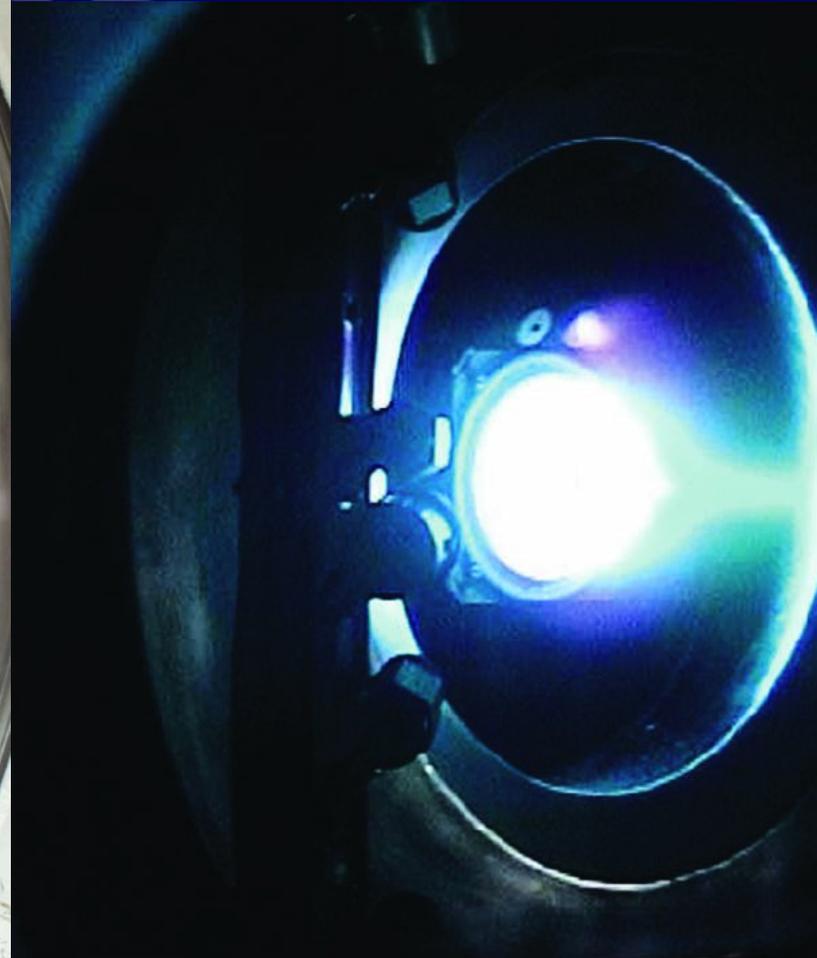
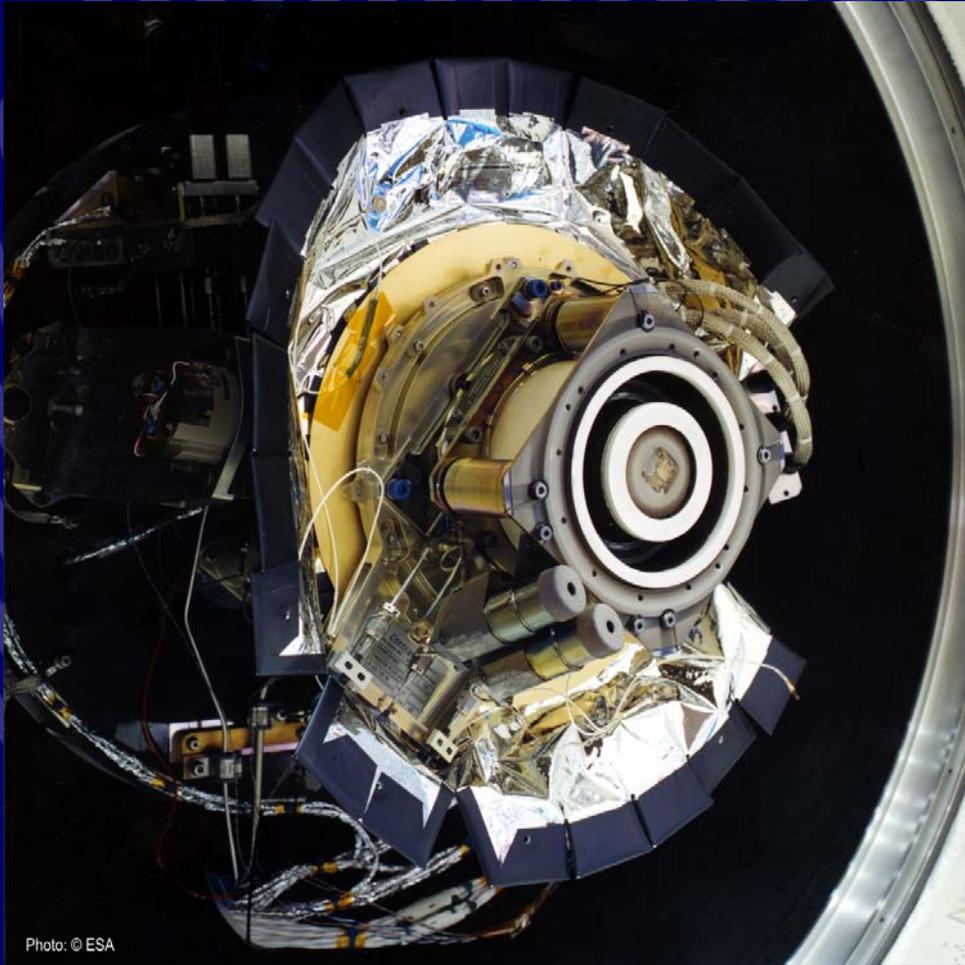


SMART-1 ***Reserve slides***

Electric Primary Propulsion: 7 g thrust, 60 liters Xenon fuel to the Moon



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Europe to the Moon

 **United States (US)**
General Dynamics: Hydrazine Propulsion System
Ithaco Space Systems Inc: Reaction wheels
L3 Communications: Electrical Ground Support Equipment
TECSTAR: Solar Cells

 **United Kingdom (UK)**
Rutherford Appleton Laboratory: Compact imaging X-ray spectrometer (D-CDS)

 **The Netherlands (NL)**
Fokker Space: Solar Arrays
TNO/TPD: Sun acquisition sensors

 **Belgium (B)**
Spacebel S.A: On-board software detailed design
Alcatel ETCA SA: Electric propulsion power processing

 **France (F)**
SAFT Division Defence et Espace: Batteries
Snecma Moteurs: Solar Array Mechanisms, Electric Propulsion System (EPS)
ATERMES: Electric propulsion pressure regulation
Arianespace: Launcher (Ariane 5)

 **Spain (E)**
Alcatel Espacio: S-band transponder
CRISA: Battery management electronics

 **Finland (FIN)**
Finnish Meteorological Institute: Space plasma electron and dust detection (SPEDE)

 **Sweden (S)**
Swedish Space Corporation: Prime Contractor
Oruulveys Instruments AB: Power Control and Distribution Unit
SAAB Ericsson Space AB: Flight Module Assembly Integration and Testing, Antennae, Remote Terminal Unit, Electromagnetic Compatibility, Thermal Subsystem

 **Denmark (DK)**
Tormo A/S: On-board Independent Software Validation
DTU Technical University of Denmark: Star tracker

 **Germany (D)**
Astrium GmbH: Deep space X/Ka-band (KaTE)
MPI Aeronomies: Near Infrared Spectrometer (SIR)

 **Switzerland (CH)**
APCO Technologies SA: Structure and Mechanical Ground Support Equipment
Contraves Space AG: Electric propulsion mechanism
CSEM: Asteroid-moon micro imager (AMIE)

 **Italy (I)**
LABEN SpA: Electric Propulsion Diagnostic (EPDP)
RSIS: Radio science investigation (RSIS)

The Launch

- V162 lift-off on 27 September 2003 at 23:14:39 UTC – The launch was perfect
- SMART-1 separated at 23:56:03 into a GTO (656 x 35,881 km): perfect injection
- 100 s later telemetry was received by Perth GS
- Automatic activation sequence worked flawlessly



