TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

FLUID MANAGEMENT SYSTEM TECHNOLOGY DISCIPLINE

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FLUID MANAGEMENT SYSTEM

TECHNOLOGY DISCIPLINE SUMMARY

- CURRENT SYSTEM

  - INTEGRATED NITROGEN SYSTEM (INS)

    - LAB EXPERIMENT GAS
    - SYSTEM PRESSURIZATION GAS
    - SYSTEM MAINTENANCE PURGE GAS
    - PROVIDES EXLSS EMERGENCY ACCESS TO NITROGEN (MANUAL CONNECTION)

  - INTEGRATED WATER SYSTEM (IWS)

    - WATER TO LAB EXPERIMENTS
    - PROVIDE ECLSS DIRECT ACCESS TO SCAVENGED NSTS FUEL CELL WATER

  - INTEGRATED WASTE GAS SYSTEM (IWGS)

    - COLLECT, STORE, AND DISPOSE OF WASTE GAS BY AC

      - LAB EXPERIMENT BULK "SAFE" WASTE GASES
      - ECLSS WASTE GASES
      - SYSTEM PRESSURIZATION VENT GASES
      - SYSTEM MAINTENANCE PURGE GASES

FLUID MANAGEMENT SYSTEM

TECHNOLOGY DISCIPLINE SUMMARY

- EXPANSION OF STATION SCIENCE ACTIVITIES
  - ADDITIONAL USER FLUIID SUPPLY SERVICES
    - GASES: Kr, Ar, He, CO_2
    - CRYOGENS: He, N_2
  - INCREASED CAPACITY OF EXISTING SYSTEMS (INS, IWS, IWGS)
- TRANSPORTATION NODE
  - HANDLING OF SUBSTANTIAL QUANTITIES OF SUBCRITICAL LH_2 AND LO_2 TO SUPPORT HEI
  - EXPANSION OF EXISTING SYSTEMS (INS, IWS)
  - SERVICING OF FREE FLYERS (OMV, COP, MTFF, AXAF, ETC.)

FLUID MANAGEMENT SYSTEM

TECHNOLOGY NEEDS NOT ADEQUATELY FUNDED

- SUBCRITICAL CRYOGENIC STORAGE AND TRANSFER
- FLUID HANDLING
- COMPONENTS / INSTRUMENTATION

FLUID MANAGEMENT SYSTEM — SUBCRITICAL CRYOGENIC STORAGE AND TRANSFER

SCOPE: This technology area addresses the general in-space fluid management issues associated with:

1. Storage of subcritical cryogenic fluids in-space including thermal control systems and pressure control systems.
2. Supply of single phase liquid to an end user including liquid acquisition systems and pressurization systems.
3. Transfer of liquids from one container to another in low gravity.

OBJECTIVES:

1. To develop the technologies of storage, supply, and transfer by performing in-space experiments for the purpose of:
   a. developing an adequate experiment data base
   b. validating analytical models of the important thermal, fluid, and thermodynamic processes
   c. demonstrating components, systems, and subsystems in a relevant environment

REQUIREMENTS:

LIQUID STORAGE-Requirements exist to store cryogenic liquids in the low-gravity space environment for periods of several hours to perhaps several years while minimizing liquid boiloff and controlling tank pressure. Minimizing liquid boiloff generally requires very efficient tank thermal insulation systems, and controlling tank pressure may require liquid mixing and thermodynamic vent systems.

LIQUID SUPPLY-Requirements exist to feed single-phase cryogenic liquids from a tank in the low-gravity environment of space. This technology area typically involves studies of continuously supplying single-phase liquid to the tank outlet and pressurization gas requirements during expulsion of liquid from the tank. Preferred techniques for liquid acquisition use fine mesh screen materials as capillary devices. However, the effectiveness of such techniques with cryogenic liquids in space remains unproven. Pressurization techniques for discharging cryogens from propellant tanks were developed for rocket vehicles with high expulsion rates and have not been characterized for the low expulsion rates anticipated for low-gravity transfer operations.

