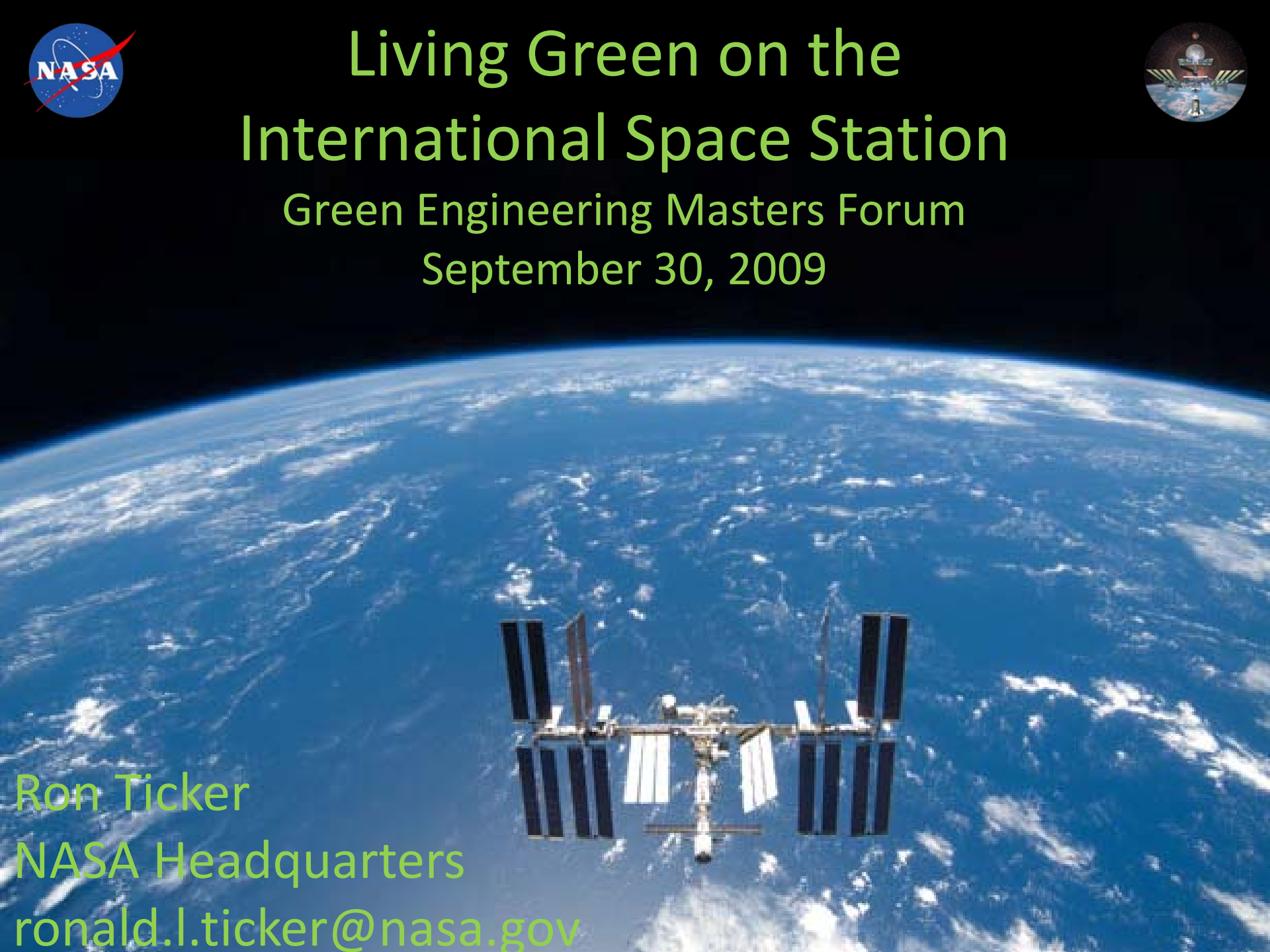
Living Green on the International Space Station

