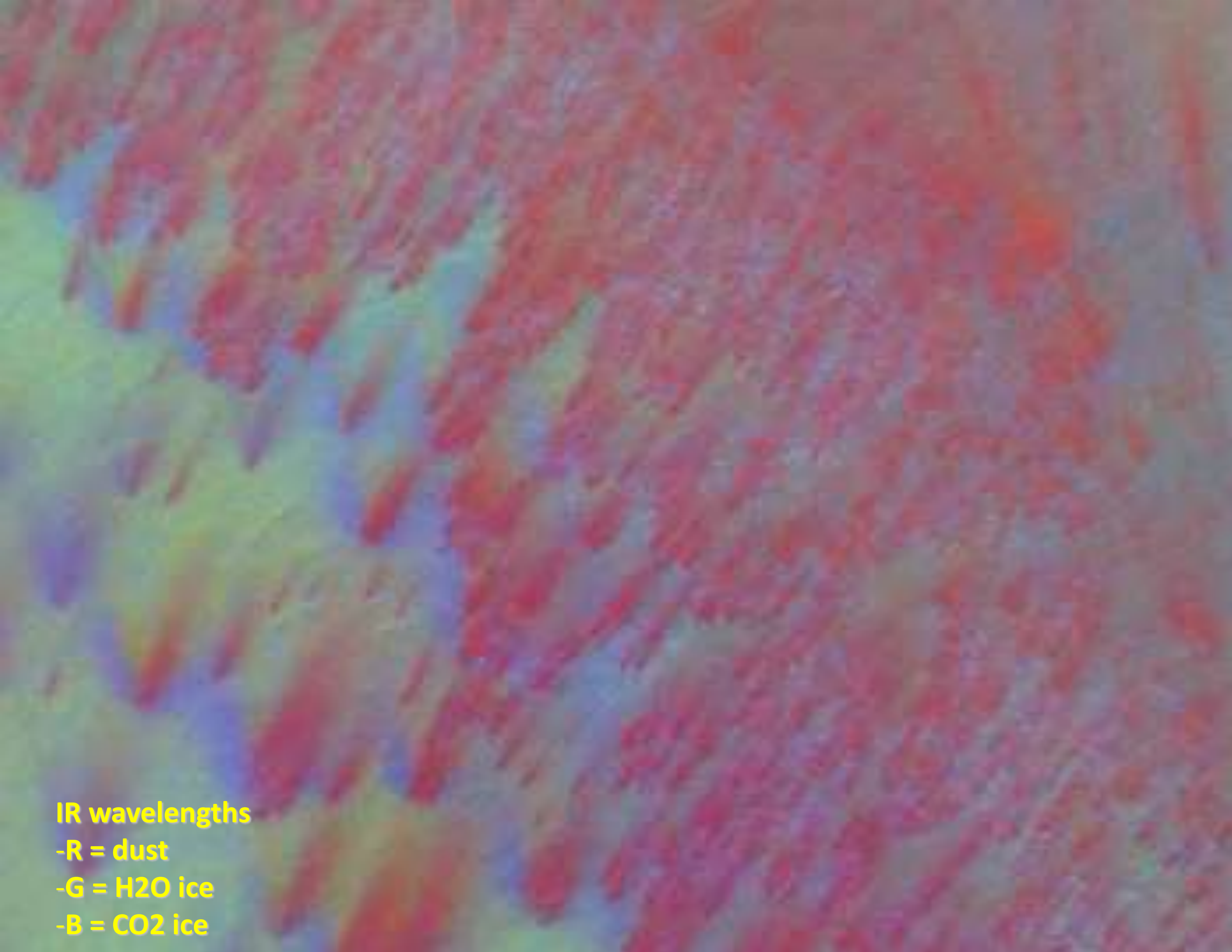
BEYOND MRO/CRISM: A HIGH RESOLUTION COMPOSITIONAL IMAGER FOR MARS

Scott Murchie[1], John Mustard[2], Nathan Bridges[1], Mike Smith[3], Mike Wolff[4], Todd Clancy[4], Raymond Arvidson[5], Bethany Ehlmann[6], John Grant[7], Ralph Milliken[2], Lisa Pratt[8], Timothy Titus[9], Kris Becker[9], J. Andrew McGovern[1], Erick Malaret[10], and Helene Winters[1]

[1]Applied Physics Laboratory, 11101 Johns Hopkins Road, Laurel, MD 20723;
[2]Brown University, Providence, RI; [3]Goddard Space Flight Center, Greenbelt, MD;
[4]Space Science Institute, Boulder, CO; [5]Washington University, St. Louis, MO;
[6]California Institute of Technology, Pasadena, CA;
[7]Smithsonian Institution, Washington, D.C.; [8]Indiana University, Bloomington, IN;
[9]U.S.G.S., Flagstaff, AZ; [10]Applied Coherent Technology, Herndon, VA

