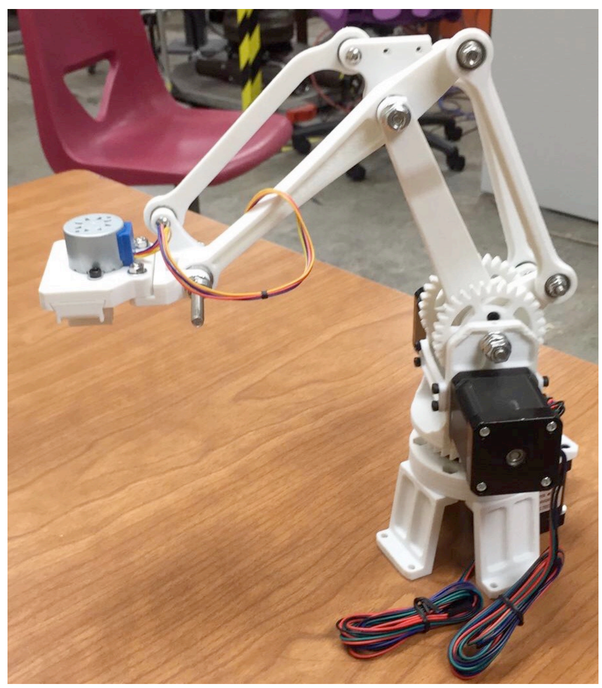
INVESTIGATING ASTROMATERIALS CURATION APPLICATIONS FOR DEXTEROUS ROBOTIC ARMS. C. J. Snead[1,2], J. H. Jang[2], T. R. Cowden[2], F. M. McCubbin[3] [1]JETS, NASA Johnson Space Center, Mailcode XI2, 2101 NASA Parkway, Houston TX 77058, USA. (christopher.j.snead@nasa.gov), [2]Texas State University, San Marcos, 601 University Dr, San Marcos, TX 78666 [3] NASA Johnson Space Center, Mailcode XI2, 2101 NASA Parkway, Houston, TX 77058, USA.

Introduction: The Astromaterials Acquisition and Curation office at NASA Johnson Space Center is currently investigating tools and methods that will enable the curation of future astromaterials collections [1]. Size and temperature constraints for astromaterials to be collected by current and future proposed missions will require the development of new robotic sample and tool handling capabilities. NASA Curation has investigated the application of robot arms in the past [2-4], and robotic 3-axis micromanipulators are currently in use for small particle curation in the Stardust and Cosmic Dust laboratories. While 3-axis micromanipulators have been extremely successful for activities involving the transfer of isolated particles in the 5-20 µm range (e.g. from microscope slide to epoxy bullet tip, beryllium SEM disk), their limited ranges of motion and lack of yaw, pitch, and roll degrees of freedom restrict their utility in other applications. For instance, curators removing particles from cosmic dust collectors by hand often employ scooping and rotating motions to successfully free trapped particles from the silicone oil coatings. Similar scooping and rotating motions are also employed when isolating a specific particle of interest from an aliquot of crushed meteorite. While cosmic dust curators have been remarkably successful with these kinds of particle manipulations using handheld tools, operator fatigue limits the number of particles that can be removed during a given extraction session. The challenges for curation of small particles will be exacerbated by mission requirements that samples be processed in N_2 sample cabinets (i.e. gloveboxes).

We have been investigating the use of compact robot arms to facilitate sample handling within gloveboxes. Six-axis robot arms potentially have applications beyond small particle manipulation. For instance, future sample return missions may involve biologically sensitive astromaterials that can be easily compromised by physical interaction with a curator [2]; other potential future returned samples may require cryogenic curation [5]. Robot arms may be combined with high resolution cameras within a sample cabinet and controlled remotely by curator. Sophisticated robot arm and hand combination systems can be programmed to mimic the movements of a curator wearing a data glove; successful implementation of such a system may ultimately allow a curator to virtually operate in a nitrogen, cryogenic, or biologically sensitive environment with dexterity comparable to that of a curator physically handling samples in a glove box.

4-Axis Robot Arm Development: Our initial objective is to develop a system that will mimic the hand motions of a curator holding a stylus to manipulate small particles. In order to investigate the viability of gesture-based control of robot arms, we have purchased two commercial 4-axis robot arms: the DoBot Magician, and the uArm Swift. The DoBot Magician is equipped with precise three stepper motors enabling a 0.2mm reproducibility. The DoBot arm's proprietary software enabled successful gesture-based control using a LeapMotion infrared controller; however, inaccuracies in the LeapMotion's positioning often caused the robot arm to lose calibration and collide with its support surface. Attempts to program motion limits were hindered by proprietary firmware installed on the DoBot Field Programmable Gate Array (FPGA) board.



The uArm Swift robot arm was acquired as an open-source, Arduino-based alternative to the DoBot Magician. While less precise than the DoBot Magician due to its servo motor drive system, the uArm Swift provided an open-source alternative to the DoBot. We were able to successfully develop software limitations for the uArm Swift that prevented arm collisions; such built-in limitations will be essential for use within a glovebox environment in order to protect valuable samples and equipment.

We have also recently 3D-printed and assembled a 4-axis robot arm driven by stepper motors, and we are currently developing control software for this robotic arm. It is our hope that the custom design will enable us to overcome the proprietary software limitations of the DoBot Magician and the low precision of the uArm Swift.

Next Steps: We have recently acquired a Mecademic Meca500 compact six-axis robot arm with 5μm reproducibility; such precision will be necessary for the successful manipulation of small particles. Our first objective is to develop a responsive and intuitive control system for the Meca500. Commercial haptic feedback devices may enable the gesture control necessary to simulate complex manipulation operations.

References: [1] McCubbin F. M. and Zeigler R. A. (2017) *Hayabusa 2017 Symposium of the Solar System Materials*. [2] Allen C. C. et al. (2000) *Concepts and Approaches for Mars Exploration*, Abstract #6197. Bell, M. S. and Allen C. C. (2005) *LPSXXXVI*, Abstract #1395. [4] Bell M S. et al. (2013) *LPS XLIV,* Abstract #2134. [5] Calaway M. J. and Allen C. C. (2013) *76th Meteoritical Society*, Abstract #5074.