N87-21144

SPACE STATION EXPERIMENT DEFINITION: LONG TERM CRYOGENIC FLUID STORAGE

David H. Riemer
Beech Aircraft Corporation
Boulder, Colorado

A preliminary design of an experiment to demonstrate and evaluate long-term cryogenic fluid storage and transfer technologies has been performed. This Long-Term Cryogenic Fluid Storage (LTCFS) experiment is a Technology Development Mission (TDM) experiment proposed by the NASA Lewis Research Center to be deployed on the Initial Operational Capability (IOC) Space Station. Technologies required by future orbital cryogenic systems such as Orbital Transfer Vehicles (OTV's) were defined, and critical technologies requiring demonstration were chosen to be included in the experiment. A three-phase test program was defined to test the following types of technologies:

Phase I - Passive Thermal Technologies
Phase II - Fluid Transfer Technologies
Phase III - Active Refrigeration Technologies

The development status of advanced technologies required for the LTCFS experiment is summarized, including current, past and future programs.

LTCFS STUDY OBJECTIVES

A Technology Development Mission (TDM) experiment was defined by the NASA Lewis Research Center to demonstrate and evaluate long-term cryogenic fluid storage and transfer technologies. The Long-Term Cryogenic Fluid Storage (LTCFS) experiment is to be deployed on the Initial Operational Capability (IOC) Space Station. Cryogenic technologies required by future orbital systems were investigated, and critical technologies required by these systems were chosen for inclusion in the experiment. A conceptual design for this experiment was developed, and Space Station interface and resource requirements were defined and entered into the NASA Space Station data base. An overall program plan for hardware development and on-orbit testing was completed, including Rough-Order-of-Magnitude (ROM) costing. The overall study objectives are as follows:

- o DEFINE THE REQUIREMENTS FOR A CRYOGENIC FLUID STORAGE AND TRANSFER EXPERIMENT IN THE FORM OF A SPACE STATION TECHNOLOGY DEVELOPMENT MISSION (TDM) SO THAT SPACE STATION DESIGN DEVELOPMENT EFFORTS WILL MEET FUTURE PROGRAM NEEDS

- o IDENTIFY CRITICAL CRYOGENIC FLUID MANAGEMENT TECHNOLOGIES THAT REQUIRE EVALUATION WITH NASA LERC'S PROPOSED TDM

- o DEVELOP A CONCEPTUAL EXPERIMENT DESIGN FOR THE TDM WHICH ACCOMMODATES THE TECHNOLOGY DEMONSTRATION OBJECTIVES IN A TIMELY MANNER

- o DEFINE AND DOCUMENT THE SPACE STATION INTERFACE AND RESOURCE REQUIREMENTS NECESSARY TO SUPPORT THE TDM

- o PREPARE A PLAN FOR THE OVERALL PROGRAM FROM HARDWARE DEVELOPMENT THROUGH EXPERIMENT COMPLETION

LTCFS EXPERIMENT DESCRIPTION

The conceptual design of the LTCFS experiment is modular, allowing testing to be performed in the three phases described below. The modularity of the experiment allows for maximum flexibility in experiment development and scheduling. Over the four-year experiment period, modules will be added to the initial configuration to perform additional testing. This modularity also allows a wide range of potential future uses of the experiment after experiment termination.

- o THE LONG TERM CRYOGENIC FLUID STORAGE EXPERIMENT IS MODULAR, CONSISTING OF THREE PHASES TO TEST THE FOLLOWING TECHNOLOGIES:

  PHASE I - PASSIVE THERMAL TECHNOLOGIES
  PHASE II - FLUID TRANSFER TECHNOLOGIES
  PHASE III - ACTIVE REFRIGERATION TECHNOLOGIES

- o THE EXPERIMENT WILL BE DEPLOYED ON THE IOC SPACE STATION FOR A PERIOD OF FOUR YEARS

- o MODULES WILL BE ADDED TO THE PHASE I HARDWARE TO RECONFIGURE THE EXPERIMENT FOR PHASE II AND III TESTING

- o THE LTCFS EXPERIMENT COULD BE UTILIZED FOR FURTHER ORBITAL TESTING OR FOR SPACE STATION CRYOGENIC STORAGE AFTER TERMINATION OF PHASE I-III TESTING

PHASE I DESCRIPTION

Phase I of the experiment, depicted in Figure 1, will test passive thermal control technologies that are utilized to achieve long term storage of cryogens. The Phase I hardware consists of a 6.5 m^3 (228 ft^3) liquid hydrogen dewar supported in a structure that will be mounted to the Space Station truss structure. The experiment dewar will utilize numerous advanced technologies, such as dual stage supports and a thick multi-layer insulation blanket that allows long term storage of the cryogen. The tank will be instrumented to allow on-orbit thermal performance of the tank to be evaluated. Phase I testing will last for a period of two years.

