Proc. of SPIE Vol. 1167, Precision Engineering and Optomechanics, ed. D Vukobratovich (Nov 1989) Copyright SPIE

Design of the GOES Telescope Secondary Mirror Mounting

Robert A. Hookman

ITT Aerospace Optical Division
Fort Wayne, Indiana

ABSTRACT

The GOES Telescope utilizes a flexure mounting system for the secondary mirror to minimize thermally induced distortions of the secondary mirror. The detailed design is presented along with a discussion of the microradian pointing requirements and how they were achieved. The methodology used to dynamically tune the flexure/secondary mirror assembly to minimize structural interactions will also be discussed.

INTRODUCTION

The Geostationary Operational Environmental Satellite (GOES) Telescope is a subsystem of the GOES instrument(see fig. 1), which is used for meteorological purposes. The GOES telescope(see fig. 2) is a cassegrian type telescope with two mirror elements, the primary mirror has a clear aperture of 12.25 inches and the secondary mirror has a clear aperture of 1.53 inches. The GOES telescope utilizes a passive athermalization system in its metering structure to maintain the prealigned spacing between the primary and secondary mirrors over the orbital operating environment.

The athermalization system consists of six INVAR metering tubes which have a very low coefficient of thermal expansion (CTE) and aluminum structures which house the mirrors, the primary cell and spider assembly. The athermalization system functions by having the aluminum counteract the expansion of the INVAR metering tubes. This method of athermalization is very effective for bulk temperature changes. The GOES telescope is housed within the instrument cavity, the telescope is exposed to reflected sunlight off the scan mirror for several hours followed by long periods of no solar heating. During the period of no solar heating the telescope components have a view of the earth and space (in a heat transfer sense). The temperature of the telescope structure is predicted to range from 1 deg. C to 54 deg. C with gradients of up to 8 deg. C in the structure.

The GOES telescope is a crucial component in the optical path of the GOES instrument, and one of the most demanding requirements for the instrument is the stability and repeatability of the pointing or boresight. The pointing stability requirements and the extreme operating temperature is the reason a flexure mounting system is utilized for the GOES telescopes secondary mirror.

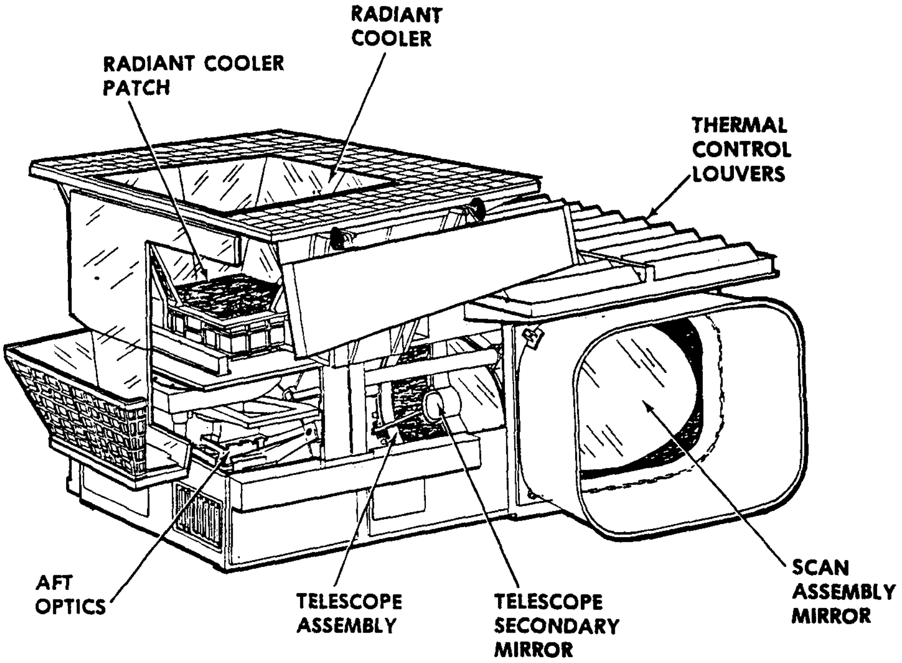
DISCUSSION

This paper will cover the design features of the GOES telescopes secondary mirror mounting. The GOES instrument does not have any means of actively correcting for optical shifts in the telescope such as focus position or boresight. For the GOES instrument to meet its registration and pointing requirements, the telescope has to have a very high degree of boresight repeatability during thermal induced boresight drifts. It is required that the GOES telescope be repeatable in boresight to within 10 microradians for the identical set of temperature conditions. Therefore the mission requirements and the instrument design configuration dictates that the GOES telescope be designed to have an extremely stable structure over its 7 year design life and to minimize any potential sources for repeatability errors during temperature transitions. First the design goals for the secondary mirror assembly will be reviewed, then the design secondary mirror mounting will be reviewed in detail. The methodology used to dynamically tune the flexure/secondary mirror assembly for minimize of structural interactions will also be reviewed.