Green Engineering Masters Forum

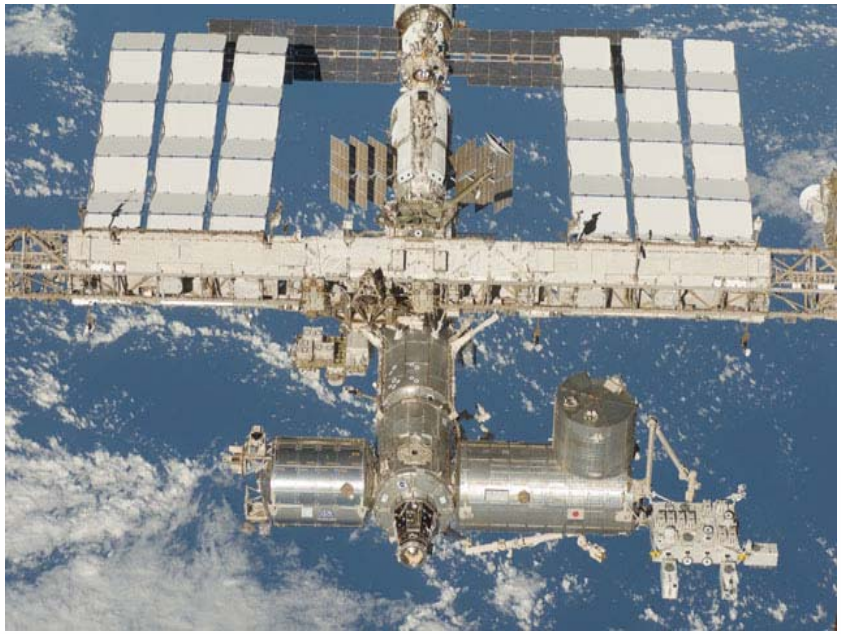
September 30, 2009



Ron Ticker
NASA Headquarters
ronald.l.ticker@nasa.gov

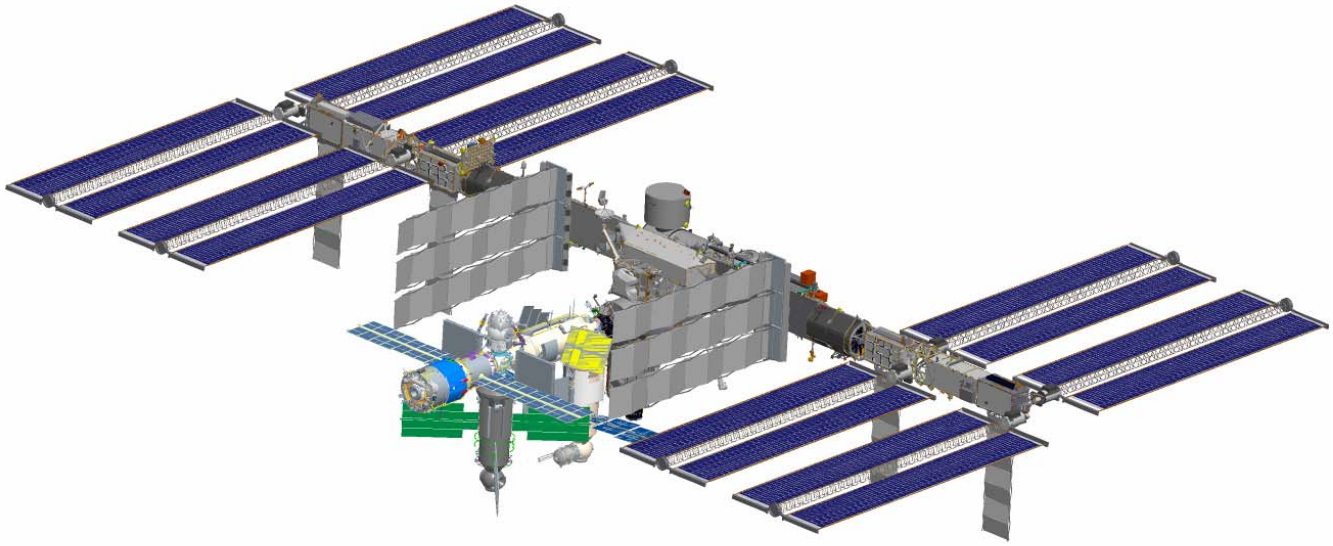
International Space Station Overview

Assembly Complete Dimensions
Length: 59 m
Width: 108.5 m
Weight: 419,573 kg
Volume: 963 cubic meters



Orbital inclination/path
51.6 degrees, covering 90% of the world's population

Altitude
Approximately 370 km above the Earth



Speed
28,000 kph, orbiting the Earth 16 times a day

The International Space Station Partners

Canadian Space Agency

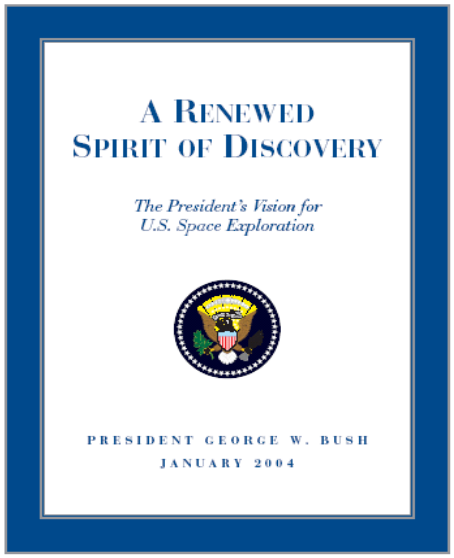
European Space Agency

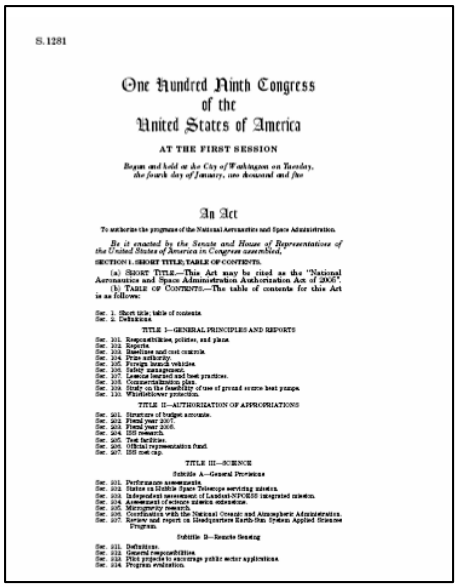
Japan Aerospace Exploration Agency

National Aeronautics and Space Administration

Russian Federal Space Agency

U.S. Research on ISS




S. 1281

One Hundred Ninth Congress
of the
United States of America

AT THE FIRST SESSION

An Act

- NASA Utilization of the ISS (Vision for Space Exploration, January 14, 2004, and NASA Authorization act of 2005)
  - Astronaut health and countermeasure development to protect crews from the space environment during long duration voyages
  - Testing research and technology developments for future exploration missions
  - Developing and validating operational procedures for long-duration space missions
- ISS National Laboratory beginning in 2010 (NASA Authorization act of 2005)
  - Opportunities for other U.S. government agencies to use ISS to meet their agency objectives
  - Opportunities for commercial interests to use ISS in the interests of economic development in space

The Challenge

- Long duration spaceflight requires a high degree of self-sustainment
  - Remote outpost
  - Cost of ISS replenishment
  - The further we go from Earth, the more difficult and complex are resupply opportunities

The
International Space Station
Biodome

Crewmember Support Requirements

Needs

Oxygen = 0.84 kg (1.84 lb)

Food Solids = 0.62 kg (1.36 lb)

Water in Food = 1.15 kg (2.54 lb)

Food Prep Water = 0.76 kg (1.67 lb)

Drink = 1.62 kg (3.56 lb)

Metabolized Water = 0.35 kg (0.76 lb)

Hand/Face Wash Water = 4.09 kg (9.00 lb)

Shower Water = 2.73 kg (6.00 lb)

Urinal Flush = 0.49 kg (1.09 lb)

Clothes Wash Water = 12.50 kg (27.50 lb)

Dish Wash Water = 5.45 kg (12.00 lb)

Total = 30.60 kg (67.32 lb)

Effluents

Carbon Dioxide = 1.00 kg (2.20 lb)

Respiration & Perspiration Water = 2.28 kg (5.02 lb)

Food Preparation, Latent Water = 0.036 kg (0.08 lb)

Urine = 1.50 kg (3.31 lb)

Urine Flush Water = 0.50 kg (1.09 lb)

Feces Water = 0.091 kg (0.20 lb)

Sweat Solids = 0.018 kg (0.04 lb)

