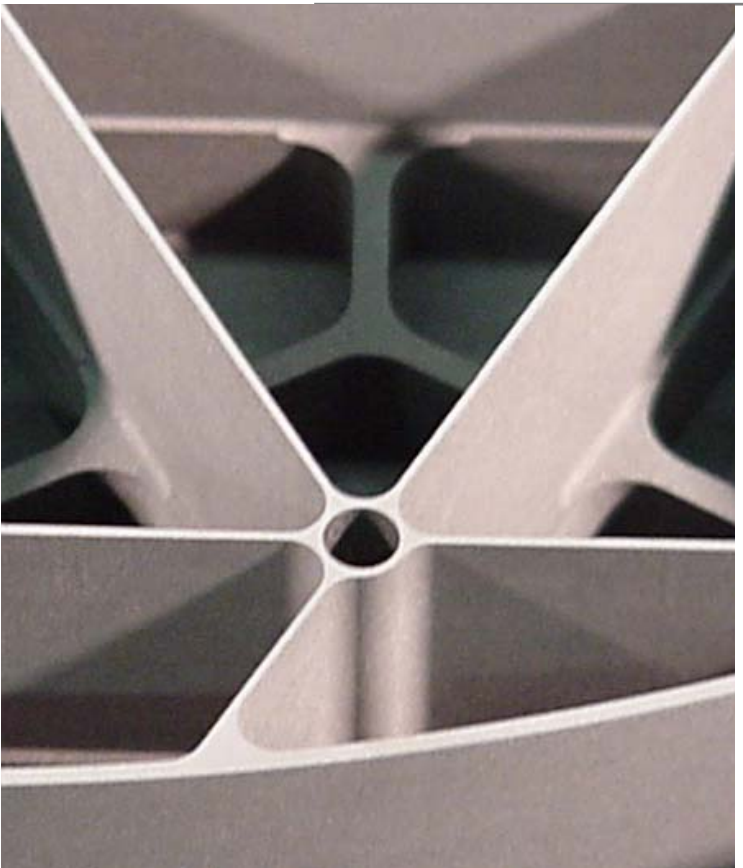
POCO SuperSiC
SiC Mirror for
Cryo-Characterization



