From Earth to the Planets and back again

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Point-of-Contact, GEOSS Task DA-07-01 and DA-09-03d
Chair, ISPRS WG IV/6 on "Global DEM Interoperability"
Chair, CEOS-WGCV Sub-group on Terrain mapping from satellites
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HRSC Science Team Member (ESA Mars Express 2003)
PI: ESA GlobAlbedo, ESA ADAM, ESA ALANIS Projects
Stereo Panoramic Camera Science Team Member (ESA ExoMARS 2018)
HiSci Stereo Camera Science Team Member (ESA-ExoMARS 2016)
MODIS & MISR Science Team Member (NASA EOS Project)
TerraSAR-X and TANDEM-X science team member (DLR-Astrium)

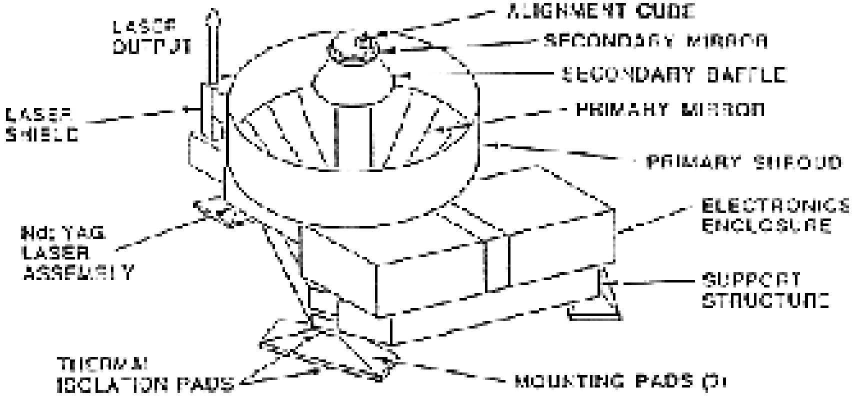
Key Common Issues

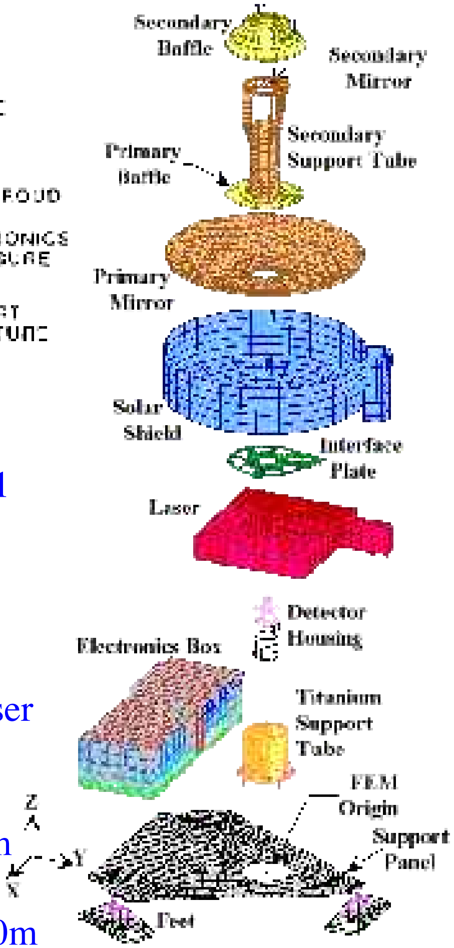
- Land topography and/or cloud topography
- Surface composition and hydrology
- Solid earth deformation and sub-surface processes
- Atmospheric dynamics and radiative transfer
- Trace gases and their possible relationship to life processes
- Detection of microbial life from fluorescence

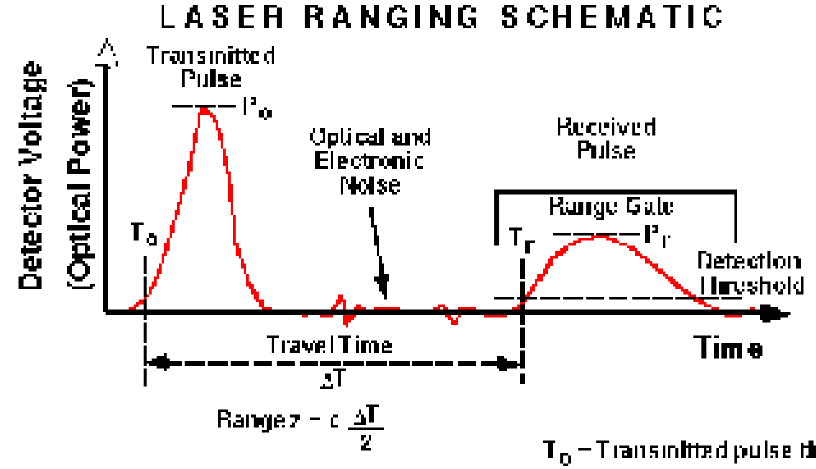
Key Common Technology requirements

- Sub-nm spectral sampling for isotopologues and fluorescence measurements in Fraunhöfer lines
- differential SAR interferometry for deformation measurements
- LiDAR and RadAlt measurements of ice-sheets
- Low frequency radars for sub-surface mapping
- Multi-angle, hyperspectral and polarimetric imaging
- Multi-angle stereo imaging for land topography

