



Post-Shuttle EVA Operations on ISS

Bill West
Hamilton Sundstrand Corp

Vince Witt
Hamilton Sundstrand Corp

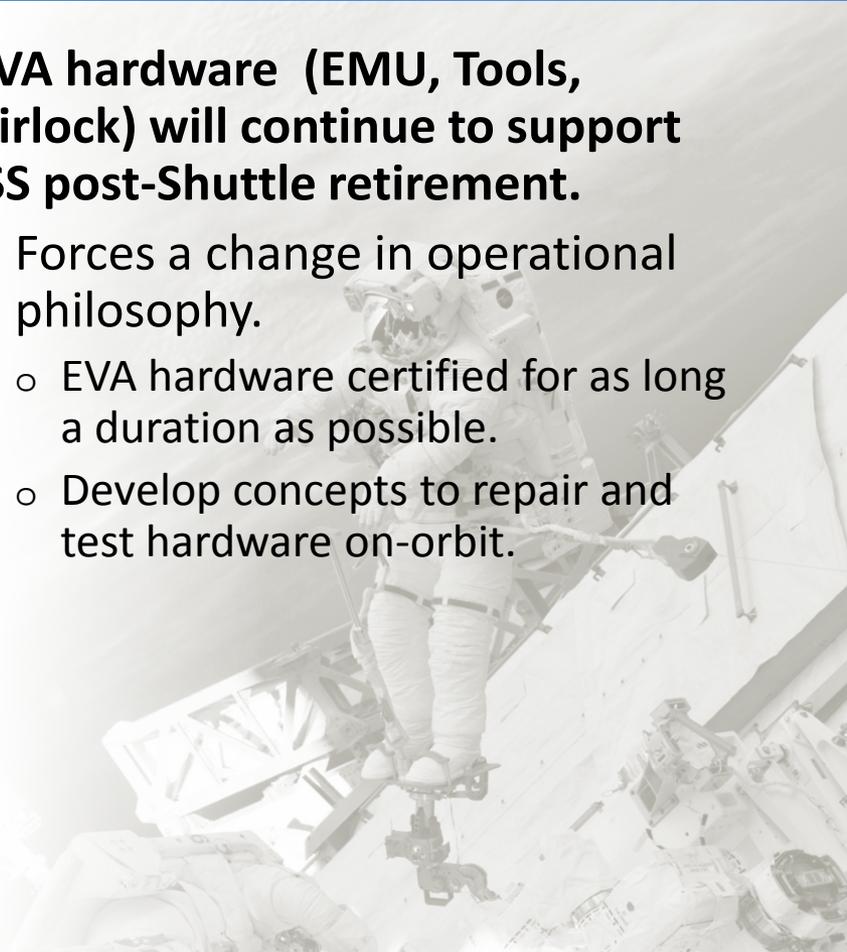
Cinda Chullen
JSC Crew & Thermal Systems Division





Challenge of Shuttle Retirement

- **EMU was originally designed in the 1970's/80's for short-duration Shuttle missions.**
 - 1-3 EVAs per Shuttle Mission
 - Refurbished and checked out between Shuttle Flights on ground.
- **Utilized as the U.S. EVA spacesuit for the International Space Station**
 - Certified for 2 years on-orbit or 25 EVAs.
 - Rotated on Shuttle missions for ground refurbishment.
- **EVA hardware (EMU, Tools, Airlock) will continue to support ISS post-Shuttle retirement.**
 - Forces a change in operational philosophy.
 - EVA hardware certified for as long a duration as possible.
 - Develop concepts to repair and test hardware on-orbit.