PHASE I - EXPERIMENT CONFIGURATION

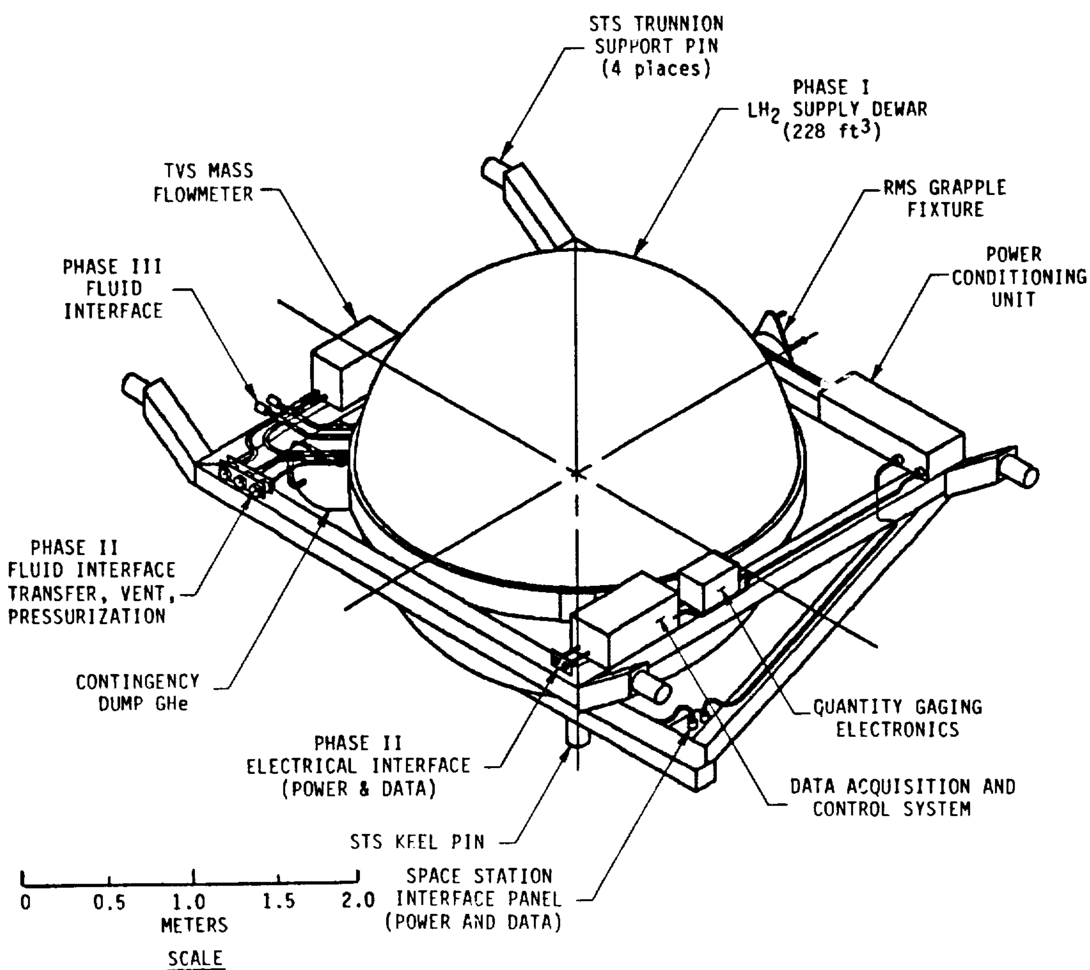

Figure 1

PHASE I - TECHNOLOGY DEMONSTRATIONS AND DEVELOPMENT STATUS

The technologies listed below are those advanced technologies required in Phase I that are not yet fully developed for flight. The development status of these technologies is outlined, including any current or future ground and flight development.

