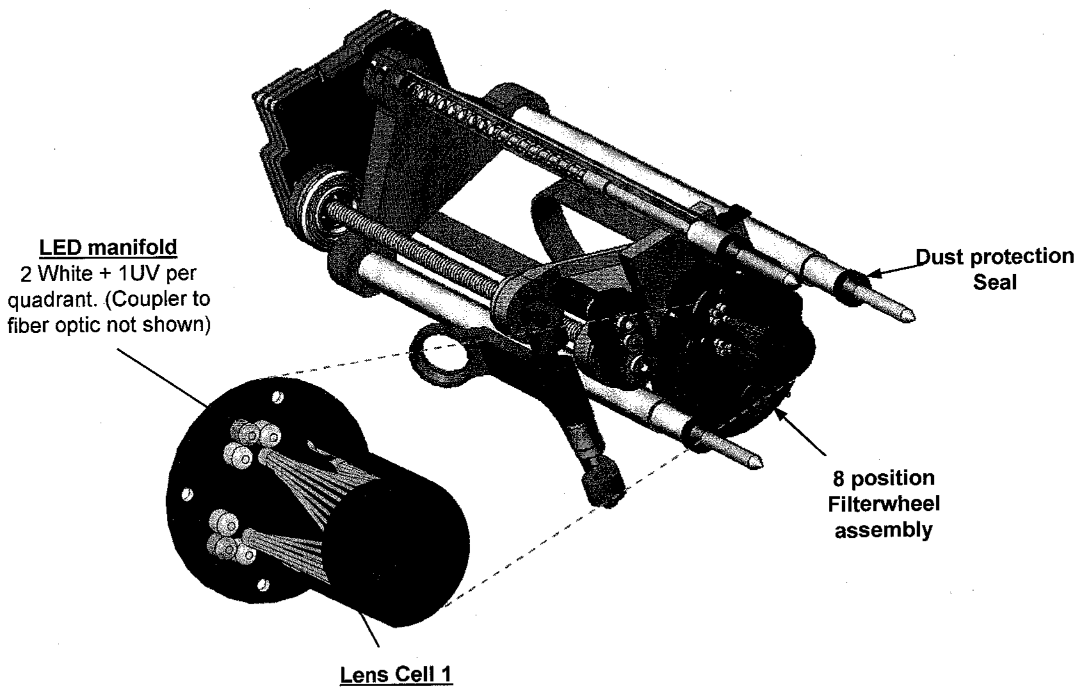
Camera, Hand lens, And Microscope Probe (CHAMP):

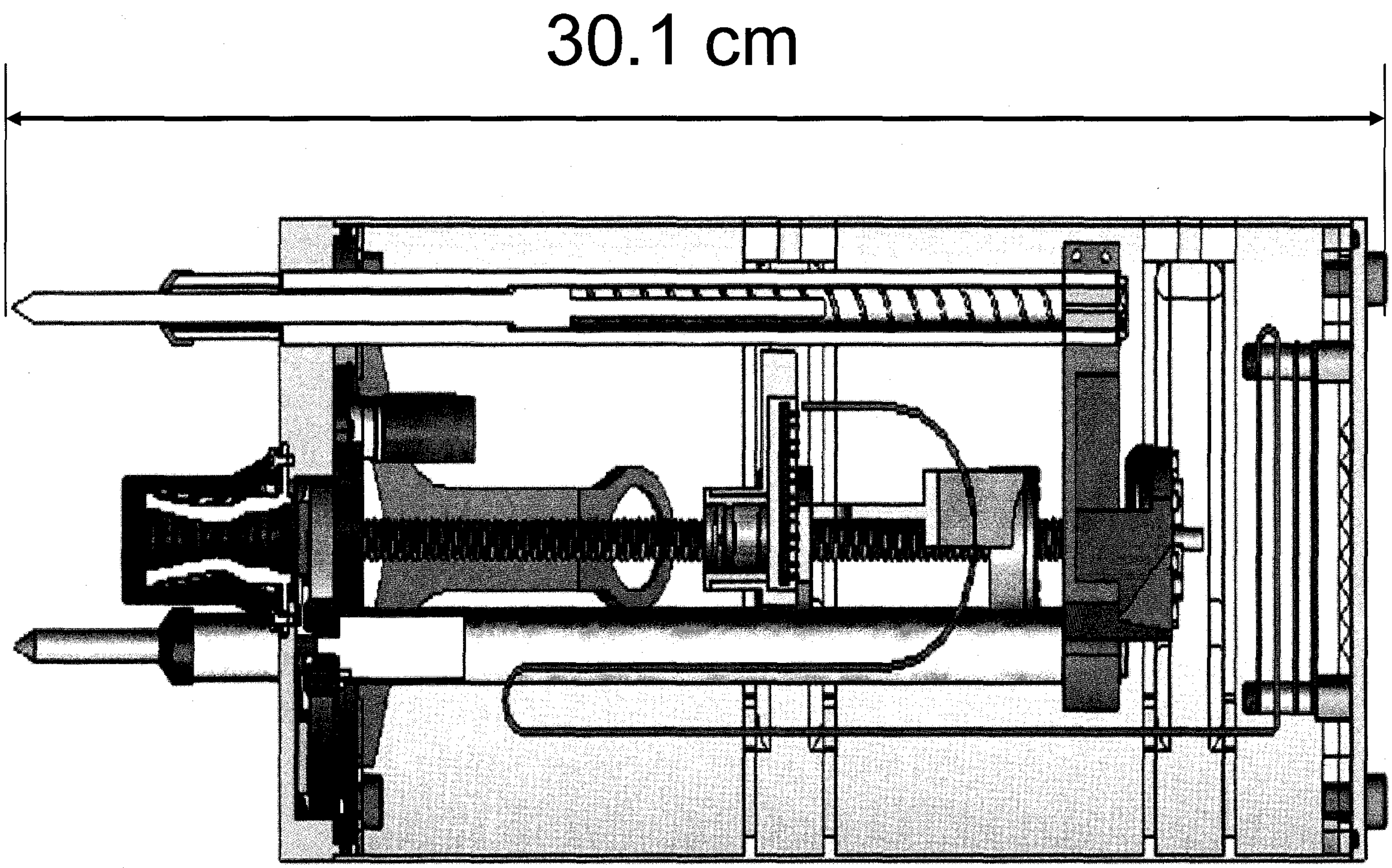
An Instrument Proposed for the 2009 MSL Rover Mission.

