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CRYOGENIC FLUID MANAGEMENT FLIGHT EXPERIMENT (CFMFE)

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Since its foundation, NASA has excelled in the study and development of microgravity fluid management technology. With the advent of space-based vehicles and systems, the use of and the ability to efficiently manage subcritical cryogens in the space environment has become necessary to our growing space program. The NASA Lewis Research Center is responsible for the planning and execution of a program which will provide advanced in-space cryogenic fluid management technology. A number of future space missions have been identified that will require or could benefit from this technology. These technology needs have been prioritized and the Cryogenic Fluid Management Flight Experiment (CFMFE) is being designed to provide the experimental data necessary for the technological development effort.

SPACE EXPERIMENTATION REQUIRED

For over twenty years NASA Lewis Research Center has been conducting ground-based testing to characterize microgravity fluid management behavior. Many papers resulting from this work, as well as from contractor studies, have been written describing state-of-the-art cryogenic fluid management as well as the future needs of the space program. Because of the strong influence of gravitational fields on the thermophysical processes associated with the technology and the limitations of ground-based testing, in-space experiments are required.

IN-SPACE EXPERIMENTATION DRIVERS

- o Fluid dynamic/heat transfer processes are strongly dependent on gravitational environment
- o Most controlling processes cannot be adequately simulated in normal gravity testing
- o Most feasibile ground-based testing has been completed
- o Low gravity testing in drop towers/aircraft has been limited to small tanks and short test durations

IN-SPACE EXPERIMENTS ARE REQUIRED TO CHARACTERIZE GOVERNING THERMOPHYSICAL PROCESSES IN LARGE FLIGHT SYSTEMS

Table 1

Recognizing the need to go to space to properly characterize the processes of cryogenic fluid management, the approach shown in Table 2 was developed. NASA LeRC has been developing analytical models to characterize a complete cryogenic fluid management system. The three CFMFE missions will provide the parametric data needed to verify these models which will become design tools for future cryogenic systems.

CFMFE APPROACH

Design, build, and carry into space a reusable test bed to provide the technology required to manage subcritical cryogens in space.

- o Conduct experiments in space to verify low-g fluid and thermal analytical models
- o Use verified models to establish design criteria for subcritical cryogenic systems in space
- o Use liquid hydrogen as test fluid
- o Design for seven Shuttle flights (current mission planning for three flights)
- o Utilize available expertise at LeRC, MSFC, JSC, KSC, ARC, JPL

Table 2

CFMFE Description

The preliminary design and mission planning for three flights of the CFMFE have been developed by Martin Marietta Denver Aerospace under contract to LeRC. The CFMFE is a Shuttle-attached, reusable test bed which will have a quarter payload bay allocation. It will be carried on a standard MDM pallet which interfaces with the Shuttle systems. The CFMFE (shown in Figure 1) is comprised of five major elements: 1) a cryogenic liquid storage and supply system, 2) a fluid transfer line and receiver tank, 3) a high pressure gas pressurization system, 4) the supporting structure including a subpallet which is attached to the MDM pallet, and 5) a facility control and data acquisition system.

Liquid hydrogen has been selected as the CFMFE experimental fluid because of its prominent planned use for future NASA and DOD missions. In addition, liquid hydrogen presents challenging in-space fluid management requirements due to its low temperature, density and suface tension properties. Obtaining low-g storage, supply, and transfer data for hydrogen will, therefore, have general applicability to other cryogenic fluids, with the exception of liquid helium.

