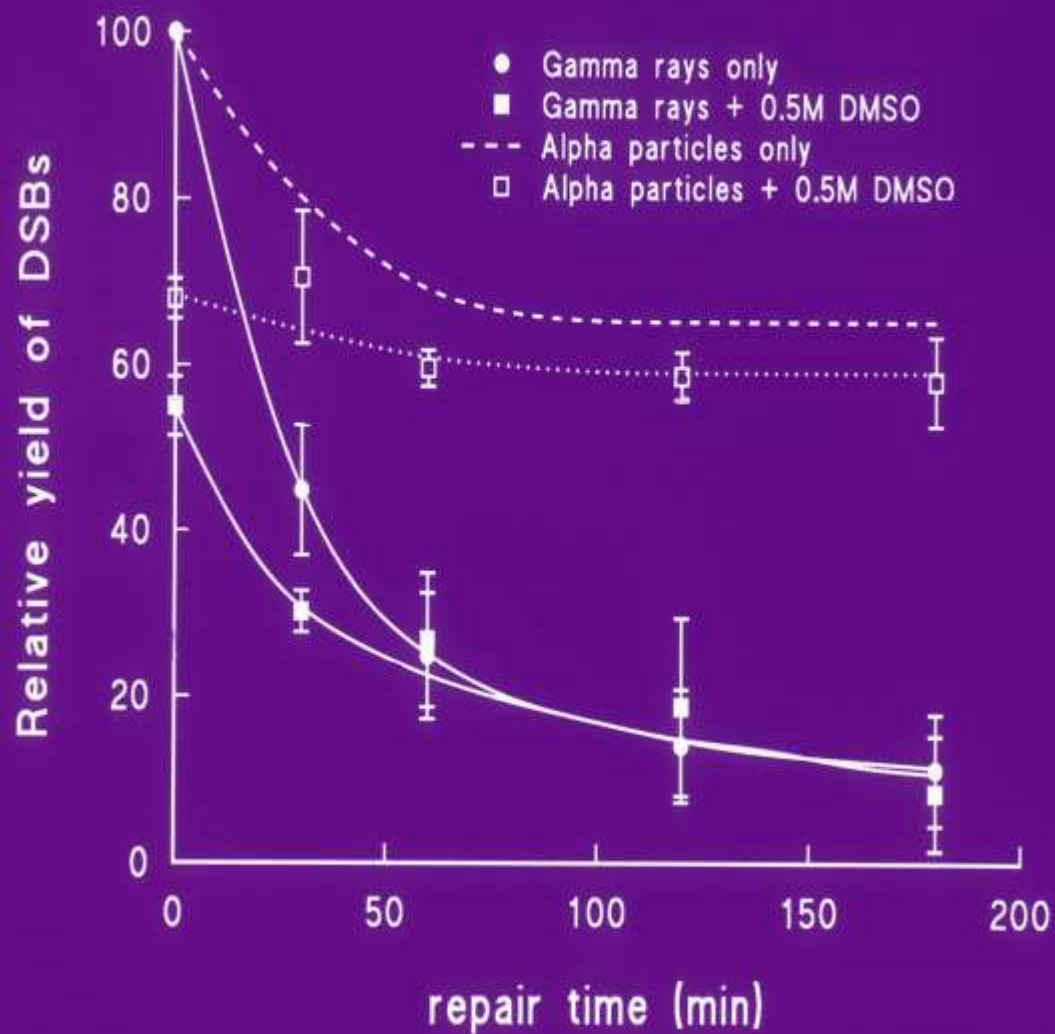


Fig. 3.5. Typical energy spectra for protons, helium ions, carbon ions, and iron ions from "top to bottom," respectively, at solar minimum. The solid line is the local interstellar spectrum (Simpson, 1983a).

Energy
Spectra
for
protons,
helium,
carbon,
and
iron.

Repair of DSB induced by Low and High LET Radiation



O'Neill et al (1995)

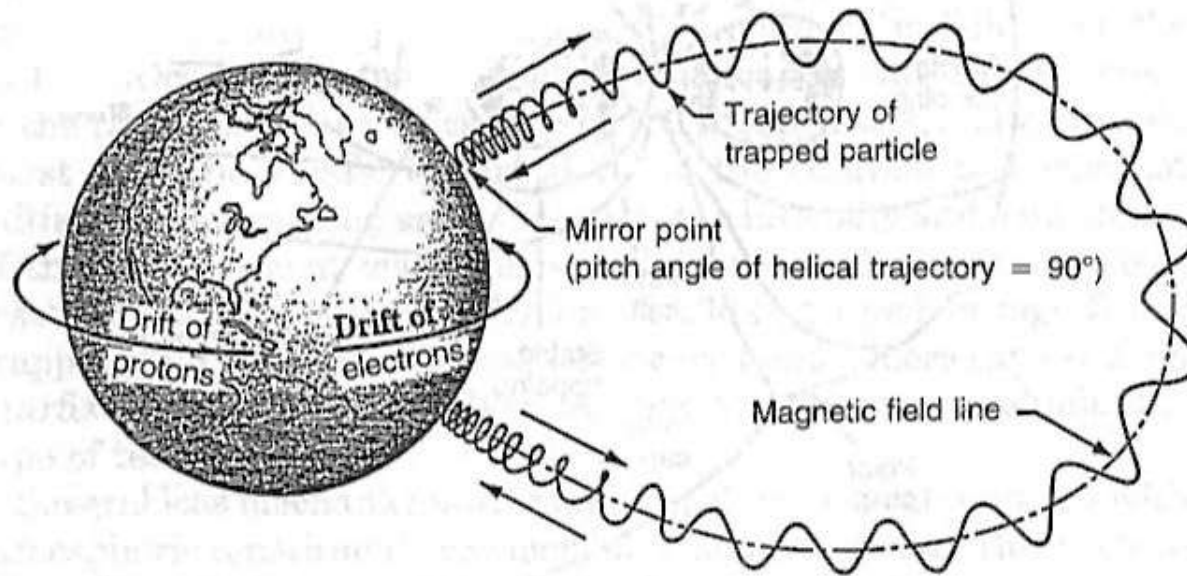


Fig. 3.2. The motion of a charged particle in a dipole magnetic field consists of three components; a helical trajectory about the magnetic field line, a bounce between polar mirror points, and a longitudinal drift around Earth (Hess, 1968).

Charged Particle Motions in Earth's Magnetic Field

Components:

Protons: ~ 0.04 to 500 MeV

Electrons: ~ 0.04 to 7 MeV

Heavier Ions: Low Energies

Location of peak levels is energy dependent

Location of populations shifts with time

Average counts vary slowly with solar cycle

Counts may increase by orders of magnitude with magnetic storms

van Allen Belt Particles

Galactic Cosmic Radiation

Nuclear composition of galactic cosmic rays.

Log fluence rate vs. atomic number.

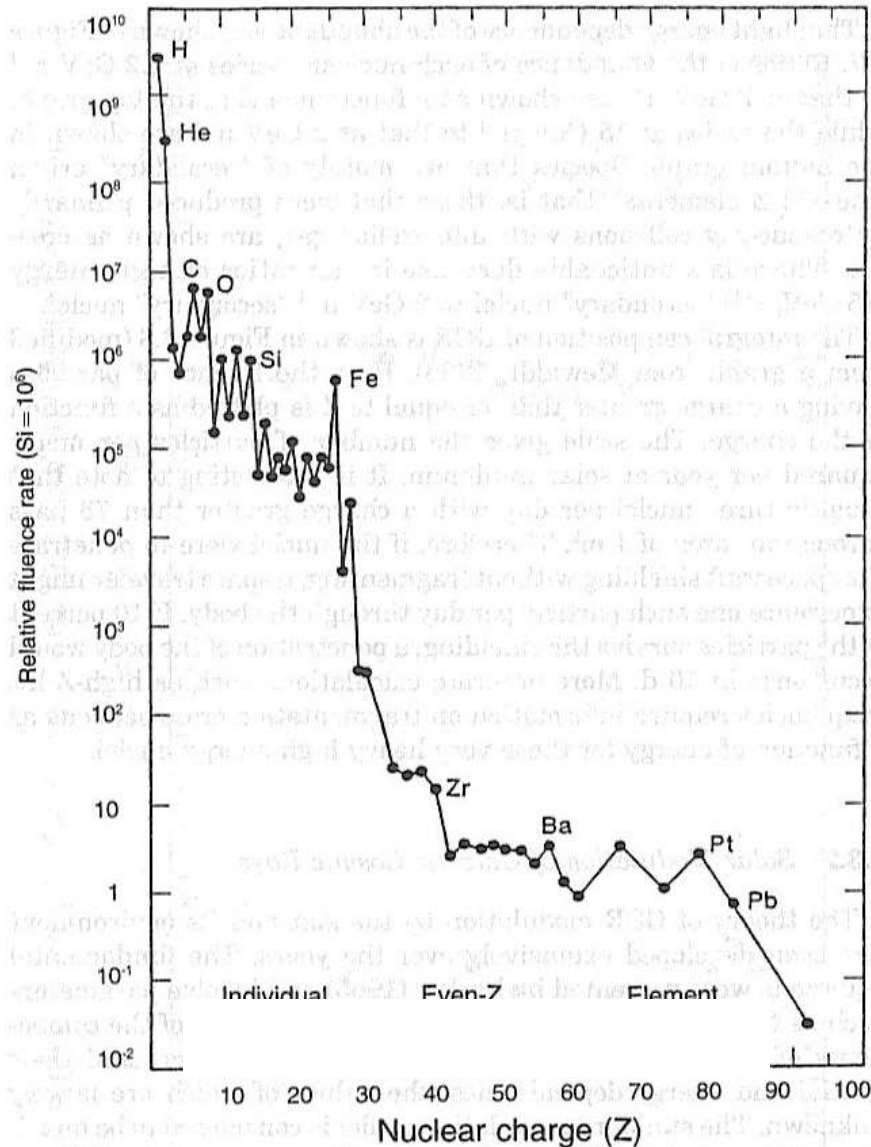
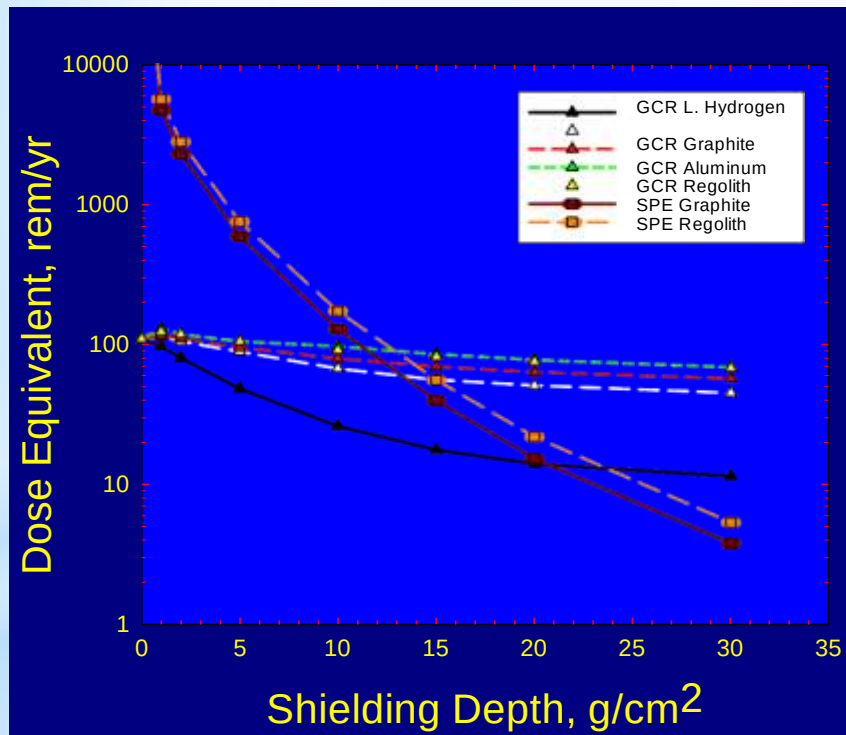


Fig. 3.6. Nuclear composition of GCR ($\sim 2 \text{ GeV n}^{-1}$) (Mewaldt, 1988).

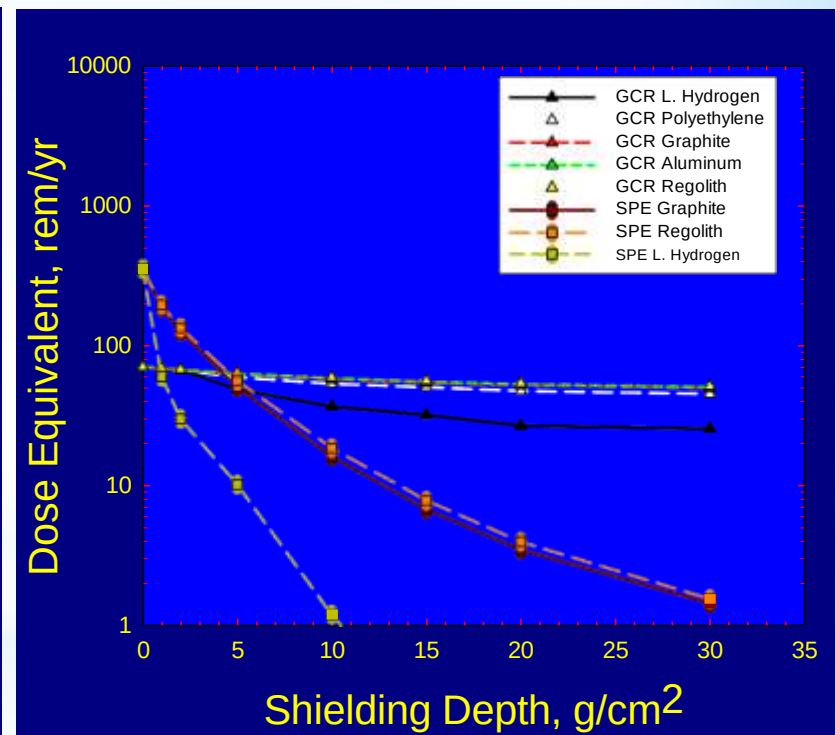
GCR and SPE Doses: Materials & Tissue

- GCR much higher energy producing secondary radiation

No Tissue Shielding



With Tissue Shielding



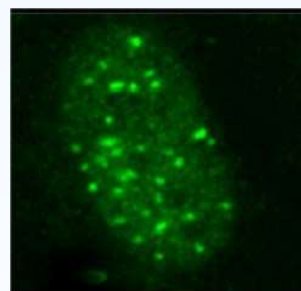
August 1972 SPE and GCR Solar Min



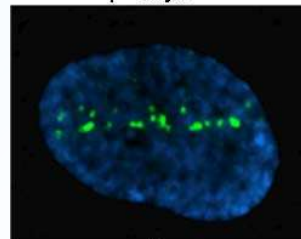
The Space Radiation Problem

Space radiation is comprised of high-energy protons and heavy ions (HZE's) and secondary protons, neutrons, and heavy ions produced in shielding

- Unique damage to biomolecules, cells, and tissues occurs from HZE ions
- No human data to estimate risk
- Animal models must be applied or developed to estimate cancer, and other risks
- Shielding has excessive costs and will not eliminate galactic cosmic rays (GCR)



