ROBOTIC SAMPLE MANIPULATOR FOR HANDLING ASTROMATERIALS INSIDE THE GEOLAB MICROGRAVITY GLOVEBOX.

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Introduction: Future human and robotic sample return missions will require isolation containment systems with strict protocols and procedures for reducing inorganic and organic contamination. Robotic handling and manipulation of astromaterials may be required for preliminary examination inside such an isolation containment system. In addition, examination of astromaterials in microgravity will require constant contact to secure samples during manipulation.

The National Space Grant Foundation exploration habitat (XHab) academic innovative challenge 2012 administered through the NASA advanced exploration systems (AES) deep space habitat (DSH) project awarded funding to the University of Bridgeport team to develop an engineering design for tools to facilitate holding and handling geological samples for analysis in a microgravity glovebox environment. The Bridgeport XHab team developed a robotic arm system with a three-finger gripper that could manipulate geologic samples within the existing GeoLab glovebox integrated into NASA's DSH – called the GeoLab Robotic Sample Manipulator (see fig. 1 and 2). This hardware was deployed and tested during the 2012 DSH mission operations tests [1].
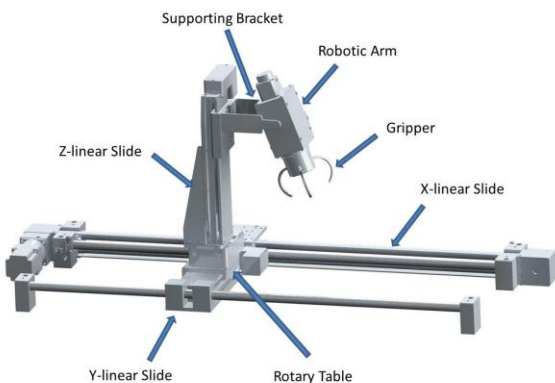

Fig. 1: GeoLab Robotic Sample Manipulator CAD design with major elements.

Design: The GeoLab glovebox is configured to allow sample capture and release from three pass through antechambers. It provides for macro and microscopic sample examination and presentation to an XRF spectrometer for chemical analysis. The X-axis used a Newmark e-belt linear slide for the length of the glovebox. The Y and Z axis each use Newmark NLS4 series precision linear stages. The Z-axis NLS4 liner stage is mounted on a Newmark RM-3 motorized rotary stage. All four (X, Y, Z, and rotation) stages are controlled by a Newmark NSC-G series motion controller.
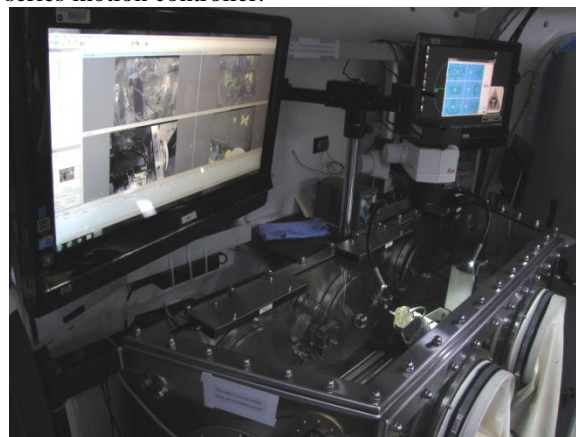

Fig. 2: GeoLab Robotic Sample Manipulator integrated into the GeoLab glovebox inside the DSH.

The robotic arm pitch uses a series of enclosed gears attached to an Applied Motion HT11-012 motor. The end effector is a three-fingered grasper with 360° rotation with two Applied Motion HT17-271 motors. All three Applied motor motors are controlled by an Applied Motion ST5-IP-EE controller. Both the Newmark and Apllied Motion controllers are Ethernet enabled and connected to the DSH avionics network switches. The software interface for the controllers was designed by the DSH software team and installed on the existing HP Touchsmart 600xt touch screen technology computer above the glovebox (see fig. 3).

