



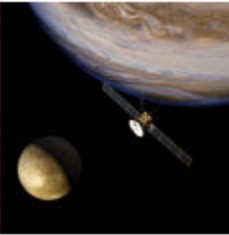
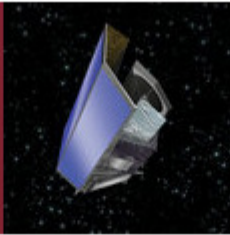
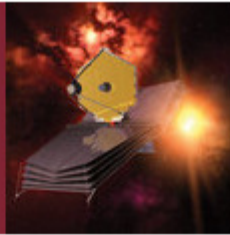



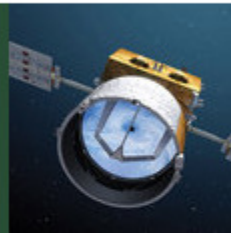


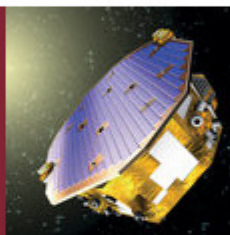


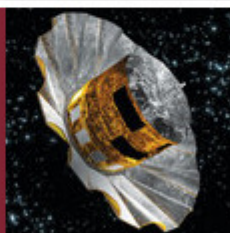





Space Environments and Effects - ESA Context


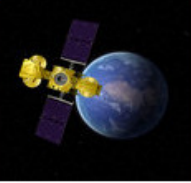




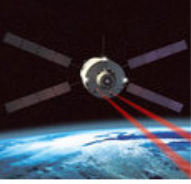


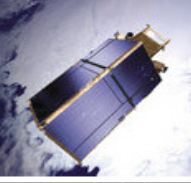











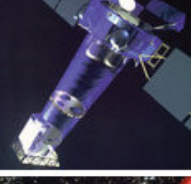

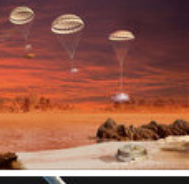
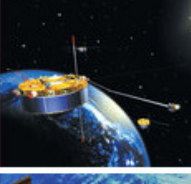






E. Daly

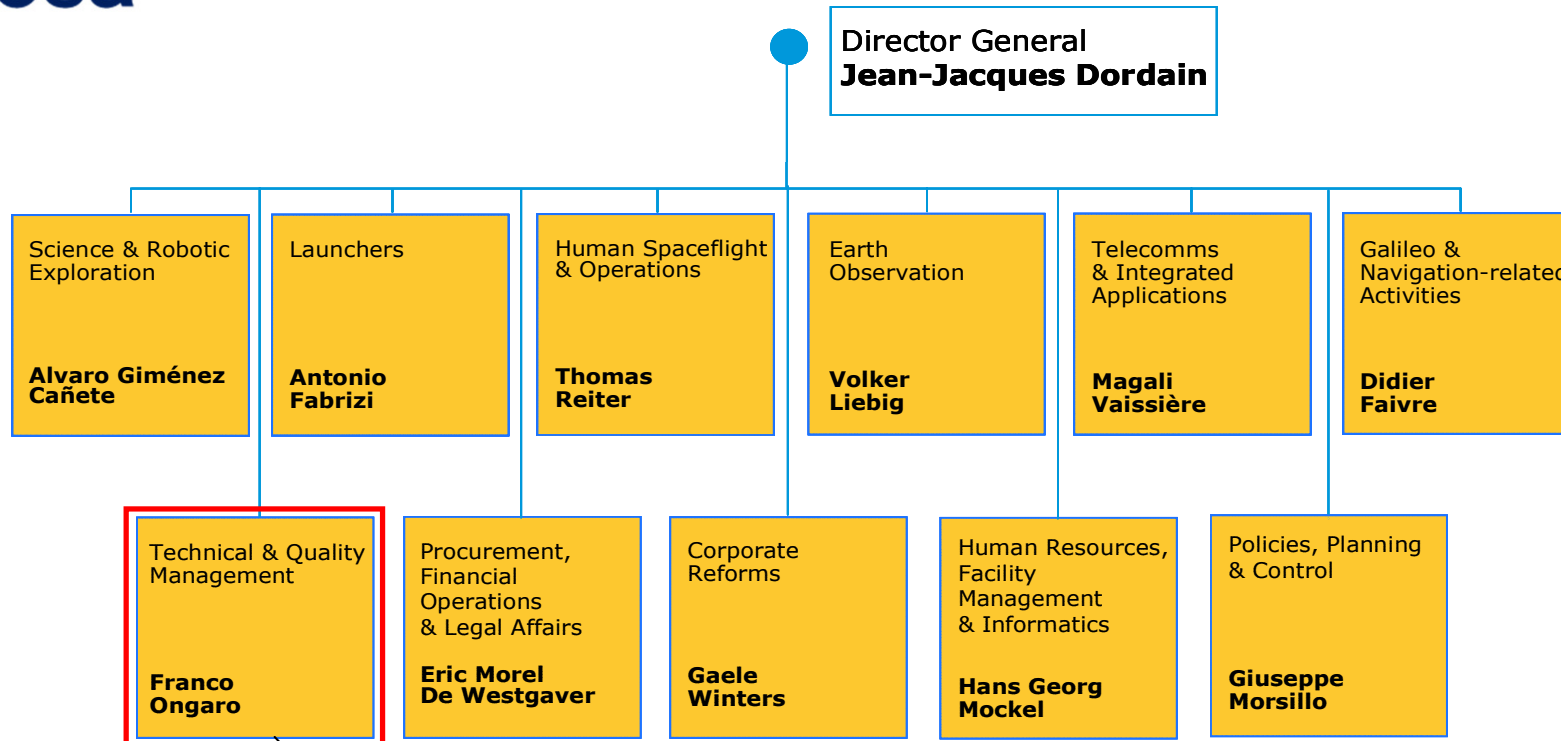
ESA Space Environments and Effects Section

