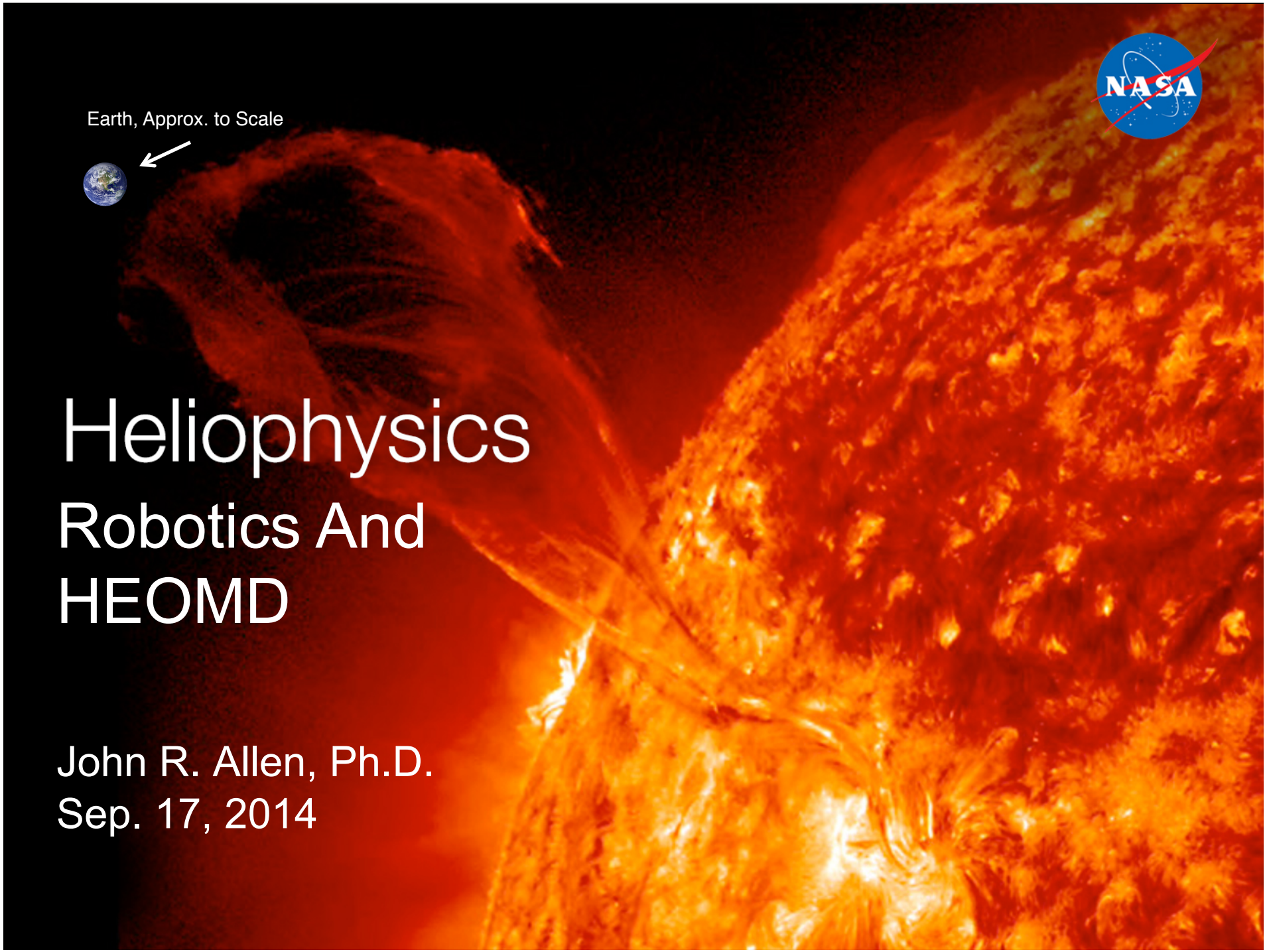
