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Strategic Research to Enable NASA's Exploration Missions Conference

Cleveland, 22-24 June, 2004

Human Support Technology

Research, Development & Demonstration

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A Journey to Inspire, Innovate, and Discover

- The Human Support Technology research, development, and demonstration program addresses the following areas at TRL 1 through 6:
  - *Advanced Power and Propulsion*
  - *Cryogenic fluid management*
  - *Closed-loop life support and Habitability*
  - *Extravehicular activity systems*
  - *Scientific data collection and analysis*
  - *Planetary in-situ resource utilization*

Human Support Technology Program
Overview

Program Goal

- Our single purpose is to **reduce the human support systems' development risks to an acceptable level**
  - The risks we address are documented in the Bioastronautics Critical Path Roadmap and fall into three categories:
    - *Risks to the safety and health of the crew and mission success due to the hazardous environment, autonomy, and isolation*
    - *Risks to the affordability of the missions by requiring excessive logistical support for the humans in terms of buffers, critical system resources, and non-regenerative supplies*
    - *Risks to the human support systems in terms of the 'ilities' (operability, reliability, maintainability, etc.)*
  - Each risk is further characterized by research enabling questions (Bioastronautics Critical Path Roadmap - BCPR)

- Acceptable mitigation through development of products that answer the enabling questions is required for all of the types of risks

NASA/CP—2004-213205/VOL1

Human Support Technology Program

BCPR Risks relevant to HST

	AHST Risk Rating Criteria for System Performance Risks
Rating	
R	Considerable potential for improvement in efficiency in many areas, or proposed missions may be infeasible without improvements.
Y	Considerable potential for improvement in efficiency in a few areas
G	Minimum or limited potential for improvement in efficiency.

RISK NUMBER	Theme	Discipline	Risk Category	ISS (1yr)	Moon (30d)	Mars (30m)
7	HHC	Env Health	Define Acceptable Limits for Trace Contaminants in Air and Water			
29	BH&P	SHFE	Mismatch between Crew Cognitive Capabilities and Task Demands			
36	AHST	AEMC	Monitor Air Quality	Y	R	R
37	AHST	AEMC	Monitor External Environment	Y	R	R
38	AHST	AEMC	Monitor Water Quality	Y	R	R
39	AHST	AEMC	Monitor Surfaces Food and Soil	Y	R	R
40	AHST	AEMC	Provide Integrated Autonomous Control of Life Support Systems	G	Y	R
41	AHST	AEVA	Provide Space Suits and Portable Life Support Systems	G	Y	R
42	AHST	AFT	Maintain Food Quantity and Quality	Y	G	R
43	AHST	ALS	Maintain Acceptable Atmosphere	G	Y	R
44	AHST	ALS	Maintain Thermal Balance in Habitable Areas	G	Y	R
45	AHST	ALS	Manage Waste	G	Y	R
46	AHST	ALS	Provide and Maintain Bioregenerative Life Support Systems	G	Y	R
47	AHST	ALS	Provide and Recover Potable Water	G	Y	R
48	AHST	AHST	Inadequate Mission Resources for the Human System	Y	R	R
49	AHST	SHFE	Mismatch between Crew Physical Capabilities and Task Demands	G	Y	R
50	AHST	SHFE	Mis-assignment of Responsibilities within Multi-agent Systems	Y	Y	R

Human Support Technology Program

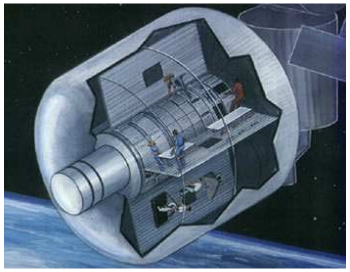
Research and Development Content

AHST

- *ADVANCED ENVIRONMENTAL MONITORING & CONTROL*
- *EXTRA-VEHICULAR ACTIVITIES TECHNOLOGY*
- *ADVANCED LIFE SUPPORT*
- *ADVANCED INTEGRATION MATRIX*
- *SPACE HUMAN FACTORS*

