PRODUCTION OF MIRROR FACETS FOR THE FACETED STRETCHED MEMBRANE DISH CONCENTRATOR

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Energy Projects Division
SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
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Science Applications International Corporation
An Employee-Owned Company

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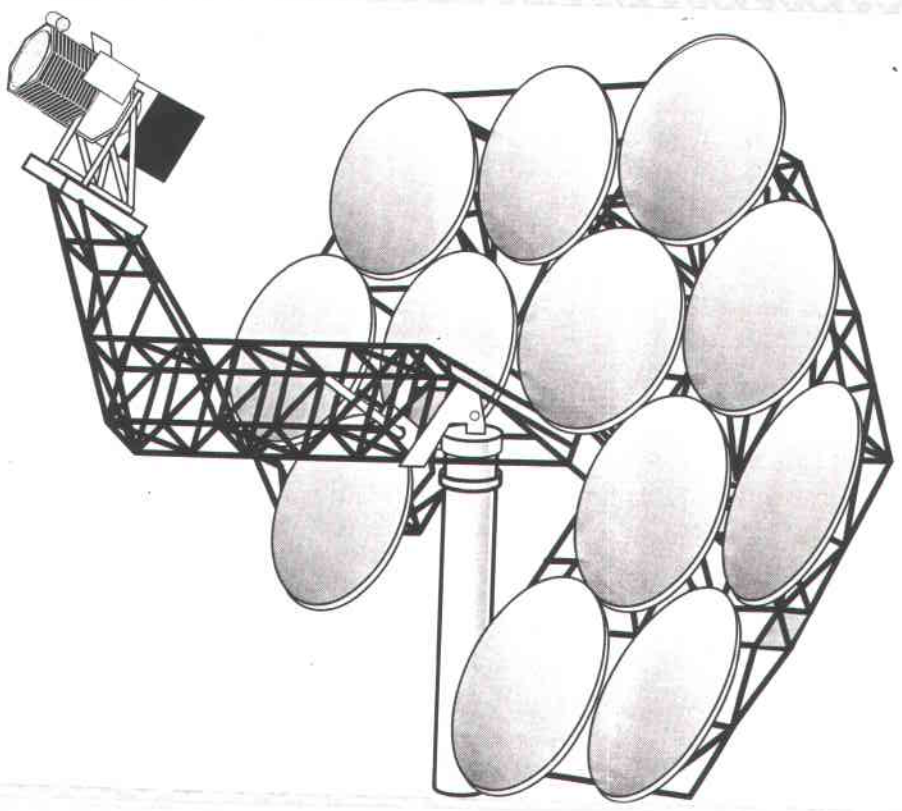
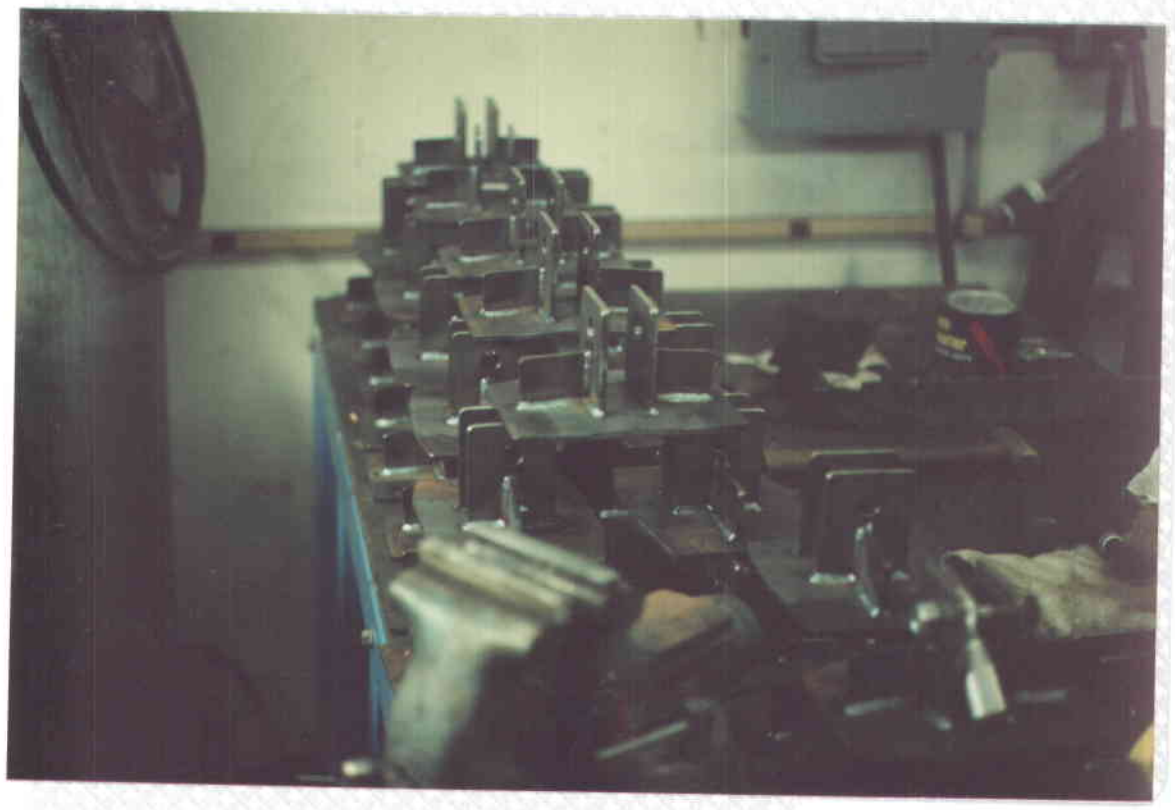
INTRODUCTION

This album documents the fabrication of 12 3-meter diameter stretched membrane dish facets by the Energy Projects Division of Science Applications International Corporation (SAIC). The facets were produced in 1992 under Phase 2 of the program titled, "Facet Fabrication for the Faceted Stretched Membrane Dish" (contract #PR 67-0291), which is part of the Solar Thermal Program of the U.S. Department of Energy and administered through Sandia National Laboratories, Albuquerque, New Mexico. The production steps for stretched membrane dish facets include fabrication and preparation of facet rings; welding of membranes from stainless steel foil; fabrication and assembly of facet focus control systems; assembly of the stretched membrane facets including welding of the membranes to the facet rings; optical testing of completed facets; and shipping of the completed facets to Sandia National Laboratories. Each of these steps is documented in the following photographs.



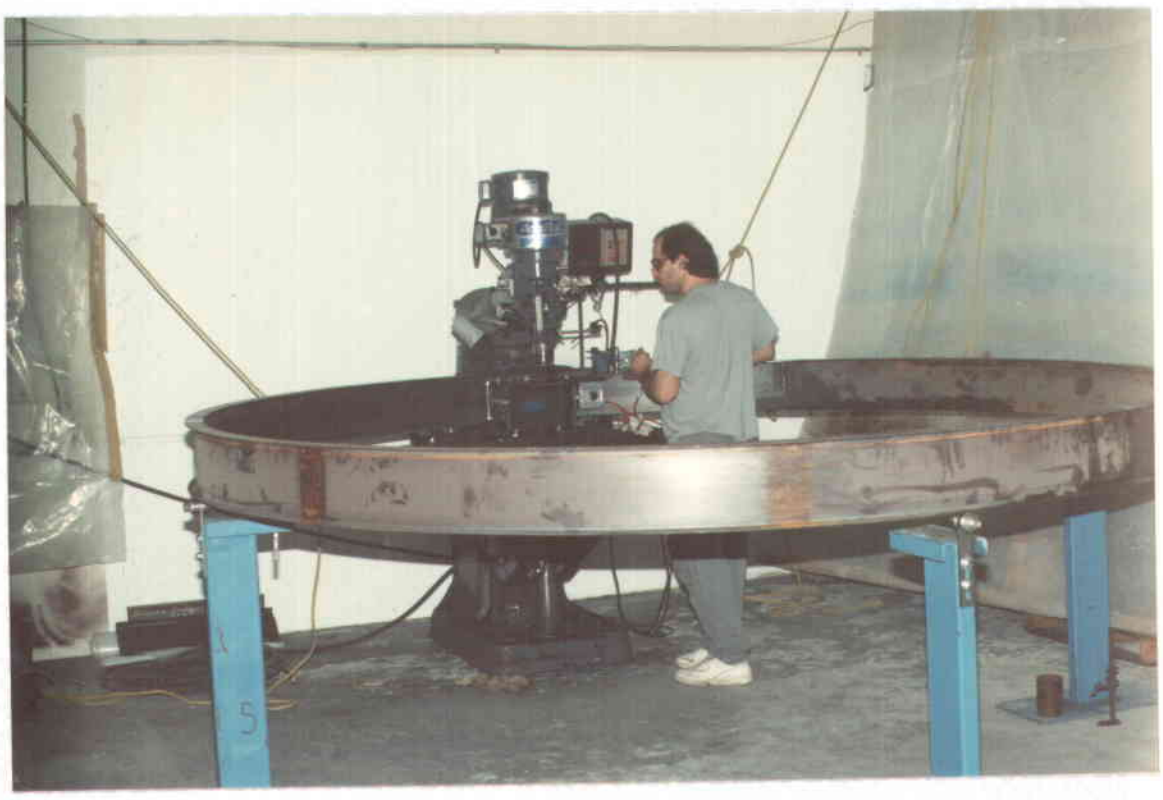
FACET RING PREPARATION

Receiving ring segments from ring roller.
Facet rings are received as one-third segments which must be welded together to form the rings. When received, segments are inspected for conformity to specifications on curvature and length.



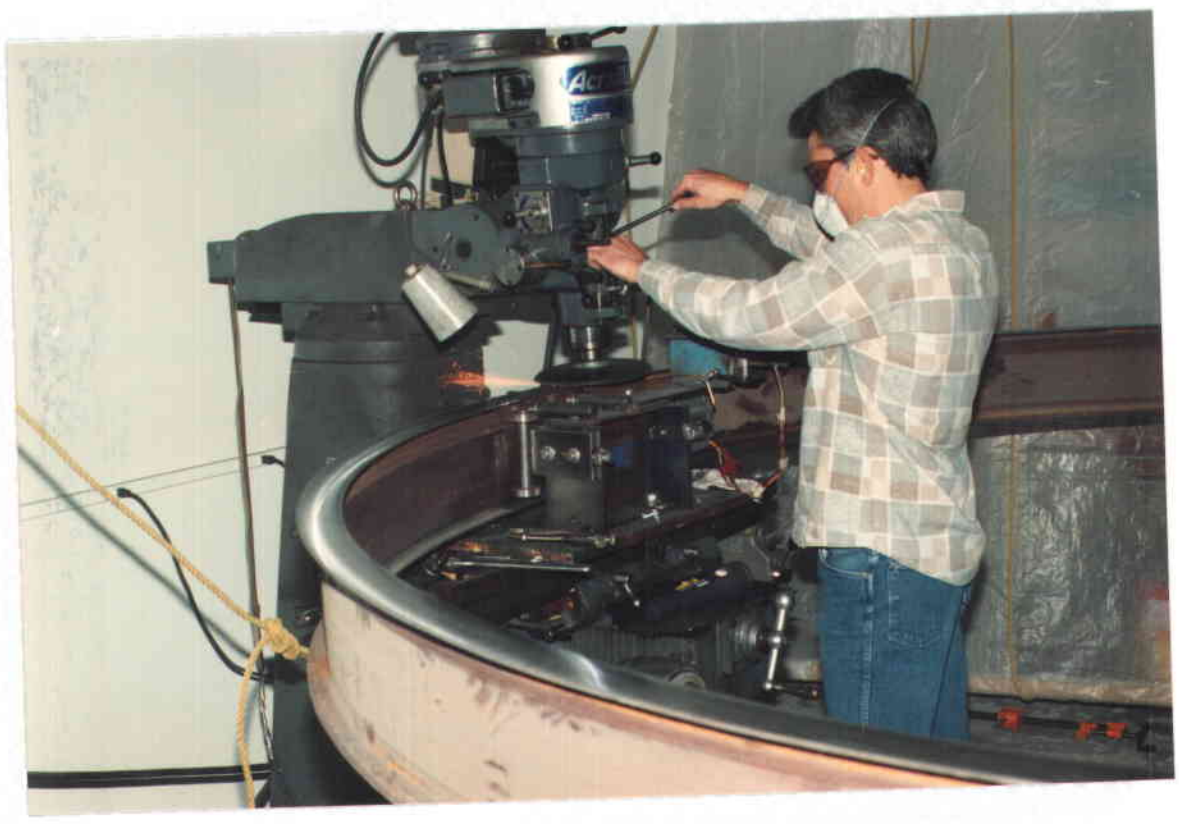
Prefabrication of facet mounting brackets.
All facet mounting hardware is prefabricated using jigs to position the pieces for welding.

