NASA-TM-108653

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SSTAC/ARTS REVIEW OF THE DRAFT INTEGRATED TECHNOLOGY PLAN (ITP)

Volume V: June 26-27

Human Support

Briefings from the June 24-28, 1991 Meeting McLean, Virginia

**National Aeronautics and Space Administration
Office of Aeronautics, Exploration and Technology
Washington, D.C. 20546**

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SSTAC/ARTS REVIEW OF THE DRAFT ITP
McLean, Virginia
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Human Support

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HUMAN SUPPORT PROGRAM AREA OF THE INTEGRATED TECHNOLOGY PLAN

Dr. JAMES P. JENKINS and PEGGY L. EVANICH

JUNE 24 - 28, 1991

OFFICE OF AERONAUTICS, EXPLORATION AND TECHNOLOGY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

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HUMAN SUPPORT PROGRAM: TECHNOLOGY NEEDS & CHALLENGES

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- EVA SYSTEMS SUPPORT
  - FLEXIBLE EASY TO USE, HIGH PRESSURE EVA GLOVES.
  - EVA SUIT MAINTAINABLE ON - ORBIT / IN - SITU BY CREW.
- LIFE SUPPORT
  - AIR RECYCLING AND WASTE (LIQUID, GAS, SOLID) PROCESSING AND RECLAMATION OF 90+%.
  - RADIATION SHIELDING TO DOE PROTECTION STANDARDS.
  - AUTOMATED LIFE SUPPORT SENSORS & CONTROL SYSTEMS.
- CREW STATION DESIGN TECHNOLOGY
  - REAL TIME RESPONSE TO VIRTUAL REALITY ENVIRONMENT WITH <.01% MOTION LAG AND ,.50 MS. VISUAL LAG.
  - TRANSFER HUMAN - COMPUTER INTERFACE DESIGN GUIDELINES TO INDUSTRY.
- FIRE SAFETY TECHNOLOGY
  - CONTINUOUS MONITORING TECHNIQUES FOR INCIPIENT EVENT.
  - FIRE EXTINGUISHING, DISPERSAL, & CLEANUP FOR FIRE EVENT.

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HUMAN SUPPORT PROGRAM: TECHNOLOGY NEEDS & CHALLENGES

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- ACCELERATED DEVELOPMENT OF KEY, HIGH-PAYOFF CAPABILITIES
  - EVA GLOVES
  - VISUALIZATION TECHNOLOGIES
  - EFFICIENT LIFE SUPPORT
- ENABLE DEMONSTRATIONS / IN-FLIGHT TESTS OF:
  - EVA & LIFE SUPPORT CONTROLS AND SENSORS
  - VIRTUAL ENVIRONMENT WORKSHOP
- AUGMENT R&T AREAS THAT ARE MINIMALLY FUNDED
  - DESIGN GUIDELINES FOR HUMAN-INTELLIGENT SYSTEMS
  - PLSS COMPONENTS (BATTERIES, CO_2 PROCESSING)
  - EVA DISPLAY AND CONTROL TECHNIQUES
  - LIFE SUPPORT SENSORS & CONTROLS
  - BIOMEDICAL SUPPORT (ZERO FUNDED)
  - FIRE SAFETY (ZERO FUNDED)
  - ADVANCED ECLSS & HABITAT THERMAL CONTROL
- TRANSFER MATURING TECHNOLOGY TO FOCUSED THRUSTS
  - HUMAN-COMPUTER INTERFACE DESIGN GUIDELINES
  - EVA SUIT MOBILITY (JOINT) AND MATERIALS (HARD & SOFT)
  - DISPLAYS FOR PROXIMITY OPERATIONS
- BIOMEDICAL SUPPORT TECHNOLOGY TO SUPPORT MEDICAL OPERATIONS
  - IMPROVED REFRIGERATION / FREEZERS
  - HEALTH CARE TECHNOLOGY
  - LIFE SCIENCE RESEARCH TECHNOLOGY NEEDS

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HUMAN SUPPORT PROGRAM: OBJECTIVES

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PERFORM FUNDAMENTAL RESEARCH IN FOUR MAJOR AREAS OF HUMAN SUPPORT TECHNOLOGIES FOR A WIDE RANGE OF NASA'S SPACE PROGRAMS, THE MAJOR SUBELEMENT TOPICS ARE:

- EVA SYSTEM SUPPORT TO HUMAN PERFORMANCE.
- LIFE SUPPORT & BIOMEDICAL SUPPORT TECHNOLOGIES.
- CREWSTATION DESIGN TECHNOLOGY.
- FIRE SAFETY TECHNOLOGY.
- HABITAT THERMAL CONTROL TECHNOLOGY.

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HUMAN SUPPORT PROGRAM: BENEFITS

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- INCREASE SAFETY, EFFECTIVENESS, AND RELIABILITY OF HUMAN ACTIVITIES IN SPACE.
- SPACE HUMAN SUPPORT KNOWLEDGE BASE ESTABLISHED.
- INCREASE DESIGN OF CLOSURE OF FUTURE SPACE LIFE SUPPORT SYSTEMS.
- ENABLE EFFICIENT AND EFFECTIVE MONITORING OF CRITICAL LIFE SUPPORT SYSTEMS.
- ENABLE EFFICIENT, NON - TOXIC THERMAL CONTROL SYSTEMS.

BENEFITS FOR OPERATIONS THRUSTS:

- EXTENSION OF MISSION LIFETIME AND RELIABILITY FOR SPACECRAFT AND SUPPORT CREW, REDUCED HUMAN ERROR DUE TO FATIGUE AND ISOLATION EFFECTS, AND INCREASED CREW EFFICIENCY.

BENEFITS FOR EXPLORATION THRUSTS:

- INCREASED MISSION RELIABILITY DUE TO LIGHTWEIGHT, ADAPTABLE SURFACE EVA SYSTEMS AND CREW WORKSTATIONS MATCHED TO MEET MISSION REQUIREMENTS AND HUMAN LIMITATIONS FOR A FAMILY OF MISSIONS OVER A WIDE VARIETY OF LUNAR AND MARTIAN SURFACES.
- ELIMINATE RESUPPLY, MAXIMIZE SELF - SUFFICIENT LIFE SUPPORT SYSTEMS.

BENEFITS FOR PLATFORM THRUST:

- CAPABILITIES FOR SIGNIFICANT INCREASE IN NUMBER OF EVA EXCURSION, ELIMINATION OF PREBREATHE REQUIREMENTS, AUTOMATIC SERVICING OF PLSS AND SUIT UNITS, ON - ORBIT REPAIRABLE EVA EGRESS, DON AND DOFFING.
- REDUCE RESUPPLY REQUIREMENTS & INCREASE MISSION DURATION.
- PROVIDE IN - SITU SENSOR & CONTROL SYSTEM FOR SSF LIFE SUPPORT.
- UTILIZE SSF AS IN - SPACE LIFE SUPPORT TESTBED.

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HUMAN SUPPORT PROGRAM: ORGANIZATION

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THRUST & W.B.S / FOCUS	HUMAN FACTORS	LIFE SUPPORT	EVA SUIT	PLSS	FIRE SAFETY
HUMAN SUPPORT					
ZERO - G SUIT	X	X	X	X	X
CHEMICAL PROCESSING	X	X	X	X	X
BIOMEDICAL SUPPORT	X	X	X	X	X
SENSORS & CONTROLS	X	X	X	X	X
CREWSTATION DESIGN	X	X	X	X	X
THERMAL CONTROL	X	X	X	X	X
EXPLORATION					
EXTRAVEHICULAR ACTIVITY	X	X	X	X	X
SPACE HUMAN FACTORS	X	X	X	X	X
REGEN. LIFE SUPPORT	X	X	X	X	X
PLATFORM					
ZERO - G EMU	X	X	X	X	X
ZERO - G LIFE SUPPORT	X	X	X	X	X
OPERATIONS					
OPERATOR SYSTEMS & TRAINING	X	X	X	X	X

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HUMAN SUPPORT STATE-OF-THE-ART

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MAJOR ELEMENTS:

- EVA
  - SHUTTLE SUIT: PREBREATHE & GROUND SERVICING HIGH PRESSURE, ZERO PREBREATHE SUITE DEMO IN LAB (AX - 5, ZPS, MOD III)
  - SHUTTLE PLSS: NON-REGENERATIVE, GROUND SERVICE (OVERALL STATEMENT).
- LIFE SUPPORT
  - RE-SUPPLIED AIR AND WATER AND REGENERATIVE CO_2 REMOVAL.
  - THERMAL: CURRENT HEAT PIPES & RADIATORS GROWTH LIMITED, LOW EFFICIENCY.
  - SENSORS: GC / MASS SPEC; MANUAL SAMPLING & CONTROLS.
  - BIOMEDICAL: LIMITED S - O - A TECHNOLOGY APPLICATION.
- CREWSTATION DESIGN
  - MODELS: PRELIMINARY KINEMATIC MODELS OF HUMAN MOTION IN ZERO-G.
  - INTERFACE: INTERFACE DESIGN GUIDELINES, NASA - STD 3000 CHAPTER FOR SSF.
- FIRE SAFETY
  - LIMIT MATERIALS TO NON - FLAMMABLES
  - FLAMMABLES ISOLATION.
  - HALON, CO_2 FIRE SUPPRESSION

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HUMAN SUPPORT PROGRAM: RECENT ACCOMPLISHMENTS

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- AX - 5 HIGH-PRESSURE SPACE SUIT DEVELOPMENT
- VISION MODEL DEMONSTRATION FOR DATA COMPRESSION AND MACHINE VISION
- HUMAN GRAPHICS SYSTEM DEVELOPED TO SUPPORT CONCEPTUAL DESIGN OF HUMAN / SYSTEM INTERFACES.
- HUMAN-COMPUTER INTERACTION GUIDELINES ADDED TO MAN-SYSTEM INTEGRATION STANDARD.
- DEMONSTRATED EXPLORATION OF THE MARTIAN SURFACE USING VIRTUAL WORKSTATION.
- EVA METABOLIC RESEARCH LABORATORY COMPLETED AND CERTIFIED.
- RIGOROUS SYSTEM ANALYSIS METHODOLOGY DEVELOPED FOR LIFE SUPPORT SYSTEM TRADES & OPTIMIZATION.
- INITIATED LIFE SUPPORT SENSOR & CONTROLS RESEARCH.
- EXTENDED DURATION ORBITER BASELINED REGENERATIVE SOLID AMINE CO_2 REMOVAL SYSTEM.

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OTHER GOVERNMENT SUPPORT TO HUMAN SUPPORT PROGRAM

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LIFE SCIENCES DIVISION, OFFICE OF SPACE SCIENCES APPLICATION

- LIFE SCIENCE RESEARCH DATA IN HUMAN PHYSIOLOGY.
- LIFE SUPPORT SYSTEMS ANALYSIS FOR CELSS TO IDENTIFY SUPPORTING TECHNOLOGY.

DEPARTMENT OF DEFENSE

- HUMAN PERFORMANCE MODELS FOR MILITARY SYSTEM APPLICATIONS.
- ADVANCED HUMAN - CREWSTATION INTERFACE DESIGN GUIDELINES.
- MODELING TOOLS FOR CREWSTATION DESIGN UNDER NASA - ARMY AIRCRAFT AIRCREW INTEGRATION (A3I).
- LIFE SUPPORT RESEARCH - WASTE MANAGEMENT RESEARCH FOR SHIPBOARD & SPACECRAFT APPLICATIONS.
- LIFE SUPPORT SENSORS & CONTROLS FOR SUBMARINE & SPACECRAFT CLOSED ENVIRONMENTS.

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HUMAN SUPPORT PROGRAM: PRIORITIES

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SSTAC COMMITTEES:

- HUMAN PERFORMANCE FOR LONG DURATION SPACE MISSIONS (SEE ISSUES) 1989 - 1991.
- LIFE SUPPORT - 1990 - 1991.
  - PLAN TO REPORT OUT JULY 1991.

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RECOMMENDATIONS FROM THE SSTAC AD HOC COMMITTEE ON HUMAN PERFORMANCE FOR LONG - DURATION SPACE MISSIONS

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1. EVA PRODUCTIVE OPERATIONS FOR FUTURE MANNED MISSIONS NEED NEW GLOVE TECHNOLOGY, ON-ORBIT / IN-SITU SUIT MAINTAINABILITY CURRENT SUITS INCOMPATIBLE FOR LUNAR OR PLANETARY SURFACE OPS.
   a) DEXTEROUS GLOVES.
   b) HIGH RELIABILITY, LOW MAINTAINABILITY SUIT SYSTEM.
   c) LIGHTWEIGHT COMPONENTS AND MATERIALS FOR PLSS & SUIT.
   d) FLEXIBLE COMMUNICATIONS.
   e) MOBILITY.
   f) MULTI-FUNCTION DISPLAYS.

2. TECHNIQUES AND TECHNOLOGY TO MAINTAIN EFFECTIVE LEVELS OF HUMAN PERFORMANCE UNDER ZERO-GRAVITY OR MICRO-GRAVITY MISSIONS, AND TO COUNTER DEBILITATING EFFECTS OF WEIGHTLESSNESS AND RADIATION EXPOSURE.
   a) MULTI-DISCIPLINARY APPROACH AND COORDINATION BETWEEN TECHNOLOGY & MEDICAL DISCIPLINES.
   b) COUNTERMEASURES OF PREVENT DEBILITATING EFFECTS.
   c) COUNTERMEASURES OF AMELIORATE DEBILITATING EFFECTS.
   d) HUMAN PERFORMANCE ENHANCEMENTS, GIVEN RESTRICTED HUMAN CAPABILITIES.

3. LIFE SUPPORT SYSTEMS (INTEGRATED PHYSICAL-CHEMICAL AND CLOSED CYCLE) FOR SPACECRAFT AND LUNAR / PLANETARY HABITS.
   a) SCIENTIFIC AND TECHNICAL DATABASES LEADING TO SYSTEM DESIGN.
   b) DEVELOPMENT OF INTEGRATED TEST AND EVALUATION CAPABILITIES.
   c) LOW WEIGHT, REDUCED VOLUME, LOW POWER, HIGH RELIABILITY COMPONENTS, LOW MAINTAINABILITY IN-SITU / ON SITE.

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RECOMMENDATIONS FROM THE SSTAC AD HOC COMMITTEE ON HUMAN PERFORMANCE FOR LONG - DURATION SPACE MISSIONS

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4. HUMAN WORK ENVIRONMENT DEFINITION AND DESIGN CONSTRAINTS FOR PLANETARY SPACECRAFT AND LUNAR / SURFACE HABITATS AND WORK AREAS.
   a) HUMAN-SYSTEM FUNCTION ALLOCATIONS, PERFORMANCE MEASUREMENT METHODS AND PREDICTIONS FOR SAFETY AND PRODUCTIVITY.
   b) HUMAN TASK, TOOLS AND JOB AIDS.
   c) DEFINITION FO TELEROBOTIC MANAGEMENT AND METHODS.
   d) CONSTRAINTS AND REQUIREMENTS DUE TO HARSH WORKING ENVIRONMENT, I.E., RADIATION, DUST, PARTIAL GRAVITY, TEMPERATURE EXTREMES, COMMUNICATIONS, SAFETY.

5. HUMAN LIVING ENVIRONMENT DEFINITION AND RELIABLE METHODS FOR QUANTITATIVE AND QUALITATIVE EVALUATIONS OF ENVIRONMENTAL FACTORS.
   a) PHYSICAL.
   b) HUMAN FACTORS STANDARDS.
   c) PHYSIOLOGICAL NEEDS.
   d) INTERFACES BETWEEN HUMAN-SYSTEM AND HUMAN-HUMAN.

6. DESIGN SUPPORT METHODS AND TOOLS.
   a) REQUIREMENTS AND GUIDELINES FOR USE OF DESIGN SUPPORT TOOLS AND CAPABILITIES, (CAD, CAM, CAE, MIDAS).

7. IDENTIFICATION OF HUMAN PERFORMANCE CAPABILITIES AND LIMITATIONS (HUMAN ERROR) FOR SAFE, EFFECTIVE AND PRODUCTIVE HUMAN PERFORMANCE FOR LONG DURATION SPACE MISSIONS, INCLUDING LUNAR AND PLANETARY SURFACE OPERATIONS.
   a) DEVELOPMENT OF A HUM;AN PERFORMANCE DATABASE AND LESSONS FROM OPERATIONAL EXPERIENCES.
   b) DEVELOPMENT OF DATA STORAGE, RETRIEVAL, AND ANALYSIS TECHNOLOGY.
   c) DEVELOPMENT AND APPLICATION OF HUMAN PERFORMANCE WORK BREAKDOWN STRUCTURE TO SPECIFY HUMAN CAPABILITIES AND HUMAN ERROR.

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RECOMMENDATIONS FROM THE SSTAC AD HOC COMMITTEE ON HUMAN PERFORMANCE FOR LONG - DURATION SPACE MISSIONS

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8. DEVELOPMENT OF ARTIFICIAL REALITY TECHNOLOGY AND COGNITIVE AIDS FOR APPLICATION IN FIELDS OF SPACE EXPLORATION, MEDICAL DIAGNOSIS AND IMPLEMENTATION, TRAINING, AND HUMAN-SYSTEM DESIGN.
   a) DEVELOPMENT OF COMPUTER SYSTEMS AND NETWORKS TO ACCOMMODATE DATABASES FOR VIRTUAL REALITY GRAPHICS, ICONS AND INTERACTIONS.
   b) LOW COST HEAD-MOUNTED DISPLAYS WITH HIGH RESOLUTION, STEREO, COLOR, AND WIDE FIELD-OF-VIEW.
   c) HUMAN-CENTERED INTERFACES AND INTERACTIVE AIDS.
   d) DATA HANDLING TECHNIQUES FOR REAL-TIME VIRTUAL REALITY INTERACTIONS.

9. SIMULATION AND TRAINING TECHNOLOGY METHODS FOR SKILL AND KNOWLEDGE DEVELOPMENT AND RETENTION FOR LONG DURATION MISSIONS.
   a) SPECIAL AND PART TASK MISSION SIMULATION.
   b) EMBEDDED TRAINING METHODS.
   c) INTELLIGENT TRAINING SYSTEMS.

10. PHYSICAL AUGMENTATIONS AND WORKSTATION DESIGN CONCEPTS TO ENHANCE PRODUCTIVITY.
   a) ENHANCEMENT OF HUMAN SENSORY AND MOTOR CONTROL CAPABILITIES THROUGH TECHNOLOGY AREAS INCLUDING TELEROBOTIC INTERFACES, EVA WORK AIDS END EFFECTORS, COMPUTATIONAL VISION METHODS AND ADVANCED IMAGING SYSTEMS.
   b) CONTINUED DEVELOPMENT OF DESIGN PRACTICES AND PRINCIPLES, EMBODIED IN NASA STANDARD 3000, "MAN-SYSTEMS INTEGRATION STANDARDS".

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HUMAN SUPPORT PROGRAM: ISSUES

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1. RESPONSIVENESS OF EXISTING AND PLANNED PROGRAM TO SSTAC RECOMMENDATIONS IN HUMAN PERFORMANCE REPORT (5.91) - RATINGS:

   A - FULLY RESPONSIVE B - MINIMALLY RESPONSIVE C - NOT RESPONSIVE

   RECOMMENDATIONS:

1 - A	6 - A
2 - C	7 - A
3 - A-	8 - A-
4 - B-	9 - B
5 - A-	10 - A-

2. DEGREE TO WHICH THE REDUCED PROGRAM IN EXPLORATION HUMAN FACTORS IS CONSIDERED RESPONSIVE TO AGENCY REQUIREMENTS.

3. DEGREE TO WHICH EXISTING AND PLANNED HUMAN SUPPORT PROGRAM MEETS NEEDS DESCRIBED IN "SPACE TECHNOLOGY TO MEET FUTURE NEEDS", NRC / NAC, 1987 (SO-CALLED SHEA REPORT) AND "HUMAN FACTORS IN AUTOMATED AND ROBOTIC SPACE SYSTEMS", COMMITTEE ON HUMAN FACTORS, NRC / NAC. 1987.

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MILESTONES

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CREWSTATION - HUMAN SUOOPRT

91 - COMPLETE ANALYSIS AND TEST AN COGNITIVE MODELS FOR HUMAN - COMPUTER INTERFACES. (JSC)

92 - COMPLETE AVALUATION OF FORCE - TORQUE DISLPAY FORMAT. (ARC)

93 - COMPLETE TESTS OF 3 - D MOTION ANALYSIS FOR VISUAL HAZARD DETECTION. (ARC0

94 - COMPLETE DESIGN GUIDELINES FOR HUMAN - COMPUTER INTERFACE WITH INTELLIGENT SYSTEMS. (ARC)

95 - REVISE NASA - STD - 3000 TO INCLUDE NEW SECTION ON TELEROBOTICS INPUT / OUTPUT. (ARC)

96 - COMPLETE DESIGN OF VALIDATION EXPERIMENTS OF IN SPACE COGNITIVE AND PERCEPTIONAL METHODS. (ARC)

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HUMAN SUPPORT PROGRAM: RESOURCES CURRENT

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FISCAL	FY 1990	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996
HUMAN SUPPORT R & T (RTOP 506-71)	4.2	4.4	5.2	5.0	5.3	5.5	5.6
HUMAN SUPPORT EXPLORATION	2.3	3.5	16.0	24.0	33.5	39.0	47.0
Rereneration Life Support	.9	2.0	8.0	12.0	18.0	20.0	24.0
Radiation Protection	---	0.53	3.0	6.0	6.5	7.0	6.0
Extravehicular Activity Systems	0.5	1.0	4.0	5.0	8.0	11.0	12.0
Exploration Human Factors	0.9	—	1.0	1.0	1.0	1.0	3.0
TOTALS:	6.8	7.9	21.2	29.0	38.8	44.5	52.6

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HUMAN SUPPORT PROGRAM: RESOURCES " 3 X "

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FISCAL	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
HUMAN SUPPORT R & T (RTOP 506-71)	4.4	5.2	5.9	7.7	8.8	9.4	10.6
HUMAN SUPPORT EXPLORATION	3.8	16.0	21.3	29.5	35.5	39.0	42.4
Rereneration Life Support	1.9	8.0	10.0	15.0	17.0	17.5	18.0
Radiation Protection	0.5	3.0	5.8	6.5	7.0	8.0	8.4
Extravehicular Activity Systems	0.9	4.0	4.5	7.0	8.5	9.5	11.0
Exploration Human Factors	0.5	1.0	1.0	1.0	3.0	4.0	5.0
SPACE STATION			4.0	9.0	15.6	18.0	18.0
Zero G Life Support			1.8	4.7	8.2	10.0	13.0
Zero G EMU			2.2	4.3	7.4	8.0	5.0
TOTALS:	8.2	21.2	31.2	46.2	59.9	66.4	71.0

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HUMAN SUPPORT PROGRAM: RESOURCES STRATEGIC

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FISCAL	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
HUMAN SUPPORT R & T (RTOP 506-71)	4.4	5.2	7.3	9.4	11.1	12.8	14.8
HUMAN SUPPORT EXPLORATION	3.8	16.0	25.9	38.9	50.9	60.3	65.8
Rereneration Life Support	1.9	8.0	12.0	18.0	20.0	24.0	25.1
Radiation Protection	0.5	3.0	6.9	7.8	8.5	9.7	10.0
Extravehicular Activity Systems	0.9	4.0	5.0	8.0	11.0	12.0	12.5
Exploration Human Factors	0.5	1.0	2.0	3.1	5.8	6.3	6.7
Artifical Gravity					1.3	1.4	3.6
Medical Support Sys.				2.0	4.3	6.9	7.9
SPACE STATION			8.4	18.1	24.2	27.5	24.6
Zero G Life Support			2.5	6.4	9.2	15.5	16.3
Zero G EMU			3.0	5.3	8.2	9.6	8.3
Adv. Refrig. Systems				2.0	3.2	1.5	
Station-Keeping Prop.			2.9	4.4	3.6	0.9	
TOTALS:	8.2	21.2	41.6	66.4	86.2	100.6	105.2

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HUMAN FACTORS PROGRAM AREA OF THE INTEGRATED TECHNOLOGY PLAN

Dr. JAMES P. JENKINS

JUNE 24 - 28, 1991

OFFICE OF AERONAUTICS, EXPLORATION AND TECHNOLOGY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

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HUMAN FACTORS DESIGN: TECHNOLOGY NEEDS AND CHALLENGES

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- DEVELOPMENT OF METHODS TO AUGMENT HUMAN SENSORY, MOTOR AND INTELLECTUAL CAPABILITIES.
- PROVIDE GUIDANCE IN WORKSTATION DESIGN AND EVALUATION .
- PROVIDE RELIABLE TECHNIQUES AND METHODS FOR EVALUATION OF HUMAN PERFORMANCE, WORKING AND LIVING ENVIRONMENTS.
- NEW TRAINING METHODS AND APPLICATIONS FOR EXTENDED DURATION IN SPACE FOR SPACE CREW AND GROUND SUPPORT STAFF.

HUMAN FACTORS DESIGN: BENEFITS

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- INCREASE SAFETY, EFFECTIVENESS AND RELIABILITY OF CREW AND GROUND SUPPORT STAFF.
- MORE EFFECTIVE WAYS TO FUSE HUMAN AUTOMATION INTERACTIONS.
- UTILIZE AERO TECHNOLOGY ADVANCES TO SPACE DOMAINS BY EXTENSION OF COCKPIT DESIGN AND CREW INTERFACE.
- BENEFITS OF FOCUSED PROGRAMS.

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HUMAN FACTORS DESIGN: OBJECTIVES

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OBJECTIVE: TO PROVIDE GUIDELINES, METHODS AND TECHNOLOGY TO ASSURE THE SAFE AND EFFECTIVE UTILIZATION OF HUMAN IN-SPACE. GOALS INCLUDE:

- DEVELOP THE HUMAN FACTORS INFORMATION AND DATABASE TO SUPPORT ALL TECHNOLOGIES NEEDED FOR HUMAN EXPLORATION OF SPACE.
- SUPPORT NATIONAL DECISIONS REGARDING THE HUMAN FACTORS ISSUES IN MISSION REQUIREMENTS AND ARCHITECTURES.
- DEVELOP THE HUMAN FACTORS KNOWLEDGE TO MAKE POSSIBLE A RANGE OF MISSION OPTIONS.
- PRODUCE RESEARCH PRODUCTS AND DEMONSTRATIONS IN THE 1990 DECADE TO SUPPORT MISSIONS FOR THE HUMAN EXPLORATION OF SPACE DECISIONS.
- CREATE INTERRELATIONSHIPS AND APPROACHES TO PROMOTE EARLY AND SUBSTANTIVE U.S. TRANSFER OF HUMAN FACTORS TECHNOLOGY DEVELOPMENTS AS THEY OCCUR.

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HUMAN FACTORS PROGRAM: ORGANIZATION

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THRUST & W.B.S / FOCUS	HUMAN FACTORS	LIFE SUPPORT	EVA SUIT	PLSS	FIRE SAFETY
HUMAN SUPPORT:					
ZERO - G SUIT	X		X	X	
CHEMICAL PROCESSING	X		X	X	
BIOMEDICAL SUPPORT	X		X	X	
SENSORS & CONTROLS	X		X	X	
CREWSTATION DESIGN	X		X	X	
THERMAL CONTROL	X		X	X	
EXPLORATION:					
EXTRAVEHICUL. ACTIVITY	X		X	X	
SPACE HUMAN FACTORS	X		X	X	
PLATFORM					
ZERO - G EMU	X		X	X	
OPERATIONS:					
OPERATOR SYSTEMS & TRAINING	X		X	X	

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HUMAN FACTORS DESIGN STATE-OF-THE-ART

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HUMAN PERFORMANCE

MODELS:
1) PRELIMINARY KINEMATIC MODELS OF HUMAN MOTION AND STRENGTH IN ZERO-GRAVITY.
2) GRAPHICS (PLAID) MODELING OF HUMAN IN SHUTTLE AND SSF.

CREW INTERFACE:
1) DESIGN GUIDELINES, NASA STD - 3000
2) HUMAN COMPUTER INTERFACE TECHNOLOGY LABORATORY, JSC VISION LABORATORY, ARC.

HUMAN - AUTOMATION - ROBOTIC SYSTEMS:
1) VIRTUAL INTERFACE ENVIRONMENT WORKSTATION DEVELOPED AND IN USE (NON - REAL TIME).
2) DATABASE OF MARTIAN (SELECTED) SURFACE.

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HUMAN FACTORS DESIGN: RECENT ACCOMPLISHMENTS

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- VISION MODEL OF HUMAN VISUAL SYSTEM USED AS ALGORITHM TO DEMONSTRATE DATA COMPRESSION AND HUMAN VISION OPERATIONS.
- GRAPHICS SYSTEM DEVELOPED TO SUPPORT CONCEPTIONAL DESIGN OF HUMAN - SYSTEM INTERFACE.
- HUMAN - COMPUTER INTERFACE GUIDELINES ADDED TO "MAN - SYSTEMS INTEGRATION STANDARDS" NASA - STD - 3000.
- DEMONSTRATED EXPLORATION OF THE MARTIAN SURFACE BY VIRTUAL WORKSTATION USING ANALOG STUDIES IN DEATH VALLEY.
- ESTABLISHED A SPACE OPERATIONAL EXPERIENCE DATABASE OF HUMAN PERFORMANCE.

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OTHER GOVERNMENT SUPPORT TO HUMAN FACTORS DESIGN

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- DOD - DESIGN OF HUMAN COMPUTER INTERFACES FOR MILITARY SYSTEMS. NASA - DOD TAG.
- FAA - STUDIES OF FLIGHT CREW PERFORMANCE; COAUTHOR OF FAA - NASA NATIONAL PLAN FOR AVIATION HF, COORDINATED THROUGH FAA - NASA COORDINATION COMMITTEE
- NATIONAL SCIENCE FOUNDATION - PERFORMANCE OF HUMANS IN ISOLATED (ANTARCTICA) ENVIRONMENTS.
- CODE SB - TRANSFER AERO RESEARCH RESULTS IN CIRCADIAN DERGNCHONOSIS TO ASTRONAUT CONDITIONING.
- CODE RC - TRANSFER OF AVIATION HUMAN FACTORS TECHNOLOGY IN CREW TRAINING AND FATIGUE COUNTERMEASURES.

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HUMAN FACTORS N DESIGN: PRIORITIES

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SS TAC COMMITTEE ON HUMAN PERFORMANCE FOR LONG DURATION SPACE MISSIONS (1989 - 1991)

1. HUMAN WORK ENVIRONMENT DEFINITION AND DESIGN CONSTRAINTS FOR PLANETARY SPACECRAFT AND LUNAR / SURFACE HABITATS AND WORK AREAS.
   a) HUMAN-SYSTEM FUNCTION ALLOCATIONS, PERFORMANCE MEASUREMENT METHODS AND PREDICTIONS FOR SAFETY AND PRODUCTIVITY.
   b) HUMAN TASK, TOOLS AND JOB AIDS.
   c) DEFINITION FO TELEROBOTIC MANAGEMENT AND METHODS.
   d) CONSTRAINTS AND REQUIREMENTS DUE TO HARSH WORKING ENVIRONMENT, I.E., RADIATION, DUST, PARTIAL GRAVITY, TEMPERATURE EXTREMES, COMMUNICATIONS, SAFETY.

2. HUMAN LIVING ENVIRONMENT DEFINITION AND RELIABLE METHODS FOR QUANTITATIVE AND QUALITATIVE EVALUATIONS OF ENVIRONMENTAL FACTORS.
   a) PHYSICAL.
   b) HUMAN FACTORS STANDARDS.
   c) PHYSIOLOGICAL NEEDS.
   d) INTERFACES BETWEEN HUMAN-SYSTEM AND HUMAN-HUMAN.

3. DESIGN SUPPORT METHODS AND TOOLS.
   a) REQUIREMENTS AND GUIDELINES FOR USE OF DESIGN SUPPORT TOOLS AND CAPABILITIES, (CAD, CAM, CAE, MIDAS).

6/25

HUMAN FACTORS DESIGN: PRIORITIES (cont.)

OAET

4. IDENTIFICATION OF HUMAN PERFORMANCE CAPABILITIES AND LIMITATIONS (HUMAN ERROR) FOR SAFE, EFFECTIVE AND PRODUCTIVE HUMAN PERFORMANCE FOR LONG DURATION SPACE MISSIONS, INCLUDING LUNAR AND PLANETARY SURFACE OPERATIONS.
   a) DEVELOPMENT OF A HUM;AN PERFORMANCE DATABASE AND LESSONS FROM OPERATIONAL EXPERIENCES.
   b) DEVELOPMENT OF DATA STORAGE, RETRIEVAL, AND ANALYSIS TECHNOLOGY.
   c) DEVELOPMENT AND APPLICATION OF HUMAN PERFORMANCE WORK BREAKDOWN STRUCTURE TO SPECIFY HUMAN CAPABILITIES AND HUMAN ERROR.
5. DEVELOPMENT OF ARTIFICIAL REALITY TECHNOLOGY AND COGNITIVE AIDS FOR APPLICATION IN FIELDS OF SPACE EXPLORATION, MEDICAL DIAGNOSIS AND IMPLEMENTATION, TRAINING, AND HUMAN-SYSTEM DESIGN.
   a) DEVELOPMENT OF COMPUTER SYSTEMS AND NETWORKS TO ACCOMMODATE DATABASES FOR VIRTUAL REALITY GRAPHICS, ICONS AND INTERACTIONS.
   b) LOW COST HEAD-MOUNTED DISPLAYS WITH HIGH RESOLUTION, STEREO, COLOR, AND WIDE FIELD-OF-VIEW.
   c) HUMAN-CENTERED INTERFACES AND INTERACTIVE AIDS.
   d) DATA HANDLING TECHNIQUES FOR REAL-TIME VIRTUAL REALITY INTERACTIONS.

6. SIMULATION AND TRAINING TECHNOLOGY METHODS FOR SKILL AND KNOWLEDGE DEVELOPMENT AND RETENTION FOR LONG DURATION MISSIONS.
   a) SPECIAL AND PART TASK MISSION SIMULATION.
   b) EMBEDDED TRAINING METHODS.
   c) INTELLIGENT TRAINING SYSTEMS.

6/25

HUMAN FACTORS DESIGN: PRIORITIES (cont.)

OAET

7. PHYSICAL AUGMENTATIONS AND WORKSTATION DESIGN CONCEPTS TO ENHANCE PRODUCTIVITY.
   a) ENHANCEMENT OF HUMAN SENSORY AND MOTOR CONTROL CAPABILITIES THROUGH TECHNOLOGY AREAS INCLUDING TELEROBOTIC INTERFACES, EVA WORK AIDS END EFFECTORS, COMPUTATIONAL VISION METHODS AND ADVANCED IMAGING SYSTEMS.
   b) CONTINUED DEVELOPMENT OF DESIGN PRACTICES AND PRINCIPLES, EMBODIED IN NASA STANDARD 3000, "MAN-SYSTEMS INTEGRATION STANDARDS".

8. IDENTIFICATION OF HUMAN PERFORMANCE CAPABILITIES AND LIMITATIONS (HUMAN ERROR) FOR SAFE, EFFECTIVE AND PRODUCTIVE HUMAN PERFORMANCE FOR LONG DURATION SPACE MISSIONS, INCLUDING LUNAR AND PLANETARY SURFACE OPERATIONS.
   a). DEVELOPMENT AND APPLICATION OF HUMAN PERFORMANCE WORK BREAKDOWN STRUCTURE TO SPECIFY HUMAN CAPABILITIES AND HUMAN ERROR.

6/25

MILESTONES

OAET

HUMAN FACTORS - EXPLORATION

92 - COMPLETE VALIDATION OF HUMAN ARM STRENGTH IN O - G AND PARTIAL G.

94 - COMPLETE REQUIREMENTS FOR CREW ACCOMMODATIONS ON LUNAR SURFACE (TRASH MANAGEMENT, FOOD, STORAGE REQUIREMENTS). (JSC)

95 - COMPLETE DEMONSTRATION OF VIRTUAL WORKSTATION WITH TELEROBOTIC COMMANDS. (LARC)

96 - ESTABLISH GUIDELINES AND REQUIREMENTS FOR OPERATOR'S VISUAL ACCESS, VIA SYNTHETIC VISION METHODS, AND IMAGE ENHANCEMENT (LIGHTING, CAMERA POSITIONING, FIELD OF VIEW).

97 - COMPLETE GUIDELINES FOR AUTOMATED SYSTEM DISPLAY, CONTROLS AND PROXIMITY OPERATIONS. (ARC)

98 - COMPLETE INTEGRATION OF LABORATORIES FOR HUMAN PERFORMANCE TESTING. (ARC, JSC)

6/25

MILESTONES

OAET

HUMAN FACTORS - OPERATIONS

94 - COMPLETE ADAPTATION OF TRANSPORT CREW TRAINING (CRM) TO SPACECRAFT CREWS. (ARC, JSC)

94 - COMPLETE ADAPTIVE COGNITIVE MODELS OF SPACE FLIGHT AND GROUND CREW (ARC).

95 - VALIDATE CIRCADIAN RHYTHM SHIFTS AND METHODS / EQUIPMENT REQUIREMENTS (JSC) AND DEVELOP INSTRUCTION MODULE (ARC).

96 - COMPLETE VIRTUAL REALITY CAPABILITIES FOR ON - BOARD SPACECRAFT TRAINING (ARC, JSC).

6/25

EVA PROGRAM: TECHNOLOGY NEEDS AND CHALLENGES

OAET

- FLEXIBLE EASY TO USE, HIGH PRESSURE EVA GLOVES WITH LOW COST TO PRODUCE AND INCREASED VERSATILITY.
- EVA / EMU DISPLAY AND CONTROL TECHNIQUES.
- MAINTAINABLE ON ORBIT / IN SITU EMU BY CREW.
- RELIABILITY INCREASE TO MATCH MISSION REQUIREMENTS.
- FLIGHT WEIGHT COMPONENTS IN PLSS AND SUIT MATERIALS FOR SURFACE OPERATIONS IN 1/3 AND 1/6 GRAVITY.
- ZERO PREBREATHE REQUIREMENTS TO REDUCE OPERATIONAL OVERHEAD.
- AIR RECYCLING AND WASTE (LIQUID, GAS, SOLID) PROCESSING AND RECLAMATION.
- RADIATION SHIELDING FOR PERSONNEL.
- DUST RESISTANT.
- EMU MOBILITY OVER ROUGH TERRAIN.
- FLEXIBILITY IN DESIGN / SINGLE DESIGN BASE WITH MULTIPLE MISSION ADAPTATION

6/25/9

EVA PROGRAM: OBJECTIVE

OAET

TO DEVELOP TECHNOLOGY BASE FOR ADVANCED EVA SUIT, GLOVES, PLSS, SUIT INTERFACES, MOBILITY AIDES WHICH ARE RUGGED, RELIABLE, AND CAPABLE OF HIGH USE RATES FOR ORBITAL AND SURFACE MISSIONS. GOALS INCLUDE:

- DEVELOP ROBUST EMU FOR SPACE STATION FREEDOM OPERATIONAL SUPPORT.
- DEVELOP LUNAR AND MARTIAN SURFACE SUIT COMPONENTS.
- PROVIDE EASY TO USE AND HIGHLY MAINTAINABLE PLSS.
- ACCELERATE DEVELOPMENT OF KEY, HIGH - PAYOFF CAPABILITIES FOR EVA GLOVES.
- TRANSFER MATURING TECHNOLOGY TO FOCUSED THRUSTS AND TO MISSIONS FOR EVA SUIT MOBILITY (JOINTS) AND SUIT MATERIALS, EVA DISPLAY AND CONTROL TECHNOLOGIES.

6/25/9

EVA PROGRAM: BENEFITS

OAET

- INCREASE ON - ORBIT EASE OF USE, EFFECTIVENESS AND MAINTAINABILITY OF EMU SYSTEM.
- APPLICATION OF R & T BASE TO THRUST (ENABLING TECHNOLOGY FOR ALL ASPECTS)

  PLATFORM - EXPLORATION (SURFACE SUIT)
- ORDER OF MAGNITUDE INCREASE IN EVA SYSTEM CAPABILITY.
- TRANSFER OF EVA TECHNOLOGY TO TERRESTRIAL APPLICATIONS.

6/25/9

EVA PROGRAM: ORGANIZATION

OAET

THRUST & W.B.S / FOCUS	HUMAN FACTORS	LIFE SUPPORT	EVA SUIT	PLSS	FIRE SAFETY
HUMAN SUPPORT					
ZERO - G SUIT			X	X	
CHEMICAL PROCESSING			X	X	
BIOMEDICAL SUPPORT			X	X	
SENSORS & CONTROLS			X	X	
CREWSTATION DESIGN			X	X	
THERMAL CONTROL			X	X	
EXPLORATION					
EXTRAVEHICUL. ACTIVITY			X	X	
SPACE HUMAN FACTORS			X	X	
PLATFORM					
ZERO - G EMU			X	X	
OPERATIONS					
OPERATOR SYSTEMS & TRAINING			X		

6/25/9

EVA STATE-OF-THE-ART

OAET

- SHUTTLE EMU OPERATION AT 4.3 PSIA:
  - REQUIRES EVA PREBREATHE 100% O_2 FOR 4 HRS. OR;
  - DEPRESS CABIN TO 10.2 PSIA - 24 HRS. WITH 40 MINUTE PREBREATHE PRIOR TO EVA
  - OPERATIONAL "R" FACTOR = 1.65 (HIGH BENDS RISK)
- SHUTTLE EMU CURRENTLY CERTIFIED FOR 3 EVA'S PER FLIGHT
  - TWO PLANNED EVA'S; ONE CONTINGENCY EVA
  - DELTA CERTIFICATION IN PROCESS FOR 25 EVAS PER FLIGHT
- SHUTTLE EMU REQUIRES MANUAL SERVICING AFTER EACH EVA
- SHUTTLE EMU REQUIRES GROUND TURNAROUND FOR MAINTENANCE AFTER EACH FLIGHT:
  - SPECIAL EQUIPMENT SUPPORT; NON - MODULAR PLSS
- LIMITED RESIZING ON - ORBIT
- HIGH LIFE CYCLE COST DUE TO LOGISTICS REQUIREMENTS
- EVA'S SCHEDULED FOR SPECIFIC SHUTTLE FLIGHTS; NOT CONSIDERED ROUTINE OPERATION FOR EVERY FLIGHT
- GLOVES ARE CUSTOM MADE AND EXPENSIVE
- PAPER DISPLAYS OF PROCEDURES

6/25/91

EVA PROGRAM: RECENT ACCOMPLISHMENTS

OAET

- AX-5 HIGH PRESSURE SUIT COMPLETED AND EVALUATED WITH MARK III AND CURRENT SHUTTLE SUITS.
- EVA METABOLIC RESEARCH LABORATORY COMPLETED AND CERTIFIED.
- EVALUATION OF A PROTOTYPE THERMAL CONTROL CONCEPT COMPLETED.
- ANALYSIS OF HELMET MOUNTED DISPLAY CONCEPT AND ELECTRONIC WRIST MOUNTED DISPLAY CONCEPT COMPLETED.
- IDENTIFIED INITIAL REQUIREMENTS FOR SURFACE SUIT.
- OPERATIONAL EXPERIENCE DATABASE TAXONOMY ESTABLISHED.
- EVALUATION OF POLYMER MATERIALS AND GLOVE MANUFACTURING TECHNIQUE FOR GLOVES COMPLETED.
- PHYSICAL METHODS TO MEASURE 1/6 GRAVITY EFFECTS ON HUMAN METABOLIC RATES COMPLETED.
- DATABASE STRUCTURED FOR HUMAN STRENGTH AND MOTION IN MICRO GRAVITY.

6/25/9

OTHER GOVERNMENT SUPPORT TO EVA PROGRAM

OAET

- NO OTHER U.S. GOVERNMENT EFFORTS, BESIDES NASA
- EUROPEAN AGENCIES UNDER EUROPEAN SPACE AGENCY DEVELOPING EVA TECHNOLOGY FOR HERMES.
- SOVIET MIR / SALYUT SUIT OPTIMIZED FOR ON - ORBIT ADJUSTMENT AND MAINTENANCE.
- CODE S - EVA MINOR MODS.
  - NO SSF DEVELOPMENT.

6/25/9

EVA PROGRAM: PRIORITIES

OAET

SS TAC COMMITTEE ON HUMAN PERFORMANCE FOR LONG DURATION SPACE MISSIONS (1989 - 1991)

1. EVA PRODUCE OPERATIONS FOR FUTURE MANNED MISSIONS NEED NEW GLOVE TECHNOLOGY, ON - ORBIT / IN - SITU MAINTAINABILITY CURRENT SUITS INCOMPATIBLE FOR LUNAR OR PLANETARY SURFACE OPERATIONS.
   a) DEXTEROUS GLOVES.
   b) HIGH RELIABILITY, LOW MAINTAINABILITY SUIT SYSTEMS.
   c) LIGHTWEIGHT COMPONENTS AND MATERIALS FOR PLSS & SUIT
   d) FLEXIBILITY COMMUNICATIONS.
   e) MOBILITY.
   f) MULTI - FUNCTION DISPLAYS.
2. PORTABLE SUPPORT SYSTEMS,.
   a) LOW WEIGHT, REDUCED VOLUME, LOW POWER. HIGH RELIABILITY COMPONENTS, LOW MAINTAINABILITY IN SITU / ON SITE.
3. COMBINE BEST FEATURES OF AX-5 AND MARK III SUITS INTO AN HYBRID SUIT FOR SUPPORT TO OPERATIONS ON SPACE STATION FREEDOM.

6/25/9

MILESTONES

OAET

EVA - EXPLORATION

92 - COMPLETE IDENTIFICATION OF LUNAR SURFACE OPERATIONAL REQUIREMENTS (DUST EFFECTS, THERMAL RAYS, MOBILITY) (JSC).

93 - PROVIDE RECOMMENDATION FOR PLANETARY EMU CONFIGURATION (ARC).

94 - LAB DEMO OF THERMAL MANAGEMENT CONCEPT FOR LUNAR OPERATIONS (JSC).

95 - COMPLETE SELECTION OF DISPLAYS FOR LUNAR SUIT AND GLOVES.

96 - COMPLETE FABRICATION OF ADVANCED PLSS (ARC).

98 - DEMONSTRATE BREADBOARD OF LUNAR SUIT / PLSS IN SIMULATED ENVIRONMENT.

