SPACE INFRARED TELESCOPE FACILITY (SIRTF)
DESIGN AND THERMAL ANALYSIS

ABSTRACT

The design and performance characteristics of an observatory (for example, SIRTF) are compared with those of a storage dewar. The critical design technologies required to increase cryogen dewar lifetime are discussed. In particular, outer shell temperature, vapor-cooled shields/multilayer insulations performance, and tank support systems are analyzed to assess their impact on cryogen dewar lifetime for both the observatory and the storage dewar. The cryogen lifetime and cryogen mass loss rate of SIRTF are compared with that of IRAS and COBE. A 0.1% mass loss per day superfluid helium dewar can be designed using current state-of-the-art dewar technology. Space-based liquid hydrogen and liquid oxygen tanks can be designed for a 5-year lifetime.

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STORAGE DEWAR AND OBSERVATORY OPERATING MODE

A typical example of an observatory (telescope system) and a storage dewar is shown. There are several salient features that distinguish the two systems. For example, the Space Infrared Telescope Facility (SIRTF) - Ref. 1, is a 1-meter class telescope that requires superfluid helium cooling to provide a two-year lifetime between cryogen replenishment. The 1-meter diameter aperture represents a break in the dewar insulation system. An aperture shade is usually required to minimize the heat load from the Sun, Earth, and Earth's albedo. On the other hand, a storage dewar (Ref. 2) usually has an insulation system that encloses the entire cryogen tank.

In a storage dewar, the boiloff from the cryogen is used solely to cool the insulation system. However, in an observatory such as SIRTF, the enthalpy from the helium provides cooling for a warm instrument station, the telescope barrel, as well as the insulation system. A substantial amount of aperture heat load is absorbed by the helium vapor. The amount of helium boiloff affects the parasitic heat leaking into the cryogen tank. For an observatory, the total tank heat load consists of the parasitic heat and the instrument heat dissipated directly into the cryogen tank. The total tank heat load for a storage dewar consists of only the parasitic heat leak into the cryogen tank via the tank supports, multilayer insulations, plumbing, and electrical wires.

If an observatory has no parasitic heat load, or in an ideal case where the dewar outer shell temperature is 0 K, the total tank heat load is just the heat load dissipated by the instruments inside the dewar. The observatory typically operates in either the "storage mode" (semi-flat region in graph) or "instrument mode" (asymptotic to the no parasitic heat line in graph). In the "storage mode", the observatory is operating as a self-compensating dewar where an increase in the instrument heat load does not increase the total tank heat load by the same amount. This effect is caused by an increase in the vapor flow which reduces the vapor cooled shield temperatures, thereby reducing the parasitic heat. As the instrument heat load increases, the resulting vapor flowrate is becoming higher which eventually would reduce the dewar parasitic heat to an insignificant amount compared to the instrument heat load. Now, the dewar is operating in the "instrument mode."

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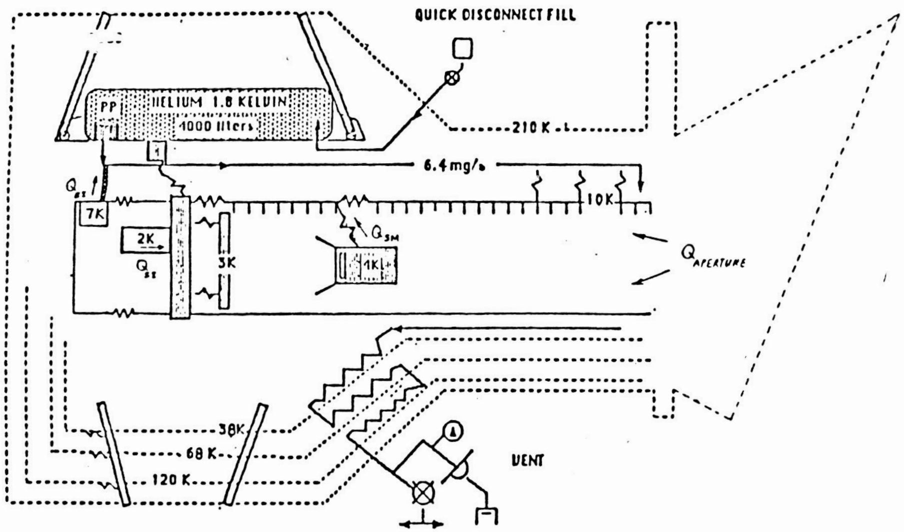
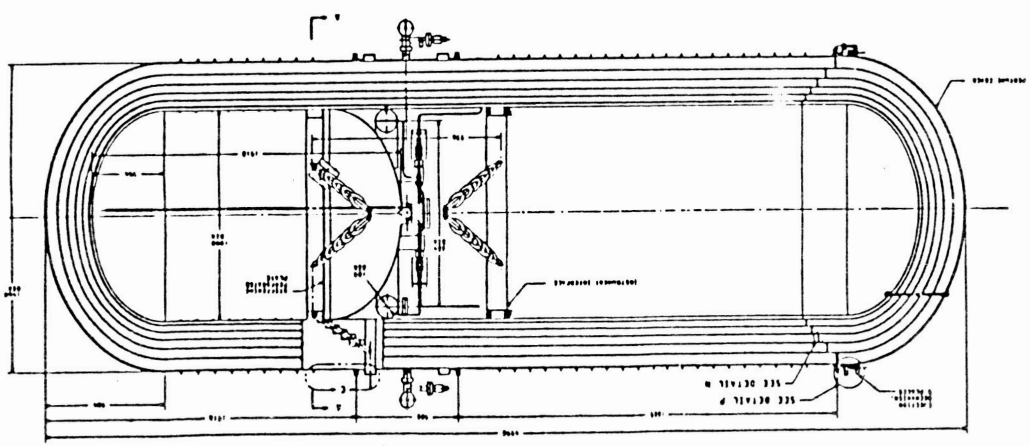
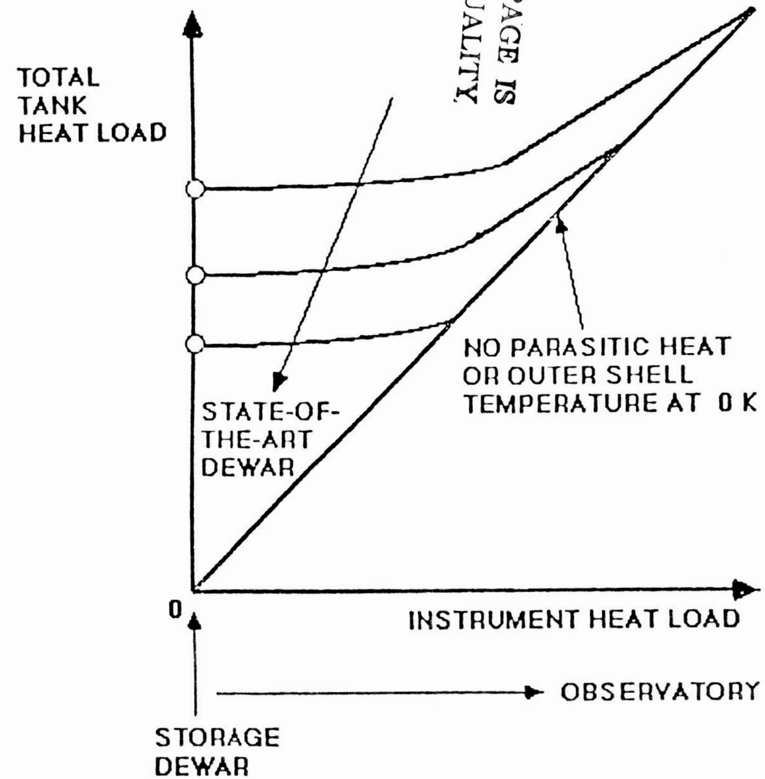
STORAGE DEWAR AND OBSERVATORY OPERATING MODE



OBSERVATORY



STORAGE DEWAR



TANK HEAT LOAD CHARACTERISTICS

KEY DESIGN PARAMETERS

The observatory has more design parameters in addition to those required to minimize parasitic heat load. Joint thermal conductance is a typical parameter to consider in a telescope system which requires stringent temperature control. Other telescope systems employ the cryogen boiloff to cool certain components; flow stability could become important if temperature stabiliy requirement is to be satisfied. Observatory pointing and slewing, as well as optics image quality requirements usually impose tight tolerance budget on structural misalignment caused by environmental loads, thermal deformation, and telescope assembly. Contamination control driven by optics requirement dictates the choice of dewar insulation materials to minimize outgassing and particulate formation inside the telescope. A monofilament spacer such as silk net or dacron net is a good candidate material for the multilayer insulation system.

