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POTENTIAL PRESSURIZED PAYLOADS; FLUID AND THERMAL EXPERIMENTS

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ABSTRACT

Space Station Freedom (SSF) presents the opportunity to perform long term fluid and thermal experiments in a microgravity environment. This presentation provides perspective on the need for fluids/thermal experimentation in a microgravity environment, addresses previous efforts, identifies possible experiments, and discusses the capabilities of a proposed fluid physics/dynamics test facility.

Numerous spacecraft systems use fluids for their operation. Thermal control, propulsion, waste management, and various operational processes are examples of such systems. However, effective ground testing is very difficult. This is because the effect of gravity induced phenomena, such as hydrostatic pressure, buoyant convection, and stratification, overcome such forces as surface tension, diffusion, electric potential, etc., which normally dominate in a microgravity environment. Hence, space experimentation is necessary to develop and validate a new fluid based technology.

Two broad types of experiments may be performed on SSF; basic research and applied research. Basic research might include experiments focusing on capillary phenomena (with or without thermal and/or solutal gradients), thermal/solutal convection, phase transitions, and multiphase flow. Representative examples of applied research might include two-phase pressure drop, two-phase flow instabilities, heat transfer coefficients, fluid tank fill/drain, tank slosh dynamics, condensate removal enhancement, and void formation within thermal energy storage materials.

In order to better support such fluid/thermal experiments on board SSF, OSSA has developed a conceptual design for a proposed Fluid Physics/Dynamics Facility (FP/DF). The proposed facility consists of one facility rack permanently located on SSF and one experimenter rack which is changed out as needed to support specific experiments. This approach will minimize the on-board integration/deintegration required for specific experiments. The FP/DF will have acceleration/vibration compensation, power and thermal interfaces, computer command/data collection, a video imaging system, and a portable glovebox for operations. This facility will allow real-time astronaut interaction with the testing.

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POTENTIAL PRESSURIZED PAYLOADS; FLUID AND THERMAL EXPERIMENTS

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OUTLINE

- PROVIDE PERSPECTIVE ON NEED FOR FLUID/THERMAL PHYSICS EXPERIMENTATION IN A MICROGRAVITY ENVIRONMENT
- ADDRESS PREVIOUS EFFORTS
- IDENTIFY LIKELY TYPES OF EXPERIMENTS
- DISCUSS PROPOSED SPACE STATION FREEDOM TEST CAPABILITIES FOR FLUID PHYSICS/DYNAMICS

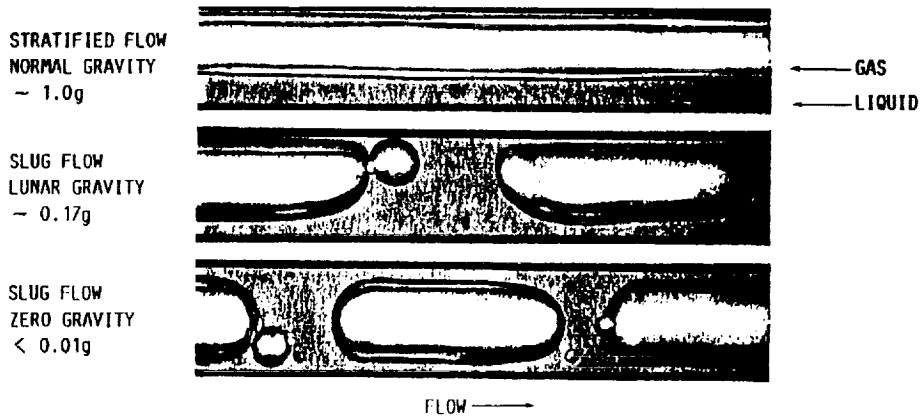
FLUID AND THERMAL EXPERIMENTS

BACKGROUND

- NUMEROUS SPACECRAFT SYSTEMS UTILIZE FLUIDS FOR OPERATION
  - THERMAL CONTROL, PROPULSION, WASTE MANAGEMENT, OPERATIONAL PROCESSES, ETC.
- GROUND TESTING SEVERELY COMPROMISED BY PRESENCE OF GRAVITY
  - HYDROSTATIC PRESSURE, BUOYANT CONVECTION, SEDIMENTATION, AND STRATIFICATION OVERCOME EFFECTS OF SURFACE TENSION, DIFFUSION PHENOMENA, ELECTRIC POTENTIAL, ETC.