6/25/9

MILESTONES

OAET

EVA - PLATFORM

93 - COMPLETE DESIGN CONCEPT FOR HYBRID SUIT.

94 - COMPLETE TESTING OF BREADBOARD FOR UPGRADED PLSS.

95 - COMPLETE TESTING OF ADVANCED DISPLAY CONCEPT.

97 - COMPLETE FABRICATION OF HYBRID PROTOTYPE SUIT.

98 - COMPLETE TESTING OF HYBRID PROTOTYPE SUIT AND COMPONENTS.

6/25

OAET

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

HUMAN SUPPORT: LIFE SUPPORT TECHNOLOGY

PEGGY L. EVANICH

JUNE 24 - 28, 1991

OFFICE OF AERONAUTICS, EXPLORATION AND TECHNOLOGY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

6/24/9

TECHNOLOGY NEEDS AND CHALLENGES

OAET

- ELIMINATE (OR MINIMIZE) RESUPPLY OR EXPENDABLES FOR LONG DURATION MISSIONS.

- WATER AND ATMOSPHERIC SUPPLIES CONTROLLED WITHIN MICROBRIAL AND CHEMICAL CONTAMINANT LIMITS.

- MINIMIZE CREW INTERACTION/INTERVENTION WITH LIFE SUPPORT SYSTEM OPERATION.

6/24

OBJECTIVE

OAET

- DEVELOP A REGENERATIVE PHYSICAL-CHEMICAL LIFE SUPPORT SYSTEMS TECHNOLOGY BASE TO ENABLE HUMAN EXPLORATION MISSIONS.
  - DEVELOP AND UTILIZE APPROPRIATE SYSTEM ANALYSIS METHODOLOGIES TO GUIDE R&T EFFORTS.
  - EFFICIENT AIR, WATER AND WASTE MANAGEMENT PROCESSORS.
  - EFFICIENT HABITAT THERMAL CONTROL.
  - SENSOR AND CONTROL SYSTEMS TECHNOLOGIES FOR AUTONOMOUS OPERATIONS.
  - DEMONSTRATE CLOSED SYSTEM OPERATIONS IN GROUND TESTBEDS.
  - VALIDATE SPACE-BASED OPERATION OF REQUIRED COMPONENTS.
- DEVELOP NASA EXPERTISE IN CHEMICAL ENGINEERING R&T APPLICABLE TO LIFE SUPPORT SYSTEMS.

6/24/9

BENEFITS

OAET

- ENABLES LONG DURATION HUMAN SPACE MISSIONS (CURRENT ABSENCE OF ANY TECHNICAL BASIS FOR LIFE SUPPORT SYSTEMS).
- LONGER DURATION MISSIONS W/O RESUPPLY. INCREASED SAFETY, CREW HEALTH, RELIABILITY, MISSION SUCCESS.
- REDUCED LIFE CYCLE COST WITH REGENERATIVE SYSTEMS.
- POTENTIAL TERRESTRIAL SPIN-OFFS IN WATER RECLAMATION, WASTE MANAGEMENT, MICROBIAL AND CHEMICAL SENSORS FOR A VARIETY OF GOVERNMENT AND COMMERCIAL APPLICATIONS.

ORGANIZATION OF PROGRAM

OAET

LIFE SUPPORT TECHNOLOGY PROGRAM

BASE R & T

ARC, JSC, LeRC

- CHEMICAL PROCESSING
- SENSORS & CONTROL
- PLSS THERMAL CONTROL
- HABITAT THERMAL CONTROL
- BIOMEDICAL SUPPORT
- FIRE SAFETY

EXPLORATION

LEAD: ARC
JSC, JPL

- TECHNOLOGY DEVELOPMENT
- LUNAR BASE LIFE SUPPORT TESTBED
- SENSORS & CONTROLS
- SYSTEMS ANALYSIS

PLATFORMS

JPL, MSFC, JSC, ARC, LeRC

- SENSORS & CONTROLS LEAD: JPL, (MSFC)
- ACTIVE THERMAL CONTROL - JSC
- TECHNOLOGY AND IN - SPACE VALIDATION - JSC, ARC
- ADV. REFRIG. SYSTEMS - JSC
- BIOMEDICAL SUPPORT - JSC
- FIRE SAFETY - LeRC

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LIFE SUPPORT STATE-OF-THE-ART

OAET

- OPEN (I.E., STORED) AND/OR RESUPPLIED AIR AND WATER SUPPLIES.
- WASTE STORAGE AND RETURN TO EARTH.
- PRIMARY MANUAL SENSING AND CONTROL AND CONTAMINANTS IN AIR, WATER.
- COMPREHENSIVE SYSTEMS RELIABILITY DATA NON-EXISTENT FOR REGENERATIVE LIFE SUPPORT OR INTEGRATED SYSTEMS.

PHYSICAL-CHEMICAL LIFE SUPPORT RECENT ACCOMPLISHMENTS

OAET

- INTRODUCED COMMERCIALLY AVAILABLE S-O-A CHEMICAL PROCESSING MODELLING TECHNIQUES AS INTEGRAL PART OF THE RESEARCH APPROACH.
- DEVELOP A COMPREHENSIVE, RIGOROUS SYSTEMS ANALYSIS METHODOLOGY FOR THE CONDUCT OF TECHNOLOGY TRADES AND SYSTEM OPTIMIZATION.
- EXTENDED DURATION ORBITER DEVELOPING THE REGENERATIVE SOLID AMINE CO_2 REMOVAL SYSTEM FOR OPERATIONAL USE.

6/24/9

OTHER GOVERNMENT AGENCIES

OAET

- US NAVY - POLLUTION - FREE NAVY BY 2000
  - SUBMARINE LIFE SUPPORT
  - SURFACE SHIP WASTE MANAGEMENT
- NATIONAL INSTITUTE FOR STANDARDS AND TECHNOLOGY
  - CHEMICAL, BIOLOGICAL SENSORS
- US ARMY - SENSORS FOR BIOLOGICAL, CHEMICAL WARFARE SYSTEMS
- NATIONAL SCIENCE FOUNDATION - ANTARCTICA BASE LIFE SUPPORT

PRIORITIES FOR LIFE SUPPORT TECHNOLOGY

OAET

1. SENSORS AND CONTROLS
   - CHEMICAL SENSORS
   - MICROBIAL SENSORS
   - ENVIRONMENTAL SENSORS
   - AUTONOMOUS CONTROL SYSTEMS

2. INTEGRATED SYSTEM TESTBED
   - INVESTIGATE COMPLEX CLOSED SYSTEM INTERACTIONS
   - DEMONSTRATE SENSOR AND CONTROL SYSTEM TECHNOLOGIES
   - DEMONSTRATE LONG LIFE SYSTEM PERFORMANCE

3. REGENERATIVE LIFE SUPPORT PROCESSOR TECHNOLOGIES
   - AIR, WATER, WASTE MANAGEMENT
   - HABITAT THERMAL CONTROL

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EXTERNAL REVIEWS OF LIFE SUPPORT

OAET

SSTAC / ARTS

- AD HOC REVIEW TEAM ON ADVANCED LIFE SUPPORT TECHNOLOGY
- CURRENTLY FORMULATING FINDINGS, RECOMMENDATIONS
- DECEMBER 1990 - JULY 1991

TECHNOLOGY ASSESSMENT

- COMPREHENSIVE REVIEW & ASSESSMENT OF THE EXISTING LIFE SUPPORT TECHNOLOGY BASE.
- WATER RECLAMATION - MID 1991
- AIR REVITALIZATION - LATE 1991
- WASTE PROCESSING - MID 1992
- SYSTEMS ANALYSIS & MATH MODELS - MID 1992

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MILESTONES

OAET

FY '91 - INITIATE INTEGRATED LUNAR BASE LIFE SUPPORT TESTBED FACILITY / TECHNOLOGY BUILDUP (CURRENT TECHNOLOGY). (JSC)

FY '91 - COMPLETE INTEGRATED LUNAR TESTBED, INITIATE OPERATIONS. (JSC)

FY '92 - INITIATE LAB / BREADBOARD TESTS OF WATER RECLAMATION, WASTE MANAGEMENT PROCESSORS. (ARC)

FY '92 - INITIATE LAB / BREADBOARD TESTS OF ADVANCED AIR PROCESSORS, HABITAT THERMAL CONTROL. (JSC)

FY '94 - COMMENCE WATER, WASTE, AIR, THERMAL CONTROL SUBSYSTEM TEST. (ARC, JSC)

FY '95 - INITIATE TECHNOLOGY TESTBED. (ARC)

FY '98 - COMPLETE ADVANCED TECHNOLOGY LUNAR BASE LIFE SUPPORT INTEGRATED SYSTEM TESTS. (JSC)

6/24/91

HUMAN SUPPORT PROGRAM: RESOURCES

OAET

FISCAL	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
HUMAN SYSTEM (RTOP 506-71)	4,400	5,200	7,300	9,400	11,100	12,800	14,800
LS (OLD) EXPLORATION	2,000	8,000	12,000	18,000	20,000	24,500	25,000
LS (NEW) EXPLORATION	2,000	8,000	10,000	15,000	17,000	17,500	18,000
LS (OLD) PLATFORMS	—	—	2,500	6,400	9,200	15,500	16,300
LS (NEW) PLATFORMS	—	—	1,800	4,700	8,200	10,000	13,000

FACILITIES : JSC: LUNAR BASE LIFE SUPPORT TESTBED.
ARC: LIFE SUPPORT LABS, TECHNOLOGY TESTBED.

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INTEGRATED TECHNOLOGY PLAN

OAET

LIFE SUPPORT ELEMENTS (PLATFORMS AND R & T BASE)

- PLATFORMS
  - SENSORS AND CONTROLS FOR SSF LIFE SUPPORT.
  - LIFE SUPPORT COMPONENT IMPROVEMENT AND IN - SPACE TESTING ABOARD SSF.
- PLATFORMS AND R & T BASE
  - ACTIVE THERMAL CONTROL FOR SSF HABITAT
- BIOMEDICAL SUPPORT (PLATFORMS AND R & T BASE)
  - ADVANCED REFRIGERATION SYSTEM FOR LIFE SCIENCES RESEARCH MISSIONS.
  - STS, SPACELAB, EDO, SSF, SEI
  - HEALTH CARE SYSTEMS TECHNOLOGY.
- FIRE SAFETY (PLATFORMS AND R & T BASE)
  - FUNDAMENTAL FIRE BEHAVIOR IN SPACE ENVIRONMENTS
  - DEVELOPMENT AND VALIDATION OF TECHNOLOGIES FOR:
    - FIRE PREVENTION
    - FIRE DETECTION
    - FIRE SUPPRESSION

6/24/9

INTEGRATED TECHNOLOGY PLAN: RESOURCES R & T BASE AND PLATFORMS

OAET

R & T BASE

FY '91	FY '92	FY '93	FY '94	FY '95	FY '96	FY '97
.5M		(PLUS INFLATION ON OUTYEARS)			(OLD)	

CURRENT CONTENT: CHEMICAL PROCESSING FOR LIFE SUPPORT ($300K), SENSORS ($50K), EVA THERMAL CONTROL ($150K).

WITH AUGMENTATION: INCREASE FUNDING FOR ELEMENTS ABOVE, ADD FUNDING FOR HABITAT THERMAL CONTROL, BIOMEDICAL SUPPORT AND FIRE SAFETY FUNDAMENTALS.

INTEGRATED TECHNOLOGY PLAN: RESOURCES R & T BASE AND PLATFORMS

OAET

PLATFORMS

($ M)

FY '93	FY '94	FY '95	FY '96	FY '97	
2.5	6.4	9.2	15.5	16.3	(OLD)
1.8	4.7	8.2	10.0	13.0	(NEW)

PROPOSED CONTENT:

SSF LIFE SUPPORT SENSORS AND CONTROLS (OLD AND NEW)

ACTIVE THERMAL CONTROL FOR SSF HABITAT (OLD AND NEW)

SSF LIFE SUPPORT COMPONENT IMPROVEMENT AND IN - SPACE TESTING: (FUNDING FULLY OR PARTIALLY UNDER OLD AND NEW: SPECIFIC CONTENT DEPENDS UPON SSF DEVELOPMENT PROGRAM AND FINAL CONFIGURATION)

6/24/F

ISSUES

OAET

- AGENCY COMMITMENT TO DEVELOPING LIFE SUPPORT TECHNOLOGY AND SYSTEMS FOR SPACE STATION FREEDOM AND EXPLORATION MISSIONS.

- RELATIVE FUNDING LEVELS OF AGENCY LIFE SUPPORT RESEARCH PROGRAMS:
  - OAET TECHNOLOGY PROGRAM FUNDING COMPARABLE WITH OSSA CONTROLLED ECOLOGICAL LIFE SUPPORT PROGRAM FUNDING.

- LACK OF SUBSTAINED OAET LIFE SUPPORT TECHNOLOGY PROGRAM IN THE R & T BASE PROGRAM AS A CAPABILITY, EXPERTISE SOURCE FOR FOCUSSED PROGRAM REQUIREMENTS.

HUMAN FACTORS
AMES RESEARCH CENTER

DR. CYNTHIA H. NULL

JUNE 26, 1991

"Many of NASA's currently planned activities such as extended duration orbiter, Space Station Freedom assembly operations, extended duration crew operations, and extended duration missions beyond earth orbit may face significant safety problems arising from inadequate consideration of human performance and human capacity. Potential human performance problems can arise from either extended normal operations that exceed the knowledge base for humans in space or from unexpected (non-normal), and even unforeseen events (unexpected and not part of the training syllabus), that will certainly occur during long-duration missions."

--Aerospace Safety Advisory Panel, 1990

CURRENT SPACE GOALS

SPACE EXPLORATION

"Develop & demonstrate critical technologies needed for *human* exploration of planetary surfaces & the emplacement of *human* outposts on the Moon & Mars."

- COMPUTATIONAL MODELS OF HUMAN PERFORMANCE
- TRAINING SPECIFIC TO SEI MISSIONS
- HUMAN/SYSTEM INTERFACE REQUIREMENTS

HUMAN FACTORS

C. NULL 6/26/91

CURRENT SPACE GOALS

OPERATIONS TECHNOLOGY

"Develop & demonstrate technology to reduce the cost of NASA operations, improve safety & reliability of those operations, & enable new, more complex activities to be undertaken with robust & flexible support systems."

- EFFECTIVE RELIABLE OPERATIONS DEPEND ON HUMAN CAPABILITIES
- DEMONSTRATION IN LAUNCH & MISSION CONTROL FOR STS

HUMAN FACTORS

C. NULL 6/26/91

CURRENT SPACE GOALS

SPACE SCIENCE TECHNOLOGY

"Develop the advanced technology required for acquiring & understanding observations from future NASA space & Earth science missions."

- SCIENCE WILL BE PERFORMED BY HUMANS WHETHER ON EARTH, SPACE PLATFORMS, OR ON PLANETARY SURFACES
- EXPLORATION REQUIRES HUMAN DISCOVERY & CREATIVITY
- USING & INTERPRETING DATA IS A HUMAN ENDEAVOR. ANALYSIS TOOLS MUST BE READILY AVAILABLE

CURRENT SPACE GOALS

SPACE PLATFORMS

"Enhance future science, exploration & commercial missions by developing & validating technologies that will enable reductions in launch weight, increase lifetime, decrease on-orbit maintenance, & decrease logistics resupply needs."

- SPACE PLATFORMS WILL BE USED FOR LIFE SCIENCE EXPERIMENTS INCLUDING HUMAN FACTORS
- MAINTENANCE WILL BE DONE BY HUMANS, OR HUMANS ASSISTED BY INTELLIGENT TOOLS REQUIRING A HUMAN-CENTERED INTERFACE

CURRENT SPACE GOALS

TRANSPORTATION TECHNOLOGY

"Provide technologies that substantially increase operability, improve reliability, provide new capabilities, while reducing costs."

- OPERABILITY INCLUDES THE HUMAN IN THE SYSTEM ON EARTH AND/OR IN SPACE

PRIORITIES

SSTAC subcommittee report identified, for all future manned space missions, specific areas needing human factors research, technology development, & guidelines

LIVING ENVIRONMENT
- human performance measures
- criteria for assessing total environment in terms of human productivity

WORK ENVIRONMENT
- mission analysis
- identify human functions,and tasks
- identify appropriate tools, job aids

WORKSTATIONS
- provide guidance to industry
- foster high payoff, high risk display technology

PRIORITIES

TRAINING
- NASA leadership role
- unique approaches for long duration missions
- new simulator technology
- advanced training methods

PHYSICAL AUGMENTATION
- telerobotics
- EVA work aids
- computational vision

INTELLECTUAL AUGMENTATION
- user models
- flexible and effective interfaces
- intelligent aids for assisting crew members

INTRODUCTION ARC

TOPICS

- **BASE R&T &AUGMENTATION**
- **EXPLORATION**
- **OPERATIONS**
- **SCIENCE**

CREWSTATION DESIGN TECHNOLOGY

BASE R & T

including AUGMENTATION

HUMAN FACTORS

C. Null

6/26/91

TECHNOLOGY NEEDS & CHALLENGES

- DESIGN GUIDELINES FOR INFORMATION MANAGEMENT SYSTEMS TO ENSURE SAFE, RELIABLE, & EFFECTIVE HUMAN INTERACTION
- HUMAN-CENTERED APPROACHES TO MISSION PLANNING, OPERATIONAL CONCEPTS AND TECHNOLOGY REQUIREMENTS
- METHODS TO EVALUATE AND DESIGN FOR HUMAN-HUMAN AND HUMAN-MACHINE COMMUNICATION REQUIREMENTS
- DESIGN GUIDELINES FOR INTELLIGENT AIDING SYSTEMS TO ENSURE SAFE, RELIABLE, & EFFECTIVE HUMAN INTERACTION

BENEFITS

INCREASED SAFETY, PRODUCTIVITY, AND RELIABILITY OF HUMAN ACTIVITIES IN SPACE

TRANSFER AERO TECHNOLOGY ADVANCES TO SPACE

APPLICATION OF BASE R & T TO THRUSTS

- EXPLORATION: HUMAN PERFORMANCE
  CREW SUPPORT
  HUMAN-SYSTEMS INTEGRATION
- OPERATIONS: CREW COORDINATION
  CIRCADIAN COUNTERMEASURES
  TRAINING
  HUMAN-CENTERED INTELLIGENT ASSISTANT
- SCIENCE: DATA VISUALIZATION

STATE-OF-THE-ART

- TELEROBOTIC CONTROL DEMONSTRATION WITH VIRTUAL WORKSTATION
- PROTOTYPE OF 3-D AUDITORY DISPLAY SYSTEM
- DEMONSTRATED VIRTUAL EXPLORATION OF MARTIAN SURFACE
- VISION MODEL DEMONSTRATION FOR DATA COMPRESSION
- NARROW BANDWIDTH METHOD FOR COLOR TRANSMISSION DEVELOPED
- PROXIMITY OPERATIONS SOFTWARE FOR EVA PLANNING AND SELF RESCUE PROTOTYPED

MILESTONES

BASE R&T

1992 Evaluate force-torque display format

1993 Test telerobotic operation and planning tools in Mars analog environment

1994 Simulate teleoperated, in-space docking

1995 Demonstrate crew support & enhancement technologies for Lunar habitat workstations & surface exploration systems

AUGMENTATION

1993 Test 3-D motion analysis for visual hazard detection

1994 Demonstrate Lunar habitat workstations

1995 Design prototype of crew command, control, communication and exploration systems for Lunar surface

1996 Design cognitive/perceptual experiments for space

1998 Validate human performance models

OTHER GOVERNMENT SUPPORT

DARPA -- ENHANCING VISUAL DISPLAY TECHNOLOGY

USAF -- TRAINING WITH VIRTUAL WORKSTATIONS

ARMY -- COGNITIVE/PERCEPTUAL MODELING, HUMAN-CENTERED DESIGN TOOLS

FAA/NASA AERO -- CREW COORDINATION, CREW TRAINING, FATIGUE/CIRCADIAN COUNTERMEASURES, WORKLOAD MEASURES, HUMAN/MACHINE INTERACTION, ETC.

EXPLORATION THRUST

"Develop & demonstrate critical technologies needed for *human* exploration of planetary surfaces & the emplacement of *human* outposts on the Moon & Mars."

EHFTP
EXPLORATION HUMAN FACTORS TECHNOLOGY PROJECT

COLLABORATION BETWEEN ARC (LEAD CENTER) & JSC (PARTICIPATING CENTER)

TECHNOLOGY NEEDS & CHALLENGES

- MISSION ANALYSIS FOCUSED ON HUMAN PARTICIPATION
- DATABASES & COMPUTATIONAL MODELS OF HUMAN PERFORMANCE
- DESIGN & PROTOTYPE EQUIPMENT TO ENABLE CREW TO PERFORM ALL OPERATIONAL & MAINTENANCE TASKS SAFELY, RELIABLY & EFFICIENTLY
- TRAINING PROGRAM SPECIFIC TO SEI MISSIONS, INCLUDING ON-BOARD TRAINING TECHNOLOGY & EXPERT SCIENCE ADVISORS
- INTEGRATION OF AUTOMATED & INTELLIGENT SYSTEMS WITH HUMAN OPERATORS

USER PULL

LMEPO has identified human factors issues as cross-cutting all exploration technologies:

- PSYCHOLOGICAL, BEHAVIORAL, & PERFORMANCE ADAPTATION TO LONG-DURATION MISSIONS
- HUMAN/SYSTEM INTERFACE REQUIREMENTS
- GROUP DYNAMICS
- COGNITIVE EFFECTS OF WORKLOAD & STRESS
- INFORMATION MANAGEMENT
- CREW SUPPORT REQUIREMENTS

- LMEPO 17 MAY 1990 REPORT TO SSTAC AD HOC COMMITTEE ON TECHNICAL REQUIREMENTS

EXPLORATION ARC

OBJECTIVES

- IDENTIFY & DEVELOP ENABLING & HIGH-LEVERAGE TECHNOLOGIES FOR EXPLORATION HUMAN SUPPORT
- ENABLE SAFE & EFFICIENT DESIGN OF CREW & MISSION SUPPORT SYSTEMS FOR HUMAN INTERACTIONS WITH ENVIRONMENTS & EQUIPMENT
- IDENTIFY & DEVELOP THE TECHNOLOGIES & THE DESIGN GUIDELINES FOR HUMAN OPERATION, MAINTENANCE, & INTERVENTION OF THE SYSTEMS NEEDED TO PERFORM A VARIETY OF EXPLORATION MISSIONS
- ENABLE SAFE & RELIABLE CREW OPERATION & MAINTENANCE (DURING NOMINAL & OFF-NOMINAL)

BENEFITS

- INCREASED SAFETY, PRODUCTIVITY, & RELIABILITY OF HUMAN ACTIVITIES IN SEI MISSIONS
- HUMAN-CENTERED MISSION PLANNING TOOLS
  - PERCEPTUAL/COGNITIVE MODELS VALIDATED FOR SEI MISSIONS
  - INTELLIGENT ADVISORS & TRAINING TOOLS
  - HUMAN-AUTOMATION INTERFACE PROTOTYPE
  - HIST TESTBED

STATE-OF-THE-ART

- DEMONSTRATION OF EVA PLANNING TOOL
- DEMONSTRATION OF VIRTUAL ENVIRONMENT WORKSTATION
- MIDAS--HUMAN-CENTERED DESIGN TOOL (though not adapted for space)
- COGNITIVE/ATTENTION PERFORMANCE MODEL

MILESTONES

1994 Identify human factors issues of systems for Lunar-surface operations
Demonstrate interactive visualization of human scale digital terrain based on virtual exploration
1995 Demonstrate virtual workstation simulated mission scenarios of telerobotic camera
1996 Demonstrate virtual environment exploration planning tool
Develop prototype of design of crew communication, control & exploration technologies for Lunar surface operations
1997 Provide recommendations for on-board training technology & protocols for EVA self-rescue.
Provide provisional design guidelines for displays & controls of automated systems, robotic assistants, proximity operations, & EVA systems for Lunar-surface operations
Validate model-based virtual visualization techniques of exploration behavior with leading planetary geoscientists

OPERATIONS THRUST

"Develop & demonstrate technology to reduce the cost of NASA operations, improve safety & reliability of those operations, & enable new, more complex activities to be undertaken with robust & flexible support systems."

TECHNOLOGY NEEDS & CHALLENGES

- LONG DURATION SPACE MISSIONS WILL INTRODUCE NEW & CHALLENGING STRESSES ON CREW PRODUCTIVITY, COMMUNICATION, COORDINATION & RESPONSE TO EMERGENCIES
- EXTENDED-DURATION SPACE OPERATIONS WILL CARRY ASTRONAUTS INTO UNKNOWN PERFORMANCE REGIMES
- CURRENT PROCEDURES MANUAL & CHECKLIST FOR STS FLIGHT DECK ARE INEFFICIENT & TIME-CONSUMING
- UNEXPECTED OCCURRENCES DURING LAUNCH SEQUENCE CAN PUSH NASA TEST DIRECTOR TO THE LIMIT OF HUMAN COGNITIVE CAPACITY & BEYOND

OPERATIONS ARC

OBJECTIVES

- ADAPT CREW COORDINATION TRAINING DEVELOPED FOR AVIATION TO THE SPECIAL NEEDS OF SPACE OPERATIONS CREWS
- ADAPT CIRCADIAN COUNTERMEASURES TO THE NEEDS OF ASTRONAUTS & GROUND CREWS
- ASSESS WORKLOAD FOR VARIOUS MISSION SCENARIOS & DEVELOP OPTIMIZED TRAINING FOR ANOMALOUS EVENTS
- REPLACE PROCEDURES MANUALS WITH HUMAN-CENTERED INTELLIGENT ASSISTANTS
- DEVELOP COGNITIVE MODEL OF NASA TEST DIRECTOR JOB & PROTOTYPE INTELLIGENT SUPPORT SYSTEM

BENEFITS

- OPTIMAL USE OF LIMITED HUMAN RESOURCES
- MAXIMUM CREW PERFORMANCE & ALERTNESS THROUGH COUNTERMEASURES TO CIRCADIAN DISRUPTION
- IMPROVED PERFORMANCE IN HIGH WORKLOAD SITUATIONS
- MAXIMIZE TRAINING EFFECTIVENESS

STATE-OF-THE-ART

- CONVENTIONAL COUNTERMEASURES FOR CIRCADIAN DISRUPTIONS USE FOR SHUTTLE CREW
- COCKPIT RESOURCE MANAGEMENT TRAINING PROGRAMS HIGHLY SUCCESSFUL IN COMMERCIAL AVIATION
- TRAINING OF FLIGHT CREW & MISSION CONTROL CREW EMPHASIZES REPETITION & OVER-LEARNING
- INITIAL NASA TEST DIRECTOR COGNITIVE MODEL
- AUTOMATED CHECKLIST TECHNOLOGY

MILESTONES

1993 Conduct mission analysis of STS procedures
Enhance knowledge base for anomaly situations
1994 Adapt transport crew training to improve coordination of space operation crews
Adapt existing countermeasure strategies, & develop instruction module
1995 Implement countermeasure strategies & evaluate
Develop intelligent support system for NASA Test Director
1996 Complete Procedures Advisor for emergencies
1997 Prototype low-mass on-board training simulator

SCIENCE

"Develop the advanced technology required for acquiring & understanding observations from future NASA space & Earth science missions."

DATA VISUALIZATION

TECHNOLOGY NEEDS & CHALLENGES

- MAKE VISUALIZATION APPROACHES COMPATIBLE WITH EVOLVING SCIENTIFIC METHODOLOGIES FOR DATA ANALYSIS
- PROVIDE VIRTUAL ENVIRONMENT INTERACTIONS WITH HIGHLY COMPLEX PLANETARY DATA BY DYNAMICALLY AND CONTINUOUSLY TUNING THE SYSTEM TO USER'S SPECIFIC INFORMATIONAL REQUIREMENTS
- DEMONSTRATE UTILITY OF VIRTUAL ENVIRONMENT SYSTEMS IN REAL-WORLD PLANETARY VISUALIZATION APPLICATIONS, INCLUDING EOS AND SEI
- INVESTIGATE BENEFITS OF VIRTUAL ENVIRONMENT SYSTEMS FOR USER INTERPRETATION OF MASSIVE QUANTITIES OF TIME-VARYING, THREE AND HIGHER DIMENSIONAL PLANETARY DATABASES

TECHNOLOGY NEEDS & CHALLENGES

- DEVELOP GUIDELINES FROM VISUAL SCIENCE TO ENSURE EFFECTIVE USE OF SHAPE, COLOR, & ANIMATION IN VISUALIZATIONS
- DEVELOP IMAGE COMPRESSION AND CODING ALGORITHMS FOR EFFECTIVE MANAGEMENT OF IMAGE INFORMATION
- SUPPORT DEVELOPMENT OF RELIABLE, COST-EFFECTIVE FLAT PANEL DISPLAY TECHNOLOGIES
- DEVELOP MULTI-RESOLUTION STRATEGIES FOR ACCESS TO & TRANSMISSION OF LARGE DATABASES

OBJECTIVES

- DEVELOP INTEGRATED FAMILY OF TECHNIQUES FOR INTERACTIVELY VISUALIZING SCIENTIFIC DATA, AS WELL AS MERGING DATA WITH MODELS
- REAL-TIME, INTERACTIVE VISUALIZATION OF DIVERSE TYPES OF REMOTELY SENSED DATA
- DERIVE IMPROVED PLANETARY VISUALIZATION CONCEPTS, METHODS, TRADEOFFS, DESIGN GUIDELINES & SYSTEM REQUIREMENTS FROM FUNDAMENTAL UNDERSTANDING OF HUMAN EXPLORATION BEHAVIOR
- EFFECTIVE USE OF HUMAN VISUAL SYSTEM & PERCEPTUAL AND MOTOR CONTROL
- RAPID & SIMPLE ACCESS TO LARGE SCIENCE DATABASES

BENEFITS

- POTENTIAL FOR SUBSTANTIAL IMPROVEMENTS IN INTERPRETABILITY OF PLANETARY DATA
- BRIDGES GAP BETWEEN GENERIC VISUALIZATION TOOLS & SPECIFIC INTERACTIVITY REQUIREMENTS OF SCIENTIFIC USERS
- FOCUS VIRTUAL ENVIRONMENT INTERACTIVITY & SYSTEMS ON CHALLENGING EOS AND SEI APPLICATIONS
- EFFICIENT DATA ACQUISITION, ARCHIVING, REDUCTION, & TRANSMISSION
- BETTER MISSION PLANNING

STATE-OF-THE-ART

- TESTBED DEVELOPED ON ADVANCED GRAPHICS COMPUTERS
- SOPHISTICATED VISUALIZATIONS ARE AVAILABLE, BUT THESE ARE CUSTOMIZED FOR SPECIFIC APPLICATION, INVOLVE INTENSIVE WORK BY VISUALIZATION SPECIALISTS AND ARE UNAVAILABLE TO TYPICAL SCIENTIST IN MOST DISCIPLINES
- VISUALIZATION TOOLS AND TECHNIQUES ARE LIMITED
- VISUALIZATION LIMITED BY INTERFACE TECHNOLOGY

SCIENCE ARC

MILESTONES

1993 Document feasibility of visualization methods
1994 Demonstrate interactive visualization of human scale digital terrain based on virtual exploration
1995 Initial image management facilities
Initial virtual user environments for data visualization
1996 Improved model building tools
1997 Demonstrate capability to conduct virtual data visualization via high-speed network
2000 Generalized graphical user interfaces

AEROSPACE HUMAN FACTORS RESEARCH DIVISION FACILITIES

Human Performance Research Laboratory

- 65,000 square feet of office and laboratories for 180 people
- Virtual Interactive Environment Workstation
- Vision Science & Technology lab
- Cognition lab
- Crew Factors lab
- Circadian Factors & Countermeasures Data Analysis lab
- Cockpit Information Transfer lab
- Man-machine Integration, Design & Analysis System
- Highbay for Exploration HF Testbed

RESEARCH STRATEGIES OVERVIEW

R&T BASE RESEARCH

PRIMARY
CREWSTATION DESIGN TECHNOLOGY

VISION SCIENCE & TECHNOLOGY
VIRTUAL DISPLAYS
3-D AUDITORY DISPLAYS
COGNITIVE MODELING

RELATED
HUMAN ENGINEERING METHODS

HF IN AVIATION

EXPLORATION

MISSION ANALYSIS
HUMAN PERFORMANCE MODELS
CREW SUPPORT TECHNOLOGIES
CREW ADVISORY & TRAINING
HUMAN-SYSTEMS INTEGRATION
TESTBEDS

OPERATIONS

CREW COORDINATION
FATIGUE COUNTERMEASURES
WORKLOAD MANAGEMENT METHODS
PROCEDURES ADVISOR TECHNOLOGY
PERFORMANCE ENHANCEMENT TECH

SCIENCE

DATA VISUALIZATION

ISSUES

- Human factors activities currently planned represent only augmentations of currently funded activities -- NO NEW INITIATIVES

- Despite acknowledgment of important role of human factors HF is not included in

  SPACE PLATFORMS THRUST
  TRANSPORTATION TECHNOLOGY THRUST

"Many of NASA's currently planned activities •••may face significant safety problems arising from inadequate consideration of human performance and human capacity."
--Aerospace Safety Advisory Panel, 1990

MAN-SYSTEMS DIVISION

BARBARA WOOLFORD

JULY 1991

HUMAN SUPPORT TECHNOLOGY AREA
JOHNSON SPACE CENTER

BARBARA WOOLFORD
MAN-SYSTEMS DIVISION

713-483-3701

MAN-SYSTEMS DIVISION

BARBARA WOOLFORD

JULY 1991

INTRODUCTION

- o JSC HAS BEEN AND WILL BE INVOLVED IN BASE R&T, EXPLORATION AND OPERATIONS THRUSTS, AND ANY OTHER THRUST THAT MIGHT REQUIRE HUMAN FACTORS INPUTS

- o R&T RESEARCH TRANSITIONS TO THRUSTS AS IT REACHES MATURITY AND IS APPLICABLE

- o THRUSTS DRIVE R&T RESEARCH BY IDENTIFYING AREAS WHERE BASIC UNDERSTANDING IS LACKING

MAN-SYSTEMS DIVISION

BARBARA WOOLFORD

JULY 1991

OBJECTIVE

- THE OBJECTIVE OF THE HUMAN SUPPORT RTOPS IS TO ADVANCE CRITICAL AREAS OF ENABLING AND ENHANCING TECHNOLOGIES WHICH SUPPORT CREW CAPABILITIES AT ALL DESIGN AND OPERATIONAL STAGES BY PROVIDING GUIDELINES, DESIGN TOOLS, AND CREW TRAINING
  - THIS PROGRAM CONSISTS OF RESEARCH AND DEVELOPMENT IN
    - HUMAN-COMPUTER INTERFACES
    - STANDARDS AND GUIDELINES FOR MAN-SYSTEMS
    - CREW TRAINING ON BOARD AND ON GROUND
    - EVA HUMAN FACTORS
    - MODELS OF HUMAN CAPABILITIES

2

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JULY 1991

RELATIONSHIP TO THRUSTS

- THE HUMAN SUPPORT RESEARCH IS PARTICULARLY RELEVANT TO
  - EXPLORATION THRUST - HUMAN EXPLORATION OF UNKNOWN TERRITORY, USING NEW TECHNOLOGIES AND EQUIPMENT, MUST BE MADE AS SAFE AS POSSIBLE
    - PROVIDE HUMAN-COMPUTER INTERFACE REQUIREMENTS AND GUIDELINES
    - PROVIDE MAN-SYSTEMS STANDARDS FOR HABITAT, VEHICLES, AND EQUIPMENT
    - PROVIDE HUMAN-FACTORED EVA EQUIPMENT
  - OPERATIONS THRUST - PREPARATION OF THE CREW FOR OPERATIONS MUST ENABLE THE CREW TO REACH AND MAINTAIN ITS FULLEST POTENTIAL IN PERFORMING THOSE OPERATIONS
    - PROVIDE TECHNOLOGIES AND GUIDELINES FOR TRAINING
    - PROVIDE OPERATIONS GUIDELINES BASED ON PRIOR EXPERIENCE

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MAN-SYSTEMS DIVISION

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JULY 1991

ORGANIZATION OF THE TECHNOLOGY PROGRAM AT JSC

- o HUMAN SUPPORT R&T -
  - o CREW STATION DESIGN
  - o EVA HUMAN FACTORS
- o EXPLORATION HUMAN FACTORS
  - o HUMAN PERFORMANCE MODELS
  - o CREW SUPPORT
  - o HUMAN-SYSTEMS INTEGRATION
  - o TESTBEDS
- o OPERATIONS THRUST
  - o TRAINING AND HUMAN FACTORS
  - o CIRCADIAN RHYTHMS
  - o CREW AIDS

4

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JULY 1991

STATE OF THE ART

- o SOFTWARE ENGINEERS DO HUMAN-COMPUTER INTERFACES BASED ON NASA-STD-3000
- o NASA-STD-3000 (MAN-SYSTEM INTEGRATION STANDARDS) USED TO DETERMINE SIZES, LABELS, COLORS, COMPONENTS, AND OTHER PARAMETERS IN SYSTEM DESIGNS
- o HAVE TAXONOMY FOR OPERATIONAL DATA BASE ESTABLISHED
- o CREW EVALUATIONS OF HUMAN FACTORS DESIGNS ARE HIGHLY SUBJECTIVE; OBJECTIVE ANALYSES BEGUN
- o MINIMUM UNDERSTANDING OF HUMAN COGNITIVE PROCESSES

5

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JULY 1991

STATE OF THE ART cont.

- ELEMENTARY MODELS OF HUMAN PHYSICAL CAPABILITIES IMPLEMENTED IN PLAID
- LOW-FIDELITY TESTBEDS
- GROUND-BASED COMPUTER SIMULATIONS HEAVILY USED FOR TRAINING
- NO INFLIGHT TRAINING

6

MAN-SYSTEMS DIVISION

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JULY 1991

RECENT ACCOMPLISHMENTS

- CREW STATION DESIGN
  - SPACE STATION COMPUTER DISPLAY REQUIREMENTS & GUIDELINES BASED ON HUMAN-COMPUTER INTERACTION STUDY SERIES
  - NASA-STD-3000 REV A RELEASED
  - PAYLOAD DEPLOYMENT AND RETRIEVAL INTELLIGENT AID INTERFACE BASED ON EXPERIMENTS IN GRAPHICAL INTERFACES TO INTELLIGENT SYSTEMS
  - OPERATIONAL EXPERIENCE DATA BASE INTEGRATED ALL MISSIONS SINCE RETURN TO FLIGHT

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JULY 1991

RECENT ACCOMPLISHMENTS cont.

- EVA AIDS
  - HELMET MOUNTED DISPLAY EVALUATED IN LAB FOR SPACE STATION
  - SPEECH RECOGNITION TESTS CARRIED OUT IN CONJUNCTION WITH HMD
  - STRENGTH MODEL IN 1-G DEVELOPED AND VALIDATED FOR ARM

MAN-SYSTEMS DIVISION

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JULY 1991

PROGRAM

- CREW STATION DESIGN
  - COMPLETE WORKSHOP AND PUBLISH BOOK ON COGNITIVE MODELS FOR HCI - 1991
  - PUBLISH GUIDELINES AND REQUIREMENTS FOR INTERFACES TO INTELLIGENT SYSTEM - 1994
  - OPERATIONAL DATA BASE AND NASA-STD-3000 ON DIAL-UP DATA BASE - 1992

- EVA HUMAN FACTORS
  - FIT, FORM, FUNCTION ELECTRONIC CUFF CHECKLIST - 1991
  - LEG STRENGTH COMPUTER MODEL - 1993
  - WHOLE BODY STRENGTH MODEL - 1996

PROGRAM cont.

- o EXPLORATION TECHNOLOGY
  - o VALIDATE ARM STRENGTH MODEL IN 0-G AND PARTIAL-G - 1992
  - o UTILIZE COGNITIVE MODELS FOR COLLABORATION BETWEEN INTELLIGENT SYSTEMS AND USER - 1995
  - o PROVIDE GUIDELINES AND REQUIREMENTS FOR POSITION, RATE, FORCE FEEDBACK AND TELEOPERATORS - 1996
  - o INTEGRATE LABS WITH MOCKUPS SO THAT INTEGRATED TESTS CAN BE RUN FROM MOCKUPS IN WETF, ABL, ROIL, AND OTHER FACILITIES WITHOUT DUPLICATING RESOURCES - 1997

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JULY 1991

PROGRAM cont.

- o OPERATIONS
  - o DEVELOP NON-UMBILICAL UNDERWATER PLSS FOR EVA TRAINING - 1996
  - o DEVELOP VIRTUAL REALITY CAPABILITIES IN BOARD AND CHIP FORM TO PERMIT ON ORBIT TRAINING - 1998
  - o DEVELOP INTERACTIVE TRAINING FROM IN-FLIGHT WORKSTATION TO GROUND BASED SIMULATOR - 1999

MAN-SYSTEMS DIVISION

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JULY 1991

PRIORITIES

1. PHYSICAL AND COGNITIVE MODELS
   - o ENHANCE DESIGN FROM PRELIMINARY STAGES THROUGH OPERATIONS

2. NASA-STD-3000 AND OPERATIONAL EXPERIENCE DATA BASE
   - o ENHANCE DESIGN FROM PRELIMINARY STAGES THROUGH OPERATIONS

3. VIRTUAL ENVIRONMENT TRAINING FACILITIES
   - o PERMIT IN-FLIGHT TRAINING AND REFRESHER COURSES

4. INTEGRATED TEST BED
   - o MAKES OTHER RESEARCH POSSIBLE

5. HUMAN FACTORS OF EVA
   - o MAKES EVA SAFER AND MORE PRODUCTIVE; ESSENTIAL FOR EXPLORATION

12

Integrated LIFE SUPPORT TECHNOLOGY PROJECTS

- Base R & T
- Exploration Technology
- Space Platforms

Presented to

INTEGRATED TECHNOLOGY PROGRAM REVIEW

SPACE SYSTEMS TECHNOLOGY ADVISORY COMMITTEE (SSTAC)

June 26, 1991

Vincent J. Bilardo, Jr., Manager
Physical/Chemical Regenerative Life Support Project

91-SAS-B-052

BRIEFING OBJECTIVE

- Present the Integrated Physical/Chemical Regenerative Life Support (P/C RLS) technology development plan
  - Base R & T
  - Exploration Technology Program (ETP)
  - Space Platforms

Integrated P/C RLS Project

KEY PROJECT OBJECTIVES

- **Advance the state-of-the-art of regenerative life support technologies to satisfy future mission requirements (Base, ETP, Platforms)**
  - Air, water, and solid waste recovery of consumables
  - Cabin thermal management
  - Sensors and control systems
- **Demonstrate integrated system performance through Technology Readiness Level 6 (ETP)**
  - Unmanned and manned
  - Demonstrate long-life system performance
- **Develop advanced technology processors/subsystems for Space Station Freedom growth (Platforms)**

Integrated Physical/Chemical Regenerative Life Support Project

TECHNOLOGY CHALLENGES FOR EXPLORATION

- **Long-life Performance**
  - Increase reliability and operating life beyond Space Station Freedom requirements
  - Minimize need for crew intervention
  - Ensure full habitability over long durations
- **Self-Sufficiency**
  - Further minimize logistics resupply
- **System Impact**
  - Minimize mass, power consumption, volume

PRELIMINARY TECHNOLOGY DEVELOPMENT GOALS

CRITICAL ISSUE	TECHNOLOGY DEVELOPMENT GOAL	TECHNOLOGY CHALLENGE		
		LONG-LIFE PERFORMANCE	SELF-SUFFICIENCY	SYSTEM IMPACT
• Processor reliability/ operating lifetime	• Satisfy mission requirements • Ensure crew safety/survival	√	√	
• Integrated system demonstrations	• Full mission duration ground demo tests	√		
• Simplified water recovery subsystem	• Minimum number of processors • Single grade water quality (potable) • Eliminate pretreatment chemicals	√	√	√
• Trace/microbial contaminant monitoring and control	• Real-time air and water quality monitors • Eliminate resupplied post-treatment chemicals	√	√	
• Solid waste processing	• 10-100x reduction in solid waste storage volume • Minimize health hazards/ enhance crew safety		√	√
• Mass/power/volume	• Satisfy mission allocations • Minimize resupply		√	√

6

PRELIMINARY TARGETS FOR SEI APPLICATION

(Based on SSF ECLSS Flight Specs Pre-Restructuring)

SUBSYSTEM	FUNCTION	MASS (lbm)	AVERAGE POWER (W)	VOLUME (ft^3)	RESUPPLY MASS [1] (lbm/90 days)	TARGET FOR SEI MISSION [2]
Air Revitalization (4 Person Units)	O_2 Generation	103	950	8.4	0	• Extended operating life.
	CO_2 Removal	286	900	19.3	0	• Extended operating life.
	CO_2 Reduction	600	600	23	94	• 75% reduction in mass, resupply mass • Extended operating life.
	Trace Contaminant Control	119	88	7.5	142	• Order of magnitude reduction in resupply mass.
Water Recovery (8 Person Units)	Urine Recovery	408	400	21	448	• Order of magnitude reduction in resupply mass; • Extended operating life.
	Hygiene Water Recovery	723	350	41	261	• Order of magnitude reduction in resupply mass; • Extended operating life.
	Potable Water Processing	612	250	41	114	• 50% reduction in mass, volume, resupply mass; • Extended operating life.

NOTES: (1) Based on 8 person crew. Values shown are for baseline technologies as of June, 1990. No explicit allocations exist for resupply mass/volume.

(2) For all processors, at least an order of magnitude decrease in total maintenance time (scheduled and unsheduled) will be required. If a nuclear power source is not available, at least a 50% reduction in in average power consumption will be required.

REGENERATIVE LIFE SUPPORT TECHNOLOGY STATE OF THE ART

SEI CANDIDATES CURRENTLY FUNDED BY P/C RLS PROJECT SHOWN IN BOLD .

