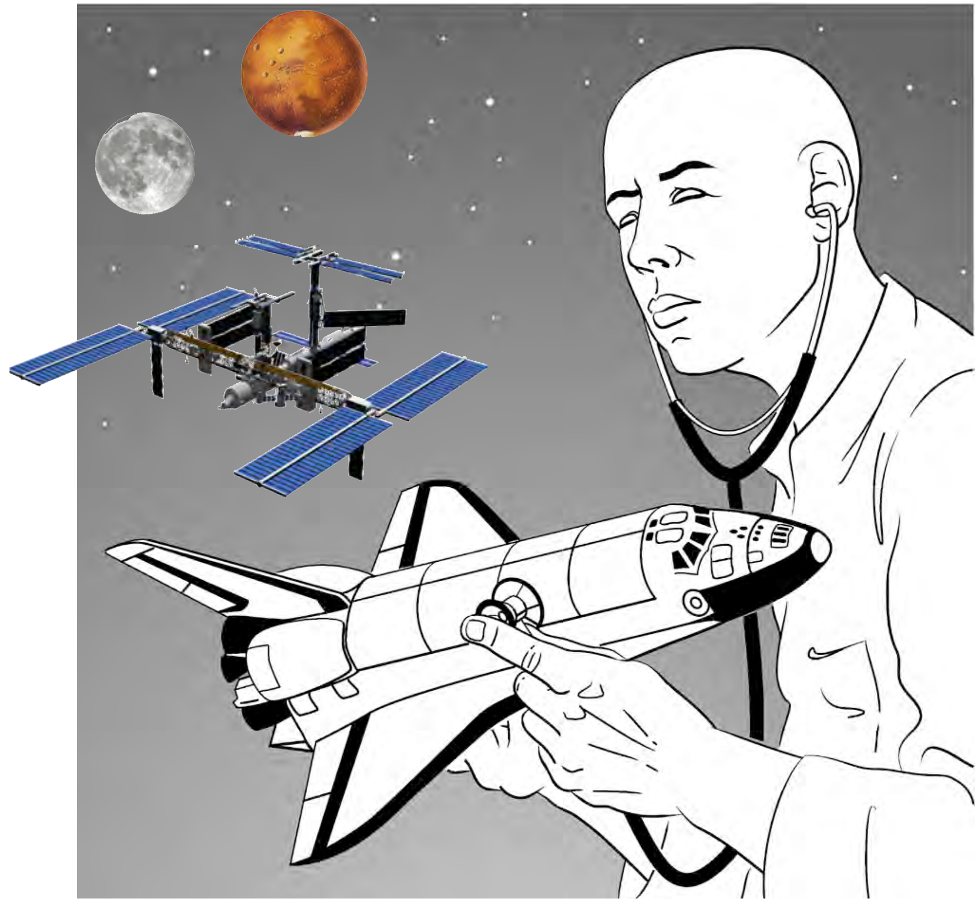
Introduction to Space Life Sciences



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Lecture Outline

- Space Life Sciences – What is it?
  Where we are

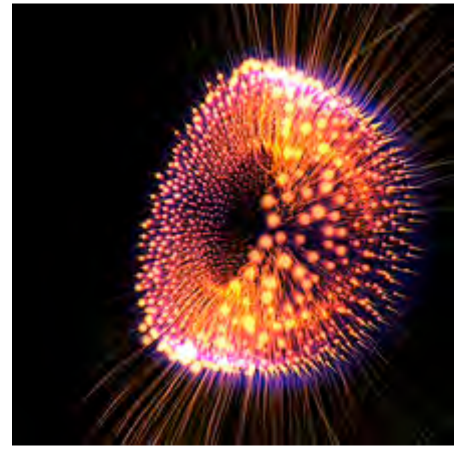
- The historical context of human space flight
  How we got there

- The importance of continuing research before long-duration exploration missions can be safely undertaken
  Where do we go from here

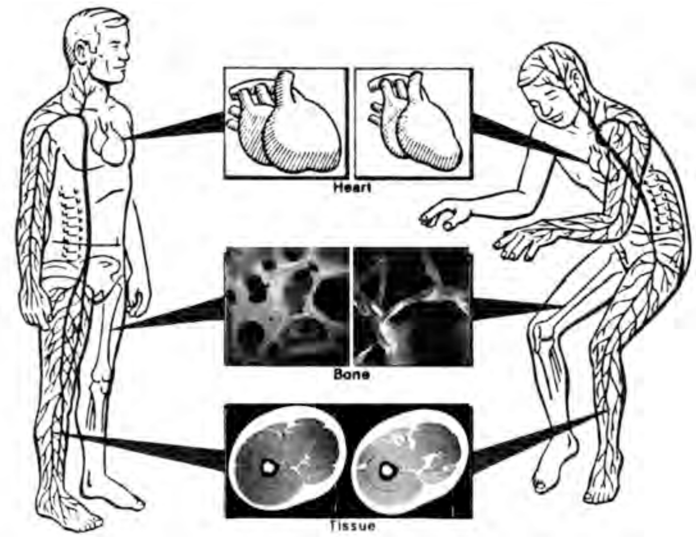
Space Life Sciences—What is it

- **Life Sciences** are specifically devoted to the working of the living world – from bacteria and plants to humans
- On Earth, all living organisms have developed as a result of constant exposure to **1-g** gravity. **Space Life Sciences** open a door to understanding ourselves, our evolution without the constraining barrier of gravity
- Beside microgravity, during space flight living organisms are also affected by **radiation**, **isolation**, **confinement**, absence of **24-hr day/night cycle**, etc.
- **Objectives of space life sciences:**
  - Enhance fundamental knowledge in biology and human physiology
  - Protect the health of astronauts
  - Develop advanced technology and applications for space & ground research

Benefits of Space Life Sciences Research



- **Biology**
  - Improve overall health of people of all ages
  - Improve crop yields using less nutrients and surface
  - Advance understanding of cell behavior
- **Biotechnology**
  - Provide information to design a new class of drugs to target specific proteins and cure specific diseases
  - Culture tissue for use in cancer research, surgery and bone and cartilage injuries
- **Medicine**
  - Enhance medical understanding of disease processes such as osteoporosis
  - Advance fundamental understanding of the nervous system and develop new methods to prevent and treat neurological disorders
  - Develop methods to keep humans healthy in reduced gravity for extended time periods
- **Education**
  - Use science on orbit to encourage and strengthen science education on Earth



Justification for Human Space Flight

- **Robotics *versus* Human crews = Apples *versus* Oranges**
  - Human Pros: intelligent operators, efficient end-effectors
  - Human Cons: expensive, complexity of habitable environment

- **Human spaceflight critics** often discount the value of Life Sciences within the "Space Sciences" — often due to following fundamentals differences:
  - Physical Sciences: more concrete discoveries in relatively unexplored sphere
  - Life Sciences: an inherently inexact science; context of background physiological variability; requirement for repeated measurements

Space Medicine *versus* Space Physiology

- **Space Medicine**
  - To solve medical problems encountered in space flight
  - Includes some adaptive changes (e.g., space motion sickness), environmental exposures, etc.
  - Includes also some non-pathologic changes which become maladaptive on return to Earth (e.g., bone loss)
  - Outlook is **operational**, views problems/peculiarities from standpoint of **mission impact**

- **Space Physiology**
  - To characterize response to space, especially 0-G
  - Necessary knowledge base for above
  - Outlook is **investigational**, views problems/peculiarities from standpoint of **scientific return**

Human Space Flight (as of 9 Sept. 2010)

- Total number of humans who have flown in space: **518***, incl. 56 ♀
- Number of human-flights (total tickets): **1,137****, including 127 ♀
- Cumulative space flight time: **100 human-years**, incl. 8 ♀ -years
- Record of space flight duration: **14 months**
- Cumulative space flight duration by individual :
  - V. Polyakov 679 days; 2 flights ~22 months
  - S. Krikalyov 804 days; 6 flights ~26.5 months

☞ How did we get there ?

