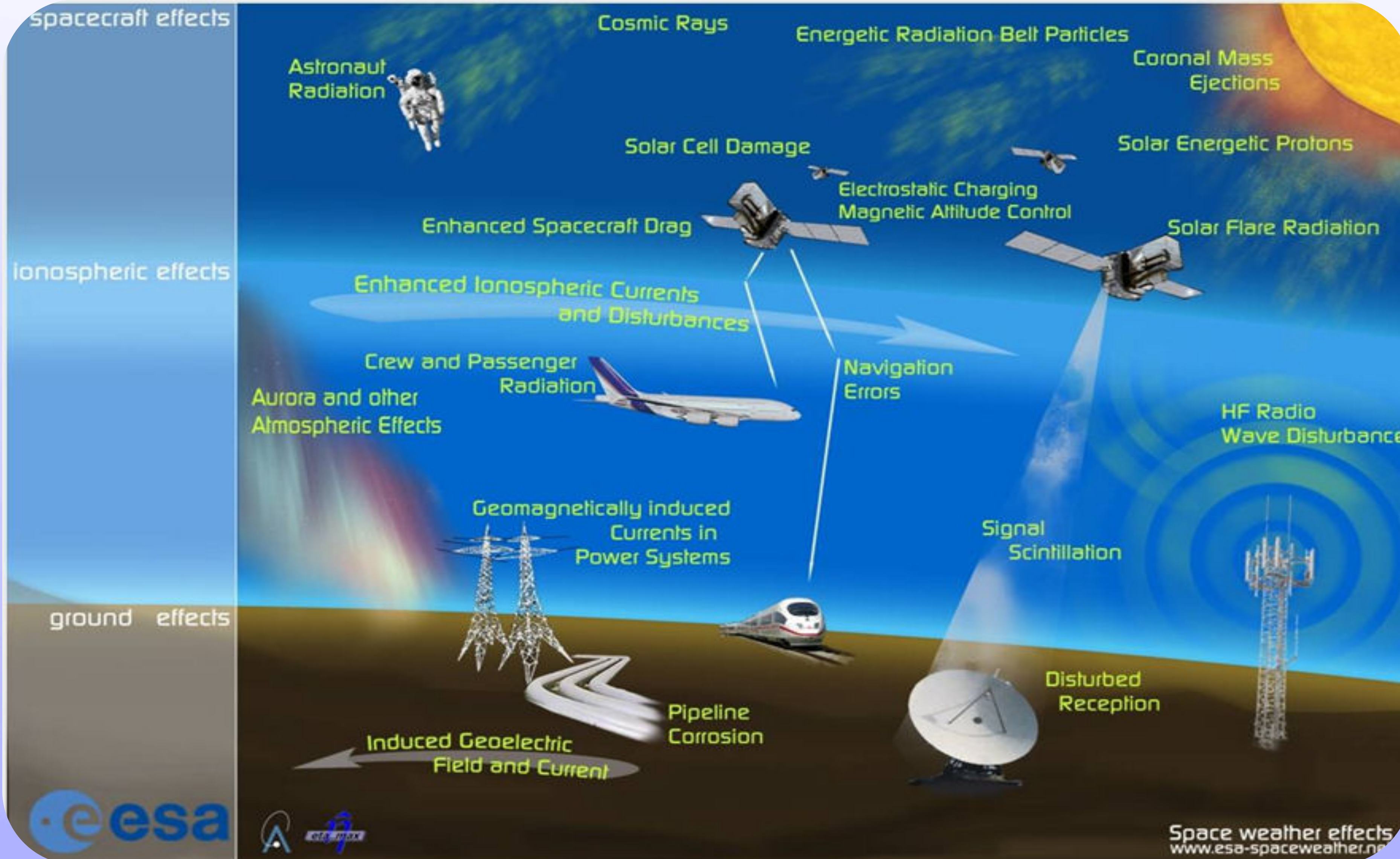
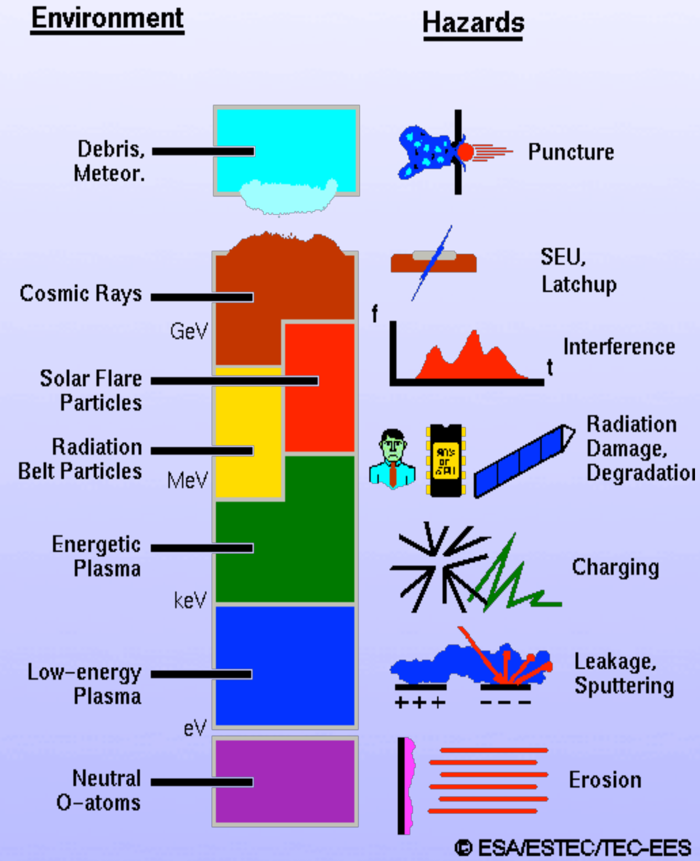
Effects on Spacecraft