Greg S. Mungas[1], Luther W. Beegle[1],
John E. Boynton[1],
Pascal Lee[2], Ritch Shidemantle[3],
Ted Fisher[4]
and the CHAMP investigation team*

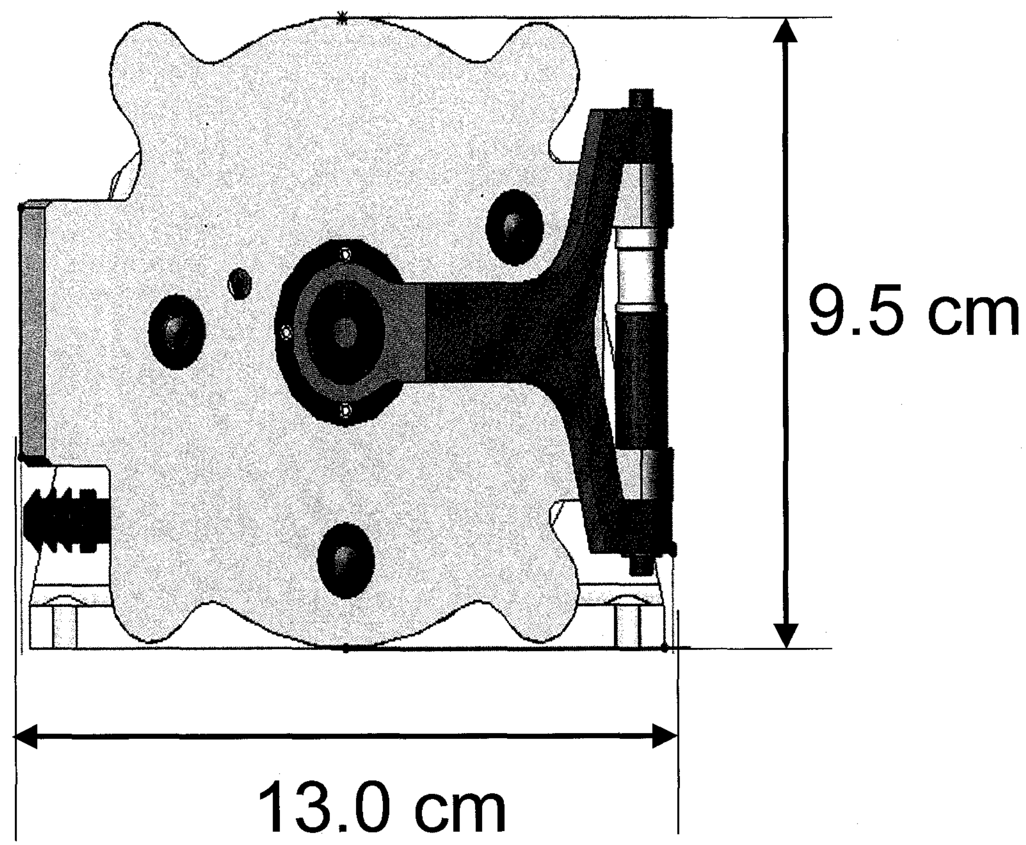
1 Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, Ca 91109
2 SETI Institute, 515 N. Whisman Rd, Mountain View Ca, 94043
3 Lockheed Martin
4 Firestar Engineering, LLC, 557 Burbank St. Unit J, Broomfield Co, 80020

The MIDP heritage CHAMP imager (Left) as shown deployed on the NASA ARC K9 Rover as it approaches a field sample (center) and in the preloaded into a target rock for stable microscopic imaging. **(Figure courtesy of Maria Bualat and MSL CHAMP team member Matt Deans)**

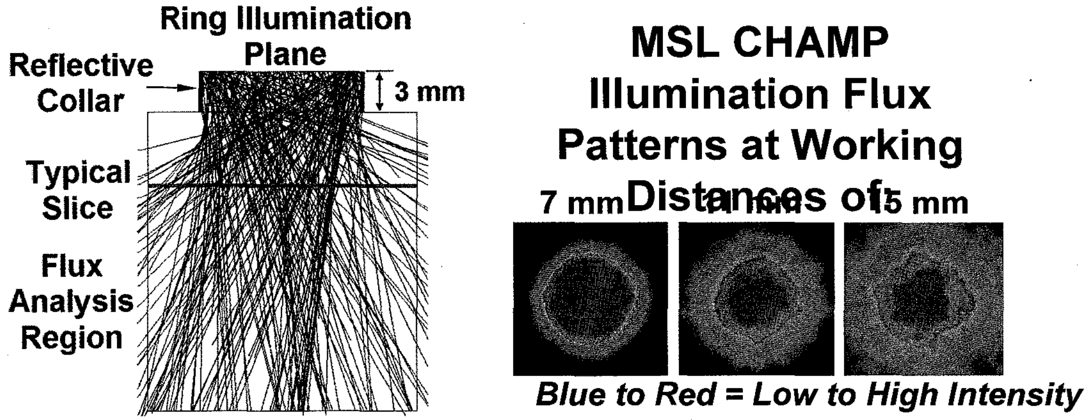

LED manifold
2 White + 1UV per quadrant. (Coupler to fiber optic not shown)
Dust protection Seal
8 position Filterwheel assembly
Lens Cell 1