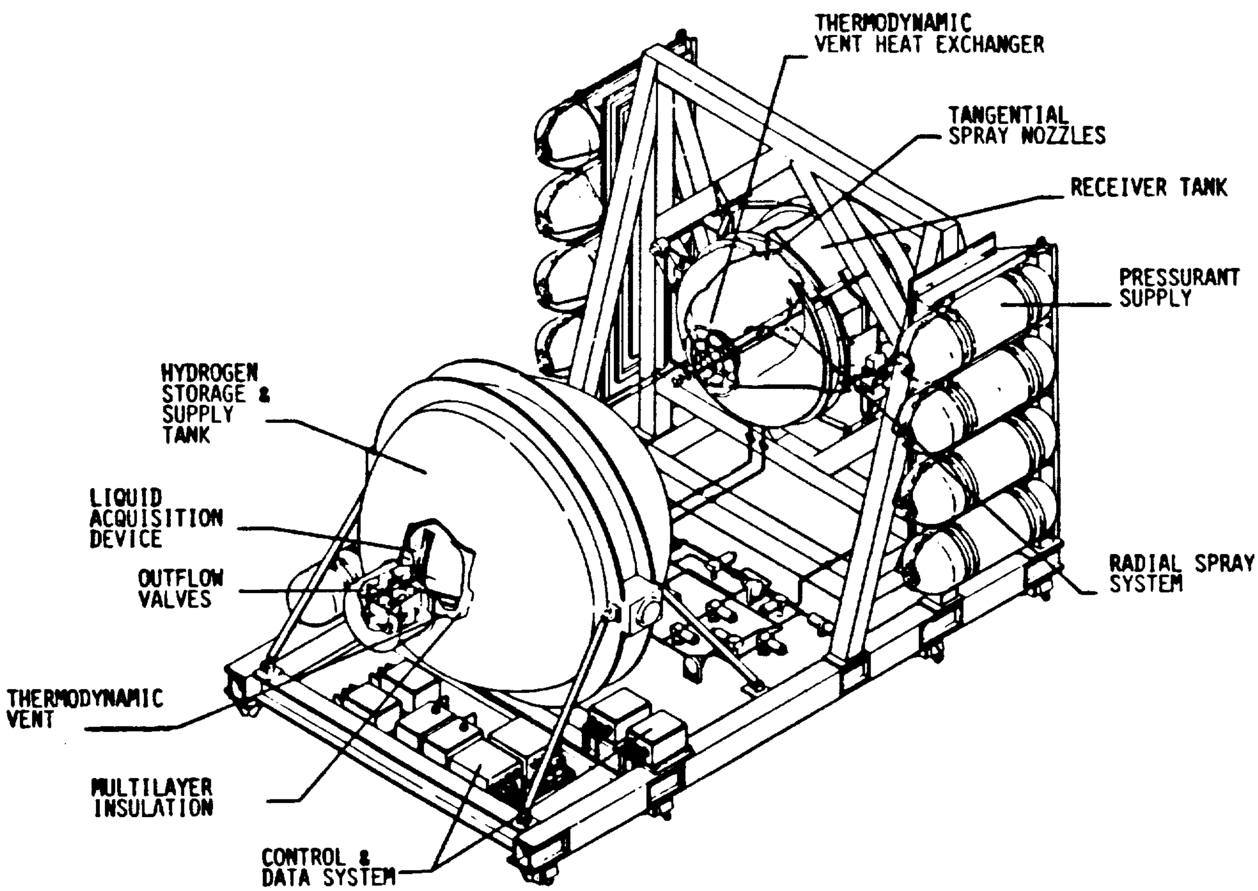

Figure 1 CFMFE Subpallet

The cryogenic fluid management technologies selected for investigation on the CFMFE are listed in Table 3. Each technical objective has been assigned a technical priority for each of the three missions. The priorities were assigned on the basis of their impact on future NASA and DOD missions and on the necessity to conduct experimentation in the space environment. These priorities will be used to determine the amount of dedicated instrumentation required to achieve each objective and the amount of parametric variation required.

CFMFE EXPERIMENTAL OBJECTIVES

	TECHNICAL PRIORITY BY MISSION I	II	III
I. Liquid Storage			
A. Storage tank thermal performance characterization	2	2	2
B. Receiver tank thermal performance characterization	3	3	3
C. Pressure control via Thermodynamic Vent Systems	2	2	2
II. Liquid Supply			
A. Pressurization			
1. Gaseous helium	2	2	2
2. Autogenous (GH_2)	2	N/A	2
B. Acquisition/Expulsion			
1. Receiver tank direct liquid outflow with low-g settling	2	2	N/A
2. Total communication capillary Liquid Acquisition Device (LAD) performance	2	2	2
3. Partial communication capillary LAD (start basket) performance	N/A	N/A	2
III. Fluid Transfer			
A. Transfer line chilldown	2	2	2
B. Thermal conditioning of liquid outflow	2	2	2
C. Receiver tank			
1. Chilldown with spray	1	1	1
2. No-vent fill	1	1	1
3. Venting of noncondensible gas	2	N/A	N/A
4. No-vent refill	1	N/A	N/A
5. Start basket fill	N/A	N/A	2
D. Supply tank			
1. No-vent refill including LAD	1	N/A	N/A
2 . No-vent fill including LAD	N/A	1	2
E. Quantity gauging instrumentation	3	3	3

