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Net Flux Radiometer for a Saturn Probe

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Abstract

A Net Flux Radiometer (NFR) concept is presented that can be included in an atmospheric structure instrument suite for any future NASA or ESA led Saturn Probe Mission. The current design has two spectral channels i.e., a solar channel (0.4-to-5 µm) and a thermal channel (4-to-50 µm). The NFR is capable of viewing five distinct viewing angles during the descent. Non-imaging Winston cones with window and filter combinations define the spectral channels with a 5° Field-Of View (FOV). Uncooled thermopile detectors are used in each spectral channel and are read out using a custom designed Application Specific Integrated Circuit (ASIC).

1. Introduction

Two notable instruments have flown in the past namely, the Large Probe Infrared Radiometer (LIR) [1] on the Venus Probe, and the Net Flux Radiometer (NFR) on the Galileo Probe [2]. The NFR builds on the lessons learned from the Galileo Probe NFR experiment and is designed to measure the net radiation flux within Saturn's harsh atmosphere [3]. The nominal measurement regime for the NFR extends from ~0.1 bar (near the tropopause) to at least 10 bars, corresponding to an altitude range of ~79 km above the 1 bar level to ~154 km below and a temperature excursion of ~85 K to ~300 K. The NFR measures the radiative energy anisotropies with altitude. In the solar channel the downward flux will determine the solar energy deposition profile and the upward flux will yield information about cloud particle absorption and scattering. In the thermal channel the net flux will define sources and sinks of planetary radiation. In conjunction with calculated gas and particulate opacities, these observations will determine the atmosphere's radiative balance.

2. Radiometer Concept

The NFR, Fig. 1, measures upward and downward radiation flux in a 5° FOV at five distinct viewing angles; ±80°, ±45°, and 0°, relative to zenith/nadir.

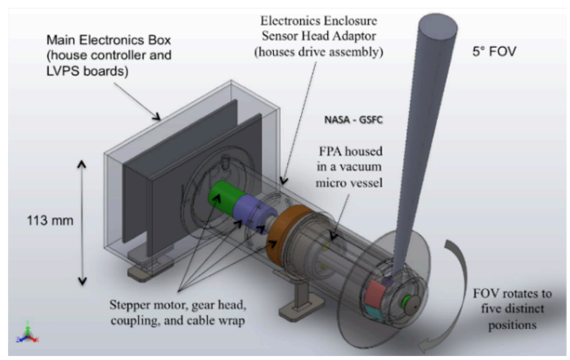

Figure 1: NFR instrument concept showing a 5° FOV that can be rotated by a stepper motor into five distinct look angles.

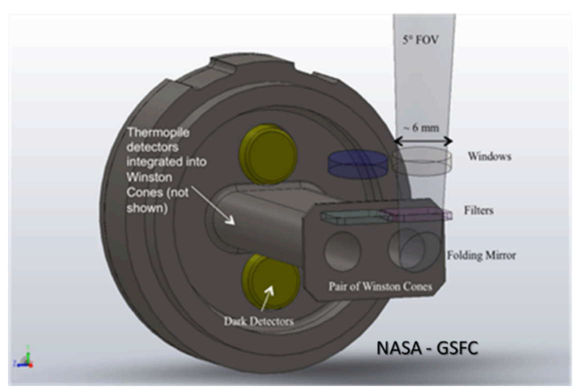

Figure 2: NFR focal plane assembly showing the dual Winston cone assembly to limit the exacting FOV in each channel. The windows and filters define the solar and thermal spectral channels.

The Focal Plane Assembly (FPA), Fig. 2, is comprised of bandpass filters, folding mirrors, non-imaging Winston cone concentrators, and radiation hard uncooled thermopile detectors housed in a windowed vacuum micro-vessel that is rotated to the viewing angle by a stepper motor. Assuming a thermopile voltage responsivity of 295 V/W, an optical efficiency of 50%, a detector noise of 18 nV/√Hz and an ASIC input referred noise of 50 nV/√Hz with 12-bit digitization gives a system signal-to-noise ratio of 300 to 470 in the solar spectral channel and 100 to 12800 in the thermal spectral channel for atmospheric temperature and pressure ranges encountered in the descent, i.e., ~85 to 300 K and 0.1 to 10 bar respectively.