PSR

- CONTINGENCY RESPONSE TECHNOLOGIES
  - FIRE PREVENTION, DETECTION, AND SUPPRESSION
  - IN-SITU FABRICATION AND REPAIR
- In Situ RESOURCE UTILIZATION for HUMAN SUPPORT
- LOW-GRAVITY and EXPLORATION RESEARCH
  - ADVANCED MATERIALS RESEARCH
  - QUANTUM TECHNOLOGIES for EXPLORATION
  - MULTIPHASE FLOW TECHNOLOGIES



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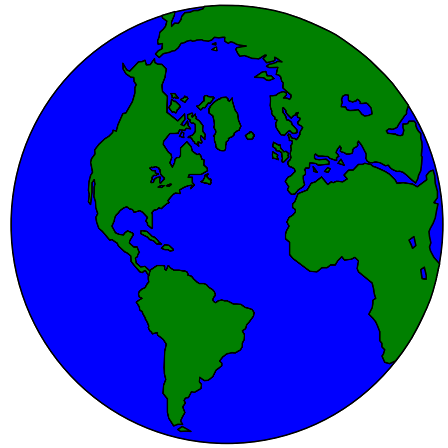
Advanced Life Support



- Duplicate the functions of the Earth in terms of human life support
- Without the benefit of the Earth's large buffers --- oceans, atmosphere, and land masses

- Question is one of how small can the requisite buffers be and yet maintain extremely high reliability over long periods of time in a hostile environment
- Space-based systems must be small, therefore must exercise high degree of control
- Long-duration missions dictate regenerative systems --- minimize re-supply