γ - rays

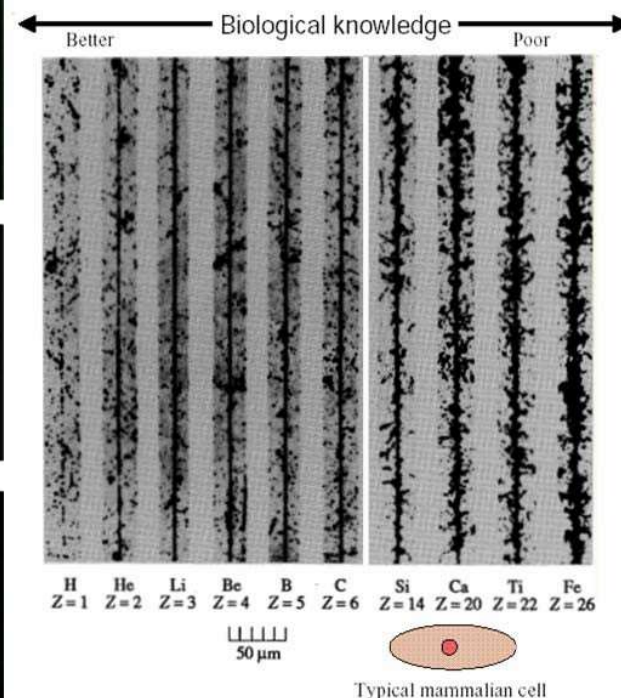


silicon



iron

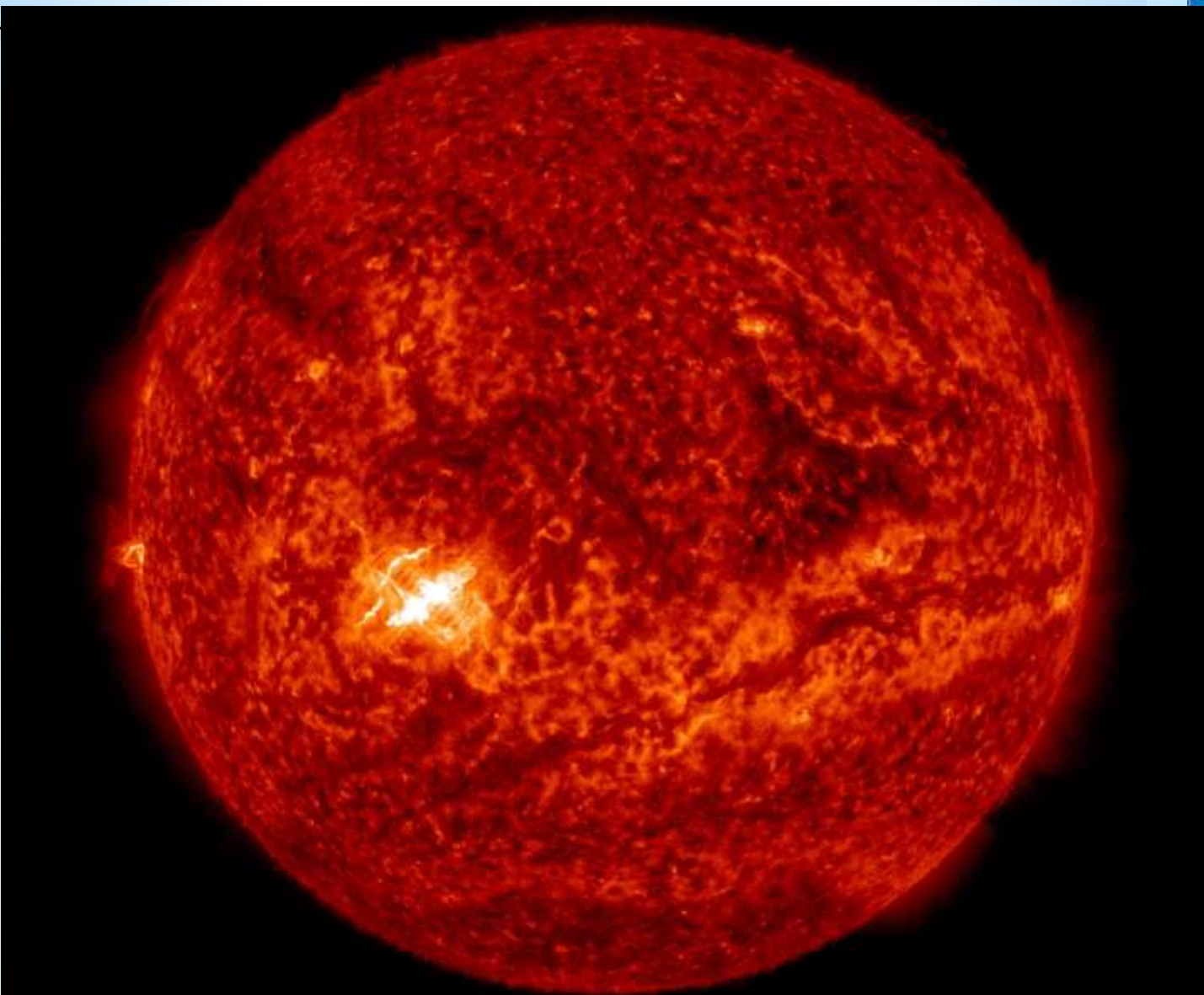
Single HZE ions in cells
And DNA breaks



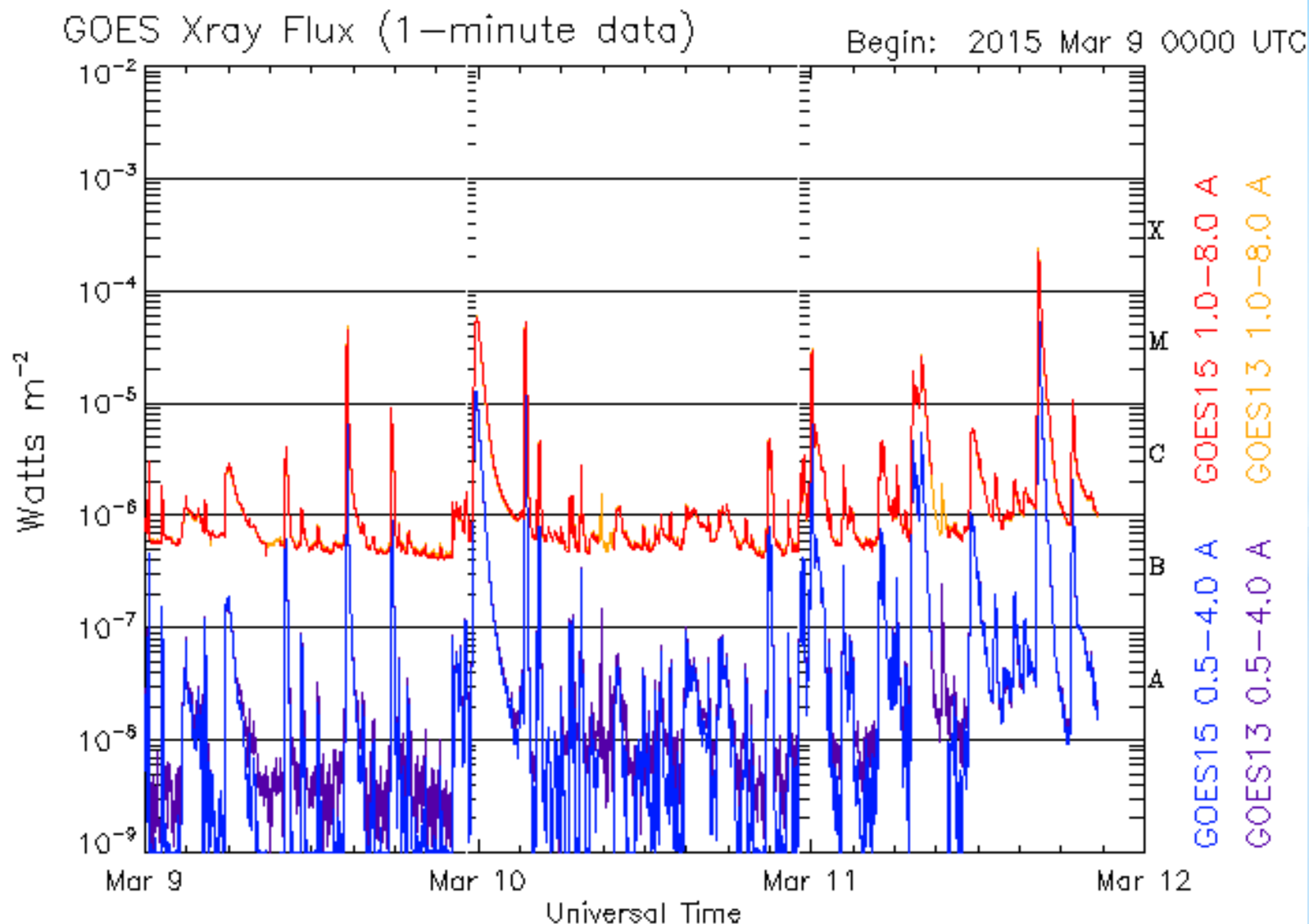
Single HZE ions in photo-emulsions
Leaving visible images