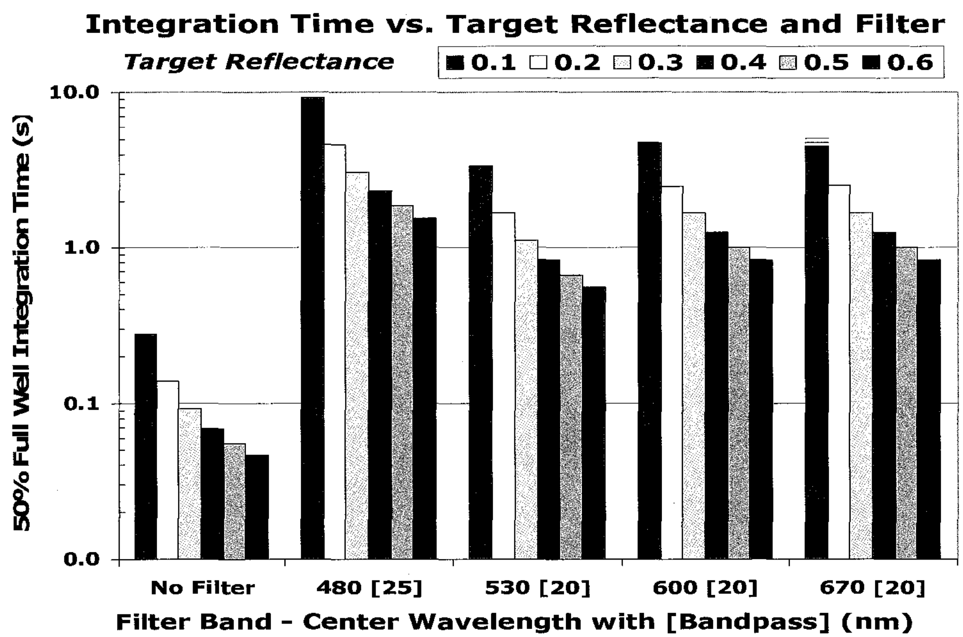


Schematic of the proposed



MSL microscopic imager





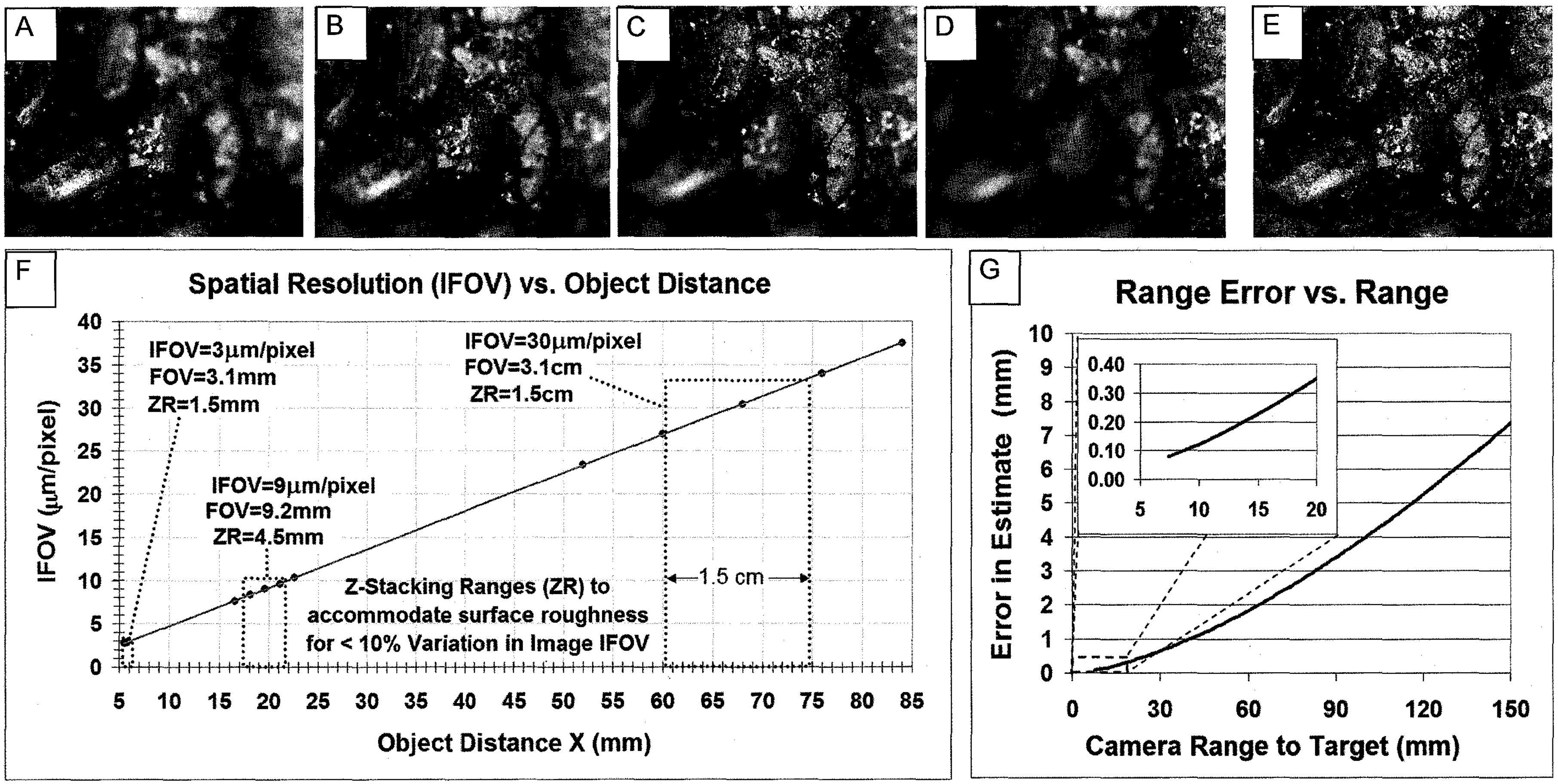
The redesigned snub nose illumination system is especially designed to achieved controlled lighting when CHAMP is utilizing the highest spatial resolution. The bottom graph shows the time to 50% Full well Using parameters from the Pancam filters and target reflectances with 4 White LED, under full quadrant illumination

CHAMP will allow examination of martian surface features and materials (terrain, rocks, soils, samples) on spatial scales ranging from kilometers to micrometers, thus enabling both microscopy and context imaging with high operational flexibility. CHAMP is designed to allow the detailed and quantitative investigation of a wide range of geologic features and processes on Mars, leading to a better quantitative understanding of the evolution of the martian surface environment through time.