John M. Casstevens

Dallas Optical Systems, Inc.,
Rockwall, Texas

Abuagela Rashed, Ronald Plummer,
Rob Gates, Donald J. Bray

POCO Graphite, Decatur, Texas

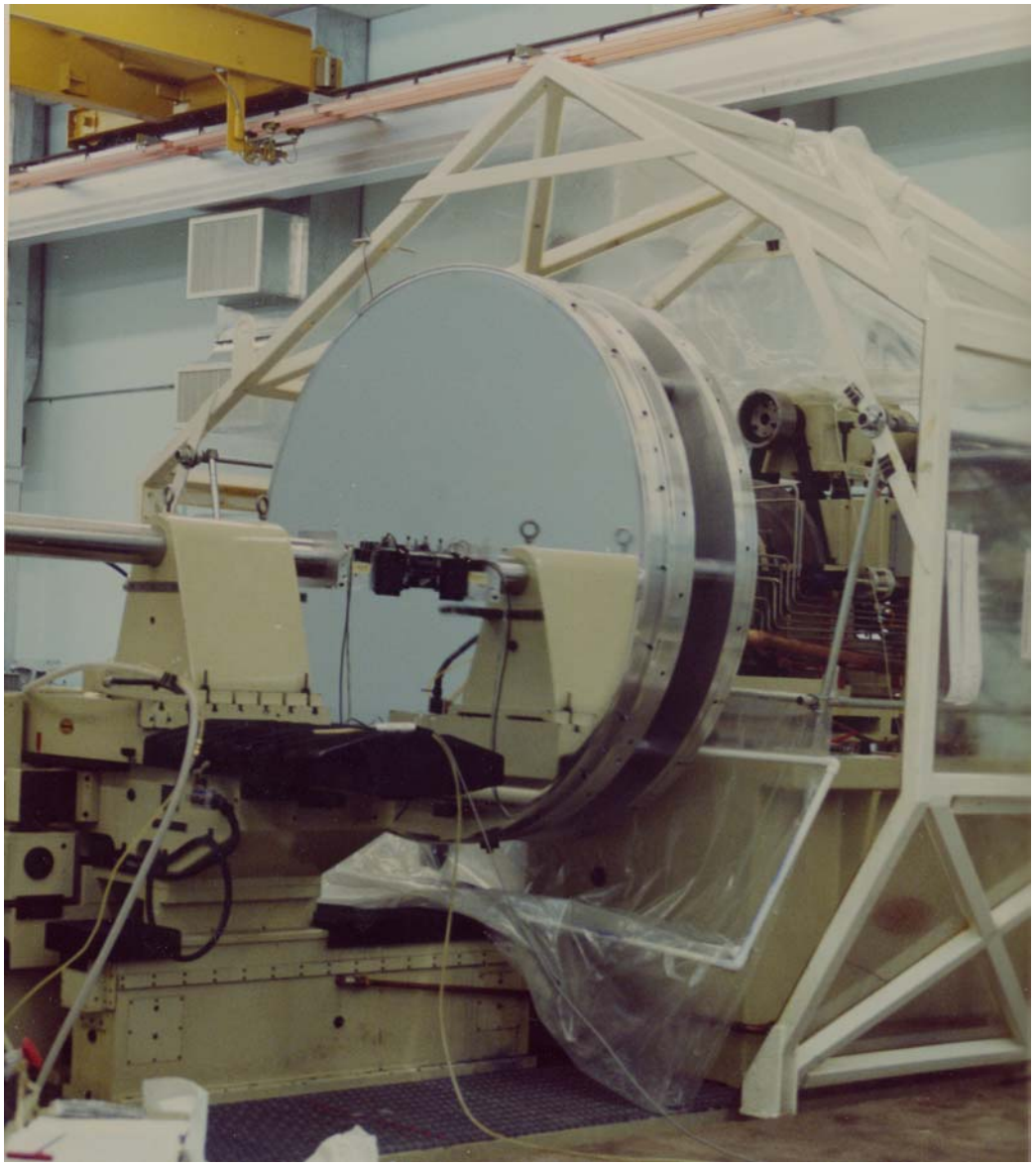
