Cryogenics on the Stratospheric TeraHertz Observatory

Gary Mills
Ball Aeropace & Technologies Corp

Abe Young, Ruben Dominguez , Brian Duffy ,Craig Kulesa, Chris Walker
University of Arizona

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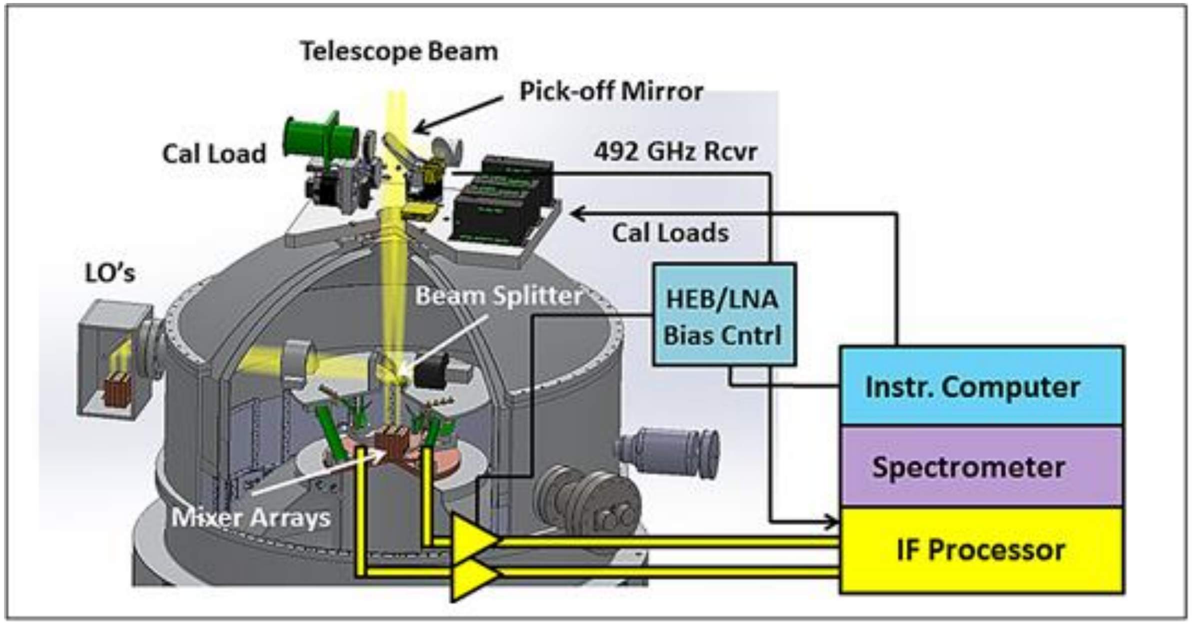
Stratospheric TeraHertz Observatory, STO-1 & 2

- **NASA-funded long duration balloon (LDB) experiment designed to address a key problem in modern astrophysics: understanding the life cycle of star-forming molecular clouds in our Milky Way Galaxy.**
- **STO is a balloon-borne 80 cm telescope with 4-pixel cryogenic heterodyne receiver arrays at 1.46 to 1.9 THz.**
- **STO-1 had a successful 14-day Antarctic flight in January 2012. The STO-2 mission will fly in December 2015. A follow-on, longer duration mission has been proposed called GUSTO.**