To minimize the time required for on-orbit tank chilldown and top-off, the dewar fluid management system should be designed to offer maximum flow conductance. Larger diameter vent lines (3/4 to 1 inch) and larger cold valves (3/4 instead of 1/2-inch) are currently used in the SIRTF design.

KEY DESIGN PARAMETERS

	STORAGE DEWAR	OBSERVATORY
OUTER SHELL TEMPERATURE	X	X
VAPOR-COOLED SHIELDS/ MULTILAYER INSULATIONS	X	X
TANK SUPPORTS	X	X
HEAT EXCHANGE EFFICIENCY (VCS, WIRES, TANK SUPPORTS)	X	X
TANK COOLDOWN, TOP-OFF	X	X
APERTURE SHADE		X
INSTRUMENT HEAT LOADS		X
THERMAL CONTACTS		X
STRUCTURAL ALIGNMENTS		X
CONTAMINANT CONTROL		X

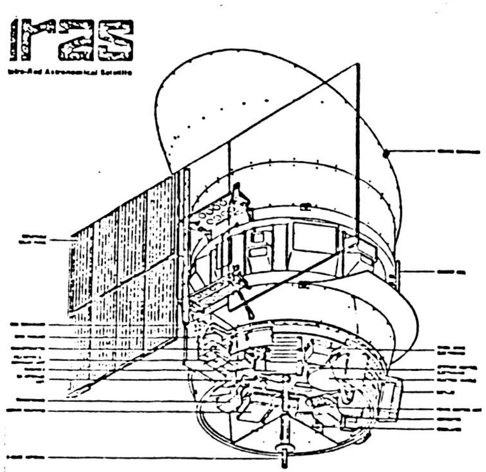
OUTER SHELL THERMAL CONTROL

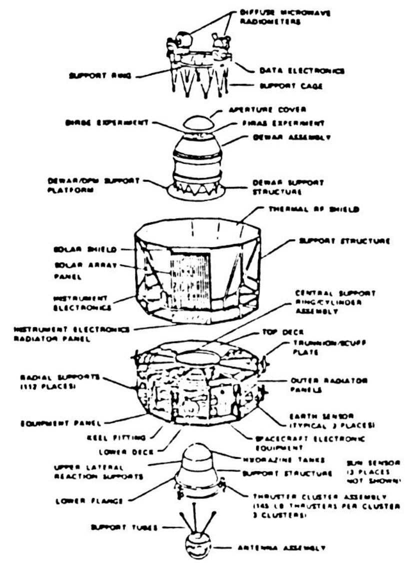
The Infrared Astronomical Satellite (IRAS) which was launched in 1983 operated in a 900 km sun-synchronous orbit. This orbit allowed IRAS to use its solar panels to block one side of its dewar from the Sun while employing an Earth skirt to minimize Earth radiation on the other side of the dewar. Other parts of the IRAS dewar also used second surface silverized teflon and zinc orthotitanate (ZOT) white paint. The COBE dewar is mounted inside a highly reflective thermal shield while the dewar outer shell is coated with a low solar absorptance high IR emittance paint. The Infrared Space Observatory (ISO) will operate in a 12-hour elliptical orbit with its perigee/apogee at 1000 km/40,000 km. The ISO will use the solar panel as a sun shield for its dewar; the outer shell temperature is predicted to be as low as 120 K.

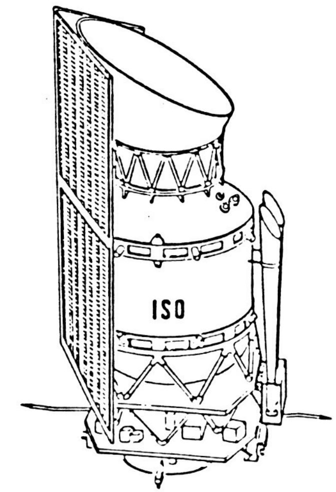
Reduction of the outer vapor cooled shield (OVCS) temperature via auxiliary cooling has essentially similar effect as reducing the dewar outer shell temperature. A mechanical refrigerator with cooling capcacity of 4 to 5 Watts at 70 K is probably adequate for a SIRTF-sized observatory. Guard cryogen such as solid methane, Argon, Nitrogen, or Carbon Monoxide could be used to maintain an observatory OVCS temperature in the 45 to 90 K range, depending on the type of cryogen used. For Space Station storage tanks with outer shell temperatures as high as 300 K, solid ammonia or carbon dioxide can maintain the storage tank OVCS to between 125 to 215 K, depending on cryogen choice. However, the option of using auxiliary cooling should be evaluate against safety, cost, complexity, mass and volume constraints.

OUTER SHELL THERMAL CONTROL

SHADES







IRAS: SOLAR PANELS, EARTH SKIRT (T = 197 K)

COBE: THERMAL SHIELD (T = 150 K)

ISO: SUN SHIELD (T = 120 K)

AUXILIARY COOLING FOR OVCS

- MECHANICAL REFRIGERATORS - 4 TO 5 WATTS AT 70 K (OBSERVATORY)
- GUARD CRYOGEN

  OBSERVATORIES (SOLID CH_4, Ar, N_2, CO)

  STORAGE TANKS (SOLID NH_3, CO_2)

RADIATORS/COATINGS

- SECOND SURFACE SILVERIZED TEFLON, WHITE PAINT

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MULTILAYER INSULATION MODELS

The data shown on the graph are obtained from Ref. 3 after converting the heat flux data into thermal conductivity values using the model proposed by Keller, et al (Ref. 6). Four MLI models are shown in the graph. The double-aluminized mylar with dacron net spacers (DAM/DN) model (Ref. 4) was used and validated with IRAS and COBE test results. The other three models are for the double-aluminized mylar with two layers of silk net as spacers (DAM/SN). Two of these models are based on flat plate calorimeter tests (Ref. 5, 6) while one is based on a 15-liter tank calorimeter test with cold boundary temperature as low as 50 K (Ref. 7). The data at temperatures greater than 100 K show good agreement with Model #3 (Keller, et al) to within a factor of 1.5. Below 100 K where MLI conduction starts to become significant, Model #3 overpredicts the data by a factor of 1.5 to 2. The difference in the number of silk net layers used as spacers in the test and assumed in Model #3 may be a contributing factor. Also, the layer densities used in the test and assumed in the model are different. There are very few MLI test data available in the low temperature region; therefore, more testing is recommended.

