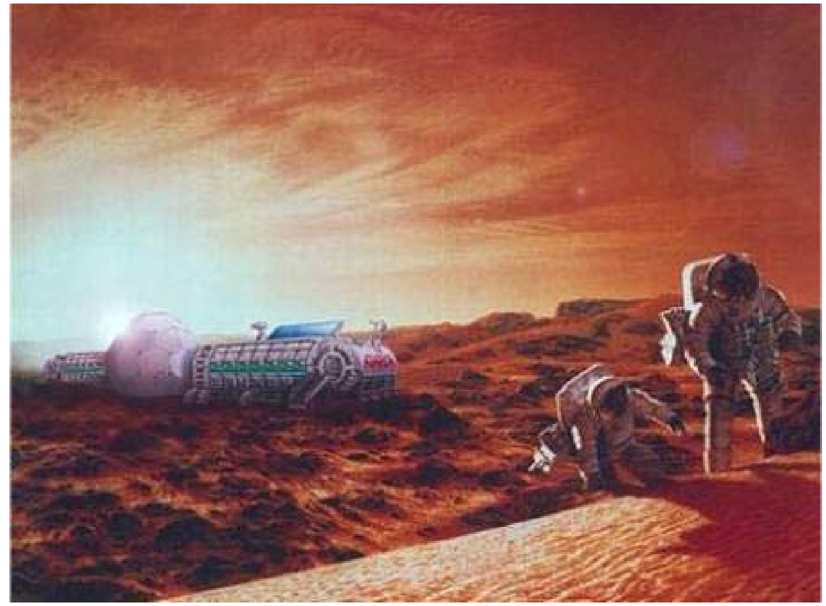
NASA/CP—2004-213205/VOL1

Advanced Life Support



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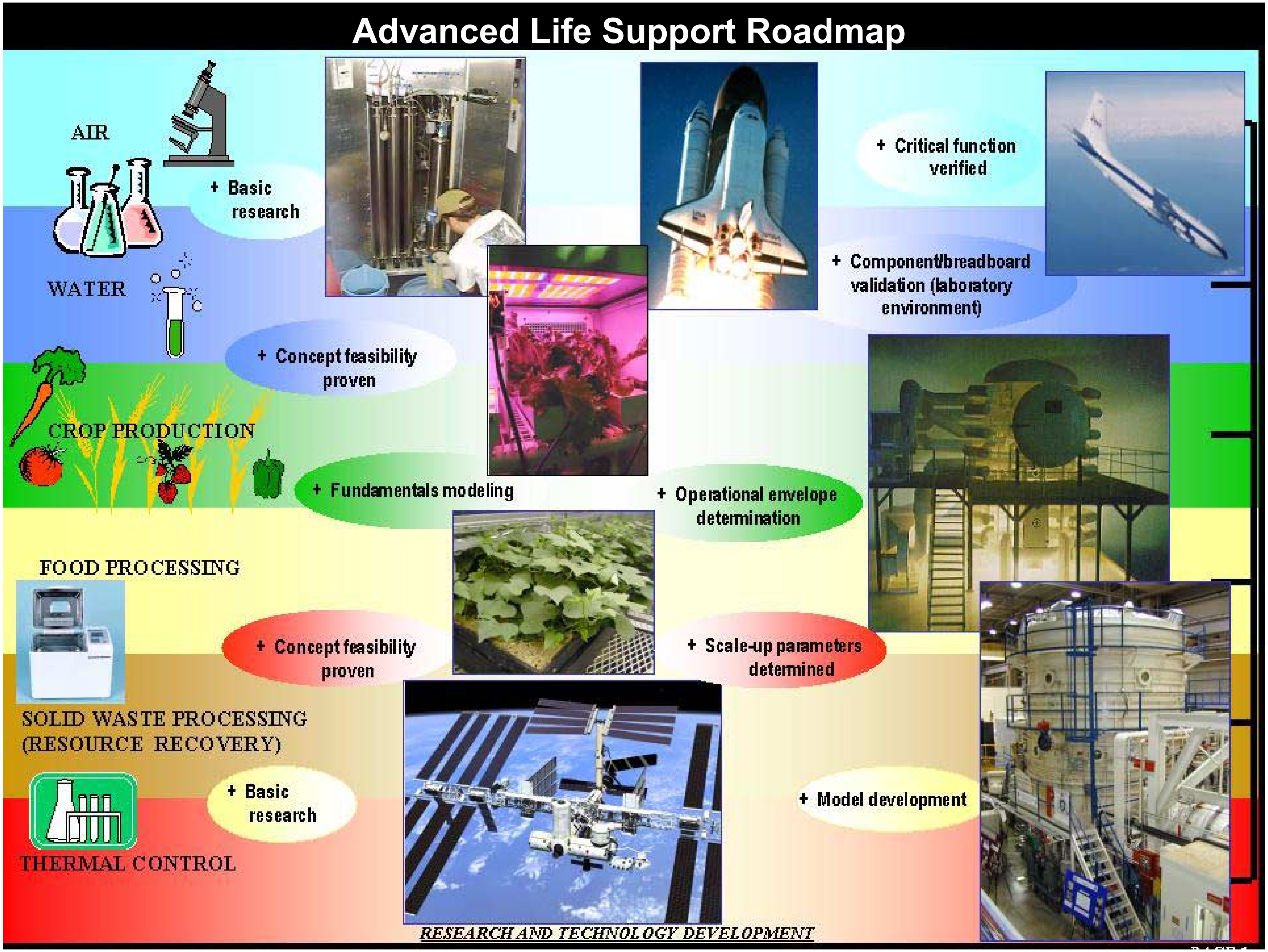
June 22, 2004


Advanced Life Support Roadmap
AIR
WATER
CROP PRODUCTION
FOOD PROCESSING
SOLID WASTE PROCESSING (RESOURCE RECOVERY)
THERMAL CONTROL
+ Basic research
+ Concept feasibility proven
+ Fundamentals modeling
+ Concept feasibility proven
+ Basic research
+ Critical function verified
+ Component/breadboard validation (laboratory environment)
+ Operational envelope determination
+ Scale-up parameters determined
+ Model development
RESEARCH AND TECHNOLOGY DEVELOPMENT

