SPACE WEATHER: STORMS FROM THE SUN

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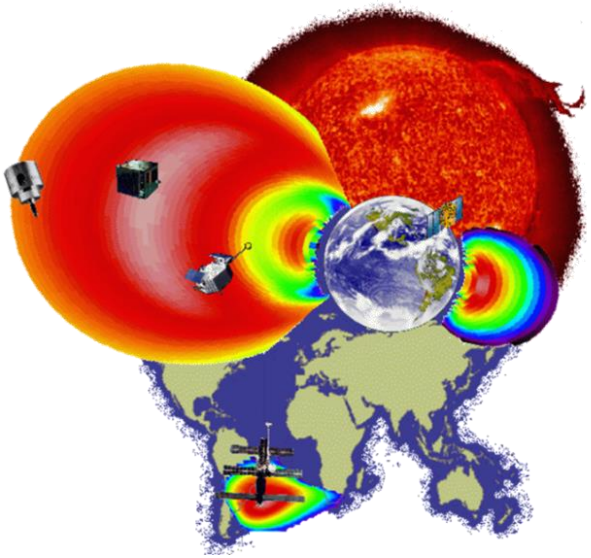
Goldberg (1962 double issue of the Bulletin of the Atomic Scientist)

Natural Hazards

in space

the
SPACE WEATHER



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OUTLINE

Part 1: Introduction to Space Weather

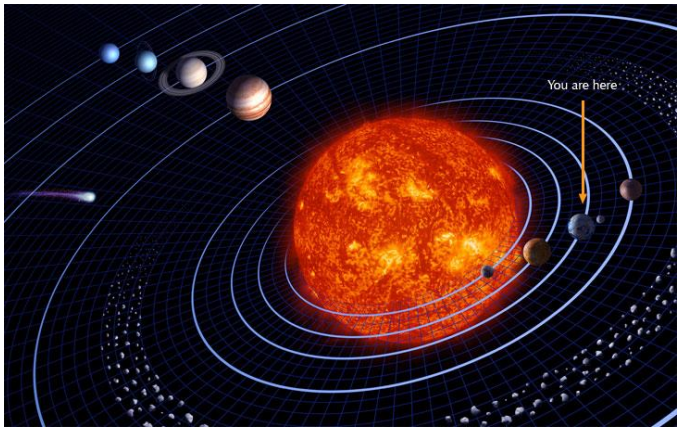
Part 2: Educational Examples

Part 1: Introduction to Space Weather

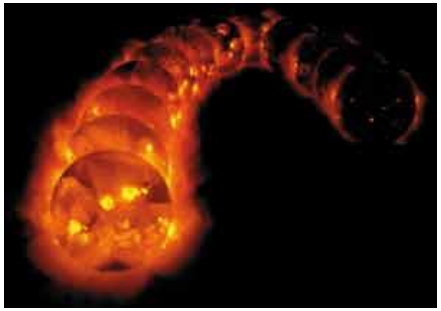
SPACE WEATHER in simple terms:

How solar activity may have unwanted effects on technological systems and human activity.

- Our location in the Solar System
- Behavior of the Sun
- Nature of Earth's magnetic field and atmosphere; or conditions on any other planet.



http://www.nationsonline.org/oneworld/earth.htm



Courtesy of Yohkoh.

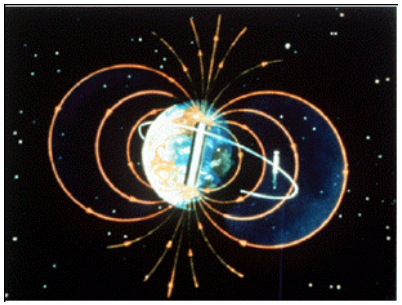


Image from NASA.