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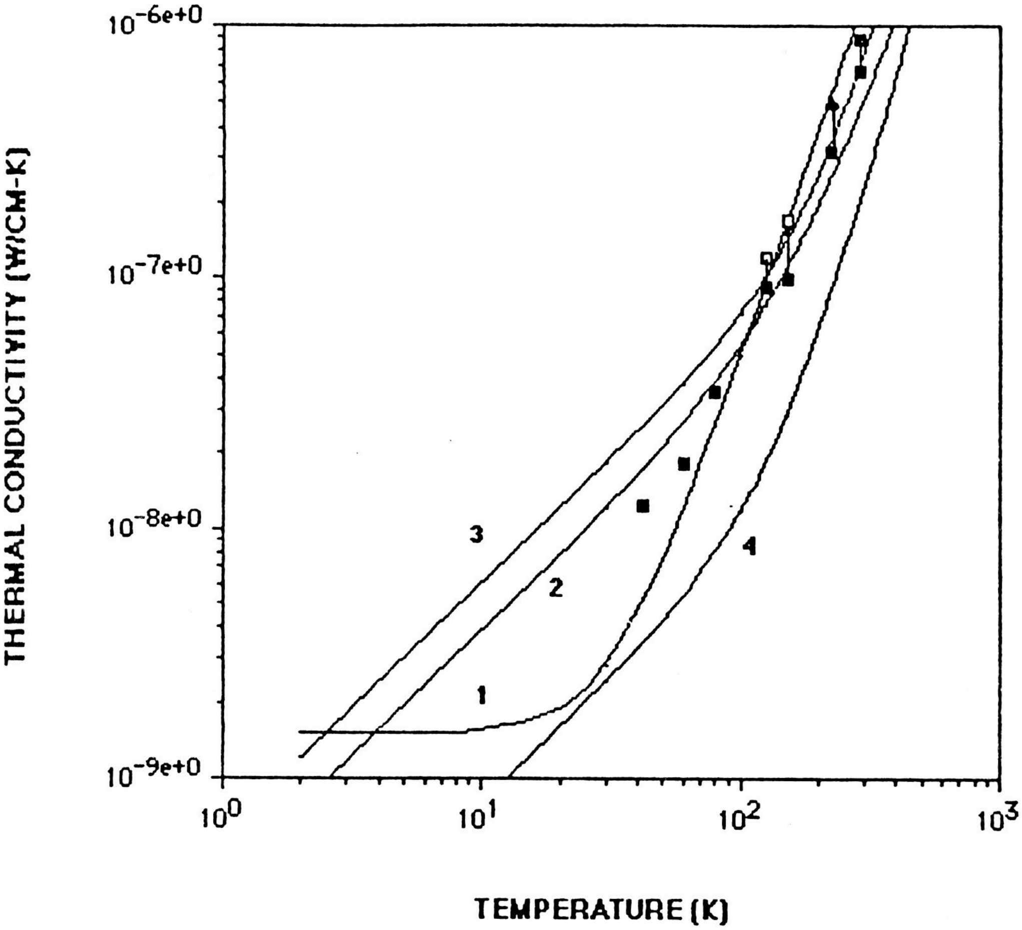
MULTILAYER INSULATION MODELS



LEGEND:

1. DAM/DN (8 TO 12 layers/cm). Used in IRAS and COBE - Ref. 4
2. DAM/2 layers silk net (20 l/cm). Flat plate calorimeter test (77 K/300 K) - Ref. 5
3. DAM/2 layers silk net (15 l/cm). Flat plate calorimeter test (T_c = 77 K) - Ref. 6
4. DAM/2 layers silk net (15 l/cm). 15 L tank calorimeter test (50 K/133 K , 55 K/295 K) - Ref. 7
5. Data extrapolated from Ref. 3, 15 L tank calorimeter test (T_c = 4 K, T_c = 77 K) DAM/SN
   - □ 1 layer silk net (12.4 l/cm)
   - ■ 3 layers silk net (11.5 l/cm)
   - ▲ 3 layers silk net (16.4 l/cm)

TANK SUPPORTS

There are several design criteria affecting the sizing of tank supports such as the tension straps used on IRAS and COBE, and the Passive Orbital Disconnect Struts IV (PODS-IV) proposed to be flown on Gravity Probe-B (GP-B). The minimum launch resonance used previously in the design and analysis of SIRTF tank supports was 35 Hz specifed before the Shuttle was flown. Now, the minimum launch/on-orbit/landing resonance for SIRTF could be as low as 6 Hz which is determined by the SIRTF mass and damping characteristics (JSC 07700 Vol. XIV). However, the Shuttle payload has to avoid having launch resonance coinciding with the Shuttle lift-off transient peaks whose effect on the payload is unknown until a coupled load analysis with the Shuttle carrier is performed. Therefore, a minimum launch resonance of 10 Hz is now used for SIRTF. The minimum orbit resonance for SIRTF is determined by setting a frequency considerably higher than its control system bandwidth, and also avoid coupling with other excitations. The previous control system used had a bandwidth of 2 Hz, now a spacecraft with a control system bandwidth of 0.2 Hz is more likely to be used. The Shuttle imposed on-orbit resonance requirement of 6 Hz has to be met. In addition, SIRTF has a secondary mirror chopper which would oscillate at as high as 5 Hz during observations. Therefore, a minimum orbit resonance frequency of 10 Hz is required for SIRTF.

With the reduction of the SIRTF resonance frequencies for launch (35 Hz) and orbit (20 Hz) to 10 Hz for both launch and orbit, the sizing of both the straps and PODS may not be frequency limited. The strap size could be driven by the fatigue strength requirement while the PODS driven by the column buckling strength requirement. Both tension straps and PODS may benefit from the use of a low thermal conductivity-to-modulus of elasticity ratio material. Takeno, et al (Ref. 8) have suggested using alumina fibers with epoxy as the tank support material. Recently, Hopkins, et al (Ref. 9) have tested some alumina/epoxy tension straps and analyzed some dewar systems using alumina/epoxy tension straps. Results show that the modulus of elasticity and fatigue strength are better than fiberglass, but the thermal conductivity is higher above 50 K.