ESTEC, Noordwijk, The Netherlands

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<p>juice Launch: 2022 Europe's first mission to the Jupiter system</p> 	<p>euclid Launch: 2020 Charting dark matter and dark energy's effects on the Universe</p> 	<p>james webb space telescope Launch: 2018 Contributing two instruments to the next great space observatory</p> 	<p>solar orbiter Launch: 2017 Europe's closest mission to the Sun</p> 
<p>mtg series Launch: 2017 Meteosat Third Generation</p> 	<p>cheops Launch: 2017 Studying planets around other stars</p> 	<p>exomars Launch: 2016, 2018 Mars orbiter and lander, followed by rover</p> 	<p>adm-aeolus Launch: 2015 Mapping Earth's global wind fields</p> 
<p>earthcare Launch: 2015 Studying the roles of clouds and aerosols in our climate</p> 	<p>bepicolombo Launch: 2015 Europe's first mission to Mercury</p> 	<p>lisa pathfinder Launch: 2014 Technology demonstration for gravitational wave detection</p> 	<p>smallgeo Launch: 2014 New small platform for geostationary telecommunications</p> 
<p>edrs First launch: 2014 Geostationary satellites for relaying satellite data</p> 	<p>alphasat Launch: 2013 Innovative satellite telecommunications platform</p> 	<p>gaia Launch: 2013 Mission to map a billion local stars in 3D</p> 	<p>swarm Launch: 2013 Trio of satellites mapping Earth's magnetic field</p> 
<p>sentinel family First launch: 2013 A portfolio of operational Earth observation missions</p> 	<p>european robotic arm Launch: 2013 Robotic arm serving Russian segment of ISS</p> 	<p>ixu Launch: 2013 Intermediate eXperimental Vehicle</p> 	<p>vega First launch: 2012 Europe's small satellite launcher</p> 

<p>galileo First launch: 2011 Europe's global satellite navigation system</p> 	<p>hylas-1 Launched: 2010 Broadband services in public-private partnership</p> 	<p>goce Launched: 2009 Mapping Earth's gravity</p> 	<p>herschel Launched: 2009 Far-infrared astronomy mission</p> 
<p>planck Launched: 2009 Mapping the cosmic microwave background</p> 	<p>smos Launched: 2009 Measuring soil moisture and ocean salinity</p> 	<p>atu Launched: 2008, 2011, 2012 Space truck for ISS resupply</p> 	<p>columbus Launched: 2008 Europe's ISS research laboratory</p> 
<p>metop series Launched: 2006, 2012 Polar meteorological services</p> 	<p>cryosat Launched: 2005 (failed), 2010 Measuring polar-ice thickness</p> 	<p>venus express Launched: 2005 Europe's first Venus orbiter</p> 	<p>gioue-a & b Launched: 2005, 2008 Technology demonstration for Galileo</p> 
<p>sloshsat Launched: 2005 Investigating fuel sloshing effects</p> 	<p>rosetta Launched: 2004 Deep space comet rendezvous mission</p> 	<p>mars express Launched: 2003 Europe's first Red Planet orbiter</p> 	<p>smart-1 Launched: 2003 Experimental Moon mission</p> 
<p>envisat Launched: 2002 10-instrument environmental satellite</p> 	<p>integral Launched: 2002 Gamma-ray astronomy</p> 	<p>msg series Launched: 2002, 2005, 2012 Second-generation European meteorology satellites</p> 	<p>artemis Launched: 2001 Technology demonstration for telecommunications</p> 
<p>proba series Launched: 2001, 2009, 2013 Technology demonstration microsatellites</p> 	<p>xmm-newton Launched: 1999 X-ray astronomy</p> 	<p>ard Launched: 1998 First European experimental reentry vehicle</p> 	<p>huygens Launched: 1997 Surface probe of Saturn's moon Titan</p> 
<p>cluster Launched: 1996 (failed), 2000 Space plasma physics in 3D</p> 	<p>iso Launched: 1995 Infrared astronomy</p> 	<p>soho Launched: 1995 Continuous observation of the Sun</p> 	<p>eureka Launched: 1992 Reusable free-flying microgravity testbed</p> 
<p>ers-1 & -2 Launched: 1991, 1995 Radar-based Earth observation</p> 	<p>hubble space telescope Launched: 1990 ESA contributed solar arrays and faint</p> 	<p>ulysses Launched: 1990 Charting space above and below the Sun's poles</p> 	<p>hipparcos Launched: 1989 Mapping the positions of more than 100 000 stars</p> 



