MSFC-2031-ABSTRACT

CONSIDERATIONS REGARDING THE DEVELOPMENT OF AN ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM FOR LUNAR SURFACE APPLICATIONS

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NASA is engaged in early architectural analyses and trade studies aimed at identifying requirements, predicting performance and resource needs, characterizing mission constraints and sensitivities, and guiding technology development planning needed to conduct a successful human exploration campaign of the lunar surface. Conceptual designs and resource estimates for environmental control and life support systems (ECLSS) within pressurized lunar surface habitats and rovers have been considered and compared in order to support these lunar campaign studies. This paper will summarize those concepts and some of the more noteworthy considerations that will likely remain as key drivers in the evolution of the lunar surface ECLSS architecture.

MSFC-2031-PRESENTATION

Considerations Regarding the Development of an Environmental Control and Life Support System for Lunar Surface Applications

"LIFE SUPPORT SYSTEMS AS A MEANS OF HUMAN EXPLORATION OF OUTER SPACE"

Moscow, September 24-27, 2008

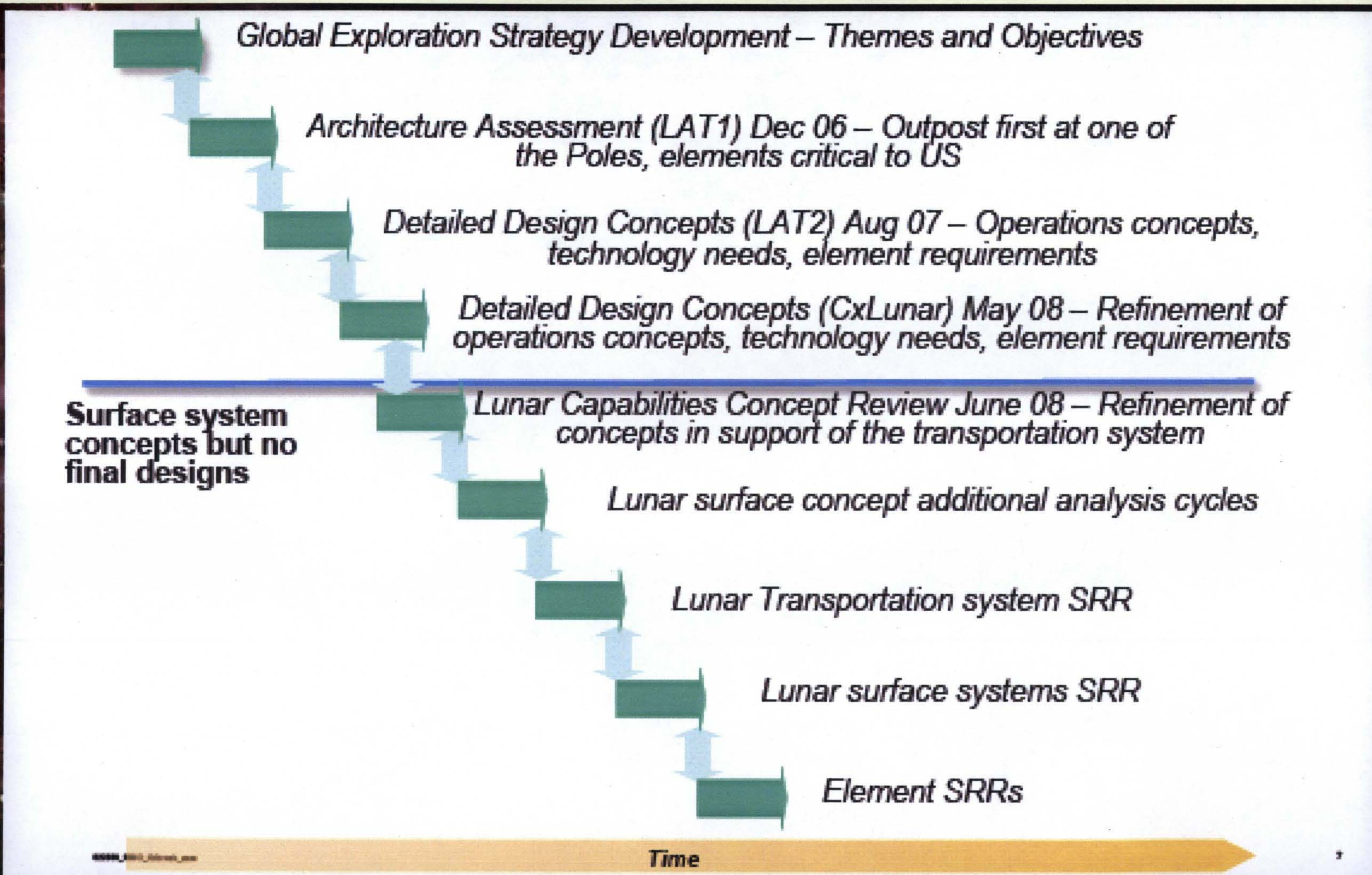
Robert M. Bagdigian

NASA Marshall Space Flight Center

Constellation Lunar Surface Systems Project Office

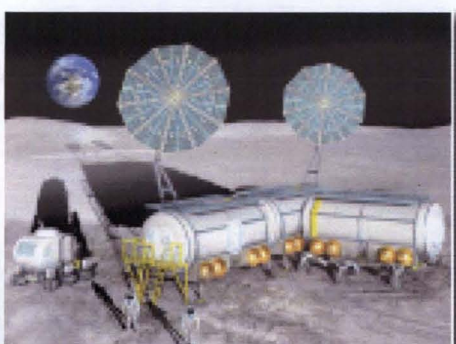
- Lunar Surface Systems Overview
- ECLSS Considerations
  - Functions
  - Loop Closure
  - Commonality
  - Mars Extensibility

Lunar Architecture Studies



Architecture Desired Attributes

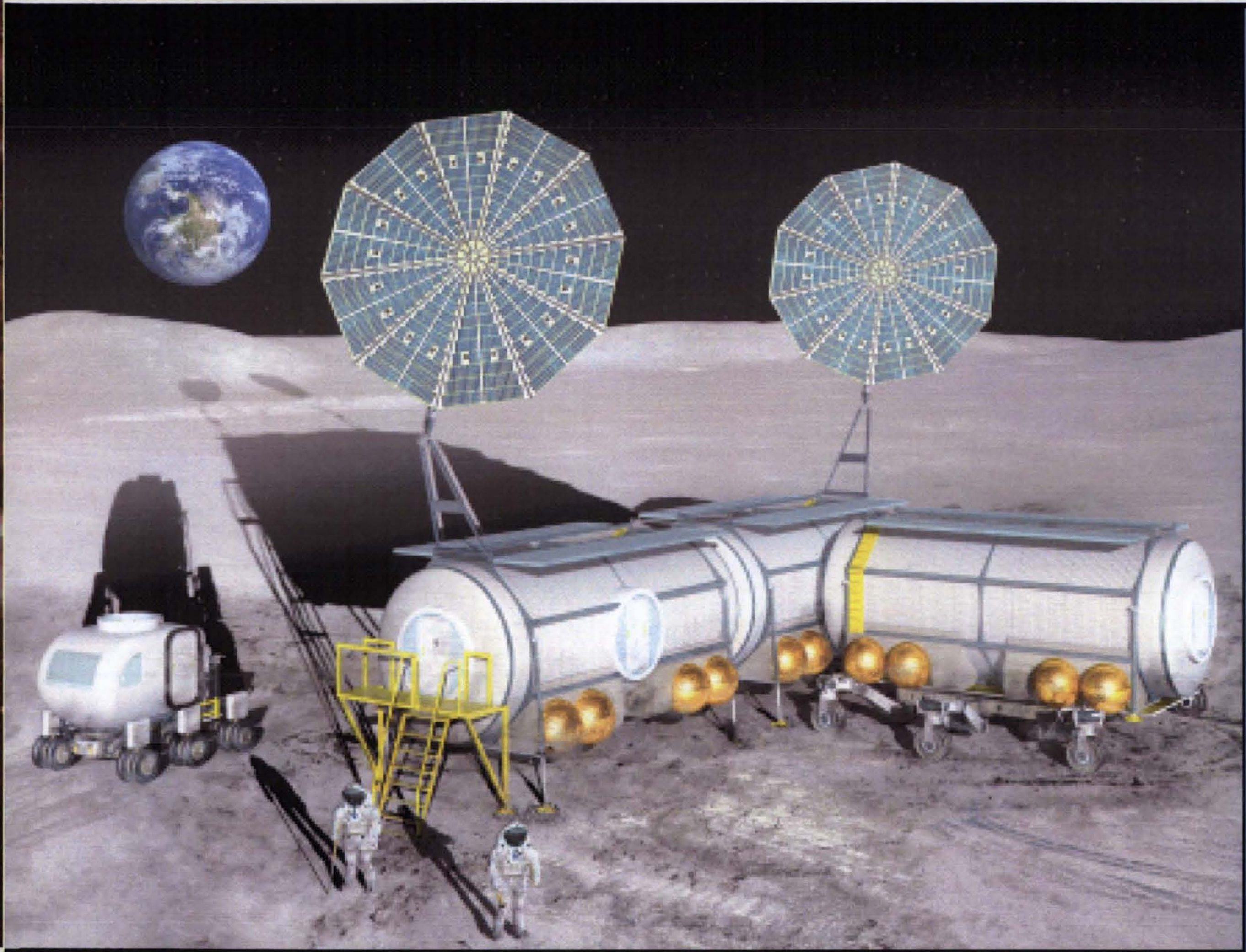
- ✓ Enable lunar sustained presence early
- ✓ Develop infrastructure while actively engaged in science and exploration
- ✓ Ensure architecture supports Objectives
- ✓ Support the establishment of Mars analog
- ✓ Allow the earliest partnership opportunities for commerce and International Partners
- ✓ Continuous and focused public engagement



