SMART-1 lunar highlights

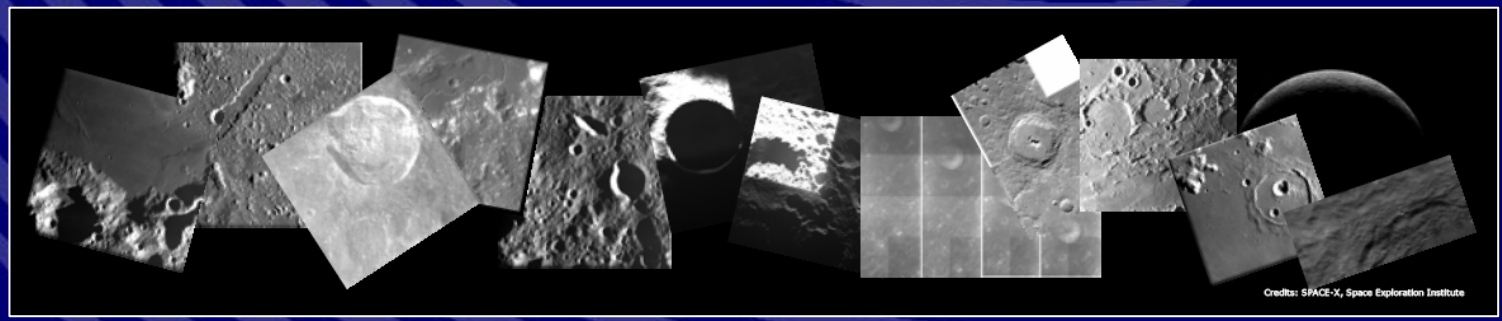
Bernard H. Foing

& SMART-1 Project & Operations team,

SMART-1 Science Technology Working Team,

SMART-1 Impact Campaign Team

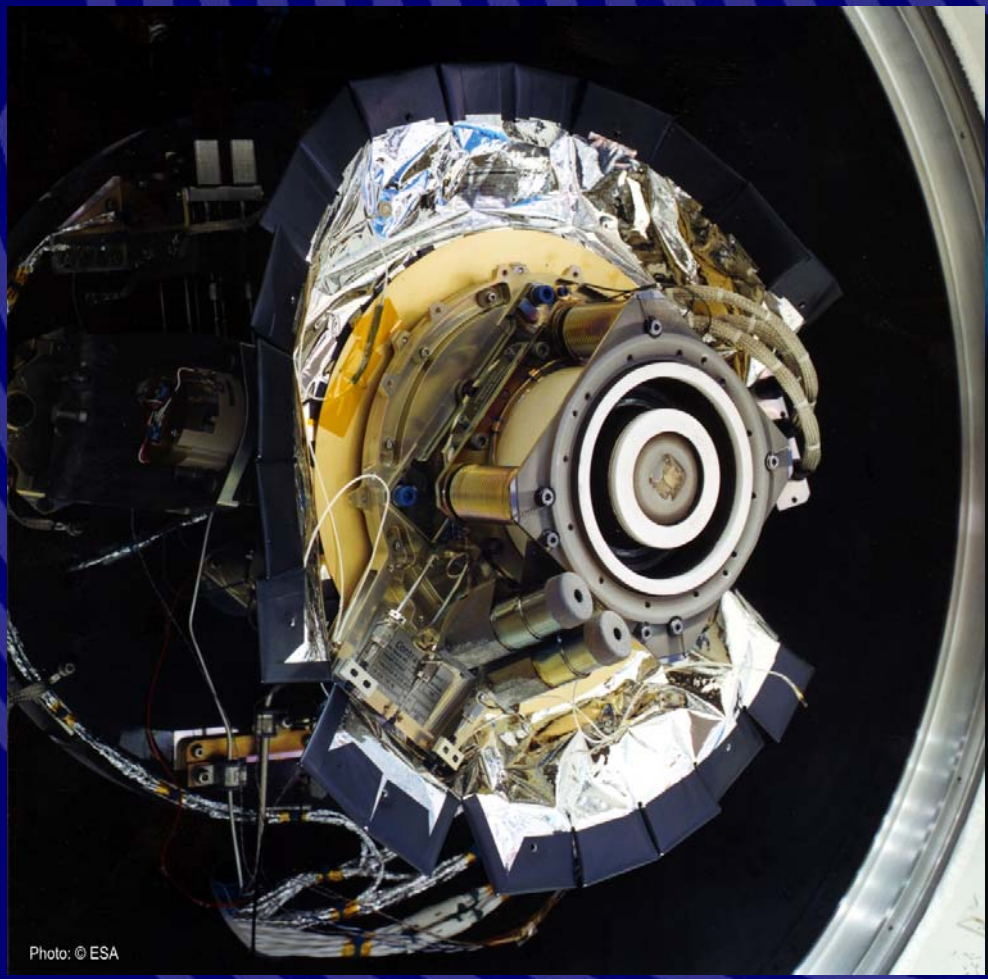
http://sci.esa.int/smart-1/, www.esa.int



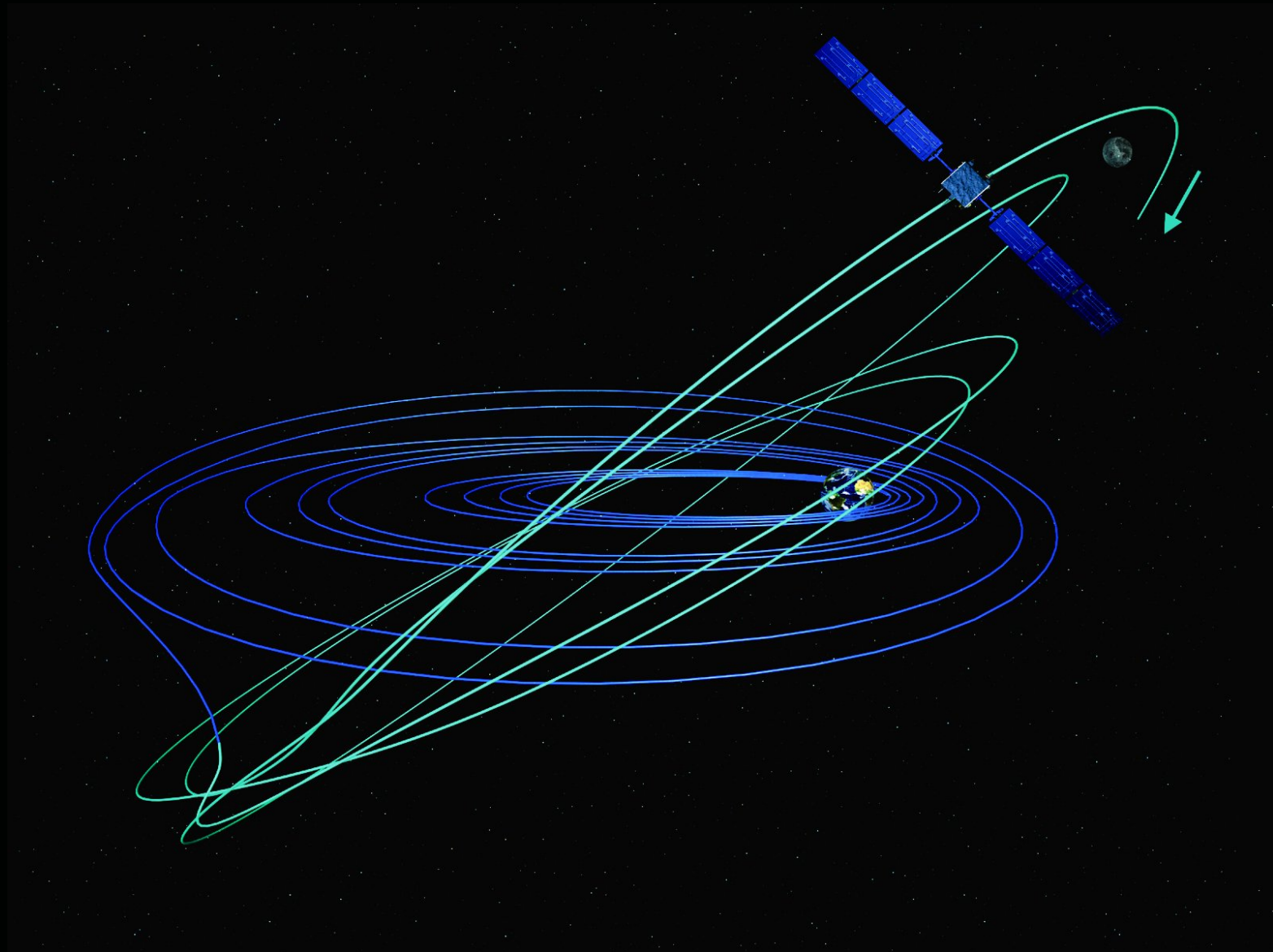
esa

Europe to the Moon: spacecraft, launch, operations (ESA+ industry)
Instruments PIs + TIs from 5 countries
Co-Is from 13 ESA + 6 non European countries

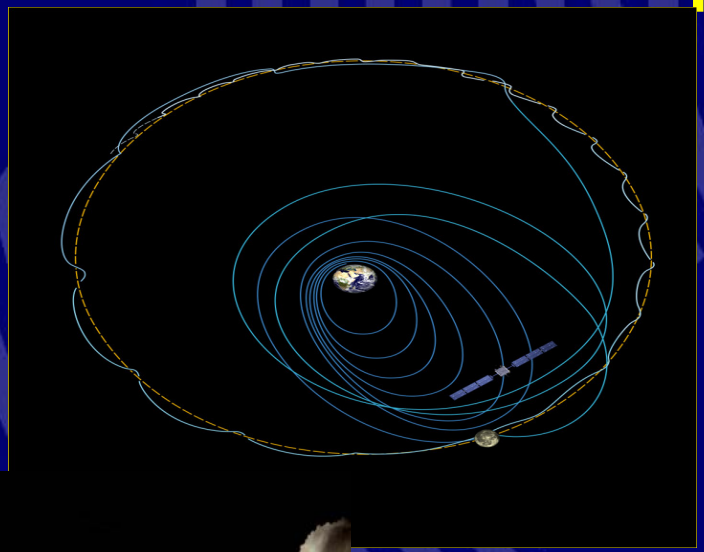
Solar Electric Primary Propulsion: 7 g thrust, 60 liters Xenon to the Moon



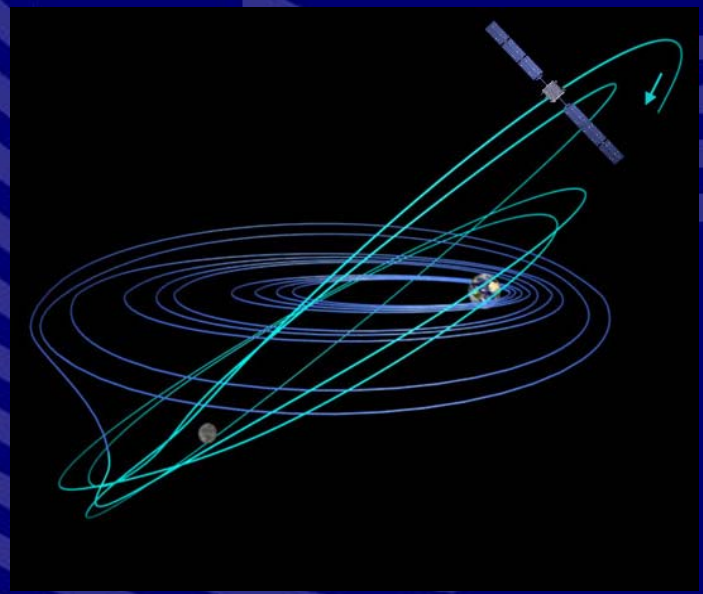
SMART-1: With Sun power to the Moon on 60 liters of fuel