- Engineering Support to ESA Project Development (Electrical, Mechanical, Software, Quality, etc.)
- Technology R&D

Space Environments and Effects Section (15 staff)

- Radiation, Plasma, Atmospheres, etc.
- Modelling, Instrumentation

- Evaluation of space environments and effects

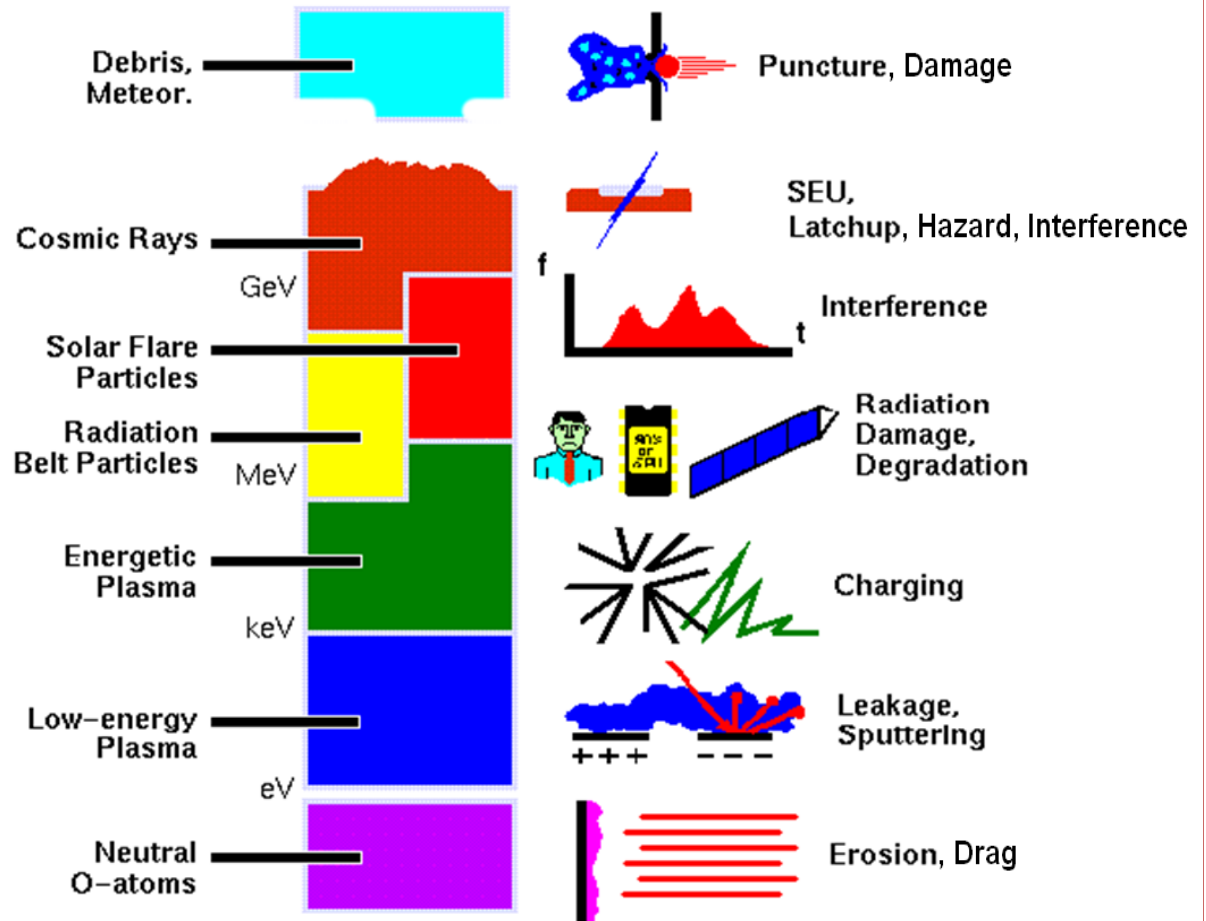
- Starts pre-phase A
 - Environment specifications
 - Tailoring of standards
 - Concurrent Design
- More detailed support in later phases
- In-orbit behaviour evaluations (anomalies, data analysis, etc.)