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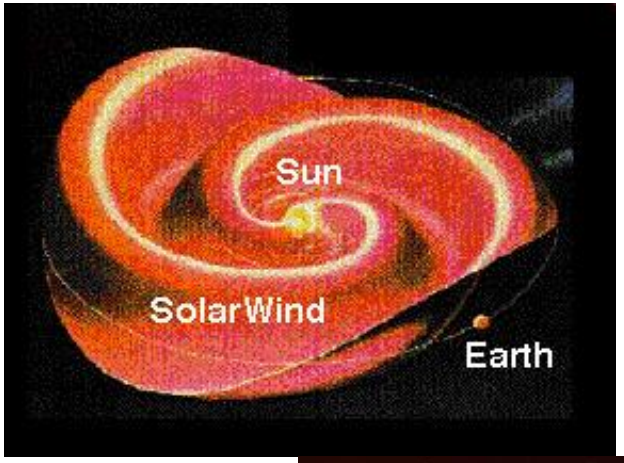
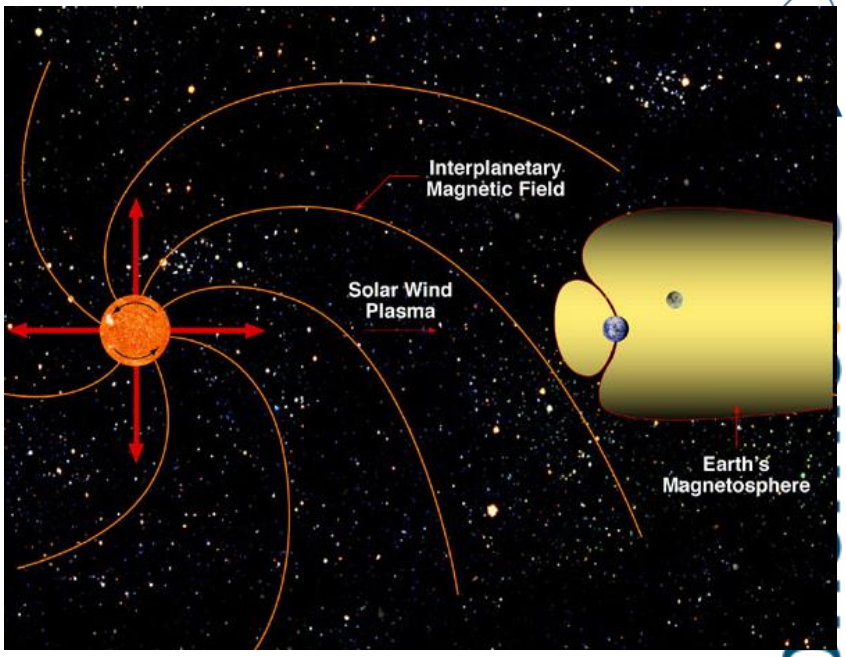
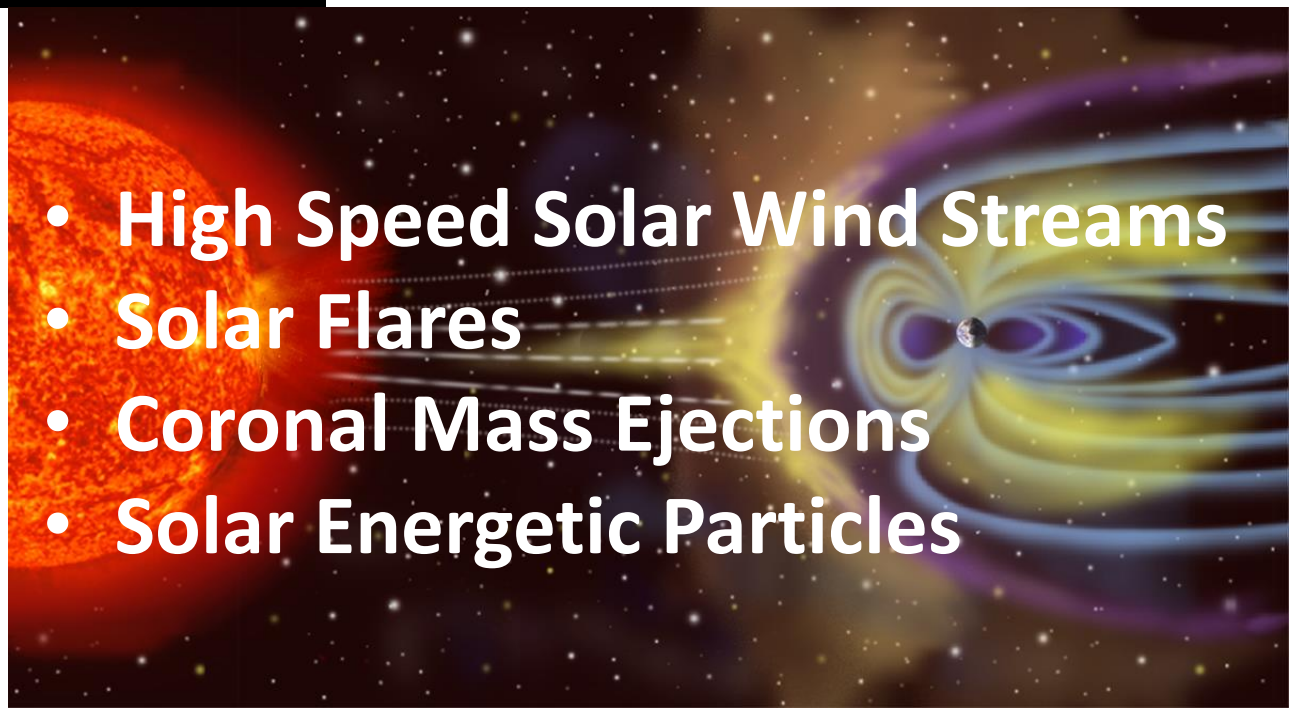
The Solar Wind