SUBSYSTEM	FUNCTION	SPACE STATION TECHNOLOGY SELECTION	TYPICAL SEI TECHNOLOGY CANDIDATES
Air Revitalization	**Oxygen Generation**	**Static Feed Water Electrolysis**	Solid Polymer Water Electrolysis
	CO2 Removal	**Four Bed Mole Sieve**	**Air Polarized Cell** Two Bed Mole Sieve
	CO2 Reduction	**Sabatier Reactor**	Advanced Carbon Reactor Advanced Bosch Reactor
	Air Trace Contaminant Control	**Activated Carbon/Catalytic Oxidation**	**Photocatalytic Oxidation** Poison-Resistant Catalysts
Water Reclamation	**Urine Processing**	**Vapor Compression Distillation**	Vapor Phase Catalytic Ammonia Removal **Wiped Film Vapor Compression Distillation**
	Hygiene/Potable Processing	**Multi-Filtration**	Electrooxidation Biofilm Resistant Technologies **Ozone Generation/UV Treatment**

Integrated P/C RLS Project

REGENERATIVE LIFE SUPPORT TECHNOLOGY STATE OF THE ART

SEI CANDIDATES CURRENTLY FUNDED BY P/C RLS PROJECT SHOW IN BOLD

SUBSYSTEM	FUNCTION	SPACE STATION TECHNOLOGY SELECTION	TYPICAL SEI TECHNOLOGY CANDIDATES
Solid Waste Management	**Solid Waste Recovery**	**Stored and Returned**	Incineration Electrochemical Incineration **Super Critical Water Oxidation**
Monitoring and Control	**Water Quality Monitoring**	**Not Selected**	**Fiberoptic TOC Sensor** Microbe/Biomembrane Sensor Spectrophotometric Sensors "Smart" Sensors
	Air Trace Contaminant Monitoring	**Mass Spectrometer**	Advanced Mass Spectrometer "Smart" Sensors

Integrated P/C RLS Project

PROJECT STATUS

NASA AMES RESEARCH CENTER
Advanced Life Support Division

91-SAS-B-052

Integrated P/C RLS Project

CURRENT STATUS

- System engineering capability established
  - Generic Modular Flow Schematic (GMFS) analysis tool (JPL)
  - Initial Lunar Outpost (ILO) LSS preliminary design and systems assessment (ARC)
  - System engineering techniques (ARC)
  - Enhanced analytical capability to support testbed design, planning, and data analysis (JSC)
  - On-line LSS database system development (ARC)
- Process simulation capability established
  - Evaluation of industry-standard chemical process simulation tools (ARC, JSC)
  - Development of detailed process simulation models of advanced technologies (ARC, JSC)
- Technology assessments performed by independent experts
  - Air and water processes (HQ)

Integrated P/C RLS Project

CURRENT STATUS (Cont'd)

- Infrastructure buildup underway
  - Build-up of personnel, laboratory equipment, computer hardware/software (ARC, JSC, JPL)
  - Assessment of existing testbed support facilities at JSC, ARC
- Innovative research program initiated
  - Process research grants established at MIT, North Carolina State, Iowa State (through ARC, JSC)
  - In house tasks initiated (ARC, JSC)
- Initiated test stand and testbed hardware projects (JSC, ARC)

NASA AMES RESEARCH CENTER
Advanced Life Support Division

Integrated P/C RLS Project

CURRENT STATUS (Cont'd)

- Project management strengthened
  - Personnel selected for key positions (ARC, JSC)
  - Developing bottoms-up critical path project plan (ARC)
    - Automated linking of project content, budgets, and schedules
  - Coordinating project implementation through Intercenter Working Group (All)
    - Budget guidelines, RTOP submittals, SBIR reviews, etc.
    - Technology development recommendations, testbed planning, etc.
  - Revising 5-Year P/C RLS Project Plan document

Integrated P/C RLS Project

TECHNOLOGY DEVELOPMENT STRATEGY

- Basic Research
- System Engineering
- Process Design
- Test Stand Validation
- Subsystem Testbed Validation
- Integrated System Testbed Validation
- Flight Experiments

Integrated P/C RLS Project

TECHNOLOGY DEVELOPMENT STRATEGY

TECHNOLOGY READINESS LEVEL ACHIEVED

1-3 • **Basic Research**
- Utilize University Grants, SBIR's, industry and in-house expertise to generate new concepts

1-6 • **System Engineering**
- Develop and apply rigorous, top down systems design and analysis capability to augment *sound engineering judgment*

4 • **Process Design**
- Utilize chemical process simulation tools to assist in the design of new physiochemical processes
- Validate processes on laboratory bench

4-5 • **Test Stand Validation**
- Test breadboard processor in stand alone mode

Integrated P/C RLS Project

TECHNOLOGY DEVELOPMENT STRATEGY

TECHNOLOGY READINESS LEVEL ACHIEVED

5+ • **Subsystem Testbed Validation**

- Test breadboard processors grouped together into a subsystem, e.g., water recovery subsystem

5-6 • **Integrated System Testbed Validation**

- Test breadboard processors integrated together with all critical subsystems present using crew simulators
- Test man-rated prototype processors in integrated, full-function demonstration with human subjects

6-7 • **Flight Experiments**

- Utilize Space Station Freedom as an advanced technology testbed
- Develop and fly selected technologies with potential microgravity sensitivities

Integrated P/C RLS Project

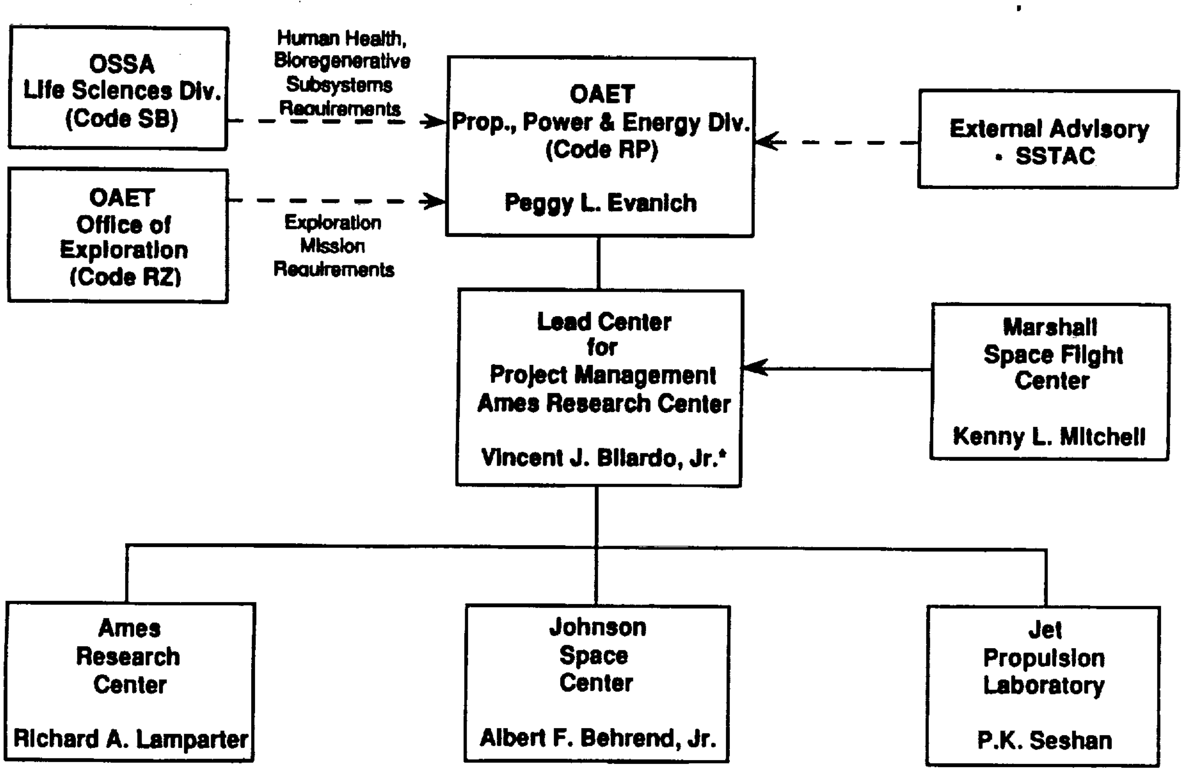
MANAGEMENT ORGANIZATION

Integrated P/C RLS Project

TECHNOLOGY MANAGEMENT APPROACH

- **Utilize existing P/C RLS Project organization to manage three technology elements**
  - Base R & T/Human Support
  - Exploration Technology Program (ETP)/Human Support
  - Space Platforms Technology Program/Space Stations/ Zero-Gravity Life Support
- **Focus each element appropriately:**
  - Base R & T ——► High risk innovative research
  - ETP ——► High priority advanced technologies for Lunar/ Mars exploration
  - Platforms ——► Growth Space Station Freedom and microgravity transfer/excursion vehicle applications

PHYSICAL/CHEMICAL REGENERATIVE LIFE SUPPORT PROJECT MANAGEMENT STRUCTURE



* Chair Intercenter Working Group

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PRELIMINARY WORK BREAKDOWN STRUCTURE

INTEGRATED P/C RLS PROJECT

- **1.0 P/C TECHNOLOGY DEVELOPMENT**
  - 1.1 Air Revitalization
  - 1.2 Water Reclamation
  - 1.3 Solid Waste Processing
  - 1.4 Thermal Control
  - 1.5 *Flight Experiments*
- **2.0 SYSTEMS ENGINEERING**
  - 2.1 Requirements Analysis
  - 2.2 Systems Design
  - 2.3 P/C Systems Analysis
  - 2.4 P/C-Bio Systems Analysis
- **3.0 SYSTEMS TESTING**
  - 3.1 *Preprototype Development System Testbed*
  - 3.2 *New Technology System Testbed*
  - 3.3 *Lunar Demonstrator System Testbed*
  - 3.4 *SS Freedom Testbed*
- **4.0 SYSTEMS CONTROL**
  - 4.1 Sensors
  - 4.2 Control Systems
  - 4.3 *Sensor/Control Integration*
- **5.0 PROJECT MANAGEMENT**
  - 5.1 *ARC Project Office*
  - 5.2 *Headquarters Reserve*

Italics = New Subelement (relative to Pathfinder 5-Year Project Plan of January 1989)

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Integrated P/C RLS Project

TECHNOLOGY ELEMENT CROSSWALK

		Base R&T 506-71	ETP 593-41	Platforms 694-21
1.0 P/C Technology Development	1.1 Air Revitalization		√	√
	1.2 Water Reclamation	√	√	√
	1.3 Solid Waste Processing	√	√	√
	1.4 Thermal Control		√	√
	1.5 Flight Experiments			√
2.0 Systems Engineering	2.1 Requirements Analysis		√	
	2.2 Systems Design		√	
	2.3 P/C Systems Analysis		√	√
	2.4 P/C-Bio Systems Analysis		√	
3.0 Systems Testing	3.1 Preprototype Development System Testbed		√	
	3.2 New Technology System Testbed		√	√
	3.3 Lunar Demonstrator System Testbed		√	√
	3.4 SS Freedom Testbed			√
4.0 Systems Control	4.1 Sensors	√	√	√
	4.2 Control Systems		√	√
	4.3 Sensor/Control Integration		√	√

Integrated P/C RLS Project

CONTENT SUMMARY

		Base R & T Element
Current Plan	506-71-21	**Chemical Processing** • Advanced process research (simulation and laboratory experimentation) - Water reclamation - Trace contaminant control
	506-71-41	**Sensors and Controls** • Advanced in situ real time chemical sensors
Augmented Plan		**Chemical Processing** • Expanded process research into additional high risk, high payoff areas - Solid waste processing **Sensors and Controls** • Microbial sensors for air and water

Integrated P/C RLS Project

CONTENT SUMMARY

		Exploration Technology Element
Current Plan	593-41-11	Air Revitalization
	593-41-21	Water Reclamation
	593-41-31	Waste Management
	593-41-51	Thermal Control
	593-41-41	Systems Integration • System Engineering (Systems analysis, design synthesis, etc.) • Integrated System Testbed Development
	593-41-61	Systems Control • Sensors • Control Systems/Advanced Automation • Sensor/Control Integration
Augmented Plan		Same elements at significantly reduced runout funding level (relative to FY91 OMB budget)

Air Revitalization, Water Reclamation, Waste Management, Thermal Control:
- Basic research
- Process development
- Breadboard procurement and test
- Subsystem testbed development

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Integrated P/C RLS Project

CONTENT SUMMARY

Space Platforms Element

Current Plan	Not applicable	
Augmented Plan	694-21	**Zero Gravity Life Support** • **Components and Subsystems** - Air Revitalization - Water Reclamation - Solid Waste Processing - Thermal Control • **Sensors and Controls** • **Space Station Freedom Testbeds** - Ground-based testbeds at MSFC in addition to ARC and JSC
	694-41	**Space Platforms Technology Flight Experiments** • **Components and Subsystems** - Air revitalization, water reclamation, solid waste processing, and thermal control components tested aboard Space Station Freedom

Emphasis on microgravity sensitive processes and SS Freedom ECLSS upgrades

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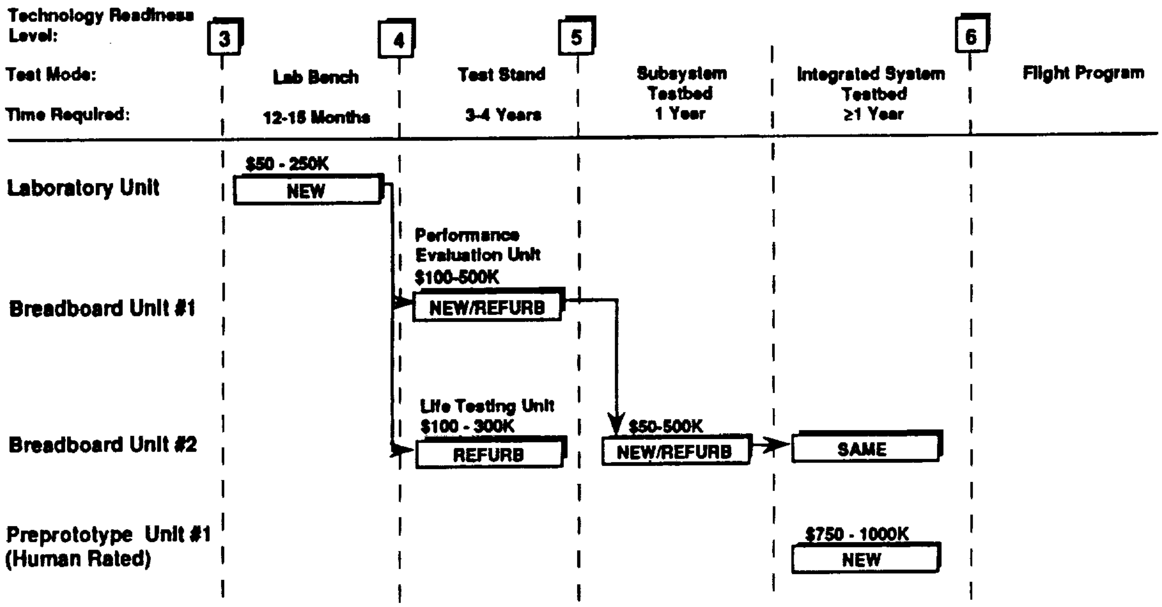
Integrated P/C RLS Project

HARDWARE DEVELOPMENT PLAN

Integrated P/C RLS Project

NEW TECHNOLOGY HARDWARE DEVELOPMENT TEMPLATE*

(All figures shown are per processor unit, e.g., an oxygen generation unit)



Total Technology Development Cost Per New Concept: $950 - 2250K**

* Developed by P/C RLS Intercenter Working Group on 4-25-91

** Strictly hardware cost; excludes cost of personnel, facilities, supplies, analytical services, system integration, etc.

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Advanced Life Support Division

91-SAS-B-052

Integrated P/C RLS Project

SUMMARY OF TESTBED STRATEGY

- Develop two integrated system testbed facilities
  - New technology emphasis at ARC
    - Breadboard grade hardware
    - Supports development of successive generations of new technology for evolving SEI program phases
  - Mature technology emphasis at JSC
    - Early identification of system-level technology issues
    - Validate long duration integrated system performance of mature LSS technologies
    - Ensures transition of technology to mission developers

Integrated P/C RLS Project

"SYSTEM O"
PREPROTOTYPE DEVELOPMENT SYSTEM TESTBED

- **Description**
  - **Integrated development system testbed**
    - -- Incorporating existing SS Freedom-era "preprototype" hardware
    - -- Installed in 20 ft. dia. environmental chamber at JSC
- **Objectives**
  - **Establish early, minimum cost integrated system testbed utilizing existing hardware and facilities**
  - **Validate long-duration integrated system performance of mature LSS technologies**
    - -- Reliability and operating life
    - -- Habitability (e.g., trace and microbial contaminant control, etc.)
    - -- System control and automation
    - -- Maintainability and crew intervention
  - **Demonstrate integrated LSS and Thermal Control System (TCS) performance**
  - **Transition into human-rated Lunar Demonstrator Integrated System Testbed (System II)**

Integrated P/C RLS Project

"SYSTEM I"
NEW TECHNOLOGY SYSTEM TESTBED

- **Description**
  - **Integrated breadboard systems testbed**
    - -- Incorporating new SEI-era LSS technology
    - -- Installed into refurbished 16 ft. dia. environmental chamber at ARC
- **Objectives**
  - **Investigate intra- and inter-subsystem interactions of new technology breadboard units developed by P/C RLS Project to meet SEI requirements**
    - -- Processor functional performance
    - -- Advanced sensors
    - -- System control and automation
  - **Validate system engineering tools and predictions**
  - **Integrate individual subsystem breadboard testbeds together to produce system-level testbed**
  - **Provide initial integrated testing of new technology prior to upgrade for high fidelity testing in System II**

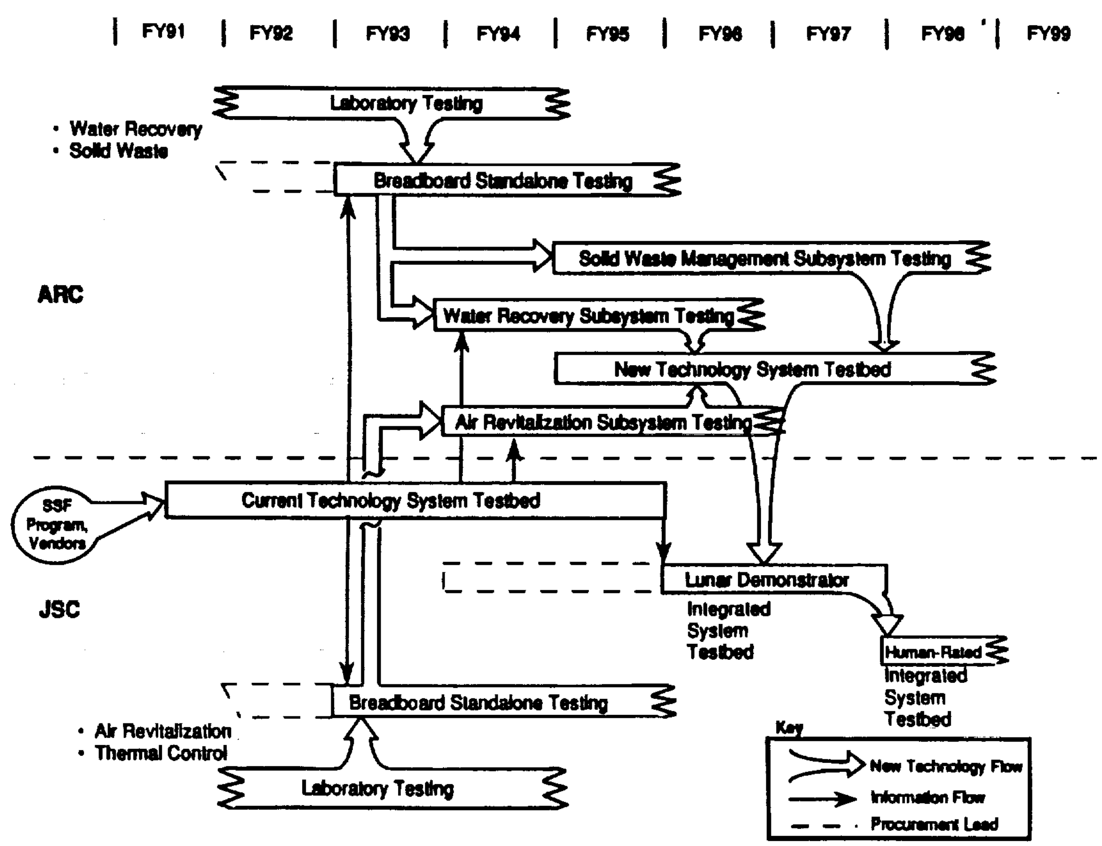
Integrated P/C RLS Project

"SYSTEM II"
LUNAR DEMONSTRATOR INTEGRATED SYSTEM TESTBED

- **Description:**
  - **Integrated Lunar Demonstrator System Testbed**
    - -- Incorporating preprototype new technology hardware developed for lunar outpost
    - -- Utilizes same facility at JSC as System O
- **Objectives**
  - **Validate long-duration integrated system performance of high fidelity, preprototype-grade hardware intended for lunar outpost mission**
    - -- Similar test objectives as System O
  - **Provide human-rated testing of lunar mission LSS technology**
    - -- Final step to achieve Technology Readiness Level 6 for Initial Lunar Outpost Technology Set
  - **Transition into facility for in-line support of lunar outpost LSS design, development, and certification activities**

Integrated P/C RLS Project

INTEGRATED LIFE SUPPORT TECHNOLOGY DEVELOPMENT PLAN



Integrated P/C RLS Project

MAJOR MILESTONES SUMMARY

ELEMENT	DATE	MILESTONE
Base R & T	1993	Advanced water reclamation processors tested in laboratory
	1996	Laboratory evaluation of solid waste processors complete
	1998	Microbial sensors for air, water streams demonstrated in testbeds
ETP + Platforms	1992	Completion of systems analysis to finalize lunar mission technology development requirements
	1993	Completion of current technology air, water integrated system testing in System O
	1994	Initiate new technology breadboard air, water subsystem testing
	1995	Initiate new technology integrated system breadboard testing
	1997	Complete unmanned integrated system demonstration testing for initial lunar outpost
	1999	Complete human validation testing for initial lunar outpost technology set
	2001	Begin SSF-based flight testing of advanced microgravity processors
	2004	Begin incorporation of upgraded technologies into SS Freedom

Integrated P/C RLS Project

SUMMARY

Benefit of the Augmented Program

- Builds robust ground-based testbed program
- Ensures development of upgraded SS Freedom processors
- Ensures development of required sensor technology

Office of Aeronautics, Exploration and Technology (OAET)
Integrated Technology Plan for Civil Space Program

Life Support Technology

- Active Thermal Control
  - Research and Technology Base Program (Augmentation)
  - Space Platforms Technology Program - Space Stations
- Life Support
  - Space Platforms Technology Program - Technology Flight Experiments
  - Instep Experiment

HQ Sponsor: Ms. Peggy Evanich/Code RP

NASA JSC Support Activities
SSTAC Meeting
June 24-28, 1991

Albert F. Behrend, Jr.
NASA JSC
Crew and Thermal Systems Division

RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL

RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL SYSTEMS

TECHNOLOGY NEEDS/CHALLENGES

- ACTIVE THERMAL CONTROL SYSTEMS TECHNOLOGY IS REQUIRED TO ENABLE HABITAT HEAT REJECTION
- TECHNOLOGY DEVELOPMENT CHALLENGES:
  - DEVELOP HIGHLY EFFICIENT, LOW MASS, RELIABLE THERMAL CONTROL SYSTEMS FOR PLANETARY HABITATS
  - SPECIFIC CHALLENGES INCLUDE:
    - Increase waste heat rejection temperature above that of the environment to enable rejection to space.
    - Utilize gravitational and thermal environment to enhance heat rejection capability.
    - Develop high temperature heat rejection devices which are remotely deployable.
    - Better understand the systems level interactions between multi-system (i.e., ISRU, power, habitat) thermal control systems technologies through development of analytical techniques.

T.Petete-JSC-6/7/91

RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL SYSTEMS

OBJECTIVES

- PROVIDE THE TECHNOLOGY BASE REQUIRED TO SUSTAIN HUMAN LIFE IN THE HOSTILE THERMAL ENVIRONMENTS ASSOCIATED WITH PLANETARY SURFACES
  - Potential technologies include gravity-aided heat pumps, high temperature heat rejection devices, convective/radiative devices, and non-toxic two-phase fluids.

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RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL SYSTEMS

BENEFITS

- ENABLE REJECTION OF MODERATE TEMPERATURE (275 K-295 K)
- REDUCE ADVERSE TRANSMISIVITY EFFECTS DUE TO PLANETARY ATMOSPHERES
- ENABLE ROBOTIC RADIATOR DEPLOYMENT IN GRAVITY ENVIRONMENT
- TAKE ADVANTAGE OF GRAVITY ENVIRONMENT AND PLANETARY ATMOSPHERE
- PROVIDE FLUID WHICH ALLOWS FOR HIGH HEAT TRANSPORT PER UNIT MASS OF FLUID, THUS SIGNIFICANTLY REDUCING POWER REQUIREMENTS
- FOSTER CONTINUING INDUSTRY COMPETITION FOR THERMAL CONTROL SYSTEMS TECHNOLOGY

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THERMAL CONTROL SYSTEMS PROGRAM JSC - LEAD

BASE R & T

- THERMAL CONTROL
  - Heat Acquisition
  - Heat Transport
  - Heat Rejection
  - Analysis

EXPLORATION THRUST

- SYSTEMS STUDIES
- INTEGRATED SYSTEM DEVELOPMENT
- SYSTEMS LEVEL TESTING
- PERFORMANCE ANALYSIS

PLATFORM THRUST

- ACTIVE THERMAL CONTROL
- HEAT REJECTION
- THERMAL STORAGE
- PERFORMANCE ANALYSIS

T.Petete-JSC-6/7/91

RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL SYSTEMS

STATE OF THE ART ASSESSMENT

- SOA heat rejection technology would impose as much as a 62% launch mass penalty compared to advanced radiator concepts.
- Current vapor compression heat pump Coefficient of Performance is at best 2.5. Technology development goal is >4.0 to reduce power requirements.
- Non-toxic two-phase fluids non-existant for room temperature operation.

  Goal: • Non-toxic fluid with a saturated vapor density > 0.64 kg/m^3 at 35 °C (Water is 0.04 kg/m^3)

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RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL SYSTEMS

RECENT ACCOMPLISHMENTS (506-41)

° Completed investigation into long-term stability of metal hydrides; final report being prepared.

° Completed preliminary fluid dynamics and heat transfer tests on Rotating Bubble Membrane Radiator.

° Completed heat pump concepts trade study; final report delivered to JSC.

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RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

PROGRAM OUTLINE FOR ACTIVE THERMAL CONTROL SYSTEMS

° 1993	INITIATE DEVELOPMENT OF SYSTEMS LEVEL ANALYTICAL TOOLS. INITIATE CRITICAL HARDWARE COMPONENT DEVELOPMENT.
° 1994	CONDUCT DESIGN AND PERFORMANCE ANALYSIS
° 1995	CONDUCT COMPONENT PROOF-OF-CONCEPT TESTING
° 1996	CONDUCT COMPONENT AND/OR BREADBOARD VALIDATION IN LABORATORY TESTING
° 1997	COMPLETE CRITICAL COMPONENT GROUND TESTING IN SIMULATED ENVIRONMENT
° 1998	INITIATE INTEGRATED SUBSYSTEM LEVEL TESTING
° 1999	COMPLETE SYSTEMS LEVEL TESTING

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RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL SYSTEMS

<u>OTHER GOVERNMENT SUPPORT</u>
TO
<u>THERMAL CONTROL SYSTEMS PROGRAM (506-41)</u>

° DEPARTMENT OF ENERGY INTERESTED IN ROTATING BUBBLE MEMBRANE RADIATOR DEVELOPMENT (NO FUNDS TRANSFERRED TO NASA)

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PRELIMINARY FY93 AUGMENTATION PRIORITIZATION
RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL SYSTEMS

- 1. **HEAT REJECTION TECHNIQUES DEVELOPMENT**
    - Applicable to Space Platforms and Exploration
- 2. **HEAT ACQUISITION AND TRANSPORT SYSTEMS DEVELOPMENT**
    - Applicable to Space Platforms and Exploration
- 3. **MONITORING AND CONTROLS**
    - Applicable to Space Platforms, Exploration and STS
- 4. **ANALYSIS AND TEST VERIFICATION**
    - Applicable to Space Platforms, Exploration and STS

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RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

THERMAL CONTROL SYSTEMS PROGRAM RESOURCES

FISCAL	FY 91	FY92	FY93	FY94	FY95
BASE R & T	**100**	**100**	**500**	**1,390**	**2,995**
	(RTOP 506-71)				
* EXPLORATION	----	1,995	3,580	4,340	6,575
* PLATFORM	----	2,400	2,850	3,200	3,675

* NO RTOP CURRENTLY EXISTS

T.Petete-JSC-6/7/91

RESEARCH AND TECHNOLOGY BASE PROGRAM AUGMENTATION

ACTIVE THERMAL CONTROL SYSTEMS

SUMMARY

- TECHNOLOGY DEVELOPMENT CHALLENGES:
  - DEVELOP HIGHLY EFFICIENT, LOW MASS, RELIABLE HABITAT THERMAL CONTROL SYSTEMS
  - SPECIFIC CHALLENGES INCLUDE:
    - Increase waste heat rejection temperature above that of the environment to enable rejection to space.
    - Utilize gravitational and thermal environment to enhance heat rejection capability.
    - Develop high temperature heat rejection devices which are remotely deployable.
    - Better understand the systems level interactions between multi-system thermal control systems technologies through development of analytical techniques.

° BENEFITS

- ENABLE REJECTION OF MODERATE TEMPERATURE (275 K-295 K)
- REDUCE ADVERSE TRANSMISIVITY EFFECTS DUE TO THE PLANETARY ATMOSPHERE
- ENABLE ROBOTIC RADIATOR DEPLOYMENT IN GRAVITY ENVIRONMENT
- TAKE ADVANTAGE OF GRAVITY ENVIRONMENT AND PLANETARY ATMOSPHERE
- PROVIDE FLUID WHICH ALLOWS FOR HIGH HEAT TRANSPORT PER UNIT MASS OF FLUID, THUS SIGNIFICANTLY REDUCING POWER REQUIREMENTS
- FOSTER CONTINUING INDUSTRY COMPETITION FOR THERMAL CONTROL SYSTEMS TECHNOLOGY

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SPACE PLATFORMS TECHNOLOGY PROGRAM - SPACE STATION

ACTIVE THERMAL CONTROL

SPACE PLATFORMS TECHNOLOGY: SPACE STATIONS

ACTIVE THERMAL CONTROL SYSTEMS

TECHNOLOGY NEEDS/CHALLENGES

- ACTIVE THERMAL CONTROL SYSTEMS TECHNOLOGY IS REQUIRED TO ACCOMMODATE HEAT REJECTION REQUIREMENTS ASSOCIATED WITH THE INCREASED POWER LEVELS AT EACH GROWTH PHASE OF STATION.
  - Increased radiator efficiencies to avoid deployment of additional radiators as heat rejection requirements increase in direct proportion to increase in power growth.
- TECHNOLOGY DEVELOPMENT CHALLENGES:
  - IMPROVE PERFORMANCE AND INCREASE EFFICIENCY OF BASELINE ACTIVE THERMAL CONTROL SYSTEM
  - SPECIFIC CHALLENGES INCLUDE:
    - Increase waste heat rejection capability while minimizing deployed radiator area.
    - Provide for a low-mass load leveling method to accommodate for peak loads.
    - Accurately predict system performance through development of analytical tools.

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SPACE PLATFORMS TECHNOLOGY: SPACE STATIONS

ACTIVE THERMAL CONTROL SYSTEMS

OBJECTIVES

- Develop thermal control systems technologies to improve performance of baseline systems.
  - Potential technologies include higher capacity heat pipe radiators, heat pumps, thermal storage units, heat exchangers, monitoring and control systems, and test and verification techniques.

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SPACE PLATFORMS TECHNOLOGY: SPACE STATIONS

ACTIVE THERMAL CONTROL SYSTEMS

BENEFITS

- INCREASE HEAT REJECTION CAPABILITIES WHILE MINIMIZING IMPACT TO EXISTING SYSTEMS
- INCREASE THERMAL CONTROL SYSTEM RELIABILITY BY REDUCING SENSITIVITY TO MICROMETEROID/ ORBITAL DEBRIS ENVIRONMENT
- MINIMIZE RADIATOR AREA GROWTH RELATED TO INCREASED POWER LEVELS
- ACCOMMODATE MODULAR GROWTH, ON-ORBIT ASSEMBLY AND MAINTENANCE
- FOSTER CONTINUING INDUSTRY COMPETITION FOR THERMAL CONTROL SYSTEMS TECHNOLOGY

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THERMAL CONTROL SYSTEMS PROGRAM JSC - LEAD

BASE R & T

- THERMAL CONTROL
  - Heat Acquisition
  - Heat Transport
  - Heat Rejection
  - Analysis

EXPLORATION THRUST

- SYSTEMS STUDIES
- INTEGRATED SYSTEM DEVELOPMENT
- SYSTEMS LEVEL TESTING
- PERFORMANCE ANALYSIS

PLATFORM THRUST

- ACTIVE THERMAL CONTROL
- HEAT REJECTION
- THERMAL STORAGE
- PERFORMANCE ANALYSIS

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ACTIVE THERMAL CONTROL SYSTEMS

STATE OF THE ART ASSESSMENT

- **THERMAL CONTROL TECHNOLOGY HAS NOT BEEN DEVELOPED TO A MATURITY LEVEL WHICH WILL EFFICIENTLY ENABLE SSF GROWTH TO 225 KW (Power level).**
  - **Current heat pipe technology permits development of micrometeroid/orbital debris insensitive radiators.**
  - **Current heat pipe technology is limited to 54,000 W-in, which leads to heavier radiators than SSF baseline. Technology development goal is 150,000 W-in heat pipe capacity.**
  - **Current vapor compression heat pump Coefficient of Performance is at best 2.5. Technology development goal is >4.0.**
  - **Thermal storage technology goal is > 600 kJ/kg. (Water is < 200 kJ/kg)**
- **EXISTING RESEARCH AND TECHNOLOGY BASE PROGRAM TO DEVELOP ACTIVE THERMAL CONTROL SYSTEM TECHNOLOGIES IS SIGNIFICANTLY UNDERFUNDED.**

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SPACE PLATFORMS TECHNOLOGY: SPACE STATIONS

ACTIVE THERMAL CONTROL SYSTEMS

RECENT ACCOMPLISHMENTS

- **Completed long-term stability investigation of metal hydrides; final report being prepared.**
- **Completed preliminary fluid dynamics and heat transfer tests on the Rotating Bubble Membrane Radiator.**

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SPACE PLATFORMS TECHNOLOGY: SPACE STATIONS

PROGRAM OUTLINE FOR ACTIVE THERMAL CONTROL SYSTEMS

- 1992 — INITIATE DEVELOPMENT OF SYSTEMS LEVEL ANALYTICAL TOOLS. INITIATE CRITICAL HARDWARE COMPONENT DEVELOPMENT.
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- 1994 — COMPLETE COMPONENT PROOF-OF-CONCEPT TESTING
- 1995 — CONDUCT COMPONENT AND/OR BREADBOARD VALIDATION IN LABORATORY TESTING
- 1996/97 — COMPLETE CRITICAL COMPONENT GROUND TESTING IN SIMULATED ENVIRONMENT
- 1998 — INITIATE SYSTEMS LEVEL TESTING

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SPACE PLATFORMS TECHNOLOGY: SPACE STATIONS

ACTIVE THERMAL CONTROL SYSTEMS

OTHER GOVERNMENT SUPPORT TO THERMAL CONTROL SYSTEMS PROGRAM

- DEPARTMENT OF ENERGY INTERESTED IN ROTATING BUBBLE MEMBRANE RADIATOR DEVELOPMENT (NO FUNDS TRANSFERRED TO NASA)

T.Petete-JSC-6/7/91

PRELIMINARY FY93 AUGMENTATION PRIORITIZATION

SPACE PLATFORMS TECHNOLOGY: SPACE STATIONS

ACTIVE THERMAL CONTROL SYSTEMS

- 1. HEAT REJECTION TECHNIQUES DEVELOPMENT
  - Applicable to SSF Growth and Exploration
- 2. HEAT ACQUISITION AND TRANSPORT SYSTEMS DEVELOPMENT
  - Applicable to SSF Growth and Exploration
- 3. MONITORS AND CONTROLS
  - Applicable to SSF Growth, Exploration and STS
- 4. ANALYSIS AND TEST VERIFICATION
  - Applicable to SSF Growth, Exploration and STS

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SPACE PLATFORMS TECHNOLOGY
SPACE STATIONS

THERMAL CONTROL SYSTEMS PROGRAM RESOURCES

FISCAL	FY 91	FY92	FY93	FY94	FY95
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* EXPLORATION	----	1,995	3,580	4,340	6,575
* PLATFORM	----	2,400	2,850	3,200	3,675

* NO RTOP CURRENTLY EXISTS

T.Petete-JSC-6/7/91

ACTIVE THERMAL CONTROL SYSTEMS

SUMMARY

- TECHNOLOGY DEVELOPMENT CHALLENGES:
  - IMPROVE PERFORMANCE AND INCREASE EFFICIENCY OF BASELINE SSF ACTIVE THERMAL CONTROL SYSTEM
  - SPECIFIC CHALLENGES INCLUDE:
    - Increase waste heat rejection capability while minimizing deployed radiator area.
    - Provide for a low-mass load leveling method to accommodate for peak loads.
    - Accurately predict system performance through development of analytical tools.
- TECHNOLOGY DEVELOPMENT BENEFITS:
  - Increase heat rejection capability with mimimal impact to existing systems
  - Increase thermal control system reliability by reducing sensitivity to micrometreoid/orbital debris environment
  - Minimize radiator area growth related to increased power levels
  - Accommodate modular growth, on-orbit assembly and maintenance
  - Foster continuing industry competition for thermal control systems technology

T.Petete-JSC-6/7/91

SPACE PLATFORMS TECHNOLOGY PROGRAM - TECHNOLOGY FLIGHT EXPERIMENTS

HUMAN LIFE SUPPORT SYSTEMS

TECHNOLOGY NEEDS/CHALLENGES

- OPTIMIZE LIFE SUPPORT SYSTEMS, INCLUDING THERMAL CONTROL, FOR EXTENDED MICROGRAVITY OPERATION
  - MAXIMIZE PERFORMANCE AND EFFICIENCY
  - MINIMIZE MASS AND VOLUME
  - MAXIMIZE RELIABILITY
- REQUIRES BETTER UNDERSTANDING OF MICROGRAVITY AND ITS LONG-TERM INFLUENCE ON LIFE SUPPORT SYSTEMS PERFORMANCE CHARACTERISTICS

OBJECTIVES

- USE SPACE STATION FREEDOM (SSF) AS A TECHNOLOGY FLIGHT TEST BED FOR GRAVITY SENSITIVE PROCESSES
  - COMPONENT LEVEL
  - SUBSYSTEM LEVEL
  - SYSTEM LEVEL (MAY BE CONSTRAINED BY AVAILABLE SSF VOLUME AND INTERFACE CAPABILITIES
- DEVELOP TWO REUSABLE MODULAR TEST BEDS
  - LIFE SUPPORT
  - THERMAL CONTROL
- DEVELOP APPROPRIATE MATH MODELS

BENEFITS

- ALLOWS EXAMINATION OF CANDIDATE FUNDAMENTAL PROCESSES ASSOCIATED WITH AIR REVITALIZATION, WASTE WATER TREATMENT, WASTE MANAGEMENT, AND ACTIVE THERMAL CONTROL (ATC) AND HOW TO TAKE ADVANTAGE OF, OR TO MINIMIZE, THE EFFECTS OF MICRO-G
- ALLOWS STUDY OF FUNDAMENTAL HEAT TRENSFER AND FLUID DYNAMIC BEHAVIOR OF TWO-PHASE FLUIDS IN MICRO-G, PRIMARILY FOR THE OPTIMIZATION OF THE ATC
- PROVIDES ASSESSMENT OF LONG-TERM PROCESS PERFORMANCE IN MICRO-G
- PROVIDES FACILITY TO FLIGHT QUALIFY EQUIPMENT FOR FUTURE LONG-TERM MICRO-G MISSIONS

SPACE PLATFORMS TECHNOLOGY PROGRAM: TECHNOLOGY FLIGHT EXPERIMENTS
HUMAN LIFE SUPPORT SYSTEMS

STATE OF THE ART ASSESSMENT

- ADEQUATE DESIGN AND MODELING CORRELATIONS AVAILABLE
- LACK OF "REAL ENVIRONMENT" OPERATIONAL DATA OFTEN RESULTS IN COSTLY OVER DESIGN

RECENT ACCOMPLISHMENTS (506-49)

- COMPLETED ASSESSMENT OF LIFE SUPPORT AND THERMAL CONTROL FUNDAMENTAL PROCESSES AFFECTED BY GRAVITY
  - PHASE SEPARATION
  - GAS ABSORPTION
  - CONDENSATION
  - EVAPORATION
  - FREE CONVECTION HEAT TRANSFER
  - TWO-PHASE FLUIDS HEAT TRANSFER
  - TWO-PHASE FLOW AND PRESSURE DROP
  - ETC.
- FINALIZING CONCEPTUAL DESIGNS BASED ON USE OF TWO SSF EQUIPMENT RACKS
  - LIMITS SSF INTERFACES TO ONLY ELECTRICAL POWER AND COOLING WATER

SPACE PLATFORMS TECHNOLOGY PROGRAM: TECHNOLOGY FLIGHT EXPERIMENTS

HUMAN LIFE SUPPORT SYSTEMS

PROGRAM OUTLINE/MILESTONES

- 1993 — DEVELOP MATHEMATICAL MODELS AND SIMULATION TECHNIQUES FOR GRAVITY-SENSITIVE LIFE SUPPORT AND THERMAL CONTROL TECHNOLOGIES
- 1994 — CONDUCT PRELIMINARY DESIGN OF LIFE SUPPORT AND THERMAL CONTROL TEST BEDS AND FIRST SET OF TEST ARTICLES
- 1995 — COMPLETE FINAL DESIGN OF LIFE SUPPORT AND THERMAL CONTROL TEST BEDS INTEGRATED WITH FIRST GROUP OF TEST ARTICLES
- 1997 — FABRICATE AND ASSEMBLE TEST BEDS AND TEST ARTICLES
- 1998 — COMPLETE GROUND TEST AND CERTIFICATION OF TEST BED AND TEST ARTICLES; DELIVER FOR FLIGHT
- TBD — FLIGHT EXPERIMENTS IN SPACE STATION FREEDOM

SPACE PLATFORMS TECHNOLOGY PROGRAM: TECHNOLOGY FLIGHT EXPERIMENTS

HUMAN LIFE SUPPORT SYSTEMS

PROGRAM OUTLINE/MILESTONES (CONT'D)

- 1999 — VALIDATE/UPGRADE MODELS AND CONDUCT PRELIMINARY DESIGN OF SECOND SET OF TEST ARTICLES
- 2000 — CONDUCT FINAL DESIGN OF SECOND SET OF TEST ARTICLES
- 2001 — FABRICATE TEST ARTICLES
- 2002 — DELIVER SECOND SET OF FLIGHT TEST ARTICLES

HUMAN LIFE SUPPORT SYSTEMS

PROJECT RESOURCES ($M)

Sub-Element Resources	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1. Advanced Life Support Test Bed	0.2	0.46	1.16	1.16	1.29	1.44	1.50	1.20	1.20	1.20
2. Advanced Thermal Control Test Bed	0.12	0.35	0.70	0.70	0.75	0.80	0.84	0.60	0.60	0.60
3. Modeling & Analysis	0.2	0.21	0.33	0.34	0.35	0.37	0.38	0.41	0.42	0.42
Sub-Elements Totals:	0.52	1.02	2.19	2.2	2.39	2.61	2.72	2.21	2.22	2.22
Program Support	0.18	0.18	0.21	0.21	0.21	0.21	0.22	0.22	0.22	0.22
TOTAL ($M)	0.7	1.20	2.40	2.41	2.60	2.82	2.84	2.43	2.44	2.44

Basis for Resource Estimates:

Sub-element 1
- $6M for advanced life support test bed and first set of test articles
- $2.0M for flight experiment integration, $2.8M for second set of flight test articles

Sub-element 2
- $3.4M for advanced thermal control test bed and first set of test articles
- $1.2M for flight experiment integration, $1.5M for second set of flight test articles

Sub-element 3
- 2 MYE for modeling and analysis before PDR. 3 MYE after PDR thru flights

SPACE PLATFORMS TECHNOLOGY PROGRAM: TECHNOLOGY FLIGHT EXPERIMENTS

HUMAN LIFE SUPPORT SYSTEMS

SUMMARY

- USE SSF AS TECHNOLOGY FLIGHT TEST BED TO OPTIMIZE LIFE SUPPORT AND ACTIVE THERMAL CONTROL SYSTEMS FOR MICROGRAVITY OPERATION

BENEFITS

- ALLOWS EXAMINATION OF CANDIDATE FUNDAMENTAL PROCESSES ASSOCIATED WITH AIR REVITALIZATION, WASTE WATER TREATMENT, WASTE MANAGEMENT, AND ACTIVE THERMAL CONTROL (ATC) AND HOW TO TAKE ADVANTAGE OF, OR TO MINIMIZE, THE EFFECTS OF MICRO-G
- ALLOWS STUDY OF FUNDAMENTAL HEAT TRENSFER AND FLUID DYNAMIC BEHAVIOR OF TWO-PHASE FLUIDS IN MICRO-G, PRIMARILY FOR THE OPTIMIZATION OF THE ATC
- PROVIDES ASSESSMENT OF LONG-TERM PROCESS PERFORMANCE IN MICRO-G
- PROVIDES FACILITY TO FLIGHT QUALIFY EQUIPMENT FOR FUTURE LONG-TERM MICRO-G MISSIONS

