New Concepts for Air Revitalization and Water Recovery for the Lunar Environment

Workshop On
Research Enabled by the Lunar Environment

Jitendra A. Joshi, Ph.D.
Advanced Capabilities Division

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Towards a Sustainable Architecture

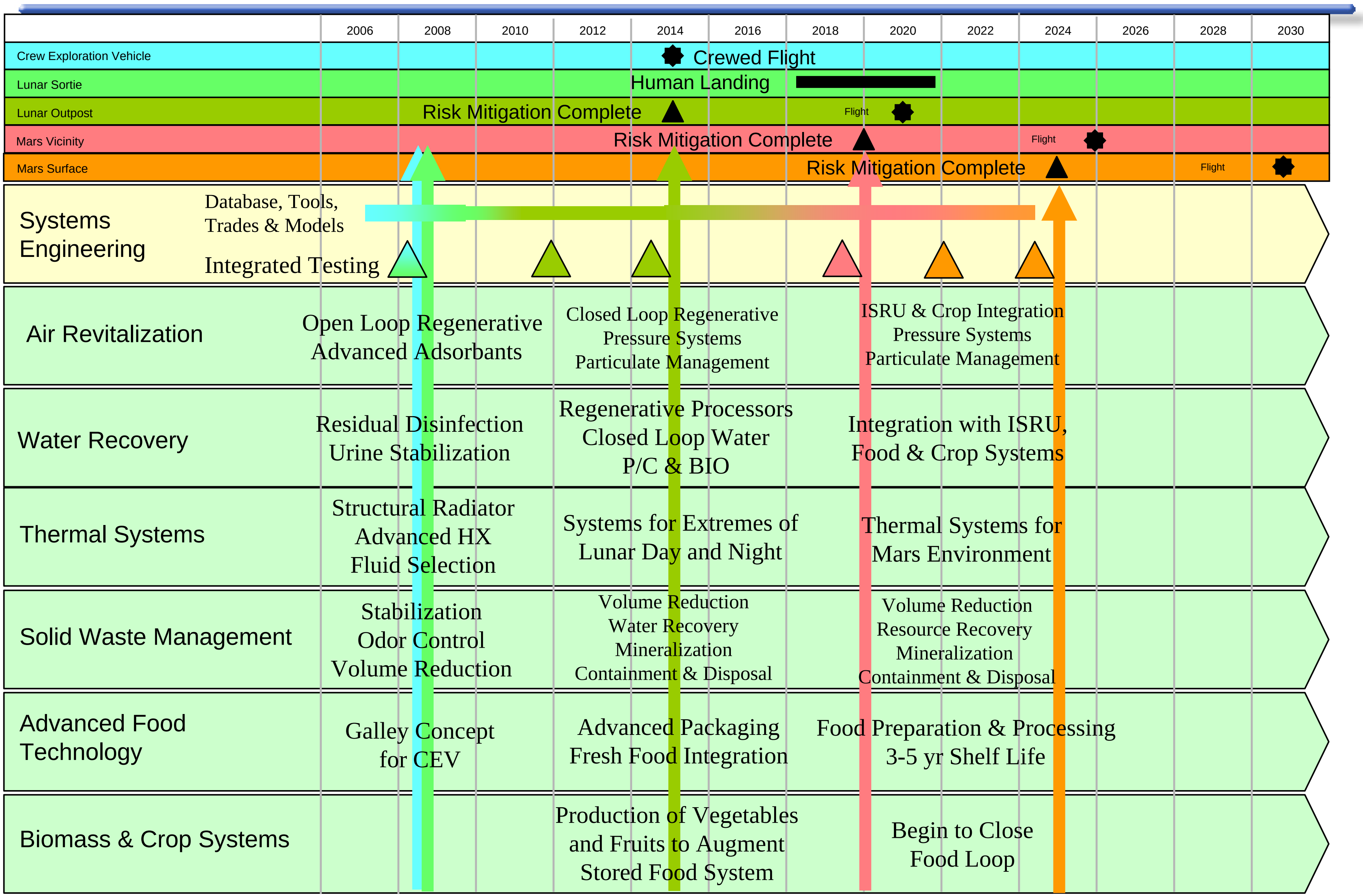
THE VISION

- Extend human presence across the solar system and beyond
- Implement a sustained and affordable human and robotic program
- Develop supporting innovative technologies, knowledge, and infrastructures
- Promote international and commercial participation in exploration