FLUID MANAGEMENT SYSTEM

SUBCRITICAL CRYOGENIC STORAGE AND TRANSFER

FLUID TRANSFER-Requirements exist to transfer cryogenic liquids from one tank to another in the low-gravity environment of space. Fluid losses associated with the transfer process must be minimized, and the tank pressures must be controlled. A "thermodynamic" technique for low-gravity transfer of fluids is the recommended approach to be investigated. This technique consists of alternately chilling, with a small quantity of cryogen, and venting the tank to be filled until the tank is cold enough to be filled without venting (tank chill-down and no-vent fill). Another approach to be explored is the positioning of the accumulating liquid away from the tank vent by use of a low-thrust propulsive system to provide liquid settling.

FLUID MANAGEMENT SYSTEM

SUBCRITICAL CRYOGENIC STORAGE AND TRANSFER

PROGRAM PLAN

APPROACH:

1. Continue to develop analytical models of the important fluid, thermal, and thermodynamic processes describing the anticipated behavior of the subcritical cryogenic storage and transfer systems under existing programs being supported by OAST, OSSA, and OSF.

2. Perform extensive ground-based experimentation utilizing the cryogenic fluids of interest in order to validate those portions of the analytical models which are insensitive to the gravitational environment by continuing existing programs being supported by OAST, OSSA, and OSF.

3. Design, fabricate, qualify, and carry into space flight experiment(s) to validate those processes which are sensitive to the gravitational environment. Immediate data and in-space experimentation is required with subcritical liquid nitrogen; future experiments with subcritical liquid hydrogen are required.

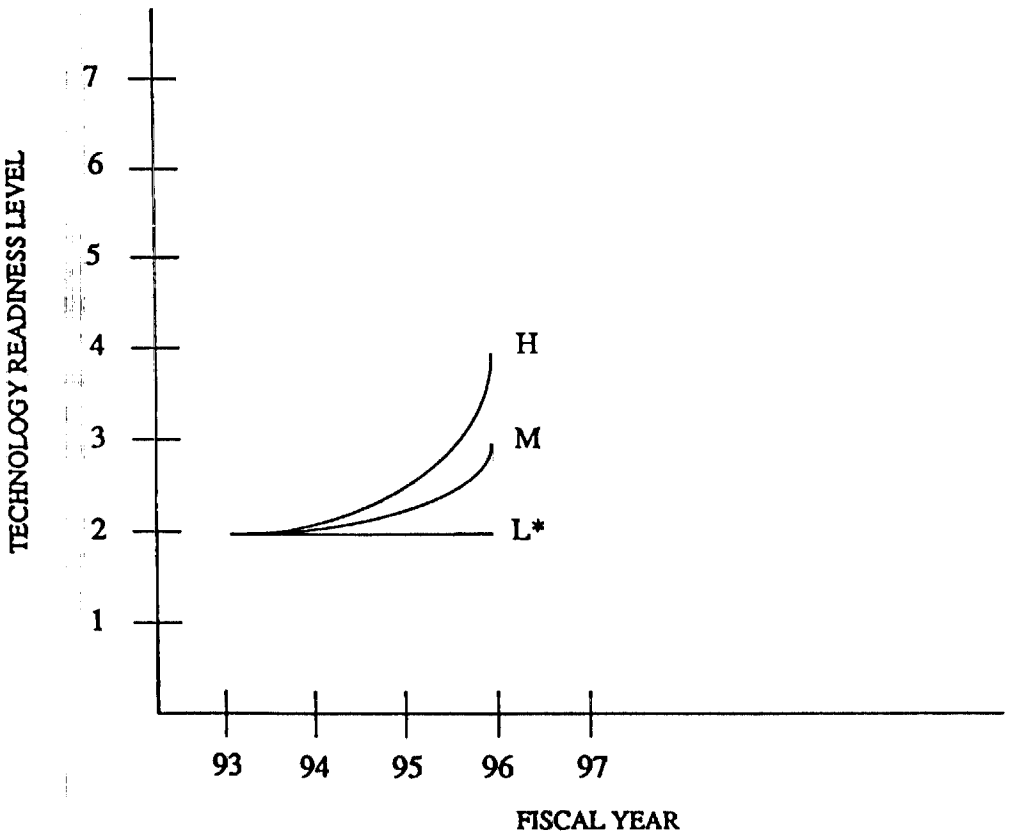
DELIVERABLES:

1. System performance data and validated analytical models that provide design criteria for the development of evolutionary subcritical cryogenic fluid storage and transfer systems.

