The Stratospheric THz Observatory (STO): 1st Test Flight

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***Abstract*— The Stratospheric TeraHertz Observatory (STO) is a NASA funded, Long Duration Balloon (LDB) experiment designed to address a key problem in modern astrophysics: understanding the Life Cycle of the Interstellar Medium (ISM). STO will survey a section of the Galactic plane in the dominant interstellar cooling line [C II] (1.9 THz) and the important star formation tracer [N II] (1.46 THz) at ~1 arc minute angular resolution, sufficient to spatially resolve atomic, ionic and molecular clouds at 10 kpc. STO itself has three main components; 1) an 80 cm optical telescope, 2) a THz instrument package, and 3) a gondola [1]. Both the telescope and gondola have flown on previous experiments [2,3]. They have been re-optimized for the current mission. The science flight receiver package will contain four [CII] and four [NII] HEB mixers, each with its own digital spectrometer. The first engineering test flight of STO was from Ft. Sumner, NM on October 15, 2009. Test flight instrumentation was used to evaluate STO's ability to point and track using gyroscopes/star cameras with a load-varying, cryogenic system onboard. The science flight receiver electronics and control system were also tested.**

I. INTRODUCTION

STO is a Long Duration Balloon (LDB) experiment designed to address a key problem in modern astrophysics: understanding the Life Cycle of the Interstellar Medium (ISM). During its upcoming science flight STO will survey a section of the Galactic plane in the dominant interstellar cooling line [C II] (158 μm) and the important star formation tracer [N II] (205 μm) at 1 arcminute angular resolution, sufficient to spatially resolve atomic, ionic and molecular clouds at 10 kpc. The goals for the survey are to:

[1] Determine the life cycle of Galactic interstellar gas.
[2] Study the creation and disruption of star-forming clouds in the Galaxy.
[3] Determine the parameters that affect the star formation rate in the galaxy.
[4] Provide templates for star formation and stellar/interstellar feedback in other galaxies

On Oct. 15, 2009 STO had its test flight from Ft. Sumner, NM. During its 12 hours at float altitude (~126,000 ft.) key components of STO were tested to help ensure the system would meet the objectives of the upcoming science flight. STO consists of 3 major components; a gondola, an 80 cm telescope, and a THz heterodyne receiver system. The gondola and telescope have been refurbished from the successful Flare Genesis Experiment. The gondola was upgraded by APL to use 3 gyroscopes for inertial guidance and an optical tracker for absolute pointing. The telescope was light-weighted and its primary and secondary mirrors re-aluminized. A room temperature receiver system and a cryostat were constructed and flown on the test flight. A computer-controlled, sliding weight was added to dynamically compensate for cryogen evaporation during flight.

2. TEST FLIGHT INSTRUMENT

The STO flight from New Mexico was designed to provide a complete and faithful test of the full Antarctic gondola, telescope, and key elements of the science instrumentation.

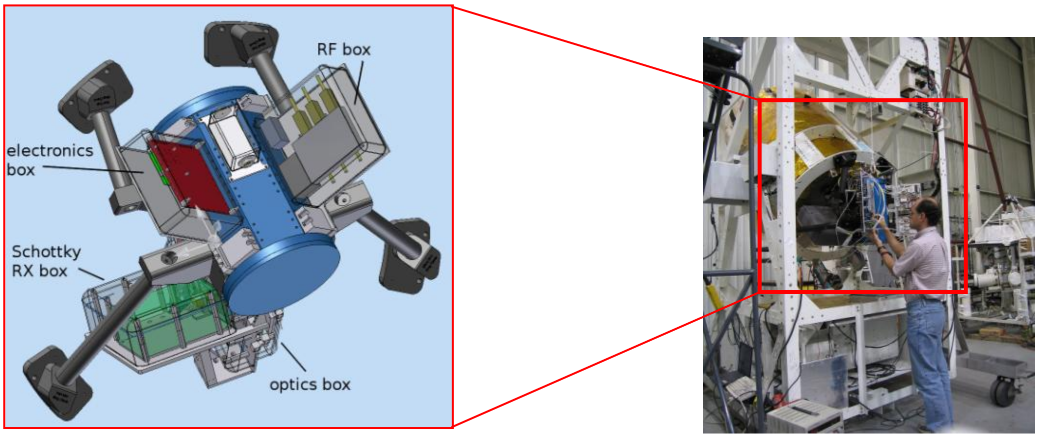


Figure 1: STO test-flight telescope and instrument package configuration, as conceptualized (left) and being integrated at Fort Sumner in early October, 2009 (right).

Antarctic ready versions of the telescope/gondola systems, instrument electronics, computing, control, and data storage systems were flown. To faithfully characterize the performance of the telescope drives and pointing system, the test flight instrument was designed with the same CG and weight as the full Antarctica flight instrument. The STO test flight carried a test cryostat and an un-cooled Schottky receiver. The receiver was used to point on the ^{13}CO J=3-2 line. The dewar was used to test the ability of a sliding weight to compensate for the loss of cryogens during flight.