NASA Mars Global Surveyor - MOLA





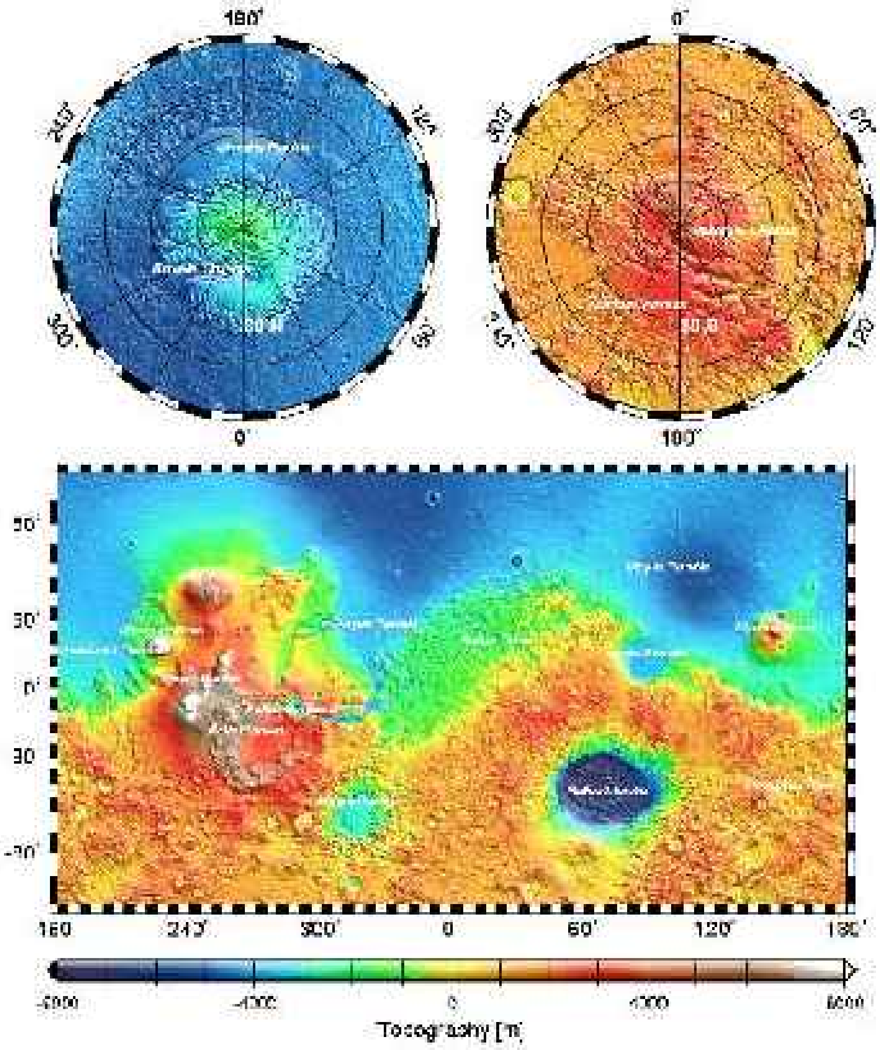


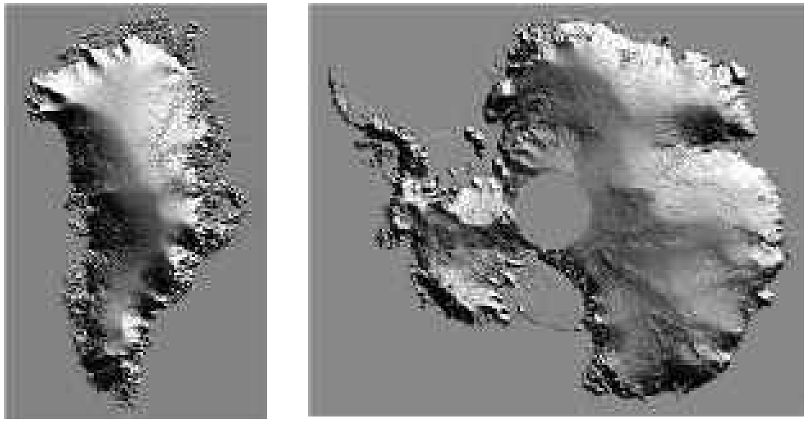
T_o – Transmitted pulse time
P_o – Transmitted pulse power
T_r – Received pulse time
P_r – Received pulse power

- launch 1996, failed 2001
- mass: 25.85kg
- power: 34.2 W
- 1064nm at 10Hz
- diode pumped
- Q-switched Nd:YAG laser
- 48mJ/pulse at launch
- 50cm parabolic mirror
- range resolution: 37.5cm
- spot size: 130m
- along-track spacing: 300m

MOLA DTM Products of ICESat

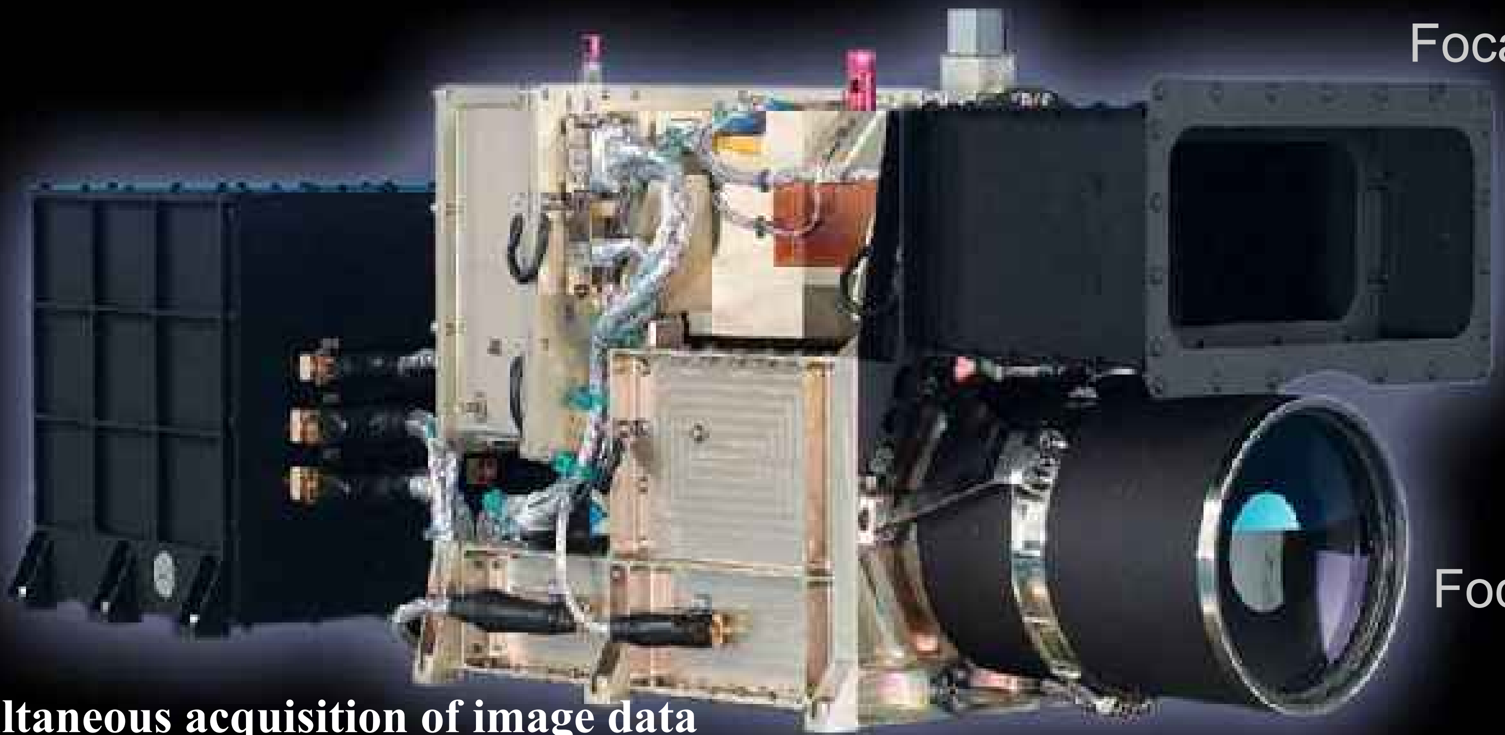
- **Global 463m DTM (2002)**
- **Across-track spacing <200m near poles**
- **Across-track spacing spacing >>3km near equator**
- **Orbit intersections indicate Zrms<<1m**
- **Provides global reference plane**





