VALIDATION OF SUBORBITAL SPACEFLIGHT EXPERIMENTS THROUGH ZERO-G FLIGHT DEMONSTRATION OF FLIGHT-READY HARDWARE. D. D. Durda[1] , C. C. C. Tsang[1], S. A. Stern[1] , C. B. Olkin[1], K. Ennico Smith[2], and E. R. Schindhelm[1], [1]Southwest Research Institute, 1050 Walnut Street Suite 300, Boulder CO 80302, [2]NASA Ames Research Center.

Introduction: Southwest Research Institute (SwRI) is playing a leading role in the burgeoning suborbital research field using next-generation, manned vehicles by becoming one of the first organizations to fly payloads with research payload specialists on these vehicles. Research applications using these suborbital vehicles include: microgravity sciences, space life sciences, Earth and space sciences, land use, education and public outreach (E/PO), and technology/space systems development and demonstration. The primary research advantages of these vehicles include: more frequent access to the space environment, lower launch cost compared to conventional sounding rockets, capability for human operator presence, better experiment affordability, gentler ascent and entry compared to sounding rockets, extended periods of turbulence-free microgravity, and increased time in the 250,000–400,000 ft (80–120 km) region of the atmosphere (the "Ignorosphere").

Experiment Background: We have developed three research payloads that we will fly on multiple suborbital spaceflights; two of the payloads are astronomical/planetary science experiments while the third is a life science payload to measure human physiological response to the suborbital flight environment. Our astronomy experiments, the BORE (Box of Rocks Experiment) and SWUIS (Southwest Ultraviolet Imaging System) payloads – a microgravity regolith study focused on understanding the surface properties and process on small near Earth asteroids and a broadband astronomy/aeronomy imaging system, respectively – are built and ready for flight test and data collection.

BORE will examine the settling of regolith blocks in low/micro-gravity conditions applicable to the surface of a small asteroid, the derivation of block shapes from imaging (i.e., comparison of derived axes ratios from 2D projection in images to known true 3D axes ratios), and measure the coefficient of resitution of rock-on-rock low-speed impacts in microgravity. The experiment consists of a simple 'box of rocks' (artificial 'bricks' of known size and shape) and a video camera to record images of the settled pile of rubble. The experiment is particularly well-matched to the objectives and flight envelopes of next-gen commercial suborbital vehicles and will advance our understanding of the morphology of small asteroid regolith structures.

Our latest, suborbital version of SWUIS, SWUIS2.0, consists of a single image-intensified CCD camera with broadband visible/near-infrared 400-900 nm response, high-quality foreoptics, a power and telemetry box with camera controls, associated cable harnessing, optical filters, a GPS interface, a laptop control computer, a 12V 10Ah NiMH battery to enable 7 hour operation lifetime, and a battery monitor. The primary SWUIS2.0 foreoptic is a fast, 135 mm/f2, but the camera can accommodate multiple lenses. ICCD frames are recorded at video rates, a requirement for jitter compensation and high time resolution needed for time-domain science (e.g., occultation studies). In the 1990s flights, SWUIS-A achieved a limiting astronomical magnitude of V=10 in <1sec in dark sky conditions [1]. In 2012 testing, SWUIS2.0 demonstrated V=8.5 in 0.3sec, V=12 in 10s. The SWUIS2.0 system (including laptop) weighs 10 kg. Performance testing of the sister UV-sensitive ICCD camera from SWUIS-S, was not part of this effort, but compatibility with the SWUIS2.0 image acquisition upgrade (i.e., laptop frame-grabber) was tested and demonstrated full performance.

SWUIS2.0 is controlled by a Dell Latitude E6520 laptop with an Imperx VCE Express frame-grabber. This subsystem replaced both the LCD camera and the VCR recorder. The absence of the latter removed undesired artifacts such as NTSC-size pixels (ratio 4:3) and amplifier overshoot (i.e. black trails after a bright compact source against a dark background). The data acquisition subsystem for SWUIS2.0 recovers the ICCD's square pixels and did not demonstrate amplifier overshoot, which had been previously seen on V>7.9 stars, compromising photometry on such starfields. Xybion autogain settings remain enabled to protect the microchannel plate. Testing revealed bright targets (V<2.5mag) are surrounded by a halo ('charge bleed'). These artifacts can be removed with specific data reduction steps. The daytime performance over 3.7-7.7 V-band mag/arcsec^2 was also assessed. With the Nikkor 135mm f/2 lens, the system demonstrated a FOV of 5.3°×4.0° with an iFOV of 0.0083°×0.0083°.

