

### NOTICE

The results of the OAST Space Technology Workshop which was held at Madison College, Harrisonburg, Virginia, August 3 -15, 1975 are contained in the following reports:

EXECUTIVE SUMMARY

- VOL I DATA PROCESSING AND TRANSFER
- VOL II SENSING AND DATA ACQUISITION
- VOL III NAVIGATION, GUIDANCE, AND CONTROL
- VOL IV POWER
- VOL V PROPULSION
- VOL VI STRUCTURE AND DYNAMICS
- VOL VII MATERIALS
- VOL VIII THERMAL CONTROL
- VOL IX ENTRY
  - VOL X BASIC RESEARCH
    - VOL XI LIFE SUPPORT

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Office of Aeronautics and Space Technology

Summer Workshop

August 3 through 16, 1975

Conducted at Madison College, Harrisonburg, Virginia

**Final Report** 

THERMAL CONTROL PANEL

Volume VIII of XI

i.

## OAST Space Technology Workshop

THERMAL CONTROL PANEL

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#### SUMMARY

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Since the Thermal Control Working Group had just recently completed a near term assessment of their technology needs [Ref. 1], the group was able to concentrate on long range identification of technology requirements. The Outlook for Space, Forecast for Technology [Ref. 2], was used as a primary reference for identifying anticipated long range technology deficiencies. Furthermore, the overriding themes which were apparent during the workshop were <u>large structures</u> and <u>cold</u> <u>controlled environments</u>. The Thermal Control Group has attempted to address its technology forecast in the perspective of these guidelines.

Thermal Control technology was divided into eleven categories: Thermal Control Surfaces; Heat Pipes; Mechanisms; Testing; Instrumentation; Contamination; Cryogenics; Analysis; Thermal Properties; Insulation; and Design Techniques. These categories include both technology requirements and tools. Particular long range needs were identified under these categories and finally, relevant flight experiments were identified and documented.

Three major thrusts, besides reduction of costs, were identified as major directions for thermal control technology development and space experiments.

- Extend the useful lifetime of cryogenic systems for space
- 2. Reduce temperature gradients

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#### 2. Improve temperature stability

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The cryogenic objective is interpreted to include such elements as methods for achieving temperatures approaching 0°K, cryogen management, passive radiation and refrigeration systems for replacing expendable cryogens, and technology for cryogen replenishment as well as devices and systems designs to extend lifetime directly by reducing losses.

Reduction of a macro-gradients (tens of degrees) in very large structures and micro-gradients (degrees and fractions of degrees) in instruments and optical systems or the effects of such gradients will be achieved by combinations of new technology in thermal control surfaces, material properties and design approaches as well as active devices such as heat pipes. For example, thermal distortion of an antenna might be reduced by use of low coefficient of expansion material for construction, thermal expansion compensated configuration or heat pipes as ribs.

Improved temperature "stability" includes improved ability to achieve a required absolute temperature, accurate prediction of equilibrium operating temperature in space, controlled transient temperatures as well as ability to maintain acceptable temperatures under varying load and lifetime conditions. Technology requirements include active devices and systems, design approaches as well as long term properties and stability of coatings, insulation, etc.

A consensus of the five key flight experiments was not

taken by the group. However, the chairman has identified four key experiments and the fifth experiment will depend on whether space processing and power experiments, or earth resources and earth science experiments are given priority. The key experiments are:

- (1.) Shuttle Contamination Effects on Thermal Control Surfaces
- (2.) Stored Cryogen System Evaluation
- (3.) He<sup>II</sup> Storage and Utilization
- (4.) Ultra-high Conductance Heat Pipe Development for very Large Structures

For space processing and/or power experiments, the fifth experiment should be:

(5.) Development of Large, Variable Heat-rejection Radiators

For earth resources and earth science experiments, the fifth experiment should be:

(5.) Development of a Deployable, Controlled Orientation Radiator

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#### REFERENCES

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- "Report of the Space Transportation Systems Technology Working Group for Thermal Control" Internal Report to Paul Herr, Program Manager, Advanced Systems Technology, OAST, February, 1975.
- "Outlook for Space Reference Volume: A Forecast of Space Technology 1980-2000", Final Draft, NASA Special Publication, July, 1975.

# INTRODUCTION

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#### I. Introduction

The technology recommendations in this report were developed during the two week NASA/OAST 1975 summer workshop, based on the background information provided and the expertise of the working group members. The supporting text and technology descriptions are intended to contain sufficient information to permit assessment as required.

The technology requirements (Section II) are not intended to be a complete listing, and the relative scope of Sections II and III (flight experiments) should not be construed to indicate the relative importance of ground based technology versus space experiments. Identification of technology requirements was an essential and accomplished step in defining meaningful space experiments. Since the primary objective of the workshop was the identification of space experiments, priority was given to their documentation for this report. In many cases, the included information was extracted from Reference 1.

For the purposes of dealing with the total of thermal control technology, several technology categories were identified. These categories included both the requirements as well as specific tools or means to meet these requirements. The sequence has no relation to relative importance, but merely provided a convenient means of organization.

In defining flight experiments, the primary criterion was

the need for space (i.e., low-g, vacuum, etc.). The question of relative cost of space vs. ground testing could not be addressed due to the constraints of time. Some technology items not included here may become candidates for space experiment, if cost effectiveness can be shown.

The working group undertook to define its scope, starting with the Outlook for Space (OFS) matrix [Ref. 2]. Thermal control has been defined by OFS as Management of Matter (maintenance of state). During the initial establishment of an approach, some technology items were not clearly identified. These included contamination, radiation and micrometeorites. The containment of pressurized fluids dealt only with thermal control materials (cryogens and phase change materials) aspects of the problem. In the area of contamination, the working group considered only the effects of contamination on the properties of thermal surfaces and some of the effects of temperature profile on contaminant transport.

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Technology related to radiation effects on thermal surfaces was included. All other aspects of radiation (i.e., model definitions, other effects, etc.) were deleted from consideration. Micrometeroid technology was omitted. The potential genificance of the above omissions is discussed in more detail in Appendix C.

Thermal control design requirements and constraints are derived from the specifics of mission, system, and subsystem design. These design drivers are typically not well defined

for advanced missions, with the result that the associated requirements for thermal technology which are interactive with other features of spacecraft design, have consequently been omitted from the Thermal Group's considerations. This omission was the undesirable but unavoidable result of not being able to define part of the required input data; the process of identifying candidate cechnology developments and flight experiments can be expected to proceed as these data become available. The recommendations herein should therefore be understood to be incomplete in this important area.

#### APPROACH

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The general approach used by the TC working group is illustrated in Figure I-1.

Since near term Thermal Control Technology requirements have been developed during the past year [Ref. 1], the working group chose to approach this workshop from a long range point of view, starting with Outlook for Space (OFS). Section II of the OFS, "Forecast of Space Technology" [Ref. 3] and the detail breakdown of that section in Reference 4, were reviewed in parallel to identify anticipated deficiencies and issues in thermal control technology to meet the overall objectives of the indicated areas of NASA emphasis in Reference 3 and in space environment opportunities to support OFS [Ref. 4]. The subdivisions or categories of thermal control in the matrix (Figure I-2) are a convenient means of organizing the approach and were subsequently carried over into organization of the report. These categories contain both the requirements that TC must meet and the tools used to meet these requirements.

Other source documents, '73 NASA Payload Model, OFS Illustrative Missions (Vol. 2), Opportunities and Choices in Space Science, '74 (National Academy of Science) etc., were reviewed to identify gaps within each technology category.

In developing the matrix (Figure I-2), considerable selectivity was inherent in identifying the need for

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additional technology. Subsequently each category was reviewed as indicated in Figure I-3. This analysis identified the need for ground based technology, flight experiments for technology development and space experiments for demonstration or verification of equipment or systems.

Flight experiment narrative (Section III) and payload descriptions (forms, Appendix B) were prepared. Each flight experiment was assigned to a primary technology category although many encompass more than one category. The report has been organized in accordance with this assignment. The organization of technology requirements narratives (Section II) and definitions (Appendix A) follow the flight experiment assignment.

#### CONCLUSIONS

Among the wide variety of requirements that drive Thermal Control Technology, the two outstanding themes for the next 25 years are COLD and LARGE.

Low temperatures (cryogenics) will be required for many of the proposed sensors, optics and experiments. New and improved technology will be required to permit achievement and practical (economical) implementation of proposed equipment and experiments.

Shuttle will make possible and viable, the launch, erection and/or assembly of structures, instruments and equipment very much larger than in the past. Practical utilization of this large equipment will require thermal control approaches significantly different than those used in the first two decades of space exploration.

Most of the technology and space experiments identifi. during the Workshop can be summarized in three key directions or objectives of thermal control technology development:

- Extend the useful lifetime of cryogenic systems in space.
- 2. Reduce temperature gradients.

3. Improve temperature stability.

A major subelement of each of these three as well as of other objectives is REDUCTION OF THERMALLY RELATED SYSTEM COST.

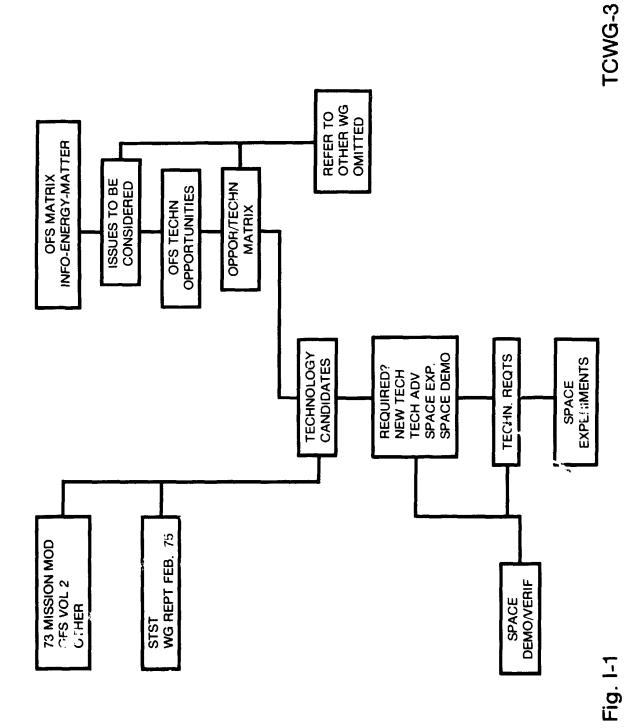
The cryogenic objective is interpreted to include such elements as methods for achieving temperatures approaching

0°K, cryogen management, passive radiation and refrigeration systems for replacing expendable cryogens, and technology for cryogen replenishment as well as devices and systems designs to extend lifetime directly by reducing losses.

Reduction of a macro-gradients (tens of degrees) in very large structures and micro-gradients (degrees and fractions of degrees) in instruments and optical systems or the effects of such gradients will be achieved by combinations of new technology in thermal control surfaces, material properties and design approaches as well as active devices such as heat pipes. For example, thermal distortion of an antenna might be reduced by use of low coefficient of expansion material for construction, thermal expansion compensated configuration or heat pipes as ribs.

Improved temperature "stability" includes improved ability to achieve a required absolute temperature, accurate prediction of equilibrium operating temperature in space, controlled transient temperatures as well as ability to maintain acceptable temperatures under varying load and lifetime conditions. Technology requirements include active devices and systems, design approaches as well as long term properties and stability of coatings, insulation, etc.

The COST objectives are primarily the thermally defined or constrained system cost per unit of science information or space operation time rather than a lower cost can of paint, heat pipe or square foot of insulation.



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THERMAL CONTROL APPROACH

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Fig. I-2

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TCWG-5

THERMAL CONTROL MATRIX OPPORTUNITY - TECHNOLOGY

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THERMAL CONTROL MATRIX

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# **OPPORTUNITY - TECHNOLOGY**

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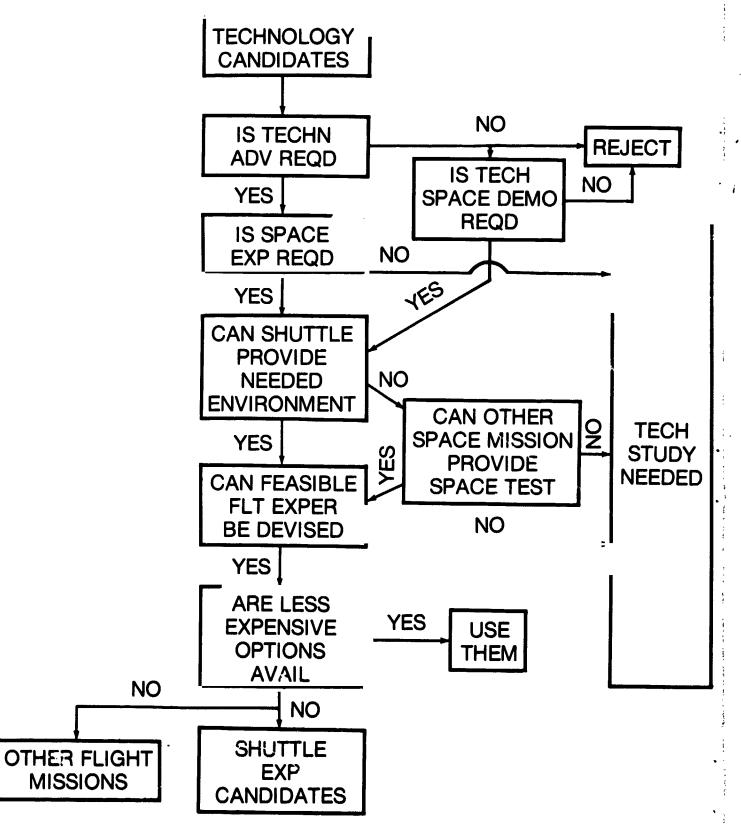
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Fig. I-2 (continued)

THERMAL CONTROL SPACE EXPERIMENT EVALUATION

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NOTE: FLOW DOES NOT INDICATE NEED OR IMPORTANCE OF SUP-PORTING TECHNOLOGY REQUIRED PRIOR TO SPACE EXPERI-MENTS

# TECHNOLOGY

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# REQUIREMENTS

#### II. Technology Requirements

#### Introduction

Technology requirements (Section II and Appendix A) as described in this report are incomplete. The emphasis at the workshop was identification and documentation of space experiments. As a result, many required technology developments discussed during the workshop were not repeated in this report since they have been previously documented [Ref. 2].

Furthermore, although the experiment descriptions in Section III and Appendix B may not specifically indicate, the preparation for and implementation of each experiment must result from, and be supported by, a sound technology program.

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#### a. Thermal Control Surfaces

Even in an era of active thermal control systems, the ultimate regulation of absorbed solar energy and radiated thermal energy will remain dependent on surface properties. Past SR & T has provided a good base of materials, with required characteristics, methods for measurement and test, and design properties data. Additional development in several areas will be required to meet future demands for coatings.

Low  $\alpha/\varepsilon$  paint. White paints with controlled optical characteristics, offer the most convenient reference surfaces for a long-term space vehicle, which requires heat rejection from the sun input (i.e., cold running surfaces). Such a coating has been used on most satellites flown to date. Application is hy normal paint spray gun on properly prepared substrate (which substrate can be a wide variety of materials, both metallic and non-metallic). The paint surface as presently applied is somewhat elastomeric and not subject to coasting. It meets the outgas standards as proposed by Sidenburg at GSFC testing. Because of a great number of flights in which the coatings have been used, and extensive measurements of the coatings thereon, the expected variation in properties is of narrow latitude. Advantages are:

- (1) Weight economical
- (2) Easy to apply

- (3) Extensive lab and limited space data on degradation rate
- (4) Very high emissivity (above 0.92)
- (5) Methyl silicones can be easily cleaned before launch and easily repaired if necessary

- (6) Passive system
- (7) Application to any size and configuration of substrate by normal spray gun

#### Disadvantages are:

- (1) Subject to soiling in handling and assembly
- (2) While not a probable source of contamination, the surface can be contaminated, with subsequent degradation of optical properties
- (3) Cleaning system for space not presently known
- (4) Repair system for space not presently developed
- (5) Thermophototrophic system of wide range not known, so variation depends on mechanical louvers or the like

Current status of development and available data indicates the feasibility of extending development to achieve a solar absorptance of approximately .08 with 1-2 years of additional work on five orthotitanate systems.

Diffuse SSM. Conventional second-surface mirrors (SSM) are specular reflectors with 85 to 90% of their total solar reflectance being specular. Since the SSM coatings are the most space stable low  $\alpha/\epsilon$  systems for spacecraft

temperature control, their current and projected use includes all types of spacecraft both manned and unmanned. Therefore, diffuse counterparts of current SSM's are required to: provide for more effective thermal analysis; eliminate concentrations of reflected energy; and provide safety for manned operations. Current OAST efforts are concentrated on providing a low cost 90 to 95% diffuse, flexible SSM of silvered FEP Teflon for possible use as the Shuttle orbiter crew systems radiator coatings and as a substitute for currently used flexible SSM coatings.

<u>Composite.</u> Vapor deposited composite  $Ag/SiO/A_2O_3$ coatings have low  $\alpha$ 's, controllable moderate  $\varepsilon$ 's have demonstrated space stability and are non-contaminating and low weight. Improvements are required in scaling of application to large area radiators.

Thin film. High modulus, radiation resistant polymeric films are currently being used to provide temperature control for large aperture spacecraft instruments, i.e., x-ray spectrometers. Current investigators are requesting these films to be approximately 0.1 mils in thickness to provide maximum resolution for their instruments. Polymide films, such as "Kapton", are not commercially available in thickness below 0.3 mils, therefore these films must be produced in the laboratory. Currently the thin polymeric films are produced by casting on an optical glass plate, oven curing to 300° C on this glass

plate, and then floating the cured film off the glass in a water bath. This is a fime-consuming, expensive process, giving only 50% good films; and it (this process) is limited by the flatness of the glass plates and the size (length and width) of these glass plates. Films of approximately 8 inches by 12 inches can currently be produced by this technique, but requirements for film as large as 14 inches by 18 inches are forecast for the near future.

Long-term data. Extended term laboratory tests, correlated with space flight data, of coating degradation is essential for reliable thermal design of future vehicles.

A number of other potential coatings tasks have been identified as shown in Table I of the STST TC WG Report Feb 1975 [Ref. 1].

Thermal control materials compatible with the space plasma/charging environment. Current typical spacecraft flexible solar array and thermal control system designs include a large number of dielectric materials facing the space environment. These materials include: silvered Teflon, Kapton (bare and aluminized), silvered quartz, and paints. Until recently, these materials and designs have appeared acceptable. There is increasing evidence, however, that there may be significant adverse interactions of these materials with the space plasma/ charging environment. A large number of spacecraft

electrical anomalies are attributed to such interactions. Spacecraft thermal control dielectric materials and applications techniques do not exist which are compatible with the space plasma/charging environment. Conductive coatings with low  $\alpha/\epsilon$  must be developed to accomplish this.

Accordingly a technology program is needed to help solve this very important space plasma/charging problem. By evaluating data from the ATS-5 and ATS-6 satellites, a model of the charging environment can be postulated. An attempt will be made to define the space environment, model the spacecraft interaction with this environment, and to simulate the environment in ground based facilities. There will be an experimental effort to determine the response of spacecraft materials to this environment and to develop new or modified materials. Later on there will be flight programs to obtain space environment data, to evaluate materials in the actual environment, and to provide a calibration for ground simulation.

<u>All</u> spacecraft that have missions to geosynchronous orbit will benefit from this technology effort.

Improved temperature control coatings for very large space structures including solar collectors. This major thrust will require inputs from all the base technology being done on thermal control coatings and surfaces. Primary emphasis will be on integrating the thermal control coating with structural elements. For example, light-weight

laminates with integral thermal control surfaces will have to be developed. High  $\alpha/\epsilon$  (values of 30 to 50) coatings for use on solar collectors must be developed. In addition this technology will be driven by the need for light weight, high efficiency, low cost, and increased performance in future very large space structures such as a space photovoltaic.

Evaluation of long-life stability of spacecraft thermal control surfaces. Long-term missions are planned in energetic radiation environments but little or no flight data is available in these environments on coatings developed in the 70's. Other coatings with greater potential are currently being developed. Laboratory testing has been shown to be only an approximation of space tests. Therefore, actual space tests are required and in the specific environment where missions are planned.

#### b. Heat Pipes

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Heat pipes have a demonstrated capability to transport large quantities of thermal energy over long distances at minimum temperature drop and weight. This characteristic allows remote heat rejection, thus permitting equipment location compatible with structure, configuration, orientation, etc., with minimized thermal control constraints. The high thermal efficiency also makes it possible for heat pipes to isothermalize surfaces which have concentrated heat inputs. Additionally, several mechanisms inherent in the heat pipe process can be used to self-regulate the amount of heat transferred and, thus, provide temperature control. こので、本語のないない、 法のないろう

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When compared to fluid loops for some applications, heat pipes inherently offer the following advantages:

- Absence of mechanical and electrical interference from pumps and moving fluid (e.g., vibration of finely pointed telescopes).
- (2) No moving mechanical parts.
- (3) Simple for parallel redundancy (e.g., minimizes effect of meteroid penetrations).
- (4) No power required (e.g., passive).

Heat pipes have already been used on several spacecraft currently operating in space.

The following is a summary of critical factors which require new or continuing technology. These are reflected, where applicable, in flight experiments.

Hydrodynamics. Assuming proper selection of materials and processes, hydrodynamic behavior generally becomes the limiting factor in the performance and reliability of heat pipes operating at temperatures below those of the liquid metals. The need to increase the capillary pressure (implies small capillary pores) without increasing flow resistance (implies larger effective pore sizes) to improve the heat pipe's hydrodynamic capacity beyond that of the simple screen wicking system. Each of these more complex wicking systems have unique problems which remain to be understood completely and then circumvented. For example, axial grooves are attractive because they can be extruded inexpensively and provide sufficient O-g performance for

many spacecraft applications. However, they have poor ability to pump liquid against gravity, making ground testing difficult and confusing the extrapolation from one to 0-g performance. Composite wicks use a variety of methods to achieve small effective pores for pumping, while maintaining a large effective pore size to reduce liquid flow resistance. It is still difficult, however, to fabricate composite wicks to achieve a predicted performance. Arterial wick systems offer the greatest hydrodynamic capacities, but have difficulty in priming reliably, especially in low pressure heat pipes. Better analytical performance predictions, fabrication techniques, and reliable arterial priming methods are required. (See Flt. Exp. b-2, Section III.)

<u>Cryogenic.</u> A significant future application of heat pipes appears to be in cooling various types in the range 2 to 150K. Two factors complicate cryogenic heat pipe designs. The first is the cryogenic fluids which increase the complexity of the wicking system and ground testing. The other is the fact that at room temperature the fluids become superclitical and may cause extremely high pressures. Considerable work remains in extrapolating room temperature heat pipe technology into the cryogenic temperature range. (See Flt. Exp. b-2, b-3, Section III.)

Electrohydrodynamic (EHD). EHD offers the potential to control heat transfer by varying electrical voltage. In addition the use of EHD flow structures to replace or augment capillary pumping in a heat pipe, may result in higher performance (ability to carry heat over long distances). Although the feasibility of EHD heat pipes has been proven in the laboratory, much work remains to develop a practical system. The potential capabilities of EHD heat pipes are sufficiently great that work should be continued, even though no specific application has been identified. The same principle may also be applicable to other fluid (i.e., propellant) acquisition and control. (See Flt. Exp. b-2, Section III.)

Vapor control. Variable conductance heat pipes have already found application on several spacecraft. These pipes, however, have used the compression and expansion of a non-condensing gas to block condensation over varying lengths of the condenser to control the rate of heat transfer. This control mechanism is very sensitive to changes in temperature at the condenser and gas storage reservoir. In cases where temperatures at these locations are high and widely varying, a new control mechanism (vapor control) offers several advantages: better control characteristics, direct control of heat source, and possibilities for standardization. Efforts are required to develop this concept into a useful, standardized controllable heat pipe for large variable heat rejection radiators. (See Flt. Exp. b-5, Section III.)

The heat pipe process inherently offers Diode. mechanisms by which heat can be transferred very efficiently in one direction, and very inefficiently in the reverse direction. A major application for heat pipe diodes is the coupling of a sensitive heat source to a space radiator. The diode will protect the source by not allowing heat to be transferred to it if the radiator should become warmer than the source due to spacecraft orientation, atmospheric entry, etc. A diode which uses excess liquid to block heat transfer in the reverse direction was flown as part of the Advanced Thermal Control Flight Experiment on ATS-F. Several other techniques exist and offer unique advantages, as well as disadvantages. These techniques require further development and understanding, especially for use in the cryogenic temperature range where the fluid properties which control heat pipe performance are less effective than at room temperature and initial start-up is from a supercritical state. (See Flt. Exp. b-1, Section III.)

High temperature. Heat pipe technology received much of its early impetus from potential applications at temperatures requiring liquid metal working fluids (e.g., Thermionic energy conversion). Problems of materials compatibility processing, and fabrication still exist. Hightemperature heat pipes may have significant applications for aircraft leading edge cooling, and other nuclear applications. (See Flt. Exp. d-3, Section III.)

\*\* Effects of heat pipes on s/c performance. As pointing systems become more sophisticated and requirements for stability enter the .01 arc sec regime, the small disturbances caused by heat pipe fluid dynamics must be ascertained. In order to quantify these values experimentally, sufficient analysis and testing is required. (See Flt. Exp. d-2, Section III.) 1

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\*\* Intermediate temperature range. Where it is required to raise the heat retention temperature of radiators, in order to reduce weight, heat pipes will have to be developed in the 300 to 800K range. Water-copper heat pipes have been used in radiator designs in this range; however, their efficiency falls off rapidly above 400K. (See Flt. Exp. b-5, Section III.) It may be noted that heat pipes in this temperature range can be used in many terrestrial applications such as solar collectors, heat recovery systems, etc.

\*\* New Technology requirements not identified in report of STS Technology working group for thermal control Technology Report Feb 75

#### c. Mechanisms and Systems

The thermal group reviewed earlier recommendations [Ref. 2] on the types of devices which might be required for future missions. The classification by type is given in Table I, together with some potential areas of application. The design requirements and constraints which seemed of importance to the thermal group are listed in Table II, as deduced from the broad considerations of the Outlook for Space and what was known of nearer term mission requirements. As noted earlier, the specifics of mission and system design will dictate the types of devices which must be developed. Some technology development recommendations for devices were given in the Report of the STS Technology Group for Thermal Control Technology (February, 1975); the working group expects that additional candidates will be identified as improved definitions of mission and system design are obtained.

A technology development leading to a flight experiment of deployable/orientable radiator systems and components is contained in Appendix A (C-3).

#### TABLE I

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#### THERMAL CONTROL DEVICES

- I. Thermal Energy Generation/Acquisition
  - Radioisotope

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- Solar
- II. Thermal Energy Storage
  - Phase change

#### III. Thermal Energy Transport

- a. Input
- b. Removal
  - high flux
  - high temperature
- c. Transfer
  - ultra-high conductance
  - variable
  - long distance
- IV. Rejection
  - Controllable
  - Radiators
- V. Systems
  - Gradient control
  - Thermostatic
  - Expendable heat sink

#### TABLE II

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#### DESIGN REQUIREMENTS & CONSTRAINTS

- 1. Low weight
- 2. Low cost
- 3. Long life
- 4. Reliability
- 5. Standardized
- 6. Precision (allowable temperature range)
- 7. Reusable
- 8. Cryogenic
- 9. High temperature
- 10. Articulating

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11. System compatible

### d. Testing

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No new technology requirements beyond those previously established [Ref. 2] were identified.

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e. Instrumentation

No new technology requirements beyond those previously established [Ref. 2] were identified.

### f. Contamination

Skylab photos indicate significant, as yet unexplained, differences in the sensitivity of low  $\alpha/\epsilon$  systems to contamination. The relative sensitivity and data on effects of contaminants on properties will be essential coating selection criteria for Shuttle payloads. In addition, the data may prove to be useful in establishing cleanliness requirements of Shuttle. Analysis of Skylab experiments and hardware will provide basis of probable contaminants for evaluation.

Protective coatings. The initial properties and stability of thermal control coatings can be adversely affected by pre-launch contamination. Elaborate procedures, such as handling constraints, protective covers and immediate pre-launch cleaning or recoating will be impractical or not cost effective for future vehicles.

Effects of shuttle induced contamination on thermal control surfaces. Current thermal control surfaces are dielectrics with ability to accept and hold charges which may attract contaminants. Many contaminants are also dielectric which may interfere with conductive coatings applied over these surfaces. Skylab DO-24 experiment has shown that significant contamination can change a low  $\alpha/\epsilon$  coating to a gray or relatively high  $\alpha/\epsilon$  coating. The possibility of this type of contamination on Shuttle is high and results could be highly significant to temperature control of Shuttle launched S/C.

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A better understanding of contamination effects on optical properties of surfaces must be obtained. Criteria for coating selection for Shuttle launched spacecraft must be developed.

Techniques for contamination protection. Advanced techniques are required for protection of optical, x-ray, and solar physics telescopes as well as thermal control surfaces.

### g. Cryogenics

A growing number of scientific and applications payloads are being proposed which require temperatures from 200°K to less than 1°K. For example, the "Outlook for Space Study" and the subsequent "Forecast of Space Technology" identified potential missions which require technology based on the devices described in Table g I. Based on the 1973 mission model, the "Future Payload Technology Requirements Study" identified the missions shown in Table g II. Additional proposed payloads are listed in Table g III.

Growing emphasis must, therefore, be placed on what appears to be a major, emerging area of thermal control cryogenics. Various techniques for achieving cryogenic temperatures are shown in Table g IV. These techniques can be divided into three general categories: (1) passive radiative coolers, (2) storable cryogens, and (3) closed cycle refrigerators. Technology development required in each of these categories will be discussed below.

Passive radiative coolers. Passive coolers have been used on several pacecraft, but nave been designed for each particular application with no common data base. Design details, performance, operational experience, and inflight contamination data need to be consolidated as an aid to future designers. In-flight contamination of the optical train remains a problem.

The AFFDL (Dayton, Ohio) currently plans to develop larger capacity, lower temperature (3-5 watts @ 70-90°K) radiators. Using heat pipe technology, passive coolers may be used to reduce parasitic heat leaks and/or provide auxiliary cooling for other methods of producing cryogenic temperatures (see Experiments b-1 and b-3 in Section III).

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<u>Storable cryogens.</u> Cryogens may be stored in three basic states: supercritical (gas), subcritical (liquid), and solid. In the special case of helium, a superfluid state is achieved below a transition temperature of approximately 2.2°K. Each state offers unique technology problems which are illustrated by the technology requirements described below:

<u>Supercritical:</u> Since they avoid the phase separation problems of subcritical fluids, supercritical cryogens have been use<sup>4</sup> reliably in low-g to produce temperatures as low as about 5°K. One method of reaching temperatures below about 5°K is by the Joule-Thomson (J-T) expansion of supe critical helium (SHe). Although SHe avoids problems of phase separation in low-g, the J-T expansion may induce thermal and acoustic noise in sensitive detectors. Theoretical predictions need to be refined and experimentally verified, and suitable expanders developed and tested in low-g (Experiment g-3, Section III).

Subcritical: The major difficulty in using subcritical cryogens in space is the lack of gravity to separate the liquid from its vapor, and to serve as a means of liquid acquisition. Ground based facilities have provided a wealth of information on reduced gravity fluid behavior, multilayer insulation systems, fluid acquisition and transfer, propellant thermal conditioning, and propellant reorientation. This information is the best that can be obtained within the limitations of ground based test facilities. Sounding rockets and aircraft flying low-g trajectories also provide insufficient low-q time for cryogenic fluids to stabilize and come to steady-state conditions. The application of these results to a long term reduced gravity environment is frequently inconclusive and, at best, hypothetical.

Space flight experiments are required to provide the type of data to both designers and users which show that the systems being advocated for spacecraft can indeed perform as intended and expected.

The specific areas of technology to be advanced by flight demonstration are described in Appendix A (Ag-1 and Ag-2). Two flight experiments (g-1 and g-2, Section III) are proposed to obtain the necessary data.

For applications involving large amounts of cryogens and gimballed instruments, it may be necessary to

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transfer the cryogen from a bulk storage tank across the gimbal to the instrument. Transfer methods which minimize impact on pointing and stabilization performance while minimizing heat leaks, need to be developed. (Experiment g-4, Section III.)

Superfluid helium (He<sup>II</sup>) has several attractive properties for cooling detectors below 2°K. These include nearly infinite thermal conductivity, nearly zero viscosity, and the "fountain" effect. To take advantage of these characteristics, the behavior of bulk He<sup>II</sup>, film coefficients, and porous plug venting need to be determined in low-g. A rocket experiment scheduled for launch in late 1975 will be the first step; more detailed analysis and longer duration orbital flight should follow. In addition to its storage and venting capabilities, distribution of He<sup>II</sup> to complex experiments and/or multiple instruments needs to be developed and flight tested. Promising techniques include temperature modulated porous plugs and He<sup>II</sup> heat pipes (Experiment g-5, Section III).

