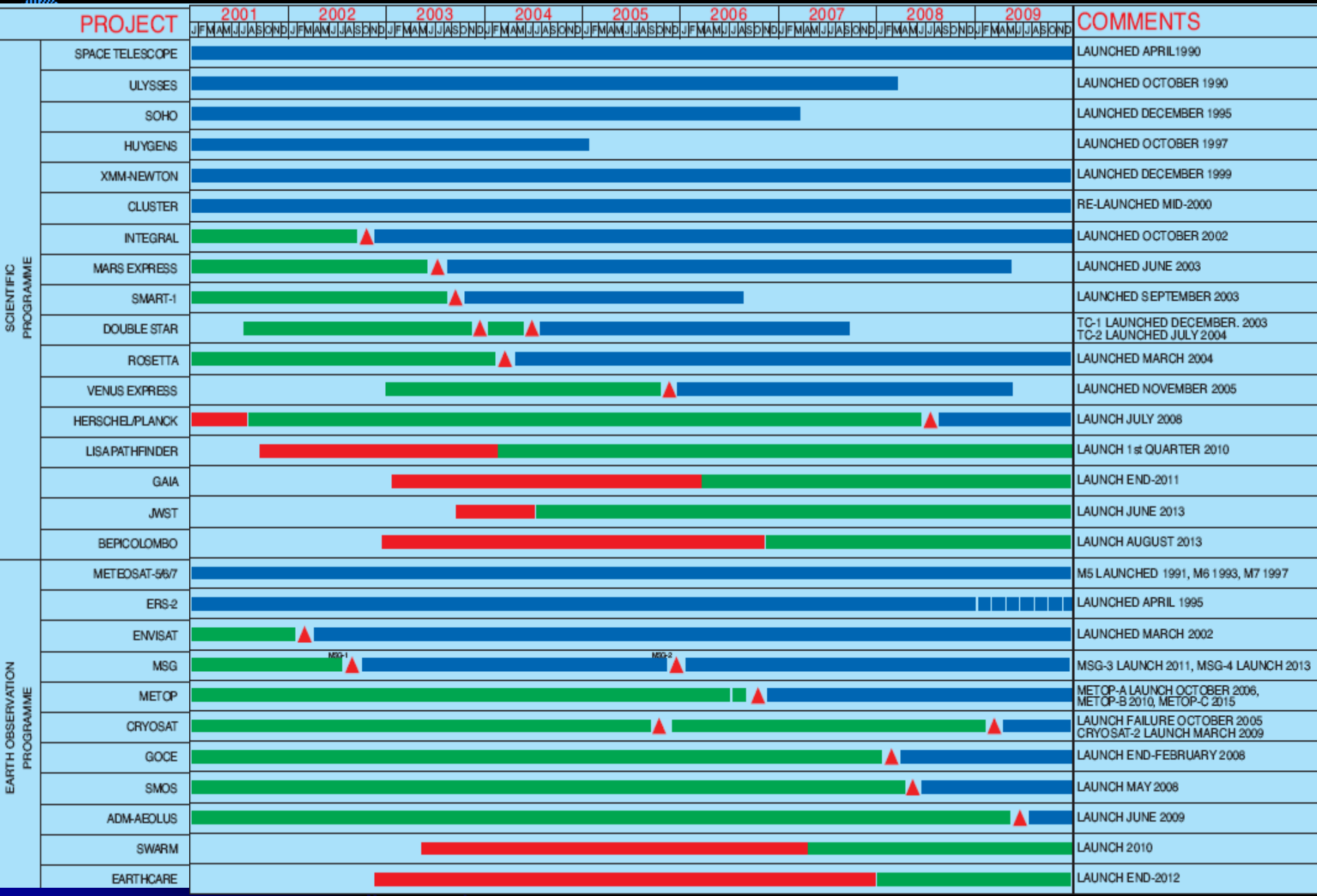
Workshop Context
Missions and their Support

E. Daly
on behalf of Space Environments and Effects Section

Outline

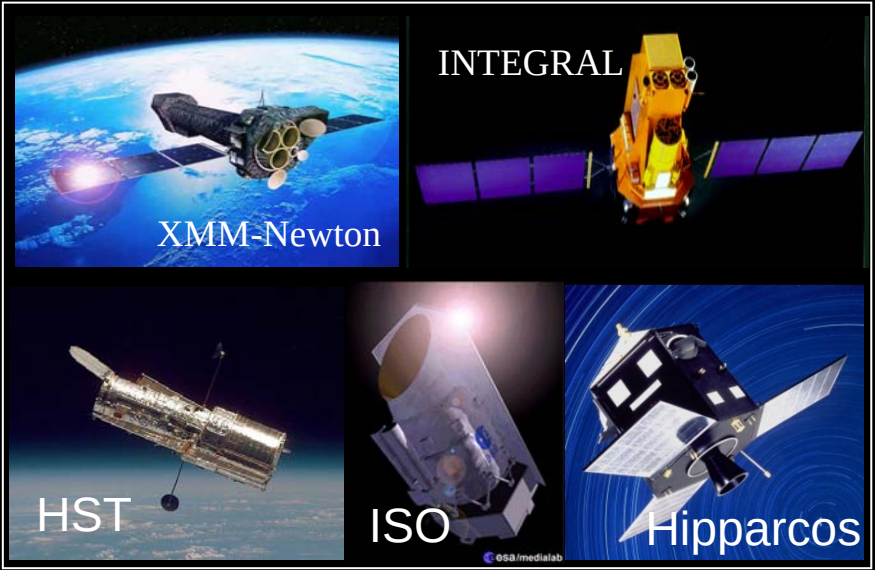
- Mission Review
- Effects
- Role of Measurements
- Things to aim at