March 11, 2015

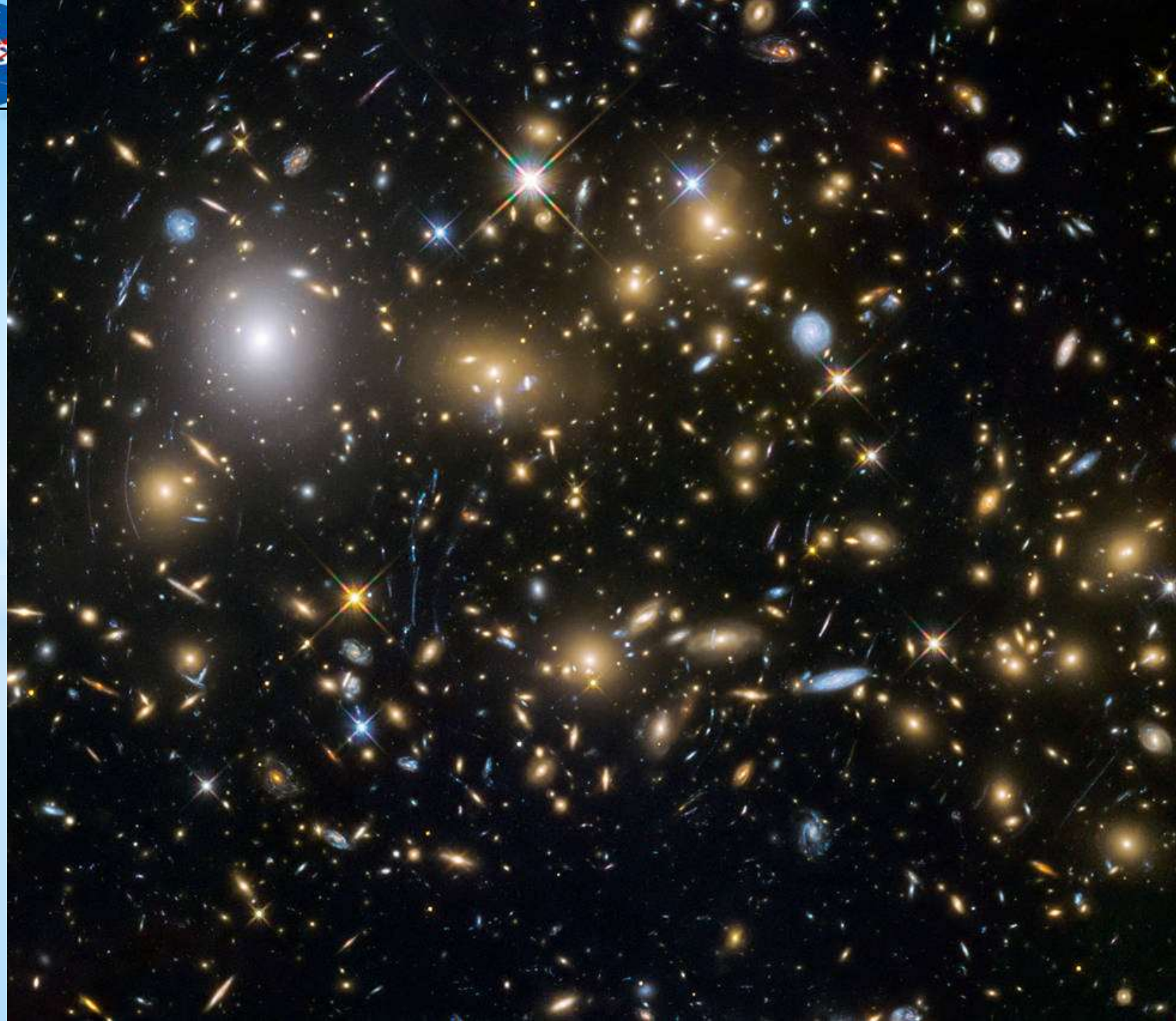


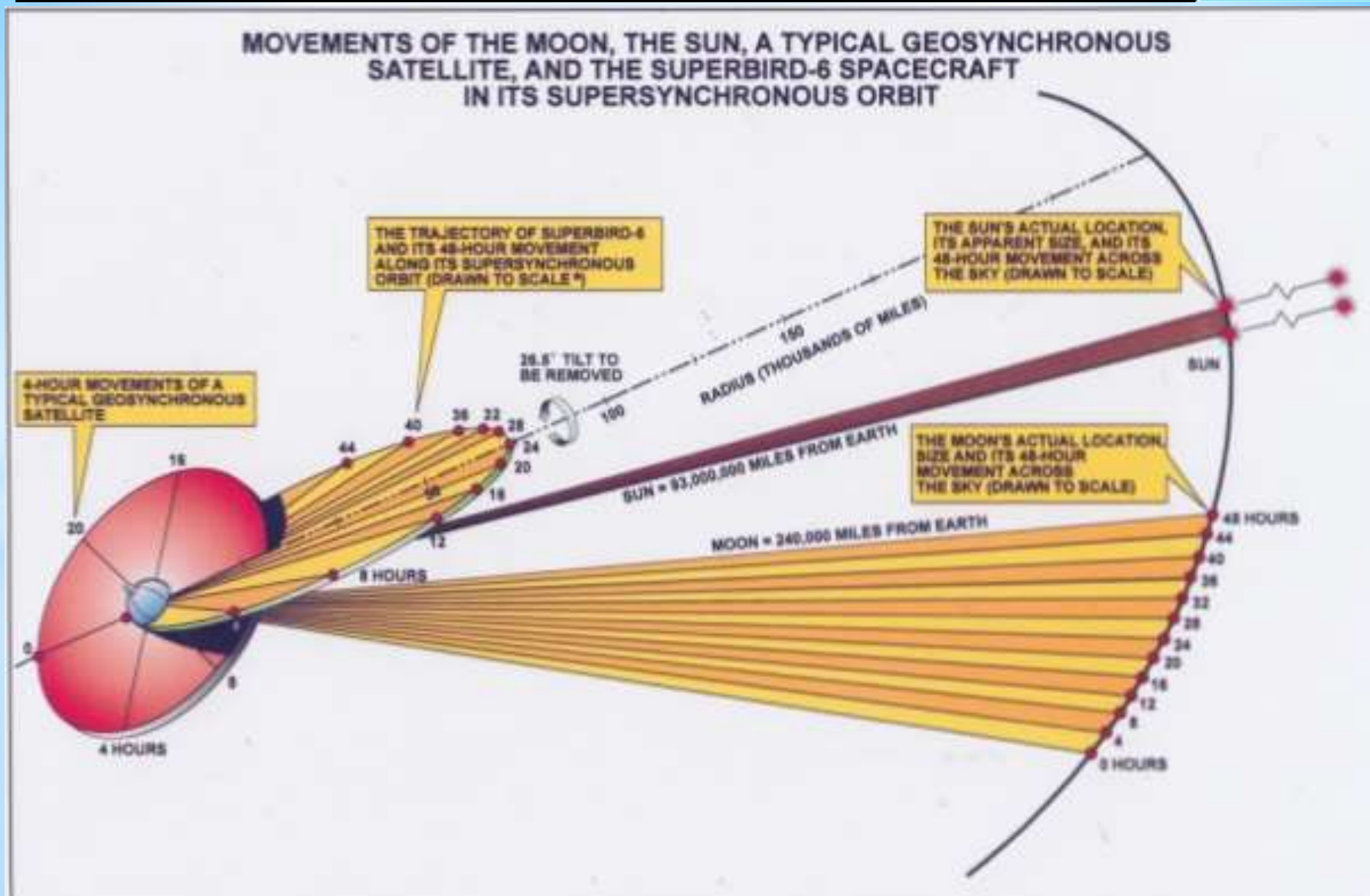
SDO/AIA 304 2015-03-11 16:25:08 UT

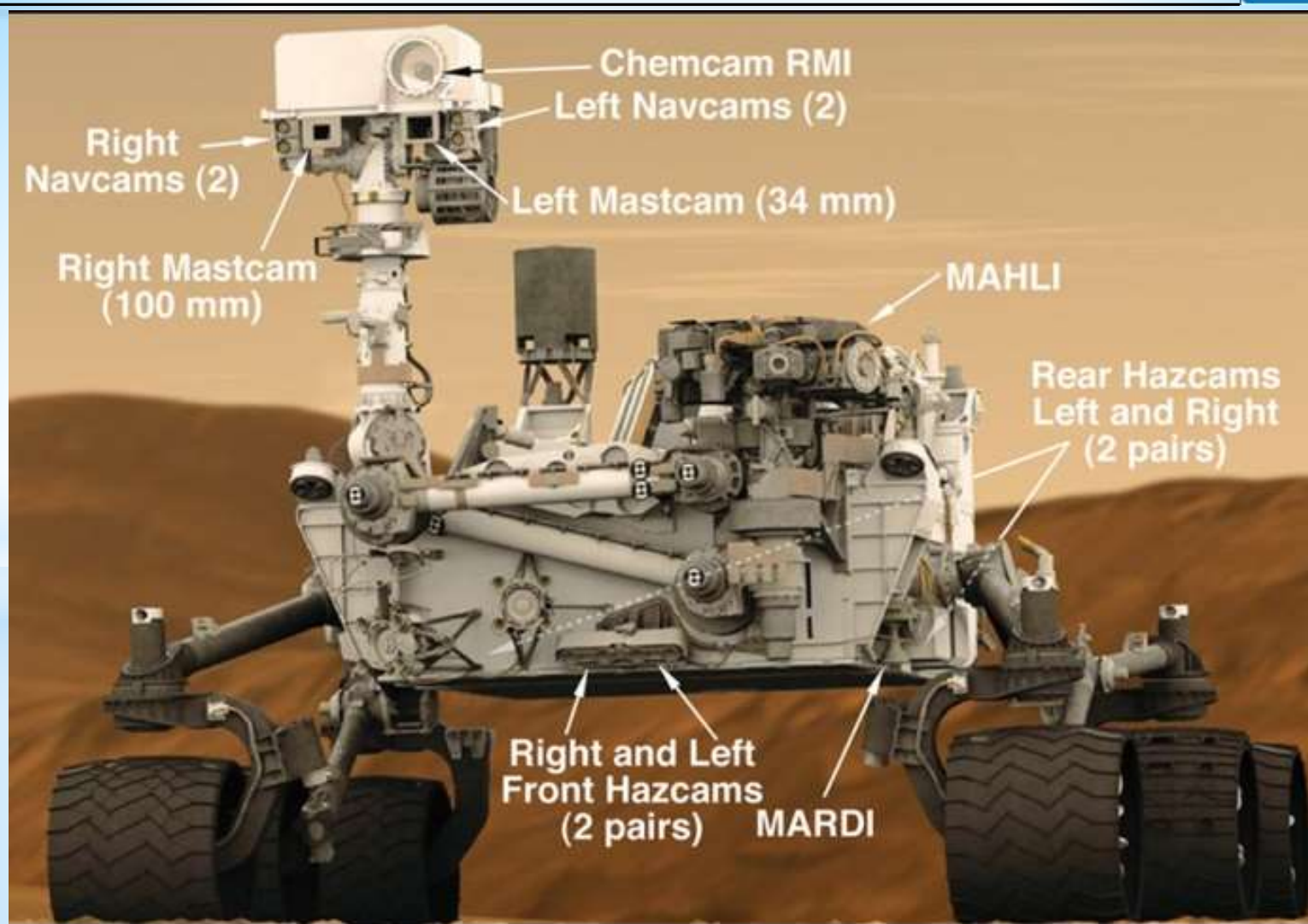


Updated 2015 Mar 11 20:36:12 UTC

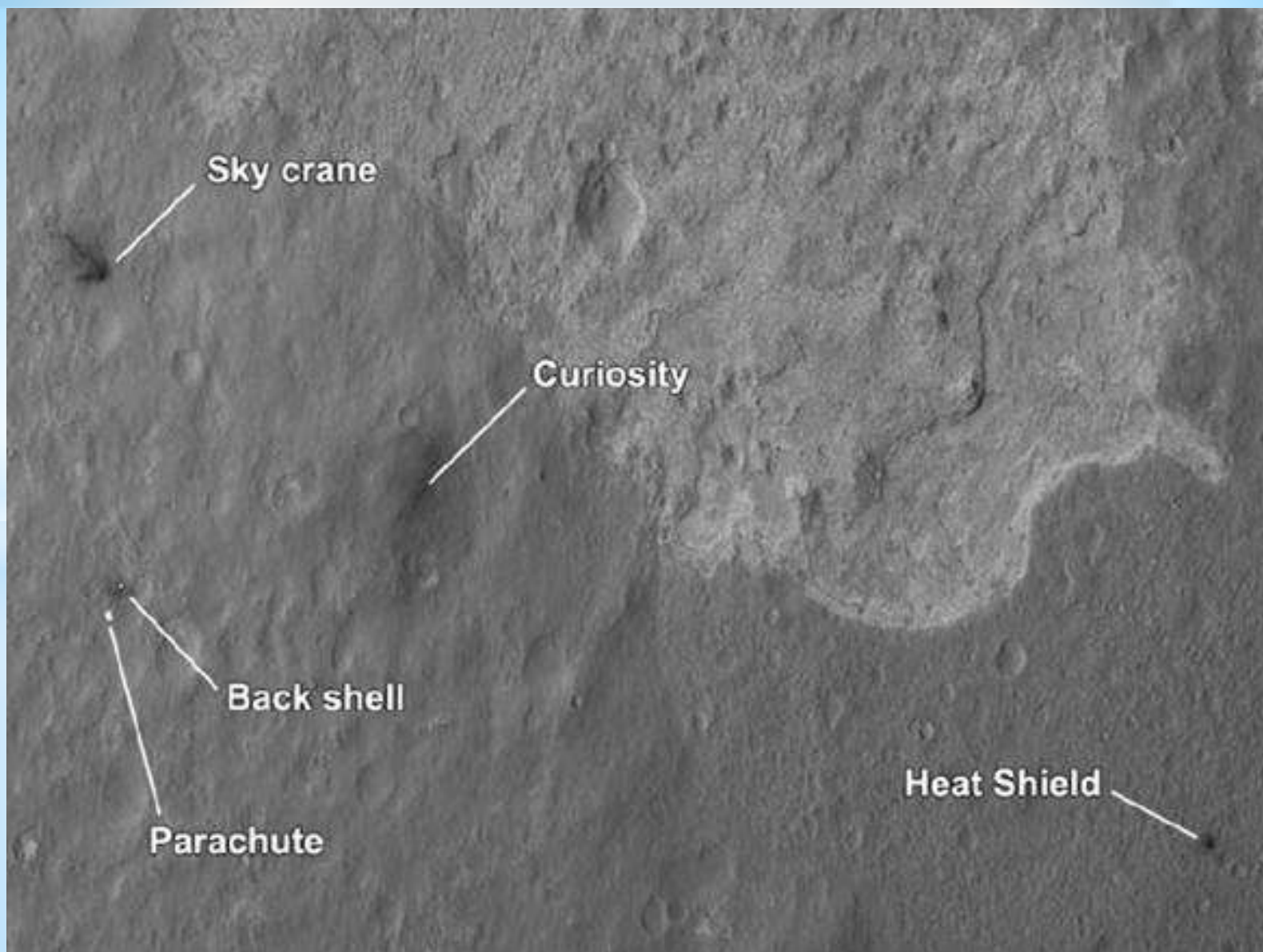
NOAA/SWPC Boulder, CO USA



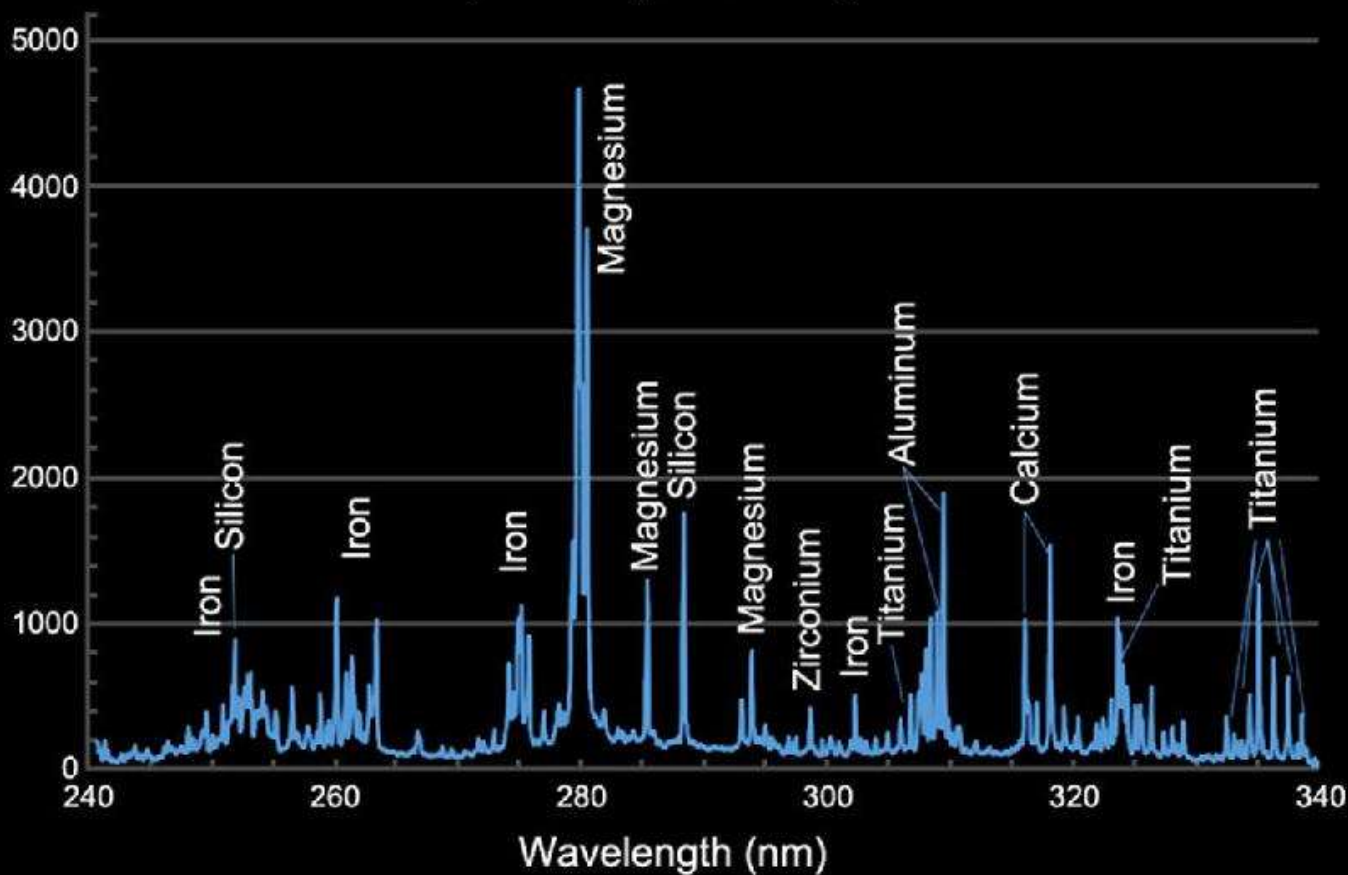




Curiosity Landing Site



ChemCam Spectrum
One of 3 spectral ranges covered by ChemCam





HiRISE

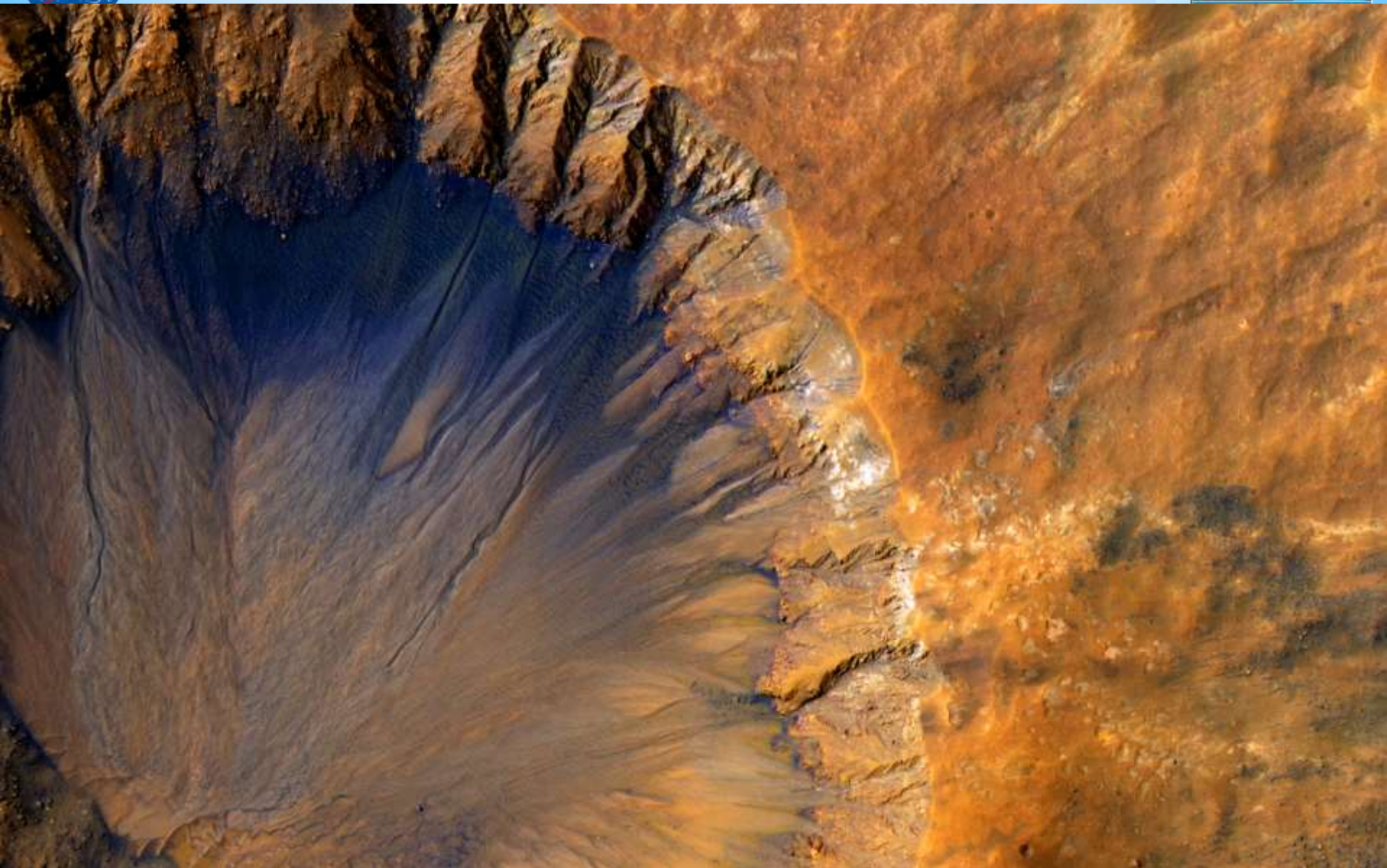
hirise.lpl.arizona.edu

Defrosting Polar Sand Dunes

PSP_007043_2650

Mars' Sand Dunes





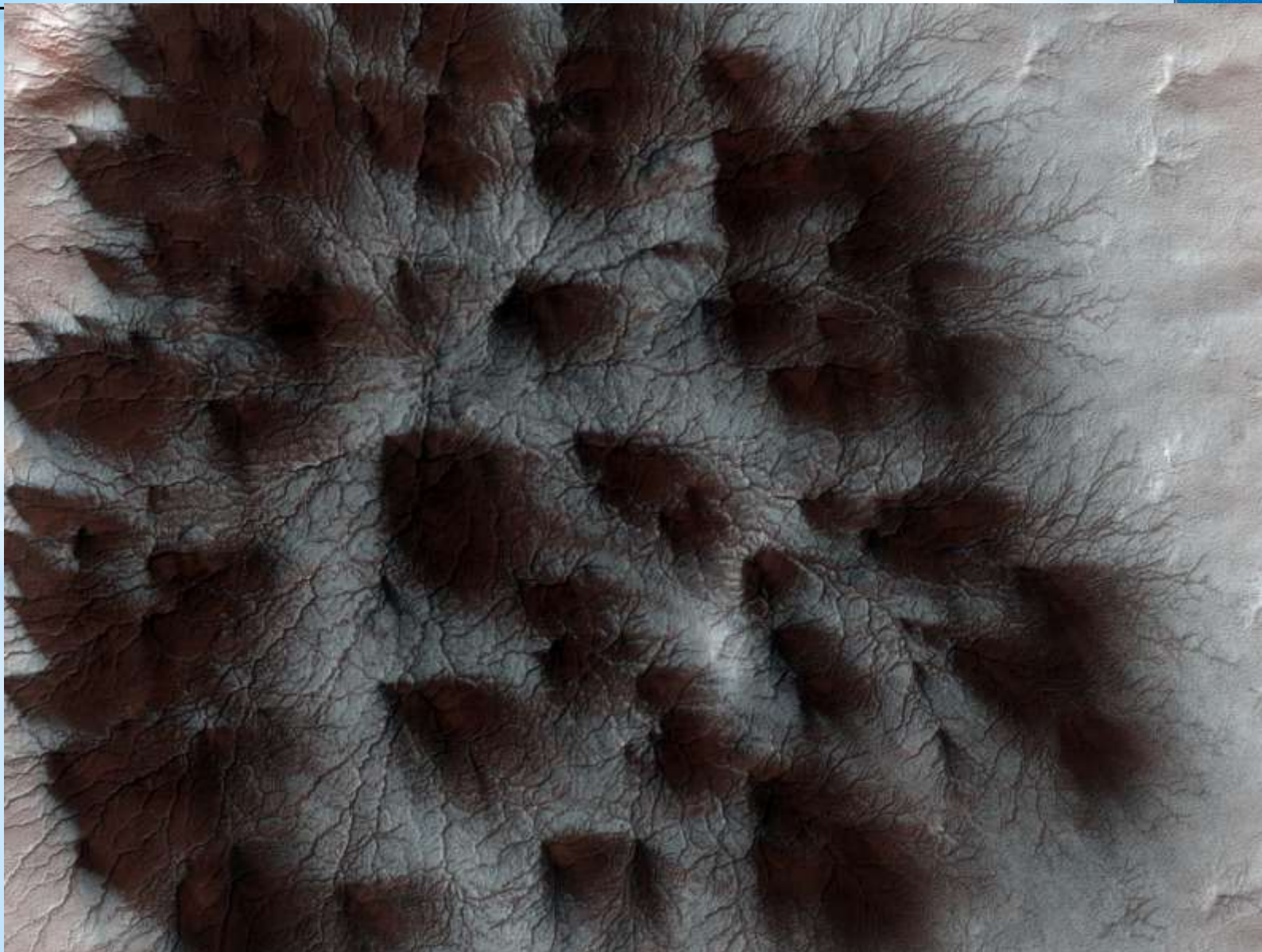
Messier 63 Galaxy