- Supporting activities:

- R&D
- Standardisation
- Collaboration

Supporting Mission Development

Overview of Space Environment

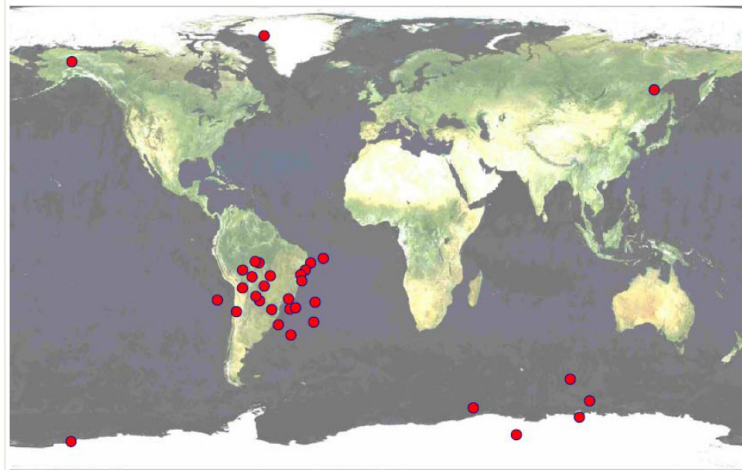


Activities During Development

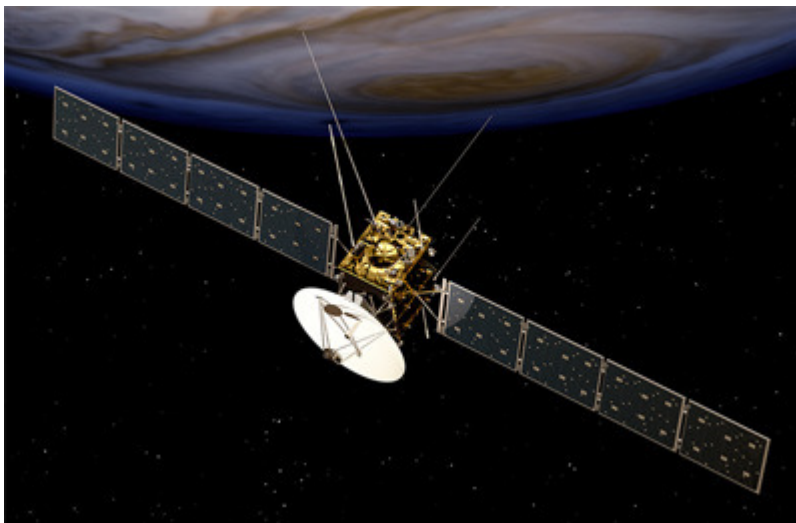
- Environment specification, *Concurrent Design*
 - early phases of most missions
- Detailed evaluation of environmental impacts:
 - Radiation interactions with electronics, payloads,...
 - Spacecraft-plasma interactions;
 - Atmospheres (esp. Mars);
 - “Microparticles” – risk analysis; puncture probability,...
- Busy areas
 - Science missions in general (complexity= susceptibility to radiation)
 - Cosmic Vision (LOFT, CHEOPS, JUICE,...):
radiation, charging/contamination, microparticles;
 - Galileo (potentially severe radiation, charging issues);
 - EO projects (mainly specifications, but growing SEU issues
e.g. METOP HRPT failure, SMOS, CRYOSAT, ...);
 - Telecoms (radiation, charging) ;
 - Human Spaceflight (human radiation hazards);
 - SSA

Radiation Support

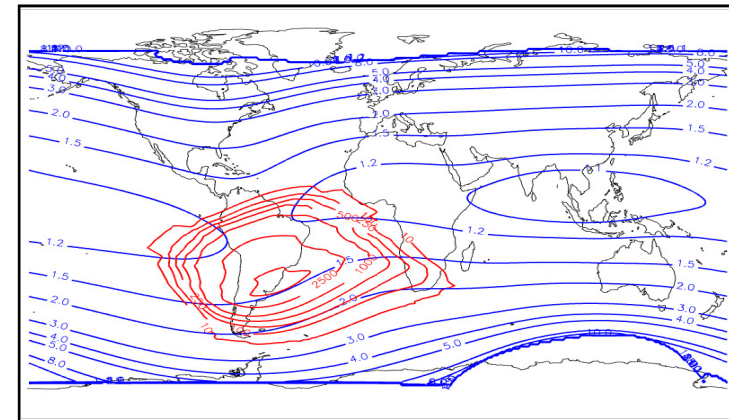
Earth observation missions' anomalies



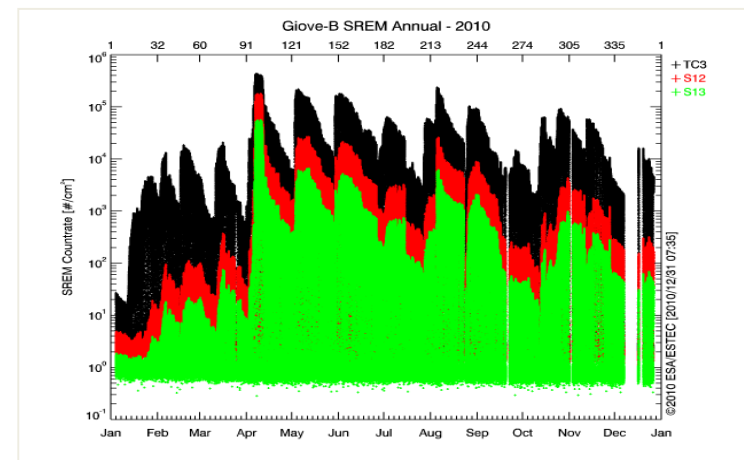
JUICE (Jupiter) Radiation Environment and Effects