TECHNOLOGY	DEVELOPMENT STATUS
DUAL STAGE SUPPORT	LOCKHEED - PODS DESIGN DEVELOPMENT AND HARDWARE TESTING BALL - RITS - DESIGN DEVELOPMENT ONLY
PARA-ORTHO H_2 CONVERSION	GROUND DEMONSTRATIONS ONLY (LOCKHEED, BEECH AIRCRAFT)
THICK MLI	CFMFE, AIR FORCE RPL
THERMODYNAMIC VENT SYSTEM	CFMFE, SHUTTLE PRSA TANKS (VAPOR COOLED SHIELDS ONLY)
STRATIFICATION CONTROL	CFMFE, CENTAUR
THERMAL CONTROL COATINGS/ DEGRADATION	LONG DURATION EXPOSURE FACILITY (LDEF) PLUS NUMEROUS SATELLITES AND MANNED SPACEFLIGHT APPLICATIONS

TECHNOLOGY ISSUES	
LOW-G LONG-TERM STRATIFICATION	NO CURRENT PROGRAMS
MICRO-METEROID PROTECTION	GROUND TESTING HAS BEEN PERFORMED (BOEING)

PHASE II DESCRIPTION

Phase II of the LTCFS experiment, depicted in Figure 2, will test fluid transfer technologies. The experiment is reconfigured by adding a module containing a receiver tank and pressurization system to the Phase I hardware. The receiver tank is a 1.3 m^3 (45 ft^3) soft outer shell tank containing spray nozzles for tank cooldown and a screen acquisition device to allow backflow into the Phase I supply dewar. The pressurization system utilizes a metal hydride compressor that collects boiloff from the supply and receiver tanks, and stores it in a 0.6 m^3 (21 ft^3), 3.4 mPa (500 psia) pressurant accumulator. When the accumulator is fully charged, a transfer operation from the supply tank to the receiver tank is performed. The thermal performance of the receiver tank will also be evaluated during Phase II. Phase II testing will be performed for a period of one year.