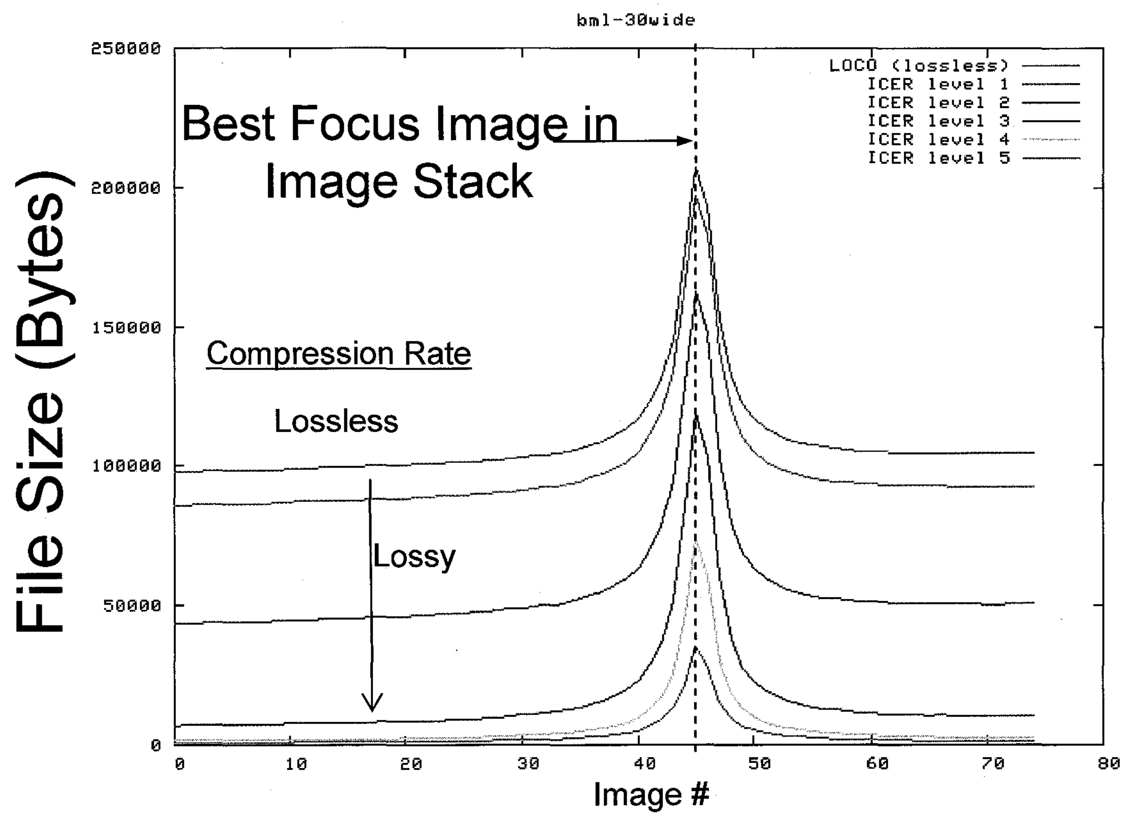
In particular, CHAMP will provide key data that will help understand the local region explored by MSL as a potential habitat for life. CHAMP will also support other anticipated MSL investigations, in particular by helping identify and select the highest priority targets for sample collection and analysis by the MSL's analytical suite.

We have proposed a single contact imaging experiment for NASA's 2009 Mars Surface Laboratory (MSL) rover mission with three core science objectives:

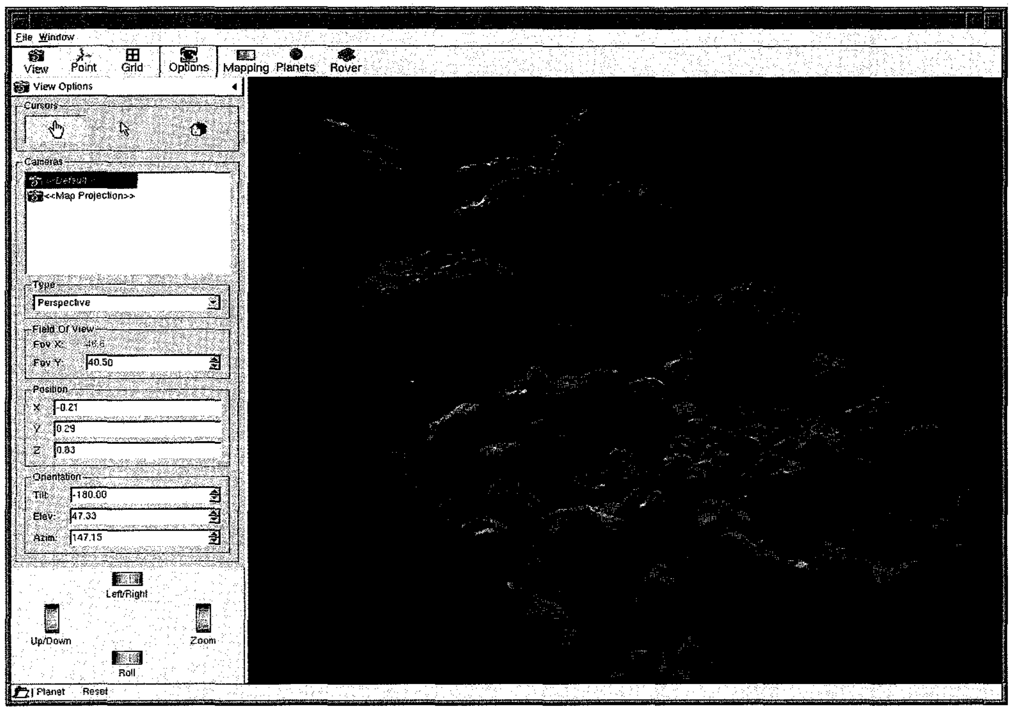
1) Assess the MSL landing region's biological potential by searching for morphologic/textural biosignatures in rocks and soil
2) Characterize potential habitats on Mars, focusing on past aqueous environments and past (or present) endolithic habitats
3) Characterize the local geology and geologic evolution of Mars, in particular in relation to H2O.