Credit: NASA





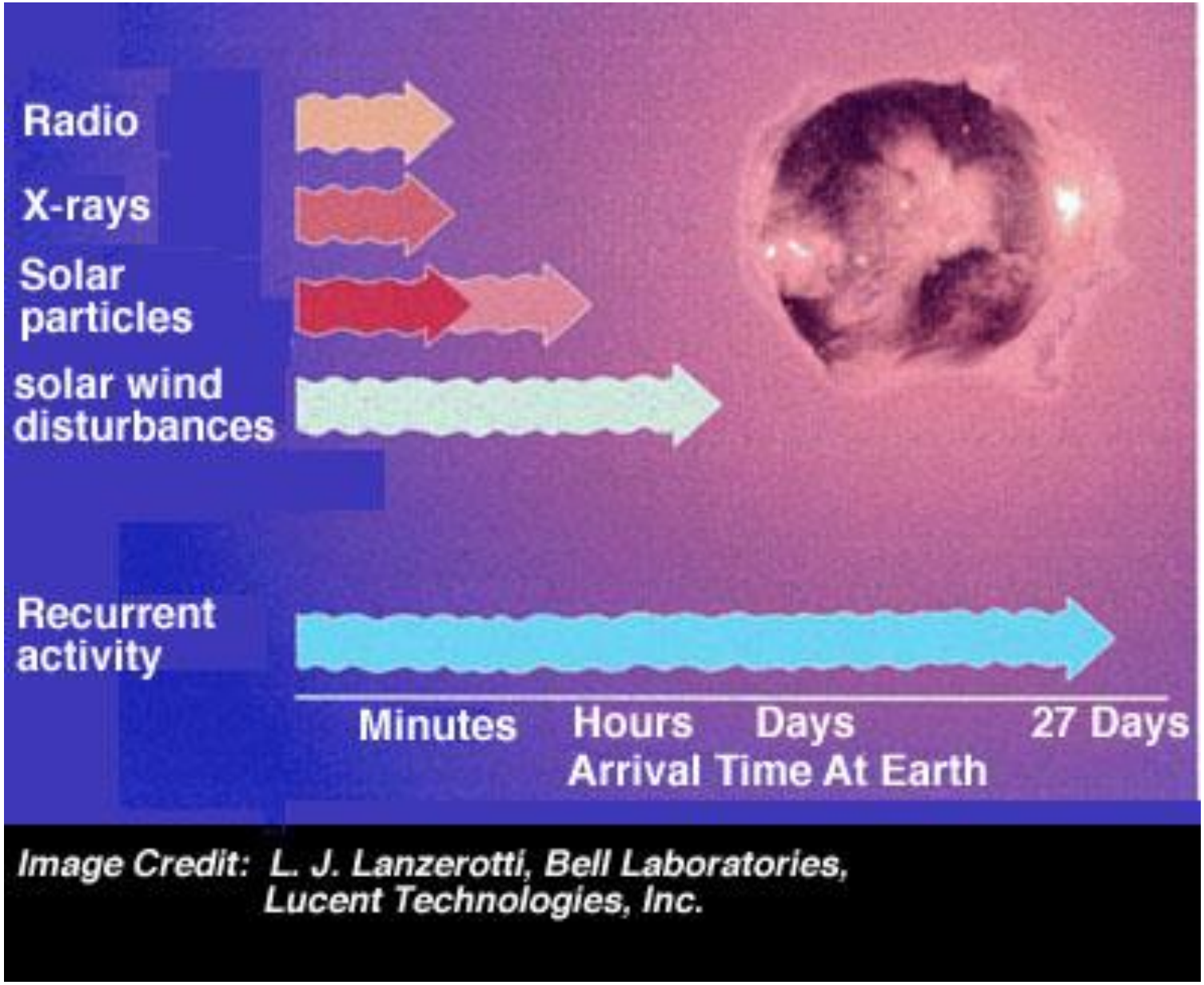
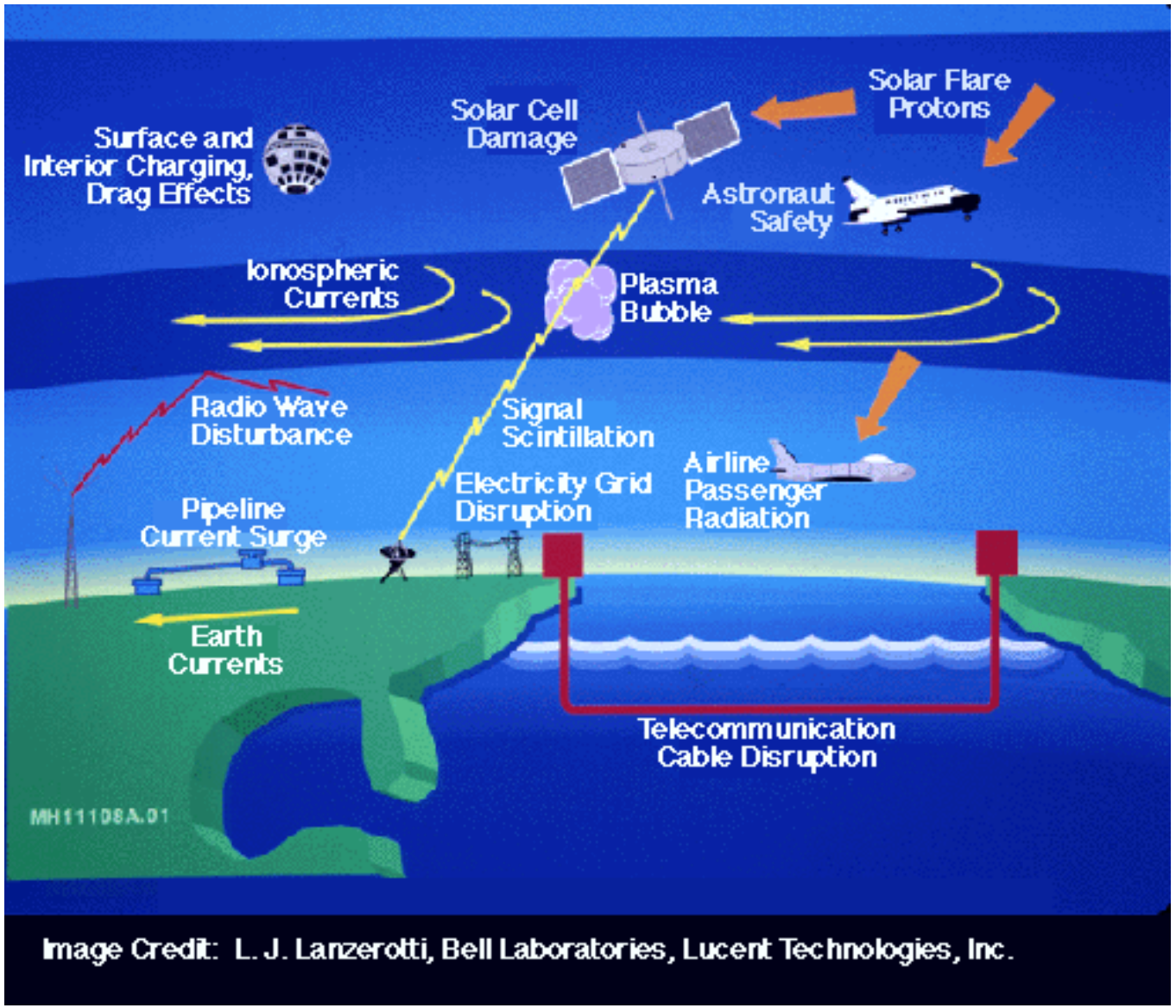


Image Credit: L. J. Lanzerotti, Bell Laboratories, Lucent Technologies, Inc.

