Cryogenics for LDR

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This paper addresses three cryogenic questions of importance to LDR: the primary cooling requirement, the secondary cooling requirement, and the instrument changeout requirement.

Principal LDR Cooling Requirements

The principal cooling requirements of LDR (1 W @ 2 K) cannot be met with present technology. There are two general choices for developing technology to satisfy this requirement: closed cycle coolers, and stored cryogens.

No closed cycle cooler exists that can meet the cooling requirement on the ground, let alone that are space-qualified or have a multiyear demonstrated lifetime. The DOD has spent a great deal of effort trying to develop coolers for the 7-10 K range. These might have the required lifetime. There is an effort to develop a 4 K magnetic refrigerator that might operate from the DOD coolers and reach 2 K. A multistage version of the GSFC/Magnavox cooler might reach 7-10 K. ARC will start a CSTI-funded effort in FY'88 to develop critical components of a cooler for this temperature range (probably a magnetic refrigerator). From the Strobridge tables one can estimate that a cooler to meet these requirements would require 7.5 kW of input power (2% of Carnot with heat rejection at 300 K) and an equal amount of heat rejection ability (a huge radiator). The cost to develop and qualify such a unit is about 10% of the estimated LDR program funds.

A number of stored cryogen systems have flown (IRAS, IRT, and SFHE) that provide cooling near 2 K. However, these did not have to provide such a large amount of cooling for so long. LDR would need 10,000 liters of superfluid helium per year. This is the current planned capacity of the liquid helium tanker. Thus, to ensure that LDR instruments never warmed up, LDR would have to be serviced at least every nine months (a resupply cannot be 100% effective). The technology to do helium resupply has not been demonstrated. A joint ARC/GSFC/JSC program plans to demonstrate the technology in the 1991 flight of the SHOOT (Superfluid Helium On-Orbit Transfer) experiment.

Secondary LDR Cooling Requirement

There is a secondary cooling requirement for a cooler in the 0.1-0.3 K range. There are three alternative approaches: ^{3}He coolers, magnetic refrigerators, and dilution refrigerators. ^{3}He coolers can reach 0.3 K. A unit that works upside down has been demonstrated at ARC. A space-qualified unit is being developed by an ARC/UC Berkeley collaboration for a flight on a Japanese mission.

For 0.1-0.3 K temperature range, magnetic coolers are being developed for SIRTF by ARC and for AXAF by GSFC. The outstanding problem is finding a better refrigerant: one that does not have water of hydration. This would greatly simplify the integration of a flight unit. This area is being worked at ARC.

Dilution refrigerators are the coolers of choice for ground operations in this temperature range. Only preliminary work has been done on developing a zero-gravity unit. There are a number of alternative ways that a zero-gravity unit could be developed; these are being pursued by ARC, JPL, and MSFC.

LDR Instrument Changeout

LDR instrument changeout requirements are poorly defined, and there has been little work in this area. SIRTF has looked at both cold and warm instrument changeout options. Cold instrument changeout involves the changing of a cold instrument without changing the cryo system. This is so difficult that it is impractical. The principal difficulties are contamination, excessive thermal loads during changeout, alignment, and making good thermal contact.

Warm instrument changeout places severe requirements on the cooling system (excessive cryogen or power to recool the instrument) as well as raising alignment and contamination questions.

Recommendations

Based on the above considerations, a number of recommendations can be made:

- Re-examine the cooling requirements to see if they can be eased to the point that stored cryogens become feasible with a 2-3 year servicing interval.
- Incorporate LDR needs into the helium tanker design.
- Support the development of a 2 K cooling stage and of sub-kelvin coolers.
- Improve definition of instrument changeout (instrument vs. all instruments at once; separate cooler for each instrument vs. common cooler; etc.).