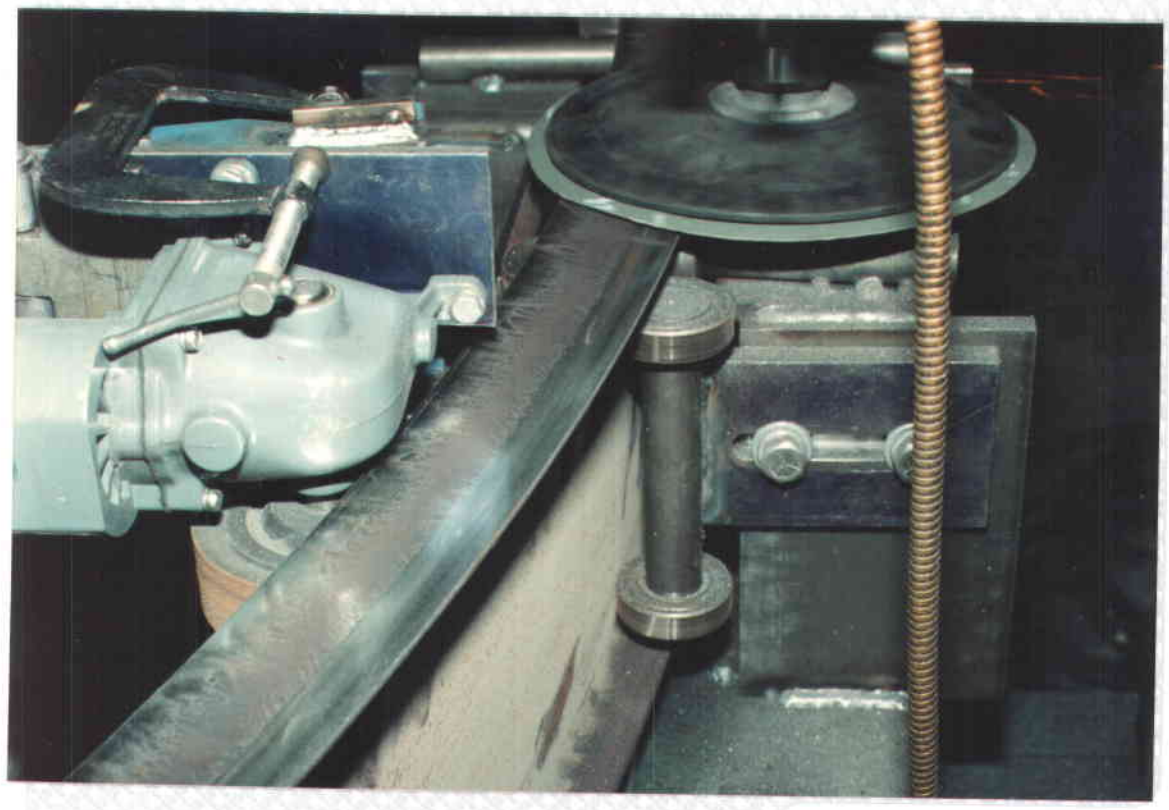
Tooling ring in place in preparation for fixturing of facet ring.
The facet ring segments are aligned within the tooling ring and welded together to form a complete ring. After the ring surfaces are ground flat, the rings are placed in the tooling ring again and all mounting brackets are welded onto the rings. Finally, the hole for the focus control system is cut out.



Setup for surfacing of facet rings.
An automated ring grinding setup was fabricated which supported the rings at four points and pulled the ring through a disk sander. Both sides of each ring were surfaced in order to provide clean, flat surfaces for welding on the membranes.

Operation of ring surfacing rig.





Detail of ring surfacing fixture.
This detail shows some of the bearings which support and guide the ring through the surfacing fixture. At the left side is the drive motor which pulls the ring through the apparatus using a rubber drive wheel.

Primer coat on finished rings.
When the welding of the rings is complete, they are stacked up, masked, and primed.

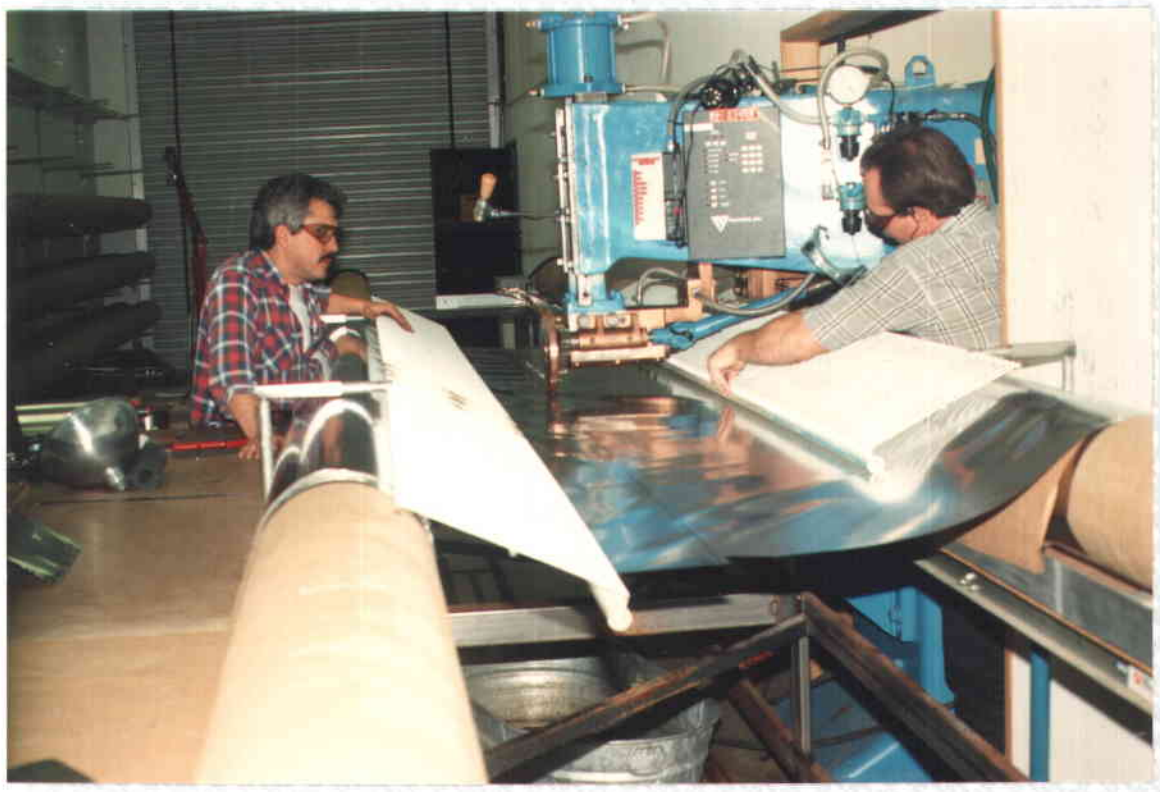
Final paint coat on rings.
After the primer coat is cured, it is followed by a coat of acrylic enamel.

MEMBRANE PREPARATION

Laminate reflective film onto front membrane.
Stainless steel foil is rolled out onto vacuum tables, and reflective film is laminated onto the foil to provide the reflective surface for the dish facets.

Trim reflective film to shape.
The reflective film is laminated onto the stainless steel foil with a mylar template outlining the desired dish facet dimensions. When the template is removed, the reflective film is cut to the template boundaries, leaving the cut-to-shape reflector.

Tack weld panels on vacuum table.
A spot welder is used to tack the stainless steel panels before seam welding. The panels are secured in position on vacuum tables for the spot welding.

