10 Meter Sub-Orbital Large Balloon Reflector (LBR)

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***Abstract*— Now in Phase II of the NASA Innovative Advanced Concepts (NIAC) Program, our team is advancing key technologies required to realize a suborbital, 10 meter class telescope suitable for operation from radio to THz frequencies. The telescope consists of an inflatable, half-aluminized spherical reflector deployed within a much larger carrier balloon - either zero pressure or super pressure.**

I. INTRODUCTION

THE realization of a large, space-based 10 meter class telescope for far-infrared/THz studies has long been a goal for NASA. Such a telescope could study the origins of stars, planets, molecular clouds, and galaxies; thus providing a much needed means of following-up on tantalizing results from recent successful missions such as Spitzer, Herschel, and SOFIA. Indeed, Herschel began its life in the US space program as the Large Deployable Reflector (LDR) – to be assembled in low Earth orbit by shuttle astronauts. Escalating costs and smaller federal budget allocations resulted in a downsizing of the mission. However, by combining successful suborbital balloon and ground-based telescope technologies, the dream of a 10 meter class telescope free of 99% of the Earth's atmospheric absorption in the far-infrared can be realized. The same telescope system can also be used to perform sensitive, high spatial resolution limb sounding studies of the Earth’s atmosphere in greenhouse gases such as CO, ClO, O_3, and water, as well as serve as a hub for telecommunications.

II. THE BALLOON REFLECTOR

Instead of attempting to maintain the pointing of a large, balloon-borne telescope at the end of a tether, we propose to deploy a telescope in the benign, protected environment ***within*** a balloon launch vehicle. The telescope is itself a balloon, spherical in shape, metalized on one side and anchored to the top of the carrier balloon via a rotating azimuth plate (see Figure 1). It is made from a high strength, high stiffness plastic, such as Mylar. Blowers are used to maintain a constant differential pressure between the inner balloon reflector and outer carrier balloon. Distortions caused by weight are counteracted by dielectric internal support curtains, which also provide a mount for the instrument.

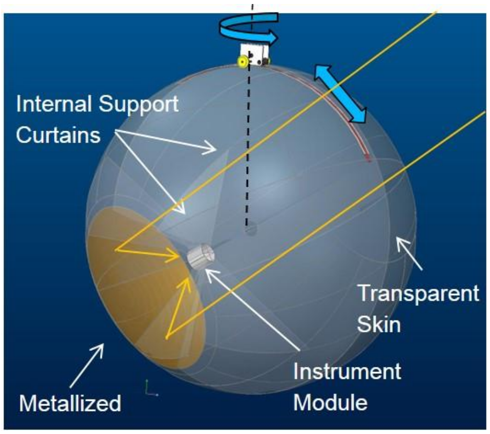

Figure 1: Large Balloon Reflector Design.

The telescope is pointed using a hybrid system; course adjustments are made by rotating the balloon reflector itself, while fine corrections (under a degree) are made by adjusting the spherical corrector. The carrier balloon serves as both a stable mount and radome for the inner balloon reflector. A three meter, roof-top prototype of LBR is shown in Figure 2. Beam maps of the Sun indicate it achieves diffraction limited performance at 115 GHz.

III. CORRECTING OPTICS

A balloon’s natural spherical shape is problematic in that, unlike a parabola, it does not focus light to a point, but rather a line. For sharp images, this spherical aberration must be counteracted. We propose using a Gregorian spherical corrector similar to that of the Arecibo telescope (see Fig. 3)

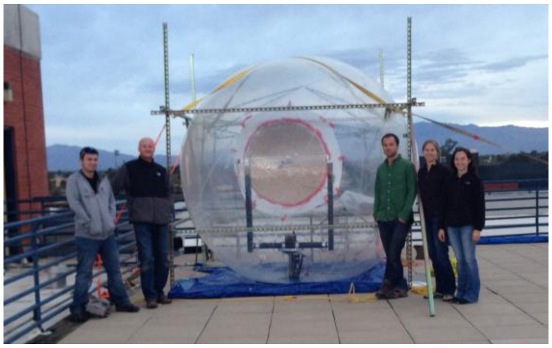

Figure 2. Roof-top, 3 meter diameter (1/8 scale) Phase I LBR prototype achieved diffraction limited performance at 115 GHz.

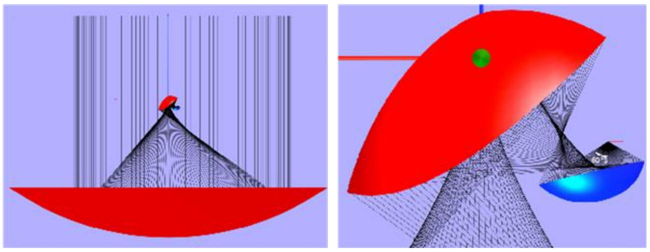

Figure 3. Off-axis spherical corrector used in Arecibo radio telescope. *Left:* Ray-tracing including blockage. *Right:* Detail of the ray-tracing on secondary and tertiary shaped reflectors, and final focal point.

[2]. For LBR the secondary optic is a computer-controlled "rubber mirror" designed to compensate for nonspherical distortions. Presuming that secondary corrections are on the order of the nonspherical distortions ($\leq$ 1 cm for a 20 meter sphere), conventional optical materials are inadequate. As a solution, we have developed a highly flexible, silicone based mirror material with broadband, sub-mm reflectivity as high as 95% (see Figure 4). A novel form of open-loop control, consisting of a high resolution surface scanner and actuators, is used to manipulate the deformable secondary optic as needed.

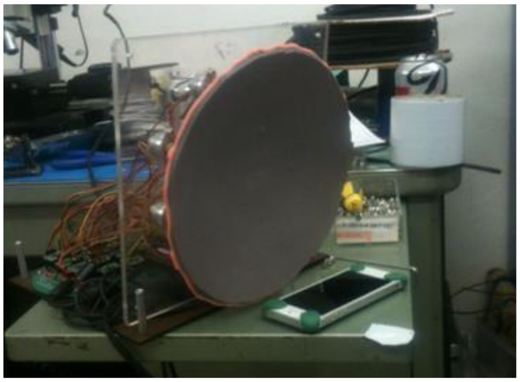

Figure 4. Adaptive corrector prototype. The LBR spherical reflector requires a spherical corrector to bring converging rays to a single focus. The spherical corrector must be adaptive to compensate for nonspherical distortions in the balloon reflector surface. Pictured is an 8 inch scale model prototype of a computer controlled, flexible corrector.

IV. SUMMARY

A 10 meter, deployable spherical reflector can be used to provide new, unique insights into the chemistry of the Earth's upper atmosphere, as well as the origin and evolution of our solar system and the Universe at large. Our NIAC study focuses on using LBR as a suborbital platform, but we are also pursuing variants for space-based applications.

REFERENCES

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