Science & Effects

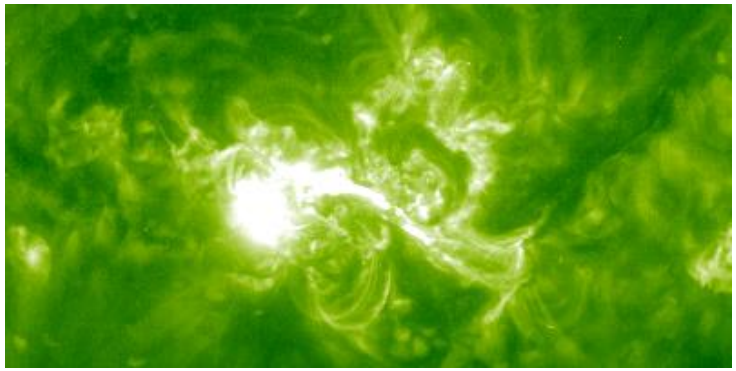


Example 1

Solar Flares

Solar Flares

- Defined as a sudden, rapid, and intense variation in brightness.
- Occurs when magnetic energy that has been built up is suddenly released by magnetic reconnection.
- As the magnetic energy is released plasma is heated and particle beams are accelerated in the solar atmosphere.
- Electromagnetic radiation is emitted from radio waves through optical emission to X-rays and gamma-rays.



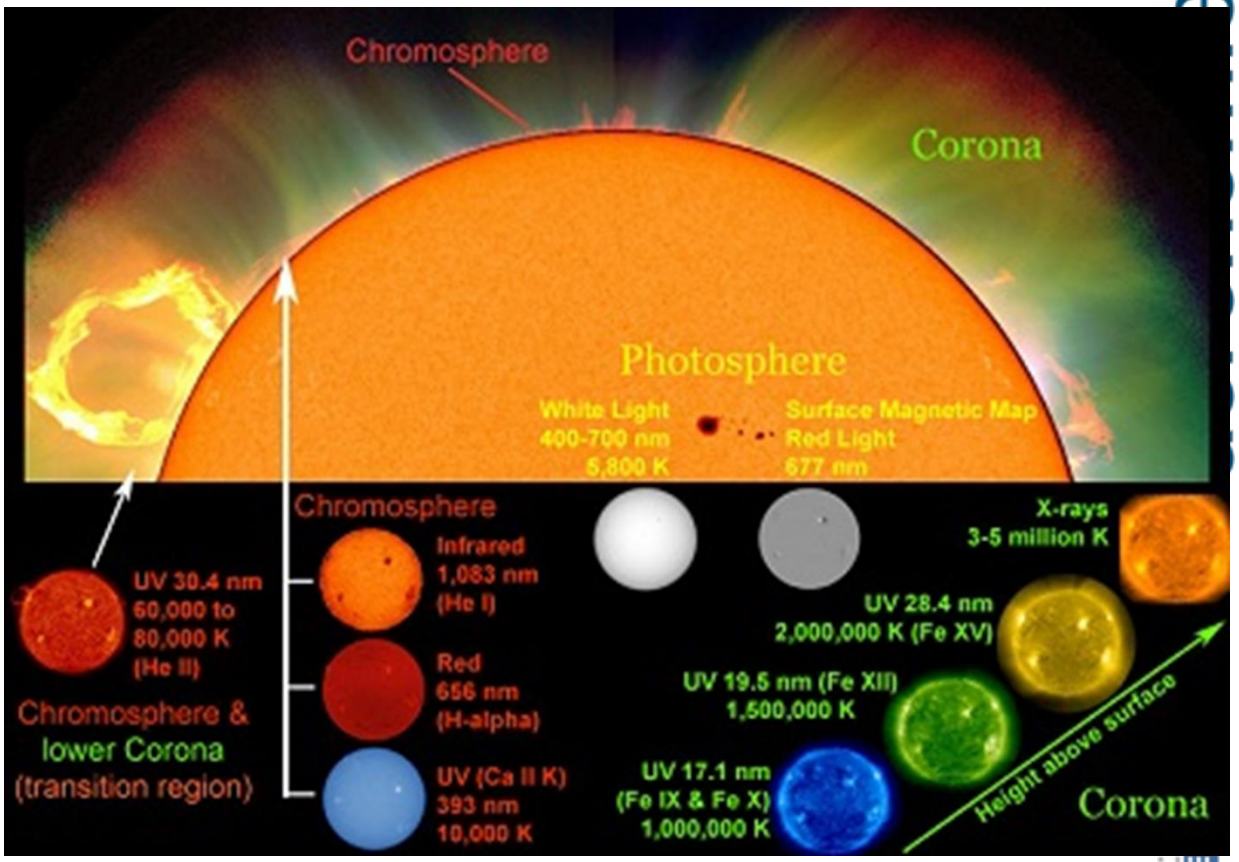
One of the Oct. 2003 solar flare events. Credit: NASA-ESA/SOHO/EIT

CHARGED PARTICLE RADIATION FROM SPACE

Energy transmitted in the form of fast-moving sub-atomic particles (electrons, protons, alpha particles, etc.).