International Workshop on Instrumentation for Planetary Missions

CRISM Image of S Polar Cap in Spring
Visible Wavelengths


IR wavelengths
-R = dust
-G = H2O ice
-B = CO2 ice

Recent Mars Compositional Mapping: Resolution is the Key

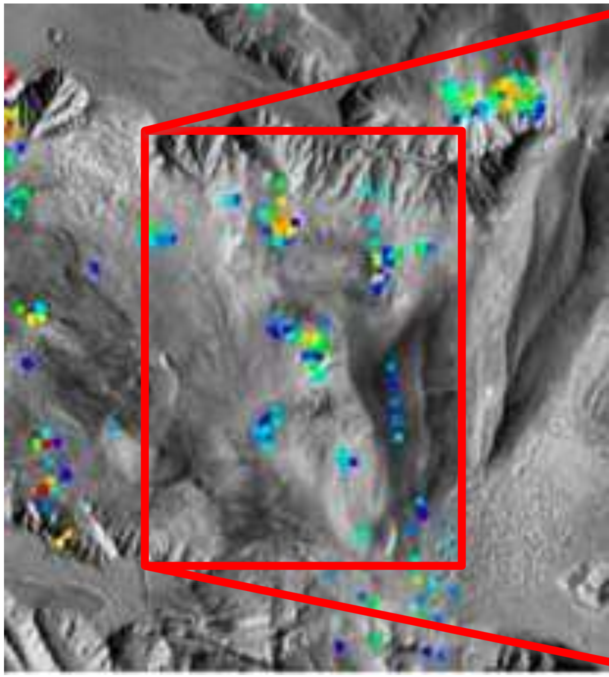
- The trend over 4 investigations is toward improved spatial resolution
- Each advance is transformational in understanding Mars

	λ, μm	Spatial Sampling, km/pixel	Minerals Reported
TES	6-50	3-6	Olivine, pyroxene, feldspar, hematite
THEMIS	7-15	0.1	Same as TES (+quartz, chloride)
OMEGA	0.4-5.1	0.3-1	Same as TES –feldspar (+poly-, monohydrated sulfates, gypsum, 3 types phyllosilicate)
CRISM	0.4-3.9	0.018	Same as OMEGA (+4 more types sulfate, 2 types carbonate, opal, zeolite, 5 more types phyllosilicate)

Improved understanding of past climate and habitable environments, the crust, and hydrated mineral resources

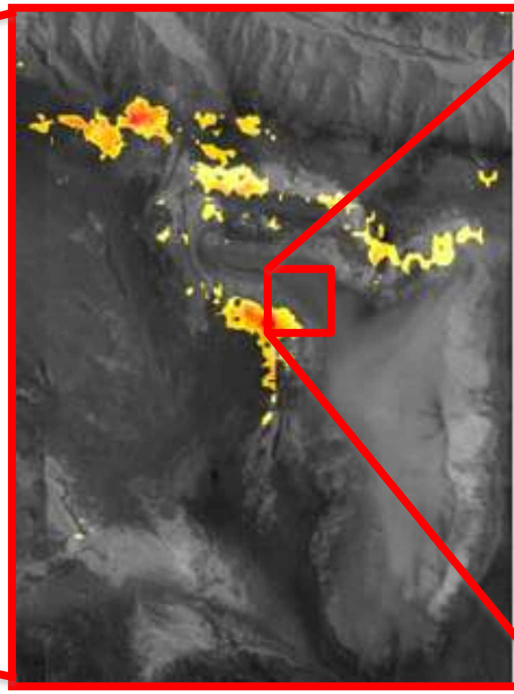
Case Study: Hematite in ILDs at Candor Mensa