A
B
C
D
E
F
Spatial Resolution (IFOV) vs. Object Distance
IFOV=3µm/pixel
FOV=3.1mm
ZR=1.5mm
IFOV=9µm/pixel
FOV=9.2mm
ZR=4.5mm
IFOV=30µm/pixel
FOV=3.1cm
ZR=1.5cm
1.5 cm
Z-Stacking Ranges (ZR) to accommodate surface roughness for < 10% Variation in Image IFOV
IFOV (µm/pixel)
Object Distance X (mm)
G
Range Error vs. Range
Error in Estimate (mm)
Camera Range to Target (mm)

Examples of Z-Stacking and range determination. Raw Images of Hematite at Different Focus Positions (A-D) “Z-Stacked” into a Single Composite In-Focus Image (E). (F) depicts CHAMP’s change in IFOV vs. Working Distance Including Z-stack Range Estimates. (G) Illustrates CHAMP’s Precision Rangefinding Capability.



A very simple and sensitive metric that has been initially proposed for MSL CHAMP is to use the compressed file size of the z-stack images given the larger file sizes required for storing in-focus images with higher spatial frequency components. Example of Best Focus Calculated from Compressed Image File Size.



	Microscopy ←—— Object Distance [mm] ——→ *Infinity*								
	7	**8**	**9**	**10**	**13**	**27**	**43**	**153**	**Infinity**
Pixel Resolution - Instantaneous Field of Fiew (IFOV) [µm/pixel]	2.9	3.1	3.5	4.3	5.8	12	21	75	0.48 millirad
Field of View (FOV) [mm]	1.9	2.0	2.2	2.8	3.7	8.1	13	49	------
Depth of field [µm]	45	48	52	62	84	220	476	4600	----
Illumination	UV or White LED				White LED		Passive Lighting		
Spectral Range/Filters	460-650nm / 7 Filters (RGB) + 1 Dark Current Calibration								

In the process of producing a in-focus Z-Staked image, topographic information can be obtained by using the best focus and range determination from a stack of 40 images.

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	CHAMP [1]	MER micro-imager [2]	Phoenix RAC [3],[4]	Beagle 2 Microscope [5]	MECA Microscope [3]
Microscopic Imaging Resolution (IFOV) w/ Working Distance	**3 micron/pixel at 6mm**	30 micron/pixel at 66mm	23 micron/pixel at 11mm	4-6 micron/pixel at ??	4 micron/pixel at ??
Field of View at Focus Position	Infinity imaging (10°) continuous down to FOV=1.50 mm	30mm	Infinity Imaging to FOV~23mm	4mm	~1.5mm
Rover Approach and Arm Pointing	Supports arm pointing to features continuously magnified	Supports Arm Pointing	Supports Arm Pointing	NA	NA
Illumination	White and UV LED's for microscopy, passive lighting for approach	Passive Lighting	3 Color LEDs	3 Red, 3 Green, 3 Blue, 3 UV	3 color +1UV LED
Spectral Bands	Filter wheel 8 band selectable (460-650nm)	400-680nm	400-700nm wideband	Dependent on illumination	Dependent on illumination
Rough Surface Accommodation	Z-stacking with 10 micron step resolution	Z-stacking with arm to ~mm's resolution	Z-stacking with ~10 micron step resolution	Z-stacking with 10 micron step resolution	?

1 Boynton et. al. 2002, “Camera Handlens Microscope (CHAMP)”, MIDP Final Report, JPL Contract #961-495

2 Herkenhoff, K.E., et. al. 2003, JGR Vol. 108, E12, 8063, doi: 10.1029/2003JE002076

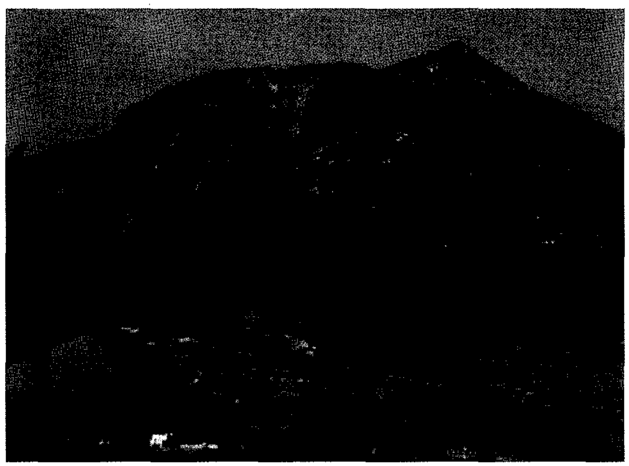
3 Smith, P., H. U. Keller, 2001, “The Robotic Arm Camera for Mars Surveyor 2001”, Workshop on Mars 2001