Figure 1 shows the STO telescope and instrument package as it was configured for the test flight. The instrument flight system as deployed contained the following subsystems:

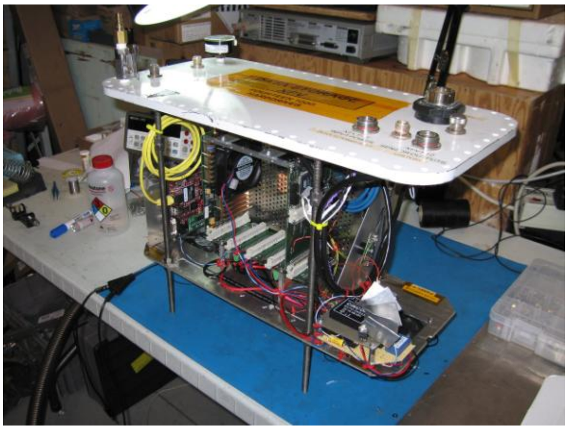


Figure 2: Pressure vessel containing the data acquisition and control computer, solid state storage, network router, and Omnisys FFT spectrometer.

- an *optics box* containing relay optics for the 330 GHz receiver and actuators to direct the telescope beam into calibration loads.
- an *electronics box* containing the instrument control computer, bias electronics for the Schottky and future HEB receivers, housekeeping temperature monitors, analog multiplexers, and solid state relays for calibration actuators.
- a *RF box* containing the LO drive synthesizers, amplifiers for the HEB mixers, and a downconverter for the Schottky mixer receiver.
- a 330 GHz *Schottky mixer receiver* from JPL, kept at ambient temperature and pressure.
- a 4K *dewar*, the nitrogen and helium cryogenic vessels were pressure-regulated to approximately sea level pressure, to maintain a helium bath temperature of 4.2K.
- A *pressure vessel* containing the FFT spectrometer, data control computer, and Cisco router to isolate the instrument network traffic from the gondola. Figure 2 shows the pressure vessel contents just before they were sealed and installed onto the gondola mezzanine level.

Figure 3 depicts the subsystem contents in a block diagram.

End-to-end testing of the complete system was performed on the ground using the ambient temperature Schottky receiver. A 330 GHz test tone was emitted by an outdoor transmitter through the telescope and instrument optics (Figure 4).

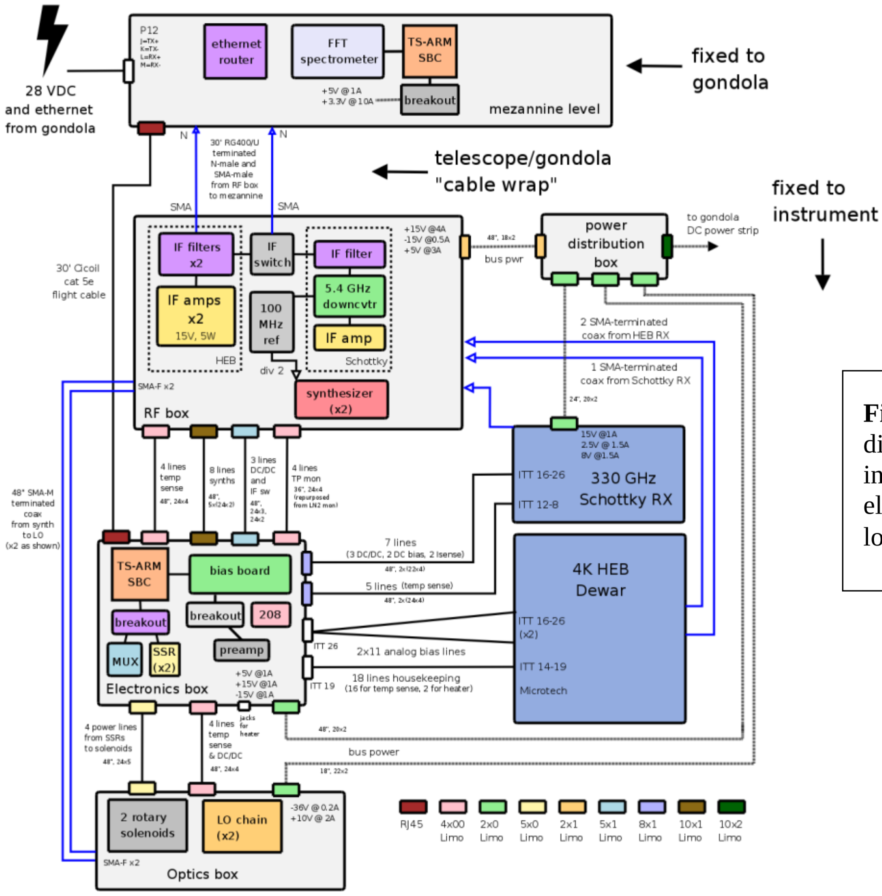
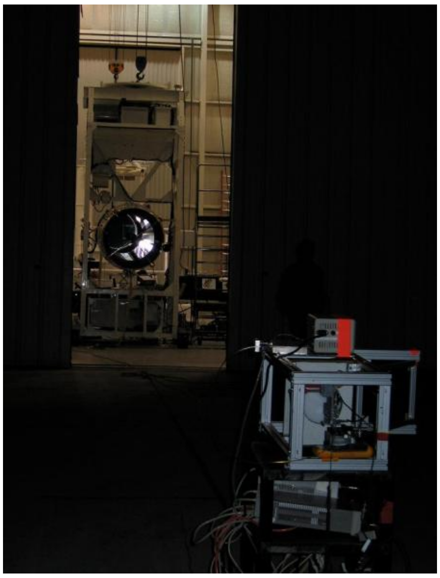


Figure 3: Detailed block diagram of the instrument control electronics and their location on the gondola.



