LPSC Special session
SMART-1 UPDATE AND IMPACT CAMPAIGN

Marina Plaza Ball room
Thursday 12:00-13:15

- SMART-1 status and planned operations (B.Foing & STOC), Orbit predictions
- coordinated observations with SMART-1 in March- August
- - targets imaging, radiometric calibrations, spectrometric observations
- - merging of SMART-1 and ground based data
- - ground based detection of SMART-1, and laser link experiment, radio detection and VLBI
- - opportunities for outreach and education, adopt your crater, amateur lunar images competition

- Impact predictions (flash, ejecta, exospheric effects, crater) and challenges
- - SMART-1 observations of previous impact sites, Prior observations of site of impact
- - straylight rehearsal, support of impact observations

- Impact observations
- - thermal infrared imaging of thermal flash, visible/infrared imaging of ejected clouds
- - spectroscopy, hydrazine flame detection
- - VLBI observations, accurate coordinates of impact crater
- - post-characterisation of ejecta, exospheric effects
- - follow up search for SMART-1 crater (in coordination with future lunar orbiters)

- Facilities and observing requests, Moon visibility conditions
- - ESO VLT, ESO La Silla, Galileo National Telescope (I), Tenerife OGS and other
- - European continental observatories, US/ Hawaii observatories, Other int'l observatories
- Discussion, Share of tasks, Preparation/consolidation of observing proposals

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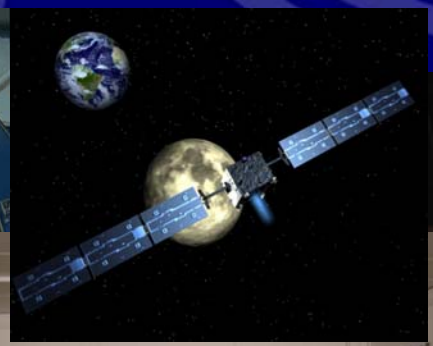
EUROPE TO THE MOON: SMART-1 STATUS

Bernard H. FOING, *SMART-1 Project Scientist & Chief Scientist, ESA SCI-S &*
J.L. Josset , M. Grande, J. Huovelin, U. Keller, A. Nathues, A. Malkki, P. McMannamon, L.Iess
& SMART-1 Science & Technology Working Team STWT
M. Almeida, D. Frew, D. Koschny, R. Lumb, J. Volp, J. Zender, RSSD & STOC
G. Racca & SMART-1 Project ESTEC , G. Schwehm, O. Camino-Ramos & S1 Operations team ESOC,
Bernard.Foing@esa.int, http://sci.esa.int/smart-1/

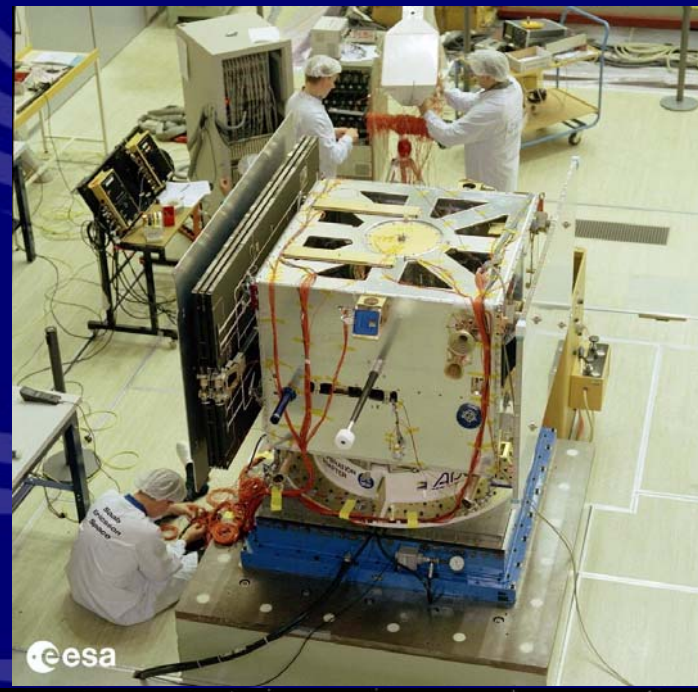
SMART-1 project team



Science Technology Working Team &
ESOC Flight Control Team

SMART-1 Mission

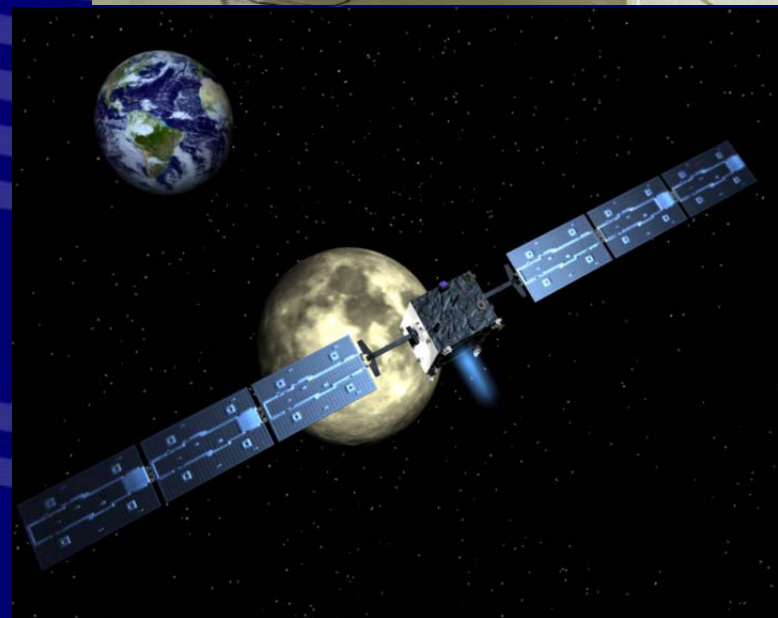
SMART-1 web page (http://sci.esa.int/smart-1/)



- ESA SMART Programme: Small Missions for Advanced Research in Technology
  - Spacecraft & payload technology demonstration for future cornerstone missions
  - Management: faster, smarter, better (& harder)
  - Early opportunity for science

SMART-1 Solar Electric Propulsion to the Moon

- Test for Bepi Colombo/Solar Orbiter
- Mission approved and payload selected 99
- 19 kg payload (delivered August 02)
- 370 kg spacecraft
- launched Ariane 5 on 27 Sept 03, Kourou



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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-CIXS)

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 Mechanism, 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)
Finish Meteorological Institute: Space plasma electron and dust detection (SPEDE)

Sweden (S)
Swedish Space Corporation: Prime Contractor
Omnisys 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

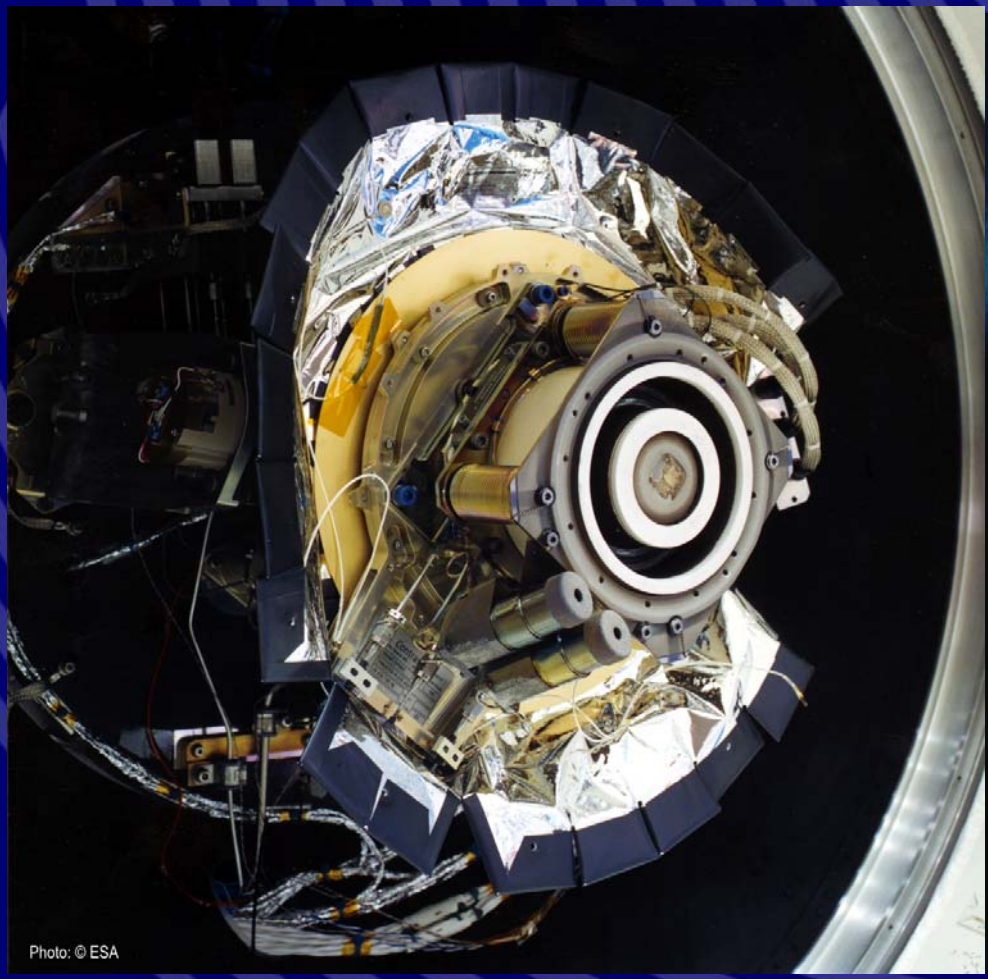
Denmark (DK)
Terma A/S: On-board Independent Software Validation
DTU Technical University of Denmark: Star tracker

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)

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



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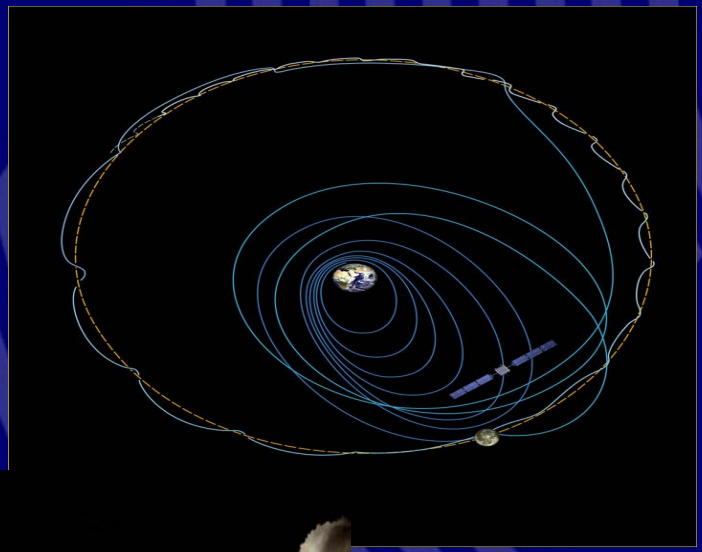
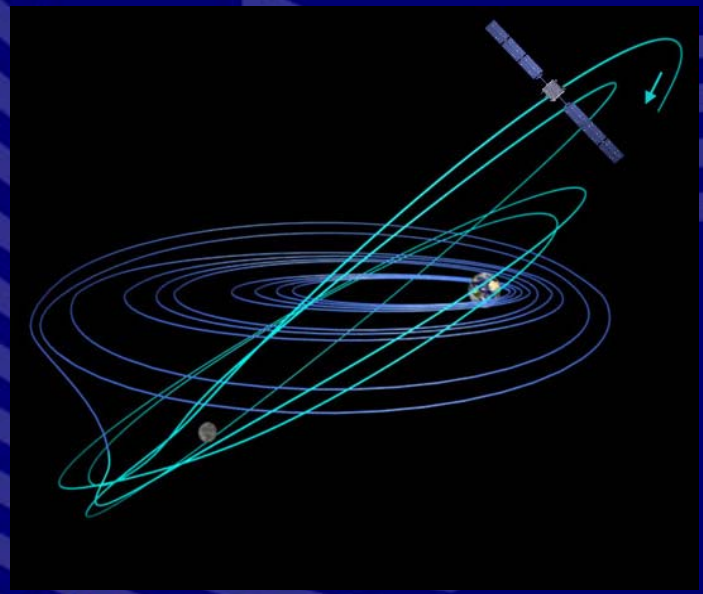
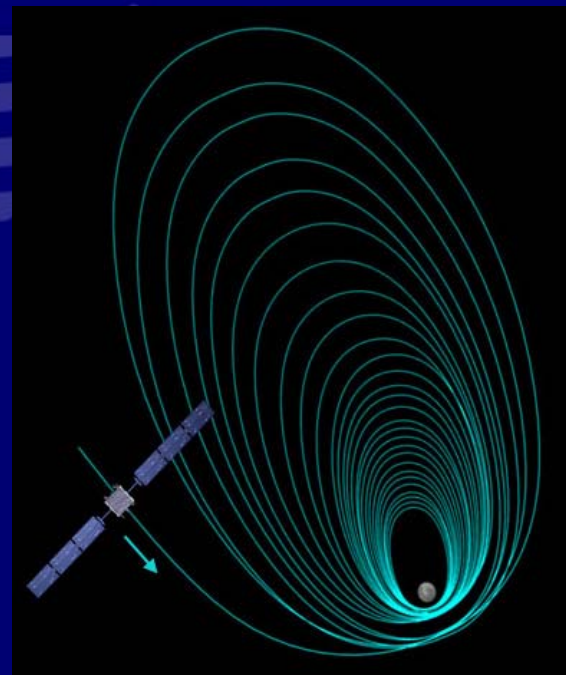
Solar Electric Propulsion to the Moon