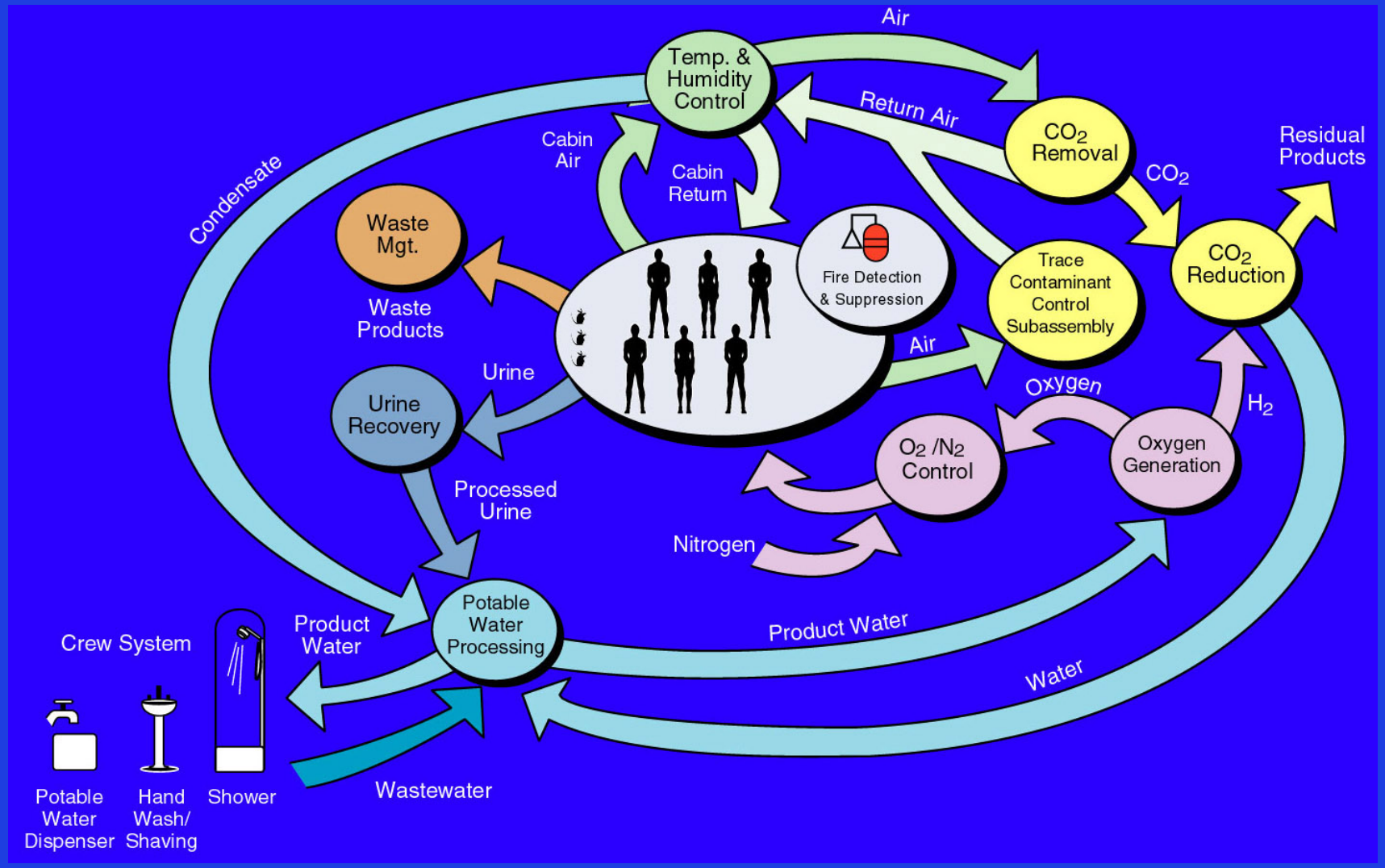
Urine Solids = 0.059 kg (0.13 lb)

Feces Solids = 0.032 kg (0.07 lb)

Hygiene Water = 12.58 kg (27.68 lb)

Clothes Wash Water
Liquid = 11.90 kg (26.17 lb)
Latent = 0.60 kg (1.33 lb)
Total = 30.60 kg (67.32 lb)

