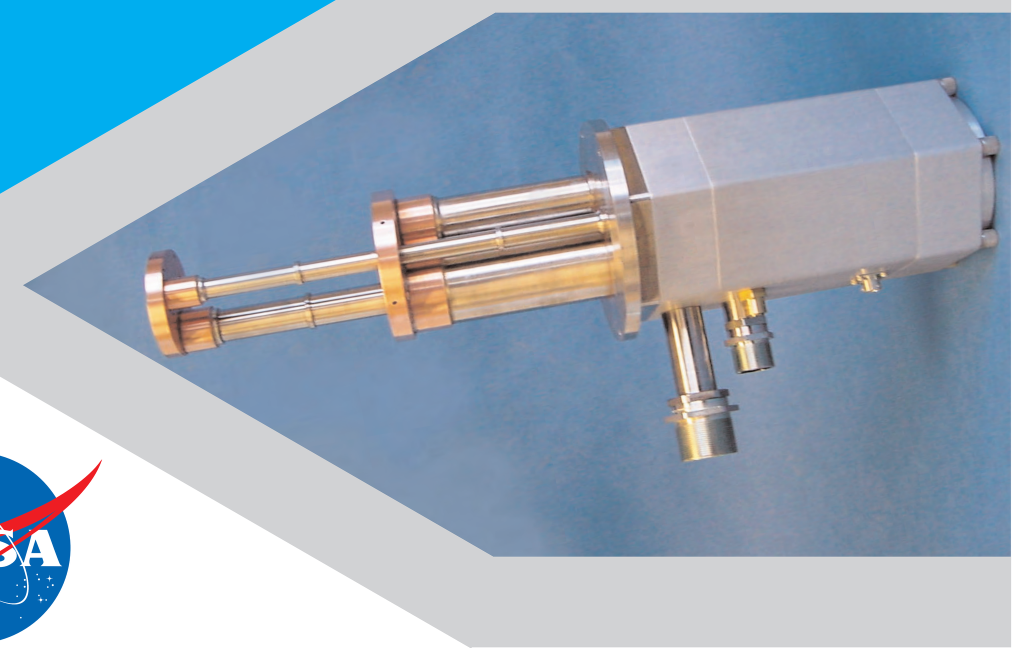
Building Bigger, Better SOFIA Instruments with Dry Cryostats



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The cylindrical instrument volume allowable on SOFIA is large, comprising perhaps 350 liters at 4K. However, the cryogen accommodation to enable this environment consumes at least 20% of the volume, and worsens mass, airworthiness/safety, and handling/operation. Present-day pulse tube coolers have negligible cold volumes, provide adequate cooling powers, and reach colder temperatures than conventional stored cryogens. In addition, they permit safer, more reliable, lower maintenance instrument operation. We have deisgned a dry cryostat for SOFIA using a pulse tube cooler. While the advantages of dry cryostats are well-known in labs and ground-based astronomical facilities, SOFIA would require some changes in accommodations to permit a pulse tube cooler to operate on board. We have tested two pulse tube coolers in order to validate their operation under SOFIA-like conditions, and find them to perform well. We present our investigation into the feasibility and desirability of making SOFIA a dry cryostat-capable observatory.