FLUID MANAGEMENT SYSTEM

SUBCRITICAL CRYOGENIC STORAGE AND TRANSFER

TECHNOLOGY ASSESSMENT



* LOW INVOLVES NO FUNDING
BEYOND EXISTING OAST, OSF, OSSA PROGRAMS

FLUID MANAGEMENT SYSTEM

FLUID HANDLING

BACKGROUND

SCOPE: This technology area addresses the general in-space fluid management issues associated with:

1. Liquid slosh dynamics and control
2. Liquid dumping/venting/emergency relief

OBJECTIVES:

1. To obtain fundamental data on low-gravity liquid slosh dynamics phenomena and to validate analytical models.
2. To assess and evaluate the effectiveness of several techniques to accomplish on-orbit dumping of liquids.

REQUIREMENTS:

1. Control of tankage and complete spacecraft (SSF, STV, Depot, Tankers, Etc.) with large fluid inventories is dependent on the ability to predict fluid motions and their attendant forces which arise from attitude control system firings, spacecraft docking, assembly operations, etc. The impact of these motions and the resulting forces and acceleration environment needs to be understood and predictable in order to effectively control space station.
2. On-orbit fluid dumping may take place under both normal as well as contingency (emergency) operations. Currently, no analytical models have been validated by experiment data. Under certain conditions of rapid depressurization, significant quantities of liquid may freeze in tanks and could cause safety problems. This process is very poorly understood at present.
3. A low-gravity data base is needed for all fluids (storable and cryogenic).

FLUID MANAGEMENT SYSTEM

FLUID HANDLING

PROGRAM PLAN

APPROACH:

1. Continue on-going efforts to develop analytical models describing both sloshing and venting/dumping/emergency relief.
2. Perform ground-based testing for partial model validations.
3. Design, fabricate, and carry into space experiments which will provide essential data. These experiments could be performed with small scale tanks using the STS.

DELIVERABLES:

- In-space experiment data to aid in the design and development and to provide validation of analytical models which describe the low-gravity slosh dynamics phenomena.

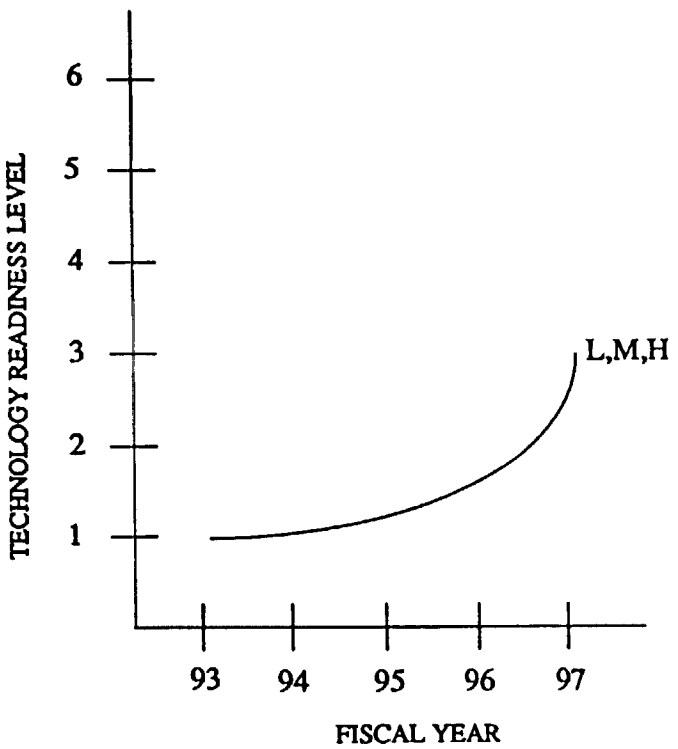
- In-space experiment data on dumping (venting/emergency relief) which will provide fundamental understanding of the problem and help to establish design criteria and operating procedures.