METOP HRPT failure/ops



Galileo: Validation and Radiation Monitors

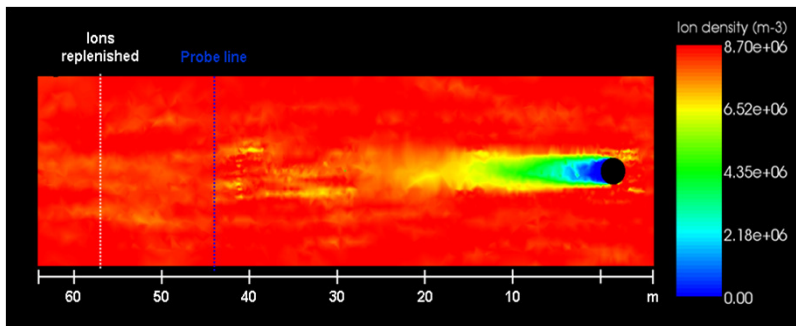
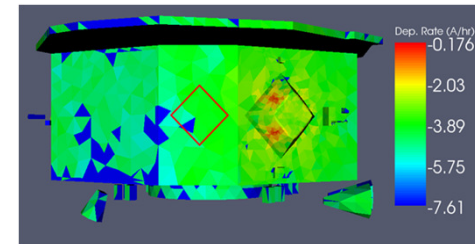
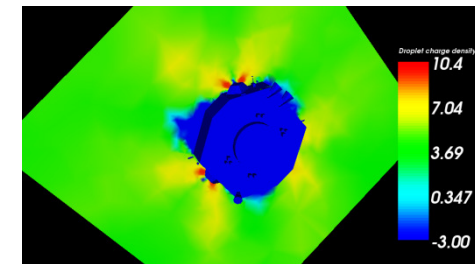
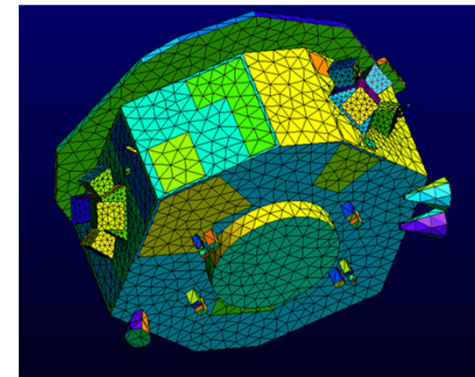
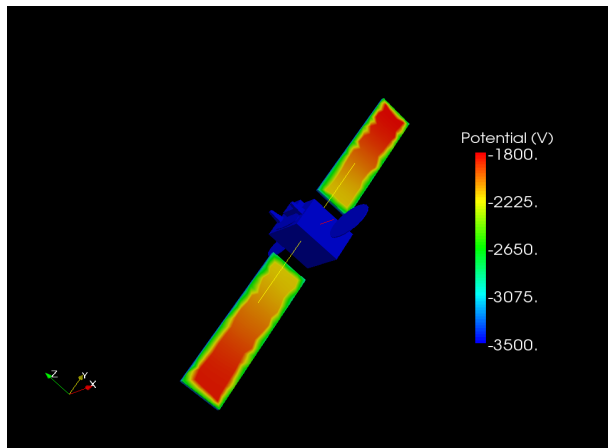


Trends lead to increased susceptibility

- ↑ Complexity of on-board systems;
 - Hazardous locations
- ↑ Spacecraft size in GEO;
- ↑ Power in GEO → large lightweight solar arrays,
- ↓ Procurement costs;
 - Minimization of operations;
- ↑ On-board processing;
 - Long-term reliability;
 - Extensive use of commercial off-the-shelf components (COTS):
 - ↓ radiation hard or poorly characterized
 - ↑ on-chip complexity.