Design Goals:

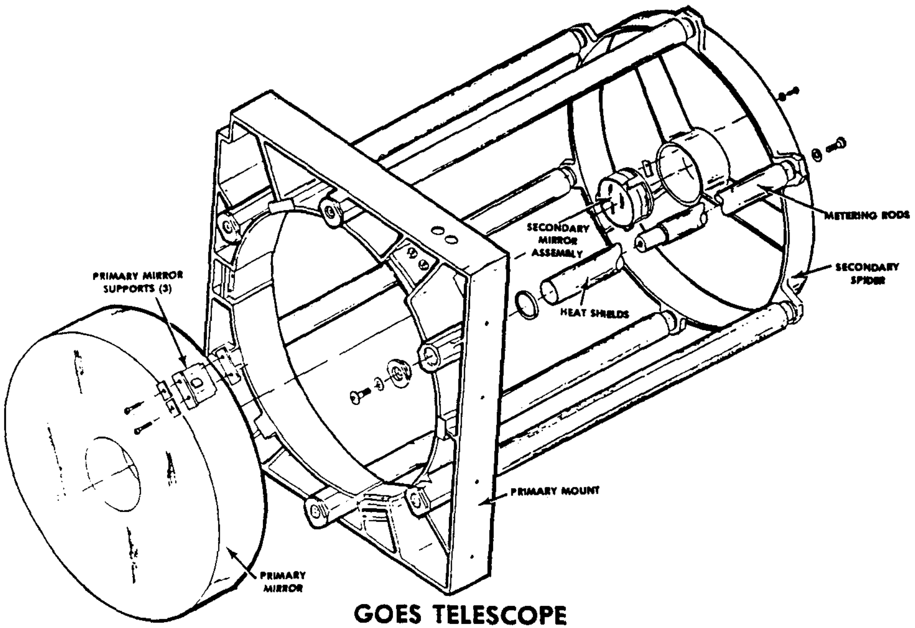
To obtain a clear understanding of what the secondary mirror mounting has to accomplish the design goals should be reviewed. They are as follows:

1. To provide a means of interfacing with the Ultra Low Expansion (ULE) material from which the secondary mirror is made, without inducing changes in the figure of the secondary mirror.
2. To maintain the axial position of the secondary mirror to approximately 10 microinch over the life of the telescope.
3. To maintain angular registration of the mirror to less than 10 microradians over a diurnal temperature cycle (this corresponds to a pointing error of 2.5 microradian for the telescope).