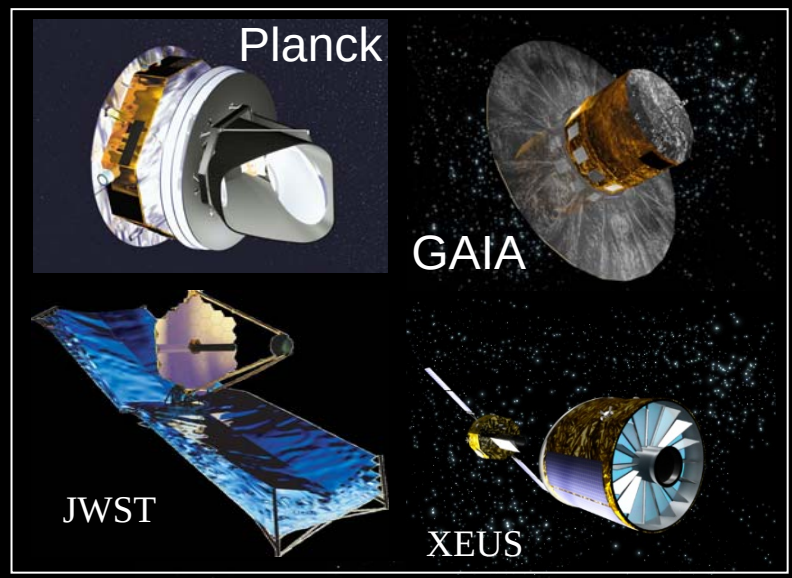

PROJECT
2001
2002
2003
2004
2005
2006
2007
2008
2009
COMMENTS
SCIENTIFIC PROGRAMME
SPACE TELESCOPE
LAUNCHED APRIL1990
ULYSSES
LAUNCHED OCTOBER 1990
SOHO
LAUNCHED DECEMBER 1995
HUYGENS
LAUNCHED OCTOBER 1997
XMM-NEWTON
LAUNCHED DECEMBER 1999
CLUSTER
RE-LAUNCHED MID-2000
INTEGRAL
LAUNCHED OCTOBER 2002
MARS EXPRESS
LAUNCHED JUNE 2003
SMART-1
LAUNCHED SEPTEMBER 2003
DOUBLE STAR
TC-1 LAUNCHED DECEMBER. 2003
TC-2 LAUNCHED JULY 2004
ROSETTA
LAUNCHED MARCH 2004
VENUS EXPRESS
LAUNCHED NOVEMBER 2005
HERSCHEL/PLANCK
LAUNCH JULY 2008
LISA PATHFINDER
LAUNCH 1st QUARTER 2010
GAIA
LAUNCH END-2011
JWST
LAUNCH JUNE 2013
BEPICOLOMBO
LAUNCH AUGUST 2013
EARTH OBSERVATION PROGRAMME
METEOSAT-5/6/7
M5 LAUNCHED 1991, M6 1993, M7 1997
ERS-2
LAUNCHED APRIL 1995
ENVISAT
LAUNCHED MARCH 2002
MSG
MSG-1
MSG-2
MSG-3 LAUNCH 2011, MSG-4 LAUNCH 2013
METOP
METOP-A LAUNCH OCTOBER 2006,
METOP-B 2010, METOP-C 2015
CRYOSAT
LAUNCH FAILURE OCTOBER 2005
CRYOSAT-2 LAUNCH MARCH 2009
GOCE
LAUNCH END-FEBRUARY 2008
SMOS
LAUNCH MAY 2008
ADM-AEOLUS
LAUNCH JUNE 2009
SWARM
LAUNCH 2010
EARTHCARE
LAUNCH END-2012

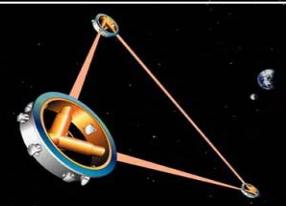

2001
2002
2003
2004
2005
2006
2007
2008
2009
J F M A M J J A S O N D
COMMENTS
COMMS./NAV. PROGRAMME
TECHNOL. PROG.
HUMAN SPACEFLIGHT, MICROGRAVITY & EXPLORATION PROGRAMME
LAUNCHER PROG.
ARTEMIS
LAUNCHED JULY 2001
ALPHABUS
LAUNCH 2011
SMALL GEO SAT.
LAUNCH END-2010
GNSS-1/EGNOS
OPERATIONS START 2007
GALILEOSAT
GIOVE-A
GIOVE-B
GIOVE-A LAUNCHED DEC. 2005
GIOVE-B LAUNCH END-2007, IOV 2009
PROBA-1
LAUNCHED OCTOBER 2001
PROBA-2
LAUNCH MAY 2008
SLOSHSAT
LAUNCHED FEBRUARY 2005
COLUMBUS
LAUNCH DECEMBER 2007
ATV
FIRST LAUNCH JANUARY 2008
NODE-2 & -3 & CUPOLA
LAUNCHES OCTOBER 2007 & APRIL 2010
CUPOLA WITH NODE-3
ERA
LAUNCH NOT BEFORE END-2009
ISS BARTER & UTIL. PREP.
MELFI 1
EDR/EUTEF/SOLAR
MELFI 2
EDR/EUTEF/SOLAR WITH COLUMBUS
EMIR/ELIPS
MFC
MSL
BIO, FSL, EPM with COLUMBUS
ASTRONAUT FLT.
AURORA CORE
EXOMARS
LAUNCH MID-2013
ARIANE-5
OPERATIONAL
VEGA
FIRST LAUNCH SEPTEMBER 2008
SOYUZ AT CSG
READY FOR LAUNCH DECEMBER 2008
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
STORAGE
LAUNCH/READY FOR LAUNCH
OPERATIONS
ADDITIONAL LIFE POSSIBLE