500m ICESat observations (2009)

HRSC and SRC – Technical Parameters



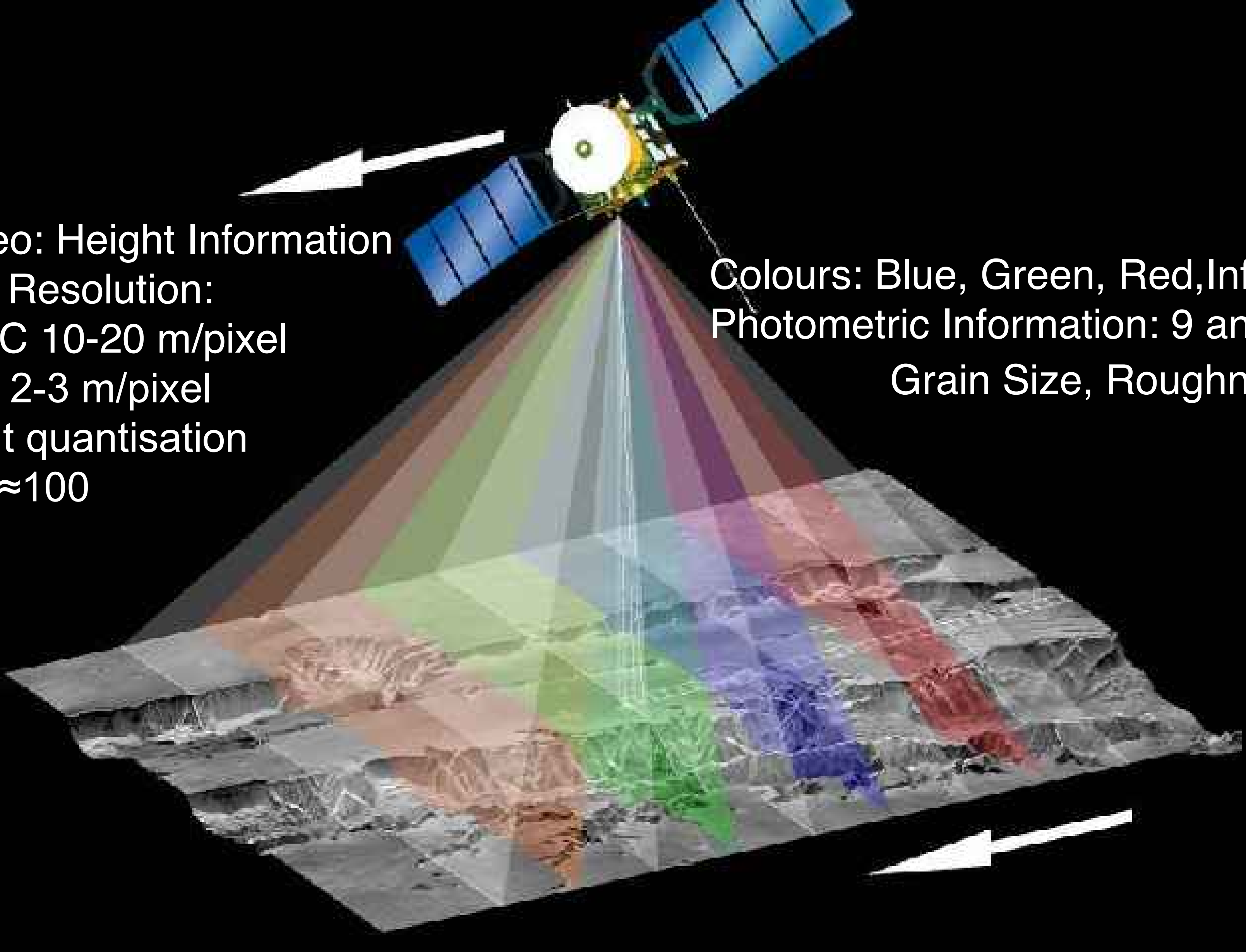
HRSC:
Focal lenght
175 mm

SRC:
Focal lenght
975 mm

Simultaneous acquisition of image data

High resolution :	**Nadir-Sensor, 10 m/Pixel from 250 km Altitude**
Stereo:	**4 Sensors, 10-20 m/Pixel from 250 km Altitude**
Color:	**4 Sensors, red, green, blue, near Infrared**
Max. Resolution (SRC):	**2-3 m/Pixel from 250 km**
Output-Datarate:	**25 Mbit/s, On chip-Compression**
Mass:	**19.6 kg**