TANK SUPPORTS

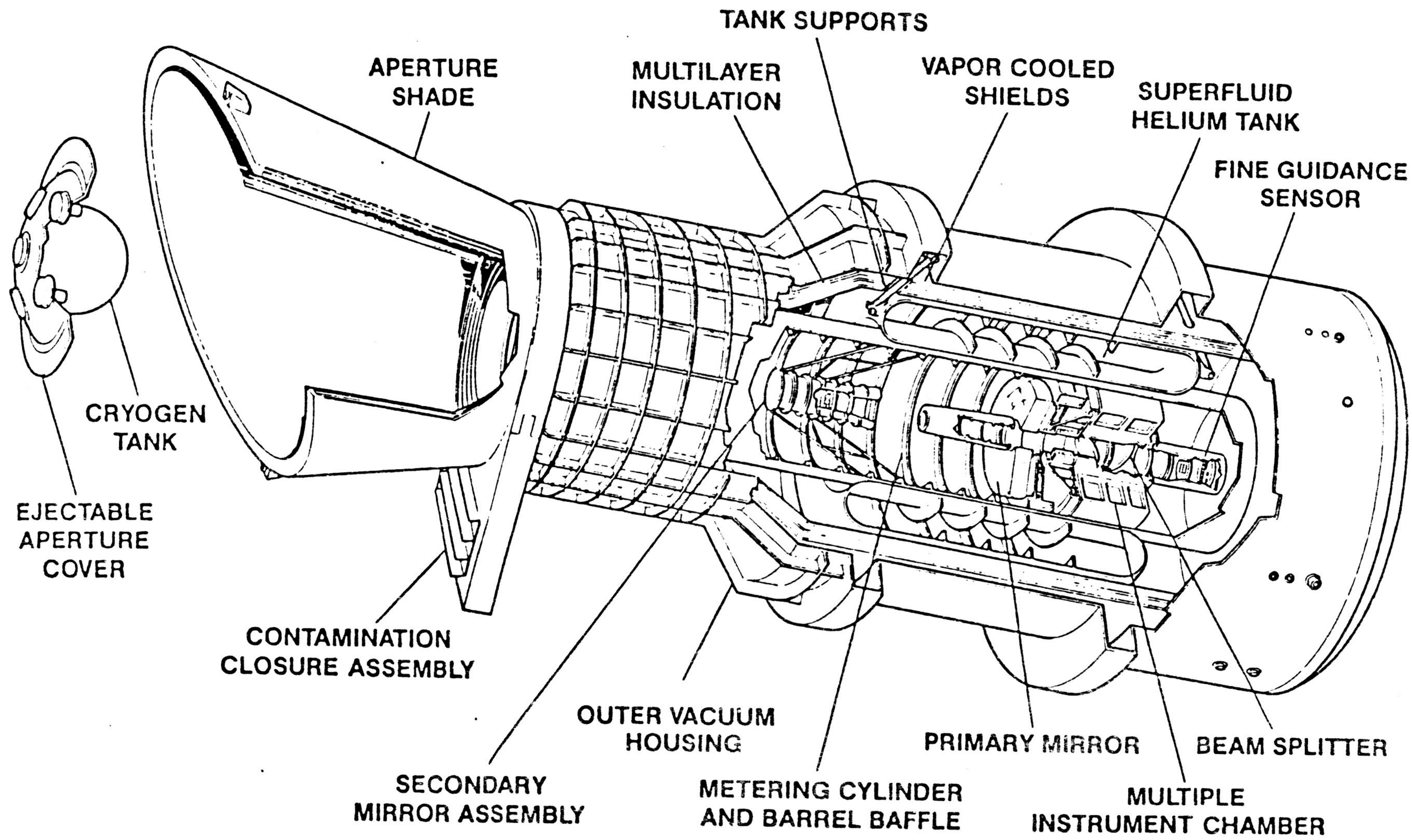
DESIGN CRITERIA	SIRTF	STORAGE TANKS
LAUNCH RESONANCE	> 6 Hz (was 35 Hz)	> 7 Hz
AVOID SHUTTLE LIFT-OFF TRANSIENT PEAKS (8,14,19,23,30 Hz)	DESIGN FOR 10 Hz	DESIGN FOR 10 Hz
ORBIT RESONANCE	> 10 Hz (was 20 Hz)	> 7 Hz
TENSILE STRENGTH	HIGH	HIGH
COLUMN BUCKLING STRENGTH	DRIVES PODS AREA, LENGTH	DRIVES PODS AREA,LENGTH
FATIGUE STRENGTH	DRIVES STRAPS AREA	DRIVES STRAPS AREA DRIVES PODS AREA
LOCAL CRIPPLING STRENGTH	AFFECTS PODS OUTER TUBE AREA	AFFECTS PODS OUTER TUBE AREA
SIDE LOAD RESISTANCE	AFFECTS PODS INNER TUBE DESIGN	AFFECTS PODS INNER TUBE DESIGN
THERMAL CONTRACTION	AFFECTS STRAP PRETENSION; AFFECTS PODS INNER TUBE DESIGN	AFFECTS STRAP PRETENSION; AFFECTS PODS INNER TUBE DESIGN
THERMAL CONDUCTIVITY	LOW	LOW

SIRTF TELESCOPE CONFIGURATION

The Space Infrared Telescope Facility (SIRTF) is currently under study and is planned to be launched in the mid-1990s. SIRTF is a 1-meter class space observatory to be flown in a 28.5 degrees, 900 km orbit. The operational lifetime is between 5 to 10 years. The initial cryogen lifetime before replenishment is planned for at least 2 years; thereafter, replenishment of SIRTF could be as frequent as every 2 years.

SIRTF's optical system is a f/24 Ritchey Chretien Cassegrain telescope with an aperture diameter greater than 85 cm. SIRTF's three science instruments, the Infrared Array Camera (IRAC), Infrared Spectrometer (IRS), and the Multiband Imaging Photometer (MIPS), will cover a spectral range of 1.8 to 700 μm. The science instruments and optical system will be cooled by a 4000-liter superfluid helium tank.

SIRTF uses an asymmetrical aperture shade to prevent Earthshine from radiating directly into the aperture while keeping the solar rays from striking the interior surface of the aperture shade. The interior surface is highly reflective and coated with vapor-deposited aluminum to minimize IR emittance. The mission average aperture heat load is estimated to be 170 mW (Ref. 10).



SIRTF TELESCOPE CONFIGURATION

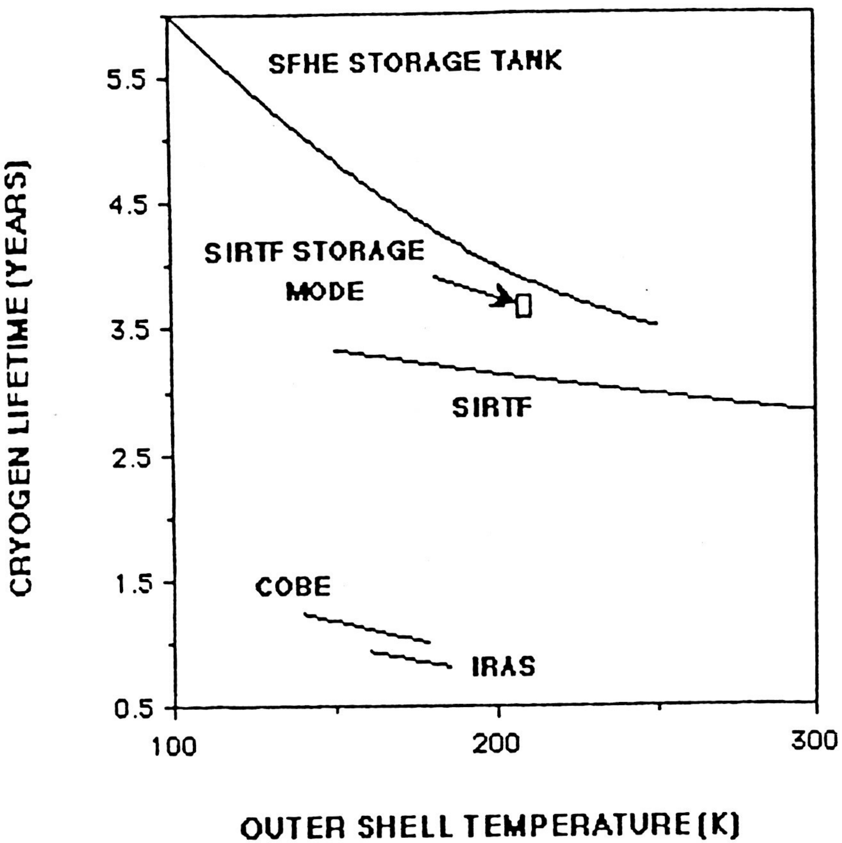
SUPERFLUID HELIUM (SFHE) SYSTEM OUTER SHELL SENSITIVITY

The result presented here for SIRTF is based on a 3 vapor-cooled shield (VCS) design with DAM/SN insulations. Tank supports are sized for 10 Hz launch and orbit resonance frequencies. SIRTF's lifetime changes by 1.2 days per degree change in outer shell temperature while IRAS and COBE change 2 days per degree Kelvin. SIRTF is not as sensitive as IRAS or COBE to outer shell temperature because the high helium flowrate generated by the high instrument heat load helps reduce the parasitic heat load. The actual IRAS on-orbit lifetime was 300 days (Ref. 11), while COBE with a cryogen tank which is 23% larger than IRAS is predicted to have a lifetime of 415 days (Ref. 12). The SFHE storage tank (Ref. 2) has 5 VCS with DAM/SN insulations, and uses 6 PODS to support the cryogen tank. Its lifetime with outer shell temperatures greater than 200 K is not as sensitive to change in outer shell temperature as that below 200 K. At high outer shell temperatures, parasitic heat from MLI dominates, whereas at low outer shell temperatures, parasitic heat from PODS and electrical wires dominates.