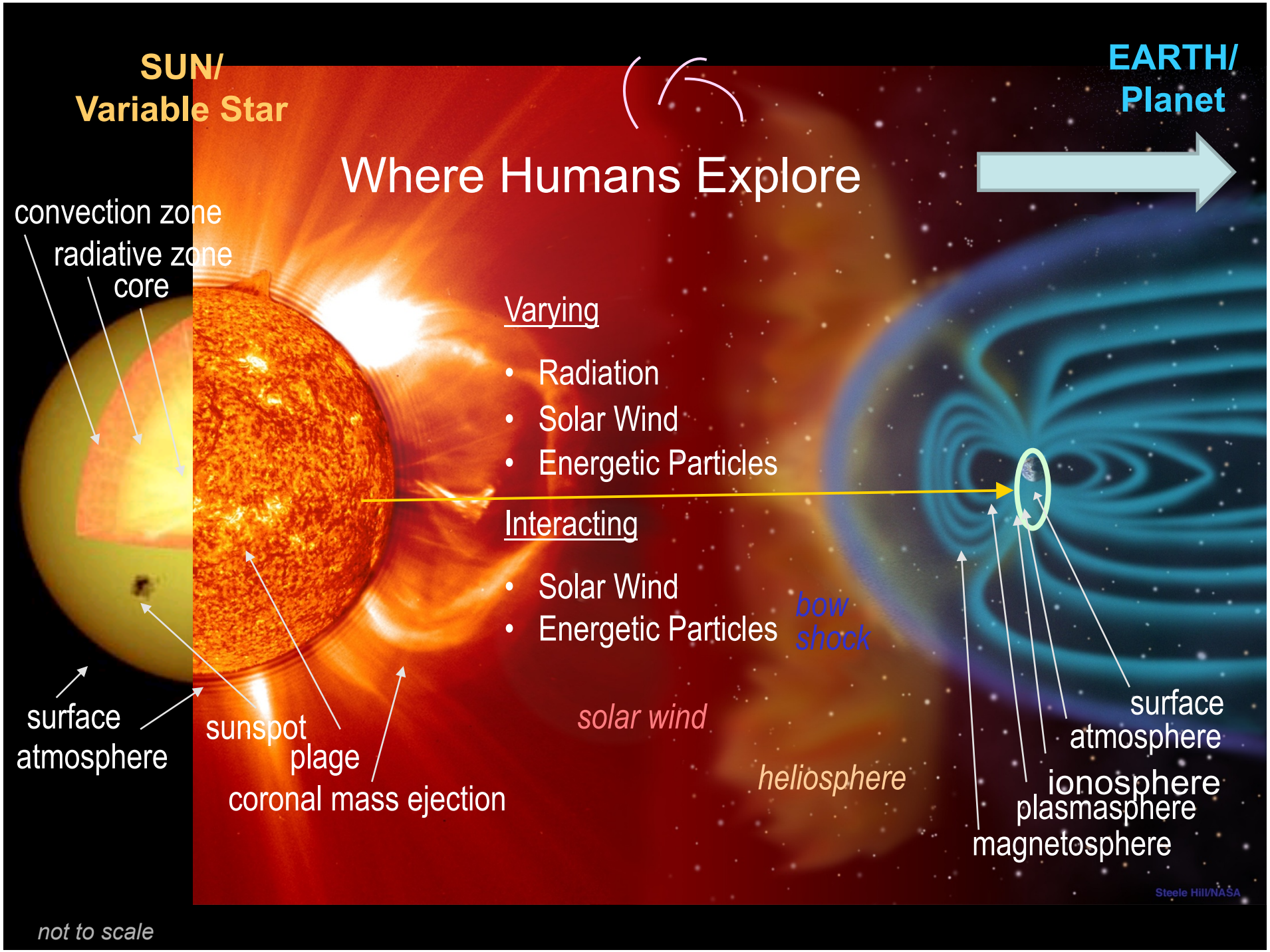