* 17 have died.
~2700 individuals have climbed Mount Everest since 1953 (216 have died)
~440 individuals have completed expeditions to the North or South poles since 1865 and 1908, respectively

** Including 794 human-flights on Space Shuttle (~70% of 1137)

Source http://space.kursknet.ru/cosmos/english/main.sht

Major Space Life Sciences Events

- 1783: 2 French gentlemen ride a hot-air (Montgolfier) balloon
- 1951: First successful (non-orbital) flight of a sounding rocket with a monkey and 11 mice (previous attempts since 1948 were not successful)
- 1957: Dog Laika first living creature into orbit (died after a few days)—followed by monkeys
- 1959: Selection of 7 American astronauts
- 1960: Selection of 11 Soviet cosmonauts
- 1961: First human to orbit the Earth (Y. Gagarin)
- 1963: First woman (V. Tereshkova) in space – second Russian woman (S. Savitskaya) did not fly until 1982
- 1965: First space walk (Extra-Vehicular Activity)

History of Human Space Flight

- First space missions were to demonstrate that humans could **survive** a journey into space
- Some people **doubted** whether humans could endure the g forces of launch and re-entry, or swallow, or sleep in the absence of gravity
- Some **predicted** that "*the bowels would not work without gravity, the heart might cavitate like a pump, or become so weakened as to prohibit return to Earth*"
- How long can humans **live** in space, and how effectively can they **work** in space are still open questions
- *Living* and *working* is far different from merely **surviving**
- After extended stays in space, can people return safely to Earth and lead normal, healthy lives? Such questions are much more difficult than questions of survival because they require sophisticated scientific **experimentation**

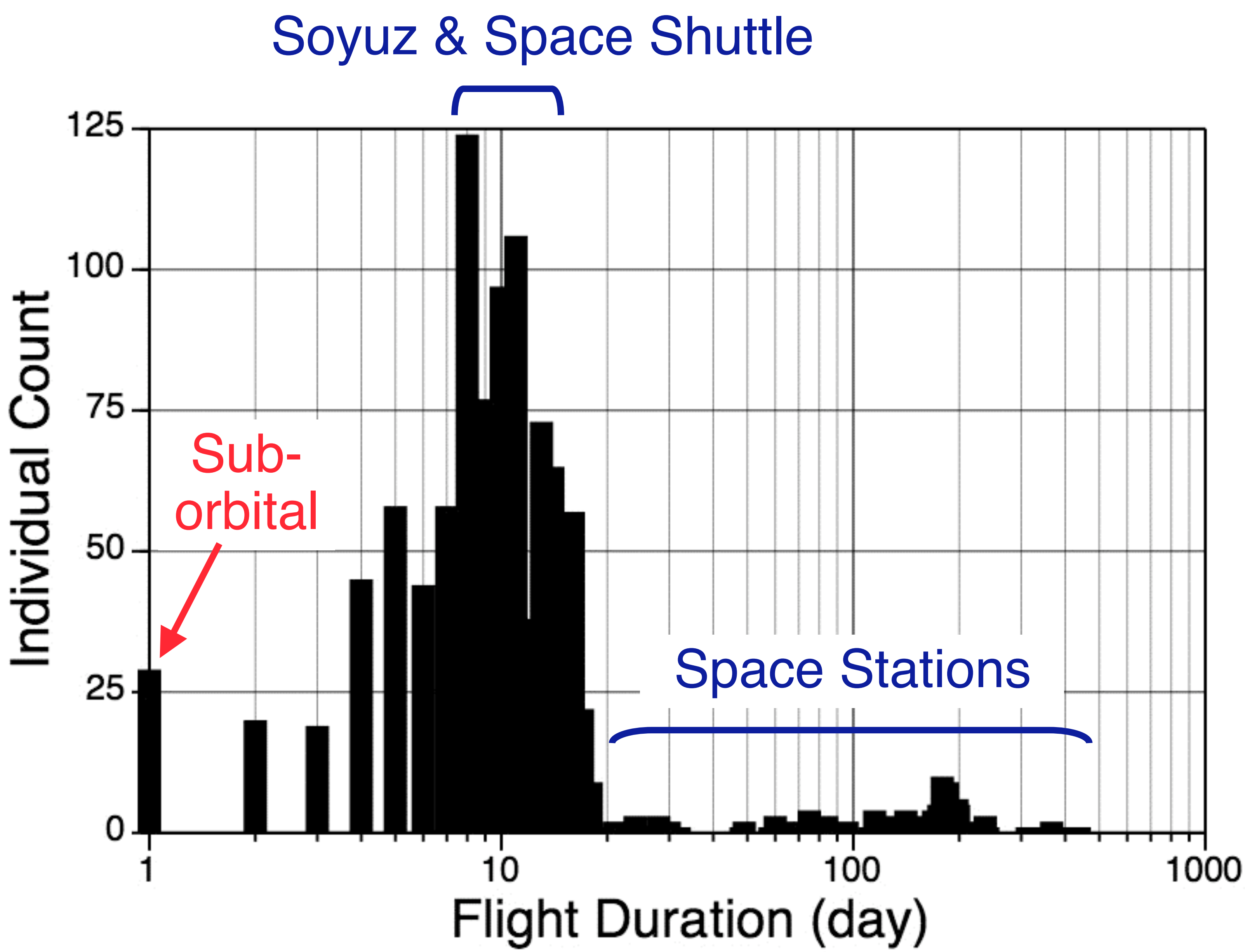
History of Human Space Flight

- 1965-66: Longest stay in space is 14 days (Gemini VII)
  - — First observations on human body adaptation
  - — Artificial gravity first tested (Gemini XI)