- 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





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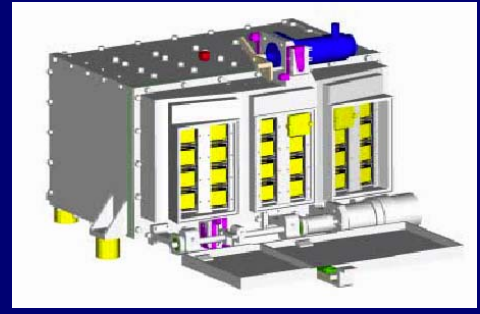
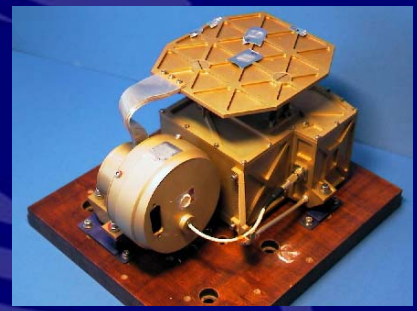
Mini-Instruments European Technologies (19 kg): eyes, nose and ears



- D-CIXS Spectrometer (UK, 5.2 kg)
- + XSM solar X-ray Monitor (SF)



- SIR Infrared Spectrometer (D, 2.3 kg)

- AMIE micro-Camera (CH, 2.1 kg)

- SPEDE Spacecraft Potential Electron Dust (SF, 0.8 kg)
- EPDP Electric Propulsion Diagnostics Package (I, 2.4 kg)

- KATE Deep Space Communications (D/ESA, 6.2 kg)
- RSIS radio science (I)

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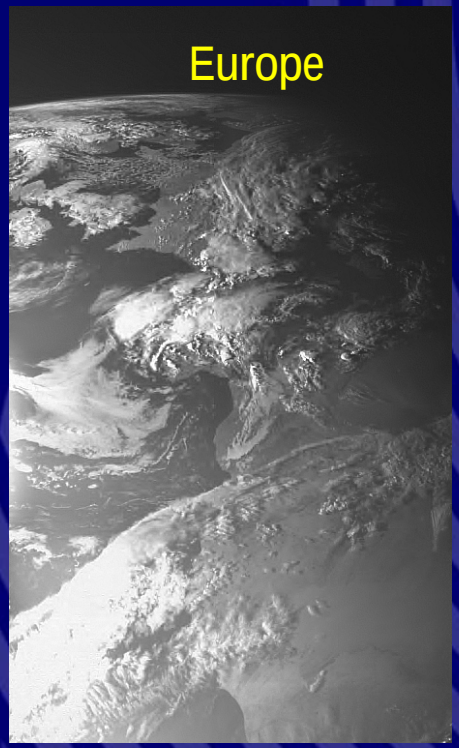
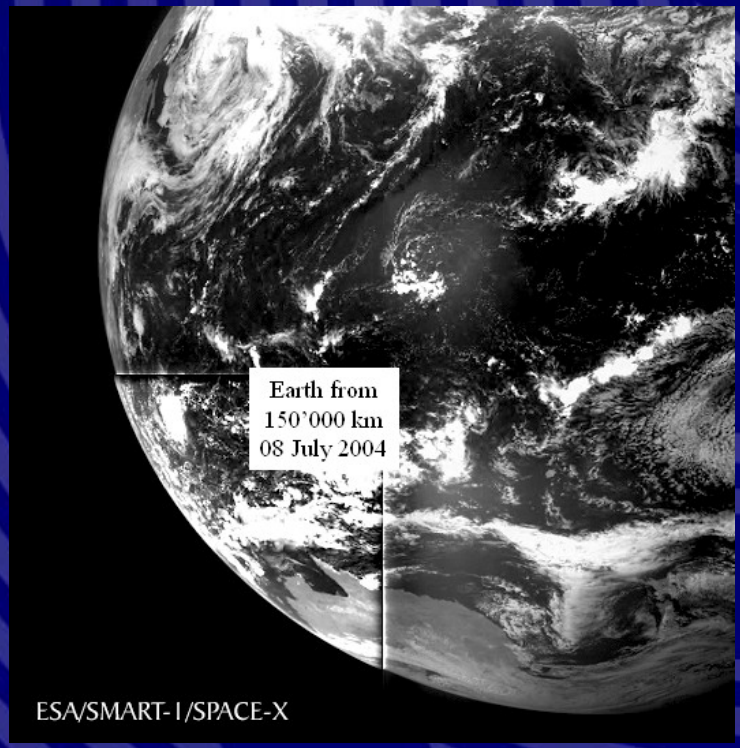
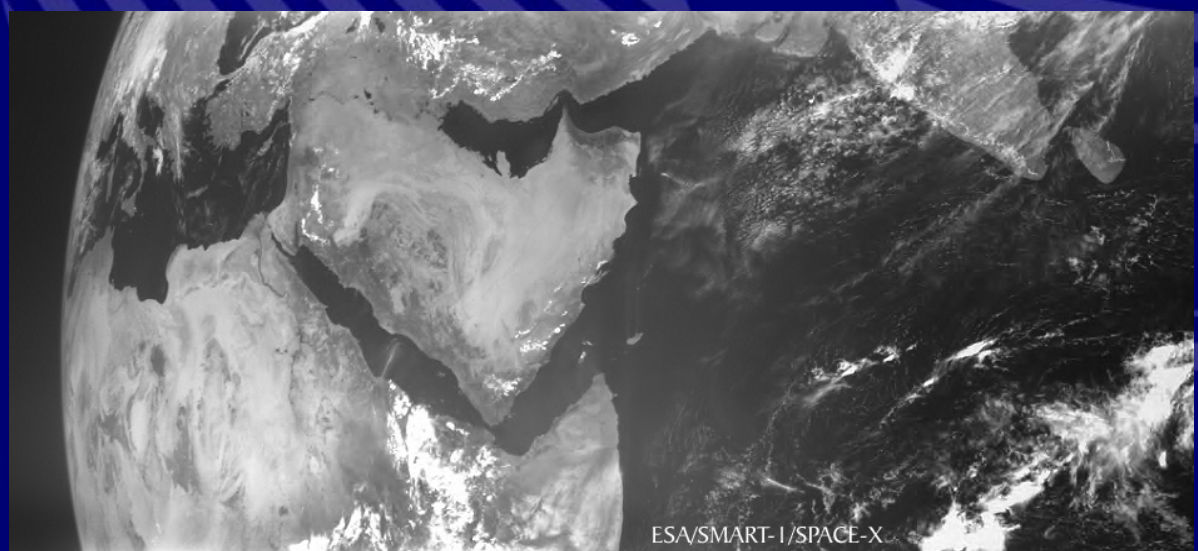
SMART-1 views planet Earth





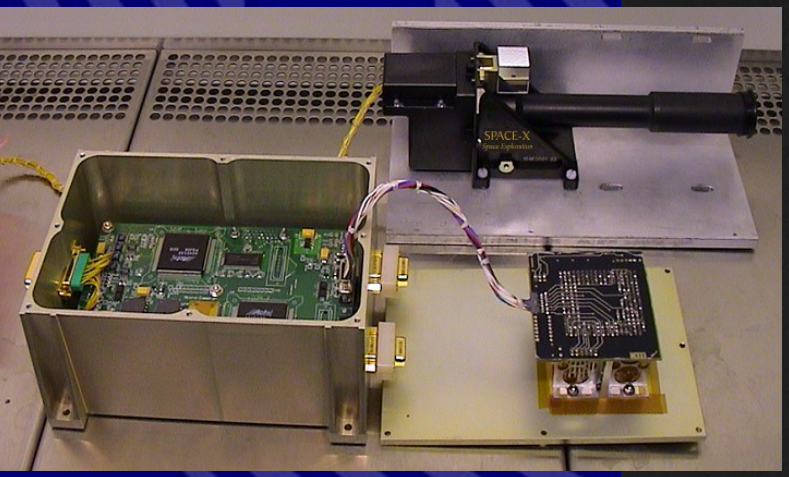


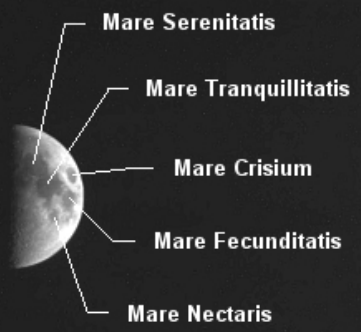
1 year launch birthday

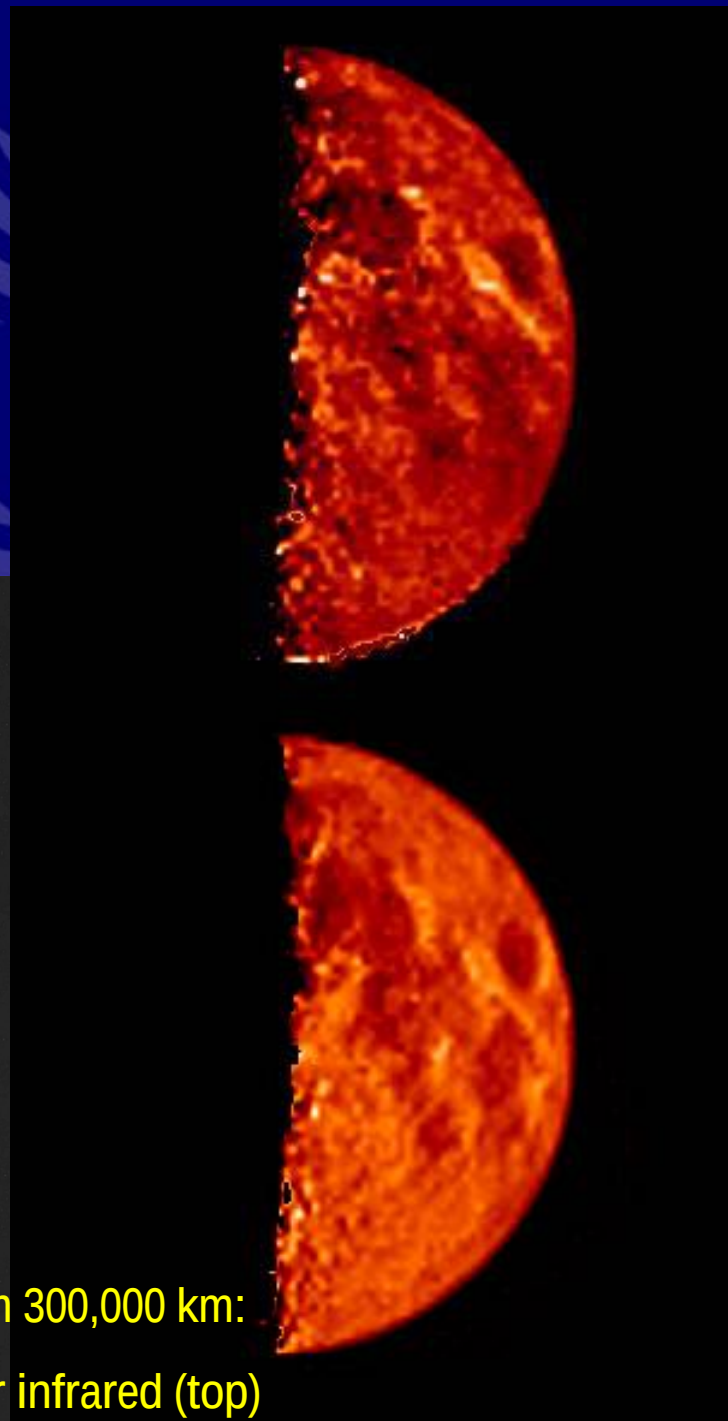
AMIE multicolour microcamera

PI:SPACE-X, CH; Co-I's I,F,CH, Fin, NL, ESA

- CCD cam & micro-electronics packed in 3-D
- 4 colour filters (red to near infrared)
- Mass 2.1 kg , optics 400 g , 5.3° view
- Support laser-link, On Board Autonomy