TES, 6 km/pixel



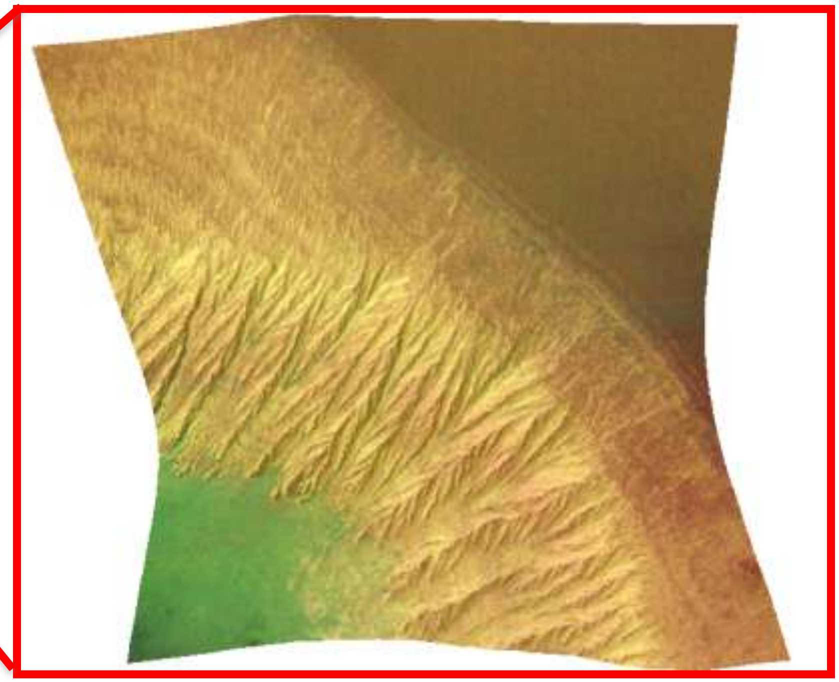
Map of gray hematite (Weitz et al., 2008) Detected on low on slope or at base

OMEGA, 0.7 km/pixel



Xtalline hematite (Mangold et al., 2008) Now resolvable as accumulations at base of slope

CRISM, 0.018 km/pixel



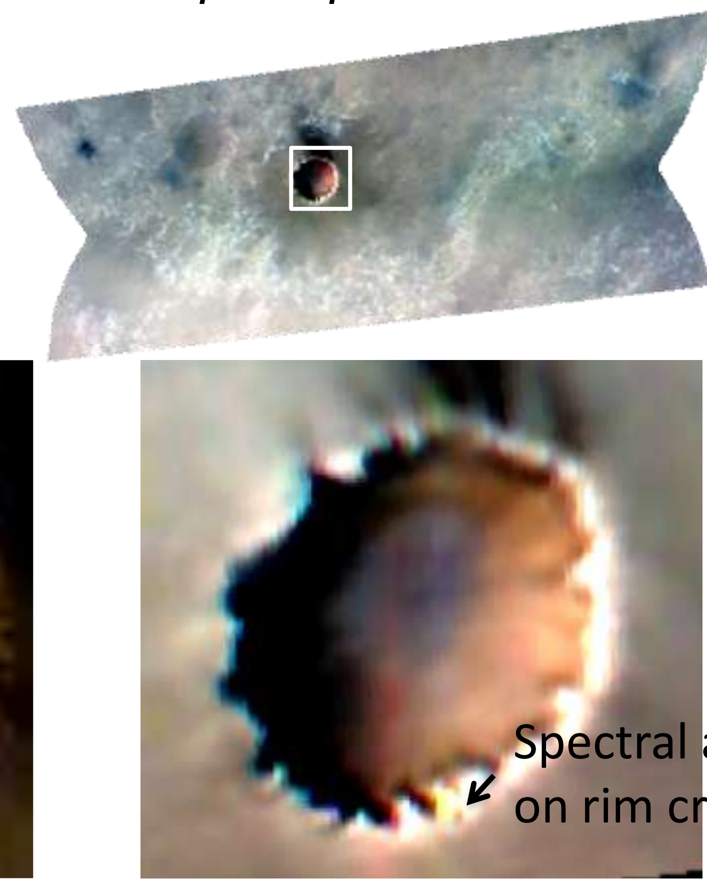
Xtalline hematite (green) and npFeOx (red) (Murchie et al., 2009) Traceable to yellow layers, forming green braided channel fill and accumulating in basal fan at lower left

Even CRISM's 18 m/pixel Resolution is a Limitation

- There are many exposures of key spectrally detectable phases at/below the limit of CRISM's resolution
- Example: until recently no hydrated minerals were detected from orbit in Victoria crater
- CRISM's new spatially oversampled observations yield 2-3x higher resolution, reveal hydrated sulfates on a fresh rim segment

