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DEVELOPMENT OF LOW-COST MICROMANIPULATION SYSTEMS FOR SMALL EXTRATERRESTRIAL SAMPLES.

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Introduction: The analysis of microscale to mm-scale astromaterials often involves the transfer of samples from storage or collection substrates to analytical substrates. These transfers are accomplished by hand (via tweezers or fine-tipped needles) or by utilizing micromanipulation instruments. Freehand manipulation of small particles is extremely challenging due to involuntary hand tremors on the order of 100µm [1] and due to the triboelectric charging [2] induced by frequent contact between the manipulation tool and the support substrate. Months or years of practice may be required before an investigator develops the necessary experience to confidently transfer a 10-20µm particle in this manner. Handling even mm-sized particles with fine-tipped tweezers can be challenging, due to the inability to precisely control the force with which grains are being held. Mechanical, hydraulic, and motorized/electrical micromanipulators enable the precise handling of microscale samples and are often utilized in laboratories where frequent small sample preparation is required. However, the price of such instruments (~ $10,000 to $100,000) makes them cost-prohibitive for some institutions. Graduate students or early-career scientists interested in conducting research on interplanetary dust particles, Itokawa particles returned by Hayabusa, or future samples returned by OSIRIS-REx [3] or Hayabusa2 [4] may experience difficulty in justifying the expense of a micromanipulator to their advisors or principle investigators. Johnson Space Center's Astromaterials Acquisition and Curation Office and the Lunar and Planetary Institute conduct annual training for early career scientists and for investigators that require experience with handling of small extraterrestrial samples. In support of this training, we have been developing low-cost mechanical alternatives to expensive micromanipulators that training participants can implement in their respective facilities.

Manipulation System Development: We have modified two microscope systems to manipulate small particles: the Nikon SMZ800N stereo zoom microscope and the Leica EZ4W stereo zoom microscope with integrated camera and WiFi. The modifications are easily reversible for both systems. The Nikon SMZ800N was equipped with a geared Nikon (P-SXY) XY stage. We clamped a test indicator holder (designed to attach to milling machine spindles) to the microscope focus mount; a glass needle held by a pin vise with a 4mm shaft diameter was inserted to the end of the indicator holder. The adjustable nature of the indicator holder allowed us to position the needle at the focal point of the microscope objective at high magnification. With this configuration, it was possible to transfer microparticles between substrates by moving the XY stage and by using the focus as a Z-axis positioner. This method has the disadvantage that the particle cannot be viewed in sharp focus until it is almost at the same position as the needle. Despite this limitation, we were routinely able to transfer 10-20µm particles into custom SEM mounts for characterization and imaging.

Our Leica EZ4W manipulation system utilized an inexpensive (~$100) geared XY stage fixed to a custom aluminum extrusion frame. A mounting bar was attached to the side of the microscope via pre-existing M3 screw hole ports intended for securing the microscope casing. We mounted a MicroSupport tweezer actuation system to this bar, and fixed the actuation control knob to the XY stage frame. As with the Nikon system, tweezers were manually positioned until the tips were at the focal plane of the microscope. Manipulation of samples as small as 0.3mm were achieved by moving the XY stage, focusing in Z to bring the tweezers to the target grain, and closing the tweezers via the manual control knob. The lack of fine Z focusing adjustments precluded the transfer of particles smaller than 0.3mm on the Leica system; however, the system achieves the goal of making manipulation of grains >300µm accessible to novices, and was tested by attendees of the 50th Lunar and Planetary Science Conference earlier this year.

Next Steps: A significant shortcoming of the Leica manipulation system is the use of the proprietary tweezer actuation system, which at ~$3000, exceeds the combined cost of all other system components (including the microscope). We are currently working to develop a low-cost tweezer actuation system that can be constructed with commercially available (or 3D-printed) components. We are also developing fine-positioning mechanisms using commercialy available equipment that will facilitate the alignment of the needle (for the Nikon sytem) or tweezer tips (for the Leica system) in the microscope focal planes.

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