Parameters for Human Life Support Across Mission Scenarios

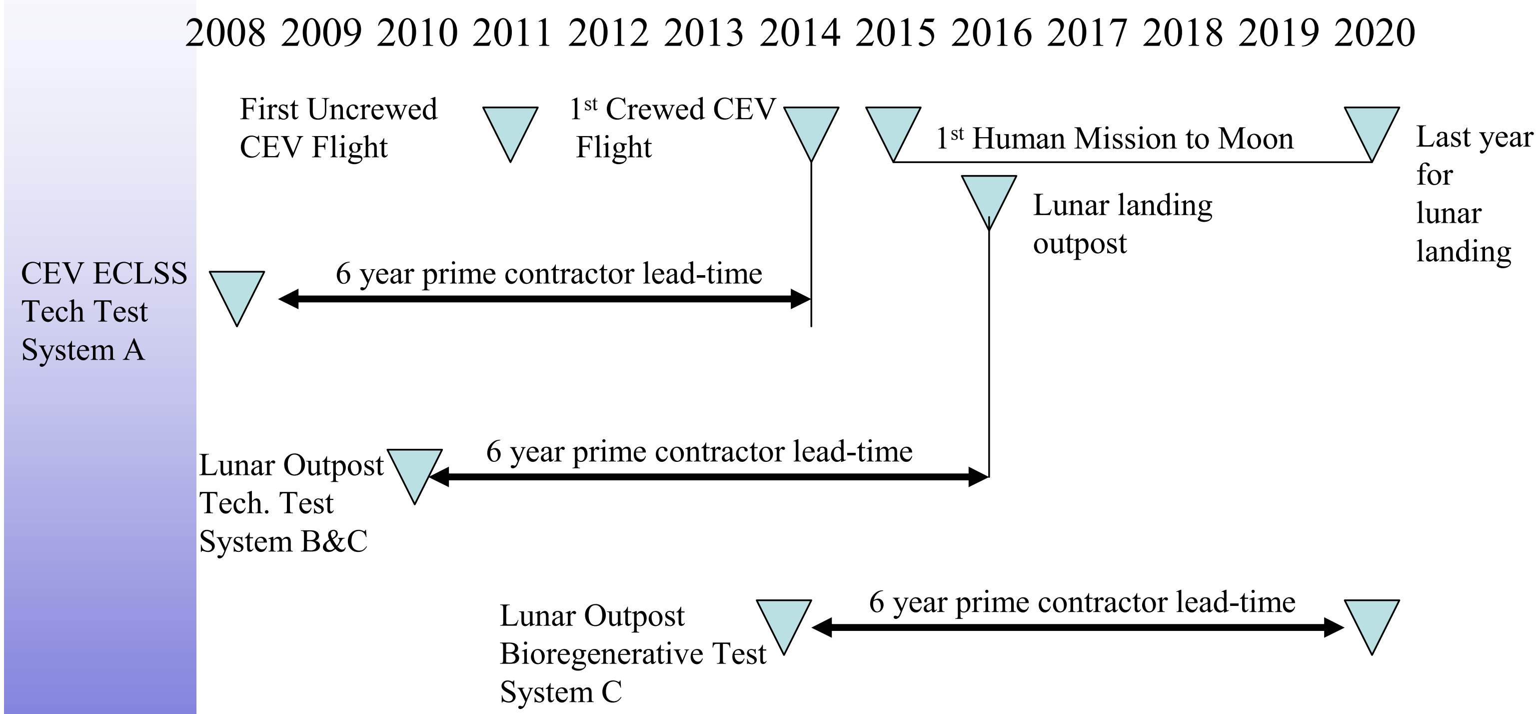
	Lunar Transit Vehicle (LTV)	Lunar Landing Vehicle (LLV)	Lunar Outpost (LO)	Mars Transit Vehicle (MTV)	Mars Landing Vehicle (MLV)	Mars Habitat (MH)	Pressurized Rover (PR)
Duration (Human Tended)	7 – 14 days (Roundtrip)	1 – 5 days	1 – 18 months	12 – 24 months (Roundtrip)	1 – 45 days	17 – 20 months	1 – 7 days
Air Revitalization	Open	Open	Closed	Closed	Open	Closed ISRU	Open
Water Recovery	Collection and Storage	Collection and Storage	Closed ISRU	Closed	Collection and Storage	Closed ISRU	Collection and Storage
Waste Management	Stored	Stored	Volume Reduction Mineralization Stabilization Resource Recovery	Volume Reduction Stabilization De-watering	Volume Reduction Stabilization	Volume Reduction Mineralization Stabilization Resource Recovery	Stored
Food Systems	Conventional Stored	Conventional Stored	Conventional Stored with Fresh Food Augmentation	Extended Shelf Life with Fresh Food Augmentation	Extended Shelf Life	Extended Shelf Life with Fresh Food Augmentation	Extended Shelf Life
Thermal Systems	LP-BR	LP-DR	HP-DR	HP-DR	LP-BR	HP-DR	LP-BR
System Configuration	System A	System A	System C	System B	System A	System C	System A

Closed Air is 75% by Mass
Closed Water is 90% by Mass
ISRU –Investigate and utilize as appropriate
Regenerative Systems will be selected over consumable systems

LP – Low Power HP – High Power
BR – Body Mounted Radiator
DR – Deployable Radiator

System A: Short-duration, micro-g
System B: Long-duration, micro-g
System C: Long-duration, planetary surface, partial-g

Exploration Timeline



Life Support Requirements
Mass Breakdown
(Per Person-Day)

DAILY INPUTS - NOMINAL

	kg
Oxygen	0.84
Food Solids	0.62
Water in Food	1.15
Food Prep Water	0.79
Drink	1.62
Hand/Face Wash Water	1.82
Shower Water	5.45
Clothes Wash Water	12.50
Dish Wash Water	5.45
Flush Water	0.50
TOTAL	30.74