1st AMIE image of Moon from 300,000 km:

White, red (bottom) and near infrared (top)

Smart-1/SIR & the infrared Moon: minerals and ice

The SIR spectrometer 0.9-2.4 microns:

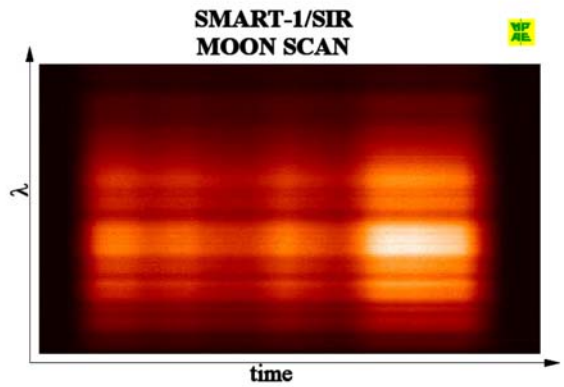
- to chart the Moon's minerals

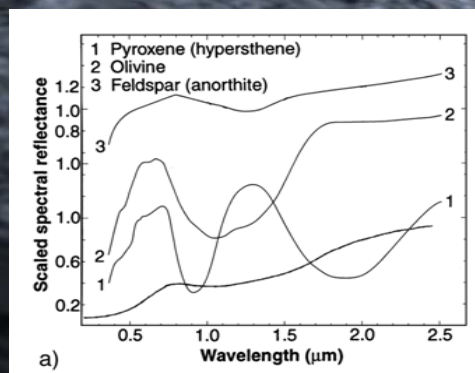
- to find the signature of volcanism and impacts

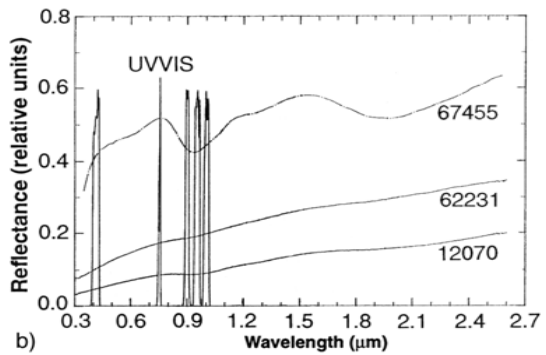
- to search for the fingerprints of water- ice by peeking into dark craters

-

1st moon observations

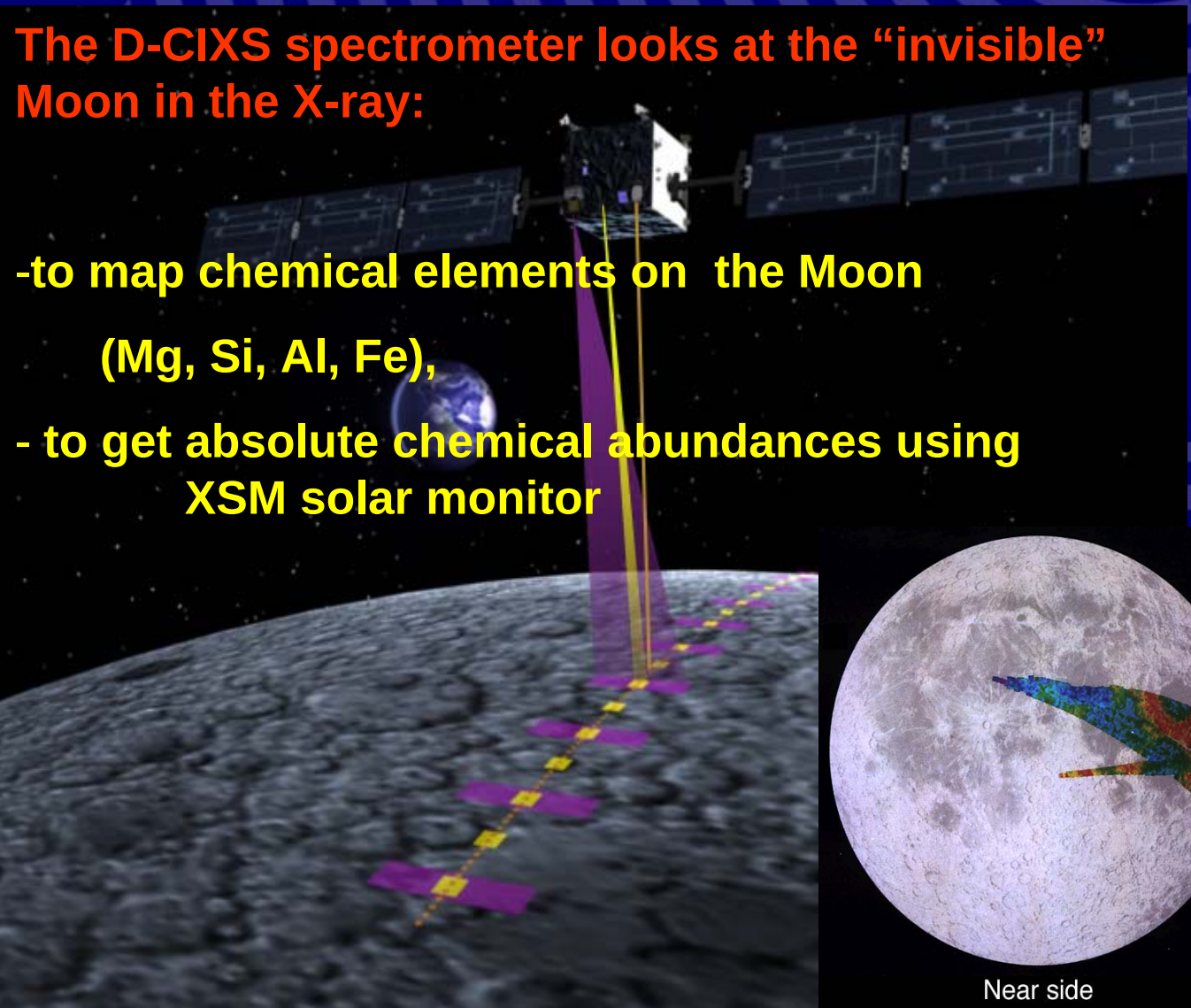






NEXT: SMART_1 D-CIXS X-ray Moon: tracing violent Earth-Moon beginnings

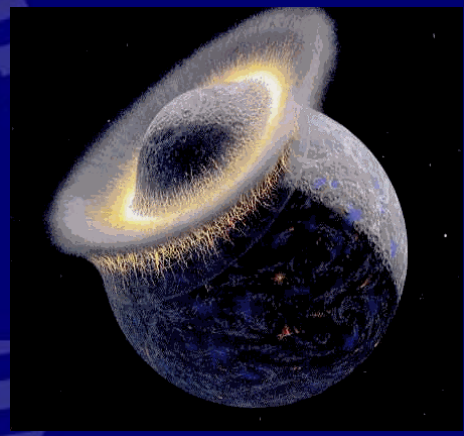
The D-CIXS spectrometer looks at the “invisible” Moon in the X-ray:

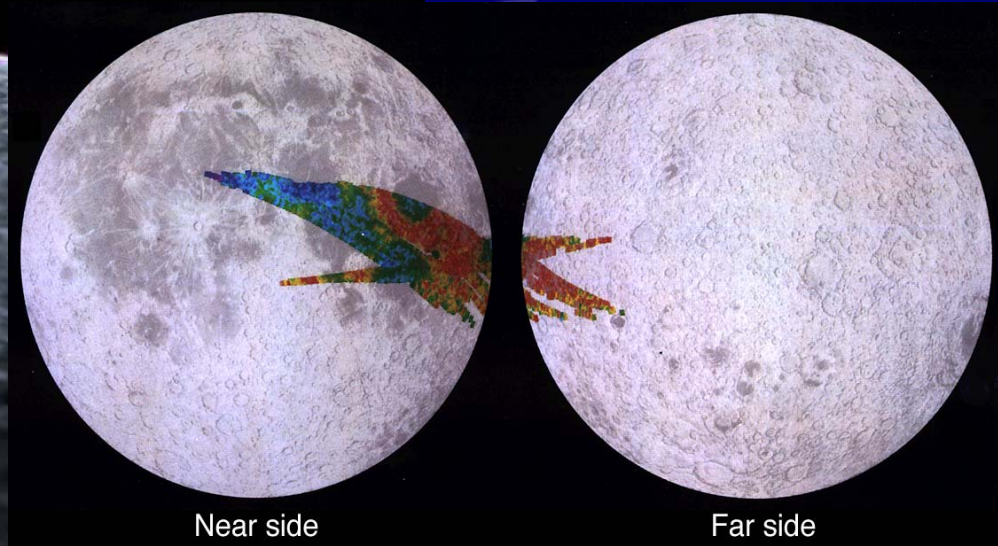


-to map chemical elements on the Moon

(Mg, Si, Al, Fe),

- to get absolute chemical abundances using XSM solar monitor





Towards Moon capture

28 Oct from
600,000 km

1st European view of North pole and far side
(12 Nov from 60,000 km),
second in space exploration history

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First Moon close-up images

First Moon close-up Images – 29 Dec. 2004

By AMIE/SMART-1

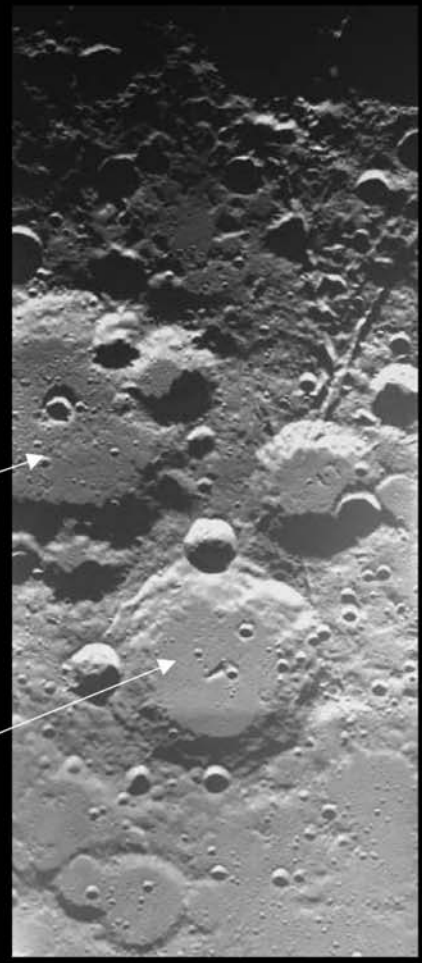
AMIE Instrument

Clear Filter

(~ 75° Lat. North)