Architecture Guidelines

- In addition to supporting the basic goals and objectives of the Vision, the Architecture must have the following:
  - Programmatic Flexibility – The Architecture must be able to adapt to changes in national priorities and budgets over several election cycles
  - Participant Flexibility – The Architecture must be able to adapt to changes in external participation (Commercial or IP) and changes to their priorities
  - Exploration Flexibility – The Architecture must be able to adapt to changes in exploration priorities and changes in exploration methods

Key Elements of an Outpost



Lander and Ascent vehicle

Extravehicular Activities System

Power

Habitation

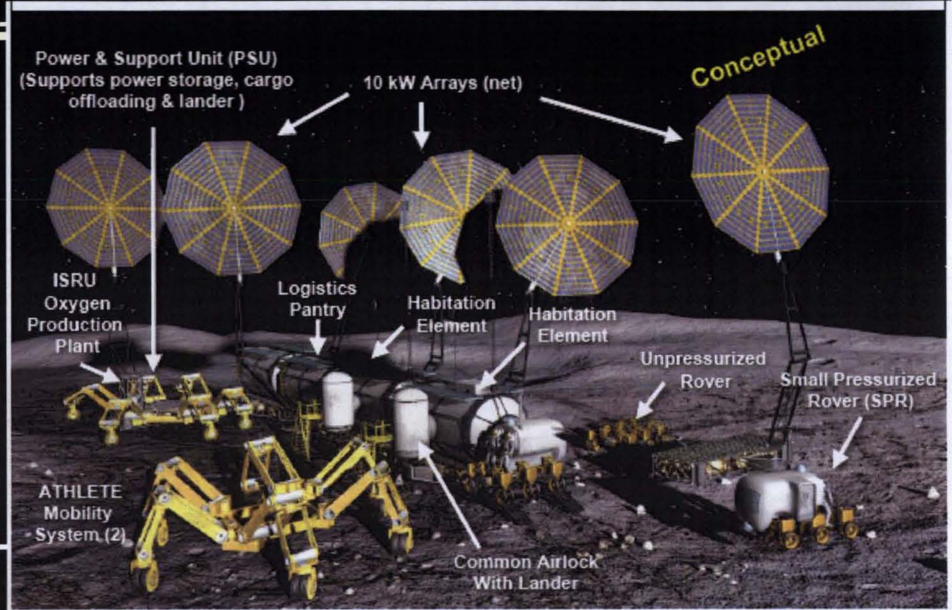
Mobility

Navigation and Communication

In-Situ Resource Utilization

Key Elements of an Outpost

- Variety of possible end-states
- Variety of possible campaigns
  - Early outpost build-up
  - Early habitation capability
  - Early mobility capability
- Common characteristics
  - Pressurized habitat(s)
  - Pressurized logistics element(s)
  - Pressurized rover(s)
  - 4 crew
  - 180-day expeditions
  - periods of un-crewed dormancy
  - frequent EVAs
  - resupply capability will not be unlimited



Lunar Surface ECLSS Functions

Pressure Control
- O_2 Storage & Supply
- N_2 Storage & Supply
- Positive Pressure Relief
- Intermodule Pressure Equalization
- Cabin Pressure Monitoring