Milky Way



Mars' Spider



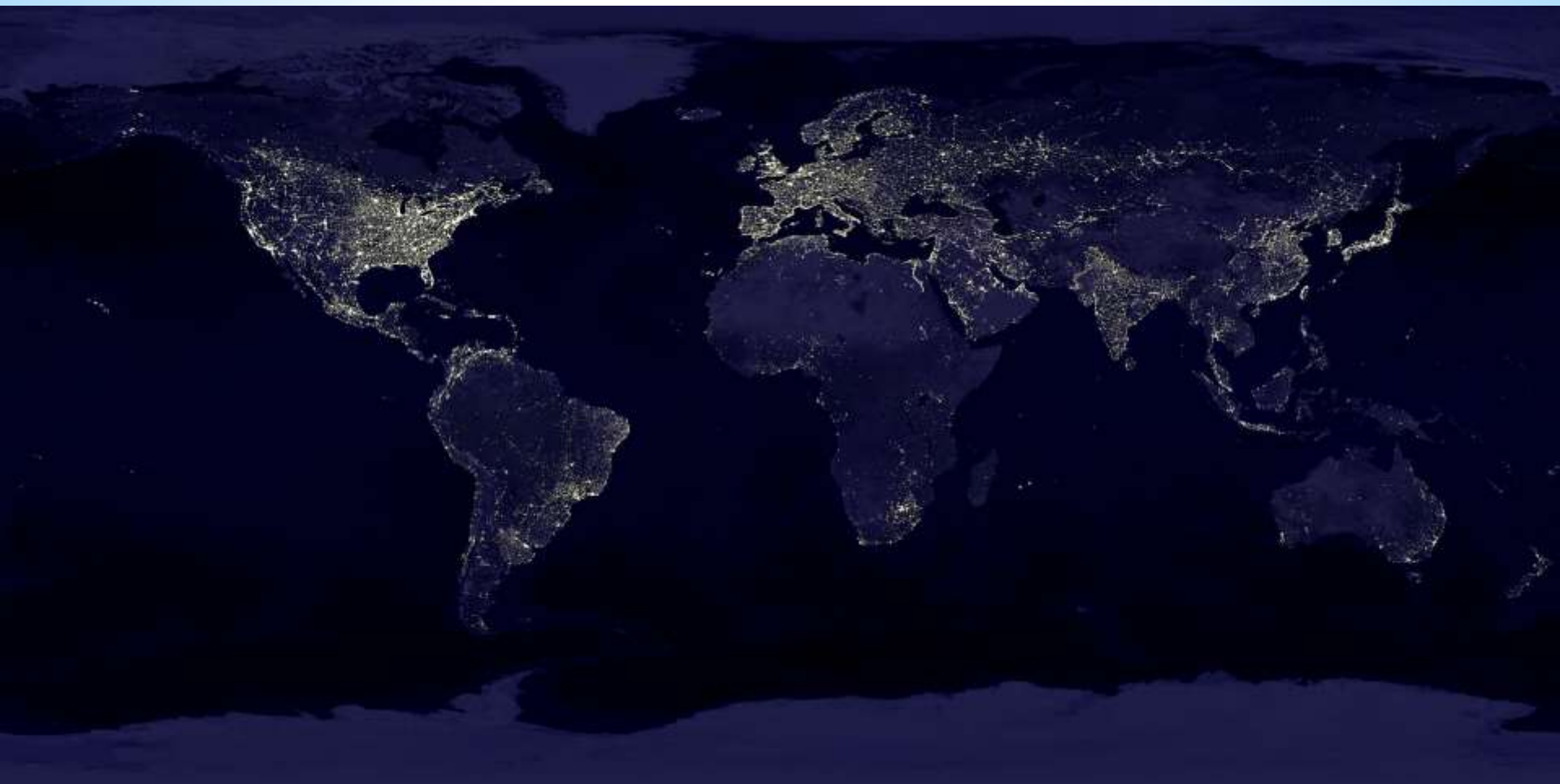
Auroras from ISS







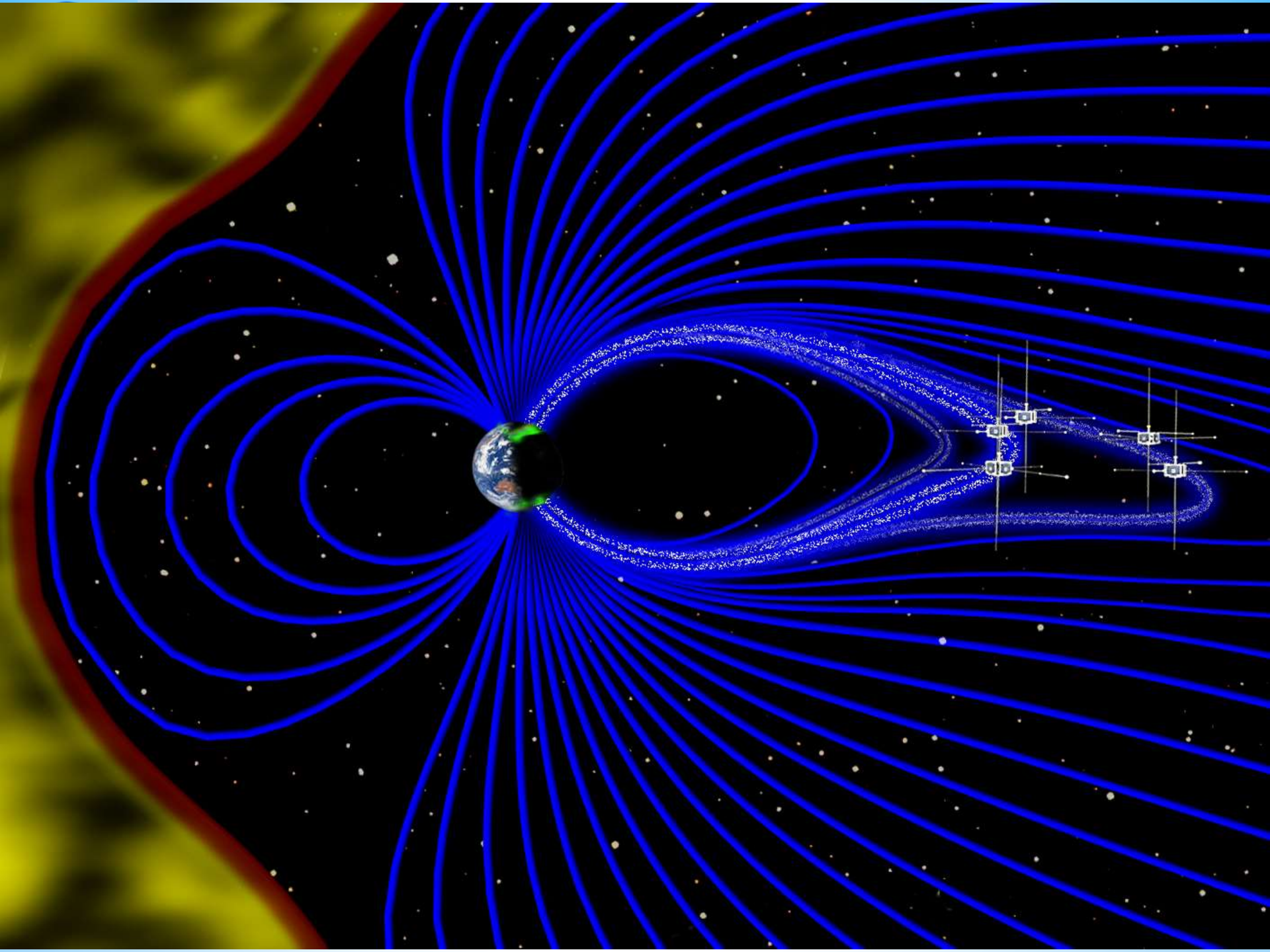
Earth at Night





T-38 and Guppy

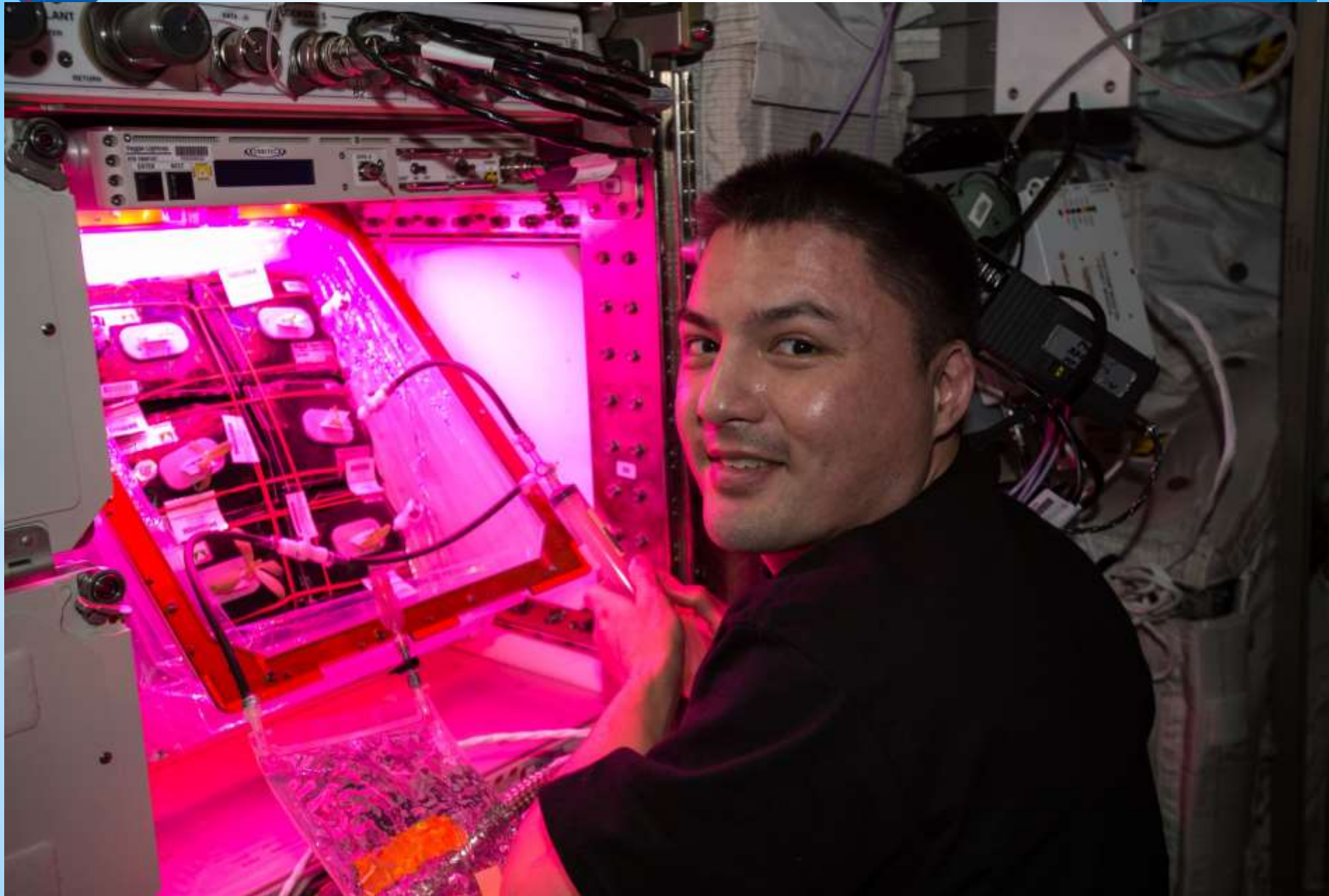








Veggie Production at ISS



Main symptoms of Carbon dioxide toxicity

Volume % in air	
7.6 mmHg	■ - 1%
22.8 mmHg	■ - 3%
38 mmHg	■ - 5%
60.8 mmHg	■ - 8%

Respiratory

- Shortness of breath

Muscular

- Tremor

Visual

- Dimmed sight

Auditory

- Reduced hearing

Central

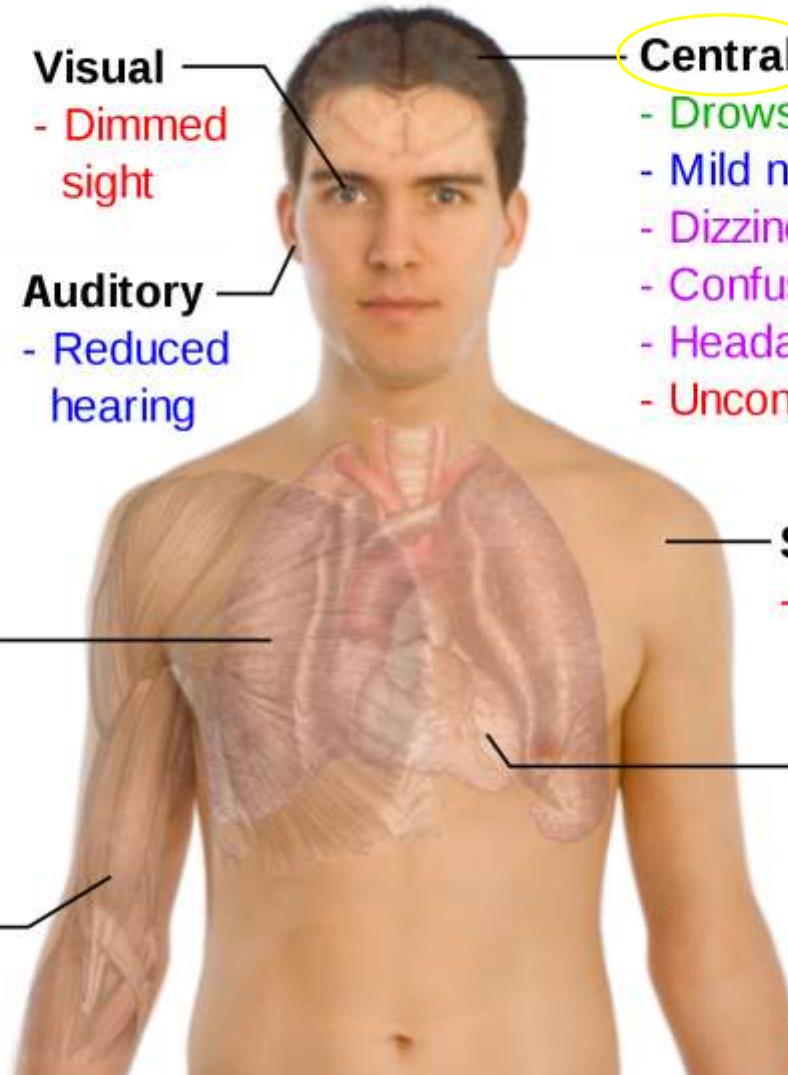
- Drowsiness
- Mild narcosis
- Dizziness
- Confusion
- Headache
- Unconsciousness