BOTH BASIC SCIENCE AND SPACECRAFT TECHNOLOGY WILL BENEFIT FORM THE STUDY OF FLUID/THERMAL PHENOMENA IN A MICROGRAVITY ENVIRONMENT

EFFECT OF GRAVITY ON FLOW REGIME



TWO-PHASE FLOW REGIMES DEMONSTRATING EFFECT OF DIFFERENT GRAVITY LEVELS (LEARJET FACILITY; AIR/WATER IN 1.27-cm-i.d. TUBE; SUPERFICIAL GAS VELOCITY, ~ 0.14 m/sec; SUPERFICIAL LIQUID VELOCITY, ~ 0.07 m/sec).

FLUID AND THERMAL EXPERIMENTS
-BACKGROUND, CONTINUED-

* PREVIOUS FLUID/THERMAL RESEARCH PROGRAMS OF THE 1960's, 1970's, AND EARLY 1980's IDENTIFIED MANY CRITICAL ISSUES, BUT THE PRIMARY EMPHASIS WAS ON SPECIFIC COMPONENTS AND SYSTEMS - NO GENERIC TECHNOLOGY BASE WAS DEVELOPED

* PREVIOUS WORKING GROUPS ALL IDENTIFIED SIMILAR NEEDS;
  - IN-SPACE RESEARCH, TECHNOLOGY, AND ENGINEERING WORKSHOP; OCTOBER 1985, WILLIAMSBURG
  - MICROGRAVITY FLUID MANAGEMENT SYMPOSIUM, SEPTEMBER, 1986, LeRC
  - WORKSHOP ON TWO-PHASE FLUID BEHAVIOR IN A SPACE ENVIRONMENT; JUNE, 1988, OCEAN CITY
  - IN-STEP 88; DECEMBER, 1988, ATLANTA

PREVIOUS FLUID/THERMAL PHYSICS MICROGRAVITY EXPERIMENTATION

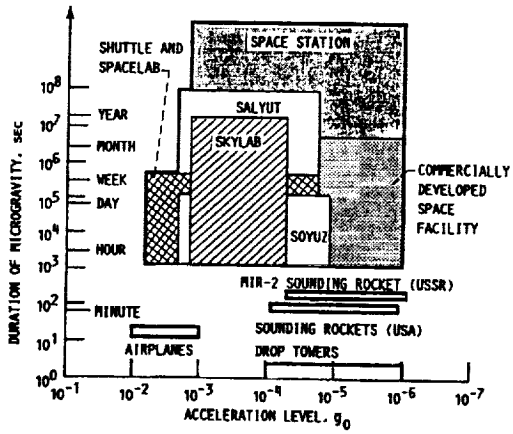
PREVIOUS MICROGRAVITY TESTING HAS GENERALLY BEEN OF VERY LIMITED TIME DURATION

* DROP TOWERS - A FEW SECONDS
* AIRCRAFT - 20 TO 25 SECONDS
* SOUNDING ROCKETS, BALLONS - MINUTES
* SHUTTLE - A FEW DAYS
  - NASA/GODDARD TEMP 2A3 EXPERIMENT ON STS 46

MANY RESEARCHERS FEEL THAT WHILE A TEST DURATION OF SECONDS MAY BE ACCEPTABLE FOR SUCH PHENOMENA AS FLOW REGIMES, MUCH LONGER TIME DURATIONS ARE NEEDED TO STUDY OTHER PHENOMENA

COMPARISON OF MICROGRAVITY ENVIRONMENTS

SPACE STATION FREEDOM OFFERS UNIQUE ENVIRONMENT FOR THERMAL/FLUID EXPERIMENTS



CHARACTERISTIC TIMES AND ACCELERATION LEVELS OF MICROGRAVITY LABORATORY FACILITIES.