4 Reynolds, R.O., et. al. 1997, SPIE Vol. 3132, pp. 78-85

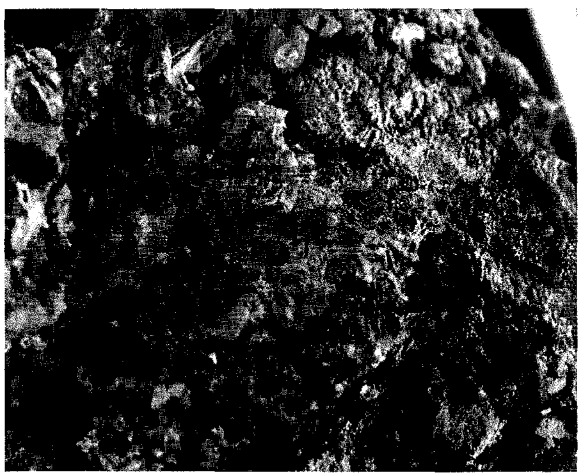
5 Thomas, N. et. al. 2003, “The Microscope for the Beagle 2 Lander…”, 6th Interntl. Conf. Mars

Examples of images obtained with the MIDP heritage CHAMP

Able to image in color (R, G, B) over several spatial scales

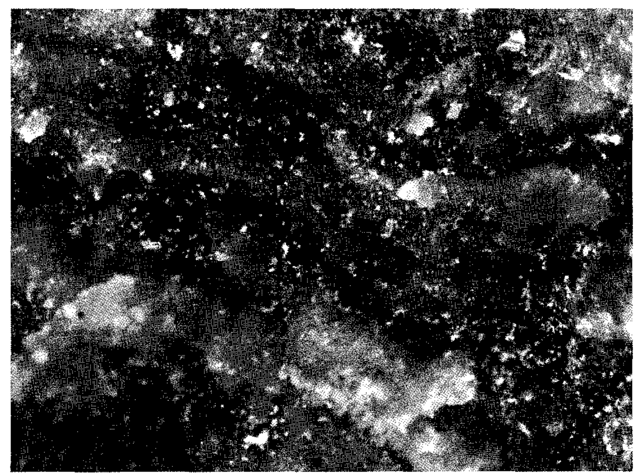


IFOV = 0.48mrad/pixl



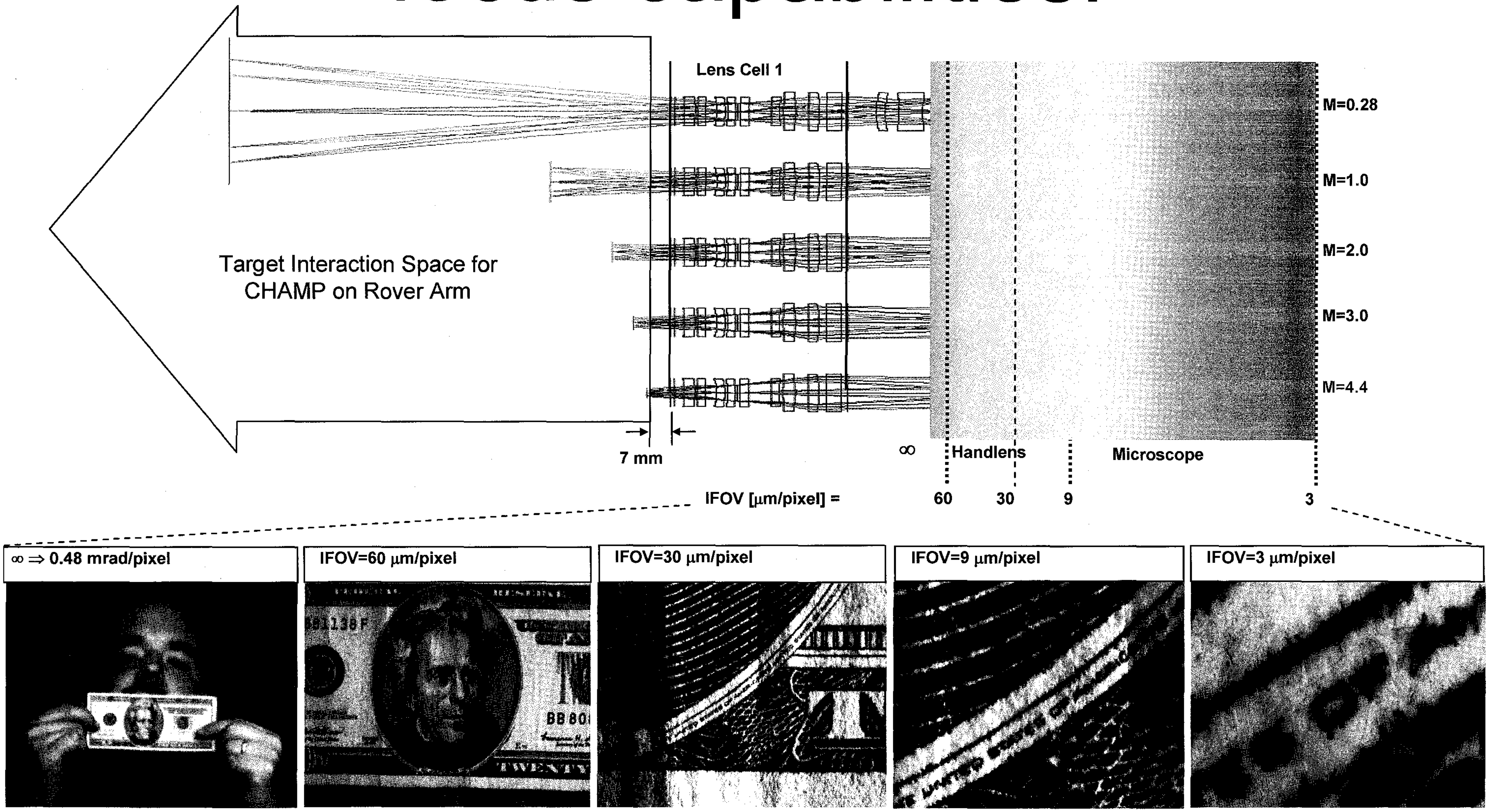
Magnification = 0.28
Horizontal FOV ~ 16.8 mm