Solid: Solid cryogens are compact, lightweight, and don't "slosh". Lifetimes, however, are difficult to accurately predict and dewars can become mechanically complex. The difficulty in using solid cryogens to cool large instruments, maintain venting and pressure control, and to dump excess cryogens prior to reentry (for Shuttle payloads

using hazardous cryogens) needs to be assessed. In addition, the use of integrated heat pipe/passive radiative cooler systems to reduce parasitic heat leaks offers extended lifetime capability (Experiment b-3, Section III). - - 1 - -

<u>Closed cycle refrigerators.</u> Closed cycle refrigerators are required for long term missions (>1 yr.). which require temperatures below those achievable (~100K) by passive radiators. A technology requirement of 1-4°K for up to 3 years has been identified in the "Future Payload Technology Requirements" (Ag-8, Appendix A) and has been proposed for flight testing (Experiment g-8, Section III). Vuilleumeir and rotary-reciprocating refrigerators which potentially have 3 years lifetime are currently being tested by the AFFDL. Minimum temperatures, however, are about 10°K. Extreme inefficiencies will be encountered in attempts to lower this minimum temperature.

Another potential closed cycle system is the demagnetization of rare earth salts. Laboratory tests have produced temperature differences of 27°K near room temperature. Work is continuing to investigate materials with Curie points approaching 4-20°K. Such a magnetic refrigerator needs to be "cascaded" or to have a cryogenic heat sink (e.g., LH<sup>2</sup>) available. The technique, however, potentially offers near-Carnot efficiencies and should be flight demonstrated (Experiment g-7, Section III).

A refrigerator capable of producing mK temperatures for periods up to 30 days is also required for several future observations and experiments. A  ${}^{3}\text{He}/{}^{4}\text{He}$  dilution refrigerator appears to be the only technique for producing mK continuously. Existing dilution refrigerators rely on gravity to separate the  ${}^{3}\text{He}$  and  ${}^{4}\text{He}$  in the mixing chamber and still. Technology needs to be developed to permit operation in low-g (See Ag-6, Appendix A) and then proven in space (Experiment g-6, Section III).

TABLE g I

Cryogenically Cooled Devices Likely To Be Used In Fulfilling The Recommendations Of The Outlook For Space Study \*

## Temperature Range: 0.1 to 10<sup>0</sup>K

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Superconducting Megnets for High Energy Detections and Identification Superconducting Megnets, Galvanometers, and Voltmeters Superconducting Computers--Based on Josephson effects Far IR Detectors--Bolometric and Superconducting Meser and Parametric Amplifiers

\* Gutlook for Space--A forecast of Space Technology Final Draft, July 15, 1975

TABLE g II

## Payload Cryogenic Requirements \* Based on 1973 Payload Model

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HE-15-S	AS-20-S	AS-15-S	AS-14-5	AS-01-S	HE-09-A	AS-11-A	AS-07-A	AS-03-A	PAYLOAD
MAGNETIC SPECTROMETER	2.5-M CRYD COOLED IR TELESCOPE	3-M AMBIENT TEMP IR TELESCOPE	1-M UNCOOLED IR TELESCOPE	1-M COOLED IR TELESCOPE	LARGE HIGH-ENERGY OBSERVATORY B	1.5-M IR TELESCOPE	3-M AMBIENT TEMP IR TELESCOPE	COSMIC BACKGRCUND EXPLORER	NAME
3 ‡ T <sub>o</sub> K	2 ± 0.5°K; 20 ± 1°K(TELESCOPE)	2 ± 1.5 <sup>0</sup> K	UNKNOWN	2 ± 0.5°K; 20 ± 1°(TELESCOPE)	4°K	1—4 <sup>0</sup> K; 20 ± 1 <sup>0</sup> K (TELESCOPE)	1–4 <sup>0</sup> K	3 <sup>0</sup> ± 1,2°K	TEMPERATURE REQUIREMENTS (DETECTORS OR MAGNETS)
7 DAYS	7 DAYS	7 DAYS	7 DAYS	7 DAYS	1-2 YEARS	3 YEARS	1-3 YEARS	1 YEAR	LIFE
L	L	L	L	1	0.2	۲	Ч	<1	(LOAD WATTS)

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\* Future Payload Technology Requirements Study

Final Report No. CASD-NAS-75-004, Contract NAS-2-8272, June 1975

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TABLE g III

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## Payload Cryogenic Requirements

# Based on Proposed Experiments Not Included in 1973 Mission Model

Name	<u>Temperature. <sup>a</sup>K</u>
Infrared Astronomy Satellite (IRAS) Gyroscopic Test of General Relativity (GTGR) LST/Infrared Science Package Shuttle Infrared Telescope Facility (SIRTF) Cosmic IR Background Gravitational Radiation Detection Equivalence Principle of General Relativity Experiments on Quantum Fluids	2.2 2.2 2.2 0.1 to 20. 0.3 to 2.2 >1.0 >1.0
Earth Observation Satellite (EOS) A,B,C: HRPI Landsat-D: Thermatic Mappes Airsat: LACATE MAPS II HRIR CIMATS CIMATS	100200. 120 65. 100. 195

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Rotary-Reciprocating (R <sup>2</sup> ) > 10	Closed Cycle Refrigerators:		(Super- 2.2	20.4 8.3-	27•2 13•5-24•5	1	ы.	3 150.0-195.4 Dioxide 125.0-217 5	Liquids and Solids: (Normal Building Pt.) (Operational	Radiative Coolers: >90	<u>Temperature</u>	ΡΑΥLCAD CC		a definition and a second s
<pre>volumets r, intersted by AFFOL * A D.25w@650K and a 5w@750K system being tested by GSFC * 1.5w@120K, 4Dw@600K system being tested by AFFDL * Both VM and R2</pre>	81 3 OK	to achieve temperatures below the normal boiling point	<pre> supercritically to avoid O-g problems * J-T expansion and pumping can be used</pre>	*	4.5 for phase separation in O≖c	- depends on de	3.7 * Total cooling capacity and lifetime	*	Solid Range)	* 90°K achievable at sync. alt. * 120°K achievable in low earth orbit * Pcwer dissipation 100mw. * Requires radiative shielding from sun, earth, and spacecraft	O <u>K</u> <u>Commerts</u>	COCLING TECHNIQUES	TABLE g IV	ан талан тал

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TABLE g IV

### PAYLOAD COOLING TECHNIQUES

page 2	Comments	Temperature differential of 27 <sup>O</sup> K demonstrated at room temp. Potentially useful and highly efficient with different materials and heat sinks down to about 4 <sup>O</sup> K.	Currently limited to non- continuous operation. Requires helium heat sink.	Systems currently in ground use, but depend on gravity for phase separation in mixinç chamber and still. Requires He <sup>II</sup> reservoir.
PAYLOAD COOLING TECHNIQUES	<u>Temperature, <sup>o</sup>K</u>	4-20	¥E	¥
	Technique	Demagnetization of rare earth salts	Adiabatic demagnetization of paramagnetic salts	<sup>3</sup> He/ <sup>4</sup> He dilution refrigerator

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h. Analysis

No new technology requirements identified.

### j. Thermal Properties

No new technology requirements identified.

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### k. Insulation

Space Vehicle Requirements

Reusable space vehicles using cryogenic propellants place severe requirements on cryogenic storage and transfer systems. The insulation systems for the various cryogenic propellant tanks on a reusable space vehicle must operate during extended ground hold, launch, ascent through the atmosphere, space coast and re-entry. In addition, the systems must be reusable. The ability of such cryogenic thermal protection systems to perform effectively after cyclic exposure to air and moisture is a new and severe requirement. Important design factors will be reliable and predictable performance under repeated thermal and environmental cycling, ease of system inspection, and ease of repair or replacement-all at low cost. Two approaches are available for meeting these cryogenic insulation system requirements: a purged multilayer system and a lightweight vacuum jacket with a loadbearing insulation system. The purged MLI system is relatively heavy and complex and has need of additional technology to provide effective purge procedures and evaluate inspection, validation, and reuse. However, it offers promise as the best system now available. The lightweight vacuum jacket with load-bearing insulation system offers promise of being

lightest in weight and having the advantages of consistent insulation performance, reusability, and simplicity.

Launch Vehicle Requirements

Single stage to orbit (SSTO) vehicles that are presently being evaluated as part of an advanced earth-toorbit transportation system have a requirement for reusable hydrogen tanks. This means that a need for a reusable insulation system for this particular use has been identified. Some past work on insulations that are internal to the tank, such as the 3-D form on the S-IVB stage has been done. Since SSTO vehicles are especially sensitive to both weight and cost, any advancements in this technology should be addressed to these requirements. As part of the system cost, special attention must be given to ruggedness and ease of repair.

### 1. Design Techniques

This area was not reviewed in detail by the thermal group. It was recognized that the thermal design features and devices must be compatible with the system and subsystem design. Too often instruments and detectors are developed independent of the thermal design only to find that when they are finally enjoined one or the other has degraded in its performance. A technology requirement which addresses this issue for the thermal control of detector systems is given in Appendix A (c-4). Other candidate technology developments are contained in the STS Technology Group Report.

### FLIGHT

### EXPERIMENTS

### III. Flight Experiments

### a. Thermal Control Surfaces

There are significant limitations to simulation of the space environments in laboratories. For evaluation of thermal control surfaces, simplifying energy distribution and rates, compromises must be made. These limitations inhibit the acceptance of new coating technology for vehicle design. Flight experiments related to thermal control fall into two general categories:

- Measure performance of coatings in space to generate dependable design data and to verify or modify laboratory simulation methods.
- (2) Demonstrate coating readiness by actual performance in space.

A variety of coating experiments have been utilized on past missions. Reuse of designs and hardware as well as new approaches (including spectral measurements in space and sample return) have been proposed for the future. An assessment of available designs and hardware, future opportunities and data requirements is essential to effective implementation of required future experiments.

In the past, coating experiments have been approved, designed and implemented on an individual project or vehicle basis. A systematic, over-all policy and plan is required to implement experiments on vehicles in various types of orbits to obtain necessary performance data.

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More frequently than not, the thermal analysis and coating technology specialists are assigned to other tasks by the time a vehicle is operational in space. With few exceptions there has been neither adequate motivation nor resources available to attempt to obtain coating data from thermal performance history of space vehicles. While much past data may be irretrievably lost, a systematic limited assessment should be made in search of useful data. Perhaps most important is the need for a systematic plan to encourage potentially useful engineering temperature measurements and provide resources and motivation to obtain data from current and future vehicles.

The second-surface mirror (SSM) coatings are the most stable space verified, low  $\alpha/\epsilon$  systems for spacecraft. The SSM's are purchased commercially and applied to the spacecraft by the use of an adhesive. Since any delamination or release of this coating from the spacecraft will result in an increase in the spacecraft operating temperature, low outgassing, long-life adhesives capable of operating at temperatures from 10.0 to 480K must be provided for use with these coatings. Current OAST efforts are evaluating commercially available and modified adhesives for bonding silvered FFP Teflon flexible SSM to aluminum.

### Potential Flight Experiments

(See Appendix B for definition of Flight Experiments.)

(1) Thermal Control Materials Compatible with the Space Plasma/Charging Environment

Jpace testing is required to support the technology efforts being advanced in an effort to solve spacecraft charging anomalies that have developed. This testing will expose candidate spacecraft thermal control materials to the space plasma/charging environment and then evaluate their compatability with the environment. Analysis and ground tests will be performed in support of the flight experiment.

Since the space plasma environment is difficult to simulate and insufficient analytical, experimental, and flight data exists to precisely define either the space plasma/ charging environment or the behavior of dielectric materials in this environment, ground tests are of little value. Space flight tests are required.

The missions that will benefit from this flight test are the communications and Synchronous Weather Satellites.

(2) Improved Temperature Control Coatings for Very Large Space Structures Including Solar Collectors

A major thrust of future space opportunities will be the development of very large space structures; for example, solar collectors and their flight applications in space. It will be necessary to integrate thermal control coatings and surfaces with the structural elements. This will include light-weight laminates, conductive high  $\alpha/\epsilon$  coatings for solar collectors ( $\alpha/\epsilon$  values of 30 to 50), and stable anodized coatings. Flight testing will be required for verification of ground testing and confirmation of coatings test data.

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### (3) Evaluation of Long-life Stability of Spacecraft Thermal Control Surfaces

The need to obtain flight operational data on the performance of s/c thermal control surfaces in long-term missions is of major concern. Long-term missions in particulate  $(e^-,p^+)$  radiation environments are planned but data on coatings developed in 1970's is not available. Flight tests will be required in the following environments: Near-earth polar orbit; Geosynchronous; Interplanetary-Venus, Mercury, Jupiter. Shuttle - LDEF payload will satisfy near-earth data requirements.

### (4) Repair/Refurbishment of Thermal Control Surface in Space Techniques for in space repair and/or refurbishment of malfunctioning of spacecraft thermal control surfaces must be assessed. Such techniques can be evaluated in ATL or SPACELAB missions.

### (5) Adhesives for Attachable Thermal Control Surfaces

The performance of attachable thermal control surfaces (i.e., second-surface mirror coatings) depends upon the integrity of their adhesive. Although laboratory tests have demonstrated good performance, earlier adhesives have demonstrated anomalous behavior under different flight conditions. Therefore, space flight tests are necessary since several radiation environments are needed. The following flight tests are required: shuttle launched - LDEF, polar orbiter; geosynchronous; and/or Scout-polar orbiter.

### b. Heat Pipes

Cryogenic Heat Pipe Technology Flight Experiments
 Experiment b-3: Improved Solid Cryogenic Lifetime

In order to cool detectors in the 65-120K region, solid cryogen coolers using such materials as methane,  $CO_2$ , and ammonia will be required. These coolers are usually multistage devices which are subjected to high spacecraft parasitic heat loads which limit lifetime (e.g., Nimbus-F had a 6 month expected life, but was designed for 1-2 years). It has been shown analytically that lifetime can be increased (by a factor of 2 or 3) or, conversely, weight decreased (by a factor of 2) by subcooling the outer container to reduce parasitic heat leaks. This can be accomplished by coupling the container thermally via a heat pipe to a passive radiator which views cold space. By flying a conventional solid cryogenic cooler and one with a heat pipe and radiator, a comparison can be made as to loss of solid cryogen with time. (See Experiment b-3, Appendix B.)

Experiment b-1: Cryogenic Heat Pipe/Radiative Cooler

Many sensors and telescopes will be operating in the cryo-,enic temperature range (100 to 150K, see Table g3) and will require heat pipes for heat management. Large multiple arrays of detectors (5-10 watts) will be remotely located from their optics and will require heat pipes to transfer thermal energy. Telescopes and sensors will have large radiators operating at cryogenic temperature which will make use of heat pipes.

Varying environments will require variable heat rejection in the form of variable conductance heat pipes and diodes. For operating in sunlight conditions or at constant temperature, phase change materials will be required. All the above elements can be incorporated into a single flight experiment wherein each can be exercised thermally to gather data on performance. (See Experiment b-1, Appendix B.)

(2) Ambient Heat Pipe Technology Flight Experiments

### Experiment b-2: Ultra High Thermal Conductance Heat Pipes

In order to isothermalize very large structures (i.e., antennae, solar collectors, etc.) to achieve levels of acceptable distortion, ultra high thermal conductance will be required. Both high and low flux densities must be transferred with extremely small temperature gradients over long lengths (T's between 0.1 and 1°C over lengths from 10 to 100m). State-of-the-art heat pipes are hydrodynamically limited to lengths of 5 to 10 meters. New concepts must be developed to extend the hydrodynamic limit and to improve heat transfer coefficients. Since ground testing is difficult to interpret due to the negating effects of gravity, a flight experiment of reasonable size (20m) must be devised. (See Experiment b-2, Appendix B.)

Experiment b-5: Large Variable Heat Rejection Radiators Radiators will be needed to accommodate a variety of instruments, each with different power levels, temperature

levels, and gradient requirements. These radiators will be required to handle power levels in the kilowatts range, be able to vary their heat rejection in order to maintain narrow temperature limits, and be adjustable to hold a variety of temperature levels. Heat pipes with variable conductance capability will permit handling of a wide variety of payloads using a standardized radiator. This universal concept will reduce analysis and manpower and ultimately result in a highly reliable radiator with no moving parts. Current designs are able to dissipate 100-200 watts at room temperature. In addition to room temperature radiators, large capacity radiators operating up to 1500K for nuclear, and space processing applications will be needed. These radiators should be flown as flight experiments in order to demonstrate performance. (See Experiment b-5, Appendix B.)

Experiment b-4: Precision Temperature Control

Many instruments, structures, and gyros, which are required to hold extremely tight temperature control (±.1°C), may require techniques involving feedback or cascaded gas controlled heat pipes. These units will either directly or indirectly sense a change in the instrument temperature and adjust their heat rejection to achieve this tight temperature control. This will ultimately minimize temperature excursions and permit fine pointing, relative low drift, and aligned stable structures. Present technology using large amounts

of heater power and sophisticated electronics is currently limited to  $\pm 1-2^{\circ}$ C. A flight experiment utilizing one or more heat pipes may be flown to demonstrate this technique. (See Experiment b-4, Appendix B.)

### c. Mechanisms and Systems

The three devices which passed the screening criteria for space test were phase change thermal storage systems, expendable material heat rejection systems and deployable/orientable radiator systems; these tests are described in Appendix B (c-1, c-2, and c-3, respectively).

The first two tests are needed because of uncertainties in fluid behavior in low-g. The latter test is intended to demonstrate adequate performance in the space environment. The rationale for this test is given below.

Shuttle and spacelab experiments and payloads have large heat rejection requirements (>2KW) and require solar or earth orientation which will require "deep space" radiator tracking. This capability is not within the currently demonstrated technology, since it requires radiators which can be deployed from the payload bay to a position beyond interference with the orbiter, and can be oriented in a continuously "arying attitude relative to the orbiter for maximum efficiency. The technologies involved include the mechanical and fluid flow components of the deployment boom, which must be l'akfree under repeated, long term use.

Since the development of thermal devices is driven by mission and system design factors, we should expect that additional flight test requirements will be identified as these factors are established and updated.

### d. Test Facilities

(1) Heat Pipe Test Facilities

Experiment d-1: Temperature Control Device Test Facility (Ambient Regime)

Various heat pipe performance phenomena must be studied in O-G because of the negative influence of gravity. Such parameters as liquid distribution, gas/vapor interfaces, and wetting are strongly affected. Improvements in heat transfer coefficients to achieve low temperature gradients at low fluxes and at high fluxes can only be measured and observed in space. Diffusion of vapors, liquids and gases in controllable heat pipes can be studied, as well as distribution of phase change material in a metallic matrix. By flying a "work bench" type facility (either automated or manually operated), these parameters can be varied in real time. Present limits on spacecraft and sounding rockets for weight, power, telemetry and operations preclude data acquisition which permits separation and study of all variables sensitive to the effects of gravity.

Experiment d-2: Zero-G Measurement of Heat Pipe Disturbances

(Introduction and Summary)

The use of heat pipes for thermal control (e.g., isothermalization), of delicate experiments or sensors which require knowledge of the forces imposed by operation of these heat pipes. Limited acceleration data on experimental heat pipe installations have been obtained; however, quantitative

force data are required for design analysis of proposed applications. Because of the small values of these forces relative to one-g forces, these measurements would best be made in the space environment. The proposed experiment would include a variety of heat pipe sizes, configurations and types, a range of heat loads with controllable heat sources, with measurements made of forces, accelerations, and temperatures. From these data, parametric relationships of operating conditions to forces for various heat pipes will be obtained.

### Experiment d-3: Facility for High Power - High Temperature Device Testing

The required technology advancement is a scalable shuttle-launched, free-flying facility for experimentation and demonstration of high-power-density devices and phenomena. The facility includes a high-power-density source, normally a radioisotope, cooled by a metallic-fluid heat pipe which heats the emitter of a thermionic converter having a collector cooled by a heat-pipe radiator. Some evaluations may require several thermionic-converter heat-pipe modules which feed their electric outputs to a power processing system that energizes instrumentation, control data-handling, and transmission equipment needed for the experimentation or demonstration.

Replacing a standard component of this facility during fabrication with an experimental element allows testing or demonstration of thermal-energy acquisition, transmission,

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conversion, rejection, or electric processing--each at high power densities.

For example, such replacements would enable tests of solar-concentrator modules, new heat pipes, improved thermionic converters, radiator modules, or the latest processing developments for low-voltage, high-current power. e. Instrumentation

No flight experiments identified.

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### f. Contamination

The fact that initial coating properties and stability are adversely affected by contamination has been recognized for many years, and has been dramatically illustrated by the returned Surveyor III equipment and by Skylab photos. While the most dramatic and most significant effects are on low  $\alpha$ coatings, changes in mechanical properties and increased  $\varepsilon$ for low  $\varepsilon$  surfaces are possible. Work in Germany (DFVLR) has shown contamination degradation of surface conductance of conductively coated second-surface mirrors.

It would seem impractical, if not impossible, to provide a contaminant-free environment for Shuttle. Thus, experiments and equipment aboard or launched from Shuttle must be contaminant tolerant.

### FLIGHT EXPERIMENTS

(1) Effects of Shuttle Induced Contamination on Thermal Control Surfaces

The need for contamination monitoring experiments on the early Shuttle missions is recognized. As a part of these experiments, it is mandatory that the effects of this contamination on S/C temperature control surfaces be determined. Flight experiments are required on LDEF (mission 3) and LDEF (mission 4), as well as integration into the design flight instrumentation package for other flights. A statistical average is necessary for proper data interpretation.

(2) Techniques for Contamination Protection

Advanced techniques are required for protection of optical, x-ray, and solar physics telescopes as well as thermal control surfaces. Referenced Convair experiment is limited in scope for techniques of accomplishing this protection. 1

Spacelab or ATL can provide excellent flight test conditions.

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### g. Cryogenics

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As described in Section II g and Tables g I-IV, a growing number of scientific and application payloads are being proposed which require that increasing emphasis be given to the development of cryogenic technology. Detailed technology requirements were discussed in Section II. Therefore, only a brief description of each experiment proposed in support of these requirements is presented below. "Future Payload Technology Testing and Development Requirement" forms for each experiment are included in Appendix Bg. Each experiment can be traced back to its driving opportunity (Table g I) and/or mission (Table g II, g III) by correlating the temperature and lifetime required with that being developed and tested.

(1) Liquid Cryogen Storage and Supply (Bg-1)

This experiment will evaluate the effects of surface tension devices and thermodynamic vents on the storage, acquisition, venting, and withdrawal of a cryogenic liquid in low-g. This experiment also has direct application to those systems currently using supercritical gas storage for life support and fuel cells. In addition, data will be obtained that can be applied to other low temperature fluids that are used in many other space applications. Not the least of these is LHe which is proposed on a variety of future scientific payloads for cooling detectors, telescope optics, and superconducting magnets. Also, by proper instrumentation, the performance of a high performance insulation can be verified in a low-g environment.

(2) Liquid Cryogen Transfer (Bg-2)

This experiment will evaluate the process of cryogenic fluid transfer in a low-g environment. This experiment will evaluate specifically propellant inflow and outflow dynamics, pressurization gas requirements, pressurization diffuser design, and insulation performance. This experiment has direct application to the potential resupply of propulsion stages in orbit and to scientific payloads that could be provided extended lifetimes if these cruogenic fluids could be replaced.

In addition, the data obtained can be related directly to the fluid parameters of all cryogenic liquids and could in turn provide size scaling data when related to the Liquid Cryogenic Storage and Supply experiment described above.

### (3) Joule-Thomson Expansion of Supercritical Helium (Bg-3)

This experiment will determine a Joule-Thomson expander with integral heat exchanger (JTX) can be used in low-g to produce temperatures below 2°K without inducing excessive noise in sensitive detectors. Although the JTX can be initially\_optimized on the ground, the behavior of the He<sup>II</sup> produced during the expansion process needs to be determined in low-g. It is possible that the creep of He<sup>II</sup>, with its negligible viscosity, into the high pressure side of the heat exchanger could cause a serious flow instability. The flight test of the JTX should be performed in a system which includes an operational detector, such as an Advanced IR Radiometer (Sensor and Data Acquisition Panel Report). Successful flight tests of the JTX would permit cooling of detectors requiring temperatures below 2.2°K, without the necessity of storing and handling LHe or He<sup>11</sup> in low-g.

(4) Transfer of Cryogens Across Gimbals (Bg-4)

This experiment will demonstrate a rotary joint which is capable of transfering cryogens, such as LHe, across a gimbal with acceptable heat losses and disturbances to the pointing system. To be an effective demonstration, the flight test should be conducted in conjunction with an operational system, such as the Modular Instrument Pointing Technology Laboratory (Navigation, Guidance, and Control Panel Report).

A successful demonstration w-uld permit the cryogen tanks to be located off the ginballed platform for longer duration, higher heat load missions, thus reducing the mass to be pointed and potential disturbances due to cryogen movement.

(5) He<sup>II</sup> Storage and Utilization (Bg-5)

This experiment will demonstrate the capability to store, vent, withdraw, and distribute He<sup>II</sup> in low-g. The proposed experiment goes beyond basic research on the behavior of He<sup>II</sup> to the task of distributing He<sup>II</sup> from a central dewar to one or more instruments or experiments. The Thermomechanical and/or mechano-caloric effects offer a potential solution. Another approach is to use helium heat pipes to transfer energy from the instruments to the dewar.

HeII is required by a large number of observations and experiments, including IR astronomy, general relativity, high energy astrophysics, and experiments involving superconductivity and quantum fluids.

(6)  ${}^{3}\text{He}/{}^{4}\text{He}$  Dilution Refrigerators (Bg-6)

This experiment will determine if a dilution refrigerator can be successfully operated in low-g to prov de temperatures less than 1°K (mK). Current dilution refrigerators depend on gravity for the separation of <sup>3</sup>He and <sup>4</sup>He. Alternate separation techniques, such as spinning to produce artificial gravity or the use of "superleaks" will be developed in the laboratory. Ultimate independence from gravity, however, must be demonstrated in low-g.

Several observations and experiments require continuous mK temperatures which only the dilution refrigerator can produce. Adiabatic demagnetization of paramagnetic salts can produce mK temperatures, but is basically a single cycle process.

(7) Magnetic Refrigeration (Bg-7)

This experiment will demonstrate in space the capability of the demagnetization of rare earth salts to achieve temperatures from 4 to 20°K. Laboratory tests are being conducted on materials of increasingly lower Curie points. A flight test demonstration will eventually be needed to demonstrate the use of single stage magnetic refrigerator using a storable cryogen (e.g., LH<sub>2</sub>) heat sink, or a cascaded system of several rare earth salts using a room temperature heat sink.

As previously mentioned, several future experiments exist for temperatures in the 4-20°K range. The potential for near Carnot efficiency makes further development and flight testing of magnetic refrigerator look attractive.

(8) Closed Cycle Helium Refrigeration (Bg-8)

This experiment will demonstrate in space the capability of a closed-cycle refrigerator to produce temperatures between 1 and 40°K for long term missions. As described in Section II g, Vuilleumier and rotary-reciprocating refrigerators currently under development will produce temperatures only as low as about 10°K. Further development of these or other refrigeration cycles will be required before a flight test can be described in detail.

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Long term missions requiring cooling for up to 3 years at temperatures from 1 to 4°K are beyond the lifetime of storable cryogens and must, by necessity, seek a closed-cycle solution.

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# APPENDIX A

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# DEFINITION OF TECHNOLOGY

# REQUIREMENT FORMS

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DEFINITION OF TECHNOLOGY REQUIRE	MENT NO
1. TECHNOLOGY REQUIREMENT (TITLE): Therma	
Materials Compatible with the Space Plasma/Cha 2. TECHNOLOGY CATEGORY:10 Environmental Contr	
3. OBJECTIVE/ADVANCEMENT REQUIRED: <u>Spacec</u> dielectric materials and applications technique	
compatible with the space plasma, charging env	vironment.
4. CURRENT STATE OF ART:	are incompatible. Many
serious spacecraft anomalies are attributed to F	o space plasma/charging effec HAS BEEN CARRIED TO LEVEI
5. DESCRIPTION OF TECHNOLOGY	
Current typical spacecraft flexible solar arr system designs include a large number of diel space environment. These materials include:	lectric materials facing the silvered teflon, kapton

(bare and aluminized), silvered quartz, and paints, for example. Until recently, these materials and designs have appeared acceptable. There is increasing evidence, however, that there may be significant adverse interactions of these materials with the space plasma/charging environment. A large number of spacecraft electrical anomalies are attributed to such interactions. Spacecraft thermal control dielectric meterials and applications techniques do not exist which are compatible with the space plasma/charging environment.

## P/L REQUIREMENTS BASED ON: $\Box$ PRE-A, $\Box$ A, $\Box$ B, $\Box$ C/D

6. RATIONALE AND ANALYSIS:

Space system designs have evolved and improved as the knowledge of the space environment improved. Significant recent information and of the space plasma/charging environment has resulted from analyses, flight experiments and analyses of flight anomalies. Future spacecraft failures can be avoided with the development of spacecraft thermal control materials and application techniques which are compatible with the space plasma/charging environment.

The projects benefiting from this technology are identified in CFS Future Payload Technology Requirements Study Report No. CASD-NAS-75-004 - Technology Categories 5.0,11.0, and 13.0. Also the inputs to the 1975 NASA OAST Workshop (OSS) Identifies a requirement for this technology.

TO BE CARRIED TO LEVEL 7

#### REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

# DEFINITION OF TECHNOLOGY REQUIREMENT NO. Aa-1 1. TECHNOLOGY REQUIREMENT(TITLE): <u>Thermal Control Materials</u> PAGE 2 OF \_\_\_\_ Compatible with the Space Plasma/Charging Environment. 7. TECHNOLOGY OPTIONS: Add electronic circuitry/complexity to desensitize spacecraft а. electrical system to effects of charging/discharging of dielectric surfaces. Prohibit use of dielectric materials on spacecraft external surfaces. b. This option is not presently compatible with spacecraft thermal design constraints. 8. TECHNICAL PROBLEMS: Insufricient analytical, experimental, and flight data exists to precisely define either the space plasma/charging environment or behavior of dielectric materials in this environment. Until such data exists, spacecraft must be designed using the best available information. Until materials, techniques and environmenus have been proven, designs may be ultraconservative, or result in future failures. The space plasma is difficult to simulate (Cont'd. See Attached Form) 9. POTENTIAL ALTERNATIVES: There is no practical way to change the space environment. Thereby it appears absolutely necessary to pursue the stated objective of developing spacecraft thermal control dielectric materials and application techniques which are compatible with the space plasma/charging environment. 10. PLANNFD PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT: RTOP 506-16-39 is a co-operative AF-NASA effort which makes use of existing orbiting spacecraft in an effort to define the space environment. Correlation in ground based facilities are to be made with a planned Air Force Satellite (SCATHA) EXPECTED UNPERTURBED LEVEL 3 11. RELATED TECHNOLOGY REQUIREMENTS: a. Flight experiments and ayalyses to establish space plasma/charging environment. b. Analyses, ground tests, and flight experiments to develop spacecraft thermal control dielectric materials compatible with the space plasma/charging environment.

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1. TECHNOLOGY REQUIREMENT (TITLE): <u>Thermal Control</u> PAGE Materials Compatible with the Space Plasma/Charging Environment

8. TECHNICAL PROBLEMS: (Continued)

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in a ground test (even if it were known with precision) because of unavoidable interactions with any practical container. Results of materials and applications technique tests made on the ground are therefore clouded with uncertainties. Definitive flight experiment tests are necessary but also difficult to achieve on a near term basis.

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DEFINITION O	FΤ	EC	HNC	DLO	GY	RE	QU	IRE	ME	ENT	•				N	10.	A	a-1	
1. TECHNOLOGY REQUIREMENT (TITLE): Thermal Control PAGE 3 OF																			
Materials Compatible	wit	h t	he S	Spac	ce	'la	sma,	/Ch	arg	ing	En	vir	onm	ent					
12. TECHNOLOGY REQUIF	REM	EN	TS	SCH	IED			ND	AR	YE	AR								
SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY 1. Define Environment	-																		
2. Ground Simulation																			
3. Analytical Model																			
<ol> <li>Develop Materials and Devices</li> <li>Flight Experiment</li> </ol>																			
APPLICATION 1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			
13. USAGE SCHEDULE:				<b>.</b>			<del>.</del>	<del></del> -	<del></del>	+		<b>.</b>						1	
TECHNOLOGY NEED DATE										$\downarrow$		ļ	<b>_</b>		+	_		гот +	AL
NUMBER OF LAUNCHES																			
14. REFERENCES: See Paragraph 6.																			
<ol> <li>LEVEL OF STATE OF</li> <li>BASIC PHENOMENA ORSERVED A</li> <li>THEORY FORMULATED TO DESC</li> <li>THEORY TESTED BY PHYSICAL OR MATHEMATICAL MODEL.</li> <li>PERTINENT FUNCTION OR CHAI E.G., MATERIAL, COMPONENT</li> </ol>	AND " CRIBE EXPL RACT	REPOI PHE: RIME ERIST	NOME NT	NA.	STRA	TED,		6. h 7. h 8. h	ENV IODE IODE IEW C OPE IELIA	L TE L TE CAPA ERAT RELIT	MEN STED STED NULIT IONAL	T IN 4 IN AL IN SI Y DL L MOR 2GRAE	THE I IRCR PACE RIVE DEL, DING	LA RO AFT E ENVI D FRO	RATO ENVIR IRONN UM A	RY. IONM MENT MUC	ENT. 1 H LES TONA	l MOL	DEL.

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1. TECHNOLOGY REQUIREMENT (TITLE): Evaluation of Long- PAGE 1 OF 2

Life Stability of S/C Thermal Control Surfaces

2. TECHNOLOGY CATEGORY: \_\_\_\_10 or 11

3. OBJECTIVE/ADVANCEMENT REQUIRED: <u>Develop flight data in various space</u> <u>radiation environments to help thermal designers select proper coatings for</u> each mission.