EVA Mobility Unit (*the "EMU"*)



Enhanced Arm Assembly



Planner Hard Upper Torso



Helmet/ Extravehicular Visor Assembly



Pivoted Hard Upper Torso



EMU Electrical Harness



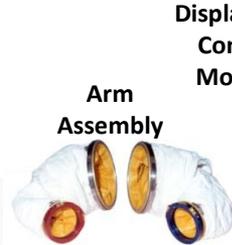
Liquid Cooling and Ventilation Garment



Enhanced Lower Torso Assembly



Insuit Drink Bag



Arm Assembly



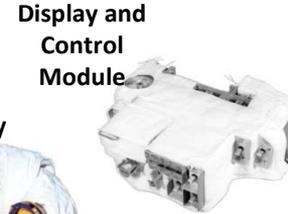
Communications Carrier assembly



Gloves



Carbon Dioxide Removal



Display and Control Module



Primary Life Support Subsystem



Secondary Oxygen Pack

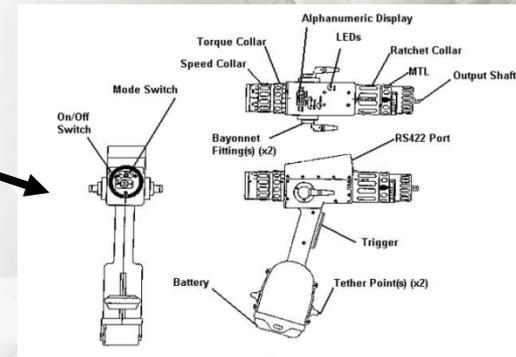
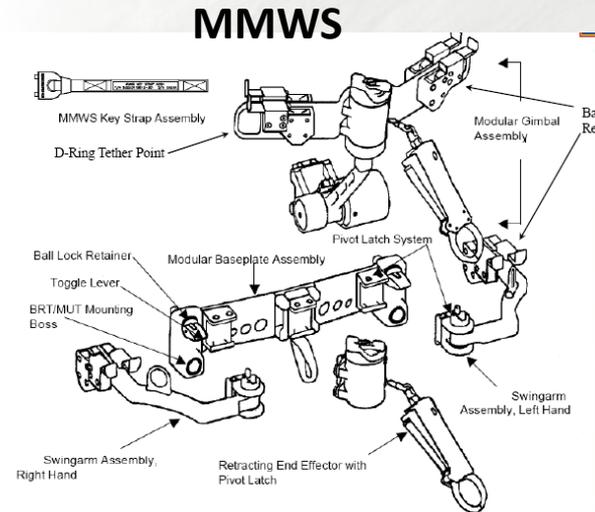


Battery

EVA Tools



Safety Tether



USOS Airlock

US Airlock Systems

2 modules

- Equipment Lock
- Crew Lock

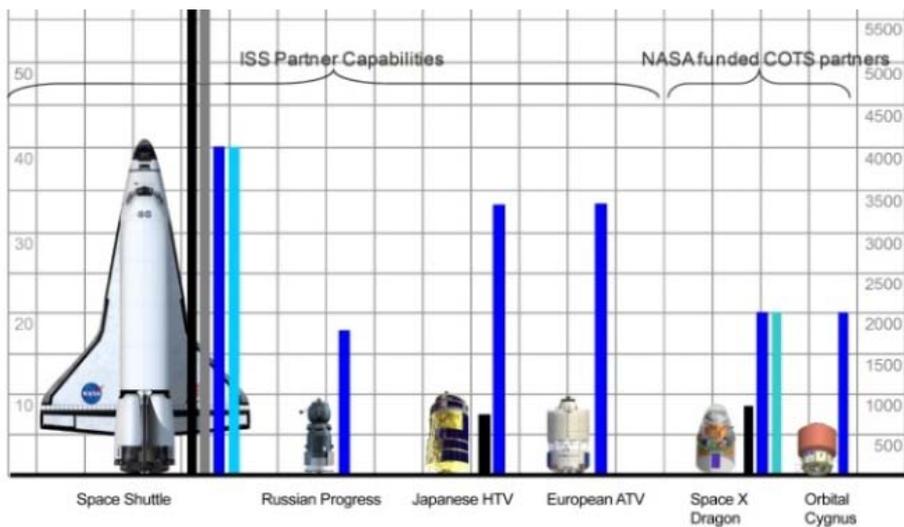
Provides capability to:

- Service & Maintain the EMUs
- Don/Doff Suits
- Store EVA Hardware
- Charge EMU/EVA Batteries
- Provide hardline communications, cooling & power to the EMU
- Egress/Ingress capability to the ISS External Environment





Average Mission Comparison



	Pressurized		Unpressurized	
	Upmass (kg)	Downmass (kg)	Upmass (kg)	Downmass (kg)
Shuttle	4000	4000	16000	16000
Progress	1800	-	-	-
HTV	2100	-	700	-
ATV	2000	-	-	-
Dragon	2000	2000	700	-
Cygnus	2000	-	-	-

Note: Most vehicle cargo carrying capacities are interchangeable with other cargo categories.

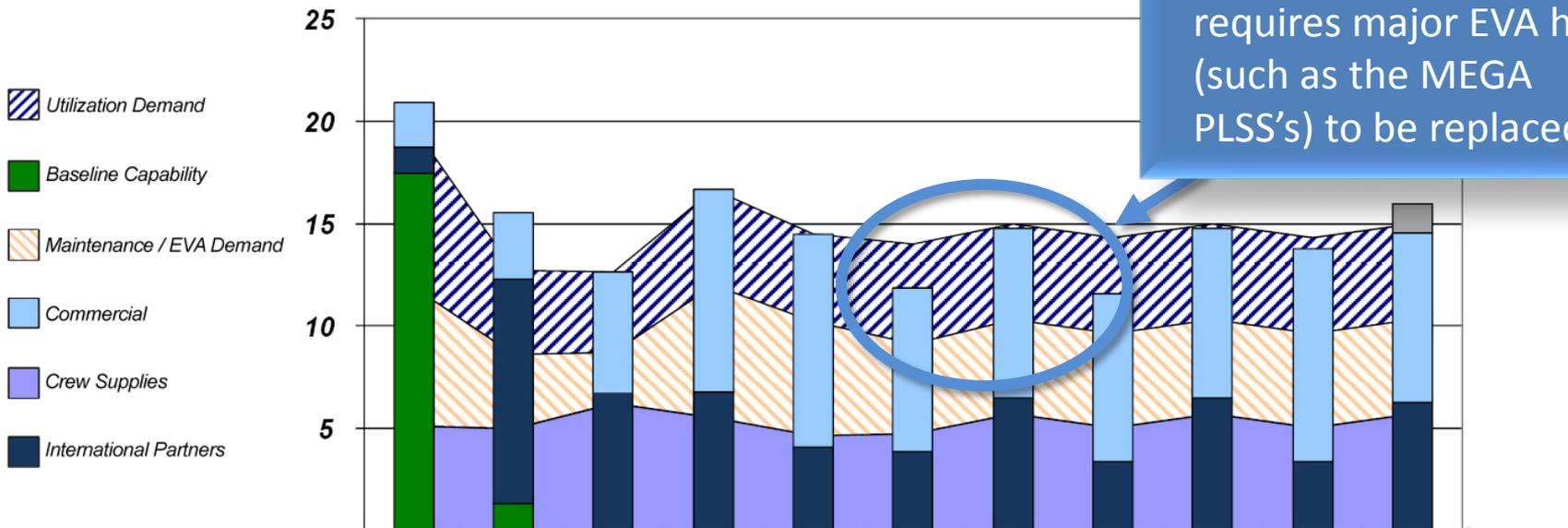
- unpressurized upmass
- unpressurized downmass
- pressurized upmass
- pressurized downmass





Critical timeframe for EVA
 – current EVA2010 plan supports to 2015, then requires major EVA h/w (such as the MEGA PLSS's) to be replaced.