5.02 - 30.74 kg per person-day

11.3 Metric Tons Per Person-Year

DAILY OUTPUTS - NOMINAL

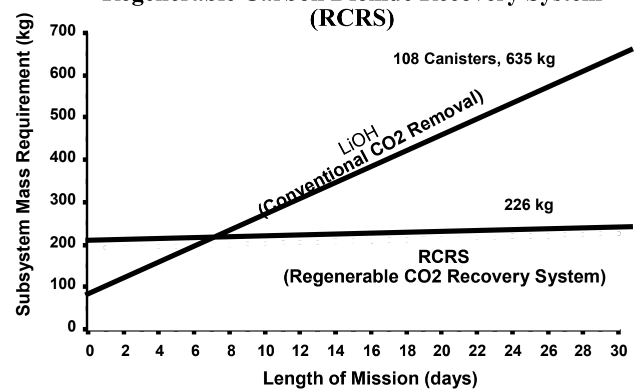
	kg
Carbon Dioxide	1.00
Respiration and Perspiration Water	2.28
Urine	1.50
Feces Water	0.09
Sweat Solids	0.02
Urine Solids	0.06
Feces Solids	0.03
Hygiene Water	6.68
Clothes Wash Water	11.90
Clothes Wash Latent Water	0.60
Other Latent Water	0.65
Dish Wash Water	5.43
Flush Water	0.50
TOTAL	30.74

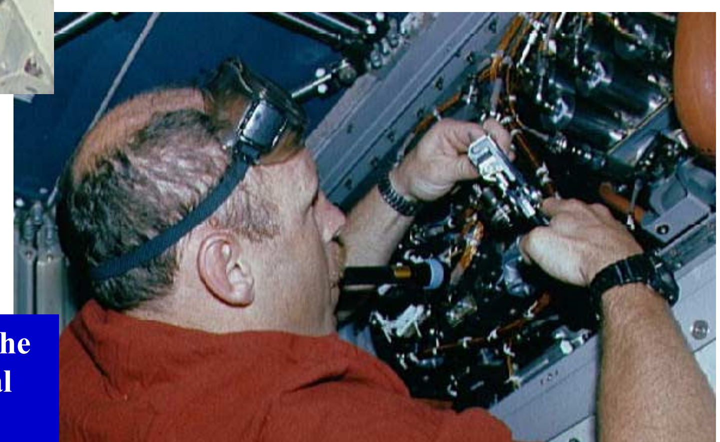
NASA/CP—2004-213205/VOL1

Advanced Life Support

Commander Lousma replaces
ARS LiOH
canisters on middeck
S82-28921 03/31/82

Mass Savings Using a Regenerative Physicochemical Subsystem: Shuttle Regenerable Carbon Dioxide Recovery System (RCRS)





Mission Pilot Ken Bowersox repairing the Regenerative Carbon Dioxide Removal System wiring.
07/09/92 STS050-20-012

Drivers for Water Purification Technologies:

Closure

- Recovery projected to be 80 % of the recycled water. Water recovery from brine essential.

Power

- Current baseline is power consuming.

Expendables

- ISS system will require ~ 400 kg filters/year

Variable Gravity Compatibility

- ***Fluids management issues pertinent to system performance in variable gravity***

Advanced Environmental Monitoring & Control (AEMC)