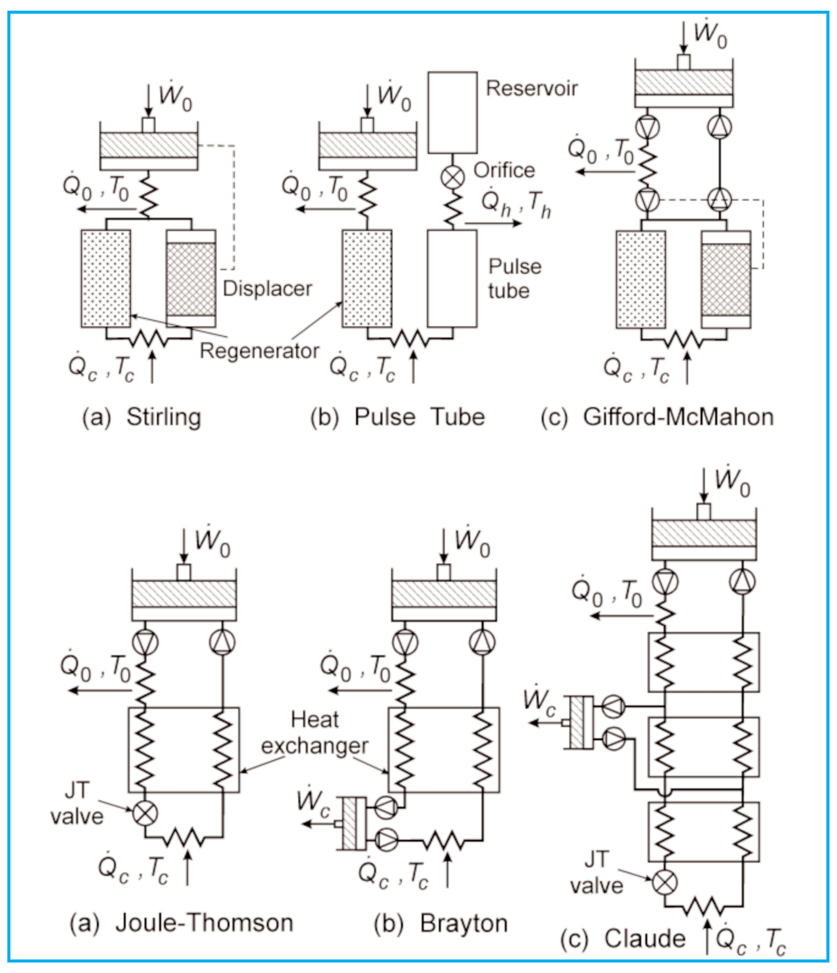
ADVANTAGES OF DRY CRYOSTATS

Form factor:
- Up to ≈2x more instrument cold volume for a given envelope
- Cooler volume inside our cryostat design is ~2 liters. HAWC has 60 liters of LHe, plus some tank and plumbing overhead.
- No cryostat plumbing whatsoever to leak or break.
- Disadvantage: need vibration isolating bellows at vacuum shell.

Life cycle cost:
- Cryomech pulse tube cooler PT405 costs ~$41K. Compare with up to $2k/week for LHe consumption of comparable cryostats.

Safety:
- Virtually no dewar explosion hazard (no burst disk?)
- No large transfer dewars or cryogen transfers aboard SOFIA.
- Tiny quantities of gas: Cryomech PTC has 64 grams of He.
- No oxygen depletion hazard.

Convenience:
- No servicing during routine operations.
- Indefinite, unattended hold time if power is available.



Cooler Type	Vibration at cold head	Minimum Temper-ature	Cooling Power	Power Draw	Form Factor
Pulse Tube	+	++	+	-	+
Stirling	-	-	++	-	+
Gifford McMahon	-	+	++	+	+
Turbo Brayton	++	-	++	++	++

Many different cryogenic cycles have been developed, and each has implementation advantages. The best of the most commercially available cycles is the pulse tube cooler.

