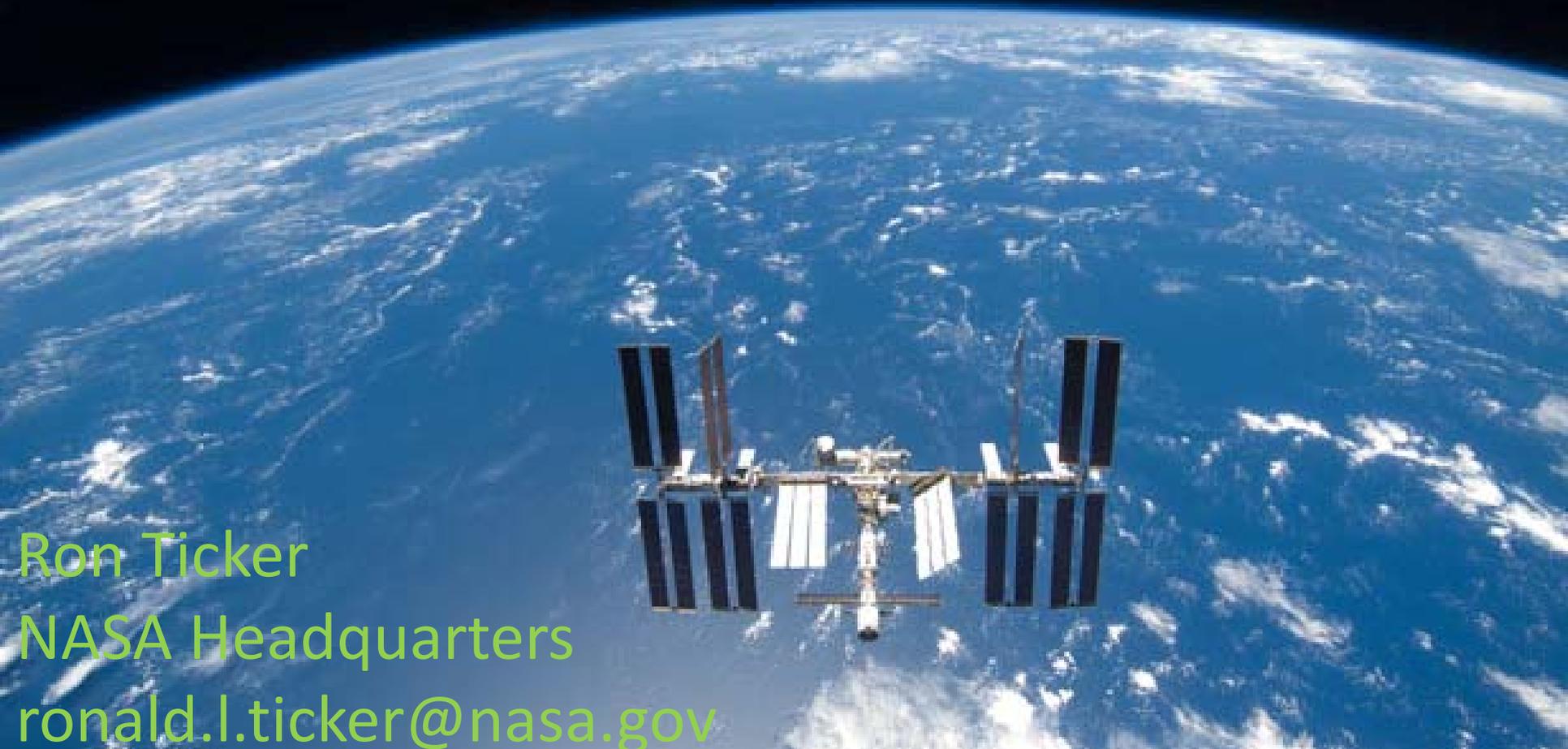




# Living Green on the International Space Station

Green Engineering Masters Forum  
September 30, 2009



Ron Ticker  
NASA Headquarters  
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# 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