Astrophysics Missions

- γ, X, UV, IR, sub-mm missions, past & future →
- Each special measurement technique responds to the radiation environment in a different way
- Problems include
  - "background"
  - detector damage
- **past** missions: often in orbits passing through the **radiation belts**
- next generation of major missions take place at **L2**:
  - JWST (IR), Herschel (Far-IR), Planck (sub-mm), GAIA (visible) and XEUS (X-ray)
- radiation exposure minimization
  major mission design driver
- "**fundamental physics**" missions to detect gravitational waves & test relativity are planned.:
  - Sensitive measurement systems susceptible to radiation induced interferences.
  - E.g LISA mission to detect gravitational radiation: triangular formation of spacecraft separated by **5×10^6 km**
    - sensing elements free of disturbances to a level of **1.8 nm $Hz^{-1/2}$**.

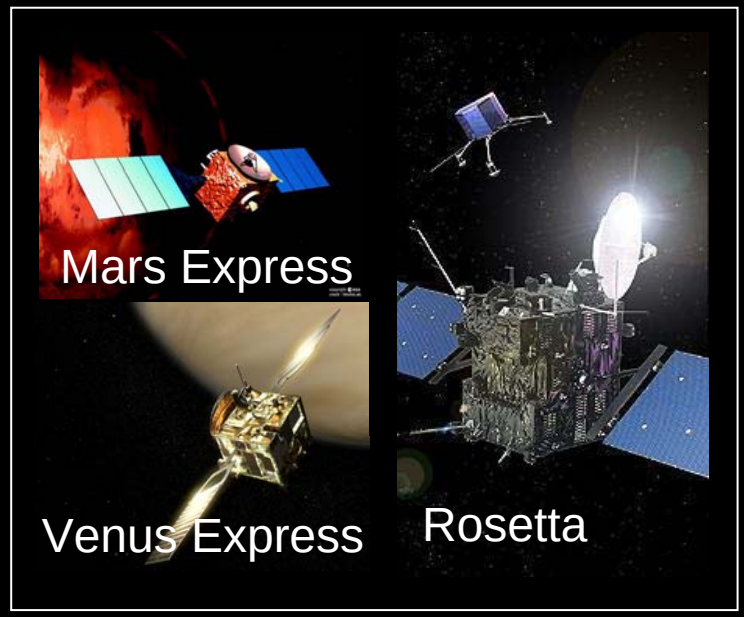


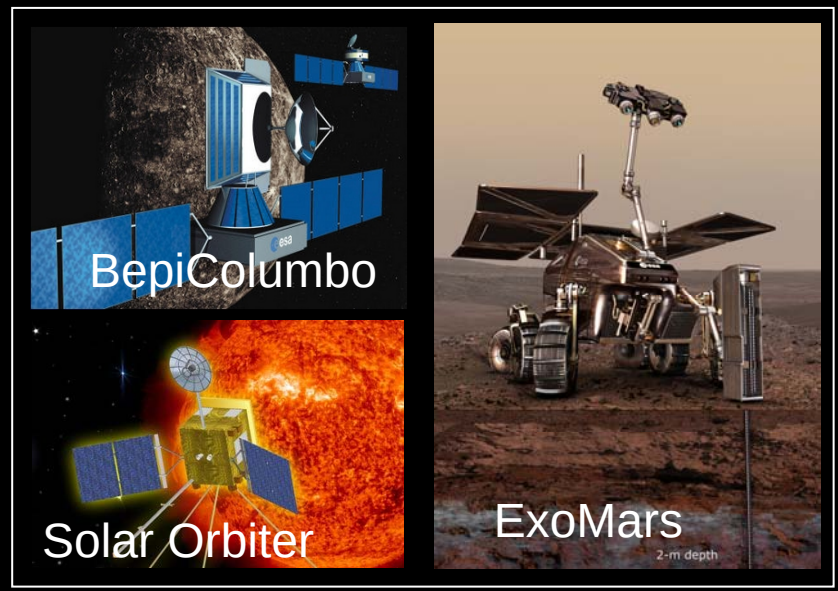




Solar System Science & Exploration Missions

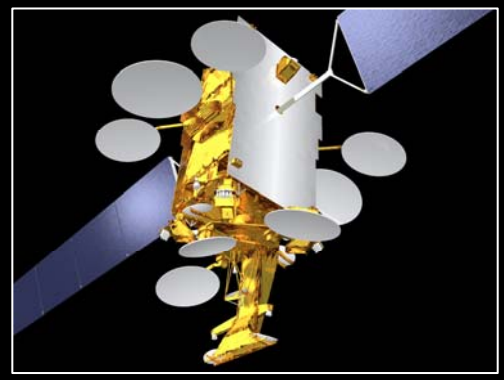
- Missions to other planets need to take account of local environments
  → **Jupiter & Saturn**
  have strong radiation belts;
- Venus, Mars: no magnetosphere;
- Mercury: weak magnetosphere;
- But:
  - ✓ concern that **solar particle events could be significantly stronger at Mercury** (~0.3AU from Sun) than at Earth;
  - ✓ operations on **surfaces of planets** (Mars, Moon) need to take account of the modifying effects of the atmosphere and surface material on the primary radiation.