GOES SOUNDER INSTRUMENT

FIGURE 1

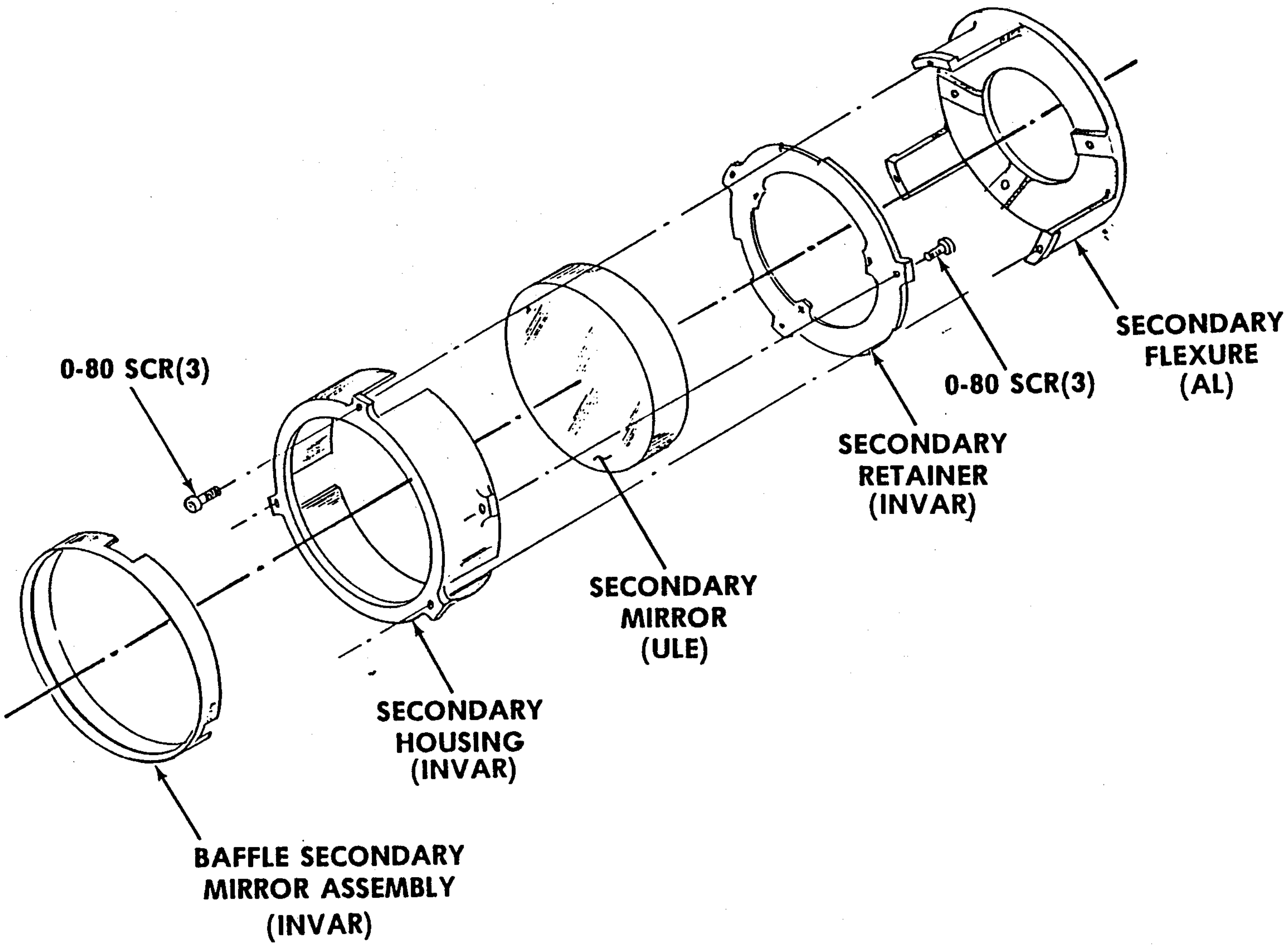


GOES TELESCOPE

FIGURE 2

SECONDARY ASSEMBLY

FIGURE 3



4. Maintain registration and axial position of the secondary mirror over the launch and the test vibration environment.
5. Minimize forces between the secondary mirror and the mounting structure.
6. Provide a means for alignment of the GOES telescope at the secondary mirror mounting location.

The above goals were used as guidelines in the design of the secondary mirror mounting and although they are very general the remaining discussions shall be much more detailed. The methodology developed for aligning the GOES telescope will not be covered in this paper.

Secondary Mirror Mount Design:

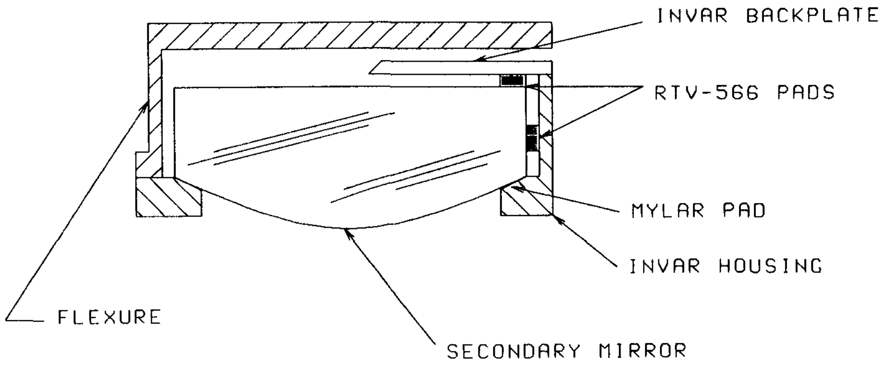
The secondary mirror mount design is shown in an exploded view in figure 3. It is comprised of a ULE secondary mirror, an INVAR secondary housing, a secondary retaining plate which is also made of INVAR, and an aluminum flexure assembly, a portion of the secondary mirror baffle is also shown. The low expansion secondary mirror(CTE = .026PPM/ C) is mounted in a low expansion INVAR housing with the use of RTV-566, which is used to form elastomeric springs, for a compliant mount in the axial and radial directions. After the secondary mirror is securely mounted into the INVAR(CTE = 1PPM/ C) housing, the low expansion materials (INVAR, ULE) need to be tied into the aluminum(high expansion CTE = 23PPM/ C) spider, without inducing large forces into the spider or the secondary mirror. This is accomplished by bridging the INVAR housing and the aluminum spider with a three aluminum flexure blades as shown in figure 3.