4. CURRENT STATE OF ART: Little flight data available on current coatings and coatings under development.

### HAS BEEN CARRIED TO LEVEL 5

#### 5. DESCRIPTION OF TECHNOLOGY

Long-term missions are planned in energetic radiation invironments but little or no flight data is available in these environments on coatings developed in the 70's. Other coatings with greater potential are currently being developed. Laboratory testing has been shown to be only an approximation of space tests. Therefore, actual space tests are required and in the specific environment where missions are planned.

# P/L REQUIREMENTS BASED ON: X PRE-A, A, B, C/D

#### 6. RATIONALE AND ANALYSIS:

Space tests have given a substantial increase in the confidence level associated with the use of coatings on spacecraft. Predictions of degradation in specific environments are always required for proper thermal design. With flight data available, thermal design is simplified and more reliable.

TO BE CARRIED TO LEVEL \_

	TECHNOLOGY REQUIREMENT(TITLE): Evaluation of Long PAGE 2 OF 2
·	Life Stability of S/C Thermal Control Surfaces
	TECHNOLOGY OPTIONS:
•	a. use of complex thermal control devices
3.	TECHNICAL PROBLEMS:
••	
	Other thermal devices are often prohibited due to right or size restrictions. Without knowledge of coating performance most S/C
	managers will not accept the coatings for their S/C. Ground test
	simulation is only an approximation of flight performance.
).	POTENTIAL ALTERNATIVES:
	None without excessive cost and time penalties.
0.	PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:
•.	
	E> PECTED UNPERTURBED LEVEL
11	. RELATED TECHNOLOGY REQUIREMENTS:

	NO. <u>Ab-5</u>
1. TECHNOLOGY REQUIREMENT ('1.TLE):	PAGE 1 OF
Intermediate Temperature Range Heat Pipes	
2. TECHNOLOGY CATEGORY: Environmental Control	
3. OBJECTIVE/ADVANCEMENT REQUIRED:	
Develop Heat Pipes in the Irtermediate Temperature Ran	g <b>e</b>
300 to 800K for Large Low Weight Radiators	
4. CURRENT STATE OF ART:	<u></u>
Present temperature range 200-300K or 800 to 1100K	RRIED TO LEVEL
5. DESCRIPTION OF TECHNOLOGY	
P/L REQUIREMENTS BASED ON:  PRE-A	A, □ A, □ B, □ C/
	ure of needed n used in
6. RATIONALE AND ANALYSIS: Where it is required to raise the heat rejection temperat radiators, in order to reduce weight, heat pipes will be in the 300-800K range. Water-copper heat pipes have been radiator designs in this range; however, their efficiency	ure of needed n used in

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. <u>Ac-3</u>
1. TECHNOLOGY REQUIREMENT (TITLE): <u>Deployable</u> , <u>Driestable</u> PAGE 1 OF <u>2</u> <u>Radiator Systems and Components</u>
2. TECHNOLOGY CATEGORY:
3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop and demonstrate space
environment compatibility of deployable, orientable radiator systems and com- ponents, including low temperature radiators, leak-free gimbals, aru deep space tracking systems.
1. CURRENT STATE OF ART: Current demonstrated capability is fixed or limited-deployment radiators. Deployable, orientable system concepts and components are available and have been ground-tested to a limited extent as components. No system has been designed, or HAS BEEN CARRIED TO LEVEL components tested in space environment.
5. DESCRIPTION OF TECHNOLOGY
A complete radiator system would be designed capable of handling representative Spacelab experiment heat loads in earth-oriented or S lar- oriented modes. The radiators would be required to deploy from the Shuttle cargo bay to minimize interference with or by orbiter systems, and to track "deep space" in a continuous or near-continuous mode.
I (1. REQUIREMENTS BASED ON: ] PRE-A, ] A, ] B, ] C/D
6 RATIONALE AND AND SISS:
a.
b. Shuttle payloads such as solar physics which have high heat rejection requirements. #68, #36, #35, #33, #34
c. Would provide more weight- and cost-effective radiator systems, or would permit fewer thermal constraints on mission performance (durations, attitudes).
d. A complete working model tested in space environment.
TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT	<b>NO.</b> c-3
1. TECHNOLOGY REQUIREMENT(TITLE):	PAGE 2 OF 2
7. TECHNOLOGY OPTIONS:	
	<u> </u>
8. TECHNICAL PROBLEMS:	
Difficulties with fluid lcop components under continuous or gimbal motions at operational temperatures and pressures.	repzated
9. POTENTIAL ALTERNATIVES:	
Limit experiment durations, orientations.	
10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVAN	CEMENT:
EXPECTED UNPER	TURBED LEVEL
11. RELATED TECHNOLOGY REQUIREMENTS:	

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DEFINITION OF TECHNOLOGY REQUIREMENT	NO. <u>Ac-4</u>
1. TECHNOLOGY REQUIREMENT (TITLE): Integrated Sensur/Thermal Control System	PAGE 1 OF
<ol> <li>TECHNOLOGY CATEGORY: <u>Environmental Control</u></li> <li>OBJECTIVE/ADVANCEMENT REQUIRED: <u>Determining sensor</u> tying a thermal control system to a detector system</li> </ol>	r performance when
4. CURRENT STATE OF ART: Sensor performance has not bee T.C. System HAS BEEN CA	n mapped with
5. DESCRIPTION OF TECHNOLOGY	
Develop a series of integrated sensor/thermal control sy will demonstrate whether sensor performance is degraded elements of thermal system. Such things, in the case of fluid loops, as container materials, fluids, flow rates studied.	by virtue of heat pipes and should be
P/L REQUIREMENTS BASED ON:  PRE- RATIONA: AND ANALYSIS:	
6. RATIONAL AND ANALISIS: Current sensors and instruments are being developed inde how they will be thermally controlled in orbit. The que to whether or not the sensor performance will be degrade to an active or passive thermal control system.	stion arises as
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DEFINITION OF TECHNOLOGY REQUIPEMENT	NO. c-4
1. TECHNOLOGY REQUIREMENT(TITLE): <u>Sensor/T.C.</u> System	PAGE 2 OF <u>2</u>
7. TECHNOLOGY OPTIONS:	
8. TECHNICAL PROBLEMS:	
Develop integrated system which will fit geometric, weight, constraints without affecting sensor performance.	, power
9. POTENTIAL ALTERNATIVES:	
Cool sensors using passive techniques which will not contro.	l temperature
level or gradients and accept sensor performance degradation	
	NCEMENT
10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVAL	CEMENT.
EXPECTED UNPER	TURBED LEVEL
11. RELATED TECHNOLOGY REQUIREMENTS:	
Sensors and thermal system must be integrated early in dev	velopment.

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NO. <u>Ad-2</u>

1. TECHNOLOGY REQUIREMENT (TITLE): Zero-G Measurement of \_\_\_\_ PAGE 1 OF \_\_\_\_

Heat-Pipe Disturbance Forces

2. TECHNOLOGY CATEGORY: \_

3. OBJECTIVE/ADVANCEMENT REQUIRED: To quantify experimentally in a zero-

G environment the disturbing forces induced by various types of heat pipes under a range of heat transfer rates, and to evaluate concepts and configurations which would minimize these forces.

1. CURRENT STATE OF ART: Disturbance sources have been observed, but magnitudes of forces have not been determined. No quantitative data exist which would permit analytical determination of where heat pipes can or cannot be applied because of distrubance effects. HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

A variety of heat pipe installations, with controlled heat sources and sinks would be instrumented thermally and mechanically to measure the very small magnitudes of disturbance effects, fluid mass shifts, etc., as a function of thermal conditions and configurations.

# P/L REQUIREMENTS BASED ON: DPRE-A, A, B, C/D

6. RATIONALE AND ANALYSIS:

a.

- b. Payloads such as optical experiments and others requiring precise pointing or quiescent conditions. #26, #12, #30
- c. Would permit reliable application of heat pipes instead of other less efficient passive control methods, providing weight and cost savings.
- d. Models tested in space environment with sufficient data obtained to determine relationships described in 5 above.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.
1. TECHNOLOGY REQUIREMENT(TITLE):	PAGE 2 OF
7. TECHNOLOGY OPTIONS:	
8. TECHNICAL PROBLEMS:	
Difficulty in designing experiment mounting system and inst to asure very small forces.	trumenting
9. POTENTIAL ALTERNATIVES:	——————————————————————————————————————
Ignore heat pipe disturbance effects. Do not apply heat pi experiments.	ipes to sensitive
10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVAN	NCEMENT:
EXPECTED UNPER	TURBED LEVEL
11. RELATED TECHNOLOGY REQUIREMENTS:	

NO. <u>Ad-3</u>

TECHNOLOGY REQUIREMENT (TITLE): <u>Metallic-Fluid Heat</u> PAGE 1 OF \_\_\_\_\_
 Pipes

2. TECHNOLOGY CATEGORY: <u>Thermal Control</u>

3. OBJECTIVE/ADVANCEMENT REQUIRED: Acquire the technology for

production and space application of economical, durable, effective

metallic-fluid heat pipes.

I. CURRENT STATE OF ART: pumped systems that can transport great thermal power densities (to 15 KW.cm<sup>2</sup> or more) at high temperatures (to 1800K or higher) with small thermal gradients (order of 0.19/cm). But contaminants accelerated corrosion and solution can be HAS BEEN CARRIED TO LEVEL

J. DESCRIPTION OF TECHNOLOGY

Metallic-fluid heat pipes have potentialities to transport thermal pow r densities up to two orders of magnitude greater than those of their ammonia counterparts. For example, a lithium heat pipe operating at 1500°C can transport 15,000 W/cm<sup>2</sup> with a 0.1/cm gradient. However, these reactive heat-pipe fluids combined with tenacious low-concentration contaminants like oxygen, that accelerate corrosion and solution particularly at high operating temperatures, can cause serious material problems. Effective, economical processing must be established to minimize contaminant effects and maximize lifetimes. Simple high-performance wick, envelope configurations must be developed to reduce costs, ease processing, and cecrease contamination. Special application problems such as those of the head-pipe-choked reactor and of the thermionic-converter, heat-pipe module must be solved.

# P/L REQUIREMENTS BASED ON: PRE-A, A, B, C/D

## 6. RATIONALE AND ANALYSIS:

a. Nuclear electric power and propulsion for over JOO kWe missions near the end of the twentieth century need light-weight thermal-transport systems that handle great power densities at high temperatures with small thermal gradients. Metallic-fluid heat pipes can meet these requirements.

b. Beginning in the 1990's, nuclear electric power and propulsion should provide for planetary, earth-orbit, and nuclear waste-disposal propulsion and for large-space-station and lunar-base power.

c. Simple effective configurations and processing of metallic-fluid heat pipes can make these high-performance therm transport systems economical, light-weight, and long-lived. And their capability to carry great thermal energy densities in thin-walled tubes with relatively low pressures at high temperatures and small thermal gradients is unparalleled.

d. The technology advancement requires establishment of simple, effective, ext udable configurations; compatible, economical materials and fabrication techniques; efficient, low-cost processing; and demonstration of performances and life times with space-flight verification. Nuclear electric power and propulsion demand special integration developments and evaluations.

NO.

1. '	TECHNOLOGY REG	QUIREMENT(TITLE	: Metallic-Fluid Heat Pipes	PAGE 2 OF	3
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#### 7. TECHNOLOGY OPTIONS:

Because the heat pipe is a thermal-transport system other heat transfer systems are competitors. Previous sections contain heat-pipe advantages.

8. TECHNICAL PROBLEMS:

Technical problems appear in 5 and 6d.

9. POTENTIAL ALTERNATIVES:

Section 7 indicates alternatives while 4, 5, and 6c give heat-pipe gains.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP: 506-16-31

EXPECTED 'NPERTURBED LEVEL

#### 11. RELATED TECHNOLOGY REQUIREMENTS:

- a. Select and evaluate materials (compatibility and strength).
- b. Develop simple, efficient, extrudable heat-pipe designs (general heat-pipe problem).
- c. Establish economical, effective processing and fabrication to assure long lifetimes (general heat-pipe problem).

DEFINITION C	F T	ECI	HNC	DLC	GY	RE	QU	IRE	ME	NT	•				1	10.	A	d-3	
1. TECHNOLOGY REQUIN Pipes	REM	EN'	Г (Л	TT:	LE)	: <u>M</u>	e <u>ta</u>	111	c-F:	lui	d H	eat		F	•AC	E 3	OI	`	-
12. TECHNOLOGY REQUI	REM	IEN	TS	SCI	HED			ND.	AR	YE	AR					<del>.</del>	<b></b>	1	
SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
<pre>TECHNOLOGY 1. Select, screen, test.    metallic-fluid heat-    pipe materials and    components 2. Performance- and    life-test metallic-    fluid heat-pipes 3. Provide space-flight    verification</pre>																			
APPLICATION (Example:	Nu	dlea	ar f	le	tr	ic f	hwe	<b>†</b> 4	hd	Pr	apu:	lsi	n)						
1. Design (Ph. C)				+	┿╍	╂	+-												
2. Devl/Fab (Ph. D)							+	+	┿╍	┾-	╉╸	╉╼	╉╌╸	┾-					
3. Operations														+-			-		
4. > 100 kWe missions																<u> </u>			
13. USAGE SCHEDULE:						-1			-1					- <b>T</b> -	<b>-</b>				
TECHNOLOGY NEED DAT	E					].				$\bot$	1	$\perp$	╇	+	╇		+		AL
NUMBER OF LAUNCHES																			
14. REFERENCES: Outlook for Space Future Payload Tech RTOP's 506-16-31 am NASA, ERDA Thermion	nd 5	06-2	24-2	21				Rev	∕iev	NS									
<ol> <li>LEVEL OF STATE</li> <li>BASIC PHENOMENA ORSERVE</li> <li>THEORY FORMULATED TO D</li> <li>THEORY FORMULATED TO D</li> <li>THEORY TESTED BY PHYSIC OR MATHEMATICAL MGOL</li> <li>PERTINENT FUNCTION OR C E.G., MATERIAL, CONTO</li> </ol>	.D ANI ESCRI AL EX L, HARA(	D REP BE PI PERIN CTERI	ORTE IENO! AENT STIC	4ENA		RATE	D,	6. 7. 8.	EI MOI MOI NEW O	NVIR DEL 1 DEL 1 V CA1 PER/	ONME LESTE PABLE ATION	DIN DIN DIN ITY I AL M	N THI AIRC SPAC DLRIV IODE	E LAI RAFI TE EN /ED F L.	ORA FEN VIRC ROM	TORY /IRON DNME: A MU	MEN MEN JCH I	ELEV/ F. ESSEF	I ODEL

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. <u>Af-1</u>
1. TECHNOLOGY REQUIREMENT (TITLE): Effects of Shuttle PAGE 1 OF 2 Induced Contamination on Thermal Control Surfaces
2. TECHNOLOGY CATEGORY: 10 or 11
3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop understanding of contamina-
tion effects and provide selection criterion for thermal control surfaces on
shuttle launched S/C.
4. CURRENT STATE OF ART: <u>Data from skylab DO-24 experiment and</u> laboratory testing is available.
HAS BEEN CARRIED TO LEVEL
5. DESCRIPTION OF TECHNOLOGY
and hold charges which may attract contaminants. Many contaminants are also dielectric which may interfere with conductive coatings applied over these surfaces. Skylab DD-24 experiment has shown that significant contamination can change a low α/ε coating to a gray or relatively high ε coating. The possibility of this type of contamination on Shuttle is high and results could be highly significant to temperature control of Shuttle launched S/C. P/L REQUIREMENTS BASED ON: □ PRE-A, □ A, □ B, □ C/D
6. RATIONALE AND ANALYSIS:
<ul> <li>a. Develop better understanding of contamination effects on optical properties of surfaces.</li> </ul>
b. Develop criterion for coating selection for Shuttle launched S/C.
TO BE CARRIED TO LEVEL <u>7</u>

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1.	TECHNOLOGY REQUIREMENT(TITLE):	nuttle Induced PAGE 2 OF
	Contamination on Thermal Control Surface	5

#### 7. TECHNOLOGY OPTIONS:

a. Add complex thermal control devices to compensate for changes in  $\alpha/\epsilon$ .

b. Eliminate all possible contaminants from Shuttle.

#### 8. TECHNICAL PROBLEMS:

Insufficient analytical, experimental and flight data exist to define problem of contamination, and to predict quantity and type of contamination available from Shuttle. Ground testing can only provide an approximation of actual flight testing.

### 9. POTENTIAL ALTERNATIVES:

Clean up all possible contaminants from Shuttle by active or passive techniques. This is extremely expensive and technology is not currently available.

### 10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The development of partially conducting coatings will substantially help eliminate this problem. AFML is currently performing laboratory studies on these effects of contamination on coatings.

EXPECTED UNPERTURBED LEVEL

### 11. RELATED TECHNOLOGY REQUIREMENTS:

Quantitative and qualitative analysis of contaminants on Shuttle during actual flight conditions.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. Ag-1
1. TECHNOLOGY REQUIREMENT (TITLE): The Storage, Supply PAGE 1 OF and Transfer of Cryogenic Fluids in Space
<ol> <li>TECHNOLOGY CATEGORY: <u>12 Cryogenic Control</u></li> <li>OBJECTIVE/ADVANCEMENT REQUIRED: <u>(1) Reusable high performance</u> insulation, (2) behavior of cryogenic fluids in low-g, (3) venting of cryogenic fluids in low-g, (4) control of cryogenic fluids in low-g</li> <li>CURRENT STATE OF ART: <u>Within the limits of ground ased facilities</u>, the control of cryogenic fluids have been evaluated in low-g HAS BEEN CARRIED TO LEVEL <u>3</u></li> <li>DESCRIPTION OF TECHNOLOGY</li> <li>Ground based facilities have provided a wealth of information on reduced gravity fluid behavior, multilayer insulation systems, fluid acquisition and transfer, propellant thermal conditioning, and propellant reorientation. This information is the best that can be obtained within the limitations of ground based test facilities. The application of these results to a long term reduced gravity environment is frequently inconclusive and, at best, hypothetical.</li> </ol>
P/L REQUIREMENTS BASED ON: $\Box$ PRE-A, $\Box$ A, $\Box$ B, $\Box$ C/D
6. RATIONALE AND ANALYSIS:
The specific areas of technology to be advanced by flight demonstration are: (a) data on the reusability of insulation (b) data that will allow the determination of the behavior in reduced gravity of LH <sub>2</sub> , LF <sub>2</sub> , LO <sub>2</sub> , LHe, and LAr (c) pressurization gas and diffuser performance data (d) outflow and inflow propellant dynamics
Requires a space flight demonstration to provide verification of system designs. Flight program to evaluate the necessary fluid parameters to establish the level of assurance required by spacecraft designers.
TO BE CARRIED TO LEVEL 7

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	DEFINITION OF TECHNOLOGY REQUIREMENT NO. Ag-2
l.	TECHNOLOGY REQUIREMENT(TITLE): The Storage, Supply and PAGE 2 OF _
	Transfer of Cryogenic Fluids in Space
7.	TECHNOLOGY OPTIONS:
•	
	The option to using cryogenics as energy sources in space is to use
	propellants that are identified as earth storable. These propellants are less efficient, cause reductions in payload, and produce
	environmental pollution.
8.	TECHNICAL PROBLEMS:
9.	POTENTIAL ALTERNATIVES:
	There are no alternatives to obtaining space flight dats on cryogenic
	fluids.
0	. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:
	RTOP 506-21-10 describes work that will carry this technology as for an
	it can be carried without space flight testing.
	EXPECTED UNPERTURBED LEVEL
11	. RELATED TECHNOLOGY REQUIREMENTS:
	High performance insulation development.

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. Ag-1 Ag-2																			
1. TECHNOLOGY REQUIREMENT (TITLE): The Storage, PAGE 3 OF																			
Supply and Transfer of Cryogenic Fluids in Space																			
12. TECHNOLOGY REQUIREMENTS SCHEDULE: CALENDAR YEAR																			
SCHEDULE ITEM		20		-						-						<u> </u>			
	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY 1. Conceptual Design	*	<b></b>																	
2. Detail Design																			
3. Fabrication				+ +		4													
4. Flight Qualification																			
5, Flight Test							-,												
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<ol> <li>Design (Ph. C)</li> <li>Devl/Fab (Ph. D)</li> </ol>																			
3. Operations																			
4.																			
13. USAGE SCHEDULE:	<u> </u>			L				L.					L				1	<u> </u>	Ц
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14. REFERENCES;	<b>L</b>	1	<u> </u>	_			1				<u> </u>		1			<b></b>		<u> </u>	
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<ul><li>(1) "Outlook for Space</li><li>(2) "Future Payload Te</li></ul>				in ar	~ ~ `	Tec	+in/	<b>.</b>		Dev			<b>n+</b>	Rea			n+c	H	
FT-WP-001																L	1163		
<ul><li>(3) "Future Payload Te</li><li>(4) 1975 NASA DAST Sum</li></ul>					uire	emei	nts	Sti	naà.		LAS	U= (	5-0	U4					
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15. LEVEL OF STATE OF 1. BASIC PHENOMENA OBSERVED			RTUD.						ENV	TRO	(M?'N	1 IN	T:IIL	DARD LAHO AFT I	RATE	DRY.		.EVAN	
<ol> <li>THEORY FORMULATED TO DES</li> <li>THEORY TESTED BY PHYSICAL</li> </ol>	CR3 BE	PIE	NOME					7. 1	AOD7. IEW	1. Т. Гара	STEP BELIT	AN SI Y DL	PACE .8955	ENV D FR	IF 3	MENI	•		
<ul> <li>3. THEORY TESTED BY PHYSICAL EXPERIMENT</li> <li>4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.</li> <li>4. NEW CAPABLE HY DURINED FROM A MODEL.</li> <li>5. NEW CAPABLE HY DURINED FROM A MODEL.</li> <li>6. NEW CAPABLE HY DURINED FROM A MODEL.</li> </ul>																			

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AS-03-A Pre Phase A HE-09-A Phase B AS-15-S Pre Phase AS-07-A Pre Phase A AS-01-S Pre Phase A AS-20-S Pre Phase AS-11-A Pre Phase A AS-14-S Pre Phase A HE-15-S Phase B a. Temperature requirements result from two factors: (1) Requirements for superconduction which defines operational temperatur of magnets and permits low power measurement of particle energies. (2) Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources. b. See Table 2 c. The use of LHe closed cycle systems permit long life missions without re-upply or large dewar requirements		DEFINITION OI	F TECHNOLOGY	REQUIREMENT	<u>۲</u>	NO
<ul> <li>OBJECTIVE/ADVANCEMENT REQUIRED: Provide LHe refrigeration machines to cool payloed items noted below.</li> <li>CURRENT STATE OF ART: Elements of machine under construction and tes Engineering model will be available for testing by 1-1976. HAS BEEN CARRIED TO LEVEL BAS BEEN CARRIED TO LEVEL HAS BEEN CARRIED TO LEVEL BAS BEEN CARRIED TO LEVEL CONTRUCTION OF TECHNOLOGY The DoD has been funding development of low temperature refrigerators. An early investigation was a thregen program to develop a long life 3.6K, one wath load refrigerator for use with a superconducting computer system. The effort by Arth ~ D. Little, Inc. was terminated after one year. Three companies have since been funded for development of closed cycle refrigeration systems; they are: Hughes Aircraft Corp. North American Phillips, Inc. Arthur D. Little, Inc.</li> <li>(continued on page 4) See Table 1 below P/L REQUIREMENTS BASED ON: PRE-A, A, B, C</li> <li>6. RATIONALE AND ANALYSIS: Table 1. Payload Requirements Savload Status Pavload Status Pavload Status AS-03-A Pre Phase A A5-01-S Pre Phase A A5-15-S Pre Phase AS-07-A Pre Phase A A5-01-S Pre Phase A A5-20-S Pre Phase BS-07-A Pre Phase A A5-01-S Pre Phase A HE-15-S Phase B AS-07-A Pre Phase A A5-01-S Pre Phase A HE-15-S Phase B</li> <li>a. Temperature requirements for superconduction which de inco operational temperatur of magnets and permits low power measurement of particle energies.</li> <li>(2) Requirements for superconduction which de inco operational temperatur of magnets and permits low power measurement of particle energies.</li> <li>(2) Requirements for superconduction which de inco operational temperatur of magnets and permits low power measurement of particle energies.</li> <li>(2) Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources.</li> <li>See Table 2</li> </ul>	1.	TECHNOLOGY REQUIRE	EMENT (TITLE)	:LHe Recyclin	g Unit	PAGE 1 OF _6_
<pre>machines to cool payload items noted below.  I. CURRENT STATE OF ART:Elements of machine under construction and tes Engineering model will be available for testing by 1-1976. HAS BEEN CARRIED TO LEVEI  S. DESCRUPTION OF TECHNOLOGY The DoD has been funding development of low temperature refrigerators. An early investigation was a threyear program to develop a long life 3.6K, one watt load refrigerator for use with a superconducting computer system. The effort by Arth - D. Little, Inc. was terminated after one year. Three companies have since been funded for development of closed cycle refrigeration systems; they are: Hughes Aircraft Corp. North American Phillips,Inc. Arthur D. Little, Inc.  (continued on page 4) See Table 1 below P/L REQUIREMENTS BASED ON: PRE-A. A, B, C  6. RATIONALE AND ANALYSIS: Table 1. Payload Requirements Payload Status A5-01-5 Pre Phase A A5-01-5 Pre Phase B A S-01-4 Pre Phase A A5-01-5 Pre Phase A A5-01-5 Pre Phase A A5-01-5 Pre Phase B A S-01-4 Pre Phase A A5-01-5 Pre Phase A A5-01-5 Pre Phase B A S-01-4 Pre Phase A A5-01-5 Pre Phase A A5-01-5 Pre Phase B A S-01-4 Pre Phase A A5-01-5 Pre Phase A A5-01-5 Pre Phase A A5-01-5 Pre Phase B A S-01-4 Pre Phase A A5-01-5 Pre Phase A A5-01-5 Pre Phase B A S-01-4 Pre Phase A A5-01-5 Pre Phase A A5-01-5 Pre Phase B A S-01-4 Pre Phase A A5-01-5 Pre Phase B A S-01-4 Pre Phase A A5-01-5 Pre Phase B A S-01-6 Pre Phase A A5-01-5 Pre Phase B A S-01-7 Pre Phase A A5-01-5 Pre Phase B A S-01-7 Pre Phase A A5-01-5 Pre Phase B A S-01-7 Pre Phase A A5-01-5 Pre Phase B A S-01-7 Pre Phase A A5-01-5 Pre Phase B A S-01-7 Pre Phase A A5-01-5 Pre Prase B A S-01-7 Pre Phase A A5-01-5 Pre Prase B A S-01-7 Pre Prase A A5-01-7 Pre Prase A A5-01-7 Pre Prase A</pre>	2.	TECH. Schogy CATEGO	RY: <u>Cryogen</u>	ic Control		······································
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HAS BEEN CARRIED TO LEVEL         5. DESCRIPTION OF TECHNOLOGY         The DoD has been funding development of low temperature refrigerators. An early investigation was a threyear program to develop a long life 3.6K, one watt load refrigerator for use with a superconducting computer system. The effort by Arth ~ D. Little, Inc. was terminated after one year.         Three companies have since been funded for development of closed cycle refrigeration systems; they are: Hughes Aircraft Corp. North American Phillips, Inc. Arthur D. Little, Inc.         (continued on page 4)       See Table 1 below         P/1. REQUIREMENTS BASED ON:       PRE-A. A. B. C         6. RATIONALE AND ANALYSIS:       Table 1. Payload Requirements         Payload       Status       Payload       Status Payload         Status       Payload       Status       Payload       Status Payload       Status Payload         AS-03-A       Pre Phase A       AS-01-S       Pre Phase A       AS-20-S       Pre Phase Pre Phase B         AS-01-A       Pre Phase A       AS-14-S       Pre Phase B       AS-11-A       Pre Phase A       AS-20-S       Pre Phase B         a. Temperature requirements result from two factors:       (1) Requirements for superconduction which defines operational temperatur of magnets and permits low power measurement of particle energies.       (2) Requirements for high detectability and high S/N ratic which requires detector cooling and allows detection of faint I	١.	CURRENT STATE OF A	RT: <u>Elements</u>	of machine und	er constru	ction and test.
<ul> <li>5. DESCRIPTION OF TECHNOLOGY The DoD has been funding development of low temperature refrigerators. An early investigation was a thregear program to develop a long life 3.6K, one watt load refrigerator for use with a superconducting computer system. The effort by Arth &gt; D. Little, Inc. was terminated after one year. Three companies have since been funded for development of closed cycle refrigeration systems; they are: Hughes Aircraft Corp. North American Phillips, Inc. Arthur D. Little, Inc. (continued on page 4) See Table 1 below P/1. REQUIREMENTS BASED ON: pre-A, A, B, C 6. RATIONALE AND ANALYSIS: Table 1. Payload Requirements Savload Status Payload Status Pre Phase A AS-01-S Pre Phase B AS-11-A Pre Phase A AS-01-S Pre Phase B</li></ul>		<u>Engineering model will</u>	be available			
The DoD has been funding development of low temperature refrigerators. An early investigation was a threyear program to develop a long life 3.6K, one watt load refrigerator for use with a superconducting computer system. The effort by Arth = D. Little, Inc. was terminated after one year. Three companies have since been funded for development of closed cycle refrigeration systems; they are: Hughes Aircraft Corp. North American Phillips, Inc. Arthur D. Little, Inc. (continued on page 4) See Table 1 below P/L REQUIREMENTS BASED ON: PRE-A. A. B. C 6. RATIONALE AND ANALYSIS: Table 1. Payload Requirements Payload Status Payload Status Payload Status AS-03-A Pre Phase A HE-09-A Phase B AS-15-5 Pre Phase AS-01-A Pre Phase A AS-01-S Pre Phase A AS-20-5 Pre Phase BS-01-A Pre Phase A AS-01-S Pre Phase A HE-15-5 Prase B AS-11-A Pre Phase A AS-01-S Pre Phase A HE-15-5 Prase B a. Temperature requirements result from two factors: (1) Requirements for superconduction which de inco operational temperature of magnets and permits low power measurement of particle energies. (2) Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources. 5. See Table 2 5. The use of LHe closed cycle systems permit long life mission: without re-upply or large dewar requirements	_			HAS B	EEN CARR	IED TO LEVEL _4
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refrigeration systems; they are: Hughes Aircraft Corp. North American Phillips, Inc. Arthur D. Little, Inc. (continued on page 4) <u>P/1. REQUIREMENTS BASED ON:</u> <u>PRE-A.</u> <u>A.</u> <u>B,</u> <u>(</u> 6. RATIONALE AND ANALYSIS: Table 1. Payload Requirements <u>Payload</u> <u>Status</u> <u>Payload</u> <u>Status</u> <u>Payload</u> <u>Status</u> AS-03-A Pre Phase A <u>HE-09-A</u> Phase B <u>AS-15-5</u> Pre Phase AS-07-A Pre Phase A <u>AS-01-5</u> Pre Phase A <u>AS-20-5</u> Pre Phase AS-11-A Pre Phase A <u>AS-14-5</u> Pre Phase A <u>HE-15-5</u> Prage B a. Temperature requirements result from two factors: (1) Requirements for superconduction which defines operational temperatur of magnets and permits low pueser measurement of particle energies. (2) Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources. b. See Table 2 :. The use of LHe closed cycle systems permit long life missions without re-upply or large dewar requirements		An early investigatio 3.6K, one watt load r system. The effort b year.	n was a thre efrigerator fo y Arth - D. Li	year program to r use with a su ttle, Inc. was	develop a perconduct terminated	a long life ing computer after one
North American Phillips, Inc. Arthur D. Little, Inc. (continued on page 4) P/1. REQUIREMENTS BASED ON: PRE-A. A, B, ( 6. RATIONALE AND ANALYSIS: Table 1. Payload Requirements Payload Status Payload Status Payload Status AS-03-A Pre Phase A HE-09-A Phase B AS-15-S Pre Phase AS-07-A Pre Phase A AS-01-S Pre Phase A AS-20-S Pre Phase AS-11-A Pre Phase A AS-14-S Pre Phase A HE-15-S Phase B a. Temperature requirements result from two factors: (1) Requirements for superconduction which defines operational temperature of magnets and permits low power measurement of particle energies. (2) Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources. 5. See Table 2 5. The use of LHe closed cycle systems permit long life missions without re-upply or large dewar requirements						
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<ul> <li>6. RATIONALE AND ANALYSIS: Table 1. Payload Requirements</li> <li>Payload Status Payload Status Payload Status Payload Status AS-03-A Pre Phase A HE-09-A Phase B AS-15-S Pre Phase A AS-07-A Pre Phase A AS-01-S Pre Phase A AS-20-S Pre Phase A AS-11-A Pre Phase A AS-14-S Pre Phase A HE-15-S Phase B</li> <li>a. Temperature requirements result from two factors: <ol> <li>Requirements for superconduction which defines operational temperatur of magnets and permits low power measurement of particle energies.</li> <li>Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources.</li> </ol> </li> <li>b. See Table 2</li> <li>c. The use of LHe closed cycle systems permit long life missions without resupply or large dewar requirements</li> </ul>						
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AS-03-A Pre Phase A HE-09-A Phase B AS-15-S Pre Phase AS-07-A Pre Phase A AS-01-S Pre Phase A AS-20-S Pre Phase AS-11-A Pre Phase A AS-14-S Pre Phase A HE-15-S Phase B a. Temperature requirements result from two factors: (1) Requirements for superconduction which defines operational temperatur of magnets and permits low power measurement of particle energies. (2) Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources. b. See Table 2 c. The use of LHe closed cycle systems permit long life missions without re-upply or large dewar requirements						
<ul> <li>AS-07-A Pre Phase A AS-01-S Pre Phase A AS-20-S Pre Phase A AS-11-A Pre Phase A AS-14-S Pre Phase A HE-15-S Phase B</li> <li>a. Temperature requirements result from two factors: <ul> <li>(1) Requirements for superconduction which defines operational temperatur of magnets and permits low power measurement of particle energies.</li> <li>(2) Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources.</li> </ul> </li> <li>b. See Table 2</li> <li>c. The use of LHe closed cycle systems permit long life missions without resupply or large dewar requirements</li> </ul>				· · · · · · · · · · · · · · · · · · ·		
<ul> <li>a. Temperature requirements result from two factors: <ol> <li>Requirements for superconduction which defines operational temperatur of magnets and permits low power measurement of particle energies.</li> <li>Requirements for high detectability and high S/N ratio which requires detector cooling and allows detection of faint IR sources.</li> </ol> </li> <li>b. See Table 2</li> <li>c. The use of LHe closed cycle systems permit long life missions without recupply or large dewar requirements</li> </ul>			AS-01-5	Pre Phase A	AS-20-5	Pre Phase A
<ul> <li>See Table 2</li> <li>The use of LHe closed cycle systems permit long life missions without requirements</li> </ul>		Temperature requiremen (1) Requirements for of magnets and pe (2) Requirements for	ts result from superconductio rmits low powe high detectabi	two factors: n which defines r measurement o lity and high S	operation f particle /N ratio w	al temperature energies. hich requires
re upply or large dewar requirements		detector cooling				
. Space flight testing of a prototype model	D.					
	•	See Table 2 The use of LHe closed (	cy <b>cle</b> systems	permit long lif	e missions	without
	•	See Table 2 The use of LHe closed ( re upply or large dewa	cycle systems j r requirements	permit long lif	e missions	without
<b>TO BE CARRIED TO LEVEL</b>	•	See Table 2 The use of LHe closed ( re upply or large dewa	cycle systems j r requirements	permit long lif	e missions	without