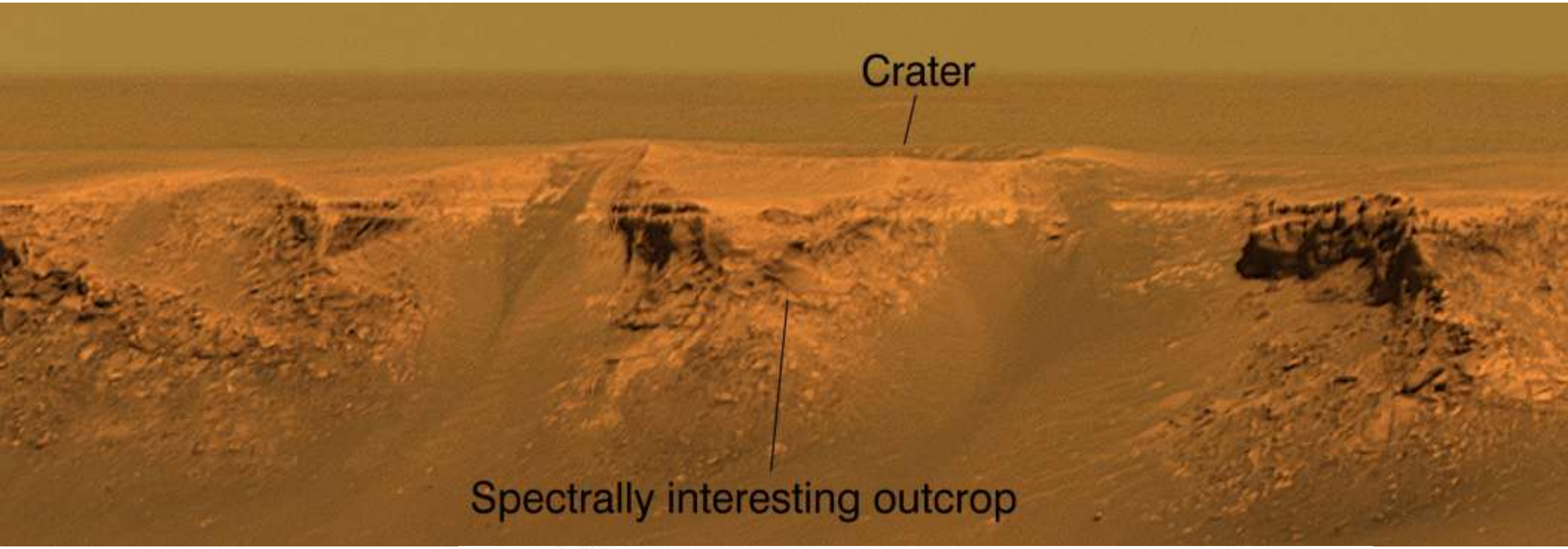
Normal observation, 18 m/pixel

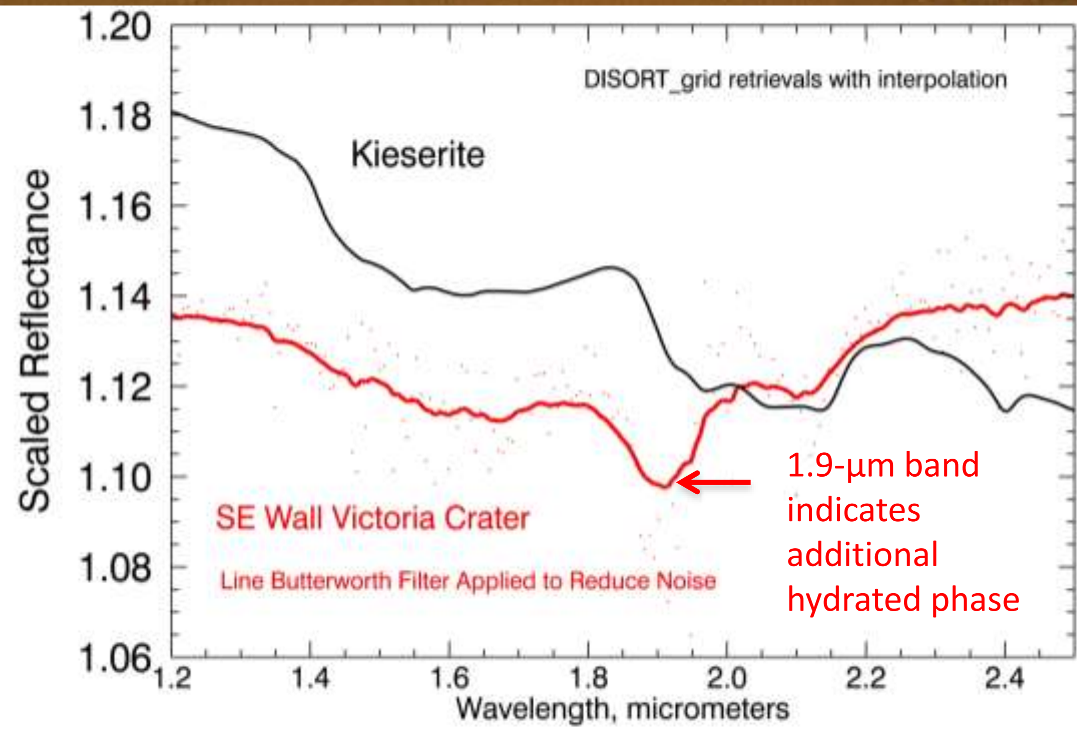
Oversampled, processed to ~6 m/pixel



Fraeman et al., LPSC, 2012

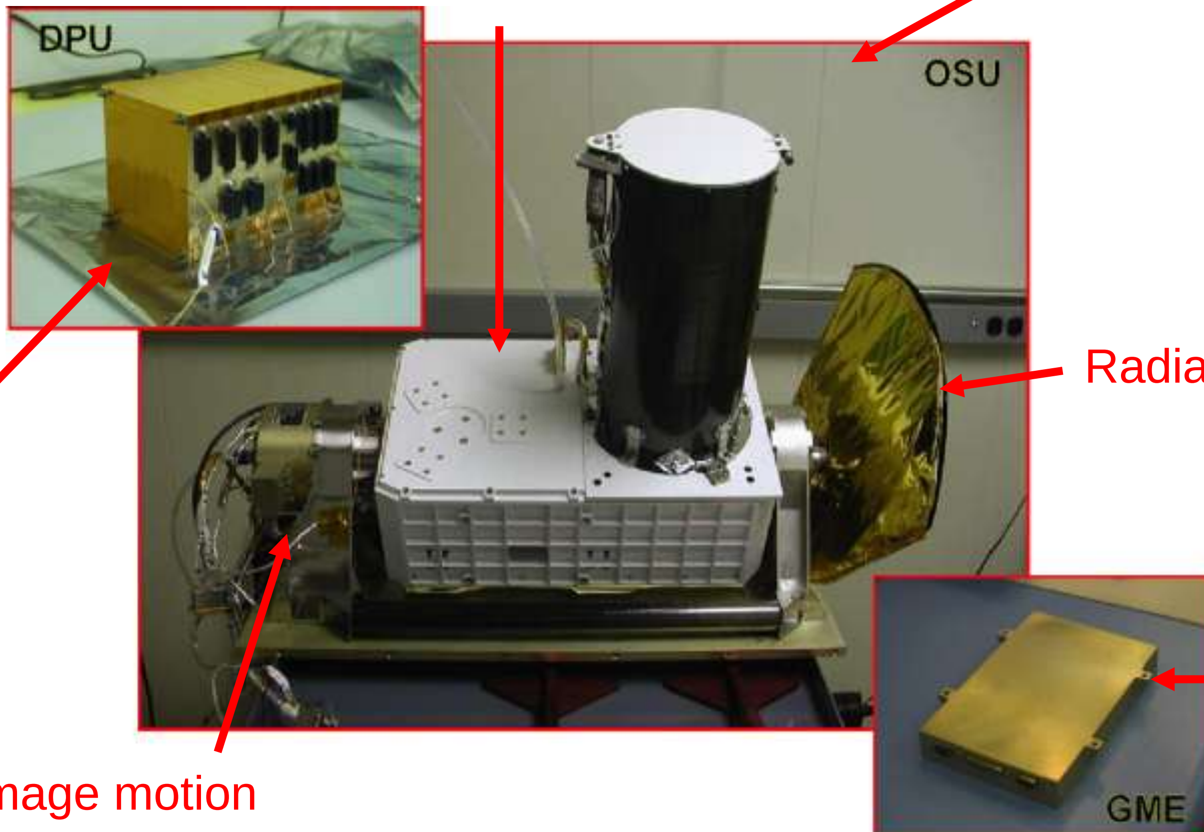
The Other Side of the Crater from MER





Arvidson, pers. comm.

Better Resolution? Starting Point of the Hardware



Wavelength range	0.4-3.9 µm
Spectral sampling	6.55 nm/channel
Spatial sampling	18 m/pixel from 300 km
Mass	32.9 kg
Power (orbit average)	45 W