Technology Achievements

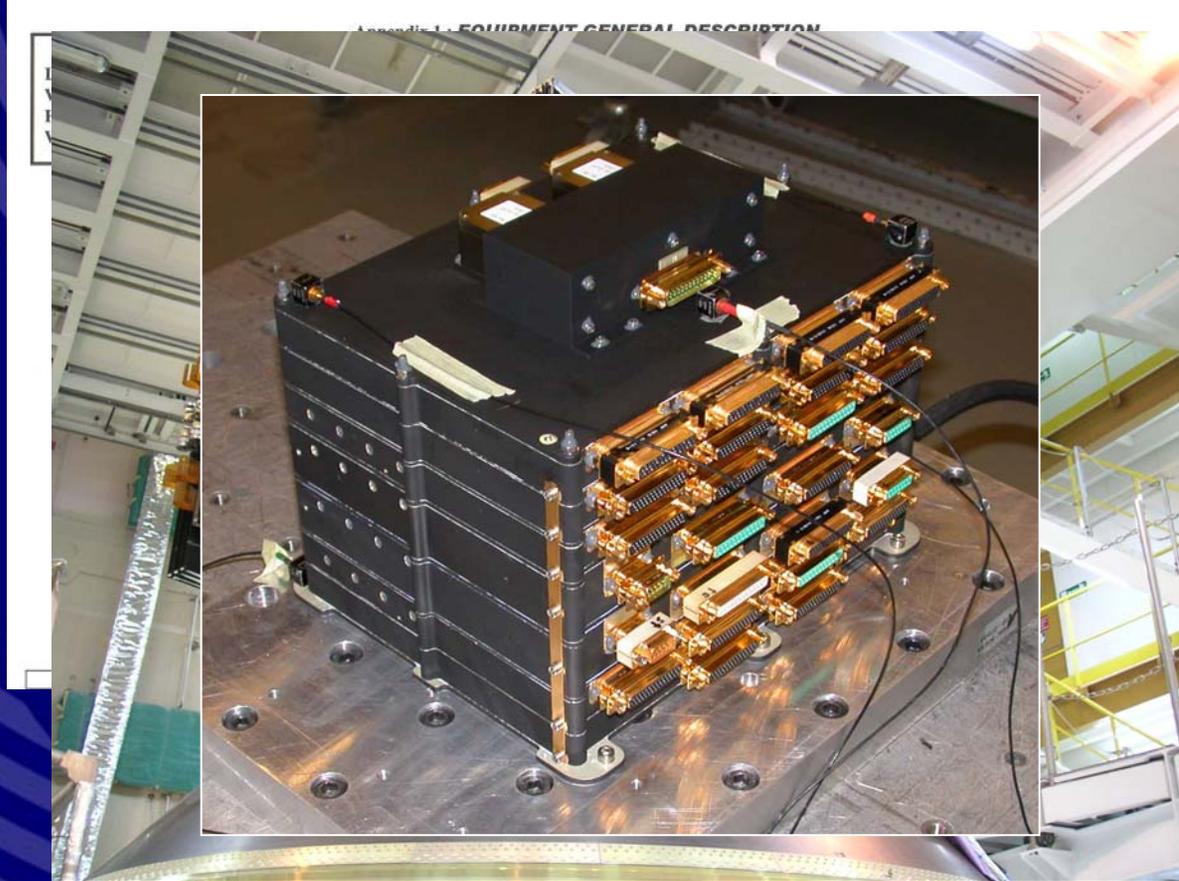
Technology objectives fully achieved, through:

- Flight Earth-Moon powered by Solar Electric Primary Propulsion and making use of the lunar gravity assists and weak stability boundaries;
- Technology demonstration
 - advanced communications (Ka-band, Laser Link),
 - autonomy, novel navigation,
 - miniaturisation of instruments
 - spacecraft technologies (batteries, solar cells, computer, software)

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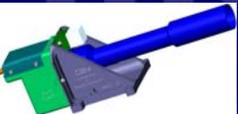
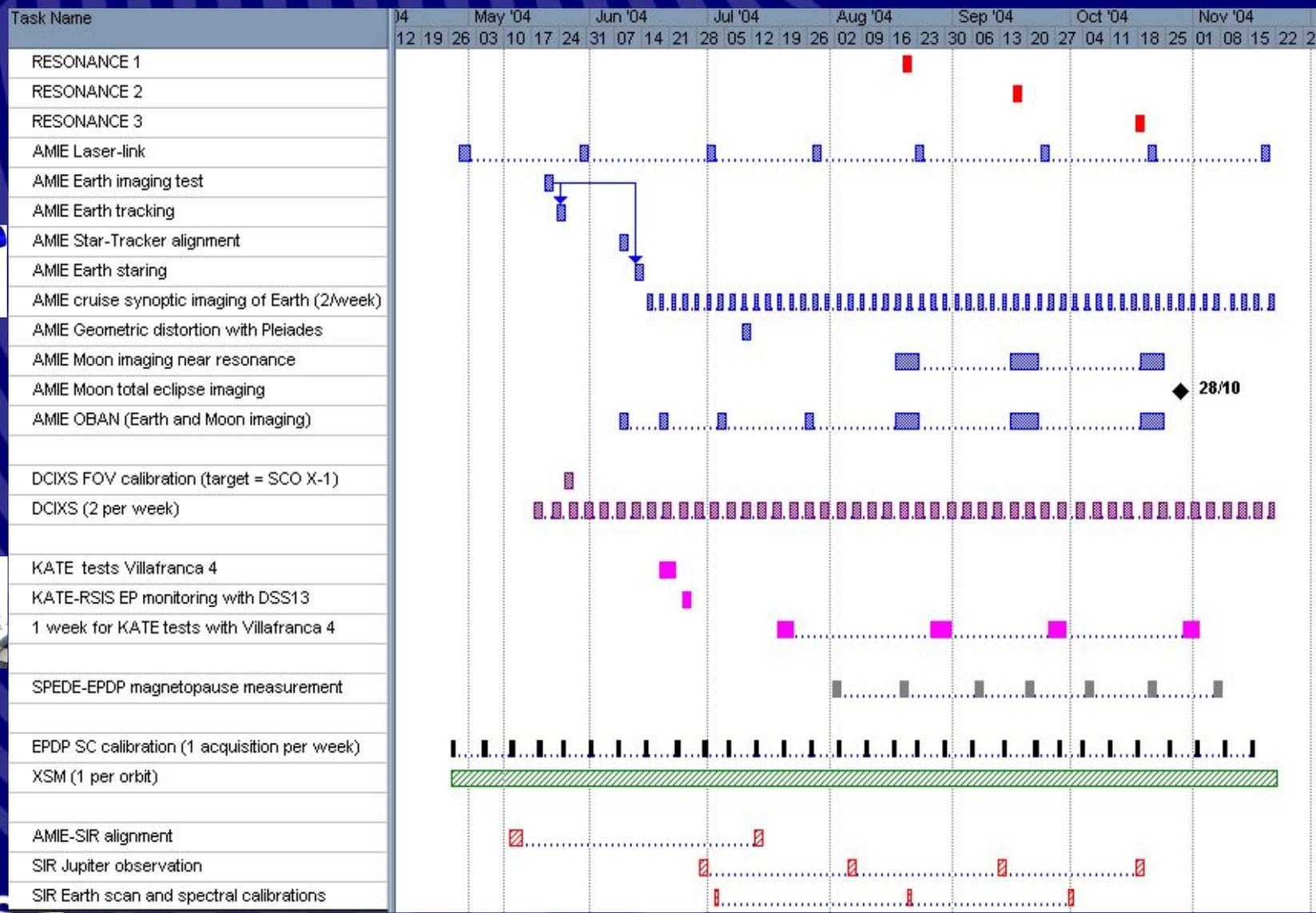
Spacecraft Technology

- New type of batteries, which allowed the spacecraft to withstand eclipses longer than expected,
- New types of solar cells, which resisted very well to the heavy bombardment in the radiation belts
- Compact onboard computer,
- Sophisticated SW which allowed to solve problems