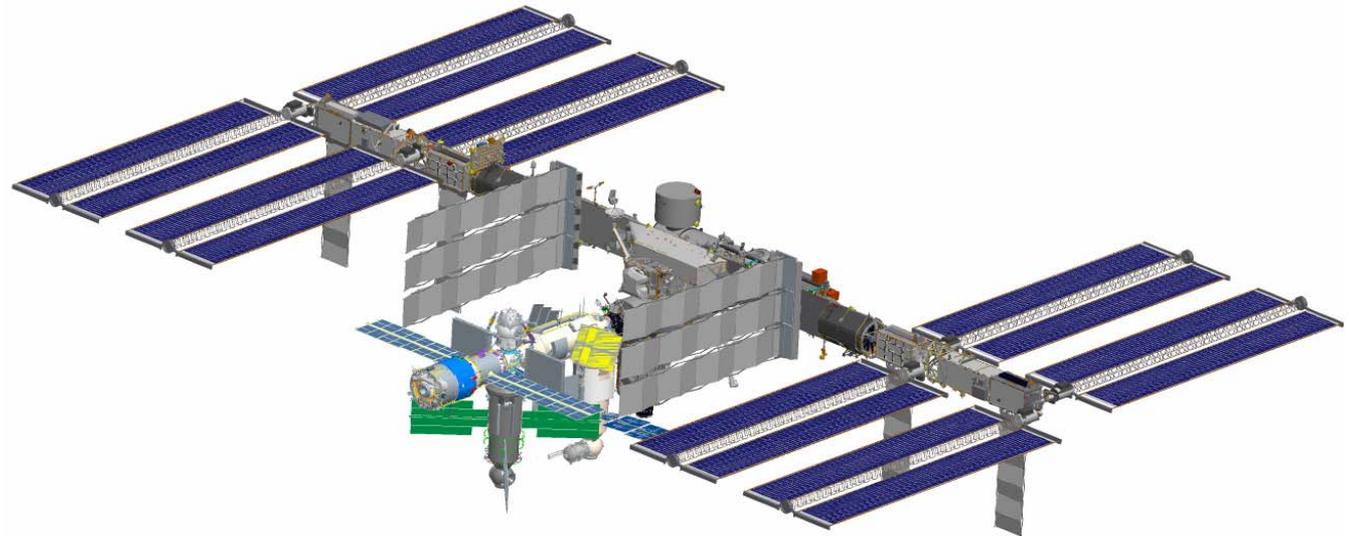


## Altitude

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**



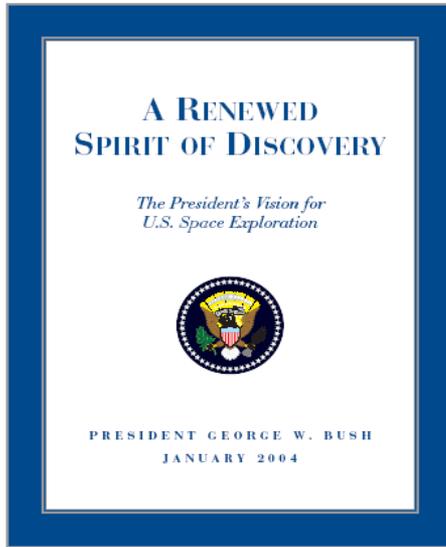
**National Aeronautics and Space Administration**



**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  
Began and held in the City of Washington on Tuesday,  
the fourth day of January, one thousand and five

An Act  
To enhance the program of the National Aeronautics and Space Administration,  
As enacted by the Senate and House of Representatives of  
the United States of America in Congress assembled,  
SECTION 1. SHORT TITLE; TABLE OF CONTENTS.

(a) SHORT TITLE.—This Act may be cited as the “National  
Aeronautics and Space Administration Authorization Act of 2005”.

(b) TABLE OF CONTENTS.—The table of contents for this Act  
is as follows:

Sec. 1. Short title; table of contents.

Sec. 2. TABLE OF CONTENTS.

    TITLE I—GENERAL PRINCIPLES AND REPORTS

Sec. 101. Requirements, priorities, and plans.

Sec. 102. Reports.

Sec. 103. Information and cost account.

Sec. 104. Evaluation.

Sec. 105. Foreign launch vehicles.

Sec. 106. Launch, operations, and recovery systems.

Sec. 107. Launch, operations, and recovery systems.

Sec. 108. Commercialization plan.

Sec. 109. Study on the feasibility of use of private sector launch systems.

Sec. 110. Workforce development.

    TITLE II—ADMINISTRATION OF APPROPRIATIONS

Sec. 201. Timeliness of budget accounts.

Sec. 202. Fiscal year 2005.

Sec. 203. Fiscal year 2006.

Sec. 204. Reports.

Sec. 205. The Budget.

Sec. 206. Technical Requirements Fund.

Sec. 207. Use of Roy.

    TITLE III—SCIENCE

    Subtitle A—General Provisions

Sec. 301. Performance assessment.

Sec. 302. Status on Human Space Flight—working models.

Sec. 303. Independent Assessment of Landmark/Orbit: Integrated mission.

Sec. 304. Assessment of science research opportunities.

Sec. 305. Microgravity research.

Sec. 306. Coordination with the National Center and Atmospheric Administration.

Sec. 307. Science and report on International Earth-Satellite System Applied Science Program.

    Subtitle B—Remote Sensing

Sec. 401. Definition.

Sec. 402. Goals and capabilities.

Sec. 403. Data provided to encourage public sector applications.

Sec. 404. Program evaluation.

- 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)