Advanced Life Support Topics

1. Fundamental Need for Advanced Life Support
2. ALS organization
   - Areas of research and development
   - Project management techniques
3. Requirements and Rationale
4. Past Integrated tests
5. The need for improvements in life support systems
6. ALS approach to meet exploration goals
   - Candidate groups of systems
7. ALS Projects showing promise to meet exploration goals
8. GRC involvement in ALS

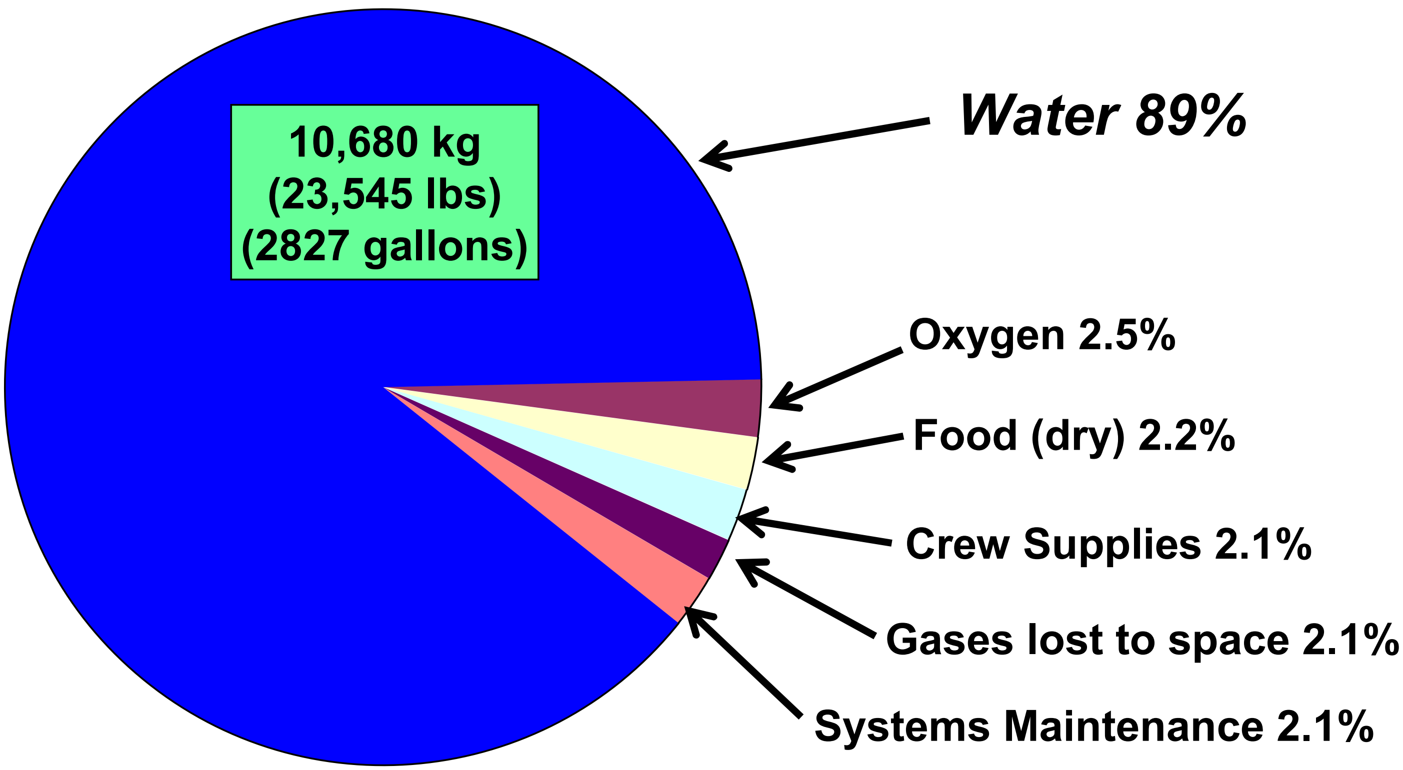
Human Life Support System Requirements

Consumables	Kilograms per person per day	
Gases		**0.8**
Oxygen	0.84	
Water		**23.4**
Drinking	1.62	
Water content of food	1.15	
Food preparation water	0.79	
Shower and hand wash	6.82	
Clothes wash	12.50	
Urine flush	0.50	
Solids		**0.6**
Food	0.62	
TOTAL		**24.8**