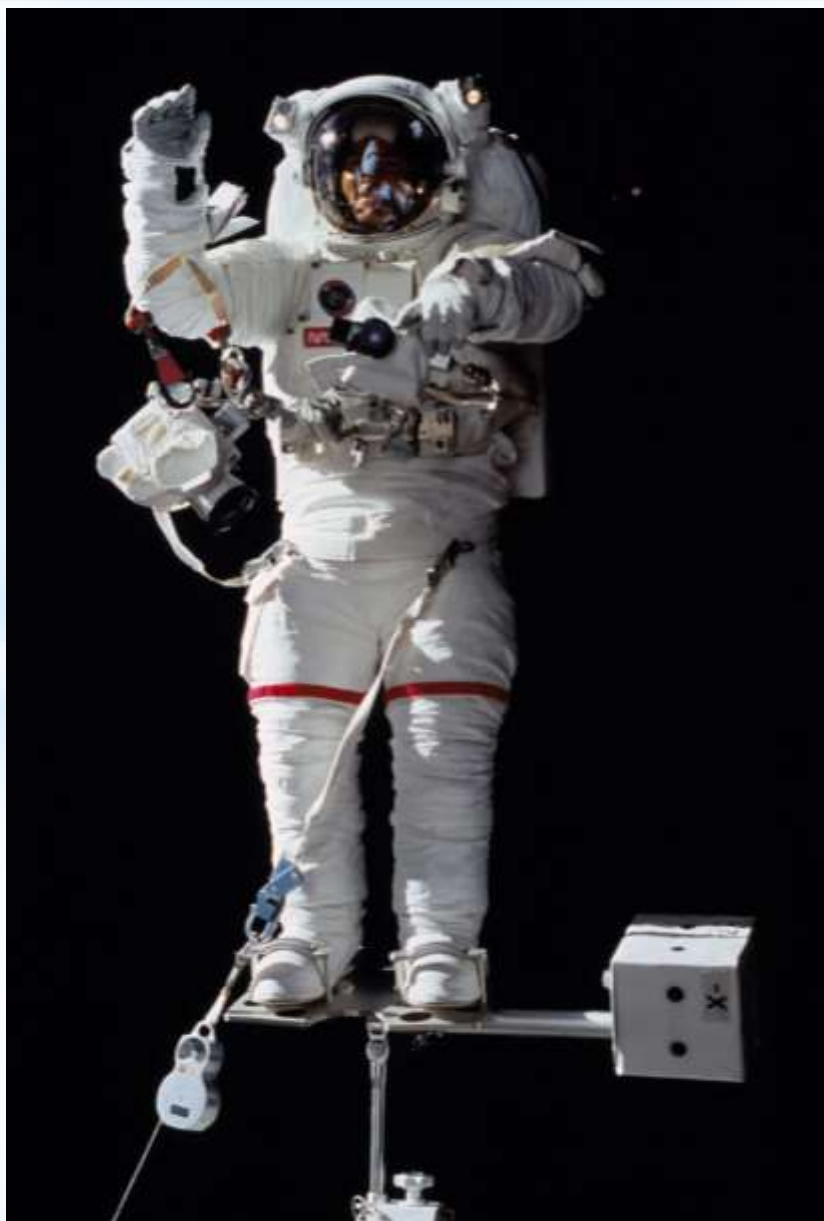
Skin

- Sweating

Heart

- Increased heart rate and blood pressure







EVA Preparation





EVA Ready



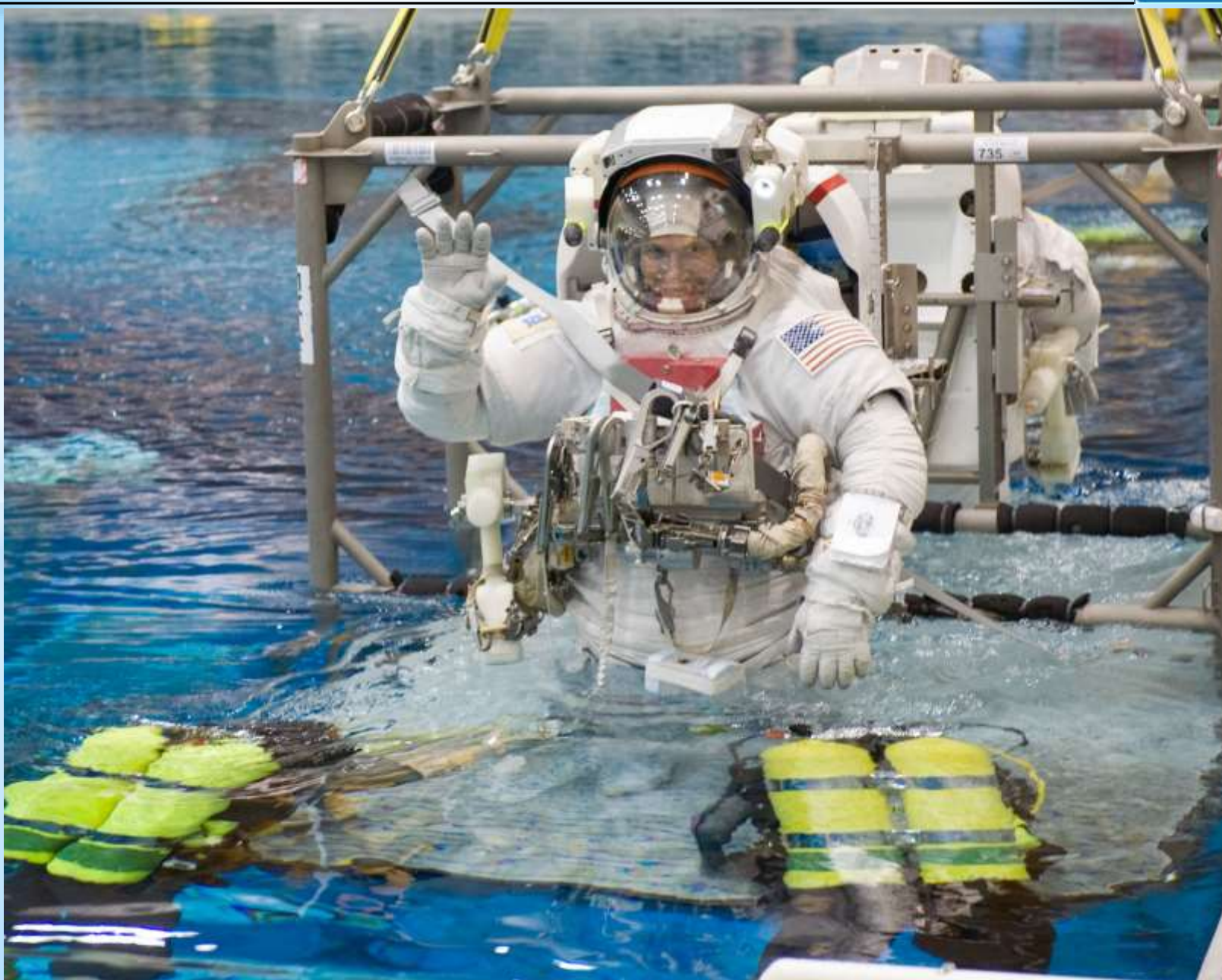
Pre-breathe Protocol





EVA for Action





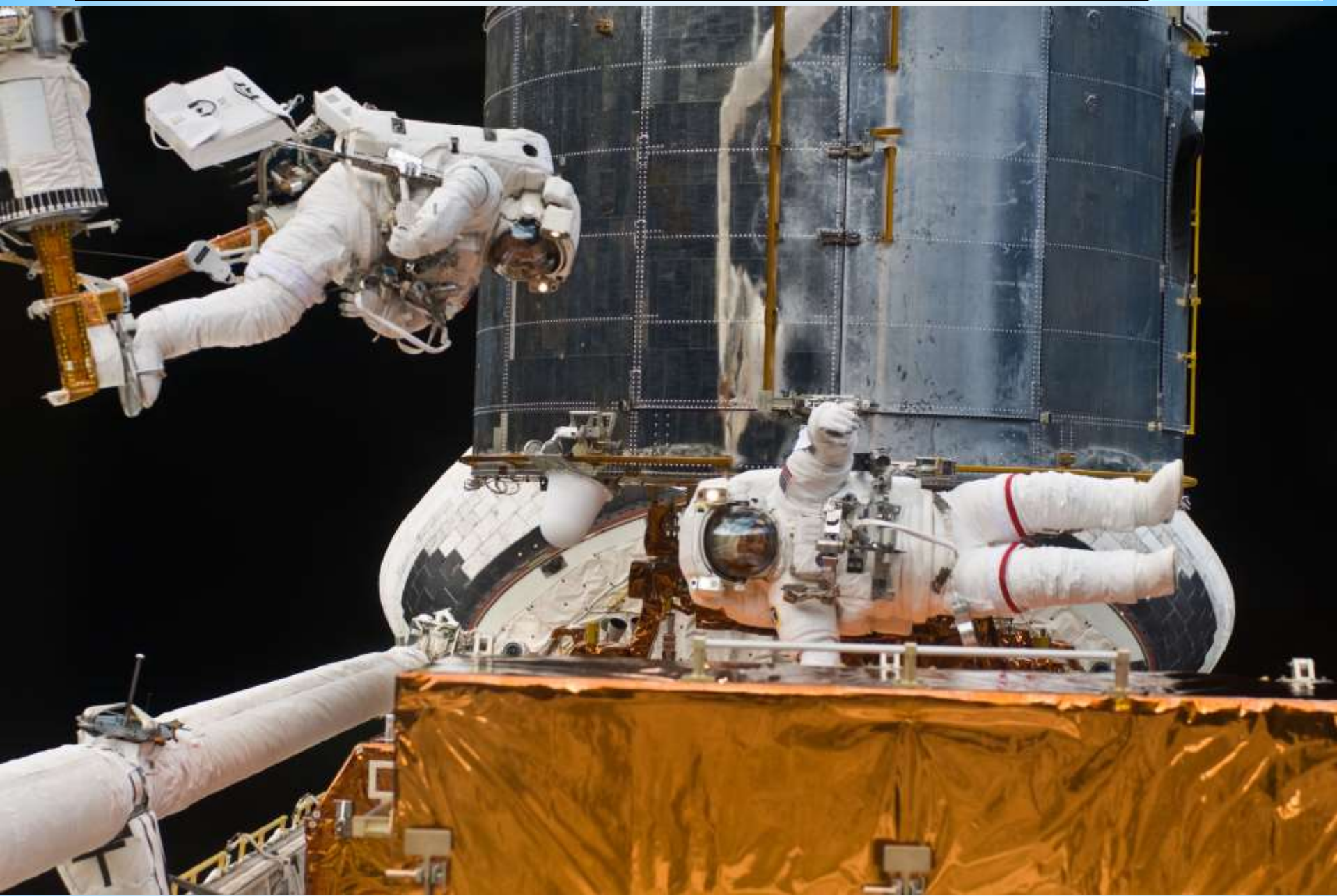


EVA Activity - ISS





EVA - Hubble Repair at the Shuttle Bay





On the fifth day of STS-54, astronauts spent almost five hours in Endeavour's open payload bay performing a series of tasks designed to increase NASA's knowledge of working in space, necessary for the building of a space station. The astronauts tested their abilities to move freely in the cargo bay and climb into foot restraints without using their hands.

The whole spacewalk experience was incredible. I shut down, as I peered out into infinity I really had a sense of The Divine, and it was very strong. I now have a better appreciation for the vastness and enormity of the Universe—I guess you can say I had a brother's look at God's handiwork.
—Mario Runco, Astronaut



January 13-19, 1991





Education Material from NASA



<https://www.nasa.gov/audience/foreducators/spacesuits/home/misc-videos.html>



NASA's Vision

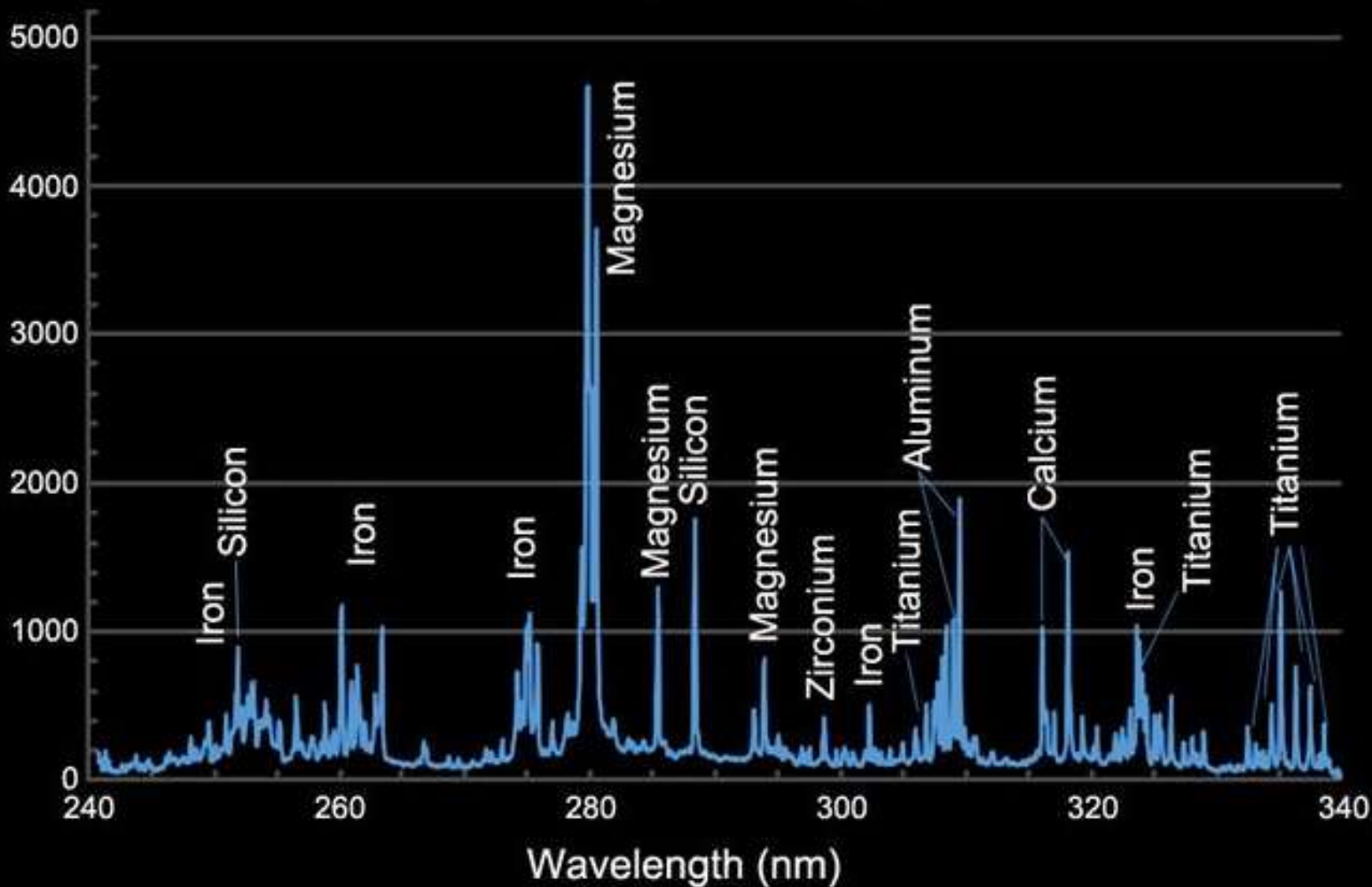


Things that are known
and things that are unknown
in between is Exploration

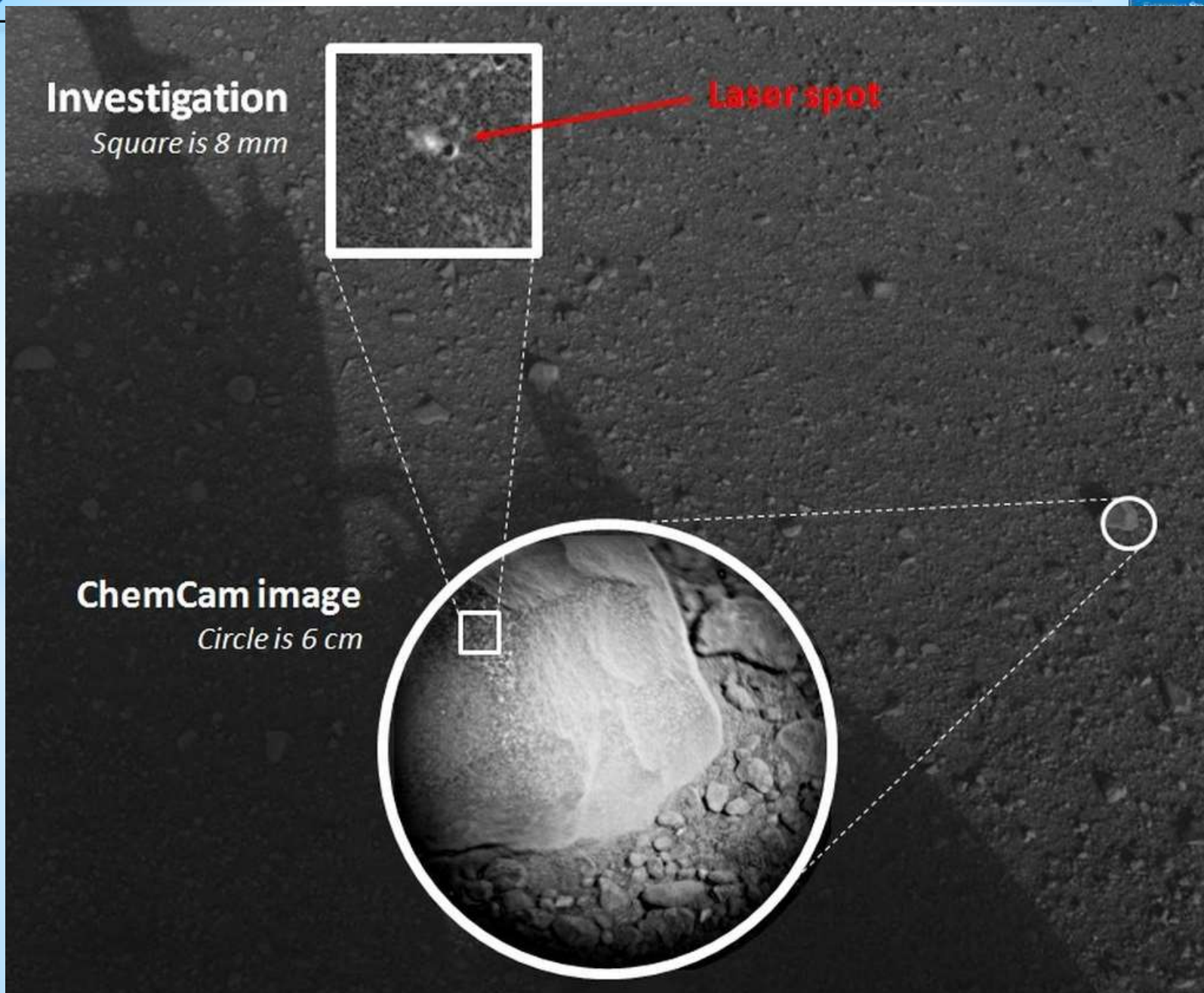
I do not know the answers for the following Questions

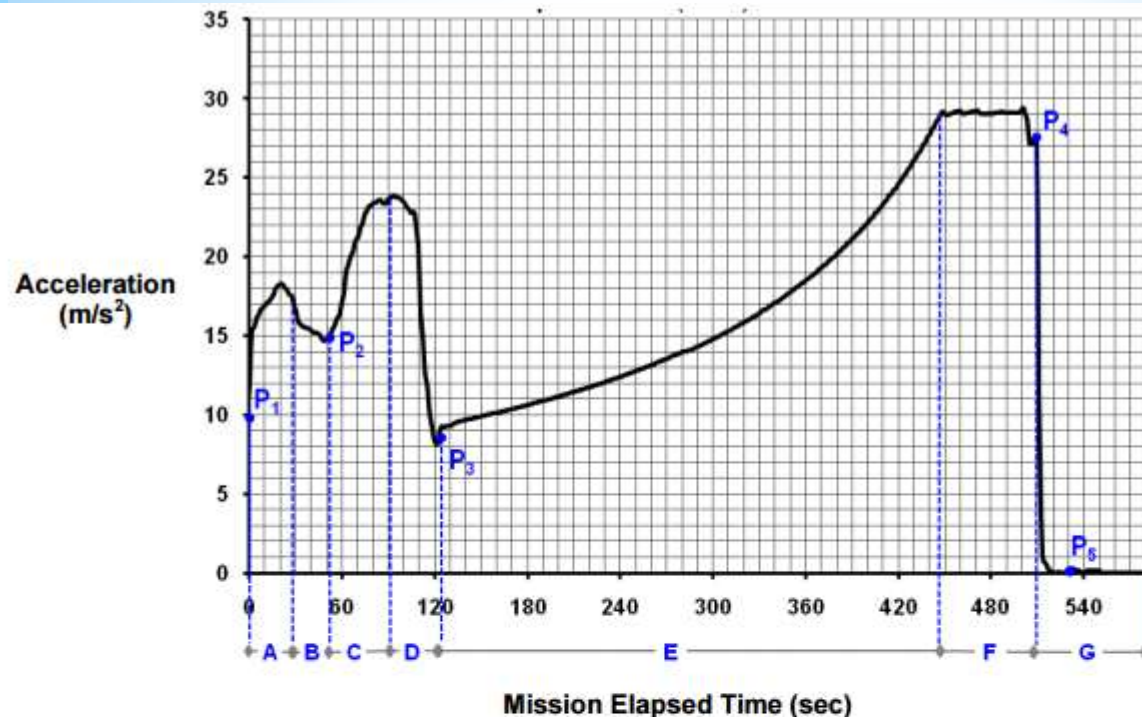
- 1) Is there possibilities for parallel Universe?
- 2) The comet "Love Joy" is hypothetically credited for creating life on earth
- 3) What do you mean by locomotice rocket?
- 4) Life elsewhere in the Universe?

ChemCam Spectrum
One of 3 spectral ranges covered by ChemCam



Laser Zapped Mars Rock (2012)





A. The following events take place during the launch of a space shuttle. Compare the rates of change of acceleration in Graph 1 and determine which event occurs at the marked time periods (A through G) and points (P₁ through P₅).

- | | |
|--|--|
| _____ External Tank separation | |
| _____ Aerodynamic stress on the spacecraft in atmospheric flight is at its highest (Max Q) | |
| _____ Space Shuttle Main Engines provide smoothly changing acceleration | |
| _____ Throttle down | _____ Solid Rocket Boosters burning out |
| _____ On orbit | _____ Negative rate of change of acceleration (large air drag) |
| _____ Throttle up | _____ Constant acceleration (3 g's) |
| _____ Main Engine Cuto | _____ Solid Rocket Booster separation |
| | _____ Space shuttle lift-off |





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 (electromagnetic radiation), which has to be converted into sound by the astronauts' headsets.



