ISS Environmental Control and Life Support System (ECLSS) Future Development for Exploration

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Earth Provides for Us

- Air to breathe
- Water to drink
- Food to eat
As We Leave Earth, We Still Need...

• Air to breathe
• Water to drink
• Food to eat
Average Human Metabolic Balance (lb/person-day)

- Oxygen 1.84
- Water 7.77
  - Drink 3.56
  - In food 2.54
  - Food Prep 1.67
- Food Solids 1.36
  - Oxygen 0.44
  - Hydrogen 0.08
  - Carbon 0.60
  - Other 0.24
- Total In 10.97

Sustaining people in space requires managing all of their “ins and outs”
Functions Performed by ECLSS

- Control Cabin Pressure
- Control Cabin Atmosphere Composition & Purity
- Control Temperature, Humidity, & Particulates
- Monitor Cabin Environment
- Supply Oxygen
- Remove Carbon Dioxide
- Supply Water
- Collect, Stabilize, Store, & Dispose of Wastes
- Detect and Suppress Fires
- Ventilate Cabin
- Recycle Water
- Recycle Oxygen
- Recycle Oxygen
- Respond to and Recover from Environmental Emergencies

All Missions
Long Missions
What ECLSS Capabilities Exist Today?

Atmosphere Management

• Circulation
  – Fans (cabin & intermodule), valves, ducting, mufflers, filter elements

• Conditioning
  – Remove CO2 (expendable, regenerative open, regenerative closed)
  – Remove humidity (regenerative open, condensing heat exchangers closed)
  – Control temperature (non-condensing heat exchangers)
  – Recovery of ~50% O2 from CO2 (Sabatier process)
  – Supply O2 (stored gas, expendable perchlorate candles, H2O electrolysis)

• Emergency Services
  – Fire detection (optical) & suppression (CO2, N2)
  – Fire recovery (emergency return, scrub or vent cabin)
  – Toxic spills & medical response (respirators, O2 masks)

• Monitoring
  – Major constituents (mass spectrometry)
  – Trace constituents (primarily grab sample return with experimental onboard instruments)

• Pressure Management
What ECLSS Capabilities Exist Today?
Water Management

- Manage Potable Water
  - Stored water (earth-supplied, bellows tanks, collapsible bags)
  - Microbial control (iodine)

- Manage Waste Water
  - Collect wastewater (urine and humidity condensate air/liquid spin separators)
  - Stabilize wastewater (urine pretreatment)
  - Recover water from urine (vapor compression distillation)
  - Recover water from humidity condensate (filtration, adsorption, ion exchange, catalytic oxidation, gas/liquid membrane separators)
  - Dispose of unrecovered wastewater “brine” (store and disposal)

- Monitoring
  - On-line conductivity
  - Off-line total organic carbon, iodine
  - Samples returned to earth
What ECLSS Capabilities Exist Today?

Waste Management

- Manage Logistical Waste (packaging, containers, etc.)
  - Gather & store
  - Dispose (in re-entry craft)

- Manage Trash
  - Gather & store
  - Dispose (in re-entry craft)

- Manage Metabolic Waste
  - Collect (air-flow assisted)
  - Contain
  - Vent odor & bacterial control (sorbent, filter, vent overboard)
  - Dispose (in re-entry craft)
The Challenges of Going Beyond the ISS for ECLSS

~1-3 years transit time

390 kilometers

Atmosphere samples

Spare hardware, consumables

Emergency Crew Return

Trash

~ 2 days transit time

228,000,000 kilometers

390 kilometers
What ECLSS Capabilities Do We Need Beyond ISS?

Atmosphere Management

- Circulation
  - Fans: quiet
  - Filtration: high capacity, low maintenance, surface dust filtration
- Conditioning
  - Remove CO2: durable sorbents & substrates (non-dusting)
  - Remove humidity: durable desiccants, energy-efficient water save, combined CO2 & humidity removal (open loop)
  - Control temperature: durable heat exchanger coatings, lightweight heat exchangers & coldplates
  - Recover O2 from CO2: >50% recovery
  - Supply O2: more reliable and simpler O2 generator, high pressure electrolysis (3600 psia), O2 scavenging from cabin air
- Emergency Services
  - Fire detection: acid gases, CO (replace obsolete ISS tech – long duration & withstand vacuum exposure)
  - Fire suppression: non-toxic water mist for small spacecraft
  - Fire recovery: “smoke eater”
  - Toxic spills & medical response: filtering mask, non-venting O2 masks
- Monitoring
  - Reliable Major Constituent device
  - On-board trace constituents: miniaturized, with front end for H2O sample prep
  - On-board microbial with species identification & quantification
- Pressure Management
  - Variable pressure regulator (for space suits)
What ECLSS Capabilities Do We Need Beyond ISS?

