ISS Regenerative Life Support: Challenges and Success in the Quest for Long-Term Habitability in Space

May 5-6, 2015

AIAA Improving Space Operations Workshop

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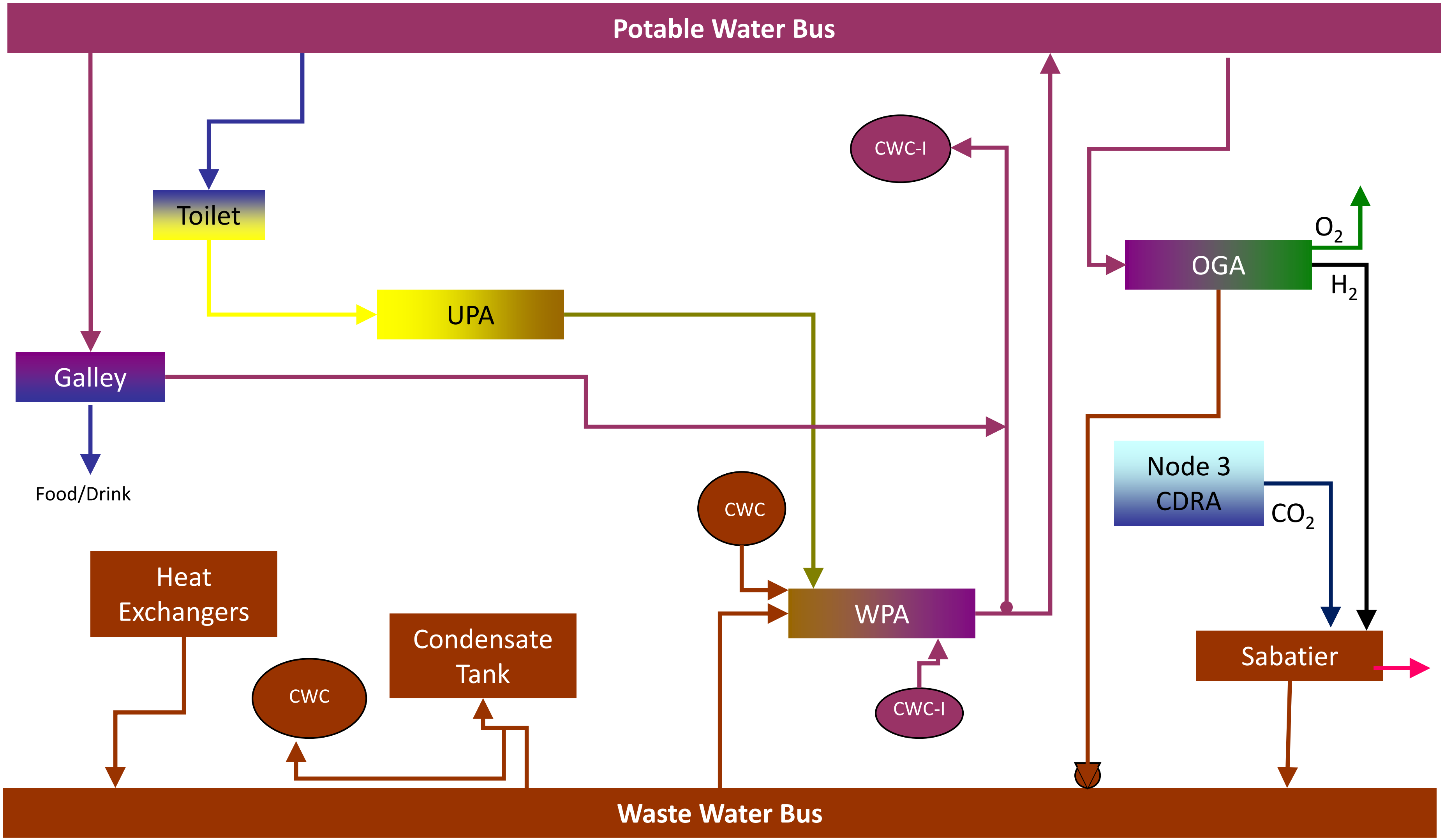
Outline

- Regen ECLSS Intro
- Water Balance Challenges
- Common System Failure Modes
- Important Lessons Learned

Regenerative ECLSS Overview



Primary Systems

- Urine Processing Assembly (UPA)
  - Receives pre-treated Urine from toilet and produces distillate for WPA
- Water Processing Assembly (WPA)
  - Receives UPA distillate and Condensate (Waste Water) and produces Iodinated Potable Water for crew and OGA consumption
- Oxygen Generating Assembly (OGA)
  - Takes Potable Water and produces Oxygen (to cabin) and Hydrogen (vented overboard or sent to Sabatier)

Primary Systems

- Carbon Dioxide Removal Assembly (CDRA)
  - Regenerative means to remove Carbon Dioxide to vent overboard or send to Sabatier
- Sabatier Reactor Assembly (SRA)
  - Combines Hydrogen and Carbon Dioxide to produce water for Waste Water bus and Methane (vented overboard)