Asteroids



- Asteroids are leftovers from the formation of our solar system about 4.6 billion years ago.
- The birth of Jupiter prevented any planetary bodies from forming in the gap between Mars and Jupiter, causing the small objects that were there to collide with each other and fragment into the asteroids seen today.
- In 1801, while making a star map, Italian priest and astronomer Giuseppe Piazzi accidentally discovered the first and largest asteroid, Ceres. 940 km wide

Recent Incident :

On Feb. 15, 2013, an asteroid slammed into the atmosphere over the Russian city of Chelyabinsk, creating a shock wave that injured 1,200 people.

The space rock is thought to have measured about 65 feet (20 meters) wide when it entered Earth's atmosphere.

Recent Visit by a Robot

In 2006, Japan's Hayabusa became the first spacecraft to land on and take off from an asteroid.

It returned to Earth in June 2010, and the samples it recovered are currently under study.



Alberta, Canada. Aurora and Fireball





Is there any living organism in any other part of Universe? Are we alone?



Habitable Zone

TOO HOT

JUST RIGHT

TOO COLD

Planet size: 1-2x Earth



Black Hole : Gravitational Force Extreme; Even Light can not escape



A large cloud named Cygnus X-3 and a smaller cloud, nicknamed the "Little Friend," both appear in white. Jets of gas emitted from "Little Friend" from star formation are shown in blue and red.

Credit: X-ray: NASA/CXC/SAO/M.McCollough et al, Radio: ASIAA/SAO/SMA

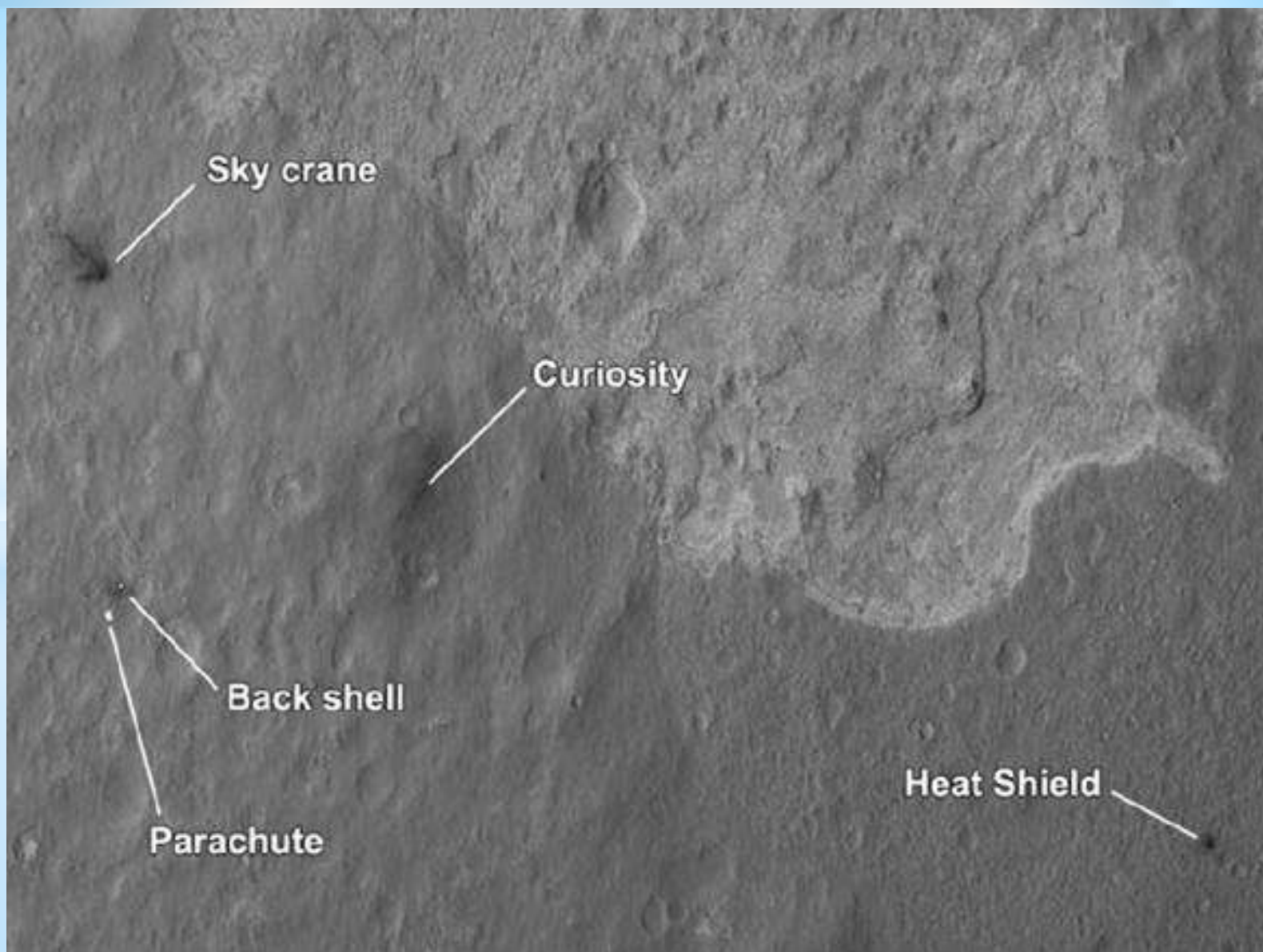


Ultrasound at ISS; Spinal Elongation

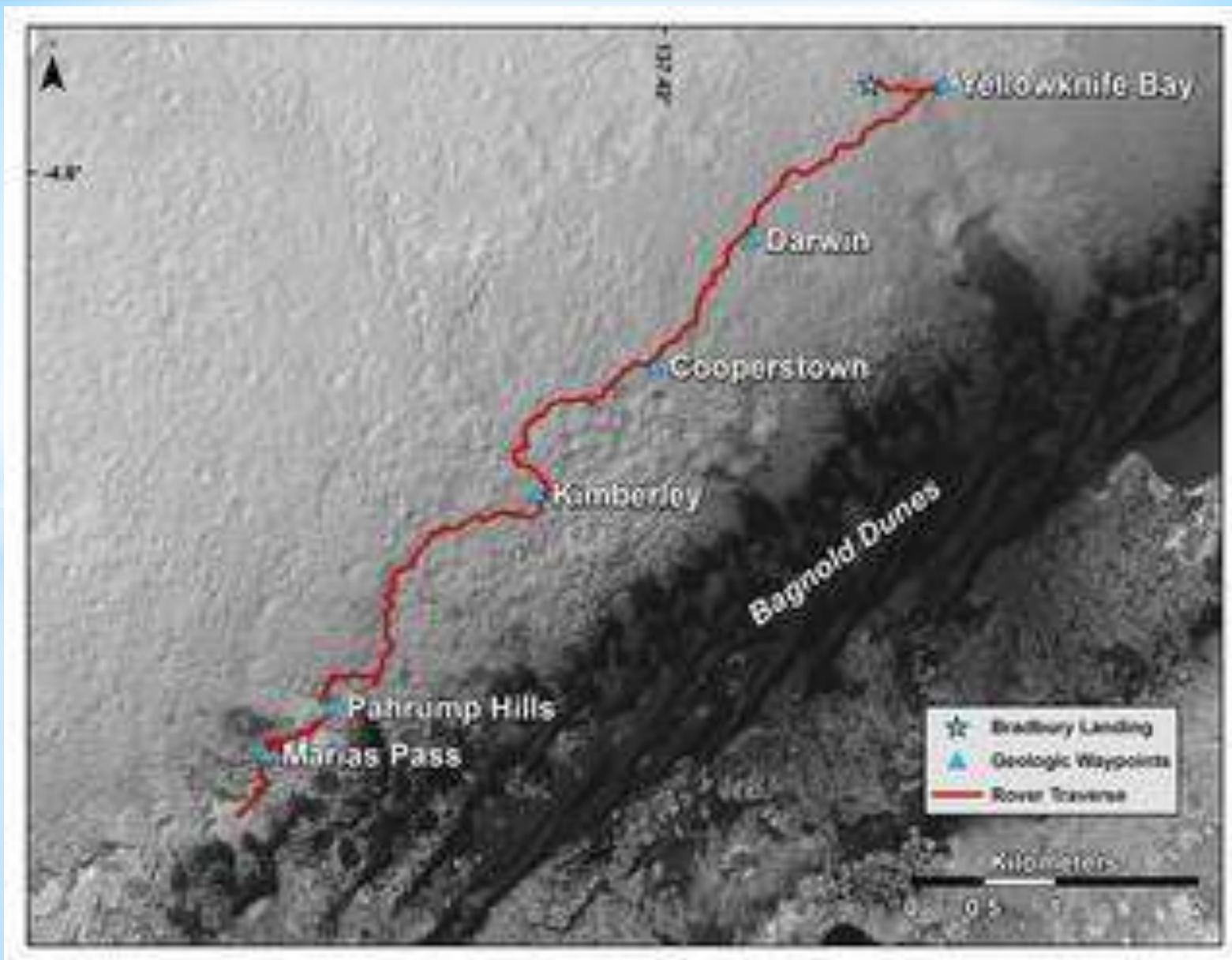


Addressing Critical Health Issues for Exploration: ISS research has found that a health issue related to long duration space exposure is that visual acuity changes are occurring in over 76% of crew.

Curiosity Landing Site



Curiosity's Track





LEDs for Growing Plants

Red...photosynthesis

Blue...photomorphogenesis

Green...human vision



*John Sager, KSC, Testing Prototype
Flight Plant Chambers with LEDs*



India's Mars Mission





Lyman Alpha Photometer (LAP)

Lyman Alpha Photometer (LAP) is an absorption cell photometer. It measures the relative abundance of deuterium and hydrogen from Lyman-alpha emission in the Martian upper atmosphere (typically Exosphere and exobase). Measurement of D/H (Deuterium to Hydrogen abundance Ratio) allows us to understand especially the loss process of water from the planet.



Methane Sensor for Mars (MSM)

MSM is designed to measure Methane (CH_4) in the Martian atmosphere with PPR accuracy and map its sources. Data is acquired only over illuminated scene as the sensor measures reflected solar radiation. Methane concentration in the Martian atmosphere undergoes spatial and temporal variations.

Atmospheric studies



Mars Exospheric Neutral Composition Analyser (MENCA)

MENCA is a quadrupole mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 amu with unit mass resolution. The heritage of this payload is from Chandra's Altitudinal Composition Explorer (CHACE) payload

Particle environment studies



Mars Color Camera (MCC)

This tri-color Mars Color camera gives images & information about the surface features and composition of Martian surface. They are useful to monitor the dynamic events and weather of Mars. MCC will also be used for probing the two-satellites of Mars – Phobos & Deimos. It also provides the context information for other science payloads.



Thermal Infrared Imaging Spectrometer (TIS)

TIS measure the thermal emission and can be operated during both day and night. Temperature and emissivity are the two basic physical parameters estimated from thermal emission measurement. Many minerals and soil types have characteristic spectra in TIR region. TIS can map surface composition and mineralogy of Mars.

Surface Imaging Studies

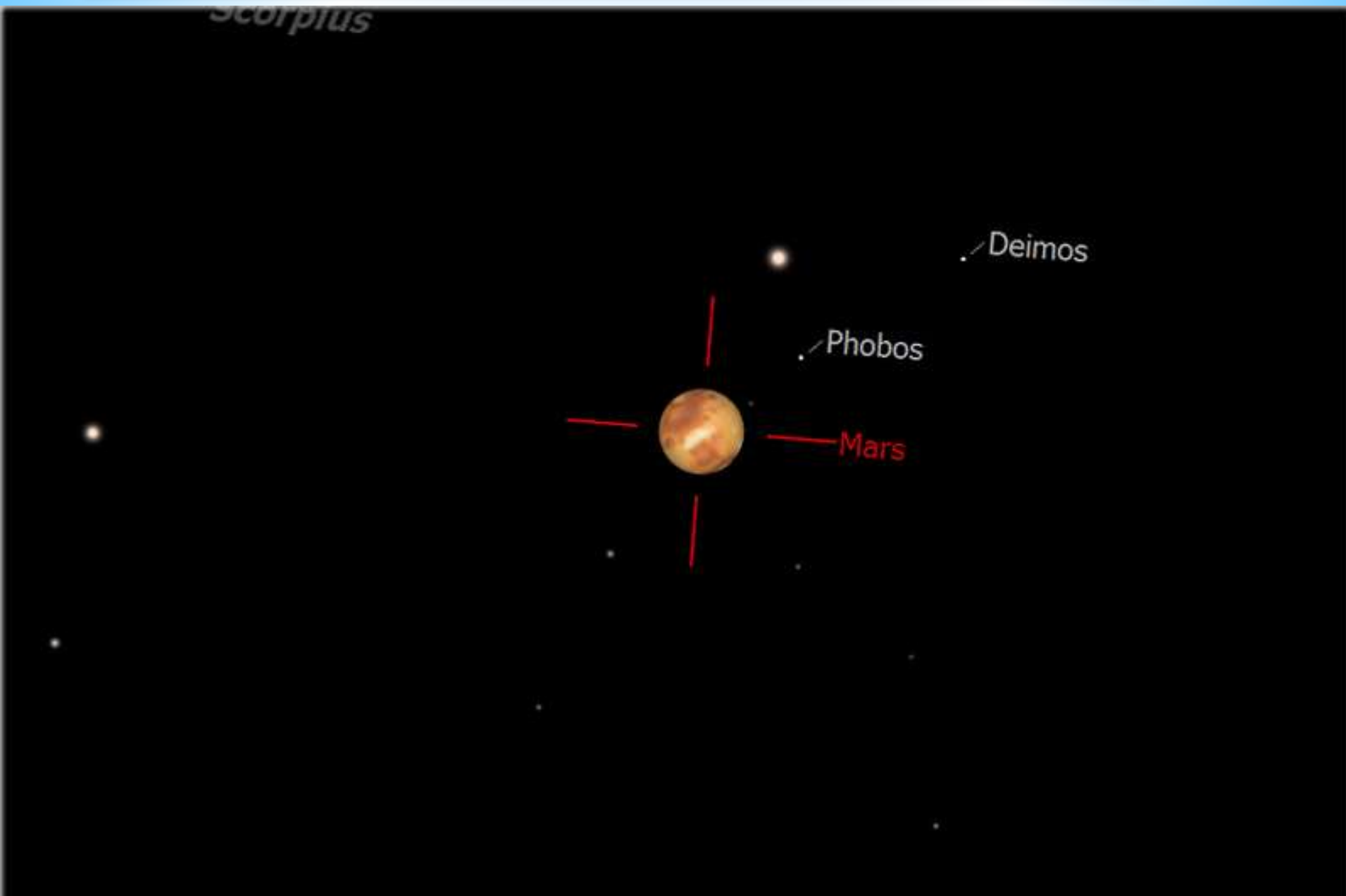




Guppy



Moons of Mars



Phobos (Mars' Moon)

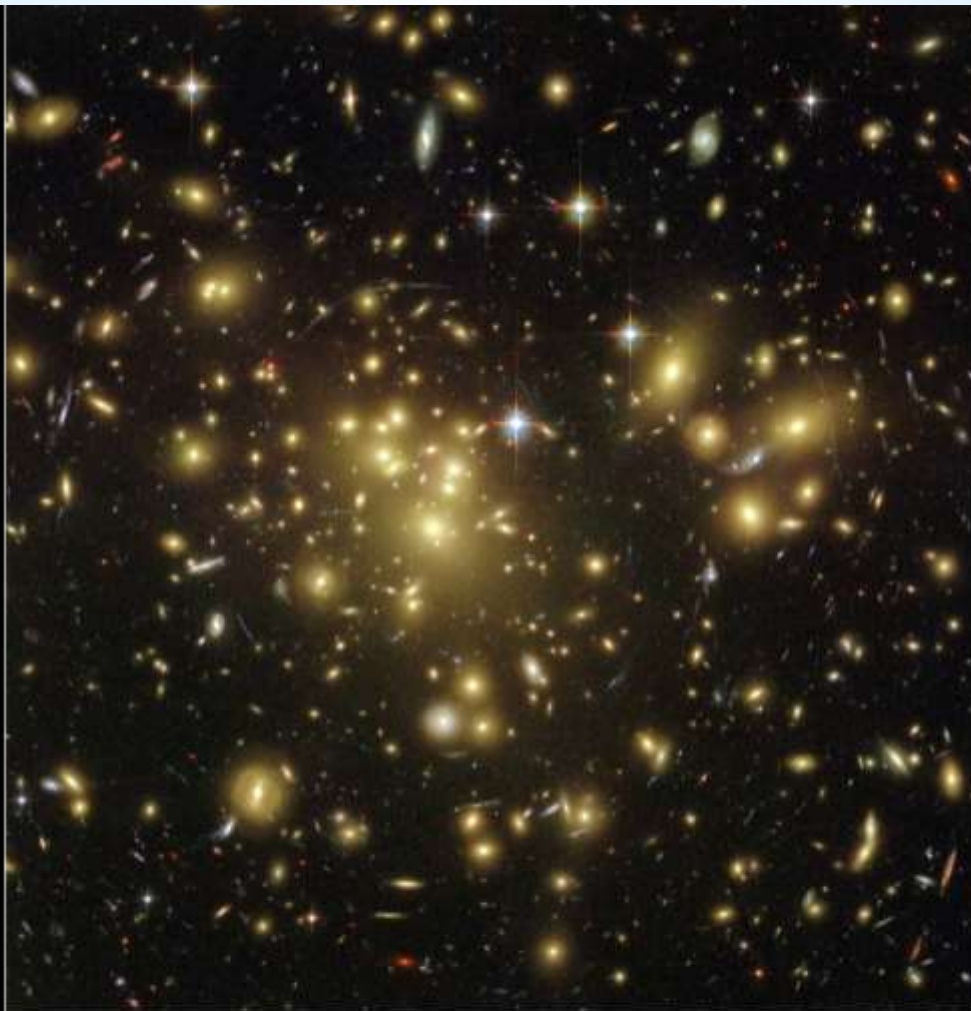




Orion Launch







Galaxy Cluster Abell 1689
Hubble Space Telescope • Advanced Camera for Surveys

NASA, N. Benitez (JHU), T. Broadhurst (The Hebrew University), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA
STScI-PRC03-01a