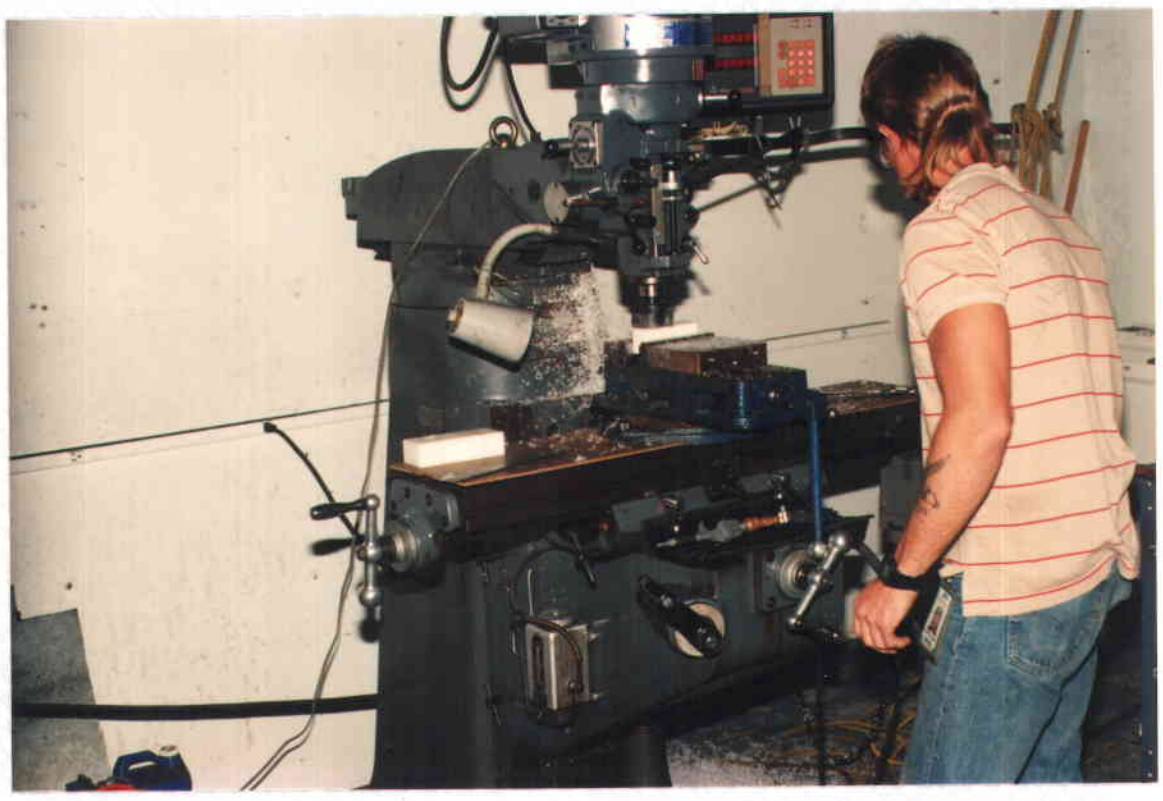


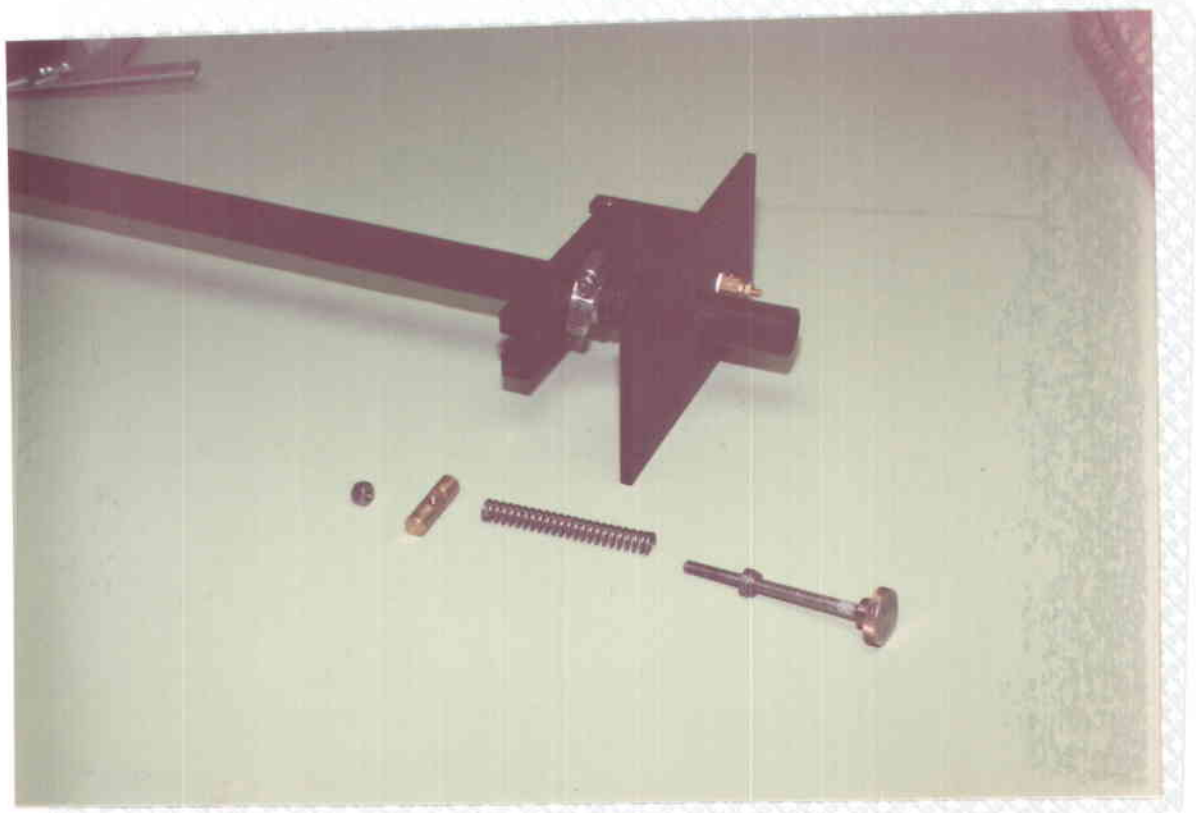
Seam weld panels using stationary welder and moving carriage. The stainless steel foil is stretched between two rolls mounted on a carriage, and the carriage is moved through the roll-resistance seam welder to complete the membrane welding.

Tape welded seams between panels with reflective tape. Welded seams on the front membranes are covered with reflective tape (ECP-244) to protect the edges of the reflective film. Then, the completed membrane is rolled onto a storage tube to await facet assembly.

FOCUS CONTROL SYSTEM FABRICATION

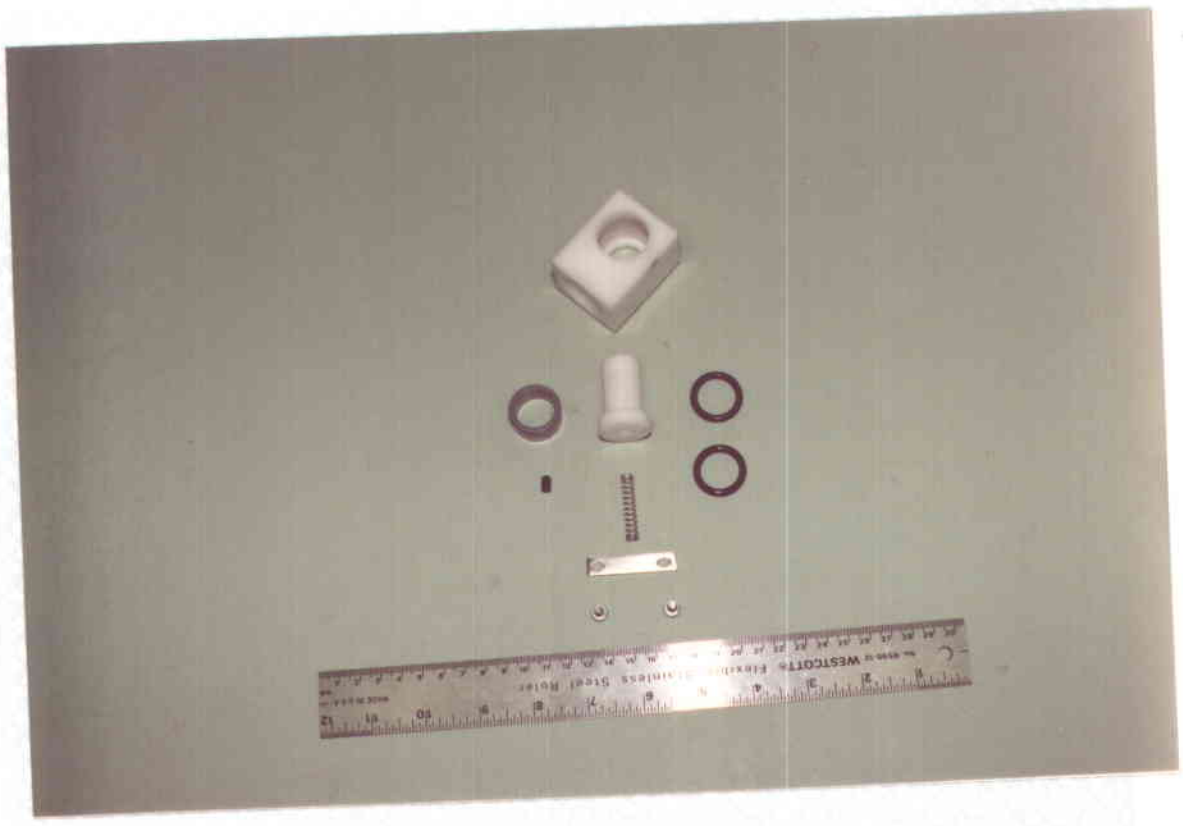
Machining of valve parts.
This photograph shows the machining of focus control valve bodies from delrin. Other parts produced by machining are the valve poppets and spring support links.





Assembly of facet focus control components.
This photograph shows the facet focus control assembly with some of the parts of the adjustment mechanism disassembled.

Facet focus control focus adjustment assembly.
The completely assembled facet focus control assembly.