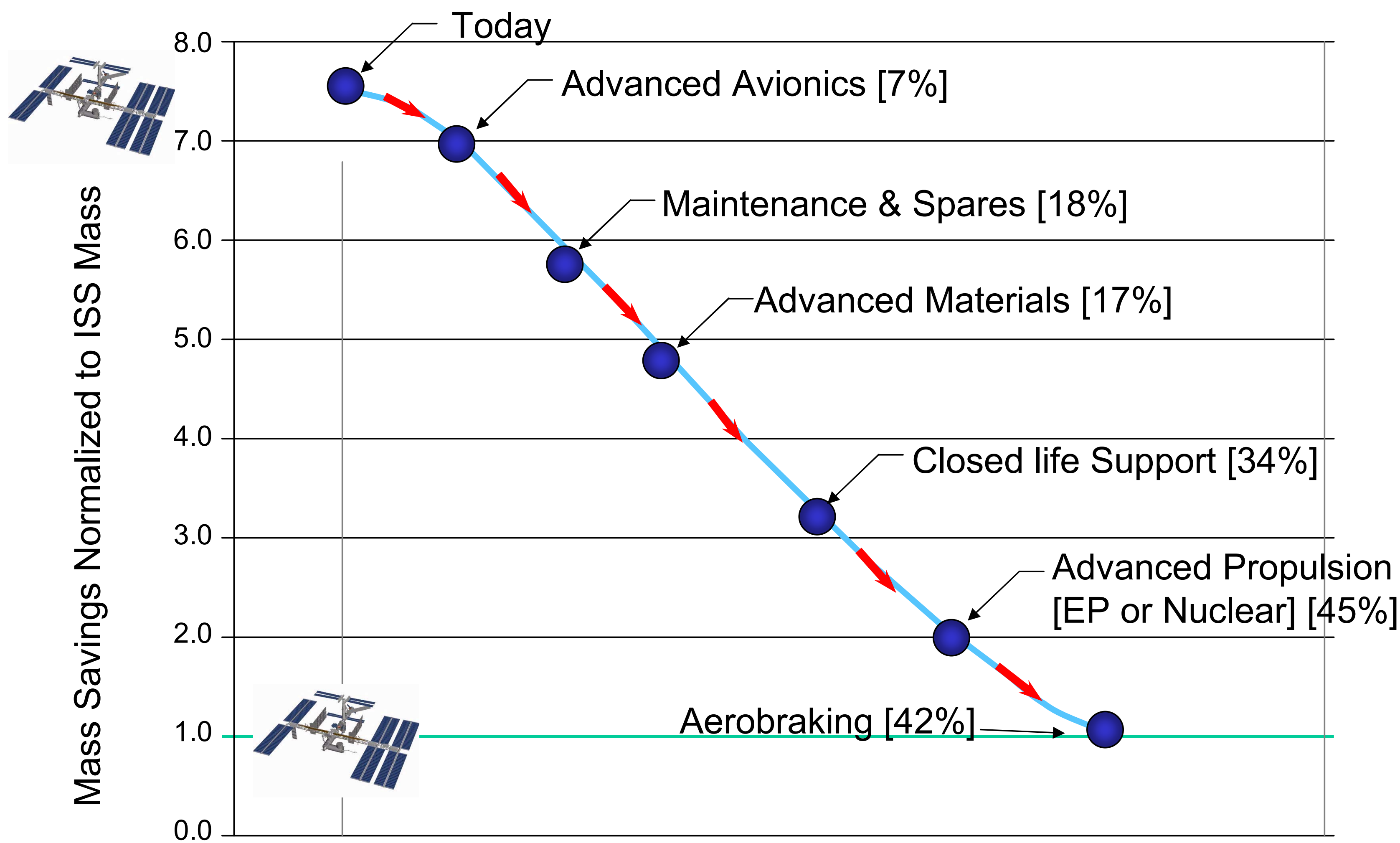
Wastes	Kilograms per person per day	
Gases		**1.0**
Carbon Dioxide	1.00	
Water		**23.7**
Urine	1.50	
Perspiration/respiration	2.28	
Fecal water	0.09	
Shower and hand wash	6.51	
Clothes wash	11.90	
Urine flush	0.50	
Humidity condensate	0.95	
Solids		**0.2**
Urine	0.06	
Feces	0.03	
Perspiration	0.02	
Shower & hand wash	0.01	
Clothes wash	0.08	
TOTAL		**24.9**

Human Life Support System Requirements

Open-Loop Life Support System
Resupply Mass - 12,000 kg/person-year
(26,500 lbs/person-year)



Mass Cost of Human Mars Mission Using Today's Technologies



The NASA Exploration Team [NExT]

Advanced Life Support (ALS)

ALS research and technology development provides technology options that either address:

- Bioastronautics Critical Path Roadmap (BCPR) risk

- Improved efficiency (lower mass, power and volume)

- Closure of the air, and water loops is critical
  - Solid Waste, Thermal Control improvements contribute to efficiency
- Technology development is undertaken after rigorous systems analysis including the current baseline (ISS and Shuttle) systems.
- Technology maturation is accomplished through validation and demonstration in integrated test beds and flight experiments
  - ALS takes technologies from very low Technology Readiness Level concepts (TRL 1-3) to mature technologies at TRL 6 via test and analysis
  - Make the technology available for consideration in an exploration vehicle

WHY MUST WE DEVELOP NEW ALS SYSTEMS?

Shuttle/ISS life support technologies are mass, power and resupply intensive.

Lunar and Mars missions

- **a high degree of closure of oxygen and water regeneration loops and efficient low mass thermal management is required.**
- **subsequent closure of the food loop along with containment and recycling of solid wastes must be pursued.**

Lunar or planetary bases - greater autonomy of life support system reduces the dependency on resupply missions, thereby increasing safety and reducing cost.

Pertinent Connections to BCPR

Risk #	Risk Title	ISS	Moon	Mars
43	Maintain Acceptable Atmosphere	G	Y	R
44	Maintain Thermal Balance in Habitable Areas	G	Y	R
45	Manage Waste	G	Y	R
46	Provide and Maintain Bioregenerative Life Support Systems	G	Y	R
47	Provide and Recover Potable Water	G	Y	R
48	Inadequate Mission Resources for the Human System	Y	R	R

Many enabling questions are addressed in the seven principal risks listed above
This effort also addresses enabling questions for shared risks of other Bioastronautics disciplines.

ALS IMPLEMENTATION

Coordinating Center: JSC

The JSC EC Advanced Life Support Manager administrates the overall Advanced Life Support Budget for JSC, ARC, KSC, MSFC, (GRC in 05)

Participants

– NASA Field Centers, including ARC, GRC, JPL, JSC, KSC, MSFC and their affiliated institutes.

– NASA Research Partnership Centers including BST, CAMMP, CSP, ES-CTSC, FTCSC, and WCSAR.

– Principal investigators with research and technology offerings sponsored through other programs such as EPSCoR and congressional earmarks.

– Contractors and small business concerns who respond to competitive contracts and SBIR/STTR program solicitations.

–Assistance and collaboration will be sought by experts within existing flight programs including ISS, Shuttle, and Project Constellation.

