FAST: a Folded Astronomical Space Telescope

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ABSTRACT

A Folded Astronomical Space Telescope (FAST) is a 2.4-m Hubble Space Telescope (HST) class of telescope that can be packaged in a 1.5-m diameter cylinder through use of a single ring of eight deployable segments. Because it has less mass and uses a much smaller booster to inject it into orbit, the cost is greatly reduced. The enabling rationale, general configuration, and optical technologies for such a telescope are presented.

2. OBJECTIVE

The goal of FAST is to make it possible to provide astronomers with large aperture space telescopes at a small fraction of the cost of the HST. Large, expensive science spacecraft are not on the realizable horizon for the first decades of the 21st Century. The guidelines today are *small, quick* and *affordable*. To meet these goals future large space optical telescopes need to be significantly different from the classical and conservative form represented by the HST. The goal is to provide a 3- to 5-meter class precision astronomical telescope that can be launched on a medium-sized unmanned booster such as Atlas or Delta.

3. BACKGROUND

The proposed Large Deployable Reflector (LDR) was an ambitious attempt to provide astronomers with a 20-m diameter telescope for infrared and sub-millimeter observations. A total of 96 mirror segments was required. Studies addressed several modes for achieving such a large telescope using the dimensional and mass constraints of the Shuttle. In the course of this project deployable and space-assembled options were studied. As practical problems were addressed it became apparent that the LDR would require both multiple Shuttle missions and assembly at a Space Station. In order to ease the precision required in assembling the primary mirror segments, the concept of "two-stage optics" was developed wherein the final phasing would be done at a 1-meter diameter segmented mirror located at an exit pupil. The estimated cost for the several scenarios showed that the LDR was unaffordable, even assuming an assembly facility at the Space Station. While such innovations as two-stage optics for alignment and phasing of the mirrors reduced the cost significantly it was clear that the LDR would have to await some day far in the future.

4. PHILOSOPHY

The philosophical approach to FAST was to reduce the cost to a point where replacement would be the most cost effective option rather than in-orbit refurbishment. This would provide more missions, economies of a sustained production line, and modular construction. More importantly, each telescope would be optimized for a particular set of science objectives. The goal would be to provide the resolution and light grasp required for post-HST astronomy.

To meet the new guidelines of *small, quick* and *affordable* we thus propose the concept of a minimally deployable primary mirror that is folded into a compact package for launching. This Folded Astronomical Space Telescope could provide the means to reach the goal of an HST-class telescope at an acceptably low cost. Coupled with this configuration would be a very fast primary focal ratio such that the deployed telescope would still be very compact and have a minimum moment of inertia.

5. DESIGN CONCEPT

The folded telescope concept is shown in Figs. 1 and 2, where the folded and deployed telescope are shown side-by-side. The eight mirror segments are in two rings of four, with the A-segments in the outer ring and the B-segments in the inner. A mechanism has also been developed that simultaneously deploys both the solar panels and the light shield structure. The very small size of a 3-meter FAST as compared with the 2.4-m HST, including the small size booster that would be required, is shown in Fig. 3.

6. COST LEVERAGE

In order to see how costs can be reduced to a point where telescopes larger than HST can be achieved within the constraints of fiscal reality, we need to examine the sources of the mission cost. There are five principal cost elements with the following per centages:

Telescope	10%
Focal plane instrumentation	10%
Balance of spacecraft	20%
Booster (STS or major booster)	30%
Non-hardware program costs	30%

The fast focal ratio and folded launch configuration would have leverage on costs through a smaller telescope structure and mass. The added complexity of the deployable aspects of the mirror and light shield probably would raise costs and offset gains from the smaller size of the telescope structure. The smaller mass and dimensions would mean a smaller moment of inertia, which would lead to a smaller power requirement for control of the spacecraft. Most importantly, the compactness and small mass of the payload would lead to a smaller booster. Altogether these several factors would provide leverage on 60% of the total mission cost. Selective, optimized science would have leverage on only 10% of the mission cost.