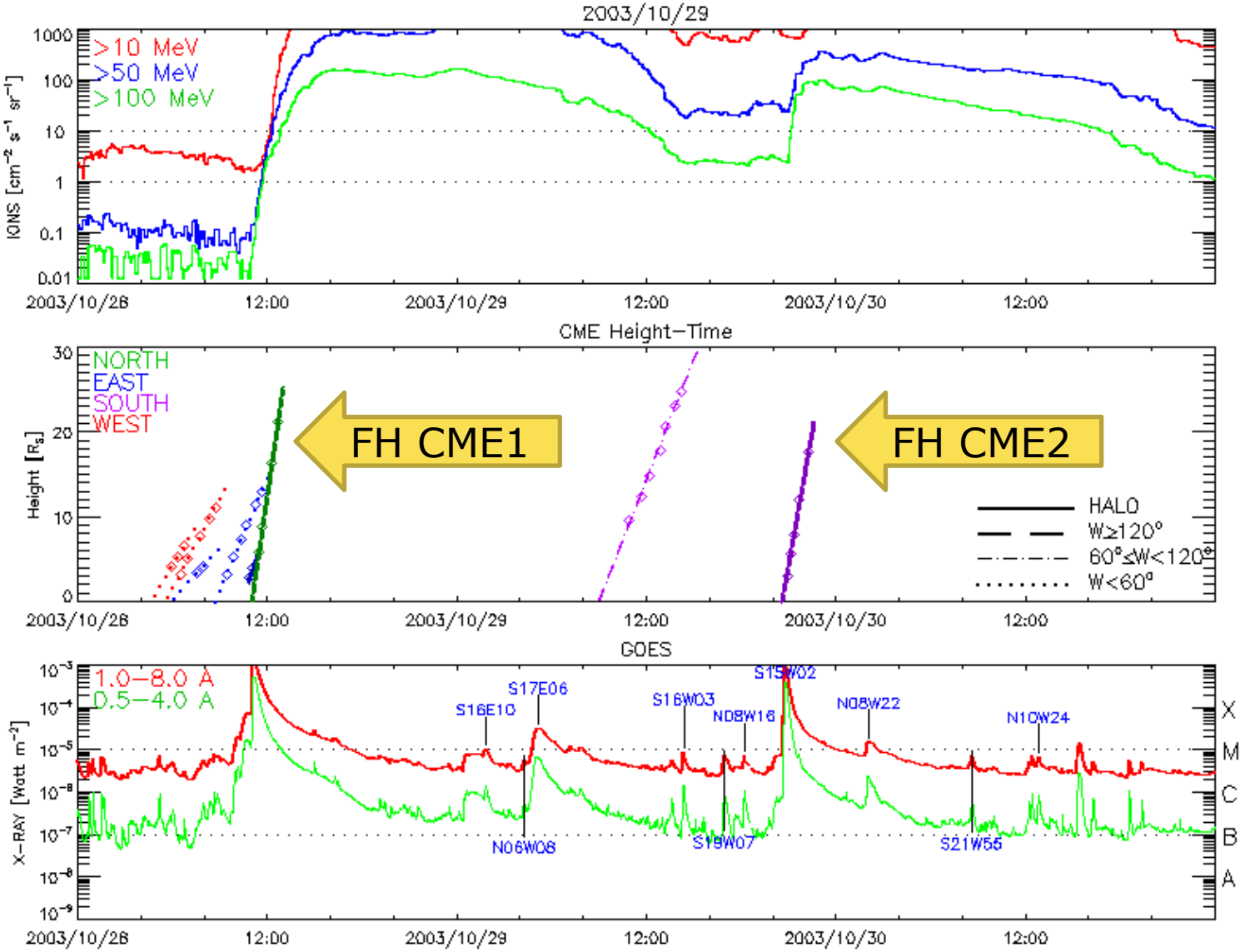
ELECTROMAGNETIC RADIATION FROM SPACE

Energy transmitted in the form of photons (electromagnetic waves).



Composite image courtesy of Windows to the Universe using images from SOHO (NASA and ESA), NCAR/HAO/MLSO, Big Bear Solar Observatory, and SDO/AIA.

29 Oct. 2003 event



Credit: SOHO/LASCO CME catalog

Emissions from the Sun (including, the highly variable X-ray and ultraviolet output) cause the upper atmosphere of Earth to heat and expand.

Image Credit: Skylab image courtesy of NASA. Newspaper image courtesy of L. J. Lanzerotti, Bell Laboratories, Lucent Technologies, Inc.

Example 2

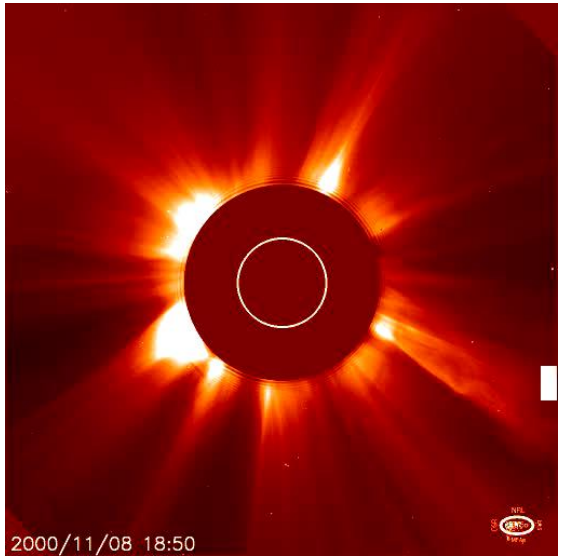
Coronal Mass Ejections

Coronal Mass Ejection [CMEs]

- Powerful eruptions on the Sun's surface.
- Caused by instabilities in the Sun's magnetic field.
- Enormous bubbles of plasma are ejected from the Sun at speeds from 100 to over 2000 km/s.

LASCO (Large Angle and Spectrometric Coronagraph): a set of three "coronagraph" telescopes on-board the SOHO satellite.

ARTIFICIAL ECLIPSE



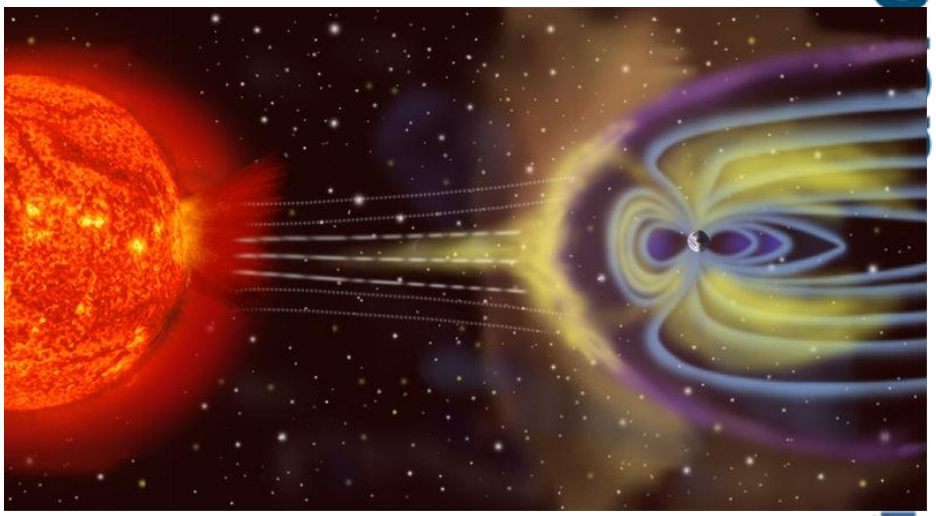
Credit: NASA-ESA/SOHO/LASCO

Geomagnetic Storms

Geomagnetic Storms are temporary disturbances in the Earth's magnetosphere caused by solar wind disturbances associated primarily with Earth-bound CMEs.