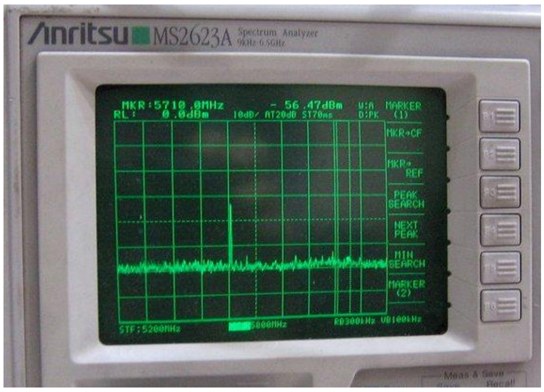


Figure 4: (Left) End-to-end testing of the entire STO instrument using the ambient temperature Schottky receiver and a 330 GHz test transmitter placed ~50m away from the telescope. (Right) Spectrum analyzer view of the Schottky receiver IF, showing the test transmitter tone passing through all telescope and instrument optics and downconverted and amplified by the IF processor. This test represented the final "go" for launch.

3.0 TEST FLIGHT RESULTS

STO was uneventfully launched at 10:03 AM MDT on 15 October, 2009 from the NASA facility at Fort Sumner, New Mexico under excellent launch conditions (Figure 5).

The primary results from the test flight were:

1) The gyros performed well, allowing the telescope/gondola to track at the 5 arcsecond level (rms) after settling from a slew or a momentum transfer.
2) The star tracker demonstrated it can provide absolute pointing knowledge that meets mission requirements.
3) The sliding weight successfully controlled the telescope CG during all phases of flight.
4) The room temperature receiver, instrument control electronics, IF processor, and spectrometer performed well throughout the flight.
5) Control of the telescope, gondola, and instrument was maintained throughout the flight.
6) As an end-to-end test of the system, a ^{13}CO J=3-2 spectrum of the Orion molecular cloud was obtained by STO at float altitude (see Figure 6).

4.0 FUTURE PLANS

STO is scheduled to have its first LDB science flight from McMurdo, Antarctic in December 2011. For the science flight STO will employ a long (~28 day) hold time cryostat built by Ball Aerospace. STO's four 1.9THz and four 1.45THz HEB mixers and their L-band IF amplifiers will reside in an insert thermally strapped to the Ball cryostat's helium vessel. Optical and electrical connections to the mixer arrays will be made through the insert. The solid-state local oscillators and associated Fabre-Perot diplexer will reside in an ambient temperature optics box bolted to the top of the cryostat. The optics box will also contain reimaging mirrors and a calibrated black body load. There will be eight, 1GHz wide FFT spectrometers in the pressure vessel to process the IF signals.

Figure 5: (Left) Balloon inflation is nearly complete at 9:50 AM on 15 October. (Center) STO launches at 10:03 AM, and reaches float altitude two hours later, hanging overhead (Right) for nearly the entire flight, and landing < 100 miles away at 1:15 AM on 16 October.

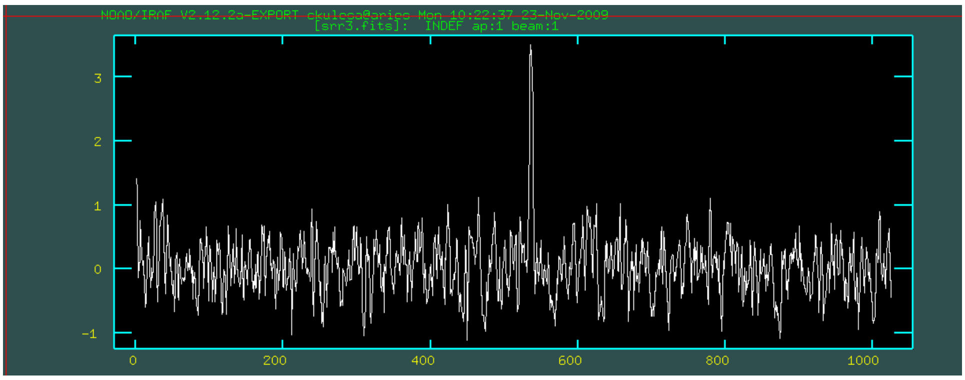


Figure 6: STO first-light spectral observation of the ^{13}CO J=3-2 line toward Orion taken from float altitude.

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