Brianchon

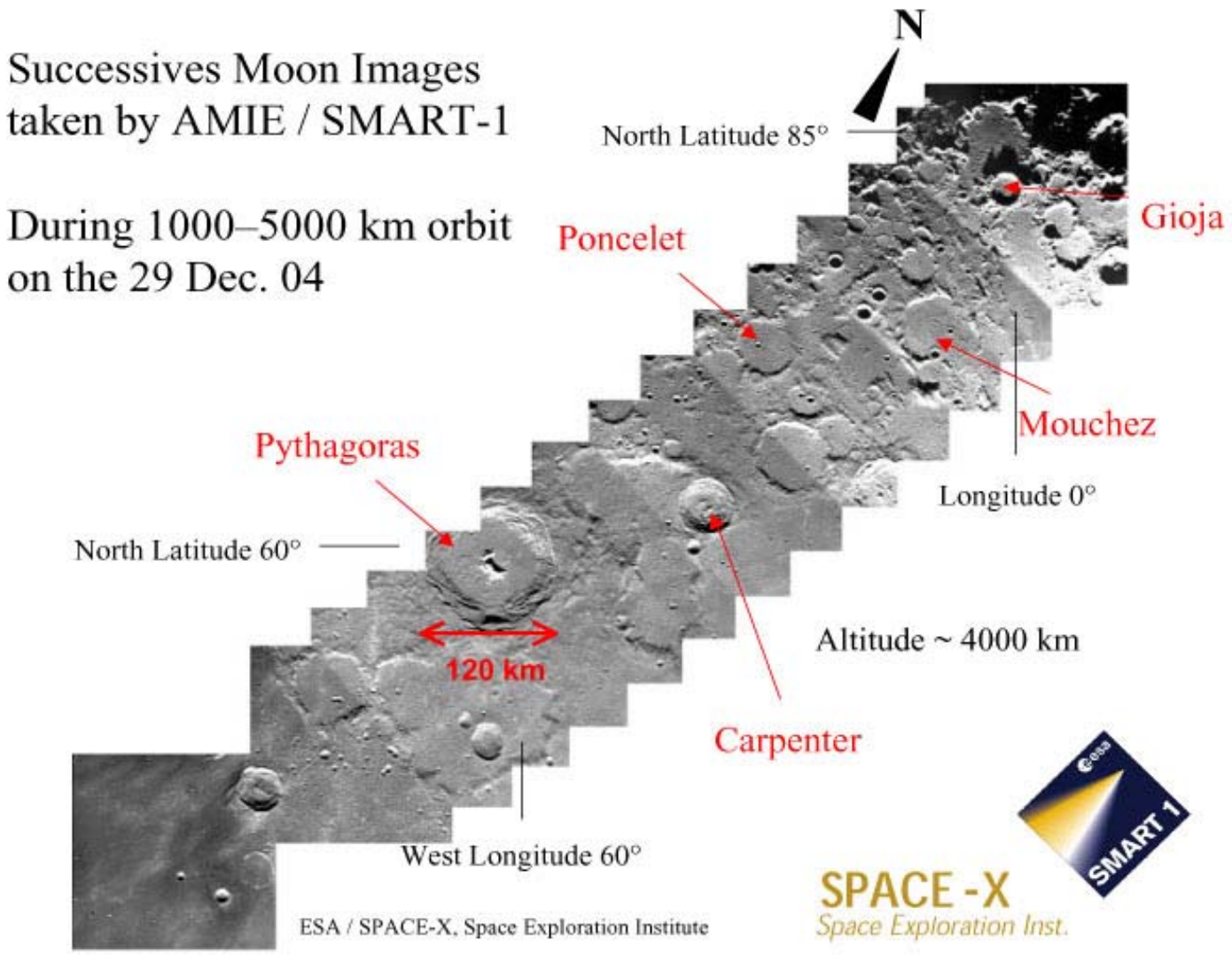
Pascal



Area covered by 3 Filters

esa SPACE-X Space Exploration Inst.

Mosaic of images along SMART-1 from orbit 1000-4500 km



SMART-1: Science and Exploration Themes (B.H. Foing et al, continued)

A) TECHNOLOGY AND DEMONSTRATION (spacecraft and instruments work)

B) CRUISE PHASE SCIENCE (analysis and interpretation)

C) *HOW DO EARTH-LIKE PLANETS WORK?*

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

D) *HOW DO ROCKY PLANETS FORM AND EVOLVE?*

GEOCHEMISTRY: chemical composition, Earth-Moon origin, Moon evolution

accretion and collisions, giant bombardment

E) PREPARING FUTURE LUNAR/PLANETARY EXPLORATION

LUNAR RESOURCES SURVEY (minerals, volatiles, illumination)

HIGH RESOLUTION MAPS for future landing sites and outposts

SUPPORT TO FUTURE EXPLORATION and coordination with other missions

F) PUBLIC OUTREACH AND EDUCATION: INSPIRING PUBLIC AND YOUTH

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Impact cratering processes

- Glushko crater, a young impact caught after the act
- Fresh 43 km crater: wall, fresh rims, central peak and collapse, ejecta

ESA / SPACE-X, Space Exploration Institute

Cassini Crater flooded by lava in Imbrium mare

-outer rim
-small fresh crater exhuming deeper basement or debris?
-volcanic center with rilles?

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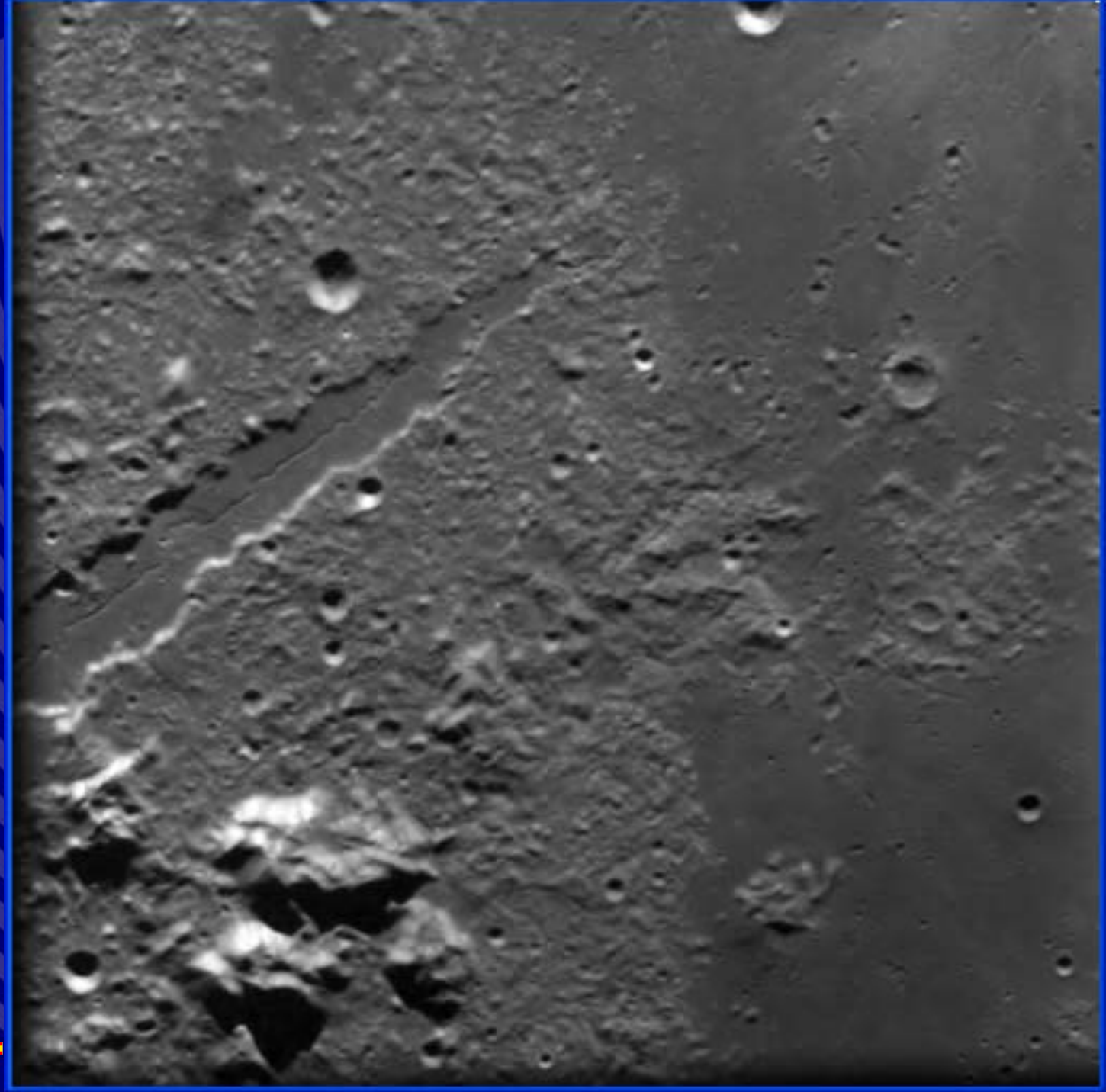
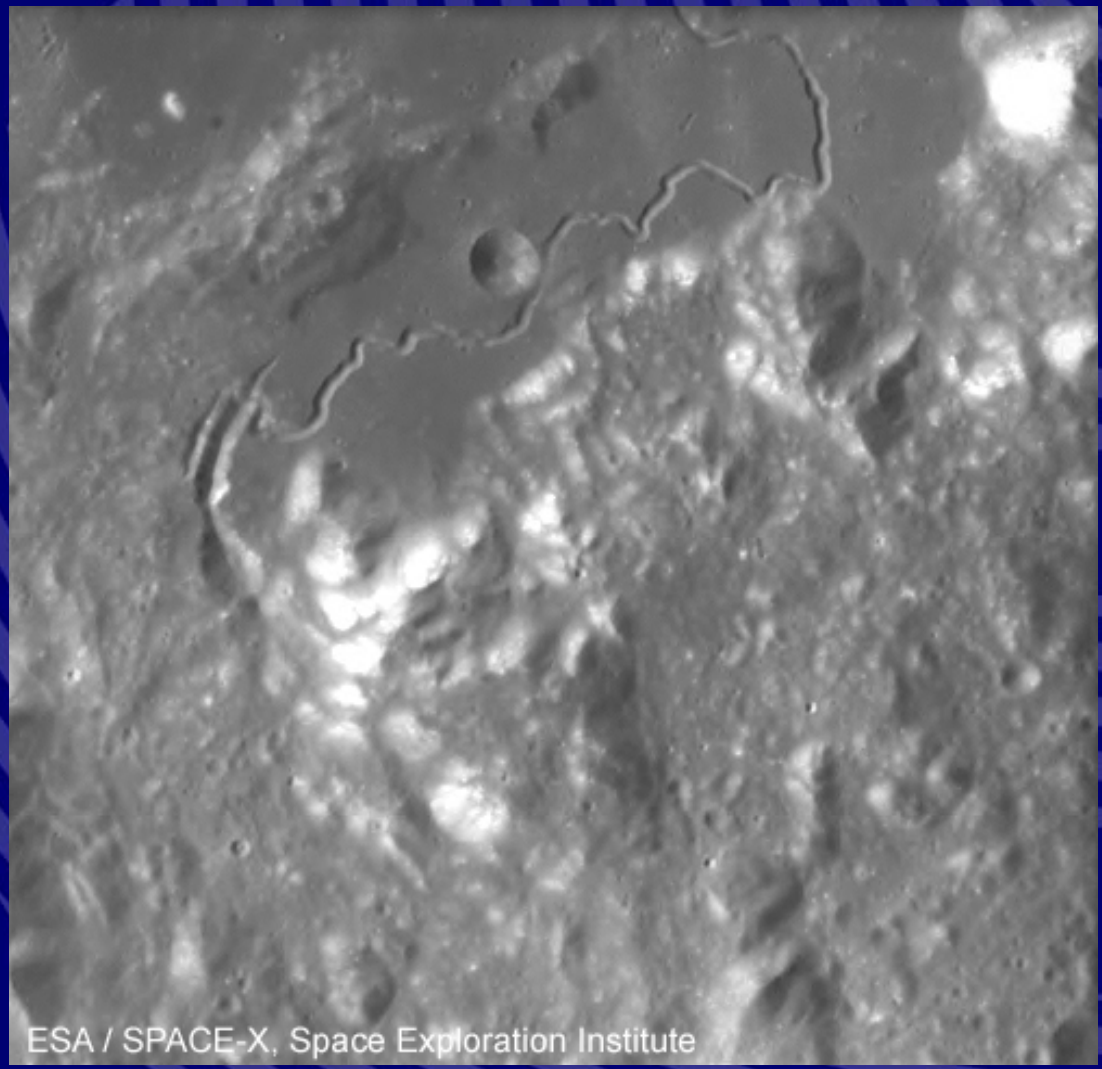
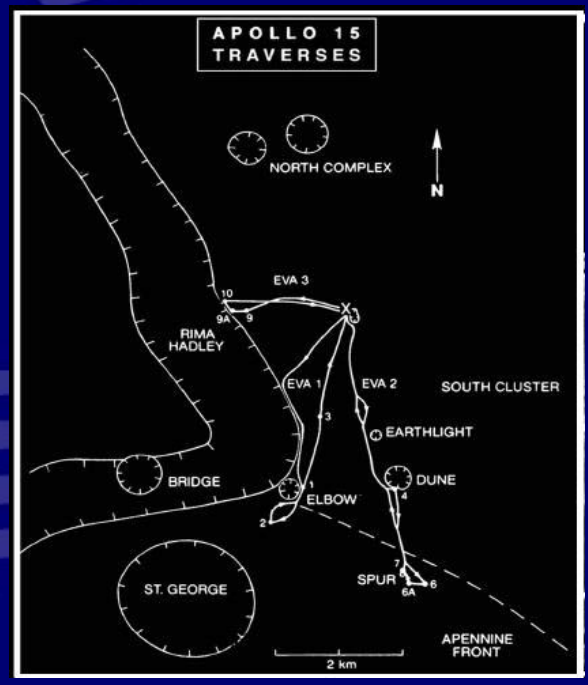