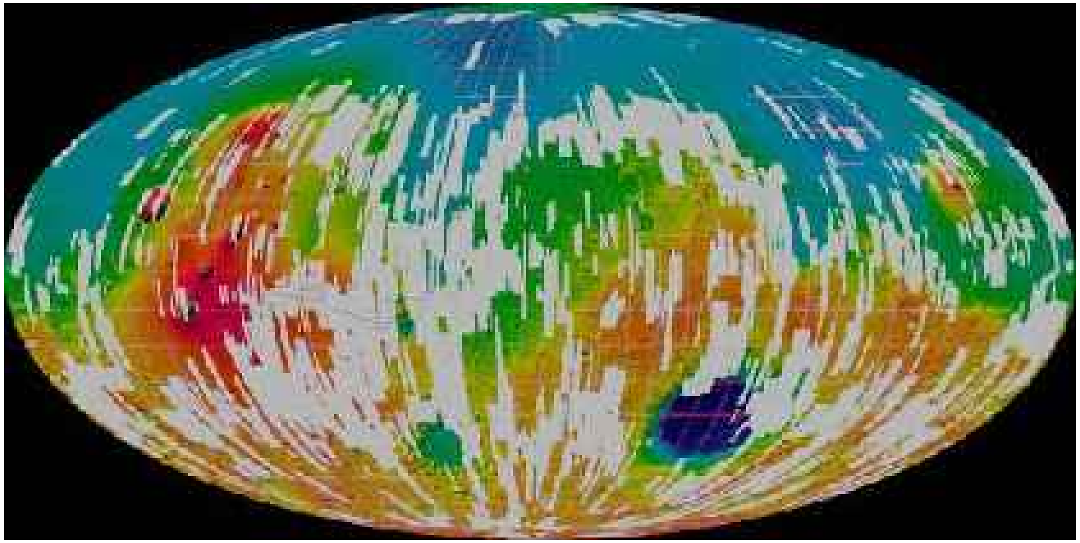
Imaging Principles of the HRSC



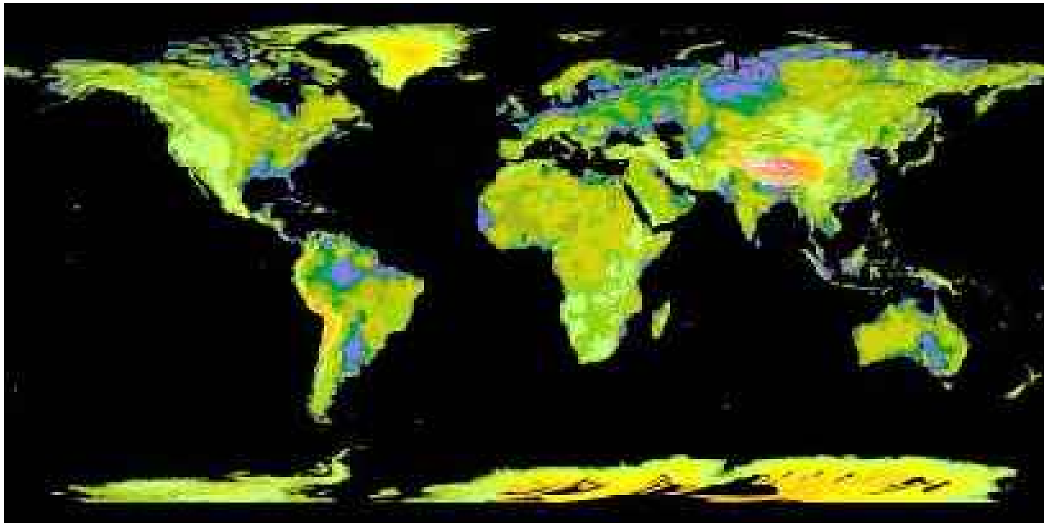
Stereo: Height Information
High Resolution:
HRSC 10-20 m/pixel
SRC 2-3 m/pixel
14-bit quantisation
SNR≈100

Colours: Blue, Green, Red,Infrared
Photometric Information: 9 angles
Grain Size, Roughness

