Spinning Aperture Telescope: A novel approach to Hubble's Space Telescope

Spinning Aperture Telescope

A circular mirror was replaced with a rectangular strip in the design, where the length of the rectangle is equivalent to the diameter of the intended circular trace. The rectangular strip has a length that corresponds to the diameter of the circular mirror, which is 8 ft. The strip is attached to a motor at the center, which when activated, traces a circular shape. The images captured are fragmented and require a computer at the secondary mirror's focal point for assembling. Digital image processing techniques are utilized to decipher the image, which is then transmitted to the Earth via an antenna. The computer performs the function of collecting the individual pieces of the image, combining them, and producing the final image

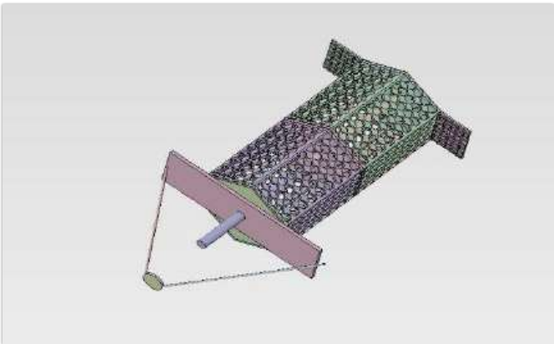

Figure 1. Orthographic view of Spinning Aperture Telescope

Reducing the weight of a telescope significantly compared to other space telescopes like Hubble and James Webb, a rectangular strip can be divided and made foldable through the use of origami with the addition of actuators or servos at the cuts. This also allows for a significant reduction in cost by 82 percent as per Meinel's Law, changing the price from 100,000 dollars for a circular primary mirror to just 18,000 dollars by using a strip. The angular resolution, which determines the mirror's ability to distinguish small details of an object, remains unchanged - the most crucial aspect of astronomy. Instead of using a CubeSat design, a HexSat is proposed as the hexagon shape is one of the strongest, has a high strength-to-weight ratio and rigidity, and is closest to a circle compared to a square.

Hexagonal Structure

Hexagons are the only regular polygon that can fit together and overlap for strength, they are frequently observed in nature. When compared to a square, it is the most like a circle. A hexagonal skeleton will be used to hold the electronic components in the craft.

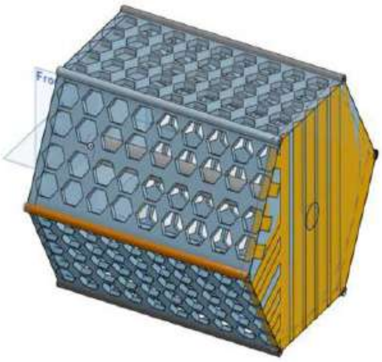

Figure 2. Hexagonal Mesh

Design

The prototype design was executed utilizing OnShape software. The skeleton was fabricated using aluminum 6061, incorporating a carbon fiber shaft and incorporating two concave mirrors. The primary mirror measures approximately 500mm in length and 150mm in width, while the secondary mirror features a radius of approximately 50mm. The overall length of the skeleton is 600mm, with each side of the hexagonal base measuring approximately 150mm. The power source for the engine is provided by solar panels affixed to the base of the skeleton.