Lunar Alps ridge
- flooding
- volcanic channel and late rille

SMART-1 view of Hadley Rille near Apollo 15 landing site





100 km field

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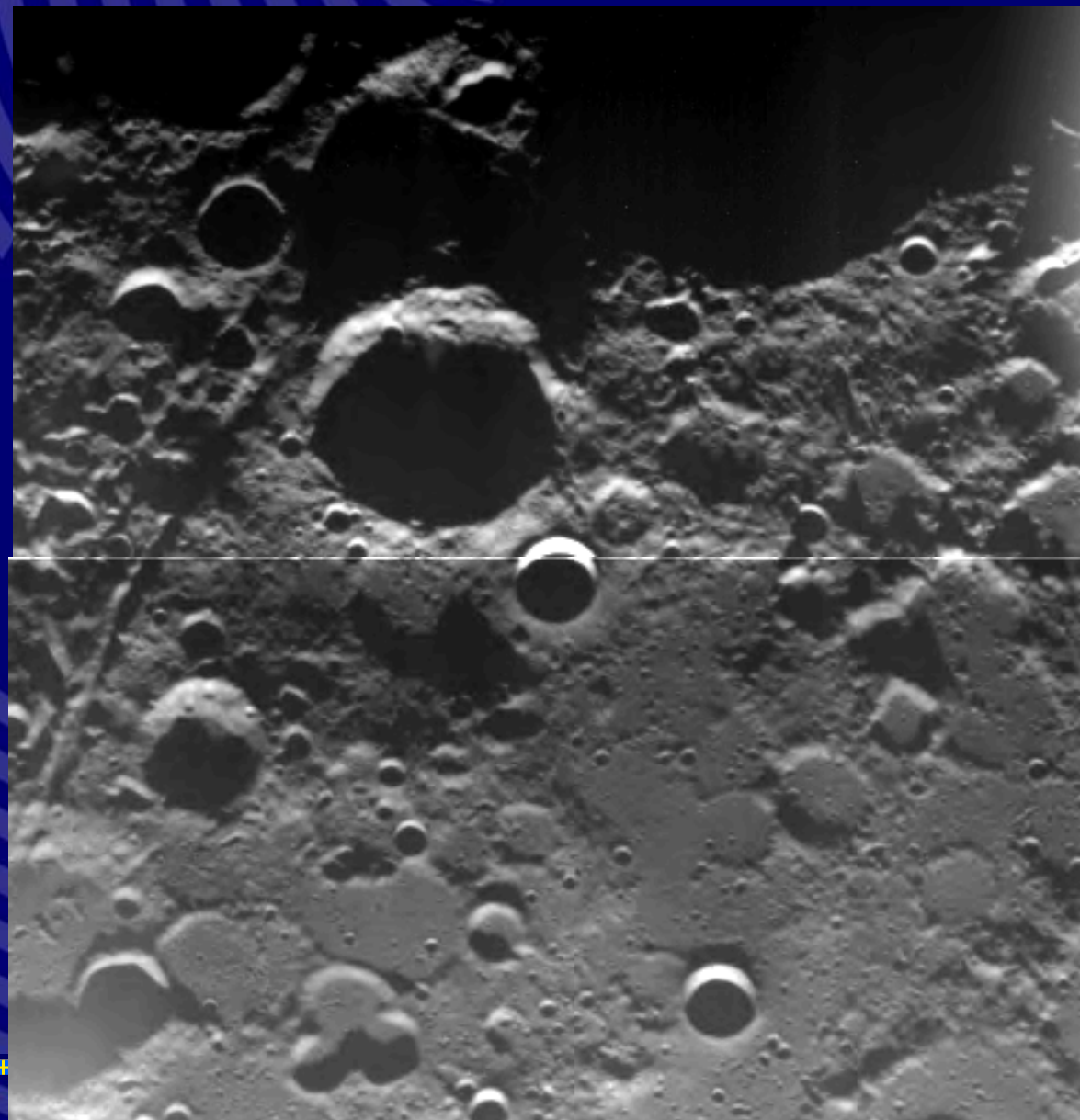
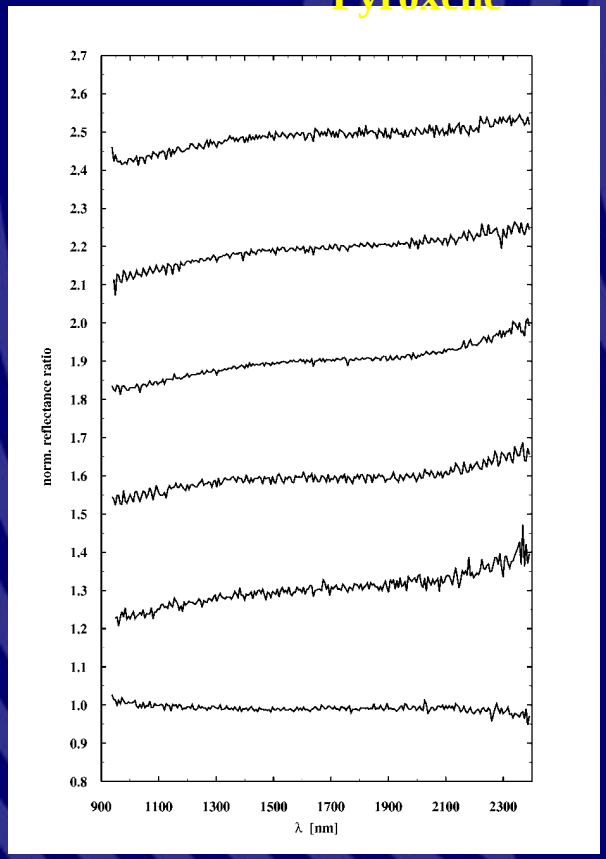
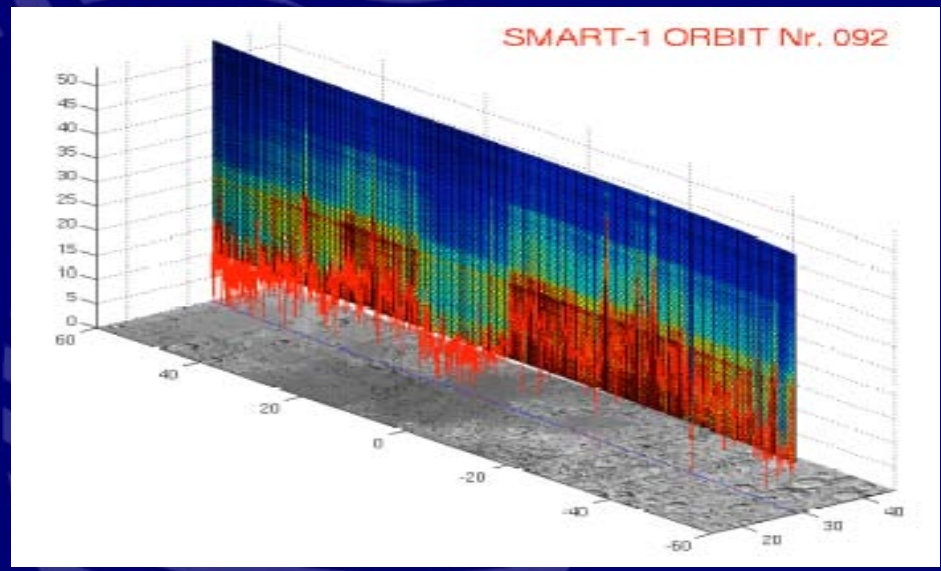
North polar highlands on West near side: from saturated ancient cratered to flooded terrains tectonic faults, feeding dykes/pit chains?

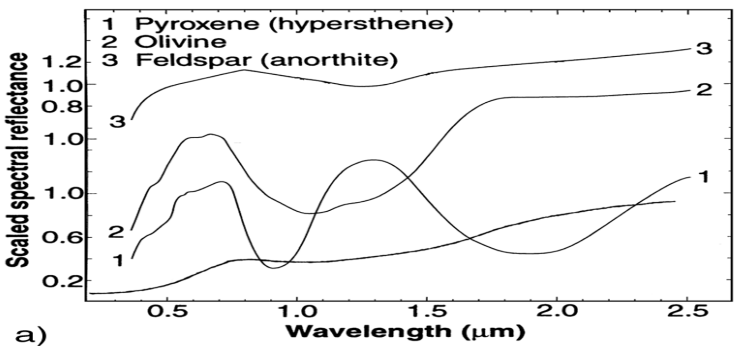
200 km field
Filtered images

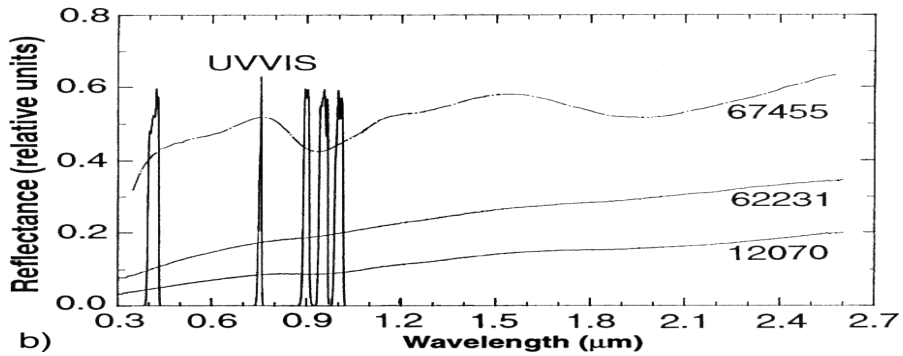


SIR lunar infrared spectra





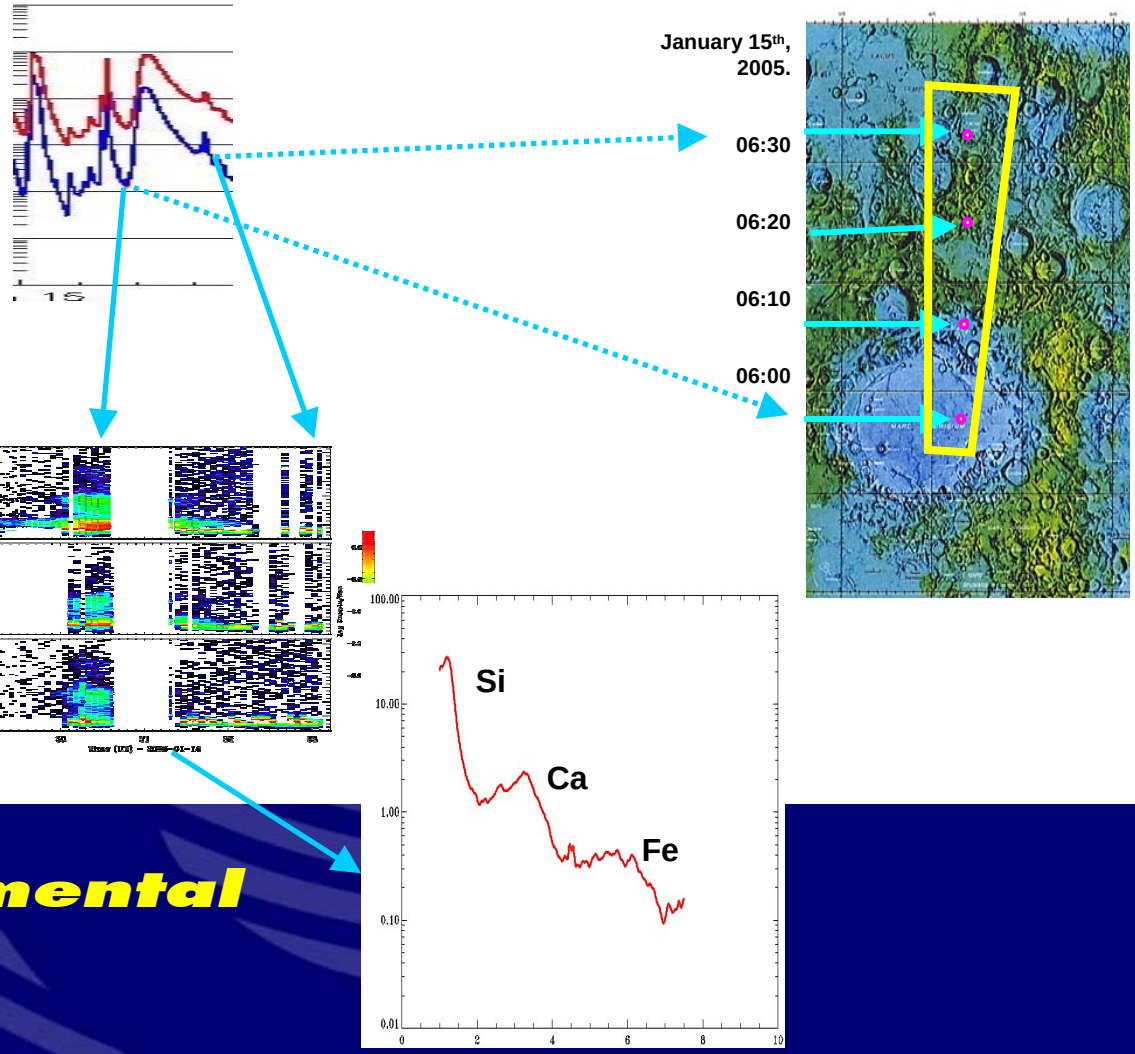




The Sun shines X-rays

The Moon glows

-> D-CIXS



Derived elemental composition

1st detection of Calcium and Magnesium from orbit (D-CIXS)