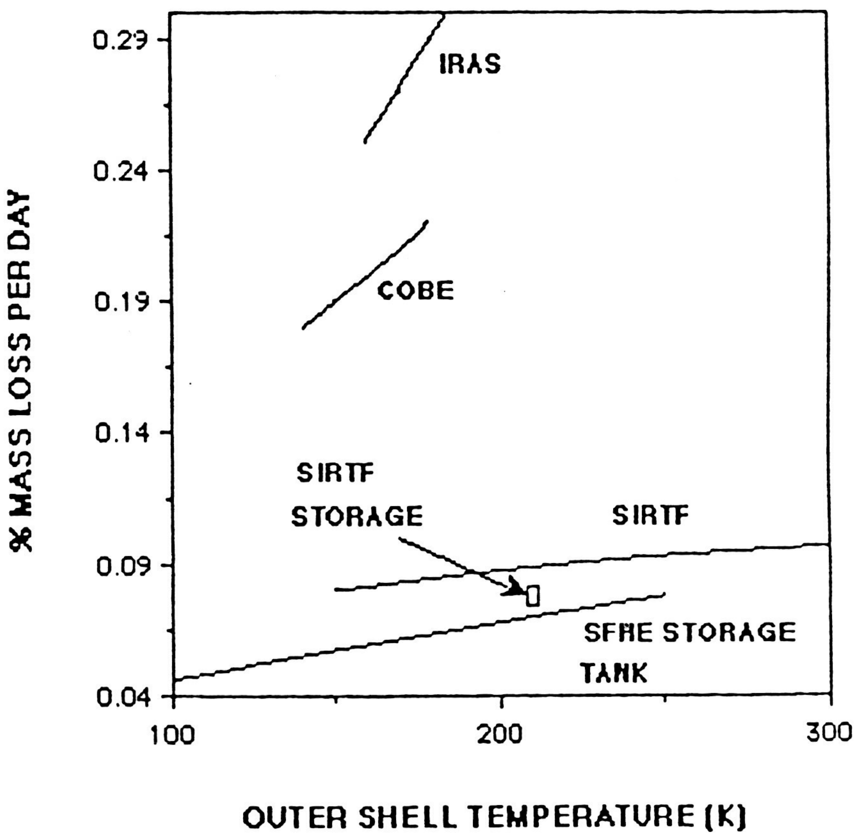
The cryogen mass loss rates calculated are based on a full cryogen tank; ullage and ground-hold losses are neglected. A typical commercial helium dewar has loss rate of 0.4% per day while an IRAS dewar with 4 VCS can have loss rate of 0.1% per day (Ref. 13). A 10,000-Liter helium storage dewar using PODS and 3 VCS can have loss rate of 0.14% per day with a 300 K outer shell(Ref. 14). SIRTF in a storage mode (no instrument heat) has a predicted loss rate of 0.075% per day with a 210 K outer shell.

SFHE SYSTEM OUTER SHELL SENSITIVITY

CRYOGEN LIFETIME



% CRYOGEN MASS LOSS



SIRTF :	4000 L TANK, PREDICTED ON-ORBIT LIFETIME 3.1 YEARS AT T(OS) = 210 K, 115 mW INSTRUMENT HEAT
SFHE STORAGE: TANK	1000 L TANK, PREDICTED ON-ORBIT LIFETIME 4 YEARS AT T(OS) = 200 K, 11 mW INSTRUMENT HEAT
IRAS:	550 L TANK, ACTUAL ON-ORBIT LIFETIME 300 DAYS AT T(OS) = 197 K, 20 mW INSTRUMENT HEAT
COBE:	660 L TANK, PREDICTED ON-ORBIT LIFETIME 415 DAYS AT T(OS) = 150 K, 23 mW INSTRUMENT HEAT

PARASITIC HEAT FROM TANK SUPPORTS AND MLI

The results shown here are based on the performance of a SIRTF dewar using either PODS or straps sized for 20 Hz orbit and 35 Hz launch resonance frequencies. In the PODS dewar, MLI dominates the parasitic heat until the IVCS temperature decreases as a result of the higher flowrate caused by higher instrument heat load. In the straps dewar, straps dominate the parasitic heat even more as the flow rate increases. In either the straps or PODS dewar, both the MLI and tank supports together contribute about 75% of the total parasitic heat; the rest of the parasitic heat comes from aperture heat, wiring, and plumbing.

PARASITIC HEAT FROM TANK SUPPORTS AND MLI

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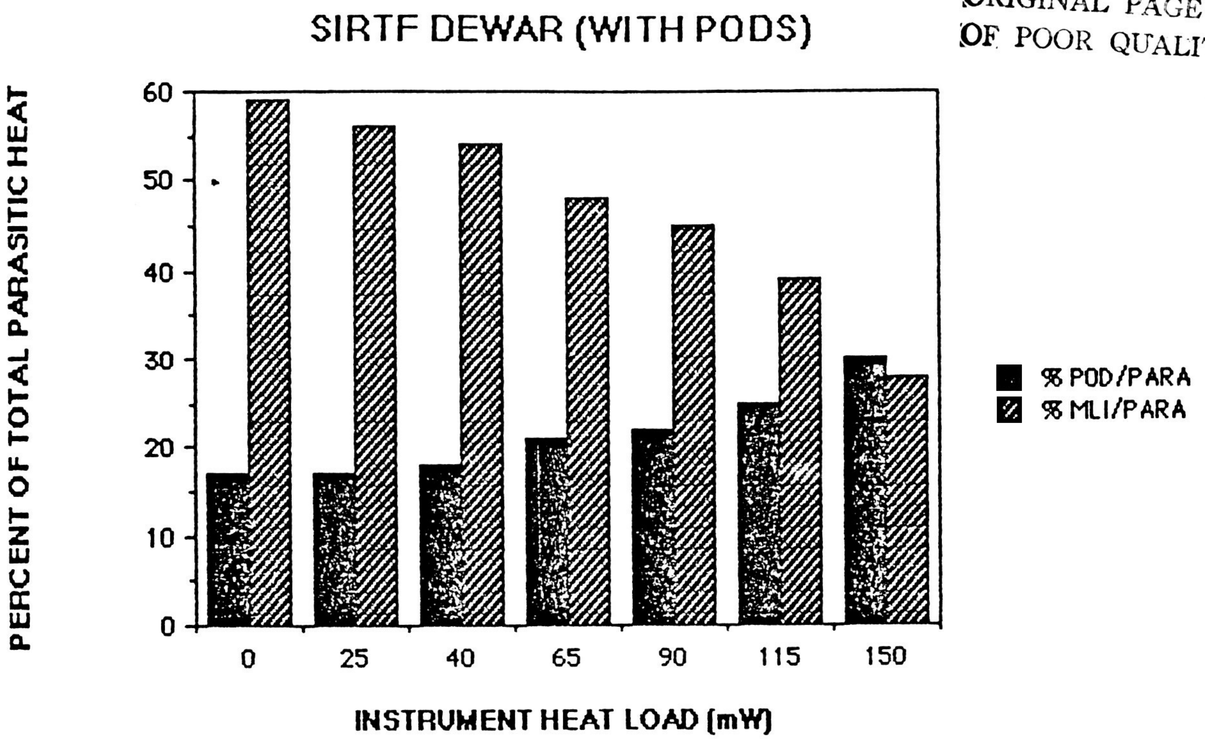

