N87-21158

SHUTTLE MIDDECK FLUID TRANSFER EXPERIMENT - LESSONS LEARNED

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This presentation is based on the experience gained from having integrated and flown a shuttle middeck experiment. The experiment, which demonstrated filling, expulsion, and fluid behavior of a liquid storage system under low-gravity conditions, is briefly described. The advantages and disadvantages of middeck payloads compared to other shuttle payload provisions are discussed. A general approach to the integration process is described. The requirements for the shuttle interfaces--such as structures, pressurized systems, materials, instrumentation, and electrical power--are defined and the approach that was used to satisfy these requirements is presented. Currently the middeck experiment is being used as a test bed for the development of various space fluid system components.

A shuttle middeck experiment that was flown provided first-hand experience regarding the integration and operations process. Selection of the experiment concept and definition of the design parameters had to be carefully tailored to the integration and safety requirements. The experiment was very successful, with no hardware problems being experienced during the flight operations. All objectives were achieved, providing valuable data on fluid behavior under low-gravity conditions (Refs 1 and 2).

INTRODUCTION

Presentation is based on experience gained from Storable Fluid Management Demonstration (SFMD).

- o Shuttle middeck secondary payload
- o Experiment operated flawlessly on STS Mission 51-C, January 1985
- o Joint endeavor among Martin Marietta, NASA, and USAF
- o Objectives successfully achieved:
  1) Low-g refill of tank
  2) Low-g expulsion of tank
  3) Low-g fluid behavior

Figure 1

The ways in which the Shuttle Orbiter can carry payloads into orbit are listed below. Selection of the mode for a given payload is dependent upon a number of factors.

Concentrating on middeck payloads, their limits are defined below. The advantages and disadvantages of middeck payloads are listed. The suitability of a middeck payload in achieving the experiment objectives must be evaluated.

PAYLOAD CONSIDERATIONS

o TYPES OF PAYLOADS

MIDDECK:
- Carried in locker
- Installed in lieu of lockers

PAYLOAD BAY:
- Get Away Special
- Installed on truss, pallet, etc.
- Spacelab

o STANDARD MIDDECK PAYLOAD

Less than 3 locker volumes
Less than 130 pounds
Electrical power limits
Passive cooling

o MIDDECK PAYLOAD IN LIEU OF LOCKERS

ADVANTAGES

Direct astronaut involvement
- Operation, monitoring, contingency
Simple structural interface
Cost effective
Available data acquisition

DISADVANTAGES

Limited weight and size
Limits on flight opportunities
- Priorities, size of crew, crew time
Constraints on test liquids

Figure 2

After the shuttle interface and safety requirements are understood, an approach to verifying that the payload satisfies these requirements should be defined. Safety reviews and design reviews will establish the suitability of the approach. Safety is the prime concern.

INTEGRATION APPROACH

- o Interface Control Document (Ref. 3) and Shuttle Safety Documents define requirements imposed on payload
- o Payload design and verification plan establishes how requirements are met
- o Safety reviews verify that approach adequately satisfies safety requirements
- o Payload functioning and reliability is responsibility of payload organization

Figure 3

The safe design of pressurized systems requires that worst-case operating conditions be defined and the proper design margins be selected. The approach used for the transparent plastic tanks and the plumbing system of the SFMD is presented here.

FLUID SYSTEM DESIGN

MOP - Maximum operating pressure (pressure at which the system actually operates)

MAWP - Maximum allowable working pressure (a worst-case condition)

- Pressure Vessels - no fracture control

  Proof Pressure - 1.6 x MAWP
  Burst Pressure - 4 x MAWP
  Collapse Pressure - 2 x MOP
  Pressure Cycles - 1.5 x MOP applied 2 times maximum number of cycles

  Compensate test pressures for maximum temperature when performing room temperature test

- Lines and Fittings

  Diameter less than 1.5 inch - ultimate safety factor of 4
  Diameter greater than 1.5 inch - ultimate safety factor of 1.5

Figure 4

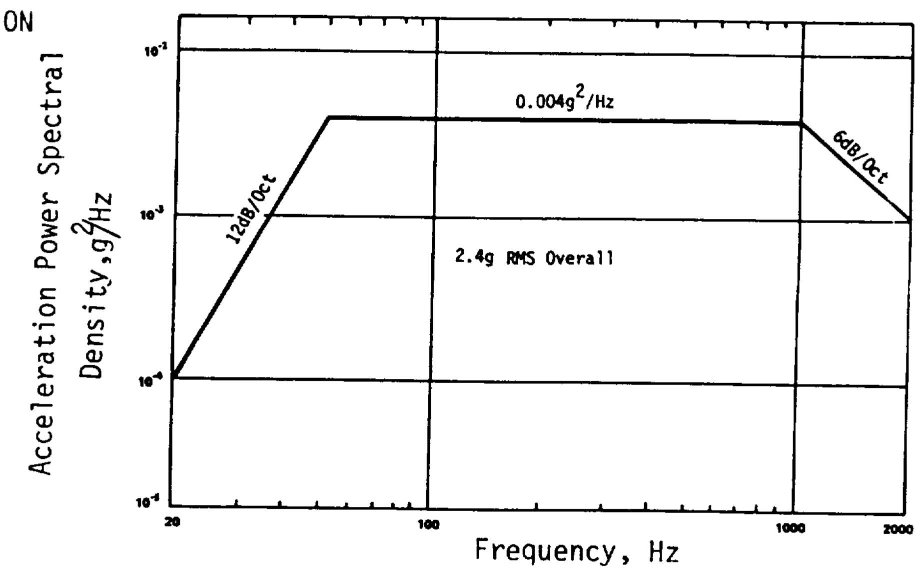
Steady and vibrational loads were combined to produce the load factors in the table below. The random vibration environment was specifically derived from measurements in the middeck area. These qualification levels are applied for one minute in all three axes. Structural design proceeds from these requirements and the factors of safety listed below.