CENTRAL REGION OF THE MILKY WAY
NASA'S GREAT OBSERVATORIES

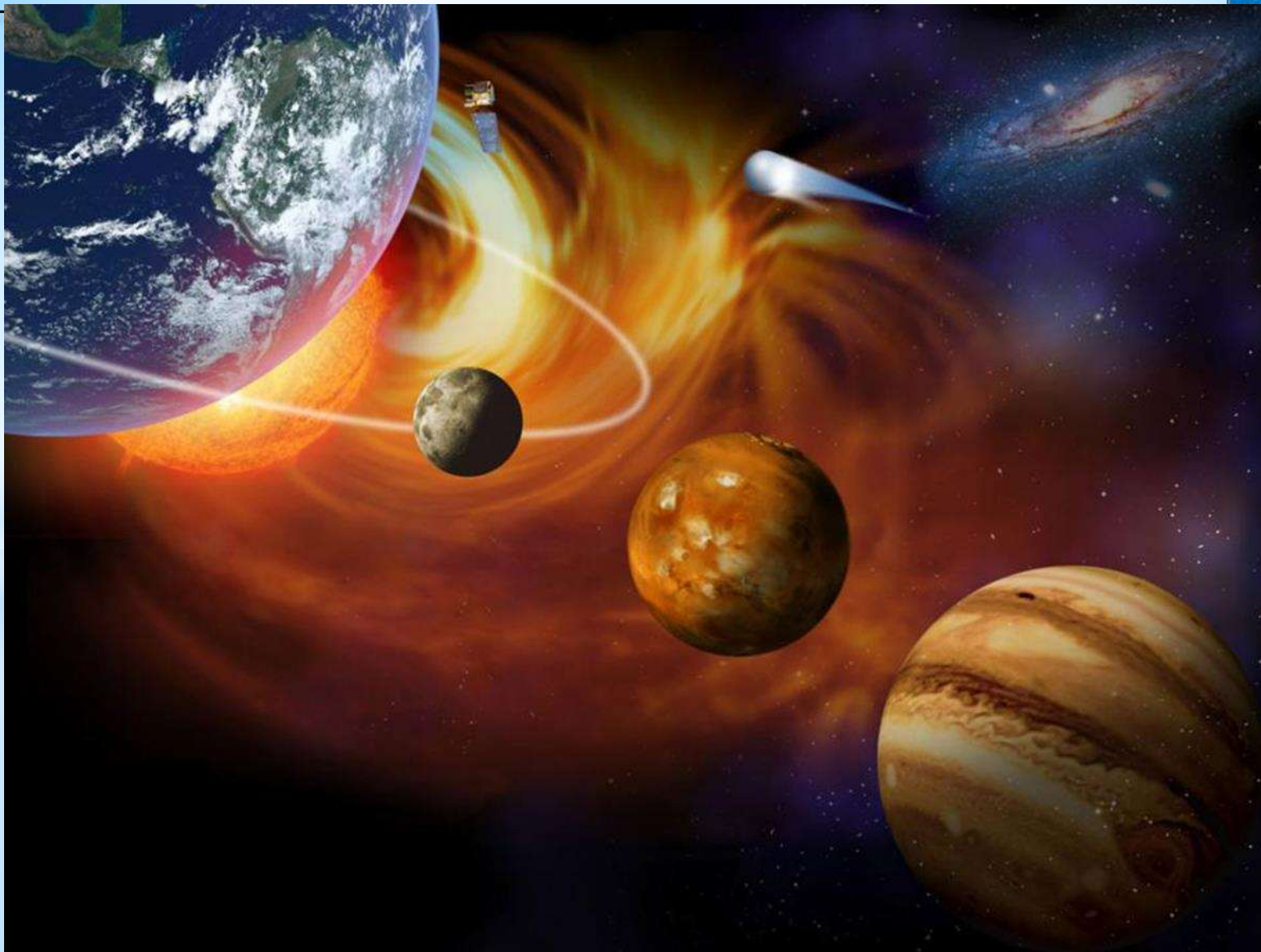


NASA, ESA, CXO, SSC, AND STScI

STScI-PRC09-28A



Near-term Human Exploration Domains







Mars Panoramic View (Images from Curiosity)





Jupiter's Moons : Europa







Still
daylight in
California.

Chicago

Cities of Boston, New
York, Philadelphia and
Washington.

Dallas

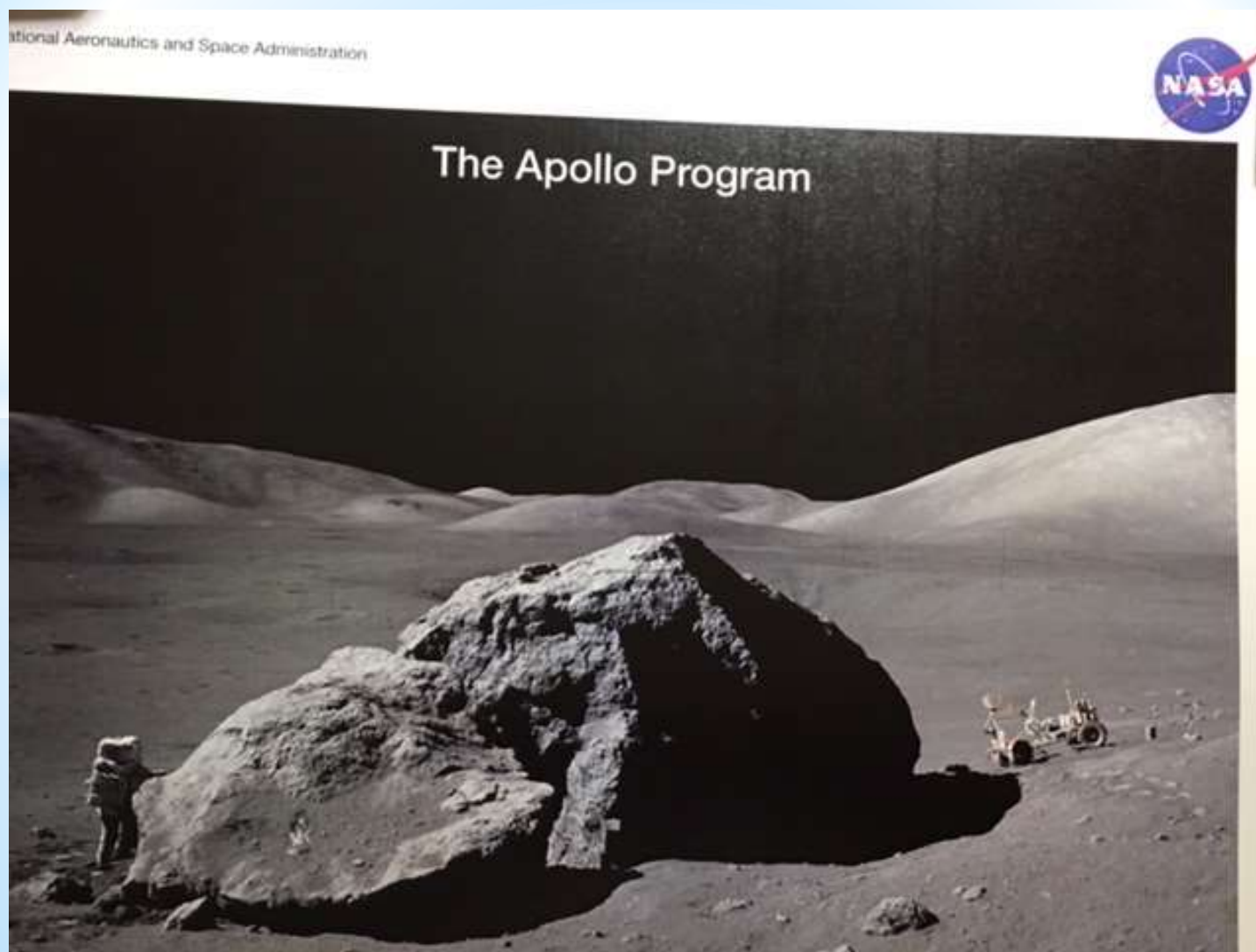
Houston

Miami

Puerto Rico

Apollo-17 : Jack Schmitt (Geologist)

Regolith : Youngest 10 m soil “Maria”
Oldest : Oldest 20 m soil “Highlands”

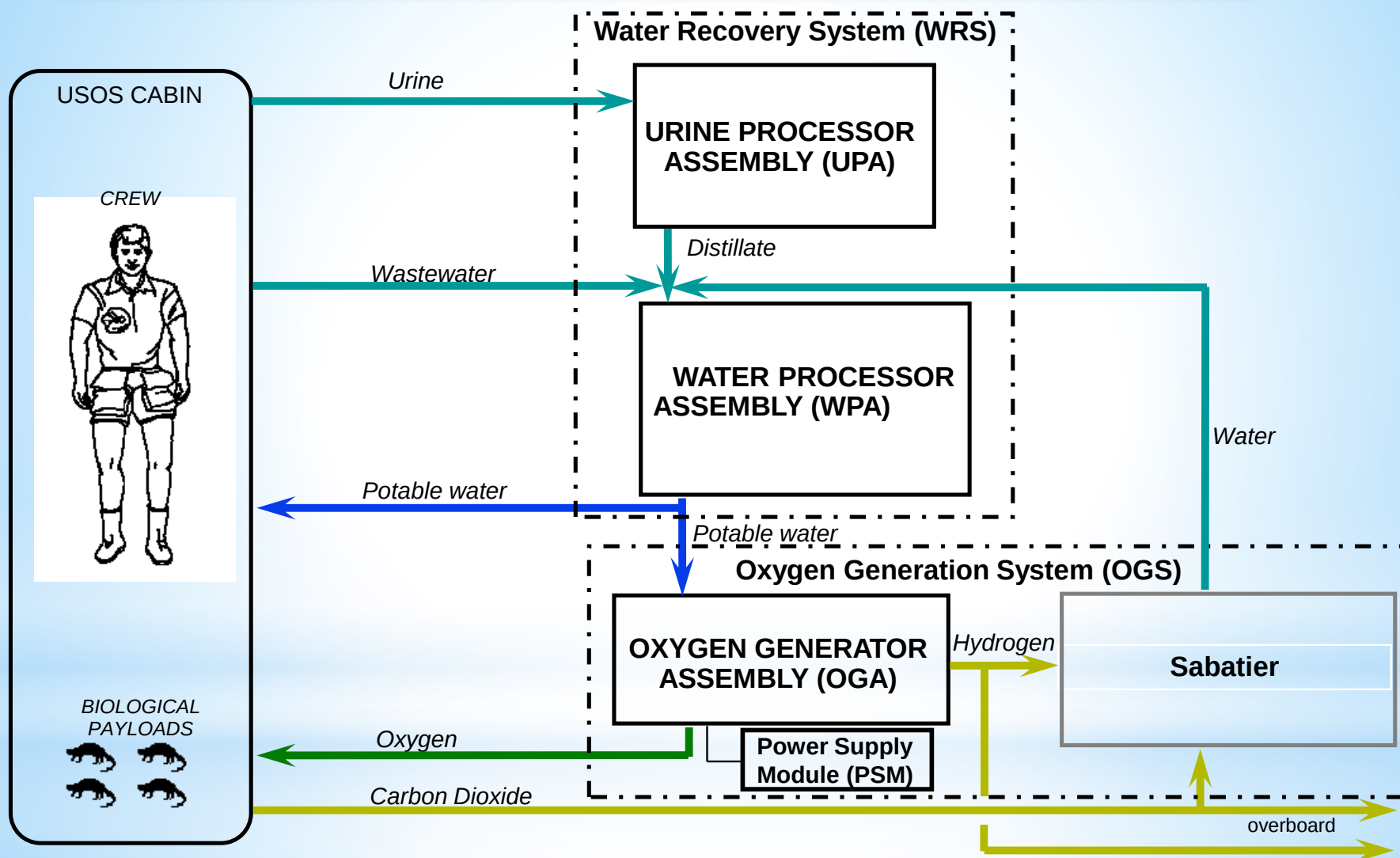


Is it Earth?