The Imperx frame-grabbing software is capable of continuous or selective (by time) image grabbing, along with file date and time-stamping. In addition, an external trigger can be configured to enable/disable image capture. This flexibility allows for scripting an observational strategy and also allows for an external control if access to the laptop keyboard is prohibited within a suborbital vehicle.

Zero-G Flight Test: On 17 November 2013 we flew the BORE and SWUIS experiment payloads on a zero-gravity research flight aboard a modified Boeing 727-200. Our primary objectives for the flight were: (1) to raise the TRL of BORE and SWUIS to TRL5 by flight validating their function in actual zero-g conditions; (2) to achieve an end-to-end test under relevant flight conditions of the BORE and SWUIS experiments in order to identify any critical design/operation flaws in a relatively inexpensive flight test environment; and (3) to bring these experiments/payloads to final flight-ready status for suborbital space flights. We also had an important secondary objective of (4) providing SwRI payload specialists Stern, Durda, and Olkin direct, hands-on experience with the behavior of the BORE and SWUIS equipment payloads in zero-g conditions like those that they will experience during flights on suborbital vehicles.

Figure 1: The BORE and SWUIS experiment payloads being operated during a zero-g research flight. (Top) BORE was operated in free-float mode in order to minimize acceleration perturbations due to turbulence affecting the aircraft's parabolic trajectory. (Bottom) The SWUIS camera was hand-held to evaluate and practice target acquisition and pointing operations like those we will use on suborbital spaceflights.

Flight Test Results: Both the BORE and SWUIS payloads performed flawlessly and as planned during extensive pre-flight conops development and rehearsal. Fig. 1 shows our flight team operating both payloads during zero-g flight. BORE was flown in a two-box configuration allowing invenstigation of two different regolith simulants (regularly-shaped, rectangular blocks to investigate 3D shape reconstruction from 2D projected images and naturally-shaped iregular rock fragments to examine microgravity interaction of natural regolith fragments) (Fig. 2). The as-flown SWUIS zero-G operation concept revealed a need for two major changes: (1) remove the tether between SWUIS & BORE and, (2) ensure one person holds the SWUIS equipment. Both will implemented as part of normal work to integrate SWUIS with its suborbital host vehicle. Handling the 6.5 lbs. (3 kg) SWUIS camera was significantly easier in zero-G, demonstrating hand-held operations is possible and not-time consuming, taking only a few seconds to position and acquire a target. Targeting accuracy and repeatability and focus exercises were demonstrated during the flight (Fig. 3). For both payloads, remote operations via tablet devices also proved a powerful operations addition, providing for both passive situation awareness and optional active control.

Figure 2: Data camera views of the interior of BORE.

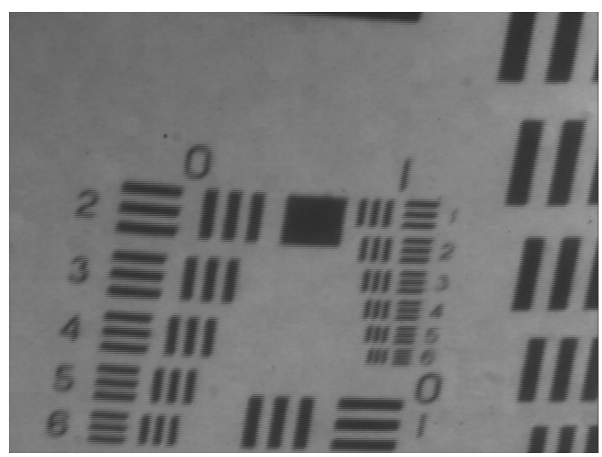

Figure 3. Part of focus-test target for SWUIS. SWUIS's FOV is 5.3°×4.0°.