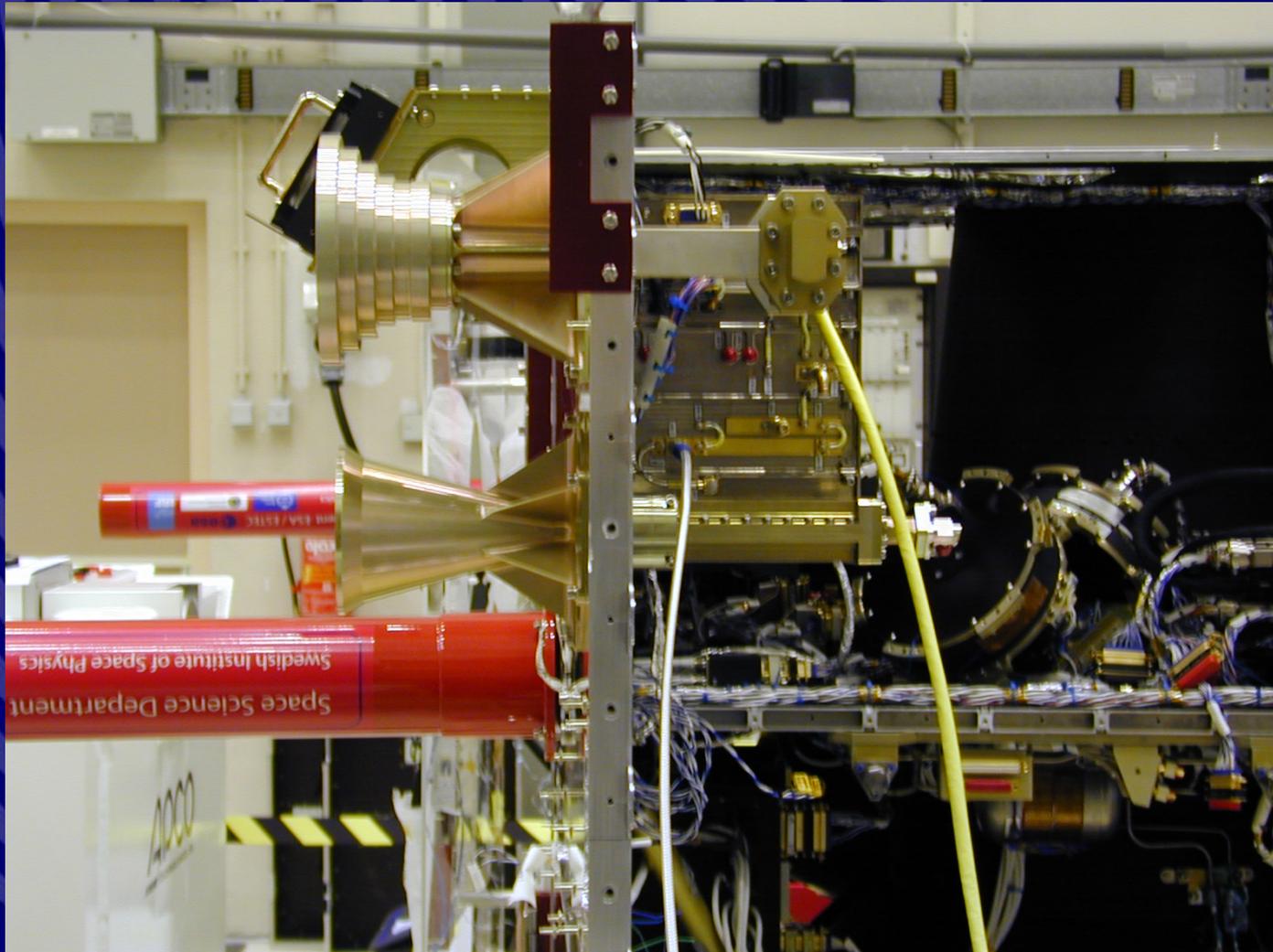


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Cruise April-Nov 04 planning: a Smart musical score



Communication Technology: Ka-band



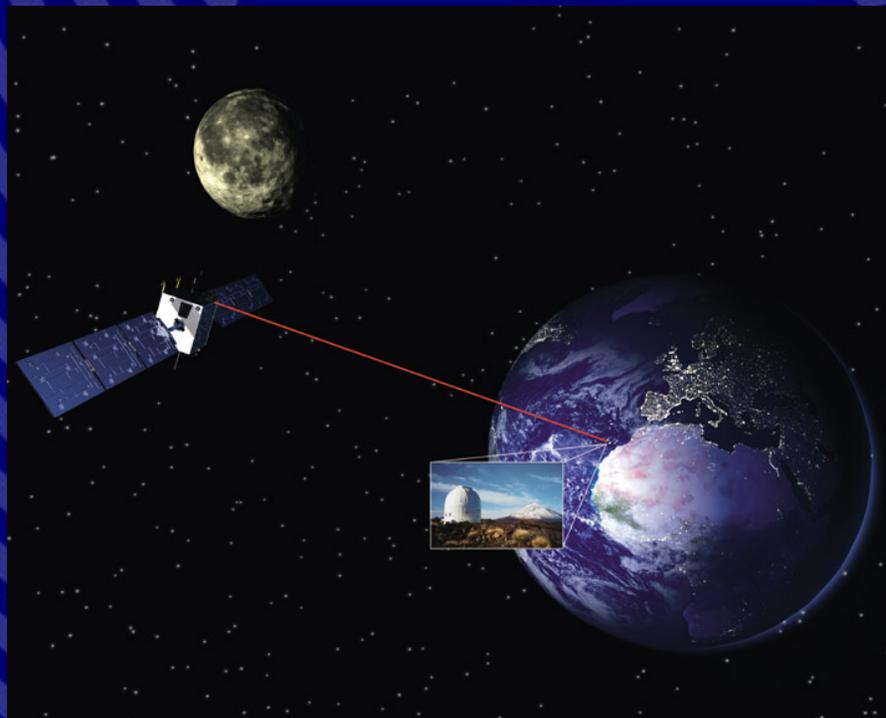
© 2005 SPC

KaTE ground station



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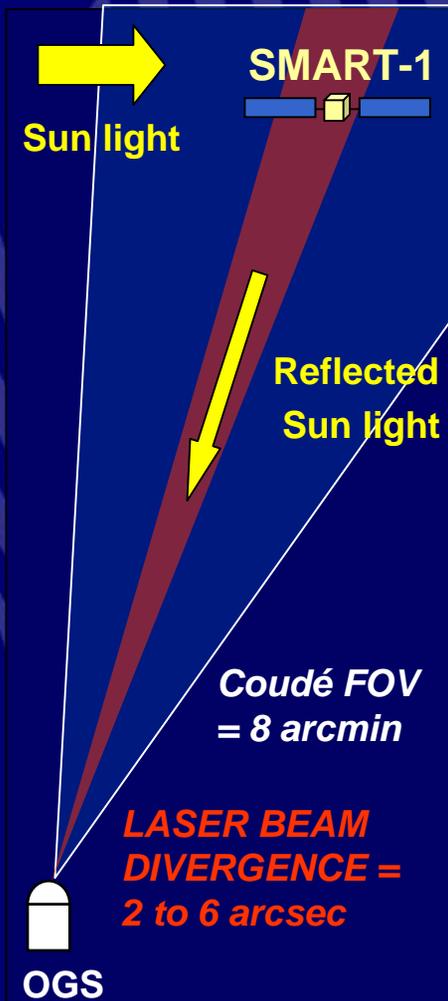
Laser Link experiment



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Laser Link

Demonstration for future deep space optical communication



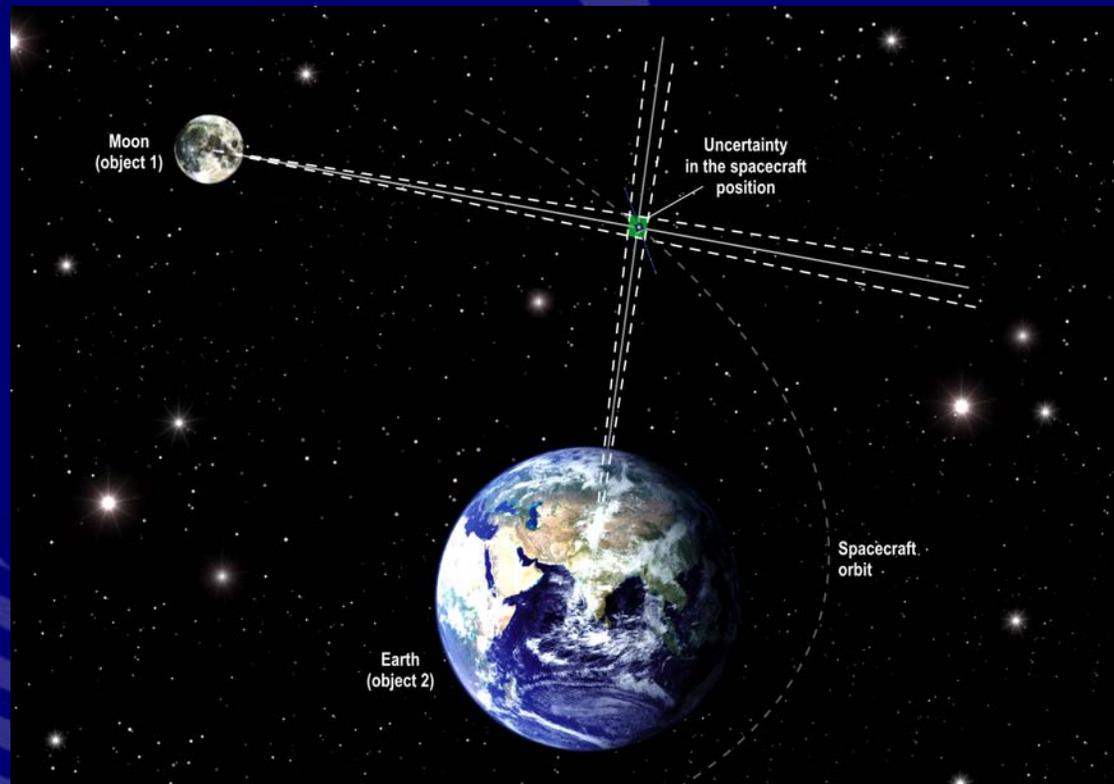
- Determination of an accurate alignment procedure
- Characterization of laser beam propagation through atmosphere & space for various link distances and elevations



