CHAMP – Camera, Handlens, And Microscope Probe. G.S. Mungas[1], L.W. Beegle[1], J. Boynton[1], C.A. Sepulveda[1], T.A. Fisher[2], M.A. Balzer[1], H.R. Sobel[1], M. Deans[3], P. Lee[3]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109, [2]Firestar Engineering, LLC, Broomfield, CO 80020, [3] NASA Ames Research Center, Moffett Field, CA 94035.

Introduction: CHAMP (Camera, Handlens And Microscope Probe) is a novel field microscope capable of color imaging with continuously variable spatial resolution from infinity imaging down to diffraction-limited microscopy (3 micron/pixel). As an arm-mounted imager, CHAMP supports stereo-imaging with variable baselines, can continuously image targets at an increasing magnification during an arm approach, can provide precision range-finding estimates to targets, and can accommodate microscopic imaging of rough surfaces through a image filtering process called z-stacking. Currently designed with a filter wheel with 4 different filters, so that color and black and white images can be obtained over the entire Field-of-View, future designs will increase the number of filter positions to include 8 different filters. Finally, CHAMP incorporates controlled white and UV illumination so that images can be obtained regardless of sun position, and any potential fluorescent species can be identified so the most astrobiologically interesting samples can be identified.

CHAMP was originally developed through the Mars Instrument Development Program (MIDP) in support of robotic field investigations, but may also find application in new areas such as robotic in-orbit servicing and maintenance operations associated with spacecraft and human operations. Modifications to the MIDP instrument have been designed and will be incorporated into the next generation CHAMP. We discuss features of the MIDP instrument as well as proposed modifications to the instrument for future flight and field missions.

Lens cells: CHAMP was designed with 2 lens cells that move relative to each other to achieve variable working-distance and magnification capability. Lens cell one is fixed with respect to the instrument. Lens cell 2 travels linearly though <10cm where infinity imaging takes place at ~1cm behind cell 1, and highest resolution imaging occurs ~10 cm from cell 1. The linear traverse of lens cell 2 is accomplished by a stepper-motor driven linear actuator. Location knowledge of lens cell 2 permits accurate range determination of the target distance. This capability allows CHAMP to be used for accurate position of a robotic arm to within CHAMP's ~3mm field-of-view at peak magnification.

Dust cover: The MIDP instrument was designed with an iris dust cover mechanism. During field trials, this design was prone to freezing, so it was redesigned to flip out much like the MER microimager dust cover.

Illumination system: At peak magnification the working distance is 7 mm, which necessitates the inclusion of a controlled white lighting for image acquisition. The MIDP instrument was designed with 24 white LEDs equally spaced around the front end of the instrument. The redesign of the dust cover decreased the amount of LED accommodation space for LEDS on the space on the front of the instrument. The illumination system has therefore been redesigned internal to the instrument, UV illumination incorporated, and the light transmitted to the target by fiber optics.

Varriable focusing and Z-Stacking: The variable focus mechanism incorporated in the lens cell design, allows CHAMP to image targets with significant surface roughness. Z-stack image compression is performed by sampling a three-dimensional surface over a range of closely spaced working distances (particularly useful for field microsocopy). In such a case, an auto-focus solution for the target is first found by locating the best-focus position for lens cell 2 (Note lens cell 2 translates relative to lens cell 1 in the mechanical implementation of the instrument). Once a best focus solution has been found, multiple raw images (typically 10's of images ultimately dependent on surface roughness) spaced at a maximum distance of the instruments depth-of-field are acquired about the best focus position in order to produce a "z-stack" of images of the target (Figure 4). The in-focus portions of the image z-stack are then software-filtered to remove the large volume of "out-of-focus" image data in the z-stack of images. This filtering process effectively compresses the z-stack of images down into a single "in-focus" image

Conclusions: CHAMP is an instrument that has been developed under MIDP and has recently undergone a redesign using internal JPL funds. It can undertake a wide variety of field investigations where imaging at from infinity to 3 microns per pixel resolution is necessary. It has been demonstrated as part of the K-9 rover in field trials, and recently been modified for use in flight missions. This flight unit would weigh ~700 gm, and operate with <5 watts of power.