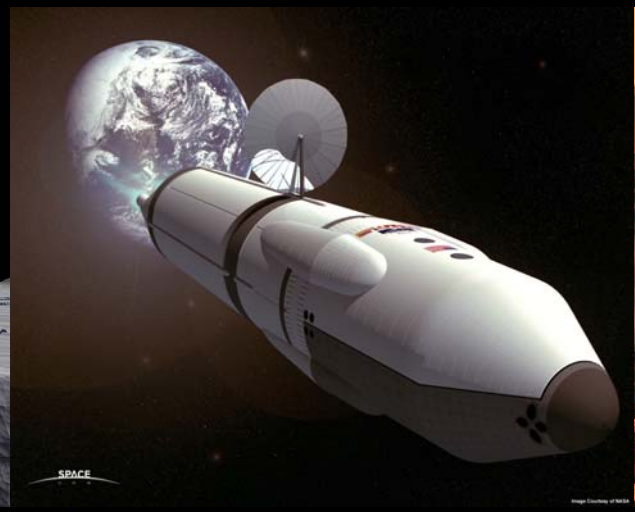
Commercial, Applications & Earth Observation Missions

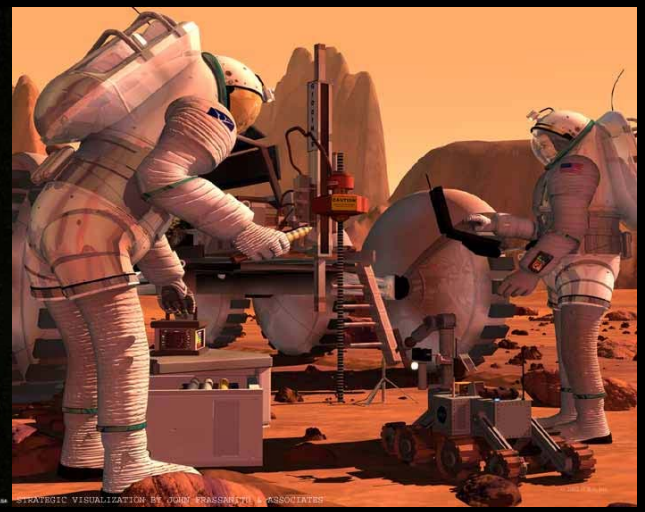
- **Telecommunications** spacecraft in GEO:
  - environment dominated by energetic e^- of the outer radiation belt;
  - High lifetime dose
- Low altitude constellations (e.g. **Globalstar** at 1400km)
  - Mixed environment; High lifetime dose
- **Earth observation** and Earth science:
  - "sun-synchronous" polar orbit ~600-900 km; Mixed environment
- **Navigation** systems
  - medium altitude, highly inclined, circular orbits.
  - Galileo at ~25000km and ~55º incl. → heart of the radiation belts.
- **Trends** have major radiation implications:
  - ↑complexity of on-board systems;
  - ↑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.



Manned Missions

- Manned missions have their own special radiation issues.
- Radiation exposure on long duration missions is one of the main mission design drivers
  - *design of habitats should minimize doses from Cosmic Rays*
  - *special measures to warn and protect from solar particle events will also be necessary*
- Electronic and other systems supporting manned missions also have to have high reliability & radiation hardness.





Radiation Effects

Environment	Effects
Cosmic Rays	Upsets in electronics; Long-term hazards to crew; Interference with sensors;
Solar Energetic Particle Events	Radiation damage of various kinds; Upsets in electronics; Serious prompt hazards to crew; Massive interference with sensors;
Radiation Belts	Radiation damage of various kinds; Upsets in space electronics; Hazards to astronauts; Considerable interference with sensors; Electrostatic charging and discharges