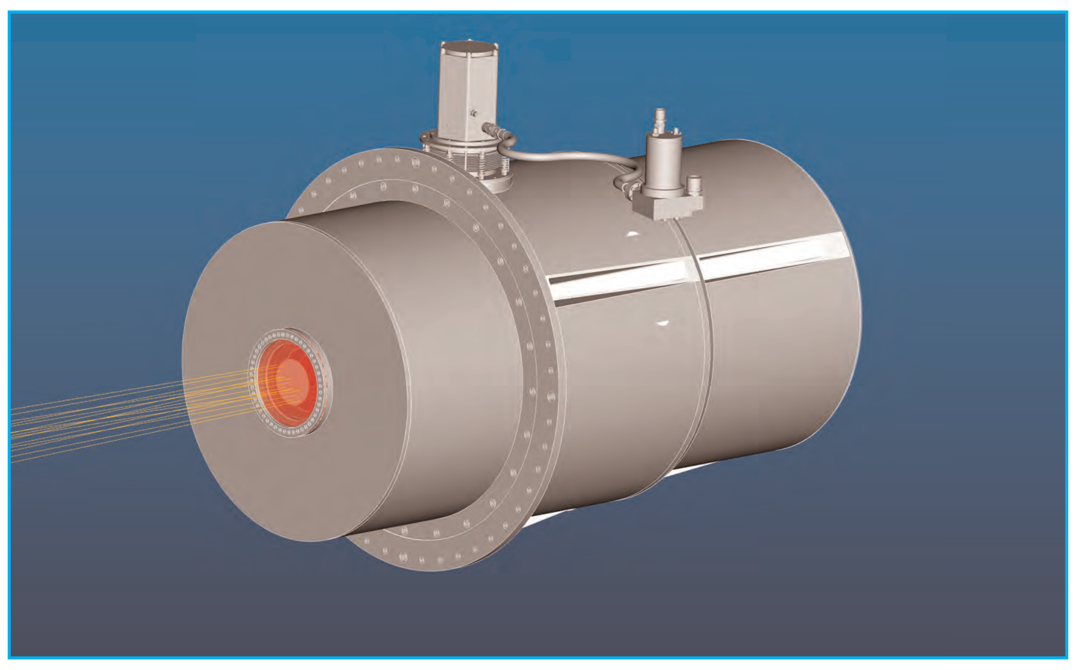
To use a pulse tube cooler aboard SOFIA, the following accommodations are required:
- Compressed Helium lines routed through the CLAD.
- Compressor location / tie down points.
- During flights, needs to dump around 5kW of heat.
- Electrical: Cryomech 405 uses ≈7kVA max, 220V 3ϕ

Rogues' gallery: from left to right, the Sumitomo SRP-062B can lift 500mW at 4.2K; the Vericold VT4-200 100mW; the Vericold VT4-500 450mW; the PT405 500mW; and the PT410 lifts 1000mW. We purchased PT405s because of their ability to be air-cooled and their high ratio of lift to electrical power consumption (4.9kW).