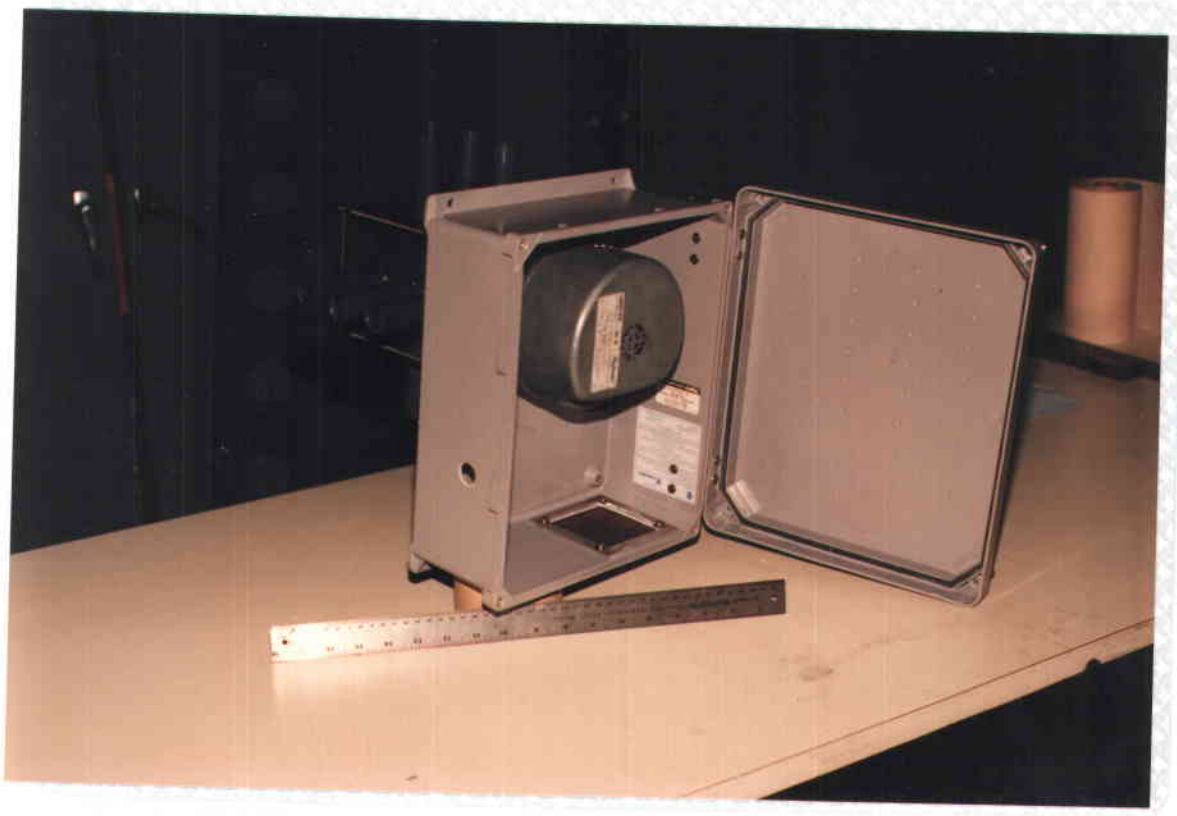


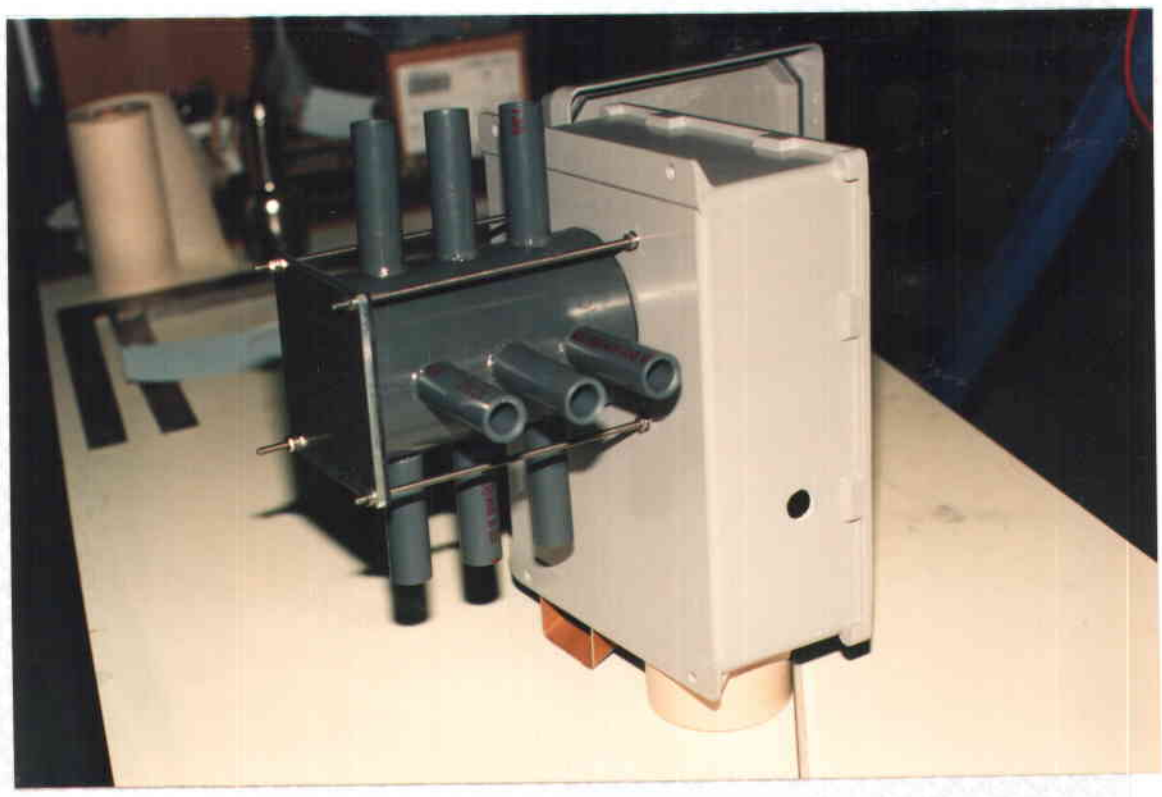
Focus control valve parts.
The valve body, valve poppet, O-rings, and other parts of the focus control valve.

Assembled focus control valve.
The completed focus control valve from the top (left), and bottom (right), as installed on the end of the focus control arm.

Completed facet focus control assembly.
An assembly like this is installed in each facet in order to control the focussing of the facet. The focal length of each facet is able to be adjusted separately.

Focus control blower box (blower installation).
A single electric blower is used to provide suction to focus all twelve facets on the faceted dish. The blower is mounted in an enclosure to protect it from the elements. Ventilation and exhaust are provided by screened vents installed in the box.

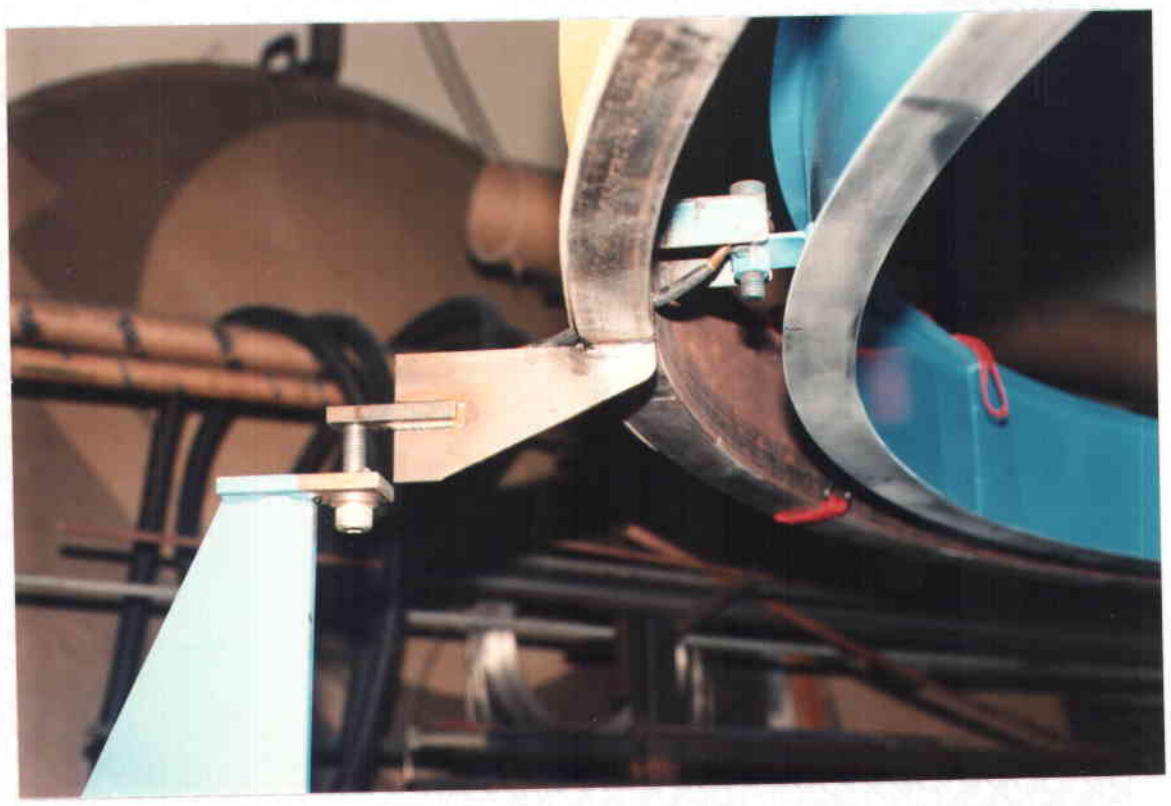




Focus control blower box (rear).
Attached to the back of the blower enclosure is a manifold for connection of the hoses to the twelve mirror facets. The manifold is constructed of PVC pipe.

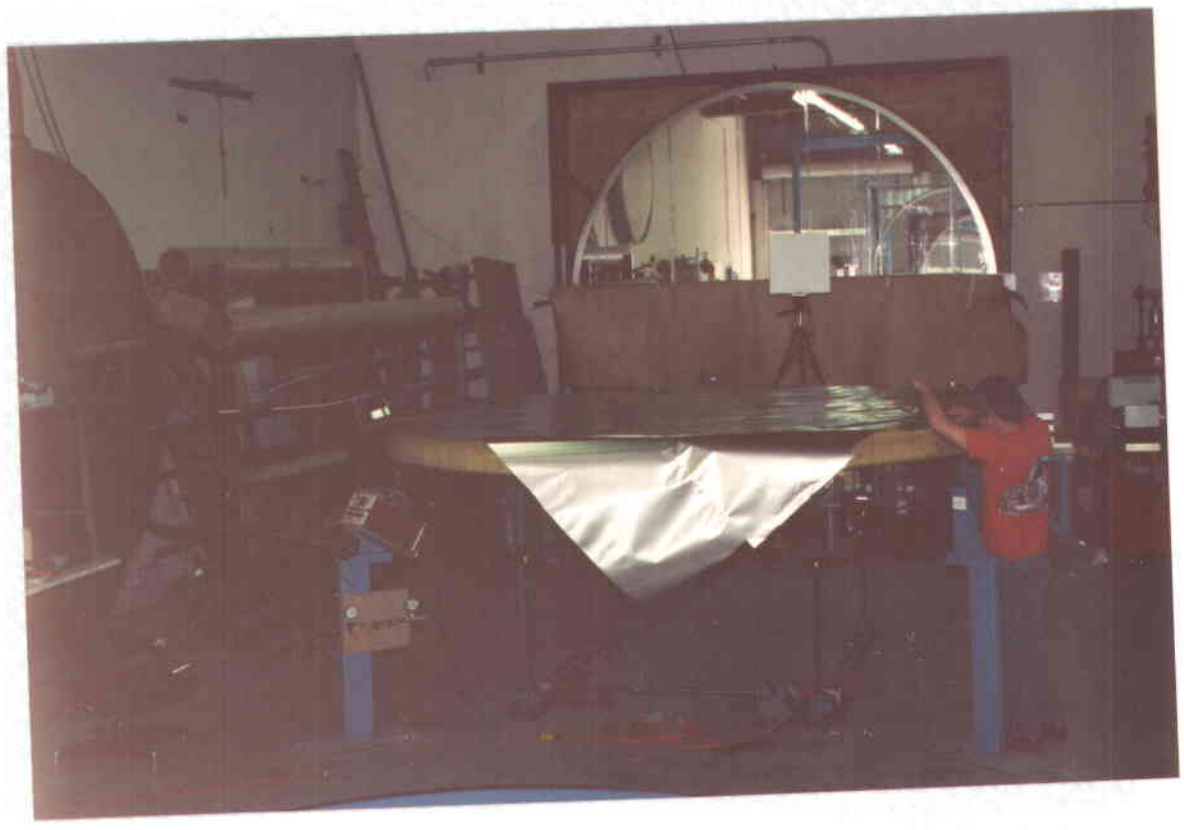
FACET ASSEMBLY

Facet ring inserted in tooling ring with tensioning bladder in place.
The facet ring to which membranes will be attached is mounted and leveled within the tooling ring, and the tensioning bladder is installed. (Note: the tensioning bladder shown is of the design used for the first six facets only).



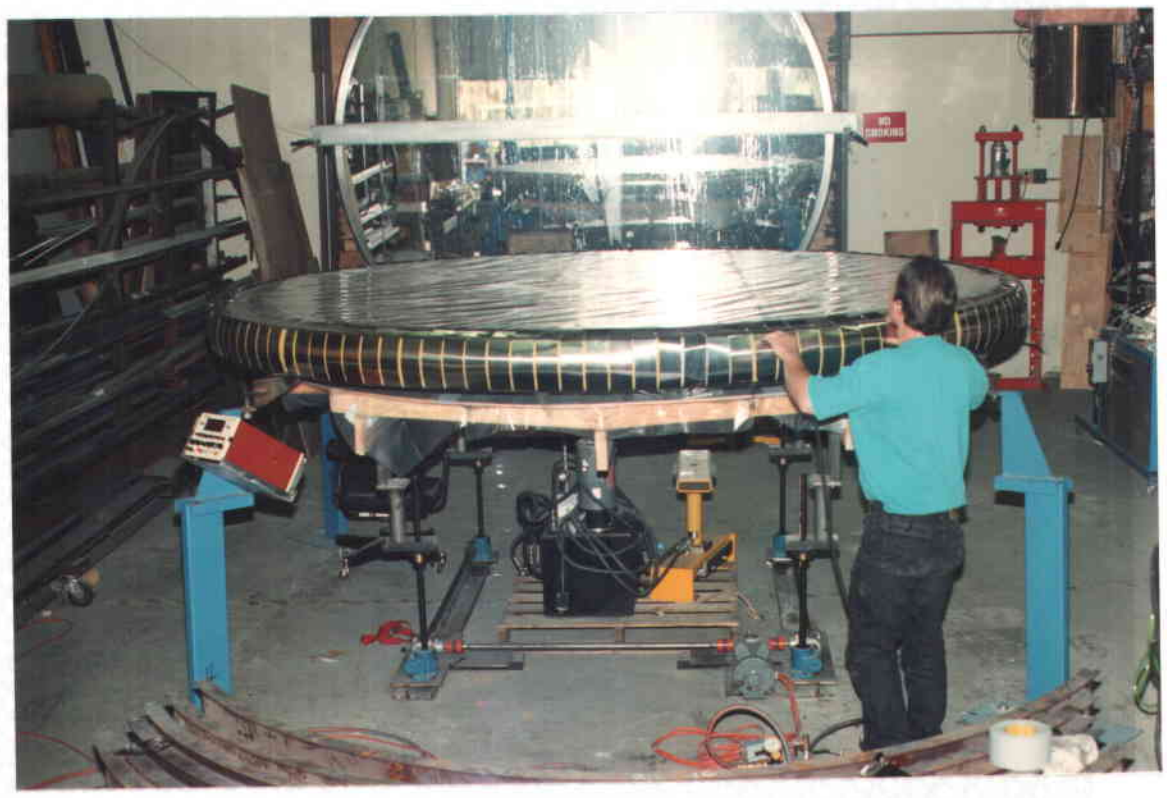
Detail of facet ring supported in tooling ring.
The facet ring is supported by radial support brackets from the tooling ring which allow for vertical adjustment and leveling of the ring. In this way, the top and bottom surfaces of the facet ring are kept free for attachment of the membranes.

