ROBOTIC ARM DEVELOPMENTS TOWARDS ASTROMATERIALS CURATION APPLICATIONS.

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Introduction: As a part of the ongoing efforts to develop new curation tools and techniques for astromaterials [1] within the Astromaterials Acquisition and Curation office at NASA's Johnson Space Center, we are developing a variety of manually and electrically controlled micromanipulation systems. Most current techniques require manual manipulation, and in some cases the manipulation task is being done entirely freehand. The motorized systems available are restricted to three degrees of freedom and use proprietary control systems. For example, the MicroSupport AxisPro manipulation system currently used in microscale particle experiments is limited in its range of motion, as it can only move the manipulators in a three axis Cartesian range over a predetermined area above microscope slides. While having an efficient user interface, the control system is proprietary and prevents custom development and optimization to extend the viable applications of the system. In order to address some of these limitations, we have been testing robotic designs with multiple degrees of freedom and of a variety of designs [2]. We are currently investigating the Meca500 robotic arm by Mecademic as a potential manipulation system to overcome some of these obstacles.

Meca500 Development: The Meca500 is a desktop-size industrial six-axis robotic arm with a range of motion reaching 260 mm, enabling it to reach further than currently implemented systems and making it suitable to a diversity of applications within micromanipulation and glovebox operations. Adding to the range of potential applications, the six-axes of motion allow for approaching points of interest from a variety of angles, which improves the effectiveness of tweezer operations. The manufacturer indicates that the system is capable of 5 μm of repeatability, but testing indicates it is capable of 1 μm increments of motion in the Cartesian motion format. While the Meca500 is proprietary, it connects using TCP/IP protocols and a standard Ethernet cable, and with the implementation of RoboDK, a software platform for controlling industrial robots, the control system can itself effectively be controlled through RoboDK, allowing for real time user operation of the arm as demonstrated in Figure 1. Recently, Mecademic has created a new version of the Mecca500 that includes Python language support and allows for passing commands without using their web terminal or any third party software. Using the Python programming language, several forms of control input have been made available, and user friendly control systems are being developed for future use. Currently, an interface that allows click and drag commands from a mouse, as well as single Cartesian axis motion of user-determined size increments, has been developed and is being investigated for use in curatorial facilities.

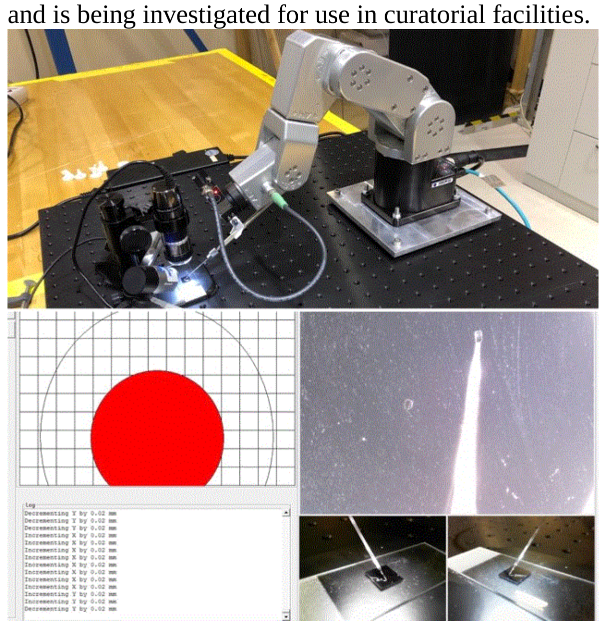

Figure 1: Custom Python based software for controlling the Meca500

3D Printed Manipulators: Having demonstrated the accuracy of motion through real time control, a variety of end effectors for the robotic arm were developed. The first of these end effectors was a stylus mount, which allowed a pen to be held by the arm and controlled through our interface, allowing us to test the motion output of our controls as well as identify and correct a drift in the vertical axis when moving in the x-y plane. The next end effectors consisted of a few different sets of jaws that connected to a Schunk MEGP 25 miniature electrical parallel gripper. These sets of jaws allowed us to pick up 0.5-2 mm sized glass beads and, with some software modification, would allow us to determine and limit the force applied to gripping the object of interest. One of these jaws included a groove that could hold a pin vice. The pin vice held a glass rod that was then used to manipulate 10-30 um sized magnetite grains. As an intermediate component between the previous two designs, a set of mounts were designed to hold tweezers and operate them using the MEGP 25 gripper. However, the design of the MEGP 25 gripper does not allow for steps between entirely open and entirely closed, preventing efficient tweezer operation. Future developments on this approach will be continued, but with a different gripper design. The latest in manipulator prototypes is a mount to directly hold a pin vice allowing for more stability in manipulating small particles than the grooved jaw. All of these are first stage prototypes for designs that would be machined out of aluminum or steel to match materials requirements and limitations within curation laboratories. Some designs such as the tweezer manipulators in Figure 2 are also appropriate for manual operations and have been built from aluminum and tested in curation procedures.

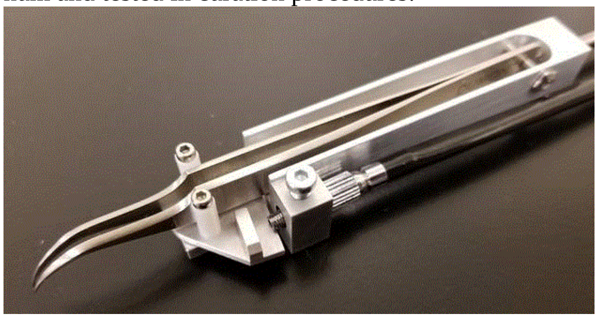

Figure 2: Milled aluminum tweezer manipulator

Next Steps: While significant progress has been made towards a system that can be used for processing Astromaterials within curation laboratories [3], further development is necessary. For instance, not all of the materials used to construct the Meca500 are allowed in the labs; however, it should be possible to replace or isolate non-compliant components. In addition, we intend to refine and optimize end effector designs for the Meca500 using additive manufacturing techniques. Additional components will also be machined or built using commercially available components to satisfy materials compliance requirements for curation labs.

References: [1] McCubbin et al. (2019) *Space Science Reviews*, 215, doi.org/10.1007/s11214-019-0615-9. [2] C. J. Snead et al. (2018) LPS XLVIII Abstract #2572. [3] Cowden T. R. et al. (2019) 82nd Annual Meeting of the Meteoritical Society Abstract #6364