TYPES OF EXPERIMENTS

TWO BROAD CATEGORIES OF EXPERIMENTS;

- BASIC RESEARCH
  - NO SPECIFIC APPLICATION; INVESTIGATION OF BASIC FLUID AND THERMAL PHENOMENA
- APPLIED SCIENCE
  - GOAL IS TO UNDERSTAND PHENOMENA SO AS TO SOLVE A GIVEN DESIGN PROBLEM

BASIC SCIENCE EXPERIMENTS

FIVE BROAD CLASSES;*

- CAPILLARY PHENOMENA IN A ISOTHERMAL/ISO-SOLUTAL ENVIRONMENT
- CAPILLARY PHENOMENA WITH THERMAL/SOLUTAL GRADIENTS
- THERMAL/SOLUTAL CONVECTION
- FIRST AND SECOND ORDER PHASE TRANSITIONS IN A STATIC FLUID
- MULTIPHASE FLOW

* REFERENCE; LOW-GRAVITY FLUID PHYSICS: A PROGRAM OVERVIEW LEWIS RESEARCH CENTER, CLEVELAND, OHIO

APPLIED SCIENCE EXPERIMENTS

REPRESENTATIVE EXAMPLES

- TWO-PHASE PRESSURE DROP
- TWO-PHASE FLOW INSTABILITIES
- TWO-PHASE FLOW THROUGH LINES, DUCTS, AND FITTINGS
- HEAT TRANSFER COEFFICIENTS
- FLUID TANK FILL/DRAIN
- FLUID TANK SLOSH DYNAMICS
- FLUID REORIENTATION WITHIN A TANK
- CONDENSATE REMOVAL ENHANCEMENT
- VOID FORMATION/DISTRIBUTION IN THERMAL ENERGY STORAGE MATERIALS

PROPOSED SPACE STATION FREEDOM FLUID PHYSICS RESEARCH CAPABILITIES*

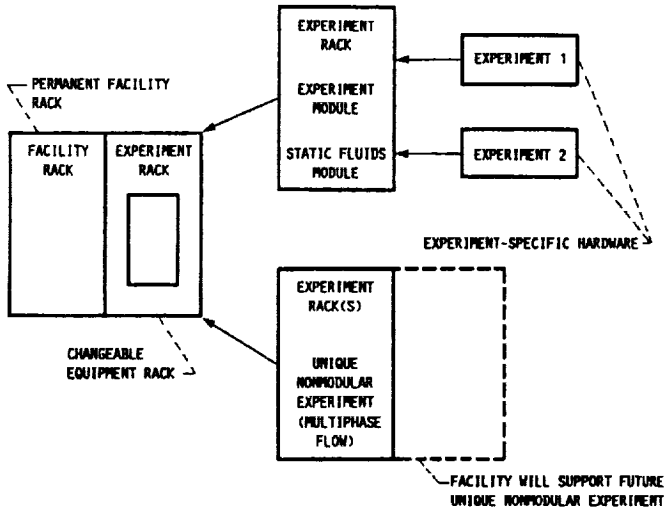
* NASA'S OSSA TASKED LeRC TO CONDUCT A WORKSHOP TO DEFINE A FLUID PHYSICS/DYNAMICS FACILITY (FP/FD) FOR SSF

* RESULTING CONCEPTUAL DESIGN IS A MODULAR, TWO RACK FACILITY;
  - FACILITY RACK; PERMANENT, BUT UPGRADABLE
  - EXPERIMENT RACK; EXPERIMENT SPECIFIC MODULES AND EQUIPMENT

* TWO-RACK CONCEPT CHOSEN BECAUSE;
  - MAXIMIZES VOLUME THAT CAN BE REORIENTED WITH RESPECT TO THE QUASI-STEADY STATE ACCELERATION VECTOR
  - MINIMIZES ON-BOARD INTEGRATION/DEINTEGRATION EFFORT FOR EXPERIMENT SPECIFIC HARDWARE