Secondary Mirror Housing and Elastomeric Spring Design:

To meet the system requirements the secondary mirror must be securely mounted in place without any possibility of shift during thermal excursions or when exposed to the launch vibration environment. To accomplish this the secondary mirror was deterministically mounted within the housing and the mount induced loads along with the load paths were considered. A cross section of the secondary mirror mounting is shown in figure 4. The secondary mirror is registered off its front surface outside the clear aperture, against three raised mylar(.002 inch thick) pads. The mylar pads are equally spaced around the perimeter of the housing and are then bonded in place with epoxy to the housing, this method guarantees that the mirror is registered at three deterministic points. The use of the mylar also insures that there is no glass to metal contact. Now that the front surface of the mirror is seated, to prevent the mirror from translating radially, three radial elastomeric springs are formed using RTV-566. The radial elastomeric springs are located on the neutral axis of the mirror, to prevent any bending of the mirror, the pads of RTV-566 are .20 inch in diameter and .010 inch thick. Similar RTV pads are utilized to retain the secondary mirror in its axial position, in this direction the RTV pads have a preload applied to them to prevent/preclude any axial shifts in the secondary mirrors axial position during launch or vibration testing. The RTV-566 is potted in place to form a .20 inch diameter and a thickness of .025 inch,

SECONDARY MIRROR CROSS SECTION

FIGURE 4



the preload was accomplished by compressing the RTV pads .002 inch, this resulted in having a preload force of 2.15 lb minimum. The axial RTV pads are located directly above the mylar pad so that the preload forces will not cause distortions in the secondary mirror. After the mirror is retained within the housing, a check of its figure is made to verify that the mirror is not distorted. The method of mounting the secondary mirror is very deterministic and meet the goals set for the assembly.

Secondary Mirror Flexure:

After the secondary mirror is securely mounted into the INVAR housing with the use of the RTV-566, the low expansion materials (INVAR, ULE) need to be tied into the aluminum (high expansion rate) spider, without inducing large forces. This is accomplished by bridging the INVAR housing and the aluminum spider with a single piece aluminum flexure as shown in figure 3. The flexure is designed to be radially complaint, so that when the structures experience bulk temperature changes only minimal radial forces can be transmitted into the secondary mirror. Since only small forces are transmitted through the interfaces, this also guarantees that there will not be any slippage at the interfaces. The secondary mirror flexure consists of three blade flexures equally spaced at 120 degrees, machined from a single piece of aluminum alloy 6061-T651. The flexure blades are .50 inches long, .32 inch wide and are .020 inches thick. The end of the flexure has a threaded attachment hole and the secondary mirror housing is bolted at 3 locations around the perimeter, with #0-80 UNC cap screws. The finished assembly forms a very stiff, efficient and compact assembly which can withstand large bulk temperature changes with out changing the figure of the secondary mirror. With this type of design there are no sources of repeatability error.

Secondary Mirror Dynamics:

The secondary mirror assembly is the last component out at the end of a multiple degree of freedom cantilevered system. The first mode of vibration of the GOES telescope is 72 Hz and the system is very mode rich with extremely high amplification ratios to beyond 1500 Hz. Refer to figure 5 for a typical dynamic response from the GOES telescope spider. The goal for the design of the secondary mirror flexure is to avoid having the first mode of natural frequency interact with one of the telescopes. There are two methods of determining the precise natural frequency of a complex dynamic system, one is to model the system analytically with finite element methods and the second is to determine it experimentally. In this case experiential methods were used to correlate analytical equations of motion for the first mode of vibration.