Heliophysics

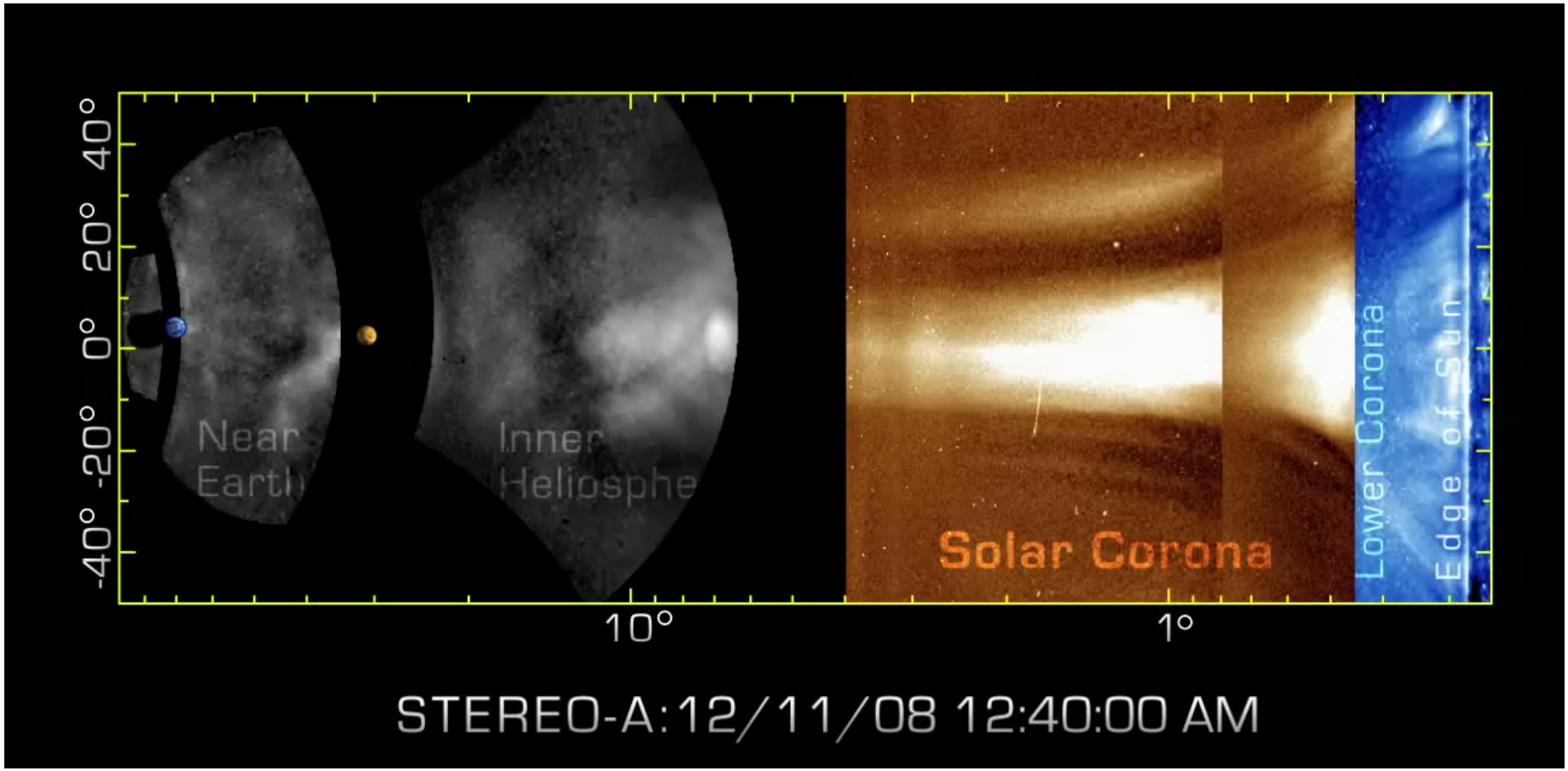
Robotics And HEOMD

John R. Allen, Ph.D.