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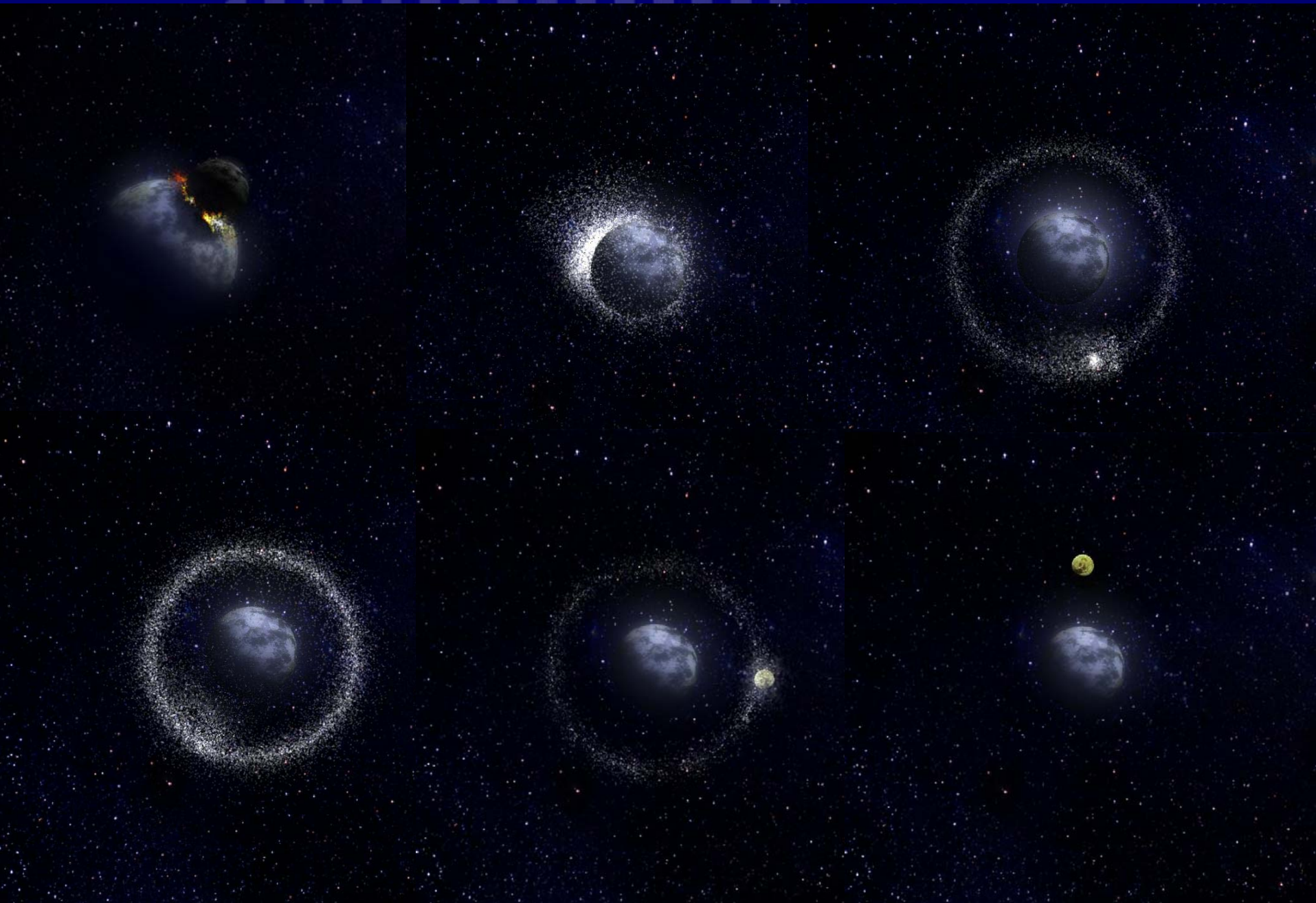
The Moon, daughter of the Earth , 4.5 billion years ago

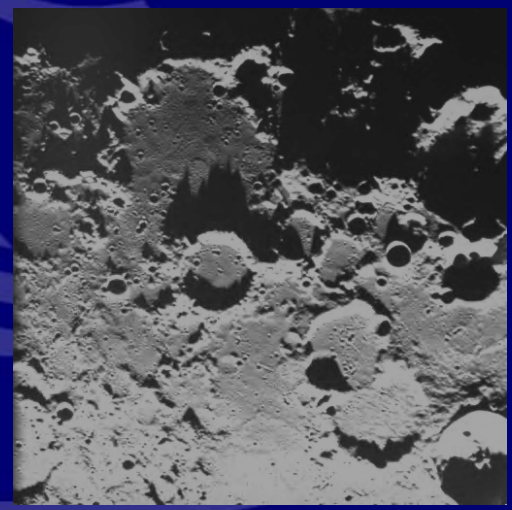


SMART-1 results presentations

- LPSC Moon missions posters Thursday
  - Foing et al, SMART-1 highlights
  - Kellett , Grande et al, DCIXS results
  - Josset et al, AMIE camera ,
  - Cerroni et al Colour imaging
- EGU Vienna April 06: session lunar science and SMART-1 results

5 months to SMART-1 impact

- S/C pushbroom AMIE colour (oct- 17 dec & april-may)
- Extend DCIXS regional/global cover
- Extend SIR/AMIE coverage
- Extend equator/north cover
- Fill gaps in survey
- Stereo, Multi-angle, tracking
- Off nadir Central peaks of craters SIR
- Polar peaks of eternal light
- Search for ice in permanent dark areas



N. Pole Smart-1

- Support international collaborations
- Mapping potential future landing sites
- Operations at perilune < 300 km after 10 June
- Preparation for end of mission impact 1-2 Sept 06

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SMART-1 & Upcoming lunar missions

- Science/exploration:
  - Earth-Moon formation & evolution
  - water ice and resources
  - conditions for future sciences & life
  - sites for future robots/humans

- SMART-1 precursor for future missions

  2007 Chinese Chang'e 1

  2007 JAXA Selene

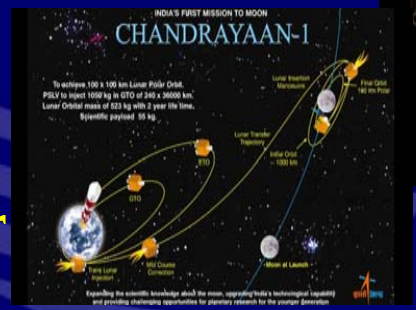
  2007 Indian ISRO Chandrayaan-1

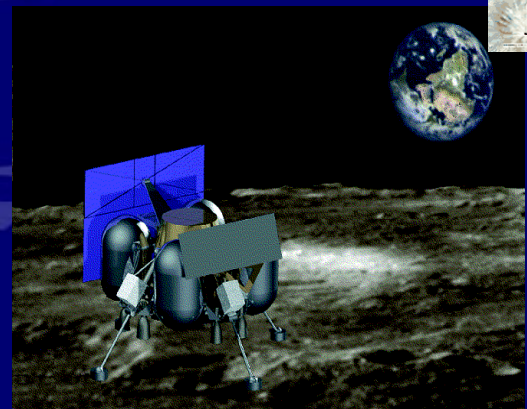
  2008 US Lunar Reconnaissance Orbiter

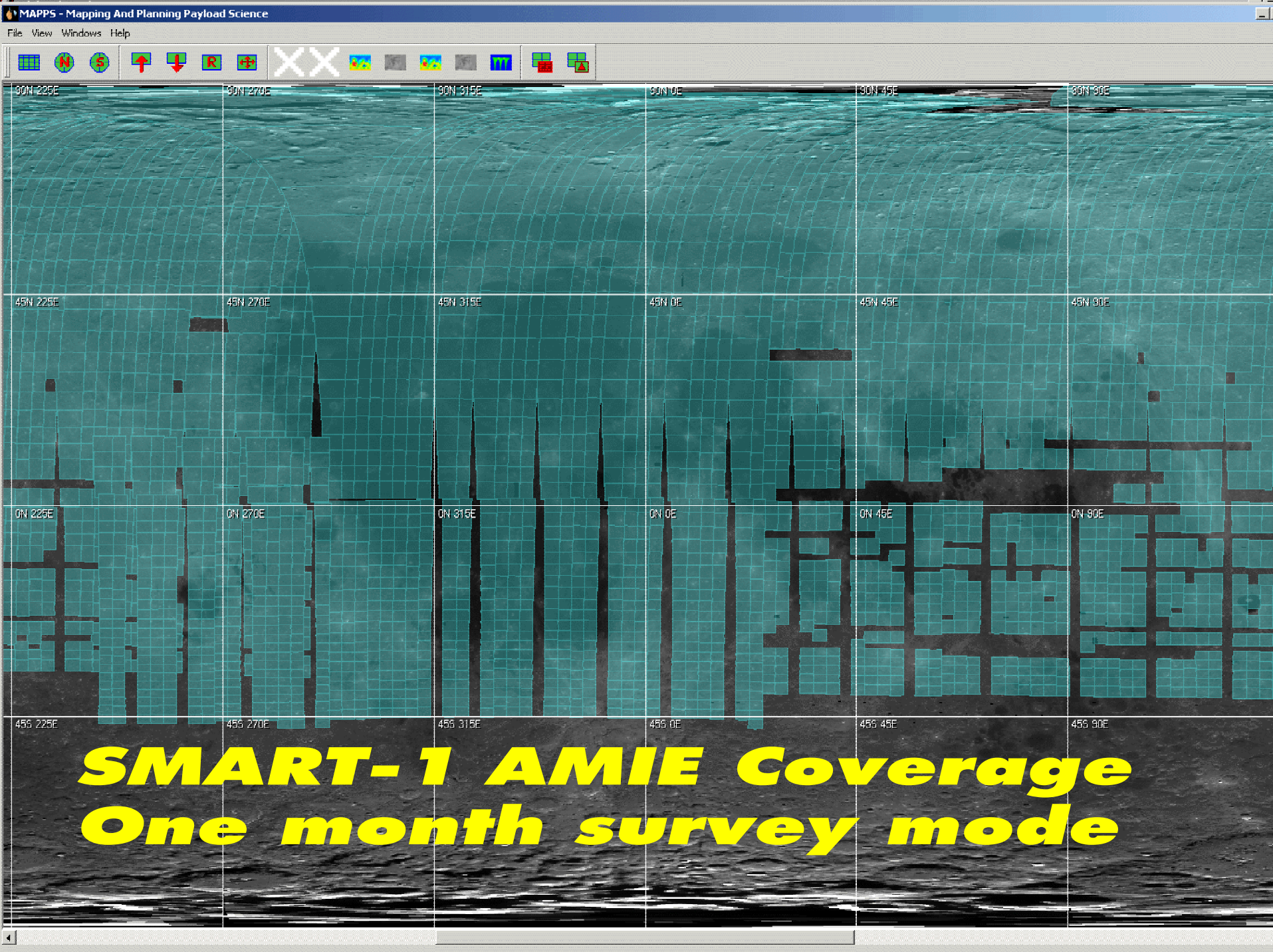
  TBD JAXA Lunar A penetrator

  2010-2012 landers, rovers, technology testbeds (US, China, Japan, India, Europe)