Issues

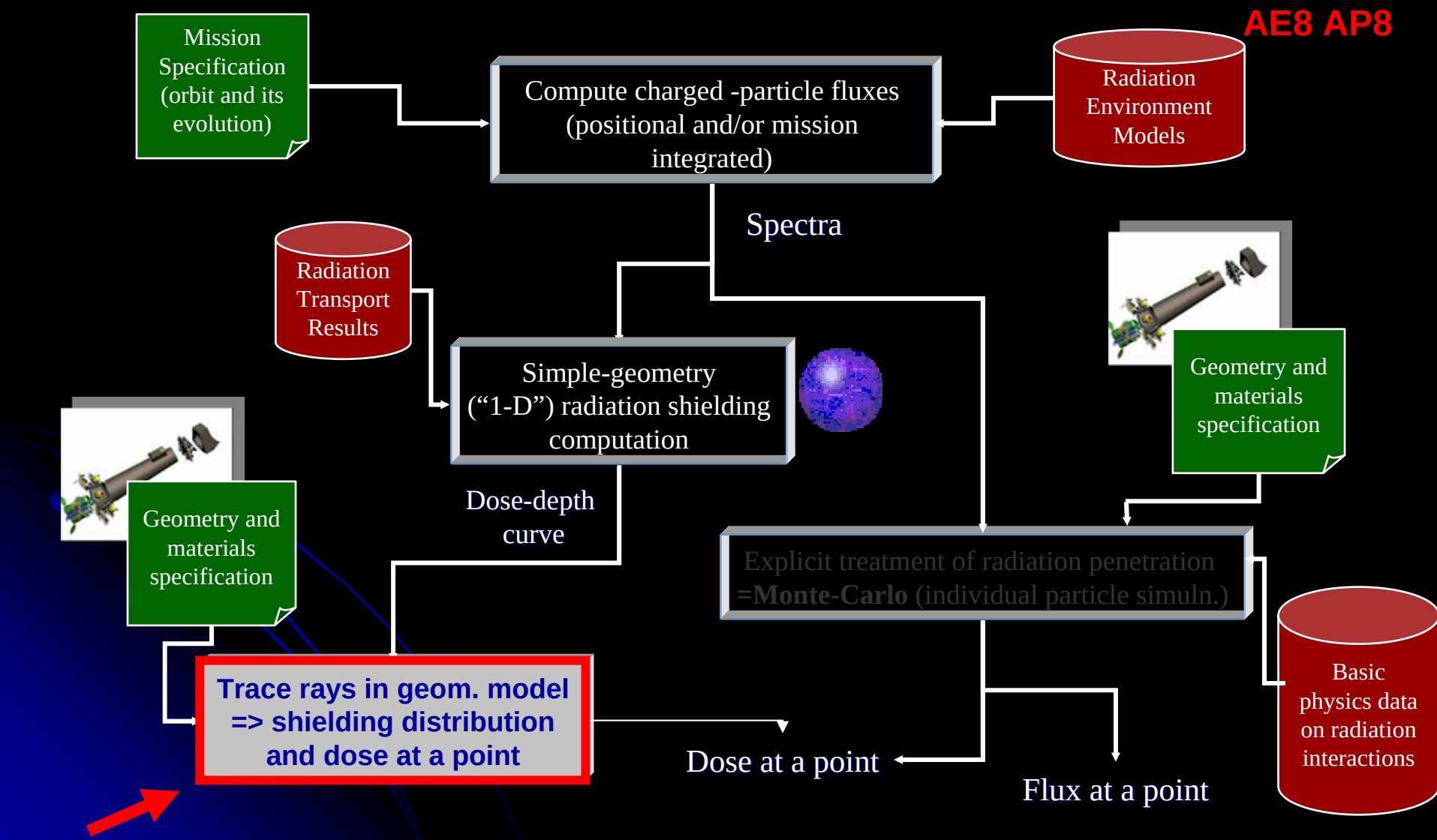
- Environment models (fluxes vs. E) - the starting point
- Transport of radiation through spacecraft
- Effects

In-flight experiments must address all 3
and validate methods of:

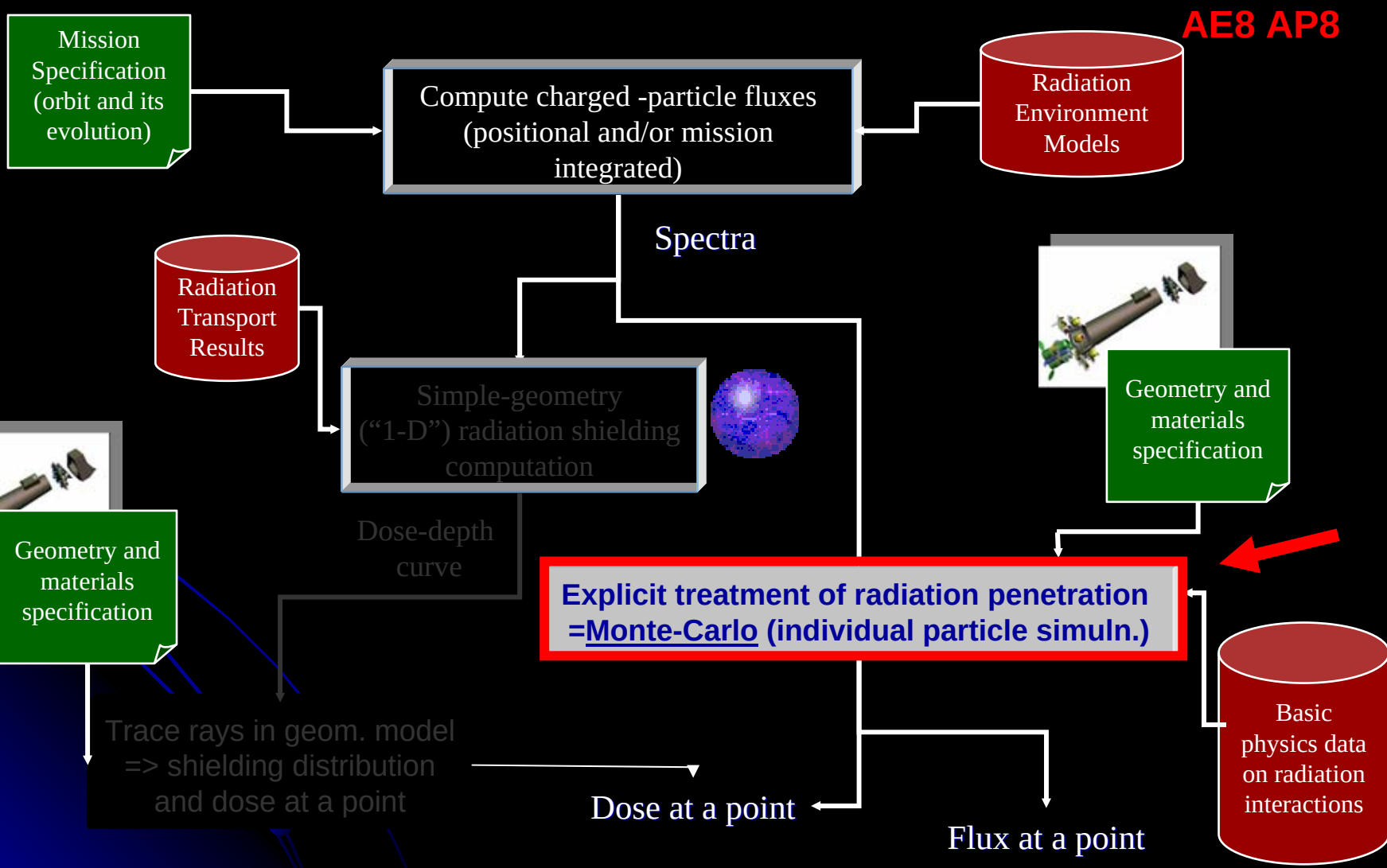
- Analysis (computational tools, models)
- Ground-based testing
  (we do not closely represent the space environment in tests)