Mars 50-100m DTMs from HRSC (37% to date) cf ASTER 30m GDEM

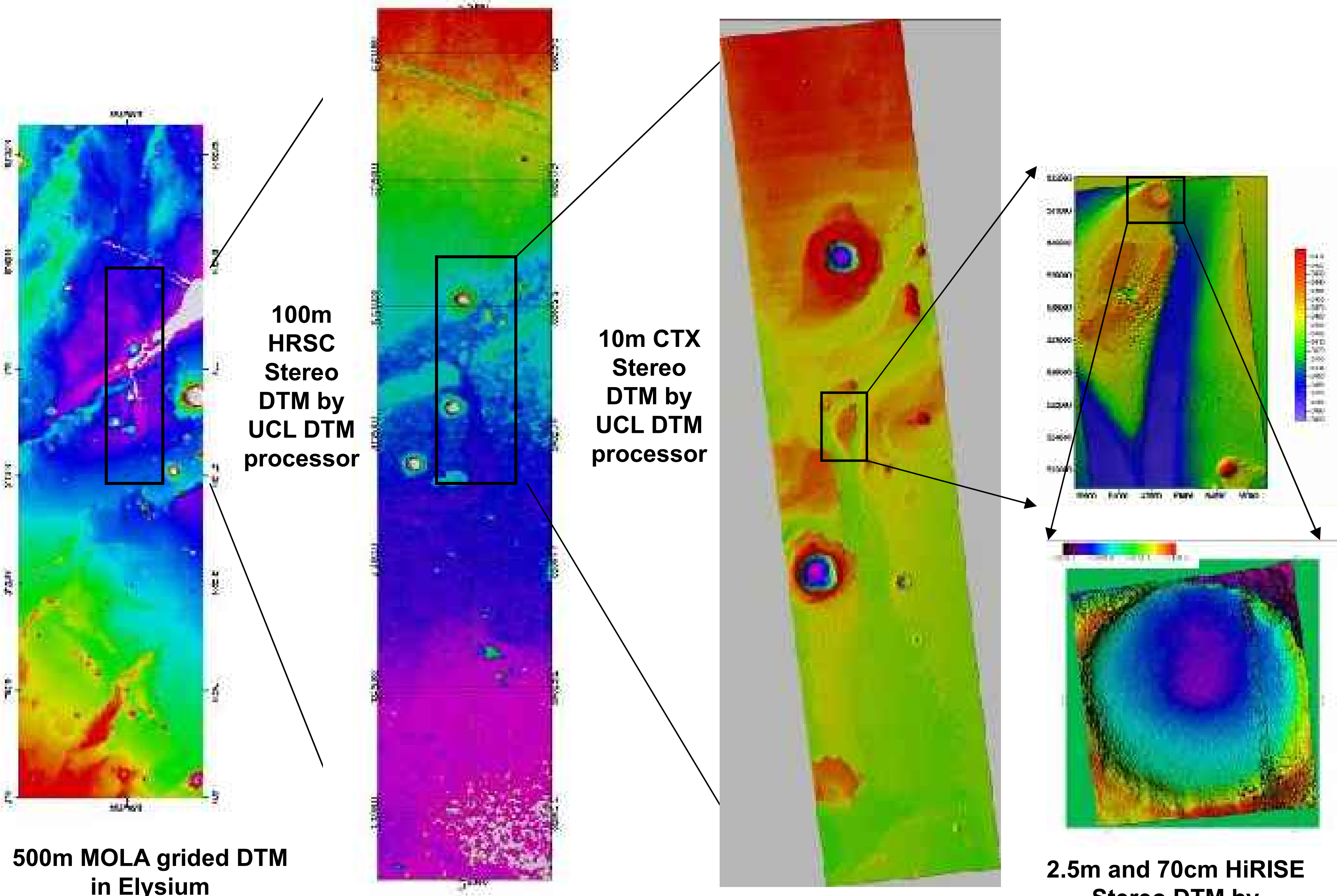


Scholten, DLR, 7-Sep-11



asterweb.jpl.nasa.gov

Multi resolution DTM from MOLA, HRSC, CTX, HiRise: Elysium/Athabasca Vallis



500m MOLA grided DTM in Elysium

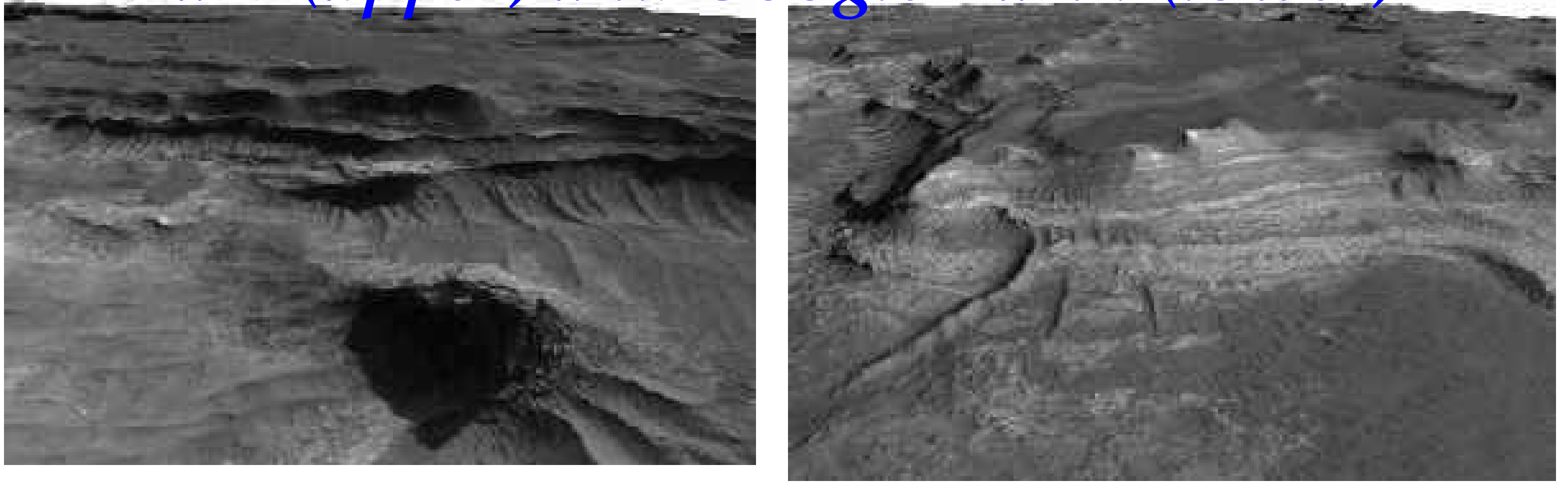
100m HRSC Stereo DTM by UCL DTM processor

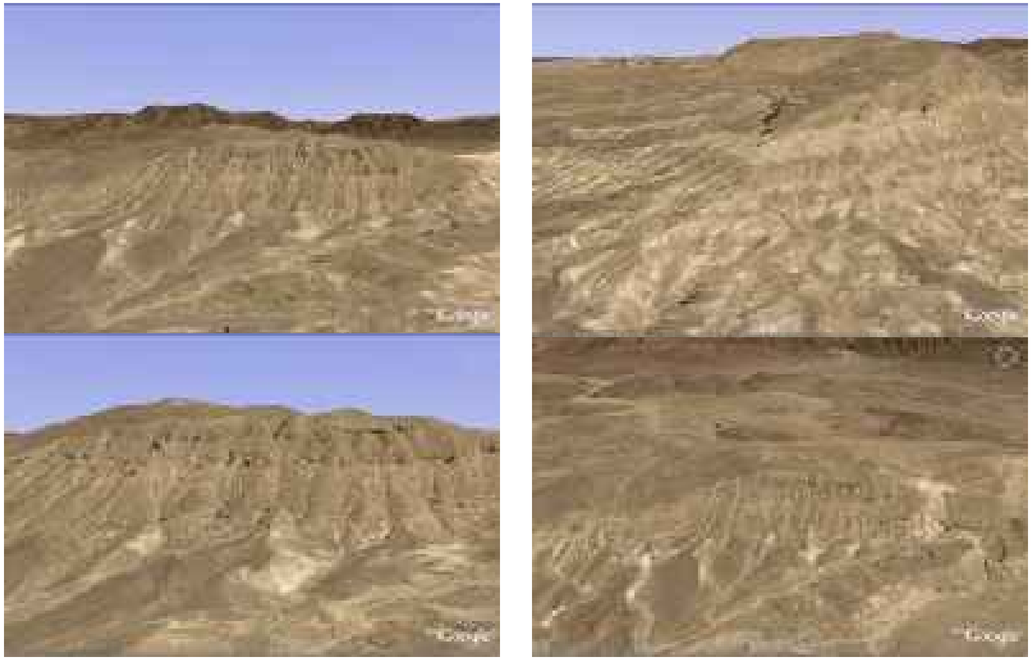
10m CTX Stereo DTM by UCL DTM processor

2.5m and 70cm HiRISE Stereo DTM by UCL DTM processor

Kim & Muller, Planetary Space Science10

How and what can we map from space? Mars (upper) and Google Earth (lower)





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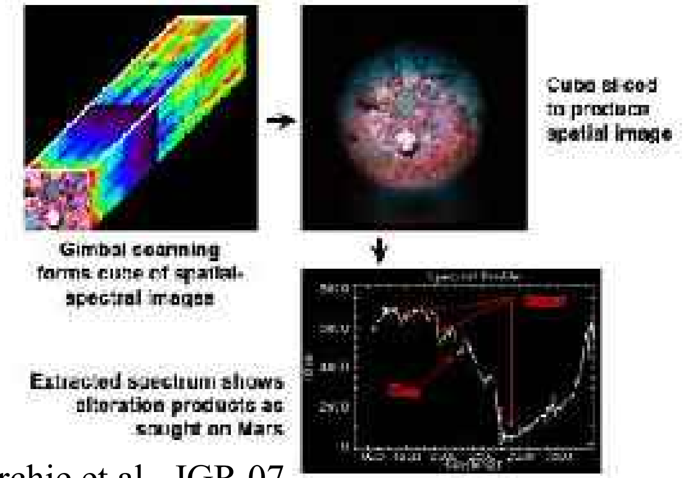
Perspective view of horizontal sedimentary beds in cliff faces over Mars - Eberswalde crater (upper) and Egypt (lower) at the SAME scale (courtesy of Sanjeev Gupta, Imperial College)

Hyperspectral: MRO CRISM cf OMEGA

- Global coverage at 2-3 times the resolution of OMEGA and better SNR
- Targeted hyperspectral data can better characterise deposits but still dependent on aerosol correction
- Current mapping ignores spectral BRDF
- MERIS, CHRIS & Hyperion



Murchie et al., JGR 07

QuickTime™ and a
decompressor
are needed to see this picture.

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decompressor
are needed to see this picture.