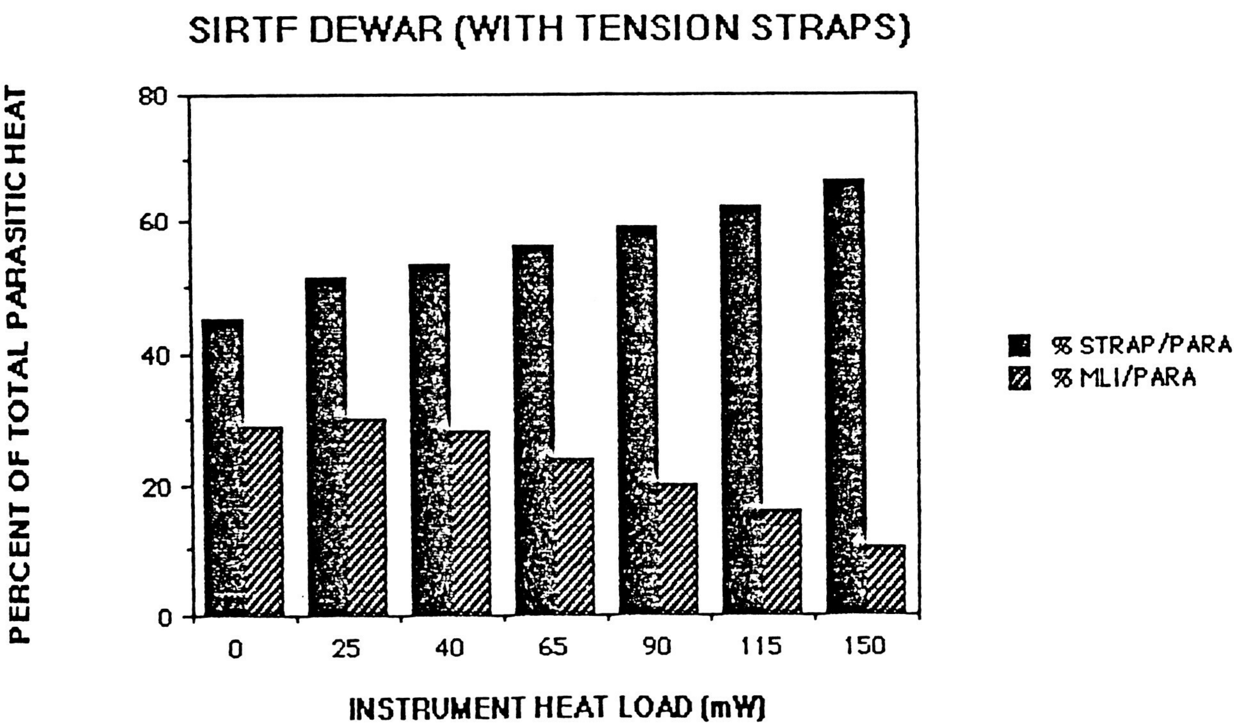

SPACE STORAGE SYSTEMS PERFORMANCE

The results of the space station storage tank performance were obtained from Ref. 16. The storage tanks were sized for liquid hydrogen and liquid oxygen with 5 years lifetime. Both tanks were assumed to be vented to maintain constant cryogen bath temperature. The tanks used DAM/SN insulations and 12 PODS sized for 35 Hz launch and 10 Hz orbit resonance frequencies. The liquid oxygen mass could not be higher than 28,000 kg. because of the Shuttle launch constraint. It is more advantageous to use VCS in a LH_2 rather than in a LO_2 storage tank because LH_2 has a lower bath temperature (20 K) than LO_2 (90 K). In addition, the specific heat of gaseous hydrogen could be several times higher than that for gaseous oxygen; therefore, the LH_2 system has a higher sensible heat available to cool its shields.

The Hydrogen Thermal Test Article (HTTA) and Oxygen Thermal Test Article (OTTA) tanks designed and manufactured by Beech Aircraft have a 2 VCS insulation system (Ref. 17). The HTTA tank has a capacity of 22600 liters while the OTTA tank has a capacity of 6400 liters. The estimated cryogen loss rate were based on a 333 K outer shell for both tanks.

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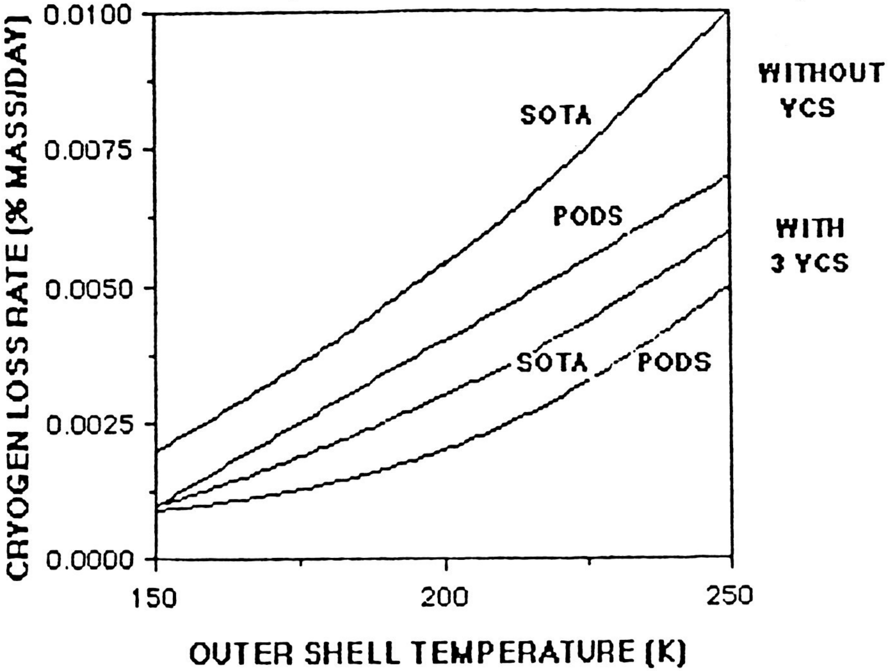
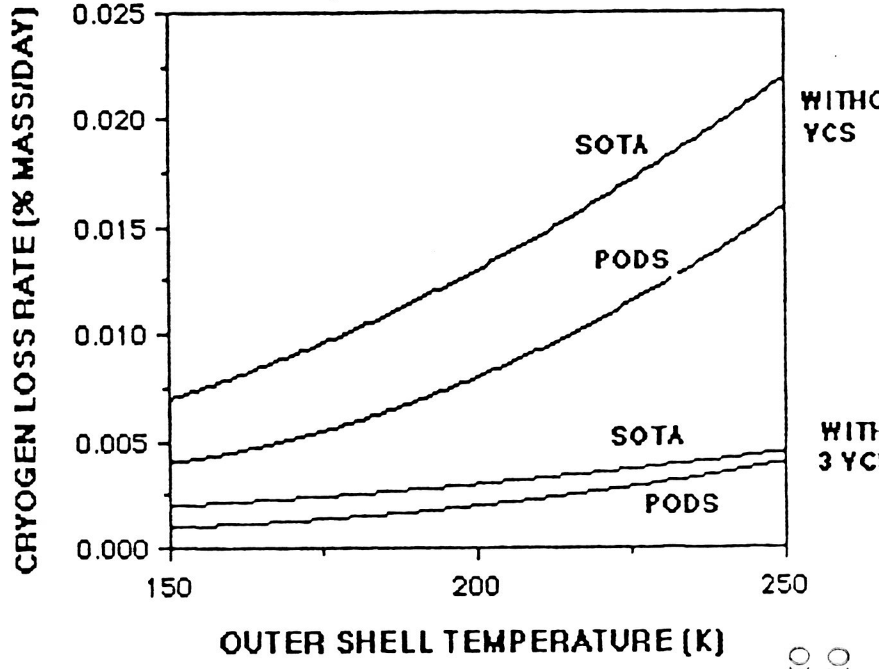
SPACE STORAGE SYSTEMS PERFORMANCE