Magnification = 0.70
Horizontal FOV ~ 6.5 mm

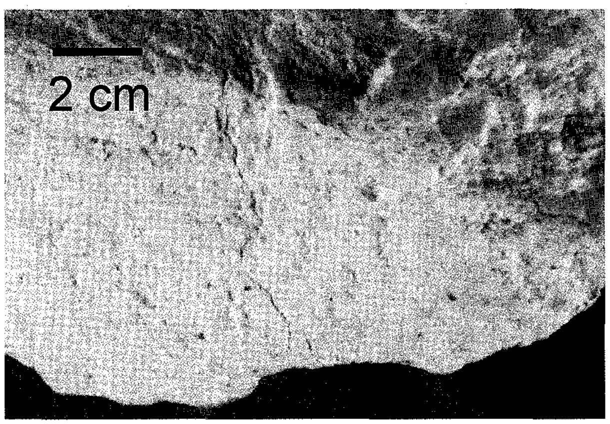


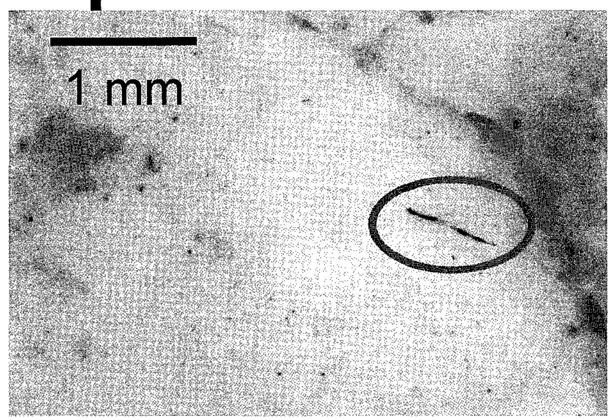
Magnification = 4.5
Horizontal FOV ~ 1.0 mm

Continuously variable focus capabilities.

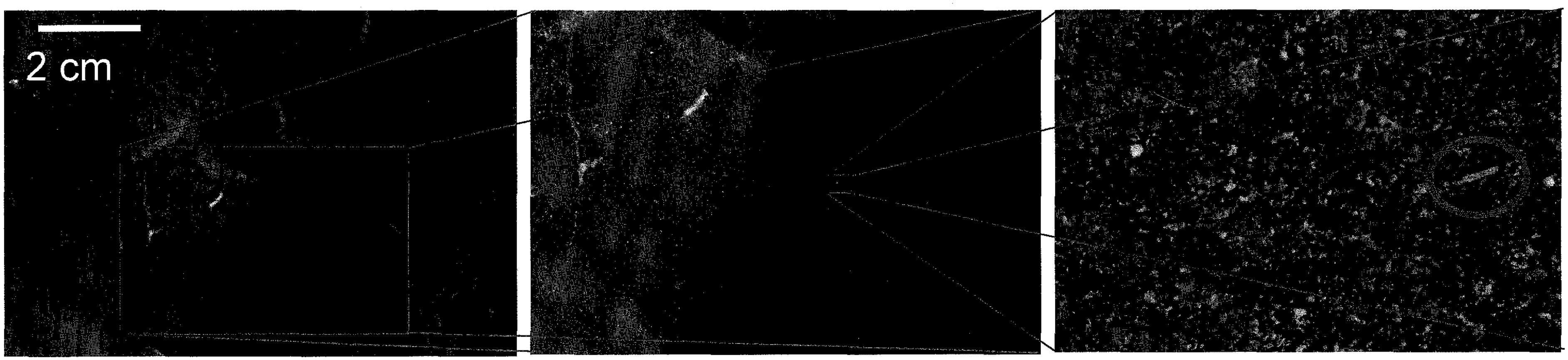


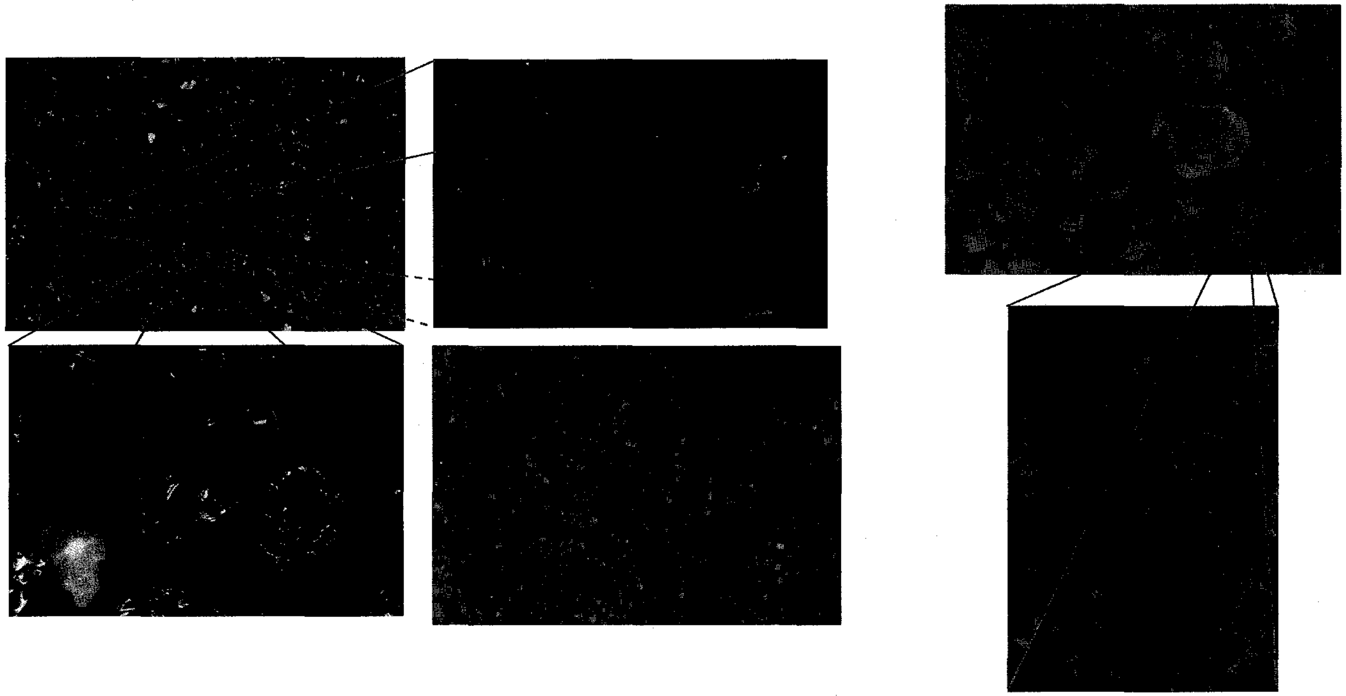
Maximum spatial resolution of 3 microns/pixel