Water Management

• Manage Potable Water
  – Microbial control: biocide, safe for consumption, on-orbit replenishment

• Manage Waste Water
  – Stabilize wastewater: non-toxic urine pretreat, prevent solids precipitation
  – Recover water from urine: simplified, reliable 85% recovery
  – Recover water from humidity condensate: robust moderate temperature oxidation catalyst, high capacity sorbents & resins
  – Water recovery from concentrated brine

• Monitoring
  – Total organic carbon
  – Biocide
  – Microbial: viable, speciation
  – Organic constituents: front-end sample processor for atmosphere monitor

• Dormancy
  – System must be able to operate after extended periods of dormancy at destination
What ECLSS Capabilities Do We Need Beyond ISS?

Waste Management

- **Manage Logistical Waste** (packaging, containers, etc)
  - Gather & store: reduce
  - Dispose: re-purpose

- **Manage Trash**
  - Gather & store: reduce
  - Dispose: re-purpose, stabilize, recover water & resources
    - Including crew radiation protection & planetary protection

- **Manage Metabolic Waste**
  - Collect: common system suitable for broad range of exploration vehicles & habitats
  - Contain
  - Dispose: re-purpose, stabilize, recover water & resources
    - Including crew radiation protection & planetary protection
Current ECLSS Evolution Plans and Projects

• The ECLSS community has developed a detailed roadmap for evolution needs, with detailed plans and budgets for closing gaps using the ISS as a testbed

• Current activities include:
  – Flight this year of new “CDRA-4” CO2 removal beds for improved sorbent robustness and containment
  – Ground development of various atmosphere and fire product monitors; flight demonstration of GC-DMS-based and GC-MS-based trace gas monitors
  – Development and planned flight of water mist fire extinguisher on ISS
  – Development and flight of emergency mask (dual cartridge) on ISS
  – Development of improved major constituent monitor for ISS and Orion
  – Development of a candidate microbial monitor for possible flight demonstration on ISS
  – Development of an alternate ISS urine pretreatment to address precipitation issues
  – Redesign of ISS water processor multifiltration bed for extended life

• Also in planning stages:
  – Upgrades to ISS urine processor, oxygen generator, and water processor for improved reliability and life extension
  – Universal commode
  – Development of other potential CO2 removal improvements
  – Assessment of dormancy impacts
  – Ground development of silver biocide
  – Technologies to recover >50% O2 from CO2 (low TRL)
  – Technologies to recover water from urine brine (low TRL)
ECLSS Benefits to Humanity

• Microbial check valve resin originally developed for Space Shuttle and adapted for use in ISS Water Processor.
• Commercial rights sold to Water Security Corporation, Reno, NV
• MCV disinfection offers advantages of low maintenance, reliable and consistent delivery, no electricity required, and ability to leave residual disinfection.
• World Wide Water Company has delivered thousands of their Survival Bag to many regions of the world for disaster relief and disaster preparedness situations.
  – One survival bag weighs 2 kg and provides 9000 liters of purified water
Vera Cruz, Mexico

- October, 2008 flood relief
Kendala, Northern Iraq

- System mounted on truck services multiple Kurdish villages, cleaning well water
- Sponsored by Concern For Kids, non-profit charity in collaboration with U.S. Army
Mexico Rural Villages

- Over 800 systems deployed in small remote villages providing only potable water

- Chiapas, Mexico school – students refill water bottles from “hydration station” mounted on the side of the filtration system
Kampang Salak, Malaysia

• Pedal-powered unit providing only safe drinking water to community of 600 people
• Pursuing development of network of systems in 11 Southeast Asia countries.
Sabana San Juan, Dominican Republic

- 300 person mountain village
- Nearest drinkable water 5 miles away
- Permanent unit cleans contaminated spring water, using solar power
Balakot, Pakistan

- Earthquake relief
- Water gravity fed from mountain stream
Smithsonian Folklife Festival, June/July ‘08
For additional information……

NASA Technical Area Roadmaps, 2012
• covering 14 different technical areas
• Available at
  http://www.nasa.gov/offices/oct/home/roadmaps/

Global Space Exploration Conference, May 2012
• ECLSS Roadmap, GLEX-2012_10_1_1x12284
• Available at
  https://www.aiaa.org