PHASE II EXPERIMENT CONFIGURATION

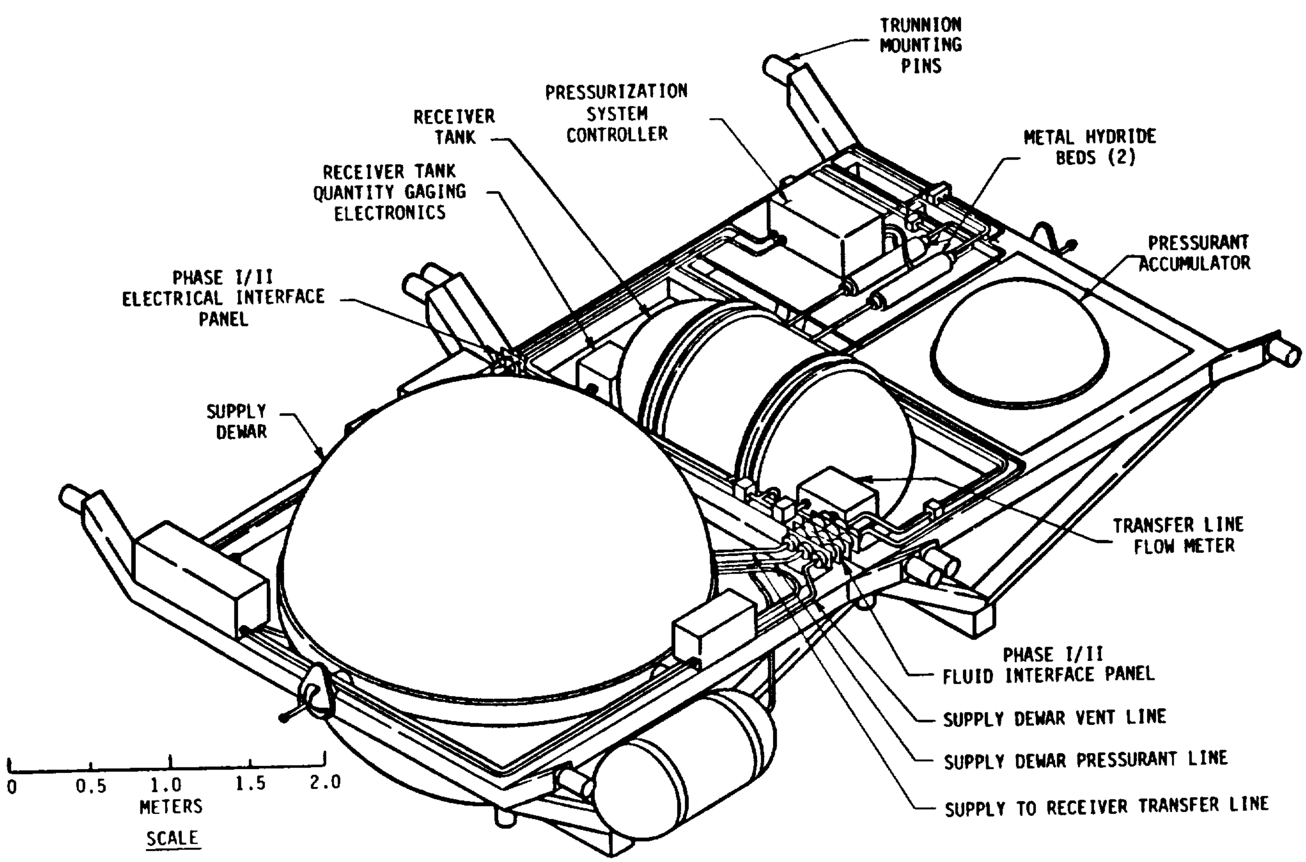

Figure 2

PHASE II - TECHNOLOGY DEMONSTRATIONS AND DEVELOPMENT STATUS

The technologies listed below are those advanced technologies required in Phase II that are not yet fully developed for flight. The development status of these technologies is outlined, including any current or future ground and flight development.

TECHNOLOGY DEMONSTRATED	DEVELOPMENT STATUS/PROGRAMS
CAPILLARY ACQUISITION	CFMFE
QUANTITY GAGING	CFMFE, NASA-JSC RF GAGING (NO FLIGHT TESTING)
MASS FLOW METERS	CFMFE
LOW HEAT LEAK VALVES	GROUND DEVELOPMENT
LOW HEAT LEAK TRANSFER LINES	GROUND DEVELOPMENT
CRYOGENIC DISCONNECTS	GROUND DEVELOPMENT, ORBITAL REFUELING DISCONNECT FOR EARTH-STORABLE FLUIDS UNDER DEVELOPMENT (JSC)
BOILOFF COLLECTION FOR EXTERNAL PRESSURIZATION	CONCEPTUAL DESIGN ONLY
METAL HYDRIDE COMPRESSOR	GROUND DEVELOPMENT
SOFT OUTER SHELL TANK	SEVERAL GROUND TESTS, CFMFE
SOFT OUTER SHELL PERFORMANCE DEGRADATION	NO CURRENT PROGRAMS

PHASE III DESCRIPTION

Phase III of the experiment, depicted in Figure 3, will test active refrigeration technologies. The experiment is reconfigured by interfacing an active refrigeration unit with the Phase I supply dewar. This refrigeration unit will circulate coolant through a parallel path within the supply dewar's thermodynamic vent system to provide refrigeration to the tank and reduce or eliminate tank boiloff. The Phase III module will utilize a high reliability, long-lifetime cryogenic refrigerator.