Effetti su Spacecraft

The space environment consists of many hazards. Most of these hazards have specific effects on spacecraft and their components

- Radiation: Van Allen belts, source of energetic charged particles, surround the Earth. Sun activity create additional energetic particles in sudden bursts. High energy heavy charged particles reach the Earth vicinity from outside the solar system
- Plasma, ionised gases around Earth: electrostatic charging of surfaces when energetic plasma is injected near the busy GEO (magnetospheric storms/substorms). Discharges can severely disturb operations. The cold ionospheric plasma is a problem for operating high power systems because of its conductivity
- Micro-meteoroids and space debris can seriously damage satellites (manned missions). Increasing space activities add to the space debris problem in popular orbits while the meteoroid environment is an ever-present sporadic feature
- Others environments include the residue of the atmosphere at low orbital altitudes including highly-reactive atomic oxygen, contamination, dust …

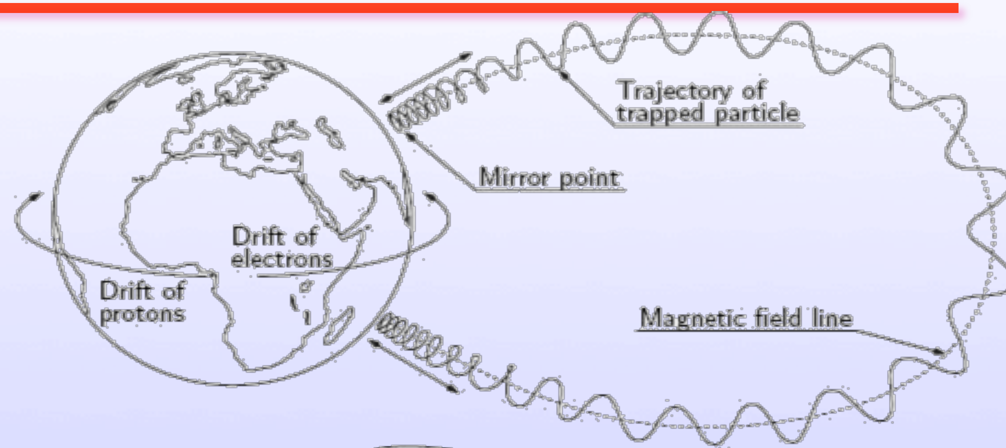


Space Environment

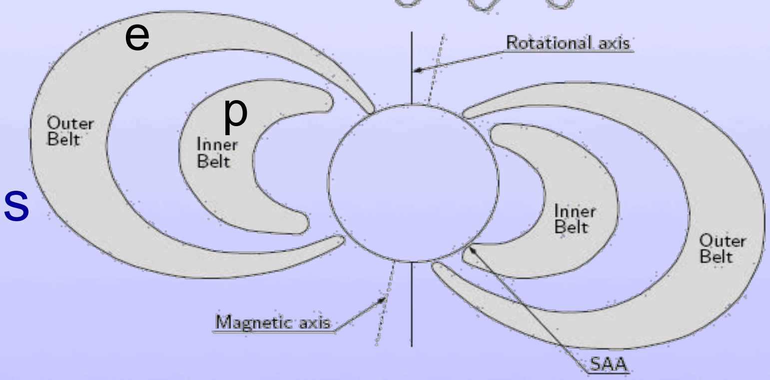
- Radiation
- Plasma
- Geomagnetic field
- Space debris
- Micro-particles & Meteorids
- Atomic Oxigen
- Contamination

Radiation Environment

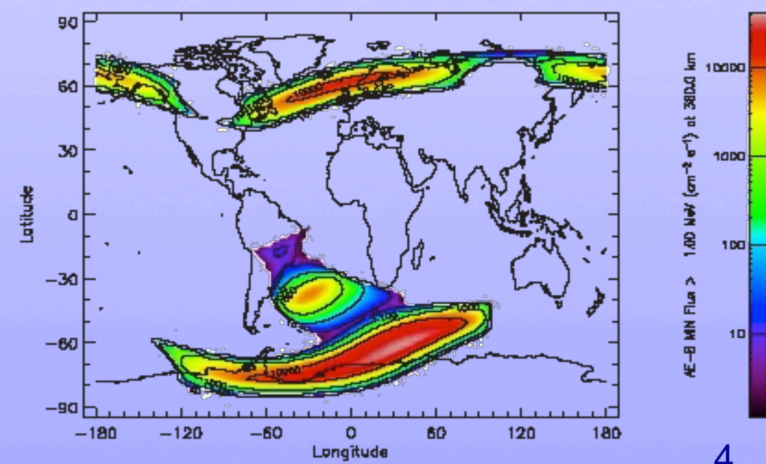
- Trapped particle belts
  - electrons of up to a few MeV
  - protons of up to several 100 MeV
  - low altitude (LEO)



- Solar particle events
  - large fluxes of energetic protons, peak flux in excess of ~10^6 p/cm^2/s, ≥10 MeV
  - Geomagnetic shielding but reach polar regions and high altitudes (GEO)

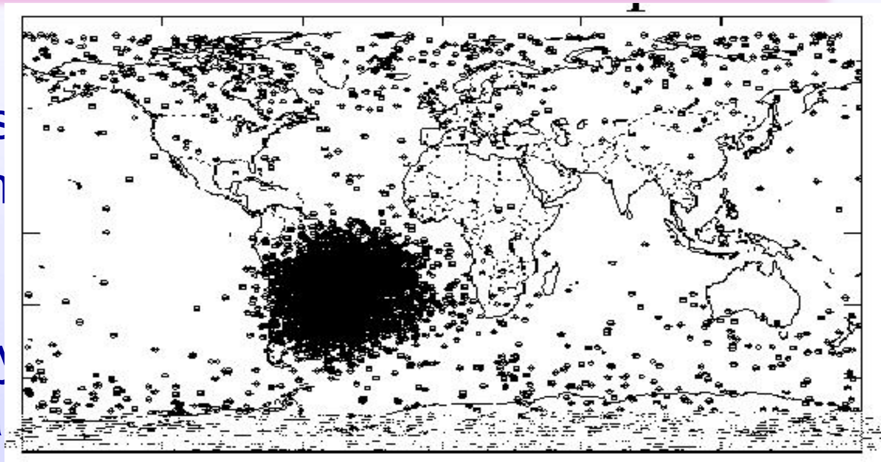


- Cosmic rays
  - originated outside the solar system, low fluxes but heavy-energetic ions (iron)
  - intense ionisation passing through matter, significant hazard (difficult to shield) for integrated electronic components, solar cells, interference and radiobiological effect