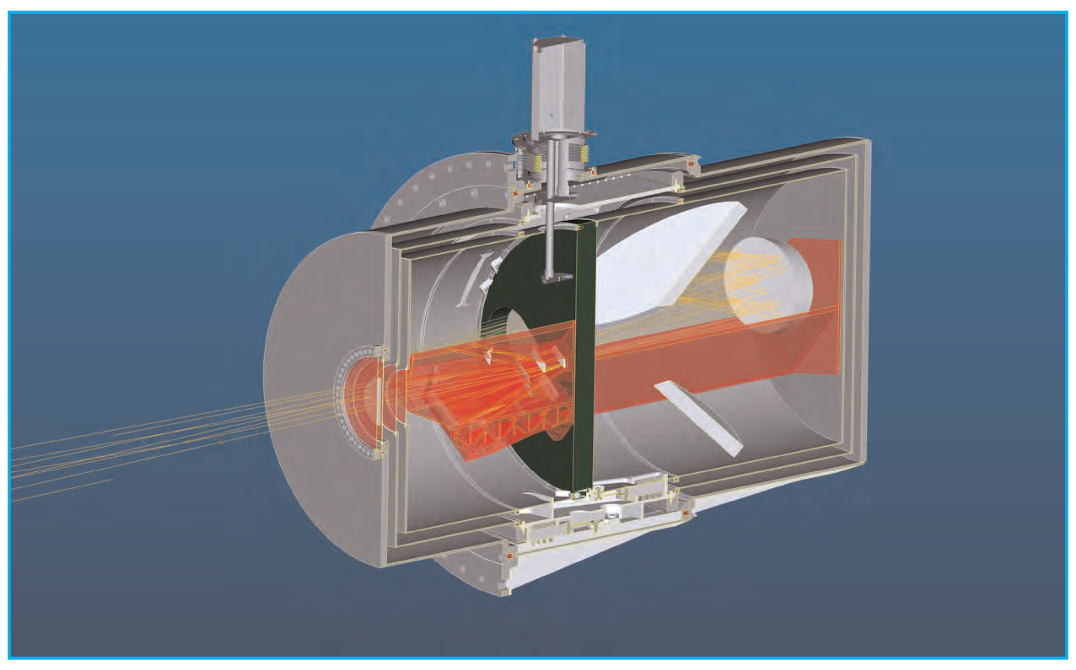




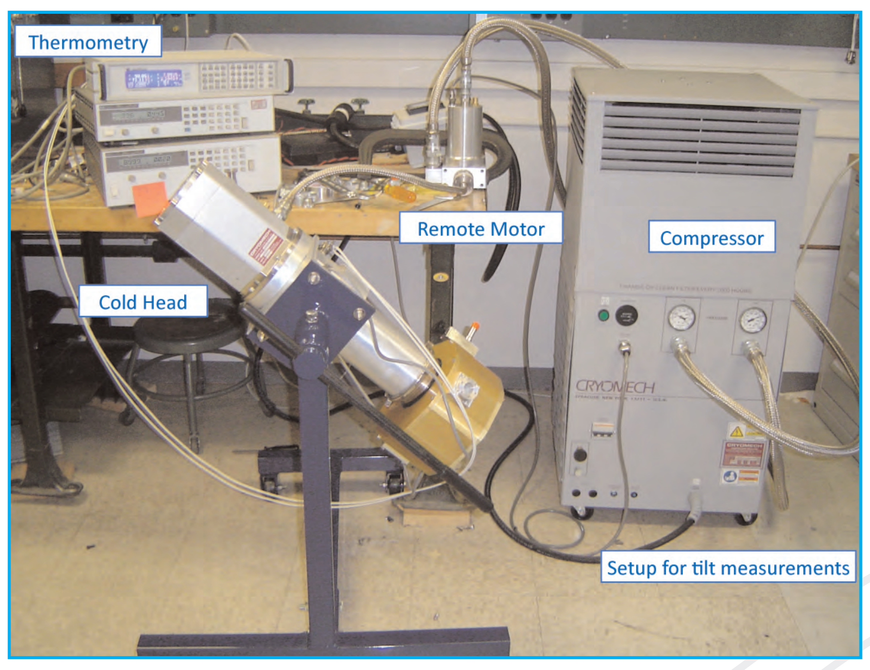
DESIGN OF A DRY CRYOSTAT FOR SOFIA



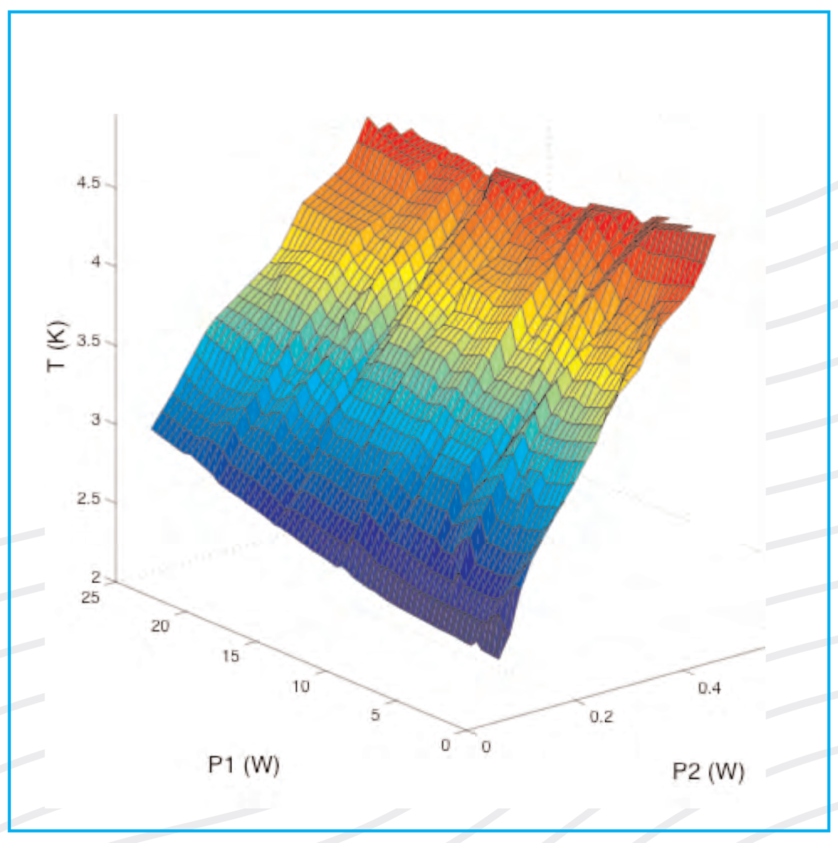
We have designed a modular, symmetric, kinematically suspended cylindrical cryostat of SOFIA. This generic design permits nearly maximum instrument volume for a horizontal cylinder on SOFIA, even using the space in the tub behind the instrument mounting flange. For scale, the outer diameter at the mounting flange is 1m.