History of Human Space Flight

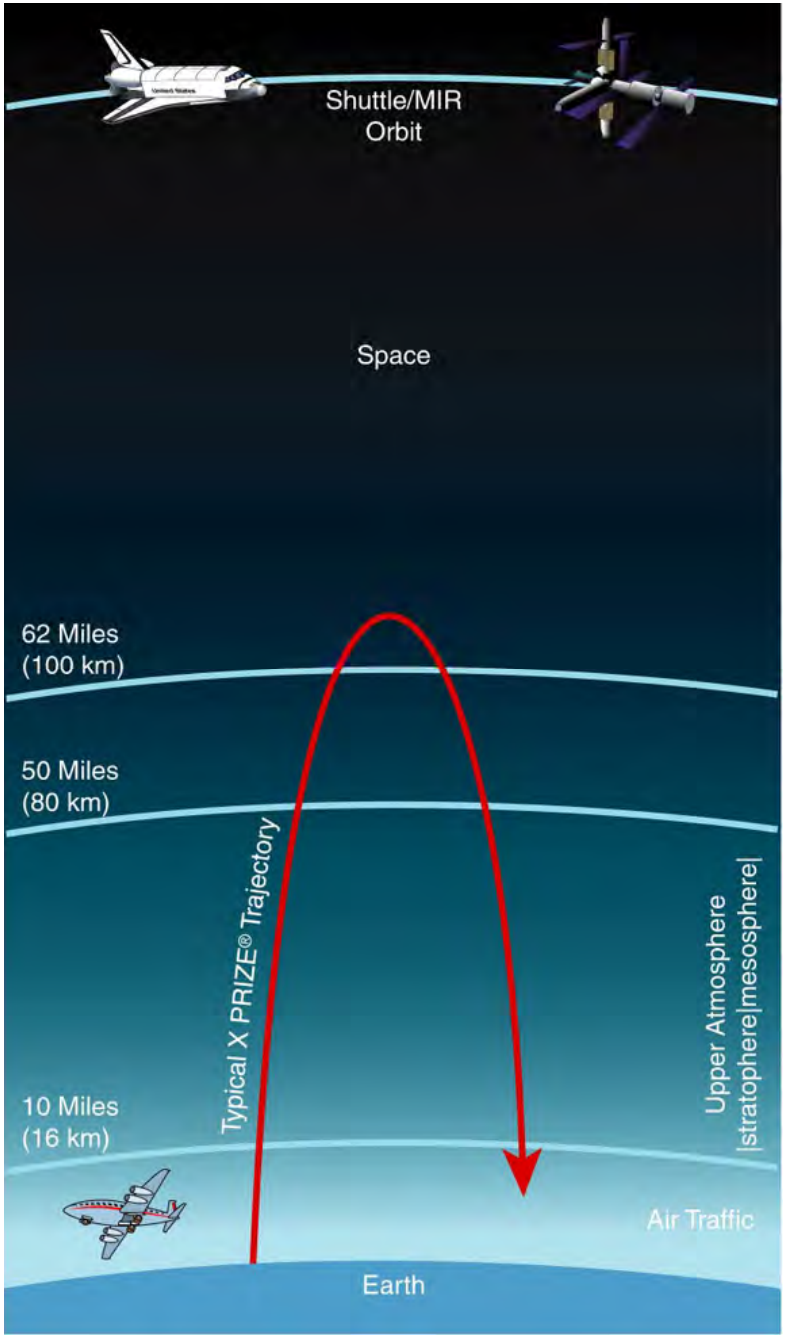
- 1969-72: Apollo missions – Extra-vehicular activity. Transitions between gravitational levels (1g ➡ 0g ➡ 0.16g ➡ 0g ➡ 1g)
- 70's : Salyut, Skylab – detailed investigations on effects of space flight environment on humans, animals, and plants
- 1981: First space vehicle piloted during return (Shuttle)
- 1994: Longest stay in space is 14 months (Mir)
- 2000: First expedition crew on board International Space Station (ISS)
- 2001: First "fee-paying" space tourist visited the ISS

Human Space Flight Experience



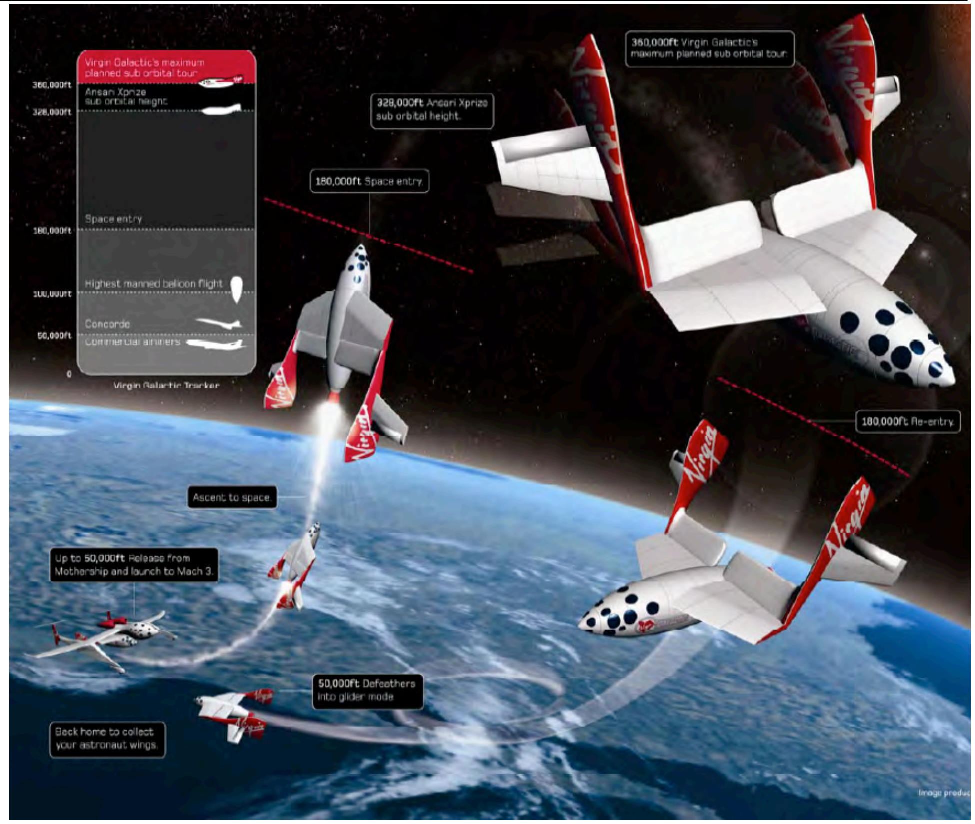
The Future

- Now is an exciting time of change within space activities
  - Continue research on ISS through 2020 with a specific emphasis on human research and countermeasures
  - Develop innovative technologies, knowledge, and infrastructure to support exploration mission to Mars
  - Promote international and commercial participation
  - Suborbital tourists and scientists



Challenges for Suborbital Participants

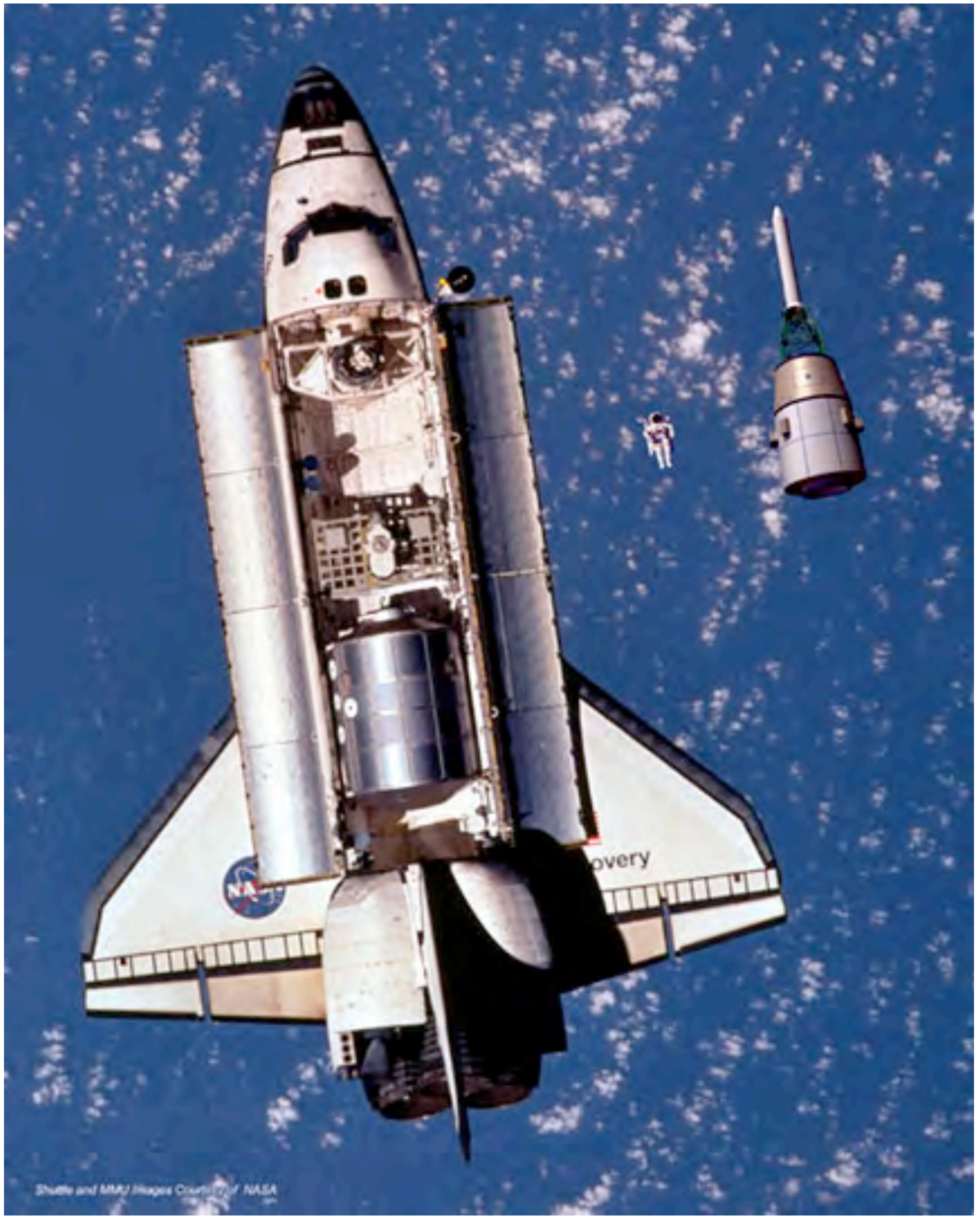
- **No medical standards**
  - Only FAA guidelines
- **Population**
  - Age: 25 to 75 years
  - Gender: 80% ♂ ; 20% ♀
  - Medical status: healthy to debilitated
  - Unknown psychological status