Outline

- Introduction
- Silicon Carbide Characteristics
- Poco SuperSiC Manufacturing Process
- SuperSiC Mirror Design

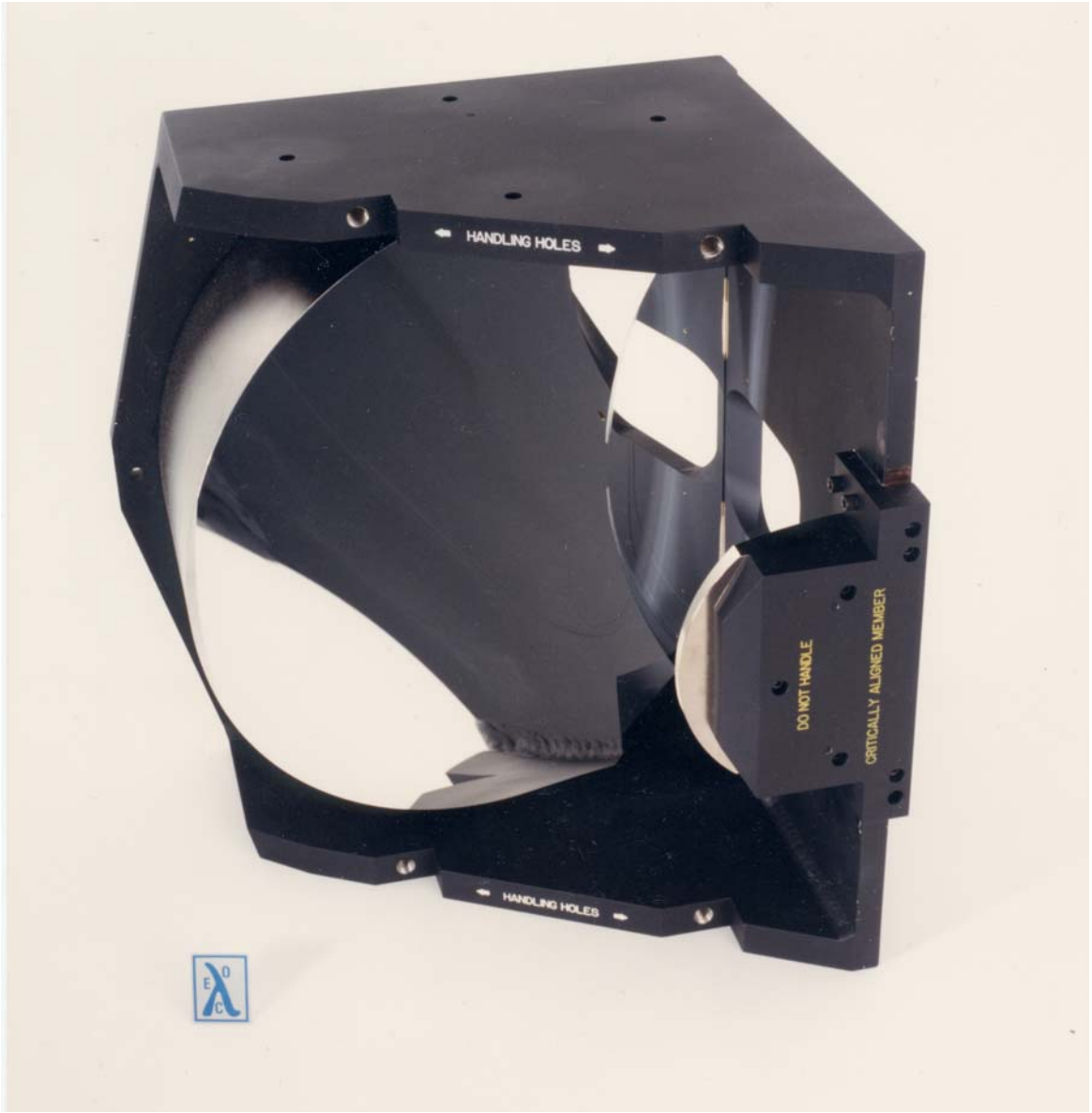
Dallas Optical Systems, Inc.