While the concept of a three finger grasper has been used by numerous research groups for manipulations in controlled environments, the Bridgeport team developed each finger to have a large curvature such that random variations in rock sample shapes could be accommodated. This lowered the surface area that would come into contact with the sample minimizing contamination while still allowing a significant capture force to be applied to uneven surfaces of geologic materials (fig. 4 and 5).
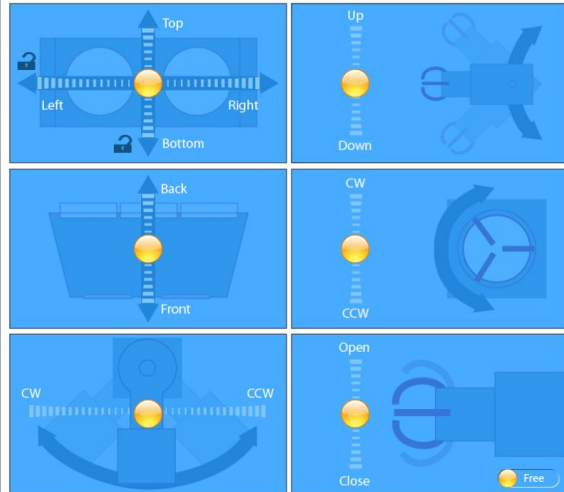
Fig. 3: GeoLab Robotic Arm Controller (GRAC) software with touch screen interface, screen shot.
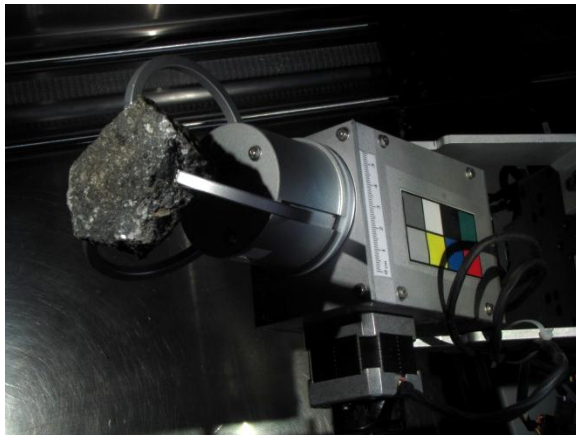

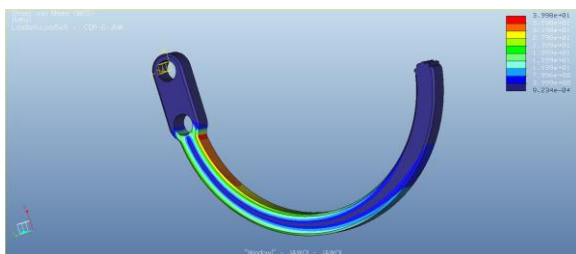Fig. 4: GeoLab Robotic Sample Manipulator with three finger gasper holding a rock sample.

Fig. 5: CAD structural stress analysis on the grasper finger.

Discussion: The GeoLab Robotic Sample Manipulator design was problematic since the glovebox was originally designed to accommodate only a gloved human interface. Ideally, the design of an isolation containment environment for examination of samples (e.g. glovebox) would be approached as a "system" to optimize robotic and human gloved sample manipulation capabilities. The three fingered grasper described here works well for uniform shear faced rock samples. However, we are exploring innovative gripper designs that can accommodate a wider range of regular and irregularly shaped samples understanding that a low-gravity environment may mitigate this problem.

The ability to move each finger in-line with the end effector rotation would allow more exact positioning of each finger and improve perpendicular alignment with non-uniform rock surfaces. A force sensor for each finger would also allow force limits to be applied to fragile geologic material. While this is a first generation prototype robotic manipulator designed and built with a modest budget (~$25K hardware only), a cleanroom rating requires a design that minimizes particle shedding, material outgassing, and maximizes cleanability. As such, wires and gears cannot be exposed

Summary: Future robotic sample manipulators will require technology developed for autonomous use in unstructured environments – environments in which the robotic manipulator cannot rely on complete knowledge about its surroundings. The deployment of autonomous robots in unstructured and dynamic environments poses a number of challenges that cannot easily be addressed by approaches developed for highly controlled environments. In unstructured environments, perceiving the environment becomes one of the key challenges. Robots have to autonomously and continuously acquire the information necessary to support decision making. Moreover, robots cannot assume that their actions succeed reliably. Instead, they have to continuously monitor their effect on the environment and possibly react to undesired events. In contrast, many existing, well-established techniques in robotics rely on perfect knowledge of the world and perfect control of the environment.

Continuing Research: Our current goals for sample science in the context of planetary exploration is to have autonomous robotic systems, assisted by human crew members when required, that can 1) provide robotic reconnaissance of sampling sites, 2) collect and stow samples in an archival manner, 3) conduct preliminary examination of samples collected either by humans or robots, 4) downlink the data to Earth-based mission scientists for sample return prioritization, and 5) accomplish these tasks according to rigorous curation protocols that preserve the scientific integrity of the samples. Our research is progressing toward providing structure to robotics through human/robot interactions.

References: [1] Evans C.A. et al. (2012) *LPS LXXV*, this volume; [2]Francois et al. (1991) *IEEE Proc. International Conference on Robotics and Automation*, 2261-2266.