  Preparation for human lunar missions






MAPPS - Mapping And Planning Payload Science
File View Windows Help
90N 225E
90N 270E
90N 315E
90N 0E
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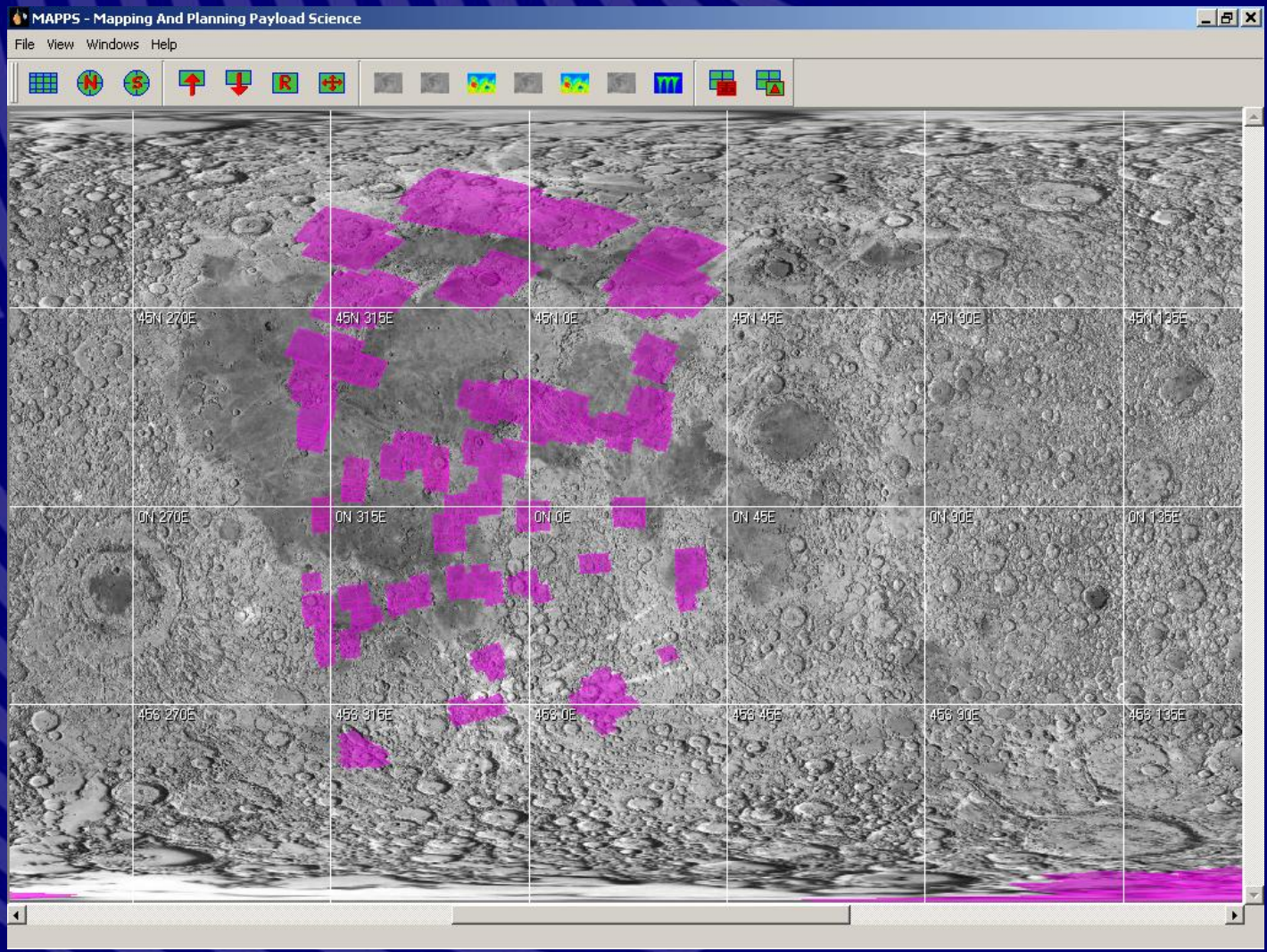
SMART-1 AMIE Coverage
One month survey mode

SMART-1 AMIE Coverage Week 2, January 2006



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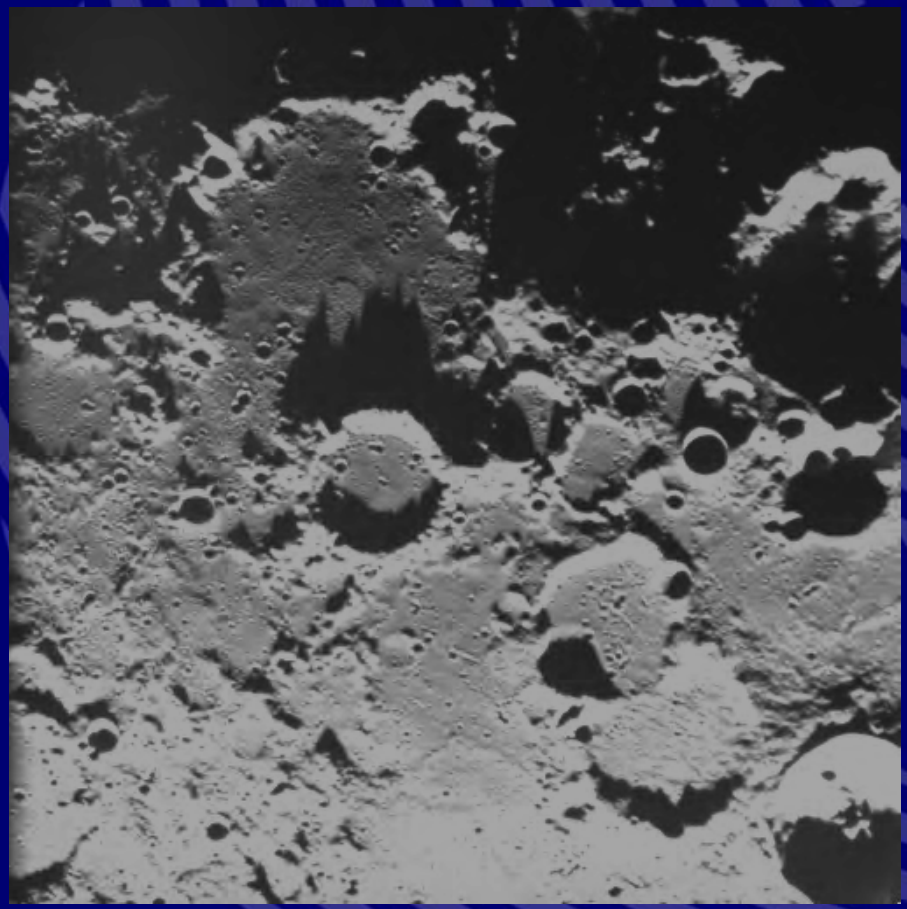
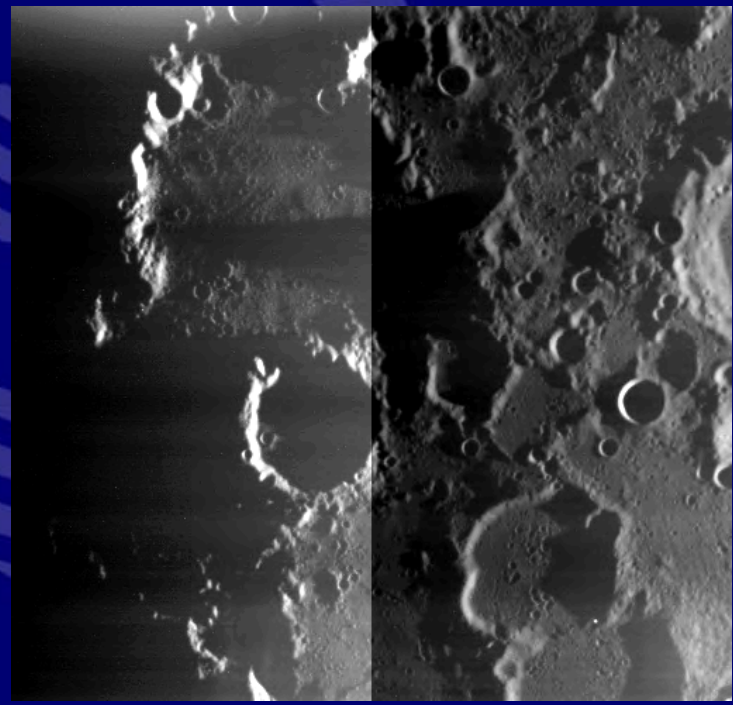
North polar winter shadows variations: near side around Byrd crater