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1. TEC	CHNOLOGY REQUIREMENT (TITLE):
Dil	lution Refrigerator - Operable in O-g
2. TEC	HNOLOGY CATEGORY:Cryogenic Temperature Control
3. OB.	JECTIVE/ADVANCEMENT REQUIRED: Produce mK temperature in the
	g environment of space.
4. CU	RRENT STATE OF ART:He/4He dilution_refrigerators have been
dev	veloped for use on the ground. but depend on gravity for the separation HAS BEEN CARRIED TO LEVE
5. DE	SCRIPTION OF TECHNOLOGY
pro	velop a <sup>3</sup> He/ <sup>4</sup> He dilution refrigerator which is capable of continuously oducing, in O-g and for periods up to 30 days, temperatures in the mange.
Fo: bas	other methods exist for continuously producing mK temperatures. r example, the adiabatic demagnetization of paramagnetic salt is sically a single-cycle method of cooling. Pumping on <sup>4</sup> He and <sup>3</sup> He n only produce, at least, 0.5 and 0.3K.
	P/L REQUIREMENTS BASED ON: DPRE-A, A, B, D
6. RA	P/L REQUIREMENTS BASED ON:  PRE-A, A, B, TIONALE AND ANALYSIS:
	TIONALE AND ANALYSIS: Ultimate sensitivity of some advanced detectors (e.g., IR) depends on their operation at mK temperatures. Some physics experiments,
	TIONALE AND ANALYSIS: Ultimate sensitivity of some advanced detectors (e.g., IR) depends on their operation at mK temperatures. Some physics experiments, especially quantum fluids, may require mK temperatures.
1.	TIONALE AND ANALYSIS: Ultimate sensitivity of some advanced detectors (e.g., IR) depends on their operation at mK temperatures. Some physics experiments, especially quantum fluids, may require mK temperatures. Benefiting payloads include IR telescopes, gravitational radiation detectors and Spacelab physics experiments.
1. 2. 3.	TIONALE AND ANALYSIS: Ultimate sensitivity of some advanced detectors (e.g., IR) depends on their operation at mK temperatures. Some physics experiments, especially quantum fluids, may require mK temperatures. Benefiting payloads include IR telescopes, gravitational radiation detectors and Spacelab physics experiments. Integration time for detectors decreased as the square of the temperature, therefore allowing significantly more data to be gather during a given mission. Increased sensitivity may also allow the us
1. 2. 3.	TIONALE AND ANALYSIS: Ultimate sensitivity of some advanced detectors (e.g., IR) depends on their operation at mK temperatures. Some physics experiments, especially quantum fluids, may require mK temperatures. Benefiting payloads include IR telescopes, gravitational radiation detectors and Spacelab physics experiments. Integration time for detectors decreased as the square of the temperature, therefore allowing significantly more data to be gather during a given mission. Increased sensitivity may also allow the us of smaller telescopes. Since the major thrust of this technology effort is to develop
1. 2. 3.	TIONALE AND ANALYSIS: Ultimate sensitivity of some advanced detectors (e.g., IR) depends on their operation at mK temperatures. Some physics experiments, especially quantum fluids, may require mK temperatures. Benefiting payloads include IR telescopes, gravitational radiation detectors and Spacelab physics experiments. Integration time for detectors decreased as the square of the temperature, therefore allowing significantly more data to be gather during a given mission. Increased sensitivity may also allow the us of smaller telescopes. Since the major thrust of this technology effort is to develop

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	DEFINITION OF TECHNOLOGY REQUIREMENT	NO.
•	TECHNOLOGY REQUIREMENT(TITLE):	PAGE 2 OF
	TECHNOLOGY OPTIONS:	
	In the case of detectors, trade-offs exist between sensitive mission duration, and temperature. There may be no other of however, for physics experiments.	
	TECHNICAL PROBLEMS:	
	Current dilution refrigerators depend on gravity for separa <sup>3</sup> He and <sup>4</sup> He phases in the mixing chamber and still. Altern of separation must be developed.	
).	POTENTIAL ALTERNATIVES:	
	No other techniques are known to exist which cen continuous mK tempcratures for periods up to 30 days.	sly produce
0.	PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVA	NCEMENT:
	Dilution refrigerators have been built for ground and airc: No program currently exists for a system to be operable in Ames anticipates initiating such a program in FY '76.	raft applications. O-g. However,
-	EXPECTED UNPE	RTURBED LEVEL <u>4</u>
11.	RELATED TECHNOLOGY REQUIREMENTS:	
	Hell storage and utilization	

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	DEFINITION OF TECHNOLOGY REQUIREMENT NO. Ag-8
1.	TECHNOLOGY REQUIREMENT(TITLE): LHe Recycling Unit PAGE 2 OF 6
7.	TECHNOLOGY OPTIONS:
	Two Brayton cycles and various others should be investigated; they are:
	1. Reciprocating Reverse Brayton Cycle
	2. Rotary Reverse Brayton Cycle
	3. Rotary Claude Cycle
	4. Dual Phased Recuperated Vuilleumeir Process
	5. Hybrid Systems - which combine mechanical refrigeration with other techniques such as dielectric cooling
	TECHNICAL PROBLEMS: In discussion with Arthur D. Little, Inc., it was determined that primary tech nical problems are in the area of fabrication of system items and no major pro- blems are foreseen. It can be seen from the scheduled availability of the ADU unit for life testing as of January 1976, that the unit modified to the neces- sary cooling requirements will not be available by the technology need date. The early payloads may be more suited to using the dewars currently under de- velopment until the technology is developed by WPAFB for cooling machines. Maintenance of close tolerances during operation.
9.	POTENTIAL ALTERNATIVES: It can be seen from Table 2 that a number of the payloads which are listed
	as desirable to incorporate closed cycle systems are Shuttle sortie payloads of seven-day duration. The weights of the refrigerators are estimated as:
	North American Phillips VM - 130 pounds
	Hughes VM - 180 pounds ADL Rotary Reciprocating - 300 pounds prior to modification for lower temperatures (continued on page 5)
10.	PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:
	The ADL unit will be at the stage for initiating life testing about January 1976; however, the minimum temperature it will be capable of operating to will be 11.5K at 0.3 watts. No modification to lower temperature capa- bilities required for these payloads is planned.
	EXPECTED UNPERTURBED LEVEL
11	. RELATED TECHNOLOGY REQUIREMENTS:
	Use of closed cycle systems will require a source of high power. Related technology will be highly efficient large solar arrays, or focusing solar collectors capable of providing thermal power.

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DEFINITION OF TECHNOLOGY REQUIREMENT NO. Ag-8																			
1. TECHNOLOGY REQUIREMENT (TITLE): LHe Recycling Unit PAGE 3 OF																			
12. TECHNOLOGY REQUIREMENTS SCHEDULE: CALENDAR YEAR																			
SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY 1. Engineering Model Design 2. Life Testing		-					NOT	E:	in	pad	ts	red	ui	ed	tin	se ie i ing	or	usl	У
<ol> <li>Bevelopment through development testing</li> <li>4.</li> <li>5.</li> </ol>	1		-																
APPLICATION 1. Design (Ph. C)				•															
2. Devi/Fab (Ph. D) 3. Operations A5-03-A A5-07-A A5-11-A 4. HE-09-A																			
13. USAGE SCHEDULE:		L	<b>L</b>	<b>I</b>	L	L			<b>L</b>	L	L	<b>I</b>		i	L	L	<u> </u>	<u>i</u>	<b>L</b>
TECHNOLOGY NEED DATE			⊽		Γ	Γ		Ι	Γ	Ι							1	от	AL
NUMBER OF LAUNCHES					1	4	5	5	8	4	3	2	4	3	5	4	4	5	2
<ol> <li>NUMBER OF LAUNCHES</li> <li>14. REFERENCES:</li> <li>14. Conversation between R. W. Breckenridge, Arthur D. Little, Inc., and P. R. Fagan, Rockwell International, Inc., Nov. 27, 1974.</li> <li>2. Conversation between J. Kirkpatrick, NASA-ARC, and P. R. Fagan, Rockwell International, Inc., Nov. 20, 1974.</li> <li>3. Development of Rotary Reciprocating Cryogenic Refrigerator for Space Applications, R. W. Breckenridge, Jr., et al, Arthur D. Little, Inc., AFFDL-TR-72-88.</li> <li>4. Letter from R. S. Hurt, Garrett-Airresearch Co., to H. Ikerd, GDCA, January 6, 1975.</li> <li>5. Letter from J. Kirkpatrick, NASA-ARC, to H. Ikerd, GDCA, January 6, 1975.</li> <li>7. Letter from C. McCreight, NASA-Arc, to H. Ikerd, GDCA, January 7, 1975.</li> </ol>																			
<ol> <li>BASIC PHENOMENA ORSERVED A</li> <li>THEORY FORMULATED TO DESC</li> <li>THEORY TESTED BY PHYSICAL I</li> <li>OR MATHEMATICAL MODEL.</li> </ol>	<ol> <li>LEVEL OF STATE OF ART         <ol> <li>BABIC PHENOMENA OBSERVED AND REFORTED.</li> <li>THEORY FORMULATED TO DESCRIBE PHENOMENA.</li> <li>THEORY FORMULATED TO DESCRIBE PHENOMENA.</li> <li>THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.</li> <li>PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED.</li> </ol> </li> <li>BABIC PHENOMENA OBSERVED AND REFORTED.</li> <li>COMPONENT IN THE LABORATORY.</li> <li>MODEL TESTED IN AIRCRAFT ENVIRONMENT.</li> <li>MODEL TESTED IN SPACE ENVIRONMENT.</li> <li>MODEL TESTED IN SPACE ENVIRONMENT.</li> <li>NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.</li> <li>RELABILITY UPGRADING OF AN OPERATIONAL MODEL.</li> </ol>																		

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1. TECHNOLOGY REQUIREMENT (TITLE): \_\_LHe Recycling Unit\_\_\_

PAGE 4 OF 6

Description of Technology (continued)

The Hughes Vuilleumier (VM) cycle refrigerator is the furthest along in the development cycle and is best suited for near-term missions. However, its performance at low temperatures is relatively poor. Unattended operational life on the order of three years is problematic as the dry lubricated Hughes VM has not been able to demonstrate long life, as yet.

Hughes and North American Phillips are both developing VM cycles and the requirements to which they are working are to simultaneously produce:

0.3w at 11.5K 10w at 33K 12w at 75K

Additional requirements are to draw 2700 watts in the all electric mode and in the thermol-electric mode draw 2600w or less of thermal power and 500 watts of electric power.

For missions beyond the near term, the Arthur D. Little (ADL) rotary reciprocating refrigerator offers the greatest potential. It is a positive displacement machine, but because of funding lags the VM in development cycle. The prototype is in the fabrication cycle and complete refrigeration testing is expected about January 1976. The ADL device has the advantage of relatively high performance and long life, by virtue of hydrodynamic lubrication achieved by the pistons stroking motion. The ADL device is capable of simultaneously producing:

1.4w at 12K 40w at 60K

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It can be seen from Table 2 that the above minimum temperatures of the three noted companies are too high for detectors or superconducting magnets, although they are suitable for providing internal cooling to the IR telescopes.

In discussions with R. W. Breckenridge, Arthur D. Little, Inc., he stated that the rotary reciprocating unit currently under development and noted above is capable of one watt load at 3.6K at a required input power of 1300 watts. Further extrapolation to 2.5K will result in a requirement for about 1900 watts for a one watt load. This capability could be achieved through the addition of another Joule-Thompson loop which will require another stage compressor and heat exchanger.

VM cycles cannot be operated at temperatures on the order of those required for detectors listed in Table 2.

NO. Ag-8

- 1. TECHNOLOGY REQUIREMENT (TITLE): \_\_LHe Recycling Unit \_\_\_\_ PAGE 5 OF \_6\_\_\_
- 5. Description of Technology (continued)

The potential availability of an LHe cryogenic machine can be tempered somewhat by:

- As yet no complete miniature He refrigerator (or liquefier) has demonstrated the capability for providing useful refrigeration at any temperature under 10K.
- 2. The longest endurance run that has been conducted to date on a cryogenic refrigerator (Vuilleumier device operating at 80K) is slightly in excess of 5000 hours. Demonstrating the capability of operating for periods in excess of one year may prove to be a practical impossibility due to outgassing or the accumulation of wear products irrespective of quantities involved.
- No tests have been done to confirm the possibility that no LHe cryogenic machine can withstand the launch and space vehicle environmental conditions.
- 9. Potential Alternatives (continued)

Additionally the machine will require a power input on the order of two to three thousand watts. At least for short term Shuttle sortie missions of 7 days it appears feasible to consider open cycle phase change dewars. The advantages are no or little power requirements and probable operation within the weights defined above. A prototype dewar is presently being prepared for thermal testing at Ball Brothers. It was designed for one year operation at 30 milliwatt heat leak and weight of 200 pounds. The dewar will cool the relativity gyroscope to 1.6K. (See RI,12.1)

# APPENDIX B

# FLIGHT EXPERIMENT FORMS

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	FUTURE PAYLOAD TECHNOLOGY NOBa-1											
	TESTING AND DEVELOPMENT REQUIREMENT PAGE 1											
1.	REF. NO11         PREP DATE8/8/75         REV DATELTR											
	CATEGORYEnvironmental Protection											
2.	TITLEThermal Control Materials Compatible with the Space Plasma/											
	Charging Environment											
3.	TECHNOLOGY ADVANCEMENT REQUIRED											
	Current typical spacecraft flexible CURRENT UNPERTURBED REQUIRED											
	solar array and thermal control system 2 3 7											
	designs include a large number of dielectric materials facing the space											
	environment. There is increasing evidence that there may be significant											
	adverse interactions of these materials with the space plasma/charging											
	environment. Spacecraft thermal control dielectric materials and applications											
	techniques do not exist which are compatible with the space plasma/charging environment. The objective of this experiment is to expose candidate space-											
	environment. The objective of this experiment is to expose candidate space- eraft thermal control materials to the space plasma/charging environment and											
	then to evaluate their compatibility with the environment. Analyses and											
	ground tests would be performed in support of the (continued on attached form)											
_	Earliest available											
4.												
	PAYLOAD DEVELOPMENT LEAD TIMEYEARS. TECHNOLOGY NEED DATE											
5.	All sync. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS orbit											
	TECHNICAL BENEFITS In some cases it has been postulated that high potential											
	discharges have destroyed orbiting spacecraft. In those cases where the											
	spacecraft may not be destroyed the gathering of data is interfered with.											
	POTENTIAL COST BENEFITS <u>Any loss of the spacecraft is a costly failure.</u>											
	ESTIMATED COST SAVINGS \$											
6.	RISK IN TECHNOLOGY ADVANCEMENT											
	TECHNICAL PROBLEMS Insufficient analytical experimental and flight data											
	exists to precisely define either the space plasma/charging environment or											
	the behavior of dielectric materials in this environment. The space plasma											
	is difficult to simulate. Ground tests are therefore of dubious value.											
	REQUIRED SUPPORTING TECHNOLOGIES _ Spacecraft analytical model, materials											
	(haracterization, study of charging and discharging mechanisms, development											
	of conductive materials with required surface properties.											
7.	REFERENCE DOCUMENTS/COMMENTS OFS Future Payload Technology											
	Requirements Study Report No. CASD-NAS-75-004 - Technology											
	Categories 5.0, 11.0, and 13.0. Office of Space science											
	input document to 1975 NASA OAST Workshop.											

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	TEST DESCRIPT		_/		km, INC				deg, T	IME _	hr				
	BENEFIT OF SPACE TEST:														
	EQUIPMENT: POINTING	WEIGHT			kg, \$			_ X	x		ſ	n, <b>POV</b>	/ER		kW
	ORIENTATION			``	CABIL	LIIY NEW:	NO.	OP	ERATI	VA ONS/0	URAT				
	ORIENTATION CREW: NO OPERATIONS/DURATION/														
	<del></del>					-					EX				
									 	TEST	CONFIL	DENCI			
9.	GROUND TEST OPTION TEST ARTICLE:														
	SPECIAL GROUND FACILITIES:EXISTING: YES NO														
	GROUND TEST LIMITATIONS:														
	TEST CONFIDENCE														
10.	SCHEDULE &	COST		SPA	CE TE	ST OP	TION		Ĭ	(	ROU		EST O	PTION	1
	ASK	CY		T		<u> </u>		COST (S)	ᢔ──	<b></b>				Γ	COST (S
•	1. ANALYSIS			╉──	<u> </u>				╢───	<u> </u>		<b> </b>		┣	
	2. DESIGN				ĺ		[					ſ			
	3. MFG & C/O			1	[		[		[]	[				[	{
	4. TEST & EVAL														Į
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		<u>L</u>		BRAN						6	RAN		AL		
11.	VALUE OF SP	PROG	RAM	COST	s <b>s _</b>			.)							
12.	DOMINANT R	ISK/TE	CH PRO	BLEM	1				(	COST IMPACT PROBABILITY					
	COST RISK \$			-											

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	TESTING AND DEVELOPME											
	REF. NOPREP DATECATEGORY	REV DATE _										
•												
		LEVEL OF STA										
<b>B</b> .	TECHNOLOGY ADVANCEMENT REQUIRED flight experiment. Guidelines would	CURRENT UNPERTUR		REQUIRED								
	be issued for materials and application	-										
	techniques based on the flight data.											
			~									
•												
		YEARS. TECHNOLOGY NEE	D DATE _	•								
•	BENEFIT OF ADVANCEMENT	NUMBER OF PAY	LOADS									
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			<u> </u>	<del></del>								
		······································										
	POTENTIAL COST BENEFITS											
	ESTIMATED COST SAVINGS \$											
3.	RISK IN TECHNOLOGY ADVANCEMENT											
		<u></u>										
		<u> </u>										
		<u> </u>										
7.	REFERENCE DOCUMENTS/COMMENTS											
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		СО	MPA	RISON C	OF SPACE	. & GRO		ST OPT	IONS			
3.	SPACE TEST (	OPTIO	N	TEST	ARTICLE	: <u>Pigc</u>	yback	package	3			
	<b>TEST DESCRIPTIO</b> Evaluate mat	N: terial	AL ls ex	T. (max/mi posed t	n) sync :o space	enviro	bit k	m, INCL.		deg, TIME	hr	
	BENEFIT OF SPACE TEST:Ground simulation difficult and uncertain											
	EQUIPMENT:	WEIGH	T		kg, SIZE		x	×	m, POV	VER	kW	
	POINTING											
	ORIENTATION known or controlled CREW: NO OPERATIONS/DURATION/											
	SPECIAL GROUND FACILITIES:											
									EXISTIN		NO	
								TES	T CONFIDENCI	<u> </u>		
).	GROUND TEST OPTION TEST ARTICLE: <u>Samples exposed to simulated environment</u>											
	withstand simulated environment.  SPECIAL GROUND FACILITIES: Need to develop special simulation facilities  EXISTING: YES NO GROUND TEST LIMITATIONS: Poor repre:.entation of space environment											
									EXISTIN		_ N0 [	
								ce envi	EXISTIN		) NO []	
								ce envi	EXISTIN			
				Poor		tation		ce envi	EXISTIN	G: YES [		
0.	GROUND TEST LH			Poor	cepre:,en	tation OPTION	of spac	ce envi	EXISTIN	G: YES [		
D. T	GROUND TEST LN	COST		Poor	cepre:,en	tation OPTION		ce envi	EXISTIN	G: YES [		
о. Т	GROUND TEST LH	COST		Poor	cepre:,en	tation OPTION	of spac	ce envi	EXISTIN	G: YES [		
D. T	GROUND TEST LH SCHEDULE & ( ASK 1. ANALYSIS	COST		Poor	cepre:,en	tation OPTION	of spac	ce envi	EXISTIN	G: YES [		
<u>.</u> D. Т	GROUND TEST LI SCHEDULE & ( ASK 1. ANALYSIS 2. DESIGN	COST		Poor	cepre:,en	tation OPTION	of spac	ce envi	EXISTIN	G: YES [		
о. Т	GROUND TEST LH SCHEDULE & ( ASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O	COST		Poor	cepre:,en	tation OPTION	of spac	ce envi	EXISTIN	G: YES [		
0. T	GROUND TEST LI SCHEDULE & ( ASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL	COST		Poor I	cepre:,en	tation OPTION	of spac	ce envi	EXISTIN	G: YES		
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	TESTING AND DEVELOPM	ENT REQUIR	EMENT PA	GE 1
1.	REF. NOPREP DATECATEGORY	8/9/75 10 or 11	REV DATE	LTR
2.	TITLE Improved Temperature Control Coat Including Solar Collectors	tings For Ve:	ry Large Space S	tructures
3.	TECHNOLOGY ADVANCEMENT REQUIRED		EVEL OF STATE OF	ART
	Integrate the thermal control coating	CURRENT	UNPERTURBED	REQUIRED
	with the structural elements. Will			I
	include light-weight laminates, conduct $(\alpha/\epsilon \text{ values } 30 \text{ to } 50)$ , stable anodized	tive α/ε coa coatings.	tings for solar	collectors
	Will require flight testing for verific confirmation of coating test data.		ound testing and	
4.	SCHEDULE REQUIREMENTS FIRST PAYLO PAYLOAD DEVELOPMENT LEAD TIME			
5.	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Light weight, high ef performance. POTENTIAL COST BENEFITS	ficiency. lo	DWBER OF PAYLOADS	
6.	RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS R & D required in co	pating develo	opment	
	REQUIRED SUPPORTING TECHNOLOGIES			
7.				

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	OMPARISON OF SPACE &			
8. SPACE TEST OPTIC				
				······
TEST DESCRIPTION :	ALT. (max/min)	_/ k	m, INCL	deg, TIME hr
BENEFIT OF SPACE TES	ST:			
EQUIPMENT: WEIGH	1T kg, SIZE	x	X m, POW	/ER kW
POINTING	STABILITY		DATA	······································
	CREW:			
SPECIAL GROUND FAC	LITIES:			
·			EXISTIN	G: YES NO
······				
	TION TEST ARTICLE:			
	QUIREMENTS:			
SPECIAL GROUND FAC	ILITIES:			
			EXISTING	VES TI NO T
GROUND TEST LIMITAT	ГІОNS:			
		<u> </u>	TEST CONFIDENCE	
IO. SCHEDULE & COST				
	SPACE TEST OPT		GROUND TE	
TASK	┝╼╌┼╌┝╶┥┥	COST (\$)		COST (
1. ANALYSIS				
2. DESIG \ 3. MFG & C/O				
4. TEST & EVAL				
TECH NEED DATE			┝╍╋╾╂╾╂╌┥	
	GRAND TOTAL		GRAND TOT	AL
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	TESTING AND DEVELOPM				GE 1
•	REF. NOPREP DATECATEGORY	8/9/75 10 or 11	REV DATE		LTR
	TITLE _ Evaluation of Long-Life Stabilit	v of S/C Th	ermal Contr	ol Sur	faces
			LEVEL OF STA	TE OF A	ART
•	The need to obtain flight operational	CURRENT	UNPERTU	RBED	REQUIRED
	data on the performance of s/c thermal	-			
	control surfaces in long-term missions	is of major	concern.	Long-t	term
	missions in particulate (e-, p+) radia				
	on coatings developed in 1970's is not				
	required in following environments: No				
	Interplanetary - Venus, Mercury, Jupit				
	satisfy near-earth data - requirements		pd	YICGG !	
	Sarsay node sar on data - redationenta	·			
			······		
	<u></u>				
				<u></u>	
	SCHEDULE REQUIREMENTS FIRST PAYLO	AD FLIGHT DAT	TE <u>1981</u>		
	PAYLOAD DEVELOPMENT LEAD TIME2				1070
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature = coating performance and coating select	<b>NI</b> stability th	JMBER OF PAY	YLOADS	
•	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	<b>NI</b> stability th	JMBER OF PAY	YLOADS	
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature = coating performance and coating select	<b>NI</b> stability th	JMBER OF PAY	YLOADS	
5.	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature :	<b>NI</b> stability th	JMBER OF PAy	YLOADS ictable	8
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature :	NW stability th ion.	JMBER OF PAy	YLOADS ictable	8
_	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature =	NW stability th ion.	JMBER OF PAy	YLOADS ictable	8
_	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature	NW stability th ion.	JMBER OF PAy	YLOADS ictable	8
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature	NW stability th ion.	JMBER OF PAy	YLOADS ictable	8
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature	NW stability th ion.	JMBER OF PAy	YLOADS ictable	8
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature	NW stability th ion.	JMBER OF PAy	YLOADS ictable	8
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature	Nu stability th ion. ESTIMATED	JMBER OF PAY	YLOADS ictable	
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature	Nu stability th ion. ESTIMATED	JMBER OF PAY	YLOADS ictable	
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	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature	Nu stability th ion. ESTIMATED	JMBER OF PAY	YLOADS ictable	
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	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSBetter temperature	Nu stability th ion. ESTIMATED	JMBER OF PAY	YLOADS ictable	

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	COMPA		GROUND TI	EST OPTIC	ONS		· · · · · · · · · · · · · · · · · · ·
8. SPACE TEST OP only shuttle p payloads; other	payload (	TEST ARTICLE:					
	: AL	T. (max/min)	/	km, INCL	de	ng, TIME _	hr
BENEFIT OF SPACE	TEST:	ctual Radiation v	s Time				······
EQUIPMENT: WE	EIGHT	kg, SIZE	x	×	m, POWE	R	kW
POINTING		STABILITY		DA	TA		· · · · · · · · · · · · · · · · · · ·
		CREW:				/	
SPECIAL GROUND F	ACILITIES	::					
		·····			EXISTING:	YES 🗌	] NO[
				TEST (	CONFIDENCE		
9. GROUND TEST	OPTION	TEST ARTICLE					
							<u></u>
	_						
		Radiation tecti			EXISTING:	YES	
		Radiation testi		does no	<b>EXISTING</b> : ht ma <u>tch</u>	YES	-
GROUND TEST LIMI				does no	EXISTING:	YES	-
GROUND TEST LIMI			ng in lab	does no	<b>EXISTING</b> : ht ma <u>tch</u>	YES fligh:	t test
GROUND TEST LIMI data.		Radiation testi	ng in lab	_d <u>oes_no</u>	EXISTING: ht_match FIDENCE	YES fligh:	t test
GROUND TEST LIMI data. 10. SCHEDULE & CO		Radiation testi	ng in lab_ ION	_d <u>oes_no</u>	EXISTING: ht_match FIDENCE	YES fligh:	t test
GROUND TEST LIMI data. 10. SCHEDULE & CO TASK		Radiation testi	ng in lab_ ION	_d <u>oes_no</u>	EXISTING: ht_match FIDENCE	YES fligh:	t test
GROUND TEST LIMI data. 10. SCHEDULE & CO TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O		Radiation testi	ng in lab_ ION	_d <u>oes_no</u>	EXISTING: ht_match FIDENCE	YES fligh:	t test
GROUND TEST LIMI data. 10. SCHEDULE & CO TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL		Radiation testi	ng in lab_ ION	_d <u>oes_no</u>	EXISTING: ht_match FIDENCE	YES fligh:	t test
GROUND TEST LIMI data. 10. SCHEDULE & CO TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O		Radiation testi	ng in lab_ ION		EXISTING:	YES	t test
GROUND TEST LIMI data. 10. SCHEDULE & CO TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL		Radiation testi	ng in lab_ ION		EXISTING: ht_match FIDENCE	YES	t test
GROUND TEST LIMI data. 10. SCHEDULE & CO TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL	DST CY	Radiation testi	ng in lab_ ION COST (\$)		EXISTING:	YES f   i g h: T OPTIO	t_test N COST (\$
GROUND TEST LIMI data. 10. SCHEDULE & CO TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL TECH NEED DATE		Radiation testi	ng in lab_ ION COST (\$)	does no TEST CON	EXISTING:	YES	t_test N COST (S
GROUND TEST LIMI data. 10. SCHEDULE & CO TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL TECH NEED DATE 11. VALUE OF SPAC		Radiation testi	ng in lab_ ION COST (\$)	does no TEST CON	EXISTING:	YES	t_test N COST (S

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	REF. NO PREP DA	TE 8/9/75	REV DATE	GE 1
	CATEGO	RY 10 or 11	NEV DATE	LIN
	TITLE <u>Repair/Refurbishment of Therm</u>	mai control Sur	aces in Space	
	TECHNOLOGY ADVANCEMENT REQUIRE		EVEL OF STATE OF	
	Development of techniques for repair		UNPERTURBED	REQUIRE
	refurbishment of thermal control		<u> </u>	<u> </u>
	surfaces in space on malfunctioning		. Techniques ca	an be
	evaluated in ATL or spacelab mission	ns		
		·		
		······································		
	SCHEDULE REQUIREMENTS FIRST PA		E	<u>.</u>
	PAYLOAD DEVELOPMENT LEAD TIME	YEARS. TECH	NOLOGY NEED DATI	E
	BENEFILUF AUVANGEMENT	<b>N</b> 11		
	BENEFIT OF ADVANCEMENT		MBER OF PAYLOADS	
	TECHNICAL BENEFITS Repair and reorbi	it of spacecraft	; provide techni	
		it of spacecraft	; provide techni	
	TECHNICAL BENEFITS Repair and reorbi	it of spacecraft	; provide techni	
	TECHNICAL BENEFITS Repair and reorbi	it of spacecraft	; provide techni	
	TECHNICAL BENEFITS Repair and reorbi	it of spacecraft	; provide techni	
	TECHNICAL BENEFITS <u>Repair</u> and reorbine emergency repairs; eliminate need to	it of spacecraft	; provide techni	
	TECHNICAL BENEFITS <u>Repair</u> and reorbine emergency repairs; eliminate need to	it of spacecraft	; provide techni	
	TECHNICAL BENEFITS <u>Repair</u> and reorbine emergency repairs; eliminate need to	it of spacecraft or backup spaced	; provide techni raft.	
	TECHNICAL BENEFITS <u>Repair</u> and reorbine emergency repairs; eliminate need to	it of spacecraft or backup spaced	; provide techni	
	TECHNICAL BENEFITS <u>Repair</u> and reorbine emergency repairs; eliminate need to	it of spacecraft or backup spaced	; provide techni raft.	
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS Repair and reorbing emergency repairs; eliminate need to	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	it of spacecraft or backup spaced	; provide techni raft. COST SAVINGS \$	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	ESTIMATED	c thermal control	iques for
_	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	ESTIMATED	c thermal control	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	ESTIMATED	c thermal control	iques for
	TECHNICAL BENEFITS       Repair and reorbing emergency repairs; eliminate need to the second se	ESTIMATED	c thermal control	iques for