If decision, contracting and review processes could be streamlined one could foresee a shorter time to launch and leverage on 30% of the mission cost.

7. WAVEFRONT UPGRADING

Deployability has the cost of upgrading the wavefront, depending on the wavelength and resolution requirements. The primary mirror could be aligned for diffraction-limited operation beyond 20 mm by mechanical techniques. For shorter wavelengths the wavefront would need to be upgraded. This can be done directly on the primary mirror or at an exit pupil[1]. An off-axis configuration for the exit pupil mirror is shown in Fig. 4. The former choice would minimize the total number of reflections in the telescope, such as for far UV observations. The latter would entail two additional optical elements, usually mirrors, such as for visible and near infrared observations.

8. TECHNOLOGY CHALLENGES

Our examination of a preliminary mechanical design for FAST shows that the required technology is within that currently under exploration and development by the optics community, and that it could be included in the NASA Optics Initiative.

9. ACKNOWLEDGMENTS

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10. REFERENCES

1. Aden B. Meinel and Marjorie P. Meinel, "Two-stage optics: high-acuity performance from low-acuity optical systems," *Opt. Eng.* **31**(11), 2271-2281 (1992).

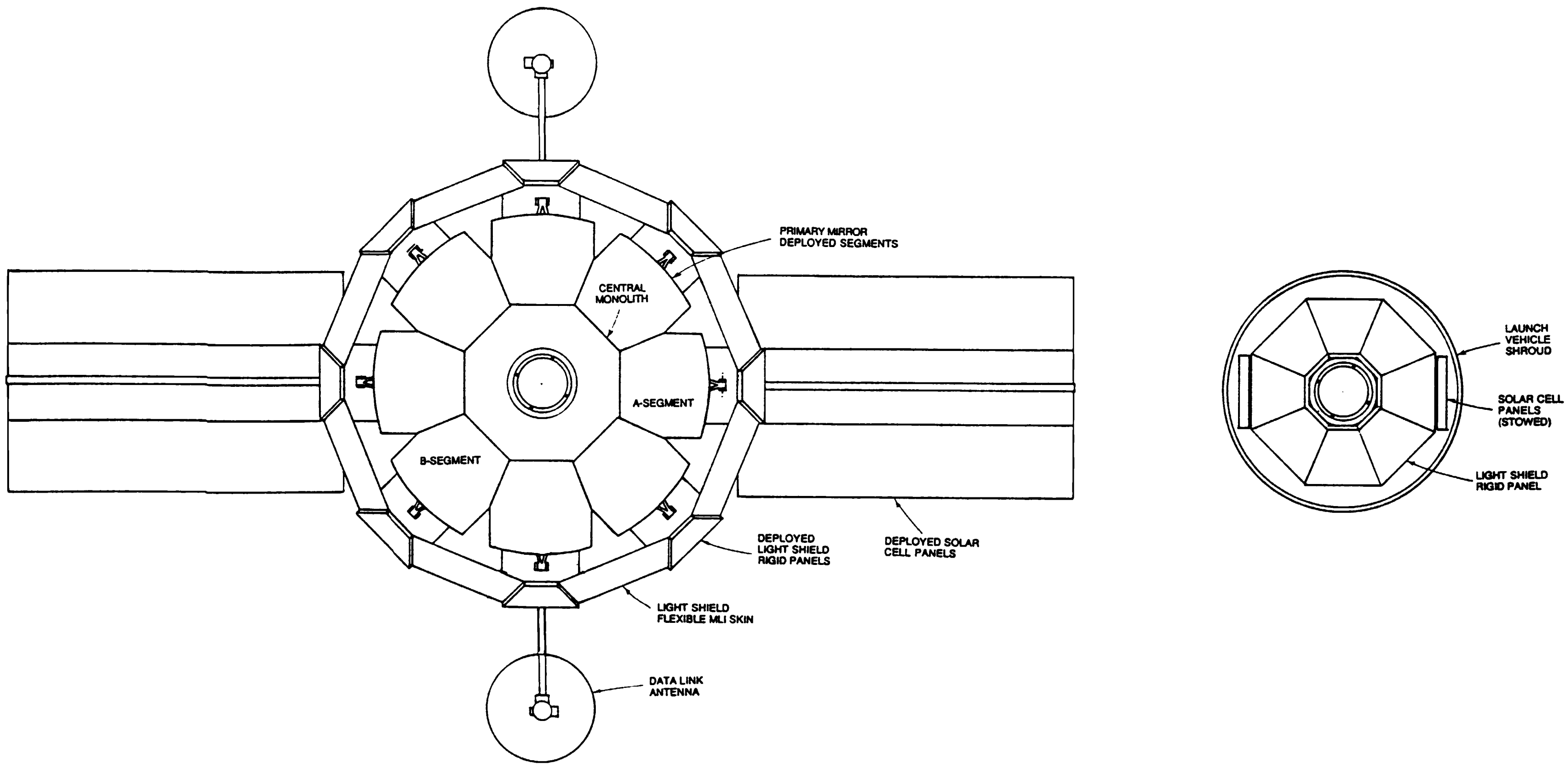

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Fig. 1. Front view of a Folded Astronomical Space Telescope configuration having an eight-segment primary mirror.