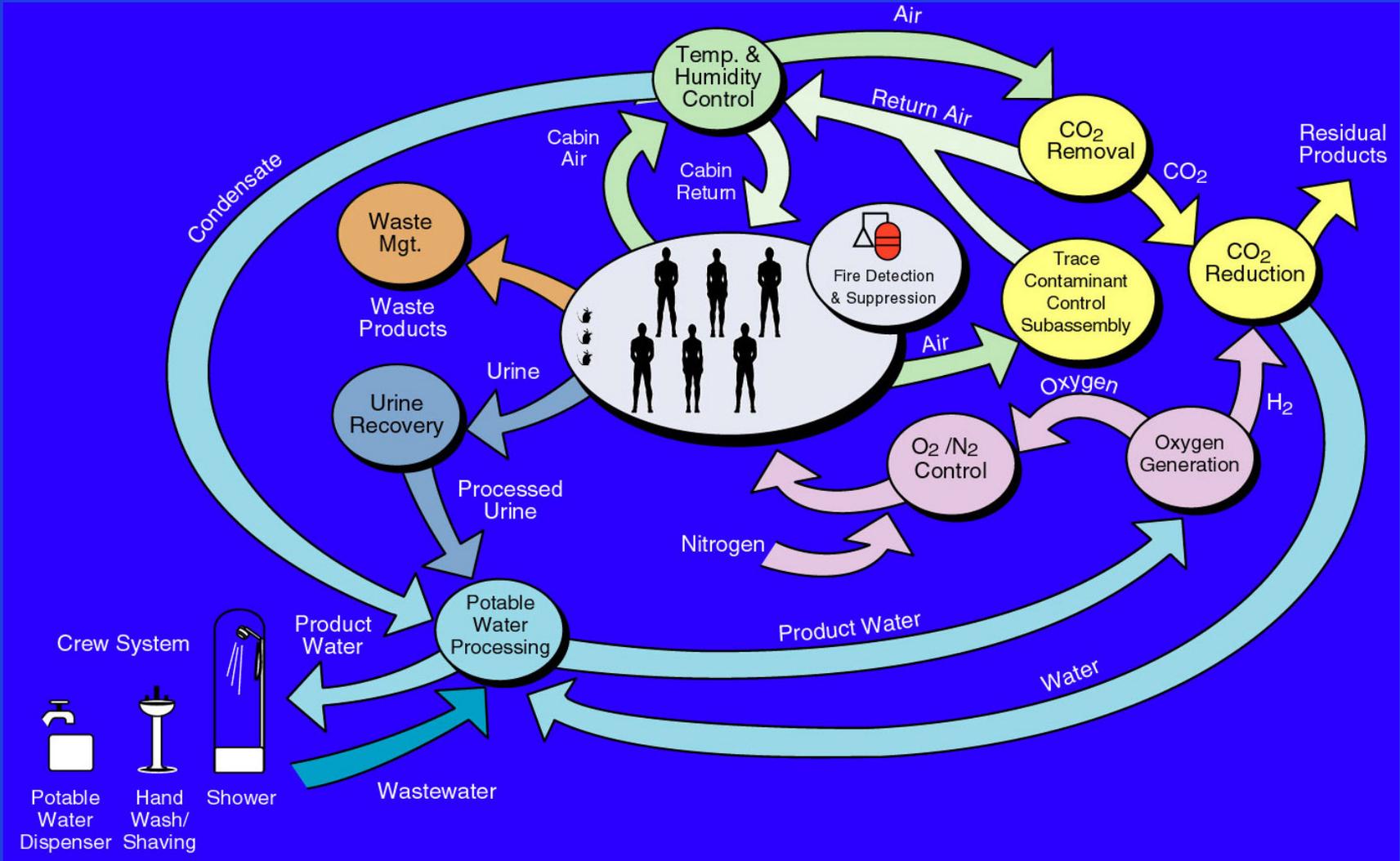
Urine Solids = 0.059 kg (0.13 lb)

