

REQUEST FOR PROPOSAL

FOR

**FEASIBILITY STUDY FOR PRODUCTION OF
SILICON CARBIDE MIRROR SEGMENTS FOR THE
THIRTY-METER TELESCOPE**

AURA, Inc.

**Operating the
National Optical Astronomy Observatories
Tucson, Arizona**

PROPOSALS DUE: 3:00 P.M (MST) Monday, February 23, 2004

Prepared by:

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SECTION III

A. SCOPE OF WORK

1. General

1.1 Contractor shall review the Segment Specification provided in this scope of work and develop a mirror segment design concept consistent with the Segment Specification. The Contractor is encouraged to work with AURA to propose refinements to the Segment Specification, where modifications could provide higher performance, lower cost or both. Changes in overall thickness and light-weighting geometry may be proposed to accommodate specific process limitations. The final Segment Specification used by the Contractor shall be explicitly stated and must be approved by AURA. Sufficient dimensional and material property details of the design concept shall be provided such that a thermal-structural finite element model can be created by AURA and performance of the Segment evaluated under different gravity and thermal environments.

1.2 Contractor shall develop a manufacturing process that will allow efficient, low-cost production of the Segments. The process shall include a description of the facilities that need to be used, noting which portions are currently available and which will need to be built. The description shall include all required processes and equipment required to verify that the Segments meet the Segment Specification.

1.3 (a) Contractor shall prepare a cost estimate for production of 1200 Segments measuring 1.0 meter corner to corner as defined in drawing NIO-0100-0004 of the Segment Specification and according to the delivery schedule listed in Section 2.. Contractor shall provide a work breakdown structure (WBS) with detail cost information that supports the cost estimate. The level of detail shall be consistent with that proposed by the Contractor in the proposal documents.

(b) Contractor shall prepare a cost estimate for production of 540 Segments measuring 1.5 meter corner to corner as defined in drawing NIO-0100-0005 of the Segment Specification and according to the delivery schedule listed in Section 2. Contractor shall provide a work breakdown structure (WBS) with detail cost information that supports the cost estimate. The level of detail shall be consistent with that proposed by the Contractor in the proposal documents. If 1.5 meters is too large for a cost competitive proposal, the contractor shall indicate and estimate the costs of producing the largest reasonable Segment size that can be accommodated.

1.4 Contractor shall prepare and deliver a report on production of Silicon Carbide Segments for TMT, which contains the information outlined in sections 1.1 through 1.3 above. The report shall consist of the following sections:

- a. An executive summary suitable for public release (see Section 3, below, on Proprietary Information). This summary must include, at a minimum: (1) a pictorial (i.e., not dimensioned) drawing of the proposed Segment design; (2) a description of the properties of the material in the Segment; (3) a general description of the process to be employed in manufacturing the Segment; (4) a summary of the delivery schedule; (5) a description of the Contractor's relevant experience.
- b. A description of the Segment design on which the study is based, including a drawing of the Segment structure with dimensions clearly indicated. The Contractor is not required to provide any warranty about the suitability of the design for TMT's purposes.
- c. A description of the properties of the materials that would be used for the Segments including an estimate of the uncertainty of these properties and an estimate of the variation of these properties between Segments.
- d. A description of the manufacturing process that would be used to produce the Segments.
- e. An estimate indicating the projected cost, by year, to produce the Segments on the proposed schedule. This should be the full cost to AURA, including Contractor's profit margin.
- f. A summary of any suggested changes to improve manufacturing feasibility, including, for example, changes to the Segment Specification or delivery schedule. The reasons for and benefits of the proposed changes should be explained.
- g. A summary of any and all available results from previous studies of the thermal and temporal stability of the material when used as a substrate for optical products.
- h. A plan for further development studies, if any, required to prepare the Contractor to be able to submit a minimum-cost, fixed-price bid for production of the full complement of either 500 or 700 Segments. This plan should indicate the required sequence and duration of the studies, and the estimated cost of each.

2. Segment Delivery Schedule

2.1 For purposes of the Feasibility Study, the planned delivery of Segments shall be according to the following schedule, relative to the Sub-award start date:

- a. Delivery of 4 full-size, pre-production prototypes 18 months after start.
- b. Delivery of first 20 production Segments 24 months after start.
- c. Delivery of 10 Segments or more per month during months 25 through 30.
- d. Delivery of 20 Segments or more per month during months until completion.
- e. The delivery location shall be Tucson Arizona USA.

3. Proprietary Information

3.1 AURA shall protect the proprietary information of Contractor, provided it is clearly marked with the words "proprietary". Each page of the report that contains proprietary information must be clearly marked with the words "proprietary" at the bottom of each page. Note that it is not AURA's intention that Contractor divulge detailed manufacturing process information that would be considered a "trade secret", and such information should not be included in the report. AURA simply needs sufficient information about process steps to be able to judge the credibility of the plan, estimate, any associated cost and schedule risks.

3.2 AURA needs basic information about Segment manufacturing feasibility that can be discussed in open meetings, which shall include, at minimum, the information described in Section 1.4-a of the Scope of Work.

4. Meetings - Reviews

4.1 There shall be a kick-off meeting shortly after the sub-award starts. This meeting shall be held at a location to be determined by the contractor.

4.2 The Contractor shall present a draft of the final report not later than two weeks prior to delivery of the final report. This presentation shall be held at a location determined by the contractor for its convenience. AURA representatives shall have an opportunity to comment on the draft. These comments shall be taken into account in the delivered final report.

4.3 Although it is not expected, AURA reserves the right to call and conduct meetings, at the Contractor's location, as it may deem necessary for the purposes of review, discussion, presentation or coordination of the work.