CRISM RGB image on CTX Miliken on Holden crater MSL site

QuickTime™ and a
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CRISM high resolution mapping

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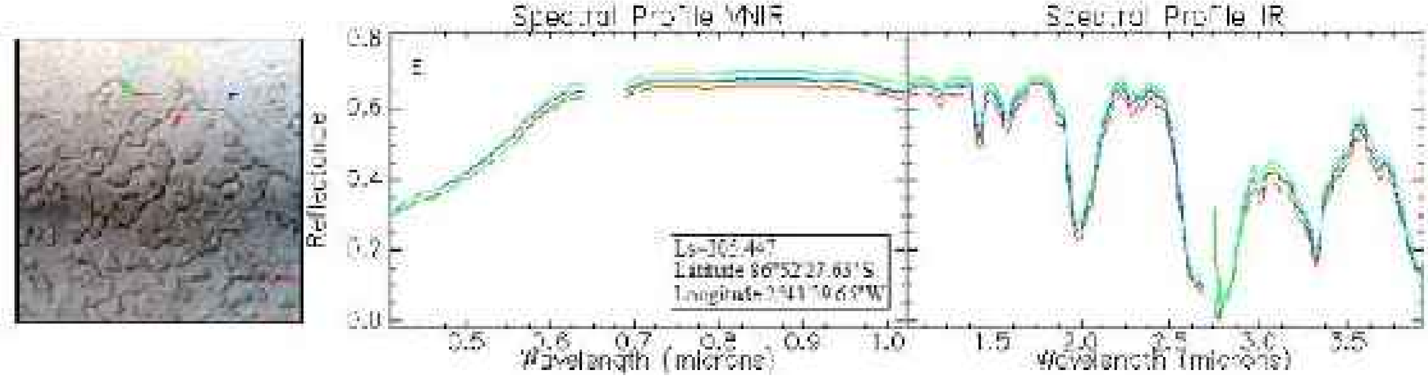
Fe Minerals

Mafic Minerals

Clay Minerals



Angles, MSc11

CO2/H2O with a hint of PAH

THEMIS mapping of rock types

QuickTime™ and a decompressor are needed to see this picture.

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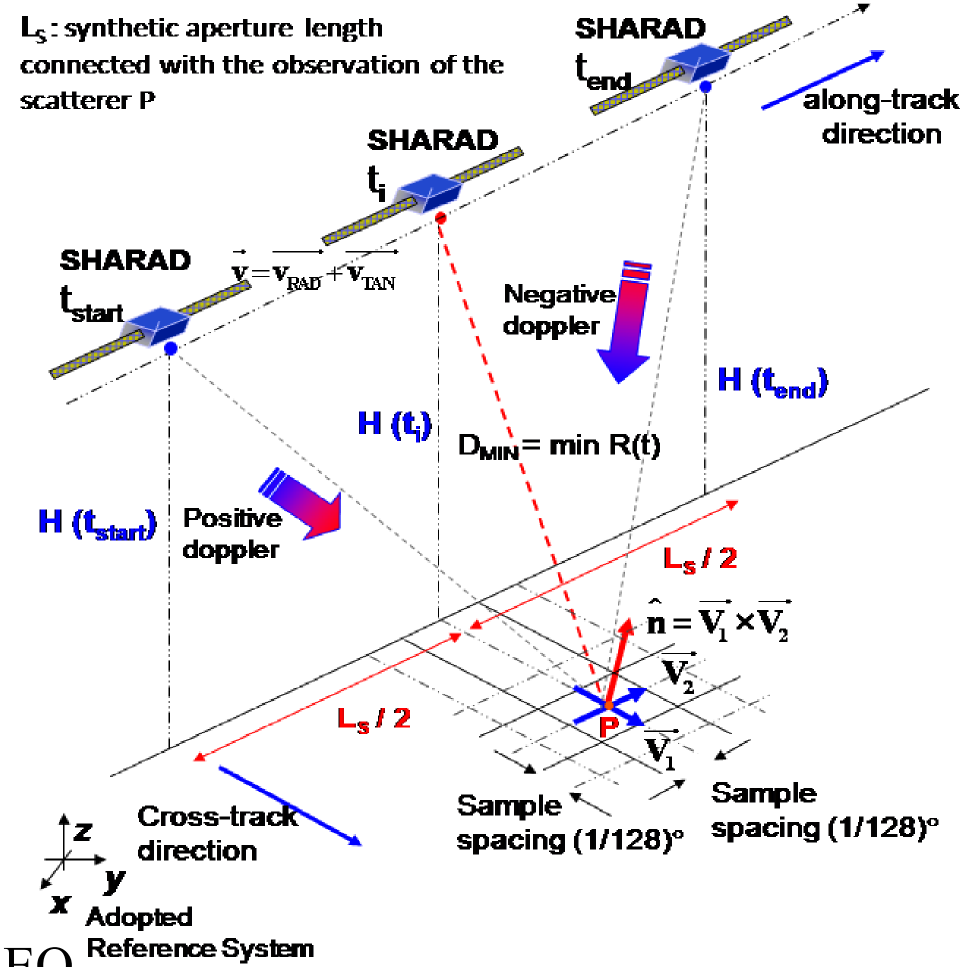
Olivine basalt 1　Olivine basalt 2　Dust

THEMIS: 3-15μm flat response multispectral microbolometer (2001)