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<sub>2</sub> Removal



Elektron  
O<sub>2</sub> Generator



Condensate Water  
Processor

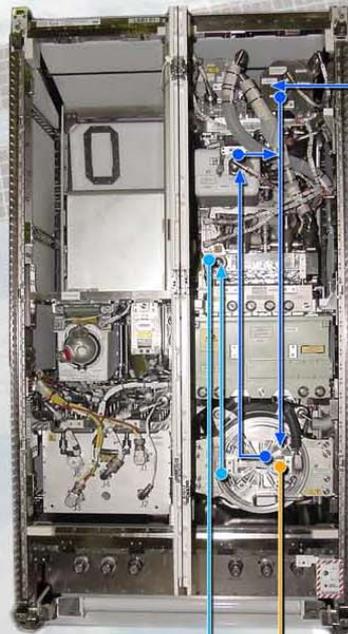


# International Space Station Regenerative ECLSS

National Aeronautics and Space Administration



## OXYGEN GENERATION SYSTEM

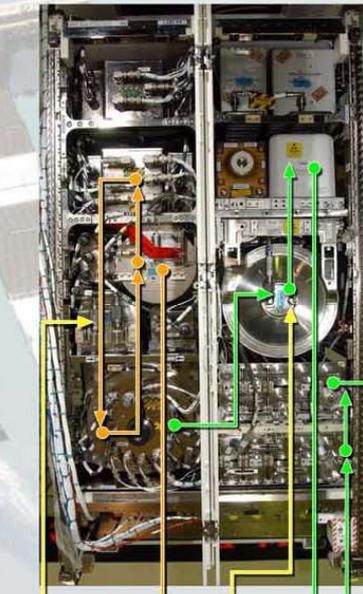


HYDROGEN  
OXYGEN

## WATER RECOVERY SYSTEM



POTABLE WATER



URINE  
BRINE  
HUMIDITY  
CONDENSATE

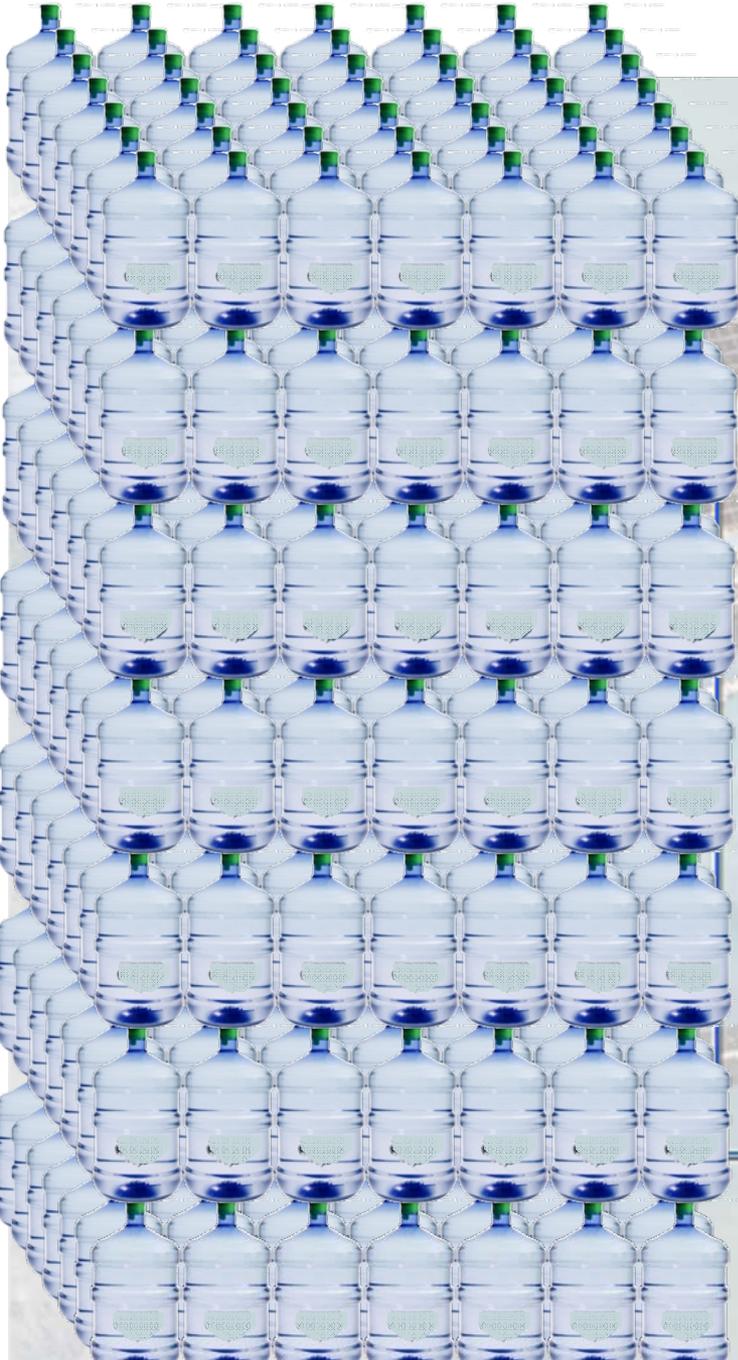
PROCESS WATER

## ISS Regenerative Environmental Control and Life Support System (ECLSS)

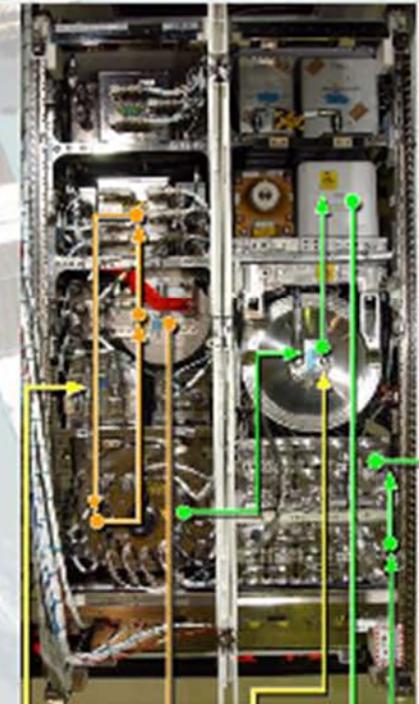
# Annual Water Produced by ISS Water Recovery System