Fire Detection & Suppression
- Fire Detection (function potentially provided or supported by atmosphere monitoring equipment)
- Fire Suppression

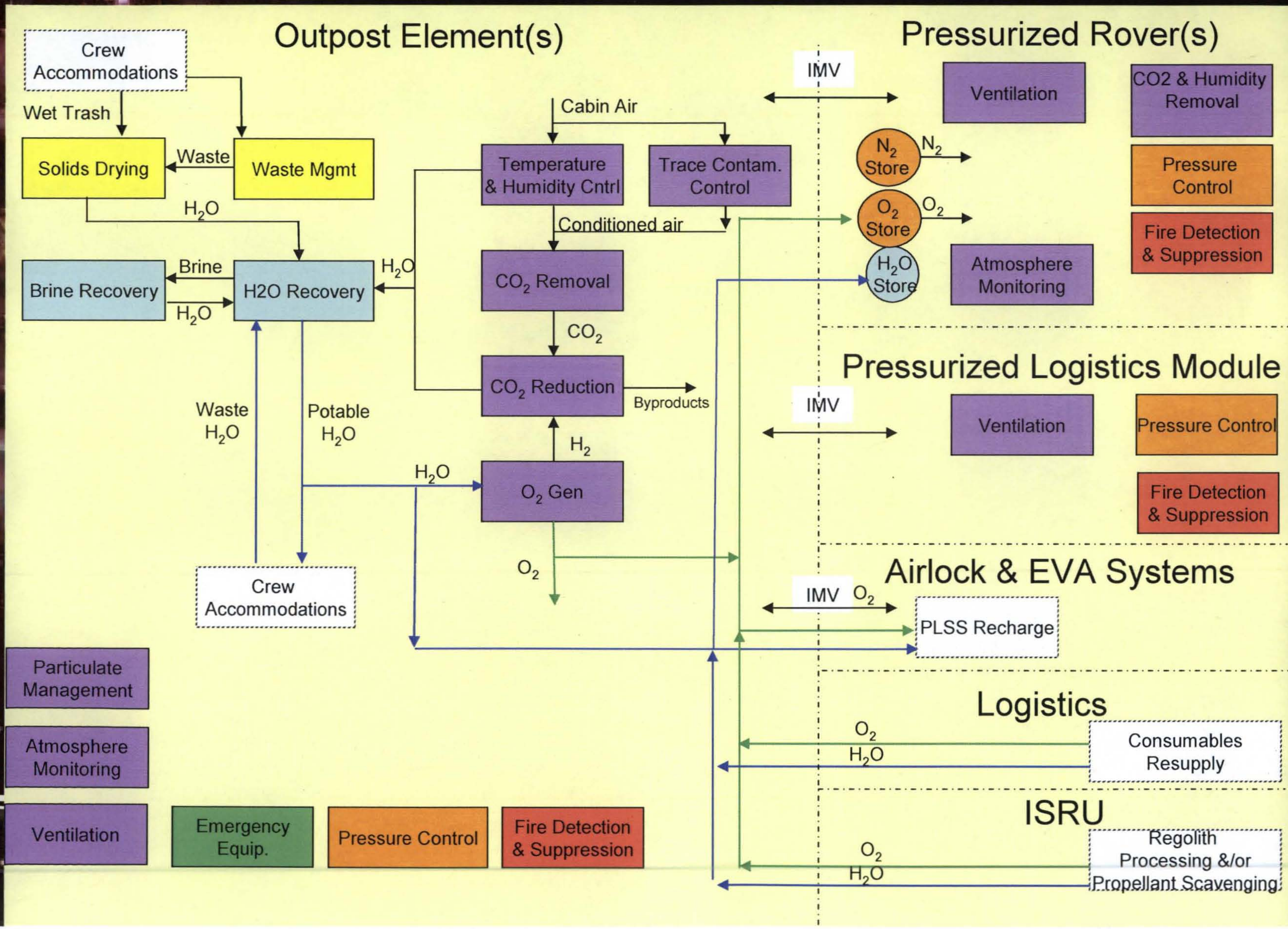
Emergency Response
- O_2 Masks
- Toxic Masks

Air Revitalization
- CO_2 Removal
- CO_2 Reduction
- O_2 Generation
- Temperature & Humidity Control
- Trace Contaminant Control
  - regenerative
  - non-regenerative (for module ingress)
- Ventilation
  - intra-module
  - inter-module
- Airborne Particulate Control and Monitoring
- Atmosphere Composition Monitoring
  - ppO_2
  - pp CO_2
  - pp H_2O (v)
  - Trace Contaminants

