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LDR Cryogenics

T. Nast
Lockheed Research Laboratory
Palo Alto, CA 94304

A brief summary from the 1985 LDR Asilomar II workshop of the requirements for LDR cryogenic cooling is shown in FIGURE 1. The heat rates are simply the sum of the individual heat rates from the instruments. Consideration of duty cycle will have a dramatic effect on cooling requirements. There are many possible combinations of cooling techniques for each of the three temperatures zones. The 0.2 K requirement can be satisfied possibly by ADR, He^3, or dilution refrigerators, while the 2-4 K region could use either He-II or a mechanical refrigerator (MR). The 20 K region can be satisfied by vapor cooling from the He-II at 2-4 K. The vapor on the average will provide approximately 4 watts cooling at 20 K for every watt at 2 K.

T	Q	All-Stored	Hybrid	All Mechanical
K	mW[b]			
0.2	.01	ADR, He^3, Dilution	ADR, ^3He, Dilution	ADR, ^3He, Dilution
2-4	980	He-II[a]	He-II	MR
20	2,610	He-II Boil-off[c]	MR[d,e]	MR

Notes:
(a) Approximately 20,000 liters for 2 years.
(b) Duty cycle needs better definition.
(c) Vapor cooling can provide approximately 4 W cooling.
(d) MR is Mechanical Refrigeration.
(e) Use of MR at 20 K allows He vapor usage elsewhere.

FIGURE 1. LDR Cooling Requirements

For the all refrigerator approaches there are several options for the 20 K stage (Stirling, pulse tube, etc.), while the 2 K requires development of a new refrigerator technology. The continuous-cycle magnetic refrigerator is an efficient system thermally, but has the undesirable feature of moving parts at a low temperature. Much new technology is required here.

Satisfaction of the cooling requirements by an all-stored cryogen system (He-II) may require as much as 20,000 liters based on a 2-year orbital resupply interval. Current orbital tanker studies for He-II may have capabilities in the area of 10,000 liters; therefore, two tankers would be required to resupply 20,000 liters.

If an all-stored He-II approach is pursued it may be worthwhile to consider a new approach: that of launching the system dry (without helium), assembling in space, and then filling with He-II. This option has only recently become viable due to the work on orbital He-II supply. Some of the advantages and disadvantages of a dry launch are summarized in FIGURES 2 and 3, respectively. It is expected that additional advantages and disadvantages will be exposed upon further study. The principal drivers appear to be related to instrument considerations and weight benefits.

- o Reduced weight since vacuum shell not required (or increased lifetime for same weight).
- o Reduced cost (elimination of vacuum shell simplifies design).
- o No safety problems (catastrophic loss of vacuum).
- o No complex ground operations for top-off/fill of helium.
- o Reduced risk of sensor contamination by condensibles (air leakage through O-rings on ground eliminated).
- o Lower heat leak through support since weight of LHe not carried during launch.
- o Opportunities for astronaut-adjusted supports in orbit (warm) to reduce heat leak.
- o Permits assembly of components on-orbit without special design or precautions/measures to limit heat rates prior to assembly of sunshields, etc.

FIGURE 2. Advantages of Dry (without LHe) Launch Approach

- o Additional helium fill in orbit.
- o Additional risk of particulate contamination? (No vacuum shell)
- o Instrument cool-down in orbit (operation and alignment not checked just before launch).
- o Additional structural requirements due to ascent depressurization (vapor cooled shields).

FIGURE 3. Disadvantages of Dry Launch

It is clear that much further system study is needed to determine what type of cooling system is required (He-II, hybrid or mechanical) and what size and power is required. As the instruments, along with their duty cycles and heat rates, become better defined it will be possible to better determine the optimum cooling systems.