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

• Carbon Dioxide		2.20
• Water		8.53
	Urine	3.31
	Sweat & respiration	5.02
	Feces	0.20
• Solids		0.24
	In urine	0.13
	In sweat	0.04
	In feces	0.07
• Total Out		10.97

Sustaining people in space requires managing all of their "ins and outs"

Functions Performed by ECLSS

Supply Water

Supply Oxygen

Collect, Stabilize,
Store, & Dispose of Wastes

Remove Carbon Dioxide

Control Cabin Pressure

Detect and Suppress
Fires

All Missions

Long Missions

Control Cabin Atmosphere
Composition & Purity

Monitor Cabin
Environment

Control Temperature,
Humidity, & Particulates

Ventilate Cabin

Recycle Water

Respond to and Recover
from Environmental
Emergencies

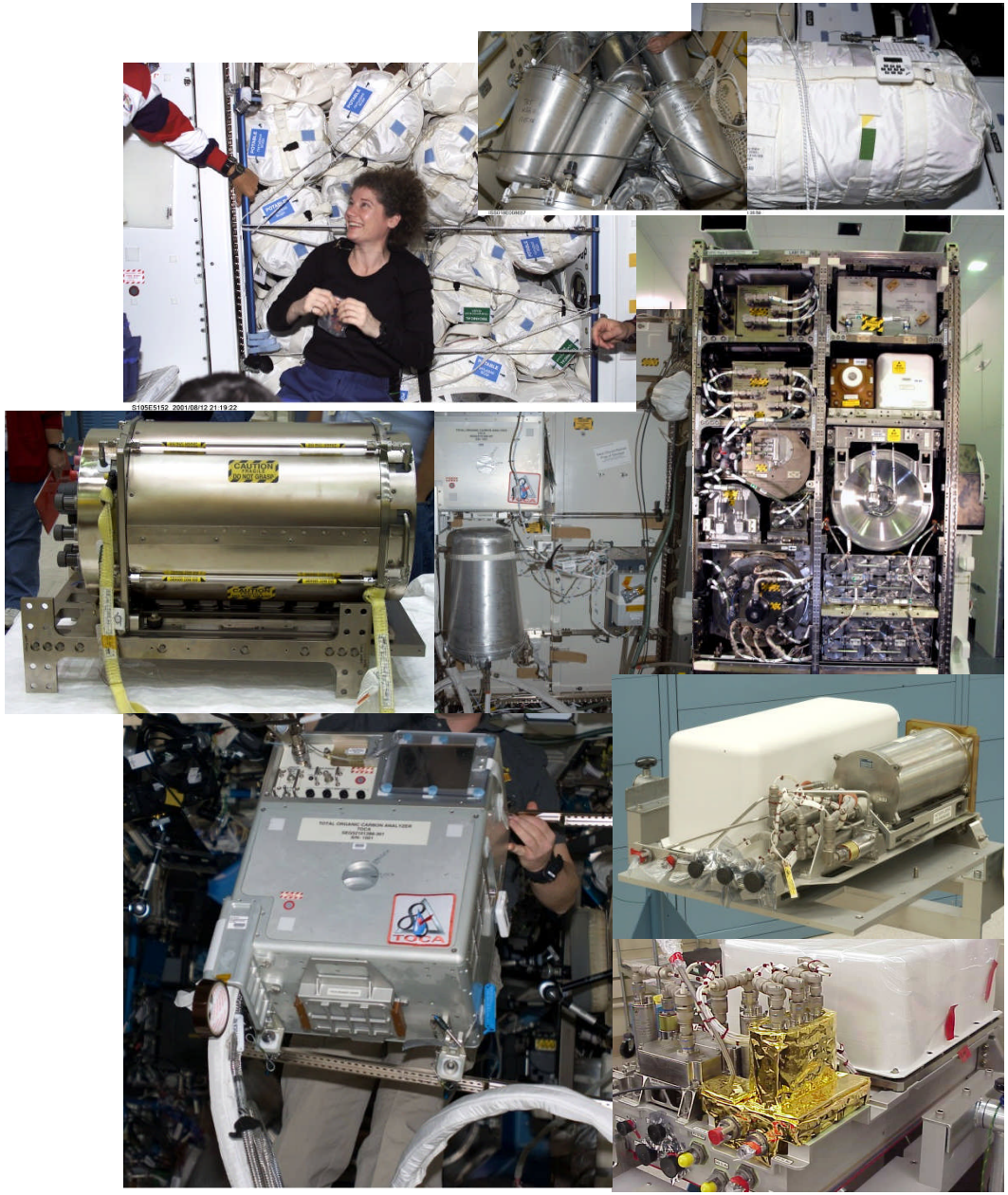
Recycle Oxygen

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

228,000,000 kilometers

~1-3years transit time

~ 2 days transit time

390 kilometers

Atmosphere samples

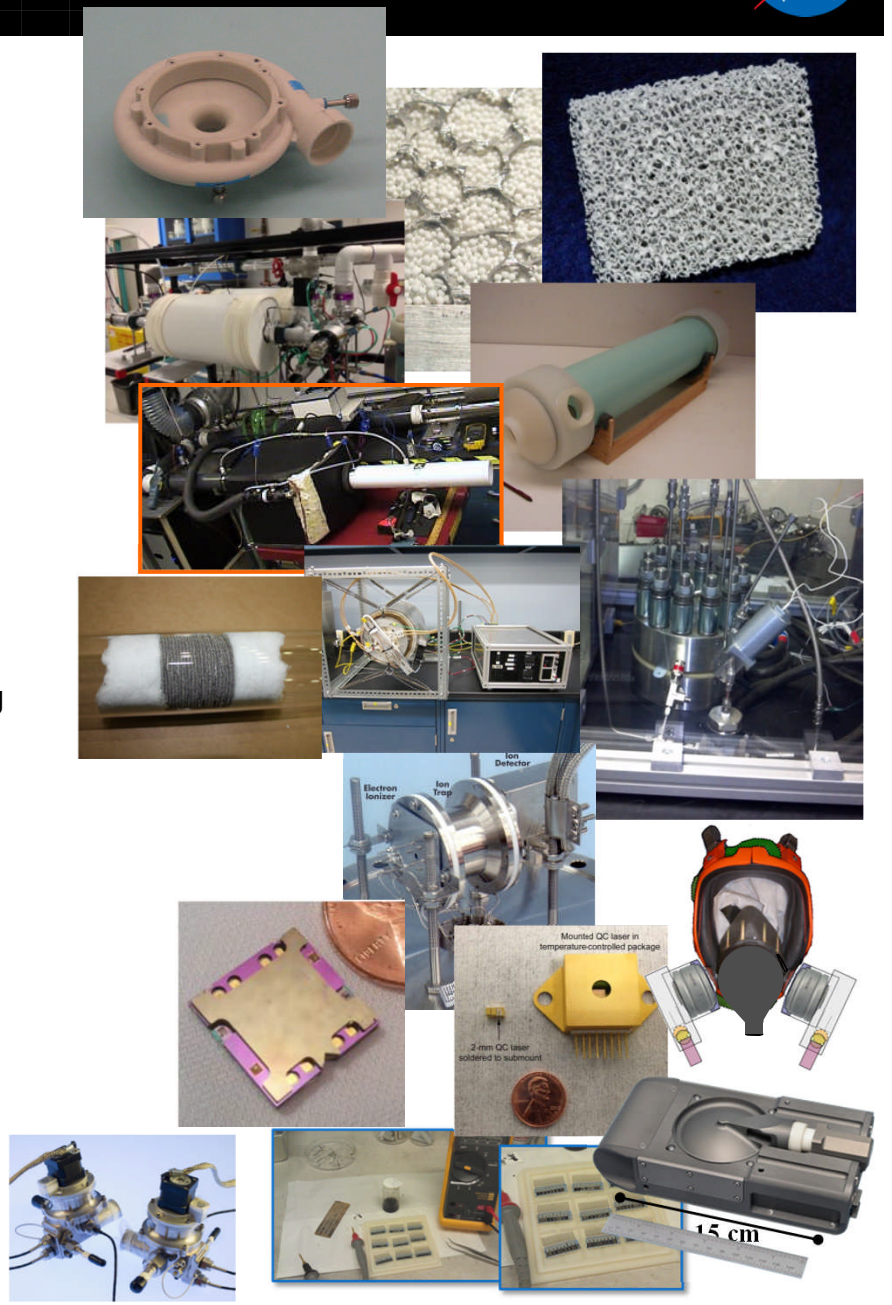
Spare hardware, consumables

Emergency Crew Return

Trash

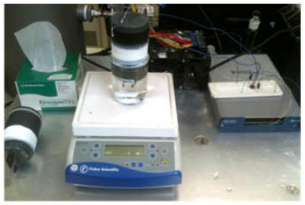
What ECLSS Capabilities Do We Need Beyond ISS?
Atmosphere Management

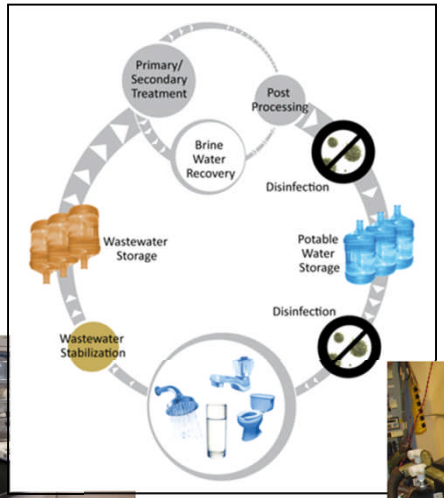
- Circulation
  - Fans: quiet
  - Filtration: high capacity, low maintenance, surface dust filtration
- Conditioning
  - Remove CO2 : durable sorbents & substrates (non-dusting)