2010 – 2020 Capability vs. Delivery Demand (MT)



Vehicles (CY)		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Baseline	Shuttle	5											5
	USOS Progress/MRM1*	4 MT	1.3 MT										5.3 MT
	USOS Soyuz	2	2	2	2	2	2						12
International Partners	ATV	1	1	1	1			1		1		1	7
	HTV		2	1	1	1	1	1	1	1	1	1	11
Commercial	SpaceX	1	2	2	3	3	2	3	3	3	3	3	28
	Orbital		1	1	2	2	2	1	1	1	2	1	14

* Value shown in usable cargo (does not include packing, FSE, or accommodations)



ISS Ops Post-Shuttle

Assumptions

- Continue using EMU for ISS EVA post-Shuttle retirement.
 - Assume hardware is disposable and will not be returned
 - Assume 8 increment EVAs per year with EMU
 - Supports both scheduled & contingency EVAs.

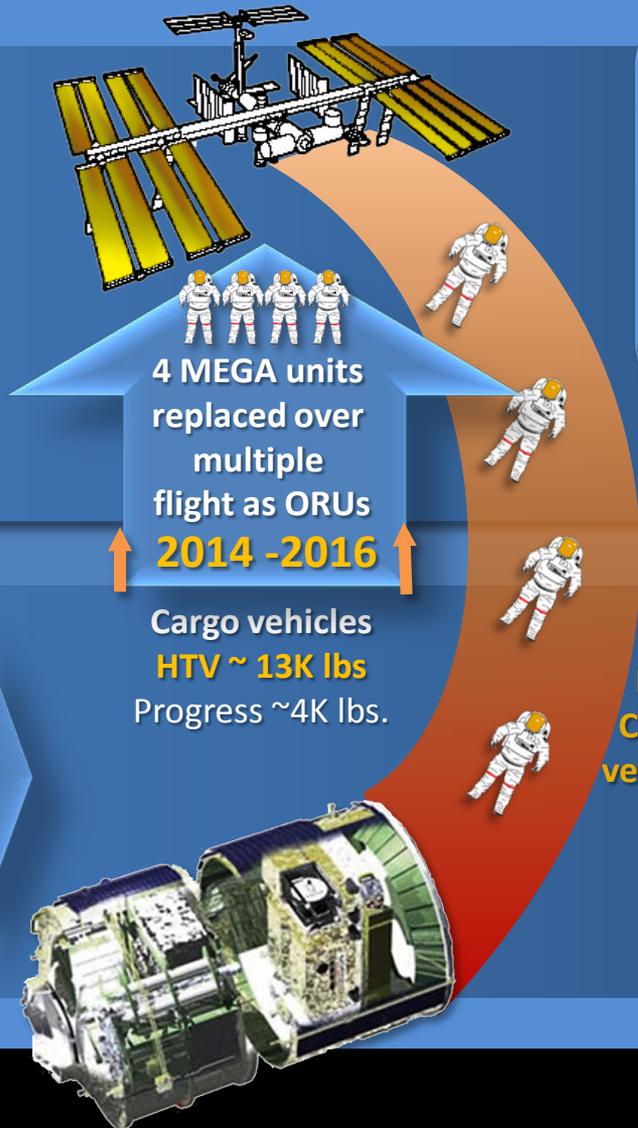
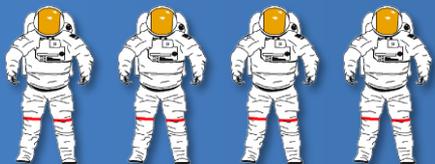
- **EVA hardware (EMU, tools) will be launched on the Japanese HTV**
 - Other IP vehicles (ATV, Progress, & Soyuz) may be utilized to launch EVA hardware to ISS.
 - U.S. Commercial vehicles will be utilized once they are operational.
- **EVA hardware Life Extension**
 - Extend EMU to 6 years on-orbit (“MEGA” EMU)
 - Extend certification for EVA Tools
 - Develop plan to calibrate Pistol Grip Tool on-orbit.