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	COM	PARISON	OF SP/	ACE &	GROUND	TEST O	PTIO	NS				
B. SPACE TEST C	OPTION	TE	ST ARTIC	CLE:								
TEST DESCRIPTIO	)N :	ALT. (max	/min)		/	_ km, INC	L		d	leg, Tik	AE	t
BENEFIT OF SPACE TEST: VAC; EVA compatibility												
EQUIPMENT: POINTING	WEIGHT		kg, S	SIZE	x	x		m,	, POWE			kV
POINTING			STABIL	.ITY			_DAT	A		<u> </u>		
									DN		/_	<u> </u>
SPECIAL GROUND	D FACÌLI											F
			-									-
							IEST C		CNUL			
. GROUND TES	Τ ΟΡΤΙΟ	ON TE	ST ARTI	CLE: _								
TEST DESCRIPTIO			e.									
1231 DESCRIPTIC			<b>.</b>									
	D FACILI	TIES:										
•								EXI	STING	: YES		NO
GROUND TEST LI	MITATIO	NS: nee	d 0-g									
		·····					-					
						IES	T CONF		<u> </u>			
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0. SCHEDULE & (	соѕт	S	PACE TE	ST OPT	ION		G	ROUN	ID TE	ST OP		
D. SCHEDULE & (	COST CY	s	PACE TE	ST OPT	COST (	<b>(\$)</b>	G	ROUN	ID TE	ST OP		
		s	PACE TE	ST OPT		(\$)	G	ROUN	ID TE	ST OP		
TASK			PACE TE	ST OPT		(\$)	G	ROUN		ST OP		
TASK 1. ANALYSIS		s l	PACE TE	ST OPT		( <b>s</b> )	G	ROUN		ST OP		
TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL		s	PACE TE	ST OPT		<b>(\$)</b>	G	ROUN	ID TE	ST OP		
1. ANALYSIS 2. DESIGN 3. MFG & C/O						(\$) 						
TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL			PACE TE			<b>(s)</b>		ROUN				
TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL TECH NEED DATE	СҮ	GR	AND TOT	TAL	COST		G	RAND	) TOT	AL		
TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL		GR GR GT \$	AND TOT	TAL	COST	DF PROG	G	RAND	) TOT,	AL		COST
TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL TECH NEED DATE 1. VALUE OF SPA		GR GR GT \$	AND TOT	TAL	COST	DF PROG	G	RAND	) TOT,	AL		COST

FT (TDR-2) 7/75

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	REF. NO.		8/9/75	REV DATE	
Ι.	ner. 190.	CATEGORY	10 or 11		LIN
2	TITLE _ Adhesives for	Attachable Thermal	Control Su	rfaces	
				······································	
3.	TECHNOLOGY ADVANC			EVEL OF STATE OF	ART
	The performance of a		- CORRENT	UNPERTURBED	REQUIRED
	control surfaces (i.			l	<u> </u>
	mirror coatings) dep				
	laboratory tests have		فتكاسم والمتحد فتتكر الرابعة بالمتحد		
	demonstrated anomalo	معتوكية المتعديدي ويستعد معدانات المنتية بولينها بالمتعتقب المجمعه			
	space flight tests a				
	needed, the following				d - LDEF,
	polar orbiter; geosy	nchronous; and/or S	<u>cout-polar</u>	orbiter.	
	······································		·		
				····	
<b>I</b> .	SCHEDULE REQUIREME	NTS FIRST PAYLOA	D FLIGHT DAT	Έ	
	PAYLOAD DEVELOPMENT L		YEARS. TECH	INOLOGY NEED DAT	Έ
5.		ncreased reliability	NL of attacha	JMBER OF PAYLOAD ble thermal cont	<b>S</b> trol surface
5.		MENT ncreased reliability	NL of attacha	JMBER OF PAYLOAD ble thermal cont	S trol surface
5.	BENEFIT OF ADVANCE	MENT ncreased reliability ts and increased rel	NL of attacha	JMBER OF PAYLOAD ble thermal cont	<b>S</b> trol surface
5.	BENEFIT OF ADVANCE TECHNICAL BENEFITS	MENT ncreased reliability ts and increased rel	NL of attacha iability in	JMBER OF PAYLOAD ble thermal cont	S trol surface mal
	BENEFIT OF ADVANCE TECHNICAL BENEFITS	MENT ncreased reliability ts and increased rel	NL of attacha iability in	JM8ER OF PAYLOAD	S trol surface mal
	BENEFIT OF ADVANCE TECHNICAL BENEFITS	MENT <u>icreased reliability</u> <u>ts and increased rel</u> <u>S</u> <u>ADVANCEMENT</u>	NL of attacha iability in	JM8ER OF PAYLOAD	S trol surface mal
	BENEFIT OF ADVANCE TECHNICAL BENEFITSIr in space environmen performance of s/c. POTENTIAL COST BENEF!	MENT <u>icreased reliability</u> <u>ts and increased rel</u> <u>S</u> <u>ADVANCEMENT</u>	NL of attacha iability in	JM8ER OF PAYLOAD	S trol surface mal
	BENEFIT OF ADVANCE TECHNICAL BENEFITS	MENT <u>icreased reliability</u> <u>ts and increased rel</u> <u>S</u> <u>ADVANCEMENT</u>	NL of attacha iability in	JM8ER OF PAYLOAD	S trol surface mal
	BENEFIT OF ADVANCE TECHNICAL BENEFITS	MENT <u>icreased reliability</u> <u>ts and increased rel</u> <u>S</u> <u>ADVANCEMENT</u>	NL of attacha iability in	JM8ER OF PAYLOAD	S trol surface mal
	BENEFIT OF ADVANCE TECHNICAL BENEFITS	MENT <u>icreased reliability</u> <u>ts and increased rel</u> <u>S</u> <u>ADVANCEMENT</u>	NL of attacha iability in	JM8ER OF PAYLOAD	S trol surface mal
	BENEFIT OF ADVANCE TECHNICAL BENEFITS	MENT <u>icreased reliability</u> <u>is and increased rel</u> <u>icreased rel</u> <u>icreased rel</u> <u>icreased rel</u>	NL of attacha iability in	JM8ER OF PAYLOAD	S trol surface mal
	BENEFIT OF ADVANCE TECHNICAL BENEFITS	MENT hcreased reliability ts and increased rel S ADVANCEMENT Honc.	NL of attacha iability in 	JMBER OF PAYLOAD ble thermal cont predicted therr COST SAVINGS \$	S
	BENEFIT OF ADVANCE TECHNICAL BENEFITSIr _in_space_enviromen: _performance_of_s/c. POTENTIAL COST BENEF!';; RISK IN TECHNOLOGY TECHNICAL PROBLEMS	MENT icreased reliability is and increased rel S ADVANCEMENT ionc. CHNOLOGIES Adhesi	NL of attacha iability in ESTIMATED	JMBER OF PAYLOAD ble thermal cont predicted therr COST SAVINGS \$	S
	BENEFIT OF ADVANCES TECHNICAL BENEFITSIr in_space_enviromen performance_of_s/c. POTENTIAL COST BENEF!?;; RISK IN TECHNOLOGY TECHNICAL PROBLEMS REQUIRED SUPPORTING TI	MENT icreased reliability is and increased rel S ADVANCEMENT ionc. CHNOLOGIES Adhesi	NL of attacha iability in ESTIMATED	JMBER OF PAYLOAD ble thermal cont predicted therr COST SAVINGS \$	S
	BENEFIT OF ADVANCES TECHNICAL BENEFITSIr in_space_enviromen performance_of_s/c. POTENTIAL COST BENEF!?;; RISK IN TECHNOLOGY TECHNICAL PROBLEMS REQUIRED SUPPORTING TI	MENT icreased reliability is and increased rel S ADVANCEMENT ionc. CHNOLOGIES Adhesi	NL of attacha iability in ESTIMATED	JMBER OF PAYLOAD ble thermal cont predicted therr COST SAVINGS \$	S
5.	BENEFIT OF ADVANCE TECHNICAL BENEFITSIn in space_enviro.men performance_of_s/c. POTENTIAL COST BENEF!';; 	MENT icreased reliability is and increased rel S ADVANCEMENT donc. CHNOLOGIES Adhesi tachable thermal cor	NL of attacha iability in 	JMBER OF PAYLOAD ble thermal cont predicted therr COST SAVINGS \$ COST SAVINGS \$ ment for second ses.	S
	BENEFIT OF ADVANCES TECHNICAL BENEFITSIr in_space_enviromen performance_of_s/c. POTENTIAL COST BENEF!?;; RISK IN TECHNOLOGY TECHNICAL PROBLEMS REQUIRED SUPPORTING TI	MENT icreased reliability is and increased rel S ADVANCEMENT donc. CHNOLOGIES Adhesi tachable thermal cor	NL of attacha iability in 	JMBER OF PAYLOAD ble thermal cont predicted therr COST SAVINGS \$ COST SAVINGS \$ ment for second ses.	S
5.	BENEFIT OF ADVANCE TECHNICAL BENEFITSIn in space_enviro.men performance_of_s/c. POTENTIAL COST BENEF!';; 	MENT icreased reliability is and increased rel S ADVANCEMENT donc. CHNOLOGIES Adhesi tachable thermal cor	NL of attacha iability in 	JMBER OF PAYLOAD ble thermal cont predicted therr COST SAVINGS \$ COST SAVINGS \$ ment for second ses.	S

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TITLE										ю	
									P/	AGE	2
C			F SPAC	E & GF		EST C	PTIO	NS_			
8. SPACE TEST OPTI	ON	TEST	ARTICLI	E:							
TEST DESCRIPTION :	AL	T. (max/min	)	/		km, INI			deç	, TIME	hr
BENEFIT OF SPACE TE	ST:										
EQUIPMENT: WEIG	HT		kg, SiZl	E	×	x		m,	POWER	,	kW
POINTING		S	TABILITY	۲			DA1	TA			
ORIENTATION									NC	·	
SPECIAL GROUND FAC	CILITIES										
<u></u>	····				. <u></u>						
							TEST	ONFID	ENCE _		
9. GROUND TEST OF	TION	TEST	ARTICL	E:							
<u> </u>											
TEST DESCRIPTION/R		MENIS:									
SPECIAL GROUND FA	CILITIES										
								EXIS	STINC:	YES [	
GROUND TEST LIMITA	TIONS:										
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						TES	TCON	FIDENC	E		
IO. SCHEDULE & COS	r 🔤	SPAC	CE TEST	OPTIO	J	][	G	ROUN	D TESI	OPTIC	N
TASK CY					COST (S	3					COST (S
1. ANALYSIS						1					
2. DESIGN											
3. MFG & C/O											
4. TEST & EVAL					_						_
TECH NEED DATE	44				<u> </u>	┫┝───					
		GRANE	D TOTAL	•			G	RAND	TOTAL		
11. VALUE OF SPACE	TEST \$			<b></b>	(SUM OF	PROG	iram	COSTS	\$		_)
12. DOMINANT RISK/	ECH P	ROBLEM	]			(	COST	IMPAC	T	PROE	ABILITY
COST RISK \$											

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	TESTING AND DEV		10/75			E 1						
1.		DATE 8	nvironmen	REV DATE _ t Control &	Crvoa	LTF enic C	lontro					
2.	TITLE <u>Cryogenic Heat Pipe Radiat</u>	ive Cool	ers									
_												
3.	TECHNOLOGY ADVANCEMENT REQUI	RED		EVEL OF STA								
	Many sensors and telescopes will	be	CURRENT	UNPERTUR	BED	REQU	HRED					
	operating in the cryogenic range (100 to											
	150%) and will require heat pipes to transport heat. Large multiple arrays of detectors (5-10 watts) will be remotely located from their optics and											
	will require heat pipes to isothe											
	have large radiators operating at of heat pipes. Varying environme											
	devices in the form of variable of											
	operating in sunlight conditions											
	materials will be required.											
	SCHEDULE REQUIREMENTS FIRST	PAYLOAD	FLIGHT DAT	₽ 1980 EOS	(ED,3	) Miss	ion (					
						_						
 5.	PAYLOAD DEVELOPMENT LEAD TIME BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hance</u> temperatures at varying power and	3Y	EARS. TECH NU	NOLOGY NEEI MBER OF PAY ה of power ה	D DATE	<u>1978</u> 3–5	(E05					
 i.	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hand</u> temperatures at varving power and	3Y	EARS. TECH NU	NOLOGY NEEI MBER OF PAY ה of power ה	D DATE	<u>1978</u> 3–5	<u>(EDS</u>					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> for hand	3Y	EARS. TECH NU	NOLOGY NEEI MBER OF PAY ה of power ה	D DATE	<u>1978</u> 3–5	(E05)					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hand</u> temperatures at varving power and	3Y	EARS. TECH NU age amount ament cond	NOLOGY NEEI MBER OF PAY ה of power ה	D DATE	<u>1978</u> <u>3-5</u>	(E05)					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hand</u> temperatures at varving power and POTENTIAL COST BENLFITS	3Y	EARS. TECH NU age amount ament cond	MBER OF PAY a of power a tions.	D DATE	<u>1978</u> <u>3-5</u>	(E05)					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hand</u> temperatures at varying power and POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT	3Y	EARS. TECH	MBER OF PAY a of power tions.	D DATE	<u>1978</u> <u>3-5</u> o	(E05)					
_	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hance</u> <u>temperatures at varving power and</u> POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS <u>Present techno</u>	3y	EARS. TECH NU age amounts ment cond ESTIMATED	MBER OF PAY a of power tions.	D DATE	<u>1978</u> <u>3-5</u> o	(E05)					
-	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hand</u> temperatures at varying power and POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT	3y	EARS. TECH NU age amounts ment cond ESTIMATED	MBER OF PAY a of power tions.	D DATE	<u>1978</u> <u>3-5</u> o	(E05)					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hance</u> <u>temperatures at varving power and</u> POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS <u>Present techno</u>	3y	EARS. TECH NU age amounts ment cond ESTIMATED	MBER OF PAY a of power tions.	D DATE	<u>1978</u> <u>3-5</u> o	(E05)					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hance</u> <u>temperatures at varving power and</u> POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS <u>Present techno</u>	3y	EARS. TECH NU age amounts ment cond ESTIMATED	MBER OF PAY a of power tions.	D DATE	<u>1978</u> <u>3-5</u> o	(E05)					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hance</u> <u>temperatures at varving power and</u> POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS <u>Present techno</u>	3Y	EARS. TECH NU age amount iment cond: ESTIMATED	NOLOGY NEEL MBER OF PAY s of power s tions.	D DATE	<u>1978</u> <u>3-5</u> o	(E05)					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows for hand temperatures at varying power and POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Present technol detectors and radiators intimatel	3Y	EARS. TECH NU age amount iment cond: ESTIMATED	NOLOGY NEEL MBER OF PAY s of power s tions.	D DATE	<u>1978</u> <u>3-5</u> o	(EDS)					
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows for hand temperatures at varying power and POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Present technol detectors and radiators intimatel	3Y	EARS. TECH NU age amount iment cond: ESTIMATED	NOLOGY NEEL MBER OF PAY s of power s tions.	D DATE	<u>1978</u> <u>3-5</u> o	(E05)					
<u>5</u> . <u>3</u> .	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows for hand temperatures at varying power and POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Present technod detectors and radiators intimatel REQUIRED SUPPORTING TECHNOLOGIES	3Y	EARS. TECH	NOLOGY NEEL MBER OF PAY s of power itions.	D DATE	<u>1978</u>						
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows for hand</u> temperatures at varying power and POTENTIAL COST BENEFITS POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS <u>Present techno</u> detectors and radiators intimatel REQUIRED SUPPORTING TECHNOLOGIES REFERENCE DOCUMENTS/COMMENTS	3y	EARS. TECH NU age amounts ament conds ESTIMATED limited to ad. cryogenio	NOLOGY NEEL MBER OF PAY a of power itions. COST SAVINGS b 10-50 Mili	D DATE	<u>1978</u> <u>3-5</u> o with ts and						
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows for hand temperatures at varying power and POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Present technod detectors and radiators intimatel REQUIRED SUPPORTING TECHNOLOGIES	3y	EARS. TECH NU age amounts ament conds ESTIMATED limited to ad. cryogenio	NOLOGY NEEL MBER OF PAY a of power itions. COST SAVINGS b 10-50 Mili	D DATE	<u>1978</u> <u>3-5</u> o with ts and						

TITLE Cryogeni	c Heat	Pipe Radia	ative Cod	olers				NO. PAG	Bb-1 E 2	
	CON	APARISON (	OF SPACE	& GR(	DUND -	TEST O	PTIONS			
8. SPACE TEST heat pipes,		-					nt contai and suppo			
TEST DESCRIPTI Prefer Sync Use solar o BENEFIT OF SPA	r elect	rical powe	er to act	tivate	syste	m <u>. M</u> e				_ hr
EQUIPMENT: POINTING ORIENTATION			CREW:	NO.	500 (	OPERATIO	NS/DURATIC	POWER 6 Th DN 4 hr	00 watt   ours • /	kW
SPECIAL GROUN						1	EXIS	ENCE Hid	h (2.5/C	
9. GROUND TE Cannot be add TEST DESCRIPT SPECIAL GROUN GROUND TEST L	ION/REQU	JIREMENTS:								
		• <u>•</u> ••••••••••••••••••••••••••••••••••				TEAT				
							CONFIDENC			
10. SCHEDULE & TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL TECH NEED DATE	CY -	75 76 77	ACE TEST O 7879		COST ( 100 85 170 145 500K	\$) 	GROUN	TOTAL		T (
11. VALUE OF SP	ACE TE	ST \$			(SUM O	F PROG	RAM ( USTS	\$		
12. DOMINANT R	ISK/TEC	CH PROBLE	M			c	OST IMPAC	τ P	ROBABILIT	ΓY

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1.	REF.NO. 10 PR	EP DATE	8/8/75	REV	DATE		LTR_			
••		ATEGORY	Environme	ntal C	ontrol					
2.	TITLE Ultra-High Thermal Cond	Juctance H	eat Fipe	<u></u>	<u> </u>					
ine					·····					
~	TECHNOLOGY ADVANCEMENT REC		T	LEVEL	OF STATE O	FAR	<u>т</u>			
3.	In order to isothermalize very		CURRENT	-	PERTURBED		REQUIRED			
			-	1						
	structures, i.e., antennas, solar									
	collectors, etc., to levels of acceptable distortion, ultra-high thermal conductance will be required. Both high and low flux densities will have to									
	be transferred with extremely 1				_					
	@ T=0.1 1°C @ q=0.1 50w/cm <sup>2</sup> )									
				··						
		· · · · · · · · · · · · · · · · · · ·								
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4.	SCHEDULE REQUIREMENTS	PCT PAYLOA		TE						
₽.		<u>191 [misvr</u>								
	BAYLOAD DEVELOPMENT LEAD TIME		VEADE. TH							
<b>.</b>	PAYLOAD DEVELOPMENT LEAD TIME BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion	N	UMBER	GY NEED DA	ATE				
5.	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion	N	UMBER	GY NEED DA	ATE				
5.	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Minimizes d</u> stabilization of large structur	istortion	N for accura	UMBER	GY NEED DA	ATE				
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Minimizes d</u> stabilization of large structur	istortion res.	N for accura	UMBER	GY NEED DA	ATE				
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res.	N for_accura	COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ _	ATE	rmal.			
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res.	N for_accura	COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ _	ATE	rmal.			
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res.	N for_accura	COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ _	ATE	rmal.			
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res.	N for_accura	COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ _	ATE	rmal.			
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res.	N for_accura	COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ _	ATE	rmal.			
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res. IENT hnology is	N for_accura ESTIMATEG s limited t	D COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ W/cm <sup>2</sup> fo	ATE	lO meter			
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res. IENT hnology is	N for_accura ESTIMATEG s limited t	D COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ W/cm <sup>2</sup> fo	ATE	lO meter			
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res. IENT hnology is	N for_accura ESTIMATEG s limited t	D COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ W/cm <sup>2</sup> fo	ATE	lO meter			
<b>6</b> .	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res. IENT hnology is	N for_accura ESTIMATEG s limited t	D COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ W/cm <sup>2</sup> fo	ATE	lO meter			
	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS	istortion res. IENT hnology is	N for_accura ESTIMATEG s limited t	D COST S	GY NEED DA OF PAYLOA nting_and SAVINGS \$ W/cm <sup>2</sup> fo	ATE	lO meter			

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			OMPA	RISO	N O	F SP	ACE	GR		ST C	PTIC	NS				
8.	SPACE TEST Long Heat f	OPTIC			EST /	ARTI	CLE: .	20	møter (	shut	tle					
	TEST DESCRIPTIO	on: to f	Al	LT.(ma Pipe	x/min and	) Mea	iny isure	_/ Tem	k perature	im, INC	SL		- <u></u>	deg, T	IME	hr
	BENEFIT OF SPA on hydrodyr					onme	ent r	equi	red due	to r	egat	ing	grav	/ity	effe	cts
	EQUIPMENT: POINTING	WEIGH	T	25		_ kg, \$		01M	X20M(L	. <u>G)</u> X		•	n, POV	VER <u>·</u>	5-1.	<u>0                                    </u>
	POINTING				s	TABIL	.ITY		10		DA'	TA	- <u></u> -			
			-									URAT	ION _	2		1 <u>M</u>
	SPECIAL GROUN	U FACI		s:									ICTIN	C: VE		
														6. TE		
	to effects TEST DF3CRIPTIC															
	SPECIAL GROUN	D FACI	LITIE	S:									CT IN	G: YE		
	GROUND TEST L	IMITAT	IONS	·						<u> </u>		<sup>E^</sup>		<u> </u>	。 	
										TEST	T CON	FIDEN	CE _			
10.	SCHEDULE &	COST			SPAC	E TE	ST OP	TION		-	6	ROU		EST O	PTION	1
	'ASK	CY							COST (S)	<b> </b>				Γ		COST (S
-	1. ANALYSIS															
	2. DESIGN		i							1						
	3. MFG & C/O 4. TEST & EVAL															
-	ECH NEED DATE															4
				GR	AND	тот	AL	<b></b>			G	RAN	TOT	TAL	<b>.</b>	
11.	VALUE OF SP	ACE T	EST 1	•					(SUM OF	PROG	RAM	COST	s <b>s .</b>			.)
12.	DOMINANT R	ISK/TE	ECH P	ROBI	LEM						COST	IMPAC	 ст	P	ROBA	BILITY
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	COST RISK \$															

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	FUTURE PAYLOAD	TECHNOLOG	Y NC	<b>B</b> b-3
		ENT REQUIR	EMENT PA	GE 1
1.			REV DATE	
2.	TITLE Improved Solid Cryogenic Lifetim		<u>t</u>	
3.	TECHNOLOGY ADVANCEMENT REQUIRED	/	LEVEL OF STATE OF	ART
•-	In order to cool IR detectors to the	CURRENT	UNPERTURBED	REQUIRED
	65-120K region, solid cryogenic coolers			
	are used. These usually take the form	of multi-sta		
	heavy-weight and subject to high parasi	tic heat loa	ads. These coole	ers cculd be
	greatly enhanced by coupling them to a			
	sub-cool the container and limit parasi the need for multiple staging, which wo			
	extend lifetime (by factor of 2-3).	UIU IUNCI	ilynu, tractor c.	
			· · · · · · · · · · · · · · · · · · ·	
4.	SCHEDULE REQUIREMENTS FIRST PAYLOA	AD FLIGHT DAT	E 1980 (ECS), F	<u>20-3. OBJ.</u>
	PAYLOAD DEVELOPMENT LEAD TIME3	YEARS. TECH	INOLOGY NEED DAT	£
5.	BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Lowers Weight (Facto</u>		JMBER OF PAYLOADS	
	POTENTIAL COST BENEFITS Simpler, more re	liable desi	gn	
			COST SAVINGS \$	
6.	RISK IN TECHNOLOGY ADVANCEMENT	<u> </u>	<u> </u>	
	TECHNICAL PROBLEMS Present technology ( expected life (Design 1 yr.).	LRIR Nimbus	F) is limited to	<u>o 6-8 mo.</u>
	REQUIRED SUPPORTING TECHNOLOGIES Senser	s, Mtls., 5	truct.	
7.	REFERENCE DOCUMENTS/COMMENTS NASA Missions, AEAA Peper	. 1973 Missi(	on Model, Outloo	k for Space

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	LE Improved	d Solid	i Cryog	eric	Life	time	Expe	eriment					NO. PAGE	the second s	-3 2
_		co	MPARI	SON O	F SPA	ACE 8	GR	OUND	rest	OPTI	ONS				
8.	SPACE TEST							id cry				ith ou	uter :	shel	.1
	containing	heat p	ipes a	<u>nd pa</u>	asive	<u></u>	ler				- <u></u>				
	TEST DESCRIPTI		ALT. (	lmax/mi	n)		1		km i	MCI			les T164	£	
	Synch Alt.	or Low	Orbit	w/co.		ew o	r sp	ace și	<u>mula</u>	te de	etecto	or hea	<u>st, m</u> e	easu	ire
	temperature	over	<u>long t</u>	ime o	I ISC	over	and	rewei	<u>gh s</u>	ysten	1			<u> </u>	
	BENEFIT OF SPA	CE TES	r: <u>0-G</u>	Envir	onmer	t re	quir	ed due	to	negat	ive	gravi	ty ef	fect	ts
	on heat pipe					w=									
	EQUIPMENT:														
	POINTING														
											DURAT	10N		_/_	
	SPECIAL GROUN	U FACII	.ITIES:											<u> </u>	
			•		······							CISTING DENCE		ப	MOL
										_ 1201	UVAL			_	
9.	GROUND TES		ION	TEST	ARTIC	CLE:	Hea	t pipe	<u>s ca</u>	nnot	be ad	equat	tely 1	test	ed in
				-											
	TEST DESCRIPTI	UN/REU	UINEME	IN 15: _											
				·											
•		D EAOU				<u>.</u>	· · · · · ·								
	SPECIAL GROUN	UFALI													
											EX	ISTING	YES	n	NO T
	GROUND TEST L		ONS:												
									TI	EST CO	NFIDEN	CE			
0.		COST		SPA	CE TES	ST OP	TION				GROU	ND TE	ST OPT	ION	
T	ASK	CY						COST (	»						COST
	1. ANALYSIS									Τ	T				
	2. DESIGN										1				
	3. MFG & C/O	[									,			Į	
_	4. TEST & EVAL	<del> </del>			┢─┤					-	+	┢──╁			
				GRAN		AL			╢─		GRAN		<u>_</u>		
	VALUE OF SP	ACE TE	ST <b>\$ _</b>					(SUM O	F PRC	OGRAM	A COST	88			) )
1.										ي المحمد م					
		ISK /TE	сн рил									PT .			
	DOMINANT R	ISK/TE	сн рас	DLEM	•					CUSI	' IMPA	CT	PRC	JEAI	BILITY
	DOMINANT R	ISK/TE	CH PRC	/DL EM	•							ст 			<b></b>

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1.	TESTING AND DEVELOPME REF. NO. 18PRE? DATE		REV DATE	GE 1
	CATEGORY	nvironment (	<u>satrol</u>	
2.	TITLE Precision Temperature Control Tech	nniques Usino	sat Pipes	
3.	TECHNOLOGY ADVANCEMENT REQUIRED		VEL OF STATE OF	ART
	Many instrumests, structures, and	CURRENT	UNPERTURBED	REQUIRED
	gyros which are required to hold			
	extremely tight temperature control (± .			
	feedback or cashaded heat pipes. These			
	indirectly receive an indication from th			
	and adjust its heat rejection in order t	a noid this	tight temperat	JIE CONTIOL.
		-		
				······
	······································			<u></u>
_				
4.	SCHEDULE REQUIREMENTS FIRST PAYLOA			1001
_	PAYLOAD DEVELOPMENT LEAD TIME3	YEARS. TECHN	OLOGY NEED DAT	E 1979 1981
-				
5.	BENEFIT OF ADVANCEMENT		BER OF PAYLOAD	
	TECHNICAL BENEFITS <u>Minimizes</u> temperature			ine
	<u>pointing</u> , low drift and aligned optics t	hrough stabl	e structures	
	•			
	4 <del></del>	ESTIMATED CO	DST SAVINGS \$	
~				
6.	RISK IN TECHNOLOGY ADVANCEMENT	_		
	TECHNICAL PROBLEMS Present technology usi		unts of heat,	power and
	sophisticated electronics to maintain co	ntrol.		
				<u></u>
	REQUIRED SUPPORTING TECHNOLOGIES GN & C,	structures		
7.	REFERENCE DOCUMENTS/COMMENTS	ok for Space	("Precision N	avi-
- •	gation", Large Controllable Lightweight			<u> </u>
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TI	TLE Precisio	on Tem	perat	ure	Cont	trol	Tecl	nniqu	ues Usin	g He	at P	ipes		_ NO. _ PAG	Ē	2
		CC	OMPA	RISO	N OF	F SP/	ACE 8	GR		IST C	)PTIC	NS				
<b>B</b> .	SPACE TEST	OPTIC	)N	TI	EST A	ARTIC	CLE: _	·								
	TEST DESCRIPTI	ON: onment	AL conc	T.(max litio	x/min) ons,	rec	ord :	_/	k Dnse; i.	m, IN( e . ,	CL. drif	t, a	lign	deg, T , etc	IME	hr
	BENEFIT OF SPA				<u>ivn</u>	conm	ent :	requi	ired due	to	nega	tive	eff	ects	on	
	EQUIPMENT:	WEIGH	IT			kg, S	IZE		x	x	,		n, POV	VER		kW
	EQUIPMENT: POINTING				S1	Tabil	.ITY				DA	TA				
	ORIENTATION					_ CR	EW:	NO.	OPI	ERATI	ONS/D	URAT				
	SPECIAL GROUN	ID FAC	LITIES	š:												
	•							-			-	EX	ISTIN			
											TEST	ONFI	DENC	<u> </u>	_	
€.		ST OP1	ΓΙΟΝ	T	EST A	ARTIO					<u> </u>					
	TEST DESCRIPTI		OUNRE	MENT												- i
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	SPECIAL GROUN	D FAC	LITIES	š:												
									· · · · · · · · · · · · · · · · · · ·							
	GROUND TEST L											EX	12111	6: TE		
	GROUND TEST L		10143:						<u> </u>	·						
										TES	T CON	FIDEN	CE			
0	SCHEDULE &	COST			CDAC	ETE	ST OP							EST O		
		CY	<u>├</u> т	T					0007 (0)	<b> </b>	T		T			r
1	TASK 1. ANALYSIS			+					COST (\$)	<u> </u>						COST (S)
	2. DESIGN															
	3. MFG & C/O															
	4. TEST & EVAL				_											
1	FECH NEED DATE															
					AND						G	RAN	D TO	TAL		
1.	VALUE OF SP	ACE T	EST \$	;					(SUM OF	PROG	RAM	COST	5 \$			.)
2.	DOMINANT R	ISK/TI	ECH P	ROBL	LEM			<u></u>		(	COST	impa	CT	P	ROBA	BILITY
							* <u></u>									
	COST RISK S															

		FUTURE PAYLOAD		Y	NO.	Bb-5
	TEST		IENT REQUIR	EMENT	PAG	SE 1
١.	REF. NO. 10	PREP DATE	8/9/75	REV DATE		LTR
		CATEGORY	Enviror	iment Lontro	<u> </u>	
)	TITLE Large Variable	e Heat Rejection Ra	diators			
3.	TECHNOLOGY ADVANC	EMENT REQUIRED		LEVEL OF STAT		
	<u>In order to accommod</u>			UNPERTUR	IBED	REQUIRED
	very fine pointing i			<u> </u>	l	
	with different power radiators will be ne					
	levels in the kilowa					
	maintain narrow temp					
	temperature level.					
	the main source of c	ومحمد والمتكاف المتعار والمتعاد والمتعاد والمتعاد والمحاد والمحاد والمحاد والمحاد والمحاد والمحاد والمحاد والم				
	n 1200 <sup>0</sup> C for nuclear	propulsion.				
			<u></u>			·····
<b>.</b>	SCHEDULE REQUIREME	ENTS FIRST PAYLO	AD FLIGHT DA	TE <u>Missio</u>	n 33	<u> </u>
 i.	BENEFIT OF ADVANCES TECHNICAL BENEFITS Wing one type of rac	<b>MENT</b> ill allow for a wid	N	UMBER OF PAY	LOADS	······································
•	BENEFIT OF ADVANCE	MENT ill allow for a wid diator.	N e variety of	<b>UMBER OF PAY</b> payloads t	LOADS	andled
•	BENEFIT OF ADVANCE TECHNICAL BENEFITS Wi using one type of rac	MENT ill allow for a wid diator. S <u>Will reduce ana</u>	N e variety of	<b>UMBER OF PAY</b> payloads t	LOADS	andled
•	BENEFIT OF ADVANCES TECHNICAL BENEFITS Wi using one type of rac	MENT ill allow for a wid diator. S <u>Will reduce ana</u>	N e variety of lysis and ma	UMBER OF PAY	LOADS	andled
j.	BENEFIT OF ADVANCES TECHNICAL BENEFITS Wi using one type of rac	MENT ill allow for a wid diator. S <u>Will reduce ana</u>	N e variety of lysis and ma	<b>UMBER OF PAY</b> payloads t	LOADS	andled
	BENEFIT OF ADVANCES TECHNICAL BENEFITS Wi using one type of rac	MENT ill allow for a wid diator. S <u>Will reduce ana</u> moving parts. ADVANCEMENT Present technology with wider tempera	N e variety of lysis and ma ESTIMATED is limited ture limits.	UMBER OF PAY payloads to power will COST SAVINGS to 100-200 v	LOADS	andled equire apability
5.	BENEFIT OF ADVANCES TECHNICAL BENEFITS	MENT ill allow for a wid diator. S <u>Will reduce ana</u> moving parts. ADVANCEMENT Present technology with wider tempera a have not been flo	N e variety of lysis and ma 	UMBER OF PAY payloads to power will COST SAVINGS to 100-200 w Large capa	LOADS	andled equire apability