Manual Water Storage Capabilities

- Contingency Water Container (CWC)
  - Stores Technical (silver-biocide) or Potable (silver-biocide + minerals) water
  - Can be processed by Russian equipment or processed in WPA
- Contingency Water Container – Iodine (CWC-I)
  - Stores Iodinated water for re-introduction to WPA or Potable Bus

Water Balance Basics

- Ideally:

Input = Output

- Reality:
  - Input = function (# of crew onboard, crew metabolic rates, Sabatier production)
  - Output = function (# of crew drinking, crew drinking rates, OGA production, payloads usage)
  - Can vary largely from day-to-day or week-to-week (operations domain), but usually more stable in long-term (logistics domain)
  - Failure of any Regen ECLSS system can wildly change the balance

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Water Balance Challenges

- Regenerative ECLSS fluid tanks are under-sized compared to input/output volume
  - Need to manage all tanks, which have individual quantity constraints, to prevent over-filling or running out of water
- Crew specified metabolic rates does not always equal actual values
  - Creates challenges at beginning of new crew time period to understand how to manage system
- With OGA running, have a long-term water deficit due to added consumption of water
  - Requires periodic adding of water into the WPA from stored water

Water Balance Operations

- Spreadsheets help predict and manage water systems
  - Console utilizes spreadsheets to predict tank quantities and manage the system, within constraints, for next several days
  - Shown to be unpredictable more than ~5 days out, though

	A	B	C	D	E	F	G	H	I	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	Day	Activity	GMT day	GMT time	Delta Days	WSTA Tank Q%	WW Tank Q% (Qty1)	WS Tank Q% (Qty 2)	RTFA Load (TFP in liters)	Brine Fill Qty (liters)	WS Qty (L)	Lab Conds Tank (L)	Conds Collection rate (L/day)	WSTA Delta (UPA Proc)	WW Delta (WPA Proc)	WS Delta (CWC-I Fill) [same as AC=-20.4]	RFTA Filling?	WHC Flush Counter	OGA Production Rate %	% Time OGA On	N3 CDRA # of crew removed	Sabatier On/Off (1/0)
794	Sun Mar06	UPA Process Start	65	18:00	0.12	15	65.0	37.4	45.80	39.24	21.20	5.8	13.20	0	0	0	0	6728	0	100	3.7	Of
795	Sun Mar06	UPA Process End	65	18:05	0.00	18	68.7	39.6	49.90	39.24	22.45	5.8	13.20	1	0	0	0	6728	0	100	3.7	Of
796	Sun Mar06	WPA Process Start	65	18:55	0.03	21	69.7	39.0	49.90	39.24	22.09	5.8	13.20	0	0	0	0	6729	0	100	3.7	Of
797	Sun Mar06	WPA Process End	65	19:55	0.04	24	4.0	90.8	49.90	39.24	51.46	5.8	13.20	0	1	0	0	6731	0	100	3.7	Of
798	Sun Mar06	**ULF5 Hatch Close**	65	20:13	0.01	25	4.4	90.6	49.90	39.24	51.36	5.8	7.10	0	0	0	0	6731	0	100	3.7	Of
799	Mon Mar07	data point	66	1:45	0.23	50	64.3	44.3	49.90	39.24	25.11	5.8	7.10	0	0	0	0	6737	0	100	3.7	Of
800	Mon Mar07	WPA Process Start	66	2:58	0.05	50	64.8	44.4	49.90	39.24	25.17	5.8	7.10	0	0	0	0	6738	0	100	3.7	Of
801	Mon Mar07	WPA Process End	66	9:13	0.26	52	7.1	91.7	49.90	39.24	51.98	5.8	7.10	0	1	0	0	6745	0	100	3.7	Of
802	Mon Mar07	UPA Process Start	66	13:32	0.18	62	8.7	86.5	49.90	39.24	49.04	5.8	7.10	0	0	0	0	6749	0	100	3.7	Of
803	Mon Mar07	UPA Process End	66	19:29	0.25	8	33.5	81.5	56.92	39.24	46.20	5.8	7.10	1	0	0	0	6755	0	100	3.7	Of
804	Mon Mar07		66	22:00	0.10	14	35.1	80.0	56.92	39.24	45.37	5.8	7.10	0	0	0	0	6758	0	100	3.7	Of
805	Mon Mar07		66	23:00	0.04	17	35.8	79.5	56.92	39.24	45.04	5.8	7.10	0	0	0	0	6759	0	100	3.7	Of
806	Tue Mar08		67	3:00	0.17	28	37.6	81.6	59.87	39.24	46.23	5.8	6.00	0	0	0	0	6763	0	100	3.7	Of
807	Tue Mar08		67	14:15	0.47	54	43.7	71.1	59.87	39.24	40.31	5.8	6.00	0	0	0	0	6775	0	100	3.7	Of
808	Tue Mar08	UPA Process Start	67	17:30	0.14	62	46.3	71.1	59.87	39.24	40.31	5.8	5.10	0	0	0	0	6778	0	100	3.7	Of
809	Tue Mar08	UPA Process End	67	17:31	0.00	8	61.8	71.1	66.89	39.24	40.30	5.8	5.10	1	0	0	0	6778	0	100	3.7	Of
810	Wed Mar09	WPA Process Start	68	0:00	0.27	25	64.8	67.3	66.89	39.24	38.16	5.8	5.10	0	0	0	0	6785	0	100	3.7	Of
811	Wed Mar09	WPA Process End	68	0:01	0.00	25	30.2	95.0	66.89	39.24	53.85	5.8	5.10	0	1	0	0	6785	0	100	3.7	Of
812	Wed Mar09		68	6:00	0.25	40	33.0	91.5	66.89	39.24	51.88	5.8	5.10	0	0	0	0	6791	0	100	3.7	Of
813	Wed Mar09	UPA Process Start	68	15:00	0.38	63	37.2	86.3	66.89	39.24	48.91	5.8	5.10	0	0	0	0	6801	0	100	3.7	Of
814	Wed Mar09	UPA Process End	68	15:01	0.00	8	52.9	86.3	74.01	39.24	48.90	5.8	5.10	1	0	0	0	6801	0	100	3.7	Of
815	Wed Mar09		68	23:00	0.33	28	56.6	81.6	74.01	39.24	46.27	5.8	5.10	0	0	0	0	6809	0	100	3.7	Of
816	Thu Mar10	UPA Process Start	69	12:00	0.54	61	62.7	74.0	74.01	39.24	41.98	5.8	5.10	0	0	0	0	6823	0	100	3.7	Of
817	Thu Mar10	UPA Process End	69	12:01	0.00	8	**78.1**	74.0	80.96	39.24	41.97	5.8	5.10	1	0	0	0	6823	0	100	3.7	Of
818	Thu Mar10	WPA Process Start	69	12:02	0.00	8	**78.1**	74.0	80.96	39.24	41.96	5.8	5.10	0	0	0	0	6823	0	100	3.7	Of
819	Thu Mar10	WPA Process End	69	12:03	0.00	8	51.8	95.0	80.96	39.24	53.85	5.8	5.10	0	1	0	0	6823	0	100	3.7	Of
820	Thu Mar10	OGA On 50%	69	16:00	0.16	18	53.7	91.2	80.96	39.24	51.69	5.8	5.10	0	0	0	0	6827	50	100	3.7	Of
821	Thu Mar10		69	23:00	0.29	36	57.0	84.4	80.96	39.24	47.86	5.8	5.10	0	0	0	0	6834	50	100	3.7	Of

