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THE MMT CONVERSION

Study of Considerations for Conversion of the Multiple Mirror Telescope to a Large, Single-Mirror Telescope

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PREFACE

This report is expected to be of greatest interest to those who are intimately familiar with the present Multiple Mirror Telescope (MMT) and who have participated in the deliberations already undertaken relative to its conversion to a large single-mirror telescope. The additional following information may be helpful, however, to provide appropriate background for others.

The MMT is a high-quality astronomical telescope with an equivalent aperture diameter of 176 inches (4.47 m), the world's third largest. It is of a unique configuration consisting of six identical individual 72 inch telescopes arranged in a hexagonal pattern within a single optics support structure (OSS) which, in turn, is supported by a yoke in an elevation-over- azimuth mount. The MMT is surrounded by a close-fitting, co-rotating, rectilinear building. The MMT has been in operation since 1978 and was formally dedicated May 9, 1979. It is located approximately 40 miles south of Tucson, Arizona on the 8560 foot summit of Mt. Hopkins on the grounds of the F.L. Whipple Observatory. It is operated and administered jointly by the Smithsonian Institution (SI) and the University of Arizona (UA) via the Multiple Mirror Telescope Observatory (MMTO) with offices located at the Steward Observatory (SO) on the UA campus.

This study was performed by Thomas E. Hoffman who was the original MMT Project Engineer from its inception until the end of 1978. At that time he was also head of the Engineering Department of the Smithsonian Astrophysical Observatory (SAO). Accordingly, he is uniquely qualified to have undertaken this study and did so as an independent consulting engineer under a commission from the MMTO. The major portion of this study was performed from mid-July through mid-October 1987. Hoffman presented preliminary results of this study orally in Cambridge, MA at SAO on 14 October and in Tucson, AZ at SO on 28 October 1987.

INTRODUCTION

The following is a report of a study relative to the conversion of the present Multiple Mirror Telescope (MMT) to a large, single-mirror telescope. This study identifies and quantifies the physical implications of such a conversion of the MMT. It derived from, and is the logical extension of, earlier efforts including a workshop discussion of the issues of such a conversion[1], a preliminary design for a typical wide-field optical layout[2], a preliminary configuration for a specific MMT conversion[3], and an exploratory design for a large, lightweight, spun-cast borosilicate mirror in the appropriate size range[4].

This study was conducted under the generally accepted guidelines of a preliminary engineering design. As such, the accuracy of derived values and dimensions generated from layouts is consistent with that approach and must be reconfirmed by subsequent specific and detail design studies. In addition, the study was performed using English engineering units except that primary mirror diameters are presented also in metric units.

APPROACH

The thrust of this study was fourfold. First, the feasibility of converting the MMT to a large single-mirror telescope was investigated from an engineering judgement perspective. Second, the range of primary mirror diameters and focal ratios compatible with such an MMT conversion within given limitations was generated. Third, the physical and operational limitations and implications of accomplishing the conversion within the mirror diameter and focal ratio range were determined. And last, the estimated relative costs and schedule implications for achieving the conversion were established.

The MMTO staff, in concurrence with the author, established several initial guidelines to limit the extent of the study to within practical bounds. These guidelines limit consideration of conversions to: (1) those which would not overload and/or require modifications to or replacement of the mount azimuth bearing, the bearing support, the azimuth drive or the pier; and (2) those which would not overload and/or require modifications to or replacement of the building azimuth support wheel assemblies, the track, the drive, the basic building structure or the foundation. These guidelines, however, did allow consideration of conversions which might require modifications to the mount above the azimuth bearing (e.g. further separation of the yoke arms) and/or non-major modifications to the building (e.g. extending the shutters).

In addition, it was decided at the outset that the primary mirror would be of the new type under development by UA's Large Mirror Group directed by Roger Angel. That is, the primary mirror would be a flat-backed, parabolic spun-cast borosilicate mirror lightweighted by about 80% (i.e., approximately 20% the weight of a solid mirror) via internal honeycomb cavities and it would have an aspect ratio (diameter/average thickness) of 8.0[4].

Also, for purposes of this study, it was determined that the optical configuration of the converted MMT should closely follow the layout and proportions developed by H. Epps in his earlier specific optical design[2]. Accordingly, the focal plane was placed 24 inches behind the flat back of the primary mirror and the generic optical layout was configured for a field of view of 45 arcminutes minimum.