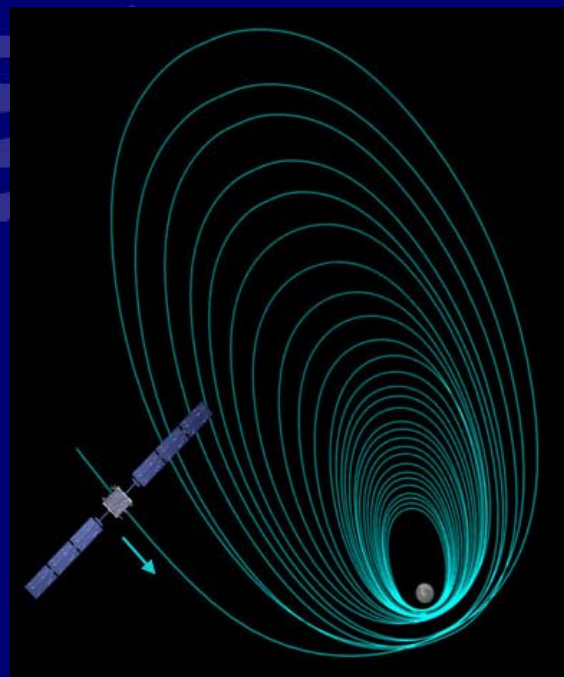


Solar Electric Propulsion to the Moon

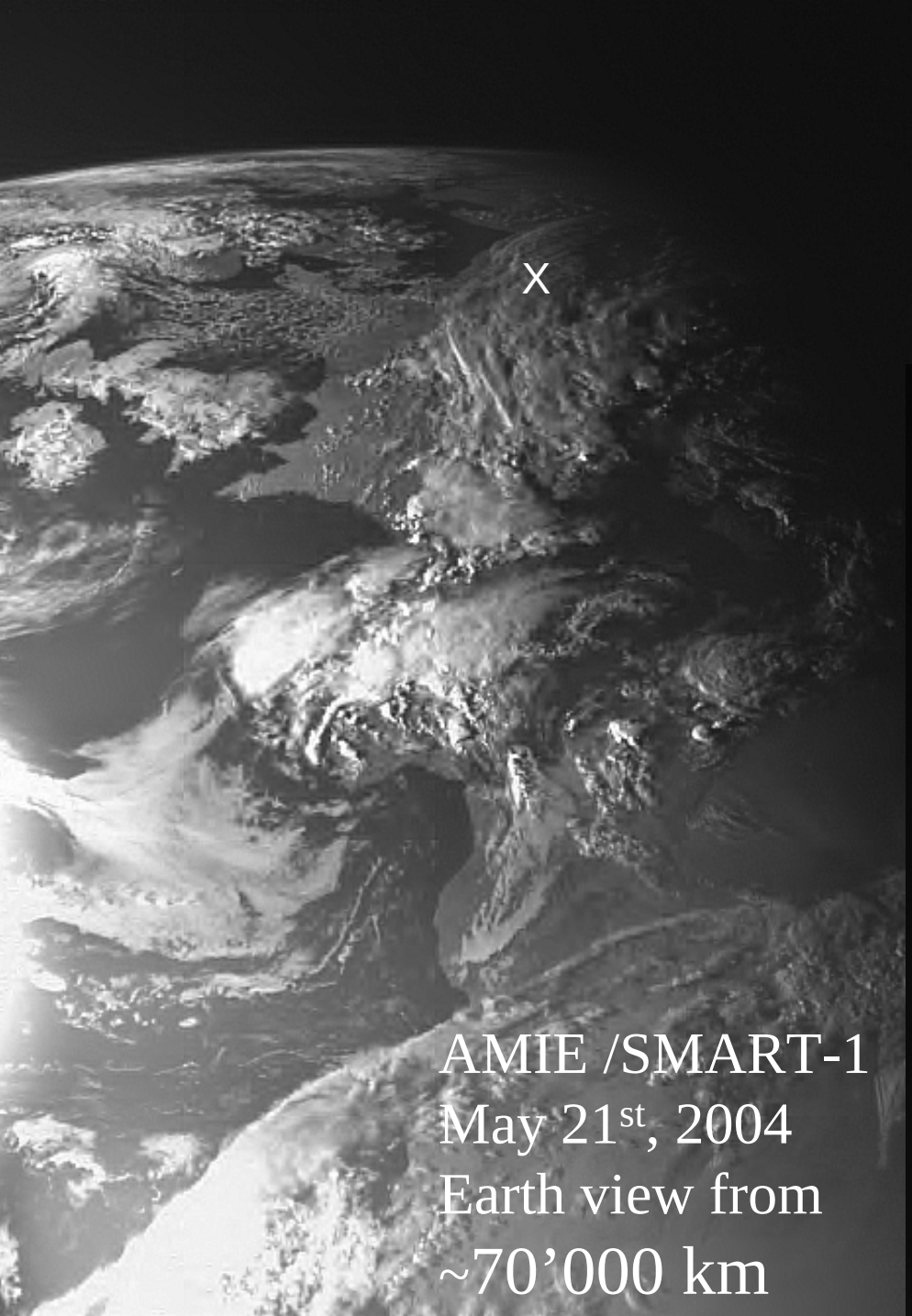


- Launched 27 Sept 2003 as Auxiliary passenger on Ariane 5 into Geostationary Transfer Orbit
- Spiral out cruise (13.5 month):
- lunar capture 15 November 2004, spiral down
- arrival 15 March 05 science(450 -2900 km): commissioned spacecraft/instruments at Moon, nominal science mission March-July 05
- *reboosting 2 aug-15 Sept 05 to increase orbit lifetime for extension phase* until Aug 2006