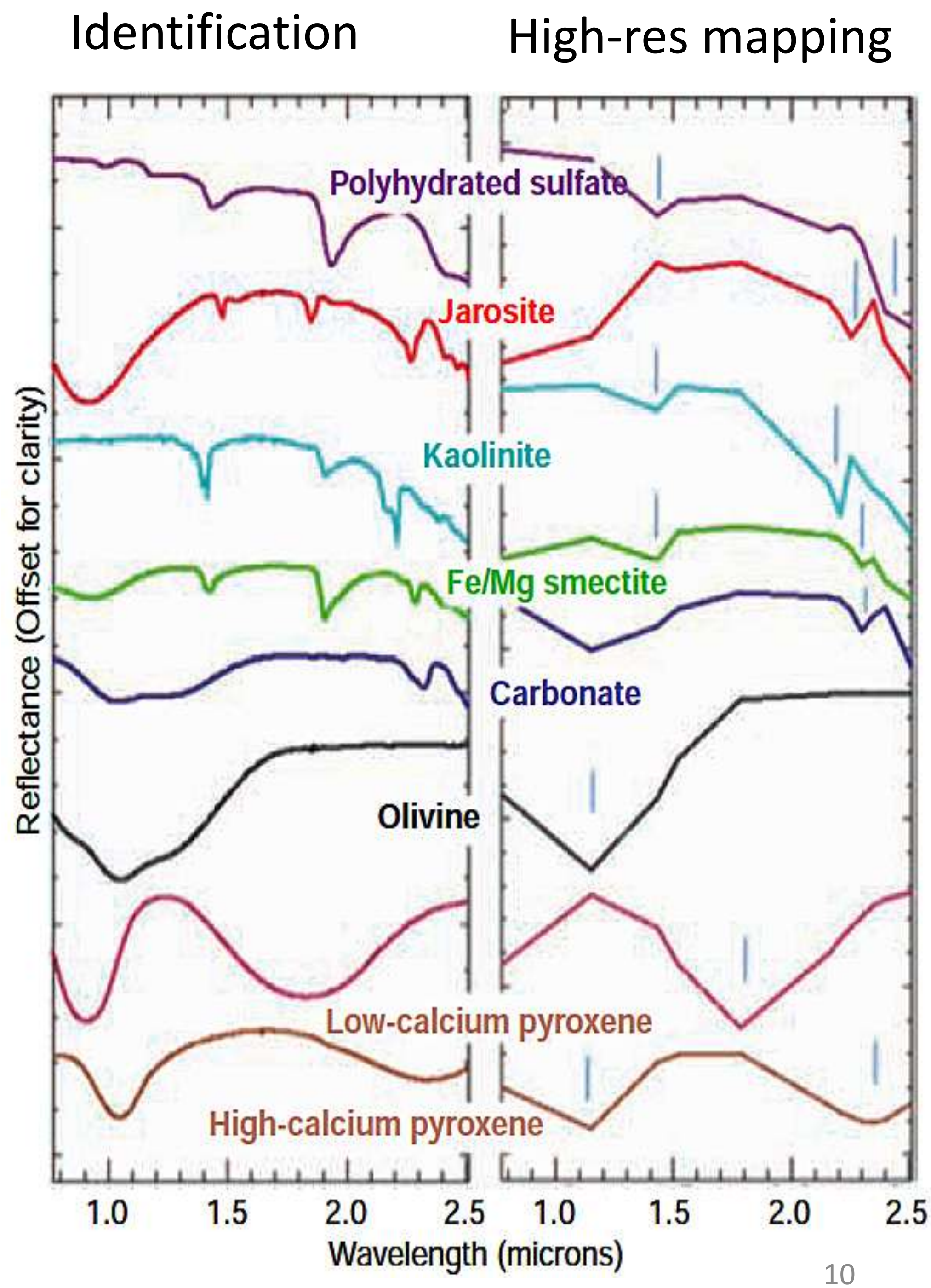
Building A Higher-Resolution Vis-NIR System Than CRISM

- For CRISM, ~100,000 e^-/pixel is typical (SNR ~250); >40,000 is needed for SNR approaching 200
- To improve resolution, possible trades are (1) efficiency (# surfaces, transmission or reflectance losses), (2) spectral bandpass, (3) aperture size
- Improved sampling to ~2 m/pixel, and retaining good SNR, can be achieved by switching to a multispectral camera from an imaging spectrometer (fewer losses, wider bandpass)

	CRISM	IR Multispectral Imager
m/pixel	18	2
Bandwidth, nm	6.7	50
Efficiency	0.15	0.45
Aperture, cm	10	20
Exposure, ms	200	200
F#	4.3	18
e- per exposure	100,000	50,000