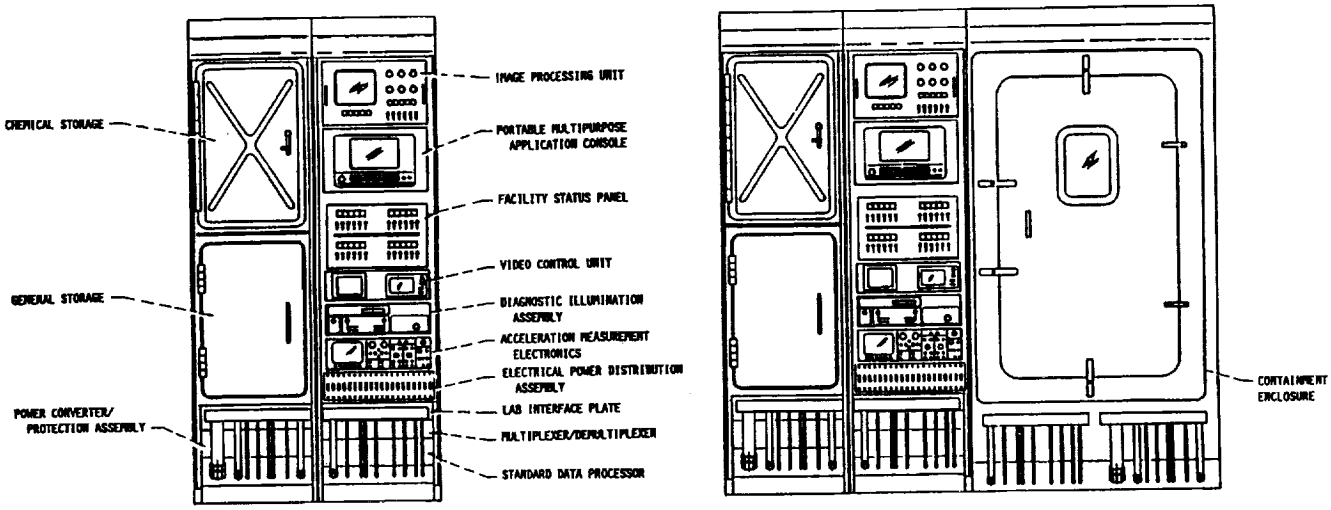
* REFERENCE; NASA TECHNICAL MEMORANDUM, "STATUS REPORT ON CONCEPTUAL DESIGN FOR THE SPACE STATION FREEDOM FLUID PHYSICS/DYNAMICS FACILITY

MODULAR CONCEPT FOR PROPOSED SSF FLUID PHYSICS/DYNAMICS FACILITY*



* REFERENCE; NASA TECHNICAL MEMORANDUM, "STATUS REPORT ON THE CONCEPTUAL DESIGN FOR THE SPACE STATION FREEDOM FLUID PHYSICS/DYNAMICS FACILITY"

LAYOUT OF PROPOSED SSF FLUID PHYSICS/DYNAMICS FACILITY



REPRESENTATIVE EXPERIMENTS SUGGESTED FOR FP/DF

* SURFACE TENSION INDUCED INSTABILITIES
* SURFACE TENSION DRIVEN CONVECTION
* FREE SURFACE PHENOMENA
* BUBBLE/DROPLET DYNAMICS
* THERMAL AND DOUBLE DIFFUSE CONVECTION
* MULTIPHASE FLOW
* FIRST ORDER TRANSITIONS
* CHEMICAL DEPOSITION
* THERMAL GRADIENT EFFECTS ON ENTRY-FLOW
* FLUID PHENOMENA DURING SOLIDIFICATION
* FLUID MIXTURE HEAT AND MASS TRANSFER