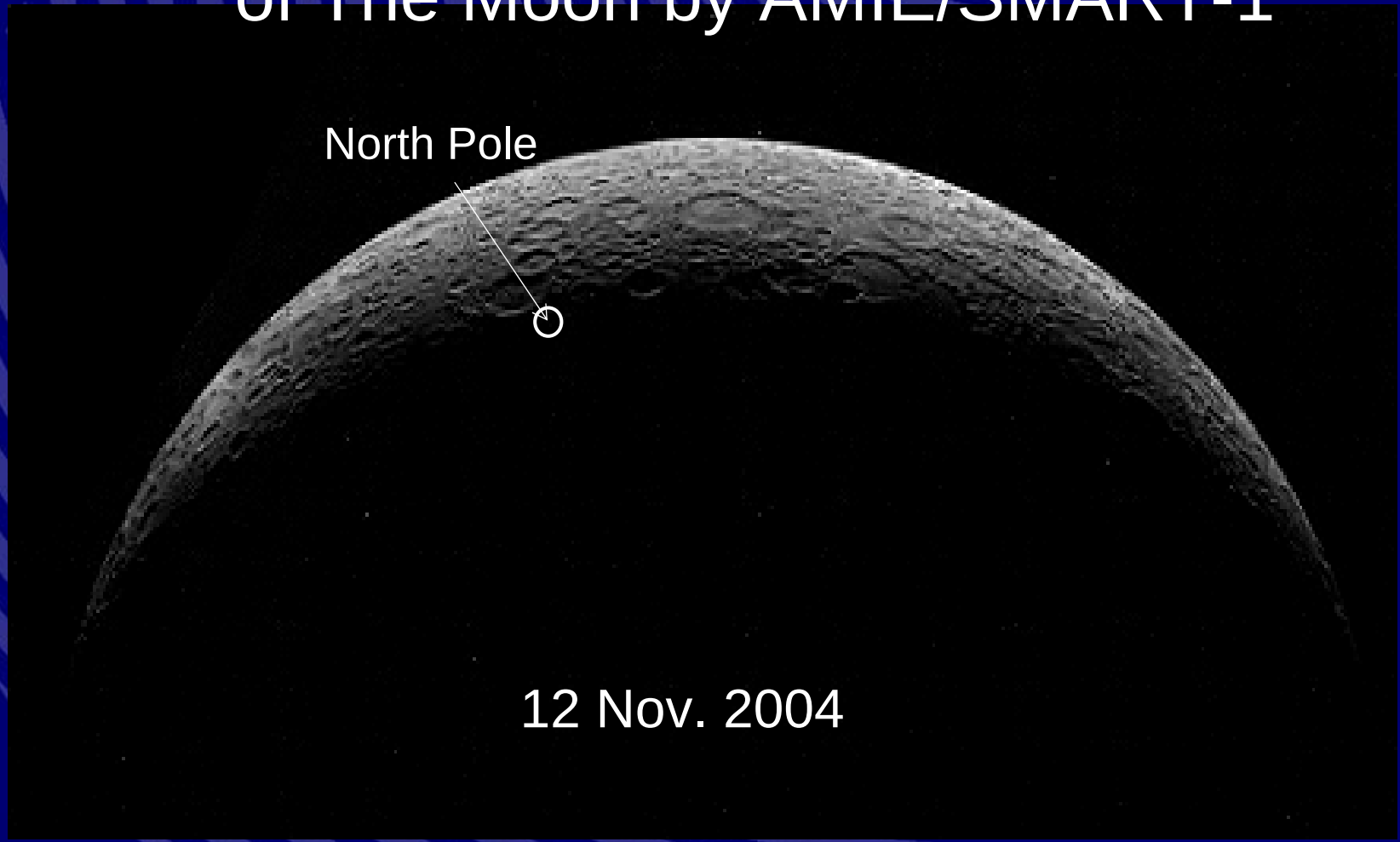
esa



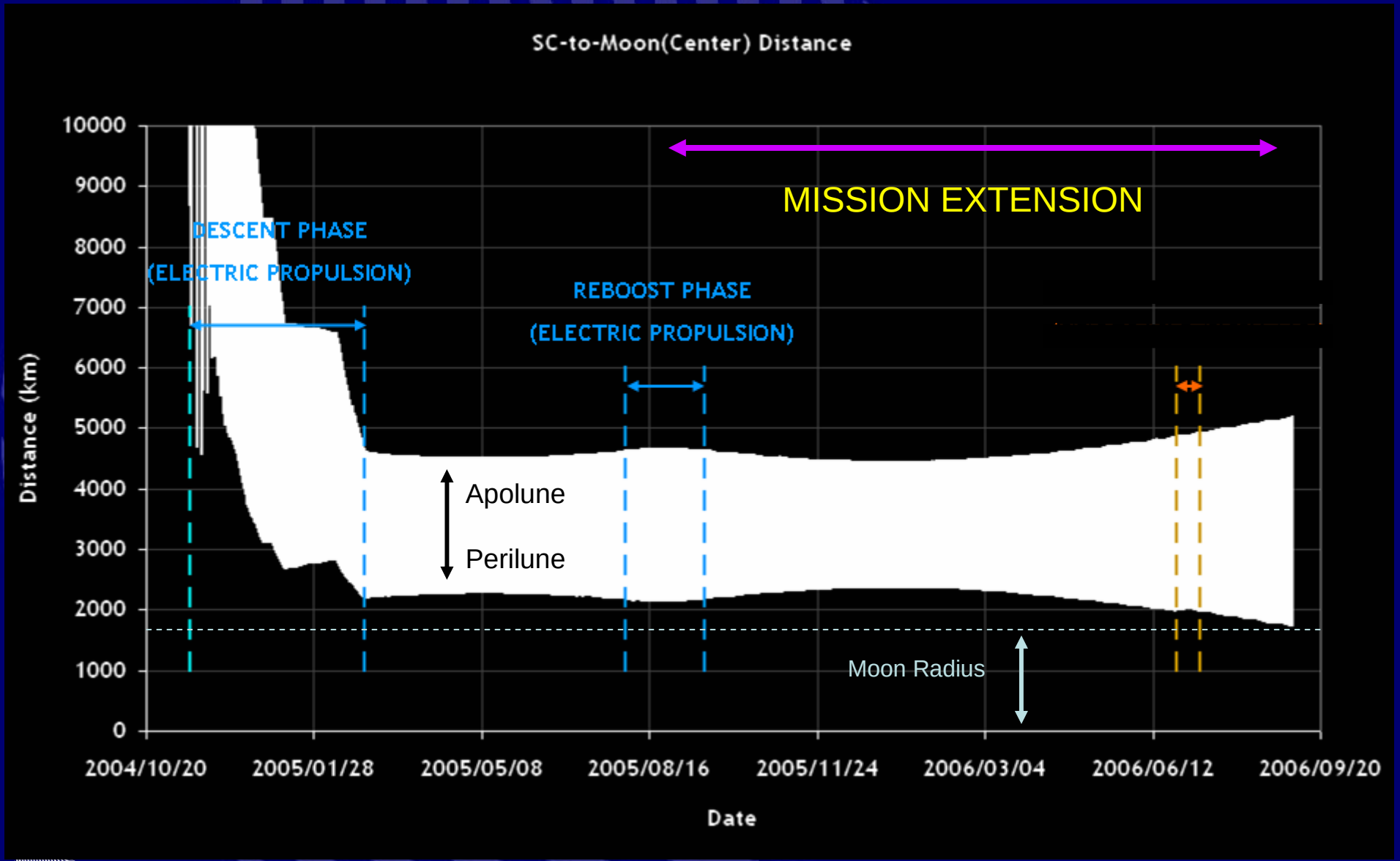
AMIE /SMART-1
End August 2006

Earth set & rise from the Moon

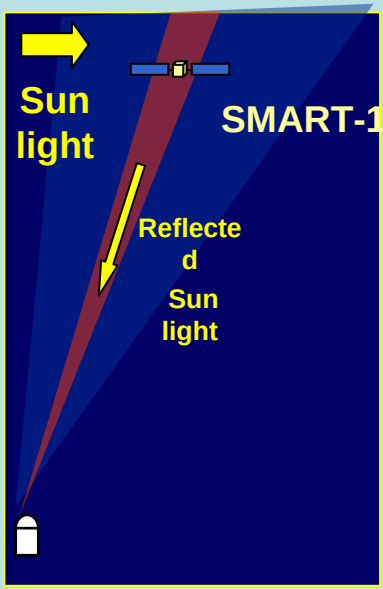
First European Far Side Image of The Moon by AMIE/SMART-1



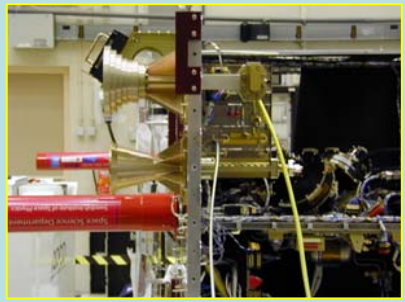
Moon Phase & Mission Extension



Why the Moon: Innovative Technologies on Smart-1

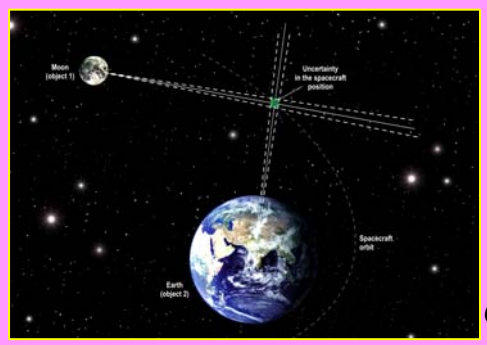


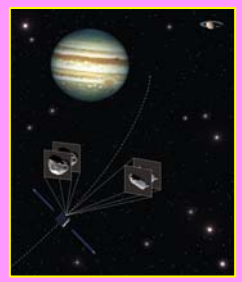
Laser Link



KA-band antenna

Communication





OBAN

Autonomy

Triple junction solar cells

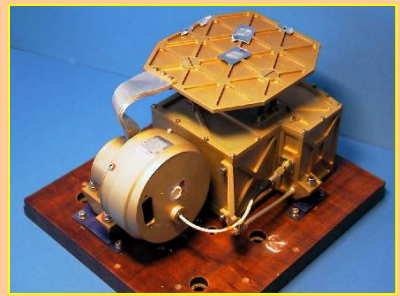
On-board computer

Lithium ion batteries

Platform Technologies

Multicolor microcamera

X-Ray Spectrometer



Infrared Spectrometer

Miniaturisation

esa

BHF 2007

SMART-1
Science and Exploration Themes

HOW DO EARTH-LIKE PLANETS WORK?

GEOPHYSICS: volcanism, tectonics, craters, erosion, space weather , ices

HOW DO ROCKY PLANETS FORM AND EVOLVE?

GEOCHEMISTRY: chemical composition, Earth-Moon origin, Moon evolution, accretion, collisions, giant bombardment

PREPARING FUTURE LUNAR/PLANETARY EXPLORATION

LUNAR RESOURCES SURVEY (minerals, volatiles, illumination)

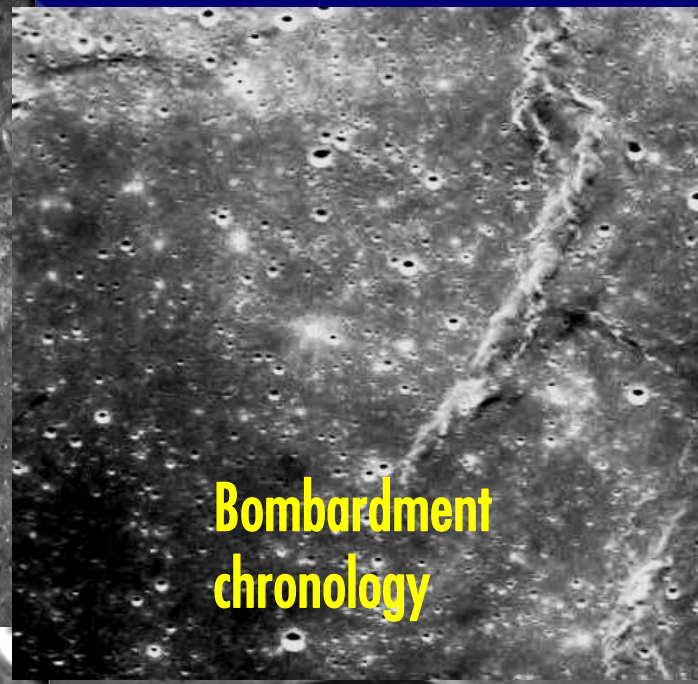
HIGH RESOLUTION MAPS: for future LANDING SITES and OUTPOSTS

SUPPORT TO FUTURE MISSIONS AND EXPLORATION

PUBLIC OUTREACH, INSPIRATION AND EDUCATION

What shapes rocky planets?

Why the Moon?
A laboratory
for Geophysics



erosion,
volatiles

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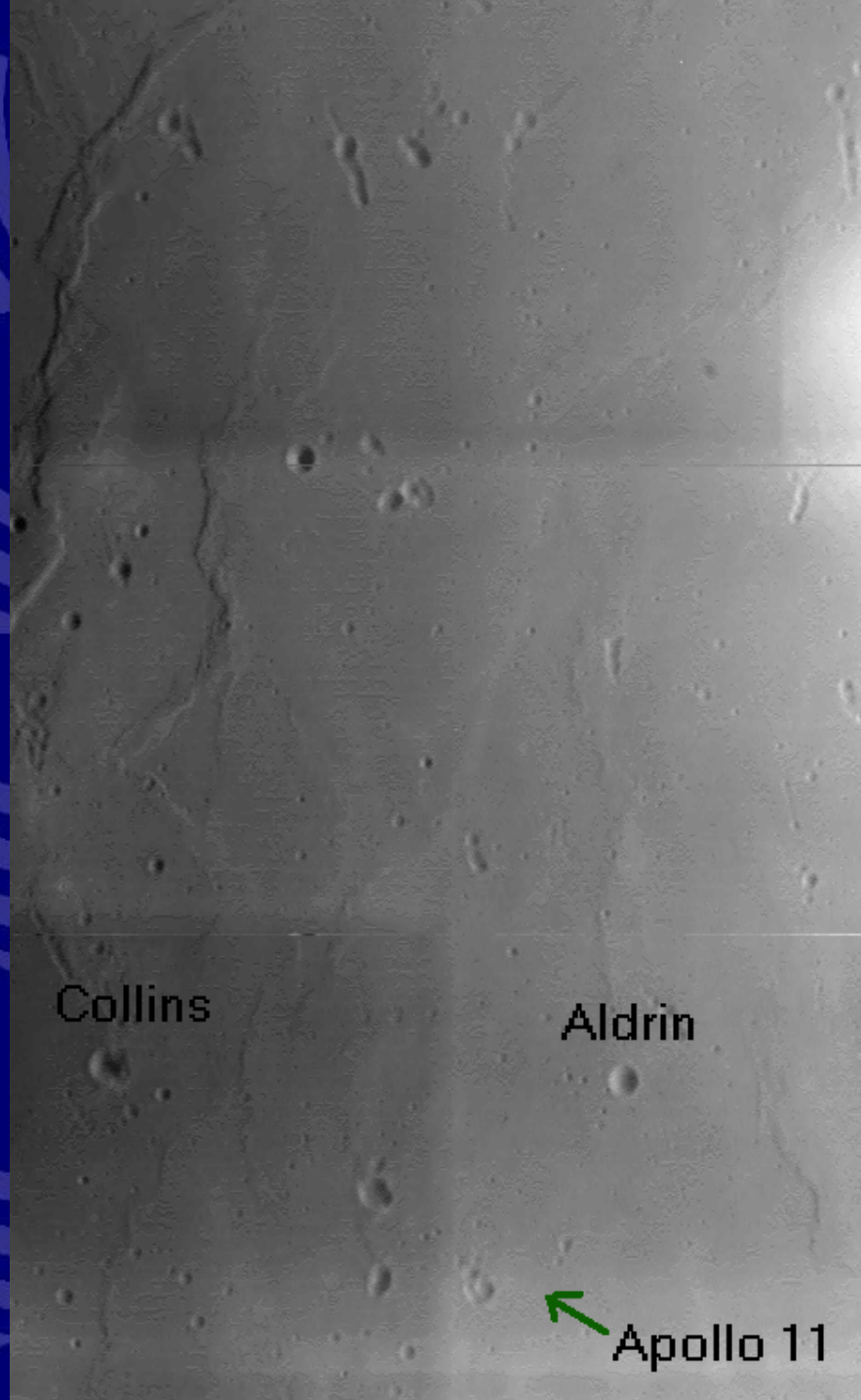
Calibration & Ground Truth

SMART-1 view of Apollo 11 site

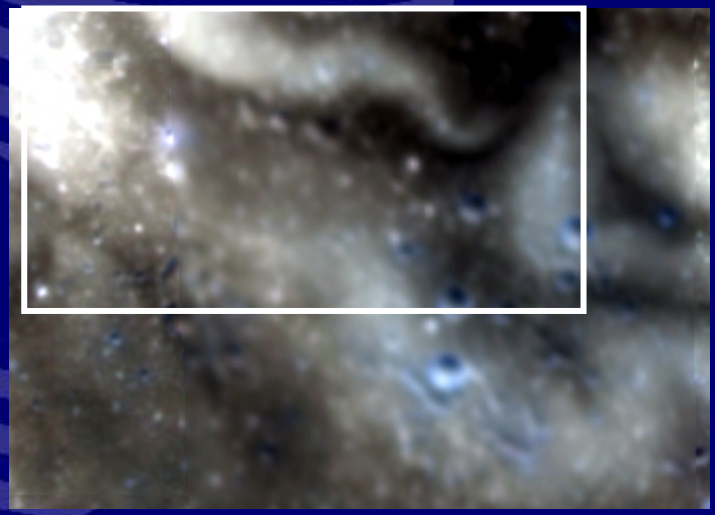
- Distance 1764 km
- FOV 80 x 120 km

- Calibrations, see also
- Despan et al : geometrical analysis
- Kaydash et al: photogrammetry