Water Recovery & Mgmt
- H_2O Recovery
  - Humidity Condensate
  - Waste Hygiene
  - Urine
- Brine Recovery
- Water Storage & Distribution
- Water Quality Monitoring

Waste Mgmt
- Urine Collection & Pretreat
- Fecal Collection & Drying
- Trash Collection & Drying

Typical Distribution of ECLSS Functions



Notional Daily 4-Person Metabolic Mass Balance

Needs

Oxygen = 3.5 kg

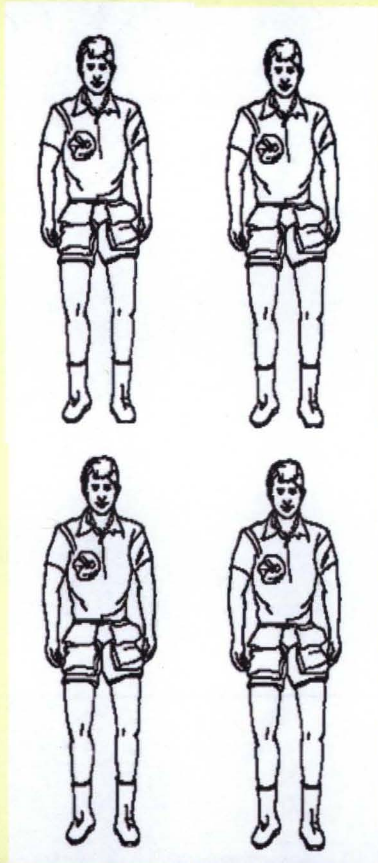
Food Prep Water = 2.0 kg

Drink = 8.0 kg

Water in Food = 1.0 kg

Food Solids = 2.6 kg

Total = 17.1 kg



Wastes

Carbon Dioxide = 4.4 kg

Respiration & Perspiration Water = 6.6 kg

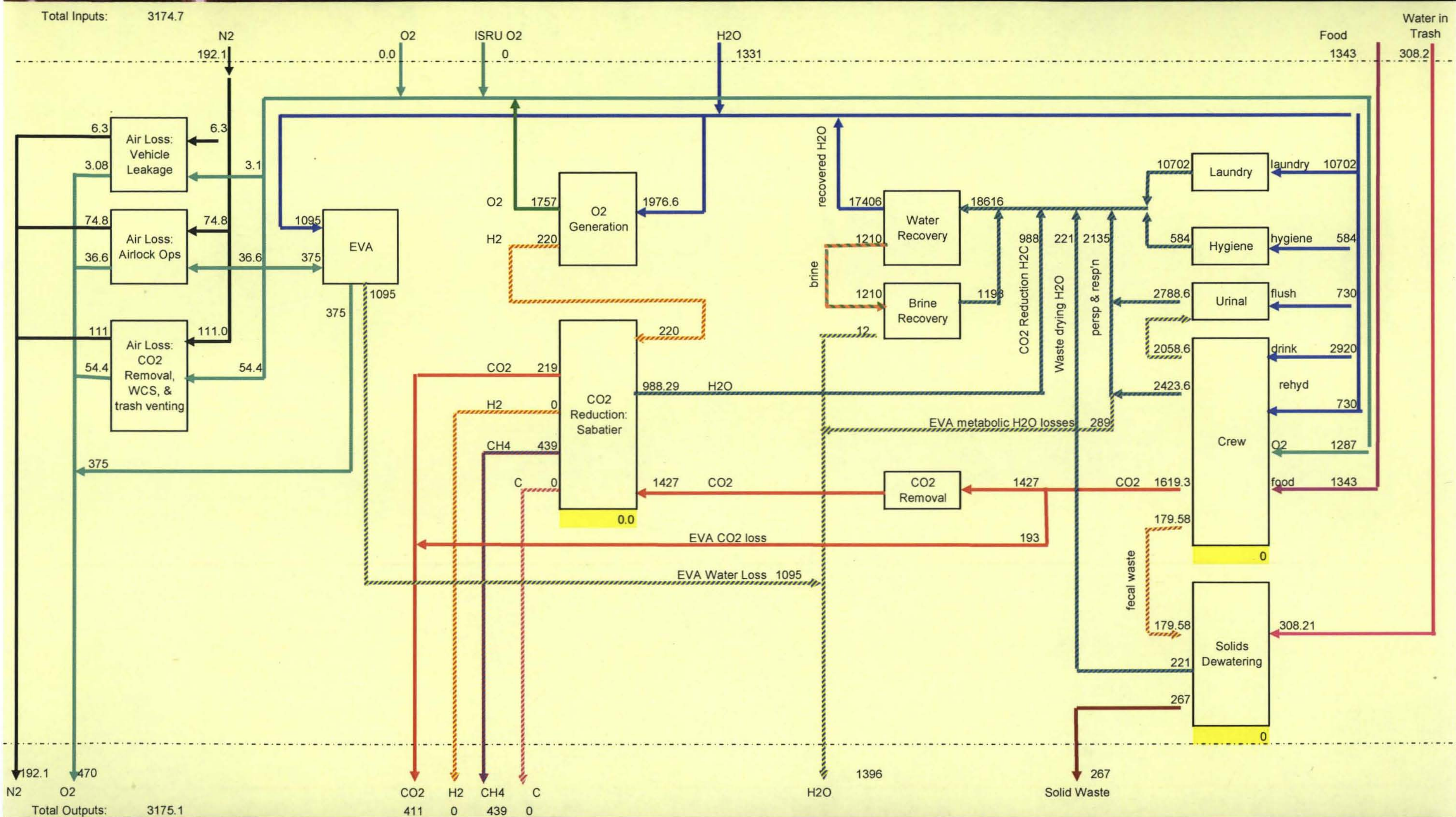