## WATER RECOVERY SYSTEM



POTABLE WATER



URINE

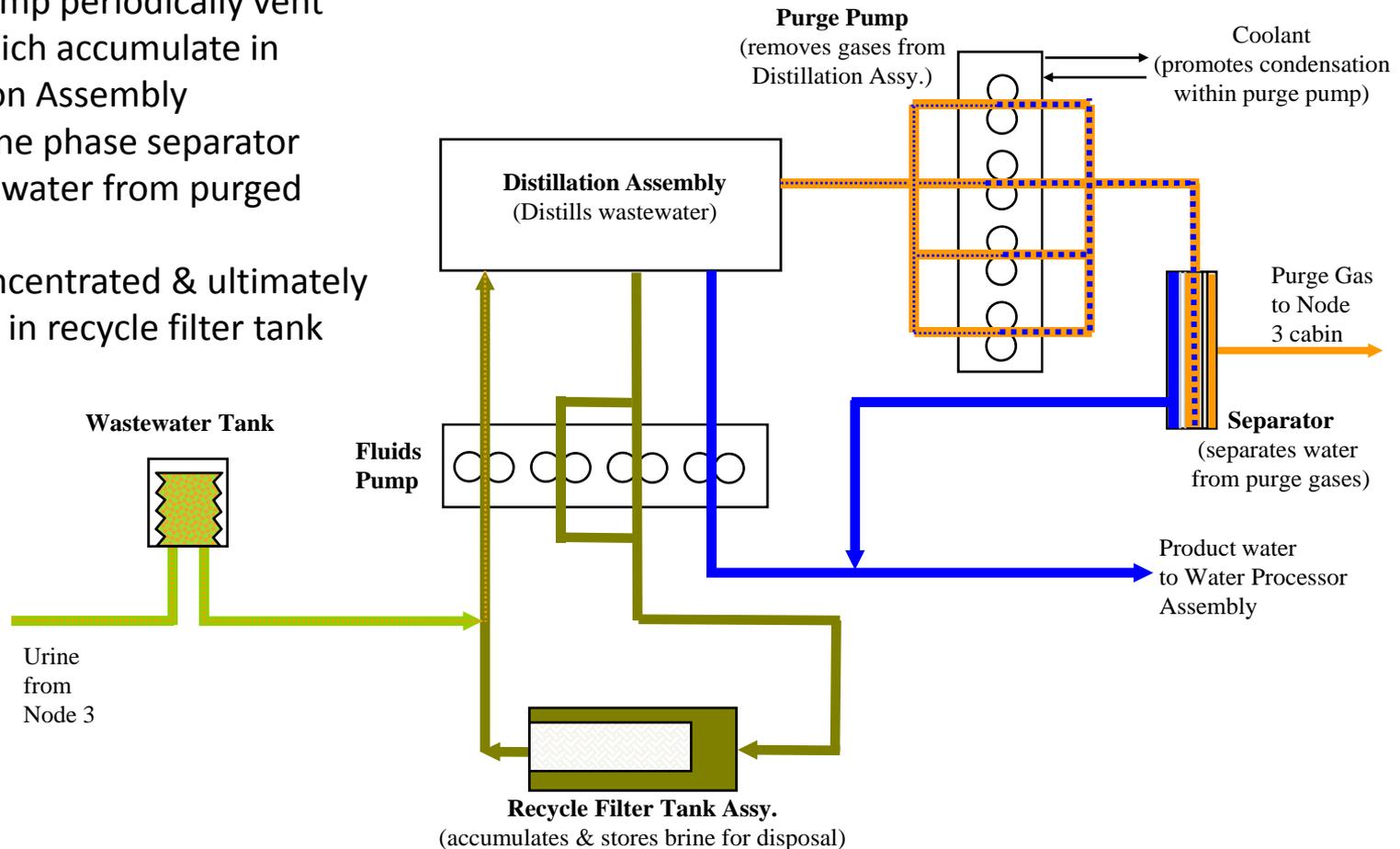
BRINE

HUMIDITY  
CONDENSATE

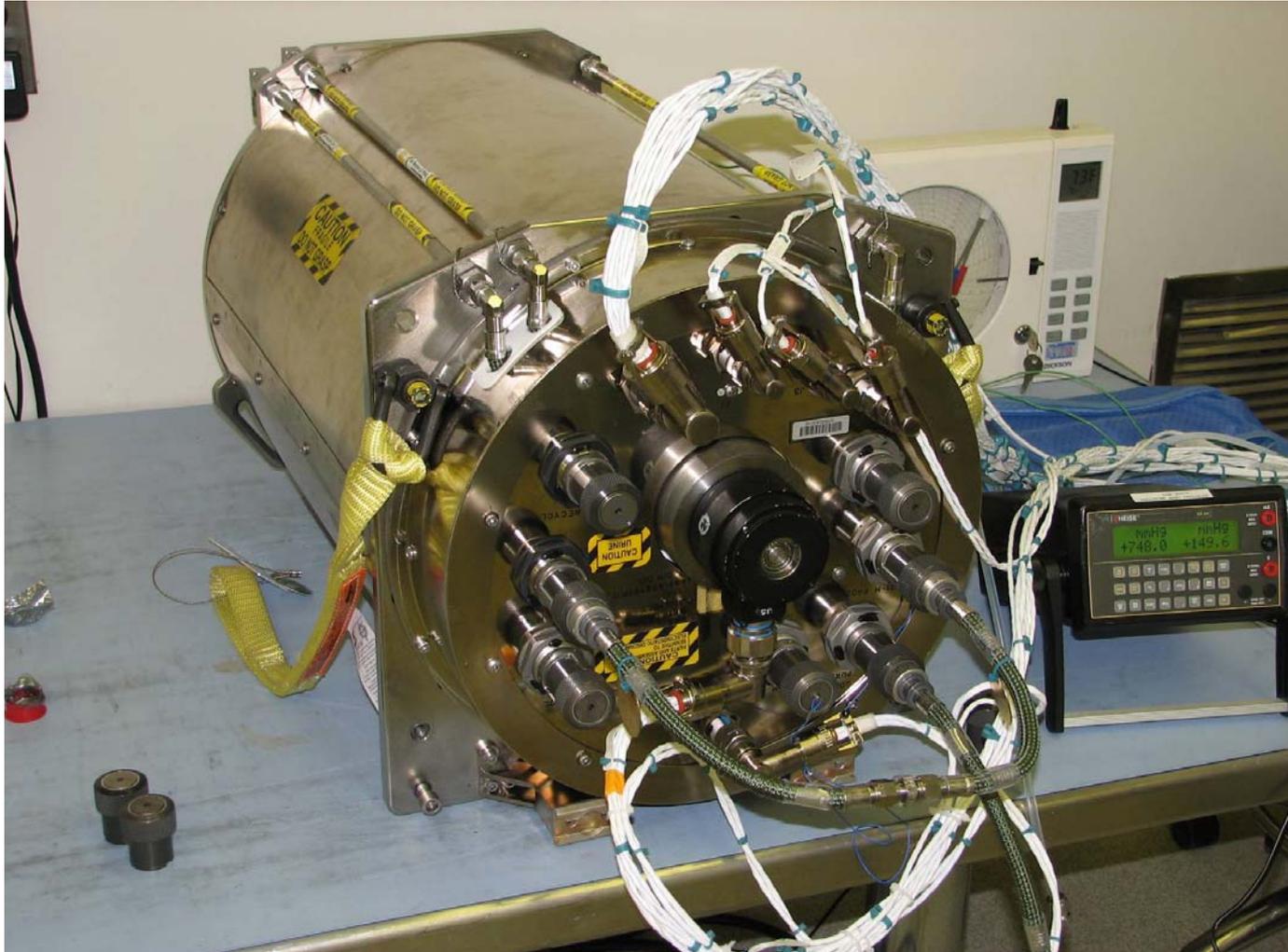
PROCESS WATER

# Urine Processor Description

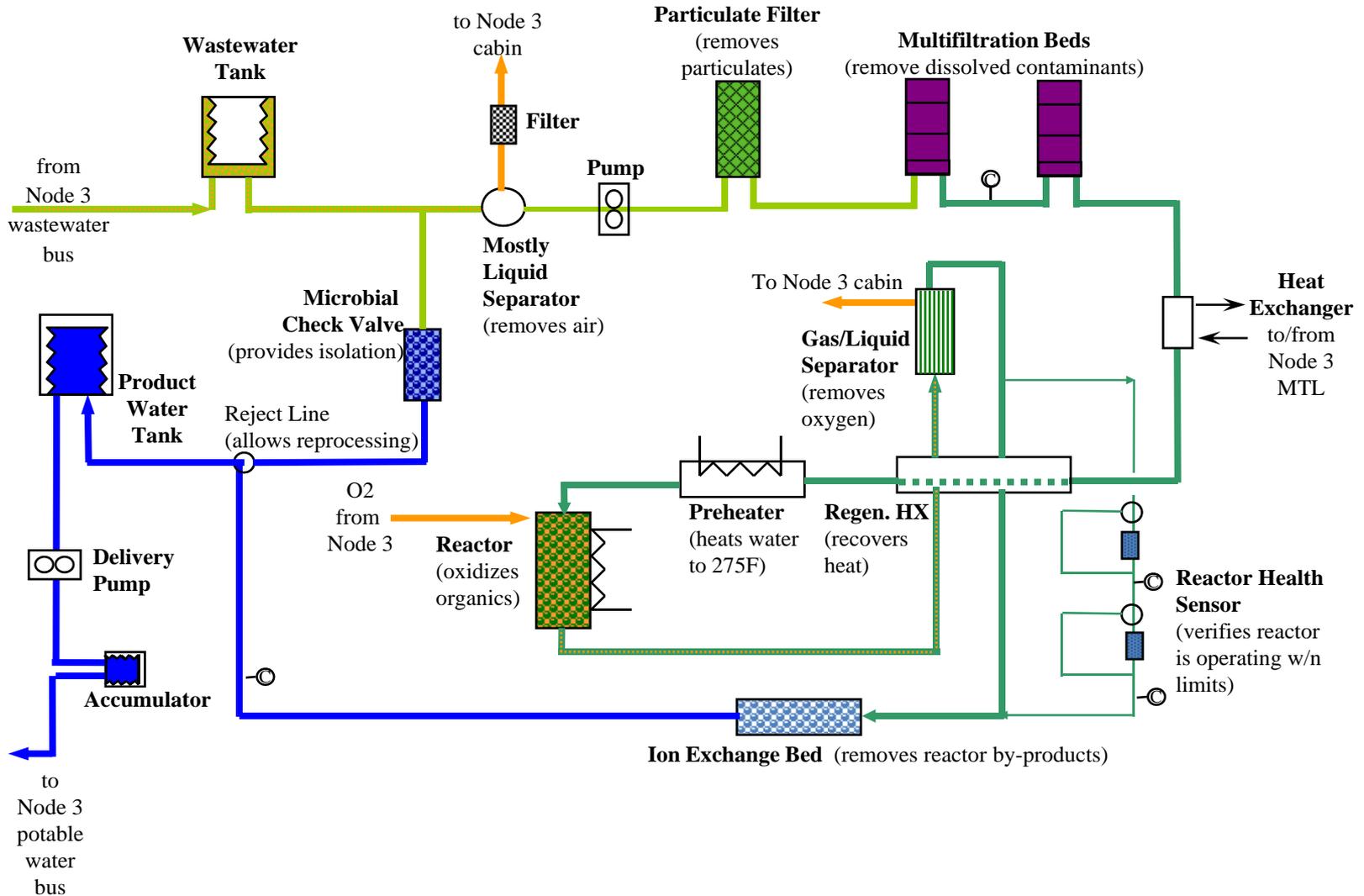
- Integrated Process
  - Pretreated urine temporarily stored prior to processing
  - Fluids pump circulates urine brine and removes product water through DA
    - » Purge pump periodically vent gases which accumulate in Distillation Assembly
    - » Membrane phase separator recovers water from purged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