OAET INSTEP PROGRAM

ELECTROLYSIS PERFORMANCE IMPROVEMENT CONCEPT STUDIES (EPICS) EXPERIMENT

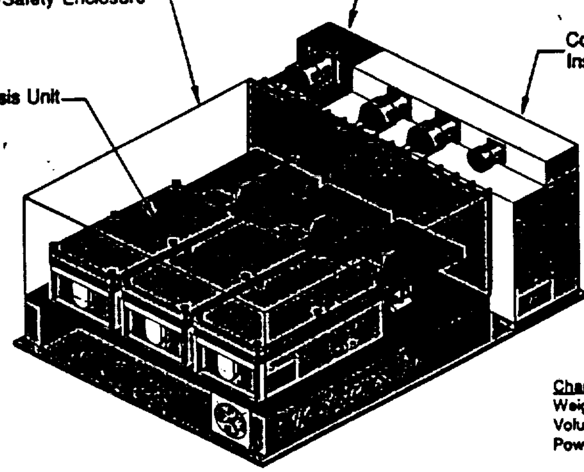
- Objective
  - Investigate ways low-g environment can improve water electrolysis performance by experimenting with electrochemical cells having various components of different microstructural catalytic characteristics and fluid flow paths
- **Benefits**
  - **Improvement in performance will lower power requirements**
  - **Results will validate electrolysis concept planned for Space Station Freedom life support application**
  - **Results may offer design improvements to other electrochemical processes involving a gas/liquid interface**

ELECTROLYSIS PERFORMANCE IMPROVEMENT CONCEPT STUDIES (EPICS) EXPERIMENT

- Technical Description

  - Be self-contained experiment with its own microprocessor data collection and storage capability
  - Employs three cells of differing microstructural characteristics at anode, cathode, and electrolyte matrix
  - Current density and temperature will be varied to determine effect on cell operating voltage
  - Electrolysis feed water is continuously replenished by a fuel cell recombiner reaction
  - Crew interface is minimized with single switch start-up and shutdown with unit contained in a Shuttle middeck payload locker

EPICS EXPERIMENT PACKAGING CONCEPT



Characteristics
Weight, lb: 37.6
Volume, ft^3: 1.9
Power, W: 100

ELECTROLYSIS PERFORMANCE IMPROVEMENT CONCEPT STUDIES (EPICS) EXPERIMENT

- Status
  - Two separate Statements of Work for the Phase B and optional Phase C/D have been prepared
  - RFP will be released from JSC to Life Systems, Inc., on June 24, 1991
  - Contract will be initiated on September 25, 1991
- Milestones/Schedule
  - 31-month Program: 6-month Phase B and 25-month Phase C/D
    - Conduct Concept Design Review - March 1992
    - Complete Non-Advocate Review - April 1992
    - Conduct Preliminary Design Review - June 1992
    - Begin Engineering Model Fabrication (3.5 months) - September 1992
  - Anticipated Launch Date - April 1994

ELECTROLYSIS PERFORMANCE IMPROVEMENT CONCEPT STUDIES (EPICS) EXPERIMENT

- Projected Program Cost
  - Phase B - $134K
  - Phase C/D - $1198K
  - Total - $1332K

JPL

HUMAN SUPPORT PROGRAM FOR INTEGRATED TECHNOLOGY PLAN

SENSORS AND CONTROLS FOR SPACE STATION
LIFE SUPPORT TECHNOLOGY (PLATFORMS)

PROPOSED AUGMENTATION

Dr. Gerald E. Voecks

JUNE 26, 1991

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

JPL <u>SENSORS AND CONTROLS FOR SSF LIFE SUPPORT</u>

CONTENTS

JPL SENSORS AND CONTROLS FOR SSF LIFE SUPPORT

TECHNOLOGY NEEDS

- IN SITU CHEMICAL, MICROBIAL AND ENVIRONMENTAL SENSORS FOR CONTINUOUS, REAL-TIME STATUS ON PHYSICAL-CHEMICAL LIFE SUPPORT PROCESSES
- PHYSICAL-CHEMICAL PROCESSES' CONTROLS FOR AUTOMATION OF LIFE SUPPORT OPERATIONS
- COMPUTER INTEGRATION OF IN SITU SENSORS AND CONTROLS FOR RELIABLE, UNATTENDED LIFE SUPPORT SYSTEMS OPERATIONS

TECHNOLOGY CHALLENGES

- ACCURATE, DEPENDABLE, IN SITU CHEMICAL "ANALYZERS" - AIR & WATER ENVIRONMENTS
- IN SITU MICROBIAL SPECIES DETECTORS
- "INTELLIGENT" CONTROLS
- SENSORS INTEGRATION/NETWORK WITH AI

JPL SENSORS AND CONTROLS FOR SSF LIFE SUPPORT

OBJECTIVES

- DEVELOP AND VALIDATE INTEGRATED LIFE SUPPORT SENSORS AND CONTROLS
  - SENSORS TECHNOLOGIES
    - IN SITU, REAL-TIME, SELF-CALIBRATING, GRACEFUL DEGRADATION
    - CHEMICAL (VARIOUS SPECIFIC SPECIES, QUANTITY LEVELS, AND CONDITIONS)
    - MICROBIAL (SPECIFIC SPECIES, LOW LEVELS, RESPONSIVE)
    - ENVIRONMENTAL (AEROSOLS, HUMIDITY, SMOKE)
  - CONTROLS TECHNOLOGIES
    - PROCESS AND SENSORS COMPATIBLE
    - AUTONOMOUS
    - RELIABLE
  - COMPUTER INTERFACE
    - MULTIPLE LEVELS OF OPERATION
    - ARTIFICIAL INTELLIGENCE

JPL SENSORS AND CONTROLS FOR SSF LIFE SUPPORT

TECHNOLOGY BENEFITS

- NASA PROGRAM
  - STS AND EDO
  - ENABLE SSF OPERATION
  - SPACE LAB OPERATIONS AND RESEARCH
  - LUNAR/MARS HABITATS

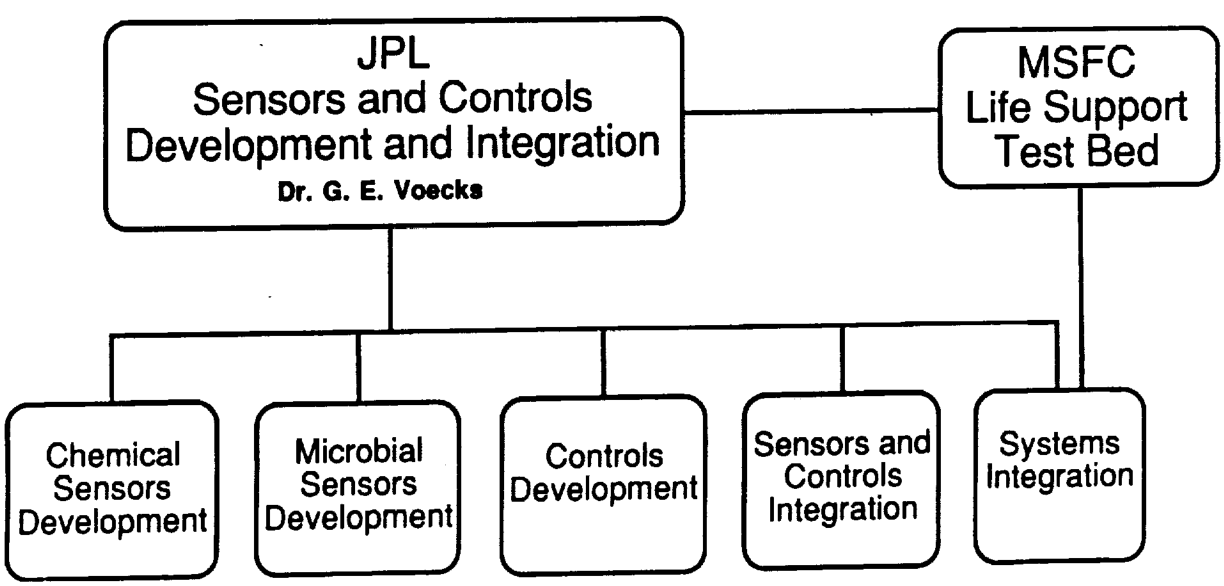
- INDUSTRY
  - CHEMICAL MANUFACTURING
  - HYDROCARBON PROCESSING
  - POWERPLANT OPERATION
  - GROUNDWATER/WASTE CONTROLS
  - "SICK BUILDING SYNDROME" MANAGEMENT

- MEDICAL DIAGNOSES AND CARE

- GOVERNMENT PROGRAMS
  - U.S. NAVY (SUBMARINES)
  - U.S. ARMY (CHEMICAL, BIOLOGICAL WARFARE PROTECTION)
  - EPA (ENVIRONMENTAL REGULATION AND CONTROLS)
  - NSF (ANTARCTICA)

JPL SENSORS AND CONTROLS FOR SSF LIFE SUPPORT

PROGRAM ORGANIZATION CHART FOR PROPOSED ACTIVITIES



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TECHNOLOGY STATE OF THE ART

SSF SENSORS/CONTROLS BASELINE

- o AIR REVITALIZATION
  - CENTRAL GC/MS MONITOR
  - INFRA RED DETECTORS FOR CO AND CO_2
  - BIOLOGICAL DETECTORS - BATCH ANALYSIS

- o WATER RECLAMATION
  - TOTAL ORGANIC CARBON - OXIDATION/CO_2 ANALYSIS
  - PH AND CONDUCTIVITY - ELECTROCHEMICAL PROBES
  - BIOLOGICAL DETECTORS - BATCH ANALYSIS

- o WASTE MANAGEMENT
  - NO CONTAMINANT ANALYSIS - STORAGE ONLY

SENSORS/MONITORS NOT DEFINED FOR MANY PROCESSING OPERATIONS

CONTROLS NOT INTEGRATED WITH SENSORS INFORMATION

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SENSORS AND CONTROLS FOR SSF LIFE SUPPORT

TECHNOLOGY STATE OF THE ART (cont'd)

CHARACTERISTICS OF GC/MS MONITOR FOR SSF

- o SAMPLE LINES FROM EACH PROCESS POINT TO ANALYZER
- o MULTI-PORT SAMPLE SELECTOR
- o SAMPLE TREATMENT/PREPARATION OPERATION
- o WASTE - EXCESS SAMPLE STORAGE/DISPOSAL PROCEDURES
- o MULTI-COMPONENT ANALYZER
- o MONITOR SUPPORT - EXPENDABLE MATERIALS, POWER, . . .
- o RELATIVELY LARGE/HEAVY COMPONENT
- o INFORMATION NOT CONTINUOUS, NOR REAL-TIME, FROM ALL LOCATIONS

JPL **SENSORS AND CONTROLS FOR SSF LIFE SUPPORT**

TECHNOLOGY STATE OF THE ART (cont'd)

- CHEMICAL SENSORS
  - NOT SELF-CALIBRATING
  - MAY BE MASKED OR ALTERED BY OTHER SPECIES
  - LIMITED LIFE AND RELIABILITY
  - UNDEPENDABLE DEGRADATION
  - HIGH SELECTIVITY IN FEW APPLICATIONS
- MICROBIAL SENSORS
  - NO CANDIDATES
- CONTROLS FOR LIFE SUPPORT NOT DESIGNED FOR AUTONOMOUS OPERATION
- INTEGRATED CONTROL NON-EXISTENT FOR LIFE SUPPORT APPLICATION

JPL **SENSORS AND CONTROLS FOR SSF LIFE SUPPORT**

RELATION TO NASA MISSIONS' REQUIREMENTS

- SHUTTLE AND SPACELAB OPERATIONS
  - IN-SPACE TEST AND INTEGRATION
- EXTENDED DURATION ORBITER (EDO)
  - IN SITU SENSOR RETROFIT TO AIR AND WATER
  - CONDUCT IN-SPACE TESTING OF LIFE SUPPORT PROCESSES/SENSORS
- SPACE STATION FREEDOM
  - SENSORS/CONTROLS RETROFIT FOR AIR AND WATER SUBSYSTEM OPERATIONS
- EVA MISSIONS
  - REGENERATIVE PORTABLE LIFE SUPPORT OPERATIONS
- LUNAR/MARS HABITATS
  - COMPLETELY AUTONOMOUS SENSORS AND CONTROLS INTEGRATED INTO SYSTEM FOR PROLONGED MISSION OPERATION

JPL SENSORS AND CONTROLS FOR SSF LIFE SUPPORT

LIFE SUPPORT SYSTEMS SENSORS/CONTROLS MILESTONES

FY 93 - COMPLETE LABORATORY SCREENING OF STATE-OF-THE-ART SENSORS

FY 94 - COMPLETE SENSORS REQUIREMENTS DEFINITION AND SYSTEM MODEL DESCRIPTION

FY 95 - DEFINE CONTROLS TECHNOLOGY DEVELOPMENTS REQUIRED FOR SYSTEMS OPERATIONS

FY 96 - DEMONSTRATE SENSORS-CONTROL-COMPUTER INTERFACE OPERATIONS

FY 97 - DEMONSTRATE CHEMICAL SENSORS FOR AIR, WATER & WASTE PROCESSING OPERATIONS

FY 98 - DEMONSTRATE CHEMICAL SENSORS AT SUBSYSTEM PROCESSES LEVEL

FY 99 - DEMONSTRATE MICROBIAL SENSORS FOR AIR, WATER & WASTE PROCESSING OPERATIONS

FY 02 - DEMONSTRATE MICROBIAL SENSORS AT SUBSYSTEM PROCESSES LEVEL

FY 04 - DEMONSTRATE COMPLETE SENSOR AND CONTROL OPERATION AT SSF INTEGRATED TESTBED

JPL SENSORS AND CONTROLS FOR SSF LIFE SUPPORT

AUGMENTED FISCAL AND SUPPORT RESOURCES

$M	FY 93	94	95	96	97	98
IN SITU SENSORS DEVELOPMENT						
o CHEMICAL SENSORS	1.0	2.0	2.0	1.5	1.0	1.0
o MICROBIAL SENSORS	0.5	1.0	1.5	2.0	2.0	2.0
COMPUTER/CONTROLS INTEGRATION						
o INTEGRATION OF SENSORS AND CONTROLS WITH COMPUTER INTERFACE		0.5	1.0	0.5	0.5	0.5
TESTBED DEMONSTRATION						
o DEMONSTRATE SENSORS/CONTROLS AND INTEGRATION IN GROUND TESTS (MSFC) AND IN SPACE OPERATIONS (SHUTTLE AND EDO)			1.0	1.0	1.5	1.5
TOTAL	1.5	3.5	5.5	5.0	5.0	5.0

JPL **SENSORS AND CONTROLS FOR SSF LIFE SUPPORT**

SUMMARY

TECHNICAL ISSUES

- o IN SITU CHEMICAL SENSORS DEVELOPMENT FOR PHYSICAL/CHEMICAL PROCESSES' MONITOR/CONTROL
- o IN SITU MICROBIAL SENSORS DEVELOPMENT FOR INCORPORATION INTO PHYSICAL/CHEMICAL PROCESSES AND OPERATIONS
- o INTEGRATION OF SENSORS WITH SSF CONTROLS

BENEFITS OF TECHNOLOGY DEVELOPMENT

- o IMPROVED RELIABILITY AND AUTONOMY OF SSF LIFE SUPPORT OPERATIONS
- o SENSORS/CONTROLS APPLICABLE TO EXISTING AND ADVANCED LIFE SUPPORT SYSTEMS
- o BASIS FOR WORKING WITH INDUSTRY AND OTHER GOVERNMENT AGENCIES
- o TECHNOLOGY APPLICABLE TO A MYRIAD COMMERCIAL OPERATIONS

INTEGRATED TECHNOLOGY PLAN
EXTERNAL REVIEW

OAET

HUMAN SUPPORT PROGRAM

FIRE SAFETY

RESEARCH AND TECHNOLOGY BASE

AND

SPACE PLATFORMS TECHNOLOGY PROGRAM

JUNE 26, 1991
ROBERT FRIEDMAN
NASA LEWIS RESEARCH CENTER
CLEVELAND OH

FIRE SAFETY PROGRAM

OAET

POLICY STATEMENT

- REALISTIC SAFETY PHILOSOPHY IS TO MINIMIZE FIRE RISK AND AVOID CREW INJURY OR ANY SPACECRAFT DAMAGE THAT THREATENS THE MISSION

TECHNOLOGY CHALLENGES

- UNUSUAL FIRE BEHAVIOR IN LOW GRAVITY
- LITTLE PAST EXPERIENCE FOR ACCURATE RISK PREDICTIONS
- EXTREME HIGH VALUE OF SPACECRAFT AND MISSION OPERATIONS
- LIMITED RESOURCES TO PROVIDE FOR COMPLETE FIRE PROTECTION

OBJECTIVES OF PROGRAM

- TO INCREASE THE UNDERSTANDING OF FIRE BEHAVIOR IN THE SPACE ENVIRONMENT AND TO APPLY THE RESULTS FOR IMPROVED AND EFFICIENT FIRE PREVENTION, DETECTION, AND SUPPRESSION IN SPACECRAFT

FIRE SAFETY IN NASA HUMAN-CREW SPACECRAFT

- FIRE SAFETY ALWAYS RECEIVES PRIORITY ATTENTION IN NASA MISSION DESIGNS AND OPERATIONS, WITH EMPHASIS ON FIRE PREVENTION AND MATERIAL ACCEPTANCE STANDARDS

- RECENTLY, INTEREST IN SPACECRAFT FIRE-SAFETY RESEARCH AND DEVELOPMENT HAS INCREASED BECAUSE

  - IMPROVED UNDERSTANDING OF THE SIGNIFICANT DIFFERENCES BETWEEN LOW-GRAVITY AND NORMAL-GRAVITY COMBUSTION SUGGESTS THAT PRESENT FIRE-SAFETY TECHNIQUES MAY BE INADEQUATE OR, AT BEST, NON-OPTIMAL

  - THE COMPLEX AND PERMANENT ORBITAL OPERATIONS IN *FREEDOM* DEMAND A HIGHER LEVEL OF SAFETY STANDARDS AND PRACTICES

FIRE SAFETY PROGRAM BENEFITS

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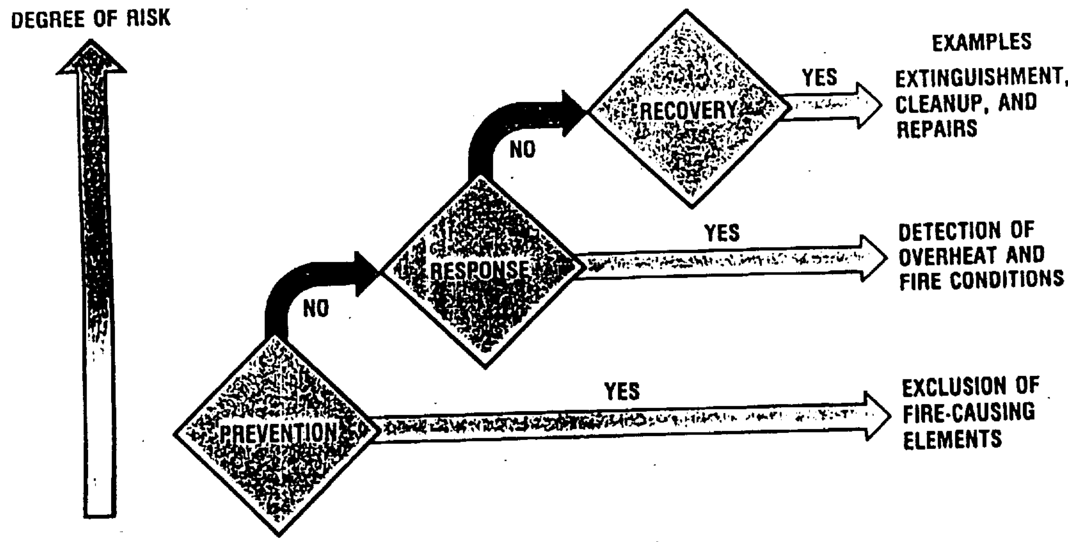
- APPLICATIONS TO IMPROVE SAFETY, EFFICIENCY, AND COST REDUCTION IN CURRENT AND FUTURE SPACECRAFT
- ADVANCED RESEARCH IN FUNDAMENTAL COMBUSTION AND FIRE SCIENCE (GREATLY AIDED BY THE ABSENCE OF THE OVERWHELMING BUOYANT FLOWS IN MICROGRAVITY)
- ENCOURAGEMENT OF SCIENTIFIC/COMMERCIAL UTILIZATION OF SPACE THROUGH WELL-DEFINED AND REALISTIC SAFETY STANDARDS
- POTENTIAL SPIN-OFFS IN NONFLAMMABLE MATERIAL AND FIRE-SENSOR KNOWLEDGE

RELATION TO OAET THRUSTS

- R &T BASE:
  - DEVELOPMENT OF FLIGHT EXPERIMENTS ON LOW-GRAVITY FIRE CHARACTERISTICS (EXPANSION OF IN-STEP PROJECT)
  - DEVELOPMENT OF FLIGHT EXPERIMENTS FOR LOW-GRAVITY MATERIAL FLAMMABILITY ASSESSMENTS (WITH CODE Q)

- FOCUSED THRUST:
  - APPLICATION OF BASIC SCIENCE AND TECHNOLOGY INFORMATION TO DEVELOPMENT OF FIRE PROTECTION FOR ADVANCED SPACECRAFT

SPACECRAFT FIRE RISK STRATEGIES



SPACECRAFT FIRE-SAFETY STATE OF THE ART

OAET

PREVENTION

- LARGE DATABASE AVAILABLE ON ACCEPTABLE "NON-FLAMMABLE" MATERIALS
- NASA TEST METHODS UNDER EVALUATION BY NIST; MODIFICATIONS ARE SUGGESTED
- RECENT RESEARCH DEFINED LOW-GRAVITY FLAMMABILITY LIMITS AND VENTILATION EFFECTS

FIRE DETECTION

- AIRPLANE SMOKE DETECTOR DESIGNS ADAPTED TO SPACECRAFT
- NO SPACE-RELATED DATA

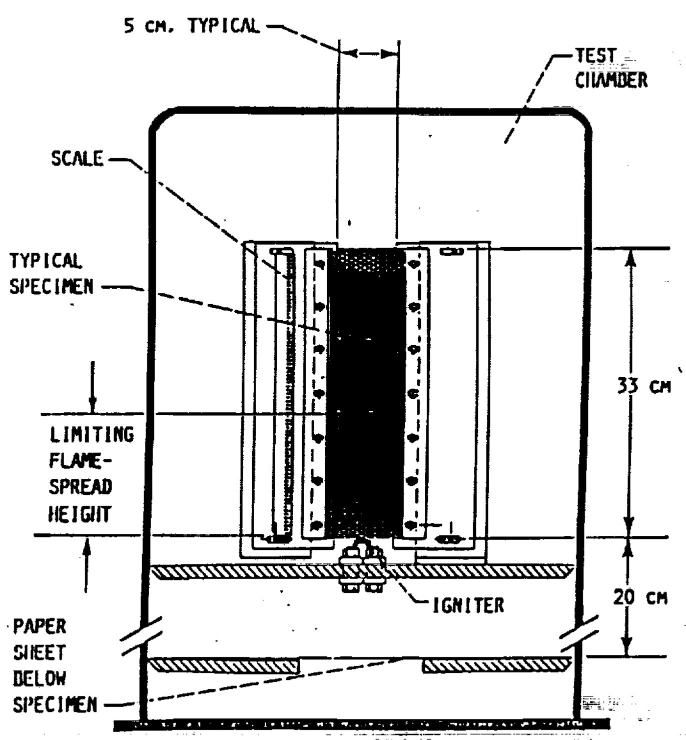
FIRE EXTINGUISHMENT

- SPACECRAFT EXTINGUISHING AGENTS SELECTED BY SYSTEM ANALYSES
- RECENT RESEARCH DEFINED RELATIVE EFFICIENCY OF AGENTS AS ATMOSPHERIC SUPPRESSANTS

CURRENT PRACTICES IN FIRE PREVENTION FOR SPACECRAFT

- LIMITING MATERIALS, AS FAR AS PRACTICAL, TO THOSE THAT ARE "NON-FLAMMABLE", BASED ON NHB 8600.1 FLAMMABILITY TESTS
- AVOIDANCE OF IGNITION SOURCES, THROUGH ELECTRICAL INSULATION AND GROUNDING, OVERPRESSURE CONTAINMENT, AND THERMAL/-ELECTRICAL OVERLOAD PROTECTION
- GOOD HOUSEKEEPING PRACTICES FOR WASTE STORAGE AND DISPOSAL, FLUID LEAK PREVENTION, "FLAMMABLES" ISOLATION, AND SO ON

UPWARD FLAME PROPAGATION TEST



NHB8060.1B APPROVAL TEST FOR SOLID MATERIALS IN HABITABLE SPACECRAFT AREAS

PROBLEMS IN FIRE PREVENTION FOR SPACECRAFT

- MANY COMMON ITEMS, PARTICULARLY COMMERCIAL INSTRUMENTS AND PERSONAL USE ITEMS, CANNOT PASS THE FLAMMABILITY TEST. THESE ARE PERMITTED ONBOARD SPACECRAFT WHEN CONTROLLED THROUGH ISOLATION, STORAGE PROTECTION, OR BARRIERS. NEVERTHELESS
  - CONFIGURATION CHANGES MAY OCCUR DURING MISSIONS
  - FOAM MATERIALS, VELCRO PATCHES, ETC., POSE SPECIAL FLAMMABILITY PROBLEMS (SMOLDERING, PARTICLE EXPULSION)

- MATERIAL FIRE HAZARDS MAY INCREASE IN THE FUTURE FOR *FREEDOM*
  - GREATER VARIETY OF COMMERCIAL AND TEST MATERIALS
  - HIGHER PROBABILITY OF EXPOSURE TO IGNITION "INCIDENTS"
  - CHANGES AND RELAXATION OF SAFETY ATTITUDES (LONG MISSIONS)

- CURRENT UNDERSTANDING OF MICROGRAVITY COMBUSTION QUESTIONS THE RELEVANCE OF NORMAL-GRAVITY-TEST ACCEPTANCE STANDARDS TO LOW-GRAVITY FLAMMABILITY BEHAVIOR

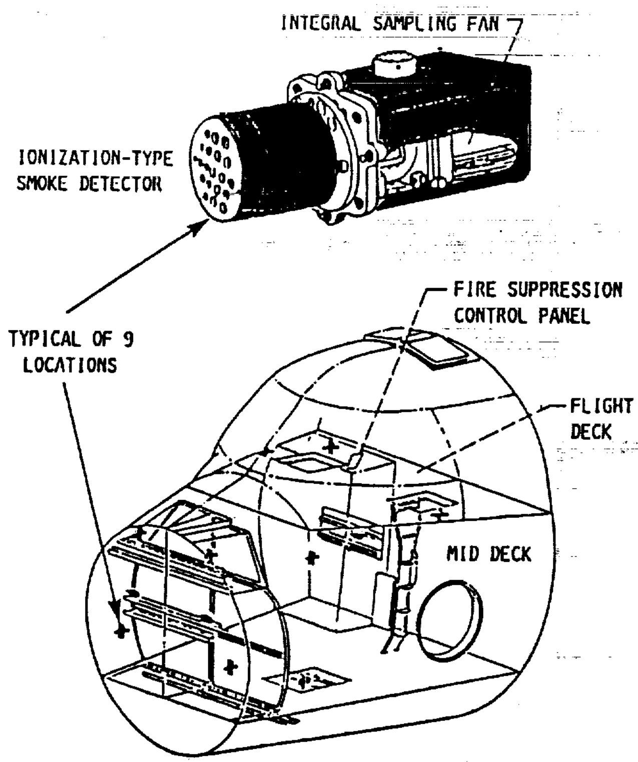
CURRENT PRACTICES IN FIRE DETECTION FOR SPACECRAFT

- SHUTTLE IS EQUIPPED WITH NINE STATE-OF-THE-ART IONIZATION SMOKE DETECTORS (CARGO-BAY LABORATORIES HAVE SIX OR MORE ADDITIONAL DETECTORS)

- SHUTTLE DETECTORS HAVE INTERNAL FANS FOR PARTICLE SEPARATION (DUST PARTICLE BYPASS OF IONIZATION CHAMBER) AND FOR ADEQUATE ATMOSPHERIC SAMPLING

- SHUTTLE DETECTORS ARE MONITORED TO MEASURE PARTICLE CONCENTRATION AND TO ALARM AT PRESET CONCENTRATIONS

FIRE DETECTION IN THE SHUTTLE



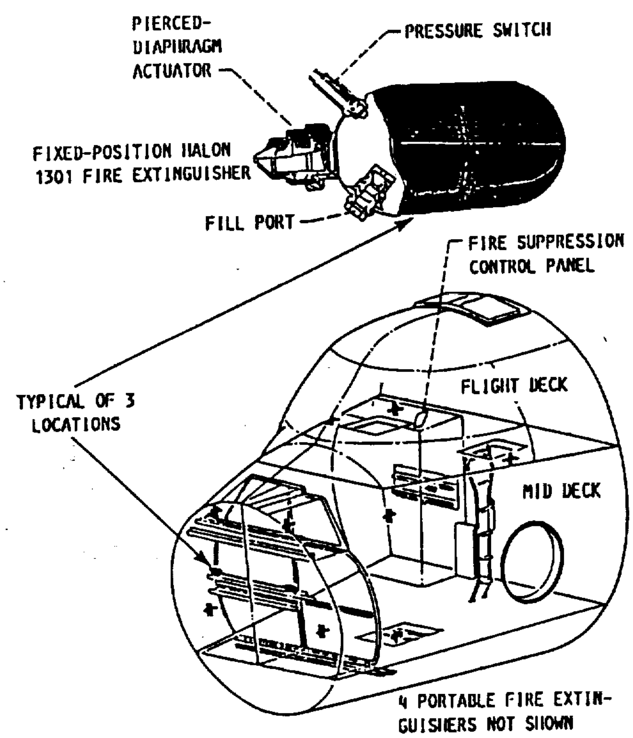
PROBLEMS IN FIRE DETECTION FOR SPACECRAFT

- THE EFFECTIVENESS OF STANDARD SENSORS IN RESPONDING TO THE UNIQUE CHARACTERISTICS OF MICROGRAVITY FIRES IS UNCERTAIN
  - SMOKE AND AEROSOL PARTICLE SIZE, SIZE DISTRIBUTION, AND DENSITY ARE UNKNOWN
  - MICROGRAVITY FLAMES ARE STEADY (FLICKER CIRCUITS DO NOT IDENTIFY THESE FLAMES)
  - THE HEAT AND MASS TRANSPORT OF FIRE "SIGNATURES" TO THE SENSOR ARE DIFFERENT, INFLUENCING RESPONSE TIMES
- SPECIFIC FIRE SCENARIOS AND RISK MODELS, NECESSARY TO GUIDE OPTIMUM SENSOR SPACING AND LOCATION, ARE LACKING
- TRADEOFFS FOR OPTIMUM DECISIONS ON SENSITIVITY VS. FALSE ALARMS, MANUAL VS. AUTOMATED RESPONSES, AND SO FORTH, ARE LACKING

CURRENT PRACTICES IN FIRE EXTINGUISHMENT FOR SPACECRAFT

- SHUTTLE EQUIPPED WITH THREE FIXED AND FOUR PORTABLE STATE-OF-THE-ART HALON 1301 FIRE EXTINGUISHERS
- OPERATION OF FIXED EXTINGUISHER FROM PANEL REQUIRES ACTUATION OF AN "ARM" SWITCH FOLLOWED BY THE "DISCHARGE" SWITCH
- NORMAL COMBUSTION PRODUCTS OF CO_2 AND WATER ARE REMOVED FROM THE ATMOSPHERE BY THE PRESENT ENVIRONMENTAL CONTROL SYSTEM
- OTHER COMBUSTION PRODUCTS, SUCH AS CO, ARE REMOVABLE, IN TRACE QUANTITIES ONLY, BY AN ACTIVATED CARBON FILTER
- MISSION WOULD BE TERMINATED AFTER EXTINGUISHER DISCHARGE FOR SUBSEQUENT GROUND CLEANUP

FIRE EXTINGUISHMENT IN THE SHUTTLE



PROBLEMS IN FIRE EXTINGUISHMENT FOR SPACECRAFT

- LIMITED SELECTION OF USEFUL EXTINGUISHING AGENTS FOR SPACE
  - NONGASEOUS OR MIXED-PHASE (FOAM) TYPES NOT SUITABLE
  - REMOVAL OF AGENT AND PRODUCTS FROM CLOSED ENVIRONMENT IS A CRITICAL CONCERN
- HALON 1301 AND SIMILAR HALOCARBONS ARE TO BE PHASED OUT OF USE IN NEXT DECADE BY INTERNATIONAL AGREEMENTS
- EFFECTIVENESS OF AGENT DISPERSAL AND DELIVERY MODE UNDER THE DIFFERING MASS AND HEAT TRANSPORT RATES IN MICROGRAVITY HAVE YET TO BE DEMONSTRATED
- FOR THE PERMANENT ORBITAL MISSIONS OF *FREEDOM*, UNKNOWN LONG-TERM TOXIC AND CORROSIVE EFFECTS OF AGENT AND PRODUCT RESIDUES ARE A CONCERN

EXPERIMENTAL STUDIES AND DEMONSTRATIONS OF MICROGRAVITY FIRE BEHAVIOR RELEVANT TO FIRE SAFETY

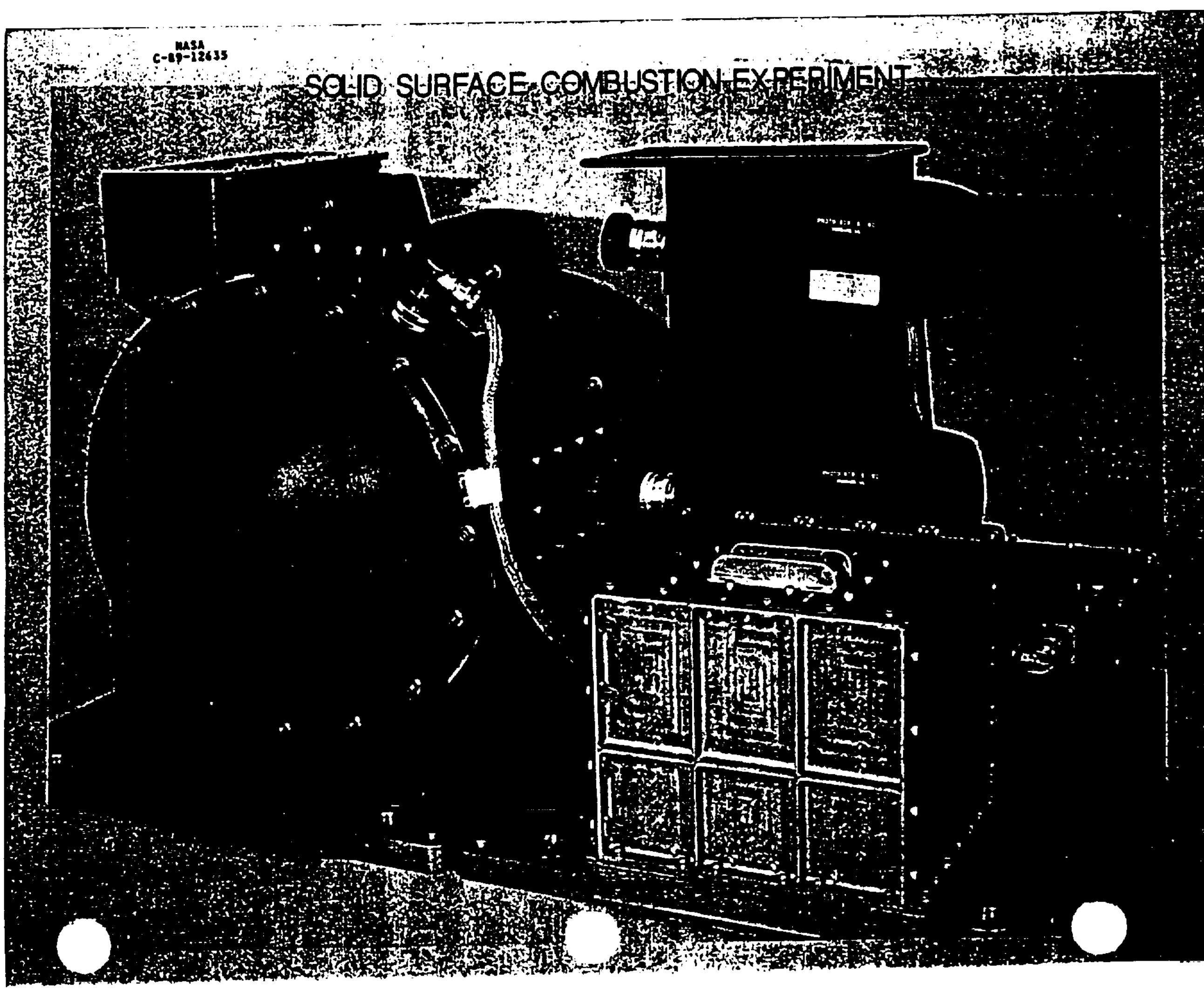
IN SPACE	SKYLAB	1974
	SHUTTLE SSCE (STS 41, 40)	1990, 1991
PARABOLIC AIRPLANE FLIGHTS	KIMZEY	1966
	NASA LEWIS, ESA	CURRENT
FREE-FALL DROP TOWERS	NASA LEWIS 5.2 SEC:	
	WIRE INSULATION	1971
	SOLID SAMPLES	1974 TO CURRENT
	NASA LEWIS 2.2 SEC:	
	SOLID SAMPLES	1970 TO CURRENT
	PARTICLE CLOUDS	1979 TO 1990
	PREMIXED GASES	1980 TO CURRENT
	VARIOUS UNIVERSITY (1.0 TO 1.4 SEC):	
	DROPLETS, AEROSOLS	CURRENT

SOLID SURFACE COMBUSTION EXPERIMENT

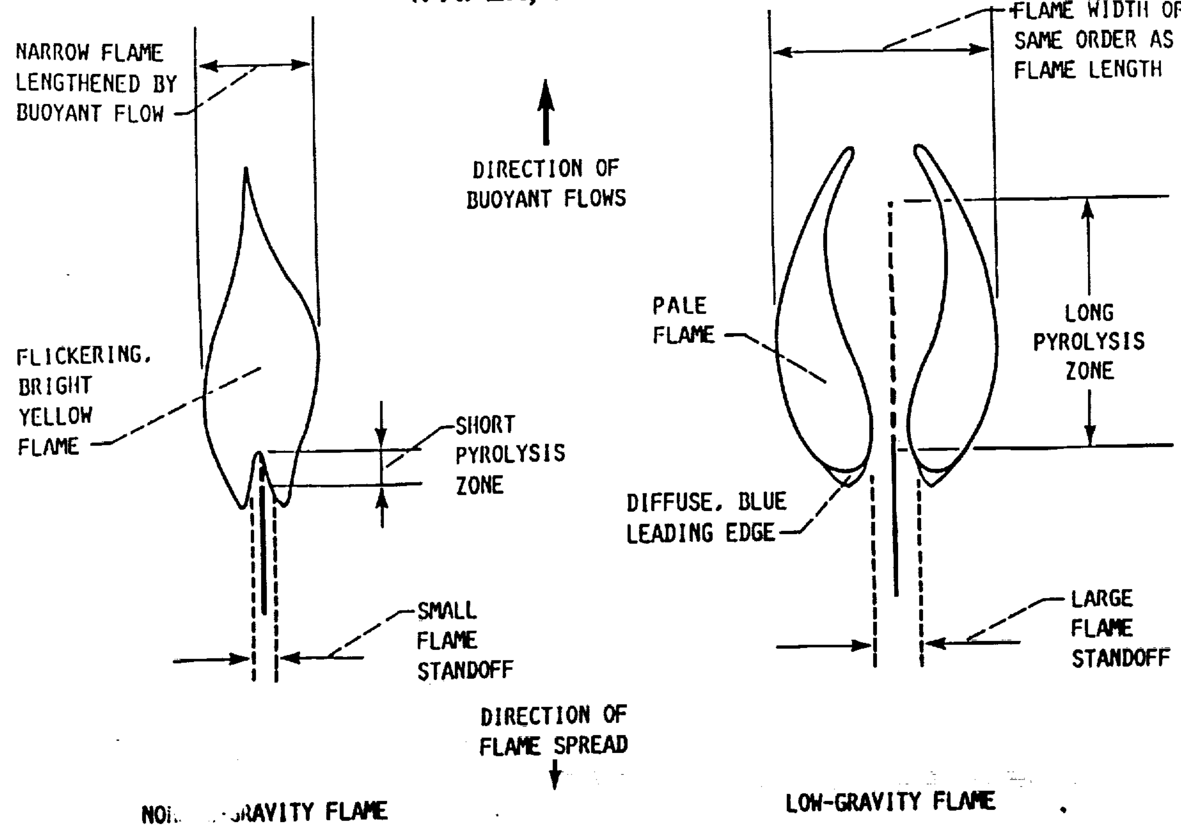
SSCE FLIGHT TEST MATRIX

TEST NUMBER	FUEL	OXYGEN CONTENT* (% by Volume)	CHAMBER PRESSURE	MISSION
1	PAPER	50	1.5 ATM	STS-41
2	PAPER	50	1.0 ATM	SLS-1
3	PAPER	50	2.0 ATM	STS-43
4	PAPER	35	1.5 ATM	USML-1
5	PAPER	35	1.0 ATM	STS-49?
6	PMMA	70	1.0 ATM	TBD
7	PMMA	50	1.0 ATM	TBD
8	PMMA	50	2.0 ATM	TBD

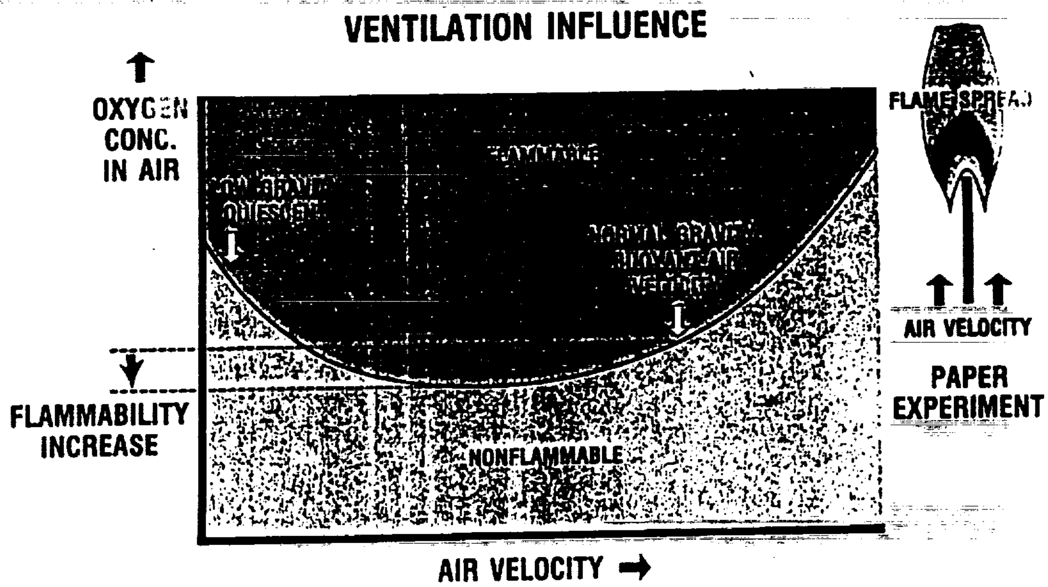
* Balance Nitrogen



COMPARISON OF FLAMES ON THIN SOLID SURFACES (PAPER, FOR EXAMPLE)



POTENTIAL ENHANCEMENT OF FLAMMABILITY BY LOW AIR FLOWS AT LOW GRAVITY



SPACE STATION *FREEDOM* FIRE PROTECTION

MAJOR ISSUES

- THE COMPLEX CONFIGURATION, VARIED CREW ACTIVITIES, AND SCIENTIFIC AND COMMERCIAL OPERATIONS MAY PROVIDE ADDITIONAL FIRE HAZARDS. THE LONG-TERM, PERMANENT ORBITAL MISSION INCREASES THE PROBABILITY OF FIRE "EVENTS" TO NEAR UNITY.
- THE INITIAL ASSEMBLY PERIOD POSES PARTICULAR CONCERNS
  - NO MEANS OF REMOTE MODULE ISOLATION OR FIRE CONTROL TO COMBAT FIRE EVENTS DURING INTERIM UNATTENDED TIMES
  - INCREASED MATERIAL FLAMMABILITY IN HIGHER-O_2-CONCENTRATION ATMOSPHERES (REQUIRED FOR EXTRAVEHICULAR ACTIVITIES)
- THE DEPENDENCIES AND TRADE-OFFS BETWEEN MANUAL AND AUTOMATED FIRE PROTECTION ARE UNRESOLVED. THE AUTOMATED DATA MANAGEMENT SYSTEM MAY FAIL DURING A FIRE, FOR EXAMPLE.
- THE APPLICATION OF THE LIMITED KNOWLEDGE OF LOW-GRAVITY FIRE BEHAVIOR TOWARD PRACTICAL FIRE-PROTECTION HARDWARE AND OPERATIONS FOR SPACE IS STILL IN A VERY EARLY STATE OF DEVELOPMENT
- SEVERE DESIGN CONSTRAINTS ON POWER, MASS, AND VOLUME DEMAND SIMPLE YET HIGHLY EFFICIENT DETECTION-SUPPRESSION SYSTEMS

DETAILED SCOPE OF PROJECTS FOR SPACECRAFT FIRE SAFETY

OAET

OAET PRIORITY PROJECTS UNDERLINED; AUGMENTED DOUBLE UNDERLINED

- R & D ON FIRE-DETECTION COMPONENTS AND SUBSYSTEMS
  - VENTILATION MODELING FOR EFFECTIVE SENSOR PLACEMENT
  - LOW-GRAVITY FIRE "SIGNATURES" AND SENSOR TECHNOLOGY
  - CENTRALIZED DETECTION SYSTEMS AND INFORMATION PROCESSING
- R & D ON FIRE-SUPPRESSION COMPONENTS AND SUBSYSTEMS
  - EVALUATION AND TESTING OF EXTINGUISHING AGENTS
  - DELIVERY SYSTEM TECHNOLOGY
- DEVELOPMENT OF RISK ASSESSMENT METHODS, DECISION ANALYSES, EXPERT SYSTEMS, AND AUTOMATION
- R & D ON POST-FIRE CLEANUP TECHNOLOGY
  - IDENTIFICATION OF LOW-GRAVITY COMBUSTION/EXTINGUISHMENT BYPRODUCTS
  - EFFECTIVE, CONTINUOIS ATMOSPHERIC MONITORING TECHNIQUES
  - HIGH-CAPACITY, EMERGENCY ATMOSPHERIC CLEAN-UP TECHNIQUES
- SPACE EXPERIMENTS TO TEST AND VERIFY SELECTED TECHNIQUES