Funding

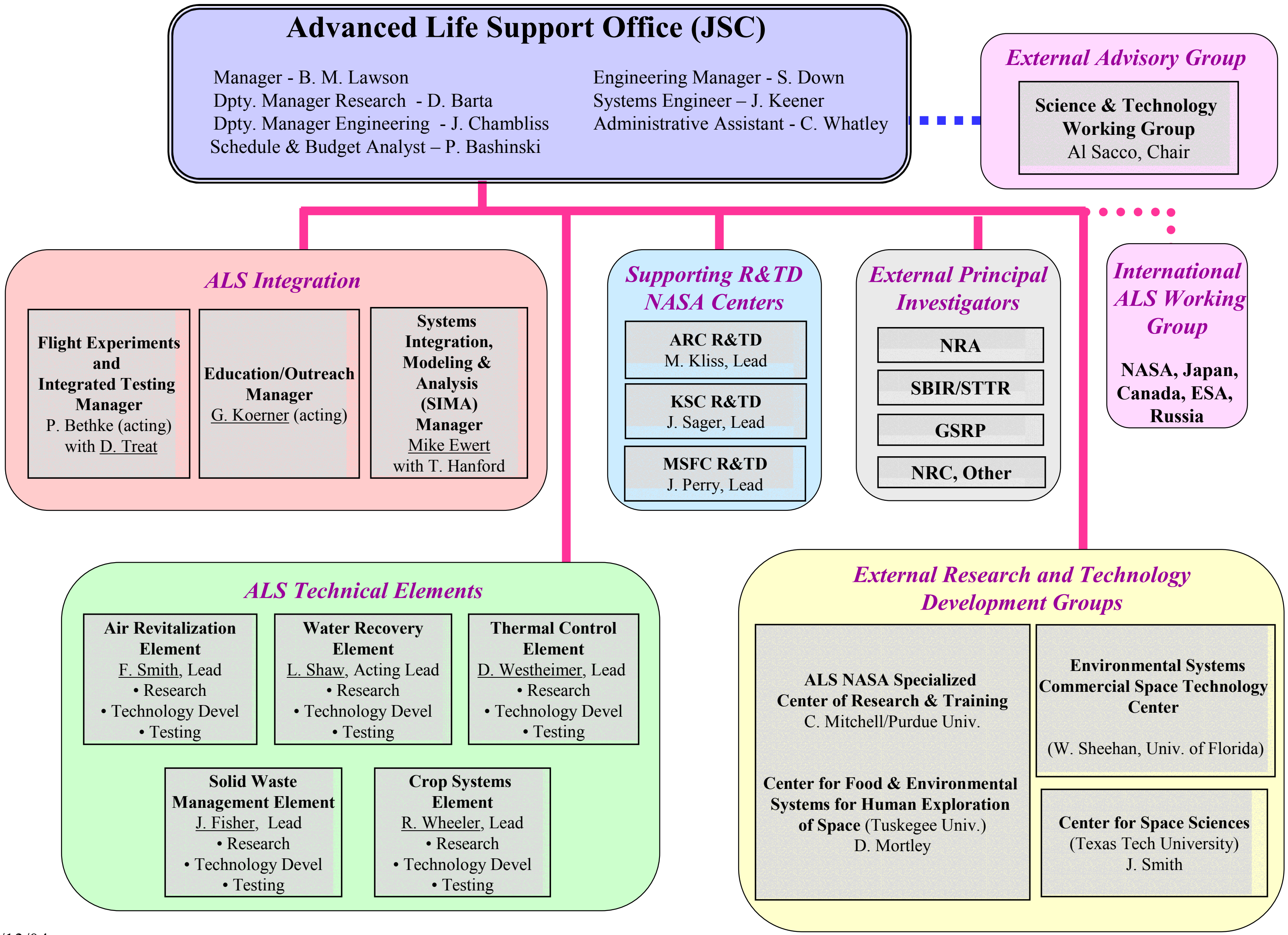
– Funding for tasks is implemented through the most appropriate method.

– Funding methods include: NASA Research Announcements, Technology Development Proposals, Technical Task Agreements, Competitive Procurements.

Leveraging

–SBIR, STTR, EPSCoR, GSRP, NRC, Code R/T/M, SFF, NASA CO-OP Program

Advanced Life Support Program Element Organization



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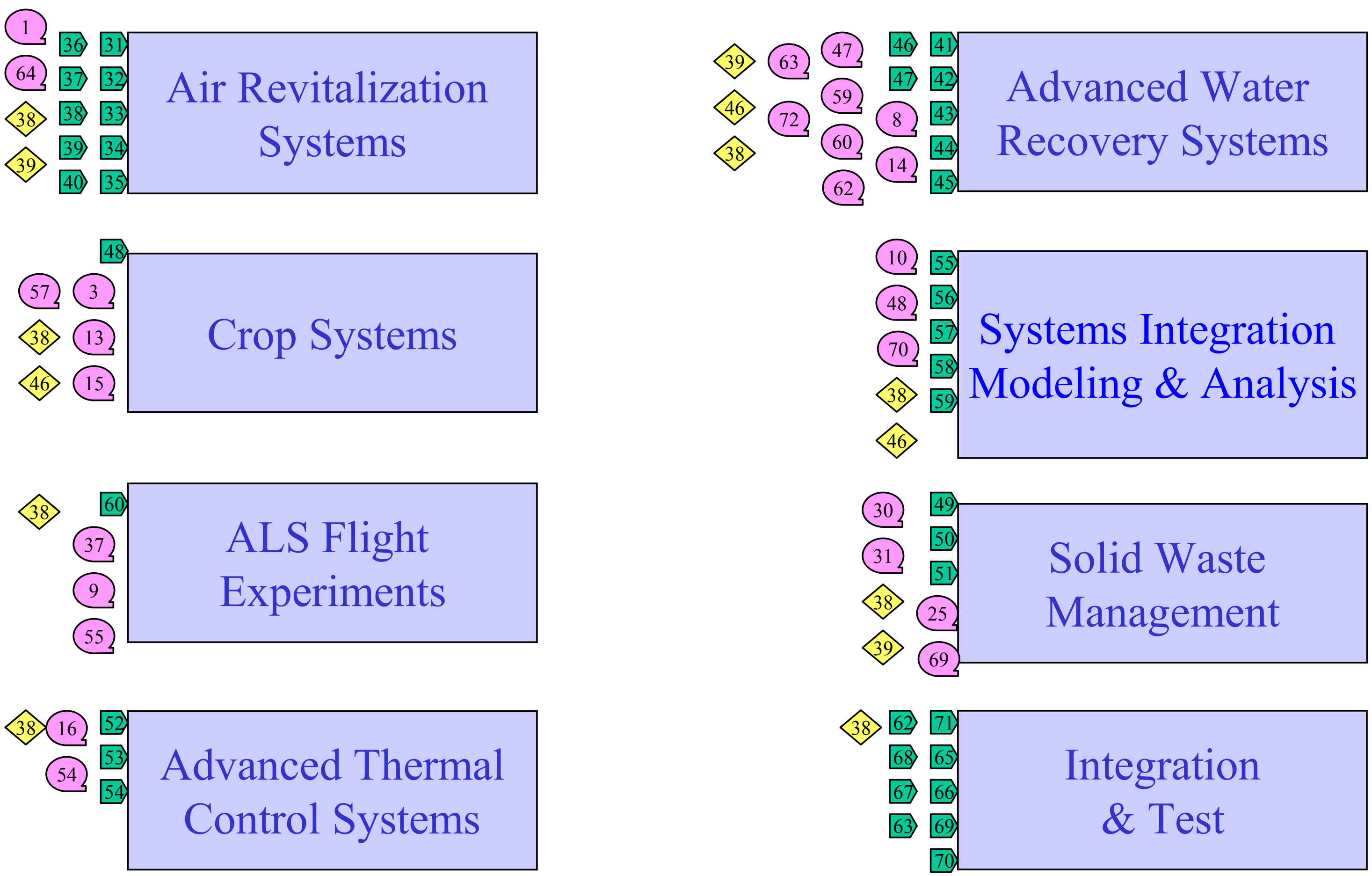
Advanced Life Support (ALS) Areas