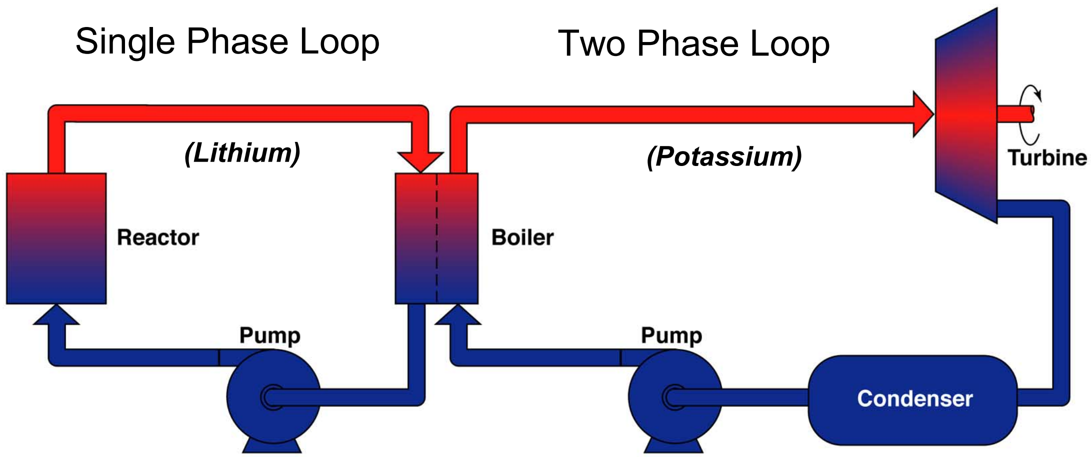
Goals and Objectives

- **Intelligent Monitoring and Control of Life Support Systems through focused system analysis, simulation and transport modeling**
- **TRL 6 Sensor Technologies for human health and process control:**
  - Internal (I), for micro and/or reduced gravity environments :
    - **Sample Acquisition and Handling optimized for multiphase (i.e., gas, liquid, solid) behavior**
    - **Monitoring Air, Water, Surface, Food and Soil Quality**
    - **Monitoring Air, Water, Surface, Food and Soil Microbial Safety**
  - External (E) EVA and/or on Planetary Surfaces environment hazards monitoring (e.g., reactive chemicals, erosive dust)
  - I/E Hardware/Software Diagnostic Signatures (leakage, acoustic signals) for Replacement or Repair
  - I/E Particulates and Leak detection
- **Tools for establishing Exploration Chemical/Microbial requirements**
  - Contamination acceptability limits and monitoring requirements
- **Miniaturization to reduce mission resource requirements**
  - Maintain high capabilities and sensitivities, while simplifying for robust design

Advanced Extravehicular Activity

- EVA is required for all phases/spirals of the Vision, both in-space and planetary
- Supporting the human outside the protective environment of the vehicle or habitat requires an integrated EVA System
- A new EVA suit/system will be required to support this new initiative
  - The current EVA suit is over 25 years old and is facing significant obsolescence issues
  - The current EVA suit is not compatible with the planetary environments of either the Moon or Mars and does not support the logistical requirements of long term missions
- Development of a new EVA suit/system requires technology advancements similar to those required in the development of a new space vehicle

Strategic Research for Space Exploration
Two Phase Flow Facility - TΦFFy

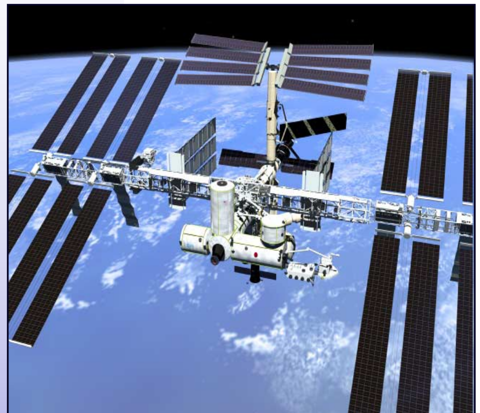


Schematic Diagram of Two-Fluid, Liquid Metal Rankine Power Conversion System

The TΦFFy Project will conduct a robust research program to address microgravity fluid physics issues associated with Flow Boiling, Condensation, Phase Separation, and System Stability of the liquid metal-based Rankine Power Conversion Systems. The project will include concept development and normal gravity testing, reduced gravity aircraft flight campaigns and flight experiment definition and development.

NASA/CP—2004-213205/VOL1

In-Situ Resource Utilization Technologies for Mars Life Support



Self-Sufficiency Options for Life Support

Complete regeneration
No leaks
Total closure (100%)

Relatively relaxed closure and leakage requirements, reliance on local resources (ISRU)

Design Drivers are
- **Reduced mass and power**
- **Increased safety and reliability**

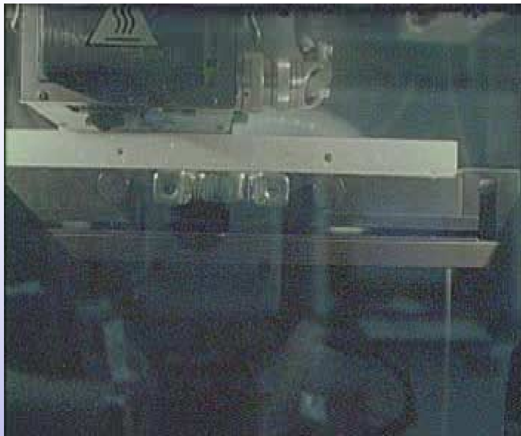
Fire Prevention, Detection, and Suppression