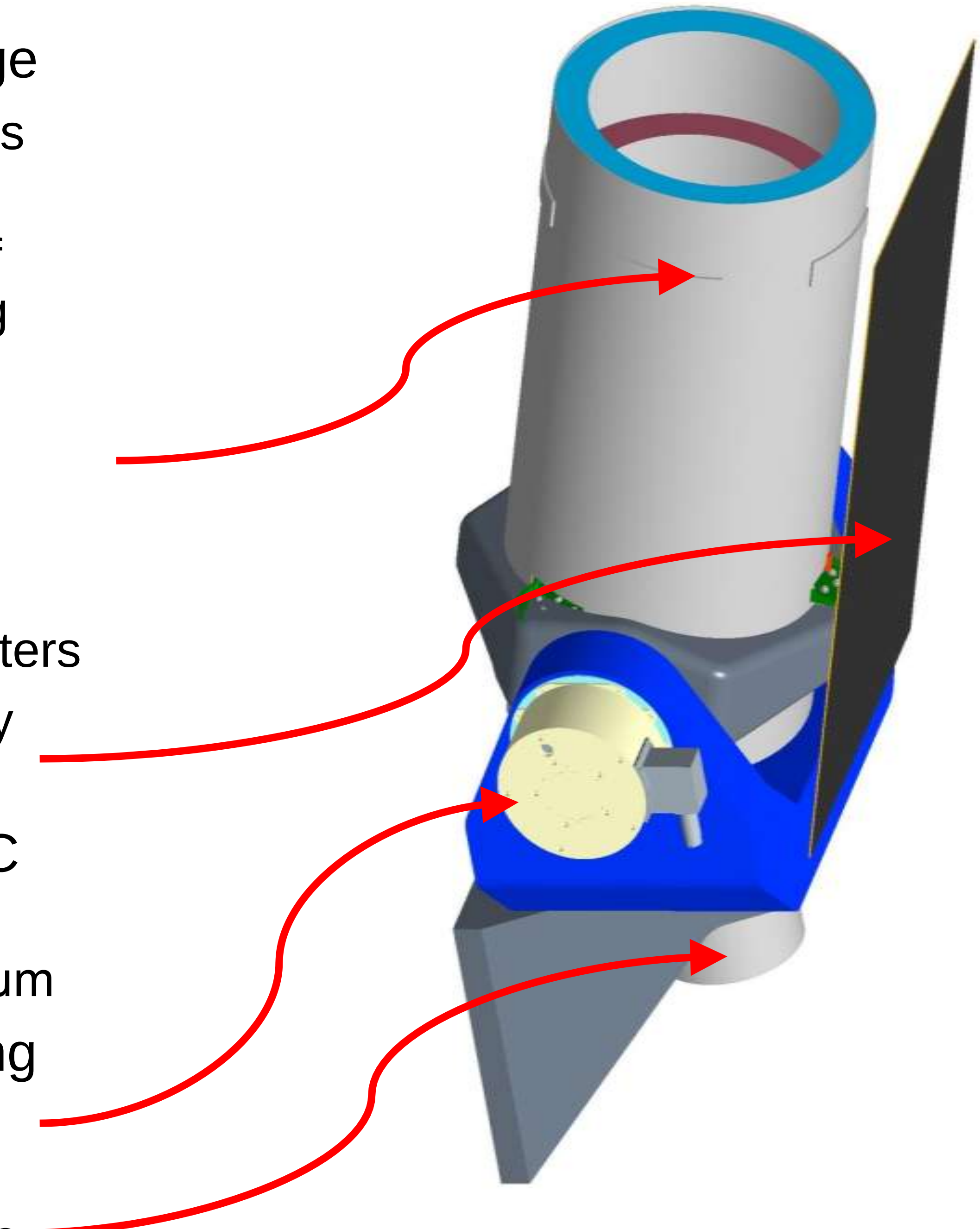
Multispectral Imaging for Composition

- CRISM and OMEGA use <u>only selected wavelengths</u> to "map out" minerals *once identified*
- Using knowledge of which minerals are present from OMEGA and CRISM, <u>~12 key wavelengths</u> can map those minerals at much higher resolution using ~50-nm bands
- The simulated spectra at right use 12 filters; they are convolved from laboratory spectra of key hydrated and igneous minerals on Mars



High Resolution Compositional imager (HRC) Concept

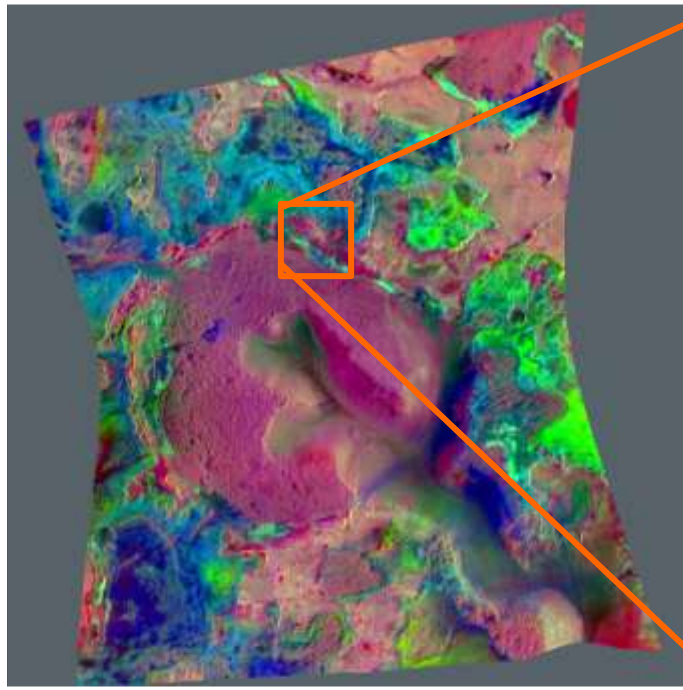
- 0.45 to 2.5 µm wavelength range
  - Covers key mineral absorptions
  - Can be extended to 3 µm for enhanced sensitivity to films of brine in RSLs, with cryocooling
- 2 m/pixel @ 400 km
- 20-cm aperture telescope, modified from New Horizons/LORRI
  - Filter wheel system,12 or 18 filters
  - 2048x2048 Hawaii Vis-IR array
- CRISM-heritage radiator cools optics, detector to below -90° C
  - Need for additional cooling depends on coverage to ≥2.5 µm
- 2-axis gimbal with target tracking for long exposures
  - “Fine” axis for image motion compensation, CRISM heritage
  - “Coarse” axis to position scan plane (optional with s/c capability)