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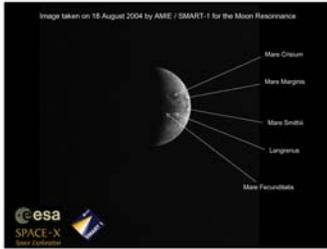
OBAN

- AMIE camera and the Star Tracker are used to make images of solar system objects
- By triangulation determine the position and the velocity of the spacecraft



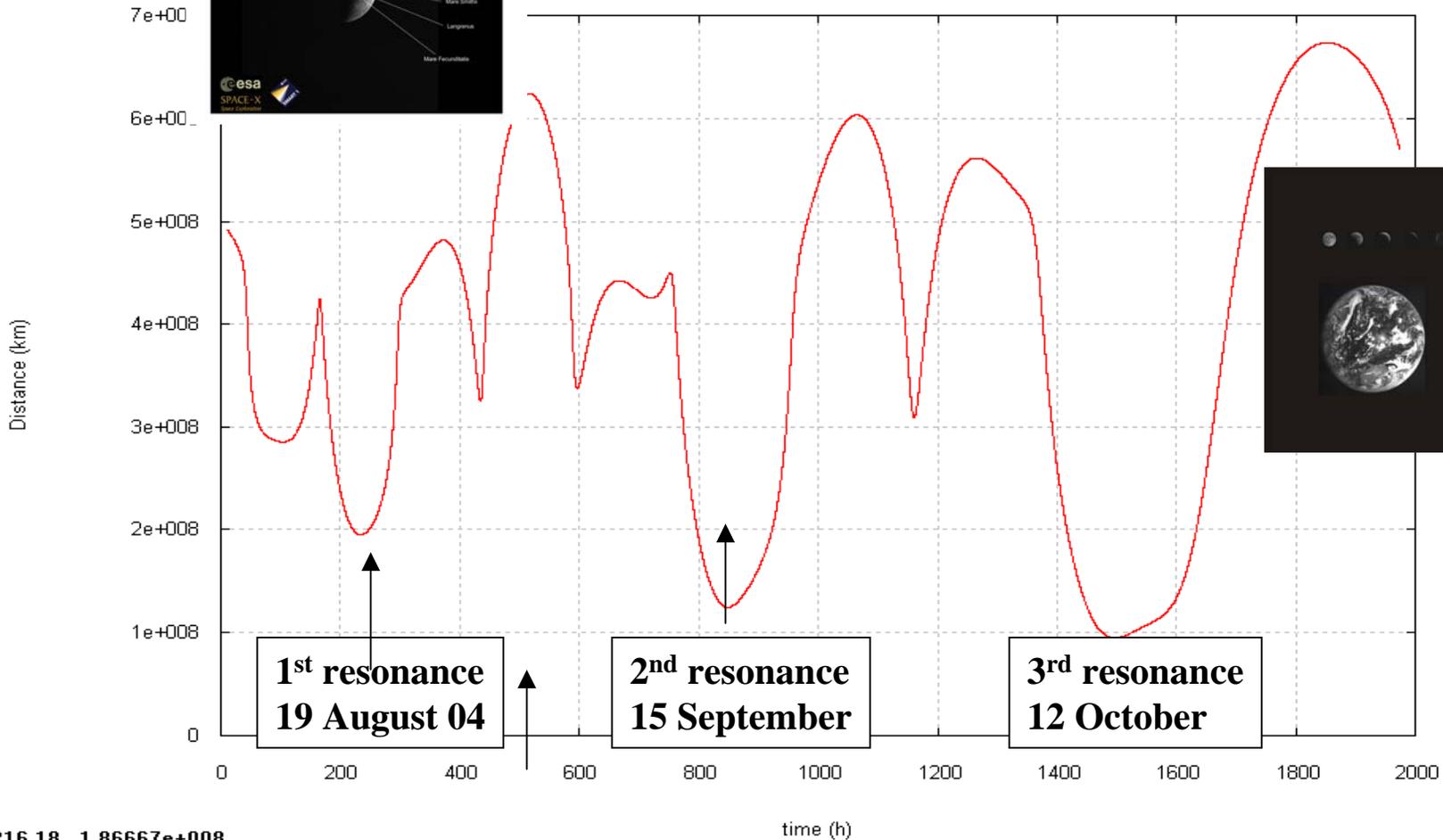
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From resonances to eclipses: SMART-1 Distance to the Moon



