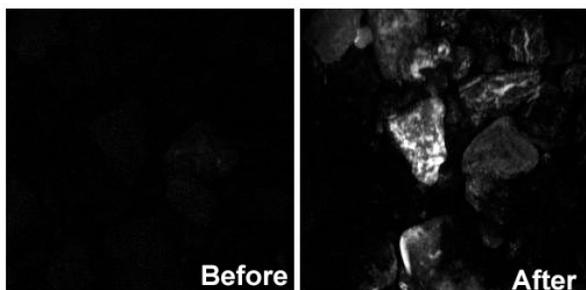


IMPLEMENTATION OF A DAYLIGHT FLUORESCENCE IMAGING SYSTEM TO AUTONOMOUSLY DETECT BIOMARKERS OF EXTANT LIFE IN THE ATACAMA DESERT. S. Weinstein¹ and D. Pane¹, K. Warren-Rhodes^{3,4}, C. Cockell⁵, L.A. Ernst¹, E. Minkley¹, G. Fisher¹, S. Emani¹, D.S. Wettergreen², M. Wagner², N. Cabrol^{3,4}, E. Grim³, A.S. Waggoner¹. ¹Molecular Biosensor and Imaging Center, Carnegie Mellon University, 4400 5th Ave, Pittsburgh, PA 15213; ²Robotics Institute, Carnegie Mellon University, Pittsburgh, PA 15213; ³NASA Ames SST. MS 245-3, Moffett Field, CA 94035-1000; ⁴SETI Institute; ⁵British Antarctic Survey (BAS), UK.

Introduction: We have integrated a biomarker detection system with a Carnegie Mellon University rover for the search for sparse life in extreme environments. The system incorporated a pulsed fluorescence imager (FI), a reagent sprayer, and a surface scraping device permitting remote detection of fluorescence signals from microbial colonies and biofilms during autonomous rover exploration.

Fluorescence detection was accomplished by imaging regions of the ground surface shaded by the rover using our FI equipped with a high-powered flashlamp synchronized with a gated CCD camera. Intrinsic fluorescence from chlorophyll of photosynthetic organisms was measured before and after application of water. Extrinsic fluorogenic probes were then applied to the target area to visualize common biomarkers of extant life. The probes are cell permeable stains that have a large fluorescence enhancement (quantum yields greater than 0.4) upon binding to their marks. Each probe specifically targets either extra-cellular polysaccharides (EPS), proteins, nucleic acids or membrane lipids, the four classes of macromolecules common in terrestrial life.

Integration into the Rover: The FI and its control were integrated into the design of the Carnegie Mellon University autonomous rover, Zoë. The FI's field-of-view pointed towards the ground directly under Zoë's chassis. It was mounted on rails to allow two degrees of motion- *x* (side-to-side) and *z* (up-and-down). Positioning in *y* was accomplished by the movement of Zoë itself. The FI was stowed in the chassis while traveling to prevent damage by



obstacles.

Figure 1: Fluorescence images of the lipid channel before and after dye under ambient light conditions. The data set is normalized to help scientist understand the positive signal.

The atomization of a sprayer was used for dye application and a plow which could be autonomously deployed was used to detect subsurface organisms.

Our experience from both our Atacama work and in general biological imaging, there is a strong desire by the scientists to avoid bit depth compression or lossy image compression on data. Our 2005 field season approach was to individually normalize each fluorescent channel after the protocol was completed and to send back 8 bit JPEG images. To preserve the approximate intensity values of the original data, the scaling factor was then saved in the META data. The observer can use this value to interpret the original values of any corresponding pixel values in the image sets.

In previous field expeditions, the protocol evolved during the field seasons as the scientists and engineers analyzed what worked. The protocol was finalized and standardized for this year's field season.

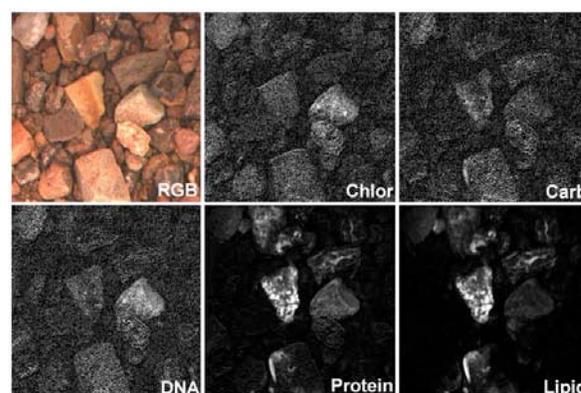


Figure 2: A positive dye sequence acquired using the FI on-board Zoë under ambient light conditions. This data set was taken in the Atacama Desert in the 2005 field expedition.

Conclusion: The FI delivered quality RGB and fluorescence images of the desert floor in the field-of-view. Ground truth pending, the FI detected what appears to be both surface and endolithic life. The dyes functioned, although further investigation is needed to improve penetration into surface life forms, such as lichens. Ground truth efforts to distinguish biotic versus mineral fluorescence are also critical and underway.