- Prevention is the first line of defense against fires in any vehicle design
  - Crew Exploration Vehicle, Habitat, EVA systems
- Acceptance criteria for material flammability in reduced gravity is generally unknown
  - Current methods are *thought* to be conservative but …
  - Margin of safety is unknown and varies with gravity level
  - Over-design based on presumed material flammability increases system mass
- Material flammability risks must be considered in the selection of atmospheres for exploration vehicles and habitats
- False positive (nuisance) alarms on ISS require crew action and reduce confidence in fire detection and suppression (FDS) system
- Spacecraft fire suppression and response based on terrestrial experience and techniques
  - Limited incorporation of fire characteristics in reduced gravity
- Suppressant effectiveness for reduced gravity fire scenarios hasn't been quantified

- Material flammability assessment requirements are written into vehicle specifications
- Performance of advanced detection and suppression systems is insufficient for down-select/design using relevant low- and partial-gravity data

In Situ Freeform Fabrication Technologies

Fused Deposition Modeling



ABS
PC
PPSF
Al2O3
Si3N4

(MSFC)

Electron Beam Freeform Fab

Aluminum
Titanium
Alloys

Ti-6Al-4V

(LaRC/JSC)

In Situ SFF Deliverables

Project Plan Summary	Collaborators	FY '05	FY '06	FY '07	FY '08	FY '09	FY '10
Fabrication Technologies							
A. Combustion Synthesis Parts and Tools for	GRC, Purdue Univ, Col School of	▼ TRL 4	◆ Optimize Design	◆ Ceram/ Glass	◆ Prototype	◆ KC-135 Demo	▼ TRL 6
B. Electron beam Freeform Fabrication	LaRC, JSC	▼ TRL 3	◆ KC-135 Demo	◆ Portability	◆ Lrg Struc Repair	▼ TRL 5	

Self-Propagating High-Temp Synthesis

Refractory carbides, borides, silicides, inter-metallics, composites, FG mat'ls

Initial Mixture

Propagating Wave

Product

(GRC)

How will we conduct our Business?

- Low TRL work through competitive NRAs
  - Long lead time items
- Rapid Technology Development Teams
  - Multi-disciplinary teams with clear objectives and deliverables
  - Mature technology to TRL 6
- Directed Research
  - Focused problems

There will be a healthy balance between intramural and extramural work.

Milestoneplan

S:	Separator
D:	Data System
K:	Chemistry
C:	Collaboration

Project nmbr.	
Project	Rapid Development of ISS Water Quality Sensors
Project code	
Project manager	
Milestoneplan name	Milestone Plan
Responsible	Supervisor
Approved by	

Planned	S	D	K	C	Code	Milestone
6/1/04				C1		Funding Received
8/31/04				C2		Kick-off Mtg and Req Review Completed
12/31/04	S1					Air-Water Separators Development Completed
12/31/04		D1				PC-based data system Development Completed
12/31/04			K1			Reagentless Calibration Development Completed
12/31/04			K2			Reagent Packaging Subsystem Completed
4/30/05	S2					SubsystemTesting and Refinement Completed
6/30/05				C3		KC-135 Subsystem Testing Completed
8/31/05				C4		Subsystem Evaluation Review Completed
12/31/05	S3					Bubble Mitigation Tech Refined & Selected
12/31/05		D2				PDA Data System Development Completed
12/31/05			K3			CSPE Methods Selected
12/31/05			K4			Reagent Shelf-life Tests Completed
3/31/06	S4					Integrated Prototype Design Completed
5/31/06				C5		Prototype Design Review Completed
9/30/06	S5					Fabricate Integrated Prototype Fabricated
9/30/06		D3				Barcode Scheme Development
12/31/06	S6					Integrated Prototype Ground Testing Completed
12/31/06			K5			Draft QA & Operating Procedures Prepared
3/31/07				C6		KC-135 Prototype Testing Completed
5/31/07				C7		Final Report and Prototype Delivered