FLUID MANAGEMENT SYSTEM

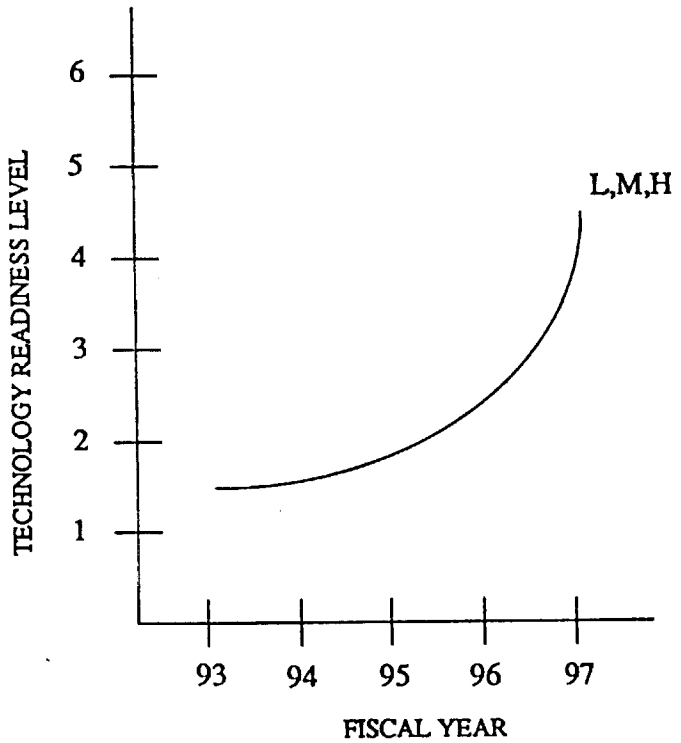
FLUID HANDLING

TECHNOLOGY ASSESSMENT

LOW-GRAVITY SLOSHING



DUMPING/VENTING/EMERGENCY RELIEF



FLUID MANAGEMENT SYSTEM

COMPONENTS AND INSTRUMENTATION

BACKGROUND

SCOPE: Certain components and instrumentation technology critical to both the current and the evolutionary Space Station Freedom fluid management system is not being addressed or requires funding augmentation.

OBJECTIVES:

To develop in-space technologies for the following:

1. Mass gaging of liquids in low-gravity environment
2. Fluid sampling/leak detection
3. Two-phase flow metering
4. Leak detection
5. Couplings/quick disconnects
6. In-space instrument calibration

REQUIREMENTS:

1. Mass Gaging: Accurate measurement (± 1% to 3% of the tank) the mass liquid contained in a vessel in low gravity is essential; no technique currently exists.
2. Fluid Sampling/Species Identification: Knowledge of what species are introduced into the fluid management system and in what quantities is required; could have safety implications.
3. Two-Phase Flow Metering: Will likely be required to assess performance of fluid systems operating in low gravity; no technique currently exists.
4. Leak Detection: All techniques currently being assessed require extensive EVA, alternatives should be evaluated which minimize EVA, identify location and magnitude of leak and isolate system.
5. Couplings/Quick Disconnects: No liquid loss, long life performance components are required.
6. In-space Instrument Calibration: No techniques currently being developed. Needed to assure accuracy of measurements in potentially safety critical systems.

FLUID MANAGEMENT SYSTEM

COMPONENTS AND INSTRUMENTATION

PROGRAM PLAN

APPROACH: INVESTIGATE PROMISING TECHNIQUES
- PERFORM LIMITED TESTING
- PREPARE DEVELOPMENT PLANS
- SELECT CANDIDATES FOR EXISTING FLIGHT EXPERIMENTS