Urine = 5.6 kg

Fecal Water = 0.4 kg

Fecal, Urine, & Sweat Solids = 0.1 kg

Total = 17.1 kg

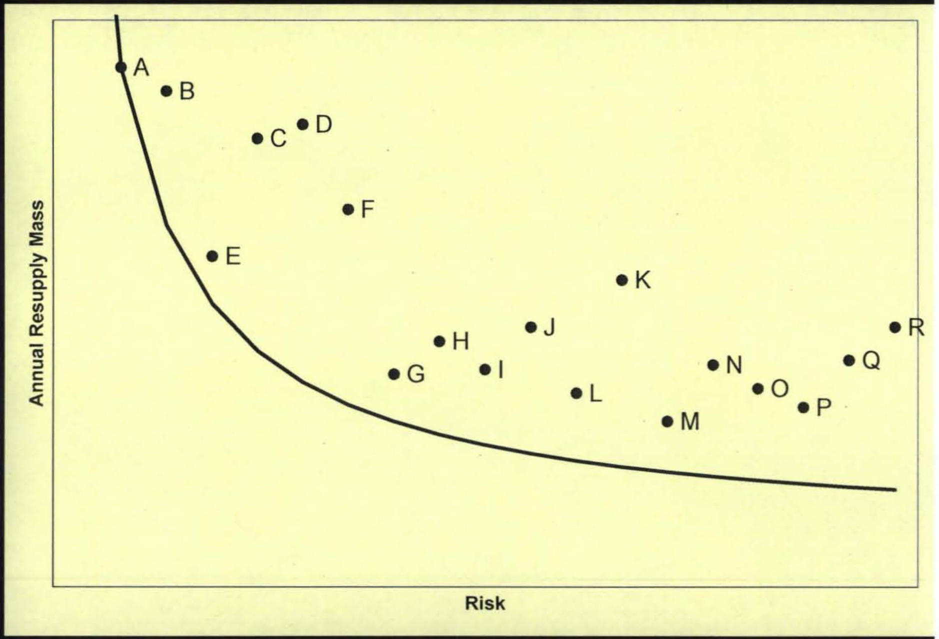
Notional Lunar Surface ECLSS Mass Balance (kg/yr)



Balancing Loop Closure vs. Risk

- Variety of candidate technology options & combinations exist for O2 & H2O recovery
- Benefit (reduced re-supply) must be considered in light of risks that would work against achieving the benefit
  - programmatic risks
  - operational risks
- Objective and complete means of assessing risks is needed
  - more difficult for low TRL candidates with little supporting data
  - uncertainties must be applied to benefit & risk estimates