THE CHALLENGE FOR LIFE SUPPORT

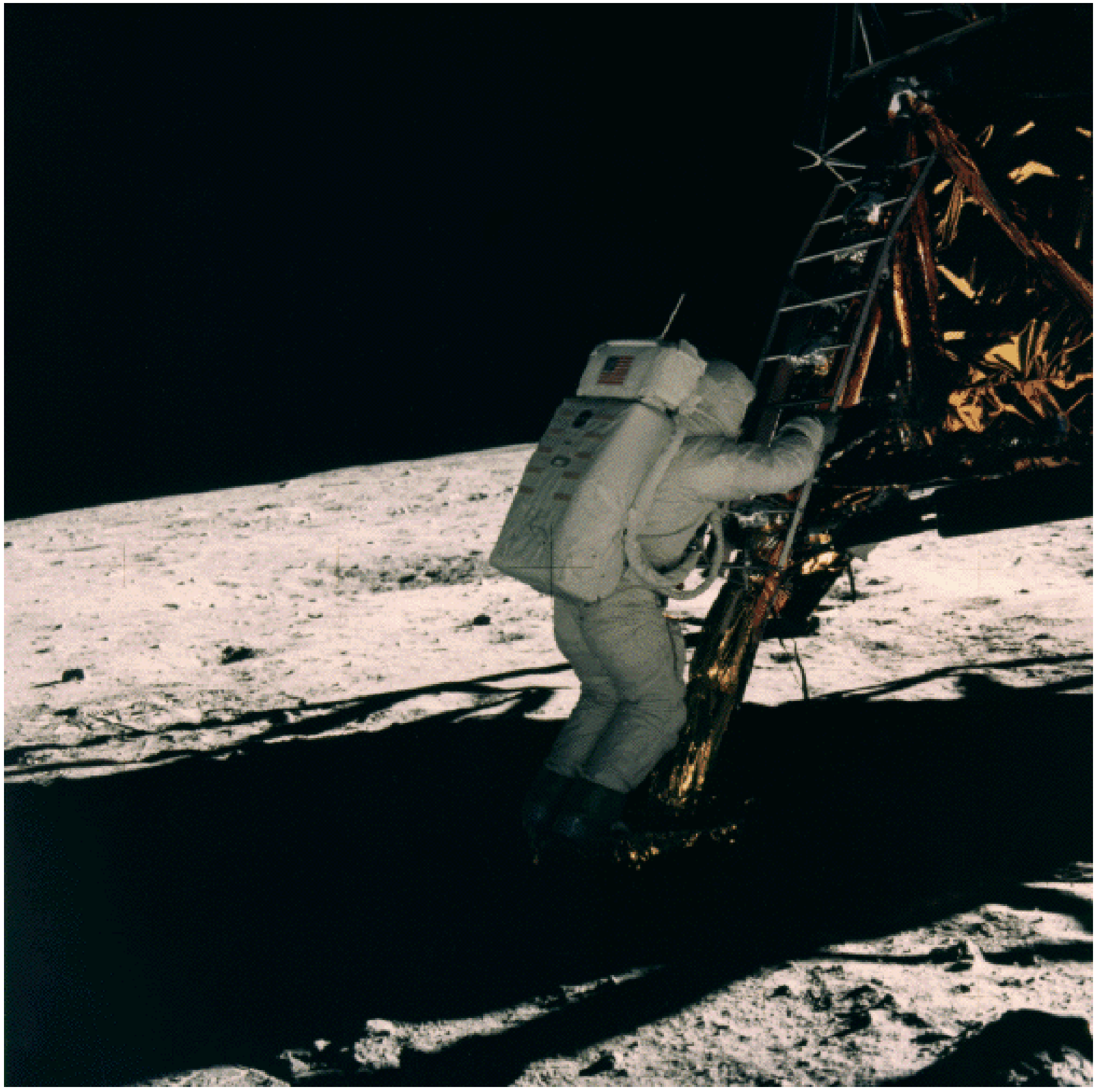
- Life Support systems contribute to a third of the overall system mass
- Reducing the Ecological Footprint
- Developing subsystems from an overall Systems perspective
- Technologies should be developed in consonance with mission needs
- Mission Duration, Destination and Abort scenarios should be the drivers for Technology Development