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B. SPACE TEST OPT Radiator_with 1200°C TEST DESCRIPTION : Any altitude, BENEFIT OF SPACE EQUIPMENT: WE POINTING ORIENTATION SPECIAL GROUND F GROUND TEST OF TEST DESCRIPTION	TION variabl includi TEST: EIGHT ACÌLITIE	TI Le <u>co</u> LT. (ma .ng af .ng af .ng s	EST A nduc x/min) pply nvirc	RTICI tanci var: onmer kg, SI rABILI _ CRE	LE:	3M) at pi / e loa equia 3m NO.	kn ads and r ced due X lm	w) arge n, INCI measu to nu X RATIC	r (5-	therm	grav , <b>POW</b>	deg, TIM respo ity e ER	AE	hr ts kW
Radiator with         1200°C         TEST DESCRIPTION:         Any altitude,         BENEFIT OF SPACE         EQUIPMENT:         POINTING         ORIENTATION         SPECIAL GROUND F         O.         GROUND TEST (0)	Variabl Alincludi TESY: EIGHT FACÌLITIE	Le col LT. (mai .ng af .ng ei 	nduc x/min) pply nvirc	var var bonmer kg, SI rABILI _ CRE	e he	at pi	kn ads and r red due X 1m	n, INCI measure to nu X	egat.	ing ( 5_ m	grav , <b>POW</b>	deg, TIM respo ity e ER	AE	hr ts kW
1200°C         TEST DESCRIPTION :         Any altitude,         BENEFIT OF SPACE         BENEFIT OF SPACE         EQUIPMENT:       WE         POINTING         ORIENTATION         SPECIAL GROUND F         ORIENTATION	: At includi TESY: EIGHT FACÌLITIE	Le col LT. (mai .ng af .ng ei 	nduc x/min) pply nvirc	var var bonmer kg, SI rABILI _ CRE	e he	at pi	kn ads and r red due X 1m	n, INCI measure to nu X	egat.	ing ( 5_ m	grav , <b>POW</b>	deg, TIM respo ity e ER	AE	hr ts kW
Any altitude, BENEFIT OF SPACE EQUIPMENT: WE POINTING ORIENTATION SPECIAL GROUND F	INCLUDI	.ng ar )-G er 50 (\$:	<u>pply</u>	var onmer kg, Si (ABILI _ CRE	iable	<u>equi</u>	<u>x lm</u>	to ni X	egat. 2 DAT	<u>ing</u>	grav , POW	ity e	ffec	tskW
EOUIPMENT: WE POINTING ORIENTATION SPECIAL GROUND F		<u>50</u>	ST	kg, SI FABILI CRE	ZE ITY EW:	<u>3m</u>	X <u>lm</u>	X	2 DAT	<u>5</u> m `A	, POW	ER		kW
POINTING ORIENTATION SPECIAL GROUND F	ACILITIE	S:	ST	CRE	EW:	NO	OPE	RATIC	_DAT	A				
ORIENTATION SPECIAL GROUND F	ACILITIE	S:		CRE	EW:	NO	OPE	RATIC	_DAT )NS/DI	A	ON			
SPECIAL GROUND F	ACILITIE	S:							INS/DI	JRATI	ON		1	
GROUND TEST (											_			
	OPTION													
	OPTION						<u></u>							
	OPTION	_						T	EST C	ONFID	ENCE			
TEST DESCRIPTION		T	EST A	ARTIC	LE:									
SPECIAL GROUND F	ACILITIE	:S:									STING	G: YES		NO 1
	TATIONS	):					-							
														e
								TESI	CONI	FIDEN	CE			
0. SCHEDULE & CO	DST		SPAC	E TES	ST OP	TION			G	ROU	ND TI	EST OF	TION	
	СҮ					Ι	COST (\$)							COST
1. ANALYSIS														
2. DESIGN														
3. MFG & C/O						Í								
4. TEST & EVAL														
TECH NEED DATE														ļ. <u>.</u>
		G	RAND	) TOT	AL				G	RAN	) TOI	TAL		
1. VALUE OF SPAC	E TEST	\$					(SUM OF	PROG	RAM	COST	s <b>\$</b>			)
2. DOMINANT RIS	K/TECH	PROB	BLEM					(	COST	IMPAC	СТ	P	ROBA	BILITY
							<u></u>					<u></u>		
COST RISK \$							<u>_</u>							

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FUTURE PAYLOAD TECHNOLOGYNO. \_\_B\_c\_1TESTING AND DEVELOPMENT REQUIREMENTPAGE 1

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PREP DATE		EMENT PA	GE 1
		REV DATE	
hase Change Materials for Therr	nal Storage		
DGY ADVANCEMENT REQUIRED		EVEL OF STATE OF	ART
ntify techniques for the	CURRENT		REQUIRE
of the solid, liquid and vapor	2	5	7
the working medium in phase-cl the performance of such devices practerize the performance of pl ent.	•		
EVELOPMENT LEAD TIME3	YEARS. TECH	MBER OF PAYLOADS	;
BENEFITS Provide basic design			
<u>phase-change heat-sink devices</u> a nearly constant temperature b			
clic or intermittant thermal lo		TEJEBSING THEIM	
COST BENEFITS May permit avoid	ance of more	e costly active	control
		·····	
	·····	· · · · · · · · · · · · · · · · · · ·	
		COST SAVINGS \$	
PROBLEMS <u>Material compatibili</u>	.ty		
SUPPORTING TECHNOLOGIES <u>Materi</u>	at propertie	is and compatibl.	Lity

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B. SPACE TEST O	فكمرغ بنبية البراجي فالت	PARISON OF S TEST AR1		SROUND I				
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EQUIPMENT: W	VEIGHT	kg STAB	, SIZE	X	X	m, POWE	ir	kW
ORIENTATION			CREW:	NO OI	PERATIONS/DU	RATION		/
						_ EXISTING		internet and
. GROUND TEST	OPTIC	N TEST ART						
TEST DESCRIPTION	N/REQU	IREMENTS:	······································					
TEST DESCRIPTION SPECIAL GROUND GROUND TEST LIM	N/REQU FACILIT	IREMENTS:						
SPECIAL GROUND	N/REQU FACILIT	IREMENTS:				_EXISTING	· YES	
SPECIAL GROUND	FACILII	IREMENTS:			TEST CONFI	_EXISTING	· YES	) NO []
SPECIAL GROUND GROUND TEST LIM	FACILII	IREMENTS:			TEST CONFI	_EXISTING	· YES	
SPECIAL GROUND GROUND TEST LIM O. SCHEDULE & CO TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL	FACILIT	IREMENTS:		TION	TEST CONFI	_EXISTING	· YES	) NO []
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1.	REF. NO	PREP DATE	8/8/75		REV DATE		LTR
		CATEGORY	10/11 †	her	mal Control		
2.	TITLE Expendable Material	s Heat Reject	ion Syste	ms			
3.	TECHNOLOGY ADVANCEMENT	REQUIRED		L	EVEL OF STATE O	)F Al	RT
	Performance of boilers/subl	limers and	CURREN	Т	UNPERTURBED	<u>&gt;</u>	REQUIRED
	other elements of expendabl	and the second			8		9
	heat rejection systems must			_		_	
	committing to their use in						
	be designed and fabricated						
	Limited specific applicatio	ons using wate	er have be	en	developed ir	the	jast.
		···					<u></u>
			<u></u>				
1.	SCHEDULE REQUIREMENTS	FIRST PAYLOA	D FLIGHT D	ATE	1981		
	PAYLOAD DEVELOPMENT LEAD TIN					\ T F	1979
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<b>)</b> .	BENEFIT OF ADVANCEMENT					De	
<b>)</b> .	BENEFIT OF ADVANCEMENT	Cov ic coolic			BER OF PAYLOA		
<b>)</b> .	TECHNICAL BENEFITSTechnol		able for	sho	rt duration o	<u>r s</u>	pecial
5.	TECHNICAL BENEFITS	ve cooling is	able for inadequa	sho te	rt duration o: or inappropri	r sı ate	pecial
5.	TECHNICAL BENEFITS Technol circumstances where radiati Cooling of shuttle payload	ve cooling is	able for inadequa	sho te	rt duration o: or inappropri	r sı ate	pecial
5.	TECHNICAL BENEFITS	ve cooling is	able for inadequa	sho te	rt duration o: or inappropri	r sı ate	pecial
5.	TECHNICAL BENEFITS Technol circumstances where radiati Cooling of shuttle payload typical applications.	ve cooling is	able for inadequa	sho te	rt duration o: or inappropri	r sı ate	pecial
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5.	TECHNICAL BENEFITS Technol circumstances where radiati Cooling of shuttle payload typical applications.	ve cooling is	able for inadequa	sho te	rt duration o: or inappropri	r sı ate	pecial
<b>5</b> .	TECHNICAL BENEFITS Technol circumstances where radiati Cooling of shuttle payload typical applications.	ve cooling is	able for inadequa power sou	sho te rce	rt duration o: or inappropri	r s ate ws a	pecial
	TECHNICAL BENEFITS <u>Technol</u> circumstances where radiati <u>Cooling of shuttle payload</u> typical applications. POTENTIAL COST BENEFITS	ve cooling is radioisotope	able for inadequa power sou	sho te rce	rt duration o or inappropri s and EVA cree	r s ate ws a	pecial
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	TECHNICAL BENEFITS         Circumstances where radiati         Cooling of shuttle payload         typical applications.         POTENTIAL COST BENEFITS	ve cooling is radioisotope CEMENT	able for inadequa power sou	sho te rce	rt duration o or inappropri s and EVA cree s and EVA cree	r s ate ws a	pecial
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· · · · · ·	TECHNICAL BENEFITS	ve cooling is radioisotope CEMENT nation contro OGIES _1) Con	able for inadequa power sou ESTIMATE	sho te rce	rt duration o or inappropri s and EVA cree OST SAVINGS \$ g provisions	r sj ate. ws a	are
6.	TECHNICAL BENEFITS Technol circumstances where radiati Cooling of shuttle payload typical applications. POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANA TECHNICAL PROBLEMS REQUIRED SUPPORTING TECHNOLO 2) Boiling of fluids in zet	ve cooling is radioisotope CEMENT nation contro OGIES 1) Con ro-g	able for inadequa power sou ESTIMATE	sho te rce	rt duration o or inappropri s and EVA cree OST SAVINGS \$ g provisions	r sj ate. ws a	are
<b>5</b> . <b>6</b> . <b>7</b> .	TECHNICAL BENEFITS	ve cooling is radioisotope CEMENT nation contro OGIES 1) Con ro-g	able for inadequa power sou ESTIMATE	sho te rce	rt duration o or inappropri s and EVA cree OST SAVINGS \$ g provisions	r sj ate. ws a	are
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TITLE Phase Chang	e Material						NO.	E	2	
							PAG	· C	2	
C	OMPARISON O	F SPACE &	GROUND	TEST (	OPTIO	NS				
8. SPACE TEST OPT various design f	ILSI.	ARTICLE: _	Assembly	of pha	ase-cl	nange	capsul	es w	ith	
<b>TEST DESCRIPTION:</b> Heating/cooling			/	<b>km, IN</b> outs	CL		deg, TI	ME	10	- <sup>hr</sup>
BENEFIT OF SPACE TE	ST: Zero gra	avity		<u></u>					* <u></u>	
EQUIPMENT: WEIG POINTING ORIENTATION	s				DAT	A				
SPECIAL GROUND FAC			NU				·	/		
9. GROUND TEST OP				_			· · · · · · · · · · · · · · · · · · ·			·····
TEST DESCRIPTION/RE	OUIREMENTS: _		·····							
SPECIAL GROUND FAC	ILITIES:					· · · · · · · · · · · · · · · · · · ·				
GROUND TEST LIMITA	TIONS:						ING: YES		NO	C
	·····			TES	TCONF	DENCE				
10. SCHEDULE & COST	SPA(	CE TEST OP1	ION		GI	ROUND	TEST OF	TION	)	
TASK CY			COST (	»		Γ			cos	T (\$
1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL										
TECH NEED DATE				┥┝──						
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11. VALUE OF SPACE 1	EST \$	·	(SUM Q	F PROG	RAMC	OSTS \$	i		)	
12. DOMINANT RISK/T	ECH PROBLEM			(	COST IN	APACT	PI	108A	BILIT	Y
COST RISK S										
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3.	TECHNOLOGY ADVANCEMENT REC	DUIRED		EVEL OF STATE O	
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4.	SCH! DULE REQUIREMENTS FIF	RST PAYLOA		E	
	PAYLOAD DEVELOPMENT LEAD TIME				
5.	BENEFIT OF ADVANCEMENT		NU	MBER OF PAYLOA	DS
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	POTENTIAL COST BENEFITS		· · · · · · · · · · · · · · · · · · ·		
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	POTENTIAL COST BENEFITS				· · · · · · · · · · · · · · · · · · ·
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6.			·····		
6.		ENT	ESTIMATED (	COST SAVINGS \$	
6.	RISK IN TECHNOLOGY ADVANCEM	ENT	ESTIMATED (	COST SAVINGS \$	
6.	RISK IN TECHNOLOGY ADVANCEM	ENT	ESTIMATED (	COST SAVINGS \$	
6.	RISK IN TECHNOLOGY ADVANCEM	ENT	ESTIMATED (	COST SAVINGS \$	
6.	RISK IN TECHNOLOGY ADVANCEM TECHNICAL PROBLEMS	ENT	ESTIMATED (	COST SAVINGS \$	
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<b>8</b> .	SPACE TEST OPTI				كالدويية: فيتغنبو		st model				syste	em			
	<u></u>		·····							<u></u>					
- - -	TEST DESCRIPTION :	A	LT. (ma	ix/min)		/_		km, lf	NCL.	<u>.</u>		deg,	TIME	15	hr
•	BENEFIT OF SPACE TE zero-g	:ST:	Accui	rate	simul	ation	of flic	<u>ht</u> e	nvir	onmer	nt, e	spe	cia	11 <u>y</u>	
I	EQUIPMENT: WEIG	нт	500		kg, SIZE	E	×		x	1	m, POV	VER	0.	1	kW
	POINTING														
	DRIENTATION									DURA				1	
:	SPECIAL GROUND FAI	CILITIE	:S:									<u></u>			
•	<u> </u>				-										NO
									TEST	CONF	DENC	E <u>~</u>	/4		
•	GROUND TEST OF or system	TION	T	EST A	RTICLI	E: <u>T</u>	est mode	l of	<u> </u>	ling	syst	em	com	cone	ints
).													com	cone	nts
	or system												COM	cone	nts
	or system TEST DESCRIPTION/R	EQUIRI	EMENI	TS:	·····										nts
	or system	EQUIRI	EMENI	TS:	·····										ints
	or system TEST DESCRIPTION/R	EQUIRI	EMENI	TS:	·····					city		ıum	pumj	ps	NO
•	or system TEST DESCRIPTION/R		EMEN1	<b>TS</b> :	ated	heat	loads; H	igh.	сара	city	Vacu	1Um G: Y	pum] /ES [	ps	
•	or system TEST DESCRIPTION/R SPECIAL GROUND FA		EMEN1	<b>TS</b> :	ated	heat	loads; H	igh. env	Capa	city E; ment;	vacu KISTIN ; 1-c	um G: Y	pumj (ES (	ps	
- - - -	or system TEST DESCRIPTION/R SPECIAL GROUND FAG GROUND TEST LIMITA		EMEN1	TS: Simul	ated	heat on of	loads; M shuttle	igh. env	Capa	city E) ment; NFIDER	Vacu KISTIN ; 1-c	1um G: Y j fi 75%	pumj (ES [	ps X)	
0.	OT SYSTEM TEST DESCRIPTION/R SPECIAL GROUND FAG GROUND TEST LIMITA SCHEDULE & COS		EMEN1	TS: Simul	ated	heat	loads; H shuttle	env	Capa	city E; ment;	Vacu KISTIN ; 1-c	1um G: Y j fi 75%	pumj (ES [	ps X)	N0 [
о. Т	OT SYSTEM TEST DESCRIPTION/R SPECIAL GROUND FAG GROUND TEST LIMITA SCHEDULE & COS ASK		EMEN1	TS: Simul	ated	heat on of	loads; M shuttle	env	Capa	city E) ment; NFIDER	Vacu KISTIN ; 1-c	1um G: Y j fi 75%	pumj (ES [	ps X)	
о. Т	OT SYSTEM TEST DESCRIPTION/R SPECIAL GROUND FAC GROUND TEST LIMITA SCHEDULE & COS ASK CY 1. ANALYSIS		EMEN1	TS: Simul	ated	heat on of	loads; H shuttle	env	Capa	city E) ment; NFIDER	Vacu KISTIN ; 1-c	1um G: Y j fi 75%	pumj (ES [	ps X)	N0 [
о. Т	Or System TEST DESCRIPTION/R SPECIAL GROUND FAM GROUND TEST LIMITA SCHEDULE & COS ASK CY 1. ANALYSIS 2. DESIGN		EMEN1	TS: Simul	ated	heat on of	loads; H shuttle	env	Capa	city E) ment; NFIDER	Vacu KISTIN ; 1-c	1um G: Y j fi 75%	pumj (ES [	ps X)	NO
	OT SYSTEM TEST DESCRIPTION/R SPECIAL GROUND FAC GROUND TEST LIMITA SCHEDULE & COS ASK CY 1. ANALYSIS		EMEN1	TS: Simul	ated	heat on of	loads; H shuttle	env	Capa	city E) ment; NFIDER	Vacu KISTIN ; 1-c	1um G: Y j fi 75%	pumj (ES [	ps X)	NO
	Or System TEST DESCRIPTION/R SPECIAL GROUND FAG GROUND TEST LIMITA SCHEDULE & COS ASK CY 1. ANALYSIS 2. DESIGN 3. MFG & C/O		EMEN1	TS: Simul	ated	heat on of	loads; H shuttle	env	Capa	city E) ment; NFIDER	Vacu KISTIN ; 1-c	1um G: Y j fi 75%	pumj (ES [	ps X)	NO
о. Т	Or System TEST DESCRIPTION/R SPECIAL GROUND FAC GROUND TEST LIMITA SCHEDULE & COS ASK CY 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL		EMENT	TS:	ated	heat on of OPTIO	loads; H shuttle	env	capa viron	city E) ment; NFIDER	Vacu KISTIN 1-g NCE	G: V fi 75%	pumj (ES [	ps X)	NO
0. T	Or System TEST DESCRIPTION/R SPECIAL GROUND FAC GROUND TEST LIMITA SCHEDULE & COS ASK CY 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL		EMENT :: :: GI	Simul Simul SPACE	ated ulati TEST	heat on of OPTIO	loads; H shuttle	env	Capa viron	city E) ment; GROL GROL	Vacu KISTIN 1-c VCE JND T	G: 1 75% EST	pum rES ( eld		N0 [

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11 (1DR-2) 7/75

1.	REF. NOPREP DATE	8/8/75	REV DATE	LTR
	CATEGORY	10 Environm	ental Control	
2.	TITL: Deployable Orientable Radiator Sys	stems and Co	mponents	
3.	TECHNOLOGY ADVANCEMENT REQUIRED	L	EVEL OF STATE OF	ART
	Develop and verify in a space	CURRENT	UNPERTURBED	REQUIRED
	environment deployable orientable			
	radiator systems including low-temperate			
	gimbals and connectors, and mechanisms a	and controls	for deep space	e tracking
	for long-term space experiments (1 to 6			
	deployment beyond interference regions of	of shuttle o	rbiter, out of	the
	pa,/load bay.			
	<b></b>			
4.	SCHEDULE REQUIREMENTS FIRST PAYLOA	D FLIGHT DATE	1981	
	PAYLOAD DEVELOPMENT LEAD TIME2	YEARS. TECH		E <u>1979</u>
5.	BENEFIT OF ADVANCEMENT	NU	BER OF PAYLOAD	s Many
		1401		
	TECHNICAL BENEFITS Achieve maximum effic			
	TECHNICAL BENEFITS <u>Achieve maximum effic</u>	ciency from	radiation syste	ems by
	TECHNICAL BENEFITS <u>Achieve maximum effice</u> permitting continuous or nearly continue	ciency from	radiation syste	ems by
		ciency from	radiation syste	ems by
		ciency from	radiation syste	ems by
	_permitting continuous or nearly continue	ciency from	radiation syste	ems by
		ciency from	radiation syste	ems by
	_permitting continuous or nearly continue	ciency from	radiation syste	ems by
	_permitting continuous or nearly continue	ciency from ous radiatio	radiation syste n to "deep spac	ems by
	_permitting continuous or nearly continue	ciency from ous radiatio	radiation syste	ems by
	_permitting continuous or nearly continue	ciency from ous radiatio	radiation syste n to "deep spac	ems by
6.	_permitting continuous or nearly continue	ciency from ous radiatio	radiation syste n to "deep spac	ems by
6.	POTENTIAL COST BENEFITS	<u>eiency from</u> <u>ous radiatio</u> <u>ESTIMATED C</u>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	ems by
6.	Permitting continuous or nearly continue	<u>eiency from</u> <u>ous radiatio</u> <u>ESTIMATED C</u>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	ems by
6.	POTENTIAL COST BENEFITS	<u>eiency from</u> <u>ous radiatio</u> <u>ESTIMATED C</u>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	ems by
<b></b> <b>6</b> .	POTENTIAL COST BENEFITS	<u>eiency from</u> <u>ous radiatio</u> <u>ESTIMATED C</u>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	ems by
6.	POTENTIAL COST BENEFITS	<u>eiency from</u> <u>ous radiatio</u> <u>ESTIMATED C</u>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	ems by
6.	POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Long-term space operation joints, gimbals, and design of mechanical	<pre>ciency from pus radiatio p</pre>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	components,
6.	POTENTIAL COST BENEFITS	<pre>ciency from pus radiatio p</pre>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	components,
6.	POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Long-term space operation joints, gimbals, and design of mechanical	<pre>ciency from pus radiatio p</pre>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	components,
6.	POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Long-term space operation joints, gimbals, and design of mechanical	<pre>ciency from pus radiatio p</pre>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	components,
	permitting continuous or nearly continue POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Long-term space operation joints, gimbals, and design of mechanical REQUIRED SUPPORTING TECHNOLOGIES Materia	<pre>ciency from pus radiatio p</pre>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	components,
<b>6</b> .	POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Long-term space operation joints, gimbals, and design of mechanical	<pre>ciency from pus radiatio p</pre>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	components,
	permitting continuous or nearly continue POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Long-term space operation joints, gimbals, and design of mechanical REQUIRED SUPPORTING TECHNOLOGIES Materia	<pre>ciency from pus radiatio p</pre>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	components,
	permitting continuous or nearly continue POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Long-term space operation joints, gimbals, and design of mechanical REQUIRED SUPPORTING TECHNOLOGIES Materia	<pre>ciency from pus radiatio p</pre>	radiation syste n to "deep space OST SAVINGS \$ on fluid loop	components,

## ORIGINAL PAGE IS POOR

11	TLE										NO. PAGE		. <u>3</u>
		CON	PARISO	ON OF	SPAC	E&GR		ST OP	TIONS				
3.	SPACE TEST												
	TEST DESCRIPTIO	DN :	ALT. (m	nax/min)		/_	k	im, INCL	•	d	leg, TIM	E	hr
	BENEFIT OF SPA					of sy	stem in	space	envi:	ronment	; -		
	EQUIPMENT: POINTING ves					0.2	_ X _ 1	x	2	m, POWE	R	?	kW
	POINTING yes			ST.	ABILITY	/	-		DATA_	therma	l/po	sitio	on
	ORIENTATION									ATION		_/	
•	GROUND TES			TEST A	RTICL	E:		TI	ST CON	FIDENCE			
)_		ON/REQ	JIREMEN	TEST A	RTICL	E:		T(	ST CON	FIDENCE			
). ).	TEST DESCRIPTIO	ON/REQ	JIREMEN	TEST A	RTICLI	E:		TI	ST CON	FIDENCE			
).	SPECIAL GROUN	ON/REQ	JIREMEN	TEST A	RTICLI	E:		TI		FIDENCE	: YES		
_	SPECIAL GROUN	ON/REQ D FACIL	JIREMEN	TEST A	RTICLI	E:		TI	ST CON	FIDENCE	: YES		
0.	TEST DESCRIPTION	ON/REQ D FACIL	JIREMEN	TEST A	RTICLI	E:		TI	ST CON		: YES		NO
0.	TEST DESCRIPTION SPECIAL GROUN GROUND TEST L SCHEDULE & TASK 1. ANALYSIS	ON/REQU D FACIL IMITATIO	JIREMEN	TEST A	RTICLI	E:		TI	ST CON		: YES		NO
0.	TEST DESCRIPTION SPECIAL GROUN GROUND TEST L SCHEDULE & TASK 1. ANALYSIS 2. DESIGN	ON/REQU D FACIL IMITATIO	JIREMEN	TEST A	RTICLI	E:		TI	ST CON		: YES		NO
	TEST DESCRIPTION SPECIAL GROUN GROUND TEST L SCHEDULE & TASK 1. ANALYSIS	ON/REQU D FACIL IMITATIO	JIREMEN	TEST A	RTICLI	E:		TI	ST CON		: YES		NO
0.	TEST DESCRIPTION SPECIAL GROUN GROUND TEST L SCHEDULE & TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O	ON/REQU D FACIL IMITATIO	JIREMEN	TEST A	RTICLI	E:		TI	ST CON		: YES		
0.	TEST DESCRIPTION SPECIAL GROUN GROUND TEST L SCHEDULE & TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL	ON/REQU D FACIL IMITATIO	JIREMEN	TEST A	ETEST	E:		TI			: YES		NO
0.	TEST DESCRIPTION SPECIAL GROUN GROUND TEST L SCHEDULE & TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL	ON/REQU D FACIL IMITATIO	JIREMEN	TEST A		E:	COST (\$)	T			: YES ST OP		NO

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F1 (1DR 2) 7/75

1.	REF. NO. 10				
		CATEGORY	Environm	ental Control	
2.	TITLE <u>Temperature Control</u>	Device Test F	acility (Am	bient Regime)	
				EVEL OF STATE OF	
3.	TECHNOLOGY ADVANCEMEN		CURRENT		REQUIRE
	Various phenomena in heat	and the second secon			
	performance must be studi 			hanatana ayah as	<u> </u>
	distribution gas/vapor_ir				
	heat transfer coefficient				
	<u>fluxes and at high fluxes</u>				
	vapors, liquids and gases				
	as distribution of phase				
	SCHEDULE REQUIREMENTS				
7.		FIRST PAYLOA	D FLIGHT DAT	Ε	
•.					
•.	PAYLOAD DEVELOPMENT LEAD T				
			EARS. TECH		E
_	PAYLOAD DEVELOPMENT LEAD T	IME	YEARS. TECH	MOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD T	for a basic un	YEARS. TECH NU derstanding	MOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows	for a basic un	YEARS. TECH NU derstanding	MOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows	for a basic un	YEARS. TECH NU derstanding	MOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> so that improvements in st	for a basic un	YEARS. TECH NU derstanding	MOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows	for a basic un	YEARS. TECH NU derstanding	MOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> so that improvements in st	for a basic un	YEARS. TECH NU derstanding	MOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> so that improvements in st	for a basic un	YEARS. TECH NU derstanding	MOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> so that improvements in st	for a basic un	YEARS. TECH NU derstanding be made.	MOLOGY NEED DAT	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> so that improvements in st	for a basic un tate-of-art can	YEARS. TECH NU derstanding be made.	MOLOGY NEED DAT	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVA	for a basic un tate-of-art can	/EARS. TECH NU derstanding be made.	MBER OF PAYLOADS	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS Present	for a basic un tate-of-art can NCEMENT t limits on spa	YEARS. TECH NU derstanding be made. 	MBER OF PAYLOADS of herit pipe pe	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS <u>Present</u> experiments as to weight,	for a basic un tate-of-art can NCEMENT t limits on spa telemetry powe	VEARS. TECH NU derstanding be made. ESTIMATED cecraft and r and opera	MBER OF PAYLOADS of herit pipe pe	E
4. 5. 6.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS Present	for a basic un tate-of-art can NCEMENT t limits on spa telemetry powe	VEARS. TECH NU derstanding be made. ESTIMATED cecraft and r and opera	MBER OF PAYLOADS of herit pipe pe	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS <u>Present</u> experiments as to weight,	for a basic un tate-of-art can NCEMENT t limits on spa telemetry powe	VEARS. TECH NU derstanding be made. ESTIMATED cecraft and r and opera	MBER OF PAYLOADS of herit pipe pe	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS <u>Allows</u> so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS <u>Present</u> experiments as to weight,	for a basic un tate-of-art can NCEMENT t limits on spa telemetry powe to separate var	YEARS. TECH NU derstanding be made. ESTIMATED cecraft and r and opera iables.	MBER OF PAYLOADS of herit pipe pe	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS Present experiments as to weight, data from being acquired to	for a basic un tate-of-art can NCEMENT t limits on spa telemetry powe to separate var	YEARS. TECH NU derstanding be made. ESTIMATED cecraft and r and opera iables.	MBER OF PAYLOADS of herit pipe pe	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS Present experiments as to weight, data from being acquired to	for a basic un tate-of-art can NCEMENT t limits on spa telemetry powe to separate var	YEARS. TECH NU derstanding be made. ESTIMATED cecraft and r and opera iables.	MBER OF PAYLOADS of herit pipe pe	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS Present experiments as to weight, data from being acquired to REQUIRED SUPPORTING TECHNOL	IME	VEARS. TECH NU derstanding be made. 	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD T BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Allows so that improvements in st POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVAN TECHNICAL PROBLEMS Present experiments as to weight, data from being acquired to	<pre>for a basic un tate-of-art can tate-of-art can NCEMENT t limits on spa telemetry powe to separate var .OGIES</pre>	/EARS. TECH NU derstanding be made. 	NOLOGY NEED DATI	E

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TIT	TLE				<u> </u>					)E GE	
_		COMPA	BISON O	E SPACE	& GR		ST OP1	IONS			
).	SPACE TEST OPT					cility în			lodule	or Pa	llet
	TEST DESCRIPTION : York bench and										
	BENEFIT OF SPACE T	'EST:[	annot be	<u>perfor</u>	med w	/o zero (	gravit	<u>v</u>			<u> </u>
	EQUIPMENT: WEI POINTING ORIENTATION		\$	STABILITY				DATA			
	SPECIAL GROUND FA										
	<del></del>		<u></u>	=				EXI			
).	GROUND TEST O	PTION	TEST	ARTICLE							
					- ·						
	TEST DESCRIPTION/	REQUIRI	EMENTS:								
			 6.								
	SPECIAL GROUND FA		ə:		<u> </u>	<u></u> _					
		··						EXI	STING: Y	ES 🗌	} NO [
	GROUND TEST LIMIT	ATIONS	:								
				• <del></del>			TEST C		F		
_	SCHEDULE & COS										
				CE TEST O	T			GROUN	D TEST (		
T		<b>*</b>		┝─┠─	+	COST (\$)				+	COST (\$
	1. ANALYSIS 2. DESIGN										
	3. MFG & C/O										
<u></u>	4. TEST & EVAL										1
-	ECH NEED DATE										
				TOTAL				GRAND	TUTAL		
1.	VALUE OF SPACE	TEST	\$			(SUM OF P	ROGRA	M COSTS	\$	<u></u>	-)
2.	DOMINANT RISK	TECH	PROBLEM	)			CO	T IMPAC	T	PROBA	BILITY
										<u></u>	
	COST REAK \$									<u></u>	

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	FUTURE PAYLOAD	TECHNOLOGY	NC	. <u></u> Bd;	2
	TESTING AND DEVELOP	IENT REQUIRE	MENT PA	GE 1	
1.	REF. NOPREP DATE			LTF	٩ ٩
	CATEGORY	10 Environm	ental Control		
2.	TITLE Zero-G Measurement of Heat-Pipe	Disturbances			
-			· · · · · · · · · · · · · · · · · · ·		
			EVEL OF STATE OF	ART	
3.	TECHNOLOGY ADVANCEMENT REQUIRED	CURRENT	UNPERTURBED		JIRED
	Quantify experimentally in space	- 4	5	7	
	environment the disturbing forces resulting from performance of a variet		. configuration		
	capacities, over a range of heat trans				cepts
	and configurations which would minimize				
			<u>_</u>		
4.	SCHEDULE REQUIREMENTS FIRST PAYLO	AD FLIGHT DAT	E <u>1981</u>		
	PAYLOAD DEVELOPMENT LEAD TIME2	_YEARS. TECH	NOLOGY NEED DAT	E <u>1979</u>	
_					
5.			MBER OF PAYLOAD		
	TECHNICAL BENEFITS Provide quantitativ				
	in lieu of less effective passive mean requiring extremely quiescent condition		control for exp	eriment	5
	TEQUITING EXTREMELY QUIESCENT CONDITION	13.			
				·····	
	PUTENTIAL COST BENEFITS				
		······································			
		ESTIMATED	COST SAVINGS \$		
6.	RISK IN TECHNOLOGY ADVANCEMENT				
	TECHNICAL PPOBLEMS _ Instrumentation dif	ficulty in de	termining very	small	
	forces precisely.				
			· · · · · · · · · · · · · · · · · · ·		
			···		
7.	REFERENCE DOCUMENTS/COMMENTS				