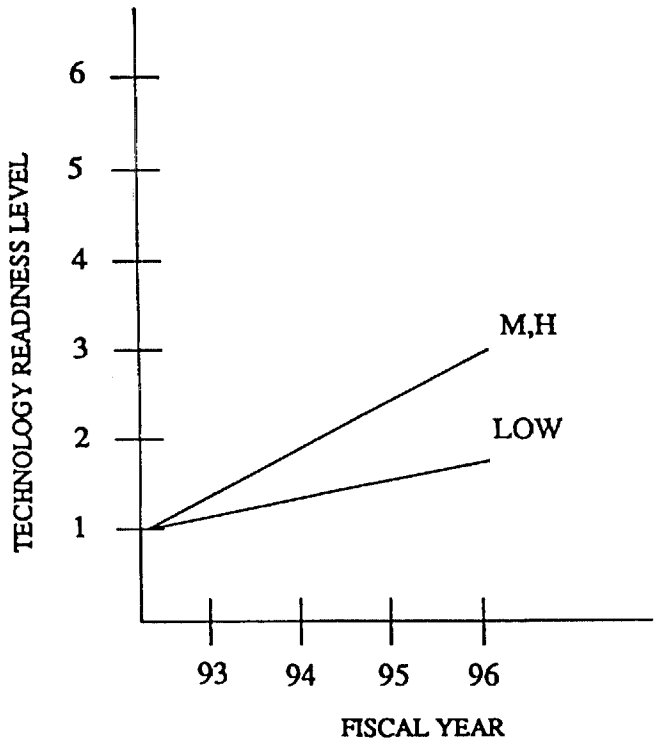
DELIVERABLES:

1. EXISTING TECHNOLOGY THAT CAN BE APPLIED TO ESSF
2. RECOMMENDED CHANGES TO ADAPT EXISTING TECHNOLOGY
3. INITIAL TEST RESULTS/PROOF OF CONCEPT
4. DEVELOPMENT PLANS

FLUID MANAGEMENT SYSTEM

COMPONENTS AND INSTRUMENTATION

TECHNOLOGY ASSESSMENT



FUNDING MAY NOT BE ADEQUATE
EVEN AT HIGHEST FUNDING LEVEL
PRIORITY GIVEN TO:

- FLUID SAMPLING/SPECIES IDENTIFICATION
- LEAK DETECTION
- ON-ORBIT CALIBRATION

FLUID MANAGEMENT SYSTEM

RECOMMENDATIONS

- IN-SPACE EXPERIMENTATION IS ESSENTIAL TO PROVIDE REQUIRED TECHNOLOGY
  - CRYOGENIC STORAGE AND TRANSFER
  - VENTING/DUMPING
  - SLOSH
- ON-GOING OAST, OSSA, AND OSF FLUID MANAGEMENT PROGRAMS MUST BE CONTINUED
- REFERENCE CONFIGURATIONS FOR EVOLUTIONARY STATION SHOULD BE MADE AVAILABLE ASAP
- ESTABLISH A REPOSITORY FOR IN-SPACE FLUID MANAGEMENT ACTIVITIES
  - POSSIBLY MANAGED/MAINTAINED BY AIAA/SAE/ASME COMMITTEES
  - UPDATED YEARLY

FLUID MANAGEMENT SYSTEM

ISSUES

FMS DESIGN

- IDENTIFICATION AND DISPOSAL OF USER-GENERATED WASTE LIQUIDS
- ADDITIONAL LINE(S) TO PROVIDE INERT GASES (E.G., He, Kr, & Ar)
- REDUNDANT ROUTING OF FLUID LINES
- CALIBRATION OF SYSTEM INSTRUMENTATION
- FMS INTERFACES FOR SERVICING MAN-TENDED FREE-FLYERS
- PROGRAM NEEDED FOR COMPONENT AND SYSTEM DEMONSTRATIONS (SPACE STATION ADVANCED DEVELOPMENT PROGRAM LACKING)

GENERAL

- IN-SPACE EXPERIMENTATION IS REQUIRED; CURRENT OAST, OSF, OSSA PROGRAMS LACK SUFFICIENT FUNDING
- POTENTIAL SAFETY ISSUES IDENTIFIED
  - RAPID TANK DEPRESSURIZATION MAY LEAD TO FORMATION OF FROZEN SOLIDS
  - SERVICING OF CO-ORBITING FREE-FLYER PROPULSION SYSTEMS (HYDRAZINE, BI-PROP)
  - SINGLE TRAY FOR ALL FLUID SERVICES