Controlled lighting (white and UV)

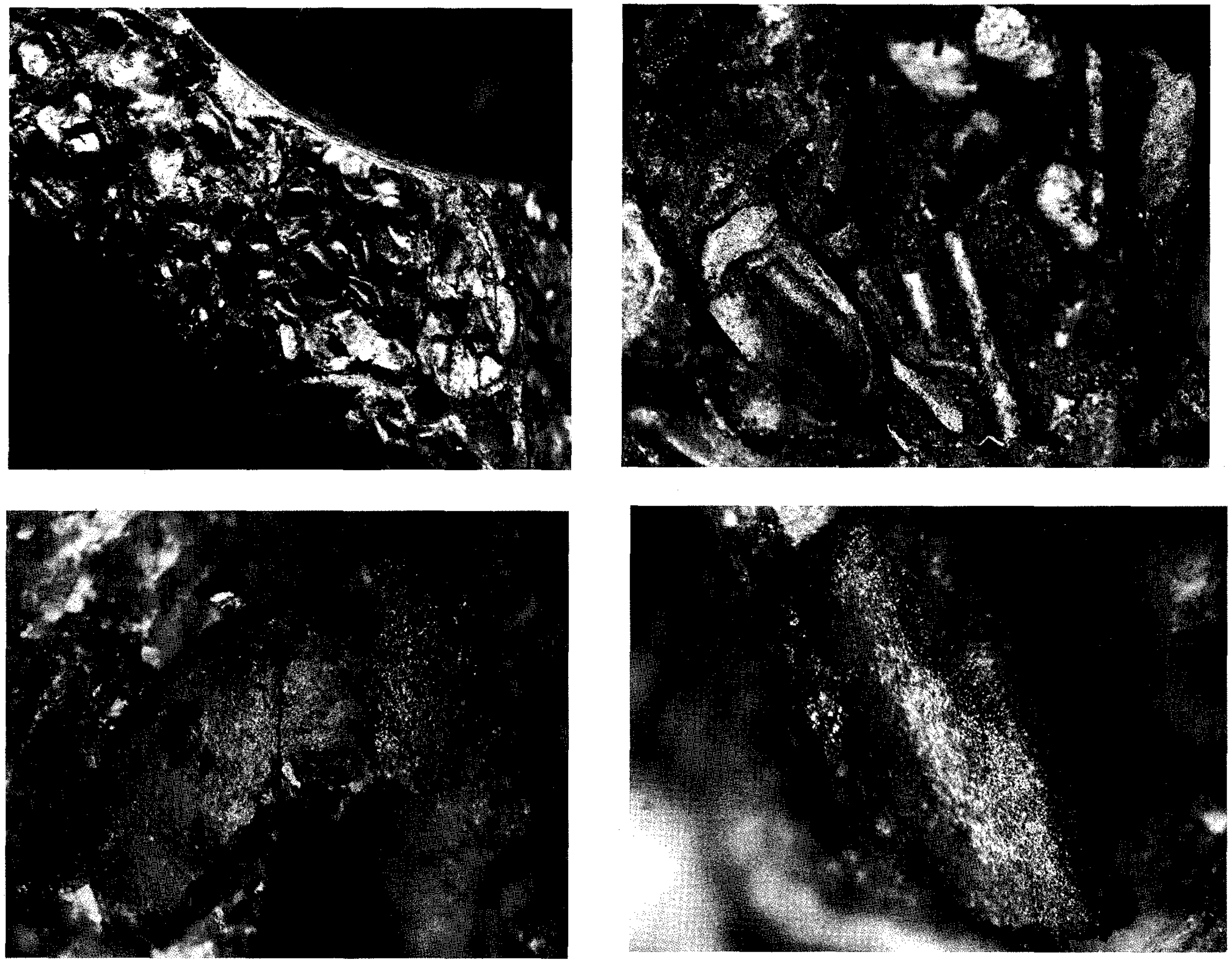




Series of images of lose, unconsolidated soil material. By imaging over several spatial ranges diversity of this material can be explored as well as particle counting so that size distributions can be determined.

IFOV=19; FOV=12.4mm | IFOV=12; FOV=8.2mm | IFOV=6; FOV=3.8mm | IFOV=3; FOV=1.9 mm

By utilizing the continual zoom when imaging a field sample we can image features that are not evident at the scale that the MER MI operates.



Color images of a hematite fossil at several spatial scale obtained with the CHAMP MNIDP instrument

Acknowledgments

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