Rear membrane rolled out on support table.
The membrane support table is raised to be even with the top of the facet ring, and the rear membrane is rolled out onto the table. Then the membrane is trimmed to the outer diameter of the tooling ring and clamped around the periphery of the tooling ring. In the picture, the rear membrane has just been unrolled onto the table and is ready to be trimmed.



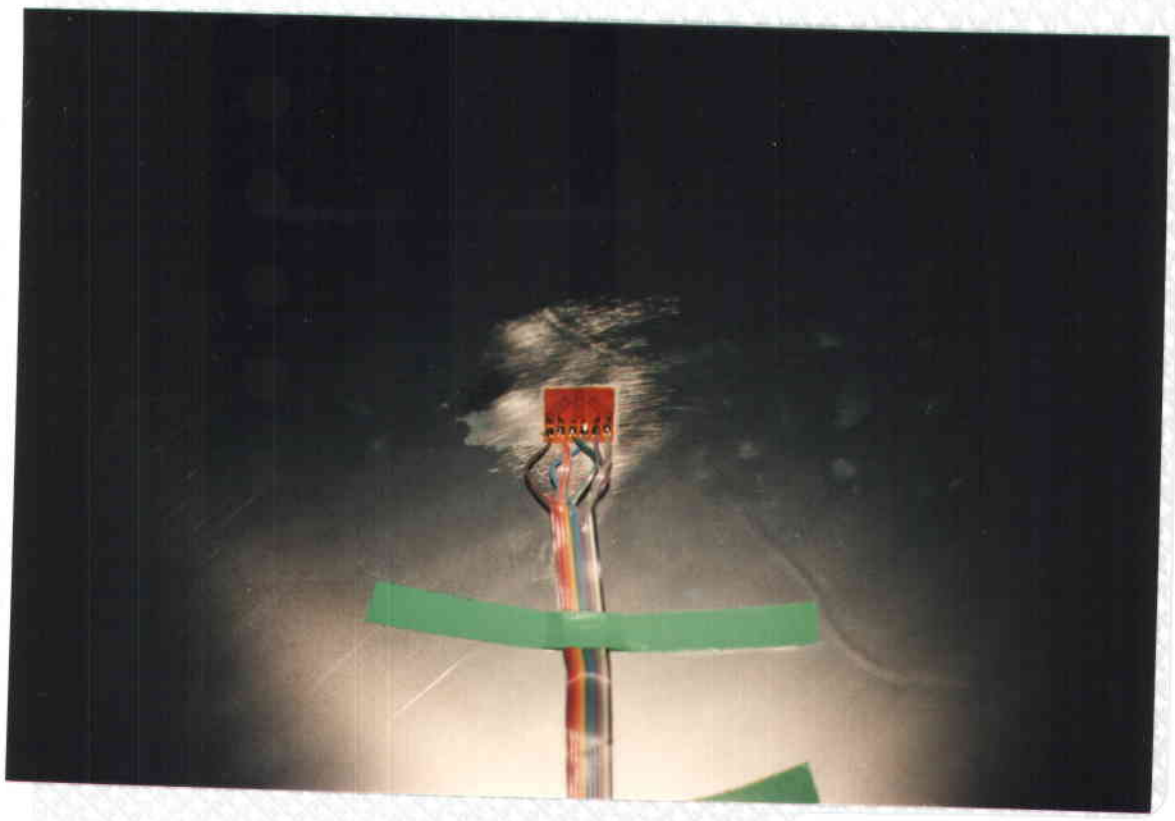
Rolling out front membrane on support table.
The membrane support table is lowered, and the front membrane is rolled out underneath the facet ring. Once it is unrolled, the table is brought up level with the bottom of the facet ring, and the membrane is trimmed to size and clamped in place temporarily.

Welding tensioning tabs onto the membranes.
Narrow strips of stainless steel are welded onto the top and bottom membranes around the outside of the tooling ring in order to form tensioning tabs. When the tensioning bladder is inflated, these tabs pull on the membranes and cause them to come to a uniform pretension.



Facet ready for installation of strain gages.
In this photograph, all of the tensioning tabs have been installed on the facet.

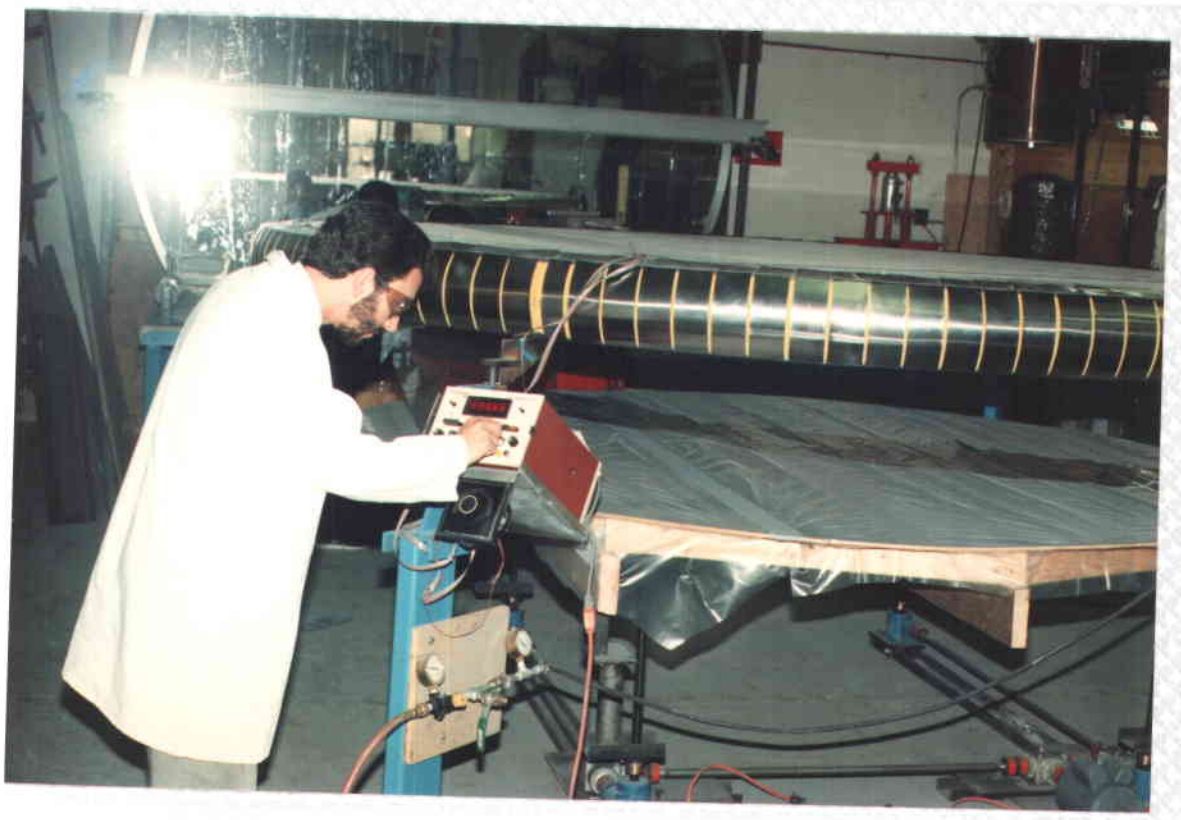
Installation of stress gages on rear membrane.
In order to measure the actual stress state of the membranes, stress gages are installed in two locations on the rear membrane of each facet.

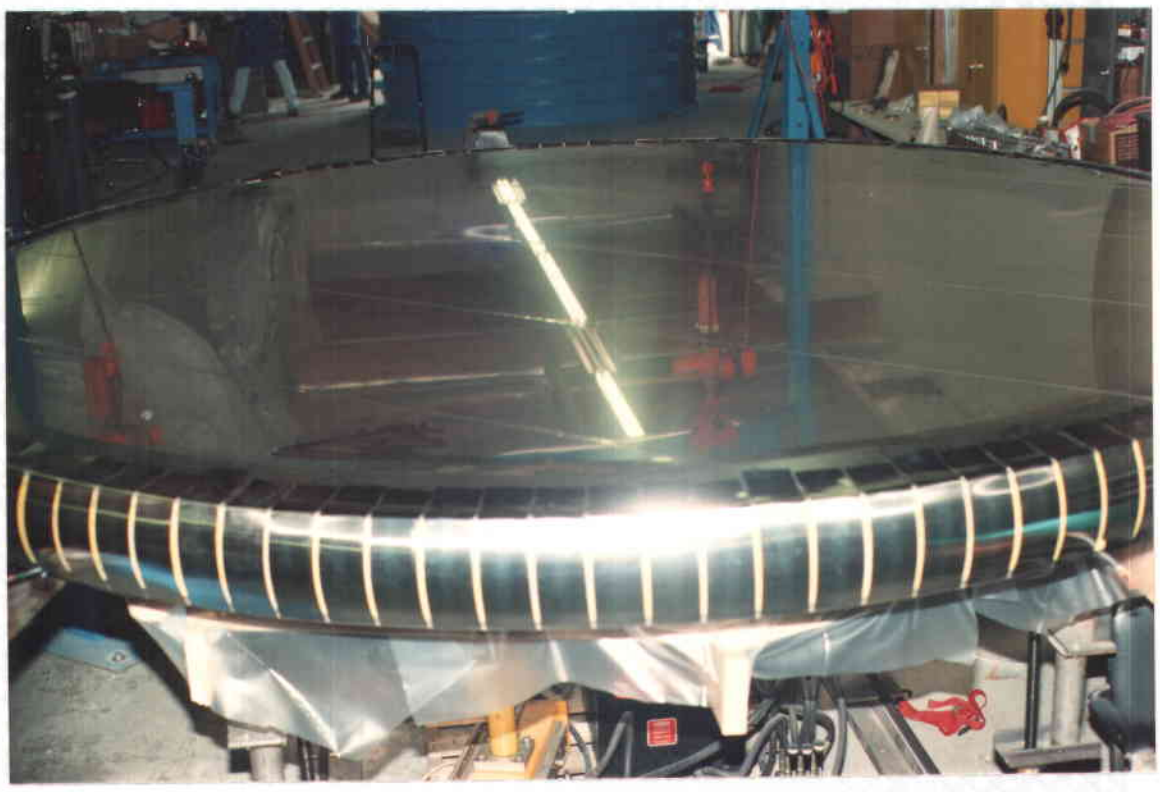


Strain gage rosette in position on rear membrane.