- Established 1991
- Rockwall, Texas
- Diamond turning, optical polishing, electroforming of optical molds.
- Precision engineering consultants

M-40 Diamond Turning Machine



Diamond Turned Northrup CASS Collimator



Diamond Turned Boeing Collimator

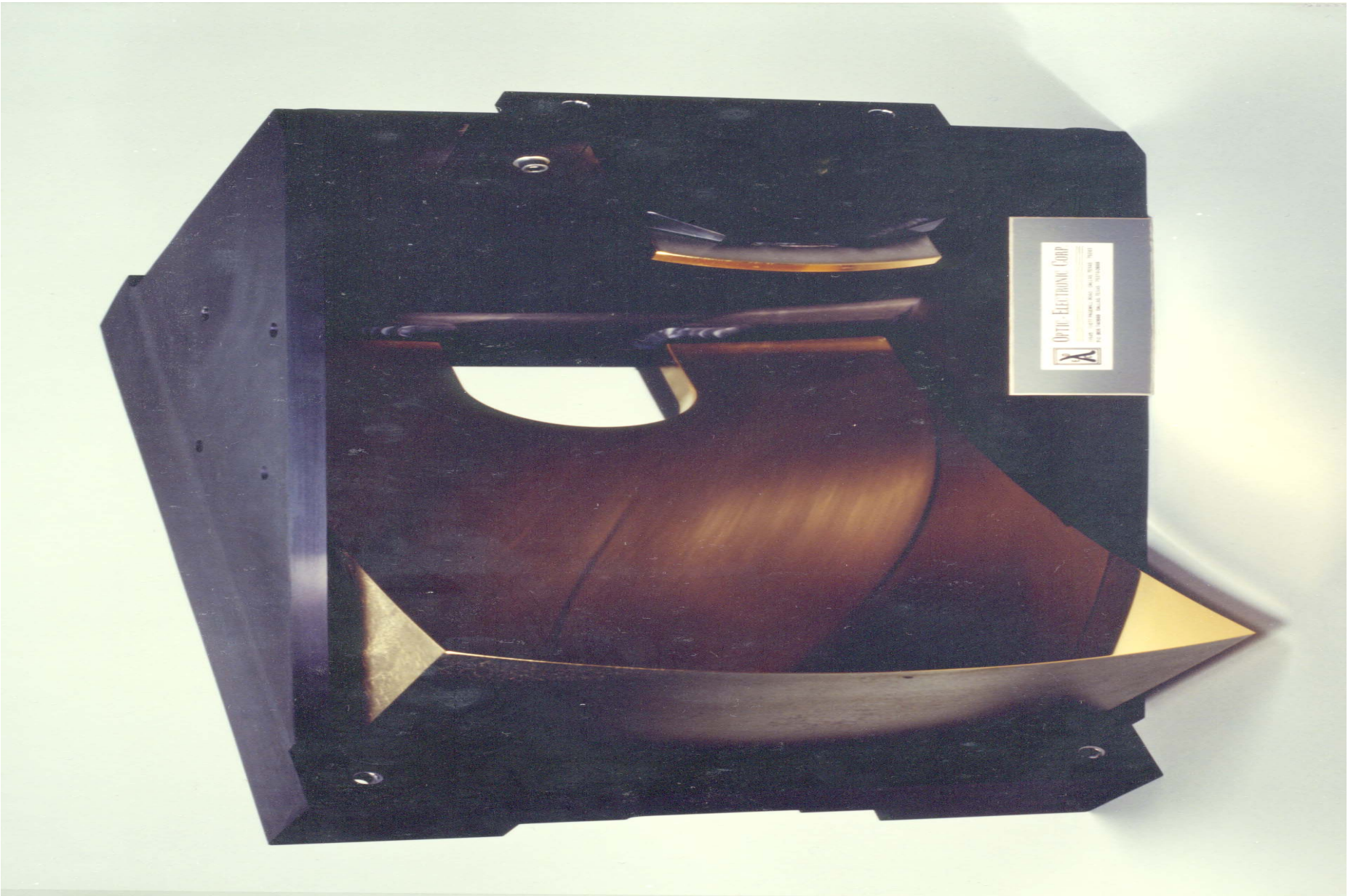
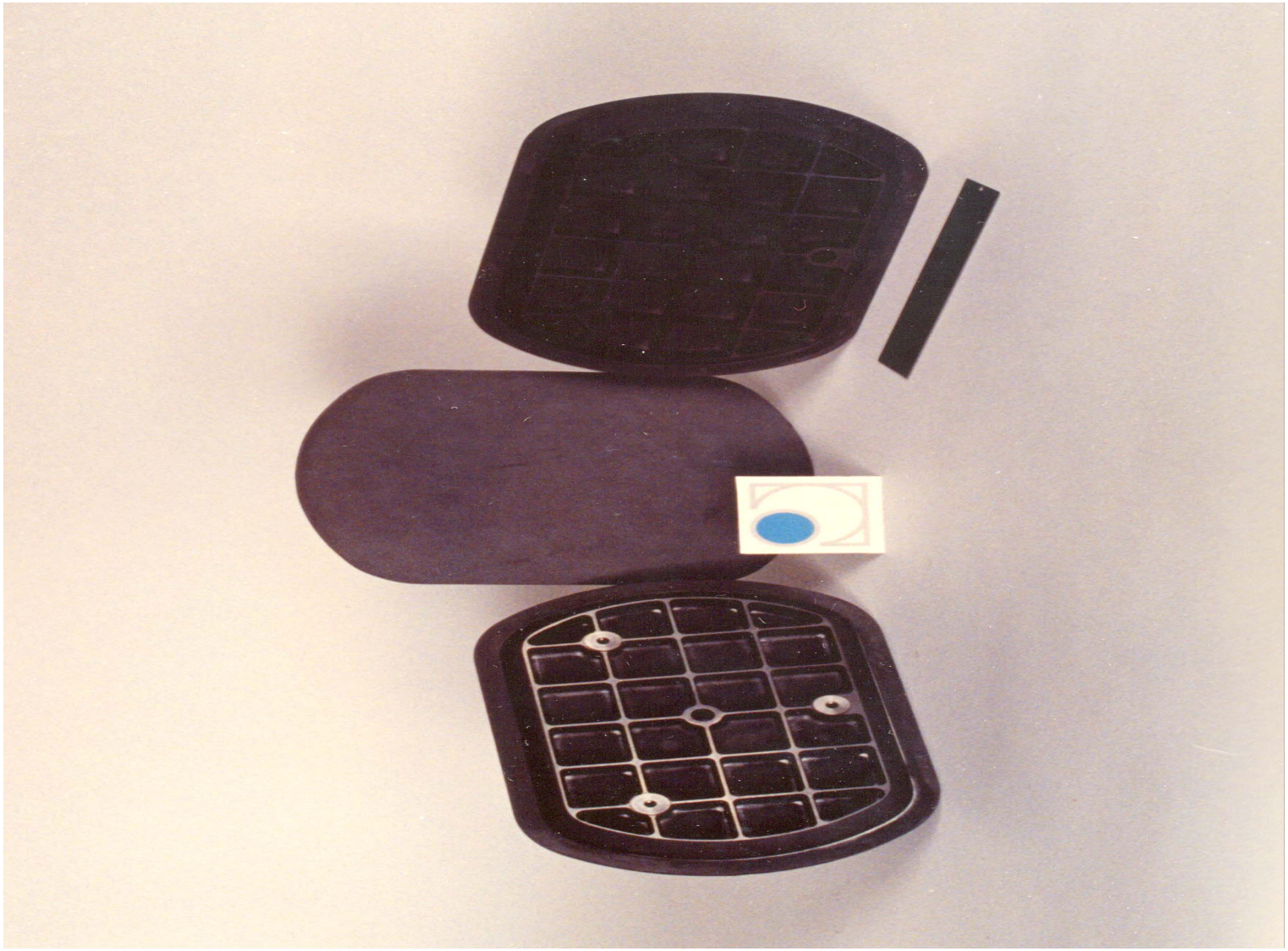