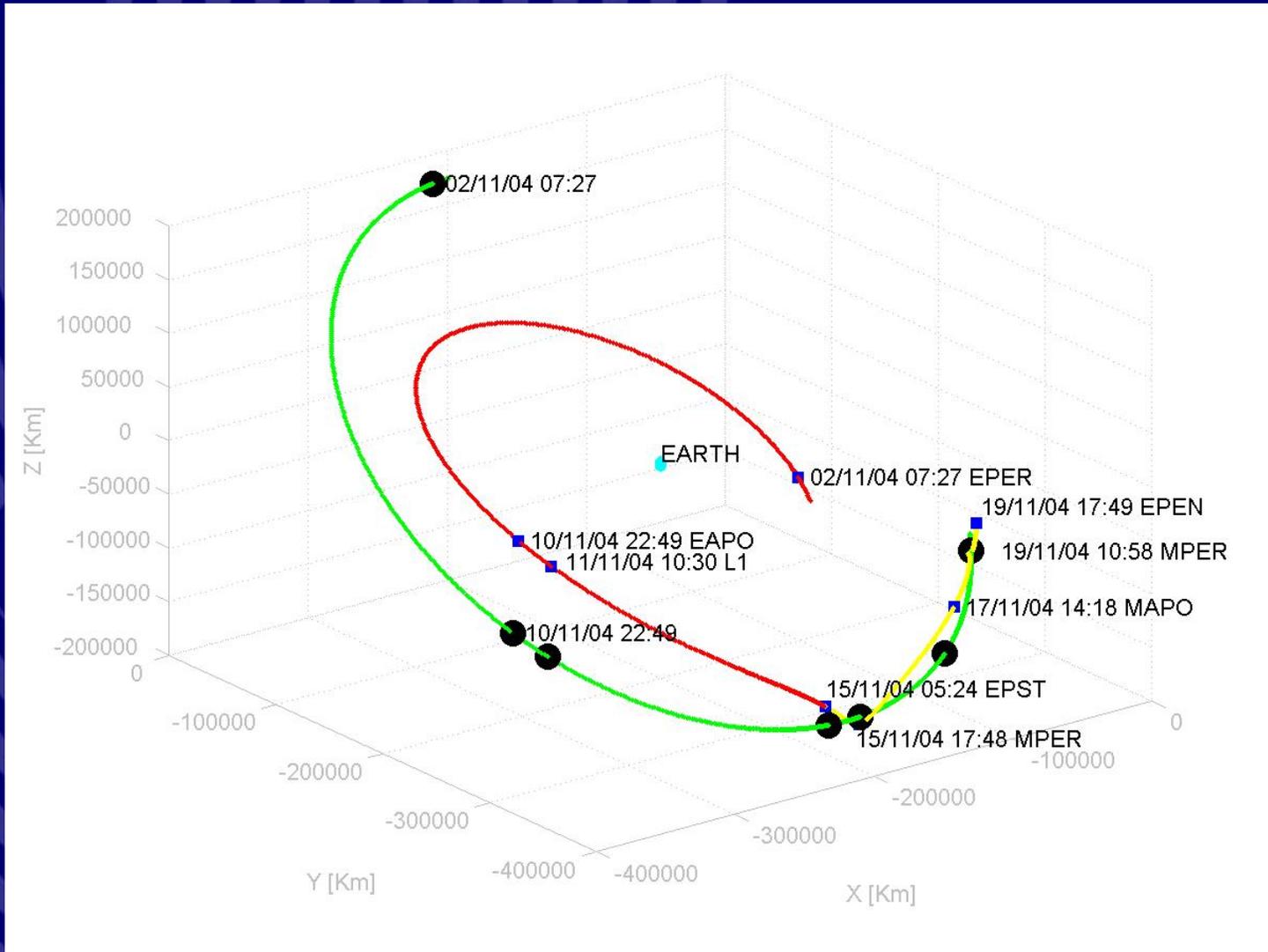
**Lunar eclipse
28 October**

Distance Moon surface - S/C since 10/08



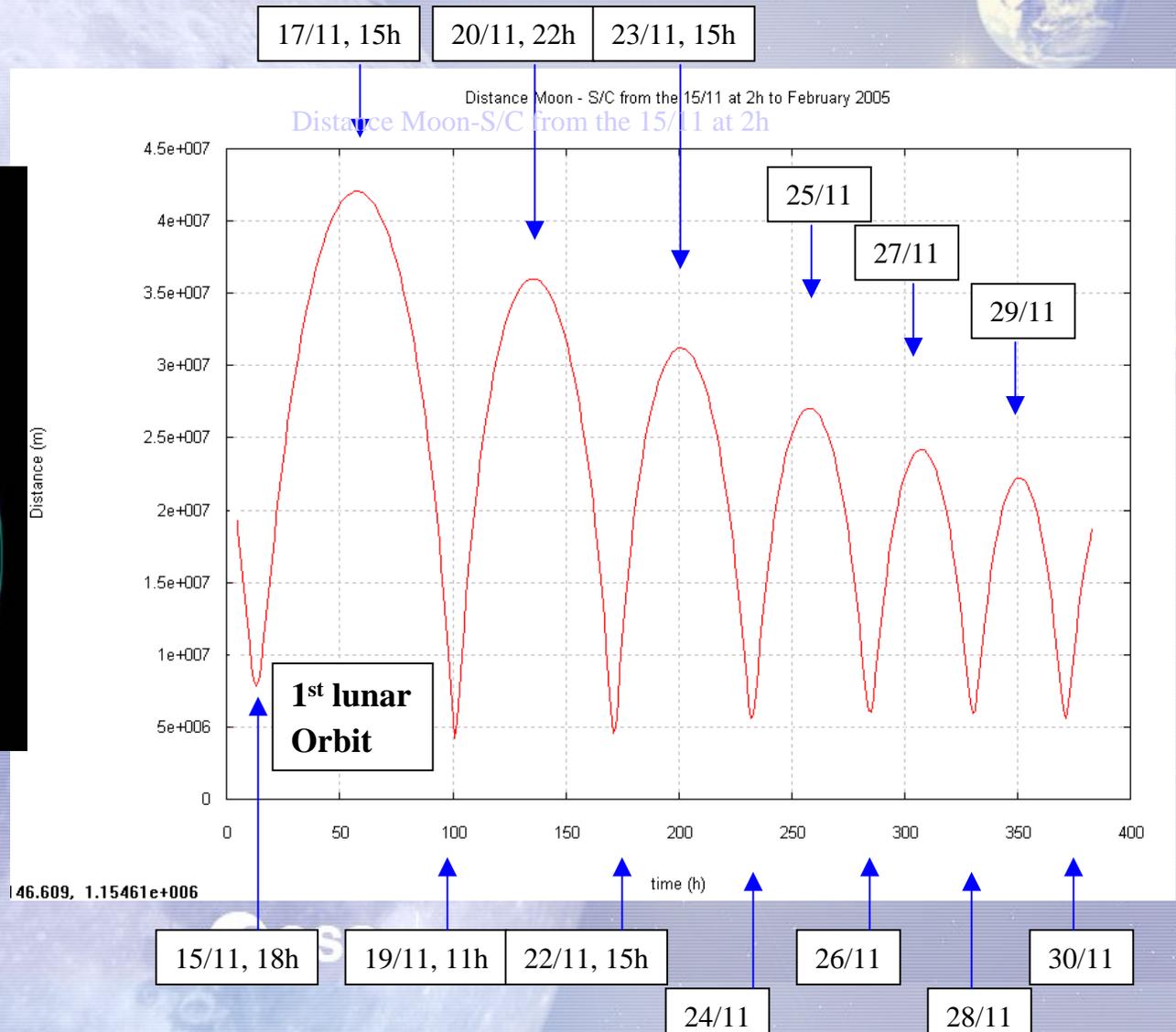
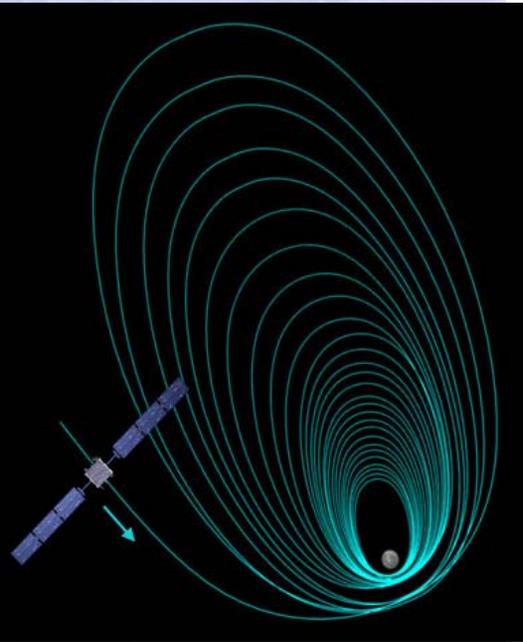
216.18, 1.86667e+008

Final approach to first lunar orbit to the Moon

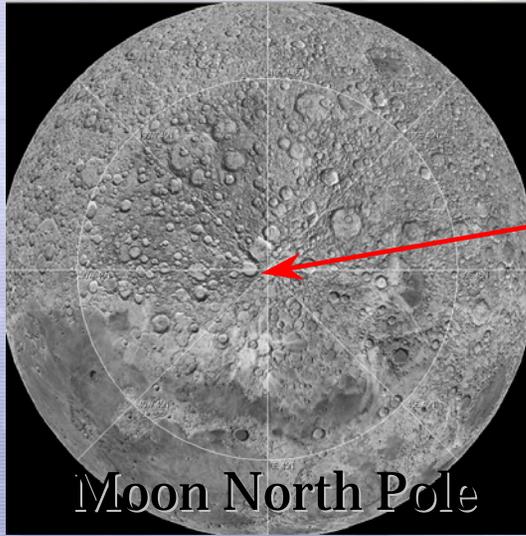


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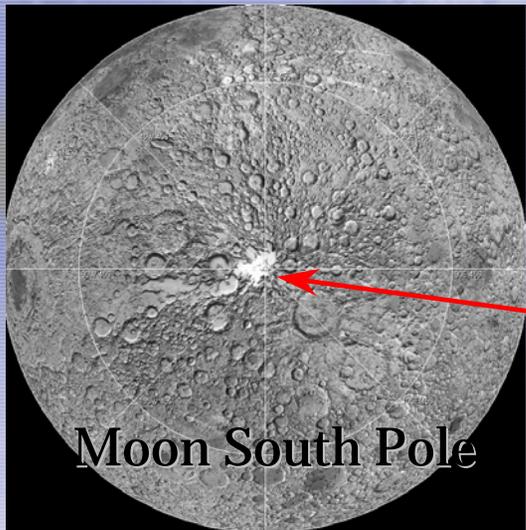
Spiralling down closer to the Moon, towards science orbit 300-3000 km after 15 January 05