Can perturb the ionosphere causing problems for Global Positioning System navigation & satellite communications.

High frequency radio communications on airplanes flying over high-latitude regions can be seriously disrupted during storms.



Credit: NASA

Geomagnetically induced currents [GICs]

- GICs are phenomena at the ground end of the space weather chain. They are due to the geomagnetic perturbations produced by enhanced currents that flow in the magnetosphere–ionosphere system during geomagnetic storms.
- GICs can have consequences for electrical power transmission systems, oil and gas pipelines, telecommunications cables and railways.
- Significant GICs leads to a loss of reactive power and if that power is not restored quickly the voltage on the grid will collapse.

13 March 1989 Event

- Fluctuations within the magnetic field of the March 1989 geo-magnetic storm caused GICs to flow through Quebec's power lines
- Conductors forwarded this current to sensitive electrical transformers, which require a certain voltage amplitude and frequency to function properly.
- To save the transformers and other electrical equipment, the power grid was taken out of commission, as circuit breakers tripped all over Quebec and shut off the power
- Within less than 90 seconds, this wave of breaking circuits left the entire Quebec power grid collapsed.
- 6 million people lost electrical power for 9 or more hours on.

Example 3

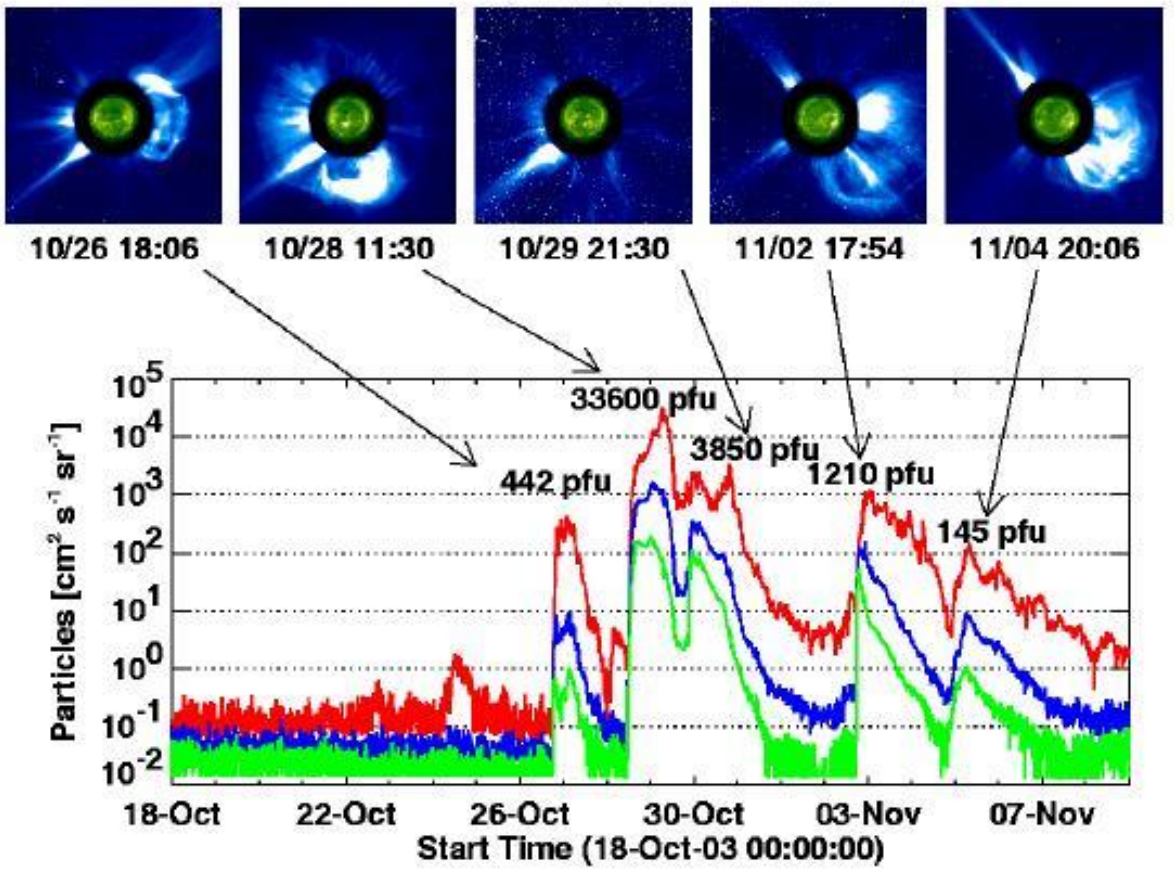
Solar Energetic Particles

Solar Energetic Particle [SEP] Events

SEPs are protons, electrons & heavy ions, up to the iron mass (and even beyond)

Energy Range: dozen of keVs to a few GeVs

Temporal Range: Sporadic [minutes to days]



SEP events from GOES (>10 MeV, >50 MeV and >100 MeV channels) and associated LASCO CMEs from the Oct.-Nov. 2003 period. Credit: Gopalswamy (2006)

Radiation Damage: On-board Electronics

Single Event Effects

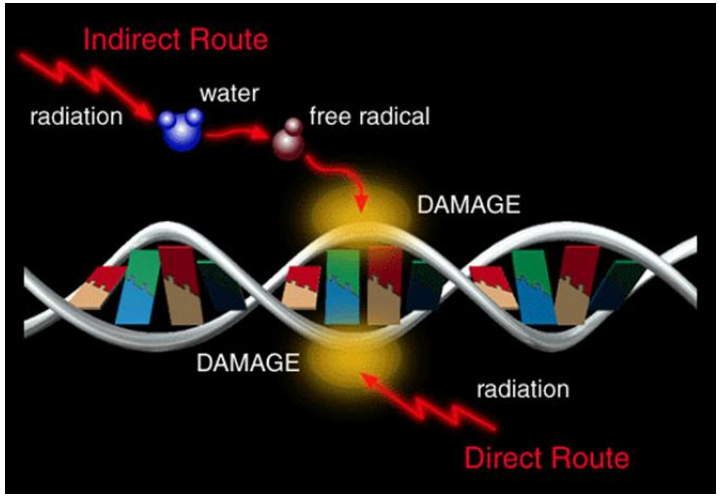
Individual events which occur when a single incident ionizing particle deposits enough energy to cause an effect in a device.