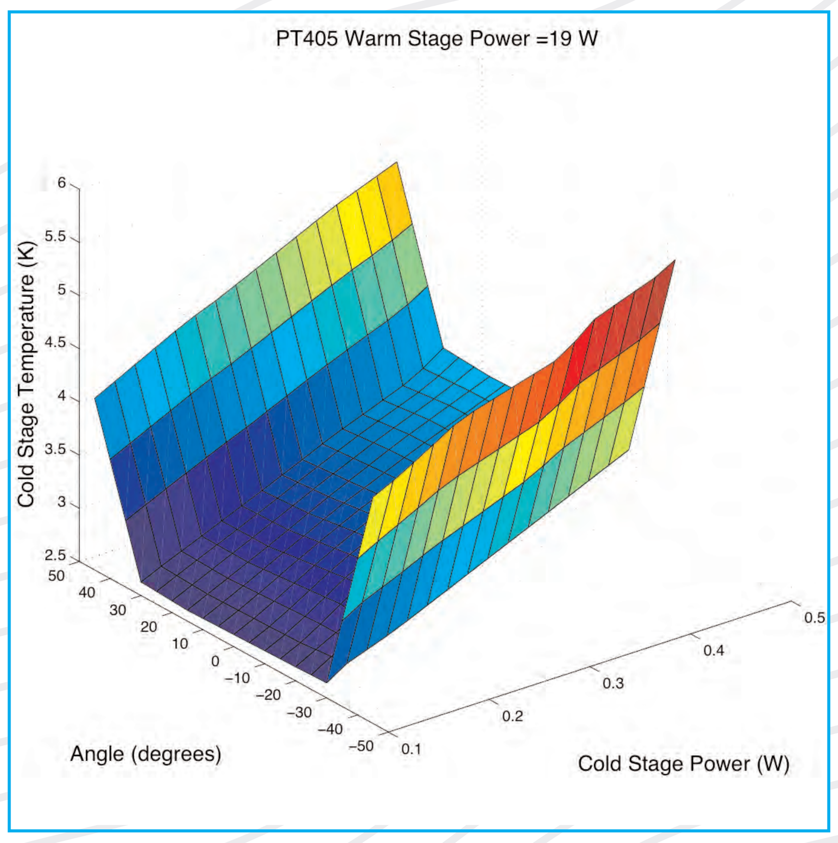


A single Cryomech PT405 cools the two internal cold plates to around 50K and 4K. Because the pulse tube is mounted high, it offers minimal interference in the optical path.



During operation on SOFIA, a pulse tube cooler will have to accommodate tilts off of vertical, and so its efficiency suffers. We have made extensive measurements of this degradation. Complete load curves (temperature on the two stages as a function of the power on each) show the ability of the pulse tube cooler to hold stable temperatures. Selected slices of the load curve surface as a function of tilt angle have shown that a pule tube cooler can tilt up to ±30° with very little degradation to its performance.





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