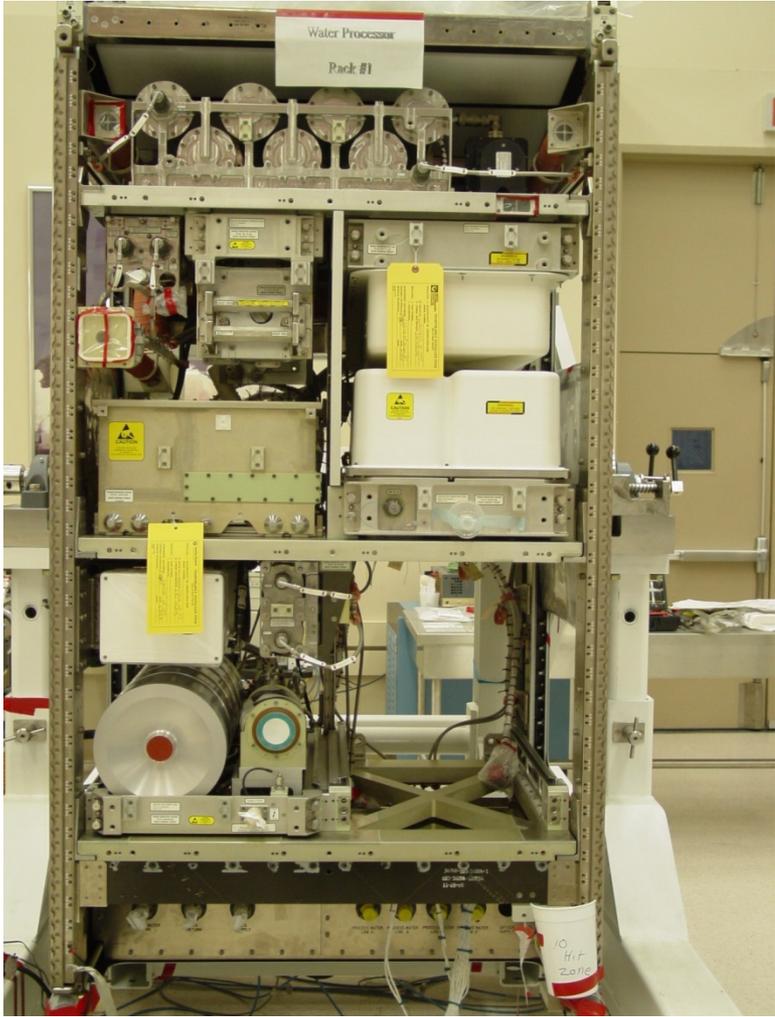
# Urine Processor Distillation Assembly



# 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

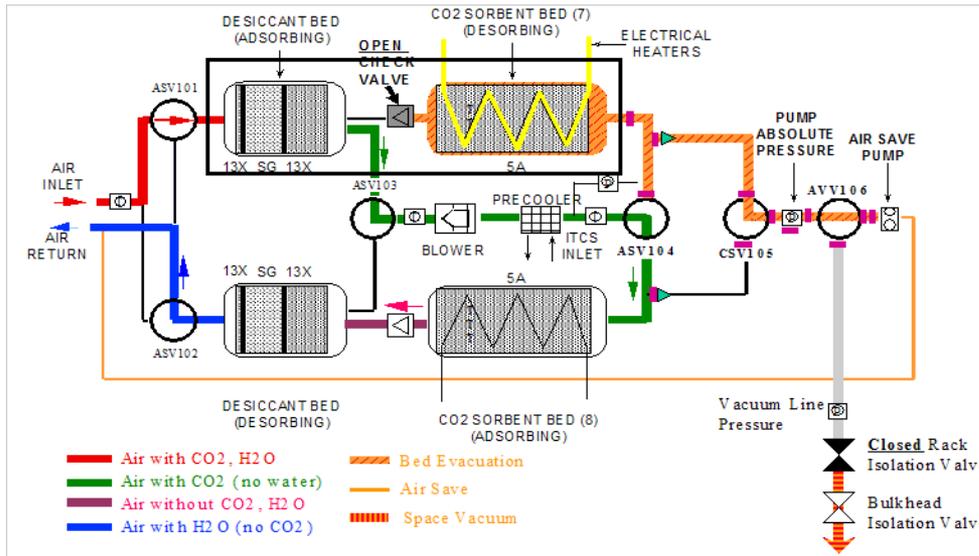




# US Oxygen Generator System

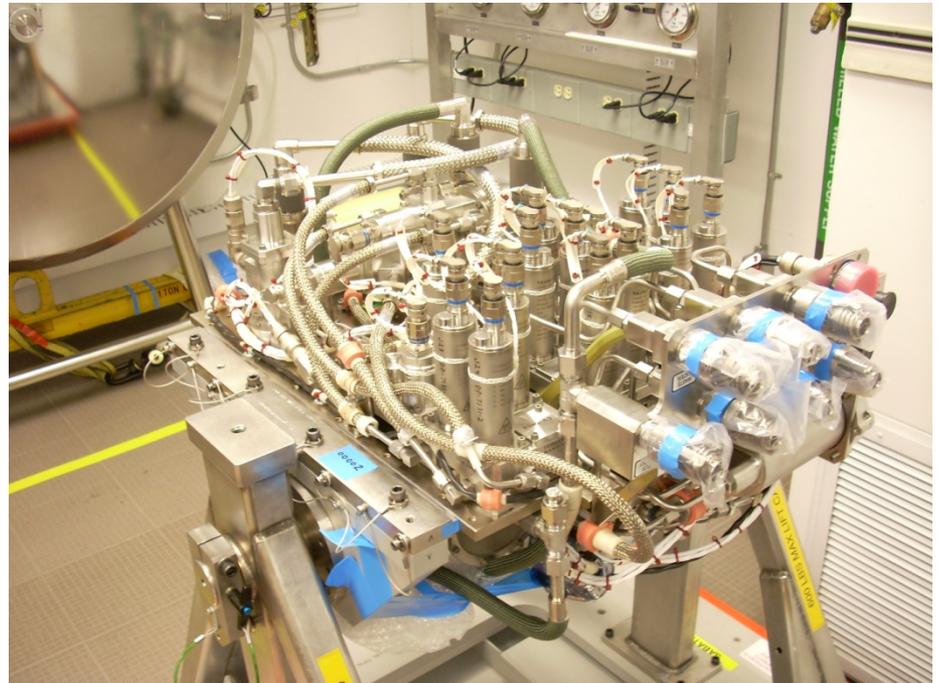


# Carbon Dioxide Removal Assembly



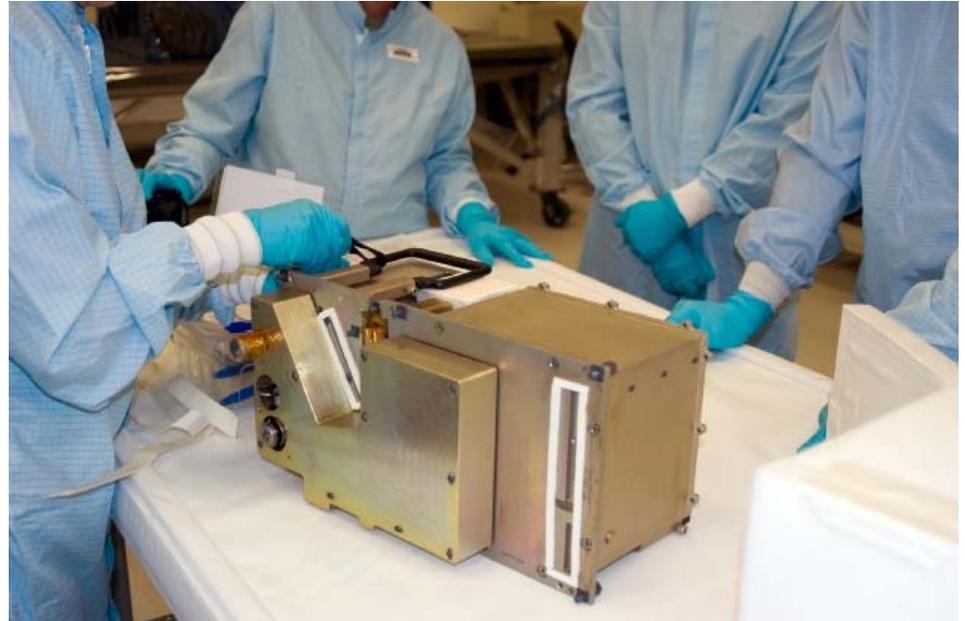
# Sabatier

- Produces up to about 2,000 kg of water from waste CO<sub>2</sub> and H<sub>2</sub>  