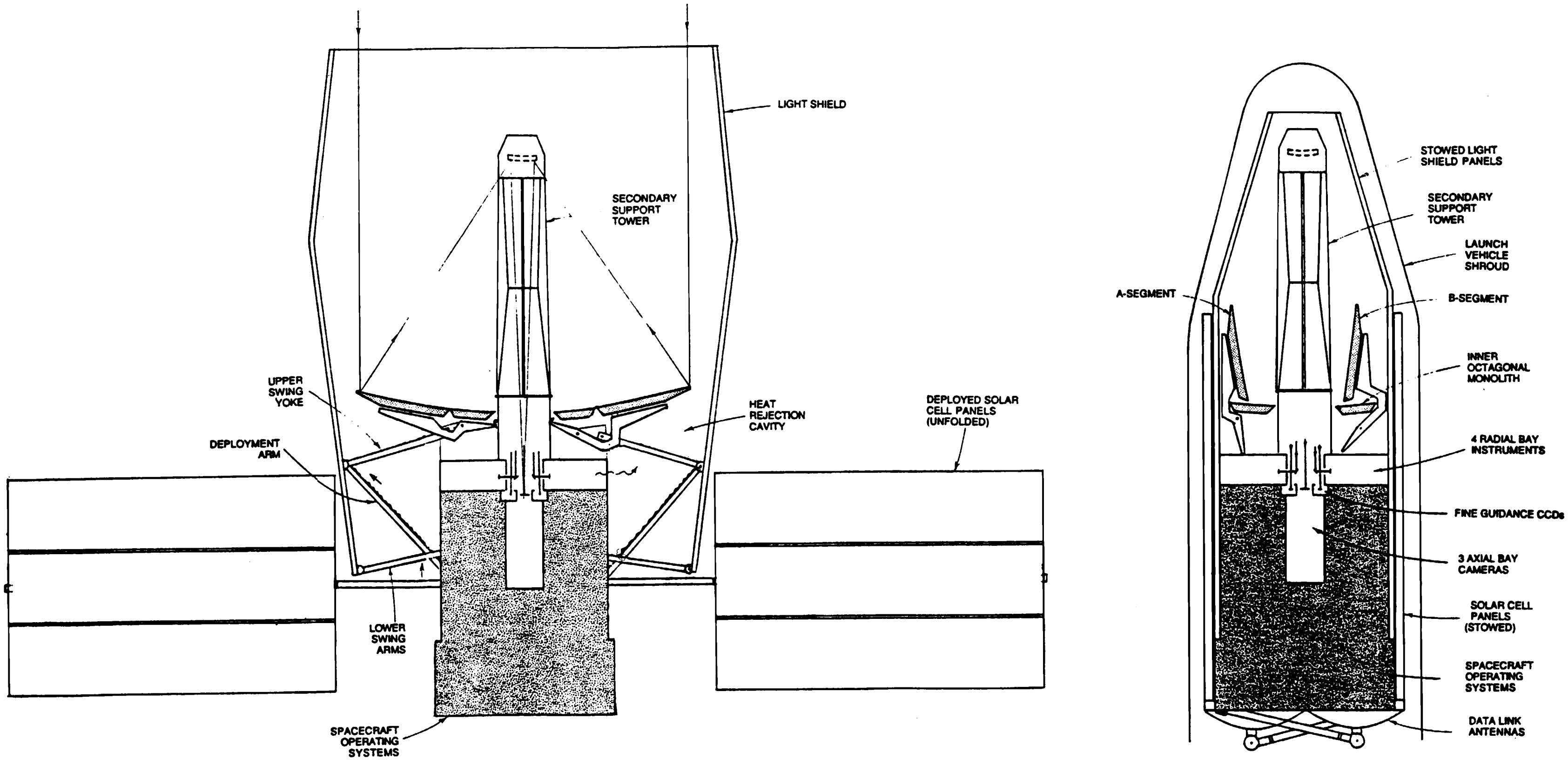

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Fig. 2. Side view of a two-mirror Folded Astronomical Space Telescope configuration showing the means for deploying both the primary mirror and the light shield.