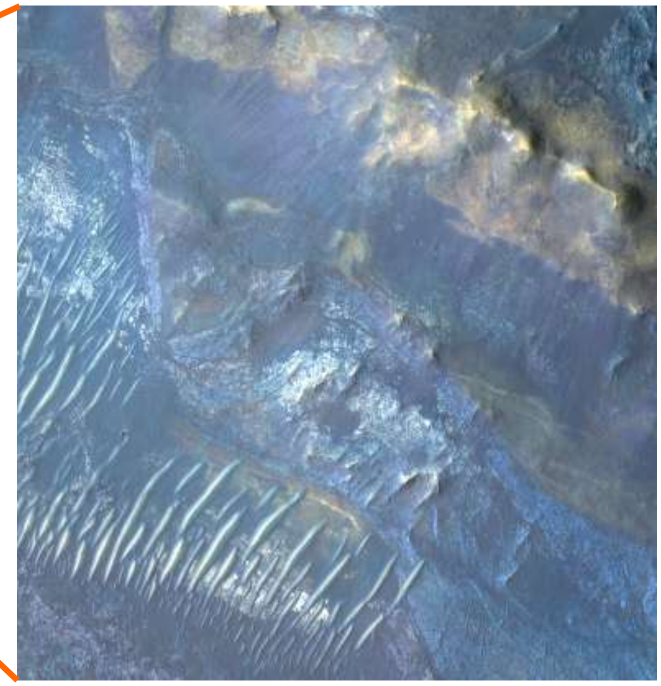
Mars at 2 m/pixel in Multiband IR

(simulated from CRISM observation FRT00003E12 convolved to 12 IR bands)

Visible-wavelength color, e.g. HiRISE, shows differences in Fe mineralogy



PCA transformation of 12 colors detects major mineral classes (olivine-blue, clay-pink, carbonate-green, basalt-red)



At 2 m/pixel, images have spatial sampling 9x better than CRISM and 3x better than CTX, adequate to resolve small-scale structure

Why Not Build a Larger CRISM?

- An alternative approach would be to re-build a CRISM with a much larger aperture to collect sufficient photons
- The masses and powers were estimated for both design approaches
- A “mega-CRISM” is <u>much</u> larger, with a larger motor for gimbaling to track the surface
- Such a system could be built but its mass, power, and probably cost would dominate the payload for an MRO-class mission

	High-resolution Compositional Imager	Scaled-up CRISM with Large Aperture
Pixel scale	1.5 m/pixel at 300 km altitude	3 m/pixel at 300 km altitude
Swath width	3.1 km at 300 km altitude	6.2 km at 300 km altitude
Spectral bands	Required: 540, 770, 1150, 1430, 1520, 1780, 2210, 2250, 2300, 2350, 2400, 2510 nm. Desired: 450, 850, 1000, 1900, 2100, 3000.	Required: 400-2550 nm; Desired: 400-3920 nm; 6.55 nm/channel
Aperture	21 cm	40 cm
Focal length	360 cm	176.4 cm
Mass w/ conting.	33 kg (39 kg for 3-µm imaging)	160 kg
Power (orbit avg.)	15 W (~30 W for 3-µm imaging)	100 W

Science Enabled at HRC Resolution

Science Question	New Measurements	Decadal Goals
Present-day liquid water	Presence of water, seasonal change in RSLs	Life, Climate
Volatile exchange	Ice ablation/condensation in seasonal caps	Climate
Amazonian climate cycles	Meters-scale PLD layering of H_2O / CO_2 ice, dust	Life, Climate
Hesperian-Amazonian exobiological oases	Silica-rich mounds at 9x smaller spatial scale	Life, Evolution
Hesperian groundwater processes	Sulfate/ferric mineralogy at the scale of individual beds in layered deposits	Life, Climate, Evolution
Nature of pre-Noachian habitable environments	Megabreccia composition at megaclast scale	Life, Climate, Evolution
Structure of the crust	Composition of crustal sections at the scale of sedimentary beds and volcanic flows	Evolution
Water resources	Beds rich in hydrated minerals	ISRU for Goal IV+

Thank You!

Questions?