Photo of Diamond Turned LTV Collimator

Slip Cast SiC Scan Mirrors for Northrup CASS

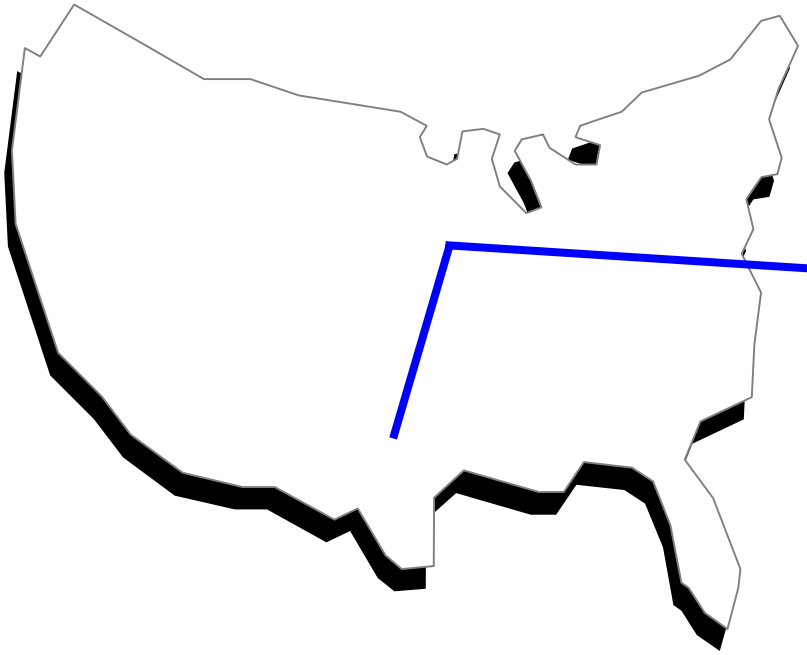
Slip Cast SiC Convex Ellipsoid Mirror for SDC, Wide Field of View (WFOV) Sensor



History of POCO

1962	Fine particle size graphite developed; POCO is spun-off from LTV Corporation
1964	Acquired by Pure Oil Co.
1965	Pure merged with Union Oil Co. of California
1985	Union Oil Co became UNOCAL. POCO develops new materials
2000	Leverage Buyout by SC Capital and Whitney - POCO becomes private, independent company with strong management team

Poco Graphite



- Offices in Chicago, San Jose, Lyons, Frankfurt, Singapore, Shanghai
- 320 employees
- $60 million+ sales

Decatur, TX

Decatur is located near the Dallas/Ft. Worth Metroplex

POCO-COI Partnership

- **POCO and COI have signed a Joint Technology Development Agreement for SiC technology for aerospace applications.**
- **POCO**
  - **Unique SiC Conversion Technology**
  - **Manufacturing SiC Components**
  - **SiC Coatings**
- **COI**
  - **Engineering Capability**
  - **Program Applications**
  - **Existing COI-Ceramics Business (Approx. $8M/yr revenue)**
  - **Experience with C-SiC materials development (IABG)**

Silicon Carbide for Optics and Precision Components

- **Best overall for precision applications.**
- **Extraordinary dimensional stability.**
- **Strong material in the range of steels.**
- **Very stiff, Young's Modulus ≥ Beryllium.**
- **High thermal conductivity, k approaches aluminum.**
- **Low thermal expansion, 2.2×10^{-6}/K.**
- **Low density, Approximately the same as aluminum.**