Radiation effects & analysis

- Degradation - radiation damage
  - o induced by the ionisation that radiation caus
    the molecular structure of a material and sin
- Single Event Upset (SEU)
  - o from ionisation produced by energetic heavy
    semiconductor chip, the free charge genera
    of the bit
  - o from energetic protons/ions hitting a nucleus in a sensitive component location. The nuclear interaction produces spallation splitting the nucleus, the spallation products generate the ionisation flipping the bit state



- Radiation Background
  - o interference with detectors (astronomy missions) increasing background
  - o Interference from secondary radiation (γ-rays, $e^{\pm}$, ions) by interactions of primaries (bremsstrahlung, nuclear interactions). In optical components: energetic particles cause scintillation (fluorescence) and Cerenkov

Radiation effects & analysis

- Degradation - radiation damage
  - induced by the ionisation that radiation causes in a material, defects created in the molecular structure of a material and similar displacement damage effects
- Single Event Upset (SEU)
  - from ionisation produced by energetic heavy ions through a sensitive part of a semiconductor chip, the free charge generated is sufficient to flip the logic state of the bit
  - from energetic protons/ions hitting a nucleus in a sensitive component location. The nuclear interaction produces spallation splitting the nucleus, the spallation products generate the ionisation flipping the bit state
- Radiation Background
  - interference with detectors (astronomy missions) increasing background
  - Interference from secondary radiation (γ-rays, $e^{\pm}$, ions) by interactions of primaries (bremsstrahlung, nuclear interactions). In optical components: energetic particles cause scintillation (fluorescence) and Cerenkov

Radiation effects & analysis

- Radiation is a concern for manned missions (low altitude, ISS)
  - The radiation risk due to highly ionising cosmic ray nuclei is of particular concern for astronauts especially for long flights such as those for the space station and for future inter-planetary missions. The radiation risk can be estimated base on the flux of particles as a function of their energy loss, LET (Linear Energy Transfer)