Furthermore, it was obvious from the beginning that the overall envelope dimensions of the converted MMT installation will depend significantly on the size, shape and weight of the maximum instrument to be utilized on that telescope. Accordingly, upon request, the MMTO defined such an instrument – a large spectrograph with a top box and image derotator – by extrapolation from a similar existing spectrograph used with the present MMT. The maximum instrument was thus determined to require a clearance of 84 inches beyond the focal plane and to weigh approximately 4000 pounds with a center-of-gravity about 36 inches aft of the focal plane. Additionally, the associated top box and image derotator together would weigh about another 2500 pounds and would logically be located midway between the mirror flat back and the focal plane.

Within the guidelines and limitations outlined above, the approach to this study entailed the parametric design of geometrically-similar telescopes within the range of primary mirror diameters and focal ratios under consideration. These generic designs were based upon a conventional telescope configuration using steel space-frame structure. They incorporate a full-diameter secondary structural support ring with a spider-supported secondary hub and mirror assembly. Additionally, to minimize overall weight, to conserve important space and to take full advantage of the geometry resulting from fast primary mirrors, the primary mirror cell was considered to be an integral part of the basic telescope structure and the logical structural location for the elevation axis support.

The primary mirror diameters considered were from 230 inches (5.8 m) to 310 inches (7.9 m). The primary mirror focal ratios considered were from 1.0, an arbitrarily established lower limit, to 2.0. Combinations of mirror diameter and focal ratio within these ranges were judged to more than cover the possible viable candidates for the MMT conversion. An additional criterion incorporated in the generic telescope design is that the transverse gravity deflection at the secondary structural ring should not exceed 5 thousandths of an inch, i.e. 5 mils. This small deflection value defines a structure having a natural frequency of 44 Hertz and may exceed the structural rigidity that can be economically achieved.

Optical considerations for fast primary mirrors indicate that decentration allowances will be in the vicinity of 1 mil or less. This stringent requirement coupled with the practical limit of structural rigidity that can be provided will require that the secondary mirror position relative to the primary mirror be controlled. This control may be achievable by clever passive means such as compensating transverse and rotational structural deflections. It is more likely, however, that an active control will be necessary. Weight and cost allowances for an active control unit have been included in this study.

Additional simplifying assumptions have been incorporated in the study to limit its scope to manageable proportions. One of these was to trade off the weight of the optical corrector cell against the weight saving corresponding to the primary mirror central hole. Thus, weight and center of gravity location calculations for primary mirrors were greatly simplified. Based on the specific optical design generated by H. Epps[2], this assumption appears to be a good one. Also, the location of the corrector cell positions it within the central hole of the primary mirror such that axial weight distribution, i.e. moments, are essentially maintained. Another assumption incorporated throughout the generic design was that the outside diameter of the primary mirror cell and the secondary structural ring be ten percent larger than the primary mirror diameter under consideration. This annular allowance for structure outside the mirror aperture is not excessive but is considered realistic for the compact design necessary to achieve an optimal conversion.

Also, because it would be impractical to generate parallel optical designs for all combinations of primary diameter and focal range of interest, a decision was made to base all the generic telescope designs on a constant secondary mirror diameter and, hence, weight. A secondary mirror diameter of 64 inches was selected. This compares to a 64.2 inch diameter secondary mirror in the Epps design[2]. A mirror of this diameter with an appropriate thickness and some lightweighting was estimated to weigh 700 pounds. This was added to weight estimates for the secondary hub, mirror supporting, focusing and positioning mechanisms and spider elements to arrive at a total of 1200 pounds as a constant load at the secondary plane.

Finally, a counterweight set at twice the maximum instrument weight, i.e. 8000 pounds, was included in the generic telescope designs. It was located axially at the elevation axis when the maximum instrument was in place. This placement results in a minimum moment of inertia for the telescope about the elevation axis. Because of the two-to-one weight ratio, the counterweight must move rearward half the distance to the instrument center of gravity when no instrument is in place. This approximates the counterweight arrangement employed in the present MMT and many conventional telescopes.

GENERIC TELESCOPE DESIGNS

The starting point for the generic telescope designs was the primary mirror. Pertinent primary mirror parameters and their analytical relationships are presented in Figure 1.