2. Radiometer Readout

A physical and functional block diagram of the NFR is shown in Fig. 3. The focal plane consists of four single pixel thermopile detectors (solar, thermal and two dark channels), bandpass filters and Winston concentrators. The Front End Electronics (FEE) readout, Fig. 4, uses a custom radiation-hardened-by-design mixed-signal ASIC for operation with immunity to 174 MeV-cm^2/mg single event latch-up and 50 Mrad (Si) total ionizing dose. The ASIC has sixteen low-noise chopper stabilized amplifier channels that have configurable gain/filtering and two temperature sensor channels that multiplex into an on-chip 16-bit sigma-delta analog-digital converter (SDADC). The ASIC uses a single input clock (~1.0 MHz) to generate all on-chip control signals such as the chopper/decimation clocks and integrator time constants. The ASIC also contains a radiation tolerant 16-bit 20 MHz Nyquist ADC for general-purpose instrumentation needs.

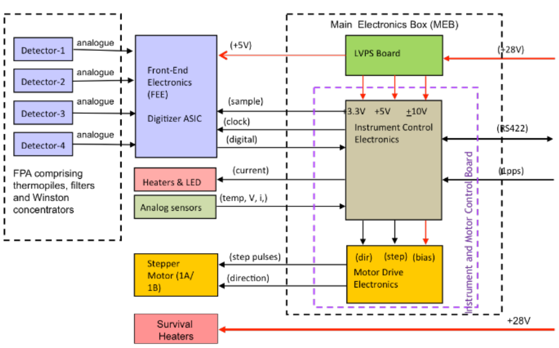

Figure 3: NFR block diagram showing the major subsystems and Probe interfaces.

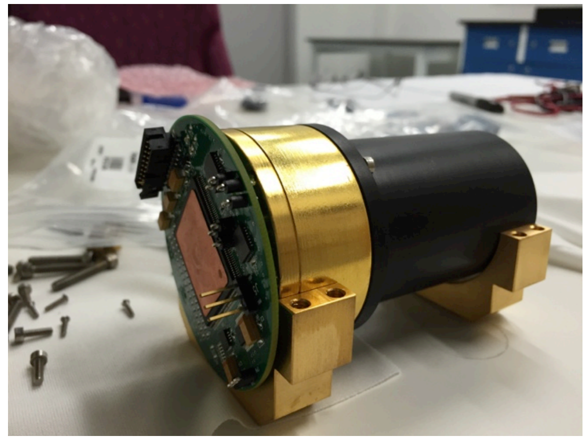

Figure 4: NASA GSFC is testing early engineering models of the critical components the NFR. Dual Winston cone assembly and thermopile FEE readout (diameter ~ 70mm) that uses a GSFC rad-hard mixed-signal ASIC.

3. Volume, Mass, Power, Data Rate

Mass: ~2.4 kg
Volume: ~113 mm x 144 mm x 279 mm
Basic Power: ~5 W
Average Data Rate: ~55 bps
Total Data Volume: ~297 kbits (90-minutes)

4. Summary and Conclusions

NASA GSFC has designed a NFR that will be suitable for integration into an atmospheric instrument suite on-board a future Saturn Probe Mission. Relaxing the FOV to 7° will enable the use of thermopile detectors with smaller integrated optics allowing the NFR focal plane design to incorporate up to seven channels with an overall reduction of volume and mass.

References

[1] Boese, R. W., et al. 1980. The Infrared Radiometer on the Sounder Probe of the Pioneer Venus Mission, IEEE transactions on Geoscience and Remote Sensing, vol. GE-18, no. 1.
[2] Sromovsky, L.A. 1998. Galileo probe measurements of thermal and solar radiation fluxes in the Jovian atmosphere, Journal of Geophysical Research, vol. 103, no. E10, pp. 22929-22977.
[3] Mousis, O., et al. 2014. Scientific Rationale and concepts for an In Situ Saturn Probe, EPSC Abstracts, Vol. 9, EPSC2014-437-1 (and references therein).