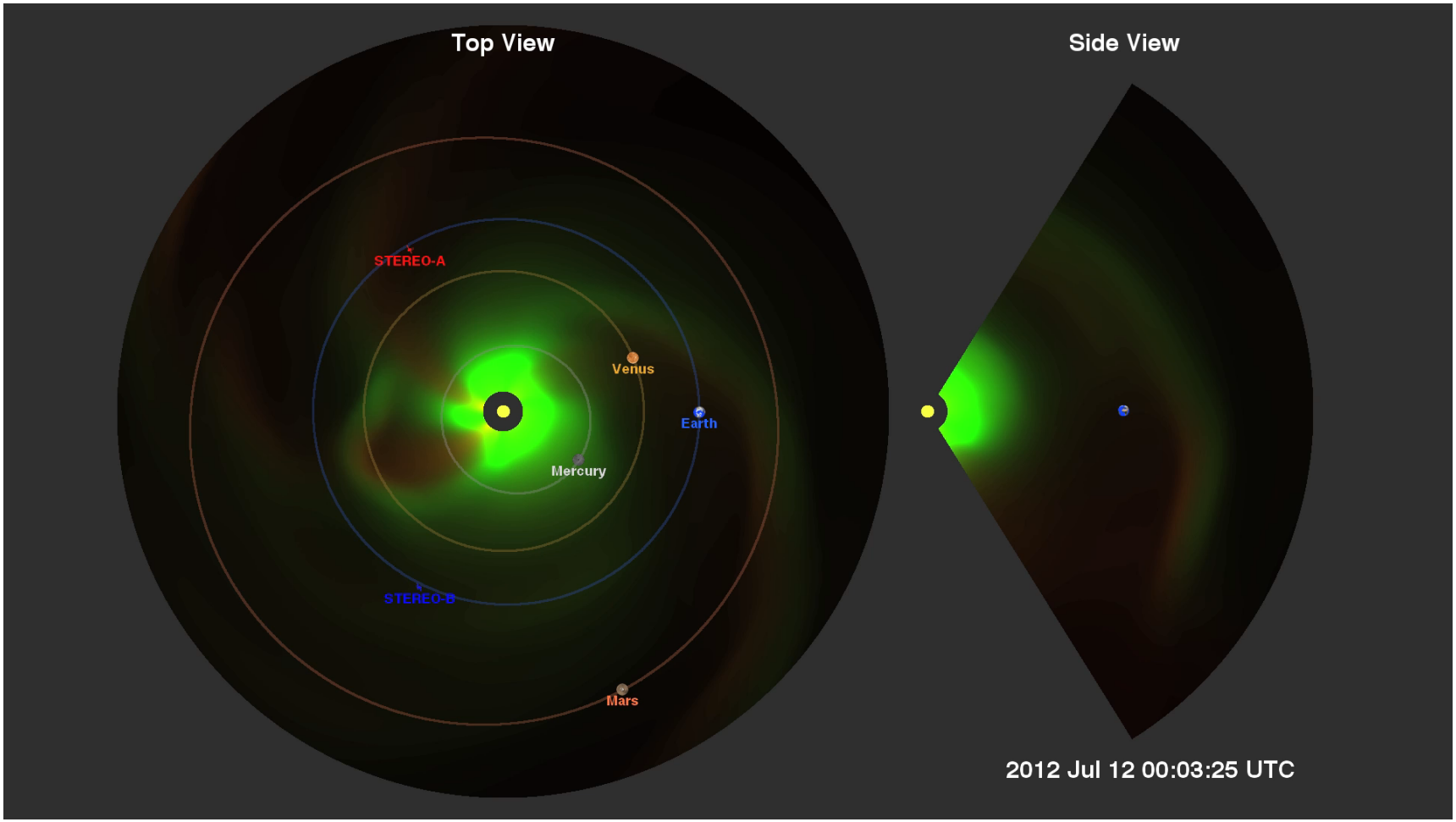
Sep. 17, 2014


SUN/
Variable Star
EARTH/
Planet
Where Humans Explore
convection zone
radiative zone
core
Varying
• Radiation
• Solar Wind
• Energetic Particles
Interacting
• Solar Wind
• Energetic Particles
bow
shock
solar wind
heliosphere
surface
atmosphere
sunspot
plage
coronal mass ejection
surface
atmosphere
ionosphere
plasmasphere
magnetosphere
Steele Hill/NASA
not to scale

STEREO Tracks a CME through Interplanetary Space



Modeling Storms Throughout the Heliosphere



Numerical model of the July 23, 2012, CME and events leading up to it.