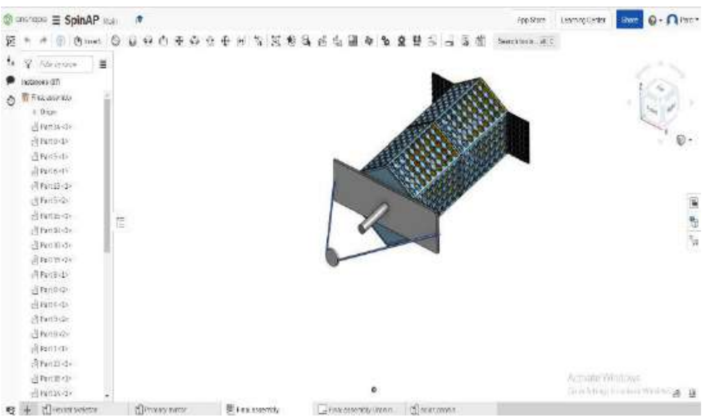

Figure 3. Final Assembly Structure

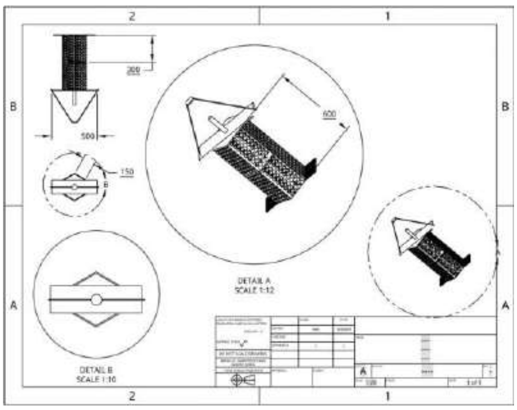

Figure 4. Dimensions of the telescope structure

Analysis

The static and dynamic analyses were performed utilizing an online open-source platform, SIMSCALE. Prior to conducting the analyses, it verifies the synchronization of the entire design. The CAD model was subsequently imported into SIMSCALE. A dynamic analysis was pursued in-depth due to the rotational aspect of the telescope. Input parameters included the utilization of Aluminium-6061 as the material, triangular elements, approximately 95.9 thousand cells, and 33.9 thousand nodes. Under boundary conditions, gravity is given as the force experienced by the body and vacuum pressure.

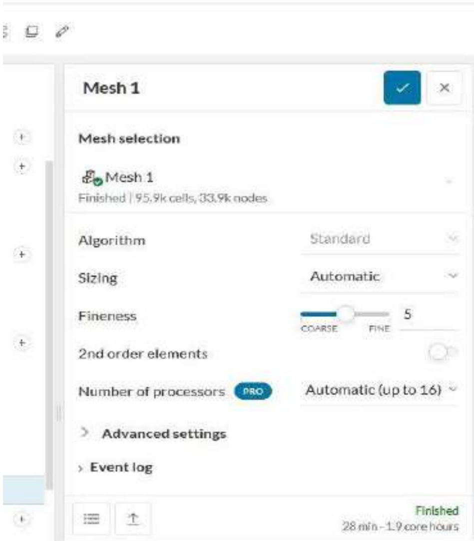

Figure 5. Mesh selection

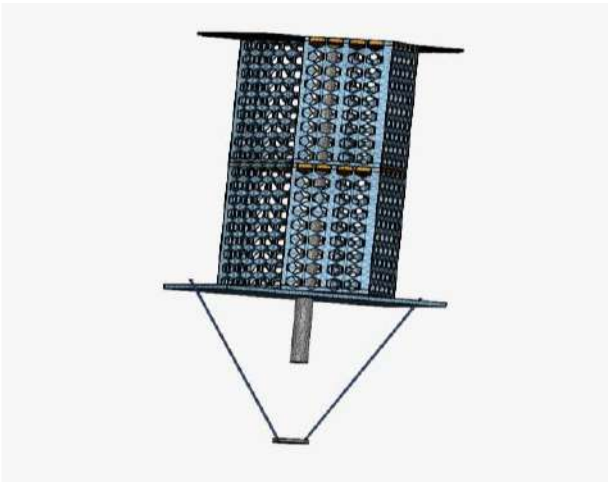

Figure 6. Side view of Spinning Aperture Telescope

Under boundary conditions, gravity is given as the force experienced by the body and vacuum pressure.

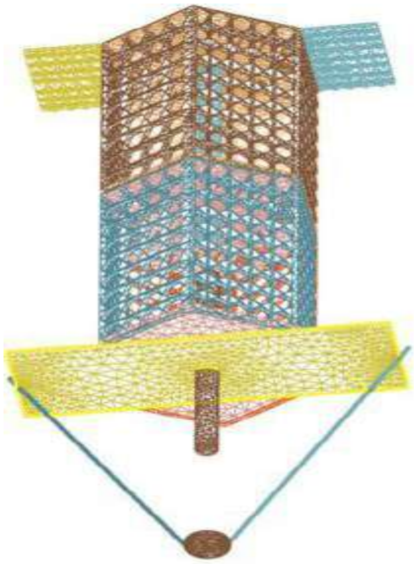

Figure 7. The force experienced by the body and vacuum pressure

Results

MATLAB analysis Gravitational Potential Function

The gravity potential function of a spacecraft denotes the amount of work that is required to move the space craft from one point to another in a reference frame. Here one can study the gravity potential function and see its relationships with spacecraft. Plotted a graph using MATLAB for a mass range of 10 Kg to 10,000 Kg.

$$V_{local}(h) = \frac{m_e}{R_e^2} mh = mgh$$

The above equation when input in MATLAB gives gravity potential function of a particular object in space, orbiting a bigger mass and under the influence of the planet's gravity.