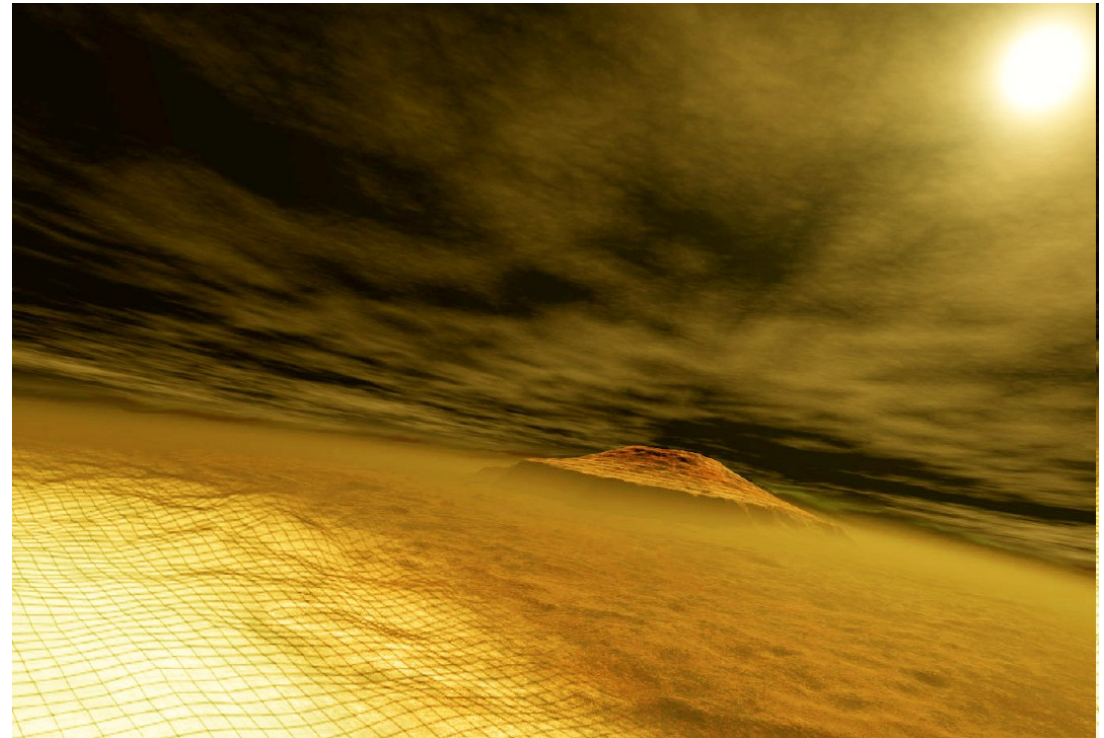
Examples

- Telecommunications satellite electrostatic charging in GEO
- LISA Pathfinder Contamination
 - electric thrusters produce neutral & charged contaminants;
 - Charge exchange occurs → neutrals become charged & re-attracted

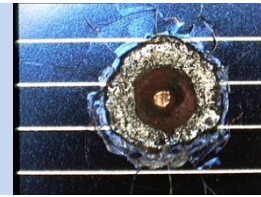


- Plasma wakes in the solar wind

- European Mars Climate Database
 - Key resource for mission design
 - Based on in-situ data and climate modelling with a global circulation model
- Earth's thermosphere
 - Tools for atomic oxygen impact and erosion

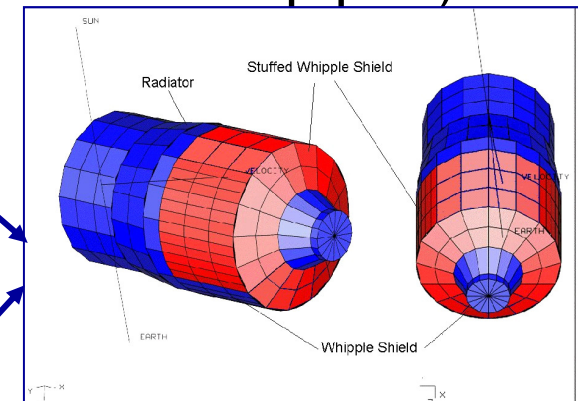
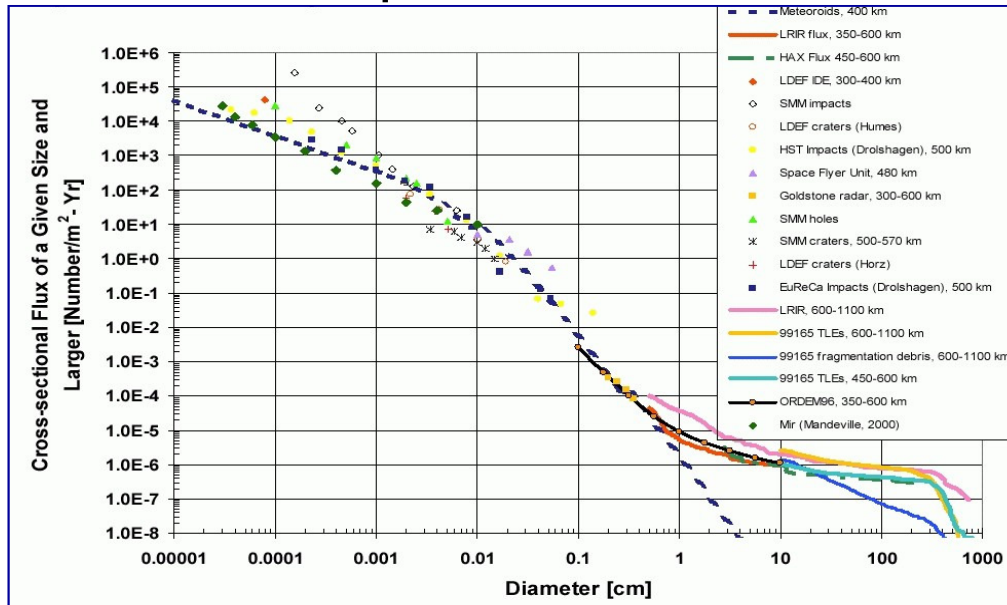