Hazards of Spaceflight

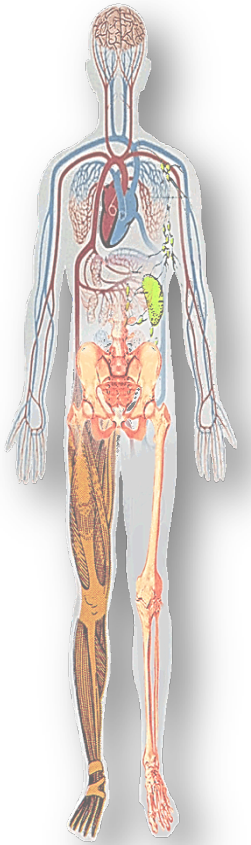
Hazards Drive Human Spaceflight Risks

Altered Gravity - Physiological Changes

Balance Disorders
Fluid Shifts
Visual Alterations
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 – CO_2 Levels, Toxic Exposures, Water, Food

Isolation & Confinement

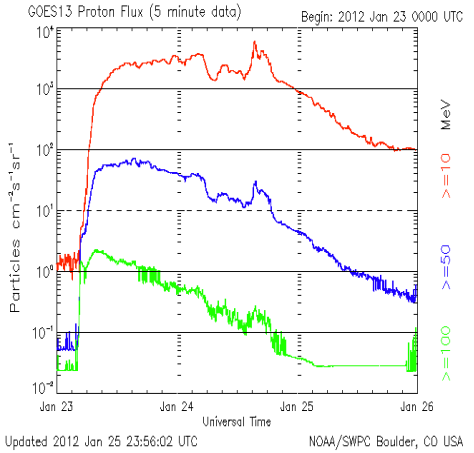
Behavioral aspect of isolation
Sleep disorders

Space Flight Health Standards Control Risks

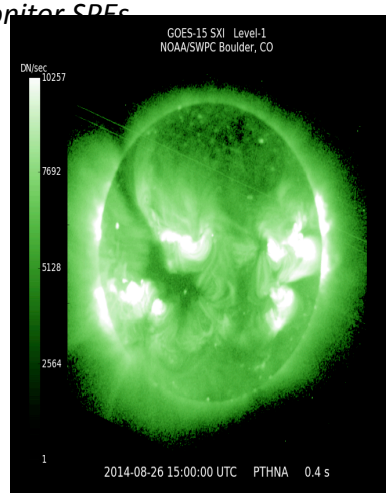
- Standards Define An Accepted Level Of Health Risk And Limit Decrements To Protect Crew Health And Safety
  - Based on best available scientific/clinical evidence, expert recommendations, and vetted with National Academies
  - All risks will be mitigated to the maximum extent possible, yet some decrements may still occur (Crew may lose bone density, but only to a medically established level)
  - Countermeasures must support these standards to protect crew health
- Three Categories Of Space Flight Health Standards
  - **Fitness for Duty (FFD – e.g. cardiovascular)**: Minimum measurable capability or capacity for a given physiological or behavioral parameter that allows successful performance of all required duties.
  - **Permissible Outcome Limits (POL – e.g. limit bone loss)**: POLs delineate an acceptable maximum decrement or change in a physiological or behavioral parameter, as the result of exposure to the space environment.
  - **Permissible Exposure Limits (PEL – e.g. radiation exposure)**: Quantifiable limit of exposure to a space flight factor over a given length of time.