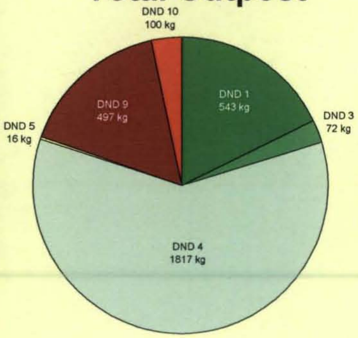
Notional Re-Supply vs. Risk Comparison for a Family of Loop Closure Technology Options



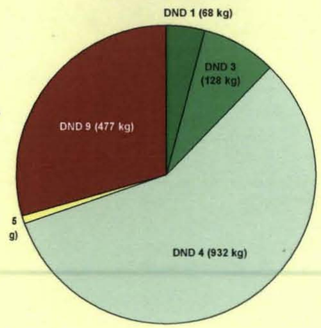
Degree of New Design for a Notional Outpost

1. "Reflight of Existing Spacecraft, Technology Readiness Level-9: Actual system "flight proven" through successful mission operations"
2. "Minor Modifications Not Requiring Re-Qualification, Technology Readiness Level-9"
3. "Minor Modifications Requiring Re-Qualification, Technology Readiness Level-9"
4. "Moderate Modifications, Technology Readiness Level-9: Actual system "flight proven" through successful mission operations"
5. "Moderate Modifications, Technology Readiness Level-8: Actual system completed and "flight qualified" through test and demonstration (ground or space)"
6. "Significant Modifications, Technology Readiness Level-7: System prototype demonstration in a space environment"
7. "Significant Modifications, Technology Readiness Level-6: System/subsystem model or prototype demonstration in a relevant environment (ground or space)"
8. "Based on a Previous Design, Technology Readiness Level-5: Component and/or breadboard validation in relevant environment"
9. "Similar to a Previous Design, Technology Readiness Level-4: Component and/or breadboard validation in laboratory environment"
10. "New Design, TRL-3 thru Technology Readiness Level-1: Analytical and experimental critical function and/or characteristic proof-of-concept"

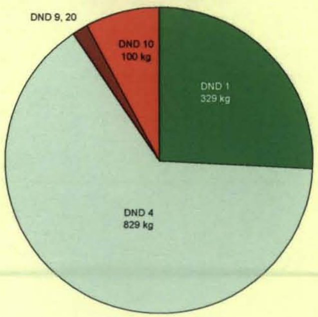
Total Outpost



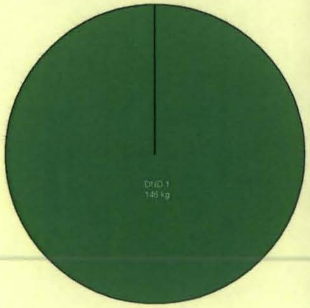
Habitat-1



Habitat-2

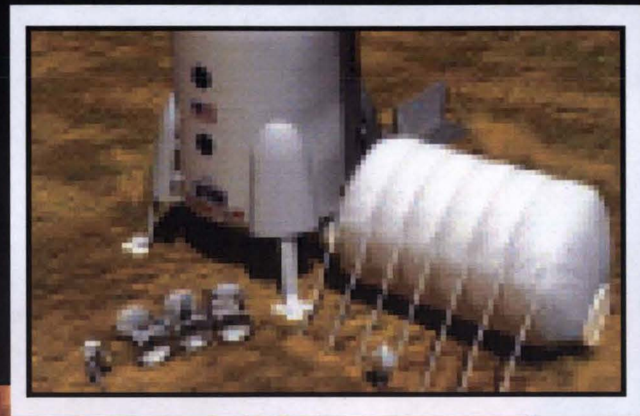


PLM



Extensibility to Mars

- Mars mission characteristics
  - months-long transits to & from
  - surface stays on the order to 500 days
  - quick emergency return unlikely
  - planetary protection policies
- How the lunar outpost ECLSS might help
  - establish & validate long-term reliability in an operational environment
  - demonstrate & gain experience with “zero-release” technologies & operations that minimize environmental impact



Lunar Surface Systems: Next Steps

- **Continue to refine lunar architecture concepts**
  - Target surface systems concept review in 2010 or 2011 timeframe
- **Continue to expand architecture participation with international and commercial entities**
- **Focus on identifying innovative approaches, complementary concepts, and necessary technologies, not on detailed designs of specific elements**
- **Explore a wide variety of scenarios that:**
  - Consider different ways to build up the Lunar capability over time
  - Assess multiple viewpoints on figures of merit for various lunar surface system capabilities