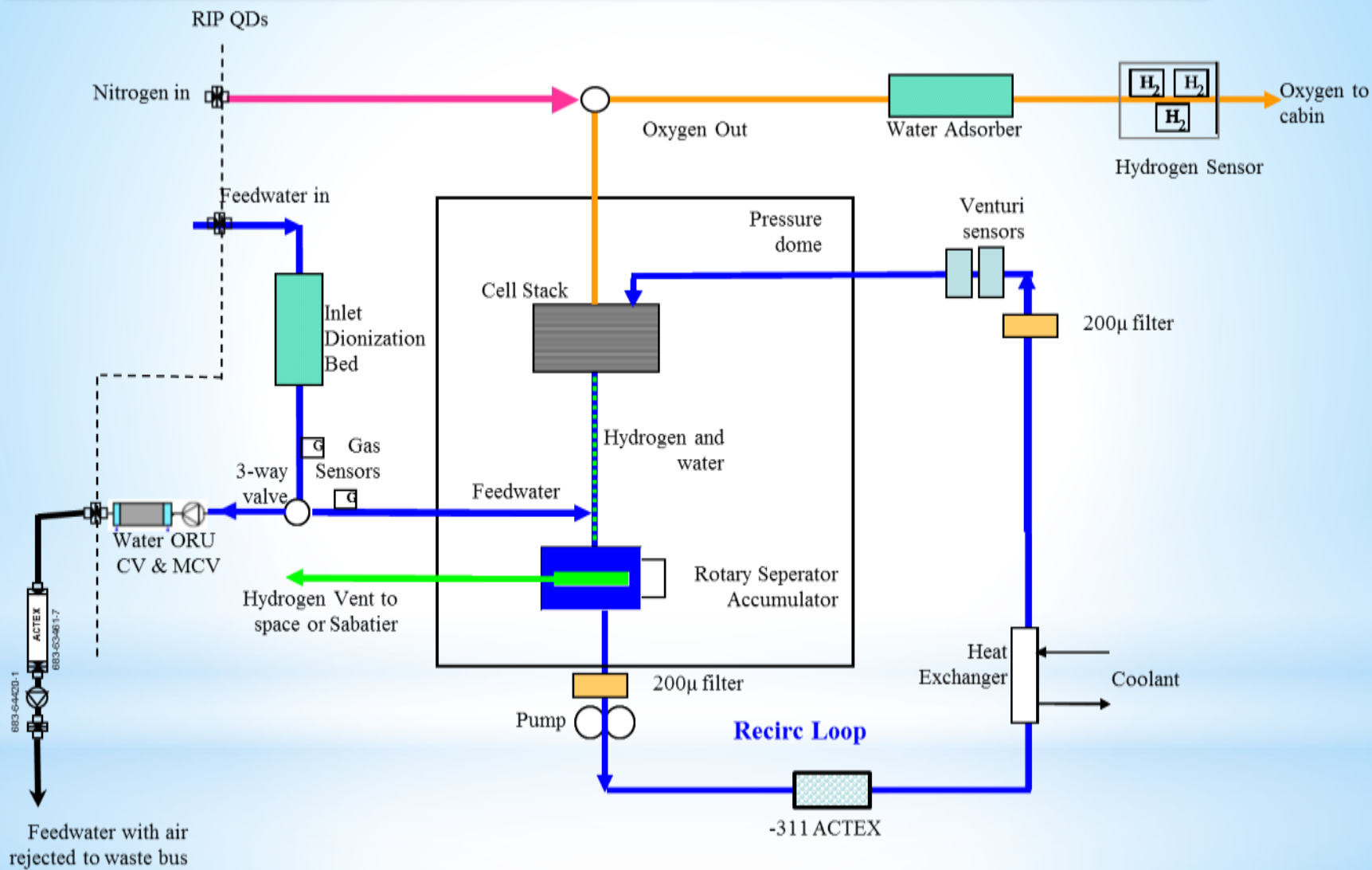


Water and CO2 Recycling

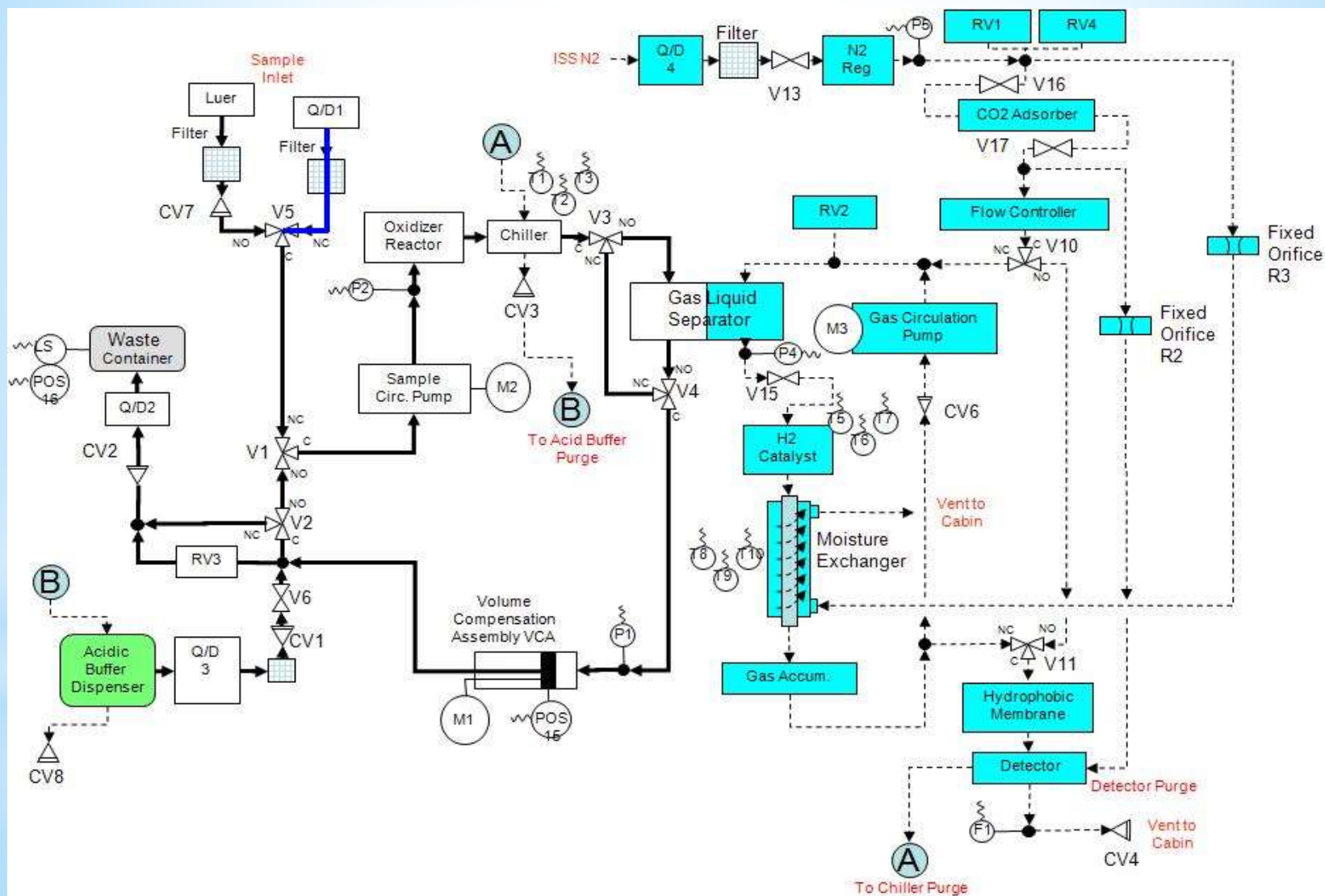




Oxygen Generation System

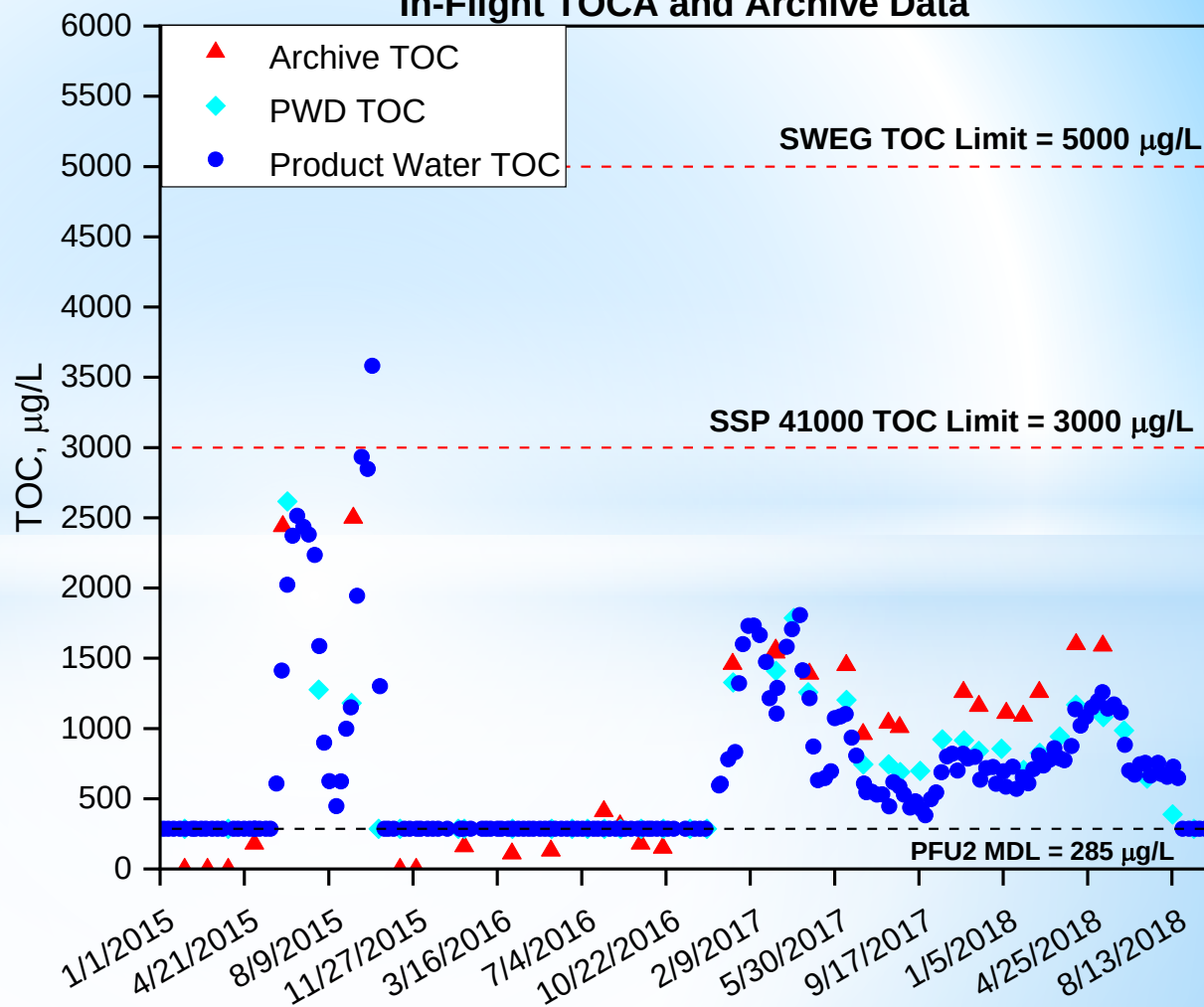


Total Organic Carbon Analyzer





ISS WPA Product Water TOC In-Flight TOCA and Archive Data



Today's Coffee - Yesterday's Coffee



“Pee Brittle”





Air Quality Monitoring



AQM 1 (624 column)	AQM 2 (DB5 column)
Acetone	Ethanol
Hexane	Dichloromethane
1,2-dichloroethane	Trimethylsilanol
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	

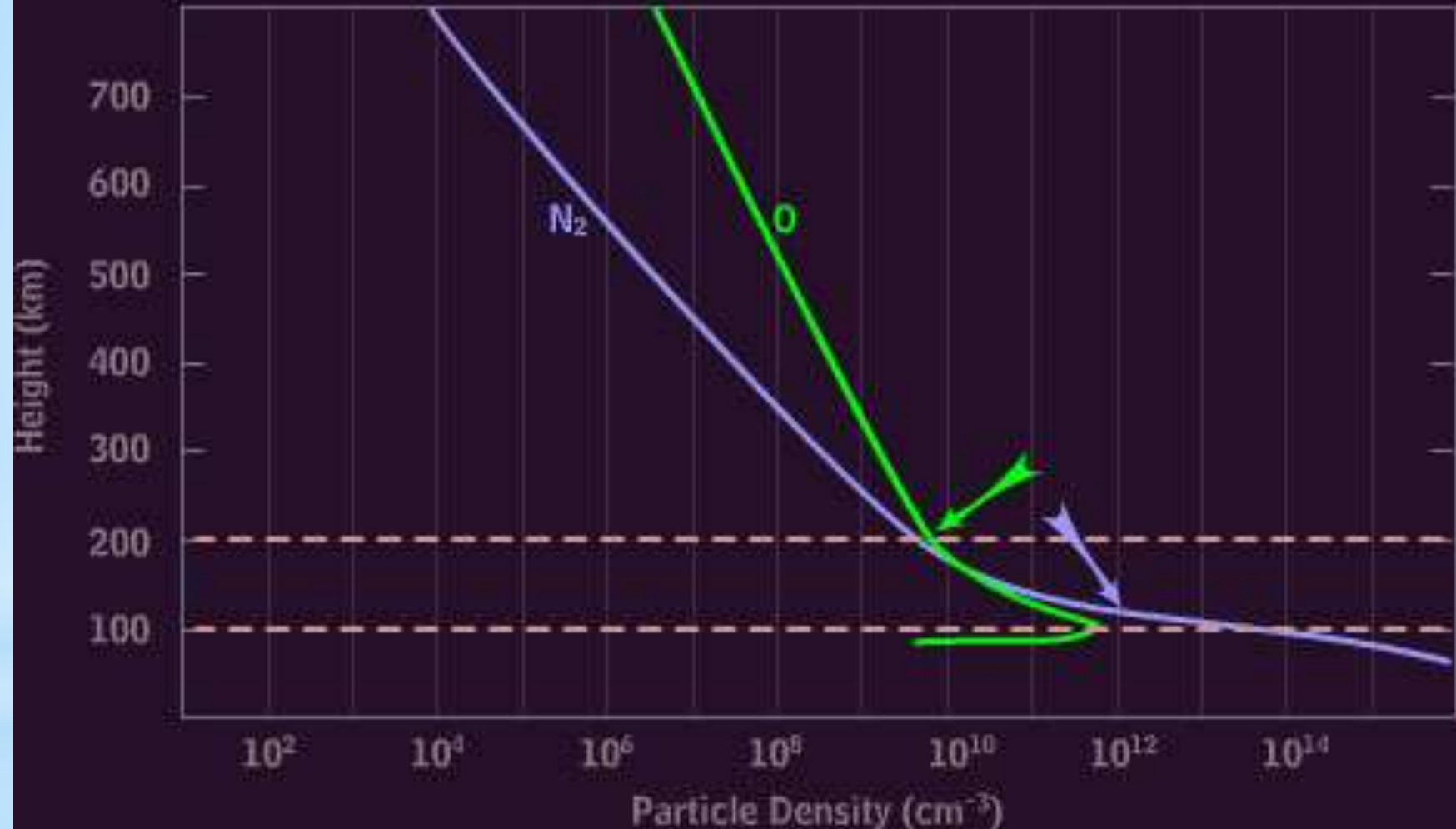


Uses combination of Tunable Diode Laser Spectroscopy and Photoacoustic Spectroscopy

Analytes :

O₂, CO₂, CO, H₂O, HF, HCl, HCN, NH₃, and N₂H₂.

Principal Constituents of the Thermosphere



MSIS E-90 Model/
 NCAR/HAO

Atomic Oxygen Emission Spectrum

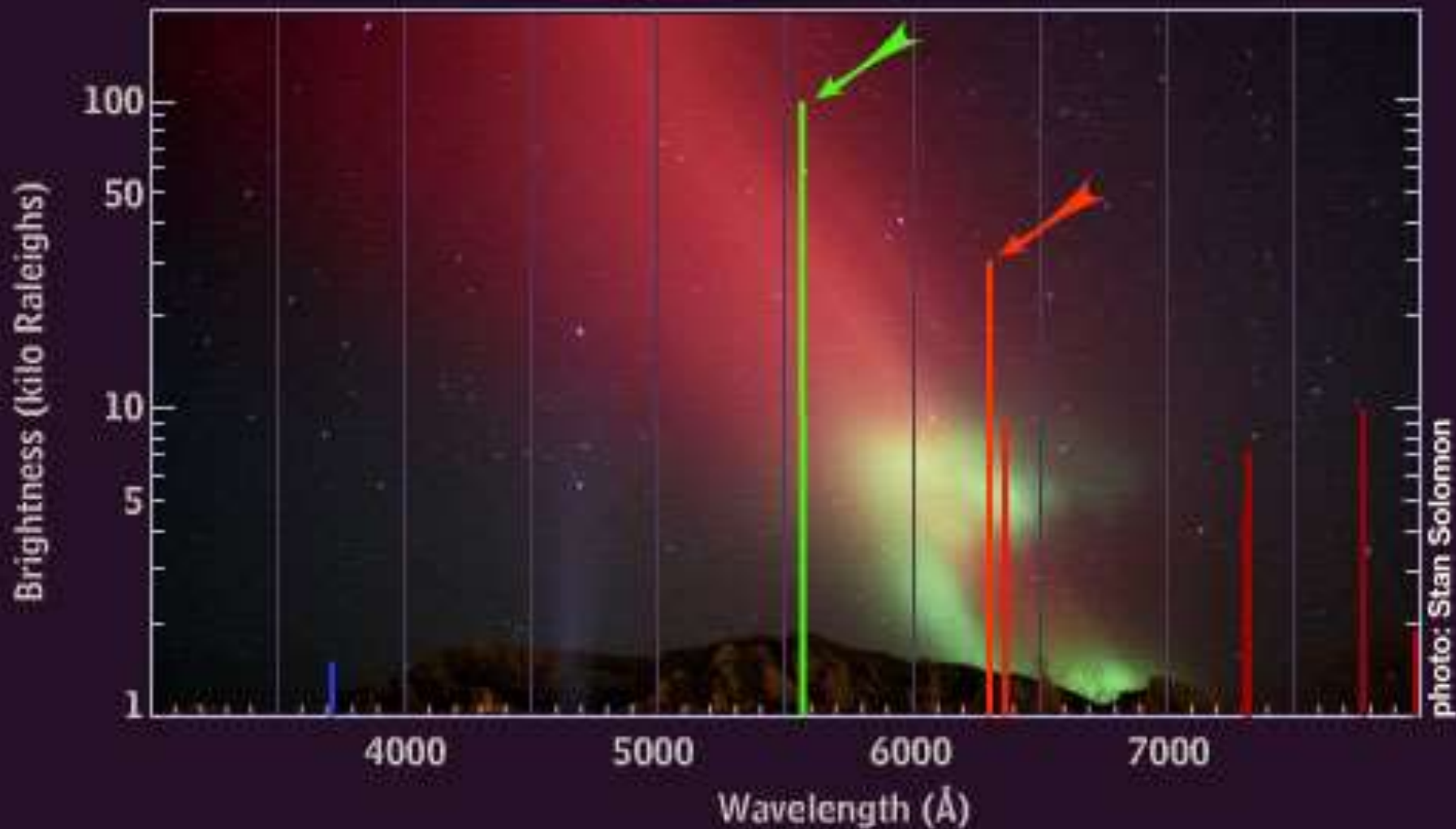


photo: Stan Solomon

Molecular Nitrogen Emission Spectrum

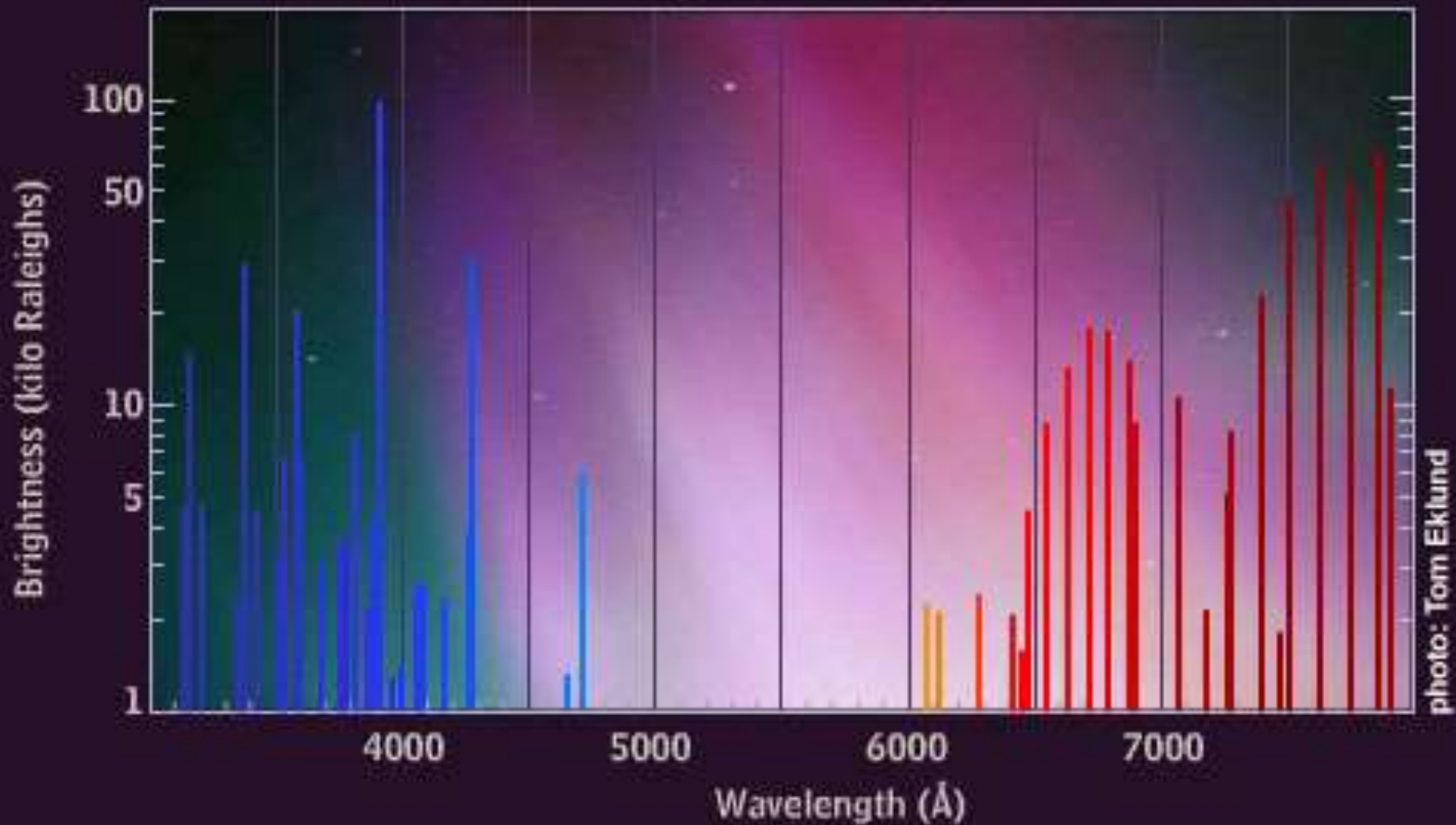


photo: Tom Eklund



Super-Woman