& identify uncertainties and margins

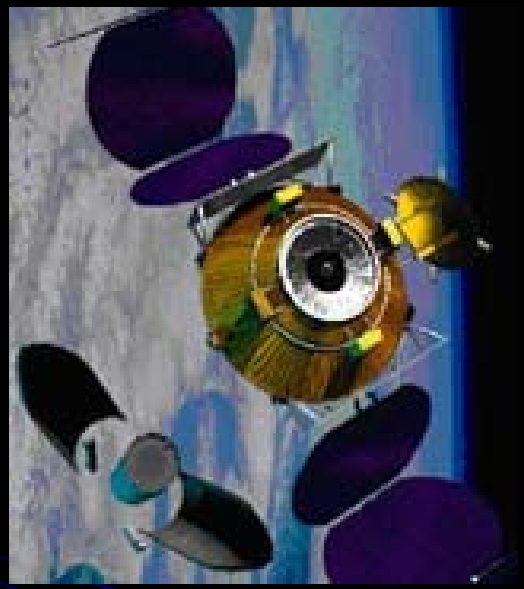
Example:
Processes for Calculation of Dose and Flux



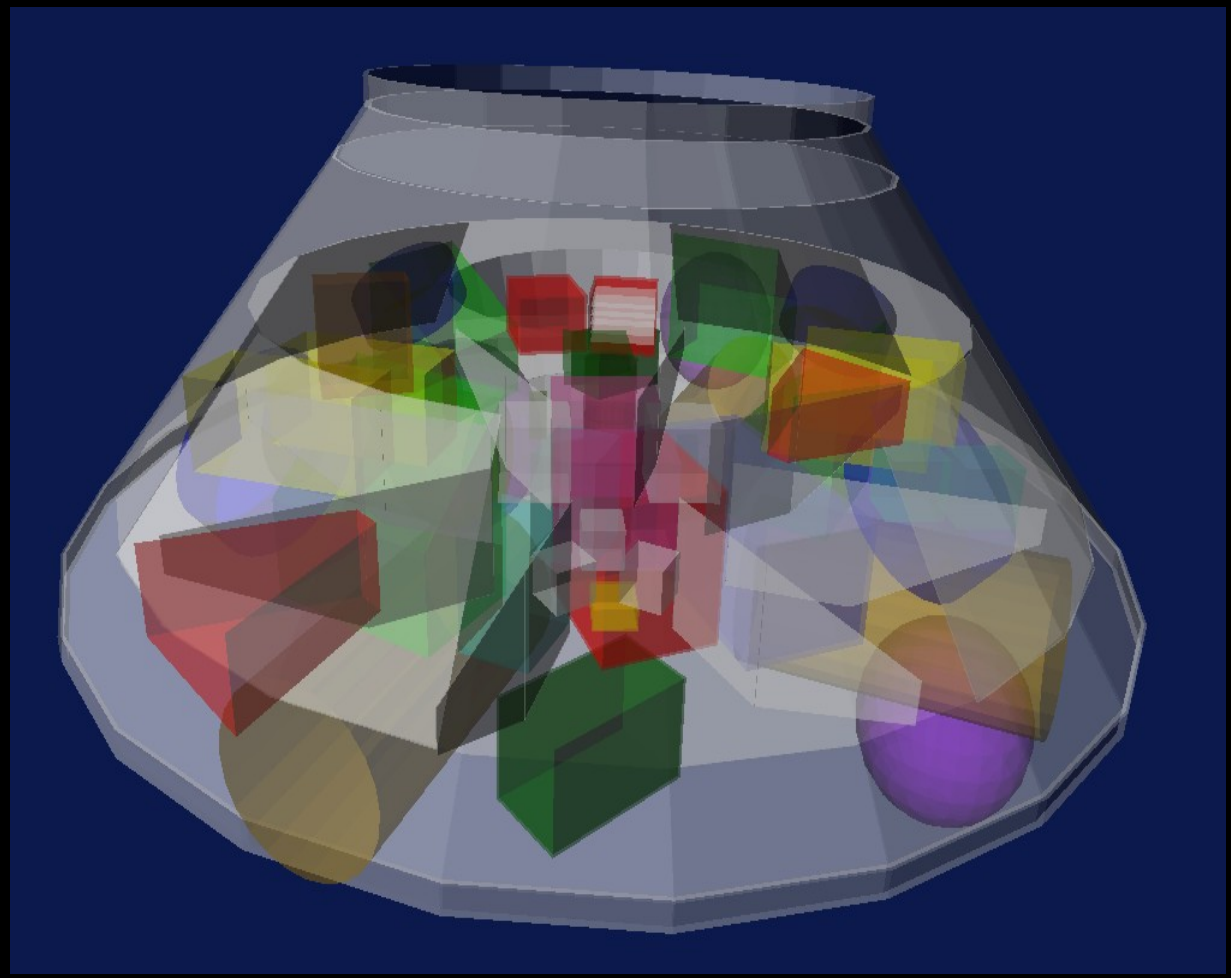
Basic Processes for Calculation of Dose and Flux