A flexure system of this type can be thought of a single beam system with a concentrated mass at the end. Since the beam is some what fixed on both ends(since this is a lightweight telescope design none of the ends can be considered infinitely rigid), modeling the system as a true cantilevered or a true guided structure cannot be assumed and the real system will behave somewhere in between. The basic equation of motion for a single degree of freedom system is as follows:

fn =(1/2pi)((k/m)**1/2)

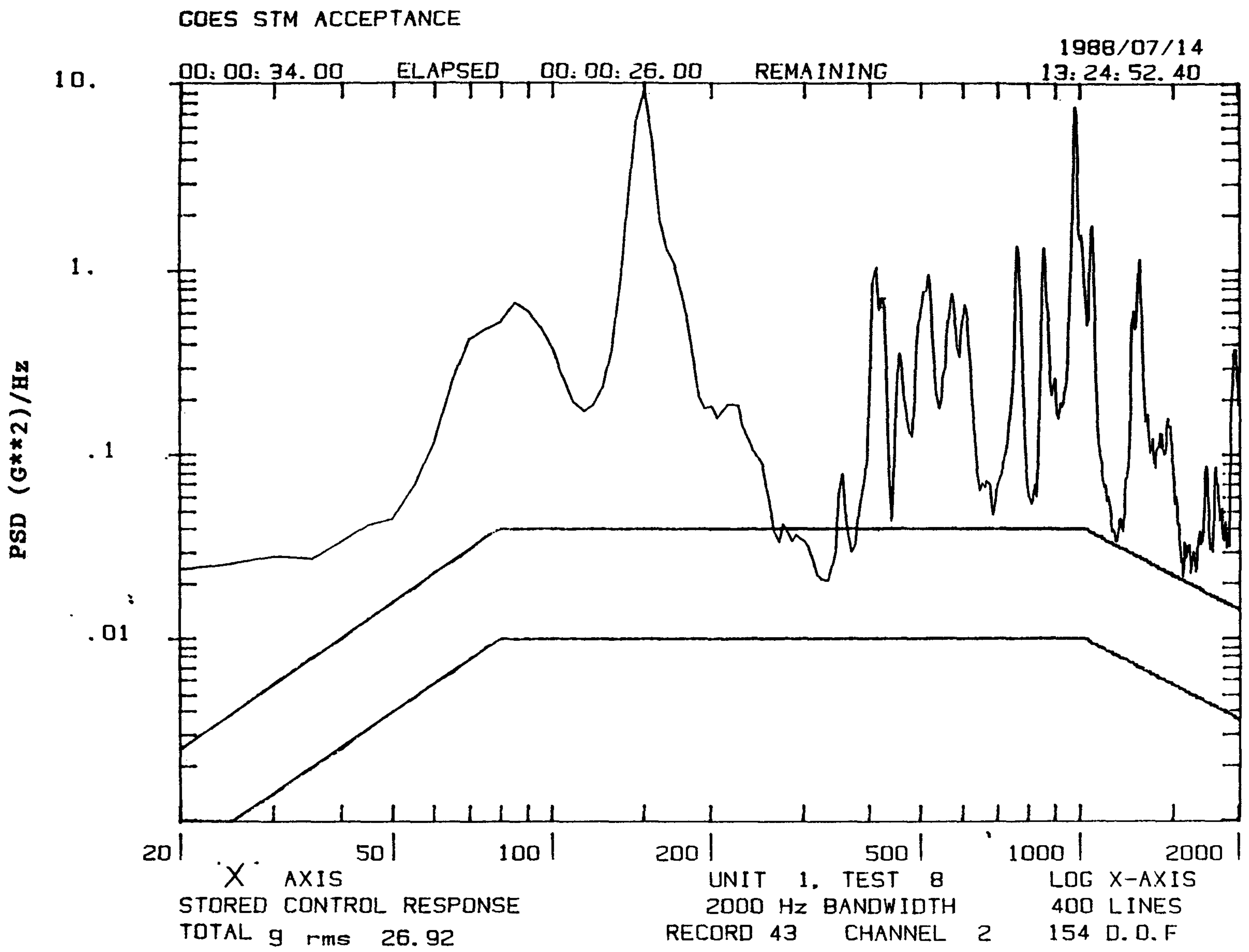
fn = natural frequency
k = system stiffness
m = system mass