Advanced Life Support
Examples of Technology Priorities by Mission



Apollo Lunar Life Support Systems: A Starting Point

- Apollo
  - 3 crew
  - 6 m^3 habitable volume
  - 6-12 day mission lengths
  - Open loop expendable (LiOH) air revitalization system
  - Overboard urine vent
  - Rudimentary solid waste collection (bags)
  - 100% oxygen environment at 5 psia
  - Potable water from fuel cells
  - Suit loop for emergency depress survival



Why can we not use the same Approach

Basic Facts about the Orion:

- Will ferry a crew of 4 to the Moon
- Vehicle remains unmanned for upto 6 months
- Vehicle volume is about 3 times that of the Apollo missions

The Lunar Architecture and implications on Life Support

- Apollo was a camping trip
- The Vision calls for setting up a small colony
- Moon is not the final destination, it is an intermediate step to go beyond
- It is not just about the US priorities, we are embarking on an international Endeavour

Impact on Systems

- Resiliency, Longevity, Dependability, and most importantly sustainability are key drivers

Air Revitalization Technology Overview
Targeted Technology Development by Mission

CEV / Lunar Sortie

- *CO_2/H_2O removal processes regenerated by vacuum*
  - *Amine-based*
  - *Physical adsorption-based*
- *Trace contaminant control*
  - *Chemical adsorbents*
  - *Physical adsorbents*
  - *Catalysts*
- *Particulate matter control*
- *Atmospheric gas storage*
- *Ground-based testing facilities*
  - *Components*
  - *Assemblies*
  - *Integrated systems*

Lunar Outpost

- *CO_2/H_20 removal processes*
  - *Evolved processes*
  - *Enable mass closure*
    - *CO_2 sequestering*
    - *H_2O conservation*
- *Resource recovery processes*
  - *Sabatier process & infrastructure*
  - *Bosch process*
  - *Methane pyrolysis process*
- *Integral trace contaminant control*
- *Oxygen generation processes*
  - *H_2O electrolysis*
  - *CO_2 electrolysis*
- *Particulate matter Control*

ARS closure →

Improvements in Key subsystems: Air

- Atmosphere loop closure
  - Improved CO_2 removal – more robust, lower power, integration with CO_2 reduction
    - Structured sorbents to preclude dust generation
    - Water separation which minimizes power/heat for regeneration
    - Mechanical or chemical adsorption-based CO_2 compression and storage
  - CO_2 reduction
    - Sabatier only
    - Sabatier plus hydrogen recovery from methane
    - Bosch

Water Recovery Technology Overview
Targeted Technology Development by Mission

CEV / Lunar Sortie	***Lunar Outpost***	***Extended Lunar Base Mars Transit Mars Surface***

• *Disinfection*
• *Biofilm prevention*
• *Urine pretreatment*
• *"Disposable" treatment systems*
	• *P/C systems*
	  • *Distillation systems*
	  • *Membrane systems*
	  • *Post-processing*
	
	- Subsystem development
	- Comparison test
	- System integration
	- Prototype refinements
		• *P/C systems*
		• *Biological systems*
		• *Brine recovery*
		• *ISRU*
		• *Certification of ISRU attained water for human consumption*

WRS closure
Wastewater volume
Wastewater sources

Improvements in Key subsystems: Water

- Improved water recovery
  - >93% water recovery from wastewater
  - Decreased expendables – filters, absorption media
    - Current ISS water recovery system uses 8 lb resupply/100 lb water recovered including maintainable items (2.7 lb expendables/100 lb water recovered)
  - Recovery of water from solid waste and brine
    - Candidate technologies include lyophilization, pyrolysis, and wick evaporation for brine
  - Consider use of partial gravity to simplify planetary base system
  - Certification of continuously recycled water for crew consumption

What we have not done optimally yet

Integrated Monitoring and Life Support:

Monitoring and Life Support are treated in near Isolation

- Monitoring is considered a medical issue
- Environmental Control as a part of the vehicle design
- Data fusion,

Future Systems need to designed with an integrated approach

- Environmental Control and Monitoring need to work in tandem
- Most of our operational systems work on a scheduled basis
- On-demand activation of life support systems needs to be integrated with environmental control
- Integration of life-support equipment with exercise devices

Treating different subsystems in isolation is sub-optimal

- Air, Water, Solid waste, Food subsystems are tightly integrated
- Emphasis should be placed on the whole System and reducing the ecological footprint