TDP (39)
NRA (26)

Research Center	Manpower	
	Civil Service	Contractor
JSC (38)	9	19
ARC (39)	5	5
KSC (46)	4	xx

Augmentation Major Products

Air

Gas Supply (2)
CO_2 Removal (3)
Advanced CO_2 Reduction
Regenerative Trace Contaminant Control
Efficient, Low Noise Air Flow System

Water

Advanced Biological Primary Water Processor
Ultrafiltration
Next Generation Phys/Chem Primary Water Processor
Reverse Osmosis
Brine Dewatering
Post Processors
Alternative Disinfection Technologies

Bioregenerative Systems

Sustained Crop Production Testing
Hypobaric Plant Test Chambers
Mineral and Water Recycling Testing
Vegetable Production Unit EDU
Microbial Risk Assessments

Thermal

Advanced Coldplate Development
Humidity Control Device
Structural Radiator Prototype
Evaporator Prototype
Sublimator Prototype

Solid Waste

Compactor
Stabilization & Containment
Water Recovery Technology
Mineralization Technology

Ground Test

20’ Chamber Certified for Reduced Pressure Testing.

Past ALS Testing
Lunar Mars Life Support Test Project

	Phase I	Phase II	Phase IIA	Phase III
Duration	15-days	30-days	60-days	91-days
Dates	Completed August '95	Completed July '96	Completed March '97	Completed December '97
Crew Size	1	4	4	4
Technologies	Air revitalization using crops with P/C	Regenerative P/C technologies	ISS life support technologies	Integration of physicochemical & biological technologies
Regeneration	Air	Air & water	Air & water	Air, water, solid waste, food

Lunar Mars Life Support Test Project

Phases III: 91-day, 4-Person Tests

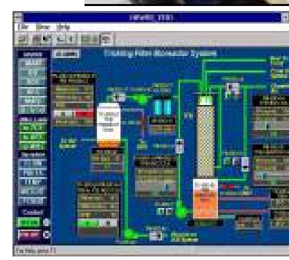
Biological Water Recovery System

Carbon Dioxide Removal System

Carbon Dioxide Reduction System

Oxygen Generation System

Control Room

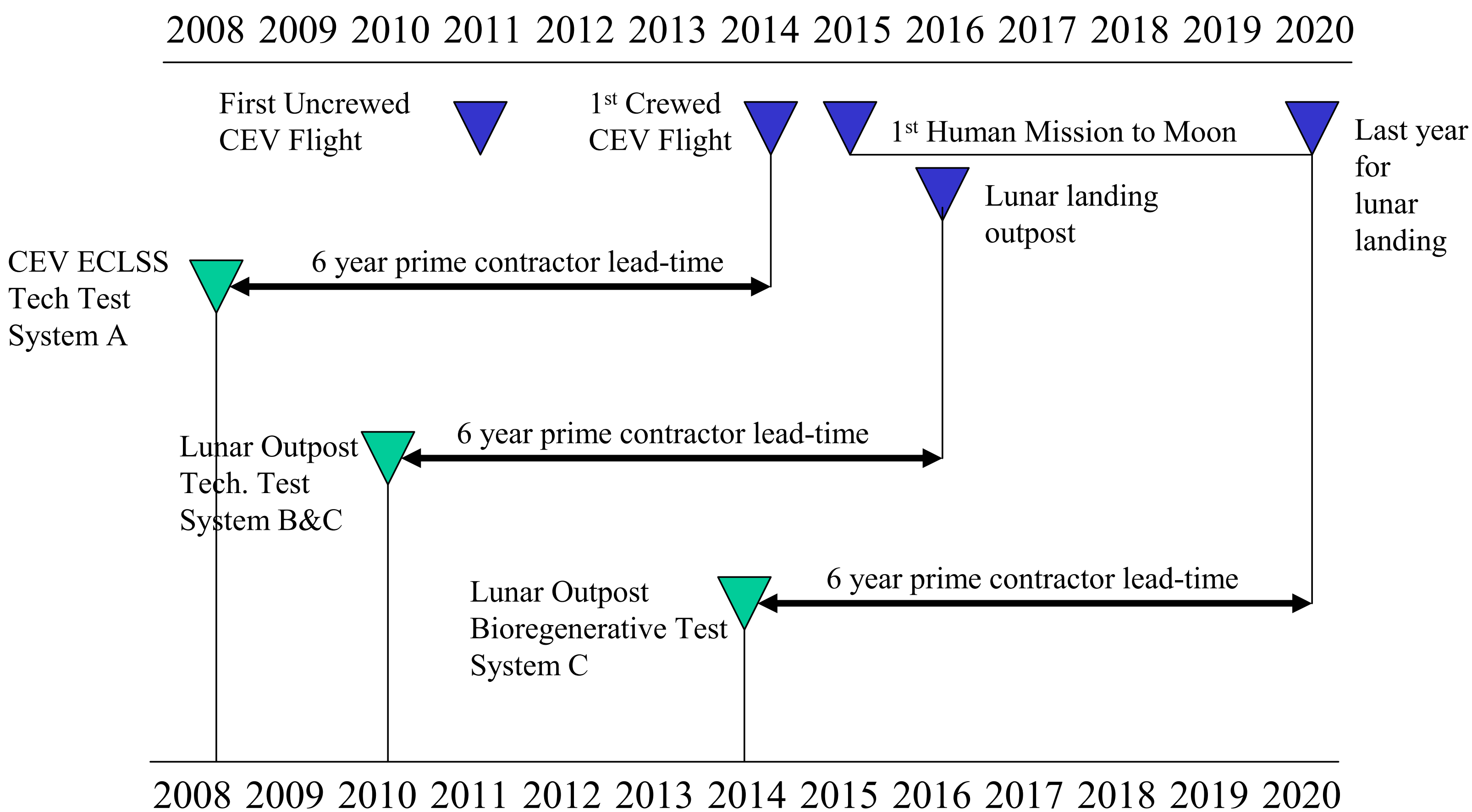


VPGC Wheat Harvest

Solid Waste Incinerator

Phase III Crew (left to right, Nigel Packham, Laura Supra, John Lewis, Vickie Kloeris)