ISS Ops Concept Post-Shuttle

ISS assembled

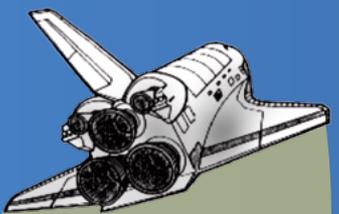
4 MEGA EMUs aboard for ISS maintenance ~ 8 EVA /yr.



- Replacement EMUs needed to complete assembly on orbit
- Occasional HUT ORU swaps for crew sizing
- SOP replacement may be needed before 2015 & 2020

2010

Shuttle retires



Soyuz provide crew rotations

2020

Present ISS planned use



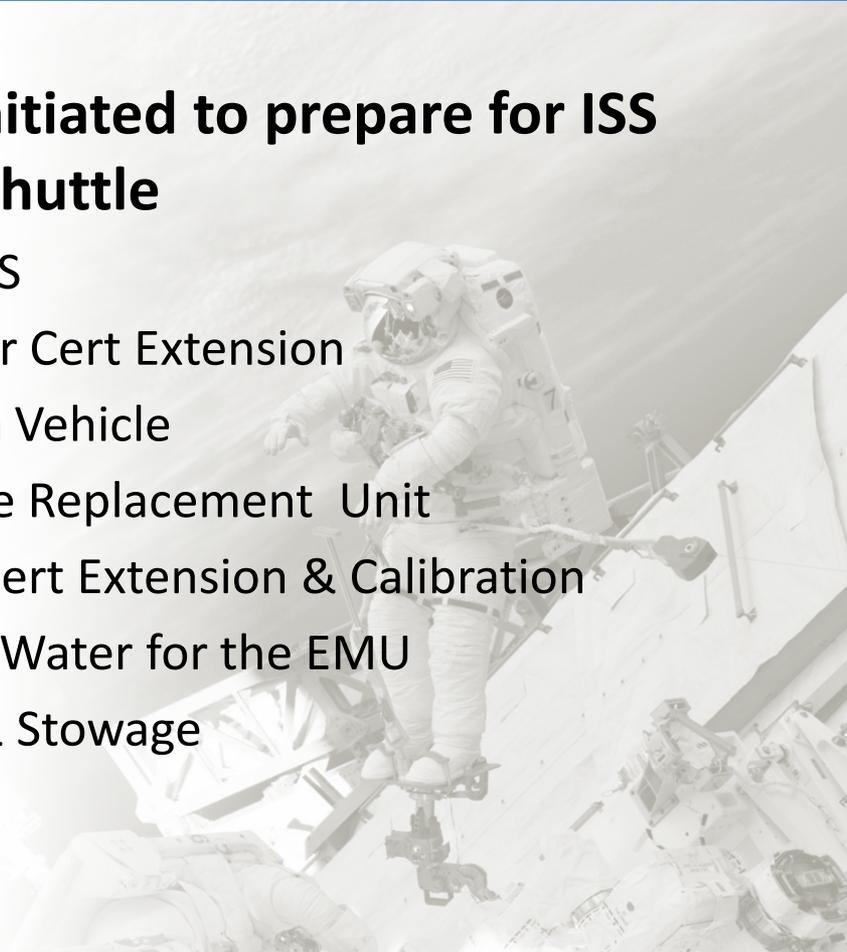
EVA 2010 Project

EVA 2010 Project

Shortly after the decision to retire the Shuttle was announced, the EVA team kicked off an effort to develop a plan for continued EVA support of ISS in the post-Shuttle environment.