1st Perilune-Apolune around the Moon



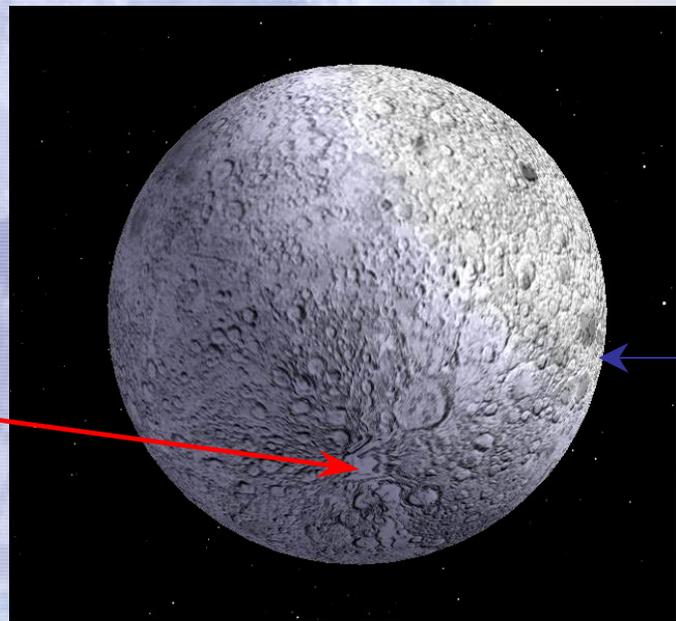
Moon North Pole



Moon South Pole



Face of the Moon at the 1st apolune From 40000 km



Face of the Moon at the 1st perilune From 5000 km



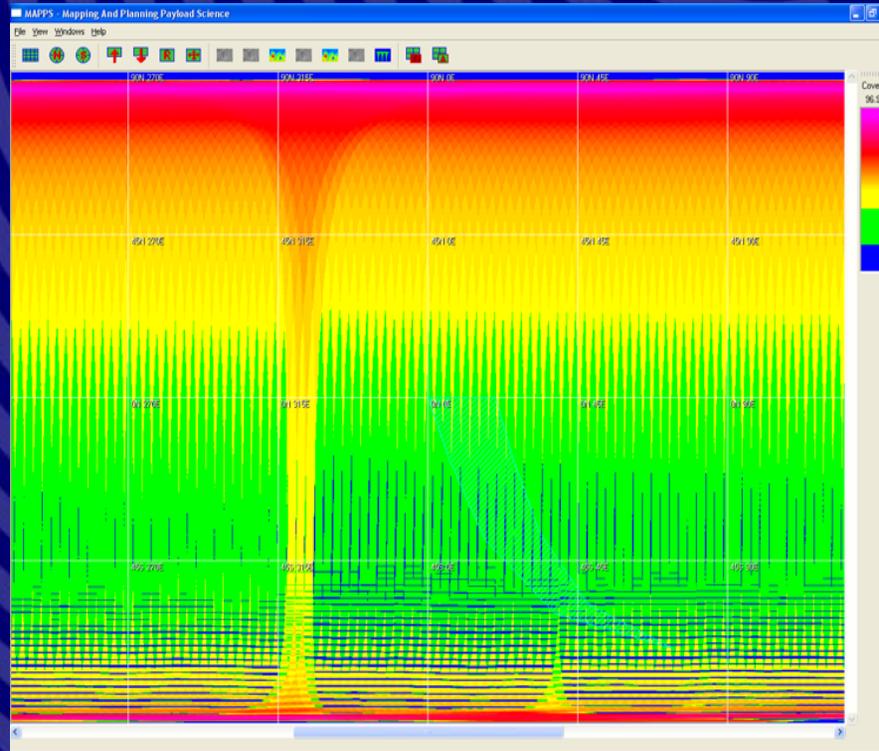


ESA-SPACE-X 01Nov 00.00.32z

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Full-frame global mapping, 50% overlap low res survey from 1000- 4500 km

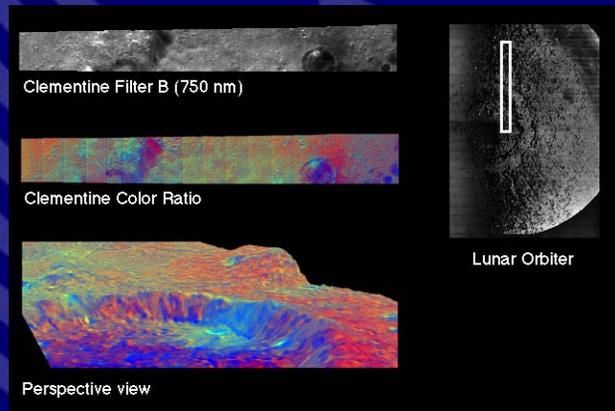
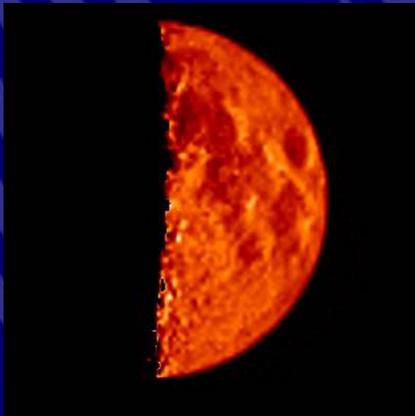


- “Simple and systematic” mode of operation – default nadir pointing and repetitive commanding

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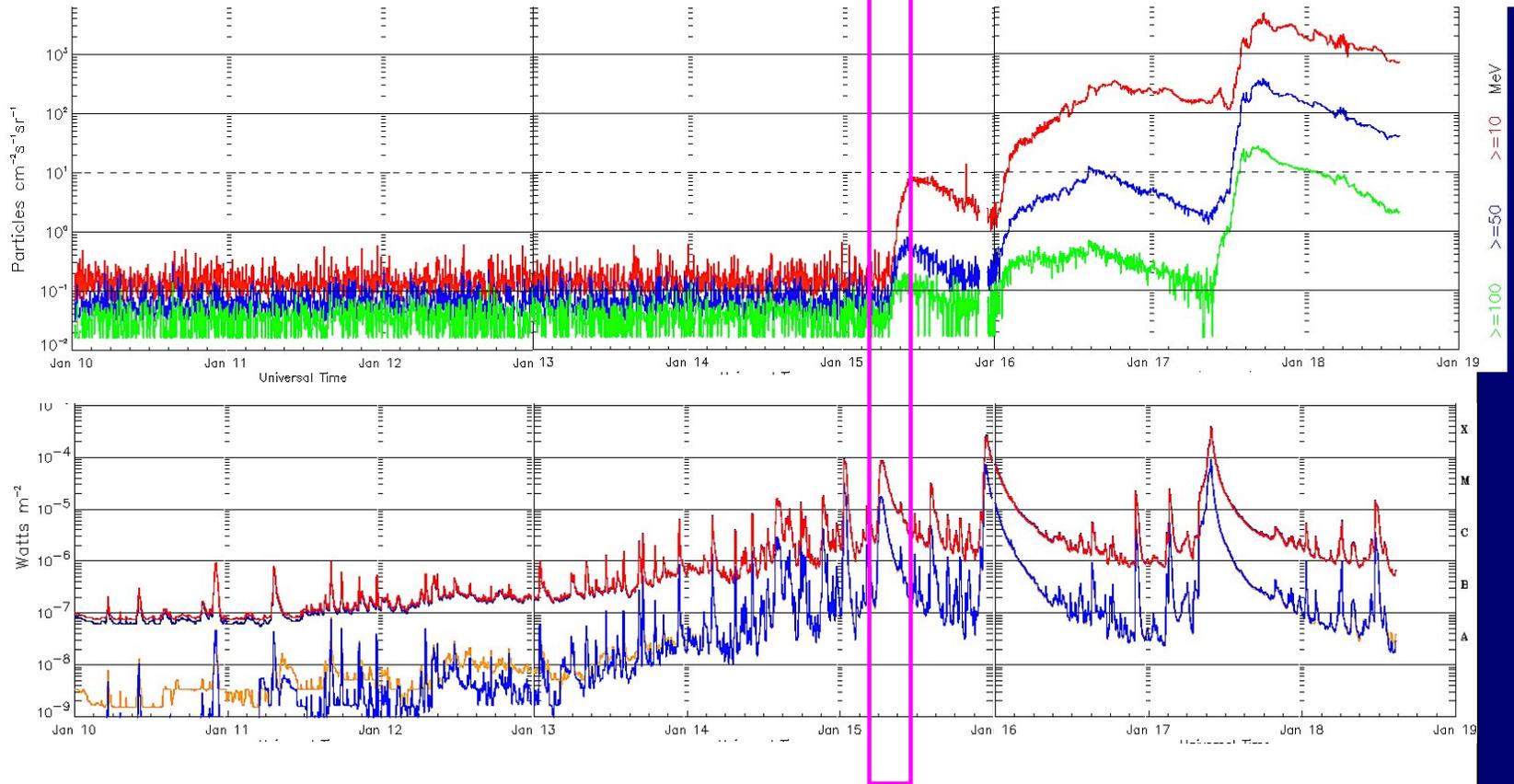
SMART-1 Science/Exploration Opportunity

- INSTRUMENTS READY FOR LUNAR TASKS
- 1st X-ray global mapping for Mg, Al, Si at 50 km resolution
- 1st infrared spectral mineralogy mapping 0.9- 2.5 microns
- Local multi-band mapping at resolution 40 m from 300 km
- Polar areas illumination and resource mapping
- Stereo mapping for Digital Elevation Models



Community support: operation, PDS archive, data analysis and science exploitation
Extension to 2006, and joint international investigations

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This is proton (top) and X-ray (bottom) data from the GOES space weather monitor. Early on January 15th there is an M9 X-ray flare...