Source Virgin Galactic

- **Medical considerations**
  - Acceleration at launch
  - No pressure suits
  - Not likely on board medical capability
  - Virtually no centrifuge data for this population

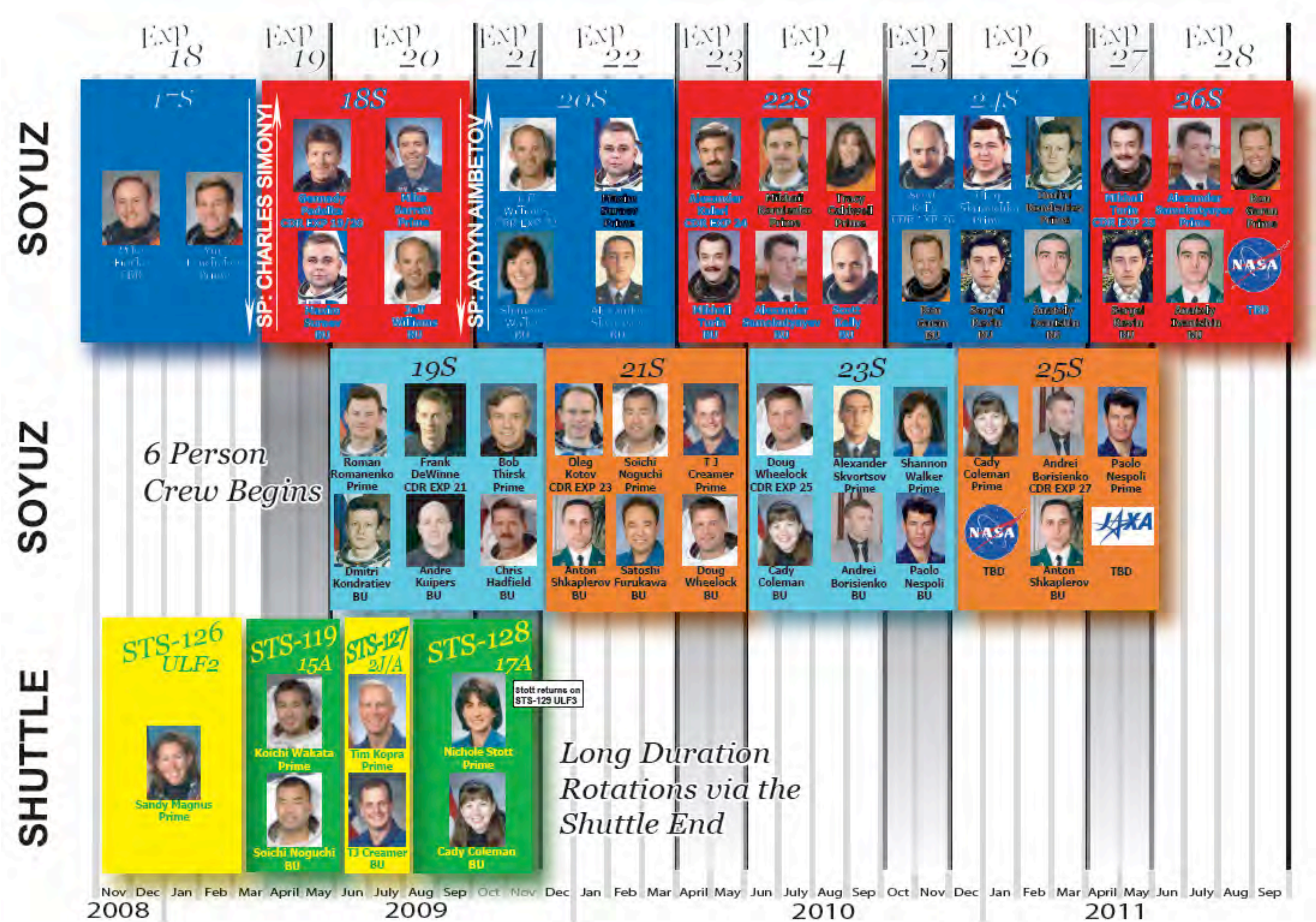
Access to International Space Station



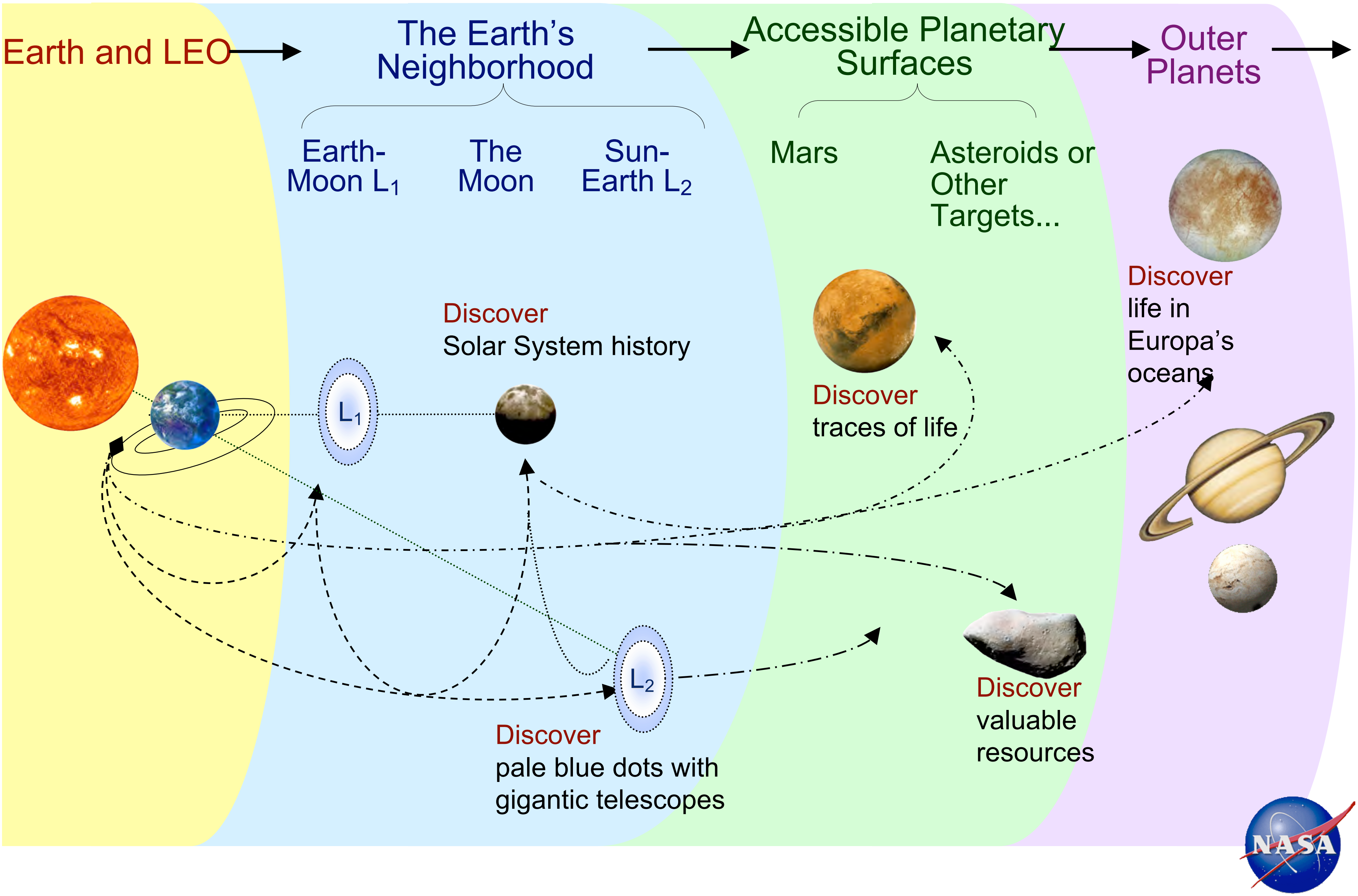
ISS Stats

- NASA Call sign: Alpha
- Orbit inclination: 51.6 deg
- Altitude: 350 km altitude (190 nmi)
- Crew: 6 (since June 2009)