Cumulative Radiation Damage

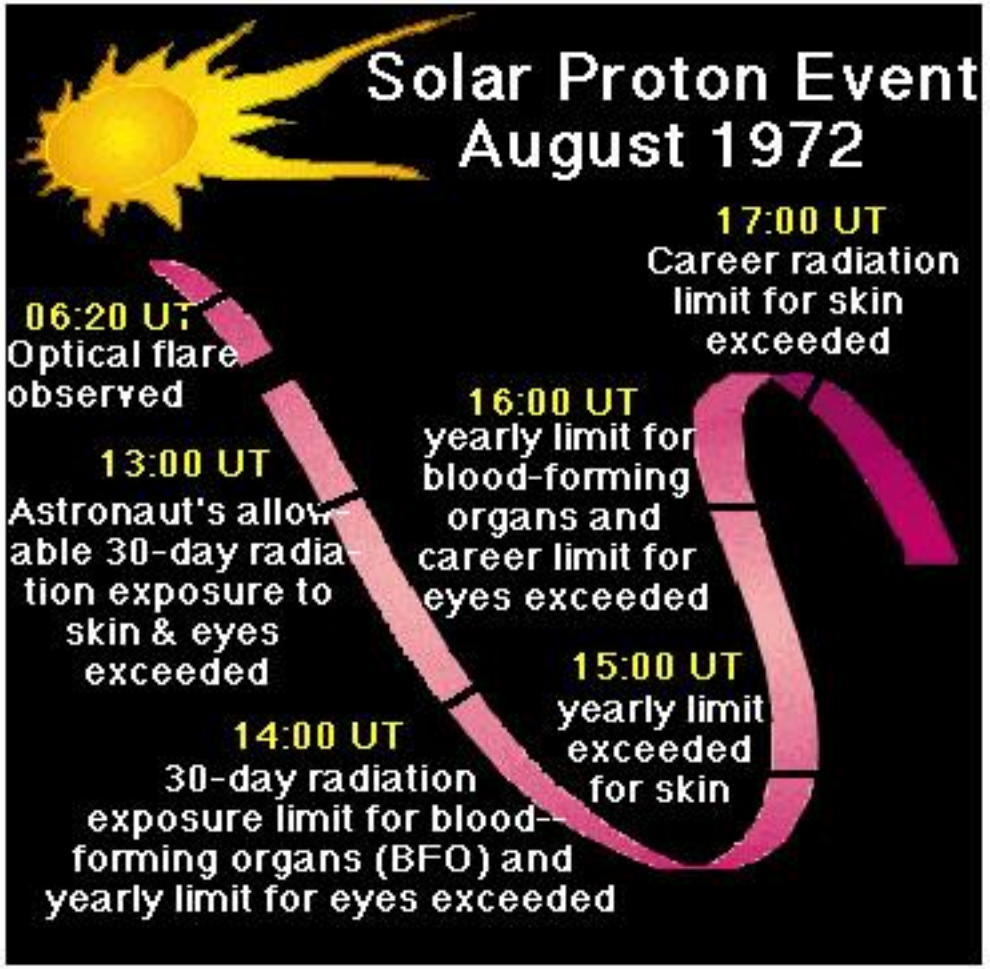
Total Ionizing Dose: When radiation penetrates the constituents of electronic components and the lost energy is stored in the material.

Total Non-Ionizing Dose (displacement damage dose): Displacement effects are caused by an atom displacement from the normal lattice position to an adjacent position, thus creating structure damage and resulting in recombining centers that deteriorate the electrical characteristics of the material.

During space missions, astronauts performing extra-vehicular activity activities are relatively unprotected.