41,000-L LO2 STORAGE TANK
(28,000 kg LO2)



110,000-L LH2 STORAGE TANK
(7700 kg LH2)



VENTED SPACE STATION TANKS SIZED FOR 5 YEARS

PODS-III AND SOTA (STATE-OF-THE-ART) STRUTS SIZED FOR 35 HZ LAUNCH AND 10 HZ ORBIT RESONANCE

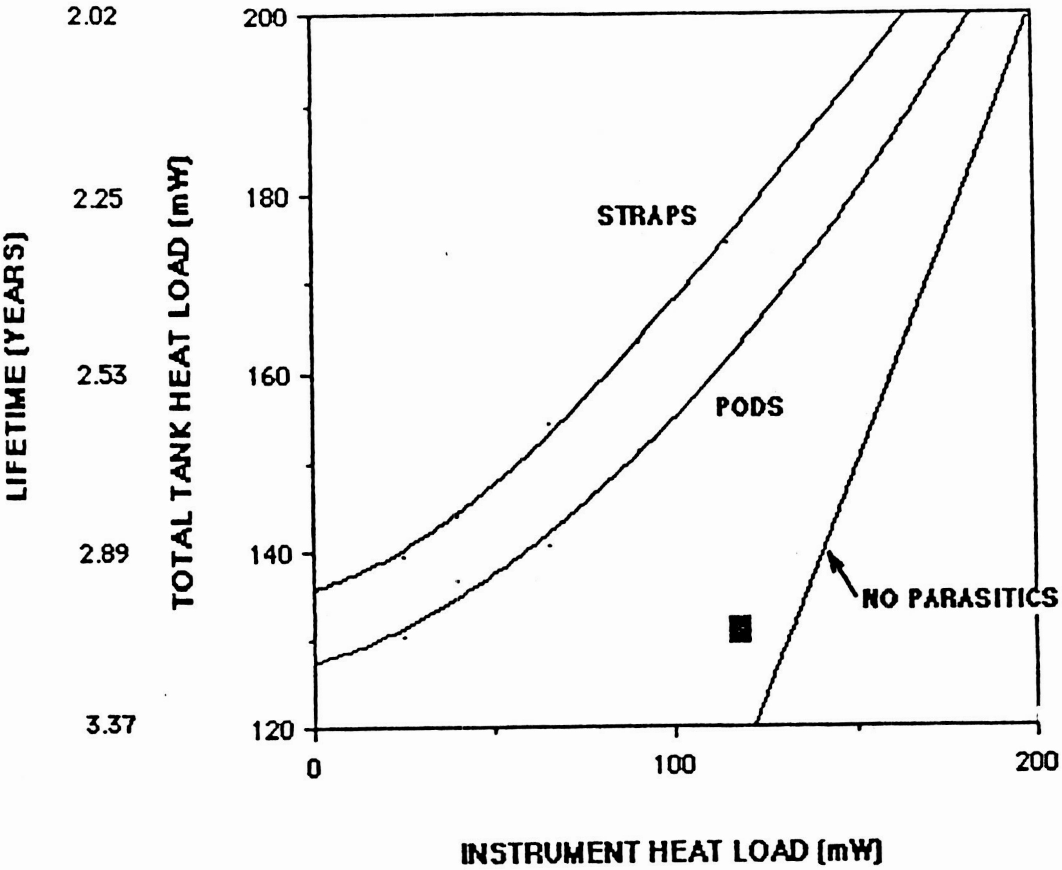
PODS ARE MORE ADVANTAGEOUS THAN SOTA STRUTS IN NON-VAPOR-COOLED SYSTEMS

PROBABLY REQUIRE STATE-OF-THE-ART DEWAR TO MEET THE PREDICTED CRYOGEN LOSS RATES PERFORMANCE

- HIGH QUALITY COMMERCIAL DEWARS (0.1% PER DAY)
- HTTA TANK (BEECH): 0.02% PER DAY FOR LH2
- OTTA TANK (BEECH): 0.01% PER DAY (LO2), 0.06% PER DAY (LH2)

SIRTF DEWAR PERFORMANCE

(4000 L SFHE)



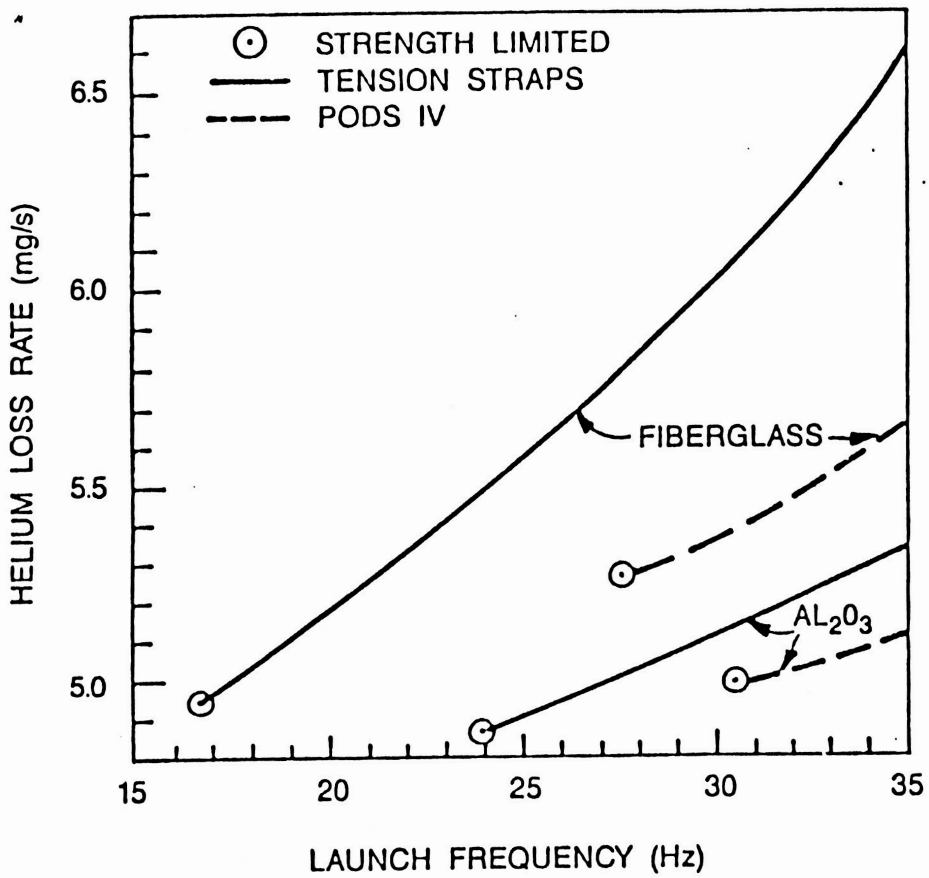
TENSION STRAPS OR PODS SIZING BASED ON 20 HZ ORBIT AND 35 HZ LAUNCH RESONANCE (FREQUENCY DOMINATED)

■ -- TENSION STRAPS SIZING BASED ON 10 HZ ORBIT AND LAUNCH RESONANCE (FATIGUE DOMINATED)

210 K OUTER SHELL TEMPERATURE

SIRTF OPERATING IN STORAGE MODE FOR INSTRUMENT HEAT LOAD LESS THAN 100 mW

SIRTF DEWAR PERFORMANCE
(TENSION STRAPS VS. PODS IV)