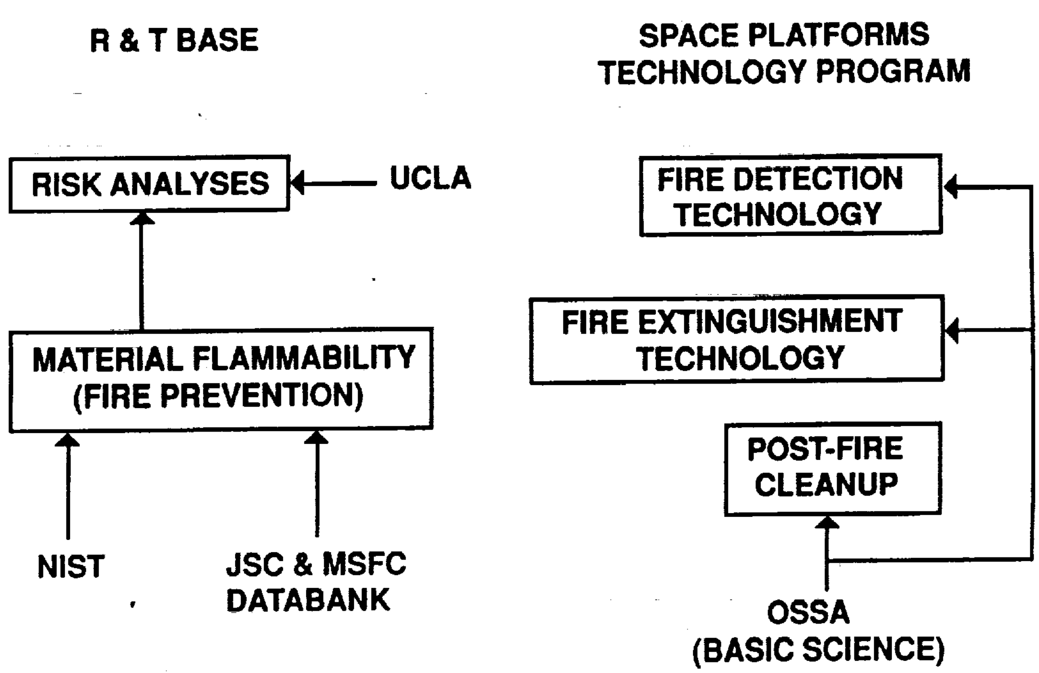
ORGANIZATION OF FIRE-SAFETY PROGRAM

OAET

BASELINE PRIORITY	AUGMENTED
RISK-BASED FIRE-SAFETY STUDY (IN PROGRESS WITH UCLA)	DEVELOPMENT OF PROBABILISTIC RISK ASSESSMENTS MODELS FOR *FREEDOM* AND ADVANCED SPACECRAFT
FLAME CHARACTERISTICS AND "SIGNATURES" FOR DETECTION IN SPACE	DEVELOPMENT OF DETECTION SYSTEMS AND LOGIC FOR *FREEDOM* AND ADVANCED SPACECRAFT
FIRE EXTINGUISHMENT METHODS FOR THE SPACE ENVIRONMENT	DEVELOPMENT OF FIRE EXTINGUISHING, DISPERSAL, AND CLEANUP SYSTEMS FOR *FREEDOM* AND ADVANCED SPACECRAFT
LOW-GRAVITY MATERIAL FLAMMABILITY ASSESSMENT (WITH CODE Q)	CONTINUOUS MONITORING TECHNIQUES FOR ATMOSPHERIC CONTROL AND EARLY WARNING

RELATIONSHIP OF OAET FIRE-SAFETY ELEMENTS

OAET



OAET FIRE-SAFETY PROGRAM ELEMENTS

O.A.E.T

SCHEDULE AND PRODUCTS

	1995	1996	1997	1998	1999	2000
MATERIAL FLAMMABILITY CORRELATIONS	▽					
FLAMMABILITY CHARACTERISTICS - SMOLDERING, ENRICHED O_2 ATM	▽					
QUANTITATIVE RISK ASSESSMENTS		▽				
FIRE-SAFETY DEMONSTRATIONS ON SHUTTLE				▽		
FIRE DETECTION-SUPPRESSION - FLIGHT EXPERIMENT ON *FREEDOM*						▽

SUMMARY

O.A.E.T

- PRESENT STATUS CURRENT SPACECRAFT FIRE-SAFETY PRACTICES, BASED MAINLY ON SKILLED APPLICATIONS OF GROUND AND AIRCRAFT TECHNIQUES, ARE CONSIDERED ADEQUATE
- ISSUES FOR FUTURE SPACECRAFT AND MISSIONS, HOWEVER, ADVANCES IN FIRE-SAFETY STANDARDS AND TECHNOLOGY ARE ESSENTIAL
  - THE GROWING BODY OF KNOWLEDGE OF MICROGRAVITY COMBUSTION SCIENCE OFFERS THE OPPORTUNITY FOR IMPROVED AND MORE EFFICIENT FIRE-SAFETY TECHNIQUES
  - THE COMPLEX, PERMANENT ORBITAL OPERATIONS OF *FREEDOM* IMPOSE NEW DEMANDS ON FIRE SAFETY AND INCREASE THE PROBABILITY OF FIRE INCIDENTS
  - NEW INFORMATION IS NEEDED ON THE APPLICATION OF MICROGRAVITY COMBUSTION SCIENCE AND QUANTITATIVE RISK ASSESSMENTS TO PRACTICAL CONCEPTS OF FIRE SAFETY
- BENEFITS RESEARCH AND TECHNOLOGY IN SPACECRAFT FIRE SAFETY PROMISE REDUCED RISK FACTORS AND IMPROVED FLEXIBILITY AND EFFICIENCY IN SPACECRAFT TECHNIQUES TO PROMOTE GREATER MISSION SAFETY AND ENCOURAGE BETTER UTILIZATION OF FUTURE SPACECRAFT

SPACE PLATFORMS TECHNOLOGY PROGRAM - SPACE STATIONS

FIRE SAFETY

OAET

OBJECTIVES

- PROGRAMMATIC

  TO DEVELOP, VERIFY, AND DEMONSTRATE IN SPACE FLIGHT, EFFICIENT FIRE DETECTION AND SUPPRESSION HARDWARE/TECHNIQUES FOR ADVANCED SPACECRAFT

- TECHNICAL

  TO ADVANCE THE KNOWLEDGE OF SPACECRAFT FIRE SAFETY THROUGH RESEARCH ON QUANTITATIVE RISK ASSESSMENTS AND MICROGRAVITY FIRE CHARACTERISTICS

SCHEDULE

- 1995 ESTABLISH MICROGRAVITY TO NORMAL-GRAVITY MATERIAL FLAMMABILITY CORRELATIONS
- 1995 COMPLETE SCALE-MODEL, GROUND-BASED MICRO-GRAVITY FIRE CHARACTERISTICS EXPERIMENTS
- 1996 ESTABLISH QUANTITATIVE RISK ASSESSMENTS FOR FIRE SAFETY
- 1998 COMPLETE SHUTTLE EXPERIMENT PROGRAM
- 2000 INITIATE FIRE DETECTION-SUPPRESSION EXPERIMENTS ON ***FREEDOM***

RESOURCES

- 1993 $2.0 M
- 1994 $3.2 M
- 1995 $5.1 M
- 1996 $5.8 M
- 1997 $5.6 M
- 1998 $5.2 M
- 1999 $3.4 M
- 2000 $1.7 M

PARTICIPANTS

- LEWIS RESEARCH CENTER
- MARSHALL SPACE FLIGHT CENTER
- JOHNSON SPACE CENTER

NASA

MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter:	Date:
Bruce McKinley, PhD	June 26, 1991

MEDICAL SUPPORT TECHNOLOGY FOR REMOTE HEALTH CARE SYSTEMS

(INFORMATION FOR SPACE SYSTEMS AND TECHNOLOGY ADVISORY COMMITTEE, INTEGRATED TECHNOLOGY PLAN, HUMAN SUPPORT PROGRAM; RP/M. L. EVANICH, COORDINATOR)

MEDICAL SCIENCES DIVISION
JOHNSON SPACE CENTER

JUNE 26, 1991

Johnson Space Center, Houston, Texas

NASA

MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter:	Date:
Bruce McKinley, PhD	June 26, 1991

TECHNOLOGY NEEDS:

Health care systems for on-site use by exploration crews:
- Medical care system
- Health monitoring and countermeasures system
- Environmental monitoring and countermeasures system

Components based on known, state of the art technologies

"Infrastructure:" dedicated work volume(s), utilities connections, information communication, management and display (local and remote)

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

OBJECTIVES:

Technology development program:

- interaction with universities, laboratories, commercial industries
- coordination of design, fabrication, test and assessment
- functional, space rated devices, systems
- systems and (medical) operations development

Development of component technologies for health care systems:

- Medical diagnostics and monitoring technology
- Integrated medical care technology
- Telemedicine technology
- Health care informatics technology
- Pharmaceuticals, IV fluids and administration technology
- Countermeasures technology and protocols

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

BENEFITS:

- Proof of concepts essential for lunar, Mars exploration missions.
- Focused development of health care methods to minimize payload, operational volume, crew time requirements.
- Development of common technologies, devices: production cost, volume, mass savings; training, operations simplicity; potential application to other space systems, e.g. EVA biomedical monitors.
- Accurate specification of equipment, supplies, work volume.
- Potential for development of modular health care systems for mission elements, program phases.
- Development of operations protocols with prototype hardware and user environment.
- NASA leadership in systems engineering applied to medical technology.
- Recognition, support of U.S., international medical communities.

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

ORGANIZATION OF (PROPOSED) TECHNOLOGY PROGRAM:

- Health care systems concept design, test coordination, requirements:

  SD/Medical Sciences Division

- Device (HW, SW) development:

  university, industry contracts; selected inhouse development projects

- Medical care system:

  SD2/Medical Operations Branch

- Health monitoring and countermeasures system:

  SD5/Space Biomedical Research Institute

- Environmental monitoring and countermeasures system:

  SD4/Biomedical Operations Research Branch

NASA

MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

PROPOSED TOPICS/STATE OF THE ART:

MEDICAL DIAGNOSTICS, MONITORING TECHNOLOGY (593-xx-01):

- Laboratory diagnostics: chemical, hematological, microbiological analysis of discrete sample using compact, easy to use, reliable instrumentation (preferably one integrated system).

- Imaging diagnostics: planar xray, computer assisted tomography, (digital) ultrasound, and/or magnetic resonance instrumentation for use at patient bedside (compact, safe, easy to use).

- Physiologic monitor: non-, minimally-invasive continuous monitors of ECG, blood pressure, cardiac output, oxygen consumption, carbon dioxide production, and metabolic rates, blood oxygen saturation.

NASA

MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

PROPOSED TOPICS/STATE OF THE ART (cont'd.):

INTEGRATED MEDICAL CARE TECHNOLOGY (593-xx-02):

- Single patient care unit, to include: patient support surface; utilities connections/portable sources (electrical power, oxygen/air, vacuum, water); biological fluid handling system; electronic data transfer, storage, management, display system; pharmaceuticals, supplies storage system; fluid formulation, administration system; ventilatory support system.
- System engineering and technology for: rescue, resuscitation, (local) patient transport; emergency surgery and critical care; long term patient care and management; long distance transport; hyperbaric treatment.
- Determination of patient care work volume(s).
- Development of treatment protocols.

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter: Bruce McKinley, PhD

Date: June 26, 1991

PROPOSED TOPICS/STATE OF THE ART (cont'd.):

TELEMEDICINE TECHNOLOGY AND DEMONSTRATION (593-xx-03):

- Identification of technologies to provide telemedicine between two or more remote locations.
- Assembly of two-way text, voice, image communication system, based on preliminary lunar outpost requirements. (remote data access, macro-/micro-scopic image transmission, image processing; medical, environmental data)
- Use in patient care in space-relevant, remote analog environment in communication with university medical center providing level 1 trauma care.

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

PROPOSED TOPICS/STATE OF THE ART (cont'd.):

HEALTH CARE INFORMATICS TECHNOLOGY(593-xx-04):

- Integrated health care informatics (automated data acquisition and management) system to provide:
  - Occupational medical care (environmental health monitoring and hazard response protocols)
  - Preventive medical care (physical health monitoring and maintenance recommendations)
  - Clinical medical care (definitive diagnosis and decision support; protocols for treatment)
- Development of common technologies:
  - Informatics systems for environment, health, medical data
  - Exercise and EVA biomedical monitor instrumentation and data interfaces
  - Data communication protocols
- Development system, mockup and trainer systems.

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

PROPOSED TOPICS/STATE OF THE ART (cont'd.):

PHARMACEUTICALS, IV FLUIDS AND ADMINISTRATION (593-xx-05):

- Space (NASA) pharmacopeia development.
- Packaging, storage system development.
- Investigation of pharmacokinetics; determination of drug dose, administration technology.
- Development of on-site IV fluid production, administration system.
- Development of blood, blood component replacement technology for space use.
- Development of nutritional support technology.
- Space human use approval of drugs and formulation, administration devices.

NASA

MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter: Bruce McKinley, PhD

Date: June 26, 1991

PROPOSED TOPICS/STATE OF THE ART (cont'd.):

COUNTERMEASURES TECHNOLOGY AND PROTOCOLS (593-xx-06):

- Design, development, test of exercise technologies and protocols to prevent or accelerate adaptation to space environment(s).
- Design, development, test of psychological support methods for individuals and groups, e.g. chronobiologic adaptation, private communication.
- Identification, development, test, approval of pharmacologic countermeasures, e.g. radioprotectants, bone deposition, muscle growth agents.

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter: Bruce McKinley, PhD

Date: June 26, 1991

PROPOSED TOPICS/STATE OF THE ART (cont'd.):

ENVIRONMENTAL MONITORING TECHNOLOGY (593-xx-07):

- Identification of technologies to provide environmental monitoring within closed habitats, esp. unknown or unspecified materials.
- Design, development, test of instrumentation, sensor, sampling systems.
- Design, development, test of microscopic imaging system, with capability for teleoperation.

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MEDICAL SUPPORT TECHNOLOGY

..CAL OPERATIONS BRANCH

Presenter:	Date:
Bruce McKinley, PhD	June 26, 1991

BASELINE PROGRAM/MILESTONES:
(Note: Dates indicate completion; technology development should start FY92.)

MEDICAL DIAGNOSTICS, MONITORING TECHNOLOGY (593-xx-01):

Identification of participants	10/93
Redesign of SSF HMF experimental systems, or restart	10/94
Clinical trial: chemistry	6/95
physiologic monitor	6/95
imaging	10/95
Redesign, miniaturize for lunar outpost habitat	10/96
Clinical trials, integration	10/98

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter:	Date:
Bruce McKinley, PhD	June 26, 1991

BASELINE PROGRAM/MILESTONES (cont'd.):

INTEGRATED MEDICAL CARE TECHNOLOGY (593-xx-02):

Design of integrated system	10/94
Biological fluid handling	10/95
Utility specifications; display technology	10/95
Work volume specification	10/96
Inventory, supply logistics	10/96
Treatment protocols	10/98

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

BASELINE PROGRAM/MILESTONES (cont'd.):

TELEMEDICINE TECHNOLOGY AND DEMONSTRATION (593-xx-03):

Identification of technologies, participants	10/93
Specification, set up experimental system	1/94
Guidelines and protocols (selected discipline)	10/95
Guidelines and protocols (selected disciplines)	10/97
Field system design, set up	10/97
Design of lunar outpost system	10/98

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH	
Presenter: Bruce McKinley, PhD	Date: June 26, 1991

BASELINE PROGRAM/MILESTONES (cont'd.):

HEALTH CARE INFORMATICS TECHNOLOGY(593-xx-04):

Concept design	10/94
Integrated informatics system:	
medical care subsystem	10/95
crew member health status subsystem	10/96
environmental health monitoring subsystem	10/97
Biomedical monitor system (medical, health, EVA application):	
experimental system (ECG, VO2, VCO2, MR, O2 sat)	10/95
test and redesign	10/98
Treatment protocols	10/98

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter: Bruce McKinley, PhD

Date: June 26, 1991

BASELINE PROGRAM/MILESTONES (cont'd.):

PHARMACEUTICALS, IV FLUIDS AND ADMINISTRATION (593-xx-05):

Space pharmacopeia	10/94
ID commercial suppliers, participants	10/96
Storage system, shelf life	10/96
Pharmacokinetics, administration technology	10/97
IV fluid production, administration technology	10/97
Blood, blood component replacement	10/97
Nutritional support technology	10/97
Space human use approval	10/98

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter: Bruce McKinley, PhD

Date: June 26, 1991

BASELINE PROGRAM/MILESTONES (cont'd.):

COUNTERMEASURES TECHNOLOGY AND PROTOCOLS (593-xx-06):

Analysis of operational health concerns	10/94
Design of exercise countermeasures for:	
reduced muscle strength, endurance	10/95
decreased aerobic capacity, anaerobic endurance	10/96
Design, test of chronobiologic modes and schedules	10/96
Identification, test of pharmacologic countermeasures	10/97

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter: Bruce McKinley, PhD

Date: June 26, 1991

BASELINE PROGRAM/MILESTONES (cont'd.):

ENVIRONMENTAL MONITORING TECHNOLOGY (593-xx-07):

Preliminary requirements; identification of technologies	10/93
Design of monitoring instrumentation, sensor, sampling systems; design of microscopic imaging system	10/95
Fabrication, test; redesign for lunar habitat	10/98

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MEDICAL SUPPORT TECHNOLOGY

MEDICAL OPERATIONS BRANCH

Presenter: Bruce McKinley, PhD

Date: June 26, 1991

PRELIMINARY FUNDING ESTIMATES:

$M

FY	93	94	95	96	97
Medical diagnostics, monitoring (593-xx-01)	0.6	0.6	0.2	1.0	0.25
Integrated medical care (593-xx-02)	0.1	0.3	0.4	0.6	0.75
Telemedicine (593-xx-03)	0.1	0.2	0.25	0.5	0.75
Health care informatics (593-xx-04)	0.1	0.35	0.65	0.7	0.8
Pharm, IV fluids, admin (593-xx-05)	0.23	0.55	1.0	1.15	1.8
Countermeasures (593-xx-06)	0.15	0.25	0.3	0.6	0.9
Environmental monitoring (593-xx-07)	0.1	0.25	0.3	0.45	0.75
Total	**1.38**	**2.50**	**3.10**	**5.00**	**6.00**

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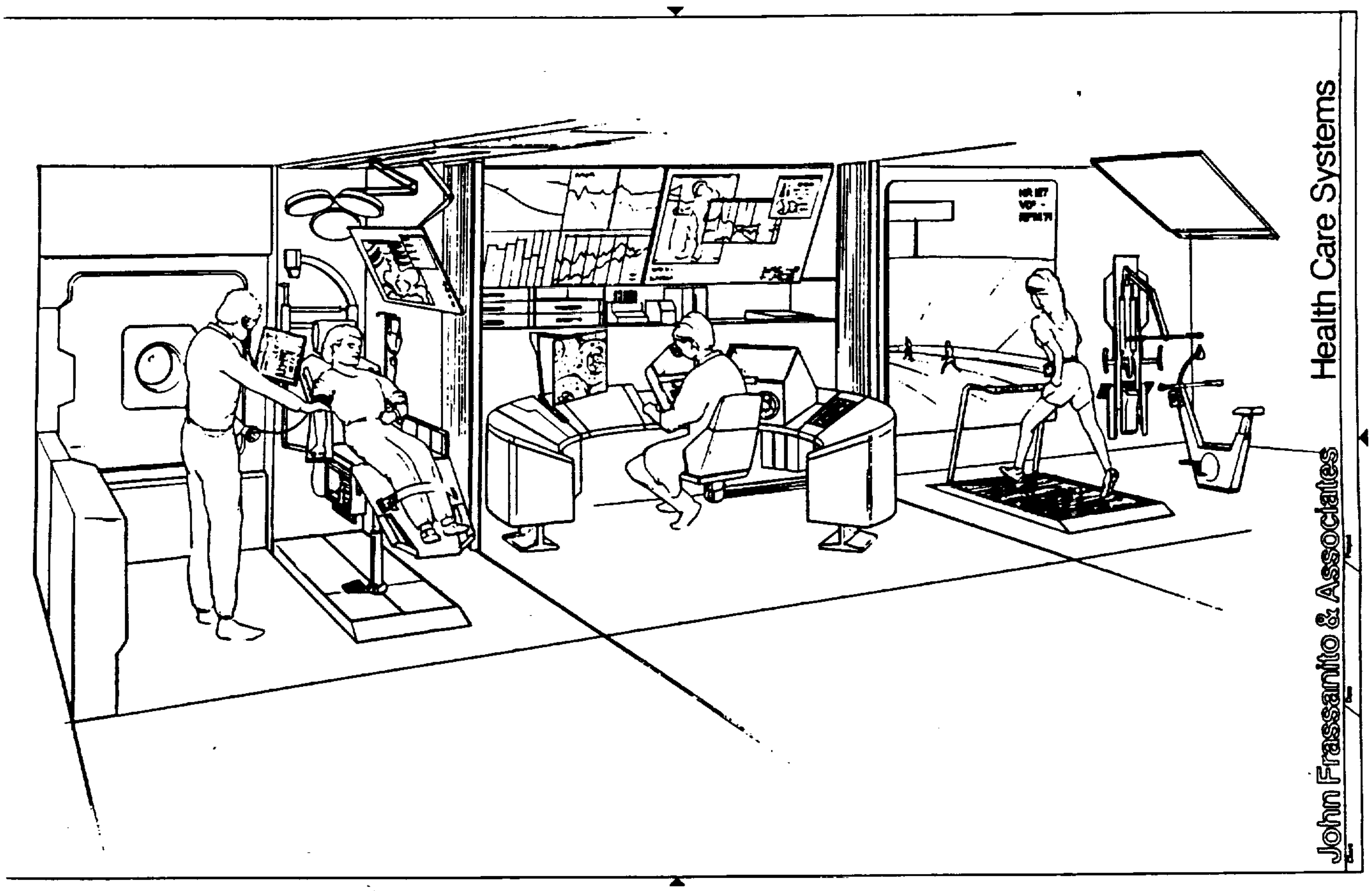
John Frassanito & Associates
Health Care Systems

Johnson Space Center, Houston, Texas

ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION

Presenter: W. HANBY

Date: 26 JUNE 91

OBJECTIVES

- **PROGRAMMATIC**

IMPROVEMENTS ARE NEEDED IN REFRIGERATION TECHNOLOGY IN THE AREAS OF RELIABILITY, SAFETY, ENERGY EFFFICIENCY, WEIGHT, AND ACOUSTIC NOISE EMISSION.

- **TECHNICAL**

PROBLEMS ENCOUNTERED DURING THE DEVELOPMENT OF REFRIGERATION EQUIPMENT FOR THE SHUTTLE AND SPACELAB HIGHLIGHT A NEED FOR IMPROVEMENTS IN REFRIGERATION TECHNOLOGY FOR SPACE PLATFORMS.

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ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION

Presenter: W. HANBY

Date: 26 JUNE 91

BENEFITS TO SPACE TECHNOLOGY

- **SPACE PLATFORMS**

HUMAN SYSTEMS SUPPORT WILL BE PROVIDED IN THE AREA OF HEALTH MAINTENANCE FACILITIES FOR COOLING /FREEZING BIOLOGICAL SAMPLES. THE SAME TECHNOLOGY CAN BE USED FOR REFRIGERATION OF PREPARED FOOD AND BEVERAGES IN THE FOOD PREPARATION AREAS.

- **SPACE SCIENCE**

THE REFRIGERATION TECHNOLOGY DEVELPED MIGHT ALSO MEET THE NEEDS OF OBSERVATORY SYSTEMS FOR DETECTOR OR OPTICAL SYSTEM COOLING.

- **EXPLORATION**

HUMAN SUPPORT AND SURFACE OPERATIONS ARE GOING TO REQUIRE SIMILAR SUPPORT FOR REFRIGERATION OF FOOD AND HEALTH MAINTENANCE.

ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION

Presenter: W. HANBY | Date: 26 JUNE 91

PROGRAM ORGANIZATION

RS/ SPACE TECHNOLOGY
(ADMINISTRATIVE DIRECTION AND FUNDING)

↓

SPACE PLATFORMS THRUST GROUP
(TECHNICAL DIRECTION)

↓

IC/ TECHNOLOGY AND COMMERCIAL PROJECTS OFFICE
(JSC OAET RTOP COORDINATION)

↓

SE/ LIFE SCIENCES PROJECT DIVISION
(SELECT TECHNOLOGY, MONITOR PROTOTYPE ASSEMBLY, TEST PROTOTYPE, COORDINATE DSO PROJECT)

↓

CONTRACTOR/UNIVERSITY/ INDUSTRY
(DESIGN AND FABRICATION)

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ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION

Presenter: W. HANBY | Date: 26 JUNE 91

STATE OF THE ART

- THE STATE OF THE ART IN REFRIGERATION IS CURRENTLY DEVELOPING IN SEVERAL DIFFERENT DIRECTIONS. LSPD WILL PERFORM A SIX MONTH SURVEY OF THOSE DISCIPLINES AND DEVELOP A NEW REFRIGERATOR/ FREEZER TO FLY ON THE SHUTTLE AS A DSO. THE TECHNOLOGIES WE PLAN TO EVALUATE ARE AS FOLLOWS:

  THERMOACOUSTIC REFRIGERATOR
  SCROLL COMPRESSOR
  GIFFORD MCMAHON REFRIGERATOR
  RESONANT ACOUSTIC REFRIGERATOR
  ROTARTY RECIPROCATING REFRIGERATOR
  STIRLING COMPRESSOR
  THERMOELECTRIC COOLERS
  NON-TOXIC REFRIGERANTS

ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION	
Presenter: W. HANBY	Date: 26 JUNE 91

RELATIONSHIP AMONG ELEMENTS

- **RS/ SPACE TECHNOLOGY**
  ADMINISTRATIVE DIRECTION AND FUNDING OF THE DEVELOPMENT PROGRAM
- **SPACE PLATFORMS THRUST GROUP**
  TECHNICAL DIRECTION AND PROGRAM COORDINATION BETWEEN RS AND JSC
- **IC/ TECHNOLOGY AND COMMERCIAL PROJECTS OFFICE**
  PROGRAM MONITOR AND RTOP COORDINATION BETWEEN RS AND SE
- **SE/ LIFE SCIENCES PROJECT DIVISION**
  EVALUATE TECHNOLOGIES, DEVELOP AND TEST PROTOTYPE, MONITOR FABRICATION OF DSO REFRIGERATOR/ FREEZER, COORDINATE SHUTTLE FLIGHT OF DSO
- **CONTRACTOR/ UNIVERSITY/ INDUSTRY**
  DESIGN AND FABRICATE PROTOTYPE AND DSO.

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ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION	
Presenter: W. HANBY	Date: 26 JUNE 91

BASELINE PROGRAM

- THIS PROGRAM IS A NEW START

AUGMENTED PROGRAM MILESTONES/PRODUCTS

- REFRIGERATION TECHNOLOGY SURVEY REPORT
- DEVELOP PROTOTYPE REFRIGERATOR/ FREEZER
- FABRICATE DSO REFRIGERATOR/ FREEZER
- COORDINATE DSO FLIGHT
- ANALYZE AND REPORT THE RESULTS OF THE DSO FLIGHT

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ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION

Presenter: W. HANBY | Date: 26 JUNE 91

PRIOROITIES

- HIGHEST TO LOWEST
  - SURVEY STATE OF THE ART IN REFRIGERATION TECHNOLOGY
  - SELECT THE OPTIMUM TECHNOLOGY TO MEET THE FORECAST REFRIGERATION REQUIREMENTS
  - PROTOTYPE A REFRIGERATOR/ FREEZER USING THE TARGET TECHNOLOGY
  - BUILD OR CONVERT THE PROTOTYPE TO A DSO REFRIGERATOR/ FREEZER
  - COORDINATE A FLIGHT EVALUATION OF THE DSO
  - EVALUATE THE PERFORMANCE OF THE DSO FOR USE OF THE TECHNOLOGY IN FUTURE APPLICAITIONS

Johnson Space Center, Houston, Texas

ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION

Presenter: W. HANBY | Date: 26 JUNE 91

RESOURCES($M)

TASKS	1992	1993	1994
SURVEY	.3		
ANALYSIS & REPORT	.3		
PROTOTYPE DEVELOPMENT		0.3	
PROTOTYPE TESTING		0.2	
DSO DEVELOPMENT		1.5	.1
DSO TESTING		0.1	.3
DSO FLIGHT			.2
DSO ANALYSIS			.1
DSO REPORT			.1
TOTALS	.6	2.1	.8

Johnson Space Center, Houston, Texas

ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION

Presenter: W. HANBY

Date: 26 JUNE 91

ISSUES

- **PROGRAMMATIC**

  COST VS. RELIABILITY (REDUNDANCY & PROVEN TECHNOLOGY)
  TIME VS. SCOPE OF INVESTIGATION
  SAFETY (REFRIGERANT TOXICITY)
  RELIABILITY PROBLEMS WITH EXISTING REFRIGERATOR/ FREEZERS
  ACOUSTIC NOISE VS. WAIVERS

- **TECHNICAL**

  CURRENT REFRIGERANT TOXICITY
  CURRENT REFRIGERATOR NOISE PROBLEMS
  ZERO G PERFORMANCE
  COMPRESSOR VS. THERMOELECTRIC VS. ACOUSTIC VS. SPACE RADIATORS
  ROTARY COMPRESSOR VS. RECIPROCATING COMPRESSOR
  BI-PHASE REFRIGERANT VS. GAS EXPANSION

Johnson Space Center, Houston, Texas

ADVANCED REFRIGERATION TECHNOLOGY

LIFE SCIENCES PROJECT DIVISION

Presenter: W. HANBY

Date: 26 JUNE 91

SUMMARY

- **TECHNICAL ISSUES**

  SIMPLICITY VS. EFFICIENCY
  PROVEN TECHNOLOGY VS. STATE OF THE ART TECHNOLOGY
  WEIGHT AND VOLUME VS. RELIABILITY,ACOUSTIC NOISE, EFFICIENCY
  REFRIGERANT TOXICITY
  ZERO G PERFORMANCE

- **BENEFITS OF THE TECHNOLOGY**

  PROBLEMS ENCOUNTERED DURING THE DEVELOPMENT OF REFRIGERATION EQUIPMENT FOR THE SHUTTLE AND SPACELAB HIGHLIGHT A NEED FOR IMPROVEMENTS IN REFRIGERATION TECHNOLOGY FOR FUTURE NASA PROGRAMS IN ZERO OR PARTIAL GRAVITY ENVIRONMENTS. THIS PROGRAM SHOULD IDENTIFY AND DEVELOP SOLUTIONS TO THOSE PROBLEMS.

OFFICE OF AERONAUTICS, EXPLORATION AND TECHNOLOGY (OAET)
INTEGRATED TECHNOLOGY PLAN FOR CIVIL SPACE PROGRAM

EXTRAVEHICULAR ACTIVITY (EVA) SUIT SYSTEM

HQ SPONSOR: DR. JAMES P. JENKINS / CODE RC
NASA-JSC SUPPORT ACTIVITIES
SSTAC MEETING
JUNE 24-28, 1991

ALBERT F. BEHREND, JR.
NASA JOHNSON SPACE CENTER
CREW AND THERMAL SYSTEMS DIVISION

SPACE EXPLORATION

SPACE EXPLORATION TECHNOLOGY: HUMANS IN SPACE
EXTRAVEHICULAR ACTIVITY SYSTEMS

TECHNOLOGY NEEDS/CHALLENGES

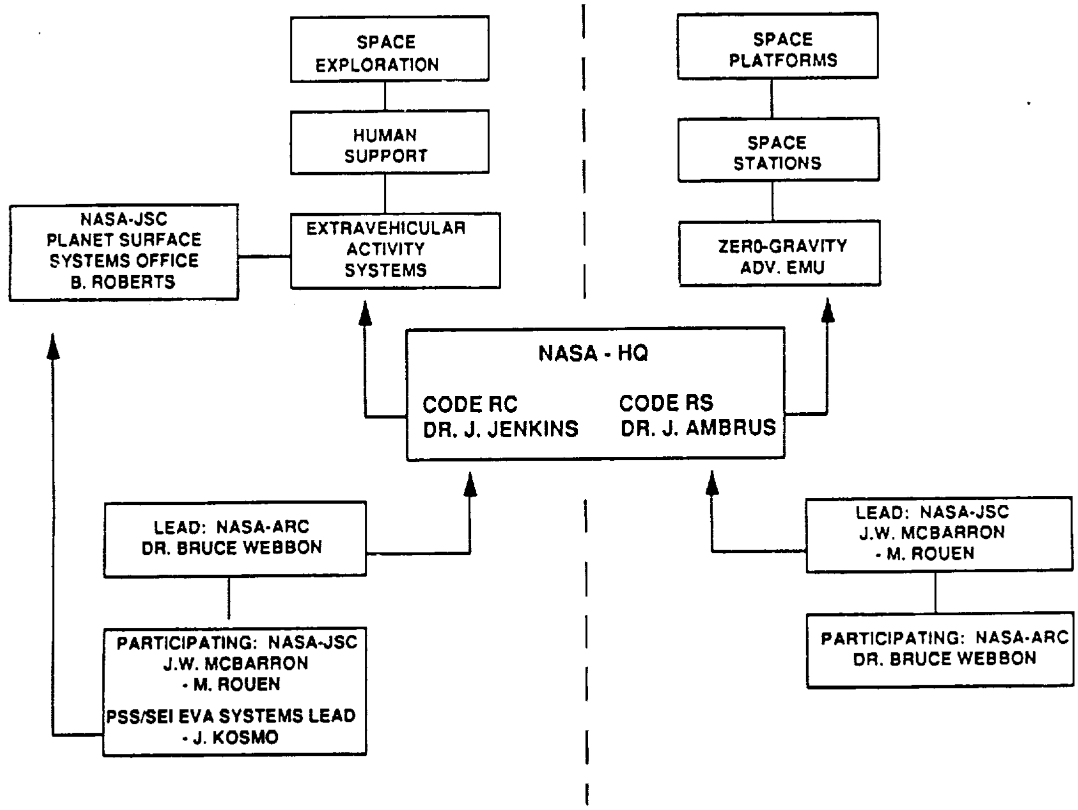
- DEVELOP AND VALIDATE TECHNOLOGIES FOR MOBILE, LIGHTWEIGHT, MULTI-USE EVA SUITS AND PLSS FOR PLANETARY SURFACE USE.
- CONTINUE DEVELOPMENT OF ANALYTICAL AND HARDWARE TECHNOLOGIES NECESSARY TO ENABLE HUMANS TO PERFORM EVA PRODUCTIVELY AND EFFICIENTLY IN THE HOSTILE ENVIRONMENTS OF THE MOON AND MARS.
- CONCENTRATE EFFORT IN FOUR TECHNOLOGY AREAS:
  - HUMAN REQUIREMENTS DEFINITION, EMPHASIZING HUMAN FACTORS.
  - EVA SYSTEMS INTEGRATION, MODELING AND TRADE STUDIES.
  - PORTABLE LIFE SUPPORT SUBSYSTEMS TECHNOLOGY: THERMAL CONTROL EMPHASIZING HEAT REJECTION; ATMOSPHERE CONTROL SUBSYSTEMS.
  - SPACE SUIT TECHNOLOGY: EMPHASIZING LIGHTWEIGHT STRUCTURAL MATERIALS, DUST PROTECTION TECHNIQUES, AND GLOVE TACTILITY AND DEXTERITY.

SPACE EXPLORATION TECHNOLOGY: HUMANS IN SPACE
EXTRAVEHICULAR ACTIVITY SYSTEMS

TECHNOLOGY BENEFITS

- LIGHTWEIGHT EMU STRUCTURAL MATERIALS
- ENHANCED SPACE SUIT/GLOVE MOBILITY FEATURES
- LONG-LIFE, DUST CONTAMINATION INSENSITIVE MATERIALS AND COMPONENTS
- LOW WEIGHT/VOLUME PORTABLE LIFE SUPPORT SUB-SYSTEMS
- REGENERABLE PORTABLE LIFE SUPPORT SYSTEM COMPONENTS
- INCREASED HUMAN PRODUCTIVITY USING ELECTRONIC DATA DISPLAYS
- HIGH FIDELITY ANALYTICAL MODELS CAPABLE OF ADDRESSING ISSUES SUCH AS RELIABILITY, MAINTAINABILITY, MANUFACTURABILITY AND LIFE CYCLE COSTS OF VARIOUS ADVANCED EMU CONCEPTS.

FOCUSED TECHNOLOGY PROGRAMS



SPACE EXPLORATION TECHNOLOGY: HUMANS IN SPACE
EXTRAVEHICULAR ACTIVITY SYSTEMS

STATE-OF-THE-ART ASSESSMENT

- EVA TECHNOLOGY DEVELOPED TO DATE HAS BEEN FOCUSED TO SUPPORT ZERO-G BASED PROGRAMS: (SHUTTLE / SPACE STATION)
- CURRENT EVA SYSTEMS ARE NOT SUPPORTIVE OF EXTENDED OPERATIONS ON THE SURFACE OF THE MOON OR MARS
  - SYSTEMS TOO HEAVY
  - DUST CONTAMINATION PROBLEMS
  - SYSTEMS NOT DESIGNED FOR PLANETARY SURFACE MOBILITY FUNCTIONS
  - CURRENT EVA SYSTEMS OPERATIONAL PENALTIES ARE NOT ACCEPTABLE FOR USE ON PLANETARY SURFACE
  - LIFE SUPPORT SYSTEM EXPENDABLES RESUPPLY LOGISTICS PROBLEM FOR LONG-TERM OPERATIONS
  - SYSTEMS NOT DESIGNED FOR MAINTAINABILITY AT MISSION USE LOCATION
- APOLLO - ERA EVA TECHNOLOGY NOT SUITABLE TO SUPPORT REQUIREMENTS:
  - POINT DESIGN ORIENTED (SHORT MISSION USE LIFE)
  - TECHNOLOGY OBSOLETE AND NOT EASILY REPRODUCIBLE TODAY (ELECTRONICS, SUIT JOINT MATERIALS)
  - SUIT HAD LIMITED MOBILITY CAPABILITY

SPACE EXPLORATION TECHNOLOGY: HUMANS IN SPACE
EXTRAVEHICULAR ACTIVITY SYSTEMS

ACCOMPLISHMENTS (FY90-91) CONTRIBUTING TO SOA

- INITIATED PRELIMINARY INVESTIGATIONS TO STUDY DUST PROTECTION DESIGN CONCEPTS
- CONDUCTED PRELIMINARY SCREENING OF CANDIDATE ABRASION RESISTANT SUIT MATERIALS
- INITIATED DEVELOPMENT OF LIGHTWEIGHT SUIT COMPONENT ELEMENTS
- CONTINUED DEVELOPMENT OF IMPROVED PROCEDURAL AIDS TO INCREASE EVA PRODUCTIVITY.
  - PROTOTYPE HELMET-MOUNTED DISPLAY SYSTEMS (SBIR EFFORTS)
  - PROTOTYE ELECTRONIC CUFF CHECKLIST (ECC) TO REPLACE CURRENT "CARDBOARD" CHECKLIST (UPN 506-71 HUMAN SUPPORT EFFORT):
    - BETTER VISIBILITY
    - MORE MEMORY
    - NO "FLIPPING" OF PAGES
    - HUMAN-FACTORED DISPLAY FORMAT

SPACE EXPLORATION TECHNOLOGY: HUMANS IN SPACE
EXTRAVEHICULAR ACTIVITY SYSTEMS

OTHER DEVELOPMENT EFFORTS

U.S. GOVERNMENT

NO OTHER DEVELOPMENT EFFORTS BEING CONDUCTED OUTSIDE OF NASA SPONSORSHIP.

U.S. INDUSTRY

LIMITED IR&D EFFORTS BEING PURSUED BY AEROSPACE COMPANIES ON PLANETARY SURFACE EVA TECHNOLOGY.

MAJORITY OF IR&D EFFORTS DIRECTED TO ORBITAL ZERO-G SHUTTLE / STATION APPLICATION.

EUROPEAN AGENCIES

CONCENTRATING EVA SYSTEMS TECHNOLOGY DEVELOPMENT EFFORTS TOWARD NEAR-EARTH ORBITAL APPLICATIONS.

SOVIETS

NO INDICATIONS OF ANY TECHNOLOGY DEVELOPMENT EFFORTS BEING EXPENDED TOWARD PLANETARY SURFACE EVA OPERATIONS.

SPACE EXPLORATION TECHNOLOGY: HUMANS IN SPACE
EXTRAVEHICULAR ACTIVITY SYSTEMS

BASELINE PROGRAM

MAJOR MILESTONES: (GOALS)

- 1992 ----- COMPLETE IDENTIFICATION OF LUNAR SURFACE OPS. REQUIREMENTS (DUST EFFECTS, THERMAL RANGES, MOBILITY, ETC.)
- 1993 ----- COMPLETE CONCEPTS FOR LUNAR THERMAL MGT.
- 1994 ----- CONDUCT LAB. DEMONSTRATION OF LUNAR PLSS THERMAL CONTROL
- 1995 ----- CONDUCT LAB. TESTS OF LUNAR EVA SUIT MOBILITY ELEMENTS
- 1996 ----- COMPLETE DEVELOPMENT OF LUNAR SUIT / GLOVES / ELECTRONIC DISPLAY METHODS
- 1997 ----- COMPLETE TECHNOLOGY FOR EARLY LUNAR EVA OPTION
- 1998 ----- DEMONSTRATE BREADBOARD LUNAR SUIT / PLSS IN SIMULATED ENVIRONMENT
- 1999 ----- COMPLETE LUNAR SURFACE EVA SUIT SYSTEMS R&T

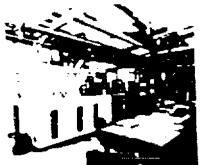
SPACE EXPLORATION TECHNOLOGY: HUMANS IN SPACE
EXTRAVEHICULAR ACTIVITY SYSTEMS

TECHNOLOGY PRIORITIES

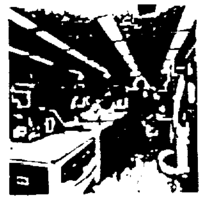
SYSTEMS STUDIES: CONDUCT SYSTEM LEVEL STUDIES TO DETERMINE:
- MISSION / ENVIRONMENT REQUIREMENT DRIVERS
- HUMAN PERFORMANCE REQUIREMENTS AND CAPABILITIES
- WORK SYSTEM INTEGRATION TASKS AND ANCILLARY EQUIPMENT

PORTABLE LIFE SUPPORT SYSTEMS: PERFORM ADVANCED TECHNOLOGY DEVELOPMENT TO DEMONSTRATE:
- LOW WEIGHT / VOLUME REGENERABLE SYSTEM COMPONENTS
- SIMPLE AND RELIABLE DESIGNS
- MINIMIZED SYSTEM WEIGHT / VOLUME EFFICIENT PACKAGING CONCEPTS
- EASE OF MAINTENANCE AND REPAIR DURING THE MISSION

EVA SUIT / GLOVES: CONTINUED FOCUSED TECHNOLOGY DEVELOPMENTS TO DEMONSTRATE:
- LIGHTWEIGHT SUIT COMPONENT ELEMENTS
- DUST PROTECTION DESIGNS AND REMOVAL TECHNIQUES
- LONG-TERM DURABILITY AND INCREASED RELIABILITY
- OPTIMUM MOBILITY WITH MINIMAL CREWMAN FATIGUE



- Advanced Life Support
  - Thermal heat rejection
  - CO_2 removal
  - H_2O removal
  - CO_2 sensor
  - Fuel cells
  - 2 Canned man test capability
  - Complete data acquisition



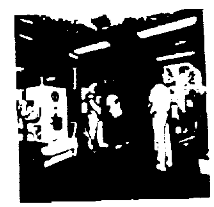
- WETF Suit Prep Lab
  - Class III Suit Assembly/Checkout
  - Repair/Maintenance Activities
  - Suit/Glove Component Test

- Displays & Controls Labs
  - Ada software development
  - Automatic cooling control
  - Helmet mounted display
  - Voice recognition

NASA-JSC Crew & Thermal Systems Division EVA Technology Development Support Laboratories

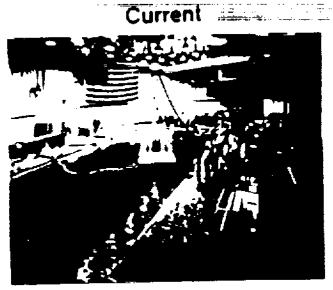
- Performance Test Lab
  - Unmanned Mobility/Torque Range Tests
  - Bench Cycle Life Component Tests

- Advanced EMU Lab
  - Mobility evaluation
  - Subject fit-checks
  - Prototype fabrication
  - Pressure/leakage tests
  - Glove evaluation



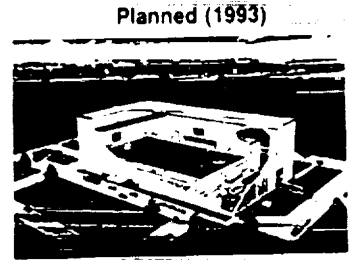
- Fit-Check Evaluation Room
  - Astronaut/Subject EMU Fit-Checks
  - Glove Box Evaluations
  - Man-Loads Testing

Current



- Weightless Environment Training Facility (WETF)
  - Depth : 25 ft. (7.6m)
  - Length: 78 ft. (24 m)
  - Width : 33 ft. (9.8 m)

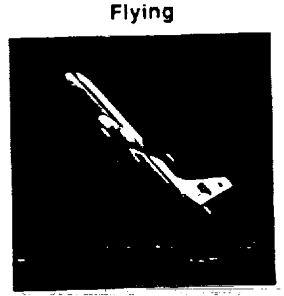
Planned (1993)



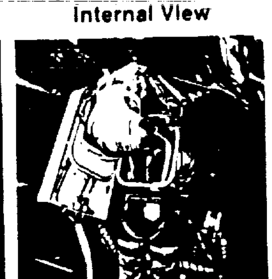
- Neutral Buoyancy Laboratory (NBL)
  - Depth : 60 ft. (18.3 m)
  - Length: 235 ft. (71.6 m)
  - Width : 135 ft. (41.1 m)

NASA - JSC Reduced Gravity Test Facilities

Flying



Internal View



- KC-135 Aircraft

G-Levels:	Durations:
0 ± 0.02g	25 sec.
1/6-g (Lunar)	30 sec.
1/3-g (Mars)	40 sec.
-0.1g	15 sec.
Hyper-G(1.8g)	3 min.