$$4\text{H}_2 + \text{CO}_2 \rightarrow 2\text{H}_2\text{O} + \text{CH}_4$$
- 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



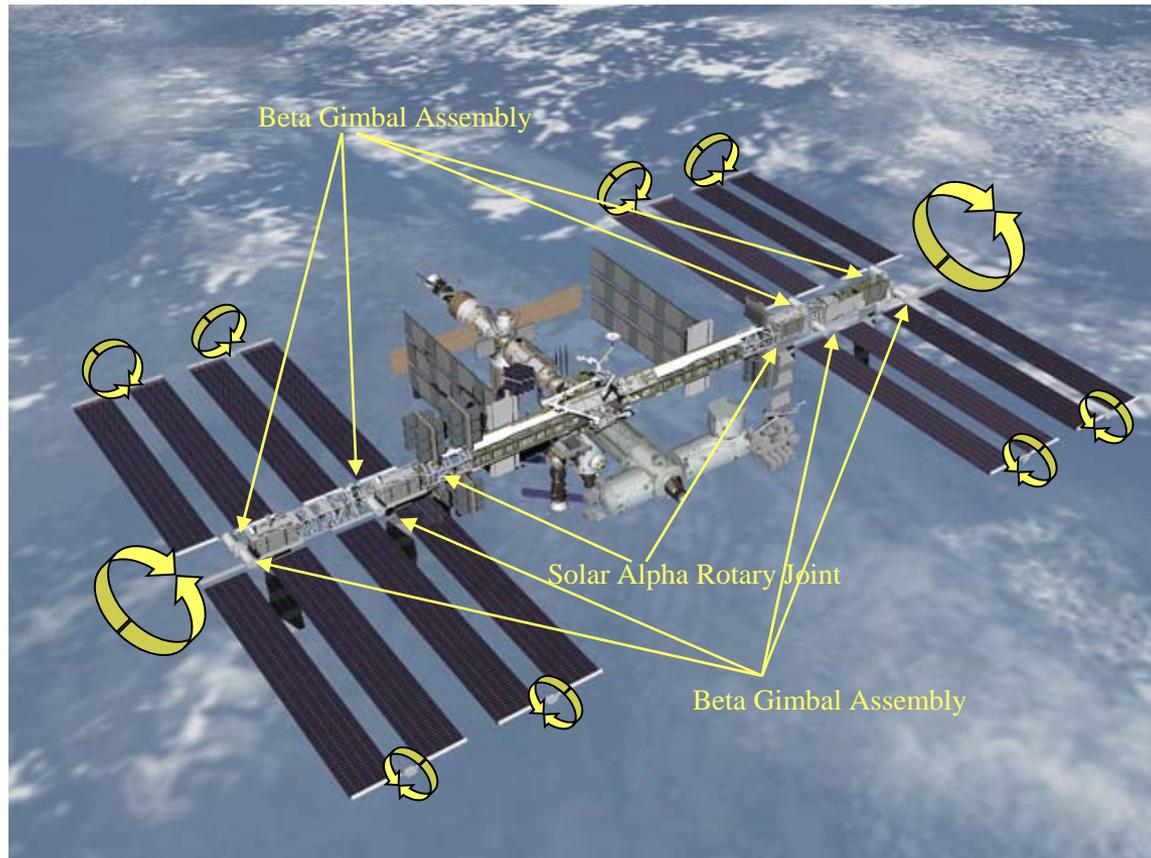
# Electrical Power Generation

- Critical to support of ISS systems and research
- Total solar array area 2,192 m<sup>2</sup>
- 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](http://www.nasa.gov/mission_pages/station/science/index.html)

ISS Interactive Reference Guide

<http://www.nasa.gov/externalflash/ISSRG>