Strain gage measurement system in use to measure membrane pretension.

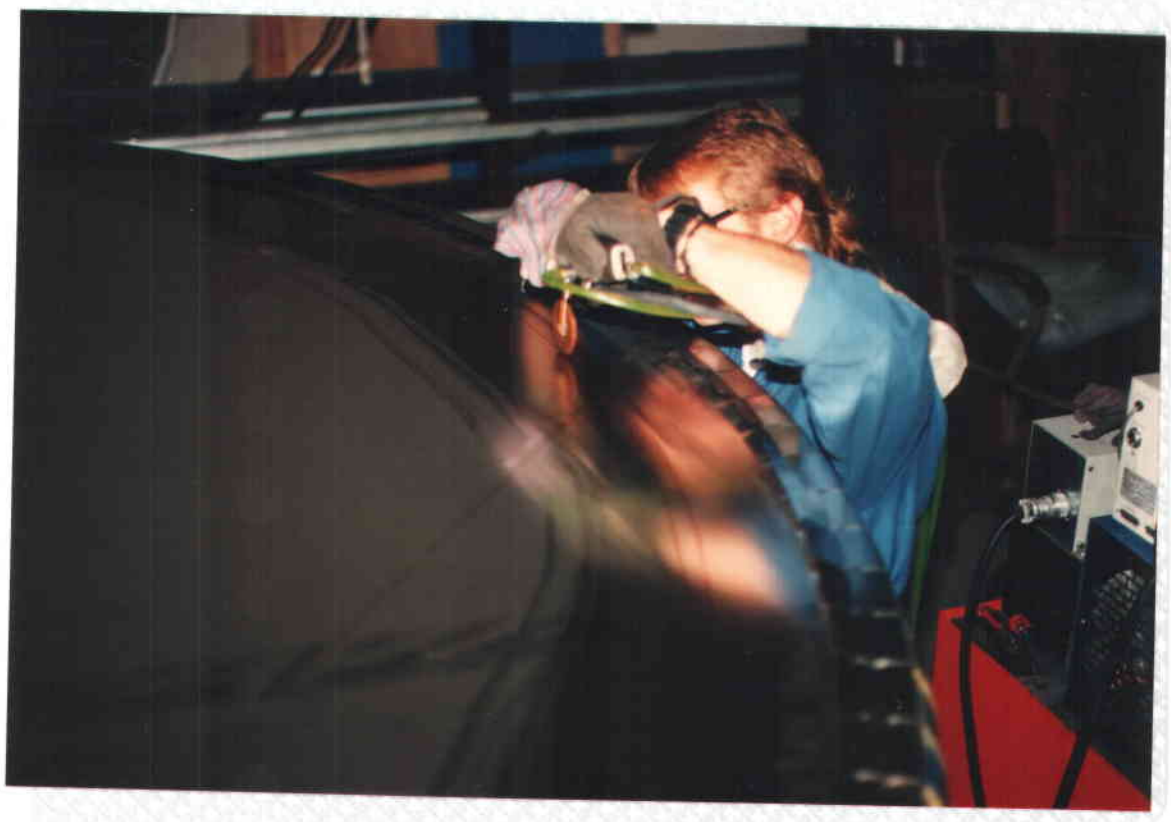
During the pretensioning of the facet, the strain gage readings are used to calculate the actual stress in the membranes in real time. The pressure in the tensioning bladder is adjusted to achieve the desired membrane pretension.





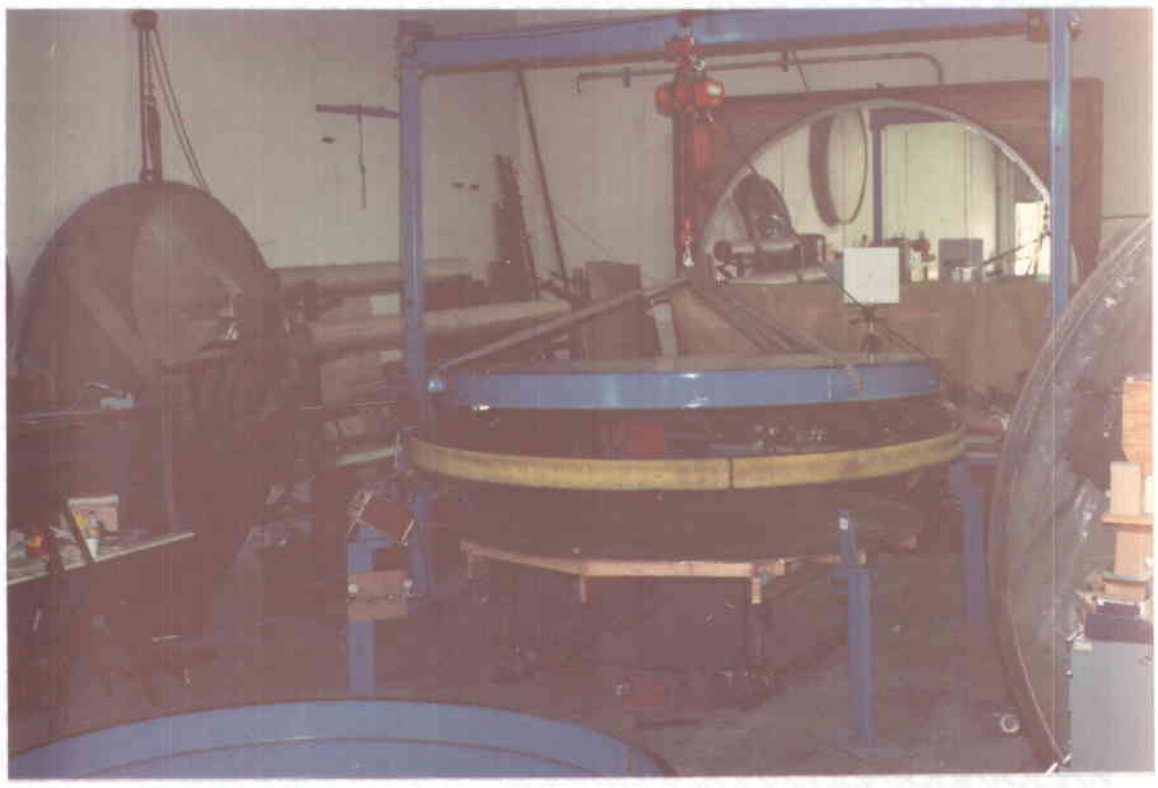
Facet under pretension before welding onto facet ring.

Result of multiple tensioning tab failure on facet 344-2
Before this facet was pretensioned, a different approach to welding the tensioning tabs was used. The failure of several tensioning tab welds led to destruction of the membranes when the bladder came loose. This accident led to a redesign of the tensioning bladder attachment and modification of the welding technique for the tensioning tabs.



Welding of membrane onto facet ring.
When the membrane pretension is correct, the membranes are welded onto the facet ring using a hand-held roll-resistance welder. Two weld passes are made on each of the top and bottom membranes, the second (outside) weld under reduced pretension.

Cutting off tensioning tabs and excess membrane material.
Once the membranes are welded onto the facet ring, the pressure in the tensioning bladder is released, and the membranes are trimmed at the outside edge of the facet ring.