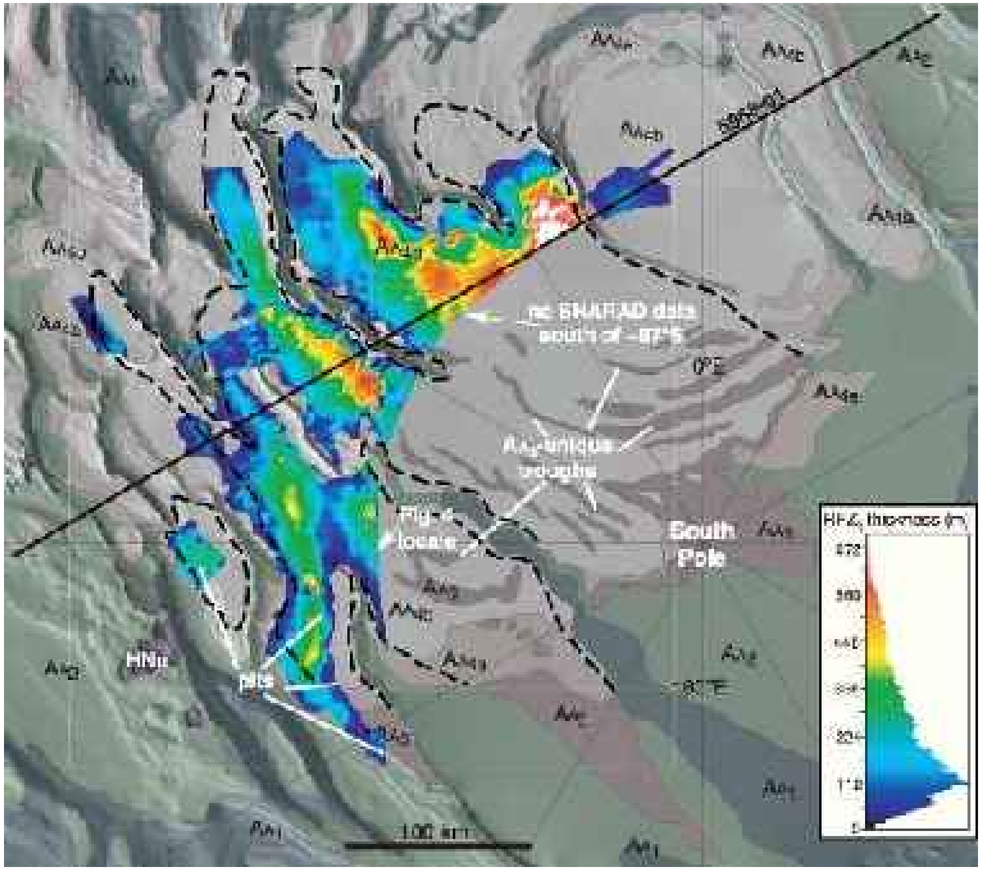
Nothing comparable in Earth Orbit

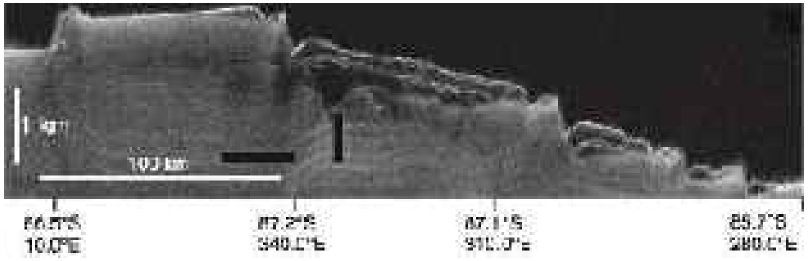
MRO SHARAD sub-surface sounding (15m wavelength)



Nothing comparable in EO

MRO SHARAD sub-surface sounding : estimation of polar cap thickness

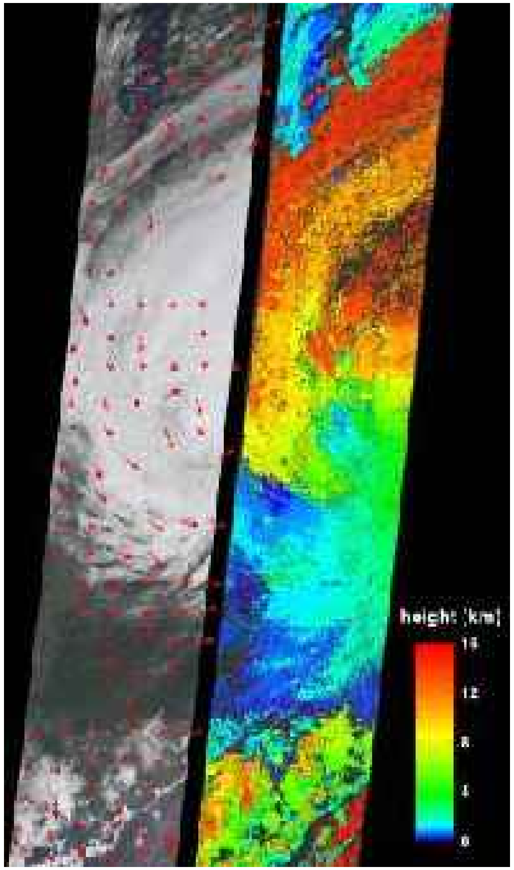




Philipps et al., Science, 2011

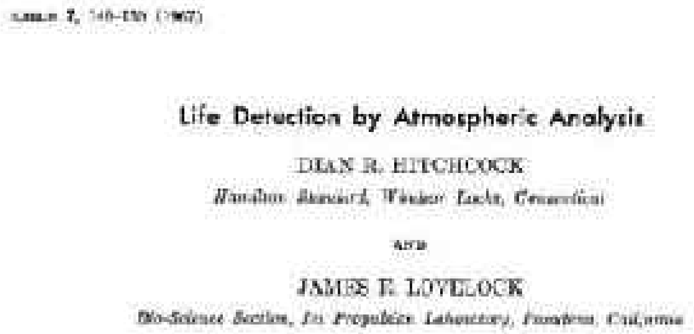
Atmospheric Dynamics using multi-angle time differencing

- **MISR and ATSR2-AATSR have demonstrated cloud-top winds and heights**
- **MISRlite (TIR) and SABLE (Venture) are smallsat versions**
- **Jupiter-Europa-Ganymede mission could include a MISRlite instrument for mapping 3D distributions of clouds**



Atmospheric Trace gas analysis

- **Prediction in 1967 that if methane were detected in Mars' atmosphere that it would be a strong indicator of biological activity**
- **Observations in 2003 show that highly variable amounts of methane (1-30ppb) detected in martian atmosphere**
- **MATMOS on ExoMars Trace Gas Orbiter 2016 should make definitive measurements from orbit**
- **SCIAMACHY methane observations from EO but no differentiation as to source(s)**



ICARUS 7, 149-159 (1967)