AMIE SMART-1 High Res Colour

Clementine



AMIE colour image Orbit 1438

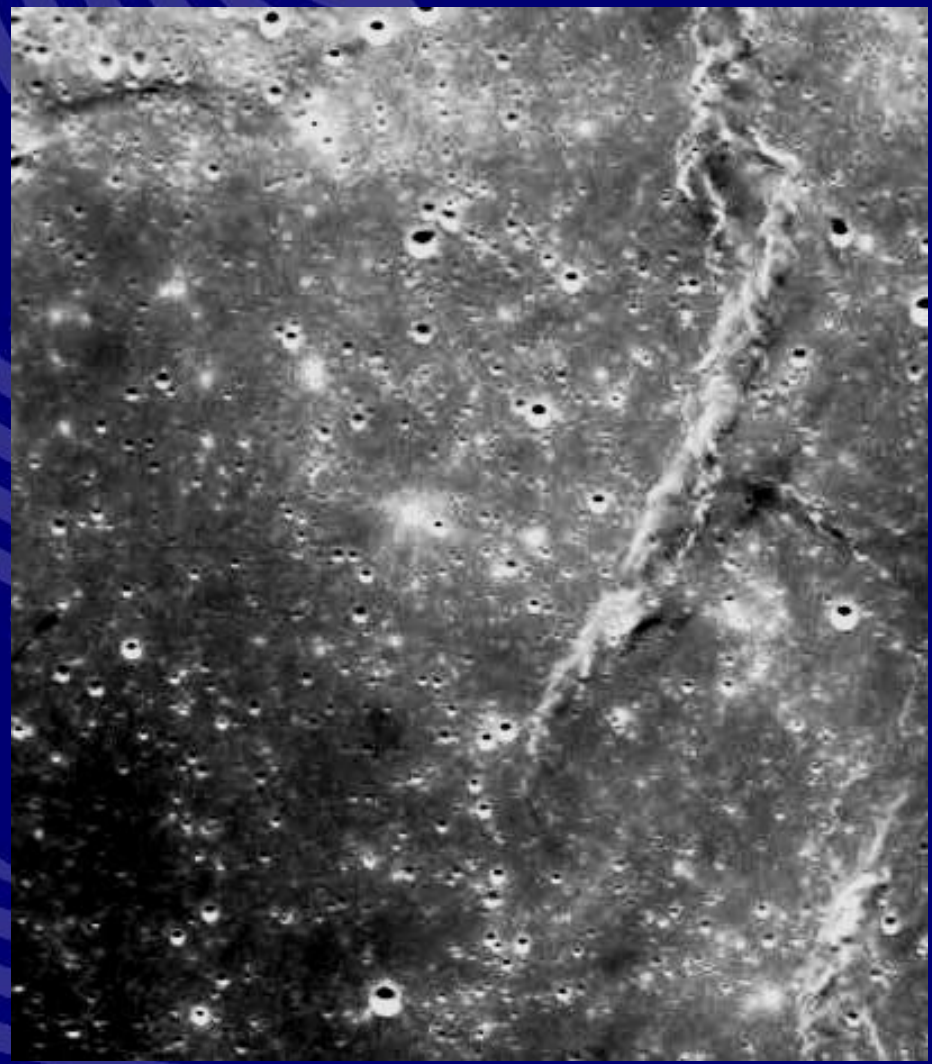
Reiner gamma
Magnetic shield

(Cerroni et al 2007)

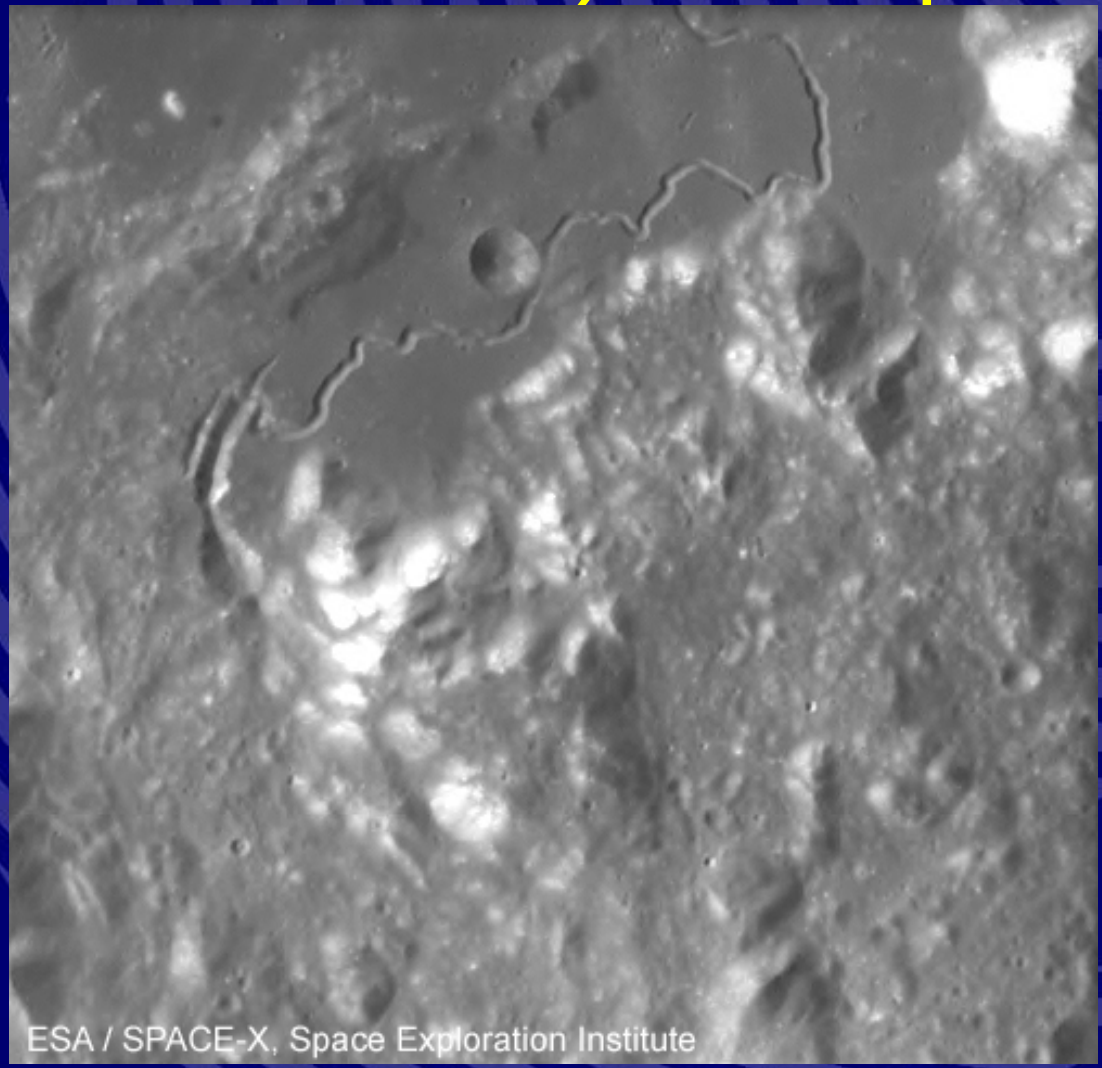
esa

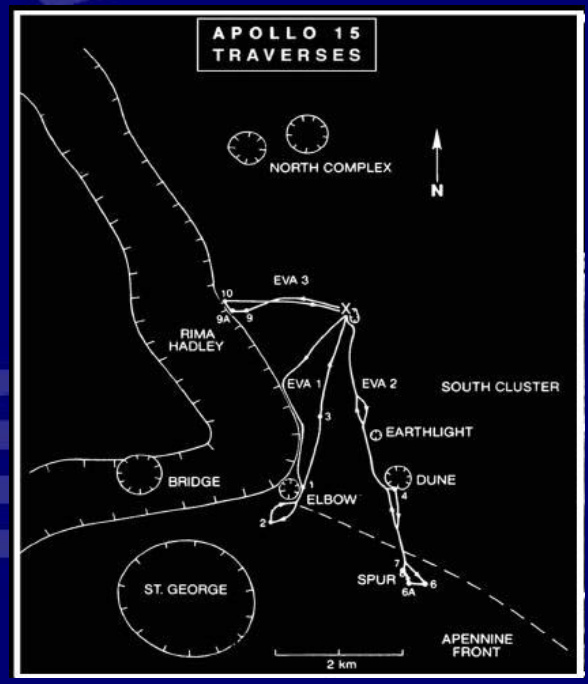
Serenitatis

Crater counts and lunar chronology



SMART-1 view of Hadley Rille (giant lava tube) near Apollo 15 landing site





100 km field

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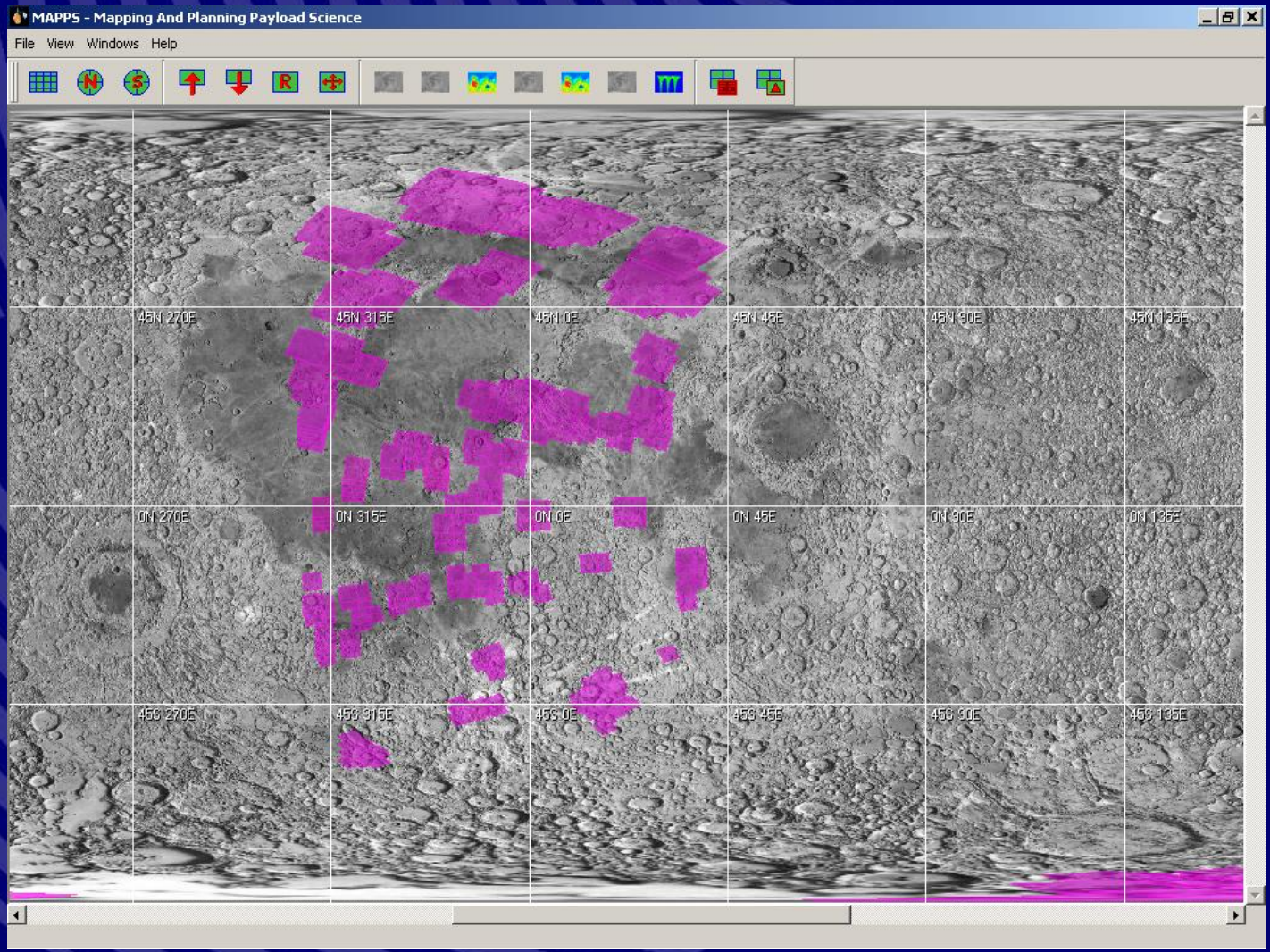
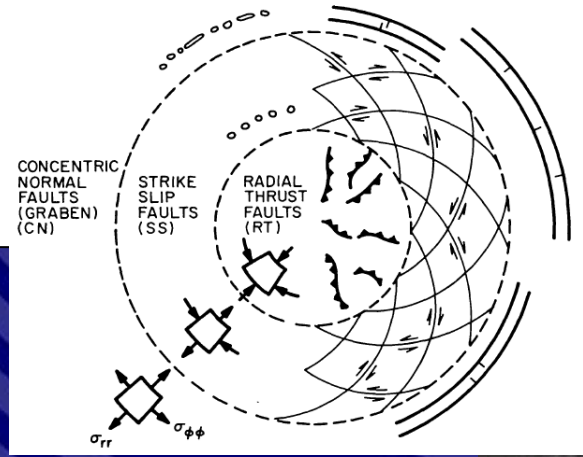
BHF 2007