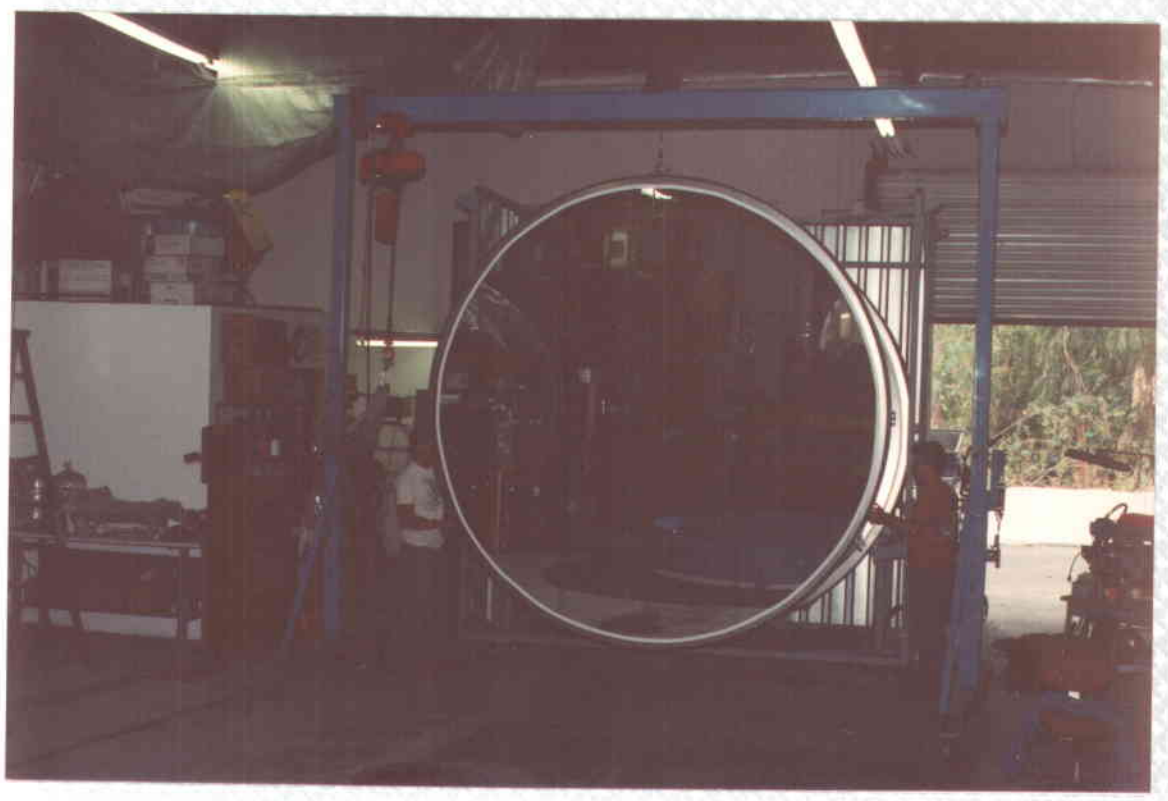


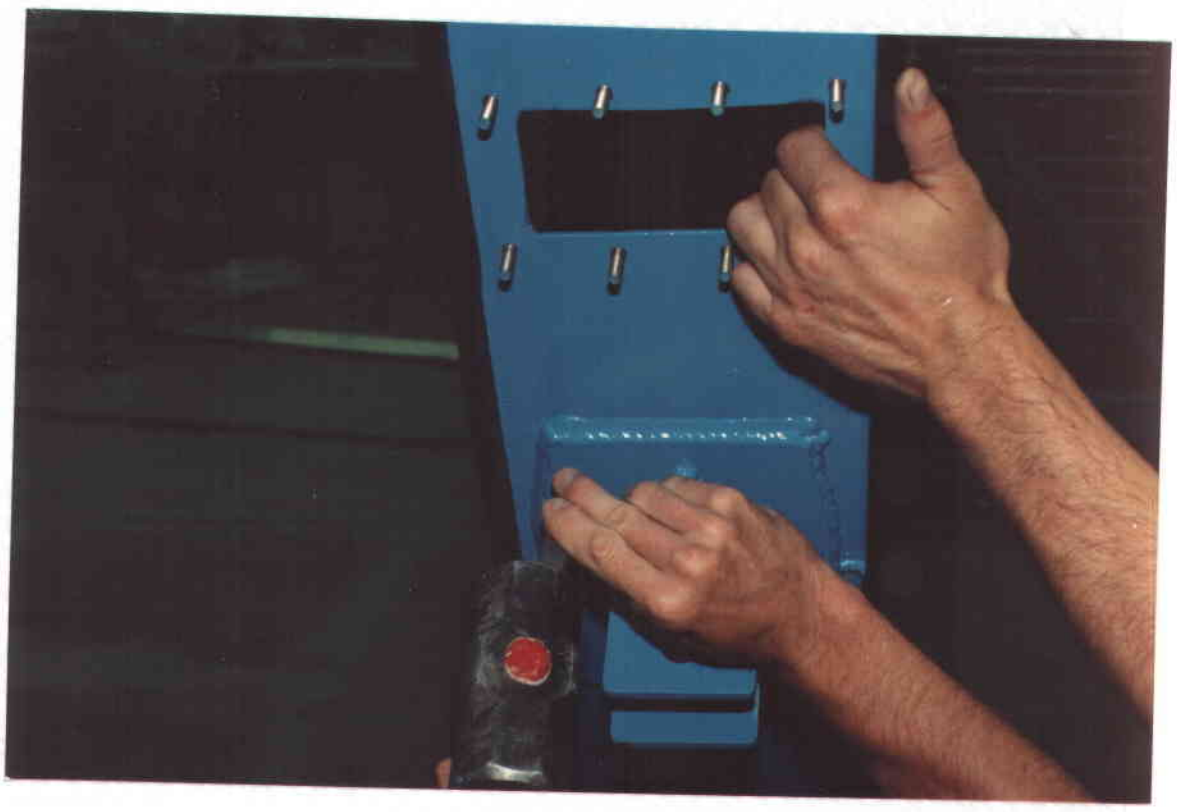
Removing completed facet from tensioning ring.
The completed facet is disengaged from its mounts and lifted from the tensioning ring.

Installing edge protection molding.
To protect against cuts, the rough edges of the membranes are covered with an edge molding on the front and back edges of the facet.

Taping edge of reflective film with Tedlar™ tape.
Tedlar™ tape is applied around the periphery of the reflective film in order to weather seal that area.

Inserting completed facet into shipping container.
Completed facets are placed in the shipping container for optical testing and eventual shipment.

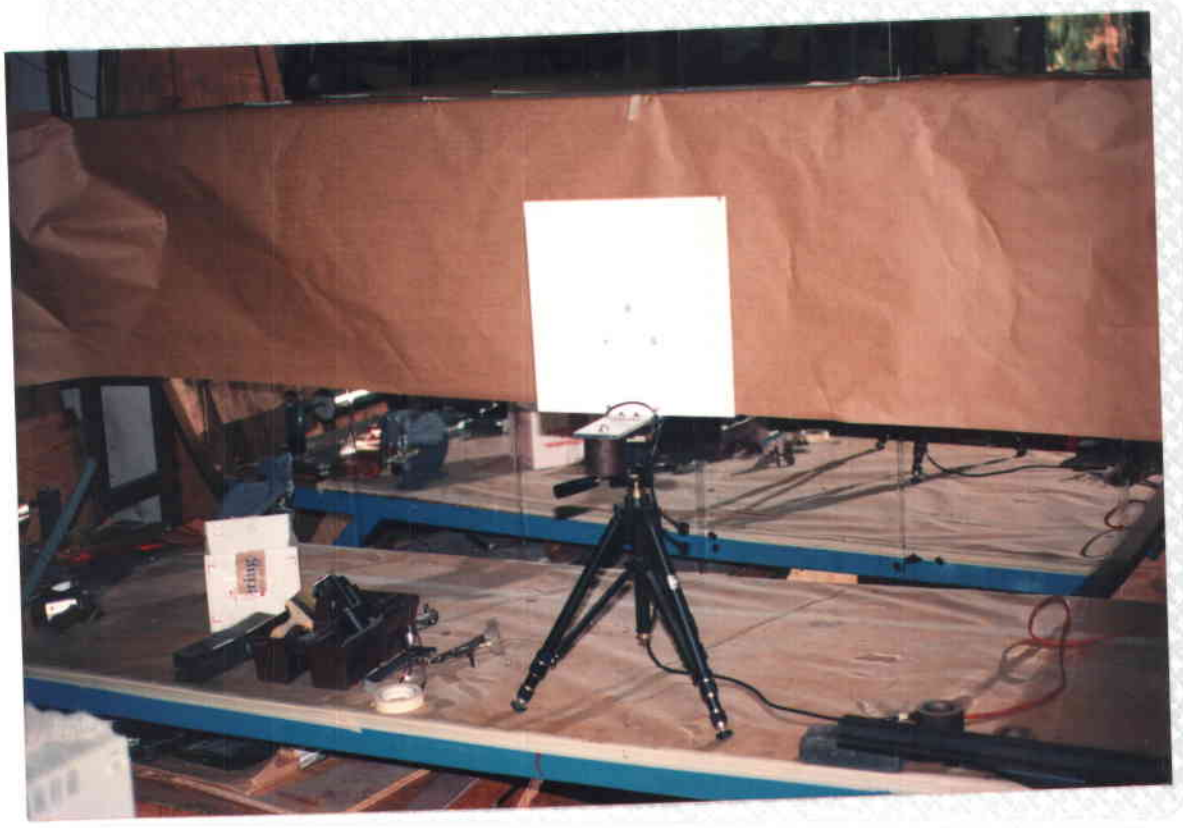




Facet serialization.
Each completed facet is marked with a serial number for identification and tracing purposes.

OPTICAL TESTING

SAIC laser ray trace apparatus.
A simple laser system is used for detailed measurement of facet optical errors. The laser beam is emitted from the center of a target placed at the 2f point of a facet, and the location of the reflected beam on the target is noted. Analysis of the deflection of the beam as the laser scans the facet allows estimation of facet slope errors.

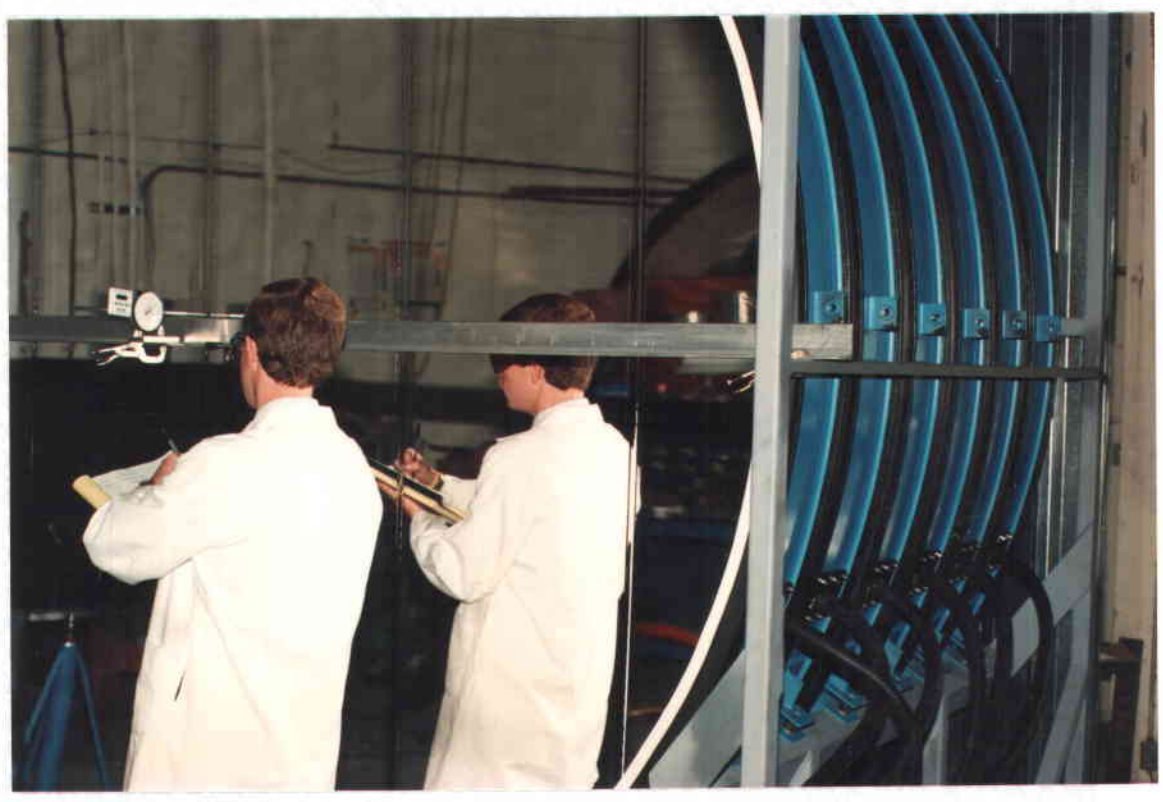


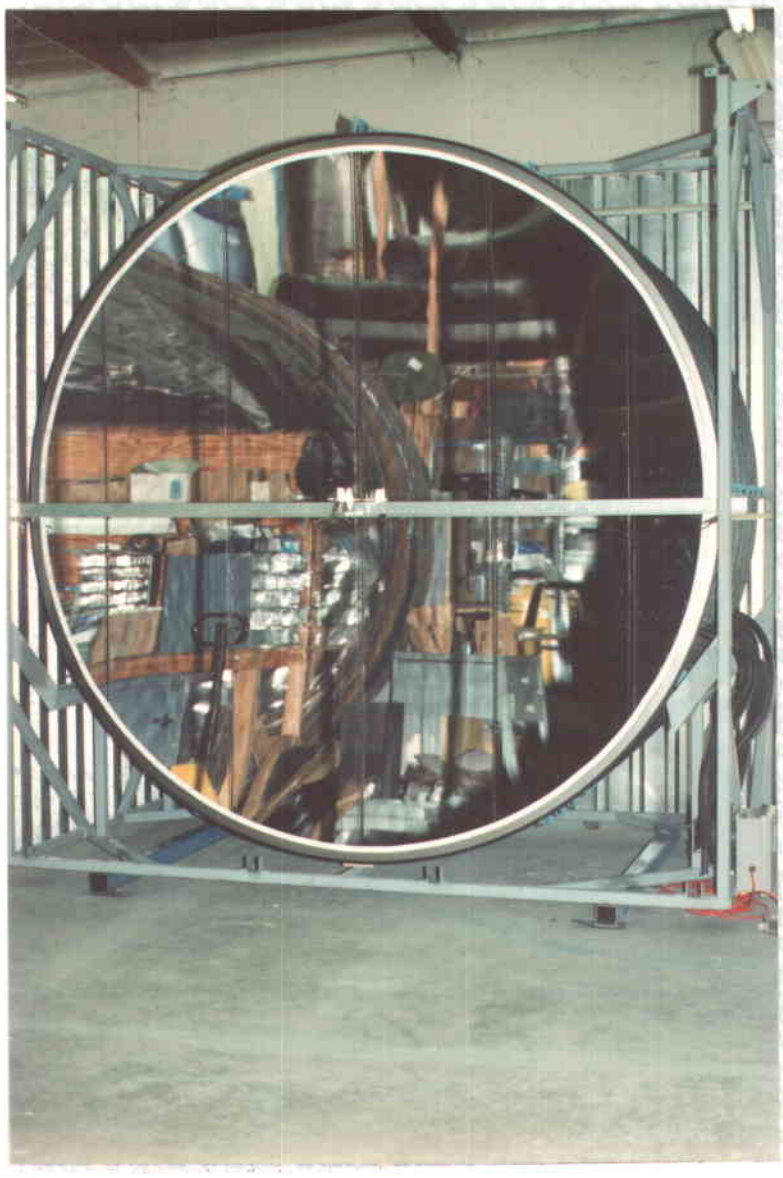
Setup of single facet for optical testing.