PHASE III EXPERIMENT CONFIGURATION

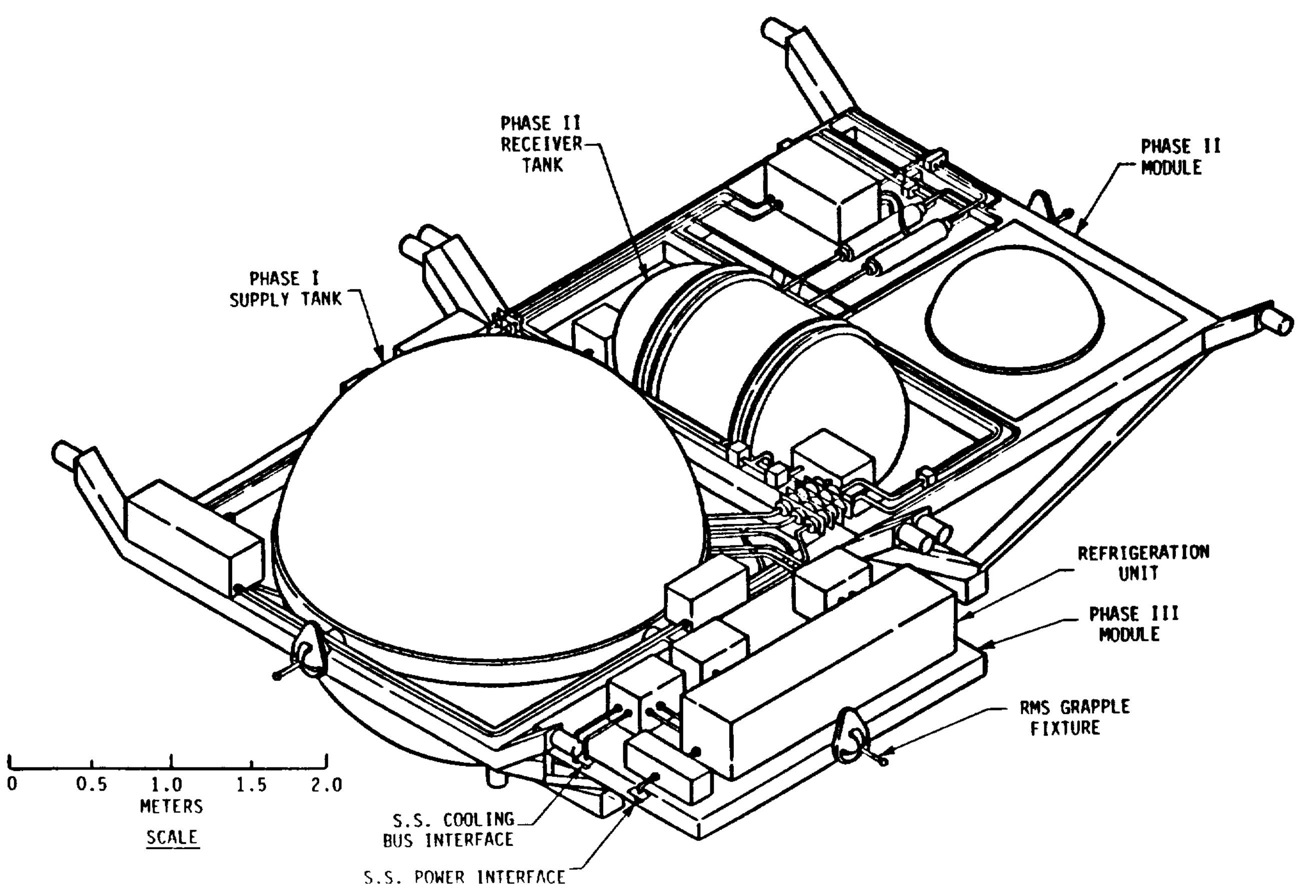

Figure 3

PHASE III – TECHNOLOGY DEMONSTRATIONS AND DEVELOPMENT STATUS

The technologies listed below are those advanced technologies required in Phase III that are not yet fully developed for flight. The development status of these technologies is outlined, including any current or future ground and flight development.

TECHNOLOGY DEMONSTRATED	DEVELOPMENT STATUS/PROGRAMS
LONG LIFETIME REFRIGERATOR	NUMEROUS GROUND DEVELOPMENT PROGRAMS: NASA - PHILLIPS MAGNETIC STIRLING - OXFORD SPLIT STIRLING CYCLE AIR FORCE - VUILLEUMIER - SORPTION REFRIGERATOR - MAGNETIC REFRIGERATOR - BRAYTON CYCLE
CRYOGENIC COOLANT CIRCULATOR	NO CURRENT DEVELOPMENT
CRYOGENIC HEAT EXCHANGER	UNITS ARE BEING DEVELOPED FOR BRAYTON CYCLE REFRIGERATOR

TECHNOLOGY HARDWARE MATRIX

The table shown below lists the advanced technologies required by Orbital Transfer Vehicle (OTV) cryogenic systems. All technologies listed require some amount of future development or flight testing prior to utilization. These requirements are outlined for the Resupply Tanker that delivers propellant to low-earth orbit, the Space Station Tank Farm that stores the propellant prior to OTV refueling, and the OTV itself. Also listed under the heading of Future Experiments are the technologies that are to be developed and/or demonstrated by the Cryogenic Fluid Management Flight Experiment (CFMFE) and the LTCFS experiment. This summary was a result of the technology investigation performed during the design study that chose critical technologies to be included in the LTCFS experiment.