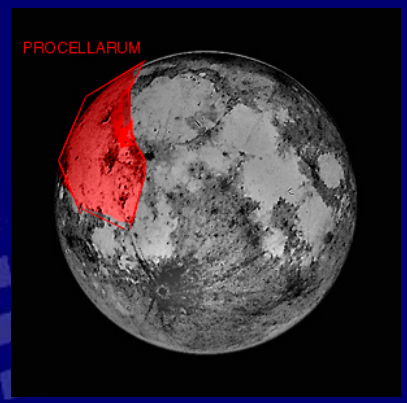
SMART-1 AMIE detailed targets: Procellarum and youngest basaltic flows

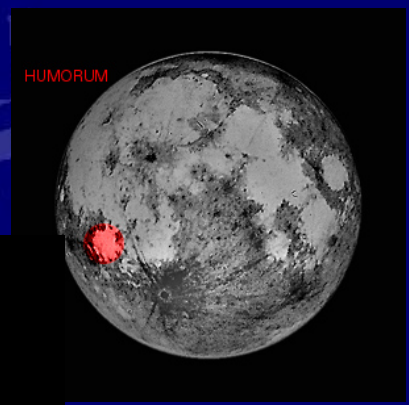


Coupling between impacts and volcanism

- Humorum: Multiringed impact basin
- Procellarum: Irregular basin
- Tectonics of mascon loading







Peters et al 2007

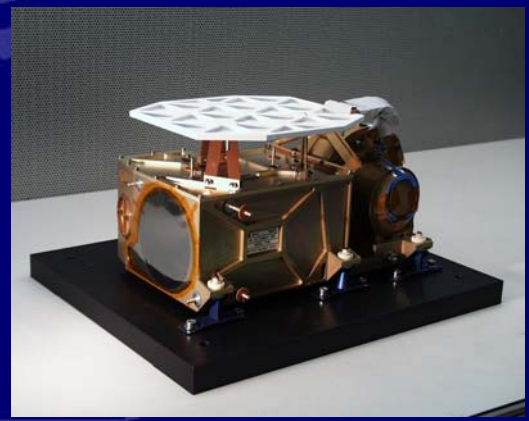

Meton: debris on the
edge of Imbrium
giant basin

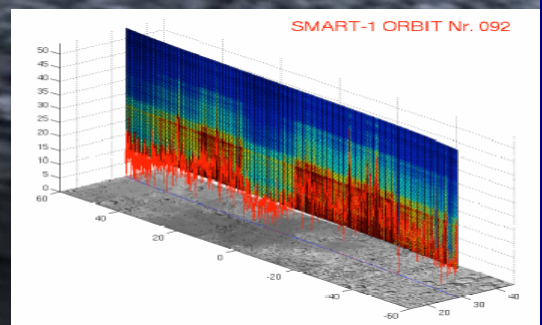
Minerals : the infrared Moon

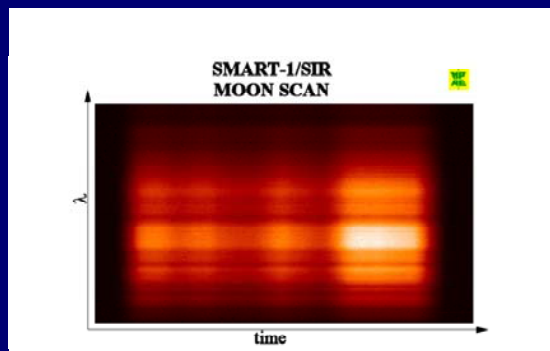
The SIR spectrometer 0.9-2.4 microns:

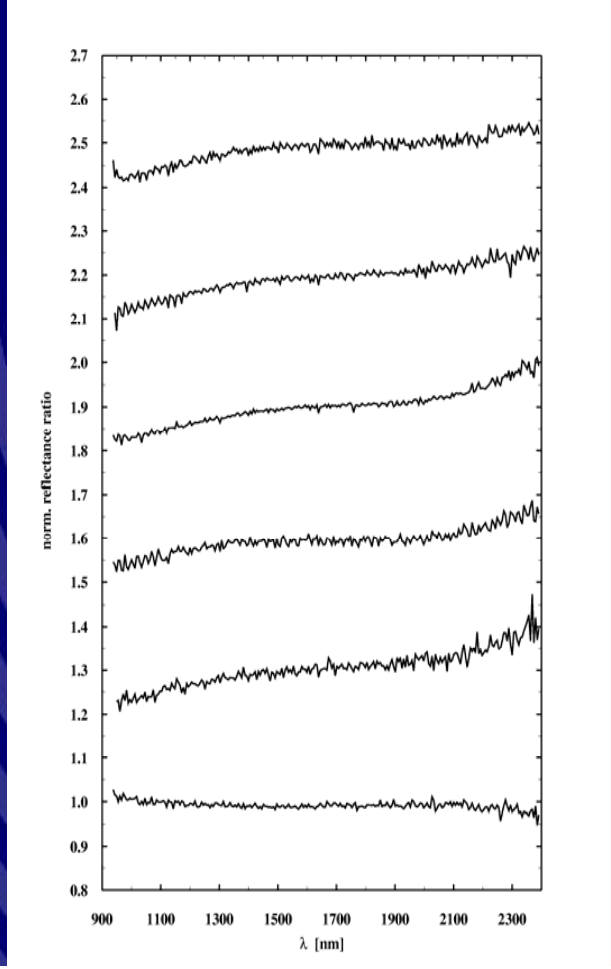
- to chart the Moon's minerals
- to find the signature of volcanism and impacts

-





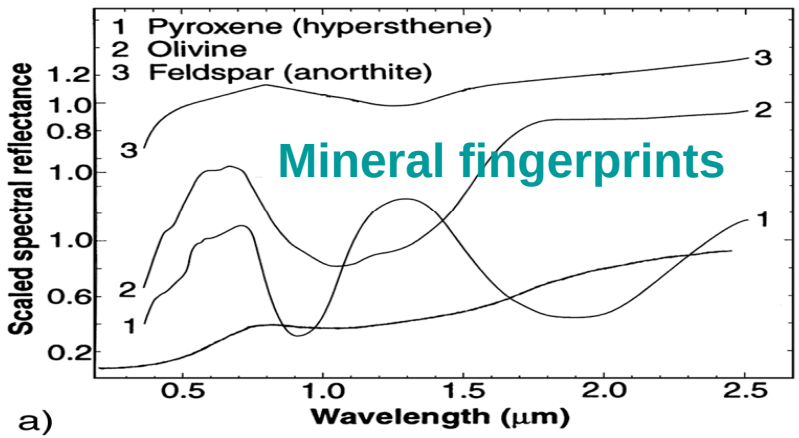


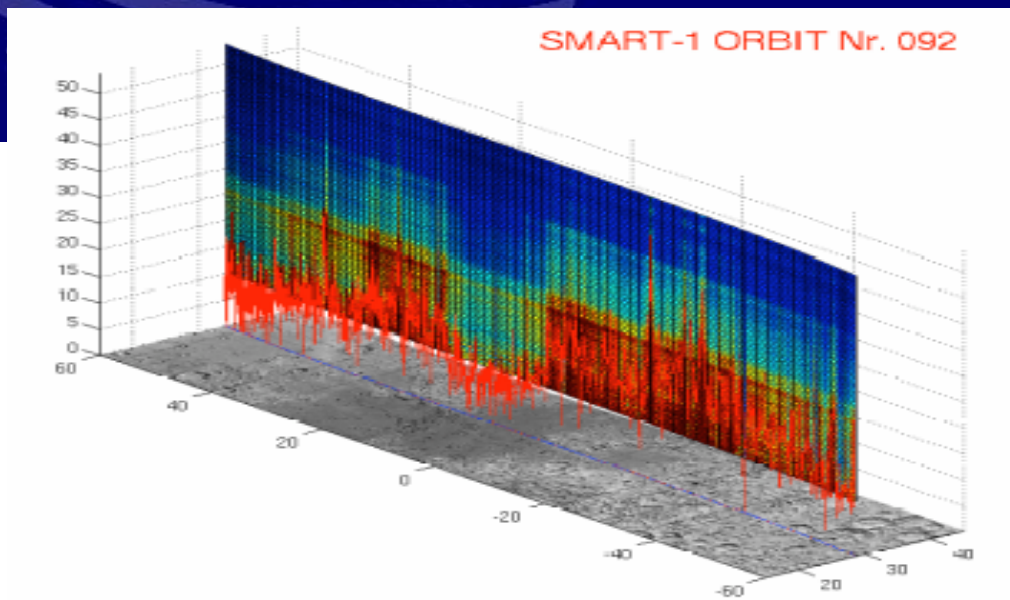


SIR infrared spectra across craters: window to the subsurface

EPSC2 talks
Vilenius et al
Wiese et al

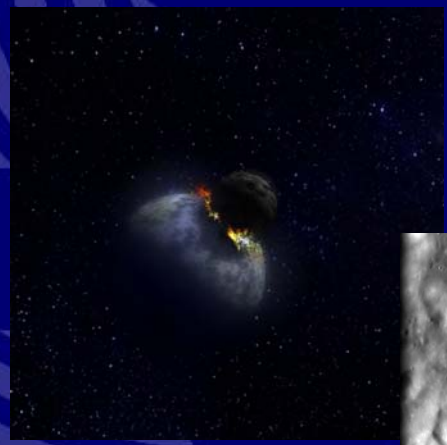
Mineral changes with SIR: from Highland to Mare



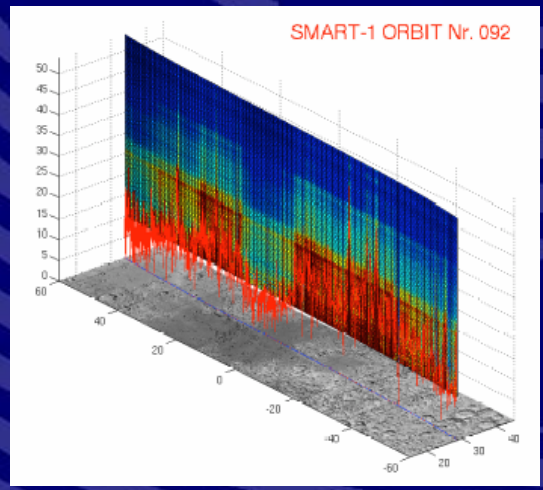


Formation and evolution of rocky planets

- Origin of the Moon: geochemistry
- Evolution of Earth/Moon system
- Impact craters and basins
- Bombardment history in the inner solar system
- South Pole Aitken Basin



Edge debris
from giant basin



SMART-1 Infrared
mineral spectroscopy

esa

Mapping chemical resources: How D-CIXS works

1 The Sun shines on the Moon (in X rays)

2 The Moon fluoresces

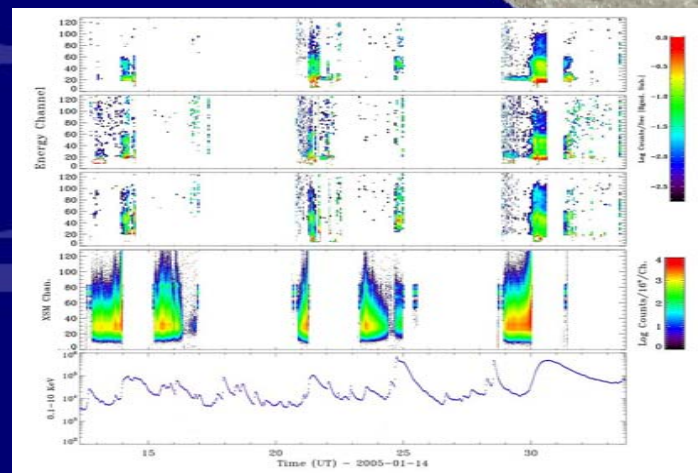
3 Each X-ray energy indicates unambiguously the abundance of a particular element