STO Instrument

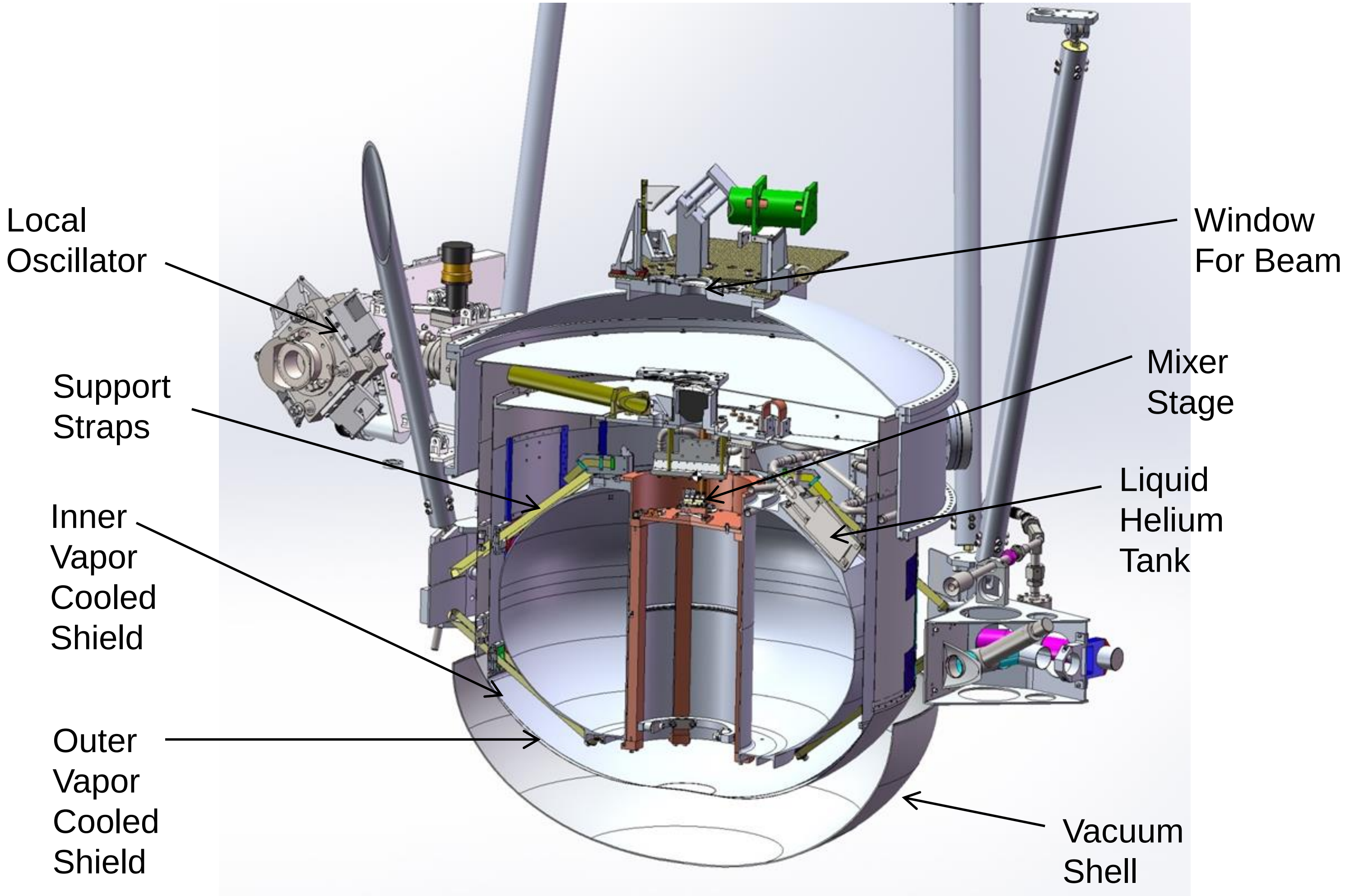
- **Several components of the STO instrument require operation at cryogenic temperatures.**
  - **Hot electron bolometer (HEB) mixer arrays require operation at less than ~6 K.**
  - **The down converted signals from the mixers are amplified to power levels suitable for digitization.**
  - **The first stage, low-noise amplifiers (LNAs) require operation at < 40 K.**