Protecting ISS Crew: Solar Particle Event (SPE) Action Summary

- Radiation flight controller returns to console during contingency operations such as SPEs
  - Alert/Warning messages to management and flight control team
  - Ensure radiation monitoring system availability
- If SPE dose projection is determined to be negligible by the flight surgeon, then no action will be taken
- If energetic solar particle event has increased above threshold or radiation detector alarm activation is confirmed, inform crew to remain in higher shielded areas during intervals of high risk orbital alignments.
- ISS higher shielded locations used to protect crew
  - Service module aft of treadmill (panel 339), Node 2 crew quarters, and U.S. Lab



Geostationary Operational Environmental Satellite (GOES) Proton Flux Monitor used to monitor SPEs

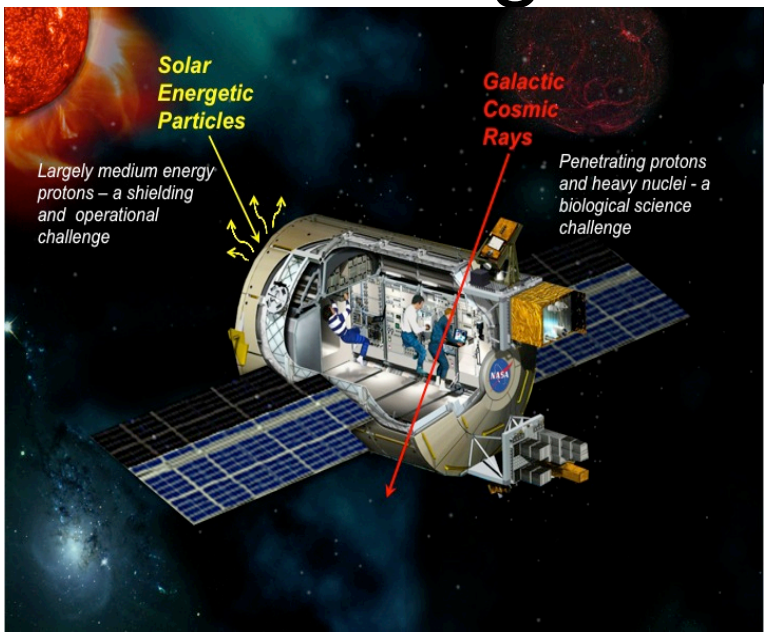


GOES Solar X-ray Image for the early detection of solar flares and coronal mass ejections

Primary Space Radiation Mitigations

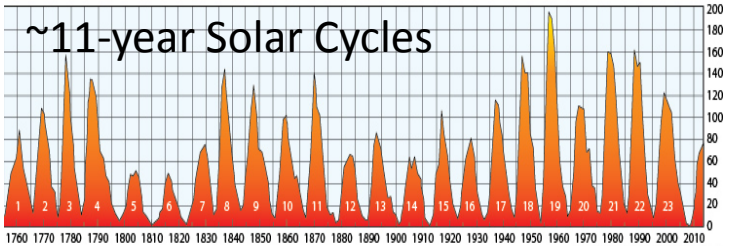
Optimized Spacecraft Shielding/Storm Shelters Can Protect Crew Against Solar Particle Events (SPEs)

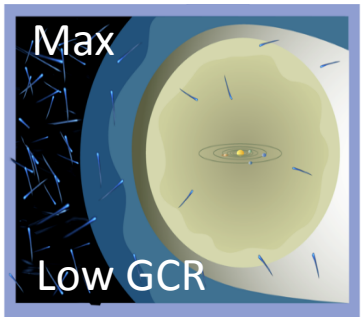
- Shielding is only marginally effective against galactic cosmic rays (GCRs)
- Increasing shielding thickness adds substantial mass with minimal additional GCR exposure reduction

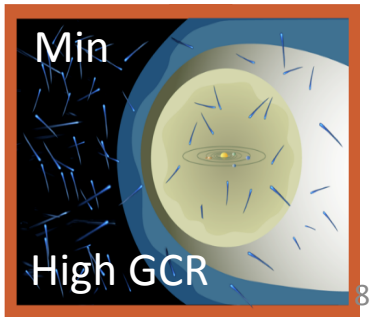


Timing A Mars Mission Around Solar Cycle's Maximum Can Help Protect Crew Against GCRs

- At solar maximum, the interplanetary magnetic field & solar wind increase to expand the heliosphere, shielding the solar system from incoming GCRs
- GCR exposure can be reduced at solar max by up to a factor of two