The Goal: Closing the Loop



Environmental Control and Life Support Systems

Vozdukh

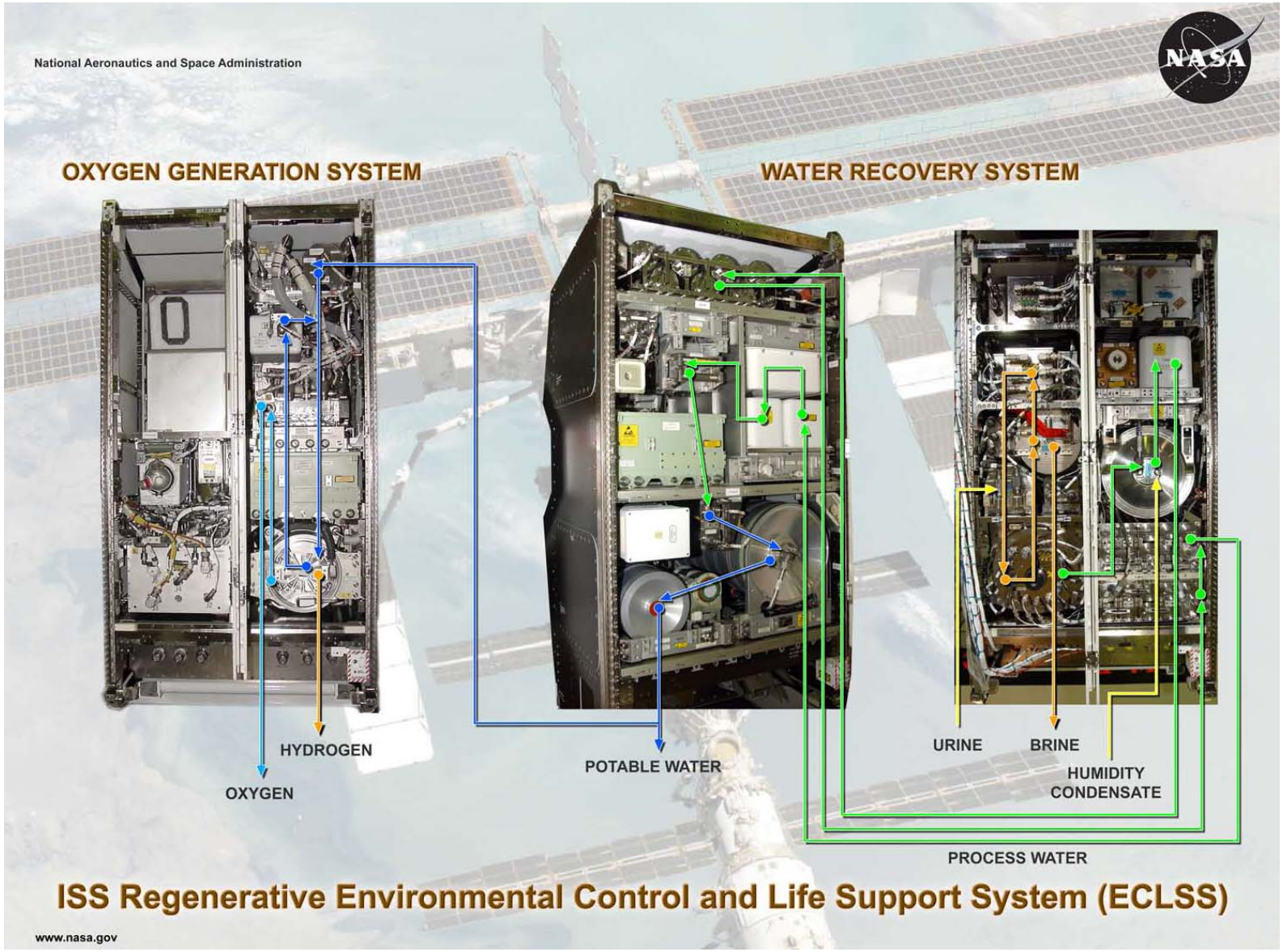
CO_2 Removal

Elektron

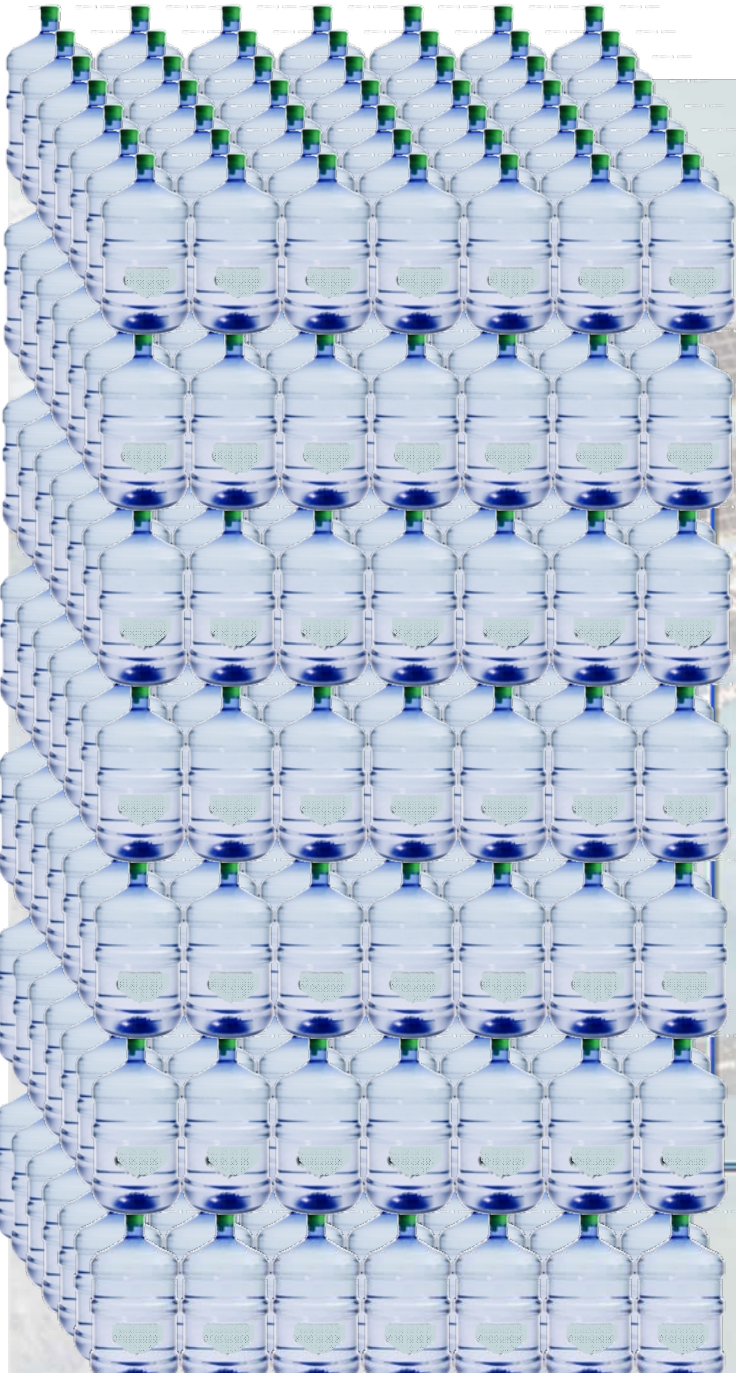
O_2 Generator