The stiffness of the secondary mirror assembly was found to behave like that of a cantilevered system the stiffness equation has the following form:

k(cantilever)= 3EI/L**3

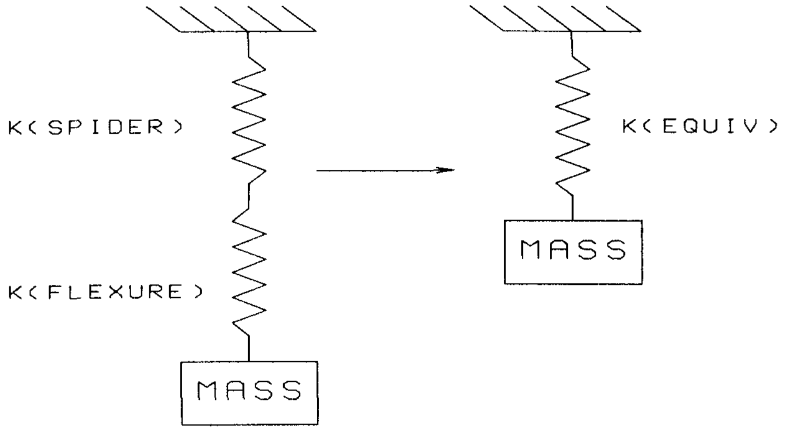
E = modulus of elasticity
I = moment of inertia
L = flexure length

The original prototype secondary mirror flexure design had the first mode of natural frequency of 750 Hz when mounted on a rigid fixture structure, but when the secondary mirror assembly was mounted on the spider of the GOES telescope prototype structure, the first mode of natural frequency dropped to 600 Hz. The natural frequency of the secondary mirror assembly landed directly over a very active mode present in the spider at 600 Hz, therefore this required a change in the natural frequency of the secondary mirror flexure assembly. After reviewing the dynamic response of the spider, it was determined that if the natural frequency were moved to around 850 Hz there would be very little dynamic or structural interaction. To determine the required stiffness change for the flexure, the system was modeled as a spring mass system comprised of two springs in series. The net system was made up of K(flexure assembly) and K(spider/telescope structure), the system stiffness is designated K(equivalent) refer to figure 6 for the equation for combining the individual springs into one equivalent spring.



GOES TELESCOPE DYNAMIC RESPONSE AT SPIDER HUB

FIGURE 5



$$\frac{1}{K(EQUIVALENT)} = \frac{1}{K(FLEXURE)} + \frac{1}{K(SPIDER)}$$

K(EQUIV)	K(FLEXURE)	K(SPIDER)	NATURAL FREQ (IN SYSTEM)
4,050 LB/IN	6,384 LB/IN	11,077 LB/IN	600 Hz
7,699 LB/IN	25,244 LB/IN	11,077 LB/IN	832 Hz

EQUIVALENT STIFFNESS METHOD
FIGURE 6

It was determined that the stiffness of the flexure assembly would have to be increased by a factor of four in order to increase the natural frequency to around 850 Hz. After the flexure design was modified to increase the stiffness, the resulting first mode of natural frequency for the flexure assembly was 1500 Hz when mounted on a rigid fixture. Using the above equation for the combination of springs, the resultant predicted natural frequency was 832 Hz. The actual natural frequency that was measured in the system was 830 Hz. The methodology for tuning the natural frequency of the secondary mirror assembly was very effective in this situation, and the interaction of two natural frequencies were avoided.

SUMMARY

The GOES telescope is required to operate in a very harsh temperature environment and meet very demanding optical requirements. The secondary mirror mounting design utilizes an INVAR housing to incase the secondary mirror, and the mirror is potted in place with RTV-566, which is used to form elastomeric springs. An aluminum flexure is then used to minimize the radial forces transmitted into the secondary mirror during bulk temperature changes. It was demonstrated that a flexure system can be reduced to an elementary model, and dynamic characteristics can be tuned to meet the needs of the system. The GOES telescope secondary mirror mounting design meets the stability and repeatability requirements of the GOES instrument.

ACKNOWEDGMENTS

This work was performed at ITT Aerospace/Optical Division on the GOES program for Ford aerospace Corporation under subcontract SC-922800-AZ and NASA under prime contract NAS-5-29500.