NASA Work to Enable Mars

Advanced Medical Approaches Applied Pre-/Post-Mission

- Understanding the individual sensitivities
- Enhancing post mission care
- Do not currently use pre-mission screening or post mission cancer monitoring

Exploration Space Radiation Storm Shelter Design and Real-time Radiation Alert System

- Development of these capabilities for exploration missions can reduce crew exposure risk to SPEs to negligible levels

MSL-RAD Measurements of Mars Radiation Environment

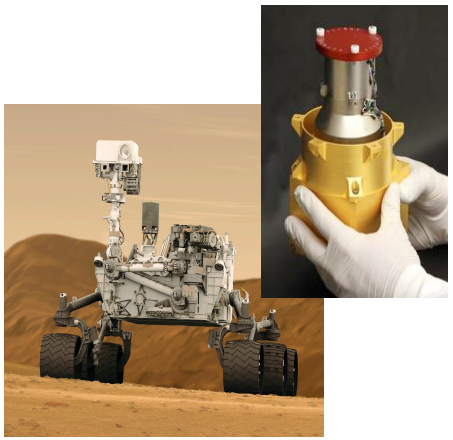
- MSL-RAD is providing important data on the radiation environment on the surface of Mars

Mars Mission Design & Advanced Deep Space Propulsion

- Reducing deep space transit times can reduce space radiation exposure and mitigate human health risks

Space Radiation Research at NSRL

- Key to reducing the space radiation health effects uncertainties, refinement of cancer risk model, and understanding cardiovascular and CNS risks



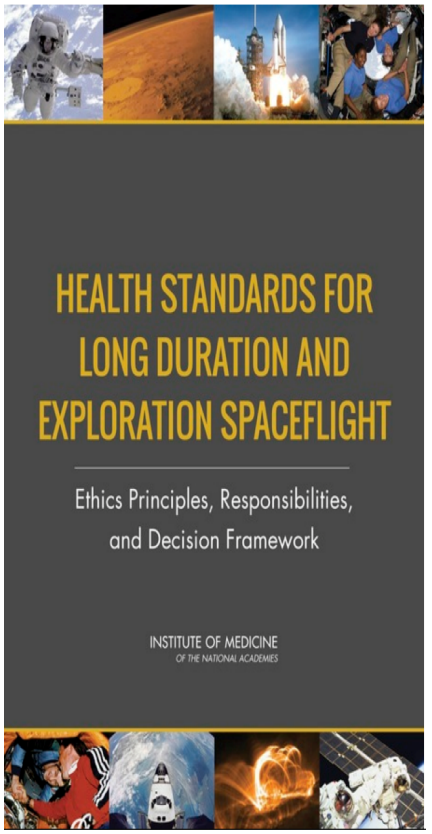
MSL-RAD is making radiation measurements on Mars

NSRL is the only USA facility that can simulate the harsh cosmic and solar radiation environment found in space

Space Flight Health Standards for Exploration

Standards for Space Exploration Missions

If existing LEO space radiation exposure standards cannot be fully met for a Mars Mission, an ethics framework, developed by the Institute of Medicine, could help to guide decision making about health standards for exploration class missions



"Health Standards for Long Duration and Exploration Spaceflight: Ethics Principles, Responsibilities, and Decision Framework" released April, 2014

- Provides information and discussion of ethical principles and responsibilities
- Office of the Chief Health and Medical Officer can incorporate into its health/medical standards processes and decision-making
- Recommendations are being implemented within the context of existing Agency decision making and risk assessment processes

National Council On Radiation Protection (NCRP) Draft Report Is Under Review

- It is anticipated that no changes will be recommended to the current NASA radiation standard (3% REID) for exploration missions

Summary

- Space Weather impacts all aspects of human exploration of space – human and robotic
- Advancements in forecasting and modeling have and will benefit both
- Understanding the nature of space weather is important for both science and operations
- Risks to “systems” can be mitigated in a variety of ways
- Result = ability to explore beyond LEO