Stratospheric Observatory for Infrared Astronomy (SOFIA): Flight Spare Mechanism for the Secondary Mirror

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The performance of modern astronomical telescopes depends critically of the quality of their secondary mirror mechanisms. Over the years, CSEM has developed a particular expertise for this type of high-precision opto-mechatronics systems. In order to ensure continuity of the Stratospheric Observatory for Infrared Astronomy (SOFIA) observatory, CSEM was mandated to manufacture a spare system for the secondary mirror.

The (SOFIA) 2.5-m telescope is sponsored jointly by the US and German aerospace agencies NASA and DLR. The telescope is carried by a revised Boeing 747-SP aircraft in a special compartment, which can be opened during flight. The telescope is operated at about 14 km altitude, at temperatures down to –55°C and a pressure of 120 mbar.

Figure 1: SOFIA Boeing 747 with the telescope door opened.

The SOFIA Secondary Mirror Mechanism (SMM) has a diameter of 350 mm and comprises a complex mechanism providing precision motion control along 8 degrees of freedom, divided into two main sub-systems:

- The Focus-Centre Mechanism (FCM) which provides the static fine alignment capability for focus, centring and tip/tilt. The FCM consists of a hexapod mechanism of particular and compact geometry.
- The dynamic Tip/tilt-Chopping Mechanism (TCM) provides the fast tip-tilt-chopping actuation. The kinematics of the mechanism relies entirely on various flexure components: elastic rods, membranes, and cross pivots which provide original frictionless mechanical links.

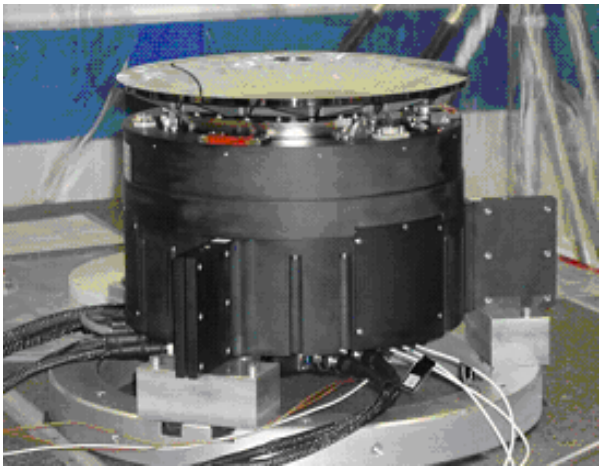

Figure 2: SOFIA SMM mechanisms (FCM + TCM).

The original SMM assembly was delivered in 2002 to the DLR. A major achievement in 2003 was the integration and final delivery and shipping to the USA of the full SOFIA Telescope. The first astronomical observation (first light) took place only in 2010.

The specifications of the SMM are given in Table 1.

Table 1: SMM main specifications.

Main Requirements	Measured performances
Focus-center mechanism	
Focus (z) range	± 5 mm
Focus resolution	≤ 0.5 µm
Center (x,y) range	± 3 mm
Center resolution	≤ 1 µm
Tip-tilt range	± 0.312°
Tip-tilt resolution	≤ 2 arcsec
Tilt-chop mechanism	
Tip-tilt range	± 0.312°
Tip-tilt blind accuracy	< 2%
Tip-tilt resolution	~ 0.07 arcsec
Chop frequency	0-20 Hz
Chop rise (transition) time	< 7 ms
Chop stability	≤ 1% of chop excursion

Currently the SOFIA telescope is flying regularly, but without any spare items for the SMM. In case of failure, the full plane and telescope is stranded with associated high costs. In 2014, CSEM was mandated to manufacture a complete spare SMM (identical parts to those made 12 years ago), including the control electronics, updated to actual FAA flight standards.

All parts are made identical to the original ones to simplify the exchanges. Unfortunately, for the electronics, most parts and chips are no longer available. Therefore, the electronics is redeveloped with parts available today (with similar specifications) and, in the same time, is made fully NASA Aeronautic Quality compatible. The cabling, pinout and overall behavior shall be held identical to the old electronics to be fully compatible and exchangeable at rack level.

In order to obtain the same mechanics quality of the spare device the same Swiss manufacture providers were selected, as far as possible. A challenge is the procurement of the critical flexure hinge materials and their advanced surface treatments required to improve their corrosion resistance.

For the electronics, the main challenge was to find new equivalent circuits, and to make the new electronic racks fully compatible and interchangeable.

The first spare actuator will be assembled and thermally tested at CSEM premises in 2015, and fully assembled in 2016. Further qualification tests are planned at NASA AMES Centre in Palmdale, USA, in close collaboration with the DSI SOFIA team.