Assumption for science payload operations:

- Standard mode: payload operations conducted over illuminated side of the Moon pole-to-pole:
 - priority 1 from south pole to 2000 km distance (with nadir or near nadir pointing)
 - priority 2 for part 2000-3000 km
 - priority 3 operations on dark side (pending spacecraft platform operations and data download)
- Off nadir pointing and targeted observations during extension phase
- STWT & Project scientist overall responsibility for science operations
 - long term science planning (with STWT and RSSD support staff)
 - mid-term and short term operations (with PIs, STOC and ESOC staff)
 - data archiving (with PIs and RSSD Planetary science archive staff)

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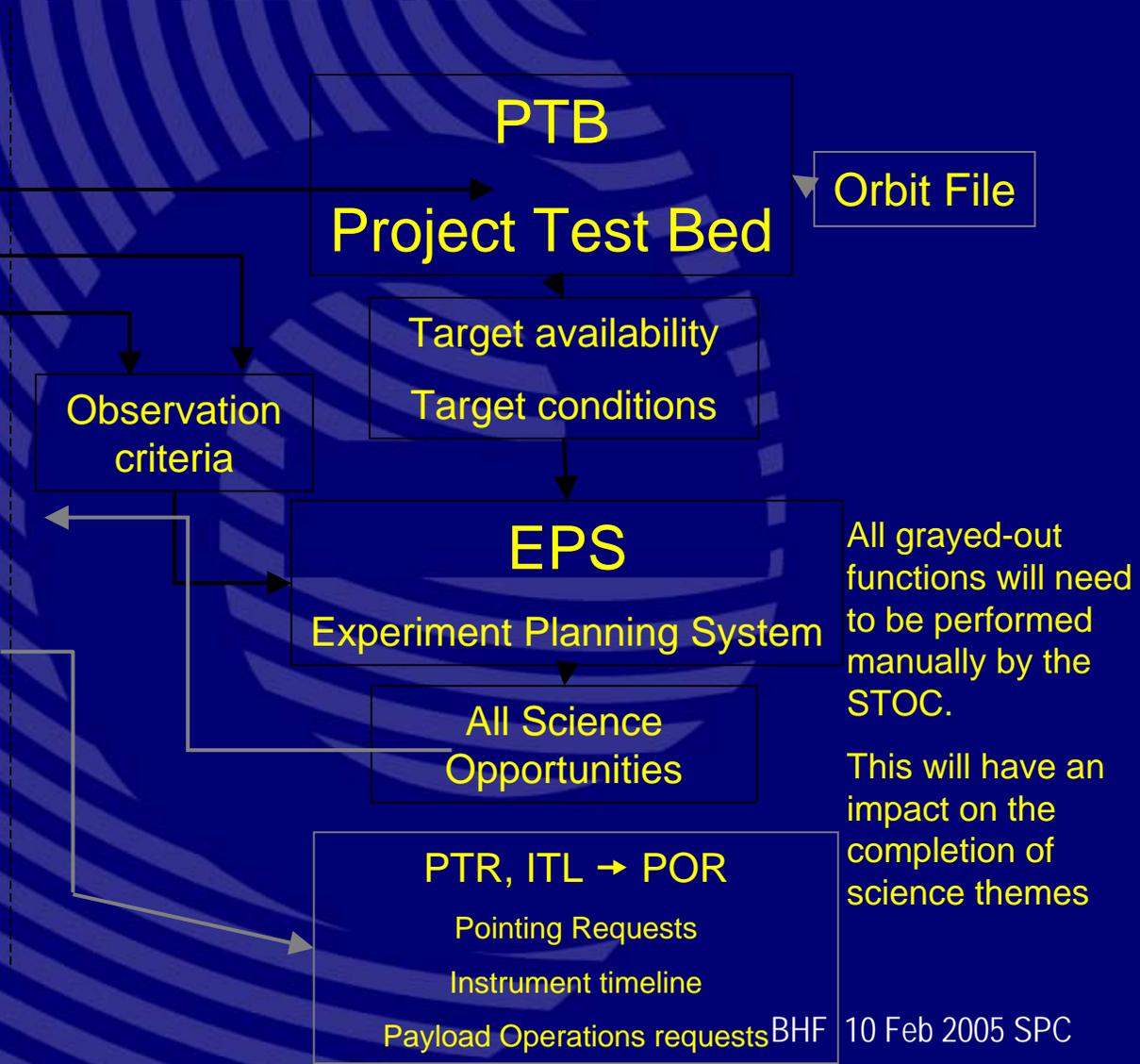
SMART-1 Science Management Plan SPC nov 99

- The ESA Project Scientist will act as the Chairman of the SMART-1 Payload Working Team (SPWT), and as such coordinate its activities.
- The ESA Project Scientist will assume responsibility for management of the SMART-1 Project at a suitable time after launch.
- The SMART-1 data rights will follow the established ESA rules (ESA/C(89)93). Therefore all scientific data obtained during the full mission duration will remain proprietary of the Investigator teams for a period of up to 6 months after they have been received from ESA.

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Science Planning Software - Present status

- SPS Functions
- Linked knowledge base:
 - Target Lists
 - Science constraints
 - Observation Requests
 - Science Themes
- Analysis:
 - Matches science opportunities to observations
 - MTP observation selection
- Record:
 - Selected observations
 - Contribution to the science themes



All grayed-out functions will need to be performed manually by the STOC.

This will have an impact on the completion of science themes

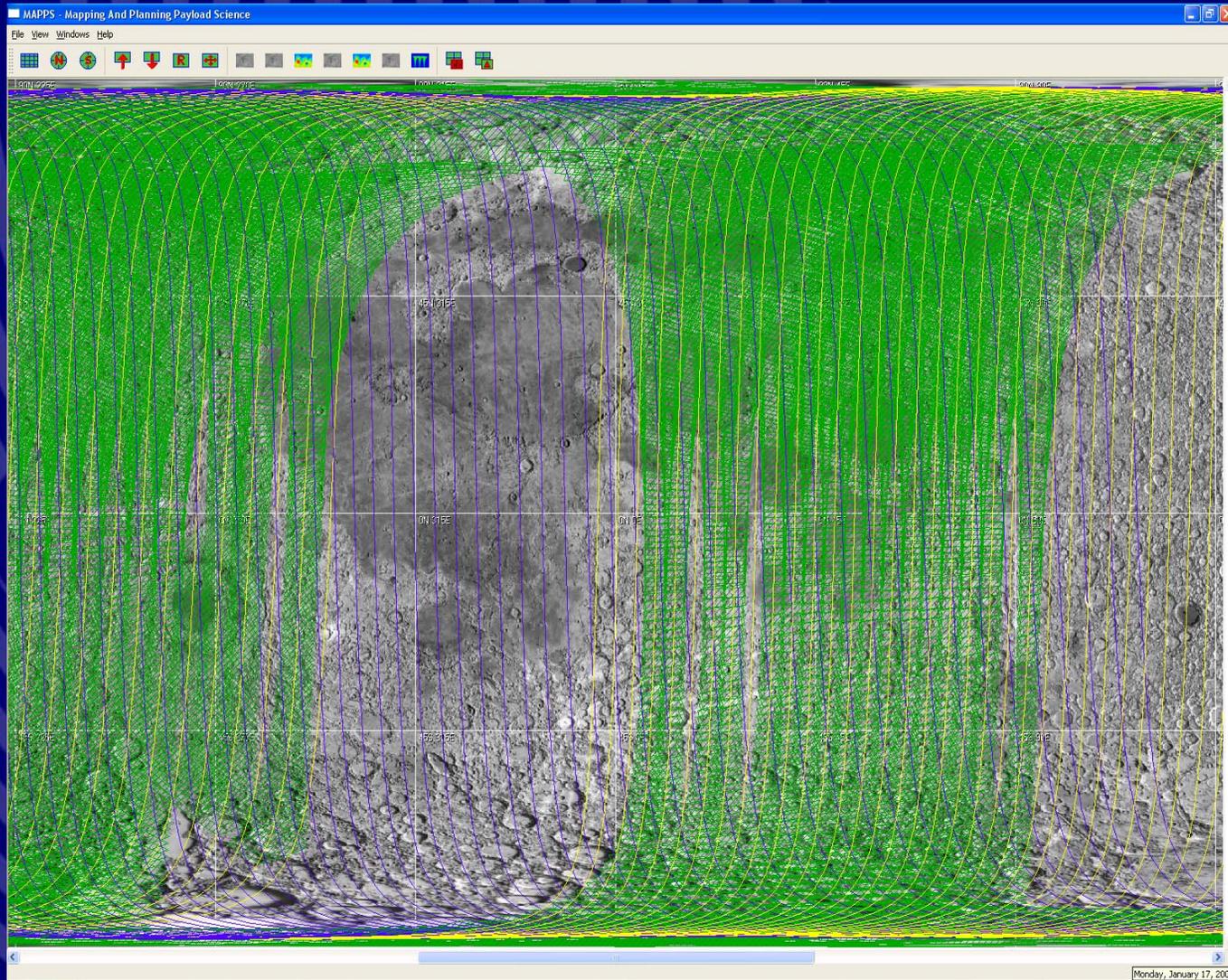
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AMIE commanding levels