Life Detection by Atmospheric Analysis

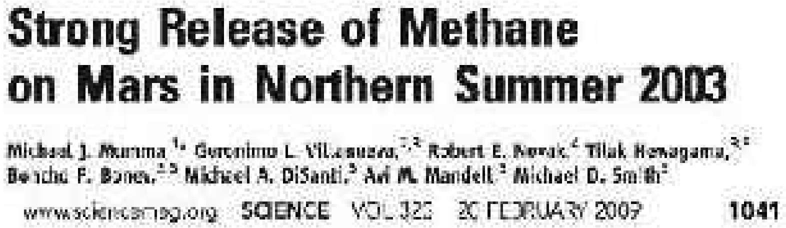
DIAN R. HITCHCOCK

Hamilton Standard, Windsor Locks, Connecticut

AND

JAMES E. LOVELOCK

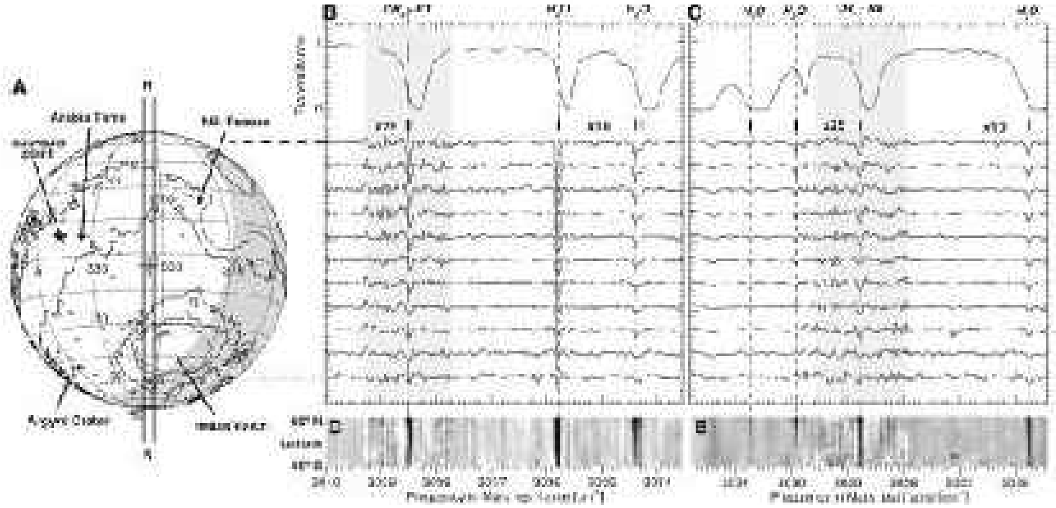
Bio-Science Section, Jet Propulsion Laboratory, Pasadena, California

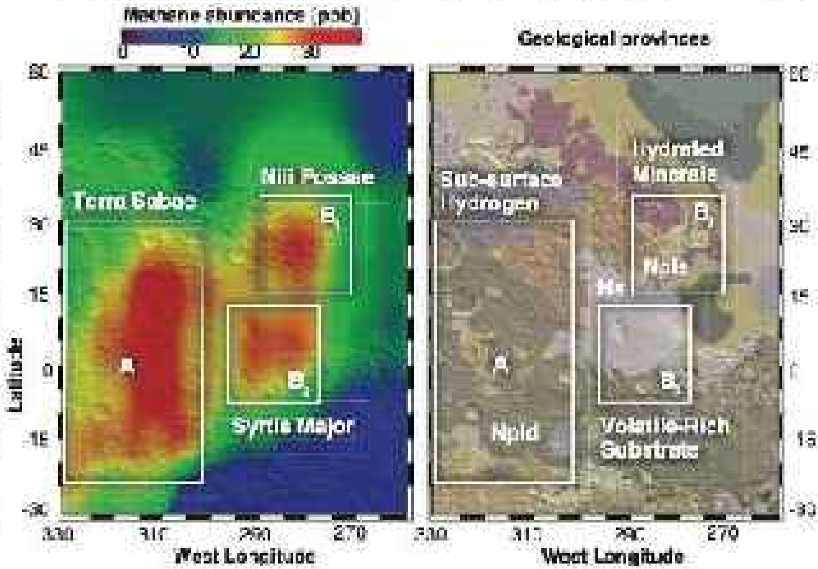


Strong Release of Methane on Mars in Northern Summer 2003

Michael J. Mumma,1* Geronimo L. Villanueva,2,3 Robert E. Novak,4 Tilak Hewagama,3,5 Boncho P. Bonev,2,3 Michael A. DiSanti,3 Avi M. Mandell,3 Michael D. Smith3

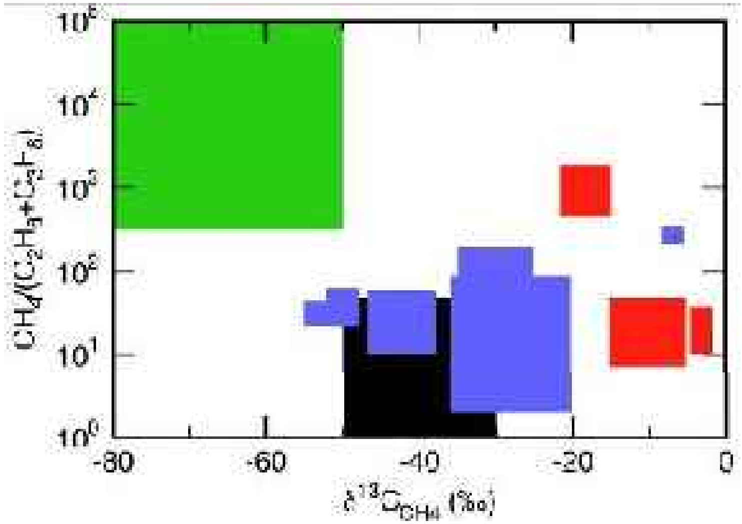
www.sciencemag.org SCIENCE VOL 323 20 FEBRUARY 2009 1041



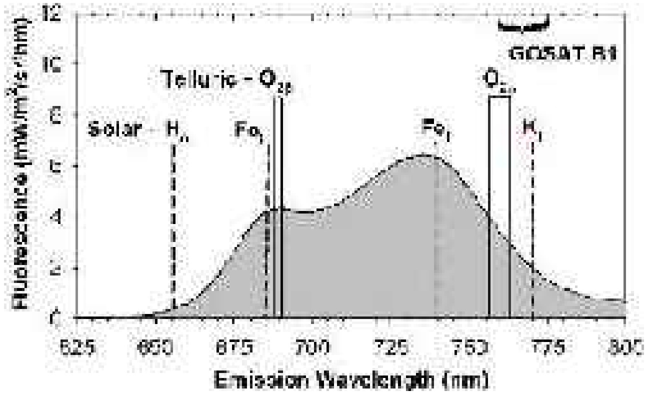


Life detection from Orbit

- **Isotopic ratios (isotopologues) combined with abundance ratios appear to provide more definitive proof of biogenic cf abiogenic origins**
- **MATMOS (FTIR on EMTGO16) Spectral resolution onboard will be suficient to determine this**
- **Randal et al (EGU, 2010) have demonstrated this already with Canadian ACE/FTS for H2O**
- **Chlorophyll fluoresence also possible to map from orbit in Fraunhöfer lines from GOSAT as demonstrated by Joiner et al (2011) for vegetation and in solar-reflected region over oceans by Gower et al (2005)**



Green area represents Biogenic (Allen, 2011)



Summary and Future Prospects

- **A great deal of new technology has been developed and tested on planetary missions which has yet to be applied in EO:**
  - **Hyperspectral high resolution (≥30m) up to 15µm**
  - **Sub-surface mapping at low frequency**
- **Similarly some EO technology has not yet been applied to planetary observations**
  - **Isotopologue and abundance ratio combinations**
  - **Fluorescence measurements from organics**
- **With a UK Space Agency and a coherent planetary exploration programme (Aurora), hope to see much more "joined-up" thinking of bi-directional technology development and transfer**