Radiation Analysis

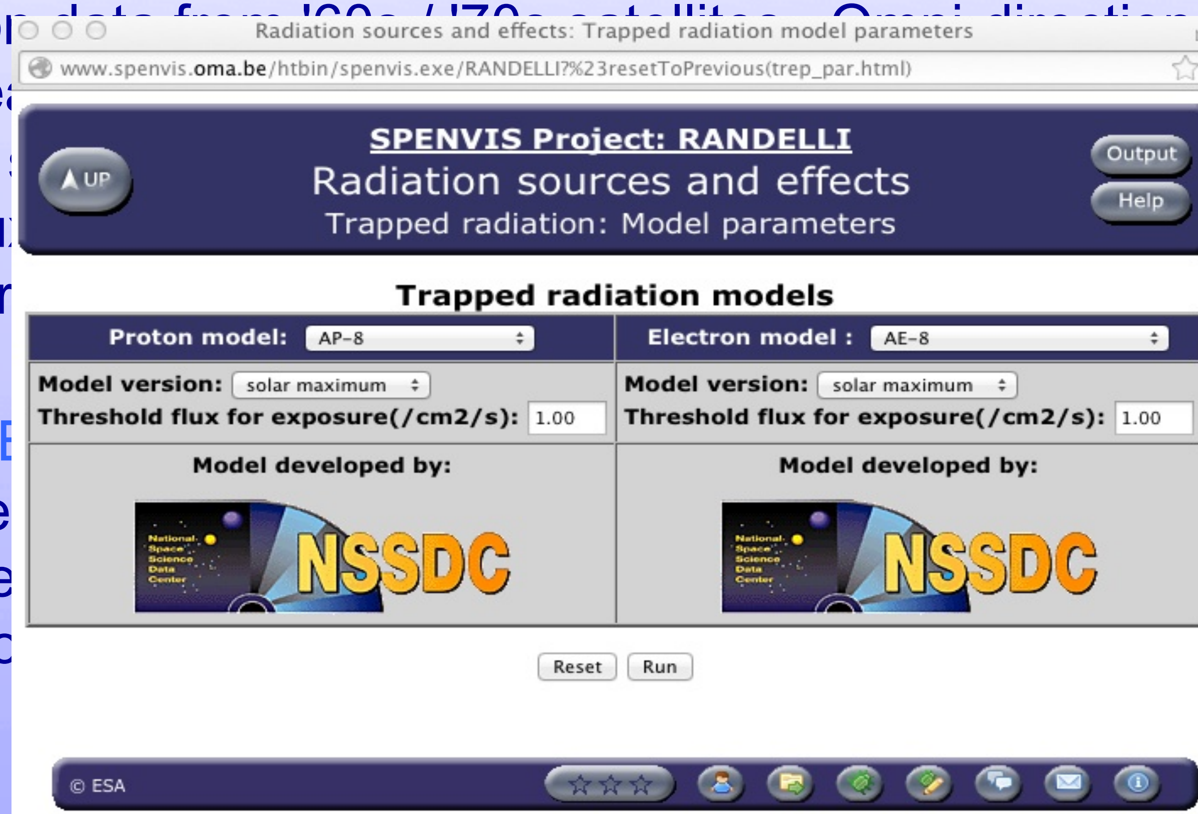
Radiation can penetrate S/C walls and deposit 100s krads in certain orbits. Shielding: mass & cost (+showering)

- Trapped particle belts
  - AE8 and AP8 models for $e^{\pm}$ / protons, developed by Vette et al. (NSSDC @NASA/GSFC) based on data from '60s / '70s satellites. Omni-directional fluxes as functions of idealised geomagnetic dipole coordinates ($B/B_0, L$) (spenvis). Apart from for solar max and min versions, no description of the temporal behaviour of fluxes while at high altitudes (GEO) fluxes vary by orders of magnitude over short times and exhibit significant diurnal variations
  - New Trapped Radiation Environment Model. Data from Meteosat, CRRES and ISEE have been used to construct databases and subsequently new anisotropy models of energetic electron flux temporal and spatial characteristics taking into account strong directionality and link to atmospheric density

Radiation Analysis

Radiation can penetrate S/C walls and deposit 100s krads in certain orbits. Shielding: mass & cost (+showering)

- Trapped particle belts
  - AE8 and AP8 models for e± / protons, developed by Vette et al. (NSSDC @NASA/GSFC) based on data from '60s / '70s satellites. Omni-directional fluxes as functions of idea… (spenvis). Apart from for … temporal behaviour of flu… orders of magnitude over … variations
  - New Trapped Radiation E… S and ISEE have been use… anisotropy models of ene… characteristics taking into … atmospheric density



Radiation Analysis

- Solar particle events (SPE)
  - It is not possible to predict the exact occurrence, intensity or duration of SPE: mission planning can be problematic
  - Short-term forecasts are necessary for any tasks requiring extra-vehicular activity (EVA) and the operation of radiation-sensitive detectors
    - Sun real-time observation can provide useful warning of solar activity, as large proton events are usually associated with the strong emission of electromagnetic radiation (visible light, radio waves, soft X-rays)
  - Long-term predictions of the radiation levels resulting from events are derived from statistical models based on past observations
    - King model: standard model used to predict mission-integrated solar proton fluences
    - JPL (Feynman) model: recently recommended for use for future mission planning

Radiation Analysis

- Cosmic rays
  - CRÈME, Cosmic-Ray environment and effects models by Adams et al. @NRL: a comprehensive set of cosmic-ray and event ion LET and energy spectra, including treatment of geomagnetic shielding and material shielding
  - CREME also includes upset/hit rate computation based on the path length distribution in a sensitive volume and can also treat in a simple manner trapped proton-induced SEUs