Table 3

The CFMFE design provides the development of on-orbit cryogenic fluid storage, supply, and transfer applicable to several fluids and a variety of space systems. Table 4 (shown below) lists some of the potential applications of this technology.

POTENTIAL APPLICATIONS

- o Earth-to-orbit transport and in-space storage of cryogenic liquids
- o On-orbit fueling of propulsive stages
- o Space Station subsystem fluid replenishment
- o Experiment and satellite fluid resupply
- o Resupply of space-based SDI reactants, coolants, and propellants

Table 4

Schedule

The CFMFE Master Schedule for the three missions currently being planned is shown in Figure 2 (below). The project is proceeding per this schedule; however, the actual launch dates may be affected by the new Shuttle manifest plan which is itself dependent on the actual data of the resumption of Shuttle operations.

CFMFE MASTER SCHEDULE

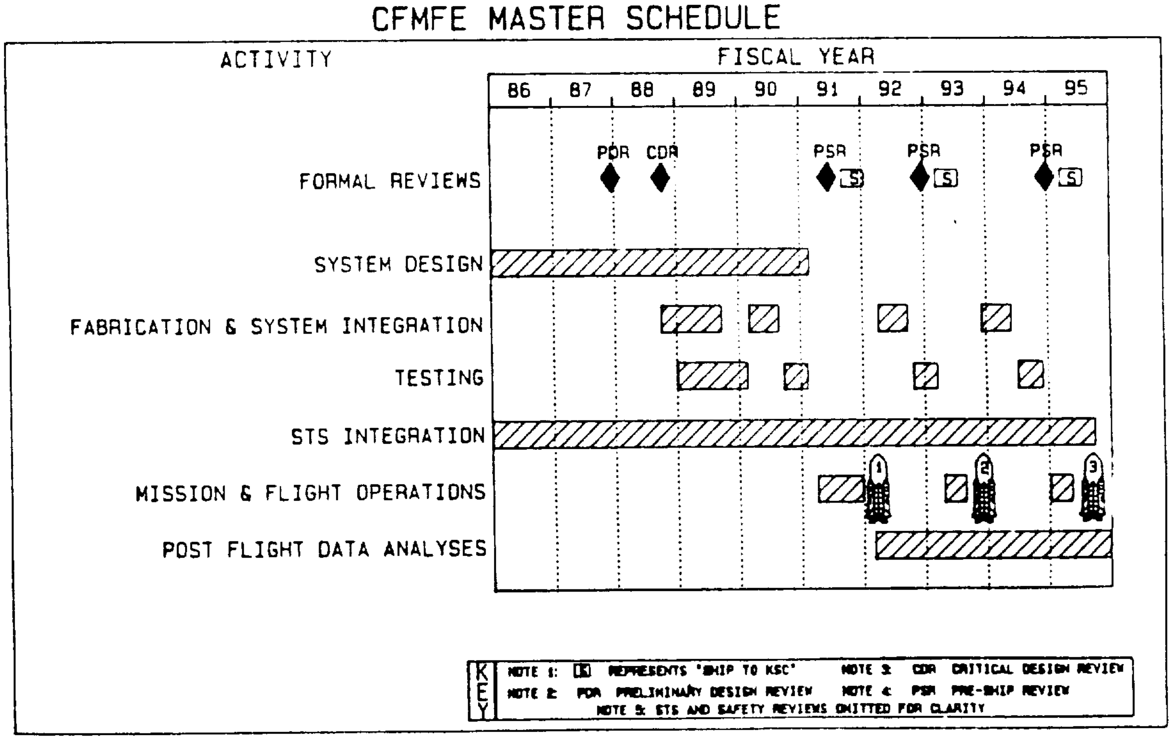

Figure 2