Cryogenic System

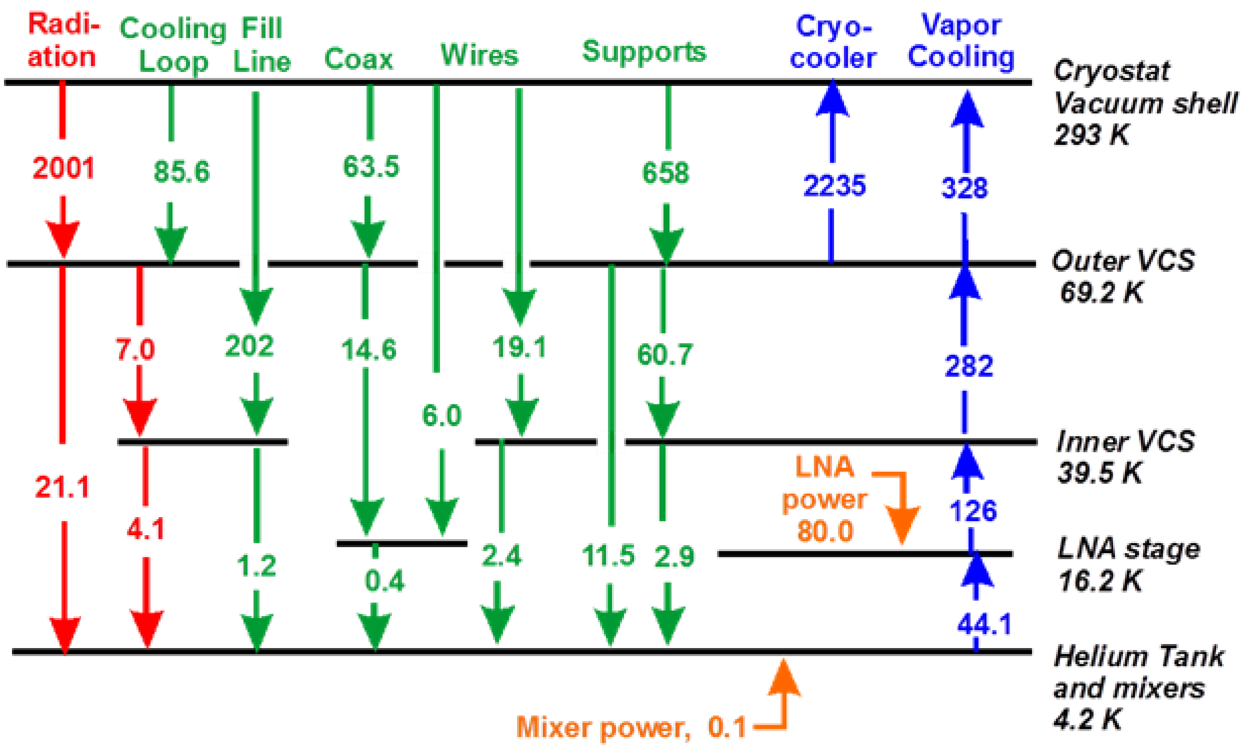
- 90 liter liquid helium cryostat was originally built as a prototype space flight cryostat for small instruments.
  - The cryogen tank consists of two aluminum alloy ellipsoidal heads welded together at the girth and at the midpoint inside of the instrument cavity.
  - The cryogen tank is supported from the girth ring by six bipod gamma alumina tension strap supports.
  - The insulation system consists of multilayer insulation (MLI) spaced by two vapor cooled shields supported through flexures by the support system.
- STO-2 will have a Sunpower Cryotel CT cryocooler to extend the helium hold time mounted on the side collar to provide additional cooling of the OVCS and beamsplitter plate.
- The STO mixer arrays and associated optics are mounted on the lower insert stage which bolts to the top of the helium tank. The mixers dissipate approximately one milliwatt of heat and operate at < 4.5 K.
- The output of each mixer is connected to a Low Noise Amplifier (LNA) via a short (~6 cm) length of stainless-steel coax. The LNAs dissipate 80 mW.

STO Cryostat Cross Section



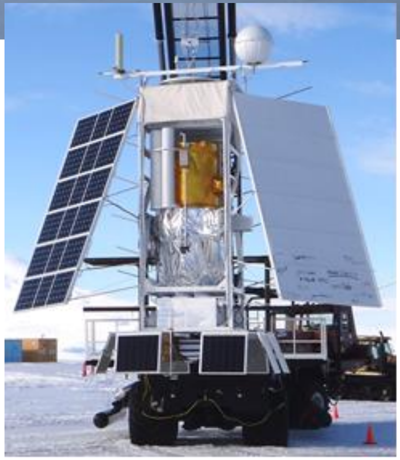
Thermal Model of Cryostat

- Created using TAK 2000 thermal modeling software
- Shows the effective use of vapor cooling and cooling from the cryocooler to minimize the heat reaching the helium tank, minimizing liquid helium boil off.
- Thermal model predicts the dewar will have a hold-time of ~60 days.



