

Larger, lighter space telescopes by implementing in-space manufacturing concepts

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By implementing in-space optical manufacturing processes, the space environment could be utilized to enable the development of extremely large optical systems while relieving the constraints defined by launch vehicle volume limitations, high launch forces, etc.

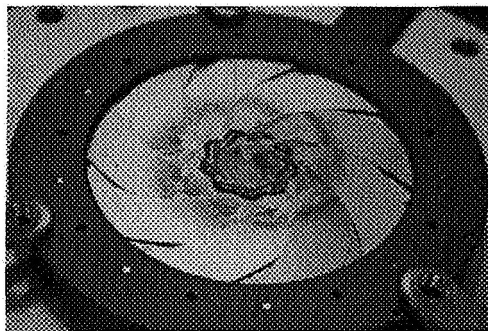


Figure 1. Glass membrane optic

There is a continuous demand for larger, lighter, and higher quality telescopes from both the astronomical and global surveillance communities- one looking up and the other down. Enabling technologies must be developed and implemented that will allow this goal to be financially and technically feasible. The optical systems needed for high spatial resolution surveillance and astronomical applications require large optical apertures with mention of future systems up to 150 meter in diameter. With traditional optical manufacturing technologies, large optical aperture means high mass and long fabrication lead times with associated high costs. Completely new approaches to optical fabrication must be developed to enable the fabrication of such optical systems.

The cost and lead time associated with the fabrication of lightweight, high quality optical systems limits the feasible size of the optics. A primary factor in the launch cost of space optical systems is volume and mass. To minimize the mass of the high quality optics, optical fabricators implement materials with high specific stiffness and use honeycomb, or other structural minimization patterns, to support the optical surface; however, the structure must still be designed to survive launch loads. This significantly adds to the fabrication difficulty and dramatically increases launch costs. One approach to minimizing launch volume and negating the need for the design to survive launch loads is to send the manufacturing facility and raw materials into space and perform the fabrication in-situ.

Traditional optical fabrication processes involve controlled grinding and polishing techniques. This entails the utilization of many large CNC machines that must scale up with the size of the optic. Such machines would not be feasible to launch. Therefore, in-space optical manufacturing requires completely new approaches to optical fabrication which utilize the space environment to greatly simplify the fabrication process for high quality optics. We are currently performing feasibility studies of initial concepts for in-space manufacturing of optical systems. By utilizing the micro-gravity and vacuum environment of space while eliminating the constraints defined by high launch forces and

limited volume of the launch vehicle, the development of large, high quality glass membrane mirrors may be feasible. Several concepts were investigated to address the manufacturing of both optical surfaces and telescope structure. We will describe one of the primary approaches to utilize the space environment for optical manufacturing and describe initial results.

The process implements an expanding iris aperture to begin with a small volume of molten glass and expand it to a large membrane, greater than 1 meter. By utilizing the micro-gravity of space and through the minimization of surface free energy, it is anticipated that such membranes can be formed into precision spherical mirrors through the use of pressure and precisely shaped rings to control the boundary conditions. This process is illustrated in Figure 2.

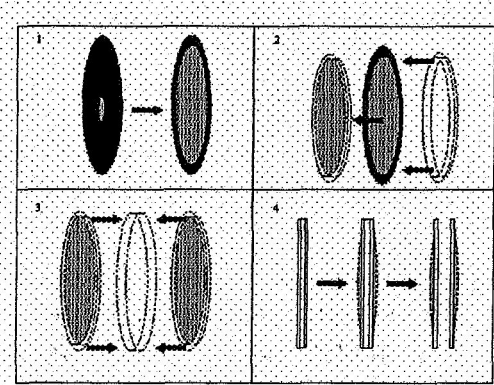


Figure 2. Process flow for glass membrane mirror formation

A significant advantage of this process is that the volume of heated space needed to create the molten glass membrane is very small. Many of the systems shown in Figure 2 could be placed in a single furnace. This will minimize the amount of energy needed to produce the mirrors. This conceptual facility is shown in Figures 3. The raw materials for the system are located in the central canisters. Therefore, only these central canisters would need to be replaced to obtain more raw materials.

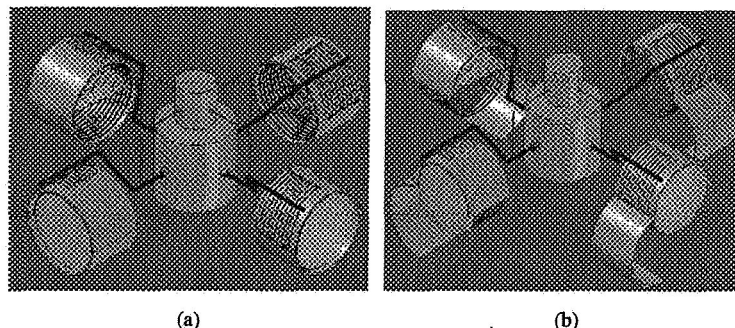


Figure 3. a) Conceptual drawing of the fabrication facility for the glass membrane concept, b) Facility with furnaces open.

Initial feasibility of this process was tested by using a high temperature iris aperture to create a membrane glass sample with a diameter 25 mm. The demonstration is shown in Figure 4. The mirror surface form, or low spatial frequency features, obtained using these processes is not representative of achievable results in a micro-gravity environment. However, the glass micro-roughness, or high spatial frequency features, should be comparable to that achieved in the micro-gravity environment. The micro-roughness of

the samples created using these processes was tested using a white light interferometer over $\sim 200 \mu\text{m} \times 200 \mu\text{m}$. The samples have acceptable micro-roughness levels for visible and infrared applications at $<1.5 \text{ nm rms}$.

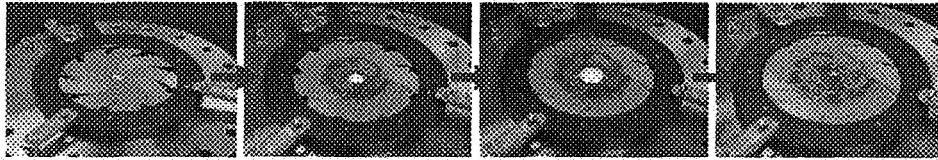


Figure 4 Glass membrane formation process

In-space optical manufacturing could enable the development of extremely large optical systems. We have developed initial concepts for both the manufacturing of both optical surfaces and the telescope structure. The results obtained from the initial feasibility studies for the optical manufacturing concepts have produced optical surfaces with acceptable micro-roughness levels. It is anticipated that by implementing these processes in the micro-gravity environment of space, large, high quality spherical mirrors could be manufactured with feasible cost and lead times. Significant research remains to continue to determine the feasibility of implementing in-space manufacturing processes to produce large optical systems.

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