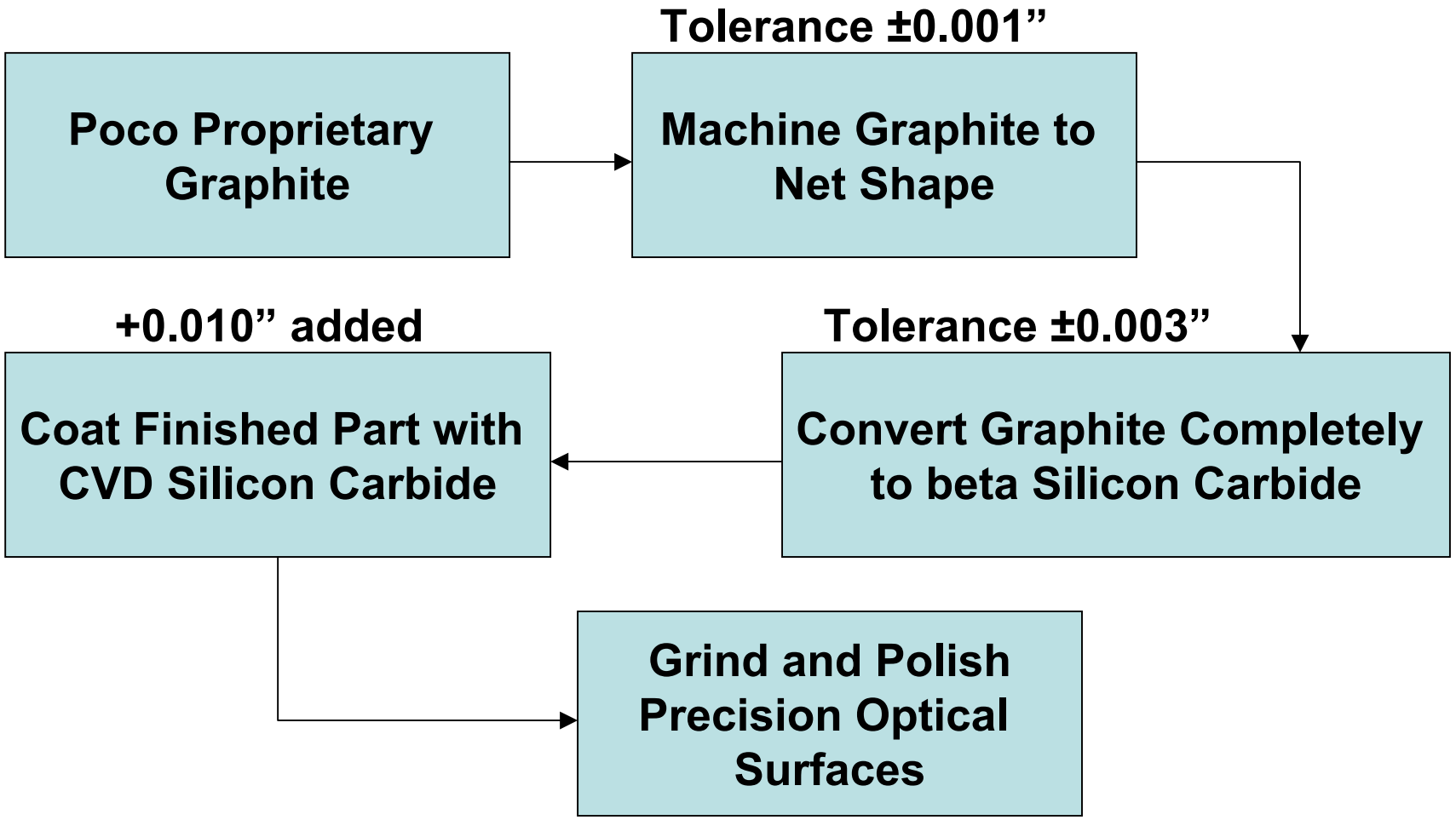
SuperSiC Compared to Other Optical Materials

Material	Density (g/cm^3)	Elastic Modulus (GPa)	Thermal Expansion (ppm/K)	Thermal Conductivity (W/m·K)	Thermal Distortion a/k	Thermal Distortion a/D
					Steady	Transient
Beryllium	1.9	287	11.4	190	0.060	N/A
Aluminum	2.7	68	23.6	170	0.134	0.483
Zerodur	2.5	92	0.0	1.6	0.0	0.0
Fused Silica	2.1	72	0.5	1.5	0.333	52.176
Silicon	2.3	110	3.8	125	0.030	0.064
POCO's SiC	**2.55**	**248**	**R.T: 19**	**170**	**0.011**	**0.019**
POCO's Si/SiC	**2.93**	**232**	**R.T: 19**	**158**	**0.009**	**0.014**

Obstacles to Wide Spread Use of Silicon Carbide

- **Silicon Carbide is harder and stronger than most other optical materials. Diamond grinding is the only effective machining method for producing precision surfaces.**
- **Cost and time required for diamond grinding to remove large amounts of material is a major obstacle to wide use of SiC**
- **Previous methods of manufacturing SiC are not cost effective for small - lot production of precision components.**
- **- Slip cast reaction bonded SiC parts require extensive grinding because of dimensional changes in siliconizing and multiple drying and firing steps.**
- **Green machining hot pressed components before siliconizing/reaction bonding requires extensive grinding because of dimensional changes.**

