DESIGNING THE PERSONAL SPACE TELESCOPE: PHASE B

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Introduction: CubeSats allow for quick development of miniaturized satellites, and can be used for used for various applications [1]. This platform is currently being utilized in the design of a space telescope that can be used by universities for research. This design is to take place over a 3 year period, following a strict progression of design review. Within Phase A, the design passed through Mission Concept Review (MCR), System Requirements Review (SRR), and the Mission Design Review (MDR). The current phase, Phase B, went back through the previous year's work from SRR onward, and continued into the Preliminary Design Review (PDR). The full series of reviews can be seen in Figure 1.

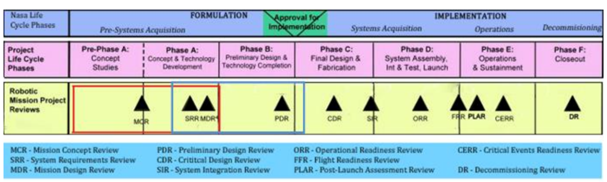

Figure 1: Design review schedule. Phase A can be seen outlined in red, and Phase B outlined in blue

Over the course of Phase B, multiple subsystems were analyzed, redesigned if needed, and checked again. These systems include optics, camera, structures, and a fine adjustment system for the telescope tube.

Optics and Camera: Upon reviewing Phase A's Scmidt-Cassegrain telescope design, it was determined that the design will not support the stated mission objectives. The Phase A design's spherical primary mirror was missing a Schmidt corrector lens, which is needed to correct optical issues such as spherical aberration and coma. Without a corrector, these aberrations present significant and non-correctable problems in final image quality, rendering any captured images unusable for research purposes. After applying the equations found in Edgar Everhart's paper to the Schmidt-Cassegrain system, the present team discovered that the deflection required to manufacture, in house, the Schmidt corrector plate was too small with the facilities available [2]. While performing physical imaging tests on the Schmidt-Cassegrain system, it was confirmed that the telescope could not focus rays at infinity and thus was not suitable for this project.

Using Lambda Research Corporation's OSLO66 EDU ray-tracing software, a series of candidate systems was assembled to investigate on designs that would better suit the project's needs [3]. In addition to fitting within system parameters of size and weight, the new systems had to be low cost or easy to produce, with a short effective focal length for maximum optical power. The choices were narrowed down to three options: a Lurie-Houghton system, a Maksutov system, and a modified Schmidt-Cassegrain system. The Lurie-Houghton system offered best overall imaging across the full field and used cheap aluminum-coated spherical mirrors and BK-7 lenses. However, because the Houghton system inherently possesses four optical elements and not two or three, it has the drawback of being the heaviest system of three candidates. The Maksutov system had the benefit of possessing only two optical elements, making it the lightest system, but the silvered secondary lens was difficult to source at a low price and was not simple to make properly in our facilities. Lastly, the modified Schmidt-Cassegrain system used cheap spherical mirrors that are easy to source or manufacture, but offered the worst image quality out of the three. Ultimately, the Lurie-Houghton system was selected as the final candidate. Plans are in place to purchase the optics and proceed with physical imaging tests as soon as possible.

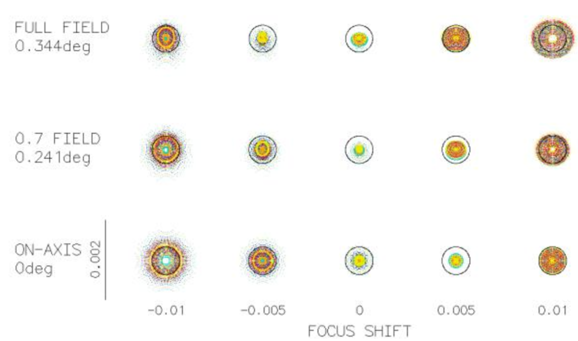

Figure 2: Houghton spot diagrams demonstrate minimal aberrations in the full field, off-axis, and on-axis

Phase A's CCD camera selection was found to be the best available choice. The IR-cut option was omitted to save on costs. Additionally, in the interest of preserving resolution across all visible wavelengths, the CCD camera will be monochrome.

Data Acquisition: An object-tracking software for the telescope was drafted using National Instruments Vision Assistant software. A functional telescope must be able to track a star as it moves in the night sky for prolonged data collection. Currently, the present team is exploring Vision Assistant's and LabView's capabilities in creating a suitable star tracker. The star-tracker will be integrated with the attitude control systems in the end product.

Structures: The primary structures that were of interest included the telescope tube, camera mount, and satellite bus. The camera mount specific parts were designed with prototyping as a primary focus, as the camera being used is a temporary test camera. All other parts were designed with manufacturing of the part being the end goal. All prototyping was done with 3-D printing.

The telescope tube was designed for the optics originally chosen from Phase A. To accommodate the new optics system, very few changes need to be made to the current design. The secondary mirror holder underwent a series of variations before finally ending on a three spider vane holder that allowed for adjustment of the secondary in the x, y, and z planes. The satellite bus itself was redesigned to allow for more space behind the telescope tube and camera. The attitude adjustment system from Phase A was swapped with another system being developed, thus allowing the area that was originally being used for attitude adjustment to now be utilized for electronics and other systems. The current design of the bus consists of four separate side panels with an inner rib system holding them together. The printed prototype of the telescope tube and the SolidWorks model of the full system can be seen in Figures 3 and 4, respectively.

Figure 3: Telescope tube prototype

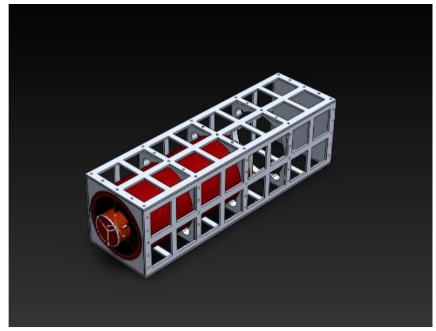

Figure 4: SolidWorks mock-up of satellite

Fine Adjustment: Mini actuator design ideas were investigated as a way of controlling fine movement of the telescope tube. This would allow the tube to move in a way for the system to better track and collect data. The primary method explored was using nitinol (Ni-Ti), a shape memory alloy (SMA), to create the actuating motion. Ni-Ti springs were made in lab, and are to be tested to attempt to characterize their behavior. SMAs were chosen based on the design seen in NASA Tech Briefings Oct. 2012 [4]. Another method investigated utilized piezoelectric materials to get the necessary movement.

Future Work and Conclusions: As this project continues on, there are several parts of the design that needs to be further developed. Primarily at this point, the mini actuator designs need to be prototyped and tested, so that a viable candidate can be determined. In addition to this, the satellite bus needs to be manufactured to begin integrating the systems. The new optics system will need to be acquired, necessary adjustments made, and the new system will need to be tested. It is imperative that each system is tested and re-verified as they are developed to allow for proper integration in the future.

References: [1] CubeSat Design Specification. California Polytechnic State University. Rev 12. [2] Edgar Everhart, "Making Corrector Plates by Schmidt's Vacuum Method," Appl. Opt. 5, 713-715 (1966) [3] Mike I. Jones, personal correspondence, July 2013, [4] Compact, Low-Force, Low-Noise Linear Actuator. NASA Tech Briefings. Oct 2012