Each facet was individually tested by mounting the facet in the shipping container for support and connecting it to the blower assembly to supply vacuum for focussing.

Measurement of focussing performance with multiple facets.

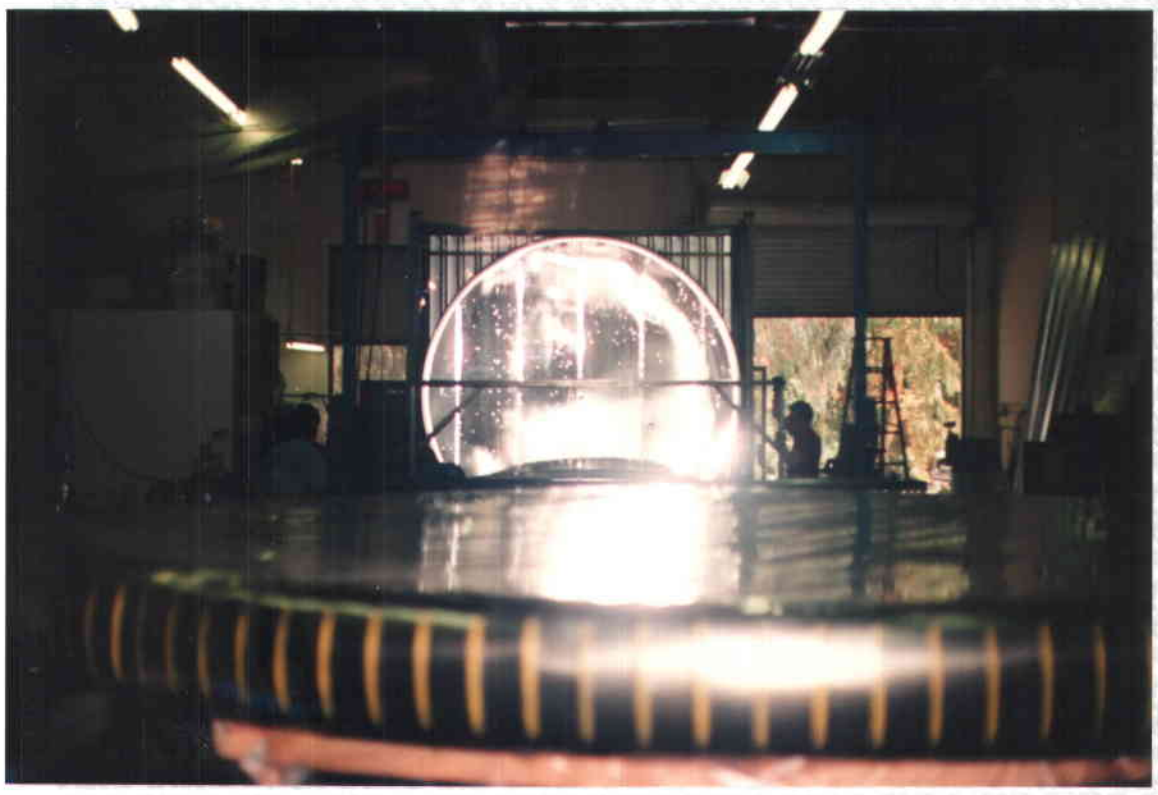
A beam was placed across the front of the facet with a dial indicator to measure the deflection of the membrane. This allowed correlation of optical test results between facets. In the figure, all six facets were being focussed at once in order to test the capabilities of the focus control blower.





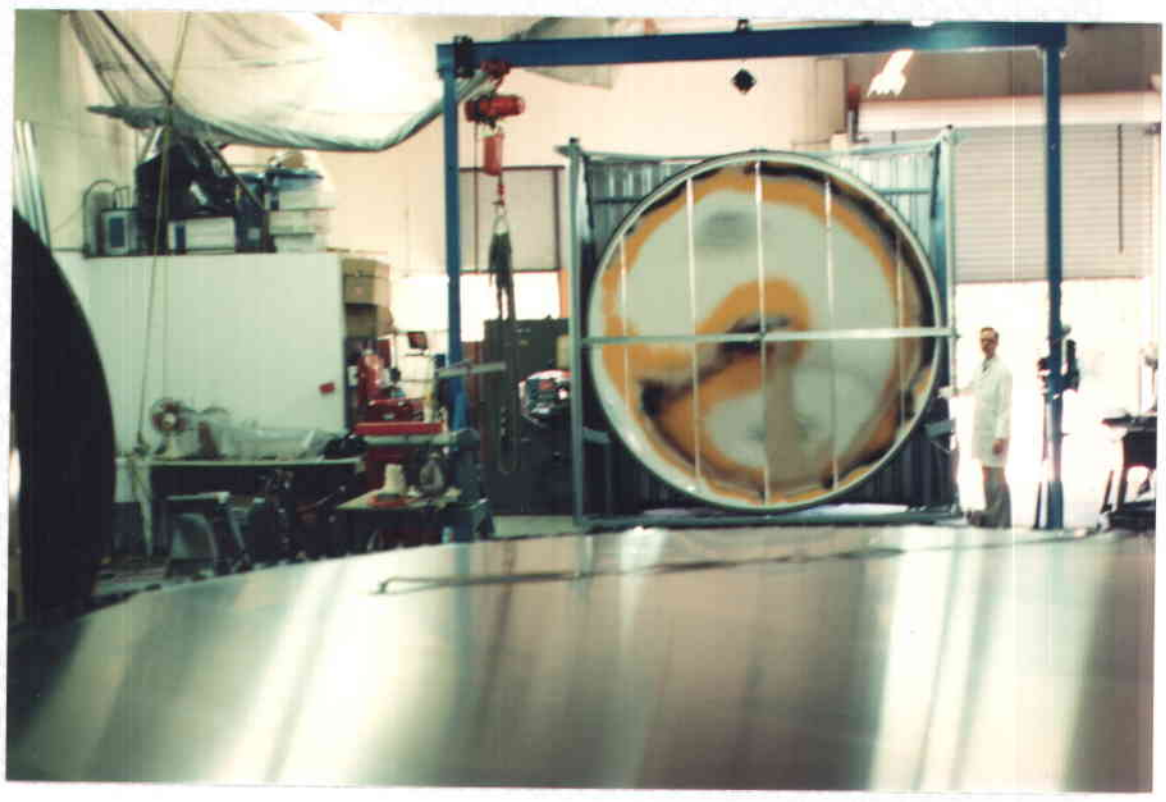
Facet in focussed condition.
A typical facet when connected to the blower assembly and focussed for testing.

Reflection of camera flash unit in focussed facet at 2-f point.
This photograph displays the view from the 2-f point. An untensioned facet is shown in the foreground.



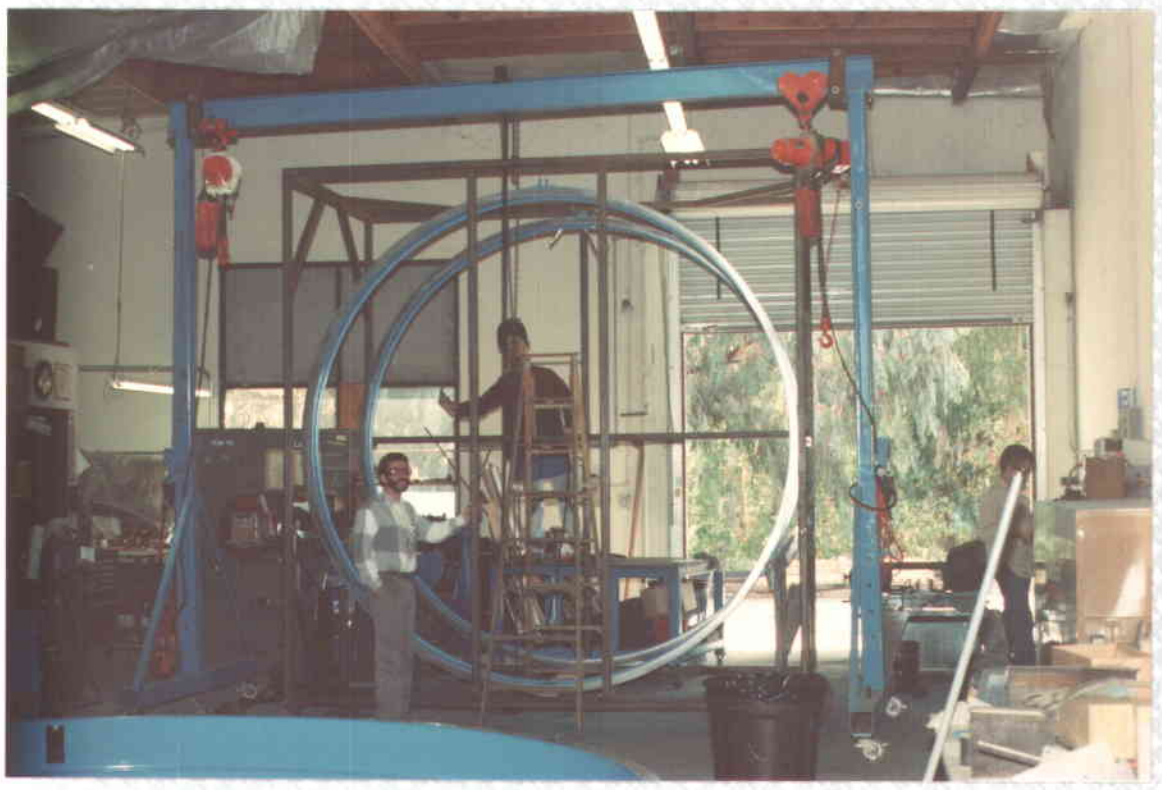
2-f optical characterization of facets.
A system for optical characterization was built using a video camera at the center of a colored radial target.

Typical image using 2-f target.
The target shows the areas of the facet with various slope errors. It has been found very useful for looking at the symmetry of the facets. At the optimum focus, the center portion of the facet shows increasing error out to about half the radius, at which point the error begins to decrease. An area of nearly zero error occurs near the edges, but the extreme edges of the dish are over-focussed and reflect completely off the target.



SHIPPING

Fabrication of shipping/storage container.
Shipping containers were fabricated for the facets. Each container was sized to hold six facets, and the containers were designed to be used for outdoor storage of the facets. Facet rings were placed in the container and used for alignment of the facet mounting rails.



Welding of facet support rail assembly.
The facets are mounted in the shipping container by their three mounting brackets. The two bottom brackets are mounted on side rails to support the weight of the facets.

Installation of outer shipping container skin.

Since the shipping containers are also designed to act as storage containers, they are sheathed with corrugated galvanized steel panels.

Fully enclosed shipping container.
This photograph shows the first shipping container, with six mirror facets loaded within it, ready for transport. The frame of the second shipping container can be seen in the background to the right.

Loading of shipping container onto truck.
The shipping container is loaded onto a low-boy truck using a fork lift. The facets and container are sized so as to require no special permits or shipping restrictions.

Shipping container secured and ready for transport.
Mounting points at the upper corners of the shipping container are used to secure it to the truck for shipment.