- 2nd KC-135 planned (FY 92)

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ISSUES

- CRITICAL DESIGN ISSUES FACING FUTURE PLANETARY SURFACE EXPLORATION MANDATES IMMEDIATE EMPHASIS IN THE DEVELOPMENT OF EVA TECHNOLOGY:
  - DESIRED LEVEL OF TECHNOLOGY READINESS WILL NOT BE FULLY ACHIEVED BY NEED DATE

SPACE PLATFORMS

SPACE PLATFORMS: SPACE STATIONS

ZERO-GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

TECHNOLOGY NEEDS / CHALLENGES

- DEVELOP ADVANCED ROBUST EMU CAPABLE OF HIGH USE RATES FOR SPACE STATION FREEDOM OPERATIONAL SUPPORT AND CAPABLE OF PLANNED EVOLUTION TO SUPPORT TRANS-LUNAR AND TRANS-MARS MISSIONS
- IMPLEMENT APPLICABLE TECHNOLOGIES FROM SUIT DEVELOPMENT ACTIVITIES (MK. III / AX-5) AND REGENERABLE PLSS DEVELOPMENT ACTIVITIES FOR ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)
  - ELIMINATE PREBREATHE TO REDUCE OPERATIONAL OVERHEAD
  - ADVANCE GLOVE TECHNOLOGY TO LOWER MANUFACTURING COST WITHOUT AFFECTING DEXTERITY
  - DEVELOP LIFE SUPPORT TECHNOLOGIES THAT PROVIDE HIGH RELIABILITY, LOW LIFE CYCLE COST AND ON-ORBIT MAINTAINABILITY
  - DEVELOP PACKAGING TECHNOLOGIES THAT ALLOW ON-ORBIT MAINTAINABILITY WITH MINIMUM CREW TIME AND LOGISTICS PENALTIES.

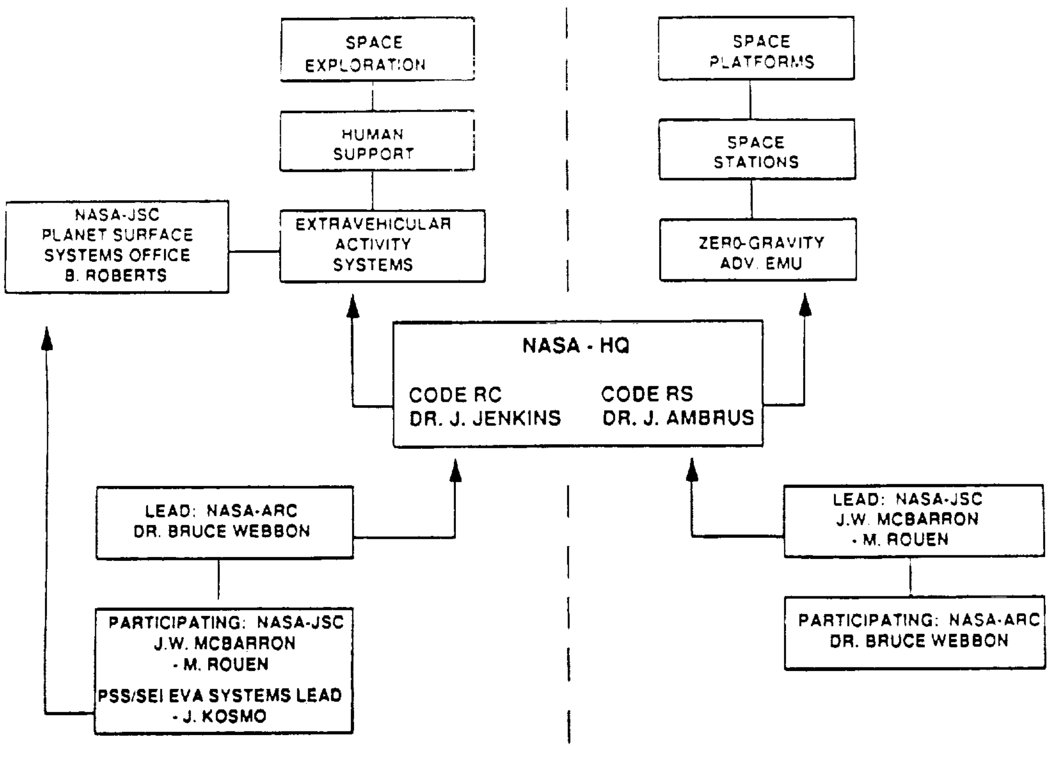
SPACE PLATFORMS: SPACE STATIONS

ZERO-GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

TECHNOLOGY BENEFITS

- HYBRID SPACE SUIT INCORPORATING "LESSONS LEARNED" FROM JOINT JSC / ARC SUIT DEVELOPMENT TEST PROGRAM (MK III / AX-5 SUITS)
- ELIMINATION OF PREBREATHE TO REDUCE EVA OPERATIONAL OVERHEAD
- ADVANCED GLOVE TECHNOLOGY INCLUDING REDUCED MANUFACTURING COST
- PLSS TECHNOLOGIES THAT PROVIDE HIGH RELIABILITY, LOW LIFE CYCLE COST AND ON-ORBIT MAINTAINABILITY
- ADVANCED ELECTRONIC DISPLAY OF MISSION / TASK INFORMATION TO THE EVA CREWPERSON
- AUTOMATED SYSTEMS DESIGN APPROACH FOR EMU CHECKOUT AND SERVICING

FOCUSED TECHNOLOGY PROGRAMS



SPACE PLATFORMS: SPACE STATIONS
ZERO - GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

STATE-OF-THE-ART ASSESSMENT

SHUTTLE EMU OPERATES AT 4.3 PSIA:

- REQUIRES EVA PREBREATHE OF 100% O2 FOR 4 HOURS OR;
- DEPRESS CABIN TO 10.2 PSIA FOR 24 HOURS WITH 40 MINUT EVA
- OPERATION "R" FACTOR = 1.65 (HIGH BENDS RISK)

SHUTTLE EMU CURRENTLY CERTIFIED FOR 3 EVA'S PER FLIGHT

- TWO PLANNED EVA'S; ONE CONTINGENCY EVA
- DELTA CERTIFICATION IN PROCESS FOR 25 EVAS FOR SSF USE

SHUTTLE EMU REQUIRES MANUAL SERVICING AND EXPENDABLES RECHARGE AFTER EACH EVA

- ADDS TO HIGH LIFE CYCLE COST DUE TO LOGISTICS REQUIREMENTS

SHUTTLE EMU SUIT CURRENTLY HAS LIMITED RESIZING CAPABILITY ON-ORBIT

- ARM AND LEG LENGTH RESIZING CAPABILITY BEING DEVELOPED FOR SSF USE

SHUTTLE EMU HAS HIGH LIFE CYCLE COST DUE TO LOGISTICS REQUIREMENTS

SPACE PLATFORMS: SPACE STATIONS

ZERO -GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

ACCOMPLISHMENTS (FY90-91) CONTRIBUTING TO SOA

- COMPLETED TESTING AND EVALUATION OF HIGHER OPERATING PRESSURE (8.3 PSI) TECHNOLOGY DEMONSTRATOR MODEL SPACE SUITS (MK III / AX-5)
- SUCCESSFULLY DEMONSTRATED AND IDENTIFIED KEY MOBILITY AND DESIGN FEATURES FOR FUTURE ORBITAL SPACE SUIT APPLICATION.

SPACE PLATFORMS: SPACE STATIONS

ZERO-GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

OTHER DEVELOPMENT EFFORTS

U.S. GOVERNMENT

NO OTHER DEVELOPMENT EFFORTS BEING CONDUCTED OUTSIDE OF NASA SPONSORSHIP.

U.S. INDUSTRY

LIMITED / FOCUSED IR&D EFFORTS BEING PURSUED BY AEROSPACE COMPANIES TO IMPROVE SPECIFIC EVA SYSTEM ELEMENTS AND COMPONENTS.

EUROPEAN SPACE AGENCY

- CONTINUE JOINT (MULTI-COUNTRY) DEVELOPMENT EFFORTS FOR HERMES EVA SUIT AND EVA GLOVES.
- OBJECTIVE TO ESTABLISH OWN EVA INFRA-STRUCTURE.
- CLOSELY FOLLOWING MK III 8.3 PSI SUIT TECHNOLOGY SOME FEATURES OF WHICH REFLECTED IN PROTOTYPE DESIGN APPROACHES.
- DEVELOPING CLOSE TIES TO SOVIET EVA PROGRAM PERSONNEL WHICH ARE ATTEMPTING TO SELL SOVIET EVA SYSTEM EQUIPMENT FOR HERMES APPLICATION.

SPACE PLATFORMS: SPACE STATIONS

ZERO-GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

OTHER DEVELOPMENT EFFORTS

(CONTINUED)

SOVIETS

- RECENTLY DEMONSTRATED IMPROVED, SECOND GENERATION OF PREVIOUSLY FLOWN SALUT/MIR EMU DURING IN-FLIGHT EVALUATION OF MANNED MANEUVERING UNIT.
- SOVIETS HAVE SHOWN HIGH INTEREST IN RECENTLY COMPLETED MK.III AND AX-5 COMPARATIVE TEST PROGRAM AND HAVE REQUESTED TEST RESULTS.
- SOVIETS HAVE REVEALED LITTLE OF THEIR ADVANCED TECHNOLOGY PROGRAM.

JAPANESE:

- EXPRESSED INTEREST TO LEASE/PROCURE SHUTTLE EMU SUITS FOR USE IN JAPANESE WATER IMMERSION TEST FACILITY THEY MAY PLAN TO BUILD AND OPERATE IN THE NEAR FUTURE.
- DEVELOPMENT OF JAPANESE EVA PROGRAM MANAGEMENT INFRA-STRUCTURE TO SUPPORT THEIR MANNED SPACEFLIGHT PROGRAM IS EXPECTED

SPACE PLATFORMS: SPACE STATIONS

ZERO-GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

AUGMENTED PROGRAM

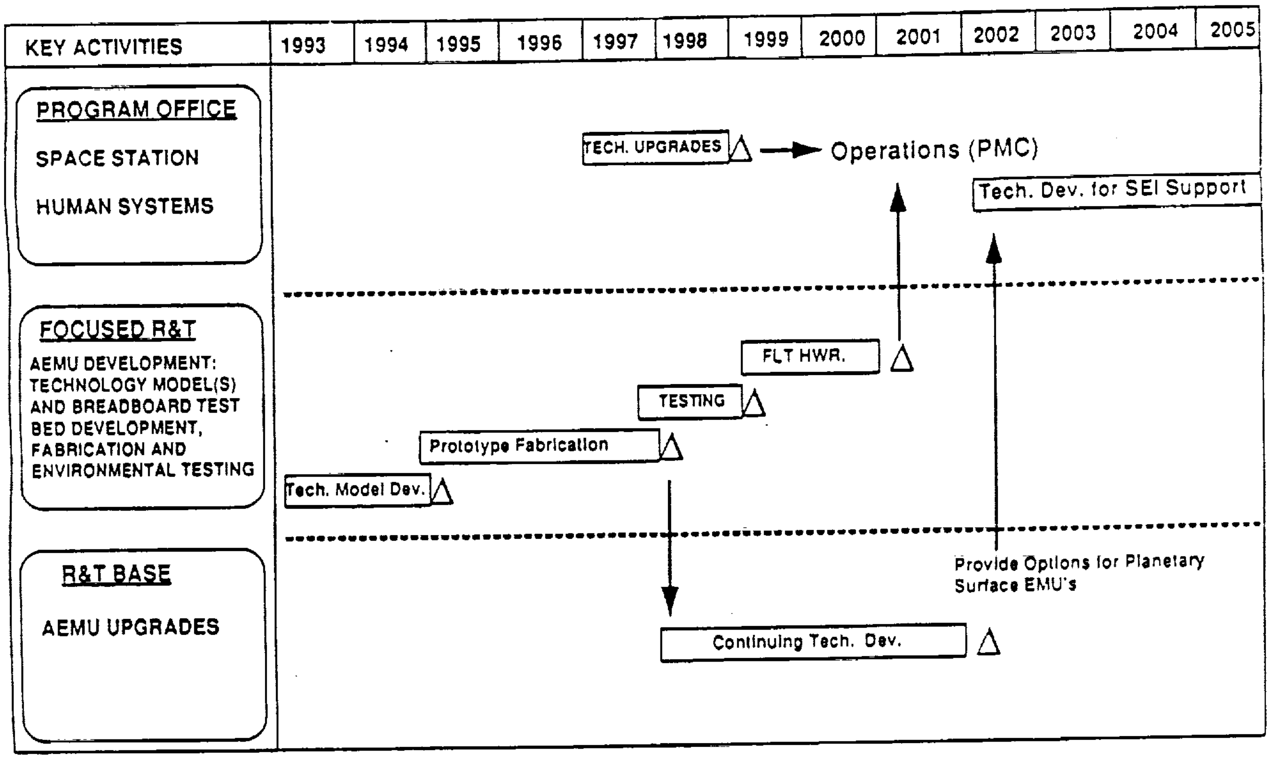
- AEMU PROGRAM IS NOT FUNDED WITHIN THE CURRENTLY STRUCTURED BASELINE PROGRAM WORK PLAN; TO BE FUNDED WITHIN AUGMENTED WORK PLAN

MAJOR MILESTONE: (GOALS)

- 1993 - AEMU TECHNOLOGY BASELINE IDENTIFIED (PDR)
- 1994 - AEMU DETAIL DESIGN COMPLETE (CDR)
- 1995 - MANUF. DRAWINGS/DETAIL SPECS. REVIEW
- 1997 - AEMU PROTOTYPE FABRICATION COMPLETE
- 1999 - AEMU ENVIRONMENTAL TESTING COMPLETE

ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

AEMU TECHNOLOGY ROADMAP/SCHEDULE



SPACE PLATFORMS: SPACE STATIONS

ZERO-GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

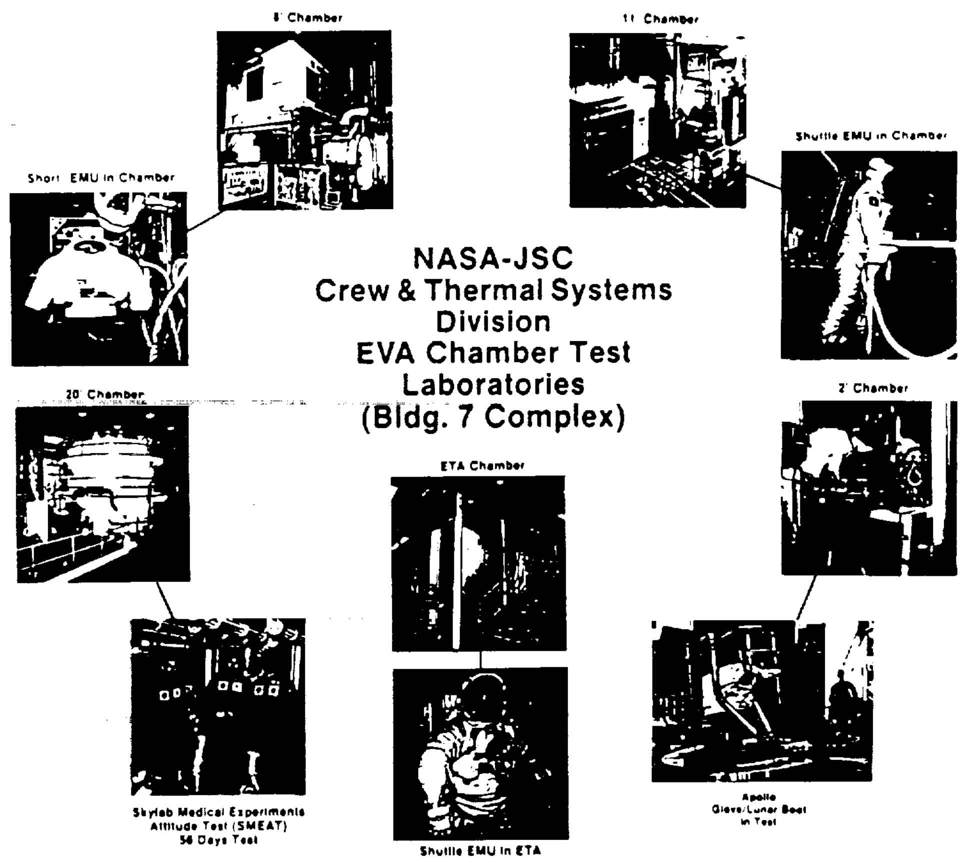
TECHNOLOGY PRIORITIES

- DEVELOP ADVANCED, ROBUST EMU CAPABLE OF THE HIGH USE RATES NEEDED FOR ROUTINE, ORBITAL EVA OPERATIONS:
  - SPACE STATION FREEDOM OPERATIONAL SUPPORT
  - SUPPORT OF TRANS-LUNAR AND TRANS-MARS MISSIONS
- ORBITAL AEMU PROGRAM IS COMPLEMENTARY TO LUNAR/MARS PLANETARY EXTRAVEHICULAR ACTIVITY SYSTEM PROGRAM.
- COMMON TECHNOLOGIES WILL BE COORDINATED AND INTEGRATED THROUGH JOINT JSC AND ARC PARTICIPATION
- UNIQUE TECHNOLOGIES WILL BE DEVELOPED IN ACCORDANCE WITH INDIVIDUAL PROJECT PLANS.

SPACE PLATFORMS: SPACE STATION
ZERO-GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

FY93 FISCAL AND SUPPORT RESOURCES
(XXX-XX) ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

- NO RTOP / W.B.S. AT THIS TIME; PLANNED FOR FY93



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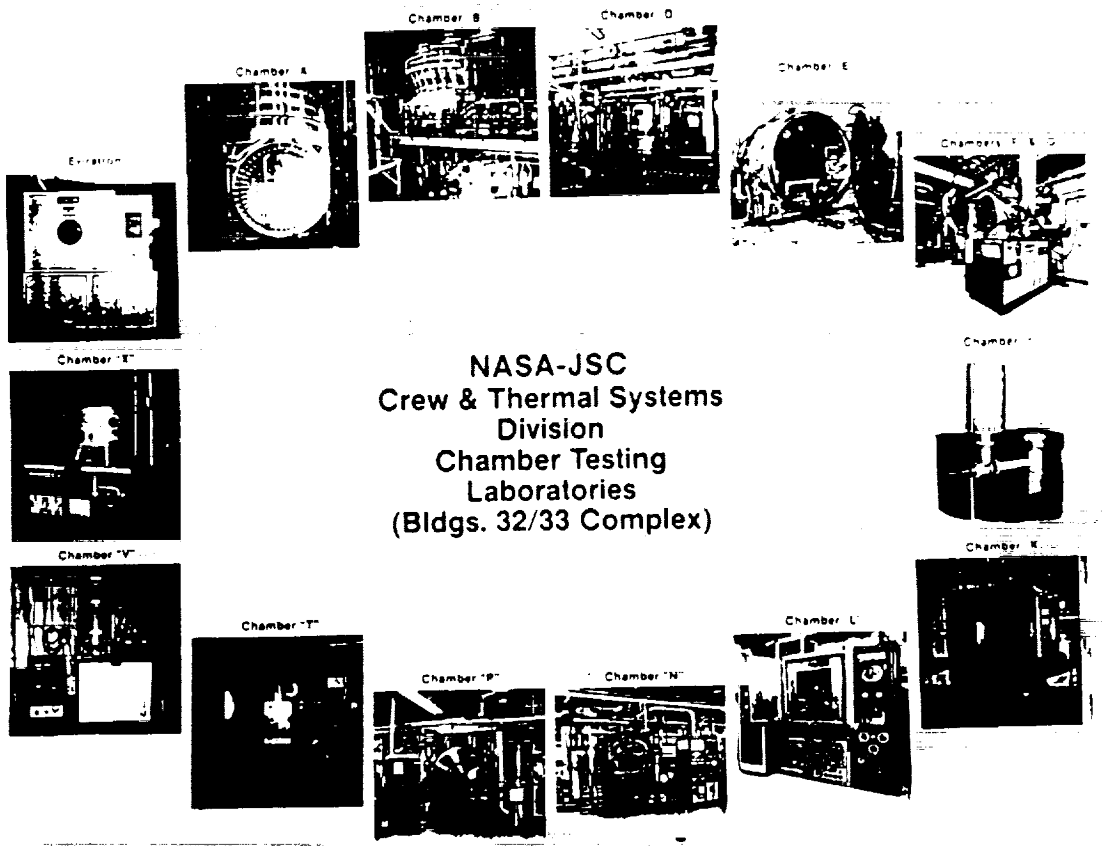


SPACE PLATFORMS: SPACE STATIONS
ZERO-GRAVITY ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

ISSUES

- DEVELOPMENT OF AEMU CONTINGENT UPON APPROVAL OF FY93 BUDGET AND CONTINUATION OF THE SPACE STATION PROGRAM

Office of Aeronautics, Exploration and Technology (OAET)
Integrated Technology Plan for Civil Space Program

ADVANCED PLSS TECHNOLOGY

HQ Sponsor: Dr. James P. Jenkins/Code RC

NASA-JSC Supporting Activities

SSTAC Meeting

June 24-28, 1991

ALBERT F. BEHREND, JR.
NASA JOHNSON SPACE CENTER
CREW AND THERMAL SYSTEMS DIVISION

Space Exploration

SPACE EXPLORATION

TECHNOLOGY NEEDS/CHALLENGES

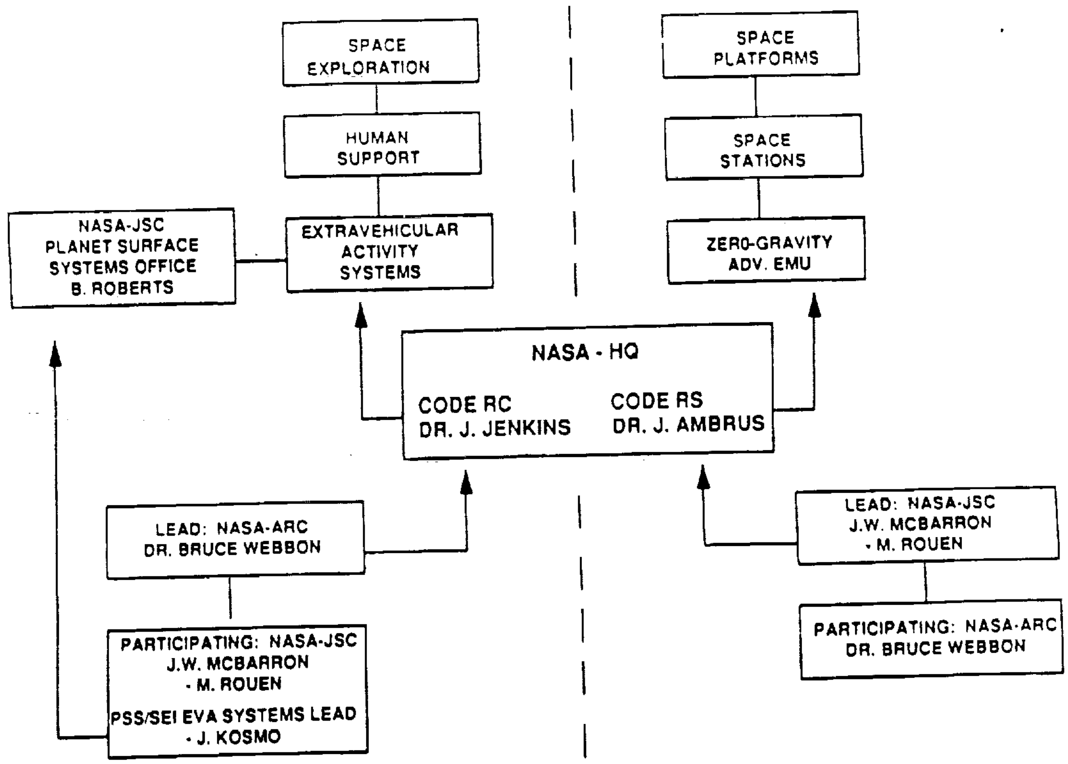
- DEVELOP AND VALIDATE TECHNOLOGIES FOR A SAFE, LIGHTWEIGHT, MULTI-USE PLSS FOR PLANETARY SURFACE USE
- DEVELOP LIFE SUPPORT TECHNOLOGIES THAT PROVIDE HIGH RELIABILITY, LOW LIFE CYCLE COST, AND ON-ORBIT MAINTAINABILITY
- DEMONSTRATE LOW LIFE CYCLE COST LIFE SUPPORT TECHNOLOGIES FOR CO_2, HUMIDITY, AND HEAT REMOVAL
- CONCENTRATE EFFORT IN SPECIFIC TECHNOLOGY AREAS:
  - CO_2 REMOVAL
  - HUMIDITY CONTROL
  - THERMAL CONTROL
  - POWER SYSTEMS
  - OXYGEN SUPPLY

Space Exploration

TECHNOLOGY BENEFITS

- LOW WEIGHT AND VOLUME PORTABLE LIFE SUPPORT SYSTEMS FOR HEAT REJECTION AND ATMOSPHERIC CONTROL
- REGENERABLE PLSS COMPONENTS - LOW LIFE CYCLE/LOGISTICS COSTS
- HIGH RELIABILITY PLSS COMPONENTS WHICH ARE ON-ORBIT MAINTAINABLE
- INCREASED CREW SAFETY FOR PORTABLE LIFE SUPPORT SYSTEMS

FOCUSED TECHNOLOGY PROGRAMS



STATE OF THE ART ASSESSMENT

- EVA TECHNOLOGY DEVELOPED TO DATE HAS BEEN FOCUSED TO SUPPORT ZERO-G BASED PROGRAMS (SHUTTLE/SPACE STATION)
- CURRENT EVA SYSTEMS ARE NOT SUPPORTIVE OF EXTENDED OPERATIONS ON LUNAR OR MARTIAN SURFACES
  - SYSTEMS ARE TOO HEAVY

EMU SYSTEM WEIGHTS HAVE INCREASED SINCE APOLLO ERA

	APOLLO	SHUTTLE	SPACE STATION FREEDOM
SPACE SUIT WEIGHT	60 LBS.	110 LBS.	~200 LBS
PLSS WEIGHT	135 LBS.	160 LBS.	~430 LBS
TOTAL WEIGHT	195 LBS.	270 LBS.	~630 LBS
OPERATING PRESSURE	3.75 PSIA	4.3 PSIA	8.3 PSIA
PLSS EXPENDABLES	RESUPPLY	RESUPPLY	REGENERABLE

STATE OF THE ART ASSESSMENT (CONT'D)

- LIFE SUPPORT SYSTEM EXPENDABLES RESUPPLY LOGISTICS
  - 10 LBS WATER AND 1.35 LBS LiOH PER EVA
- SYSTEMS ARE NOT DESIGNED FOR MAINTAINABILITY AT MISSION USE LOCATION PROBLEM FOR LONG-TERM OPERATIONS
  - SHUTTLE EMU REQUIRES SERVICING AFTER EACH EVA
- CURRENT EVA SYSTEMS OPERATIONS PENALTIES ARE NOT ACCEPTABLE FOR USE ON PLANETARY SURFACES

• APOLLO-ERA EVA TECHNOLOGY NOT SUITABLE TO SUPPORT REQUIREMENTS
  - POINT DESIGN ORIENTED
  - TECHNOLOGY OBSOLETE AND NOT EASILY REPRODUCIBLE TODAY (ELECTRONICS, PUMPS, MOTORS)

FY 90-91 ACCOMPLISHMENTS

• INITIATED EFFORTS FOR LIGHTWEIGHT/REGENERABLE SUIT COMPONENT ELEMENTS
  - HYDROGEN VENTING METAL HYDRIDE HEAT SINK
  - EMU SUBCRITICAL LIQUID OXYGEN STORAGE & SUPPLY SYSTEM
  - VENTING MEMBRANE FOR CO2 AND H2O REMOVAL

• RFP's RELEASED APRIL 8, 1991

• PROPOSALS RECEIVED FOR EVALUATION JUNE 10, 1991

• CONTRACT EXECUTION SEPTEMBER 16, 1991

OTHER DEVELOPMENT EFFORTS

- U.S. GOVERNMENT

  NO OTHER DEVELOPMENT EFFORTS BEING CONDUCTED OUTSIDE OF NASA SPONSORSHIP

- U.S. INDUSTRY

  LIMITED EFFORTS BEING PURSUED BY AEROSPACE COMPANIES ON PLANETARY SURFACE EVA TECHNOLOGIES

  MAJORITY OF IR&D EFFORTS DIRECTED TO ORBITAL/ZERO-G SHUTTLE/STATION

- EUROPEAN AGENCIES

  CONCENTRATING ON EVA SYSTEMS TECHNOLOGY DEVELOPMENT EFFORTS TOWARD NEAR-EARTH ORBITAL APPLICATIONS

- SOVIETS

  NO INDICATIONS OF ANY TECHNOLOGY DEVELOPMENT EFFORTS BEING EXPENDED TOWARD PLANETARY SURFACE EVA OPERATIONS

BASELINE PROGRAM

- INITIATION OF THREE ADVANCED PLSS TECHNOLOGY CONTRACTS
  - HYDROGEN VENTING METAL HYDRIDE HEAT SINK
  - EMU SUBCRITICAL LIQUID OXYGEN STORAGE & SUPPLY SYSTEM
  - VENTING MEMBRANE FOR CO2 AND H2O REMOVAL
- CONTRACTS IN EVALUATION AS OF JUNE 10, 1991
- CONTRACT EXECUTION SEPTEMBER 16, 1991
- CONTRACTS RANGING FROM 19 TO 20 MONTHS WITH MULTI-YEAR FUNDING PLANNED
- DELIVERY OF BREADBOARD HARDWARE FOR EACH CONTRACT SCHEDULED FOR FY 93

TECHNOLOGY PRIORITIES

- LOW WEIGHT/VOLUME PLSS COMPONENTS
- REGENERABLE/LOW EXPENDABLES PLSS COMPONENTS
- SIMPLE AND RELIABLE COMPONENT DESIGNS
- MINIMIZE SYSTEM WEIGHT /VOLUME BY EFFICIENT PACKAGING
- EASE OF MAINTENANCE AND REPAIR DURING THE MISSION

Space Exploration

ISSUES

- CRITICAL DESIGN ISSUES FACING FUTURE PLANETARY SURFACE EXPLORATION MANDATES IMMEDIATE EMPHASIS IN THE DEVELOPMENT OF EVA TECHNOLOGY:
  - DESIRED LEVEL OF TECHNOLOGY READINESS WILL NOT BE FULLY ACHIEVED BY NEED DATE

SPACE PLATFORMS

Space Platforms

TECHNOLOGY NEEDS/CHALLENGES

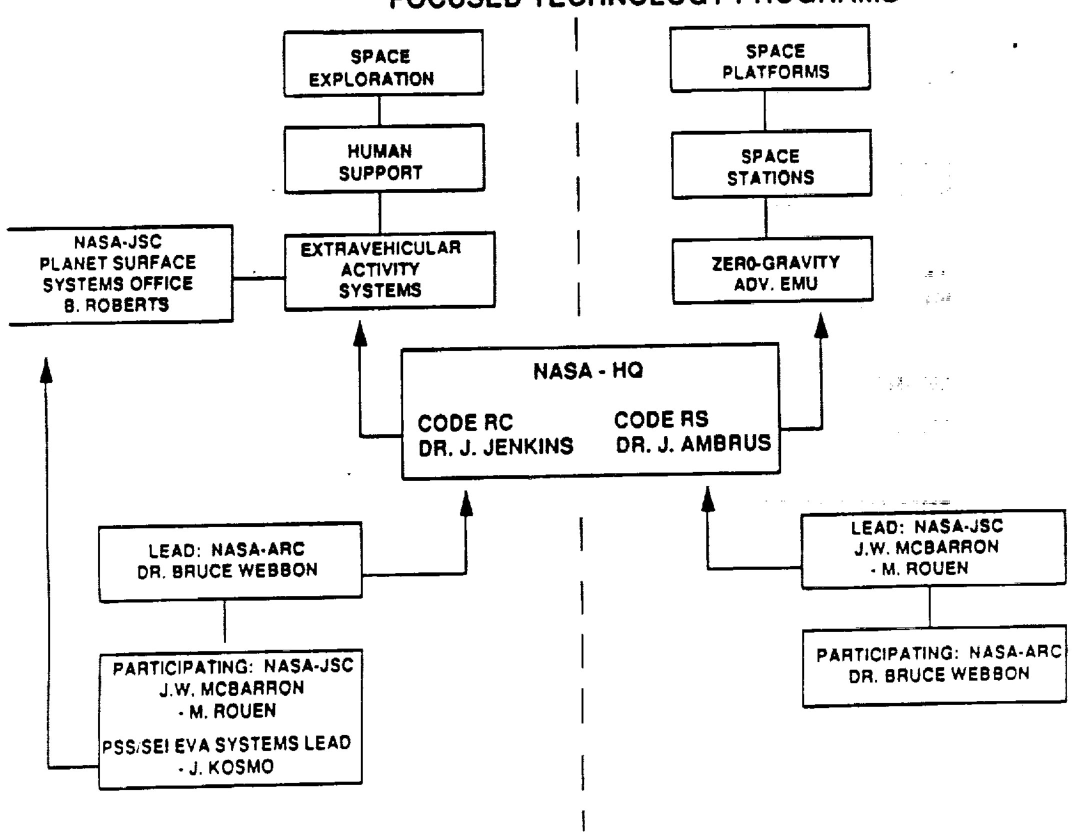
- DEVELOP AND VALIDATE TECHNOLOGIES FOR A SAFE, LIGHTWEIGHT, REGENERABLE PLSS FOR SSF USE
- DEVELOP AN ADVANCED, ROBUST EMU CAPABLE OF HIGH USE RATES NEEDED FOR SPACE STATION FREEDOM OPERATIONAL SUPPORT
- DEVELOP LIFE SUPPORT TECHNOLOGIES THAT PROVIDE HIGH RELIABILITY, LOW LIFE CYCLE COST, AND ON-ORBIT MAINTAINABILITY
- DEMONSTRATE LOW LIFE CYCLE COST LIFE SUPPORT TECHNOLOGIES FOR CO2, HUMIDITY, HEAT REMOVAL, AND POWER SUPPLY
- DEMONSTRATE HIGH RELIABILITY, LOW VOLUME, LOW MAINTENANCE FAN TECHNOLOGY
- DEMONSTRATE ELECTRONIC INFORMATION DISPLAYS TO PROVIDE GREATER ACCESS TO INFORMATION
- DEVELOP AUTOMATED COOLING CONTROL SYSTEM TO PROVIDE MORE EFFICIENT USE OF LIMITED COOLING SUPPLY

TECHNOLOGY BENEFITS

- LOW WEIGHT AND VOLUME PORTABLE LIFE SUPPORT SYSTEMS FOR HEAT REJECTION AND ATMOSPHERIC CONTROL
- REGENERABLE PLSS COMPONENTS - LOW LIFE CYCLE/LOGISTICS COSTS
- HIGH RELIABILITY PLSS COMPONENTS WHICH ARE ON-ORBIT MAINTAINABLE
- HANDS-FREE ACCESS TO INFORMATION
- REAL-TIME DATA UPDATES TO CREW CHECKLIST INFORMATION
- MORE EFFICIENT USE OF PLSS COOLING SUPPLY RESULTING IN SMALLER SYSTEM
- CONCENTRATE EFFORT IN SPECIFIC TECHNOLOGY AREAS:
  - CO2 REMOVAL
  - HUMIDITY CONTROL
  - THERMAL CONTROL
  - POWER SYSTEMS
  - OXYGEN SUPPLY
  - DISPLAYS AND CONTROLS

INTEGRATED TECHNOLOGY PLAN (ITP) FOR THE CIVIL SPACE PROGRAM

FOCUSED TECHNOLOGY PROGRAMS



STATE OF THE ART ASSESSMENT

- CURRENT SHUTTLE EVA SYSTEMS WILL SUPPORT SSF ACTIVITIES WITH THE FOLLOWING QUALIFICATIONS
  - LIFE SUPPORT SYSTEMS RESUPPLY LOGISTICS PROBLEM FOR LONG-TERM, HIGH-FREQUENCY EVA OPERATIONS
    - 10 LBS WATER AND 1.35 LBS LiOH PER EVA
  - HIGH LIFE CYCLE COST
  - SYSTEMS NOT DESIGNED FOR SIMPLE MAINTAINABILITY
    - SHUTTLE EMU REQUIRES SERVICING AFTER EACH EVA
- SSF AEMU TECHNOLOGY DEVELOPMENT REMOVED FROM SSF PROGRAM DURING SCRUB ACTIVITIES
    - SSF AEMU TECHNOLOGIES ARE IN THE PROCESS OF WINDING DOWN WITH CLOSEOUT FUNDS

Space Platforms

FY 90-91 ACCOMPLISHMENTS

- CONTINUED TERMINATION EFFORTS FOR PREPROTOTYPE TECHNOLOGIES
  - HCI METAL HYDRIDE HEAT PUMP
  - AIRESEARCH METAL OXIDE CO2 AND H2O REMOVER
  - AIRESEARCH LOW VOLUME AIR BEARING FAN
  - ERGENICS FUEL CELL
- DEVELOPMENT OF AUTOMATIC COOLING CONTROL SYSTEM IN-HOUSE TEST PROGRAM

OTHER DEVELOPMENT EFFORTS

U.S. GOVERNMENT

NO OTHER DEVELOPMENT EFFORTS BEING CONDUCTED OUTSIDE OF NASA SPONSORSHIP.

U.S. INDUSTRY

LIMITED / FOCUSED IR&D EFFORTS BEING PURSUED BY AEROSPACE COMPANIES TO IMPROVE SPECIFIC EVA SYSTEM ELEMENTS AND COMPONENTS.

EUROPEAN SPACE AGENCY

- CONTINUE JOINT (MULTI-COUNTRY) DEVELOPMENT EFFORTS FOR HERMES EVA SUIT AND EVA GLOVES.
- OBJECTIVE TO ESTABLISH OWN EVA INFRA-STRUCTURE.
- CLOSELY FOLLOWING MK III 8.3 PSI SUIT TECHNOLOGY, SOME FEATURES OF WHICH ARE REFLECTED IN EARLY PROTOTYPE DESIGN APPROACHES.
- DEVELOPING CLOSE TIES TO SOVIET EVA PROGRAM PERSONNEL WHICH ARE ATTEMPTING TO SELL SOVIET EVA SYSTEM EQUIPMENT FOR HERMES APPLICATION.

Space Platforms

OTHER DEVELOPMENT EFFORTS (CONT'D)

SOVIETS

- RECENTLY DEMONSTRATED IMPROVED, SECOND GENERATION OF PREVIOUSLY FLOWN SALUT///MIR EMU DURING IN-FLIGHT EVALUATION OF MANNED MANEUVERING UNIT.
- SOVIETS HAVE SHOWN HIGH INTEREST IN RECENTLY COMPLETED MK III AND AX-5 COMPARATIVE TEST PROGRAM AND HAVE REQUESTED TEST RESULTS.
- SOVIETS HAVE REVEALED LITTLE OF THEIR ADVANCED TECHNOLOGY PROGRAM.

JAPANESE

- EXPRESSED INTEREST TO LEASE/PROCURE SHUTTLE EMU SUITS FOR USE IN JAPANESE WATER IMMERSION TEST FACILITY WHICH THEY MAY PLAN TO BUILD AND OPERATE IN THE NEAR FUTURE.
- DEVELOPMENT OF JAPANESE EVA PROGRAM MANAGEMENT INFRA-STRUCTURE TO SUPPORT THEIR MANNED SPACEFLIGHT PROGRAM IS EXPECTED.

TECHNOLOGY PRIORITIES

- PORTABLE LIFE SUPPORT SYSTEM TECHNOLOGIES
  - LOW WEIGHT/VOLUME SYSTEM COMPONENTS
  - REGENERABLE TECHNOLOGY
  - SIMPLE, RELIABLE, EASILY MAINTAINABLE
  - MINIMIZE SYSTEM WEIGHT/VOLUME THROUGH EFFICIENT PACKAGING
  - EASE OF MAINTENANCE AND REPAIR ON ORBIT
  - INCREASE SYSTEM EFFICIENCY THROUGH THE USE OF AUTOMATED CONTROLS
  - INCREASE CREW EFFICIENCY THROUGH THE USE OF AUTOMATED CONTROLS AND INFORMATION DISPLAYS

AUGMENTED PROGRAM

- AEMU PROGRAM IS NOT FUNDED WITHIN THE CURRENTLY STRUCTURED BASELINE PROGRAM WORK PLAN; TO BE FUNDED WITHIN AUGMENTED WORK PLAN

MAJOR MILESTONE: (GOALS)

- 1993 - AEMU TECHNOLOGY BASELINE IDENTIFIED (PDR)
- 1994 - AEMU DETAIL DESIGN COMPLETE (CDR)
- 1995 - MANUF. DRAWINGS/DETAIL SPECS. REVIEW
- 1997 - AEMU PROTOTYPE FABRICATION COMPLETE
- 1999 - AEMU ENVIRONMENTAL TESTING COMPLETE

FY93 FISCAL AND SUPPORT RESOURCES
(XXX-XX) ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU)

- NO RTOP / W.B.S. AT THIS TIME; PLANNED FOR FY93

ISSUES

- DEVELOPMENT OF AEMU CONTINGENT UPON APPROVAL OF FY 93 BUDGET

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ARC-EVA Systems Research Program:
Base R&T, Exploration, and Platform Applications

Integrated Technology Plan for the Civil Space Program

Presentation To:

Space Systems and Technology Advisory Committee
Human Support Element Review

27 June 1991

Presented By:

Bruce Webbon, PhD
Chief, Extravehicular Systems Branch

ExtraVehicular Systems Branch

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Agenda

- Technology Needs and Objectives
- EVA Work System Elements
- Relationships Between Thrust Applications
- Work Breakdown Structure
- Priorities
- Current EVA Research Topics
- ARC Program Implementation
- Recent Accomplishments
- Platform Application
- Issues
- Summary
- Addendum

Overall Technology Needs and Objectives

Program Premise:
EVA is an enabling operational resource for all future manned space missions.