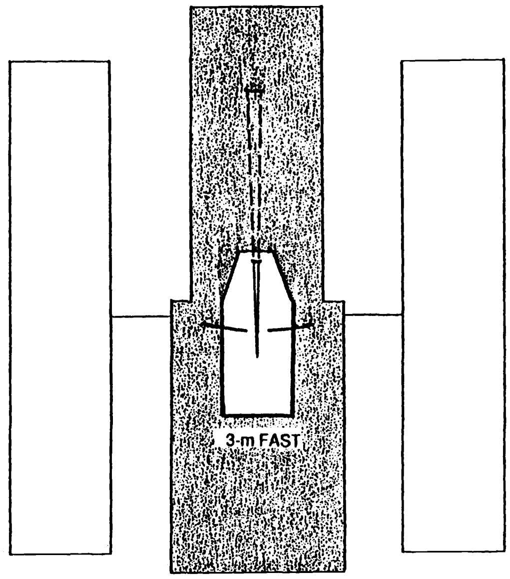

Fig. 3. Side view showing the relative size of a 3-m FAST compared to the 2.4-m HST.

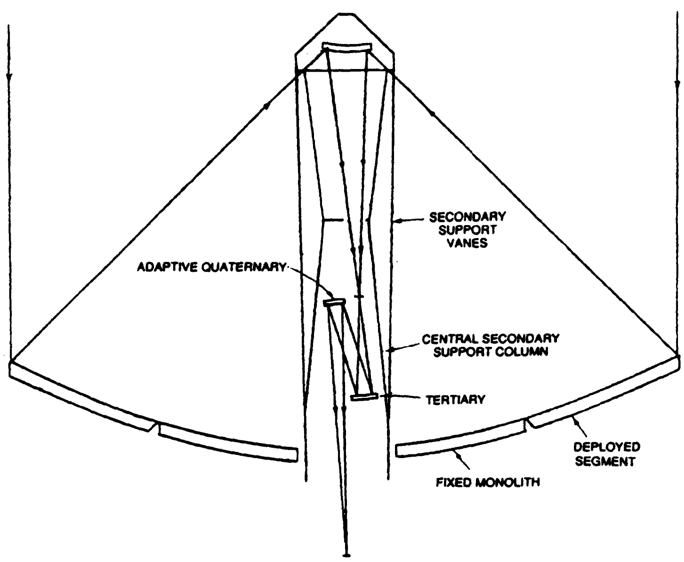

Fig. 4. A possible two-stage optical variant of FAST where wavefront upgrading is done at the small off-axis quaternary mirror.