- Mass: 300,214 kg
- Habitable volume: about 1200 m^3
- Length x width x height: 73 m x 93 m x 27 m
- Atmospheric pressure: 1013 hPa (760 mmHg)
- Days in orbit: 4,100 (as of March 1, 2010)
- Crew support: 2,722 kg of supplies per Expedition
- Meal consumption: about 20,000
- Ground: more than 100,000 personnel and 500 facilities
- Countries: 16

ISS Astronauts

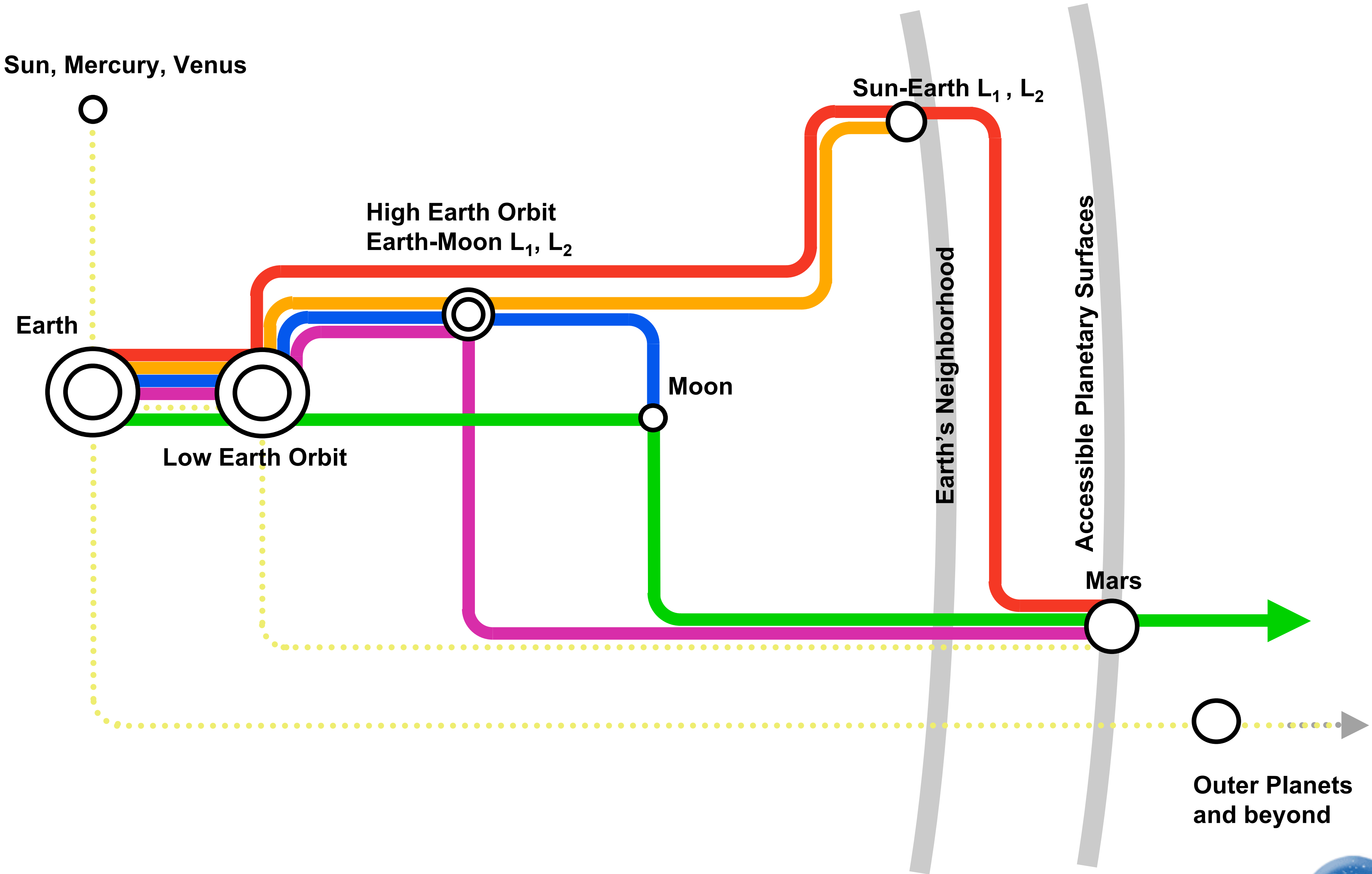


The Places for Exploration



Approach for Exploration (2004)