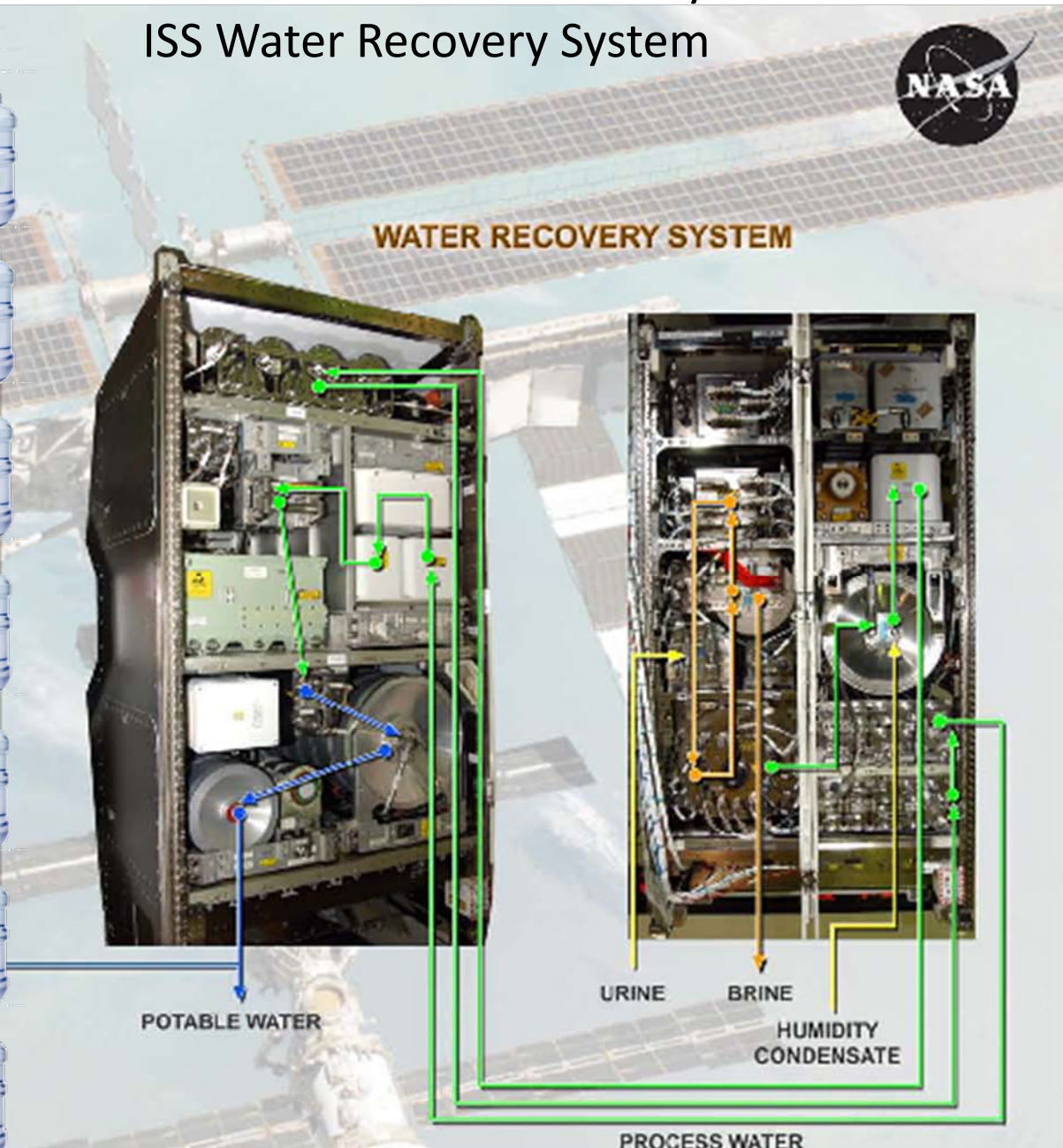
Condensate Water Processor

International Space Station Regenerative ECLSS



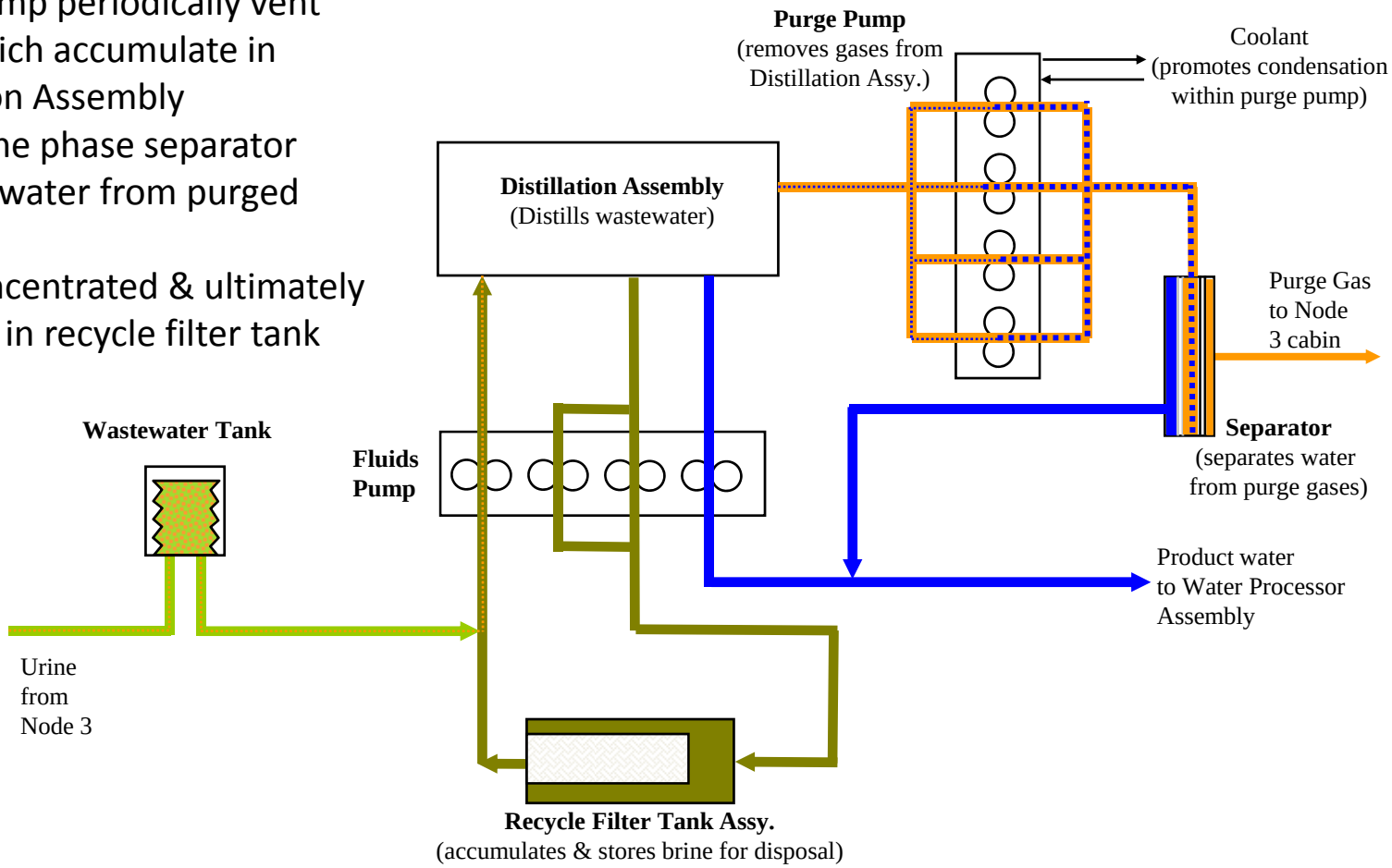
Annual Water Produced by ISS Water Recovery System