ALS Integrated Test Plans Support the Exploration Timeline



Advanced Life Support Approach for Supporting NASA Exploration

- Preliminary analysis shows the exploration program will require at least three different environmental control systems architectures
  - A) a short duration, open-loop system architecture;
  - B) a zero-g, medium duration system architecture; and
  - C) a partial-g, long duration system architecture.
- Technologies for these systems need to be matured to technology readiness level (TRL) 6, to lower program risk and to provide mature technology selections for the vehicles' integrating contractors.
- A technology development program that will demonstrate these technologies on the ground in an integrated fashion prior to committing to flight designs is essential.

Parameters for Human Life Support Across Mission Scenarios

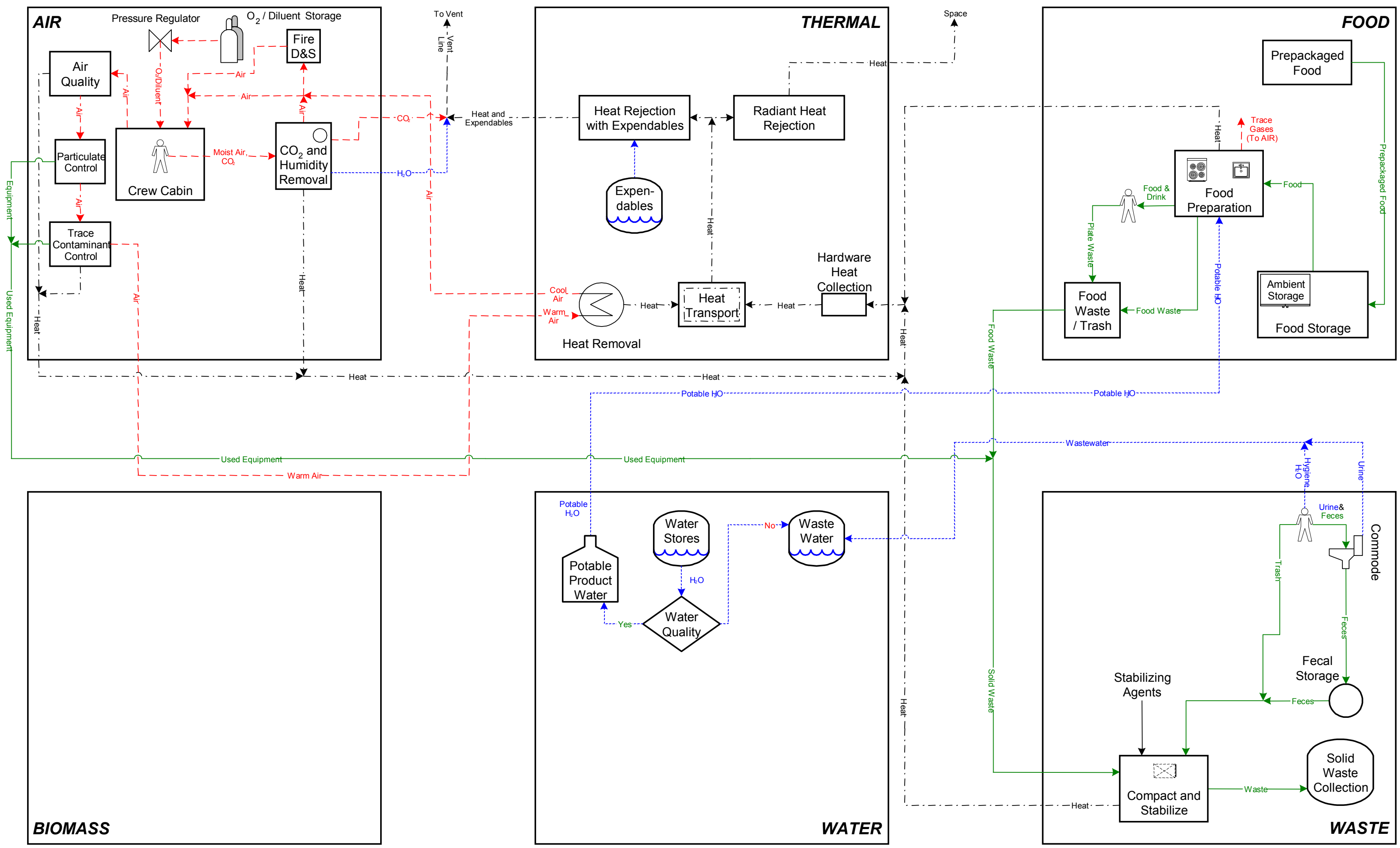
	Lunar Transit Vehicle (LTV)	Lunar Landing Vehicle (LLV)	Lunar Outpost (LO)	Mars Transit Vehicle (MTV)	Mars Landing Vehicle (MLV)	Mars Habitat (MH)	Pressurized Rover (PR)
Duration (Human Tended)	7 – 14 days (Roundtrip)	1 – 5 days	1 – 18 months	12 – 24 months (Roundtrip)	1 – 45 days	17 – 20 months	1 – 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