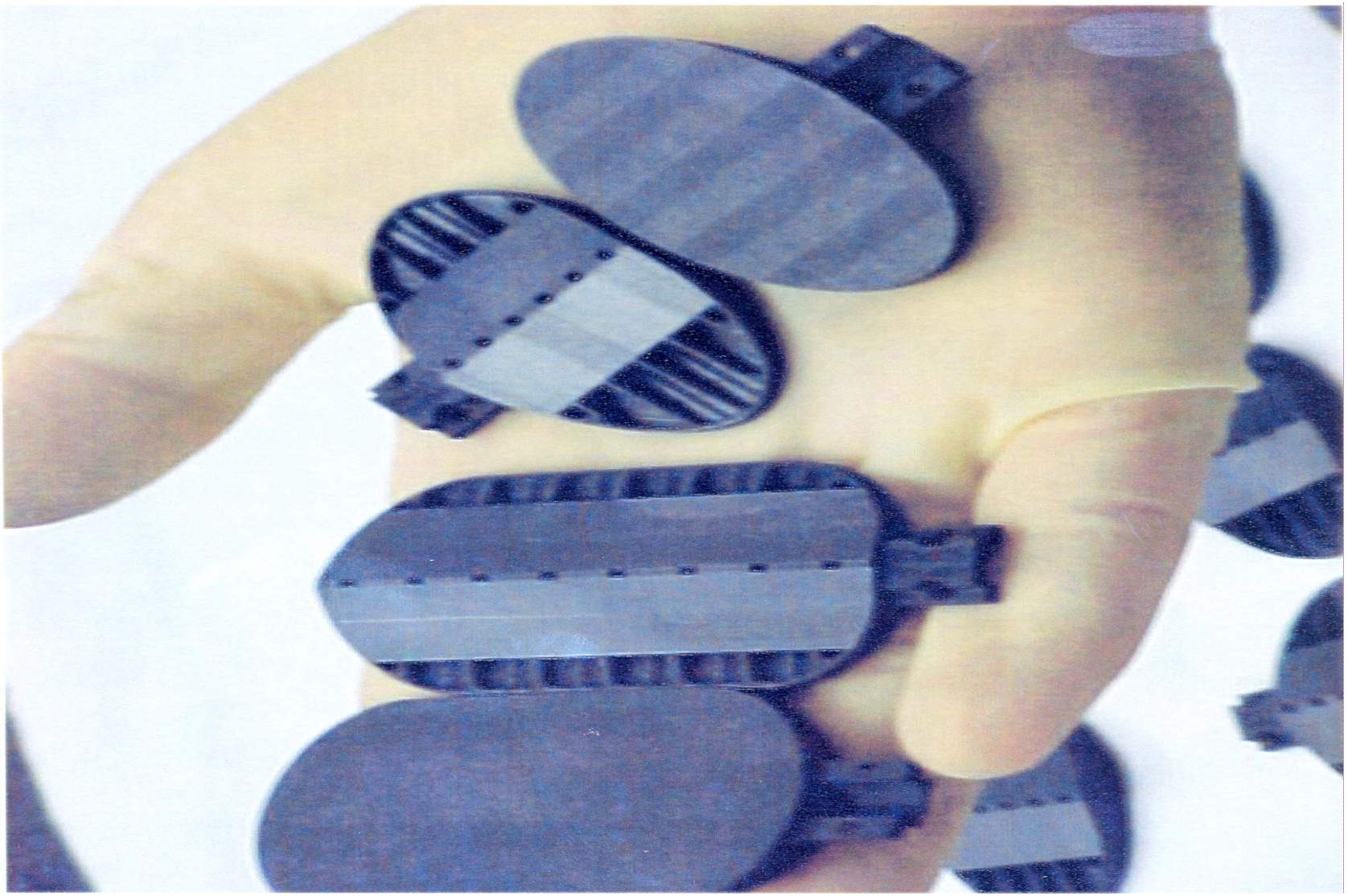
Poco SuperSiC Process



Direct Machining and Conversion

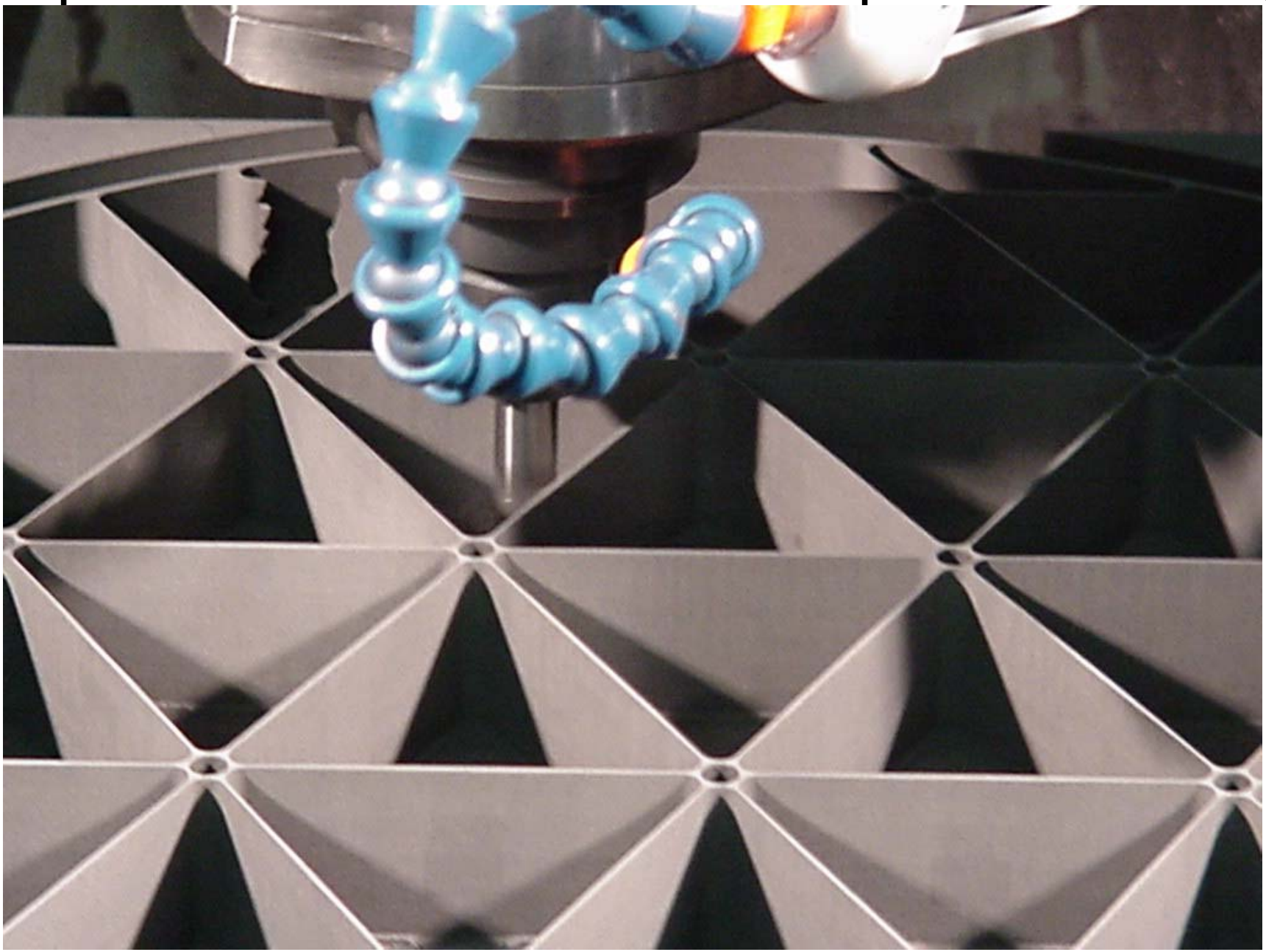
- **Very small and predictable growth means most tolerances can be met with no grinding required.**
- **High precision surfaces require only 0.002- 0.003” (50-75µm) of material removal.**
- **Direct machining of components means no molds or patterns are required.**
- **Direct machining and conversion means maximum flexibility and low cost for changes and small-lot production.**

Small POCO SuperSiC Scan Mirrors with Closed Back Structure



POCO SuperSiC 200x300 mm Scan Mirror

SuperSiC Half Meter Mirror Graphite Machining



Specifications of Half Meter SuperSiC Flat Mirror

- **Mirror weight: 2.6 Kg.(5.8 lbs.)**
- **Mirror Area: 0.201 Sq. meter**
- **Mirror Areal Density:13.06 Kg./ Sq.M.**
- **Thickness Dimension: 70 mm (2.75”)**
- **Faceplate Thickness: 1.5 mm (0.060”)**
- **Rib thickness: 1.0 mm (0.04”)**

CAD Isometric of 1/4 Meter Spherical Mirror

Specifications of 1/4 Meter Spherical Mirror