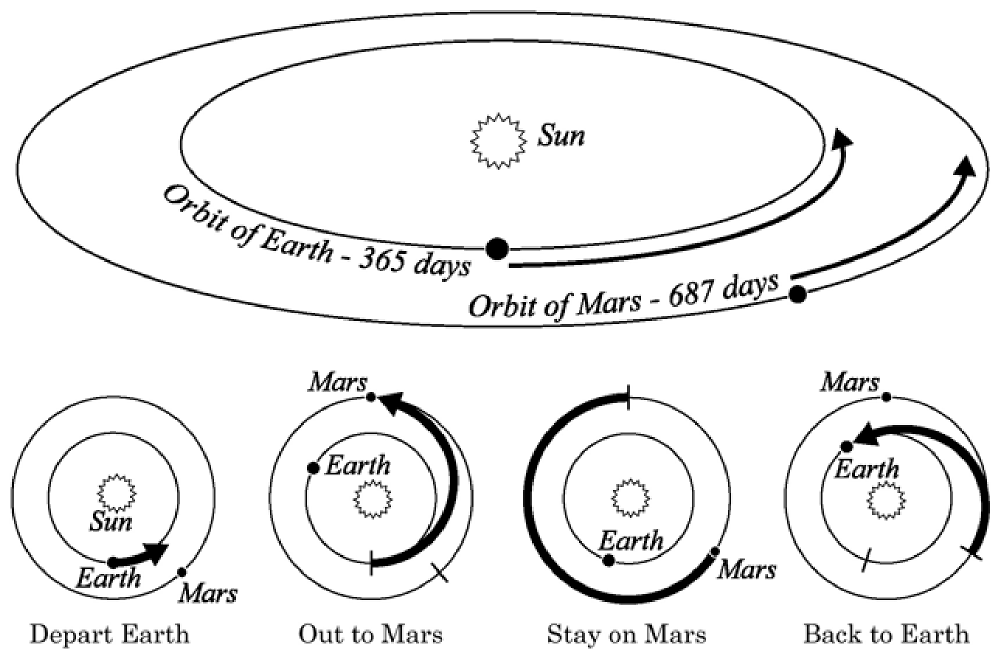
Planetary Exploration



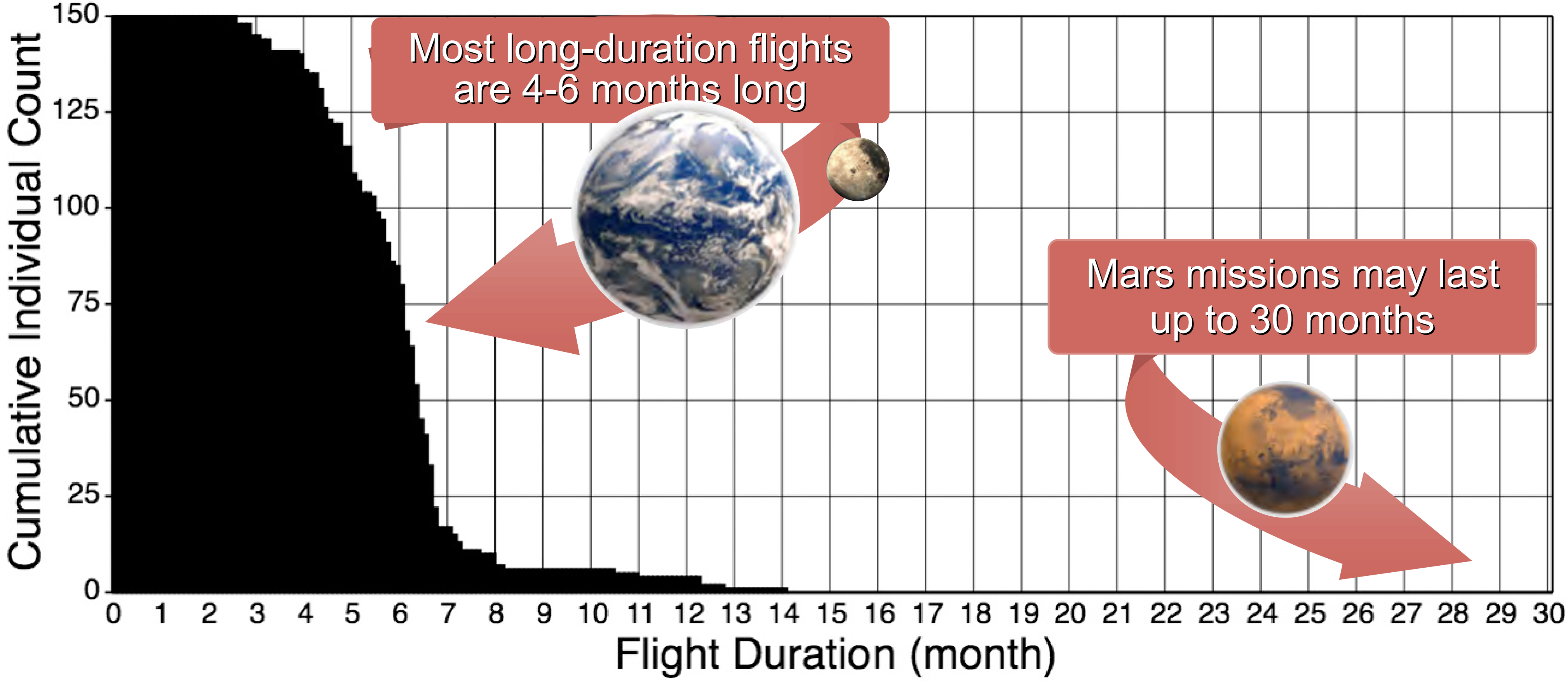
Human Mission to Mars

- **Duration ~ 2.5 years**
  - 6 months in transit (x 2)
  - 18 months on Mars
- **Gravity**
  - Reduced gravity
    - 0.38g on Mars
    - 0g in transit (unless artificial gravity is used)
  - 4 transitions between gravity levels

    1g – 0g – 0.38g – 0g – 1g



Space Flight Human Experience



Crew Recovery Status: Mir & ISS

125 days

162 days

1 year

Observed post-landing capabilities of Mir & ISS crewmembers may be predictive for just-arrived Mars crewmembers

Countermeasures

A *countermeasure* is an action, process, device, or system that can prevent or mitigate the effects of weightlessness

- Physical exercise
- Food complement
- Special garment or suit
- Procedures before returning to Earth

