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Coherent Phasing of Segmented Mirrors

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The technical issues associated with a coherently phased segmented mirror can be divided into two types. The first involves the issues of manufacturing the surface quality of the mirror segments themselves (coherent phasing of individual segments). The second involves assembly issues of initializing in "1G" and retaining in "0G" an aggregate segmented mirror (coherent phasing between individual segments).

Using a rectangular coordinate system at the vertex of a mirror segment, the rigid body motions are the six translational and rotational degrees of freedom. Assuming that two translational degrees of freedom and one rotational degree of freedom of the segments are constrained within the tolerance allocations, the unconstrained degrees of freedom of concern for sensing and control are, therefore, the two remaining rotations (segment tip and segment tilt) and one translation (segment piston).

Shown in FIGURE 1 are the radii of a 20-meter diameter, f/0.5, parabolic mirror. The inability to manufacture an optical element to the designed meridional and zonal radii directly affects the lens focal length and can contribute to spherical aberration. For a monolithic aspheric mirror, the radius is manufactured during the contour generation step and measured to the final known accuracy in an interferometric test configuration, using a null corrector. An additional metrology issue is imposed on a coherently phased segmented mirror. A mismatch between radii of the segments and the design radius of the overall mirror will also result in a wavefront error.

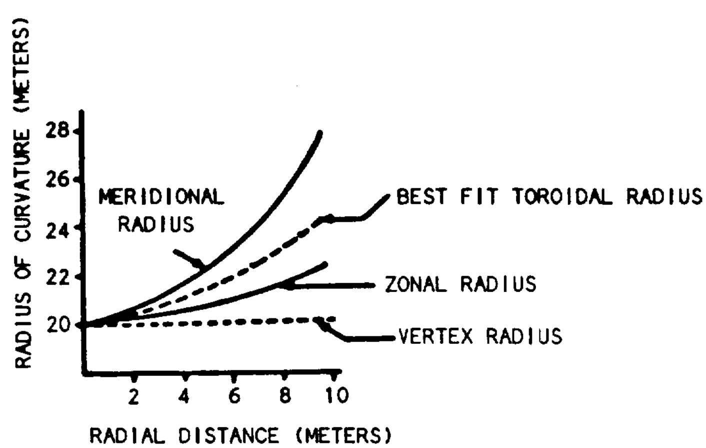

FIGURE 1. Radii for an f/0.5 Parabolic Mirror

A "first cut" primary mirror wavefront error budget is shown in FIGURE 2. For a minimum operational wavelength of 30 micrometers, the derived values from the budget are: segment surface quality (0.45 μm RMS), radius mismatch (50 PPM), segment piston error (1.3 μm), segment tip/tilt error (0.6 μrad).

Either active or passive segmented mirrors can be addressed, but if the surface quality of the off-axis segment and the radius matching requirements can be passively met, then only segment alignment (that is, segment tilt and segment piston error) need be sensed and controlled during operation in orbit. For the active mirror case, dimensional stability of the mirror material during operation is a key factor in establishing the degree of active figure control required. The impact of CTE variability on the minimum operating wavelength can be reduced by: (1) utilization of a smaller segment, (2) operation at a longer minimum wavelength, (3) development of a composite material that meets the CTE goal of $<0.03 \times 10^{-6}$ /K with low variability, and (4) active radius control (for a sphere) or active figure control (for an asphere).

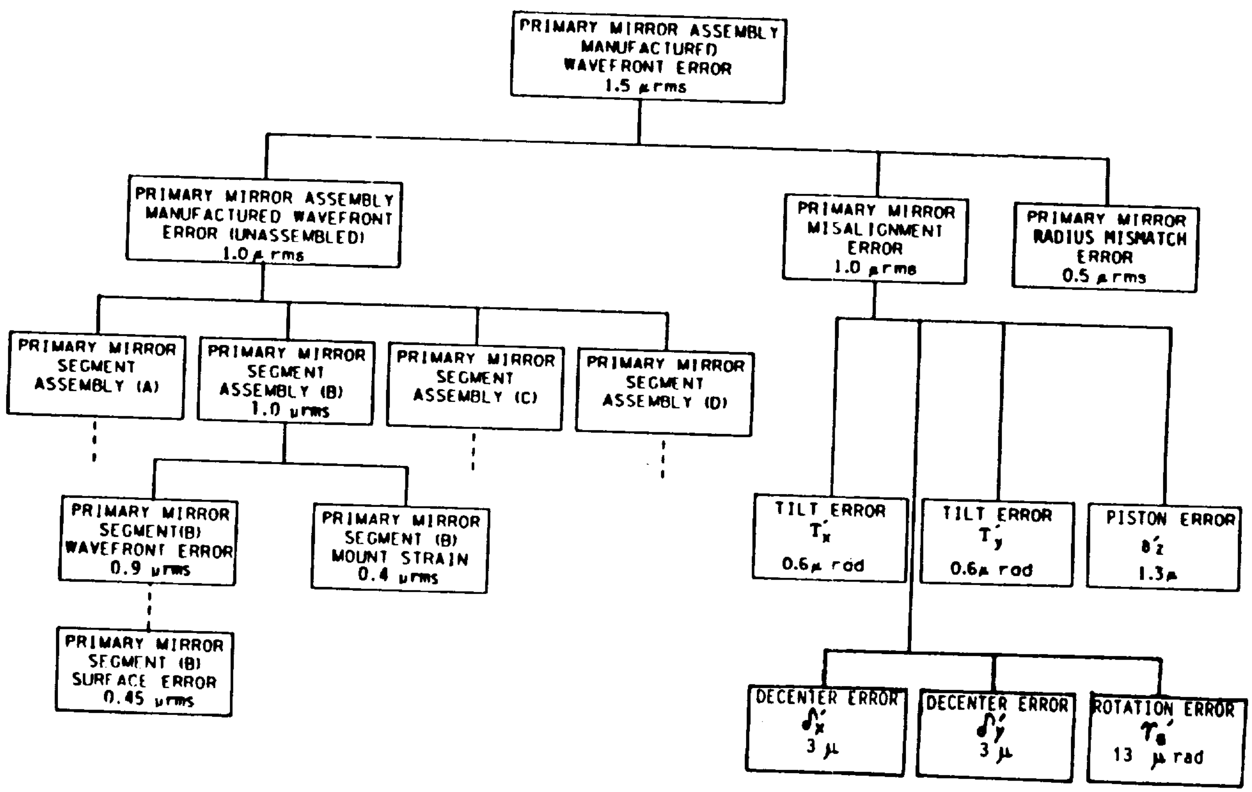

FIGURE 2. Primary Mirror Wavefront Error Budget