ConeXpress



Electric propulsion to GEO, rendezvous with client spacecraft



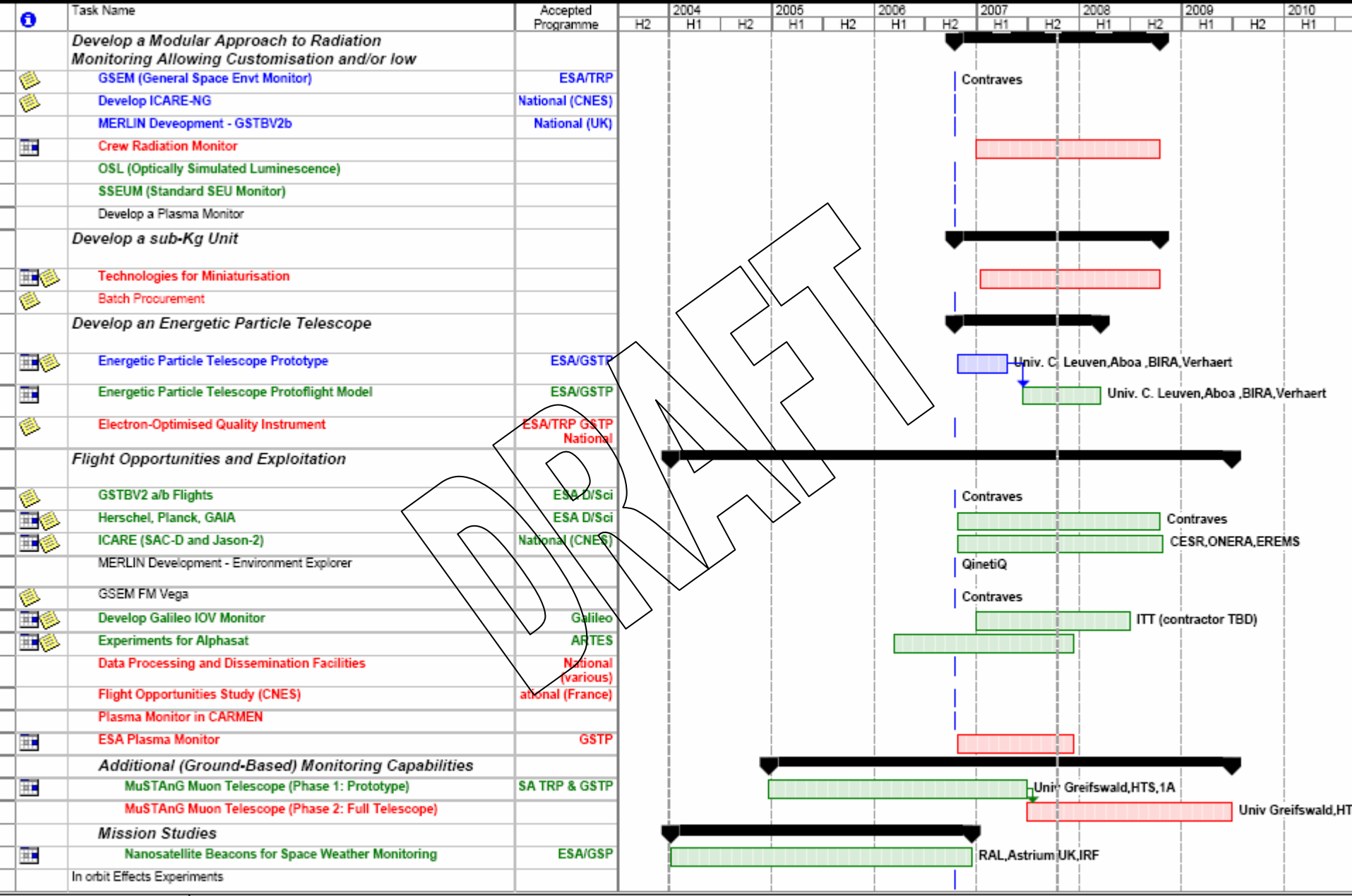
GEANT4 modelling by R. Lindberg, (ESA) –see IEEE TNS Dec. 2006