4 D-CIXS detects these X-rays

5 Solar Monitor for Solar Input required for absolute abundances

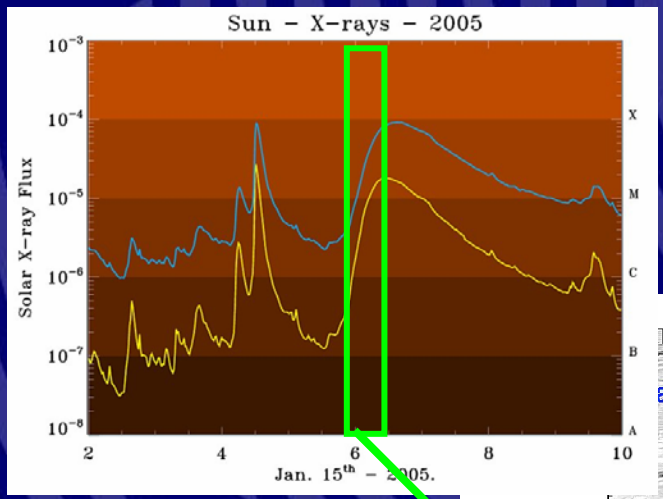
Sun Shines in X-rays

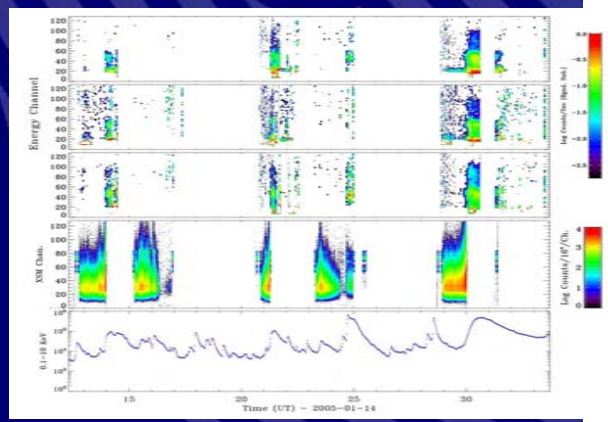
X-ray

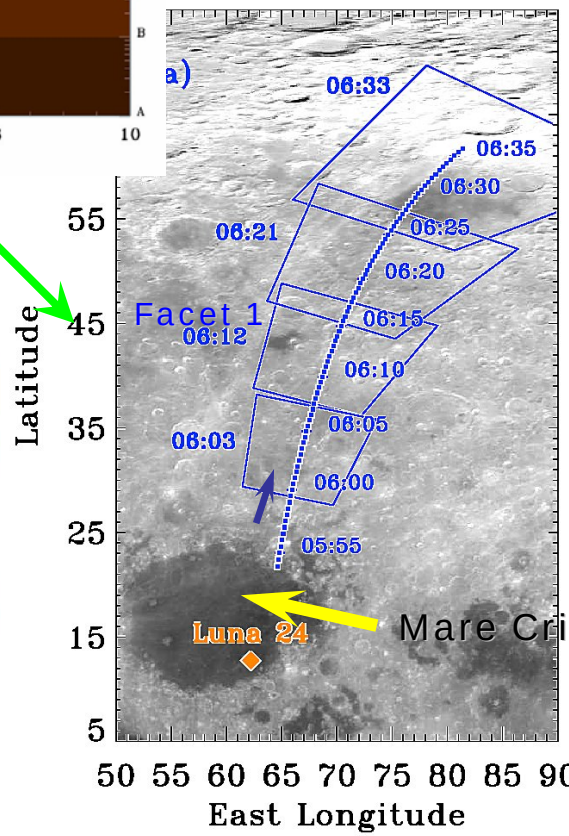


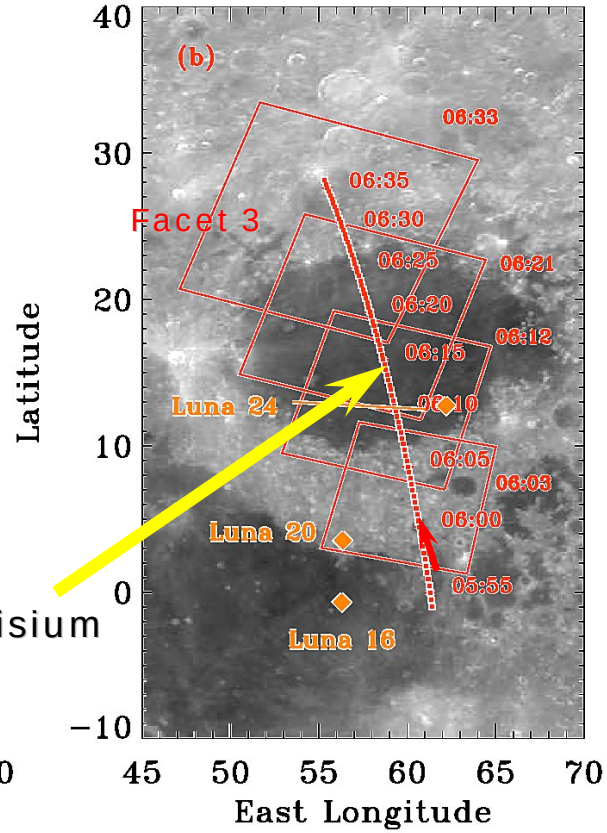
esa

SMART-1 & Luna 24 samples in Mare Crisium : Why is Ca constant while Mg varies?