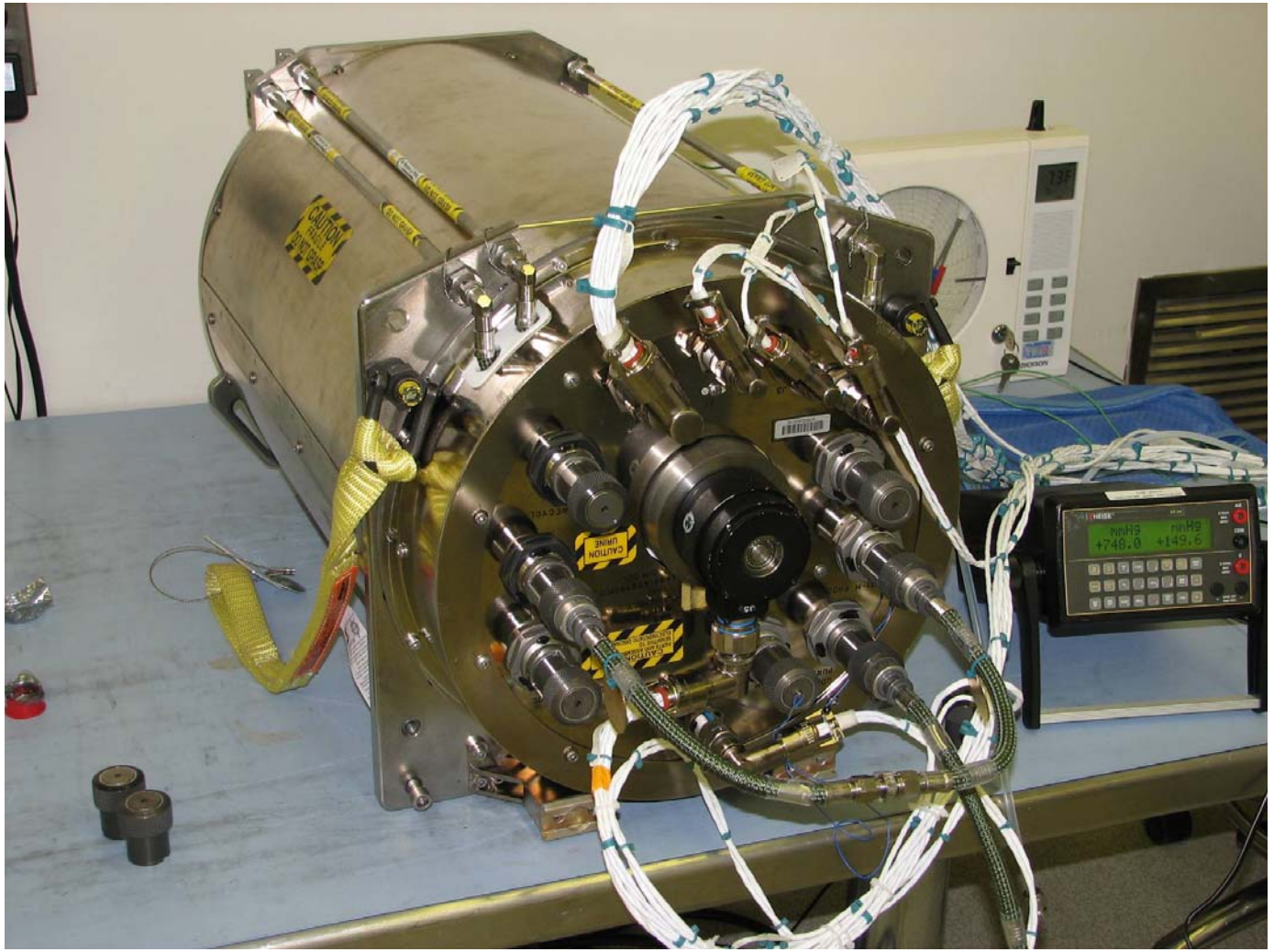


Urine Processor Description

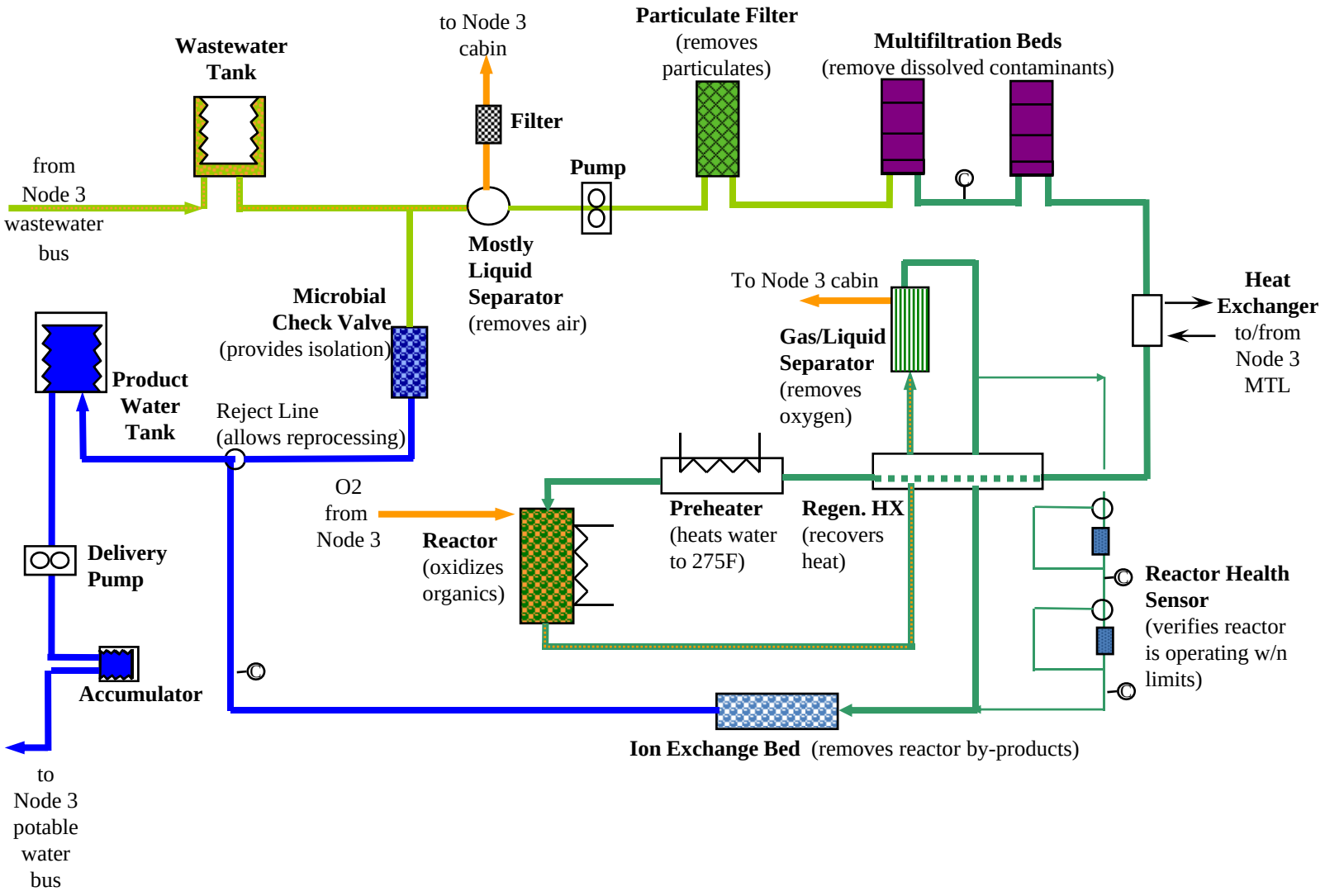
- Integrated Process
  - Pretreated urine temporarily stored prior to processing
  - Fluids pump circulates urine brine and removes product water through DA
    - » Purge pump periodically vent gases which accumulate in Distillation Assembly
    - » Membrane phase separator recovers water from purged gases
    - » Brine concentrated & ultimately removed in recycle filter tank