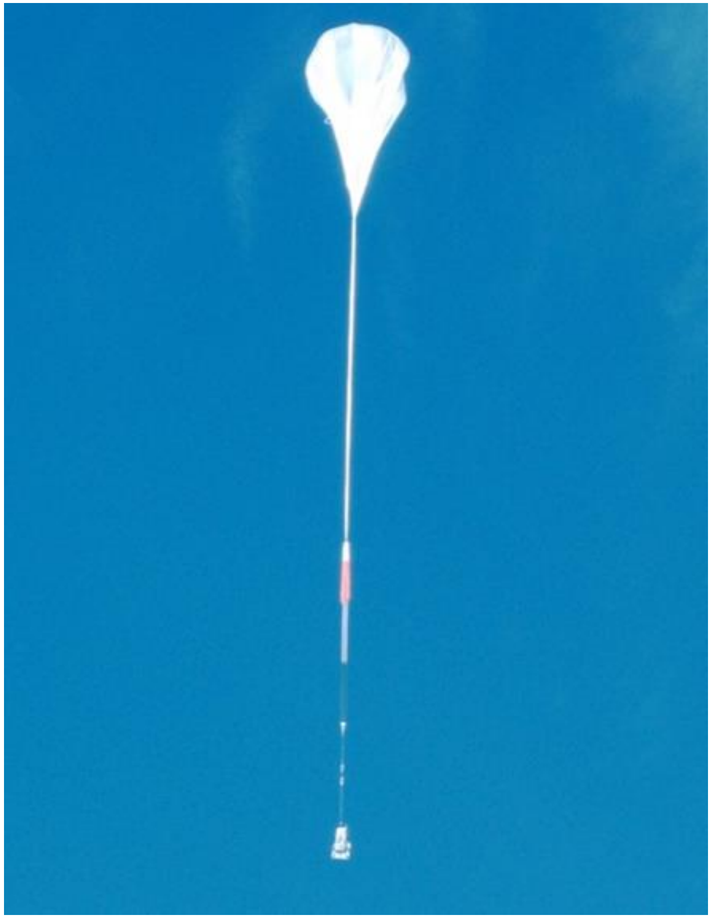
STO Operations in Antarctica

- Following a successful I&T and Hang Test in Palestine (TX) in August 2011, the gondola was cleared for flight and shipped to McMurdo Station, Antarctica.
- The gondola, including the cryostat, are prepared for launch in a hanger near the balloon launch runway.
- Before each launch attempt, the cryostat was topped off with liquid helium shipped by supply aircraft from New Zealand.
- After 8 unsuccessful launch attempts, mostly due to high wind, STO-1 was finally launched on January 15, 2012.



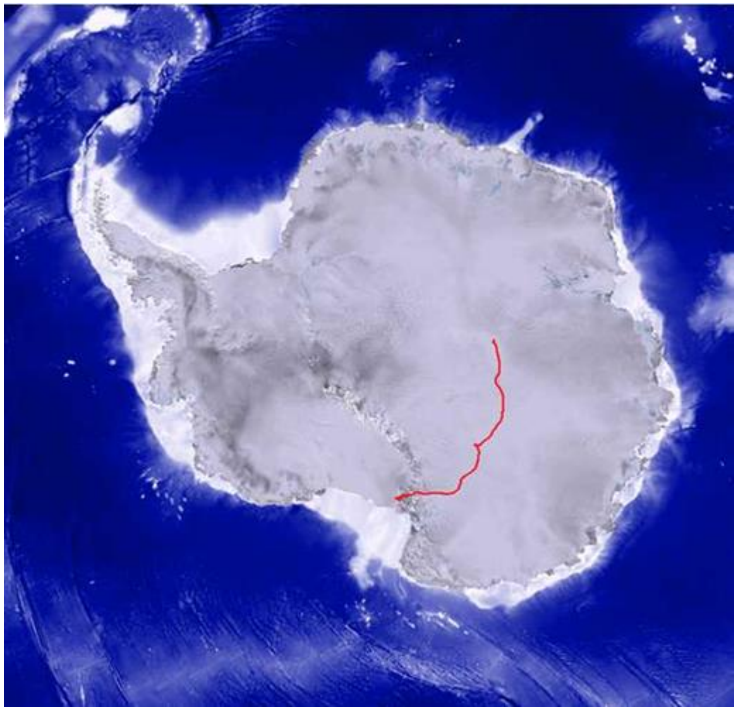
STO Operations in Antarctica, continued

- After launch, STO reached 40 km altitude in about 3 hours.
- Approximately four days into the flight, temperatures within the focal plane unit began to rise slowly, indicating a premature loss of liquid within the dewar.
- A post flight investigation revealed the helium loss was due to the pressure relief valve on the helium vent line being frozen open during ascent. With the vent line open the pressure above the helium reservoir was at ambient, corresponding to ~3 millibar by the time float altitude was achieved.
- This low pressure resulted in ~50% of the liquid helium boiling off prematurely.
- STO-2 will use a heater to keep the pressure regulator assembly safely above freezing during ascent.



STO Operations in Antarctica, continued

- **The circumpolar winds take the balloon and gondola in a counter clockwise direction around the Antarctic continent, making a complete circuit in approximately 14 days.**
- **At the end of the mission the gondola is released from the balloon and descends by parachute to a location favorable to recovery.**
- **Gondola recovery is accomplished by helicopter and/or airplane**



Conclusions

- The STO-2 cryogenic system will effectively and efficiently support the operation of the STO instrument and mission.
- The use of a re-purposed liquid helium cryostat proved feasible and provides considerable cost savings to the STO program.
- By adding an off-the-shelf cryocooler the mission lifetime and science return is significantly increased.
- Long duration balloon missions have significant advantages over space missions for terahertz astronomy
  - Lower cost
  - More instrument mass
  - More instrument volume
  - Instrument is usually recovered and can be re-flown