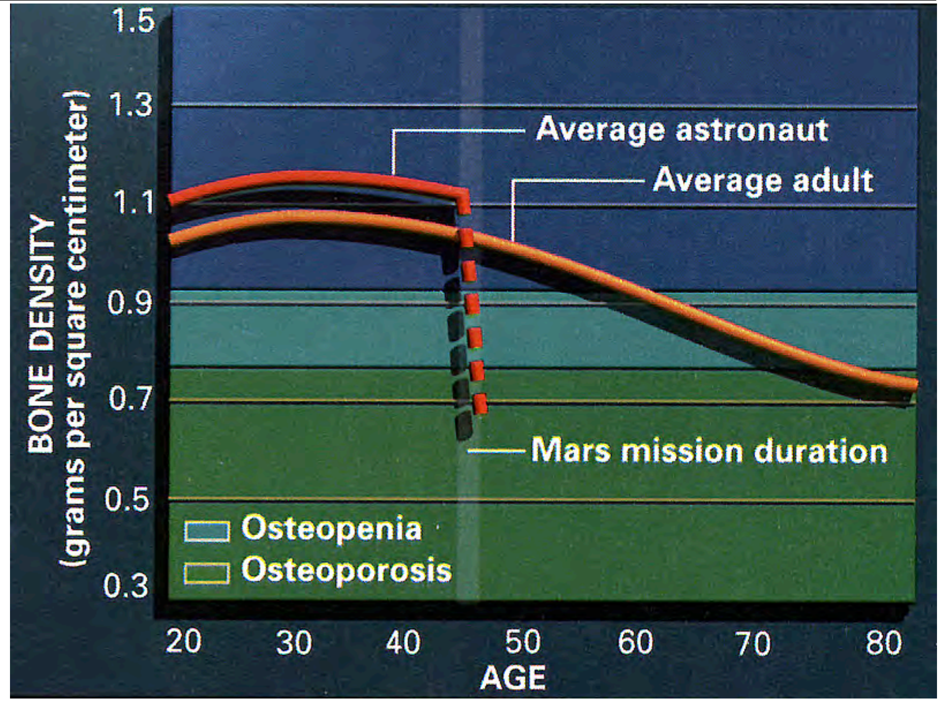
Challenges for Mars Mission

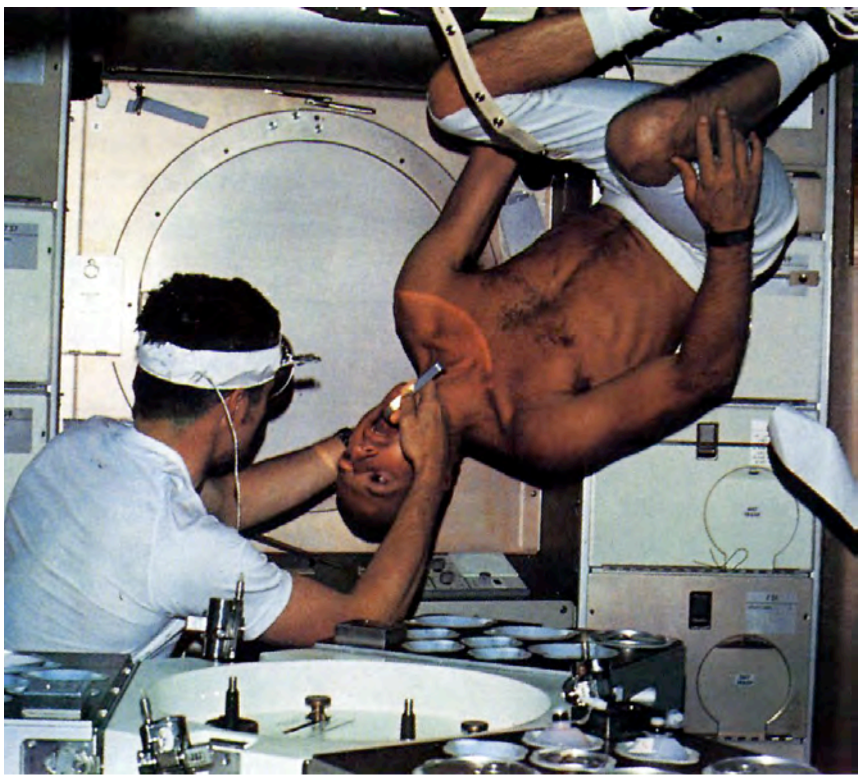
- For long-duration missions, the Mir and ISS experience indicates that current in-flight countermeasures are not optimal

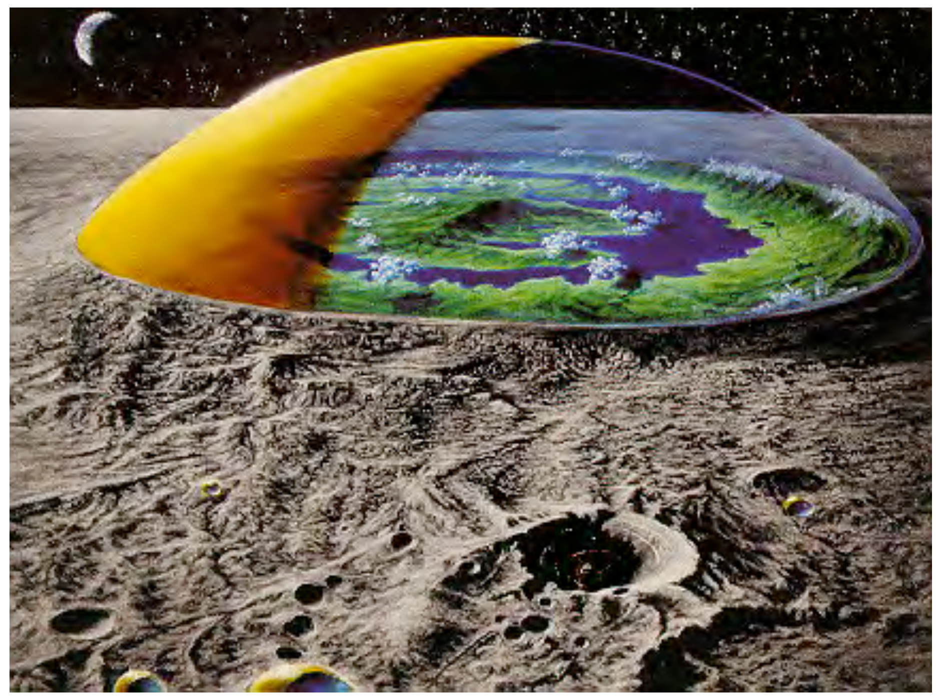
- Using the current countermeasures methods, humans would not be operational after landing on Mars
- Artificial gravity probably the most efficient countermeasure

Challenges for Planetary Missions

- Bone (and other tissues) loss
- Crew selection
- Closed Ecological Life Support Systems
- Radiation dose
- Space walk suits and tools







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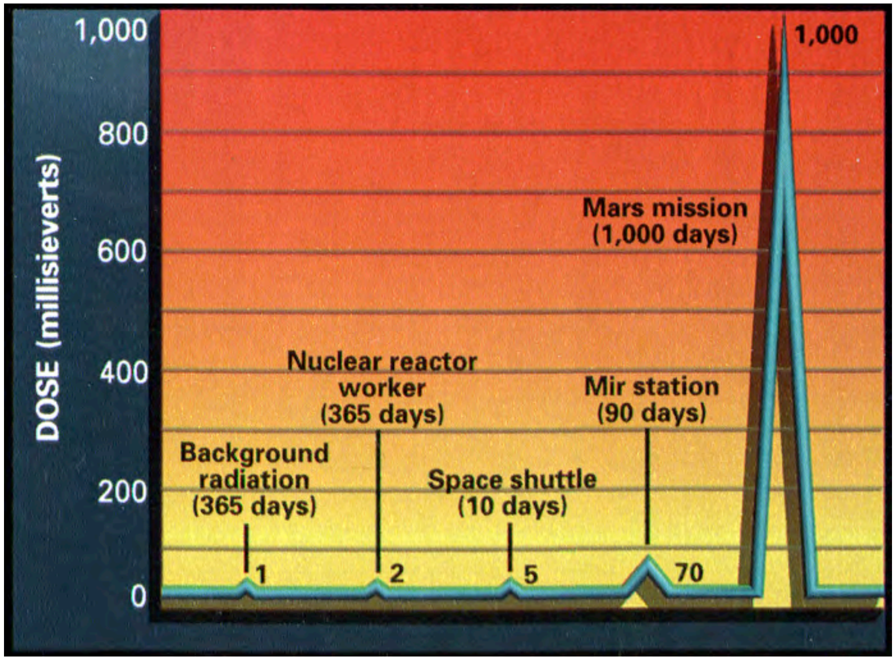
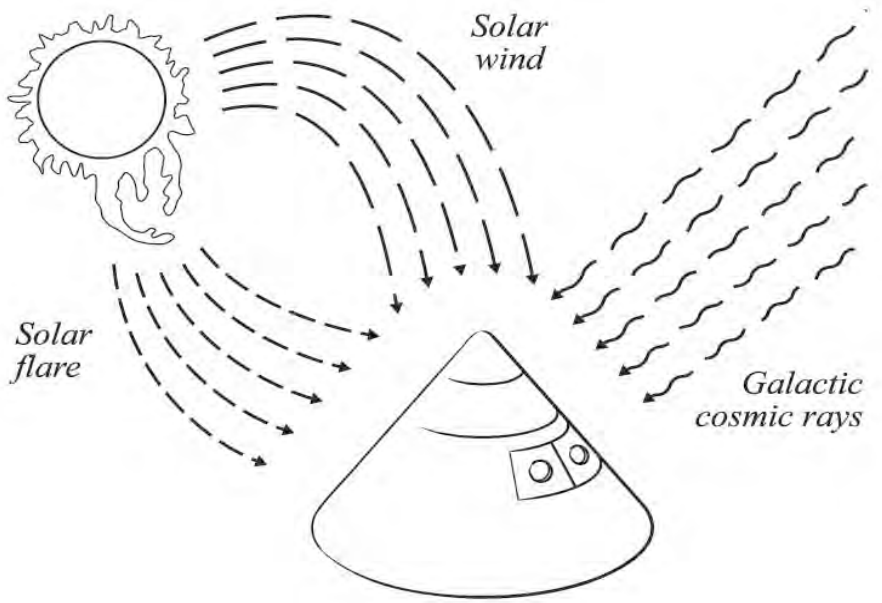
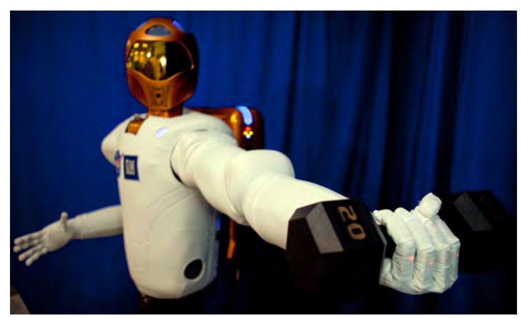
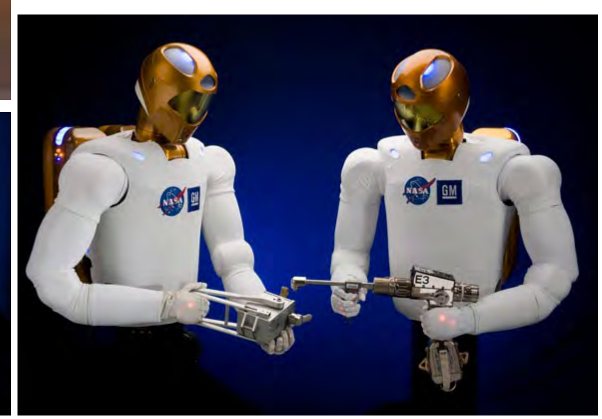