(Reproduced from Ref. 15, with permission from authors)

HELIUM LOSS RATE IS 17% HIGHER FOR STRAPS IF SIRTF IS FREQUENCY LIMITED (35 HZ LAUNCH AND 20 HZ ORBIT)

HELIUM LOSS RATE IS 6% HIGHER FOR PODS IF SIRTF IS STRENGTH LIMITED (10 HZ LAUNCH AND ORBIT)

MINIMAL DIFFERENCE IN SIRTF PERFORMANCE IF ALUMINA/EPOXY IS USED IN BOTH STRAPS AND PODS

ALUMINA/EPOXY INSTEAD OF FIBERGLASS STRAPS OFFER SIGNIFICANT PERFORMANCE IMPROVEMENT IN A FREQUENCY LIMITED SYSTEM

DEWAR CONSTRUCTION

4000 LITER SUPERFLUID HELIUM TANK (1.85 K)

OUTER SHELL PASSIVELY COOLED TO 210 K AVERAGE (SILVERIZED TEFLON SECOND SURFACE OR WHITE PAINT)

5 STAGES OF VAPOR COOLING (7 K MIC, FOREBAFFLE, IVCS, MVCS, OVCS)

HEAT LOAD

- 115 mW INSTRUMENT HEAT LOAD DISSIPATED DIRECTLY INTO TANK
- 70 mW FROM 7 K MIC AND 150 mW APERTURE HEAT ABSORBED BY VAPOR

MULTILAYER INSULATIONS (DAM/SN - 117 LAYERS TOTAL)

CRYOGEN TANK SUPPORTS (TENSION STRAPS OR PODS-IV)

SCIENCE INSTRUMENT ELECTRICAL WIRES

- 400 COAX AND 400 MANGANIN TWISTED PAIRS

DEWAR INSTRUMENTATION ELECTRICAL WIRES

- 234 MANGANIN WIRES

PLUMBING

- GROUND FILL(HIGH VENT), VENT, AND ON-ORBIT TRANSFER LINES

CONCLUSION

POSSIBLE TO APPLY TECHNOLOGY DEVELOPED FOR HELIUM SYSTEMS TO OTHER SPACE CRYOGEN STORAGE SYSTEMS

DESIGN OF STORAGE DEWARS HAS FEWER STRINGENT PERFORMANCE REQUIREMENTS TO SATISFY THAN OBSERVATORY

ADVANCES IN SUPPORT SYSTEMS AND MULTILAYER INSULATIONS HAVE BEEN MADE, NEED SPACE DEMONSTRATION TO VALIDATE SYSTEM PERFORMANCE

MULTILAYER INSULATIONS HEAT LOAD TENDS TO DOMINATE THE PARASITIC HEAT OF A LARGE STORAGE DEWAR SYSTEM; MORE TEST DATA OF MLI PERFORMANCE AT LOW TEMPERATURE IS REQUIRED

NEW MATERIAL (ALUMINA/EPOXY) FOR TANK SUPPORTS COULD INCREASE LIFETIME OF SPACE STORAGE DEWARS; COULD USE SPACE SYSTEM DEMONSTRATION TO VERIFY

MECHANICAL COOLERS CAN INCREASE STORAGE DEWAR CRYOGEN LIFETIME; DUAL CRYOGEN MAY BE ADVANTAGEOUS IF DEWAR OUTER SHELL TEMPERATURE IS HIGHER THAN 200 K

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SPEAKER: JEFFREY H. LEE/AMES RESEARCH CENTER:

David DeFelice/Lewis Research Center:

I was wondering if you could tell me what are the consequences of missing one of the servicings of liquid helium? Does that damage the instruments, or does it just cause a loss of capability until you can go back and service it with liquid helium?

Lee:

Ball and Lockheed just completed studies for us, called the STICCR studies. STICCR stands for SIRTIF Telescope Instrument Changeout and Cryogen Replenishment. We looked at two cases; one is cold transfer where the tank is still cold, and we found out how much helium is needed to top off the tank. In the other case, the filling of the warm tank initially at either 300 or 150 degrees Kelvin, and that takes 30 to 50 hours to cool the SIRTIF down, and you use up a lot more helium. In terms of the instruments, right now, they plan to put an adiabatic demat refrigerator in there. I don't think they like to let this refrigerator run warm. Thus, there is more concern with the effects of warming up the refrigerator than there is with interupting the cooling to the instruments.

Peter Mason/Jet Propulsion Laboratory:

I noticed that you are using a figure of 10 Hertz as the launch resonance requirement; the normal requirement on the shuttle is 25 Hertz. Can you explain why you feel you can manage with the 10 Hertz structural resonance?

Lee:

Did you say it is 25 Hertz or 35?

Mason:

I believe the shuttle now is 25.

Lee:

Before I used 35 hertz.

Mason:

That was the IRAS requirement for a Delta launch; the shuttle currently has a 25 Hertz requirement.

Lee:

I guess I am not familiar with that. The launch frequency I came up with was from JSC 00700. The handbook shows that you have to look at the mass and damping ratio of the payload, and that gives us 6 Hertz, but we talked to JSC and they told us that we had to avoid that transient. I am not aware that there is a minimum 25 Hertz/frequency.

Mason:

That was imposed on us, at least on Space Lab 2.

Lee:

COBE designed their tank to make it fatigue limited. They oversized the straps a little bit. The frequency came out to be 29 Hertz. I talked to Dick Hopkins who told me that the frequency certainly wasn't the criteria used for design.

Mason:

I noticed that you said ISO is going to have a 120K outer shell temperature. Is that because of the orbit?

Lee:

It is because of the orbit; the apogee is 40,000 kilometers and the perigee is 4,000 kilometers, so you have a lot of cooling due to radiation to space.

Hugh Arif/Analex Corporation--Lewis Research Center:

When you based your criteria for designing the tension straps on frequency rather than buckling, the different numbers for frequency that you obtained were around 10, 25, and 35; are those frequencies for the entire payload, or did you design each tension strap for that frequency?

Lee:

We have a set of twelve straps or PODS, which stands for Passive Orbital Disconnect Struts. Basically, we look at the first fundamental mode of the dewar and telescope. The first mode could be the axial mode, so it is the system frequency, but it could be dominated by the strap characteristics.

Arif:

If you were designing a strap for a particular frequency, you would have to have a quite high frequency for that strap so that when all the different components are added the entire payload would have a lower 35 Hertz frequency.

Lee:

From the PODS study, managed by Peter Kittel, the PODS frequency by itself is more than 120 Hertz. When you put twelve of them together, it is the other system masses that dominated and not the straps.

Bob Rudlin/Martin Marietta Denver Aerospace:

I was curious how you picked the 1.85 degree Kelvin. You can operate over quite a wide range apparently from 1.5 up to about 1.9. How did you arrive at 1.85?

Lee:

There is no magic to it, but in order to achieve the desired temperature you have to be careful in designing your plumbing. On IRAS the flow meter limited the temperature to 1.8 degrees Kelvin; we established that first. On COBE, they designed to operate at 1.6 degrees Kelvin, but they don't use a flow meter. I guess that the scientists want to operate at as low a temperature as possible. They want to stay near 1.5 or 1.4 degrees Kelvin if they can. That means we have to design the plumbing to use a bigger size vent line. The bath temperature depends on the vapor pressure over the bath, and that is determined by the size of the vacuum tubing.

Rudlin:

Concerning the porous plug apparently used on the infrared telescope; there was concern that they had liquid coming out through the porous plug. Do you have any problems like that?

Lee:

We haven't got to the stage of developing a porous plug yet. Right now, we are still doing paper studies.