Current EVA Technology Limitations:

- limits EVA productivity for routine operations, science and exploration, and contingency operations
  - bends risk is ~ 5% on each EVA
  - maximum of 42 EVA hours per shuttle flight
  - one day rest between EVA's
- imposes serious operational and logistical constraints
  - overhead intensive
  - approximately 1 kg mass expended/EVA hour
- may be difficult to evolve for Exploration mission requirements

EVA Technology Program Objectives:

- develop EVA systems to provide a safe, routine, reliable, and affordable resource for mission planners
- demonstrate subsystem technology and integrated system prototypes in realistic experimental environments
- provide support to flight systems development programs

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Technology Issues/Needs

STS EVA System

- Issue: Current EVA system does not allow routine, cost-effective EVA operations
- Need: Incorporate mature advanced technology to upgrade STS EMU

Platform Application

- Issue: STS EMU not designed to meet platform requirements
- Need: Utilize known technology and develop a space-based EMU

Lunar Application

- Issue: Currently available technology is not adequate for routine lunar EVA operations
- Need: Expand technology base, build and evaluate prototype lunar EVA work system

Mars Application

- Issue: We currently do not know how to design an EVA work system for Mars missions
- Need: Develop understanding of task and human requirements, new subsystem concepts, expand technology base, build and evaluate prototype Mars EVA work system

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EVA Work System Elements

- Extravehicular mobility unit (EMU)
  - portable life support system (PLSS)
  - pressure suit
- airlock and EMU support equipment
- tools, mobility aids, and work stations
- interfaces to teleoperated and other work aids

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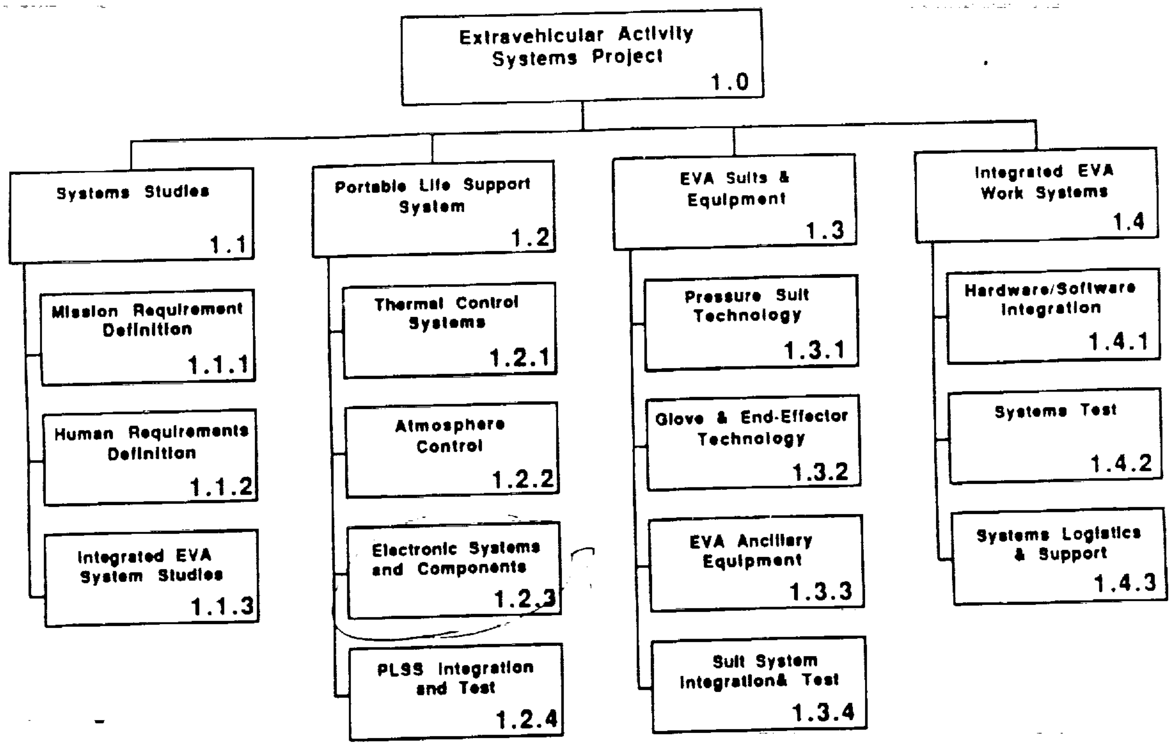
Relationship Between Thrust Applications

- Future EVA systems must accommodate:
  - Platform operations
  - Lunar exploration and operations
  - Mars exploration and operations
- Path to System Commonality:
  - No pre-conceived position regarding desirability/feasibility of EVA system commonality
  - Separately define environmental, operational, and science requirements for each mission application
  - Conduct separate studies and analyses to determine optimum EVA system(s) for each thrust application
  - Examine study results to identify common components and systems
  - Define logical EVA systems evolutionary plan

Work Breakdown Structure



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Priorities

Technology priorities are a function of the application

Platform Application - *No fundamental technology issues*
- Realistic definition of user requirements (WBS 1.1.1)
- Select optimum components from available suit and PLSS technology base (WBS 1.2.4&1.3.4)
- Build and test prototype, integrated EVA work system (WBS 1.4)

Lunar Application - *Many suit design and system integration issues, fundamental PLSS issues*
- Define mission and human requirements and conduct trade studies (WBS 1.1.1-3)
- Develop PLSS subsystem technology base (WBS 1.2.1-4)
- Design prototype suit once requirements are understood (WBS 1.3.4)
- Build and test prototype, integrated EVA work system (WBS 1.4)

Mars Application - *Fundamental issues for all EVA work system elements*
- Define mission and human requirements and conduct trade studies (WBS 1.1.1-3)
- Develop PLSS subsystem technology base (WBS 1.2.1-4)
- Develop suit subsystem technology base (WBS 1.2.1-4)
- Build and test prototype, integrated EVA work system (WBS 1.4.1-3)

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Current EVA Research Topics

- **ARC Base R&T Task Areas**
  - EVA heat balance and controls
  - Fusible materials research
  - Packed bed sorbent cannisters
  - Suit mobility elements

- **Proposed FY92 ETP Task Areas**

ARC

- WBS 1.1 Systems Studies
  - Exploration Environments, Tasks, & EVA Scenarios
  - Planetary gravity biomechanics studies
  - Planetary EVA System studies
- WBS 1.2 Portable Life Support System
  - Planetary thermal control systems
  - CO2 Sorbent modeling and concept testing
  - Electronic system architectures, controls, and displays
  - PLSS analysis and design studies
- WBS 1.3 EVA Suits&Equiipment
  - Lightweight suit elements and structures
  - End effector evaluation
  - Evaluate airlock and body restraint concepts

JSC

- Exploration mission studies
- Reduced gravity biomechanics studies
- Life support optimization program
- Venting metal hydride thermal control system
- Subcritical O2 storage & Venting CO2 membrane
- Heads-up display testing
- PLSS studies
- Fabricate composite STS torso
- Glove refinement and procure pair of advanced gloves

- **Platform Task Areas (FY 93 new start) - TBD**

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ARC Program Implementation

In-House R&D
- ARC staff performs "hands-on" research and engineering development
- Scientific work resulting in publications and patents
- Development of innovative concepts for EVA systems
- Demonstration/proof of concept by analysis and test of hardware
- Publish results and demonstrate hardware

Contracts
- Proof of concept hardware often fabricated on contract
- Small Business Innovative Research contracts
- R&D contracts

University Grants & Cooperative Agreements
- National Research Council Post-doctoral Fellows
- University grants and cooperative agreements

Collaboration with other Government Agencies/Organizations
- Naval Oceans Systems Command
- Naval Experimental Diving Unit
- Army Electronics Technology and Devices Laboratory
- USAF School of Aerospace Medicine

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University Grants & Cooperative Agreements

Current

- NRC Fellow studying Mars EVA systems
- MIT PhD student doing dissertation research in biomechanics of walking in partial gravities
- North Carolina A&T program to develop logistics software analysis techniques for EVA systems
- San Jose State University cooperative agreement for research in:
  - fusible materials
  - heat sink fluid flow
  - CO2 sorbents
  - EVA system cost modeling
- Stanford University PhD student doing dissertation research in EVA biomechanics and load carrying capabilities in partial gravity
- University of Missouri grant in EVA Thermal Control

Future

- NRC proposal for experimental research in EVA heat balance and control systems
- Georgia Institute of Technology - School of Textile Engineering
- University of California-Berkeley - Schools of Mechanical and Industrial Engineering
- University of Utah and Utah State University
- Duke University

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FY 90-91 Accomplishments

- Proved function and verified predicted performance of fusible heat sink concept
- Conducted study of Mars EVA concepts
- Demonstrated concept for integration of advanced suit arms with STS suit torso
- Identified promising materials for use in fusible heat sinks
- Analytically examined concepts for increasing utilization efficiency of packed-bed sorbents
- Examined concepts for regeneration of LiOH sorbent
- Completed study of CO2 partial pressure effects in closed environments
- Began conceptual design of advanced EVA electronics and display concepts
- Began human experiments to produce human "performance map" for PLSS automatic control
- Developed experimental method to examine biomechanical issues related to planetary EMU design
- Initiated grant research relationships with MIT and Stanford in planetary EMU biomechanics

Code SAE 1990-91 Publications and Patents

Publications

- Bennett, D.," Advanced Manufacturing Techniques for High Pressure Space Suit Gloves", Battelle Northwest Laboratories, Final Report for Contract No. NAS2-13006, June 1990
- Chase, W.,"Human Information Display Engineering", In Publication as ARC Code SAE Technical Report
- Haynes, W.,"EVA Hazards Analysis", In Publication as ARC Code SAE Technical Report
- Jacobs, G. and Vykukal, H.,"Advanced Space Suit Structures & Materials", SAE Paper No. 901429, International Conference on Environmental Systems, July 1990
- Kuznetz, L.,"Space Suits and Life Support Systems for the Exploration of Mars", AIAA paper No. 90-3732, Space Programs and Technologies Conference, September 1990
- Kuznetz, L.,"Space Suits and Life Support Systems for the Exploration of Mars-Phase 2", IAF paper No.IAF-90-670, 41st International Aerospace Federation Conference, October 1990
- Kuznetz, L.,"Mars Gravity Profile Experiment-A US Space Shuttle Mission to the Soviet MIR Space Station", IAF paper No.IAF-90-671, 41st International Aerospace Federation Conference, October 1990
- Lomax, C. and Webbon, B.,"Direct Interface Fusible Heat Sink for Astronaut Cooling", NASA TM 102835, May 1990 also SAE Paper No. 901433, International Conference on Environmental Systems, July 1990
- Luna, B.,"Planetary Regeneration of Lithium Hydroxide", In Publication as ARC Code SAE Technical Report
- Miles, John B.,"EVA Thermal Control Study: Phase I Report", University of Missouri under NASA ARC Grant No. NAG-2-589, September 1991
- Newman, D. and Webbon, B.,"Human Locomotion and Workload for Extravehicular Activity (EVA): Simulated Partial Gravity Environment", 9th International Academy of Astronautics Conference Proceedings, June 1991, Cologne, Germany

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Code SAE 1990-91 Publications and Patents (cont.)

- Ntuen,C. and Park,E.,"Economic Design Policies for EVA/Suit System Orbital Replacement Units", North Carolina A&T University under NASA-ARC Cooperative Agreement No. NCA 2-384, December 1990
- Reinhardt, A."Systems Analysis of the AX-5 Space Suit", San Jose State University Masters Thesis in Industrial Engineering, February 1990
- Reinhardt, A.and Magistad, J.,"AX-5 Space Suit Reliability Model", SAE Paper No. 901361, International Conference on Environmental Systems, July 1990
- Selvaduraay, G.,"The Properties of and Analytical Methods for Detection of Lioh and Li2Co3", San Jose State University under NASA-ARC Cooperative Agreement No. NCC2-640, February 1991
- Selvaduraay, G. and Lomax, C.,"Fusible Heat Sink Material: An Evaluation of Alternative Candidates", in publication for 1991 International Conference on Environmental Systems, July 1991
- Seter, A.,"Allowable Exposure Limits for Carbon Dioxide During Extravehicular Activity", in publication as NASA SP

Patents

- Lomax, C. and Webbon, B.,"Cooling Apparatus and Couplings Therefore", patent applied for 1991, ARC Case No. 11921-1

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Resource Issues

- **Projected base R&T program barely sufficient to maintain in-house research teams**

FY 92	93	94	95	96
$611K	$638K	$665K	$695K	$726K

- **ARC produced the Pathfinder EVA/Suit Project Plan in Oct 1988**
    - Projected (1988) Pathfinder EVA Budget:

FY 89	90	91	92	93
$1.12M	$4.25M	$6.50M	$7.30M	$8.00M

    - Actual FY 91 budget was $0.976M
    - Actual cumulative Pathfinder budget for FY89-91 approximately 20% of projected

- **1988 schedule called for completion of a prototype planetary EMU in FY96**
- **Current baseline ETP budget for EVA:**

FY 92	93	94	95	96
$4M	$5M	$8M	$11M	$12M

- **ETP schedule calls for completion of a prototype planetary EMU in FY96**
- **Revised EVA Plan in review/approval cycle**
    - Baseline budget will allow comfortable technology development program
    - Budget will ***not*** provide a complete prototype EMU by FY96
    - Overguidelines tasks required are identified in revised plan

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Program Issues

- **Revised Code R - Extravehicular Activity Systems Project Plan is currently under review**
- **Base R&T program barely sufficient to maintain research teams**
- **Proposed Exploration funding will produce EVA technology base required for Space Exploration Initiative Missions**
    - support vigorous university research program to provide trained engineers
    - Universities support relevant staff, courses, and facilities
    - Contract R&D will be an integral part of program
    - Industry direct IR&D funds to collaborative NASA/Univ/contractor JEA's
- **Currently planned Exploration funding will *not* produce planetary EMU prototype in FY96 per current Exploration Technology Program schedule**
- **NASA must maintain stable funding base for long-term business planning and project success**

Summary

Technical Issues

- Platform application requires utilization of relatively mature, currently available technology

- Planetary exploration requires advances in all areas of EVA technology

Technology Benefit

- Human exploration cannot be done effectively without a routine EVA capability

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Addendum

(The following material provides a detailed description of the current ARC program)

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Mission Requirements Definition (WBS 1.1.1)

Objective
Define and document a set of design reference EVA scenarios that can be used to derive lower level requirements as needed

Benefit
Design requirements will be solidly based on scientific, exploration, and construction tasks that must be performed by EVA

Technical Approach
- Review and collate all relevant data on the EVA environments under consideration in 0-g, the Moon, and, Mars
- Survey relevant mission planners and scientific users to define required EVA tasks for operations such as Mars exo-biology, geology, construction, etc
- Review studies concerning the mix of man and machines to perform candidate tasks
- Review EVA operational rules and requirements
- Combine the acquired data into a set of credible scenarios i.e., "A day in the life of an EVA geologist on Mars" for review by the EVA technical community
- Utilize scenarios to derive requirements as needed, for example:
  - scenario requirement "How steep a slope must an EVA geologist on Mars be able to climb to collect desired rock samples?"
  - derived requirement "What suit lower torso mobility is required to perform this scenario?"

Implementation
- Considering a cooperative agreement with the Schools of Mechanical and Industrial Engineering, University of California-Berkeley

Status/Milestones
- Discussions underway with university
- Final EVA design scenarios completed in FY93

Plans
- Distribute scenarios and solicit comments

Principal Investigator: Remus Bretoi (415) 604-6149

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Human Requirements Definition (WBS 1.1.2)

Objective
Define and understand the human requirements, capabilities, and limitations relevant to the design of the EVA work system

Benefit
Simplify and optimize the EVA work system while increasing productivity, safety, and comfort

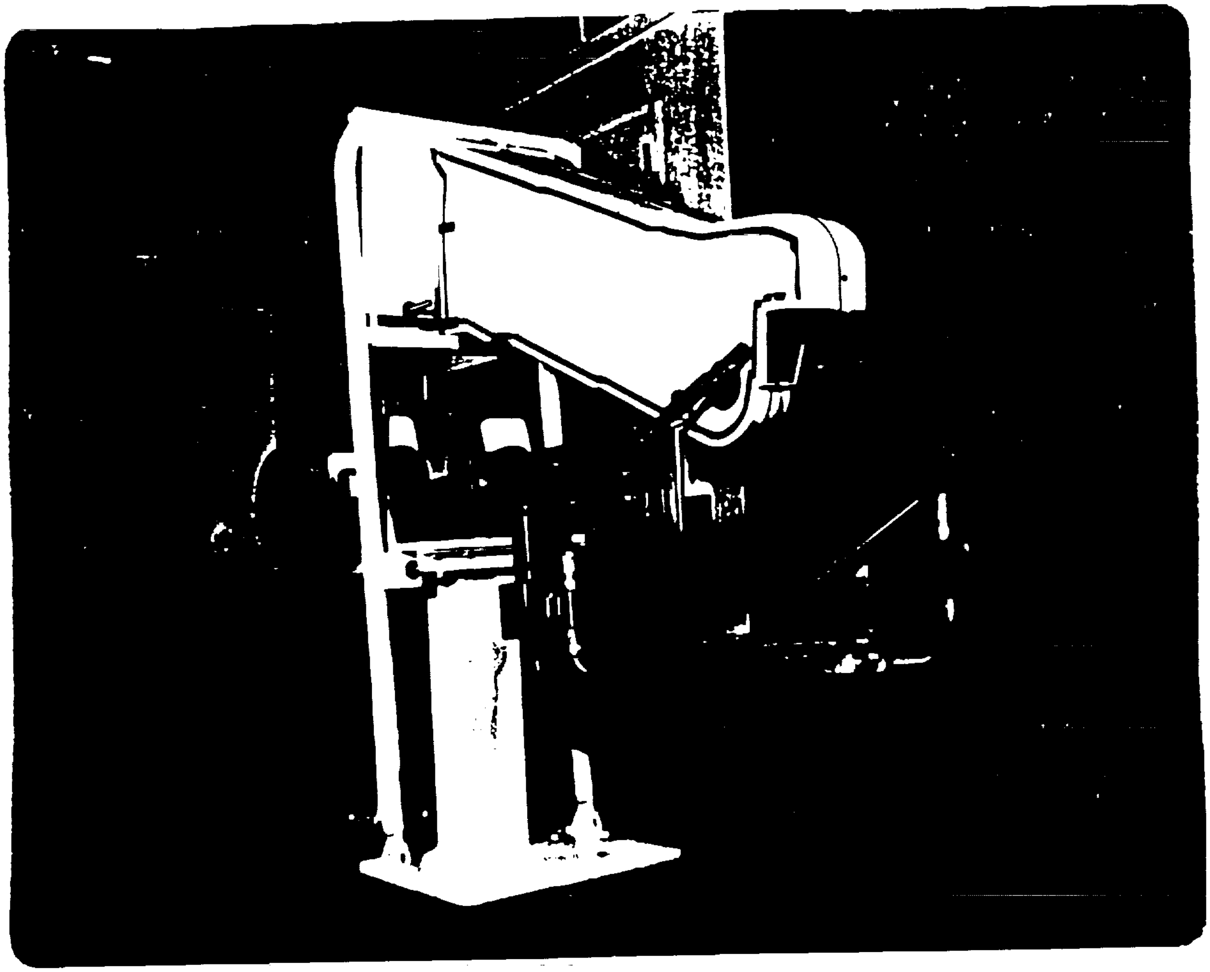
Technical Approach
- Conduct experiments using 0-g EVA work simulator to develop human performance map for use in PLSS control systems
- Develop and use a technique to simulate a partial gravity environment using buoyancy, ballast, and computer modeling
- Perform human experiments in simulated partial gravity to produce design guidelines for planetary EMU development
- Use fully developed techniques to evaluate and refine EVA subsystem prototypes

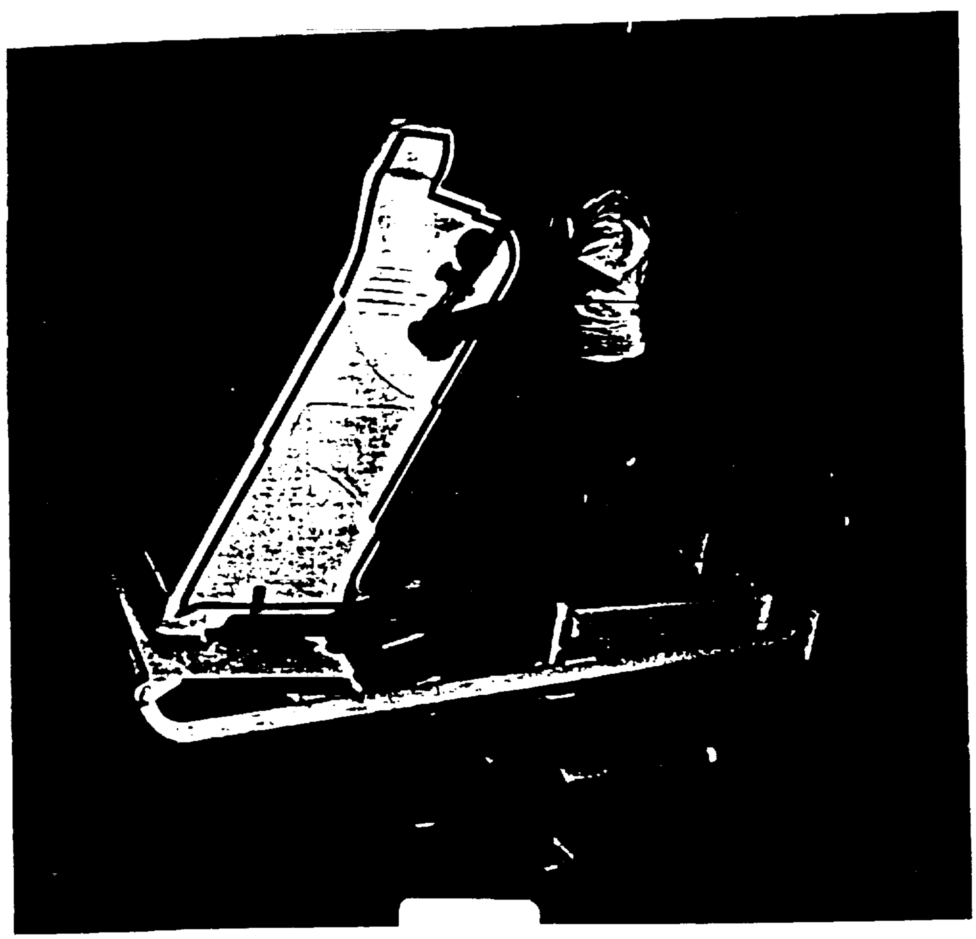
Implementation
In-house research at ARC supported by university collaborators

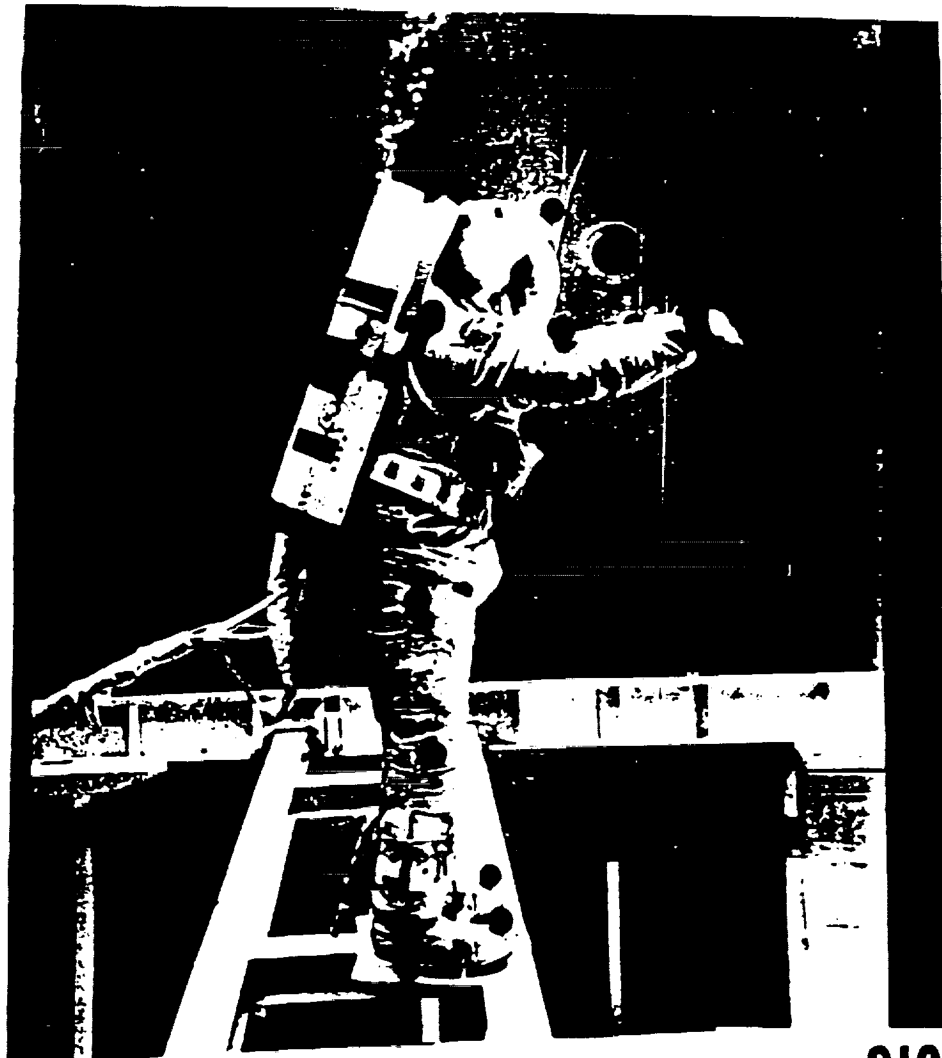
Status/Milestones
- First phase of experiments using 0-g simulator is underway
- Validation experiments for planetary gravity simulator completed, analysis of experimental data underway

Plans
- Planning collaborative experiments on JSC KC-135 aircraft this summer
- Planning next set of planetary experiments to investigate load-carrying capabilities in 1/6 and 3/8g
- Awaiting approval of NRC proposal for heat balance work using ARC simulators

Principal Investigator: Rebecca Williamson (415) 604-3685
Bruce Webbon (415) 604-6646







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Integrated EVA System Studies (WBS 1.1.3)

Objective
Develop required analytical tools for analysis of EVA systems and use analytical techniques to study candidate EVA system elements and concepts

Benefit
Evaluation of concepts analytically prior to development will filter out bad ideas prior to large investment of resources

Technical Approach
- Develop and acquire appropriate analytical tools
- Derive innovative new concepts for EVA work system elements and complete systems
- Analytically model and refine the concepts and trade and compare alternative approaches
- Recommend "best" concepts and evaluate their task performance in the EVA design scenarios
- Analysis will include factors such as supportability and life-cycle cost

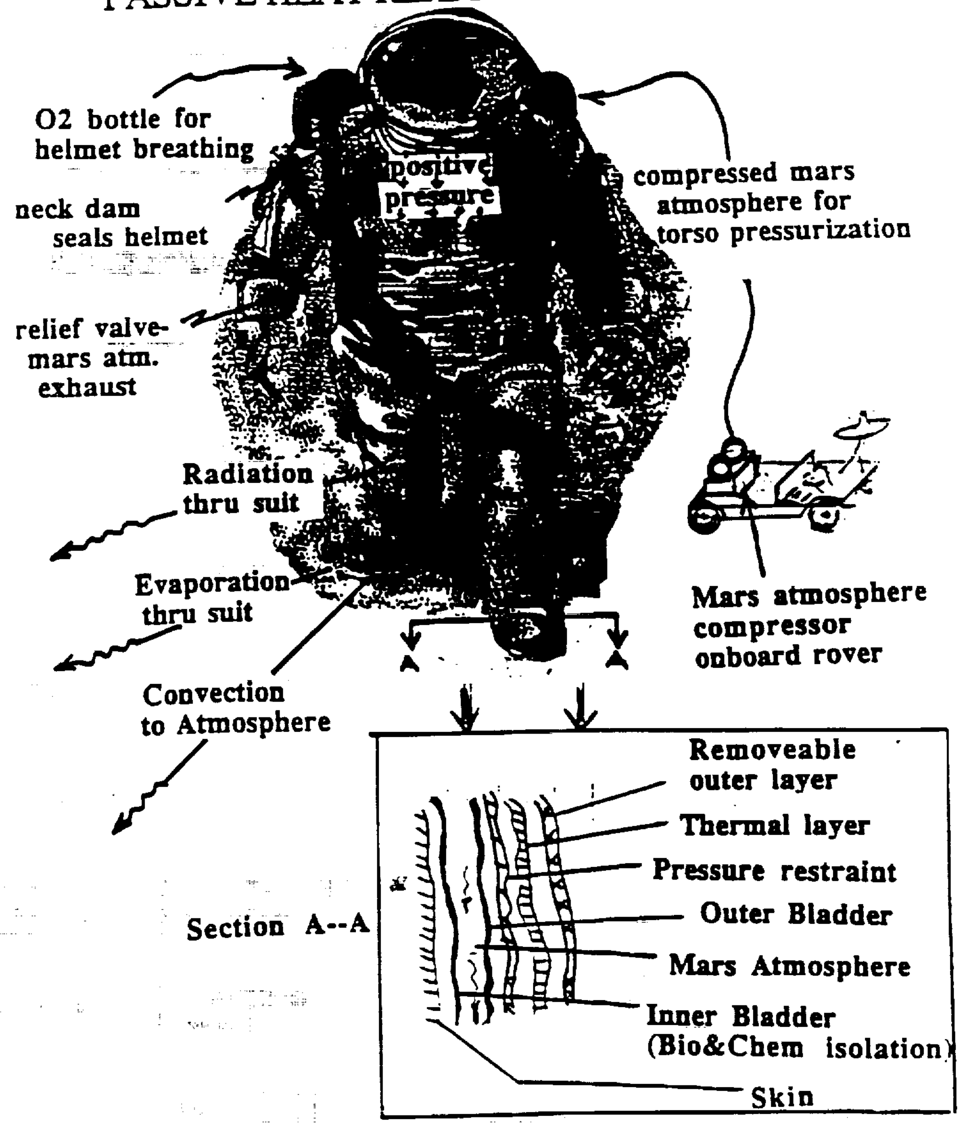
Implementation
- In-house-studies, university cooperative agreement, contractor studies

Status/Milestones
- Complete initial study of Mars EMU concepts - FY92
- Planetary EMU configuration recommendation - FY93

Plans
- Continue university grant in system supportability guidelines
- Expand in-house studies in FY92

Principal Investigator: Remus Bretoi (415) 604-6149

SUIT CONCEPT #18— MARS ATMOSPHERE PRESSURE SUIT— PASSIVE HEAT REJECTION

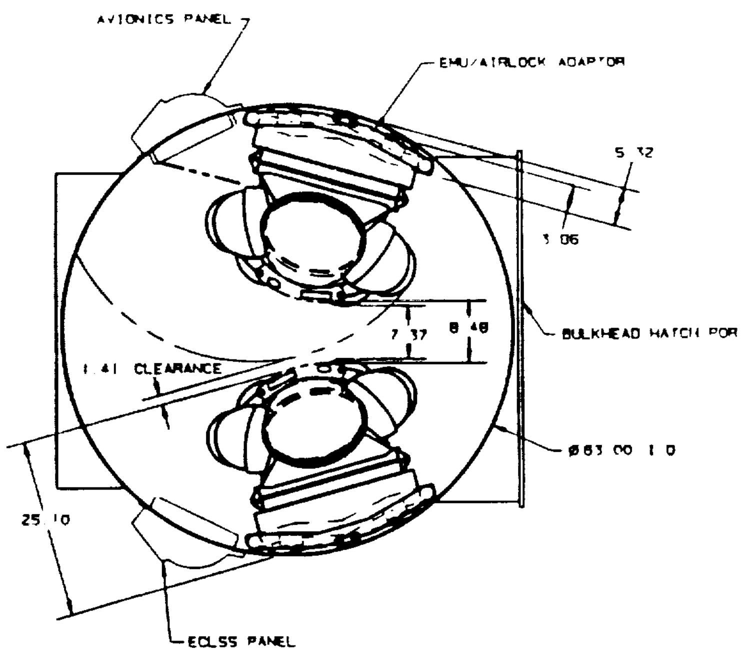


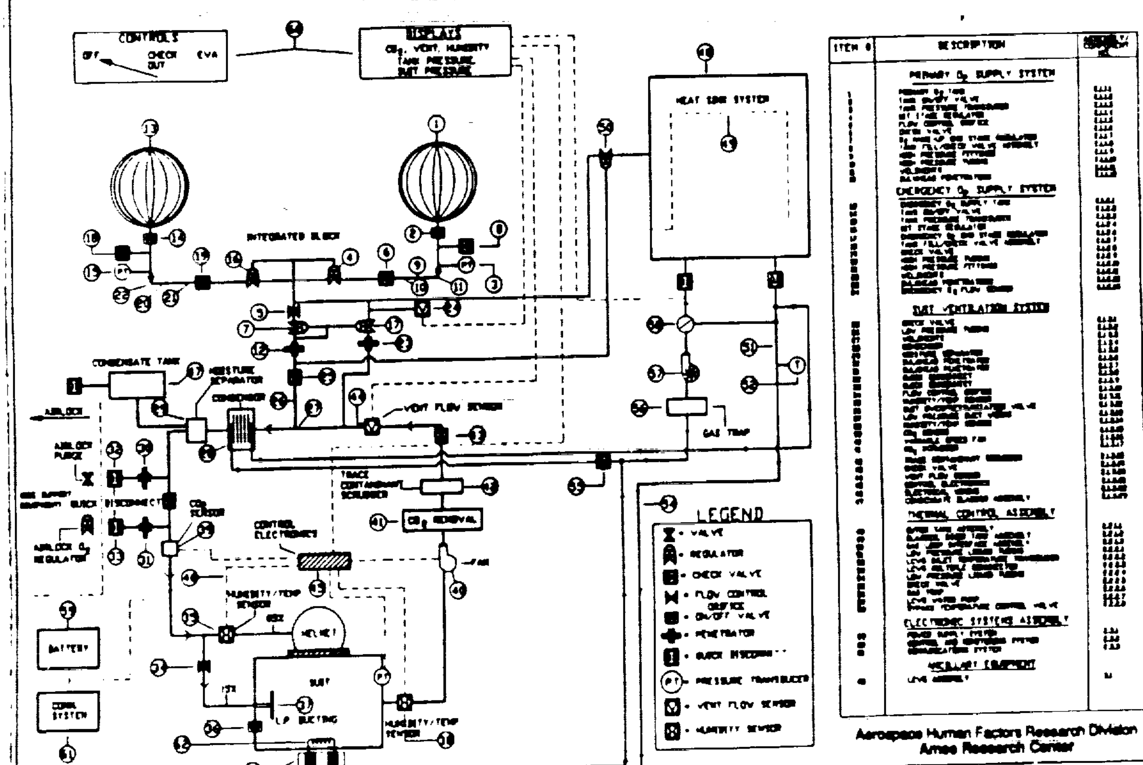
ADVANCED SUIT/SHUTTLE AIRLOCK INTEGRATION STUDY
CANDIDATE #4 DRAWING A

CONFIGURATION
- DCM REDESIGNED TO MATCH CONTOUR OF AX-5 AND REDUCED TO 4 2 IN NOMINAL THICKNESS
- PLSS AS IS. NOMINAL DEPTH 6 50 IN.
- AX-5 HATCH REDESIGNED TO ACCOMODATE PLSS
- AIRLOCK ADAPTOR PLATE REDESIGNED TO LOCATE EMU 1 25 INCHES CLOSER TO WALL AND MINIMIZE TRAVEL REQ'D FOR SUIT TO RELEASE (LEAVES APPROXIMATELY .15 INCH CLEARANCE BETWEEN CORNER OF PLSS AND WALL.)

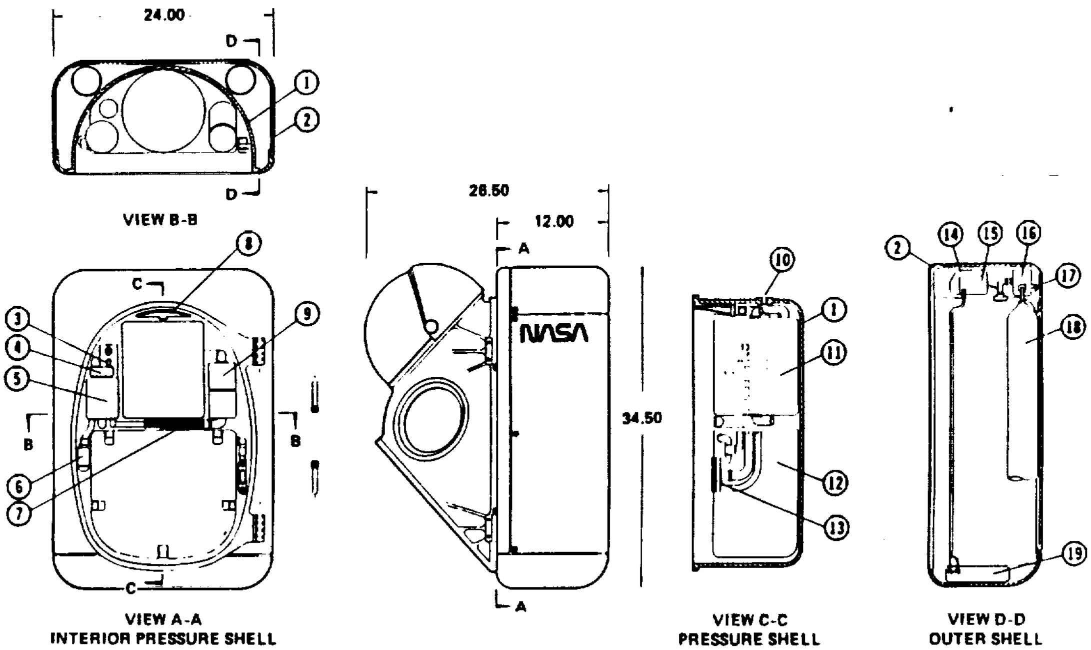
CONCLUSIONS
- POSSIBLE PROBLEM WITH LAUNCH DYNAMICS
- FITS INTO AIRLOCK
PROVIDES CLEARANCE TO RELEASE FROM AIRLOCK AS WELL AS TO Don/Doff
- VIABLE ALTERNATIVE
REQUIRES REDESIGN OF DCM & AAP

NOTES.
THIS DRAWING IS FOR STUDY PURPOSES ONLY.
NOT ALL ITEMS ARE TO SCALE.
APPROXIMATE SHOULDER WIDTH IS SHOWN
SHOULDERS MAY BE ROTATED TO REDUCE INTERFERENCE.





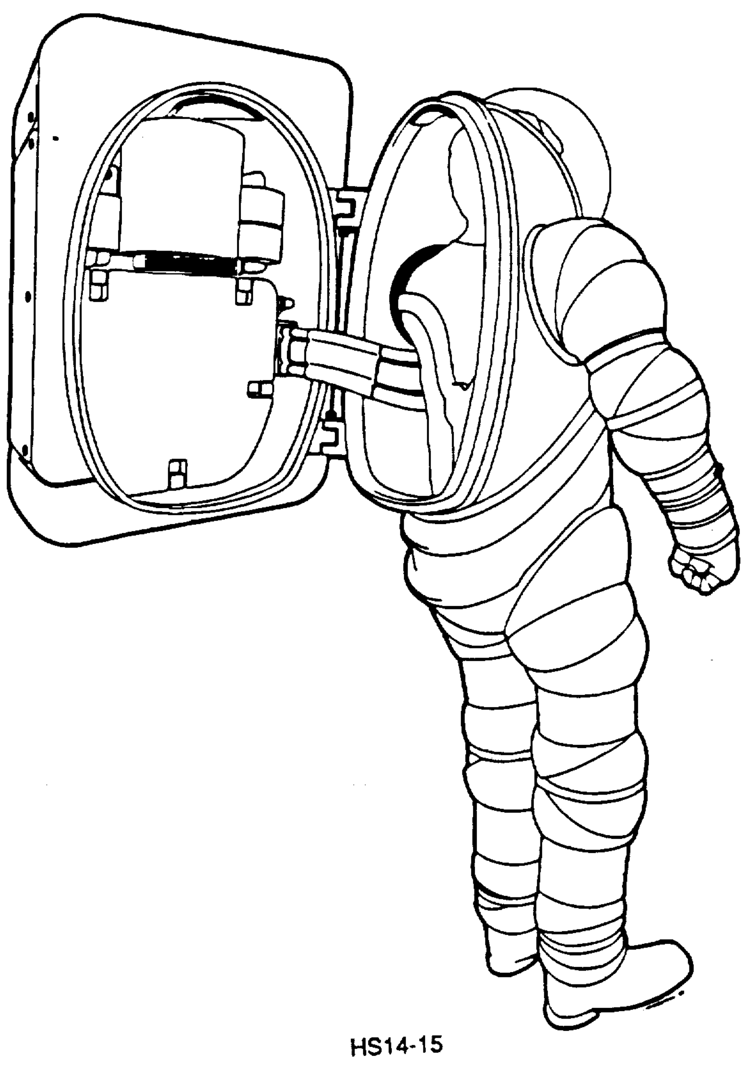
Aerospace Human Factors Research Division
Ames Research Center



(3) CONDENSATE TANK
(4) MOISTURE SEPARATOR
(5) CONDENSER
(6) WATER PUMP
(7) AIR INTAKE FILTER
(8) SUIT AIR VENT
(9) FAN

(1) PRESSURE VESSEL (HATCH)
(10) PRESSURE VESSEL PENETRATOR
(11) CO_2 REMOVAL
(12) HEAT SINK
(13) LCVG DISCONNECT

(2) PROTECTIVE OUTER SHELL
(14) COMM. SYSTEM
(15) ELECTRONICS
(16) O_2 REGULATOR
(17) O_2 RECHARGE
(18) O_2 TANKS (2)



Thermal Control Systems (WBS 1.2.1)

Objective
Invent, analyze, develop, and characterize new concepts for EVA thermal control and heat balance

Benefit
Reduced EVA system size and power requirements along with reduction in mass expended per EVA hour

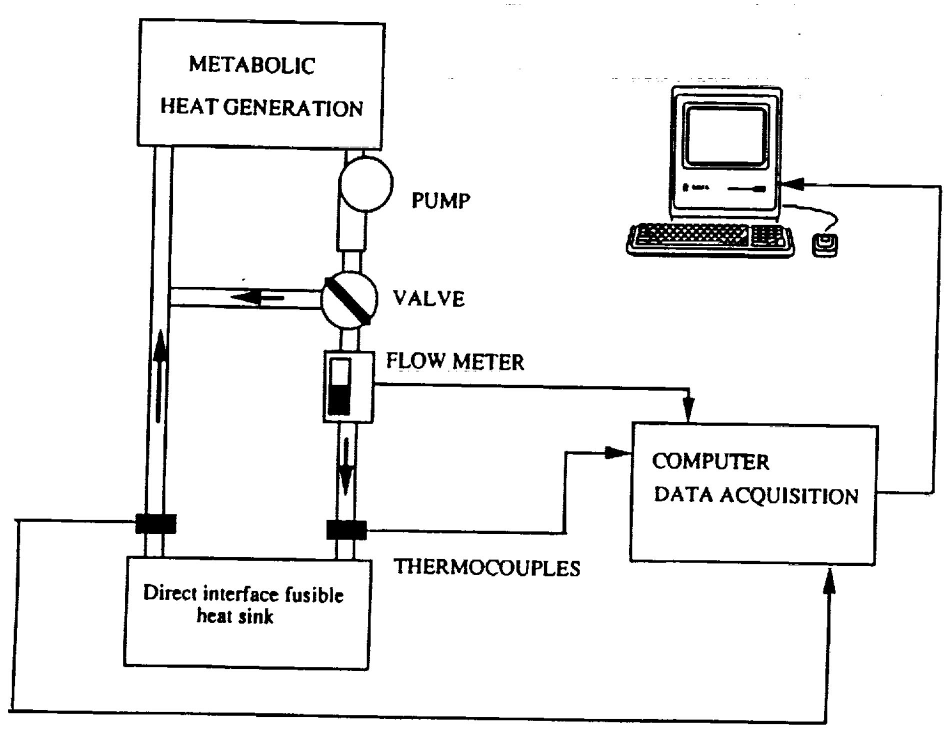
Technical Approach
- Analyze environmental and metabolic requirements for each EVA scenario to determine system requirements
- Create and evaluate new concepts for:
  - thermal energy acquistion
  - heat transport through the system
  - heat rejection to the environment
  - heat storage within the system
- Conduct proof-of-concept experiments and tests as required to verify the concepts
- Develop most promising prototypes so that they can be accurately analytically characterized in trade studies
- Select and integrate best candidates into PLSS test beds

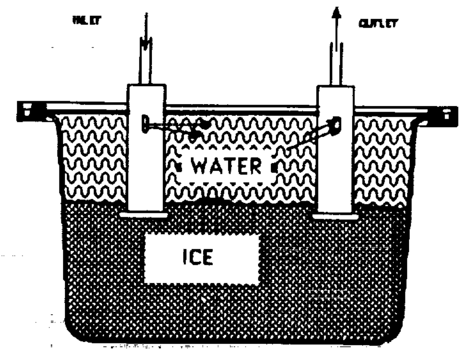
Implementation
- Continue in-house and university program
- R&D contracts to develop and refine prototypes

Status/Milestones
- Report on promising heat storage materials - FY92
- Report on promising concepts for heat rejection - FY92
- Complete proof of concept testing of 0-g fusible heat sink prototype - FY93

Plans
- Initiate competitive procurement of advanced heat sink - FY93

Principal Investigator: Curt Lomax (415) 604-3344





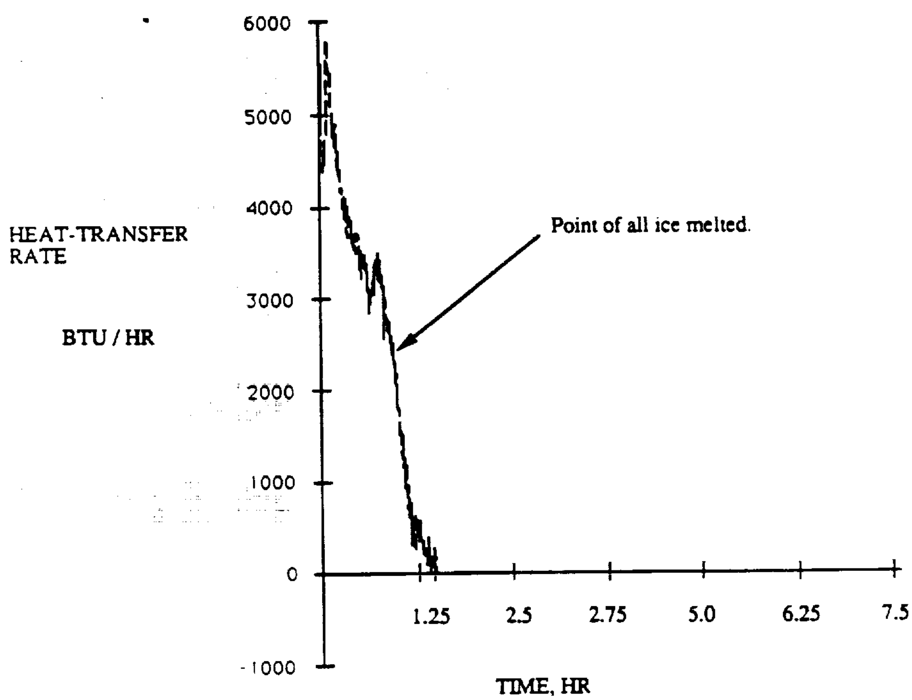
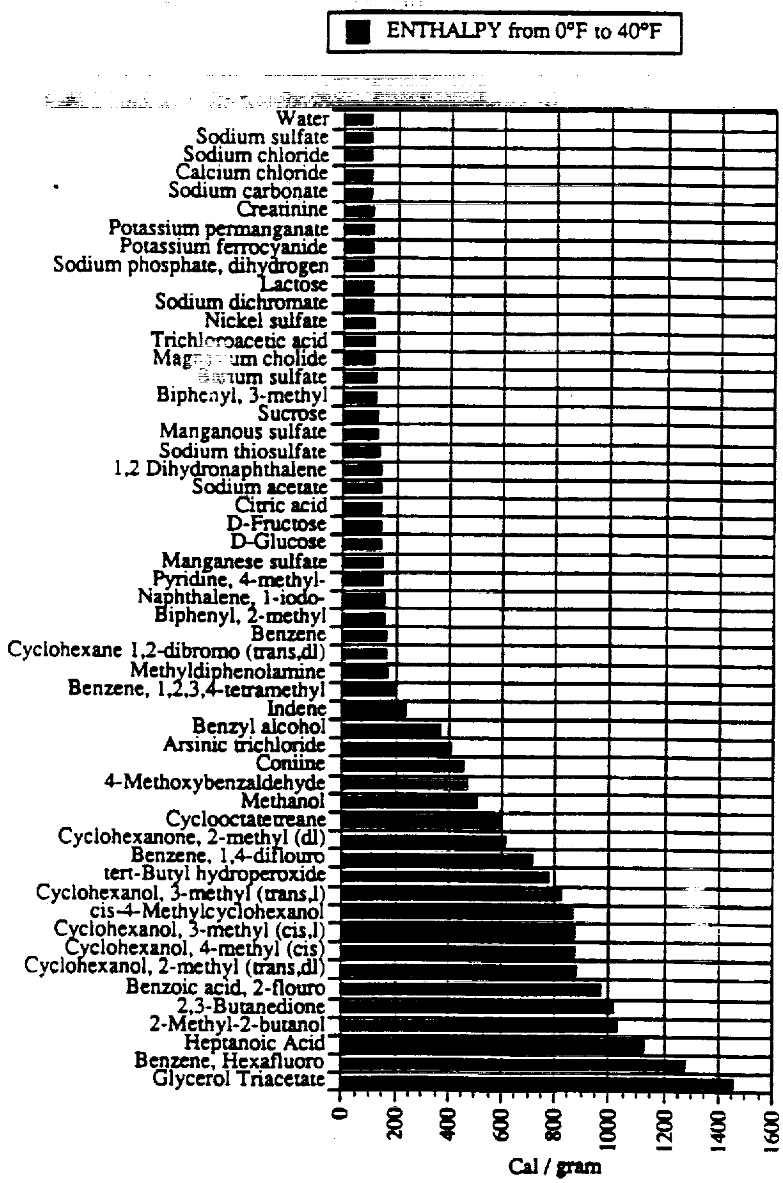