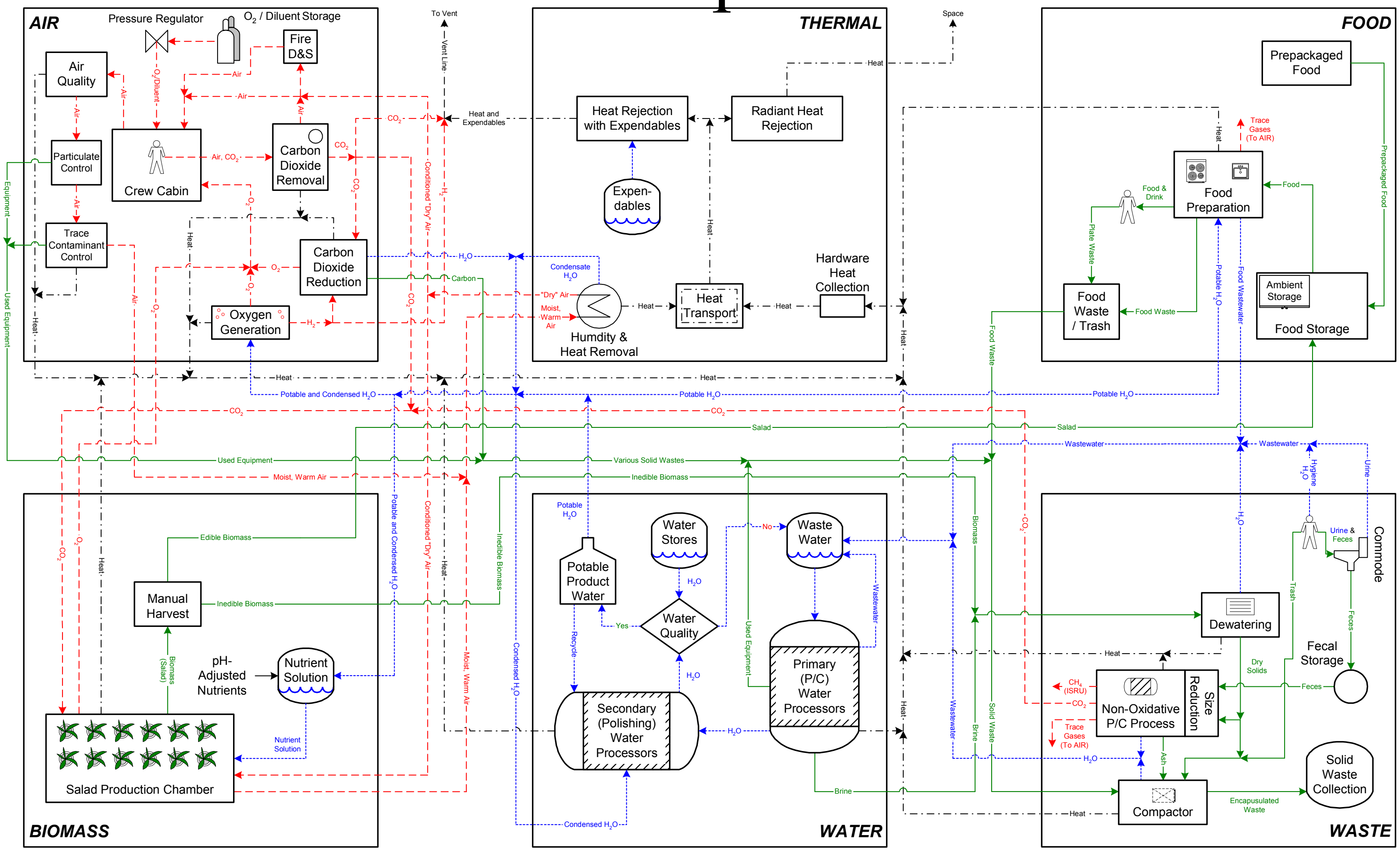
LP – Low Power HP – High Power
BR – Body Mounted Radiator
DR – Deployable Radiator