Human Robot Interaction (HRI)

- The goal of HRI is to develop more efficient, flexible, personal, pleasant human-robot relationship
- Example:
  - NASA Robonaut-2 is a torso with 2 arms and 1 leg
  - Designed to complement astronauts during EVA
  - Tele-presence control system – eyes provide depth vision to operator





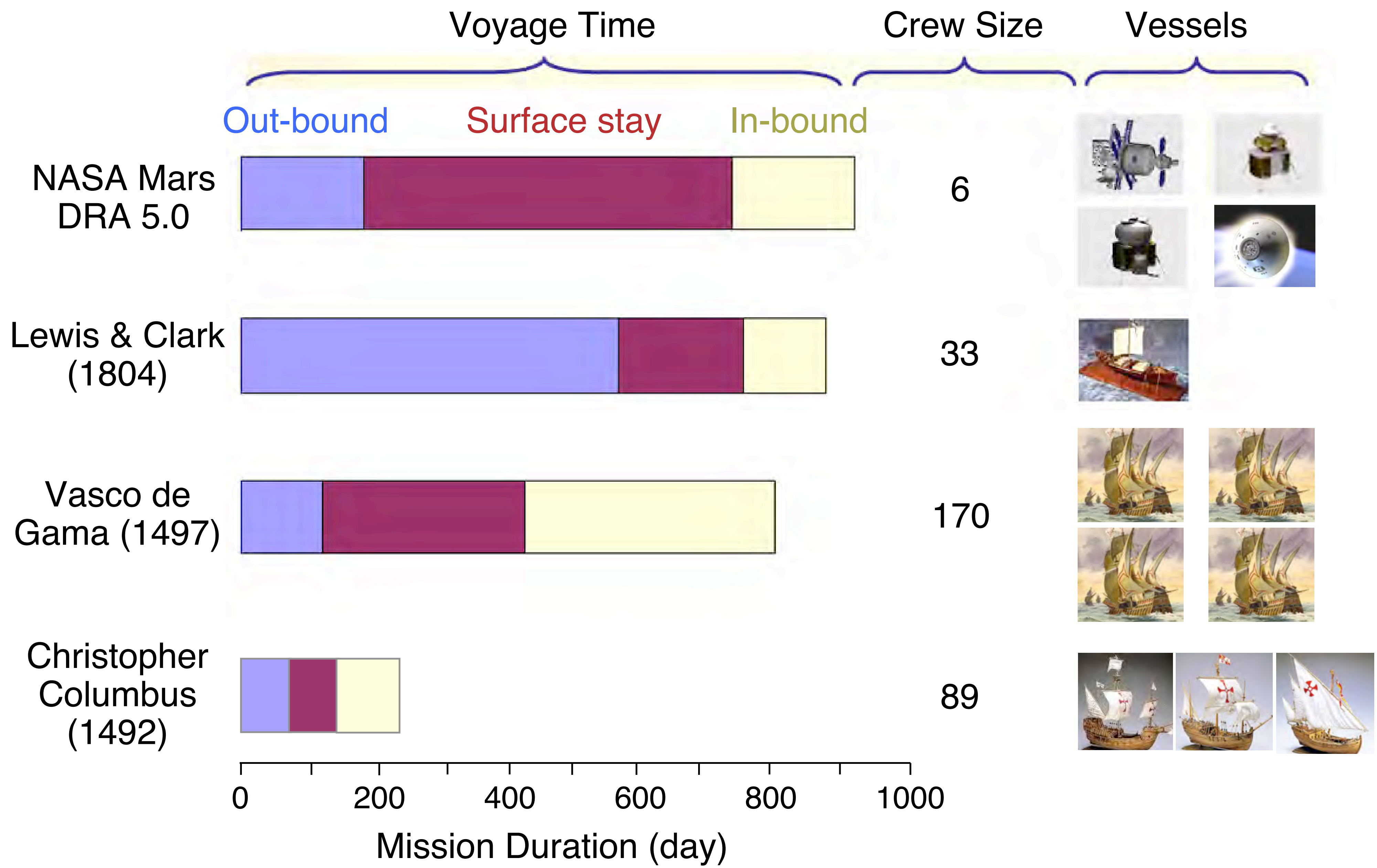
http://robonaut.jsc.nasa.gov/

Risk and Research Questions

- A lot of progress since first human space flight, ~ 50 years ago
- Exploration and commercial suborbital flight bring new questions & research opportunities
- Still a lot to be learned. NASA Human Research Roadmap has identified 27 potential risks, enabling 316 research questions in :

- Habitation Systems
  - Advanced life support
  - Environmental monitoring
  - Food technology
  - Advanced EVA
  - Human-robot interaction
  - Space human factors
  - Integration
- Radiation Effects
- Autonomous Medical Care
- Human Health and Countermeasures
  - Bone loss
  - Cardiovascular alterations
  - Immunology, infection and hematology
  - Muscle alterations
  - Neurovestibular adaptation
- Behavioral Health and Performance
  - Psychosocial adaptation
  - Sleep & circadian rhythm
  - Neurobehavioral problems

Exploration – Historical Perspective



Reading Material

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