Measurements

- Address platform requirements (alerts, operations, housekeeping)
  - e.g. Astrophysics missions XMM, Integral, GAIA, LISA, BepiColombo…
  - Manned missions: astronaut dosimetry;
- Provide data to investigate effects
  - e.g. Meteosat-2; Meteosat-3; Technology Missions; LISA
  - Technology effects test-beds (AEEF, CTTB)
- Provide data important &/or poorly covered regions:
  - e.g. Galileo; Globalstar; GEO; PEO; Jupiter; Mercury; Mars
- Provide data for wider “community” application
  - e.g. GOES
- Dedicated “science-class” instruments on appropriate platform
  - ultimate solution to modelling needs (e.g. electron spectrometer on GTO spinner)
- Crucial: costs of (miniature, standard, “science”) equipment and integration
- Data: calibration; metadata; storage; dissemination?

R&D

- Roadmapping done in 2005-2006 via the *harmonisation* process
- ESA *DRAFT* Plan 2008-2010 for TRP/GSTP developed by internal decision making process (boards)
- Inputs to this process are derived from consultations (e.g. project requirements, harmonisation, SEENoTC, workshops, ECSS WGs, …)
- Updated roadmapping being performed via SEENoTC WG
- This workshop feeds the process



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Tue 16/10/07

Planned Activities (excluding running activities)

07

- MEO radiation environment models
- Jupiter radiation environments and effects
- Space Weather data systems
- Shielding Tool (rapid prototyping toolkit)
- Rapid reverse Monte-Carlo tool
- Investigation and analysis of very high energy accelerators for radiation simulation
- Development of a predictive discharge numerical model on solar panels
- GEO-LEO radiation environment models

08-10 ***DRAFT***

Science Domain

- (*selection delayed until programme finalisation early 2008*)

Manned Domain

- Physics models for bio. effects of rad. & shielding
- Radiation shielding by ISRU and/or innovative composites for EVA, vehicles and habitats

Telecommunication Domain

- Slot Region radiation environment

Navigation Domain

- Highly miniaturized active MEO radiation monitor
- Energetic electron shielding, charging & rad. effects
- Dose enhancement in high electron environment as source of under-prediction

Generic Domain

- Highly miniaturized radiation monitoring
- Reduction of margins in radiation analysis
- Simplified MEO/GEO tools for spacecraft charging

A flavour of the process: Rad Env. & Eff. proposals (red were retained)

Physics models for biological effects of radiation and shielding
Solar electrons as precursors for solar energetic particle radiation
Space Weather Radiation Hazard Monitoring and Prediction beyond LEO
High-LET solar particle event models
Radiation shielding by ISRU and/or innovative composites for EVA, vehicles and habitats.
EVA miniature dosimeter
EVA miniature dosimeter ph 2
Induced environment and effects from nuclear propulsion
Small GEO Platform radiation monitor (GEPRAM)
Combined compact environment sensor for GEO
Slot Region radiation environment
Sensors for EMP and burst effects
Tools for nuclear burst effects analysis
Space Weather Operations Support for telecoms
Galileo Radiation and Plasma Programme (GRAPP)
Compact Electron Spectrometer
High Fidelity Electron in-flight cross-calibration
Galileo Plasma Monitor
Highly miniaturized active MEO radiation monitor Ph.A-B
Highly miniaturized active MEO radiation monitor Ph.C-D
Improvement of radiation dose model for MEO
Internal charging enhancement environment in MEO
Data-driven flux models of the MEO radiation environment
Energetic electron shielding, charging and radiation effects
Design techniques to improve radiation hardness of key systems in Navigation spacecraft
Low-dose rate effects on radiation measurements
Dose enhancement in high electron environment as source of under-prediction
Highly miniaturised radiation monitoring ph A-B
Highly miniaturised radiation monitoring Ph C-D
Recuction of margins in radiation analysis
Simplified standard MEO/GEO tools for spacecraft charging
Engineering and physics models for SEE
ESD/transients monitor
Radiation monitor joint calibrations, test activities, simulations, and pre-developments
Radiation monitor data analyses and model development for the near-Earth environment
3-D effects in internal charging
Prediction of ESD charcteristics
Combined surface and internal charging
Detailed investigation of material parameters for internal charging
Models of radiation belt enhancements on different timescales.
Models of radiation belt enhancements for large planelts
Radiation Belt Crossing Time Forecaster
CME Interception Warning System
Engineering tool for Non Ionising Energy Loss

Other Activities

- Galileo:
  - GIOVE-A, -B measurements
  - Procurement of environment measurement equipment for IOV phase
- Alphasat environment monitoring with effects experiment still in discussion
- BepiColombo: Multi Functional Spectrometer MFS (radiation monitor) procurement in progress
- Space Weather: Follow on to *Pilot Project* under discussion as part of preparations for Ministerial ‘08
- Standards development: ECSS; ISO

So?

We (the community) (probably) need to:

- Identify requirements (or “maintain” existing ones of ESCC);
- Identify and exploit available data;
- Find ways of data (& equipment) sharing which do not conflict with legitimate commercial/intellectual interests;
- Rationalise programmes;
- Address problems of “access to space” (policies, attitudes, costs)
- Make recommendations…(use the channel(s))