B. SEGMENT SPECIFICATION

1.0 Scope. This Segment Specification defines the requirements for the Silicon Carbide Segments. These requirements shall be used by the contractor in developing the processes for fabrication and testing of the Segments to be used in the Thirty Meter Telescope.

1.1 Definitions

- 1.1.1 Depending on the context, the terms "silicon carbide" or "SiC" may refer either to pure silicon carbide, or to a composite material composed largely of silicon carbide and having material properties similar in most respects to pure silicon carbide.
- 1.1.2 The term "Segment" shall mean a hexagonal mirror blank ready for optical finishing that meets the requirements in this Segment Specification.

1.2 Applicable Documents. The following documents are attached and are made part of this Segment Specification:

- (a) NIO-0100-0004 (initial release), 1.0m Segment
- (b) NIO-0100-0005 (initial release), 1.5m Segment

1.3 Environments.

1.3.1 Operating Environment. The Segment shall be capable of sustained and continuous operation in complete conformance to the requirements of this Segment Specification throughout the expected life of the observatory (as indicated in 1.7 below) while being subjected to any combination of the following environmental conditions.

Altitude: sea level to 5000m
Temperature: -25 to +25 C
Relative Humidity: 0 to 100% condensing
Wind speed: 0 to 20 m/s
Orientation: Any

1.3.2 Survival Environment. The Segment shall meet the requirements stated in 1.3.1 above without damage, after being subjected to any combination of the following environmental conditions for any duration for any number of occurrences over the expected life.

Altitude: sea level to 15500m
Temperature: -25 to +50 C

Relative Humidity: 0 to 100% condensing
Wind speed: 0 to 40 m/s
Orientation: Any
Seismic: 10G in any direction

1.4 Material properties.

1.4.1 The Segments shall be made from Silicon Carbide.

1.4.2 The density of the bulk material shall be defined by the Contractor as part of the Feasibility Study. The maximum porosity expected shall be defined by the Contractor as part of the Feasibility Study.

1.4.3 Young's Modulus of the bulk material in the Segments and Poisson's Ratio of the bulk material in the Segments shall be defined by the Contractor as part of the Feasibility Study.

1.4.4 Coefficient of thermal expansion of the bulk material in the Segments shall all be defined by the Contractor as part of the Feasibility Study in terms of the following:

- a. Value of mean linear coefficient α , absolute value over the range of -5 to 5 °C
- b. Homogeneity of the coefficient of thermal expansion of the bulk material in the Segment, as defined by 3σ , σ being the standard deviation over the sample, shall be $<0.01 \times 10^{-6} / ^\circ\text{C}$.
- c. Uniformity of the average coefficient of thermal expansion between Segments over the range of -5 to 5 °C shall be such that the maximum variation between Segments, as defined by 3σ , σ being the standard deviation over the sample, is less than $0.005 \times 10^{-6} / \text{C}$.
 $<0.005 \times 10^{-6} / \text{C}$.
- d. The average material coefficient of thermal expansion shall be measured and recorded for each delivered Segment, within an accuracy better than $0.005 \times 10^{-6} / ^\circ\text{C}$.

1.4.5 The maximum admissible tensile stress, to be considered as additional to internal residual stresses, shall be specified by the Contractor as part of the Feasibility Study

1.4.6 Fracture toughness shall be specified by the Contractor as part of the Feasibility Study.

1.5 Surface quality

1.5.1 a. Cracks or fissures shall be repaired by grinding with minimal material consumption and no sharp edges.

b. No repair is allowed on front surface.

c. Maximum number of repairs shall be 2 per Segment

- d. Average number of repairs shall be ≤ 0.1 per Segment
- e. Maximum individual repair area shall be 100 mm^2 (as projected onto the surface through which the repair is ground out)
- f. The maximum individual repair depth (measured from surface through which repair is ground out) is $1/3$ of material thickness at repair location

1.6 Light-weighting design

1.6.1 A real density shall be less than 60 Kg/m^2 for both the 1.0 meter size Segments and the 1.5 meter size Segments based on unpolished blanks without support mounts. Any light weighting shall be designed with a goal to provide minimum optical surface deformation on a six-point support when subjected to the operating conditions; changes in gravity orientation on temperature, consistent with the processes and material restrictions of the Contractor.

1.6.2 Maximum mass variation between two Segments shall be less than 5%

1.7 Lifetime

1.7.1 The expected lifetime of individual Segments is 50 years.

1.8 Polishing

1.8.1 The Segment front surface shall be capable of being polished to the following specifications with minimum material removal:

- a. Radius of curvature shall be $60\text{m} \pm 10\text{mm}$.
- b. Surface roughness shall be less than 20 angstroms rms.

1.8.2 Contractor shall determine and report, as part of the Feasibility Study, the dimensional accuracy with which the Segment optical surface can be provided from the Contractor with respect to the desired polished surface.

1.9 Coating

1.9.1 The Segments shall continue to comply with all the requirements of this Segment Specification after any number of repeated cleaning, coating and coating removal cycles over the lifetime of the Segment. Materials that may be used for such procedures, without limitation, include:

- a. Hydrochloric acid
- b. Cupric Sulfate
- c. Potassium Hydroxide
- d. Nitric acid
- e. Ceric Ammonium nitrate
- f. Calcium carbonate
- g. Hydrocarbon solvents such as methanol, propanol and acetone
- h. Potassium ferrocyanide and Sodium thiosulfate solutions

1.10 Segment Supports

1.10.1 The Contractor may assume that the support system will consist of 6 equally loaded support points bonded to the back surface of the Segment.