Tobias, B., Garr, J. & Erne, M. (2011, July 17-21). *International Space Station Water Balance Operations*. Presented at the 41st International Conference on Environmental Systems. doi:10.2514/6.2011-5150

System Clogging

- Systems tend to clog due to biofilm or precipitants in loops
  - Biofilm grows in tanks containing Condensate
  - Precipitants form when removing water (i.e. UPA)
- Affects flow through valves, pumps, lines, etc
- Control growth through tank cycling and limited reclamation
  - Bellows in tank “scrape” walls of tank clean
  - Limited reclamation prevents reaching precipitation concentration of elements (i.e. Calcium)

Water Leaks

- Multiple single-point failures can cause water to enter cabin
  - Toxicity varies from low (de-iodinated water) to moderate (urine)
- Common leak paths are through seals, Quick Disconnects (QDs), etc
  - QD leaks can be mitigated by keeping QDs connected
  - Seal leaks usually terminal to ORU and requires replacement with proper seals
- Water bags tend to leak around fittings when mis-handled

Failure Rates

- Regen-ECLSS failure rates have been varying
  - Some consistently fail several years before expected
  - Some one-year parts are still running after 6 years of operations (though showing signs of age)
- Resupply rate needs to be agile to match
  - Cannot keep up with failure rates and still figure out what failed
- ISS important test-bed for the future
  - Regenerative ECLSS never performed in space until ISS
  - Systems need to be perfected to go to Mars and Beyond

Important Lessons Learned

- Storage of excess water is invaluable
  - Available for use either in system failure or to supplement for water imbalance
- Redundancy of critical systems important
  - US water processing, oxygen production and carbon dioxide removal systems have Russian equivalent systems and contingency capabilities
- System interfaces critical
  - Regen ECLSS comprises several individual systems, each with own constraints, which all must work together to operate as one
- Water system design need to be universal
  - Regen ECLSS has countless different QD sizes and keying which require adapters and hoses for contingency interfaces

Questions?

Acronyms

- Environmental Control and Life Support System (ECLSS)
- Urine Processing Assembly (UPA)
- Water Processing Assembly (WPA)
- Oxygen Generating Assembly (OGA)
- Carbon Dioxide Removal Assembly (CDRA)
- Sabatier Reactor Assembly (SRA)
- Contingency Water Container (CWC)
- Contingency Water Container – Iodine (CWC-I)