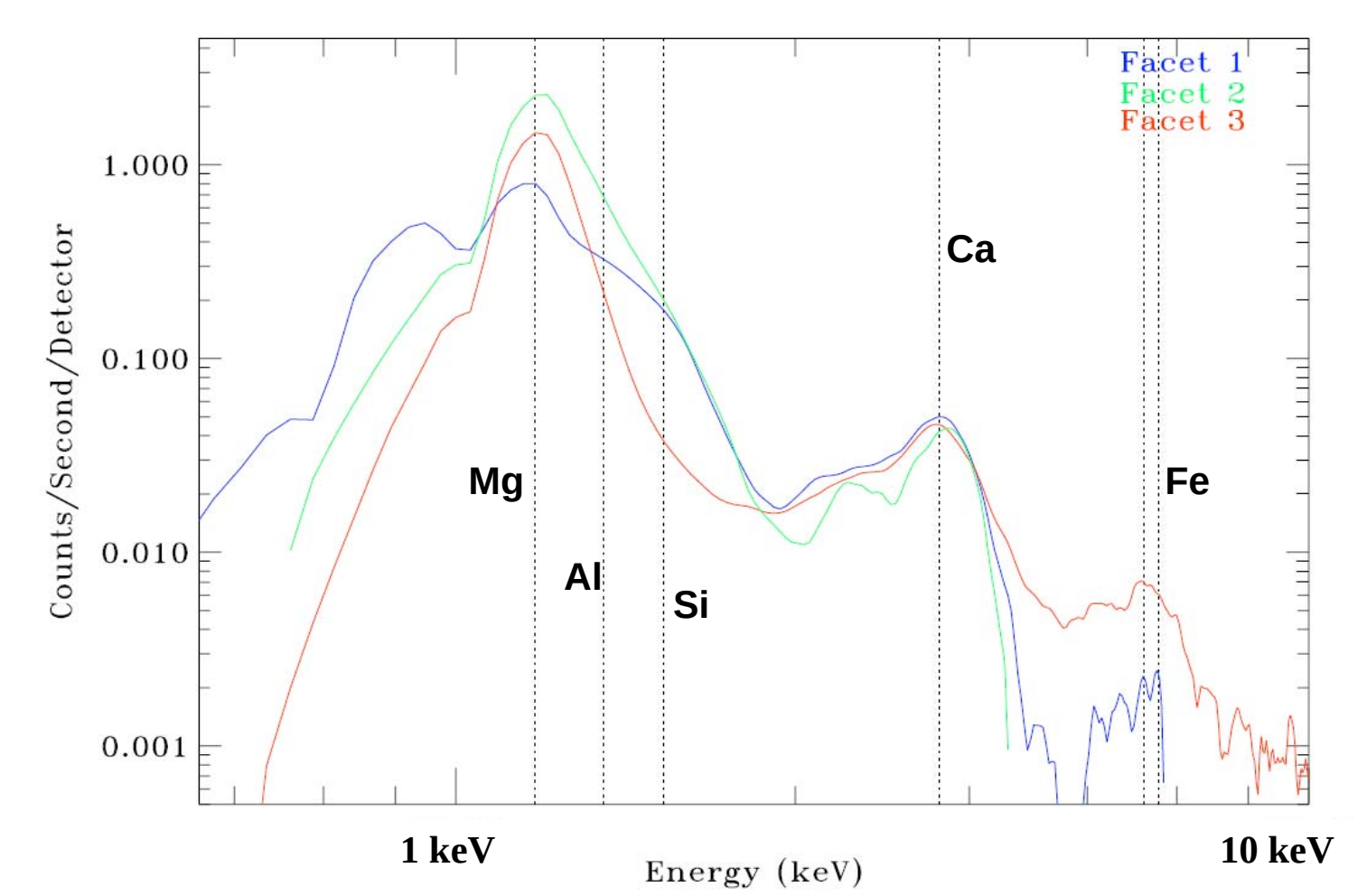




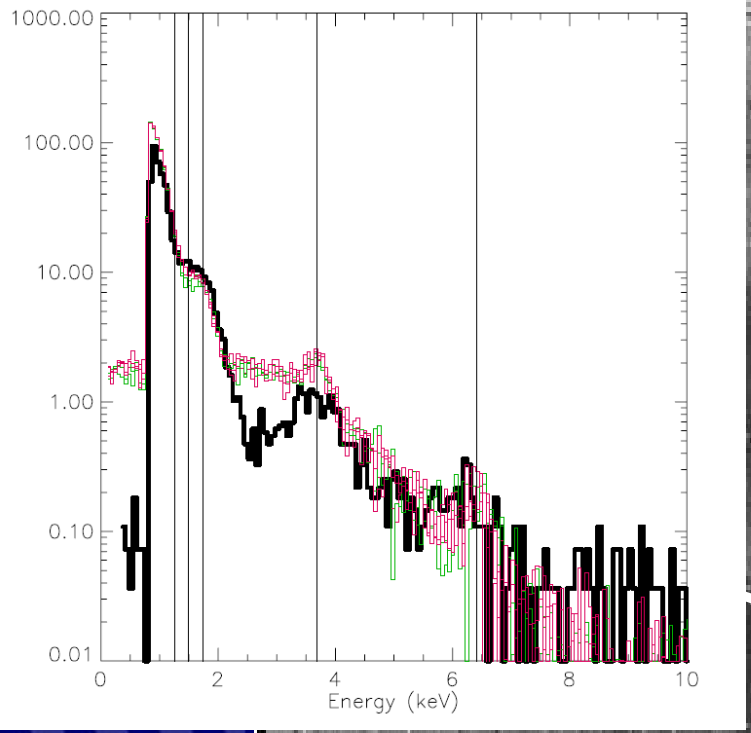


X-ray signatures of Chemical Elements

First ever remote sensing measurements of Ca at the Moon



Grande et al 2007

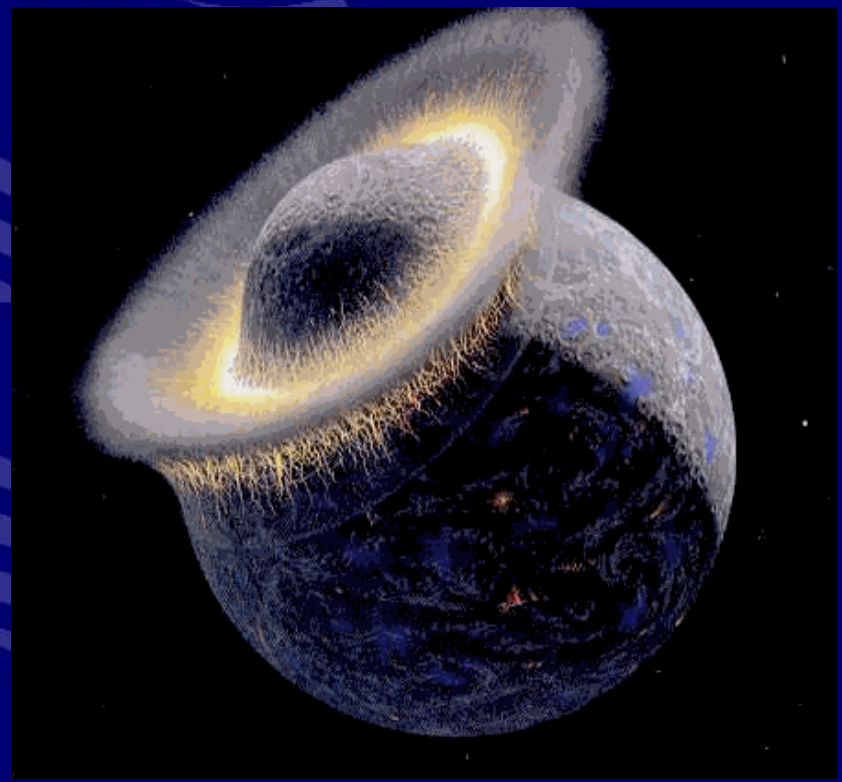


Detailed task of fitting Lunar composition to the data.

This is close to the Apollo 12 landing site

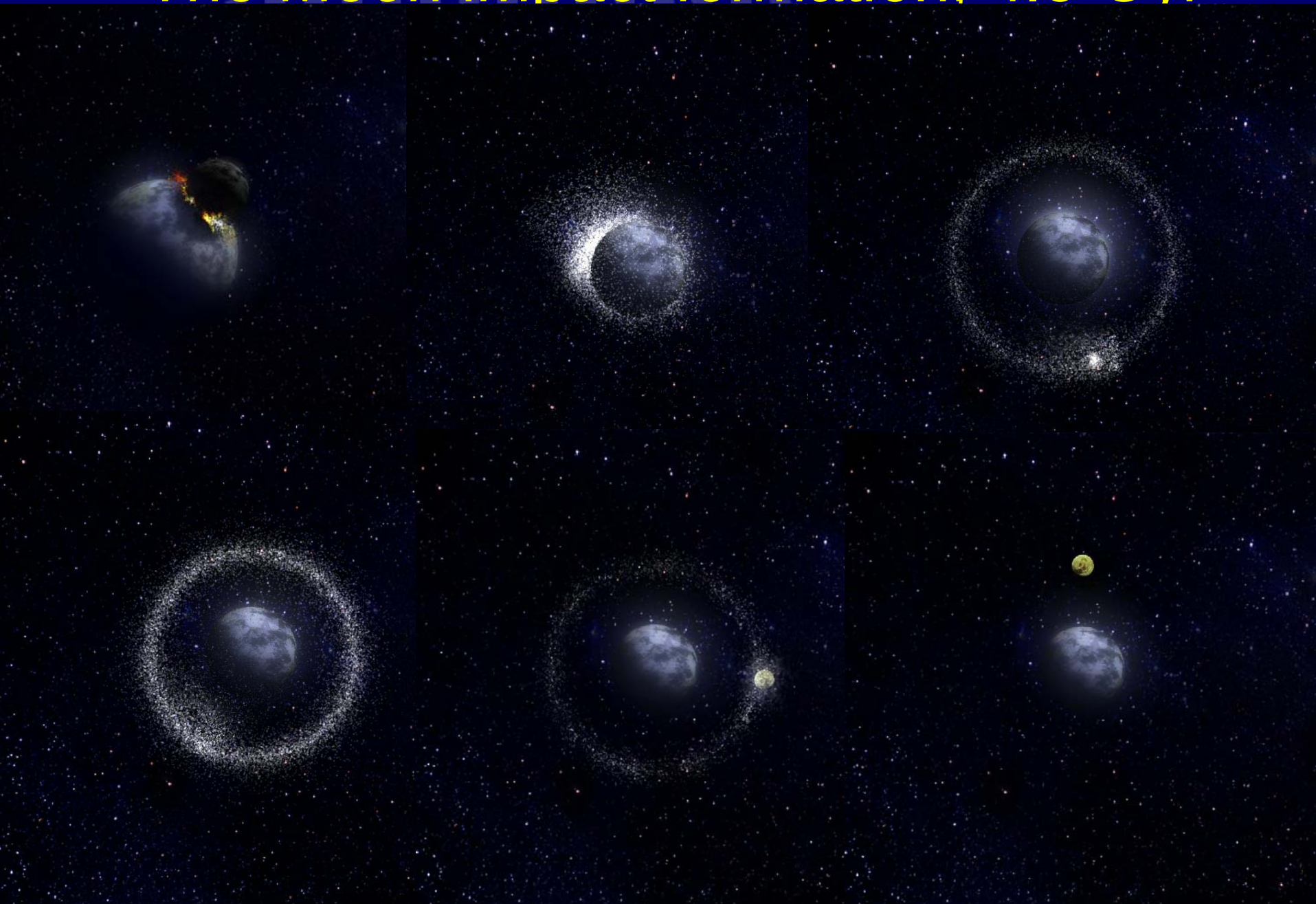
Unanswered questions about the Moon

- How did the Earth-Moon system form?
  - *Giant Impact? Origin of impactor? Volatiles?*
- How has the Moon evolved since?
  - *Magma ocean?*
- Necessary data
  - *Composition (Mg, Al…)*
  - *Age and isotopic composition*



esa

The Moon impact formation. 4.5 Gyr



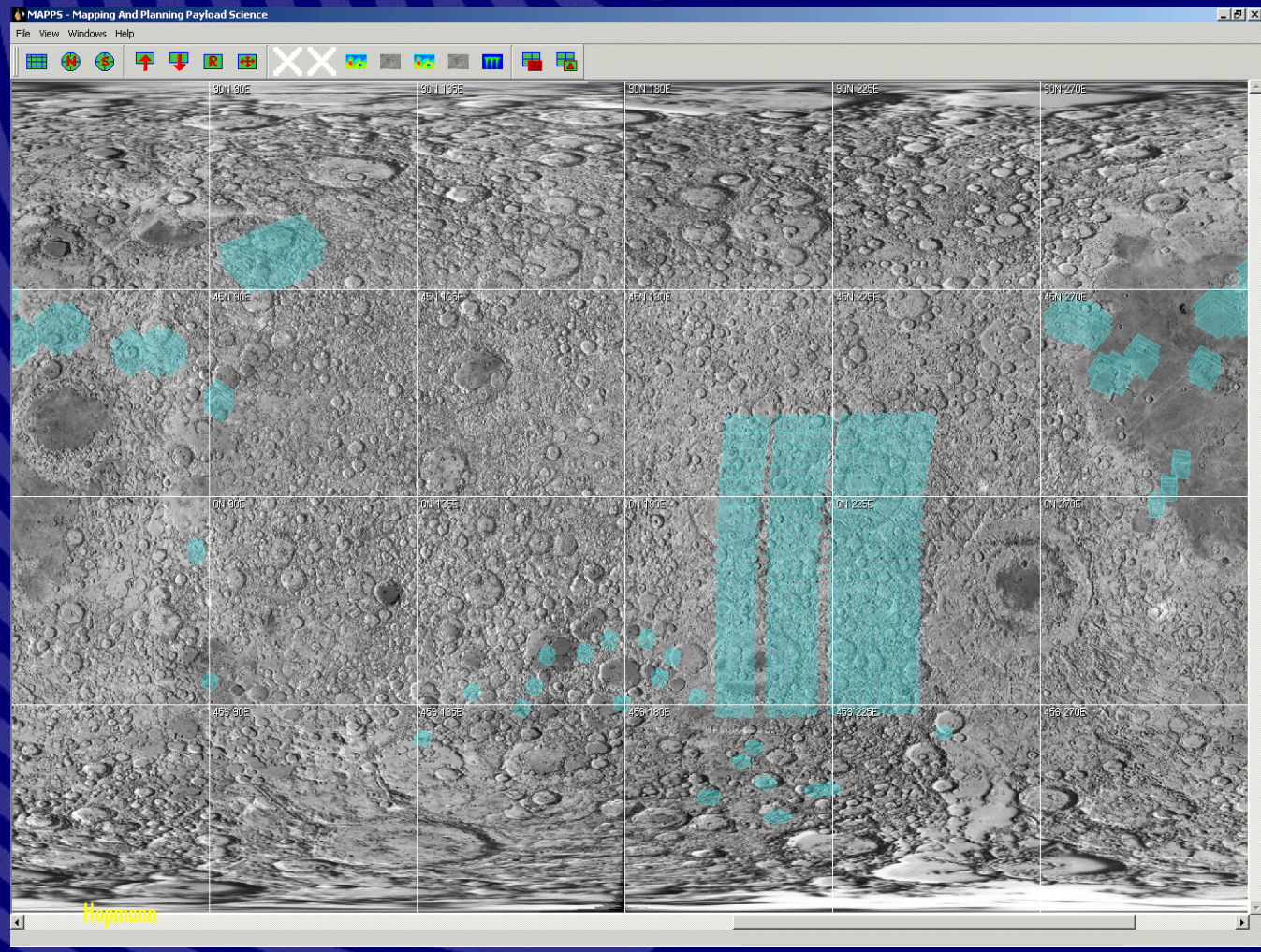
PREPARING FUTURE LUNAR/PLANETARY EXPLORATION

TECHNOLOGY LESSONS (ESTEC workshop January 2007)

LUNAR RESOURCES SURVEY
- minerals, volatiles, illumination

HIGH RESOLUTION MAPS: for future LANDING SITES and OUTPOSTS
- mid resolution map North polar region
- high res map of south polar region

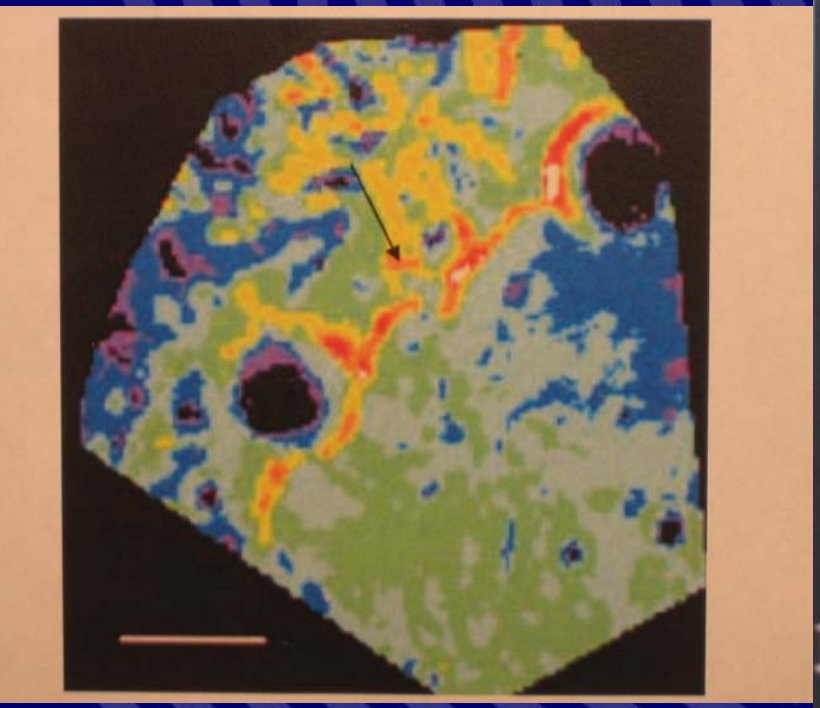
SUPPORT TO FUTURE MISSIONS AND EXPLORATION
- support Chang'E 1 ground segment validation
- support Chandrayaan-1
- collaborations Selene, LRO/LCROSS
- from SMART-1 impact campaign to future impacts
- use of SMART-1 data and experience
- support lunar landers and sample return missions design