  - Remove humidity: durable desiccants, energy-efficient water save, combined CO2 & humidity removal (open loop)
  - Control 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)

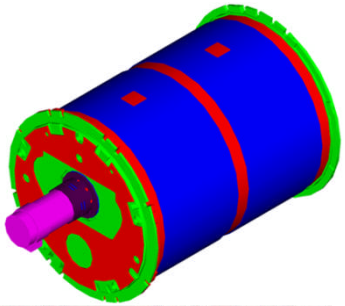


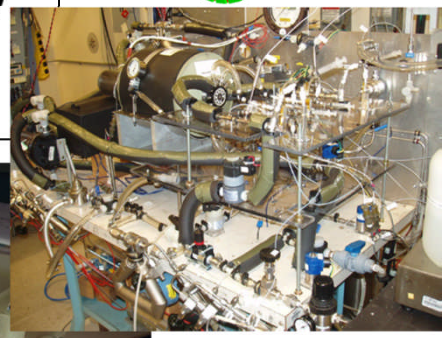
What ECLSS Capabilities Do We Need Beyond ISS? Water Management

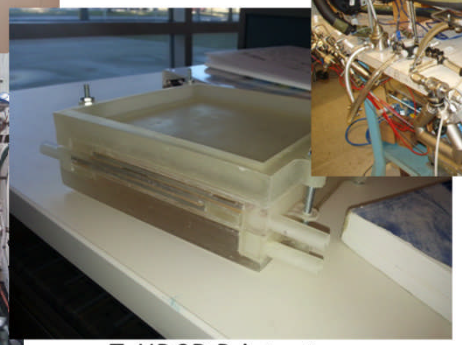
- Manage Potable Water
  - Microbial control: biocide, safe for consumption, on-orbit replenishment
- Manage Waste Water
  - Stabilize wastewater: non-toxic urine pretreat, prevent solids precipitation
  - Recover water from urine: simplified, reliable 85% recovery
  - Recover water from humidity condensate: 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