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FT (TDR-1) 7/75

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	COMPARI	SON OF SPA			ST OPT	IONS				
8. SPACE TEST OPT heat sources ar accelerations.	ION	TEST ARTICL	LE: Sev	eral (15	<b>-</b> 20) h	eat pi				;
TEST DESCRIPTION :	ALT.	(max/min)	/_	k	m, INCL.			deg, TIMS	·	_ h
BENEFIT OF SPACE TI	E <b>ST</b> :On;	ly way to a	ccurate	ly measu	re for	ces		<u> </u>		
EQUIPMENT: WEIG	GHT	kg, S12	ZE	_ ×	_ × _	(	m, <b>POW</b> (	ER		
		STAULLI CRE	W: NO.	QPI	ERATION	DATA S/DURAT			1	
SPECIAL GROUND FA										
<u></u>	• 					EX				0
9. GROUND TEST O	FIUN	IEST ARTICI		•A•	<u> </u>					
TEST DESCRIPTION/R	EQUIREME	ENTS:								_
				<u> </u>						
SPECIAL GROUND FA	CILITIES	······								
	TIONS.			<del>,,</del>			ISTING	: YES		יר
GROUND TESI LIMITA	4110/45:									
					TEST CO	DNFIDEN				
0. SCHEDULE & COS	т	SPACE TEST	OPTION			GROU	ND TE	ST OPTI	ON	
TASK CY				COST (S)		Τ			cos	ST (
	1-1-		-+			+	┟──┦		-1	
1. ANALYSIS			1	1 1	11					
2. DESIGN	!			1 1	1 I					
2. DESIGN 3. MFG & C/O										
2. DESIGN 3. MFG & C/O 4. TEST & EVAL										
2. DESIGN 3. MFG & C/O		GRAND TOTA				GRANI			4	
2. DESIGN 3. MFG & C/O 4. TEST & EVAL	TEST \$			(SUM OF 1	PROGRA					
2. DESIGN 3. MFG & C/O 4. TEST & EVAL TECH NEED DATE				(SUM OF 1			s <b>s _</b>		) ) BABILI	TY
2. DESIGN 3. MFG & C/O 4. TEST & EVAL TECH NEED DATE 1. VALUE OF SPACE				(SUM OF 1		M COST	s <b>s _</b>			TY

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	FUTURE PAYLO	DAD TECHNOLOGY	/ NC	Bd-3
	TESTING AND DEVEL	OPMENT REQUIR	EMENT PA	GE 1
1.	REF. NOPREP DA	ATE	REV DATE	
	CATEGO	RY Electric Po	wer and Thermal	Control
2.	TITLE	Free-Flying Faci	lity for High Po	DWEI
	Density Testing		<u> </u>	
3.	TECHNOLOGY ADVANCEMENT REQUIRE	ED I	EVEL OF STATE OF	ART
	The required technology advancement		UNPERTURBED	REQUIRED
	is a scalable shuttle-launched. fre			
	flying facility for experimentation		on related to h	igh-power-
	density devices and phenomena. The			
	source, normally a radioisotore, co			
	heats the emitter of a thermionic c		فوسال ويسترك فيستجو ويتباطل والمستجون والمتع	
	heat-pipe radiator. Some evaluatio			
	converter, heat-pipe modules which			
	processing system that energizes in transmission equipment needed for t			
	Replacing a standard component of t			
1.	SCHEDULE REQUIREMENTS FIRST PA			
	PAYLOAD DEVELOPMENT LEAD TIME3 to	4YEARS. TECH	NOLOGY NEED DAT	E
	<u>components</u>		······································	······································
	POTENTIAL COST BENEFITS	enables such te	sting and verif	ication
		enables such te	sting and verif	ication
	POTENTIAL COST BENEFITS	enables such te	sting and verif	ication
	without large-space-station power.		sting and verif COST SAVINGS \$ de number of missi	
6.	without large-space-station power. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _a) Radioisotope b) Use of heat pipes and converters facility components (but verificati c) Scaling to various power levels	ESTIMATED handling (perhap not verified in ion of these in a (solved by vary:	<b>COST SAVINGS \$</b> <u>de</u> number of missi as manifold heat a space as stand such a facility	pendent on ons -pipe cool- lard ing) is desir-
 5.	without large-space-station power. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS <u>a) Radioisotope</u> b) Use of heat pipes and converters facility components (but verificati c) Scaling to various power levels thermionic-converter, heat-pipe mod	ESTIMATED handling (perhap s not verified in ion of these in s (solved by vary: dules.	<b>COST SAVINGS \$</b> <u>de</u> number of missi os manifold heat n space as stand such a facility .ng the number o	pendent on ons -pipe cool- lard ing) is desir-
<u> </u>	without large-space-station power. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _a) Radioisotope b) Use of heat pipes and converters facility components (but verificati c) Scaling to various power levels thermionic-converter, heat-pipe mod REQUIRED SUPPORTING TECHNOLOGIES _TH	ESTIMATED handling (perhap not verified in ion of these in (solved by vary: dules. hermionic conversion	COST SAVINGS \$ de number of missi os manifold heat n space as stand such a facility .ng the number o	pendent on ons -pipe cool- lard ing) is desir-
6.	without large-space-station power. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _a) Radioisotope b) Use of heat pipes and converters facility components (but verifications c) Scaling to various power levels thermionic-converter, heat-pipe mode REQUIRED SUPPORTING TECHNOLOGIES _The Me	ESTIMATED handling (perhap not verified in ion of these in (solved by vary: dules. hermionic conver- etallic-fluid he	COST SAVINGS \$ de number of missi as manifold heat a space as stand such a facility .ng the number o sion at pipes	pendent on ons -pipe cool- lard ing) is desir- f able)
6.	without large-space-station power. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _a) Radioisotope b) Use of heat pipes and converters facility components (but verifications c) Scaling to various power levels thermionic-converter, heat-pipe mode REQUIRED SUPPORTING TECHNOLOGIES _The Me	ESTIMATED handling (perhap not verified in ion of these in (solved by vary: dules. hermionic conversion	COST SAVINGS \$ de number of missi as manifold heat a space as stand such a facility .ng the number o sion at pipes	pendent on ons -pipe cool- lard ing) is desir- f able,

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8.	SPACE TEST			· · · · · · · · · · · · · · · · · · ·				scribe								
	TEST DESCRIPTIO	DN :	AL	.T. (max/n	nin)		_/		_ km, i	INCL	•			deg, Ti	ME	hr
	BENEFIT OF SPA	CE TEST	r:D	escrib	ed in	5	·									
	EQUIPMENT:	WEIGHT			kg, S	SIZE	-	_ x		x	••		n, <b>POV</b>	/ER		kW
	EQUIPMENT: POINTING			<u></u>	STABIL	LITY					DAI	TA				
	ORIENTATION				CA	IEW:	NO.		OPE R/	TIO	NS/D	URAT	ION _			
	SPECIAL GROUN															
			<u>.</u> ,									_ EX	ISTIN	G: YES	s 🗖	NO
	·						<u> </u>			T	EST C	ONFIC	DENC			
9.	GROUND TES		ION	TES									-			
										_						
	SPECIAL GROUN	D FACII		S:										G: YE	; 🗖	NO C
	GROUND TEST L		IONS:	<u>    Gro</u>	und te	ests	canni	ot <u>su</u> b	stit	ute	fo.	r sp	acef	ligh <sup>.</sup>	t	
	Verificatio	<u> </u>							т	EST	CONF	IDEN	CE			
_							<u> </u>									
10.	SCHEDULE &	COST		SP	ACE TE			r	- <b> </b>  _		G	ROU			PTION	 
٦	TASK	CY					ļ	COST	( <b>S</b> )							COST (
	1. ANALYSIS					Î										
	2. DESIGN															
	3. MFG & C/O 4. TEST & EVAL															
	TECH NEED DATE							1	∦⊢	-+						4
				GRA	ND TOT	I FAL	1	<u> </u>	┥┝		 G	RANI	D TO'	TAL		<u> </u>
11.	VALUE OF SP	ACE TE	EST :					(SUM (	DF PR	OGF	RAM	COST	's <b>\$</b>			.)
12.	DOMINANT R	ISK/TE	CH P	ROBLE	EM				. <u>.</u> .	C	OST	IMPA	СТ	P	ROBA	BILITY
	······						<u>.</u> .				<u></u>			- <u></u>		
														<u>-</u>		
	COST RISK \$															

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DEFINITION OF TECHNOLOGY REQUIREMENT

NO. \_\_\_\_\_Bd-3

1. TECHNOLOGY REQUIREMENT (TITLE): <u>Scalable Shuttle-</u> Launched, Free-Flying Facility for High Power Density Testing

PAGE 2 OF 1

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3. (cont.)

an experimental element allows testing or demonstration of thermal-energy acquisition, transmission, conversion, or rejection or electric processing, each at highpower densities.

For example, such replacements would enable tests of solar-concentrator models, new heat pipes, improved thermionic converters, radiator modules, on the latest processing development for low-voltage, high-current power.

	FUTURE PAYLOAD TE TESTING AND DEVELOPME			
1.	REF. NO PREP DATE CATEGORY	8/9/75		
2.	TITLE _Effects of Shuttle Induced Contami	nation on	Thermal Control	Surfaces
3.	TECHNOLOGY ADVANCEMENT REQUIRED	L	EVEL OF STATE OF	ART
	The need for contamination monitoring	CURRENT	UNPERTURBED	REQUIRED
	experiments on the early shuttle	L		L
	missions is recognized. As a part of the the effects of this contamination on S/C			
	determined. Flight experiments are requi			
	(mission 4) as well as integrated into th			
	package for other flights. A statistical			
	interpretation.			
		·····		
<b>1</b> .	SCHEDULE REQUIREMENTS FIRST PAYLOAD	FLIGHT DAT	E1979	
	PAYLOAD DEVELOPMENT LEAD TIMEY	EARS. TECH		<u> </u>
5.	BENEFIT OF ADVANCEMENT	NU	MBER OF PAYLOADS	
	TECHNICAL BENEFITS <u>Provide data for selec</u>			or future
	shuttle payloads. Direct benefit to all	shuttle pa	yloads.	
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			<u> </u>	
	POTENTIAL COST BENEFITS	· · · · · · · · · · · · · · · · · · ·	······································	
			- <u></u>	- · · · · · · · · · · · · · · · · · · ·
		<u> </u>	······································	
		ESTIMATED	COST SAVINGS \$	<u></u>
6.	RISK IN TECHNOLOGY ADVANCEMENT			
	TECHNICAL PROBLEMS			
-				
-	TECHNICAL PROBLEMS			
	TECHNICAL PROBLEMS			
	TECHNICAL PROBLEMS			tita <b>tive</b>
		ent of tec		utitative
	REQUIRED SUPPORTING TECHNOLOGIES	ent of tec		)titative
-	REQUIRED SUPPORTING TECHNOLOGIES	ent of tec		)titative
<b>7</b> .	REQUIRED SUPPORTING TECHNOLOGIES	ent of tec	hniques for quan	
	REQUIRED SUPPORTING TECHNOLOGIES	ent of tec	hniques for quan	
	REQUIRED SUPPORTING TECHNOLOGIES	ent of tec	hniques for quan	

TIT	Surfaces										PAGE	
	cc	MPAR		OF SPAC	E& GR		EST	OPTIC	ONS			
8.	SPACE TEST OPTIO				····· ···· ··· ·					of the	ermal (	control
	TEST DESCRIPTION :	ALT.	. (max/mi	in)	/		km, IN	CL			deg, TIME	E hi
	BENEFIT OF SPACE TES	T:0_	g, Vac	cuum, S	huttle	induce	d env	/iron	ment		<u>.</u>	
	EQUIPMENT: WEIGH	T	5	kg, SIZ	E_0.3	_ × _ c	.3	K <u>0</u> .	1	m, POW	ER	kW
	POINTING											
	ORIENTATION			CREV	I: NO.	0	PERAT	IONS/D	URA	TION		
	SPECIAL GROUND FAC	LITIES:										
						_			E	XISTING	S: YES	NO
										IDENCE		
Э.	GROUND TEST OPT				E:							
		NOT		ADIE								
	TEST DESCRIPTION /DE											
	TEST DESCRIPTION/REG									<u> </u>		<u> </u>
	SPECIAL GROUND FAC						to pi	roduc	e co	ontami	inants 6: YES	
			Shu				to pi	roduc	e co	ontami		□] NO [
	SPECIAL GROUND FAC		Shu				to pi	coduc	e co E)	ontami XISTING	S: YES	N0 [
	SPECIAL GROUND FAC		Shu				to pi	coduc	e co E)	ontami	S: YES	□ N0 [
	SPECIAL GROUND FAC	QUIREM	Shu		ot ava	ilable	to pi	coduc ST CON	e co E) FIDEf	ntami KISTING NCE	S: YES	
10.	SPECIAL GROUND FAC	QUIREM	Shu	uttle n	ot ava	ilable	to pi	coduc ST CON	e co E) FIDEf	ntami KISTING NCE	S: YES	
10.	SPECIAL GROUND FACI	QUIREM	Shu	uttle n	ot ava	ilable	to pi	coduc ST CON	e co E) FIDEf	ntami KISTING NCE	S: YES	
10.	SPECIAL GROUND FACI GROUND TEST LIMITAT SCHEDULE & COST ASK	QUIREM	Shu	uttle n	ot ava	ilable	to pi	coduc ST CON	e co E) FIDEf	ntami KISTING NCE	S: YES	
10.	SPECIAL GROUND FACI GROUND TEST LIMITAT SCHEDULE & COST ASK CY 1. ANALYSIS	QUIREM	Shu	uttle n	ot ava	ilable	to pi	coduc ST CON	e co E) FIDEf	ntami KISTING NCE	S: YES	
IO. т	SPECIAL GROUND FACI GROUND TEST LIMITAT SCHEDULE & COST ASK CY 1. ANALYSIS 2. DESIGN	QUIREM	Shu	uttle n	ot ava	ilable	to pi	coduc ST CON	e co E) FIDEf	ntami KISTING NCE	S: YES	
іо. т	SPECIAL GROUND FACI GROUND TEST LIMITAT SCHEDULE & COST ASK CY 1. ANALYSIS 2. DESIGN 3. MFG & C/O	QUIREM	Shu	uttle n	ot ava	ilable	to pi	coduc ST CON	e co E) FIDEf	ntami KISTING NCE	S: YES	
<u>10.</u> т	SPECIAL GROUND FACI GROUND TEST LIMITAT SCHEDULE & COST ASK CY 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL	QUIREM	Shu	uttle n	OPTION	ilable	to pi	st con		ntami KISTING NCE	S: YES	
ю. т	SPECIAL GROUND FACI GROUND TEST LIMITAT SCHEDULE & COST ASK CY 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL		Shu		OPTION	ilable COST (	to pi		E CO	NCE	S: YES	
IO. T 	SPECIAL GROUND FACI GROUND TEST LIMITAT SCHEDULE & COST ASK CY 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL ECH NEED DATE	QUIREM	SPA	ACE TEST	OPTION	ilable COST (	to pi	ST CON	E CO	NCE	S: YES	
ю. т т і1.	SPECIAL GROUND FACI GROUND TEST LIMITAT SCHEDULE & COST ASK CY 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL ECH NEED DATE VALUE OF SPACE T	QUIREM	SPA SPA GRAN 800 H	ACE TEST	OPTION	ilable COST (	to pi	ST CON	E CO	NCE JND TE	S: YES	

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1.	REF. NOPREP DATE	8/9/75	REV DATE	I TR
	CATEGORY	10 or 11		
•	TITLE	ection	·····	
	• • • • • • • • • • • • • • • • • • •	·		
3.	TECHNOLOGY ADVANCEMENT REQUIRED		EVEL OF STATE OF	
	Advanced techniques are required for	CURRENT 3	UNPERTURBED 5	REQUIRED
	protection of optical, x-ray, and solar	L		L
	physics telescopes as well as thermal cor			
	experiment is limited in scope for techni See spacelab or ATL as providing exceller			protection
			······	
	·····			
		SELICUT DAT	E	
<b>).</b>	SCHEDULE REQUIREMENTS FIRST PAYLOAD			
۱. 	PAYLOAD DEVELOPMENT LEAD TIMEY			
		EARS. TECH	NOLOGY NEED DAT	E
	PAYLOAD DEVELOPMENT LEAD TIME	EARS. TECH	NOLOGY NEED DATI	E
	PAYLOAD DEVELOPMENT LEAD TIME	EARS. TECH	NOLOGY NEED DATI	E
	PAYLOAD DEVELOPMENT LEAD TIME	EARS. TECH	NOLOGY NEED DATI	E
	PAYLOAD DEVELOPMENT LEAD TIME	EARS. TECH	NOLOGY NEED DATI	E
<b>i</b> . 5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSLong-life operation,	EARS. TECH	NOLOGY NEED DATI	E
	PAYLOAD DEVELOPMENT LEAD TIME	EARS. TECH	NOLOGY NEED DATI	E
	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSLong-life operation,	EARS. TECH	NOLOGY NEED DATI	E
	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSLong-life operation,	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSLong-life operation,	/EARS. TECH NU less s/c cl	NOLOGY NEED DATI	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITSLong-life operation,	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation,  POTENTIAL COST BENEFITS	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation,  POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _Advanced technology d	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _Advanced technology d	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _Advanced technology d for contamination studies.	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _Advanced technology d	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _Advanced technology d for contamination studies.	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _Advanced technology d for contamination studies.	/EARS. TECH NU less s/c cl	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIME	/EARS. TECH NU less s/c cl _ESTIMATED evelopment	NOLOGY NEED DATH	E
5.	PAYLOAD DEVELOPMENT LEAD TIMEY BENEFIT OF ADVANCEMENT TECHNICAL BENEFITS Long-life operation, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS _Advanced technology d for contamination studies.	/EARS. TECH NU less s/c cl _ESTIMATED evelopment	NOLOGY NEED DATH	E

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		COM	PARIS	ON OF	SPACE	& GR	OUND TE	EST C	OPTIC	DNS				
8.	SPACE TEST OP	TION		TEST A	RTICLE:									
	TEST DESCRIPTION	:	ALT. (m	nax/min}		_/_	I	km, 1 <b>N</b> (	CL			deg, T	'IME _	hr
	BENEFIT OF SPACE	TEST												
	EQUIPMENT: WI POINTING ORIENTATION										m, POV	VER		kW
	SPECIAL GROUND F	ACILII												
9.	GROUND TEST	ΟΡΤΙΟ												
	TEST DESCRIPTION	/REQUI	REMEN	ITS:										
	SPECIAL GROUND F	ACILIT	TIES:					- <u>.</u>						
	GROUND TEST LIMI		NS:								ISTIN	G: YE	is 🕅	) NO 🗌
	4 <b>1 </b>													
								TES	T CON	FIDEN	CE			
10.	SCHEDULE & CO	DST		SPACE	TEST O	PTION			C	BROU		EST O	PTION	1
1	rask 🛛	CY					COST (\$)							COST (S)
	1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL													
	FECH NEED DATE													<b> </b>
1.4				RAND			L			RAN				
11.	VALUE OF SPAC	ETES	I \$				(SUM OF	PROG	RAM	COST	'S <b>\$</b>			_)
12.	DOMINANT RISK	(/TECł	H PROE	BLEM				(	COST	IMPA	СТ	P 	ROBA	BILITY
			· <u> </u>											
_	COST RISK \$													· · · · · · · · · · · · · · · · · · ·

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		CATEGORY	Cryogenic	Control		
	TITLE Liquid Cryogenic Tran	sfer				
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3.	TECHNOLOGY ADVANCEMENT RE	EQUIRED		LEVEL OF S		
	Reduced gravity fluid behavio	r as it	CURRENT	UNPERT	URBED	REQUIRED
	pertains to acquisition, ther					
	trol, low-g venting, and tran					
	based reduced gravity facilit proof of such systems before					
	The data to be collected will		······			
	LH2, LF2, LC2, LHe, and LAr.					
	and liquid outlet designs wil	l be verif:	.ed.			
		<u> </u>		<u> </u>		
<b>J.</b>	SCHEDULE REQUIREMENTS	IRST PAYLOA	D FLIGHT DA	TE198	4	
	PAYLOAD DEVELOPMENT LEAD TIME	2	YEARS. TEC	HNOLOGY N		1982
5.	BENEFIT OF ADVANCEMENT		N	UMBER OF P	AYLOADS	S
5.	TECHNICAL BENEFITS _ Space basi	ng of propu	lsion syst	ems, incr	eased so	acecraft
5.	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi	bility, inc	lsion syst	ems, incr	eased sp time, sp	acecraft
5.	TECHNICAL BENEFITS _ Space basi	bility, inc	lsion syst	ems, incr	eased sp time, sp	acecraft
5.	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi	bility, inc	lsion syst	ems, incr	eased sp time, sp	acecraft
5.	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi increased spacecraft payload,	bility, inc	lsion syst	ems, incr	eased sp time, sp	acecraft
5.	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi	bility, inc	lsion syst	ems, incr	eased sp time, sp	acecraft
5.	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi increased spacecraft payload,	bility, inc	lsion syst	ems, incr	eased sp time, sp	acecraft
5.	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi increased spacecraft payload,	bility, inc	ilsion syst reased crb assurance	ems, incr piter life of low-g	eased sp time, sp engine s	cacecraft pace rescue starts.
5.	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi increased spacecraft payload,	bility, inc	ilsion syst reased crb assurance	ems, incr	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi increased spacecraft payload,	bility, inc increased	ilsion syst reased crb assurance	ems, incr piter life of low-g	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS Space basi lifetime, space station feasi increased spacecraft payload, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCE	bility, inc increased MENT	lsion syst reased crb assurance _ESTIMATEC	ems, incr oiter life of low-c COST SAVI	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS <u>Space basi</u> lifetime, space station feasi increased spacecraft payload, POTENTIAL COST BENEFITS	bility, inc increased MENT	lsion syst reased crb assurance _ESTIMATEC	ems, incr oiter life of low-c COST SAVI	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS Space basi lifetime, space station feasi increased spacecraft payload, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCE	bility, inc increased MENT	lsion syst reased crb assurance _ESTIMATEC	ems, incr oiter life of low-c COST SAVI	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS Space basi lifetime, space station feasi increased spacecraft payload, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCE	bility, inc increased MENT	lsion syst reased crb assurance _ESTIMATEC	ems, incr oiter life of low-c COST SAVI	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS Space basi lifetime, space station feasi increased spacecraft payload, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCE	bility, inc increased MENT	lsion syst reased crb assurance _ESTIMATEC	ems, incr oiter life of low-c COST SAVI	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS       Space basi         lifetime, space station feasi       increased spacecraft payload,         increased spacecraft payload,	bility, inc increased MENT	ilsion syst reased crb assurance _ESTIMATEC	ems, incr piter life of low-g cost savu	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS Space basi lifetime, space station feasi increased spacecraft payload, POTENTIAL COST BENEFITS RISK IN TECHNOLOGY ADVANCE	bility, inc increased MENT	ilsion syst reased crb assurance _ESTIMATEC	ems, incr piter life of low-g cost savu	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS       Space basi         lifetime, space station feasi       increased spacecraft payload,         increased spacecraft payload,	bility, inc increased MENT	ilsion syst reased crb assurance _ESTIMATEC	ems, incr piter life of low-g cost savu	eased sp time, sp engine s	cacecraft pace rescue starts.
	TECHNICAL BENEFITS       Space basi         lifetime, space station feasi       increased spacecraft payload,         increased spacecraft payload,	bility, inc increased MENT	ilsion syst reased crb assurance _ESTIMATEC	ems, incr piter life of low-g cost savu	eased sp time, sp engine s	cacecraft pace rescue starts.
6.	TECHNICAL BENEFITS       Space basi         lifetime, space station feasi       increased spacecraft payload,         POTENTIAL COST BENEFITS	bility, inc increased MENT ES ENTS OF	S Future	Payload	<pre>eased_sp time, sp engine_s NGS\$ Technq</pre>	pacecraft pace rescue starts.
6.	TECHNICAL BENEFITS       Space basi         lifetime, space station feasi       increased spacecraft payload,         POTENTIAL COST BENEFITS	bility, inc increased MENT ES ENTS OF t No. CAS	ESTIMATEC	Payload	<pre>eased_sp time, sp engine_s NGS \$ NGS \$ Techno echnolo</pre>	ploav
<b>6</b> .	TECHNICAL BENEFITS       Space basi         lifetime, space station feasi       increased spacecraft payload,	bility, inc increased MENT ES ENTS OF t No. CAS	ESTIMATEC	Payload	<pre>eased_sp time, sp engine_s NGS \$ NGS \$ Techno echnolo</pre>	ploav

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TITLE				NO. <u>Bg-1</u> PAGE 2
	COMPARISON OF SPACE	& GROUND TO		
8. SPACE TEST OPT		Package ro	ntaining insulated	receiver
TEST DESCRIPTION :	ALT. (max/min)	/+	rm, INCL de	g, TIME hr
BENEFIT OF SPACE T expensive vehicl	EST: Assurance that s	ystem works i	tefore committing	it to an
EQUIPMENT: WEI	GHT kg, SIZE	x	X m, POWEF	3 kW
POINTING	GHT kg, SIZE STABILITY		DATA	
ORIENTATION	CREW:	NO OP	ERATIONS/DURATION	/
SPECIAL GROUND FA	CÌLITIES:			
	· · · · · · · · · · · · · · · · · · ·		EXISTING:	YES NO
			TEST CONFIDENCE _	
9. GROUND TEST O	PTION TEST ARTICLE:			
			······································	
TEST DESCRIPTION/R				
		·····		
······································				
SPECIAL GROUND FA				
				· · · · · · · · · · · · · · · · · · ·
			EXISTING:	YES NO
GROUND TEST LIMIT	ATIONS:			
			TEST CONFIDENCE	<u></u>
10. SCHEDULE & COS	T SPACE TEST O	PTION	GROUND TES	TOPTION
TASK CY		COST (\$)		
1. ANALYSIS	+-+-+-+++++++++++++++++		╠━╋╴╉╍╋╍╋	
2. DESIGN				
3. MFG & C/O				
4. TEST & EVAL				
TECH NEED DATE				
	GRAND TOTAL		GRAND TOTA	L
11. VALUE OF SPACE	TEST \$	(SUM OF	PROGRAM COSTS \$	
12. DOMINANT RISK/			COST IMPACT	
CUST BIER 6			·····	····
COST RISK \$				

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	FUTURE PAYLOAD 1	ECHNOLOG	Y NO	. <u>Bg-2</u>
•	TESTING AND DEVELOPME			GE 1
۱.	REF. NOPREP DATECATEGORY	Cryogenic (	REV DATE	LIR
	TITLE Liquid Cryogen Storage and Supply			
)	IIILE Liquid Cryogen Storage and Suppry		······································	
		1	LEVEL OF STATE OF	ART
8.	TECHNOLOGY ADVANCEMENT REQUIRED	CURRENT	UNPERTURBED	REQUIRED
	Reduced gravity fluid behavior as it pertains to acquisition, thermal contro	· F	5	7
	and transfer have been evaluated to the		around reduced a	ravity
	facilities in experiment scale and time	• The fina	l proof of such	systems
	before their adoption rests on an in-sp			
	collected will be applied to cryogenic	systems con	taining LH2, LF2	, LO <sub>2</sub> , LHe,
	and LAr.			
				<u></u>
			e Can be used a	c coop ac
	SCHEDULE REQUIREMENTS FIRST PAYLOA		available	
	PAYLOAD DEVELOPMENT LEAD TIME	YEARS. TECH		E
	BENEFIT OF ADVANCEMENT	NI	JMBER OF PAYLOADS	All shuttle
	TECHNICAL BENEFITS			flights
				ittaines
	Supercritical power and life support sys	stems, if c	onverted to subc:	
	Supercritical power and life support syn systems utilizing advanced reduced grav			ritical
				ritical
	<u>systems utilizing advanced reduced grav</u> substantial weight savings.	ity fluid t	echnology, would	ritical realize
	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve	ity fluid t	echnology, would	ritical realize
	<u>systems utilizing advanced reduced grav</u> substantial weight savings.	ity fluid t	echnology, would	ritical realize
	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve	ity fluid t shicle payl	echnology, would oad results in a	ritical realize decreased
	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve	ity fluid t shicle payl	echnology, would	ritical realize decreased
i.	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve	ity fluid t shicle payl	echnology, would oad results in a	ritical realize decreased
	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve cost of payloads in orbit. RISK IN TECHNOLOGY ADVANCEMENT	ity fluid t chicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve cost of payloads in orbit.	ity fluid t chicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
, i.	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve cost of payloads in orbit. RISK IN TECHNOLOGY ADVANCEMENT	ity fluid t chicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
<u> </u>	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve cost of payloads in orbit. RISK IN TECHNOLOGY ADVANCEMENT	ity fluid t chicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve cost of payloads in orbit. RISK IN TECHNOLOGY ADVANCEMENT	ity fluid t chicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
<b>)</b> .	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ve cost of payloads in orbit. RISK IN TECHNOLOGY ADVANCEMENT	ity fluid t chicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
<u> </u>	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ver- cost of payloads in orbit. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS	ity fluid t chicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
6.	systems utilizing advanced reduced grav substantial weight savings. POTENTIAL COST BENEFITS Any increase in ver- cost of payloads in orbit. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS	ity fluid t chicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
5.	systems utilizing advanced reduced grav substantial weight savings.  POTENTIAL COST BENEFITS Any increase in victors of payloads in orbit.  RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS REQUIRED SUPPORTING TECHNOLOGIES	ity fluid t ehicle payl ESTIMATED	echnology, would oad results in a COST SAVINGS \$	ritical realize decreased
<u> </u>	systems utilizing advanced reduced grav         substantial weight savings.         POTENTIAL COST BENEFITS Any increase in victors of payloads in orbit.         cost of payloads in orbit.         RISK IN TECHNOLOGY ADVANCEMENT         TECHNICAL PROBLEMS         REQUIRED SUPPORTING TECHNOLOGIES         OFS Future Payload Technology Req         REFERENCE DOCUMENTS/COMMENTS 75_000	ity fluid t chicle payl ESTIMATED	COST SAVINGS S	ritical realize decreased
	systems utilizing advanced reduced grav         substantial weight savings.         POTENTIAL COST BENEFITS Any increase in victors of payloads in orbit.         Cost of payloads in orbit.         RISK IN TECHNOLOGY ADVANCEMENT         TECHNICAL PROBLEMS	Lirements Technolog Lirements Lirements	COST SAVINGS S COST SAVINGS S Study Report 1 Dgy Categories 1 001, "Future Pay	ritical realize decreased
	systems utilizing advanced reduced grav         substantial weight savings.         POTENTIAL COST BENEFITS Any increase in victors of payloads in orbit.         cost of payloads in orbit.         RISK IN TECHNOLOGY ADVANCEMENT         TECHNICAL PROBLEMS         REQUIRED SUPPORTING TECHNOLOGIES         OFS Future Payload Technology Req         REFERENCE DOCUMENTS/COMMENTS 75_000	Lity fluid t chicle payl ESTIMATED Lirements Technolo pt. #FT-WP- rement", It	COST SAVINGS S COST SAVINGS S	ritical realize decreased

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FT (TDR-1) 7/75

TITLE Cryogen Storage and Supply

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8.	SPACE TEST	OPTIO	N	TEST A	RTICLE:	Packa	ge cont	ainin	g sul	bcriti	.cal ta	ank f	`or
	storing cry	ogens	and all	nece	ssary i	nstru	nents						
	TEST DESCRIPTIO	DN •	ALT. (n	nax/min)		_/	k	m, INCL	•		deg, Ti	ME	hr
	BENEFIT OF SPA			ance t	hat sys	tem w	orka be	fore	comm.	itting	it to	ne c	
	EQUIPMENT:	WEIGH	Γ		kg, SIZE _		x	× _		m, P(	WER		kW
	POINTING												
	ORIENTATION									RATION			
	SPECIAL GROUN	D FACI	LITIES: _										
										-			
9.	GROUND TES	T OPT	ION	TEST A	RTICLE:	There	e is no	grour	nd te	st op	tion.		
	TEST DESCRIPTIO	ON/REC	DUIREMEI	NTS:									
	SPECIAL GROUN	D FACI											
		·											
	GROUND TEST L	IMITAT								_EXISTI	NG: YE	s [_]	NO
								TEST	CONFI	DENCE			
10.	SCHEDULE &	COST		SPACI	E TEST OI	PTION			GI	ROUND	TEST O	PTION	)
Г	TASK	CY					COST (\$)				Τ		COST (S
	1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL												
1	ECH NEED DATE												
				GRAND	TOTAL				GP		DTAL		
11.	VALUE OF SP	ACE T	est <b>\$</b> _				(SUM OF	PROGR	RAM C	OSTS \$			.)
12.	DOMINANT R	ISK/TE	CH PRO	BLEM				C	DST IN	APACT	P	ROBA	BILITY
	COST HISK \$	****											·

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FUTURE PAYLOAD TECHNOLOGY

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TESTING AND DEVI	LOPMENT	REQUIREMENT
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PAGE 1