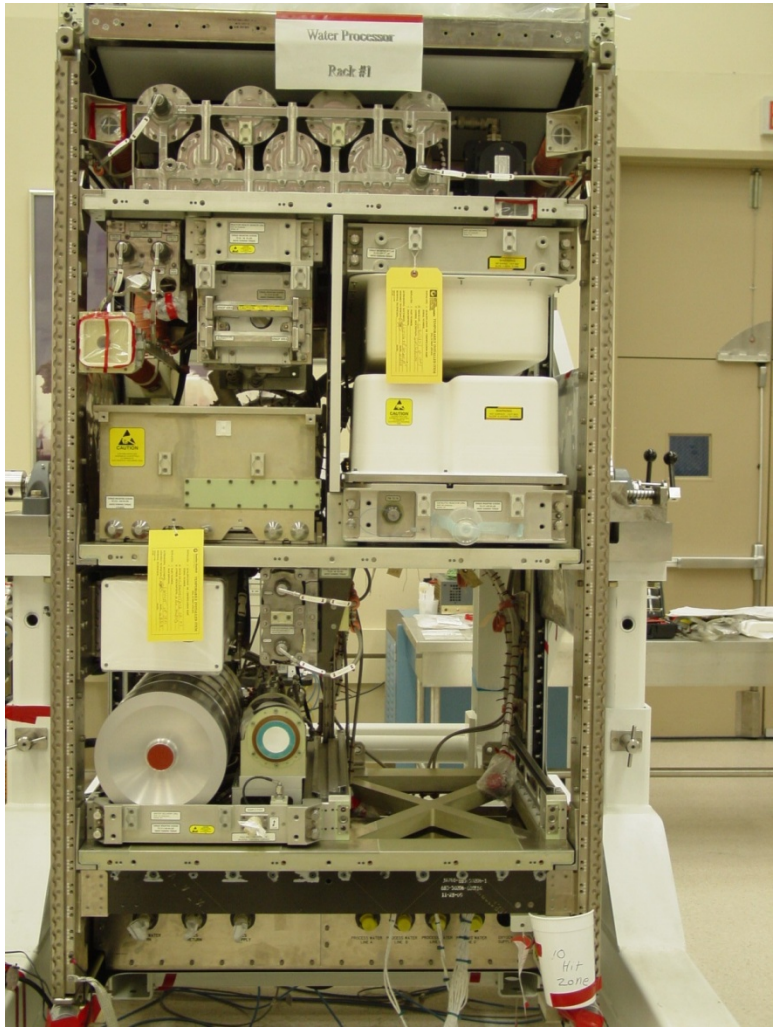
Urine Processor Distillation Assembly



ISS Water Processor Description



ISS Water Processor Assembly



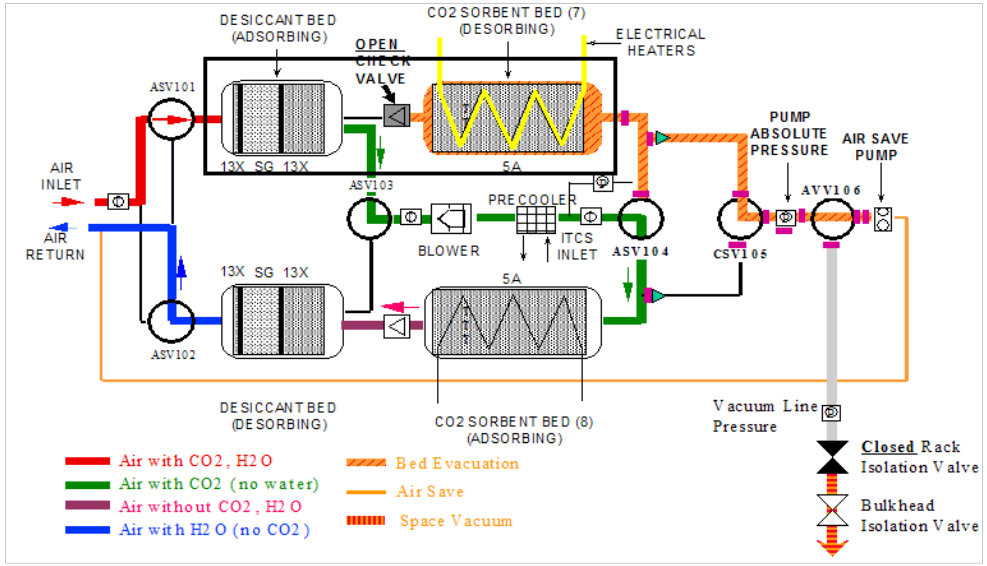
Total Organic Carbon Analyzer

- Final check on potable water prior to crew use
- Measures total organic carbon content from 250 – 25,000 ppb

Waste and Hygiene Compartment

US Oxygen Generator System

Carbon Dioxide Removal Assembly

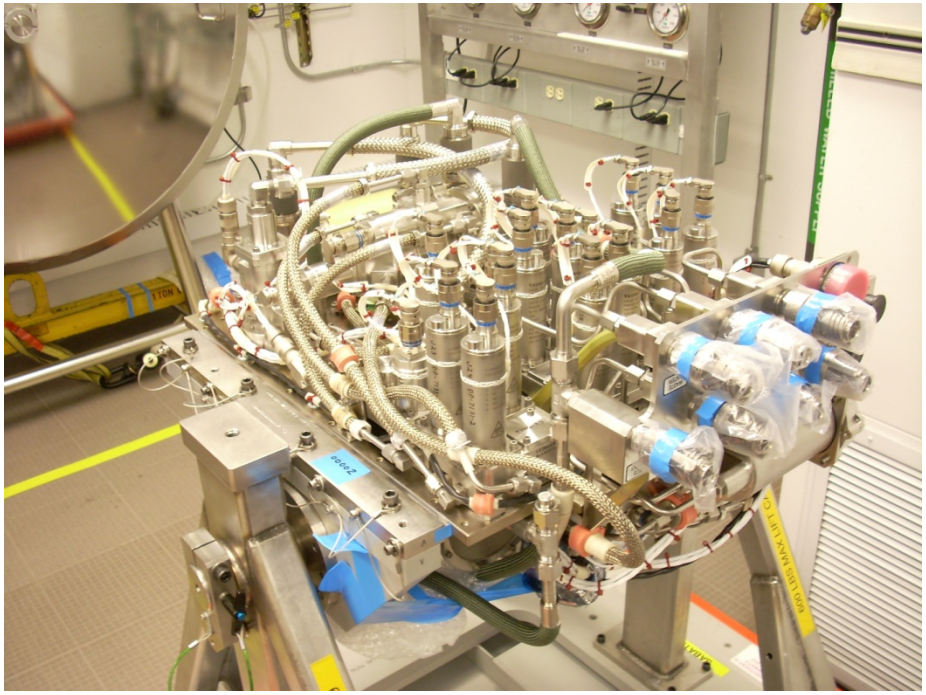


Sabatier

- Produces up to about 2,000 kg of water from waste CO_2 and H_2

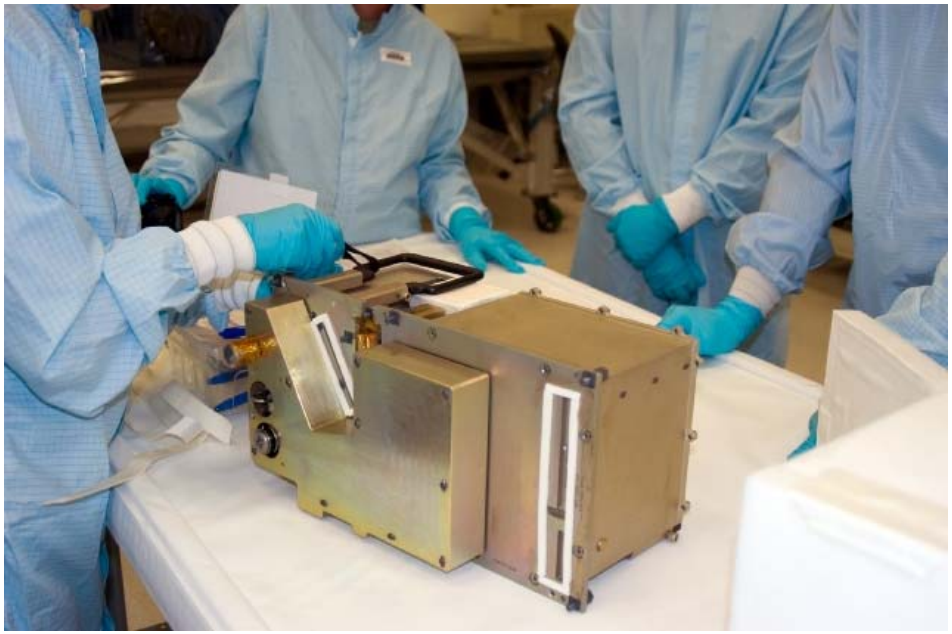
  $4H_2 + CO_2 \rightarrow 2H_2O + CH_4$

- Closes ECLSS loops to about 85%
- Innovative contracting approach with Hamilton-Sundstrand Space Systems



Major Constituent Analyzer

- Mass spectrometer continuously measures relative proportions of O_2, N_2, CO_2, H_2O, CH_4, and H_2 in the station's atmosphere