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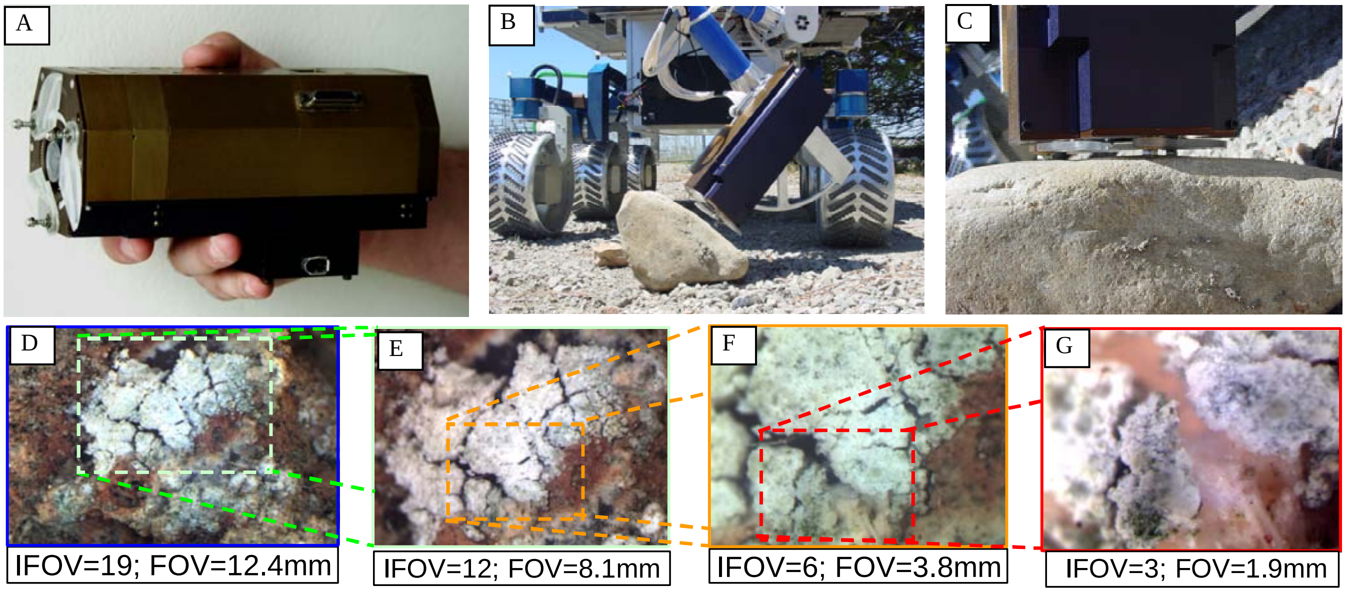

Figure 1. Image of the MIDP heritage CHAMP microscopic imager, as deployed on the end of the NASA AMES k-9 Rover, and in the best magnification position (A-C). As the robotic arm approaches a target, a seriese of images can be obtained whit increasing magnificatioin. This allows the images to be put in context so highly maginified images can be put in proper context of the larger object (D-G).

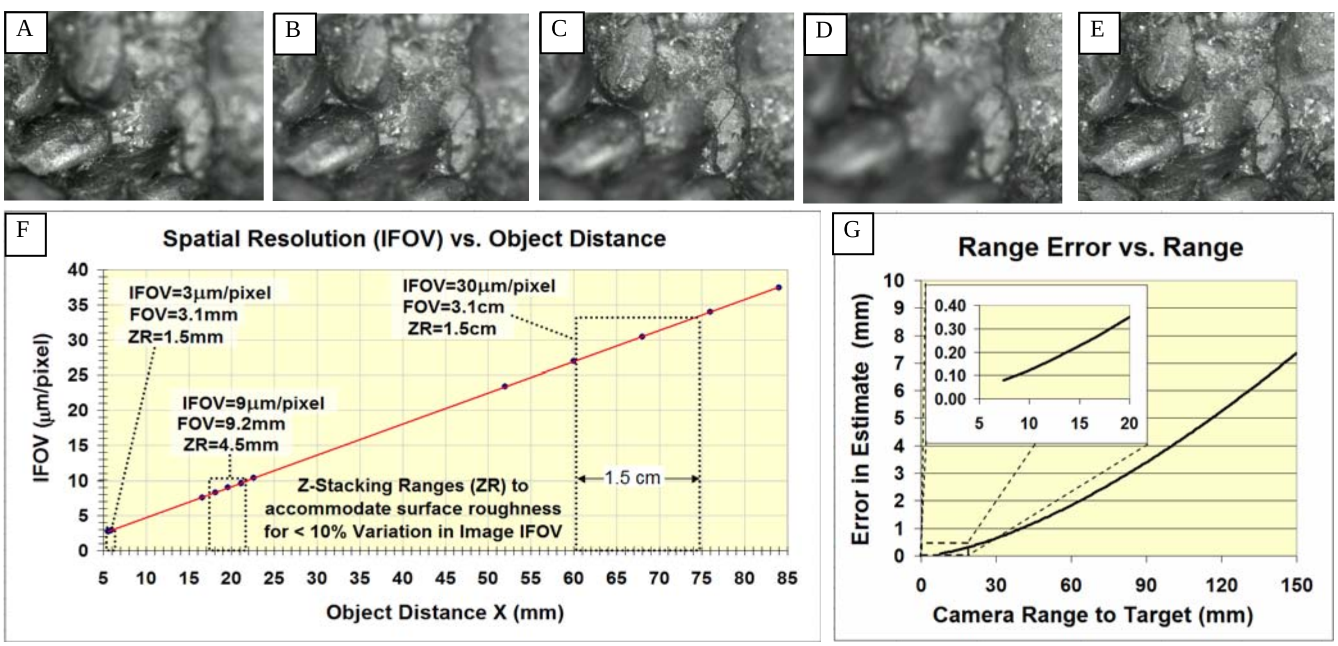

Figure 2. Images taken in different focus positions of a rough object at maximium resolution (A-D). The in-focus portions of the image z-stack are then software-filtered to remove the large volume of "out-of-focus" image data and produces a single "in-focus" image (Figure 4E). Using the position of the second lens stack relative to the first, the IFOV and the distance to object can be determined (4F, FG)