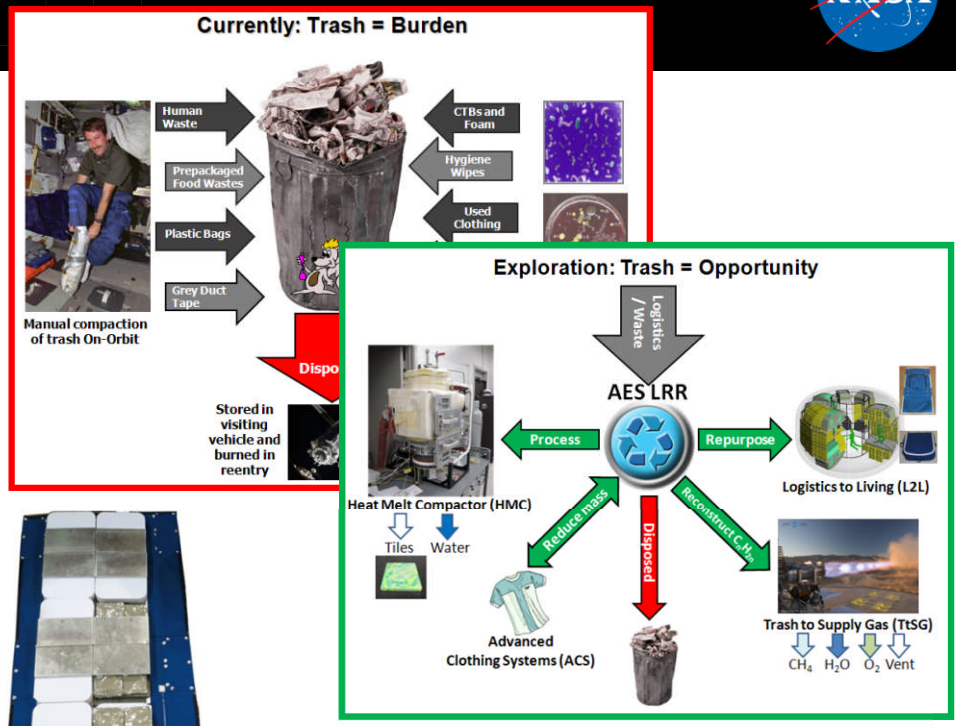




TeHP 3D Printout

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



Storm shelter MCTB w/food packs and HMC tiles


Single MCTB In launch config


Single MCTB unfolded for secondary use


Gasification reactor


Gen 1 HMC (proof of concept)


Example of volume reduction /stable tile for mixed trash (Gen 1 HMC tile)

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
  - Water Security involved in development of water filtration solutions for worldwide water quality problems.
- 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

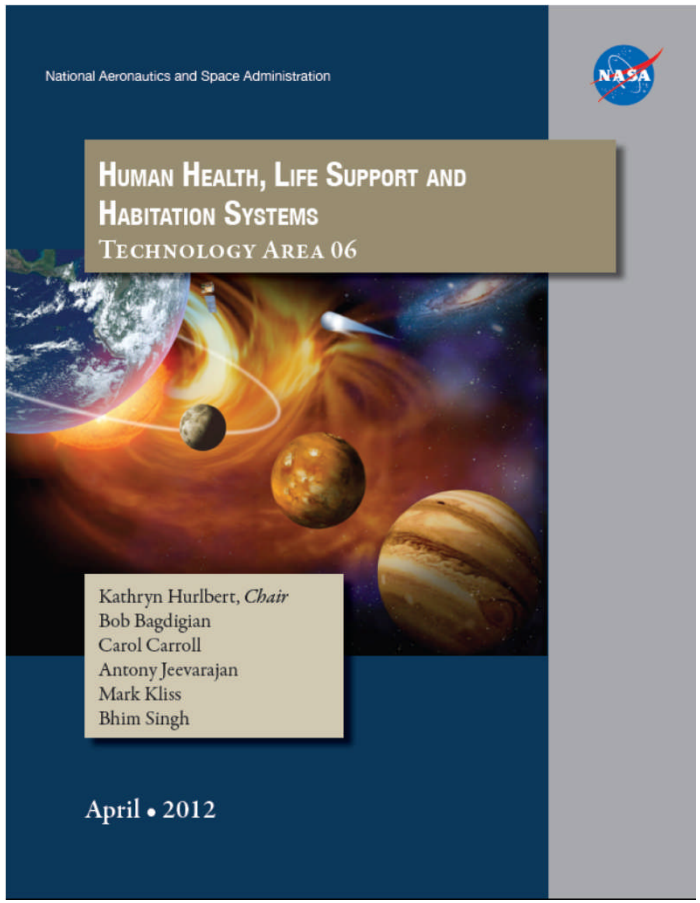
- Earthquake relief
- Water gravity fed from mountain stream

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