In the above equation:

G = Universal gravitational constant = (6.6743 × 10^{-11}) $m^3 Kg^{-1} s^{-2}$
M_e= Mass of earth = (5.972 × 10^{24}) Kg
R_e= Radius of earth = 3958.8 m
m = Mass of spacecraft = 10 Kg to 10,000 Kg
h = Height of spacecraft from the center of earth = 547 Km

The input of the above variables with respective values in MATLAB to measure the gravitational potential function for a given range of mass.

Gravity potential functions for all masses ranging from 10 Kg to 10,000 Kg werecalculated and a graph was plotted. A graph with gravity potential function on the X-axis and mass of telescope on Y-axis was plotted in figure 8.

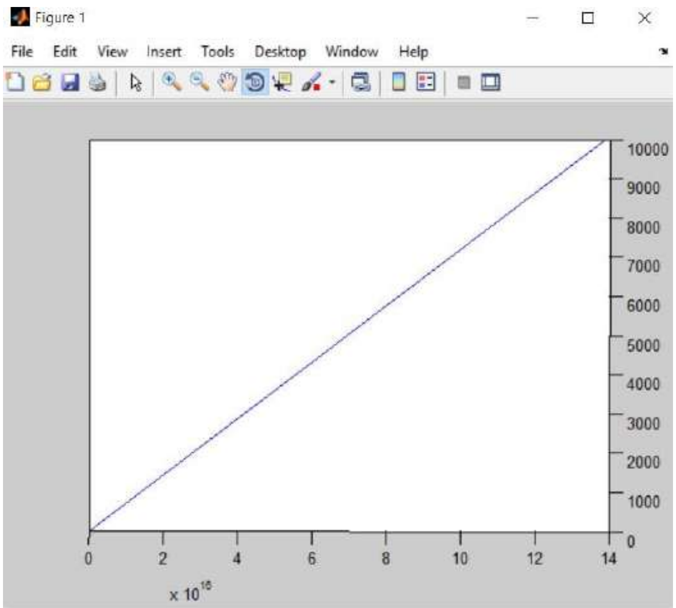

Figure 8. Graph of Gravity potential function

The conclusion drawn from the graph is that the gravitational potential function of the telescope, represented by the amount of work required to move it from one point to another in a reference frame, increases proportionally with the mass of the telescope. These observations and values were deduced under the assumption that the telescope will be in orbit around the Earth. Should the telescope be placed in orbit around another planet, such as Mars or Venus, the parameters, including the mass of the planet, the radius of the planet, and height, would need to be reevaluated.

Prototype Fabrication

A small-scale prototype was fabricated at shield technologies, Bangalore in which mild steel tubes were used to make 6 pillars of each hexagonal prism, and MS sheets were used to make bases of both hexagons. A Galvanized Iron rod was used as the shaft which was in turn connected to a DC motor operated by a switch. The prisms were wrapped using a galvanized iron mesh. One prism is made to rotate while the other acts as a base attached to a stand. Arc welding was widely used during construction. Cutting was done using lathe and hacksaw blades.

A rectangular mirror was attached to the top of the rotating hexagon in such a way that the reflecting side points outwards. A concave mirror is attached to the rectangular mirror using two carbon fiber rods connected to the shorter sides of the rectangular mirror, in such a way, when rotated, both the mirrors rotate at the same RPM.

Table 1: The following are the components used for building the prototype.

Sl. No	Components Used
1.	Mild Steel
2.	Galvanized Iron Mess

3.	Solar Panels
4.	Servo Motors
5.	Microcontroller: Arduino
6.	Support Structure frame: Mild Steel
7.	DC Vongave Motor: 90W
8.	Rectangular Mirror: (500x150) mm
9.	Circular Concave Mirror: Diameter 50 mm

Figure 9. Prototype of Spinning Aperture telescope