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

Crew Exploration Vehicle Schematic Group A

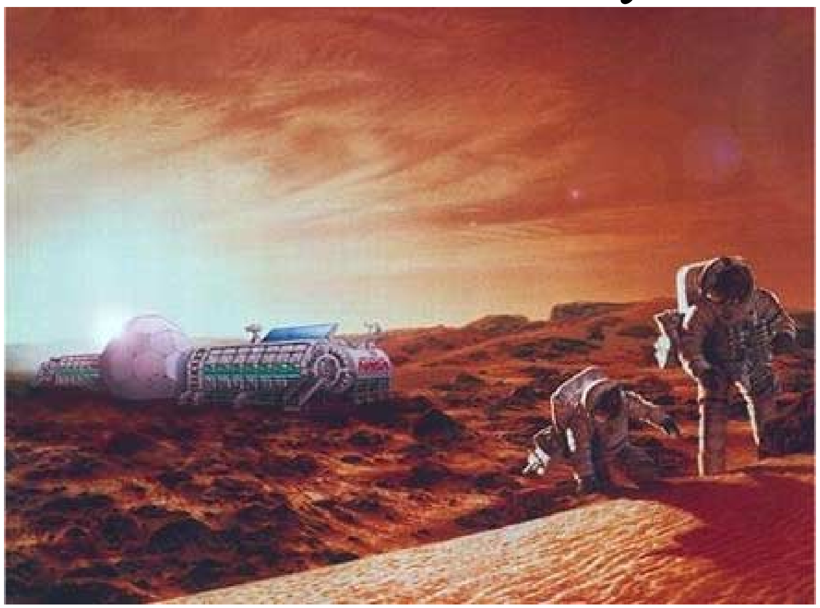


Mars Transit Vehicle Schematic Group B



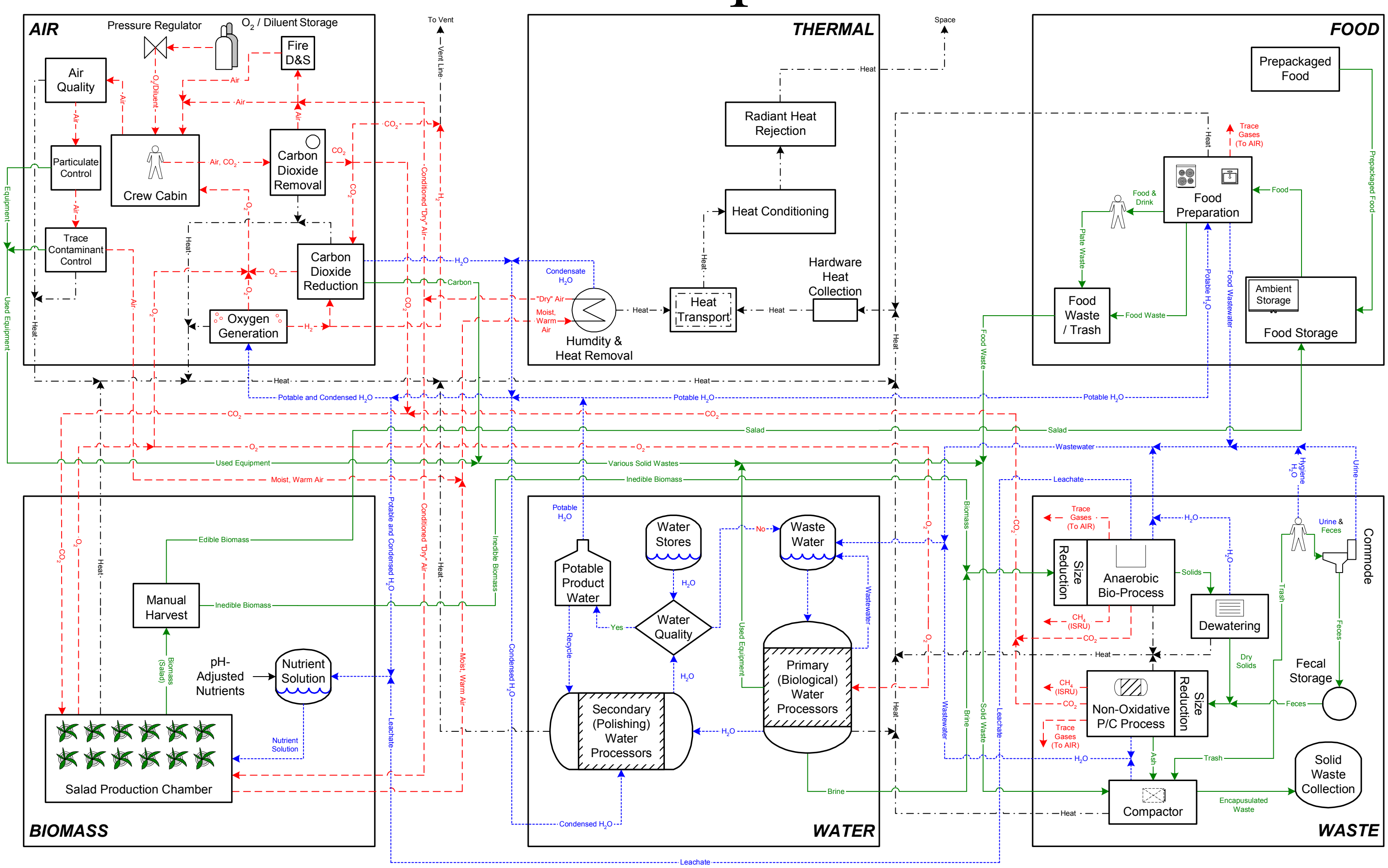
Mars Mission Concepts

Mars Planetary Base – A Sustainable Presence



- Permanent presence
- Power and volume: significantly more is available
- Hypoogravity environment
- Types of systems:
    - Integration of physicochemical and biological technologies
    - Closure of air & water loop
- Food: staple foods grown, processed by food system, contribute substantially to caloric requirements and to air and water regeneration
- Solid waste management:
    - may be processed to recover resources
- EVA: Extensive with overnight stays
- Communication:
    - highest degree of crew autonomy

Surface Habitat Schematic Group C



ALS Projects Showing Promise for Exploration

- ALS Proposed Projects show great promise to meet exploration goals
  - Sabatier- CO2 reduction
  - Advanced Trace Contaminant Control
  - Advanced CO2 removal and reduction system
  - Biological Water Processor
  - Rotating Reverse Osmosis
  - Vapor Phase Catalytic Ammonia Removal System
  - Cascade Distillation System
  - Low power two-phase Active Thermal Control System
  - Advanced thermal and humidity control
  - Multi application gravity insensitive heat pump
  - Solid waste management compaction
  - Dry and Wet Pyrolysis
  - Lyophilization (Freeze Drying)
  - Vegetable Production Unit
- Ground and Flight experimentation is needed to establish capabilities
- To evaluate technologies Systems Integrated Modeling and Analysis and integrated testing is needed

Glenn Research Center Contribution to ALS

- FY05 ALS plans call for GRC support to provide expertise in assessing microgravity and fluid physics areas related to ALS technologies
  - GRC to provide design tools, experimentally validated components, trade studies and trouble shooting
    - Two-phase separation processes
      - Gas tolerant pumping assemblies
      - Evaporative cooling techniques
      - Condensing HXs
      - Gas/Liquid separation devices
      - Liquid/Solid Separation of waste products
    - Reactor bed processes in micro and partial gravity
      - Design tools and techniques to address fine generation
      - Fluid flow processes in filtration assemblies
  - GRC to serve as technical monitor for NSCORT effort related to biofilters for trace contaminant removal
    - Related to water distribution, choking or channeling and nutrient supply

Acronyms

- BST – Bioserve Space Technologies NASA Research Partnership Center, University of Colorado.
- BWP - Biological Water Processing
- CAMMP – Center for Advanced Microgravity Materials Processing. Northeastern University, Boston, Massachusetts.
- CSP – Center for Space Power. Texas A&M University.
- EPSCoR – Experimental Program to Stimulate Competitive Research.
- ES-CSTC – Environmental Systems Commercial Space Technology Center. University of Florida
- FTCSC – Food Technology Commercial Space Center. Iowa State University.
- GSRP – Graduate Student Researchers Program
- LTV - Lunar Transit Vehicle
- LLV - Lunar Landing Vehicle
- LO - Lunar Outpost
- MTV - Mars Transit Vehicle
- MLV - Mars Landing Vehicle
- MH - Mars Habitat
- NRC – National Research Council Fellowships
- PR - Pressurized Rover
- P-C - Physiochemical
- SBIR/STTR – Small Business Innovative Research/Small Business Technology Transfer
- SFF – Summer Faculty Fellowships
- WCSAR – Wisconsin Center for Space Automation & Robotics