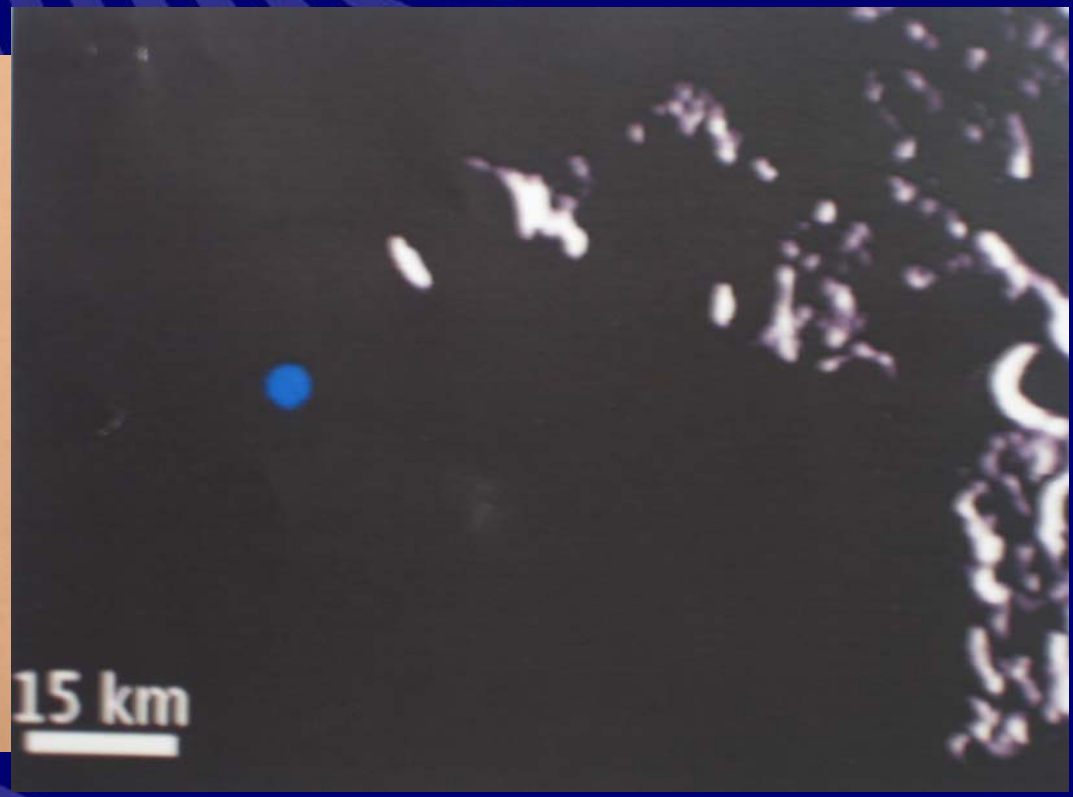


SMART-1
High res views of Targets in South Pole Aitken Basin For future sample returns

esa

North pole peaks of light





Summer average illumination
Clementine

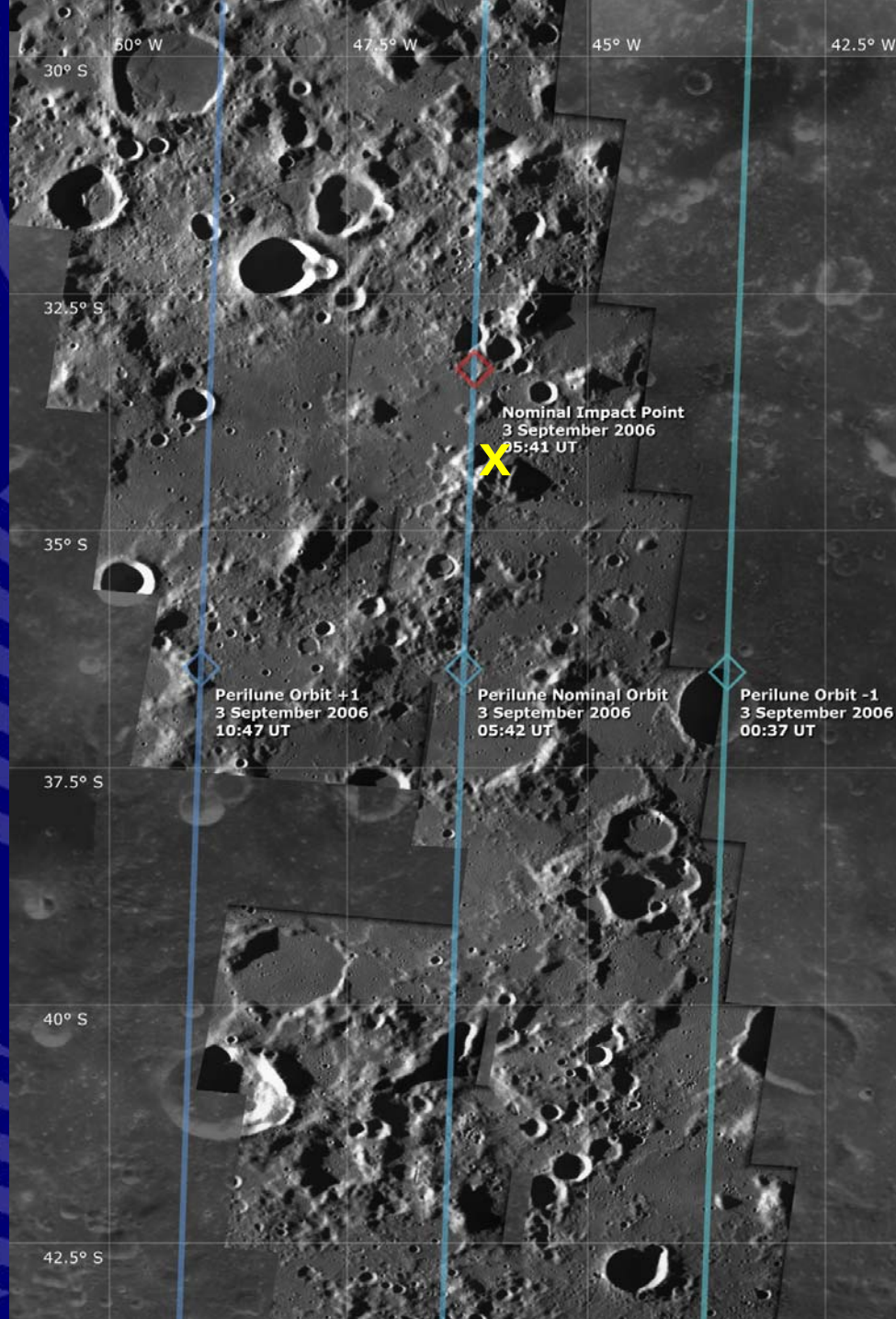
Winter image
SMART-1

SMART-1 maps its own landing site

Lake of Excellence
46.2 W 34.4 South

Highest resolution
Reference for future detection of crater and Ejectas

Impact time: 3 sept
5h42:21.7 UT
(within 1 s of prediction)



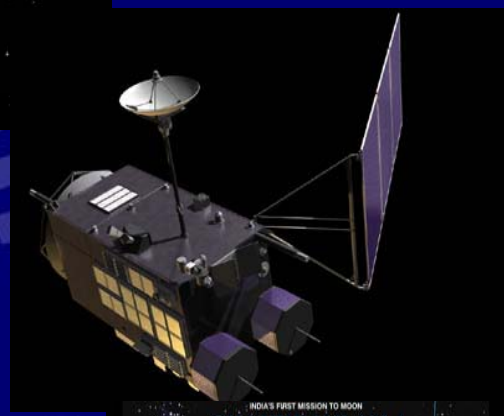
SMART-1 last orbit

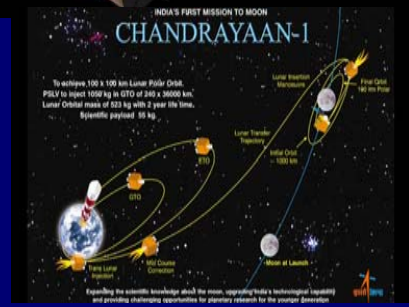
esa

Our last Moon travelling shot

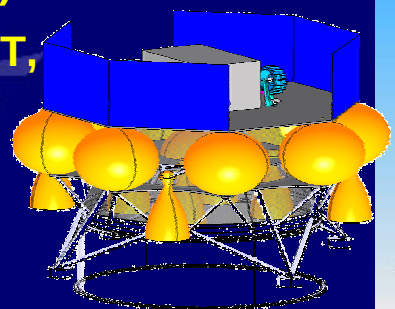
SMART-1 a bridge to Future missions

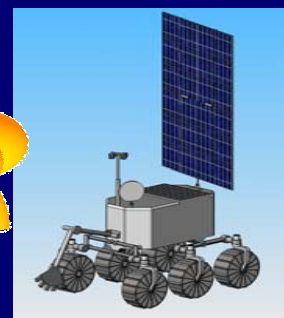
- Data analysis & Interpretation
- Technology Lessons Learned
- Science & Exploration Results
- Preparation for human lunar missions





- SMART-1 & next missions (collaborations)
  - 2007 Chinese Chang'e 1 (ground station)
  - 2007 JAXA Selene (science exchange)
  - 2008 ISRO Chandrayaan-1 (SIR2, C1XS, SARA)
  - 2008 LRO & LCROSS (planning, impact, outreach)
  - 2011- Orbiters (ESMO, ASI, Moon Lite, BW)
  - 2011- Landers, Rovers & Robotic village (US LPRP, Chang'e 2, Selene2, India, Lunaglob, ASI, D, UK, ESA)
  - 2015- Sample return: Chang'e 3, Selene3, ESA NEXT,
  - 2019- Human missions





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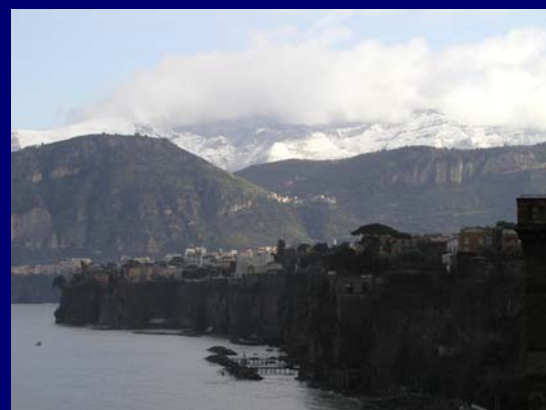
ILEWG9/ILC2007 Intl Lunar Conference

- 22-26 October 2007, Sorrento, Naples Bay, Italy, Co-hosted by ASI & ESA
- Co-chairs: S. Di Pippo (ASI), Wu Ji (China), M. Wargo (NASA), B.H.Foing (ILEWG/ESA)
- 1. Inauguration & Keynote speeches
- 2. Results from SMART-1, and latest reports from Chang'E 1 and Selene
- 3. Agencies activities and plans
- 4. Keynote speeches: Science, Technology, Human exploration
- 5. Status of Future Missions: Chandrayaan-1, LRO/ LCROSS, Future Landers/Orbiters
- 6. Science and Exploration of the Moon: Results, Open Questions and New Approaches
- 7. Technologies, Infrastructures, Resources for Future Robotic and Human exploration
- 8. Societal, legal, policy, economics
- 9 Next steps for Robotic Landers, Rovers and Outposts
- 10 International Prospects for utilization and human exploration.
- 11 Reports and recommendations from working groups
- 12 ICEUM9 recommendations and declaration
- 13 Young Lunar Explorers session
- Outreach/education for public and Youth
- 14 Posters & interactive sessions
- Geological field trip



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