	FUTURE REQUIREMENTS			FUTURE EXPERIMENTS	
	RESUPPLY TANKER	OTV	SPACE STATION TANK FARM	CFMFE	LTCFS
PASSIVE THERMAL TECHNOLOGIES					
Dual Stage Support			X		X
Para-Ortho Conversion			X		X
Thick MLI		X	X	X	X
TVS	X	X	X	X	X
Thermal Coatings		X	X		X
Soft Outer Shell		X	X	X	X
Hard Outer Shell	X			X	X
FLUID TRANSFER					
Capillary Acquisition	X	X	X	X	X
Low-G Quantity Gaging	X		X	X	X
Mass Flow Meters	X		X	X	X
Low Heat Leak Values	X		X		X
Low Heat Leak Transfer Lines	X		X		X
Cryogenic Disconnects	X	X	X		X
External Pressurization	X	X	X		X
HPG Pressurization				X	X
Metal Hydride Compressor					X
ACTIVE REFRIGERATOR					
Long Lifetime Refrigerator			X		X
Reliquefaction			X		X
Cryogenic Heat Exchanger			X		X
Refrigerator to S.S. Thermal Bus HEX			X		X

TECHNOLOGY ISSUE MATRIX

The table shown below is identical to the previous table, but outlines technology issues involved with future orbital systems. These issues include orbital environment phenomena, fluid management, and logistics. As before, issues that will be addressed by the CFMFE and LTCFS experiment are also listed.

	FUTURE REQUIREMENTS			FUTURE EXPERIMENTS	
	RESUPPLY TANKER	OTV	SPACE STATION TANK FARM	CFMFE	LTCFS
INVESTIGATED PHENOMENA					
Long-Term Stratification Effects			X		X
Soft OS Performance Degradation		X	X		X
Thermal Coating Degradation		X	X		X
Micro-Meteroid Protection		X	X		X
FLUID MANAGEMENT					
LAD Refill		X	X	X	X
Transfer Line Cooldown	X	X	X	X	X
ET Scavenging	X				POSSIBLE
Receiver Tank Cooldown	X	X	X	X	X
Receiver No-Vent Fill		X	X	X	X
Refill of Partially Full Tank			X	X	X
Propellant Settling		X		X	
Boiloff Collection			X		X
Slosh Suppression	X	X	X		
ON-ORBIT LOGISTICS					
System Safing	X	X	X	X	X
Space Station Interfacing	X	X	X		X
Space Station Operations	X	X	X		X
On-Orbit Leak Detection	X	X	X		POSSIBLE

SUMMARY

The technologies listed below are required by the LTCFS experiment but have no current flight development scheduled. Also shown are issues and technologies for which no development testing is currently defined.

o THE FOLLOWING TECHNOLOGIES REQUIRED FOR THE LTCFS EXPERIMENT CURRENTLY HAVE NO FLIGHT DEVELOPMENT SCHEDULED:

DUAL STAGE SUPPORTS
PARA-ORTHO H_2 CONVERSION
CRYOGENIC TANK MICRO-METEROID PROTECTION
LOW HEAT LEAK VALVES
LOW HEAT LEAK TRANSFER LINES
CRYOGENIC DISCONNECTS
CRYOGENIC HEAT EXCHANGER
METAL HYDRIDE COMPRESSOR
LONG LIFETIME REFRIGERATOR

o THE FOLLOWING TECHNOLOGIES HAVE NO CURRENT OR SIGNIFICANT PAST DEVELOPMENT PROGRAMS:

LOW-G LONG TERM STRATIFICATION
SOFT OUTER SHELL PERFORMANCE DEGRADATION
BOILOFF COLLECTION FOR EXTERNAL PRESSURIZATION
CRYOGENIC COOLANT CIRCULATOR