Trace Contaminant Control System

- Removes over 200 chemical compounds from the station's atmosphere

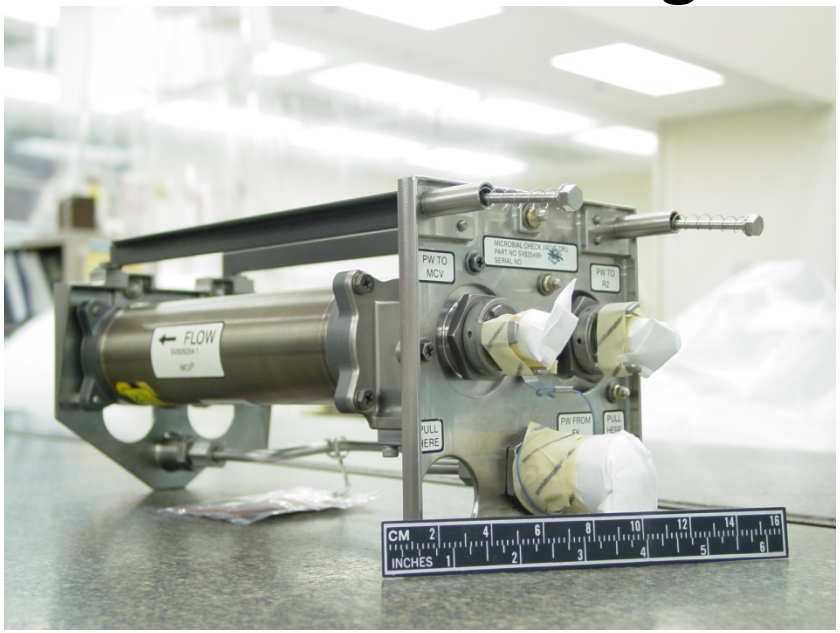
Environmental Monitoring

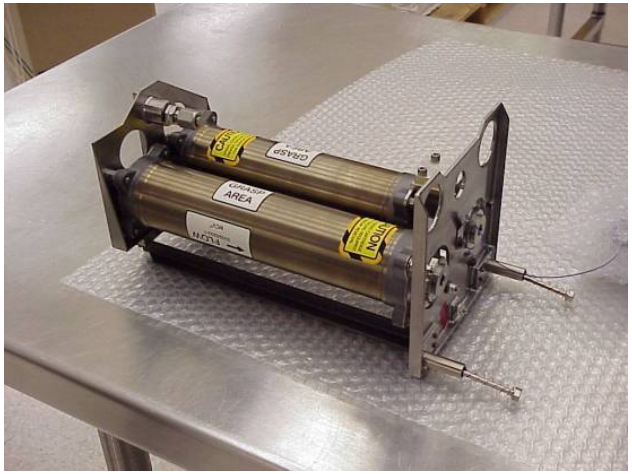
- **Environmental monitoring is performed operationally to insure the health of the spacecraft and crew**
- **Water system results:**
  - 12 bacterial strains cultured, met safe drinking water standards
  - Biocide treatments and other preventative measures are working
- **Air quality results:**
  - HEPA filters are effective in controlling trace contaminants
  - Performance and repair of Volatile Organics Analyzer
  - Lessons learned from regeneration of Metox cannisters—disruption of airflows and temporary formaldehyde accumulations
- **SWAB investigation**
  - 90% of microbes cannot be cultured
  - *Legionella*, *Cryptosporidium*, dust mites, endotoxins
  - Modern genetic approaches to follow changes in microbial communities on ISS
  - Surfaces, Air, Water

Surface, Water and Air Biocharacterization - A Comprehensive Characterization of Microorganisms and Allergens in Spacecraft Environment , PI: Duane L. Pierson, NASA JSC

Water Processor Assembly Microbial Check Valve

- Imparts residual iodine for microbial control
  - ISS water processor MCV tailored for 1-4 ppm
- Provides barrier against microbial growth





MCV Transfer from NASA to Commerical

- Microbial check valve resin originally developed for Space Shuttle by Umpqua Research, Inc.
- Umpqua also developed Iodosorb iodine scrubber used to remove iodine prior to human consumption.
- MCV 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.

Commercial Ground-Based System – Water Security Corp.

- Range of systems
- Larger unit
  - 4 GPM sufficient for small rural village
  - Sediment filter - particulates
  - Carbon filter – pesticides, herbicides, organics
  - MCV & Iodosorb for disinfection
  - Unibed filter – heavy metals
  - Polishing filter
  - 30,000 gal capacity before filter replacement

½ gal per minute
3000 gal capacity
Hand pump

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

Chiapas, Mexico

- Systems deployed in small remote villages providing only potable water

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

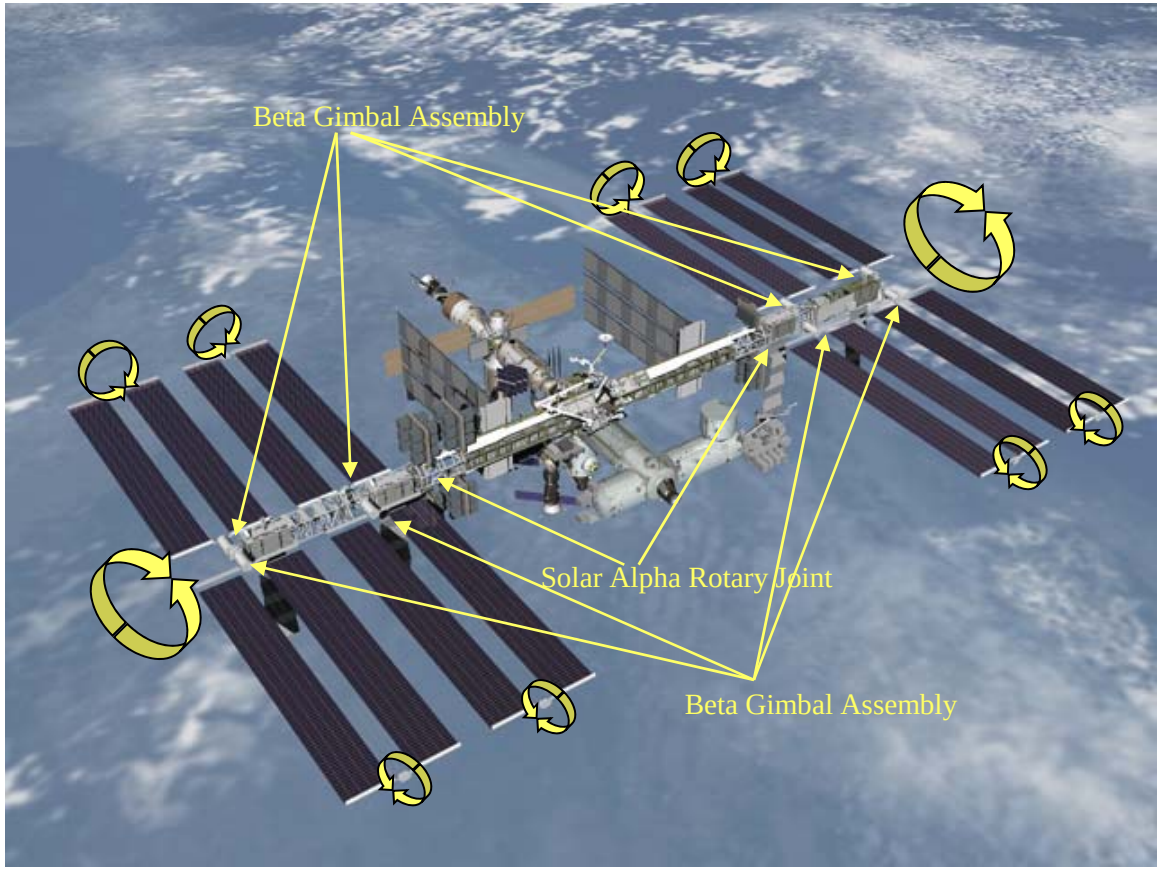
Balakot, Pakistan

- Earthquake relief
- Water gravity fed from mountain stream

Electrical Power Generation

- Critical to support of ISS systems and research
- Total solar array area 2,192 m^2
- 708,000 kW-hours per year

Getting the Most Production Out of the Solar Arrays



The International Space Station

International Space Station http://www.nasa.gov/station

ISS Research http://www.nasa.gov/mission_pages/station/science/index.html

ISS Interactive Reference Guide http://www.nasa.gov/externalflash/ISSRG