STRUCTURAL DESIGN

o LOADS

Event	Load Factor (g)		
	X	Y	Z
Lift-off	+2.4/-5.6	± 2.0	± 5.5
Landing	± 7.5	± 4.0	+12.0/-10.0
Emergency Landing	+20.0/-3.3	± 3.3	+10.0/-4.4

o RANDOM VIBRATION



o FACTORS OF SAFETY

Yield - 1.6 times limit load
Ultimate - 2.25 times limit load

Figure 5

Selection of materials must consider their safety related properties: toxicity, off-gassing, flammability, hazardous debris (e.g., broken glass), etc. Materials certification is required unless off-gassing tests are performed. The same requirements apply to test fluids.

MATERIALS

o Metals and Non-Metals

Select approved materials from references such as: JSC 02681, Non-metallic Materials Design Guidelines and Test Data Handbook or, perform off-gassing test of selected materials

o Test Liquids

Water is preferred (for example, allowable concentration of Freon 113 in cabin air is 50 ppm)

o Pressurant Gas

Air is preferred

Figure 6

For middeck experiments, Orbiter standard equipment can be used for the acquisition of data. Still cameras, movie cameras, and video recording equipment are available. Video recording is effective since a sound track and time can be combined with the scene and data quality can be verified while it is being recorded. Photo lights are also available.

The SFMD used mechanical gauges to record pressure and temperature. A built-in lighting system and flowmeter with digital readout are being incorporated.

INSTRUMENTATION AND DATA

o Standard Orbiter Equipment

Video cameras - combine voice annotation and time with video

Lighting - standard equipment available

o SFMD Instrumentation

Pressure gauges
Thermometer
Sight flow indicator
Flowmeter

Figure 7

Up to 5 amps of DC power is available in the middeck for payload use. Payload must provide connector to interface with Orbiter provided cable. Interface requirements include proper electrical design and fusing, and the electromagnetic compatibility requirements listed below.

The SFMD used no Orbiter power on its first flight. The lighting system now being incorporated introduced many complications, e.g., EMI filtering, heat dissipation, and flight qualified electrical component procurement.

ELECTRICAL POWER

o DC power available for payloads

  Maximum of 5 amps
  On-orbit use only

o Electromagnetic Compatibility

  Susceptibility
  Conducted emissions
  Radiated emissions
  Magnetic field
  Switching transient

o Electrical Bonding

Figure 8

Having flown once, the SFMD is a fully integrated and proven middeck payload. Plans for the continued use of the SFMD, through refurbishment and reverification as required, have been implemented. Within certain limitations, the SFMD can accommodate various tank shapes and components for development testing of fluid storage systems. A document defining how the SFMD may be used for such testing is available.

USE OF SFMD AS TEST BED

o Fully integrated and flight proven test bed for space fluid storage system development

o New experiments can be installed with well defined interfaces

  Interface at wall of previously qualified tank
  Interface of new tank with mounting flange

o SFMD Interface Control Document available

Figure 9

In summary, this presentation has discussed how a middeck payload is an effective means of performing experiments in space. An approach of developing an understanding of interface requirements while preparing a verification plan for the payload was found to be successful. It is important to begin coordinating safety concerns, Orbiter equipment requirements, and crew involvement as early as possible.

SUMMARY

- o Orbiter middeck payloads are an effective way of performing experiments on the Space Shuttle
- o Obtain a thorough understanding of interface requirements and define experiment verification approach
- o Begin coordinating integration early in program

Figure 10

References

1. Z. Kirkland and J. Tegart: On-Orbit Propellant Resupply Demonstration. AIAA Paper 84-1342, 20th Joint Propulsion Conference, Cincinnati, OH, June 1984.

2. J. Tegart and Z. Kirkland: On-Orbit Propellant Resupply Demonstration - Flight Results. AIAA Paper 85-1233, 21st Joint Propulsion Conference, Monterey, CA, July 1985.

3. "Orbiter Middeck/Payload Standard Interfaces Control Document," ICD-2-1M001, NASA Johnson Space Center, March 1984.