- **Mirror weight: 1.03 Kg.(2.28 lbs.)**
- **Mirror Area: 0.051Sq. meter**
- **Mirror Areal Density: 20.2 Kg./ Sq.M.**
- **Thickness Dimension: 50.8 mm (2.0”)**
- **Faceplate Thickness: 1.5 mm (0.060”)**
- **Rib thickness: 1.0 mm (0.040”)**
- **Mirror Radius of Curvature: 3 meters (118”)**

GRAIN GROWTH DURING CONVERSION ALLOWS FEATURES SUCH AS CLOSED BACKS, RIBS AND APPENDAGES TO BE INCORPORATED INTO PRECISION PARTS.

Current POCO SuperSiC Size Capacity

- Size of Graphite Billet: 60”x 24” x 6”
- Size of Conversion Chamber: 24” x 36”
- Size of SiC CVD Chamber: 40” x 60”
- Conversion Bonding allows any size to be built from available graphite billets.
- Current limit on size is the Conversion Chamber 24” diameter.

Conclusions

- **POCO Graphite will deliver a 1/4 meter diameter spherical SuperSiC mirror for Cryo-Characterization in 16 weeks ARO.**
- **Radius of Curvature 3 meters.**
- **Optical figure error to be less than 1/2 Wave P-V at 0.63nm.**
- **Surface roughness less than 10 Angstroms rms.**