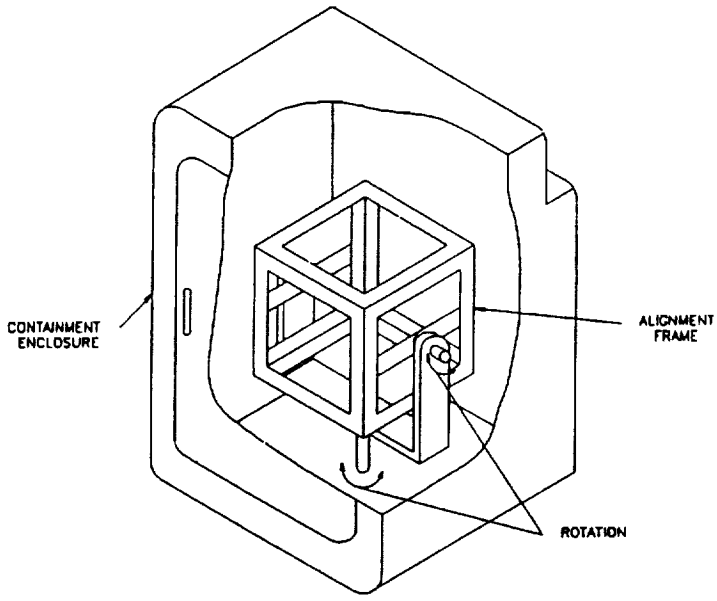
SSF MICROGRAVITY ENVIRONMENT

- NO FIRM MICROGRAVITY REQUIREMENT YET ESTABLISHED
- ANTICIPATED ENVIRONMENT HAS THREE ELEMENTS;
  - QUASI-STEADY ACCELERATION (10-5 G's)
    - 10-5 G's, 37+ DEGREES
    - THREE MAJOR FACTORS;
      - GRAVITY GRADIENT
      - ROTATIONAL
      - ATMOSPHERIC DRAG
- OSCILLATORY ACCELERATIONS
  - ROTATING MACHINERY, CREW ACTIVITIES, STRUCTURAL
- TRANSIENT ACCELERATIONS
  - CREW, THRUSTER FIRINGS, VENTING, DOCKING, EQUIPMENT ON/OFF

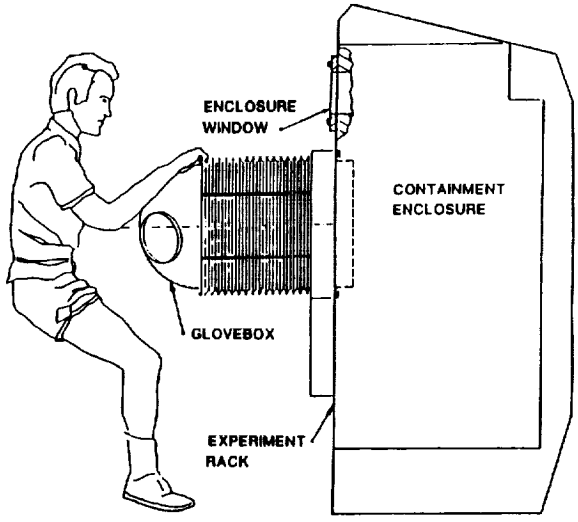
PROPOSED FP/DF CAPABILITIES

- ROTATING QUASI-STEADY ACCELERATION ALIGNMENT SYSTEM (68 CM DIA.)
- PASSIVE VIBRATION ISOLATION TECHNIQUES
- POWER; 6 KW OF 120 VDC TO FACILITY RACK,
  3 KW OF 120 VDC TO EQUIPMENT RACK,
  28 VDC AND 400 HZ AC AS REQUIRED
- THERMAL; INTERFACE HEAT EXCHANGER, COLD PLATE, AIR-TO-AIR COOLING
- FP/DF COMPUTER - NODE ON SSF COMPUTER; THREE DATA LINKS, UP TO 100 MB/SEC, VARIETY OF SENSOR ACCOMMODATIONS
- VIDEO IMAGING SYSTEM
- PORTABLE GLOVEBOX

PROPOSED SSF FP/DF QUASI-STEADY ACCELERATION ALIGNMENT SYSTEM



PROPOSED SSF FP/DF PORTABLE GLOVEBOX CONCEPT



BENEFITS OF SSF FLUID PHYSICS/DYNAMICS FACILITY

- LONG DURATION (MONTHS-YEARS)
- MICROGRAVITY AT LEVEL REPRESENATIVE OF LARGE SPACE STRUCTURES
- CREW AVAILABILITY FOR OPERATIONS
- REAL TIME HUMAN OBSERVATION
- CREW AVAILABLE FOR MODIFICATION/REPAIR
- INCREASED TEST MATRIX FLEXIBILITY

ISSUES FOR FLUIDS/THERMAL TESTING ON SSF

- ACCELERATIONS OF 10-5 TO 10-6 G's MAY BE LARGE ENOUGH TO AFFECT SOME PROCESSES - IMPACT UNKNOWN
- SAFETY CONCERNS LIMIT USE OF OPERATING FLUIDS TO BENIGN FLUIDS SUCH AS WATER, ALCOHOL, R-113, AND SILICON OILS
- MODERATE PHYSICAL SIZE