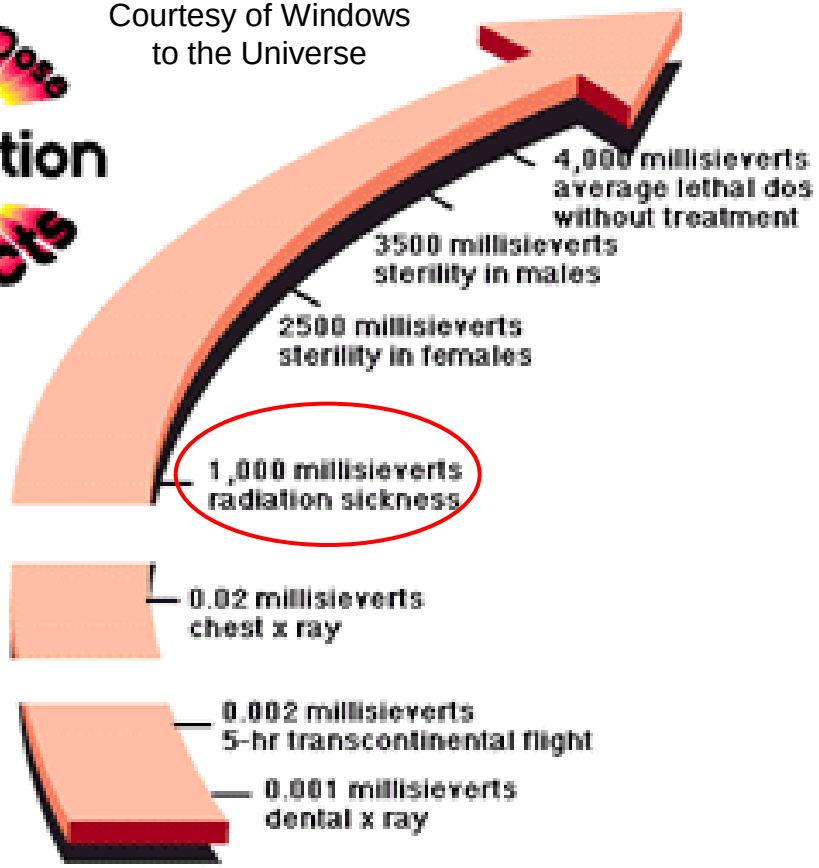
Courtesy of Windows to the Universe



Between the Apollo 16 and 17 manned space missions one of the largest solar proton events ever recorded arrived at Earth.

Single Dose Radiation Effects

Courtesy of Windows to the Universe



Mission limits, valid for older crew (male above 35 and female above 45 year old), are based on a 3% stochastic increase of cancer risk (NCRP, 2000).

The risk can be accepted for human deep space operations given the other mission risks. The one hour and one minute limits are intended as a tool for the early detection of SEPs (Wilson et al. 1997).

1 Sv is the same as 100 rem.

Table I. Proposed dose equivalent limits for a mission to Mars

	1 minute	1 hour	1 day	1 month	1 year	mission
Warning	3 μSv	0.8 mSv	10 mSv	0.20 Sv	0.40 Sv	0.80 Sv
Alarm	3 *warnings*	1.0 mSv	12 mSv	0.25 Sv	0.50 Sv	1.00 Sv

Part 2: Educational Examples

EXPLORATION SPACE

Courtesy of ESA

Curiosity about our world, and the Universe that surrounds us, has been the driving force behind human progress since prehistoric times.

EXPLORING SPACE

OBJECTIVE: Compare the first explorers who traversed the oceans over 500 years ago to those that will explore space.

EverGreene Painting Studios
Oil on Canvas
1993-1994

Courtesy of NASA

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WHY EXPLORE ?

THE OCEAN (500 Years Ago)

- Population pressure
- New land
- Untouched natural resources
- Search for knowledge
- Desire to find out what lies on the other side of the ocean

SPACE (Present and Future)

- Same answers as above???
- Questions “How did life evolve?” and “Are we alone?”.
- Practical side to space exploration (science, commerce and industry)
- International collaboration, inspiration and education

What are the differences and what are the similarities between the two scenarios?

- Preparing for the trip (funding, education, politics, …)
- Transportation technology used
- Knowledge of trip (dangers, weather, diseases,…)
- Protection against dangers “mitigation”
- How did/will the trip benefit humanity?

http://publications.agu.org/journals/

Space Weather

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Five Centuries of Exploration: From Distant Shores to Distant Planets

Norma B. Crosby, Iwan Van den Bergh, Robrecht Bollen, Jan Brabants, Jirka Cops, Yörg Dillen, Céline Doomen, Jonas Lambrechts, Thomas Stulens, Aäron Trippaers, Lucas Vanlaer, and Sebastiaan Vinkesteijn

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For millennia, humans' innate curiosity about their environment has fueled a desire to explore, leading men and women to cross vast oceans and unmapped continents on Earth and, in recent decades, to probe the endless reaches of interplanetary space. While exploration has been a key feature of nearly every civilization, historical records show that the past five centuries—starting with Europe's "Age of Discovery" in the early fifteenth century, when navigators sought to map the planet—constitute an era of intense technological development aimed at expanding the boundaries of the known world (Figure 1).

Seeking more insight into what connects past and present explorers, ten Belgian high-school students who excel in sci- and space travelers, the students separated them into two categories: (1) issues that directly mirror each other (for example, explorers have always needed patrons to fund their voyages and have had to tailor their objectives to fit their sponsors' budgets), and (2) issues where comparable motivations exist but are manifested in very different ways. An example of the second category would be the environmental conditions encountered in interplanetary space, which differ radically from those faced by Columbus and his contemporaries—space weather conditions beyond the stratosphere are unlike anything that humans experience on Earth. But whether the explorer must endure an ocean storm or a solar storm, his or her objective remains the same: to lead the vessel and crew

I LOVE MY SUN

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http://www.swsc-journal.org/

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RESEARCH ARTICLE OPEN ACCESS

The COST example for outreach to the general public: I love my Sun

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ABSTRACT

It is important to educate children about the important role that the Sun has in their lives. This paper presents an educational outreach tool entitled "I Love My Sun" that has been developed for school children in the approximate age range of 7 through 11 years. The main objective of this tool is to make children aware of space weather, the Sun, Sun-Earth relations and how they, the children, are part of this global picture. Children are given a lecture about the Sun. The lecture is preceded and followed by the children drawing a picture of the Sun. In this paper the background behind the "I Love My Sun" initiative is given and it is described how to perform an "I Love My Sun". The main results from events in Turkey, Belgium, Ukraine and Serbia are presented.

Key words. space weather – outreach – education – space environment – Sun

I LOVE MY SUN

http://www.ilovemysun.org/

ORGANISE YOUR "I LOVE MY SUN" EVENT

Part 1: Prior to School Visit [choose and contact school]

Part 2: School Visit

1. Children are asked to draw the Sun as they perceive it. "before lecture drawing".
2. A lecture on the Sun and space weather is given to the children followed by a brainstorming session.
3. Children are asked to draw the Sun again "after lecture drawing".

Part 3: After School Visit [filling in documents]

1. School Information document
2. Class Information document
3. General Impression document

IN SUMMARY

Space weather is an inter-disciplinary subject (science, engineering, medicine, business, …)

It is the perfect subject for:

- teaching classical topics (math, biology, chemistry, …).
- inspiring the next generation in regard to career opportunities (e.g. space science, engineering, space medicine, business)

Space weather affects us all !