Meteoroids & Debris Risks

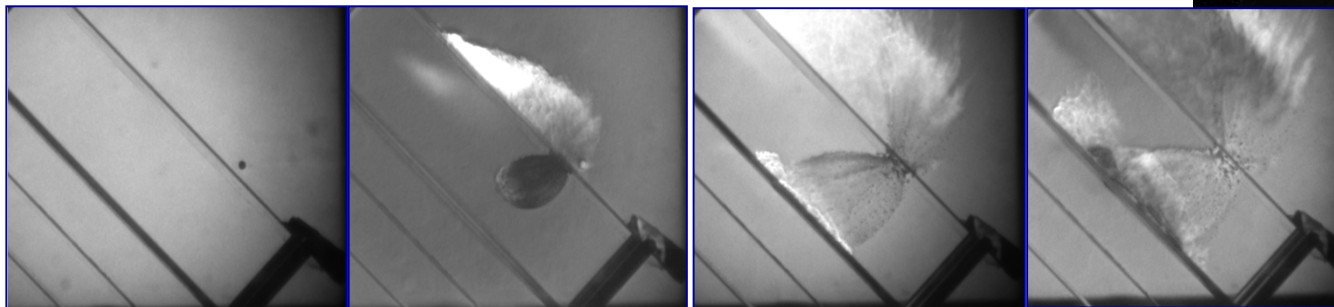


“Risk of damage”
assessment
(e.g. ATV, MPCV,
heat-pipes)

Population models



Damage characteristics (test, simulation)

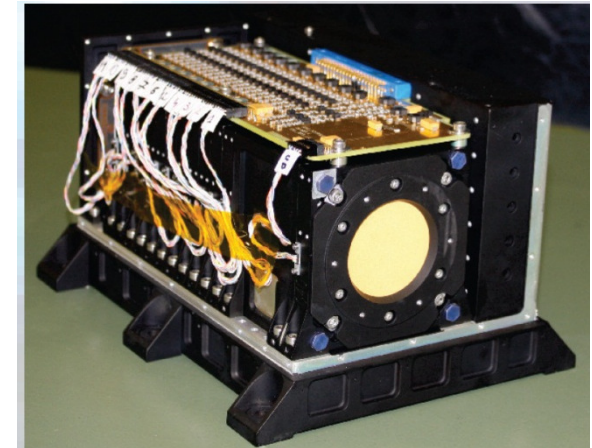


In-orbit monitoring

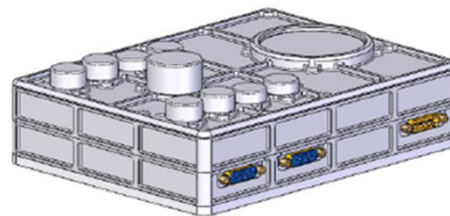


Highly Miniaturised Rad. Monitor (RAL picture)

- **Radiation** Monitors
 - Past/present: REM, SREM, EPT
 - Future: MFS, EMU, NGRM, HMIRM, 3DEES, RADEM (JUICE), ...
- **Microparticle** detectors
 - Debie-2 recently returned from ISS (EuTEF)
 - AIDA
- **Plasma** monitors
 - SEPS, MNLP
 - HOPE-M
 - Other R&D



EPT Picture courtesy CSR



ESA picture



ISS020E037331

Technology R&D

- Tools and methods of project development are developed in R&D programmes

- Plans are based on
 - evaluation of future project needs,
 - internal technical dossiers & roadmaps,
 - consultation in SEENoTC, harmonisation,
 - ... intense internal competition
- basic Technology Research Programme (TRP)
 - 2011-13 programme + some 2008-2010 leftovers;
 - Total programme 130M€ over 3 years
 - 9 “service domains” (Sci, Hum, Nav, EO, etc.), one of which is “Generic” (51M€)
- General Support Technology programme (GSTP)
 - 2009-2013
 - ~350M€
- Others
 - ARTES
 - telecommunications
 - Strategic Initiative
 - for under-return member states
 - Infrastructure
 - small investments and maintenance
 - General Studies Progr.
 - early studies
 - CTP, EGEP
 - other programme-related R&D

Spennis Outlook

- Next Generation Spennis (= the current project) is funded from GSTP-5
- Deployment in SSA system funded by SSA
- "Next" phase approach & content yet to be decided
- Issues include:
 - lessons learned & results of NG-Spennis
 - new model, tool and usability requirements
 - efficiency of delivery to users (timeliness, reliability)
 - interest of potential participants/collaborators

Related SSA/GSTP/TRP/other activities

- Space weather service developments
- Distributed Solar Imaging & Processing
- Virtual Space Weather Modelling Centre
- Open Data Interface
- Collaborative radiation shielding tool for JUICE (CIRSOS)
- Interplanetary Meteoroid Model
- Mars atmospheric model development
- Solar heavy ion modelling
- Radiation effects analysis for JUICE (Strin)
- Biological radiation effects tools

Shortly:

- GEO telecom radiation tool efficiency improvement*
- Space environment tool interoperability*
- High Accuracy SEE Tools*
- 3D Internal Charging Tool*

