# Compact total irradiance monitor flight demonstration

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**The Compact Total Irradiance Monitor (CTIM) is a CubeSat instrument that will demonstrate next-generation technology for monitoring total solar irradiance. It includes novel silicon-substrate room temperature vertically aligned carbon nanotube (VACNT) bolometers. The CTIM, an eight-channel 6U CubeSat instrument, has a goal of uncertainty <0.01% and stability <0.001%/year. The underlying technology, including the silicon substrate VACNT bolometers, has been demonstrated and tested in relevant environments in an engineering model of the detector subsystem. We are currently building and testing the flight detector unit and will integrate it with a 6U CubeSat in mid-2020, in preparation for an on-orbit demonstration in 2021.**

## INTRODUCTION

Long-term measurements of total solar irradiance (TSI) have been performed from space by a 40-year uninterrupted sequence of instruments [1-5]. In order to maintain this long-term TSI record, space-based TSI measurements need to occur indefinitely; thus, it is advantageous to use modern technological advances to develop miniaturized TSI instruments for integration in future CubeSat and SmallSat platforms, making deployment of these sensors into space significantly easier.

The Compact Total Irradiance Monitor (CTIM) is a 6U CubeSat TSI instrument consisting of two four-channel detector heads, each channel being a radiometer which utilizes vertically-aligned carbon nanotube (VACNT) optical absorbers on silicon substrates.

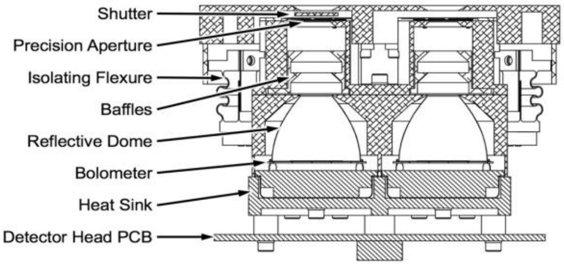

Figure 1: Cross-section of the CTIM detector head showing the optical design and key components.

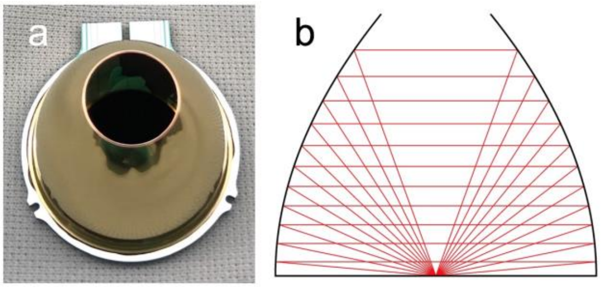

Figure 2: (a) The silicon detector with reflector dome attached. (b) Ray trace of the reflector dome showing that after two bounces off the reflector light scattered by the VACNTs is redirected back.

## INSTRUMENT DESIGN

The design of the CTIM instrument [6] follows the fundamental design of the SORCE TIM instrument [5]. The first optic solar illumination encounters is a precision 5mm diameter ion-etched silicon aperture, see figure 1. Following a short baffle section, the solar illumination then enters the detector cavity. For CTIM we are using a novel design that incorporates a planar silicon detector with a thermally integrated reflector, see figure 2.

Four of these detectors are integrated onto one detector head, and the CTIM CubeSat has two detector heads for a total of eight channels. Each channel includes a bi-stable shutter to modulate the incoming light with a period of 60-100s. The measurement uncertainty of the CTIM is detailed in Table 1.

Table 1: TSI measurement uncertainty.

| Correction | Value | Uncertainty |
|---|---:|---:|
| Aperture Area | 100% | 0.0022% |
| Diffraction Loss | 0.042% | 0.0042% |
| Detector Reflectance | 0.010% | 0.0020% |
| Heater Voltage | 100% | 0.0014% |
| Heater Resistance | 100% | 0.0028% |
| Heater Linearity | 0.050% | 0.0028% |
| Optical/Electrical Non-Equivalence | 0.005% | 0.0050% |
| Dark Signal | 1.222% | 0.0050% |
|  | *Total* | *0.0097%* |

The CTIM design also includes a number of further technology demonstration elements, such as in-situ heater resistance monitoring and wireless detection of the shutter temperature via a miniature thermopile.

## CTIM MISSION

The two flight CTIM detector heads are currently being fabricated. Once assembled, the detector heads will undergo end-to-end radiometric testing in the TSI radiometer facility to validate their measurement scale against a SI-traceable detector [7]. These two heads, and the associated electronics, will be integrated in a 6U CubeSat (~120x240x360 mm). Following flight qualification testing, the CTIM CubeSat will be delivered for a launch in 2021 with a mission lasting at least one year. The key mission goals include comparisons of the relative measurements of the eight channels with respect to each other and to the Total and Spectral Solar Irradiance Sensor Total Irradiance Monitor (TSIS-1 TIM) currently in operation on the International Space Station, allowing assessment of accuracy of CTIM relative to the 0.01% goal, and monitoring the measurement noise and long-term measurement stability of CTIM relative also to TSIS-1 TIM to assess performance relative to the stability goal of 0.001%/year.

## REFERENCES

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