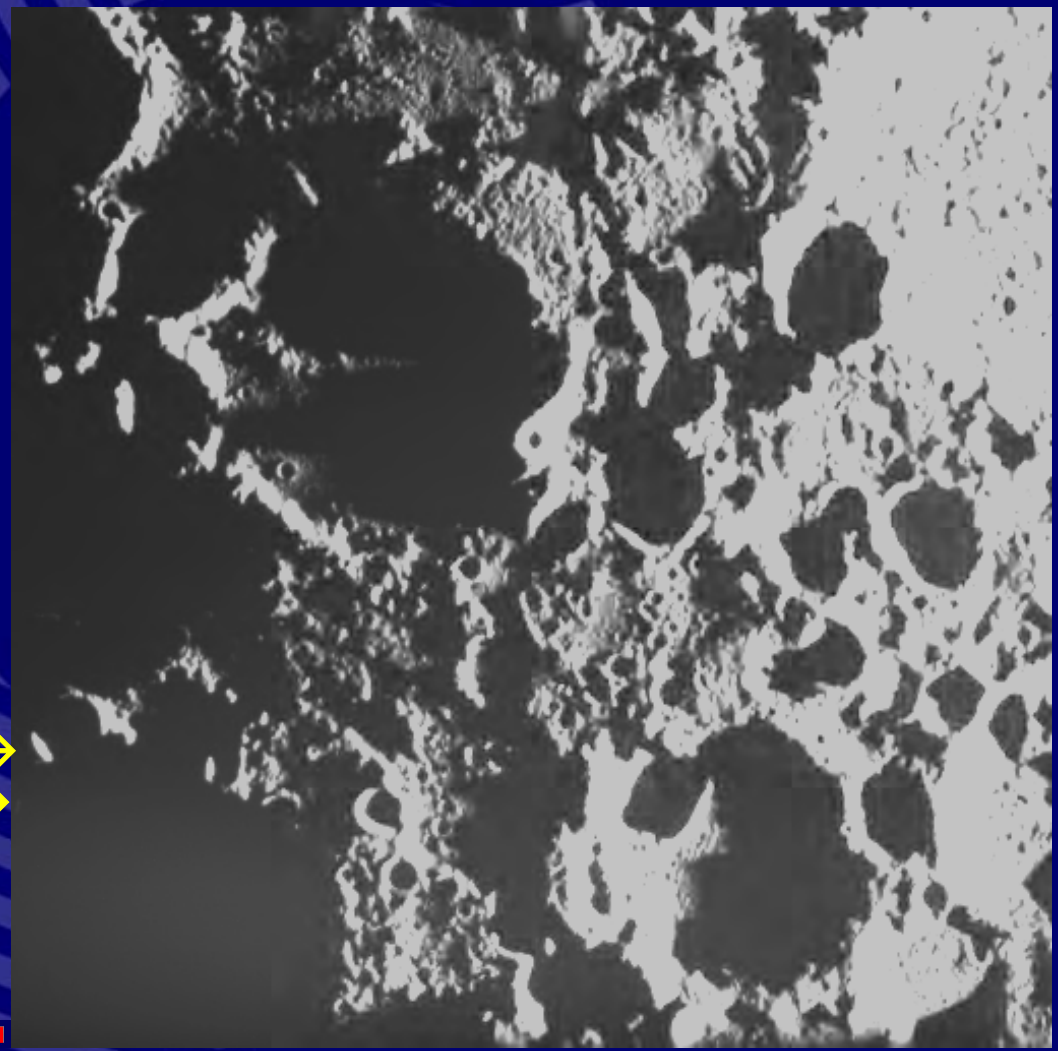
29 Dec



19 Jan



SMART-1 looks at peaks of eternal light



200 km

Far side

eternal peaks of light →

North pole →

Near side

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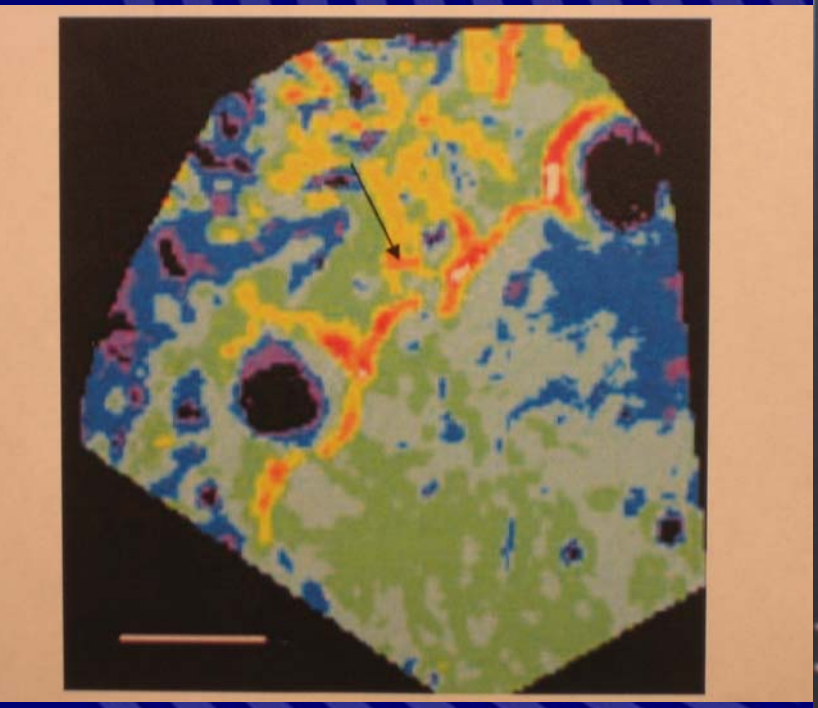
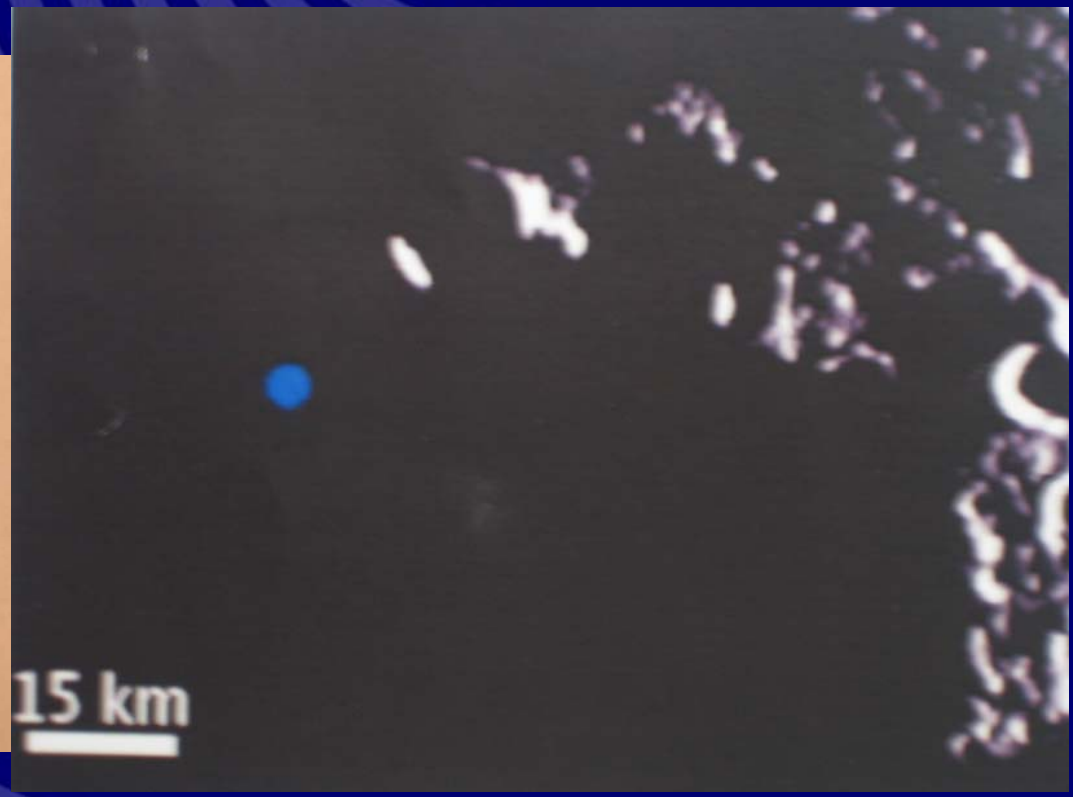
North pole peaks of light





Summer average illumination
Clementine

Winter image
SMART-1

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Coordinated observations with SMART-1

- SMART-1 status and planned operations (B.Foing & STOC), Orbit predictions
- coordinated observations with SMART-1 in March- August
- - targets imaging, radiometric calibrations, spectrometric observations
- - merging of SMART-1 and ground based data
- - ground based detection of SMART-1, and laser link experiment, radio detection and VLBI
- - opportunities for outreach and education, adopt your crater, amateur lunar images competition

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SMART-1 end of mission

- Orbit inclination 90.6 deg, from North to South
- If no maneuver Impact on 17 Aug on far side -> needed maneuver
- 2.6 kg hydrazine maneuver Maneuver on 23 June –8 July delta V 12 m/s, adjustement slots 26 July, 30 Aug
- Current impact prediction 3 sept 2006 (0:30)-2:00 UT +- 7 hours on near side in dark, near first quarter terminator
- Orbit prediction, perilune <200 km 10 July, < 120 km 7 aug
- Effect of topography (current altimetry, stereo, new observations)
- Possible locations of impact :
  - perilune 36 S, 44.2 W, impact TBC 34 S, 44.13 W
  - Previous orbit (-5 hours) , impact 36.5 S, 41.4 W
  - Orbit after: impact 37 S+- 2 deg , 47 W
- Speed 2 km/s, grazing 1 deg over 10 deg slope ,
- Artificial comet: 285 kg including 1 m3 body, 200 kg Aluminum, 3 kg Hydrazine N2H4, 0.26 kg Xenon, epoxy, 14 m carbon fiber arrays

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Impact predictions and challenges

- Low velocity grazing impact 2 km/s
- Thermal flash (bolometric magnitudes during 1 s V=7 –16 in infrared depending on efficiency 0.5-0.001)
- Probe signatures: (Al, N2H4, C)
- Ejecta, total mass, speed distribution, fraction with vertical V> 200m/s reaching sunlight
- Effective area of ejecta 50 km2 (obscuration, sunlight reflection)
- Exospheric effects (neutral emission production,
- Thermal cooling of impact hot spot over hours following impact
- Crater size (3-10 m ?) and morphology

- SMART-1 observations of previous impact sites, (e.g. rangers)
  - Muses A 300 kg, 2.7 km/s, 1 kg hydrazine flash at 2 micron
- Prior observations of site of impact in July and August
- Rehearsal 9 July, 7 Aug, Straylight calibraiton,, support of impact observations

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Impact observations

- Thermal infrared imaging of thermal flash,
- Visible/infrared imaging of dynamics of ejected clouds
  - Earthshine illumination (V=17 mag/arcsec 2) ,
  - Ejected mass 30-100 tons
  - Effective area/opacity/reflectivity of ejecta
  - Imaging of ejecta reaching sunlight (could be bright V= 5 /km2)
- Spectroscopy,
  - Al emission 396.1 nm (in low Ca II H solar Fraunhofer light)
  - hydrazine flame detection (NH3, H Balmer, Paschen , Brackett IR)
  - VLBI observations, accurate coordinates of impact crater
- Post-characterisation of ejecta, exospheric effects
- Follow up search for SMART-1 crater (with future lunar orbiters)

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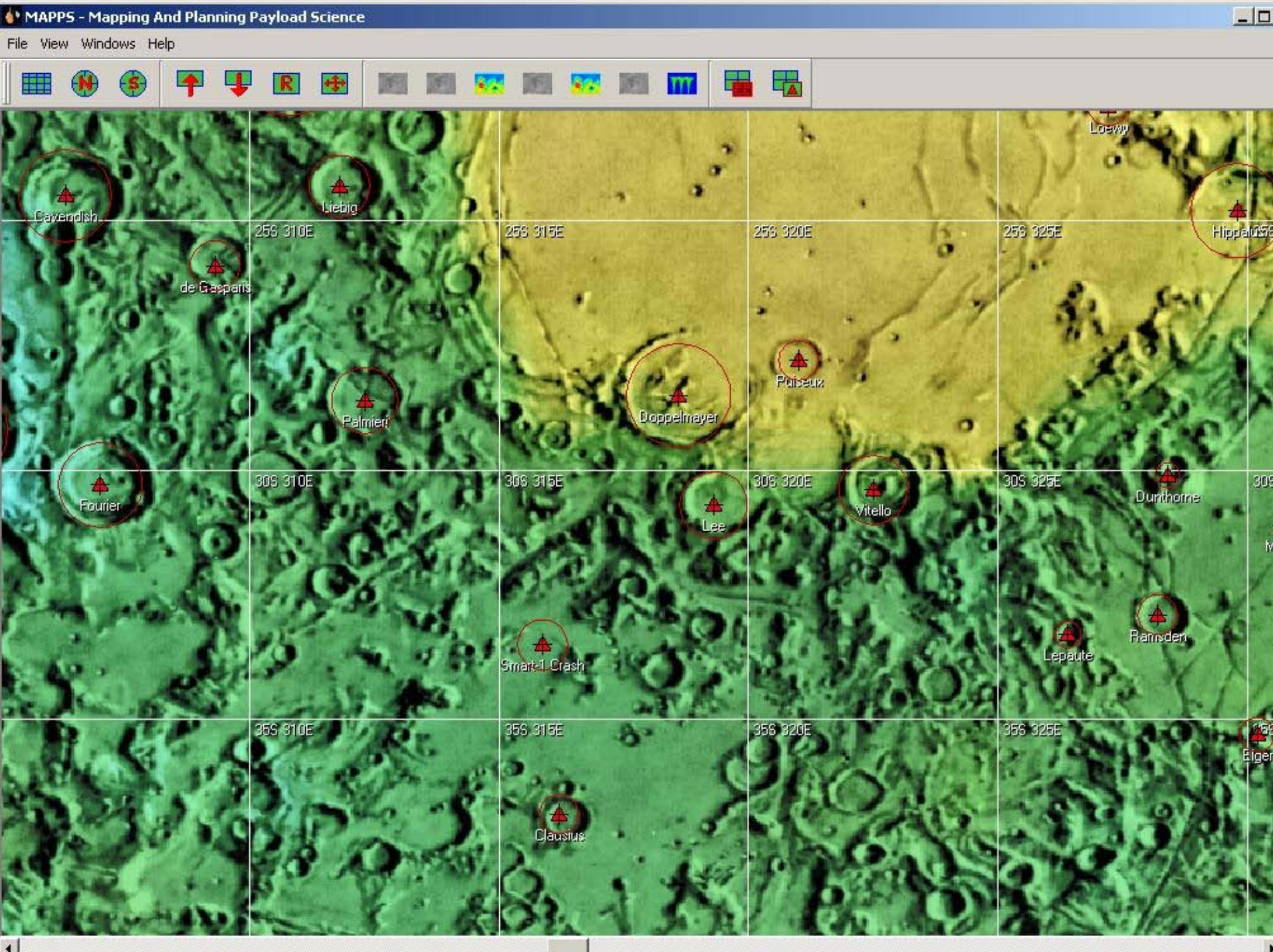
Facilities and observing requests, Moon visibility conditions

- Moon first half Moon, overlap visibility , straylight reduction
- Experience from Deep impact campaign
- ESO VLT,
- ESO La Silla,
- Galileo National Telescope (I),
- Tenerife OGS and other
- European continental observatories,
- US TBC Kitt Peak, Lowell, Palomar
- Hawaii observatories, TBC (Keck,
- Other international observatories
- Amateur observations
- Discussion
- Preparation/consolidation of observing collaborators/proposals/

Timeline for future actions and meetings

- March 15, 12h30: lunch meeting at LPSC dedicated to S1 update/ impact
- April 3-7: EGU, Vienna, Smart-1 papers in sessions PS1 Exploration, PS2 Moon science (6 April), PS12 impacts (7 April pm) and splinter meeting on "SMART-1 low altitude operations and impact"
- May 8-12: ESTEC ESLAB on impact craters (discussions with craters and deep impact experts)
- end June: two delta V hydrazine maneuvers
- 15 June: Smart-1 perilune below 300 km
- 10 July: cross tracking SMART-1 perilune below 200 km
- 27 July: near side
- 5.7 or 6.7 Aug: overflight of impact site at 120 km
- (coordinated observations and impact observations rehearsal)
- 10 - 24 Aug : farside
- 24 Aug New Moon and SMART-1 on disk edge
- 1 or 2 Sept 24:00 UTC impact (TBC), ESOC + national events
- 18-22 sept , Berlin Europlanet meeting, including session on SMART-1 results and coordinated observations
- Bernard.Foing@esa.int


MAPPS - Mapping And Planning Payload Science
File View Windows Help
Cavendish
Liebig
Loewy
Hippalus
de Gasparis
25S 310E
25S 315E
25S 320E
25S 325E
Palmieri
Doppelmayer
Puiseux
Fourier
30S 310E
30S 315E
30S 320E
30S 325E
Lee
Vitello
Dunthorne
Smart-1 Crash
Lepaute
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