+ many instrumentation developments (solar imagers, radiation, plasma, B field, microparticle)

+ FP7 (generally “underpinning” = more research-oriented)

Domain Requirements/ Approach/Focus

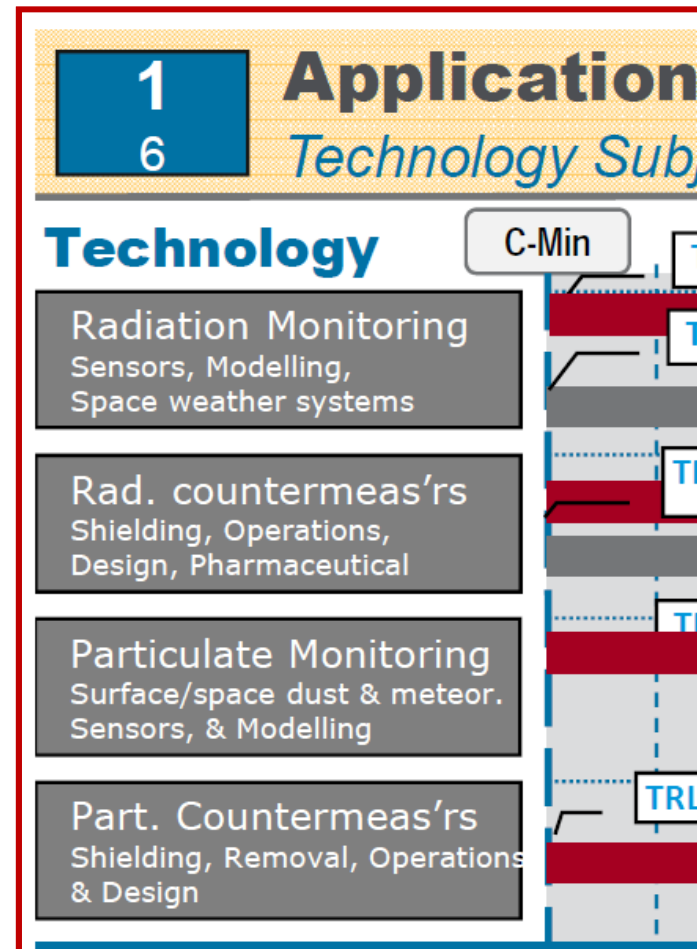
- Telecom
 - New platform technologies (efficiency, cost reductions)
- Human Spaceflight and Exploration
 - Based on technology roadmaps
- Navigation
 - Preparing for the next generation
- Science and Robotic Exploration
 - Driven by mission selection process (large, medium, small)

Technology for Exploration

Cross-cutting road-mapping action



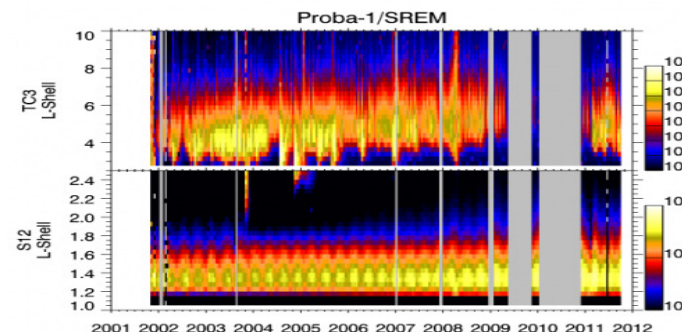
Aurora: en route to Moon en Mars. Credits: ESA



Next steps: identifying corresponding technology developments
 Transport codes; Shielding; Monitoring; Exploitation of GSI/FAIR

Recent Developments

- Selection of JUICE Jupiter mission in 2012:
radiation is a critical issue > new R&D activities
 - Improved shielding tools “iterative”, “collaborative”, accurate; implies more G4 ↔ CAD ↔ toolA ↔ toolB
 - Tailored measurement of high energy electrons (main threat);
 - Evaluations of risks, models, methods;
- Highly miniaturised (resolving) radiation monitoring realised
- GALILEO GIOVE-B mission terminated – end of excellent SREM data flow (4½ years);
 - Exploitation activities continue;
 - 2 x EMU radiation monitor to be launched 2014;
- SREM data exploitation growing:
e.g. 10 years on Proba:
- EPT launch on Proba-V



Outlook

- Continued growth in demand for tools (mission/techno trends)
- Spenvis and other IT systems:
move to distributed, collaborative environments
(not trivial either technically, organisationally or legally)
- Next TRP “selection round” in 2013 for implementation 2014-16
 - Some minor deltas were already made
to adapt to Science mission selections...
- “Ministerial” in Nov. 2012 confirmed many important programmes
 - Some R&D boost (GSTP-6); adjustments to the focus of GSTP-6
 - SSA evolution: space weather element reasonably well supported
 - Other programme evolutions:
 - Science L, M selections and new candidates - business as usual (+)
 - MPCV collaboration with NASA (++) ; lunar, ISS exploitation (~)
 - Galileo, Nav., Telecom., EO, Launchers generally positive results (+)