- Constraints: nominal uplink every 4 days = 8000
 - Max commands/APID = 4096. , POR Payload Operation Request= 9999
- Executed Operations: New Year: colour with 50% overlap at 1000-5000 km orbit
 - 137 images*9 commands*3 orbits ~ 4000/day
 - solution 1, use 4 APIDs
 - solution 2, uplink every day
 - solution 3, reduce # of commands/image (proposal to reduce to 5 tbc by AMIE)
 - solution 4, reduce number of images to 35!
- Consolidated operations: Jan 2005: colour imaging
 - 122 images*5 commands*3 orbits = ~2000/day
 - solution 1, use 2 APIDs
 - solution 2, uplink every 2 days
 - solution 3, reduce # of commands/image
 - solution 4, reduce number of images!
- Future Operations: Science phase: 20% overlap to avoid gaps due to s/c rotation
 - 150 images*5 commands*5 orbits ~ 2750/day
 - solution 1, use 3 APIDs!
 - solution 2, uplink every day
 - solution 3, reduce # of commands/image to 1 macro-command
 - solution 4, compromise: reduce # of commands/image to 2, uplink every 2 days
 - solution 5, reduce number of images to < 40

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January Low resolution Coverage



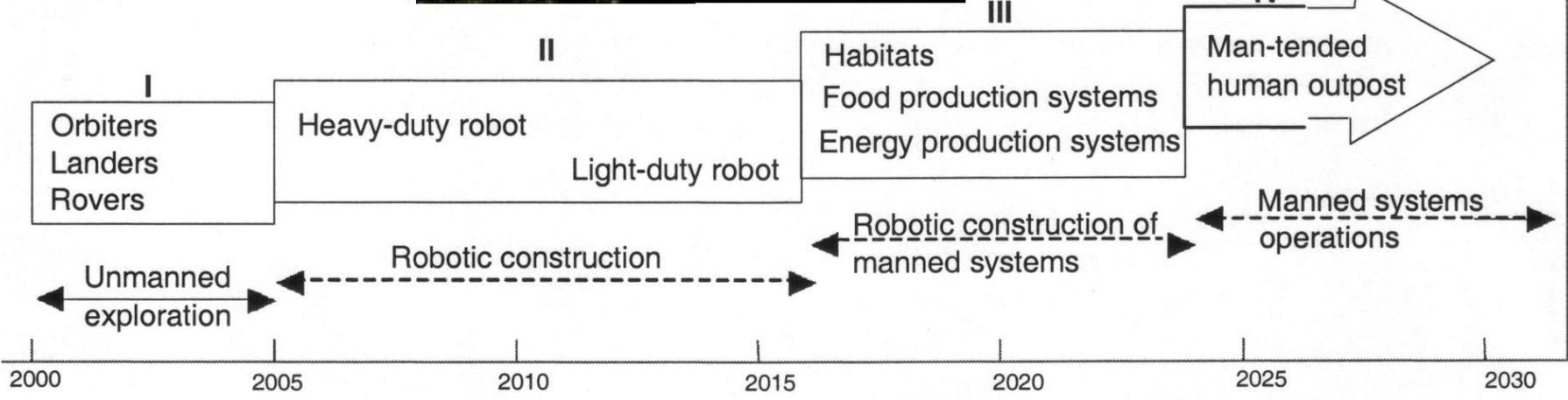
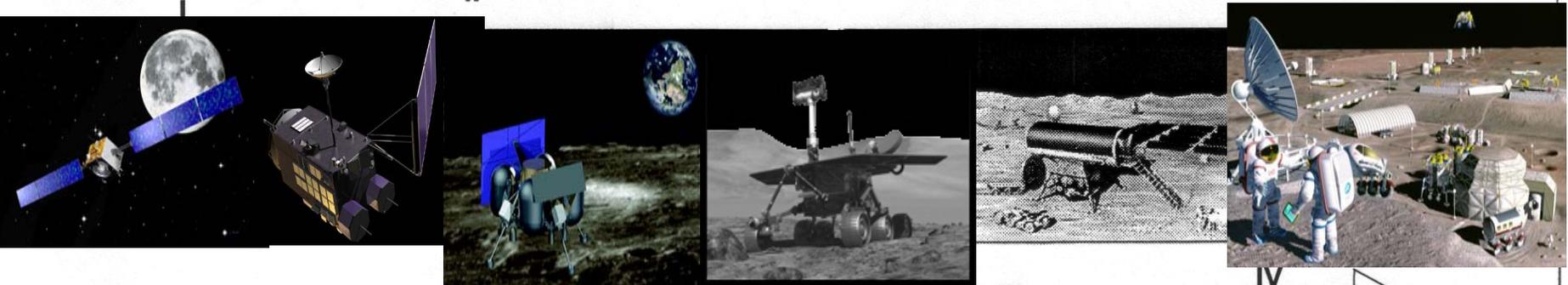
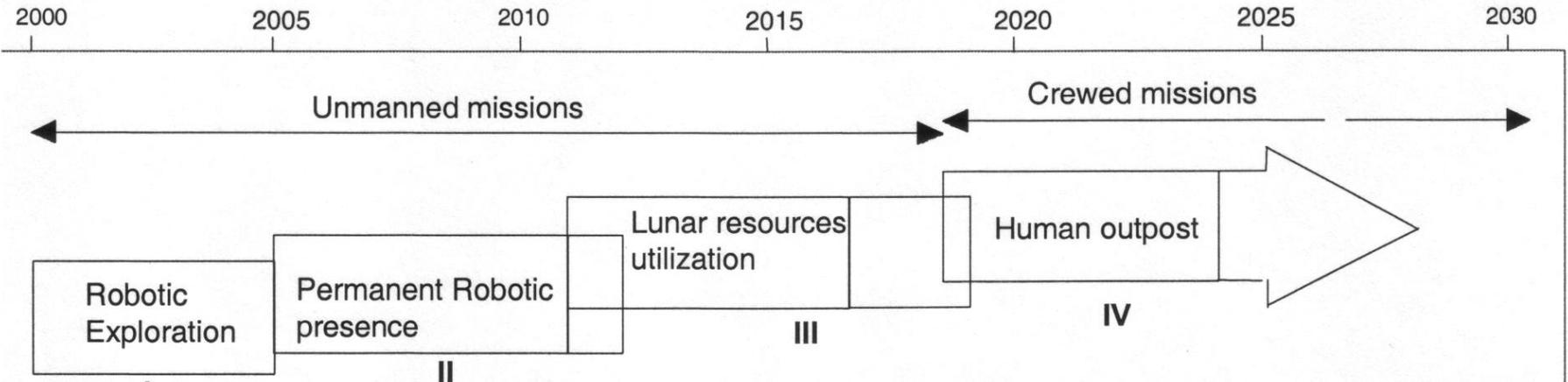
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Case for 1 year extension

- to extend the global coverage for AMIE, SIR, DCIXS
- due to 1 mrad FOV and telemetry limitations, it is expected that only a few percents of the surface will be covered by the SIR spectrometer after 6 months
- due to telemetry limitations the extension permits to augment coverage by the AMIE camera at high res colour mode
- Only 2 over 6 months give good illumination conditions for IR spectrometry, X-ray sensitivity and quantitative colour radiometry
- increases the probability of solar flares events (in rising solar activity) for very sensitive D-CIXS scans providing high res maps Fe
- to perform dedicated programmes to prepare future international lunar missions
 - mapping potential landing sites for future missions (including South pole Aitken sample return)
 - Measurements in coordination and preparation for observations with Lunar A cameras and Selene, Chandrayaan-1, Chang'E and LRO, seasonal illumination maps at high resolution)

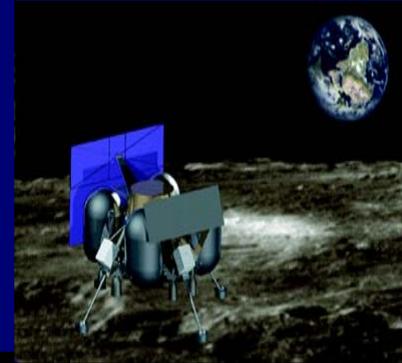
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ILEWG phased approach for lunar exploration



Roadmap for international lunar exploration

- **2014 International Robotic village**
 - Robotic outposts: geology, water ice, life sciences,
 - Advanced landers/rovers from international partners
 - In Situ Resource Utilisation (power, minerals, H, O, He3)
 - Life support systems, deploying larger infrastructures
 - Autonomous & intelligent robots prepare for humans
- **2017 Man tended missions**
- **2024 Permanent Lunar base**
 - Living off the land on another planet
- **Moon as SMART testbed for technologies**
 - human/robot optimised operations,
 - step to Mars and solar system exploration
- **Science, technology, exploration, societal synergies**
 - Aurora/exploration, Cosmic Vision 2015-2025
 - Develop Europe as strong international space partner
 - Inspiring an innovative and competitive Europe



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