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2 1

1.			REV DATE	
	CATEGORY	<u> </u>		
2.	TITLE Joule-Thomson Expansion of Supercr.	itical Heli	um	
3.	TECHNOLOGY ADVANCEMENT REQUIRED	L	EVEL OF STATE OF	ART
	Develop a Joule-Thomson expander with an	CURRENT	UNPERTURBED	REQUIRED
	integral heat exchanger which is capable	1 2	4	7
	of producing temperatures below 2 <sup>0</sup> K with	out inducir	ng excessive noi	se in
	detectors. Demonstrate its performance	in D-g prei	erably as part	of an
	operating sensor system.			
			<u> </u>	
4.	SCHEDULE REQUIREMENTS FIRST PAYLOAD		E 1980	
	PAYLOAD DEVELOPMENT LEAD TIME	EARS. TECH	NOLOGY NEED DAT	1978
5.	BENEFIT OF ADVANCEMENT	NU		
	TECHNICAL BENEFITS The use of a J-T expan	der/heat ex	changer to prod	uce
	Hell (T=2°K) allows: (1) supercritical	storage of	the helium, rat	her than
	<pre>subcritical storage with its phase separ of Hell on demand.</pre>	ation probl	ems and (2) the	production
	POTENTIAL COST BENEFITS A suitable J-Texpa	nder/best e	webseger would	21104
		· · · · · · · ·		
	use of supercritical (gasrous) helium, r of handling two-phase helium in O-g.	ather than	the more comple	x problem
	or Handring two-phase herium in o-g.			
		ESTIMATED	COST SAVINGS \$	
6.	RISK IN TECHNOLOGY ADVANCEMENT			
	TECHNICAL PROBLEMS J-T expansion to tempe	ratures bel	.ow 2°K may indu	ce
	excessive noise (acoustic and thermal) i	n sensitive	detectors. Be	havior
	excessive noise (acoustic and thermal) i of the Hell produced during the expansio			
	excessive noise (acoustic and thermal) i of the Hell produced during the expansio cause flow instabilities.			
	of the Hell produced during the expansio			
	of the Hell produced during the expansio	n is not we	ll known in O-g	
	of the Hell produced during the expansio cause flow instabilities.	n is not we	ll known in O-g	
	of the Hell produced during the expansio cause flow instabilities.	n is not we	ll known in O-g	
	of the Hell produced during the expansio cause flow instabilities.	n is not we	ll known in O-g	
7.	of the Hell produced during the expansio cause flow instabilities.	n is not we	ll known in O-g	
7.	of the Hell produced during the expansio cause flow instabilities. REQUIRED SUPPORTING TECHNOLOGIES Cryogeni	n is not we	ll known in O-g	
7.	of the Hell produced during the expansio cause flow instabilities. REQUIRED SUPPORTING TECHNOLOGIES Cryogeni	n is not we	ll known in O-g	

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TIT	LE												NO.		
										· · · · · ·			PAG		2
		00			SPA	CF &	GRC				NS				
8.	SPACE TEST	OPTION	۲ <b>۱</b>	EST A	RTIC	LE: _									
	TEST DESCRIPTI	ION :	ALT. (m	ex/min)			./	kn	n, INCI	L		(	deg, Til	ME	hr
	BENEFIT OF SPA	ACE TEST	·:												
		WEIGHT			ka Si	175		x	x			POW	50		kW
	EQUIPMENT: POINTING	WEIGHT									"" A	,			
	ORIENTATION				CR	EW:	NO.	OPE	RATIO	)NS/D	URATI	ON		1	
	SPECIAL GROUN														
											EX	STING	: YES		NO
	<u></u>								1	EST C	ONFID	ENCE		<b>س</b> ے	
9.	GROUND TE	STOPT	ION	TEST A	ARTIC										
	TEST DESCRIPT	ION/REQ	UIREMEN	ITS:											
	SPECIAL GROUI		17150.												
	SPECIAL GROUP														
											EX	STING	: YE	s 🗆	NO D
	GROUND TEST		IONS:												
									TES	r con	FIDEN	CE			
10	SCHEDULE 8	COST		SPAC	E TE	ST OP	TION			(	BROU	ND TI	EST O	PTION	1
		CY			<u> </u>			COST (\$)			<b></b>			<b></b>	COST (S)
	TASK			<b></b>						┠					
	1. ANALYSIS 2. DESIGN														
	2. DESIGN 3. MFG & C/O													1	
	4. TEST & EVAI					I									
-	TECH NEED DAT	E		1	<u>†</u>			1							1
				BRANE	D TOT	AL				G	RAN	D TOI	TAL		
11	. VALUE OF S	PACE T	EST <b>\$</b> _					(SUM OF	PROG	RAM	COST	'S <b>\$</b>			_)
12	. DOMINANT	RISK/TE	CH PRO	BLEM	1				(	COST	IMPA	CT	P	ROB	BILITY
	COST PIER &													_	-
	COST RISK \$				_										

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1	REE NO	PREP DATE			I TR
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2.	TITIE Inquefer o	f Cryogens Across Gimba	ale		
<b></b>					
3.		ANCEMENT REQUIRED	Τ ι	EVEL OF STATE OF	ART
	Develop a rotary		CURRENT	UNPERTURBED	REQUISE
		um (T=4° to 10°K)	- 3	4	7
		th acceptable heat los	ses and dist	urbances to the	instrument
		Demonstrate in space			
		·····································			<b>-</b>
			······		
A		MENTE MORTONIA		<b>1</b> 980	
4.		EMENTS FIRST PAYLOA			1070
	PAYLOAD DEVELOPME	NT LEAD THAE	YEARS. TECH	NOLC BY NEED DAT	E
_					
	DENERIT OF ADVAN				
5.	BENEFIT OF ADVAN			MBER OF PAYLOADS	-
5.	TECHNICAL BENEFITS	Many future scientifi	c instrument	ts require both	accurate
5.	TECHNICAL BENEFITS	Many future scientifi genic cooling. The de	c instrument	ts require both f a suitable rot	accurate ary joint
5.	TECHNICAL BENEFITS	Many future scientifi	c instrument	ts require both f a suitable rot	accurate ary joint
5.	TECHNICAL BENEFITS	Many future scientifi genic cooling. The de	c instrument	ts require both f a suitable rot	accurate ary joint
5.	TECHNICAL BENEFITS pointing and cryo will permit suppl	Many future scientifi genic cooling. The de y dewars (for long mis	c instrument velopment of sions) to be	ts require both f a suitable rot a located off th	accurate ary joint ne gimbals.
5.	TECHNICAL BENEFITS pointing and cryo will permit suppl	Many future scientifi genic cooling. The de	c instrument velopment of sions) to be	ts require both f a suitable rot a located off th	accurate ary joint ne gimbals.
5.	TECHNICAL BENEFITS pointing and cryo will permit suppl	Many future scientifi genic cooling. The de y dewars (for long mis	c instrument velopment of sions) to be als would si	ts require both f a suitable rot a located off th	accurate ary joint ne gimbals.
5.	TECHNICAL BENEFITS pointing and cryo will permit suppl	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb	c instrument velopment of sions) to be als would si	ts require both f a suitable rot a located off th	accurate ary joint ne gimbals.
5.	TECHNICAL BENEFITS pointing and cryo will permit suppl	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req	c instrument velopment of sions) to be als would sinuired.	ts require both f a suitable rot a located off th implify pointing	accurate ary joint e gimbals. and
5.	TECHNICAL BENEFITS pointing and cryo will permit suppl	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req	c instrument velopment of sions) to be als would sinuired.	ts require both f a suitable rot a located off th	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req	c instrument velopment of sions) to be als would sinuired.	ts require both f a suitable rot a located off th implify pointing	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce to RISK IN TECHNOLOG	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req	c instrument velopment of sions) to be als would si uired.	ts require both f a suitable rot a located off th implify pointing	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce to RISK IN TECHNOLOG TECHNICAL PROBLEMS	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req GY ADVANCEMENT Low friction, leak-t	c instrument velopment of sions) to be als would si uired. ESTIMATED ( ight cryoger	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce to RISK IN TECHNOLOG TECHNICAL PROBLEMS	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req GY ADVANCEMENT	c instrument velopment of sions) to be als would si uired. ESTIMATED ( ight cryoger	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce to RISK IN TECHNOLOG TECHNICAL PROBLEMS	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req GY ADVANCEMENT Low friction, leak-t	c instrument velopment of sions) to be als would si uired. ESTIMATED ( ight cryoger	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S	accurate ary joint e gimbals. and
<b>5</b> . <b>6</b> .	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce to RISK IN TECHNOLOG TECHNICAL PROBLEMS	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req GY ADVANCEMENT Low friction, leak-t	c instrument velopment of sions) to be als would si uired. ESTIMATED ( ight cryoger	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce t RISK IN TECHNOLOG TECHNICAL PROBLEMS low thermal condu	Many future scientifi Igenic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req SY ADVANCEMENT Low friction, leak-t ictance interfaces have	c instrument velopment of sions) to be als would si uired. 	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S nic seals and su developed.	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce t RISK IN TECHNOLOG TECHNICAL PROBLEMS low thermal condu	Many future scientifi genic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req GY ADVANCEMENT Low friction, leak-t	c instrument velopment of sions) to be als would si uired. 	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S nic seals and su developed.	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce t RISK IN TECHNOLOG TECHNICAL PROBLEMS low thermal condu	Many future scientifi Igenic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req SY ADVANCEMENT Low friction, leak-t ictance interfaces have	c instrument velopment of sions) to be als would si uired. 	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S nic seals and su developed.	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce t RISK IN TECHNOLOG TECHNICAL PROBLEMS low thermal condu	Many future scientifi Igenic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req SY ADVANCEMENT Low friction, leak-t ictance interfaces have	c instrument velopment of sions) to be als would si uired. 	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S nic seals and su developed.	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce t RISK IN TECHNOLOG TECHNICAL PROBLEMS low thermal condu	Many future scientifi Igenic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req SY ADVANCEMENT Low friction, leak-t ictance interfaces have	c instrument velopment of sions) to be als would si uired. 	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S nic seals and su developed.	accurate ary joint e gimbals. and
	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce t RISK IN TECHNOLOG TECHNICAL PROBLEMS low thermal condu	Many future scientifi Igenic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req GY ADVANCEMENT Low friction, leak-t ictance interfaces have G TECHNOLOGIES Cryoge	c instrument velopment of sions) to be als would si uired. 	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S nic seals and su developed.	accurate ary joint e gimbals. and
6.	TECHNICAL BENEFITS pointing and cryo will permit suppl POTENTIAL COST BENE possibly reduce t RISK IN TECHNOLOG TECHNICAL PROBLEMS low thermal condu	Many future scientifi Igenic cooling. The de y dewars (for long mis FITS Less mass on gimb the size of gimbals req GY ADVANCEMENT Low friction, leak-t ictance interfaces have G TECHNOLOGIES Cryoge	c instrument velopment of sions) to be als would si uired. 	ts require both f a suitable rot a located off th implify pointing COST SAVINGS S nic seals and su developed.	accurate ary joint e gimbals. and

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		COM	PARIS	SON O	F SPAC	E & GR		ST O	PTIC	) NS				
8.	SPACE TEST (													
	TEST DESCRIPTIO	)N :	ALT. (	max/min	)	/	k	m, INC	:L			deg, Tl	ME	hr
	BENEFIT OF SPAC	E TEST:												
	EQUIPMENT: POINTING			S	TABILITY	′ <u> </u>			DA'	TA				
	ORIENTATION										ION _		_/	
										EX				
9.	GROUND TES	Τ ΟΡΤΙΟ	<b>DN</b>	TEST	ARTICLE	::								
		N/REQU	IREME	NTS: _										
	SPECIAL GROUND	FACILI	TIES:											
					_						ISTIN	G: YE	s 🗖	NO 🗌
	GROUND TEST LI									FIDEN	CE			
10.	SCHEDULE & (	cost		SPAC	E TEST	OPTION				BOU		EST O	PTION	
	ASK	СЧ					COST (\$)							COST (S)
	1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL													
-	ECH NEED DATE			GRANE						RANI		[		
11.	VALUE OF SPA						(SUM OF	PROG						L . )
	DOMINANT RI									IMPA				BILITY
	COST RISK \$							<u> </u>			·			
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# REPRODUCIBILITY OF THE

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## FUTURE PAYLOAD TECHNOLOGY

NO.	Bg-5

	REF. NO	PREP DATE _		REV DATE	
		CATEGORY .			
	TITLE Hell Stora	ge and Utilization			
		NCEMENT REQUIRED		LEVEL OF STATE OF	ART
•	Develop a dewar ca		CURRENT	UNPERTURBED	REQUIRED
		rawing Hell for dis-	- 2	2	7
	tribution to a sin	gle or combination of	scientific	intruments or ex	periments.
		distribution system			
	ومحادث والمستعد المراكد المتعاد ويستعاد والمستعد والمستعد والمتعاد والمتع	ted porous plugs and/			
		-			
			<u> </u>		
		<u></u>			
	SCHEDULE REQUIRE	MENTS FIRST PAYLO		E1982	
•		T LEAD TIME3	VEARS, TECH		<b>_ 19</b> 79
	BENEFIT OF ADVAN	CEMENT	AII A	JMBER OF PAYLOADS	2
•		Many future experiment			-
		a variety of reasons o	cannot be di	rectly immersed	within
	the dewar of Hell,				
		•			
		•			
		FITS Distribution from	n a single d	ewar eliminates	
	POTENTIAL COST BENEI			ewar eliminates	
	POTENTIAL COST BENEI	FITS Distribution from		ewar eliminates	
	POTENTIAL COST BENEI	FITS Distribution from	nent.	ewar eliminates COST SAVINGS \$	the need
	POTENTIAL COST BENEI for individual dev	FITS Distribution from wars with each instrum	nent.		the need
	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG	FITS Distribution from wars with each instrum	nent. ESTIMATED	COST SAVINGS \$	the need
<b>j</b> .	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems	ent. ESTIMATED	COST SAVINGS \$	the need
·	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems and mechano-caloric e	estimated Estimated s using poro	COST SAVINGS \$	the need
	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems	estimated Estimated s using poro	COST SAVINGS \$	the need
	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems and mechano-caloric e	estimated Estimated s using poro	COST SAVINGS \$	the need
5.	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical yet to lie develop	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems and mechano-caloric of bed and tested in the	ESTIMATED s using poro effects ard laboratory.	COST SAVINGS \$ us plugs based o helium heat pipe	the need
<u>.</u>	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical yet to lie develop	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems and mechano-caloric of bed and tested in the	ESTIMATED s using poro effects ard laboratory.	COST SAVINGS \$ us plugs based o helium heat pipe	the need
<u>.</u>	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical yet to lie develop	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems and mechano-caloric e	ESTIMATED s using poro effects ard laboratory.	COST SAVINGS \$ us plugs based o helium heat pipe	the need
5.	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical yet to lie develop	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems and mechano-caloric of bed and tested in the	ESTIMATED s using poro effects ard laboratory.	COST SAVINGS \$ us plugs based o helium heat pipe	the need
3.	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical yet to lie develop	FITS Distribution from wars with each instrum SY ADVANCEMENT Hell transfer systems and mechano-caloric of bed and tested in the	ESTIMATED s using poro effects ard laboratory.	COST SAVINGS \$ us plugs based o helium heat pipe	the need
	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical yet to lie develop REQUIRED SUPPORTING	A Distribution from wars with each instrum A ADVANCEMENT Hell transfer systems and mechano-caloric e bed and tested in the A TECHNOLOGIES Hell h	ESTIMATED s using poro effects ard laboratory.	COST SAVINGS \$ us plugs based o helium heat pipe	the need
5.	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical yet to lie develop	A Distribution from wars with each instrum A ADVANCEMENT Hell transfer systems and mechano-caloric e bed and tested in the A TECHNOLOGIES Hell h	ESTIMATED s using poro effects ard laboratory.	COST SAVINGS \$ us plugs based o helium heat pipe	the need
	POTENTIAL COST BENER for individual dev RISK IN TECHNOLOG TECHNICAL PROBLEMS thermo-mechanical yet to lie develop REQUIRED SUPPORTING	A Distribution from wars with each instrum A ADVANCEMENT Hell transfer systems and mechano-caloric e bed and tested in the A TECHNOLOGIES Hell h	ESTIMATED s using poro effects ard laboratory.	COST SAVINGS \$ us plugs based o helium heat pipe	the need

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								E 67. 0	DTIC	AIC				£
8. SPACE TEST			· · · · · -			*								
TEST DESCRIPTI	<b>ON</b> :	ALT. (1	max/min	)		_/		km, INC	:L		(	deg, Til	AE	hr
BENEFIT OF SPA	CE TEST	;					····							
EQUIPMENT: POINTING	WEIGHT		s	kg, S TABIL			_ x	x		n n TA	n, <b>POW</b> I	ER		kW
ORIENTATION				CR	EW:	NO.	06	ERATI	ONS/D	URAT	ION			
SPECIAL GROUN		······································		_	<u> </u>					EX	ISTING			
9. GROUND TE	ST OPTI													
SPECIAL GROUN												: YES		NO C
					_					<b>F</b> 10 <b>F</b> 11	<u></u>			
						_		- 185			CE			
10. SCHEDULE &			SPAC		ST OP			╢──-	<u> </u>	GROU	ND TE	ST OP	T	, , <u>,</u>
TASK 1. ANALYSIS 2. DESIGN 3. MFG & C/O 4. TEST & EVAL TECH NEED DATE	CY		GRANE		A1		COST (\$)			BAN	о тот	A 1		COST (S
11. VALUE OF SP														
12. DOMINANT R														BILITY
COST RISK \$								•						

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FUTURE PAYLOAD TECHNOLOGY

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### TESTING AND DEVELOPMENT REQUIREMENT

	TESTING AND DEVELOPME	NT REQUIR	EMENT PA	GE 1
1.	REF. NOPREP DATE		REV DATE	
	CATEGORY			
2.	TITLE <u><sup>3</sup>He/<sup>4</sup>He Dilution Refrigerator - O</u>	perable in	0g	
3.	TECHNOLOGY ADVANCEMENT REQUIRED		EVEL OF STATE OF	ART
J.	Develop a ${}^{3}\text{He}/{}^{4}\text{He}$ dilution refrigerator	CURRENT	UNPERTURBED	REQUIRED
	which is capable of continuously			
	producing, in O-g for periods up to 30 da	ys, temper	atures in the mK	range.
	No other methods swich for continuously a			For
	No other methods exist for continuously p example, the adiabatic demagnetization of			
	single-cycle method of cooling and pumpin	g and <sup>3</sup> He		
	at least, temperatures of $0.5^{\circ}$ and $0.3^{\circ}$ K.		· · · · · · · · · · · · · · · · · · ·	
				<b>.</b>
4.	SCHEDULE REQUIREMENTS FIRST PAYLOAD		<b>F</b> 1981	
	PAYLOAD DEVELOPMENT LEAD TIME			1979
5.	BENEFIT OF ADVANCEMENT		IMBER OF PAYLOADS	
	TECHNICAL BENEFITS Ultimate sensitivity of			
	depends on their operation at mK temperat			ments in
	space, especially solid-state, may also a		temperatures.	<u></u>
	POTENTIAL COST BENEFITS Integration time f	or a detec	tor decreases as	the square
	of the sensitivity, therefore allowing si	gnificantl	y more data to b	e gathered
	in a single flight.			
		ESTIMATED	COST SAVINGS \$	·····
6.	RISK IN TECHNOLOGY ADVANCEMENT			
	TECHNICAL PROBLEMS _ Current dilution refr	igerators	depend on gravit	y for
	seppiration of the <sup>3</sup> He and <sup>4</sup> He phases in t	he mixing	chamber and stil	1.
	Alternate means of separation must be dev	eloped.		
	REQUIRED SUPPORTING TECHNOLOGIES Hell st			
	REQUIRED SUPPORTING TECHNOLOGIES HE ST	orage and l	Itilization	
7.	REFERENCE DOCUMENTS/COMMENTS			
			- <u></u>	
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	C	OMPAR	RISON OI	F SPA	CE &	GRO		ST O	PTIC	ONS_				
<b>8</b> .	SPACE TEST OPTIC	N	TEST /	ARTIC	LE: _									
	TEST DESCRIPTION :	ALI	ſ. (max/min	)		_/	k	m, INC	:L			deg, Ti	ME	hr
	BENEFIT OF SPACE TES	:T:												
	EQUIPMENT: WEIGH	T		kg, SI			_×	x		n	n, POW	/ER		kW
	ORIENTATION													
	SPECIAL GROUND FAC	LITIES	: <u> </u>											
							<u></u>							
9.	GROUND TEST OP													
	TEST DESCRIPTION/RE	QUIREN	MENTS:				<u></u>							
•			·····											
	SPECIAL GROUND FAC	LITIES	:	<u></u>										
	••••••••••••••••••••••••••••••••••••••						· · · · · · · · · · · · · · · · · · ·			EY	STING	. VE	· – – ,	NO [
	GROUND TEST LIMITAT	IONS:								_			·	
								TEST	r coni	FIDEN	CE			
10.	SCHEDULE & COST		SPAC	E TES	T OP	TION			G	ROU		EST O	PTION	
1	ASK CY						COST (\$)							COST (\$)
	1. ANALYSIS													
	2. DESIGN 3. MFG & C/O													
	4. TEST & EVAL													
1	ECH NEED DATE							<b></b>						
			GRAND							RAN				
11.	VALUE OF SPACE T	EST \$	·····				(SUM OF I	PROG	RAM	COST	s <b>s</b>			)
12.	DOMINANT RISK/T	ECH PF	ROBLEM		<u></u> ***			C	OST	IMPAC	ст	P	ROBA	BILITY
								<del></del>				<del></del>		
-	COST RISK \$													

F1 (1DR-2) 7/75

1.	REF. NO. PREP DATE			LTR
	CATEGORY			
2.	TITLE Magnetic Refrigeration - Demagnet	ization of R	are Earth Salt	5
3.	TECHNOLOGY ADVANCEMENT REQUIRED	LE	VEL OF STATE OF	ART
	Magnetic refrigeration techniques,	CURRENT	UNPERTURBED	REQUIRE
	currently being developed in the	- 3	4	7
	laboratory for use with superconducting	magnets, nee	ds to be devel	oped and
	demonstrated in O-g for cooling applicat	tions in the	4-20°K tempera	ture rang <b>e</b> .
			·	
<b>1</b> .	SCHEDULE REQUIREMENTS FIRST PAYLOA	D FLIGHT DATE	1984	
•.			<u> </u>	1003
	PAYLOAD DEVELOPMENT LEAD TIME2	YEARS. TECHN	IOI OGY NEED DAT	E
			CEGG: NEED DAT	
-				
5.	BENEFIT OF ADVANCEMENT		IBER OF PAYLOAD	s
5.	TECHNICAL BENEFITS Demagnetization of rar	<u>ce earth salt</u>	BER OF PAYLOAD	S
5.	TECHNICAL BENEFITS <u>Demagnetization of rar</u> efficiencies approaching Carnot efficier	ce earth salt ncy. Many ex	BER OF PAYLOAD	S
5.	TECHNICAL BENEFITS Demagnetization of rar	ce earth salt ncy. Many ex	BER OF PAYLOAD	S
5.	TECHNICAL BENEFITS <u>Demagnetization of rar</u> efficiencies approaching Carnot efficier	ce earth salt ncy. Many ex	BER OF PAYLOAD	S
5.	TECHNICAL BENEFITS <u>Demagnetization of rar</u> efficiencies approaching Carnot efficier require temperatures in the 4-20°K range	re earth salt ncy. Many ex 2.	BER OF PAYLOAD potentially periments and	S offer detectors
5.	TECHNICAL BENEFITS <u>Demagnetization of rar</u> efficiencies approaching Carnot efficier	re earth salt ncy. Many ex 2.	BER OF PAYLOAD potentially periments and	S offer detectors
5.	TECHNICAL BENEFITS <u>Demagnetization of rar</u> efficiencies approaching Carnot efficier require temperatures in the 4-20°K range	re earth salt ncy. Many ex 2.	BER OF PAYLOAD potentially periments and	S offer detectors
5.	TECHNICAL BENEFITS Demagnetization of ran efficiencies approaching Carnot efficien require temperatures in the 4-20°K range POTENTIAL COST BENEFITS Increased efficie	re earth salt ncy. Many ex 2.	BER OF PAYLOAD potentially periments and	S offer detectors
5.	TECHNICAL BENEFITS Demagnetization of ran efficiencies approaching Carnot efficien require temperatures in the 4-20°K range POTENTIAL COST BENEFITS Increased efficie	re earth salt ncy. Many ex e. ency results	BER OF PAYLOAD	S offer detectors
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	TECHNICAL BENEFITS Demagnetization of rame efficiencies approaching Carnot efficience require temperatures in the 4-20°K range POTENTIAL COST BENEFITS Increased efficience requirements. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Technique has only be near room temperature. Investigation of	re earth salt ncy. Many ex a. ency results ESTIMATED Co een demonstra	BER OF PAYLOAD spotentially periments and in lower power OST SAVINGS \$ ted in the labor material with (	S offer detectors  Dratory
	TECHNICAL BENEFITS Demagnetization of ran efficiencies approaching Carnot efficience require temperatures in the 4-20°K range POTENTIAL COST BENEFITS Increased efficience requirements. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Technique has only be	re earth salt ncy. Many ex a. ency results ESTIMATED Co een demonstra	BER OF PAYLOAD spotentially periments and in lower power OST SAVINGS \$ ted in the labor material with (	S offer detectors  Dratory
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6.	TECHNICAL BENEFITS Demagnetization of rame efficiencies approaching Carnot efficience require temperatures in the 4-20°K range POTENTIAL COST BENEFITS Increased efficience requirements. RISK IN TECHNOLOGY ADVANCEMENT TECHNICAL PROBLEMS Technique has only be near room temperature. Investigation of Points between room temperature and 4°K	ency results <b>ESTIMATED Co</b> ency demonstra additional n must be comp.	BER OF PAYLOAD spotentially periments and in lower power OST SAVINGS \$ ted in the lab material with ( leted.	S offer detectors detectors Dratory Curie
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PGINTING       STABILITY       DATA         DRIENTATION       CREW:       NO.       OPERATIONS/DURATION       /         SPECIAL GROUND FACILITIES:	TITLE										NO PAGE		2
TEST DESCRIPTION :       ALT. (max/min)       /km, INCL.       deg, TIMEh         BENEFIT OF SPACE TEST:		CON	PARIS	ON OF SPA	CE & (	GROUND 1	EST	OPTIC	ONS				•
BENEFIT OF SPACE TEST:	8. SPACE TEST	OPTION		TEST ARTIC	:LE:								
EQUIPMENT:       WEIGHTK, SIZEXDATADATADATADATA	TEST DESCRIPTI	ON :	ALT. (m	nax/min)	(	I	, km, IN	ICL			deg, TIMI	E	hr
PGINTING       STABILITY       DATA         DRIENTATION       CREW:       NO.       OPERATIONS/DURATION       /         SPECIAL GROUND FACILITIES:	BENEFIT OF SPA	CE TEST:											
SPECIAL GROUND FACILITIES:	PGINTING			STABIL	ITY			DA	TA				
O.       GROUND TEST OPTION       TEST ARTICLE:         TEST DESCRIPTION/REQUIREMENTS:			TIES:										
O.       GROUND TEST OPTION       TEST ARTICLE:         TEST DESCRIPTION/REQUIREMENTS:								TEST	CONFIC	DENCE			
GROUND TEST LIMITATIONS:			TIES:										
0.     SCHEDULE & COST     SPACE TEST OPTION     GROUND TEST OPTION       TASK     CY     COST (\$)     COST (\$)     COST (\$)       1.     ANAI.YSIS     COST (\$)     COST (\$)     COST (\$)       2.     DESIGN     SMFG & C/O     SMFG & C/O     SMFG & C/O       4.     TEST & EVAL     GRAND TOTAL     GRAND TOTAL       Image: test of tes	GROUND TEST L	MITATIC											
TASK       CY       COST (\$)       COST (         1. ANAI.YSIS       2. DESIGN       3. MFG & C/O       4. TEST & EVAL       4				·····			TE	ST CON	FIDEN	CE			
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## APPENDIX C

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### APPENDIX C

RELATED TECHNOLOGIES NOT EVALUATED BY THERMAL WORKING GROUP

The Thermal Control Working Group addressed its considerations to the technology matrix in the Outlook for Space -A Forecast of Space Technology final draft of July 13, 1975. The storing of matter (See Ref. 3 and Figure C-1) in this matrix specifically refers to temperature control, radiation control, meteoroid protection, life support systems and containment of pressurized fluids as parameters of maintenance of state (survival). The Working Group emphasized only the thermal control area since this represented its basic technological capability; however, it did assess other areas, such as radiation, to the extent that they impact thermal control devices (for example, radiation damage to thermal control coatings). In the Working Group's deliberations, cryogenics, contamination, and spacecraft charging were added to the storing of matter matrix block. It was recognized that still other related areas are of importance to NASA although these were not considered in any detail. Included were environmental design, criteria and thermal vacuum testing. This appendix is dedicated to these areas, other than thermal control, which this working group deems important for OAST to consider, particularly in view of currently declining support for such areas.

CONTAMINATION--Contamination technology includes prediction, sources, transport mechanisms, constituent

identification, active and passive protection, and effects. An ultimate objective is the development of contamination monitors, etc. Currently contamination monitoring devices are supported by OMSF whereas a logical program fulfilling OAST responsibilities would indicate that OAST have this responsibility.

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OAST provided through FY 74, the R & T base for NASA's contamination effort. OAST support has declined in the past three years from a three-center program of substantial magnitude to a very limited effort at MSFC in FY 74. OAST's R & T base program was terminated in FY 75. LDEF is considering several experiments on contamination; however, there is currently no program office to advocate these potential experiments. RADIATION EFFECTS--Basic R & T on high energy radiation at the Langley Research Center is NASA's only base effort in this area. It supports applied dosimetry and shielding design studies in OMSF relative to shuttle, etc., in aviation safety relative to high flying aircraft, and in the life sciences area. In the area of radiation, there is still need for definition of natural environments (e.g., for Jupiter) and for transport analysis.

FY 76 funding for continuation of this Langley activity on radiation has not been determined. OAST is

considering which OAST office will support it, if indeed it is determined that OAST should support it. The Thermal Control Working Group recognized the potential hazards of high energy radiation to thermal control coatings, insulation, etc., but did not consider it within its scope to propose space experiments on basic radiation effects. LDEF is currently assessing radiation experiments; however, an OAST program office will be required to advocate such experiments.

METEOROID PROTECTION--OAST has, in the past decade, conducted extensive R & T on meteoroid environments and structural protection of spacecraft from micro-meteoroid impact. The MTS (Meteoroid Technology Satellite) flight program essentially completed OAST's R & T in this area in FY 74.

For the past two years OAST emphasis has been focused on space debris and its hazards, particularly to earth orbital spacecraft. Because of limitations of ground based radar to resolve the debris population in earth orbital environments, a space flight experiment has been proposed and rejected. It is not now possible to fly such a space debris experiment to provide input for early shuttle flights.

The Thermal Control Working G oup did not consider potential shuttle payload experiments on space debris.

The TC Working Group did discuss the need for micrometeoroid studies in the planet Saturn environment but did not address the potential for flight experiments. LDEF is considering experiments on micrometeoroids and space debris.

ENVIRONMENTAL DESIGN CRITERIA--The objective of this program is to provide current and future missions with up-to-date knowledge of the space environment including planetary environment for use in design of spacecraft and missions. The value of this program has been attested to by numerous spacecraft and mission designers.

OAST supported a major program in this area which reached a climax in FY 71. Since that time a threecenter activity has declined to a clean-up action by GSFC in FY 75. The program is not being supported in FY 76. Consequently, previous monographs on space environmental design criteria are not being updated and no new monographs are being initiated.

The Thermal Control Working Group considered this subject only briefly, insofar as it refers to the understanding of the natural environment of space. In the future it appears that the collection and evaluation of such data will be the responsibility of each mission project manager.

THERMAL VACUUM TESTING--Ground based facilities can provide knowledge of materials and equipment operations in space. These space simulation facilities provide the basis by which decisions requiring space verification are made.

OAST has provided extensive facilities to perform such studies in the past. In FY 72 this major thermal vacuum testing program was terminated. Although most facilities are still intact, the availability of these facilities for studies of materials and devices is uncertain. For one thing, the up-grading of these facilities to meet current requirements is not being done to

the knowledge of the Thermal Control Working Group. If OAST is to provide the NASA R & T needed by OSS, OA, and OMSF, then areas such as those described herein should not be terminated without serious assessment of potential future requirements.

### REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

THERMAL CONTROL SCOPE

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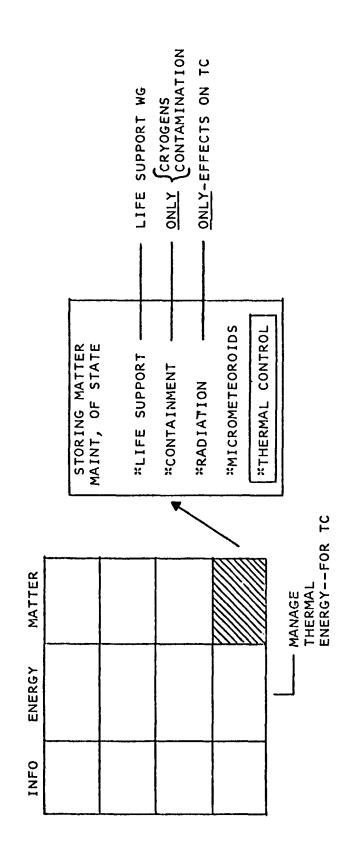
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