Figure 11

FOURTH PROTOTYPE CONFIGURATION
(CONNECTORS / NO BAFFLES / TURBULENT)



ENTHALPY from 0°F to 40°F
Water
Sodium sulfate
Sodium chloride
Calcium chloride
Sodium carbonate
Creatinine
Potassium permanganate
Potassium ferrocyanide
Sodium phosphate, dihydrogen
Lactose
Sodium dichromate
Nickel sulfate
Trichloroacetic acid
Biphenyl, 3-methyl
Sucrose
Manganous sulfate
Sodium thiosulfate
1,2 Dihydronaphthalene
Sodium acetate
Citric acid
D-Fructose
D-Glucose
Manganese sulfate
Pyridine, 4-methyl-
Naphthalene, 1-iodo-
Biphenyl, 2-methyl
Benzene
Cyclohexane 1,2-dibromo (trans,dl)
Methyldiphenolamine
Benzene, 1,2,3,4-tetramethyl
Indene
Benzyl alcohol
Arsinic trichloride
Coniine
4-Methoxybenzaldehyde
Methanol
Cyclooctatetreane
Cyclohexanone, 2-methyl (dl)
Benzene, 1,4-diflouro
tert-Butyl hydroperoxide
Cyclohexanol, 3-methyl (trans,l)
cis-4-Methylcyclohexanol
Cyclohexanol, 3-methyl (cis,l)
Cyclohexanol, 4-methyl (cis)
Cyclohexanol, 2-methyl (trans,dl)
Benzoic acid, 2-flouro
2,3-Butanedione
2-Methyl-2-butanol
Heptanoic Acid
Benzene, Hexafluoro
Glycerol Triacetate
0
200
400
600
800
1000
1200
1400
1600
Cal / gram

Atmosphere Control (WBS 1.2.2)

Objective
Invent, analyze, develop, and characterize new concepts for EVA atmosphere control

Benefit
Reduced EVA system size and power requirements along with reduction in mass expended per EVA hour

Technical Approach
- Analyze environmental and metabolic requirements for each EVA scenario to determine system requirements
- Create and evaluate new concepts for:
  - removal of contaminants (CO_2, humidity, trace gases) from suit breathing gas
  - oxygen replenishment, pressure regulation, and gas circulation
- Conduct proof-of-concept experiments and tests as required to verify the concepts
- Develop most promising prototypes so that they can be accurately analytically characterized in trade studies
- Select and integrate best candidates into PLSS test beds

Implementation
- Continue in-house and university program
- R&D contracts to develop and refine prototypes
- Current SBIR contract

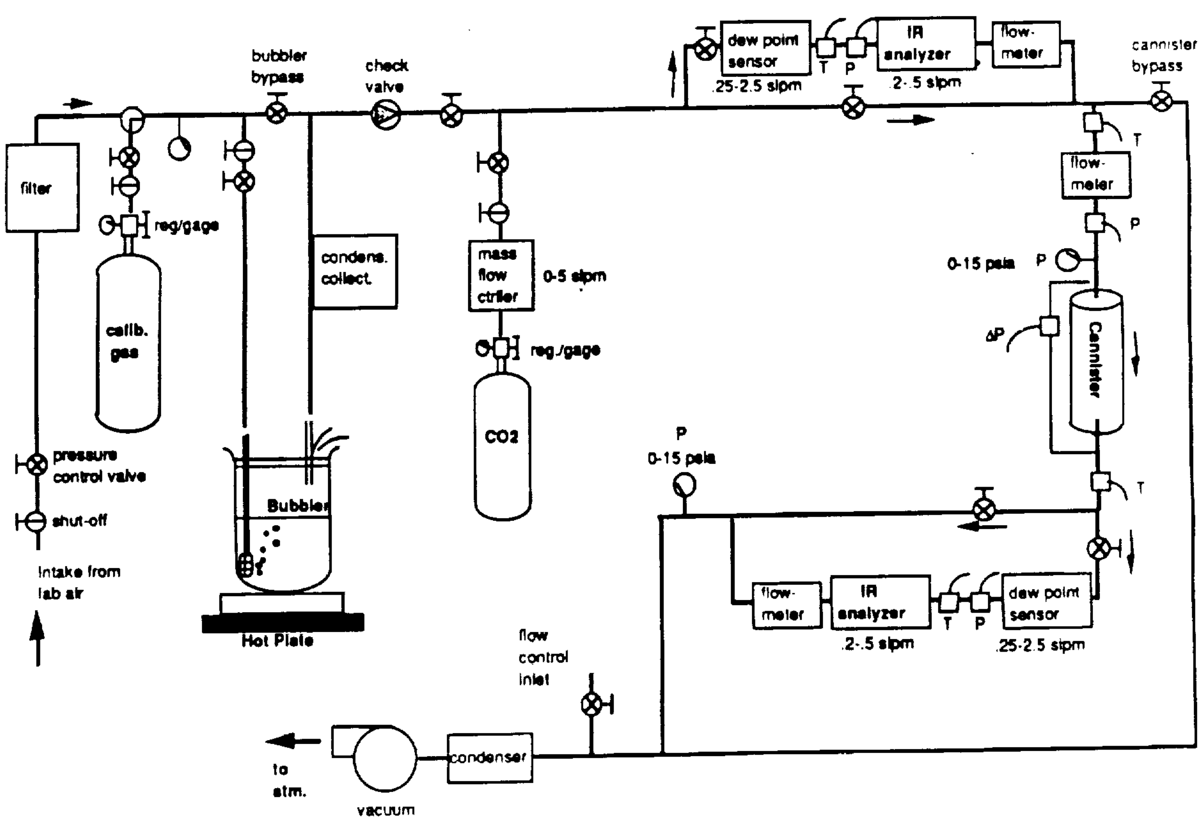
Status/Milestones
- Complete fabrication of test stand for experiments on sorbent bed optimization - FY91
- Report on feasibility of regeneration of LiOH sorbent from products of absorbent reaction - FY91
- Report on experiments to improve sorbent cannister efficiency - FY92

Plans
- Initiate development of integrated pressure control module - FY92
- Initiate studies of use of membranes for CO_2 and humidity control on Mars - FY92

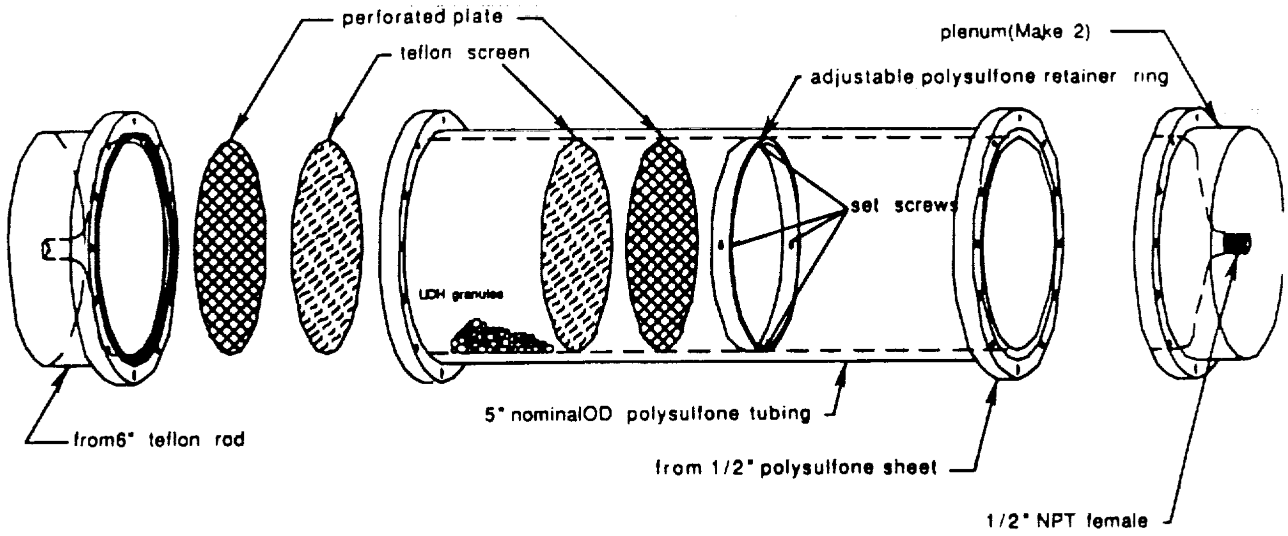
Principal Investigator: Bernadette Luna (415) 604-5250

Full-Size CO2 Cannister Test Stand

Preliminary Design



LiOH Test Cannister Preliminary Design



ExtraVehicular Systems Branch

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Ames Research Center

Electronic Systems and Components (WBS 1.2.3)

Objective
Develop electronic subsystems and components using state-of-the-art architecture and packaging

Benefit
Great increase in EVA astronaut productivity and safety along with reductions in size and power requirements

Technical Approach
- Studies of system requirements
- Determination of electronic system architecture meeting requirements
- Design of EVA information simulator to allow human experiments on optimum display techniques
- Breadboard electronic system using advanced bus architecture
- Conduct experiments integrating inputs from system sensors and outputing display and control information
- Develop and test prototype solid state devices using designs resulting from experiments

Implementation
- In-house analysis and experimental program to define requirements
- Collaboration with other government labs to develop custom solid state devices

Status/Milestones
- Report on advanced EVA electronic system requirements - FY91
- Complete preliminary design of EVA display simulator - FY92
- Report on automatic system concepts using "human performance map" - FY92

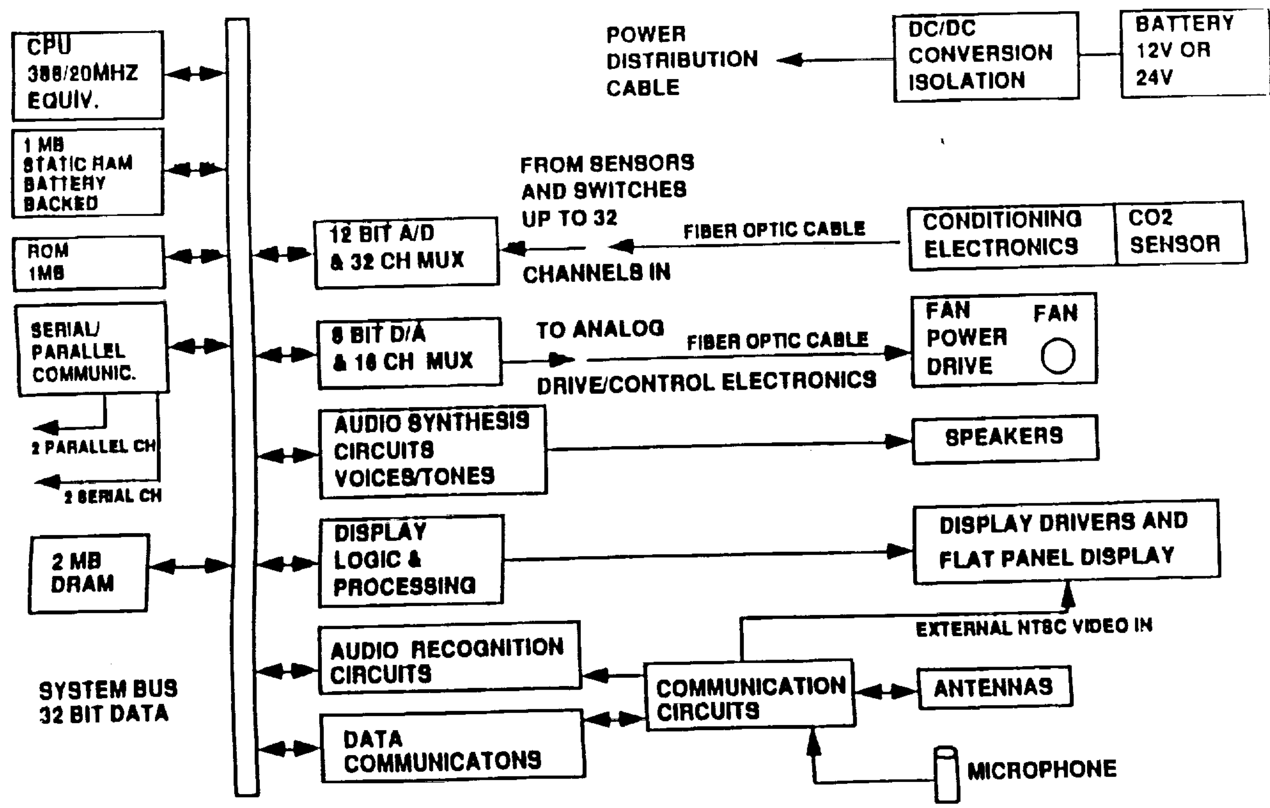
Plans
- Initiate PLSS controls experiments - FY92
- Initiate fabrication of display simulator - FY92
- Initiate human experiments using display simulator - FY94

Principal Investigator: Joe Lavelle (415) 604-6676

ExtraVehicular Systems Branch

ADVANCED ELECTRONICS ARCHITECTURE

NASA
Ames Research Center



ExtraVehicular Systems Branch

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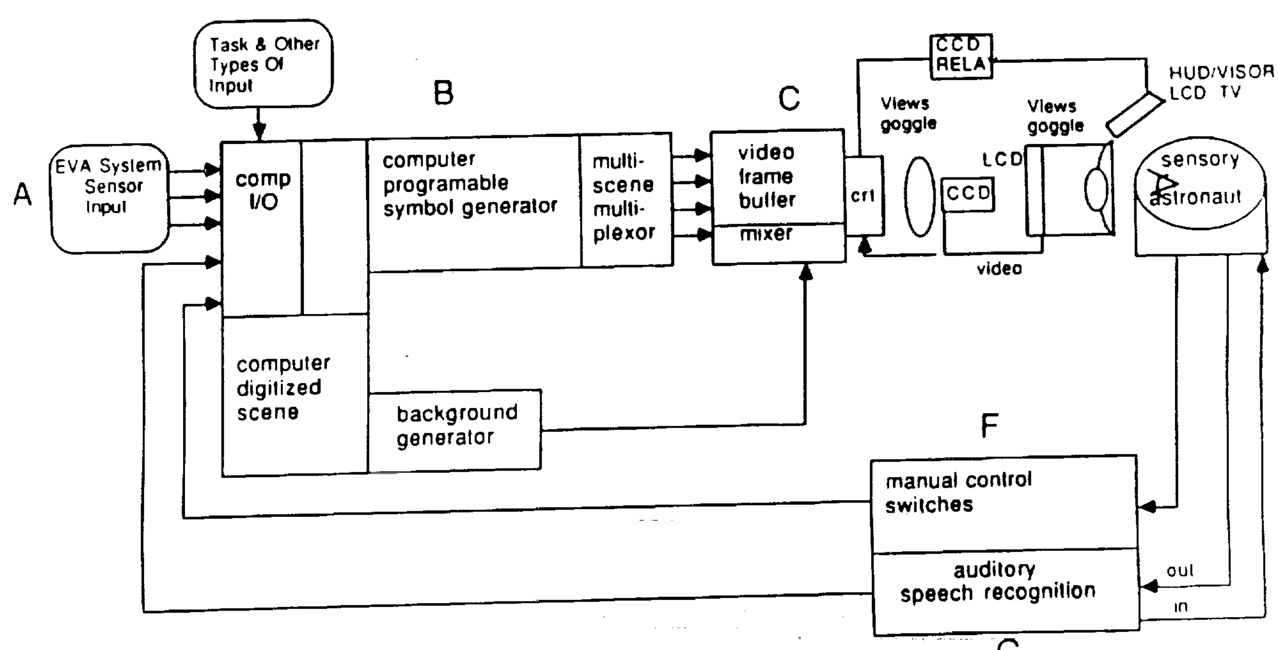
EVA(INFORMATION)DISPLAY SIMULATOR(EVADS)



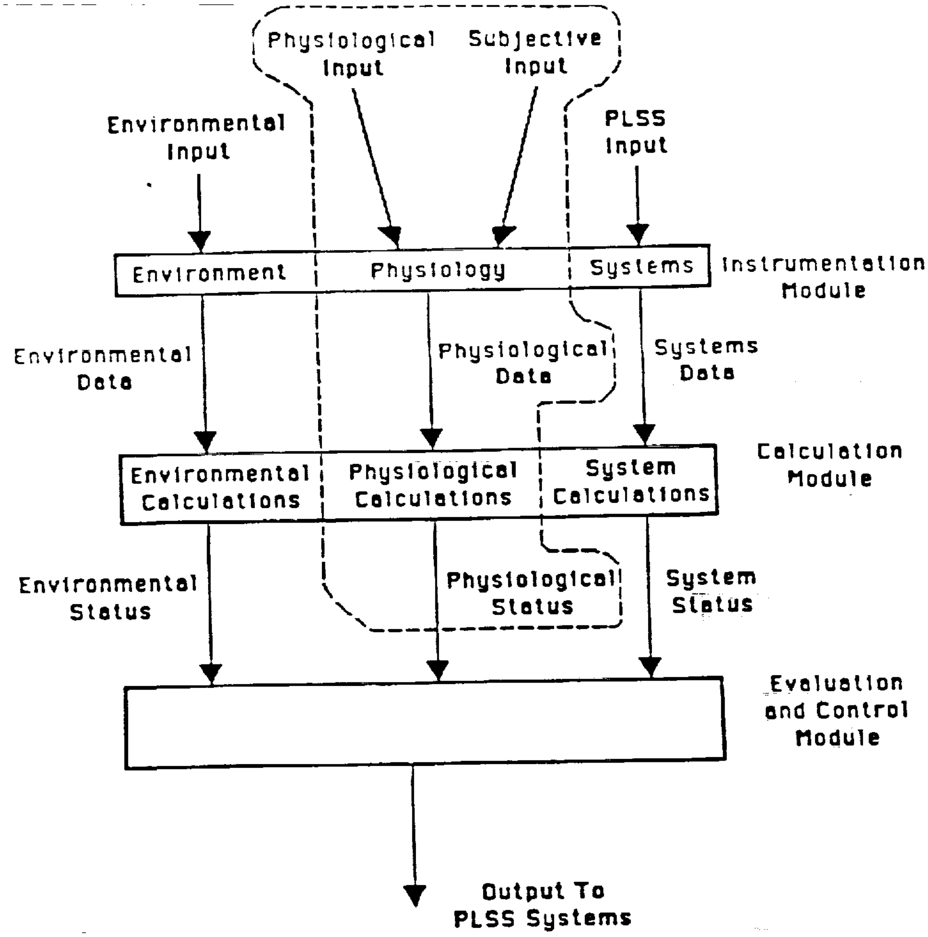


Figure 1 - Conceptual PLSS Controller

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PLSS Integration and Test (WBS 1.2.4)

Objective
Coordinate and integrate efforts in other areas to produce integrated PLSS prototypes

Benefit
Proof-of-concept for advanced PLSS prototypes at reduced cost

Technical Approach
- Use analytical characterization of subsystems to produce and analyze alternative PLSS design concepts
- Produce pereliminary designs of selected PLSS systems
- Decide on optimum approach to fabricate/procure required subsystems
- Assemble and evaluate PLSS prototypes
- Define system support and integration requirements

Implementation
- In-house and contractor analysis and fabrication of protype systems

Status/Milestones
- Report on results of studies of advanced 0-g PLSS concepts - FY92

Plans
- Initiate fabrication of integrated advanced PLSS - FY94
- Complete fabrication and initiate evaluation testing - FY96

Principal Investigator: Doug Smith (415) 604-6728

ExtraVehicular Systems Branch

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Pressure Suit Technology (WBS 1.3.1)

Objective
Develop suit materials, mobility joint, and fabrication technologies for Exploration missions

Benefit
Increase human productivity and enable EVA to become a safe, routine resource for Exploration missions

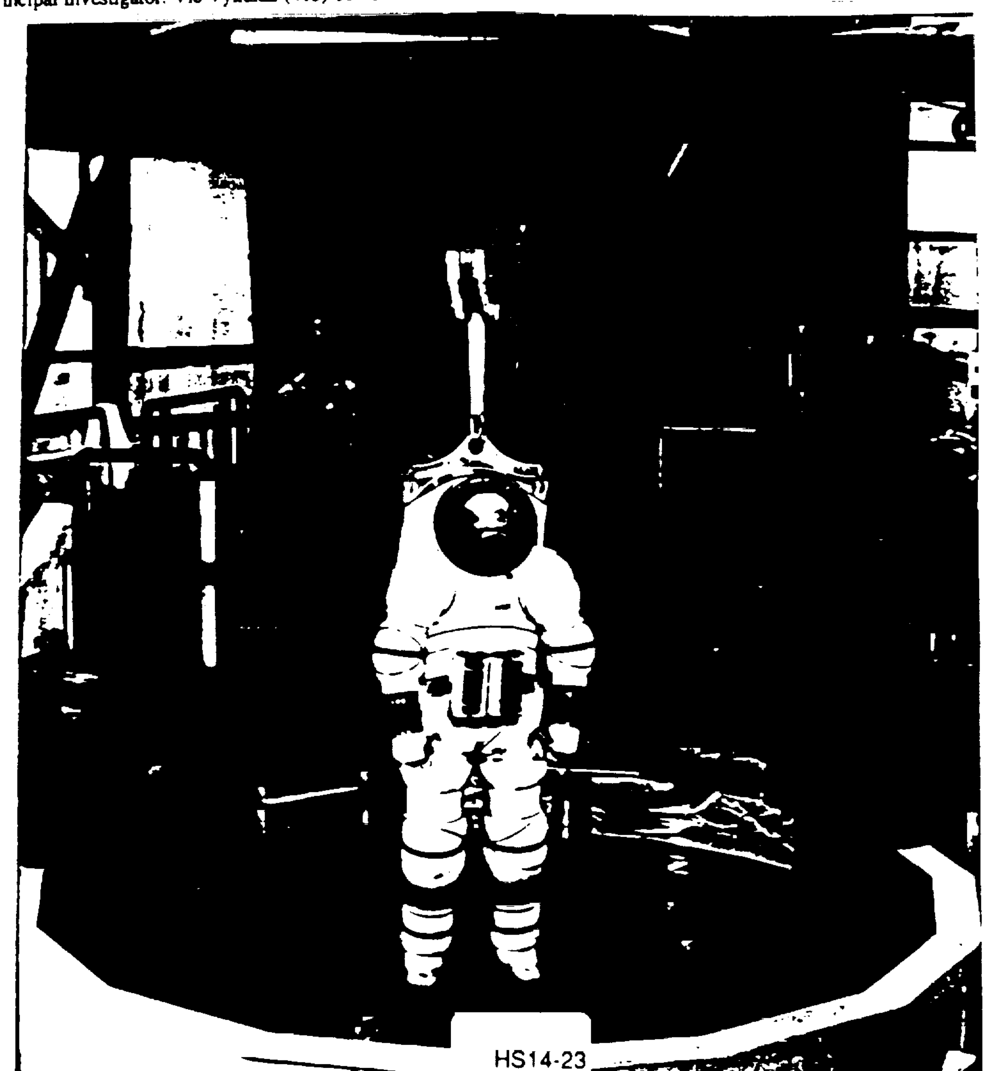
Technical Approach
- Emphasize use of advanced materials for suit weight reduction and increased durability
- Develop families of mobility joints to provide minimum operating forces at any chosen suit pressure
- Utilize results from biomechanics experiments and EVA scenarios to determine suit configuration concepts

Implementation
- In-house design and evaluation testing
- Fabrication and materials work done on contract and grant/cooperative agreement

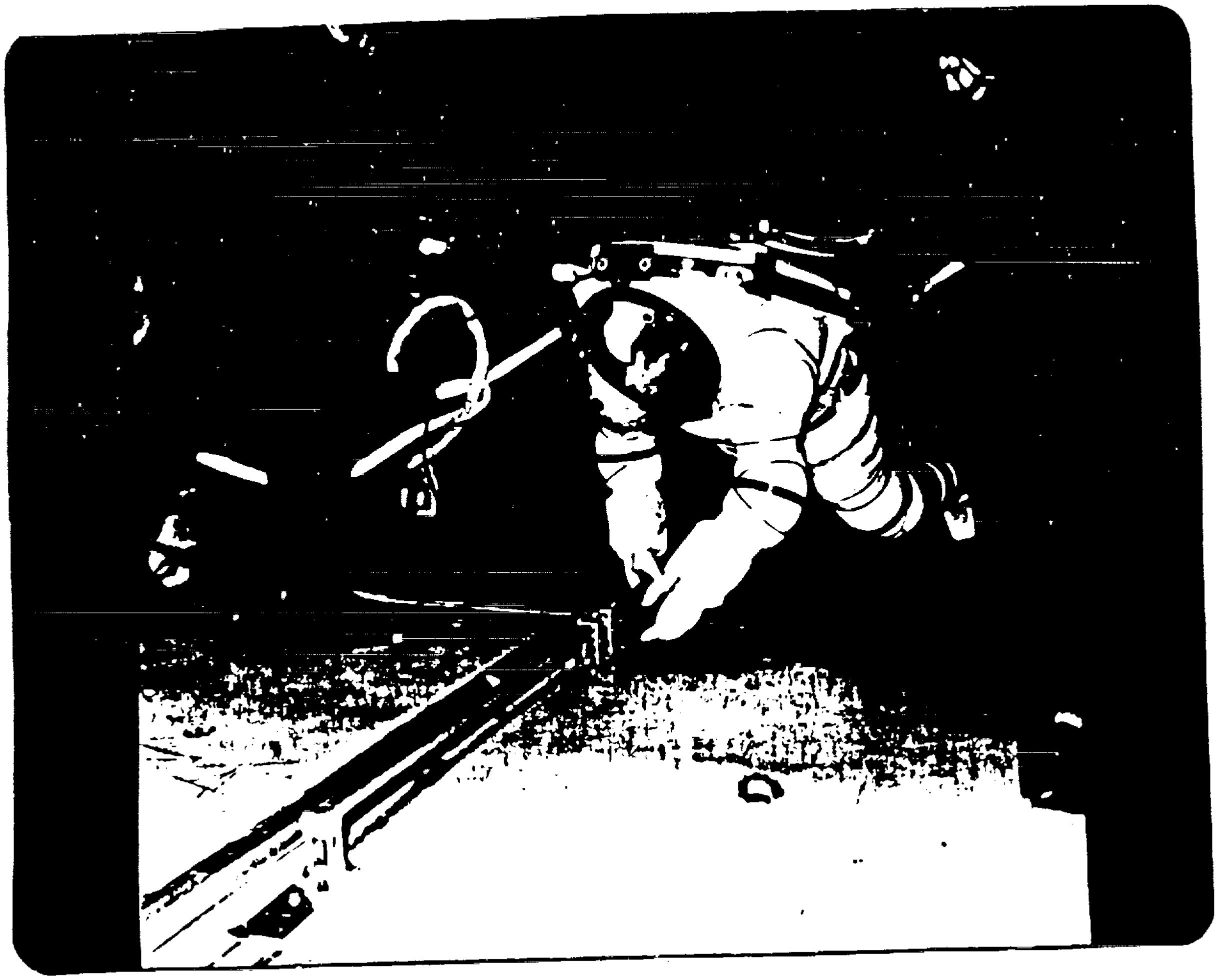
Status/Milestones
- Light weight suit element completed - FY 92
- Planetary suit configuration selection - FY 95

Plans
- Initiate design of light weight suit element - FY91
- Begin fabrication of advanced mobility joints - FY93

Principal Investigator: Vic Vykukal (415) 604-5386



HS14-23



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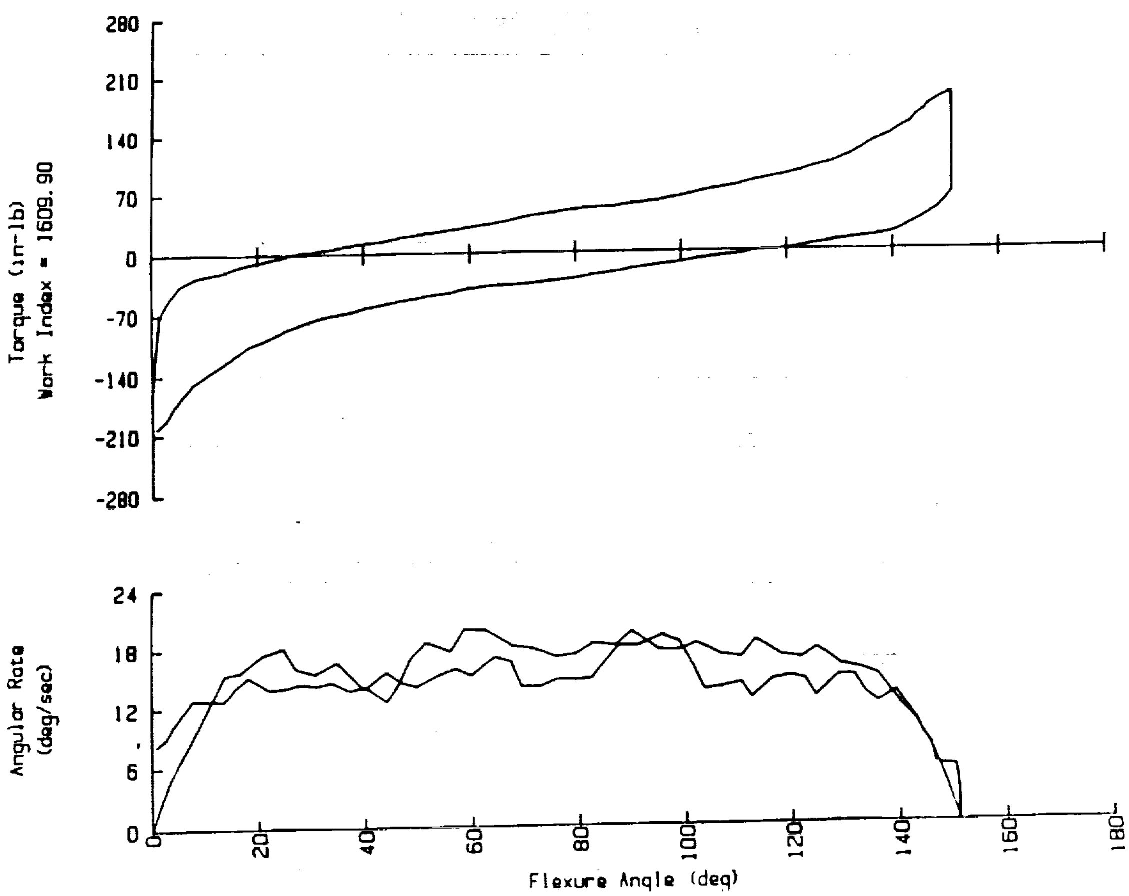
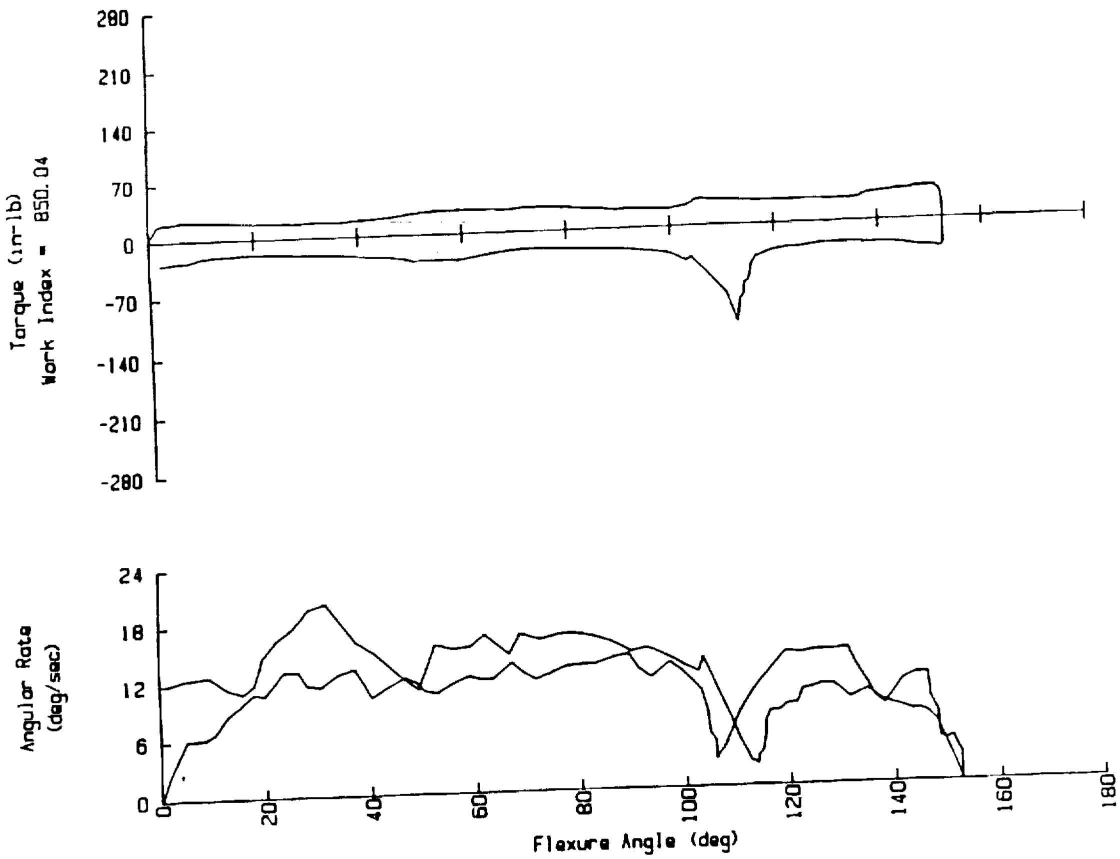
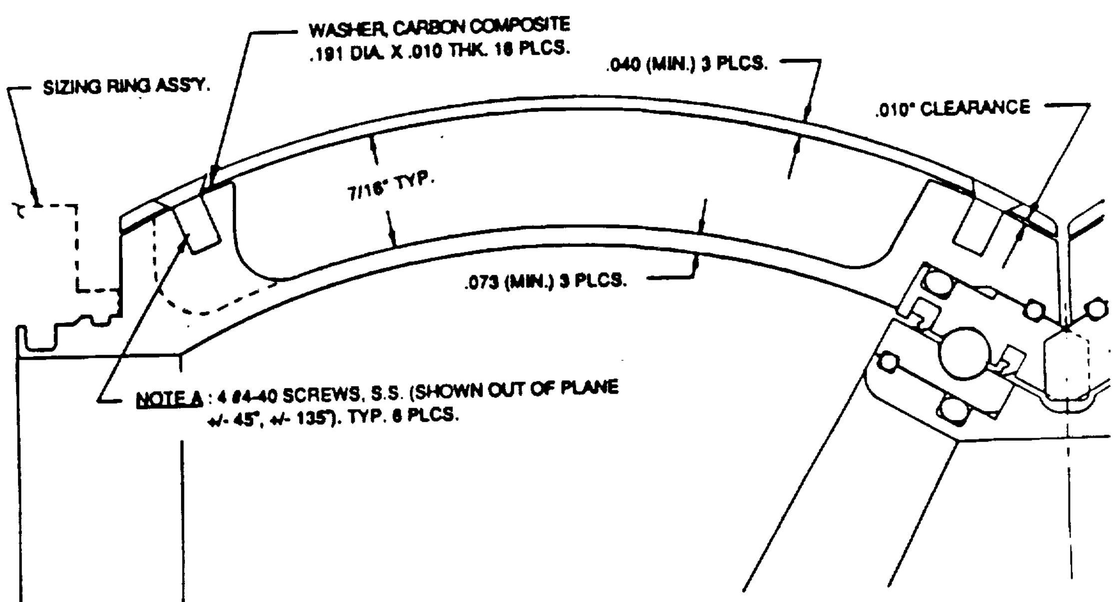


HS14-24

ASOD1



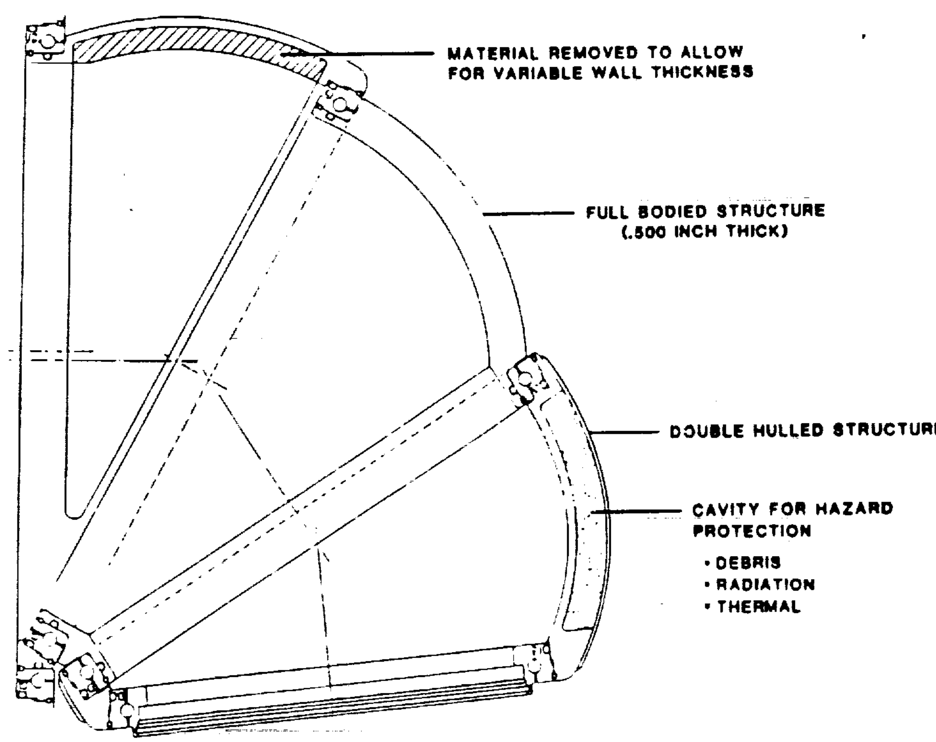


AX-5 ELBOW JOINT

STRUCTURAL DETAIL

AMES AX-5 HARD SPACE SUIT

STRUCTURAL OPTIONS



SHOULDER JOINT CONSTRUCTION
TYPICAL FOR ALL JOINTS

Glove & End Effector Technology (WBS 1.3.2)

Objective
Develop glove and end effector concepts, materials, and fabrication technologies to enable highly capable hand performance at any desired suit pressure

Benefit
Increased EVA productivity at any desired suit pressure

Technical Approach
- Gloves
  - Initially concentrate on materials and fabrication techniques
  - Longer term, develop innovative concepts for gloves

- End-effectors
  - Complete fabrication of existing designs for 1,3, and 6 degree of freedom
  - Evaluate current designs in underwater testing
  - Select best approach for additional effort

Implementation
- Materials and fabrication techniques - TBD
- End-effector work in-house

Status/Milestones
- Complete end-effector evaluation and selection - FY95

Plans
- TBD

Principal Investigator: Vic Vykukal (415) 604-5386

AC85-0271-21

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EVA Ancillary Equipment (WBS 1.3.3)

Objective
Develop new concepts for EVA support equipment such as planetary surface airlocks, body restraints, tools, etc

Benefit
Increased EVA productivity with reduced support costs

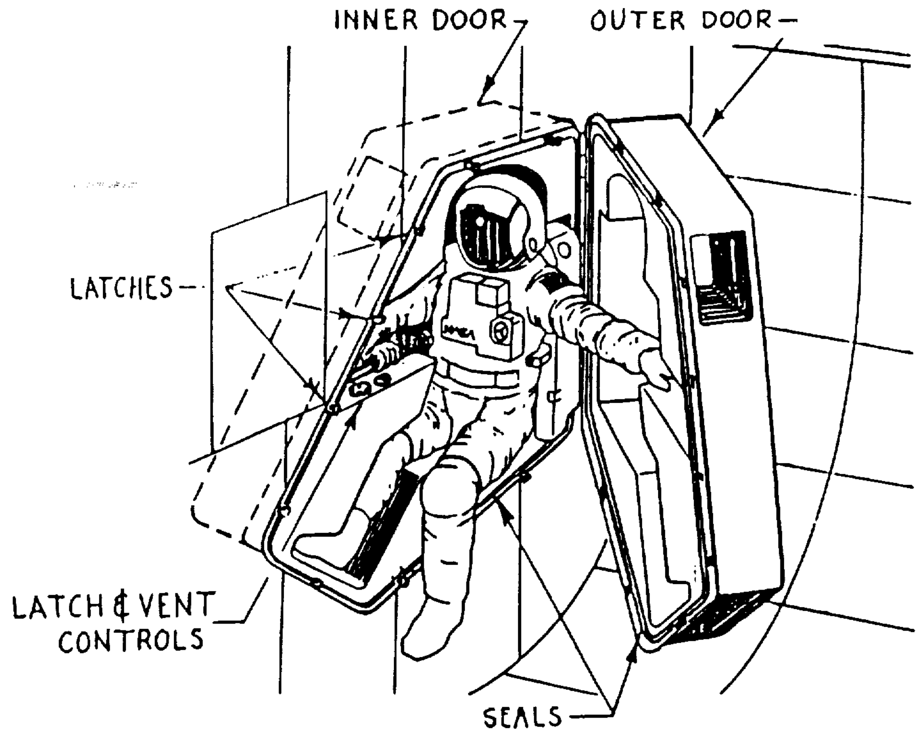
Technical Approach
- Initial plan is to concentrate on airlocks and body restraints
- Fabricate and evaluate mockups of innovative airlock concepts
- Fabricate and evaluate restraint concepts in NBTF

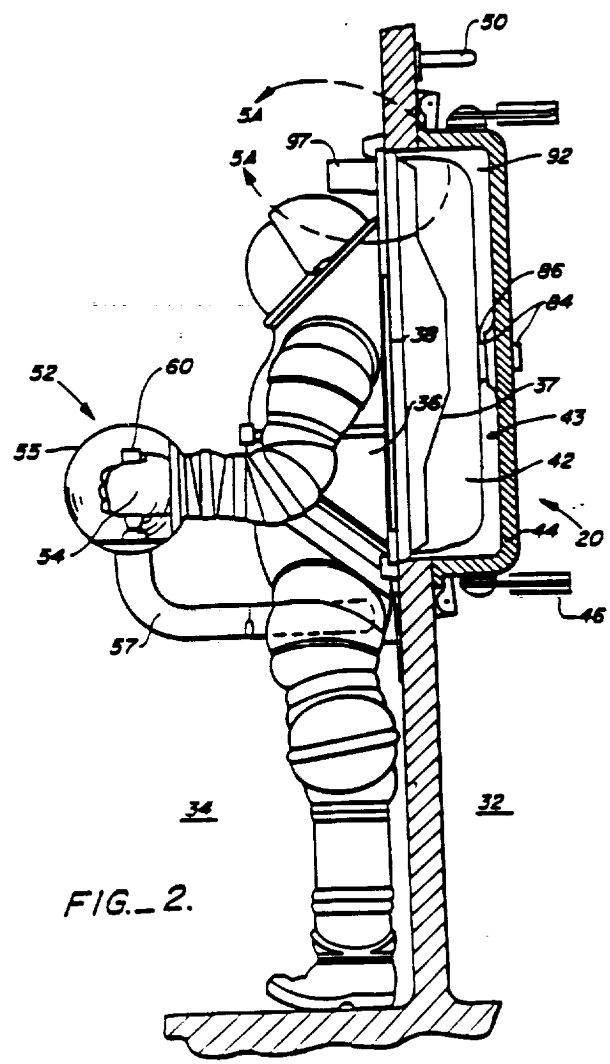
Implementation
- In-house

Status/Milestones
- Report on restraint concept evaluation - FY93
- Report on airlock concept evaluation - FY94

Plans
- Select planetary surface airlock concept(s) for mockup fabrication - FY92
- Complete fabrication of mockups - FY93

Principal Investigator: Phil Culbertson (415) 604-3345
Vic Vykukal (415) 604-5386


INNER DOOR
OUTER DOOR
LATCHES
LATCH & VENT
CONTROLS
SEALS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5A
97
5A
92
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FIG._2.

Suit System Integration & Test (WBS 1.3.4)

Objective
Assemble proof of concept prototype suits and evaluate against scenario requirements

Benefit
Final proof of suit concept's ability to perform required tasks

Technical Approach
- Fabricate prototype suits
- Test performance against requirements derived from design scenarios
- Refine prototypes based on lessons learned during testing

Implementation
- TBD

Status/Milestones
- Planetary suit demonstrator completed - FY98

Plans
- Begin fabrication of planetary suit prototype - FY95

Principal Investigator: Vic Vykukal (415) 604-5386

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Hardware/Software Integration (WBS 1.4.1)

Objective
Coordinate all subsystem elements to produce integrated EVA work system prototype

Benefit
Proof of overall system concept in realistic environment

Technical Approach
- Early definition of subsystem and system requirements
- Definition of hardware and software interfaces
- Definition of reliability and fault analysis requirements
- Creation of hardware and software interfaces
- Definition of test procedures and integrated system test beds

Implementation
TBD

Status/Milestones
No effort planned until FY 94

Plans
TBD

Principal Investigator: TBD

Systems Test (WBS 1.4.2)

Objective
Demonstrate that prototype integrated EVA work systems meet the design reference scenario requirements

Benefit
Cost effective proof of integrated system concepts

Technical Approach
- Develop integrated systems test plan
- Define and develop test facilities and equipment
- Perform integrated system tests
- Test and refine prototypes through OAET Technology Level 6-System Validated in Relevant Environment

Implementation
TBD

Status/Milestones
No effort planned until FY 94

Plans
TBD

Principal Investigator: TBD

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System Logistics & Support (WBS 1.4.3)

Objective
Consider and develop appropriate logistics and support technologies for prototype EVA work systems

Benefit
Early consideration of logistics and system supportability may affect choice of subsystem technology for development

Technical Approach
- Define and develop diagnostic approaches for candidate systems
- Analyze and define servicing and maintenance requirements and systems
- Define and develop inventory management and resupply approaches
- Define and develop an approach to supportability information management
- Consider and define specialized training requirements for candidate systems

Implementation
TBD

Status/Milestones
TBD

Plans
Approach for development of logistics analytical tools will be defined starting in FY 92-93

Principal Investigator: TBD