The Atsa Suborbital Observatory: using crewed suborbital spacecraft for a low-cost space-borne telescope.
L. S. Sollitt[1] and F. Vilas[2], [1]Department of Physics, The Citadel, 171 Moutrie Street, Charleston, SC 29409, luke.sollitt@citadel.edu, [2]MMT Observatory, P.O. Box 210065, University of Arizona, Tucson, AZ 85721-0065, fvilas@mmto.org.

Introduction: We discuss a suborbital flight program supporting NIR observations, suitable for a variety of Solar System targets. A suborbital platform gives an observatory two distinct advantages over a ground-based system. First, a suborbital telescope, at 60-100 km altitude, is above telluric water in the Earth's atmosphere, allowing access to the complete IR spectrum of an object. Second, an inexpensive telescope can observe inside the solar exclusion angles of robotic orbital telescopes. For example, the solid angle excluded for the Hubble Space Telescope is 50°[1]; for Spitzer Space Telescope, it is 82.5°[2]. Observations of the Aten and Apohele asteroids, Vulcanoid searches, Sun-grazing comets, comets reaching perihelion at heliocentric distances < 1 AU, and the planets Mercury and Venus, all must be made in the vicinity of the Sun.

Instrument Concept: The Atsa Suborbital Observatory ("atsa" is the Navajo word for eagle) system would consist of a Schmidt-Cassegrain telescope, potentially a ruggedized commercially-available Celestron tube with an aperture of 356 mm and a focal length of 3.97 m ("telescope"), along with a commercially-available Silver 220 SWIR infrared camera at the focal plane (a FLIR Thermovision SC4000 is also possible) ("camera"). The camera accomodates a filter wheel, and is sensitive to the spectral range of 0.8-2.5 µm with a quantum efficiency over 70%. The telescope is attached to a gimbal system and drive motors. The exact configuration will depend on the vehicle used: in the case of Virgin Galactic's SpaceShip2, the gimbals would be attached to the front aperture of the telescope, and attach, via a frame or bracket, to the SS2 porthole. The aperture opening is kept very close to the porthole. Gross telescope steering would be provided by the spacecraft; fine steering is provided through the gimbal system. This telescope would have diffraction-limited resolution of about 2.6 km/pixel on the Moon near 2.0 µm for lunar observations. Actuation might be motor-driven, potentially with a steadicam-like system to track the target through perturbations of the spacecraft (similar systems currently fly on Air Force Predator and Reaper drones). The initial target acquisition would be done manually by the operator. Control of the telescope, including data acquisition, would be done with a ruggedized laptop computer.

Observations with Atsa require a judicious selection of filters. For asteroids, the filters should concentrate on defining the existence and characteristics of the mafic silicates having absorption features near 1.0 and 2.0 µm (pyroxene, olivine), or the existence of water of hydration by observing OH and H_2O near 1.4 and 1.9 µm, and the overall trend of the slope of a featureless spectrum. A possible suite of filters to use with these asteroid observations includes medium-band (200 Å FWHM) filters centered at 0.9 µm, 0.93 µm, 0.96 µm, 1.00 µm, 1.10 µm, 1.25 µm, 1.40 µm, 1.90, 2.00, 2.30 µm, in order to identify and discern spectral features of pyroxenes or olivines or both near 1.0 µm (shape of M1 mafic silicate feature for pyroxenes and olivines), pyroxenes near 2.0 µm, plagioclase at 1.25 µm, the water of hydration combinations and overtones at 1.4 and 1.9 µm, and the overall shape of the spectrum. As the object gets closer to the Sun, the thermal component in the spectrum dominates at shorter wavelengths in the near IR, and will need to be characterized and removed from the photometry.

Heritage and development status: The telescope and focal plane components are all commercially available. The parts that must be custom fabricated include the interface between the telescope and the camera, the mounting system (gimbals, bracket, etc.), the drive system, and specified filters. Depending on available spacecraft, a simple, hand-steered first iteration of the telescope could be ready in as little as a few months.

Size, mass, power, data: The notional telescope diameter is 14 in, length is 31 in. The tube weight is 45 lb. The camera is ~ 6.5 lb, and ~ 8 in long. The computer is 5.1 lb. Truss and drive motors are loosely estimated here at 50 lb. Total mass is ~ 100 lb. The camera uses a power source that accepts 80-240V AC, and would either need a power from the spacecraft, or an on-board battery. Likewise, the camera can be battery-powered. The duration of the flight is short enough that battery power should be sufficient for both devices. The gimbal drives might similarly be battery-powered, but this is subject to power availability on the vehicle and current draw of the gimbal drives. All data would be stored on the computer hard drive using commercially available software. There would be no real-time data streaming from the instrument, and no data storage requirements levied on the vehicle.

Requirements on a suborbital spacecraft: Use of a suborbital spacecraft for astronomical observations may impose new requirements on vehicles that might be planning for tourist flights. Some targets may require a night launch, which might require upgrades to the craft's avionics to allow for night flight. It may be necessary for a single experiment to take up an entire launch: in the case of SpaceShip2, instruments would

be restricted to looking out of portholes, and unless the instruments are looking at the same target (and are in coplanar portholes), it is unlikely that two different instruments could be accommodated on the same flight. An observatory flight would likely not be suitable for flying tourists. On the one hand, the spacecraft may have to fly in an attitude which is disadvantageous for Earth viewing in order to accommodate pointing at the target; on the other hand, pointing stability requirements of the telescope will likely necessitate all participants remaining seated, and not hitting the side of the spacecraft (as they would do if free-flying), even if the telescope were isolated from passengers.

Flight planning and training requirements. As the period of time above the atmosphere is mere minutes, effective time management is critical to mission success. This will require choreographing the mission beforehand, and understanding the timing of critical events, such as maneuvers and deployments, to the second. Flight training for the crew should include NASA-like practice of the mission profile, with plenty of simulated missions run before the real thing.

Window. The spacecraft window must have good transmissivity across the desired spectral range (tentatively, 0.4 – 2.5 μm for the infrared telescope concept). It could be that a special window must be fitted to the craft (as is planned for XCOR's Mk 2 Lynx vehicle [3]); also, provision must be made in the craft to accommodate the instrument (attachment points, etc.). The ideal location for an instrument would be on the exterior of the spacecraft to avoid all issues with window tranmissivity.

Stray light. Accommodation for stray light issues will depend on the spacecraft configuration. In the case of SpaceShip2, this may include essentially turning off all lights inside the cabin to avoid reflections from the window, and optically shielding the data acquisition station from the telescope. Scattered light from the spacecraft exterior must also be accounted for: this may mean using a certain attitude to put the telescope in the spacecraft shadow, or even altering the spacecraft exterior to minimize reflected light. Given that one of the great strengths of a low-cost suborbital system is its ability to observe close to the Sun, thorough understanding of and planning for light reflected from the spacecraft will be critical to mission success. Accomodation issues should be worked with spacecraft designers early in their process.

Pointing requirements: The drift rate should be less than perhaps 20 seconds for the target to cross the FOV; overall spacecraft pointing control needs to be within the field of regard of the telescope, which will depend on the window size versus the telescope diameter, etc. One important point is that if we are using a pre-existing window, which ostensibly has a constant thickness, we will want to limit the movement of the telescope so that we do not see time-dependent effects due to seeing a changing transmission coefficient at different angles (at different points during the observation).

References:

[1] HST Primer for Cycle 17, 2.3 Pointing Constraints (2007). [2] Gerhz, et al., Rev. Sci. Instrum. 78, 011302 (2007). [3] Greason, J., personal communication