■ Projects Initiated to prepare for ISS ops post-Shuttle

- MEGA PLSS
- EMU 3-6 yr Cert Extension
- Alt Launch Vehicle
- Removable Replacement Unit
- EVA Tool Cert Extension & Calibration
- Use of ISS Water for the EMU
- Logistics & Stowage





EVA 2010 Project: MEGA EMUs

- **Post-Shuttle retirement USOS EVA capability will be performed with EMUs using “MEGA” Portable Life Support Systems (PLSS’s)**
- **A MEGA PLSS is a refurbished PLSS that will have all new components and limited life items such that it can support a total of 25 EVAs.**
 - Recoated water tank structure, Aluminum horn, and sublimator face flange
 - All Components lined up to last until 2016 (new builds, refurb)
 - Reset limited life items table to 0 EVAs
- **7-9 MEGAs are planned to support ISS from 2010-2020**
- **Early MEGAs will be delivered and staged on ISS pre-Shuttle retirement**
- **Follow-on MEGA’s will be launched on Japanese HTV starting in 2014-2015**
 - Out of life MEGA PLSS’s will be discarded when HTV undocks and burns up
 - Some components from the MEGAs may be salvaged prior to being discarded



EMU 3 to 6 Year Life Extension

- **Current EMU maintenance cycle is 3 years.**
 - Effort in work to extend the EMUs certified maintenance cycle to 6 yrs.
 - 2014-2016 for the first set of Mega EMUs and 2020 for the next set of Mega EMUs.
- **On-orbit diagnostic kit will be utilized to insure EMUs**





Japanese HTV Cargo Vehicle

- **H-II Transfer Vehicle (HTV)**
 - Robotic arm captures and berths HTV to ISS
 - Provides atmospheric gas re-supply to the ISS
 - Capable of re-supplying ISS with water
 - Non-removable racks are loaded much like the Shuttle with cargo transfer bags
 - Unpressurized external cargo capability with the HTV external pallet
- **HTV is expendable and offers no recoverable return capability**
 - Non-recoverable cargo and water can be disposed of on re-entry

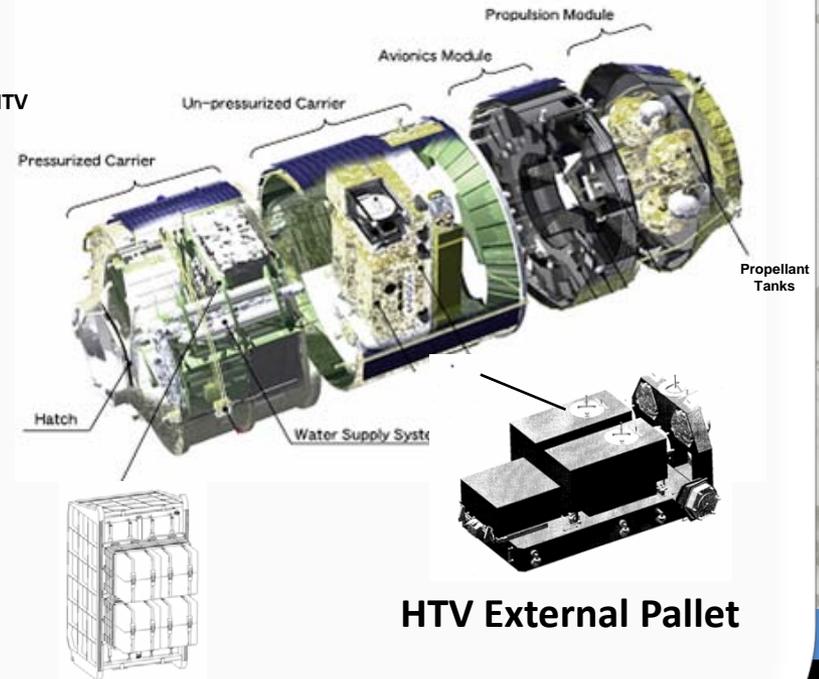
H-IIB Launch Vehicle



HTV Average Capability

Cargo Type	Mass (kg)
Internal	2,100
External	700
Water	300
N ₂	-
O ₂	-
Propellant	-

H-II Transfer Vehicle (HTV)

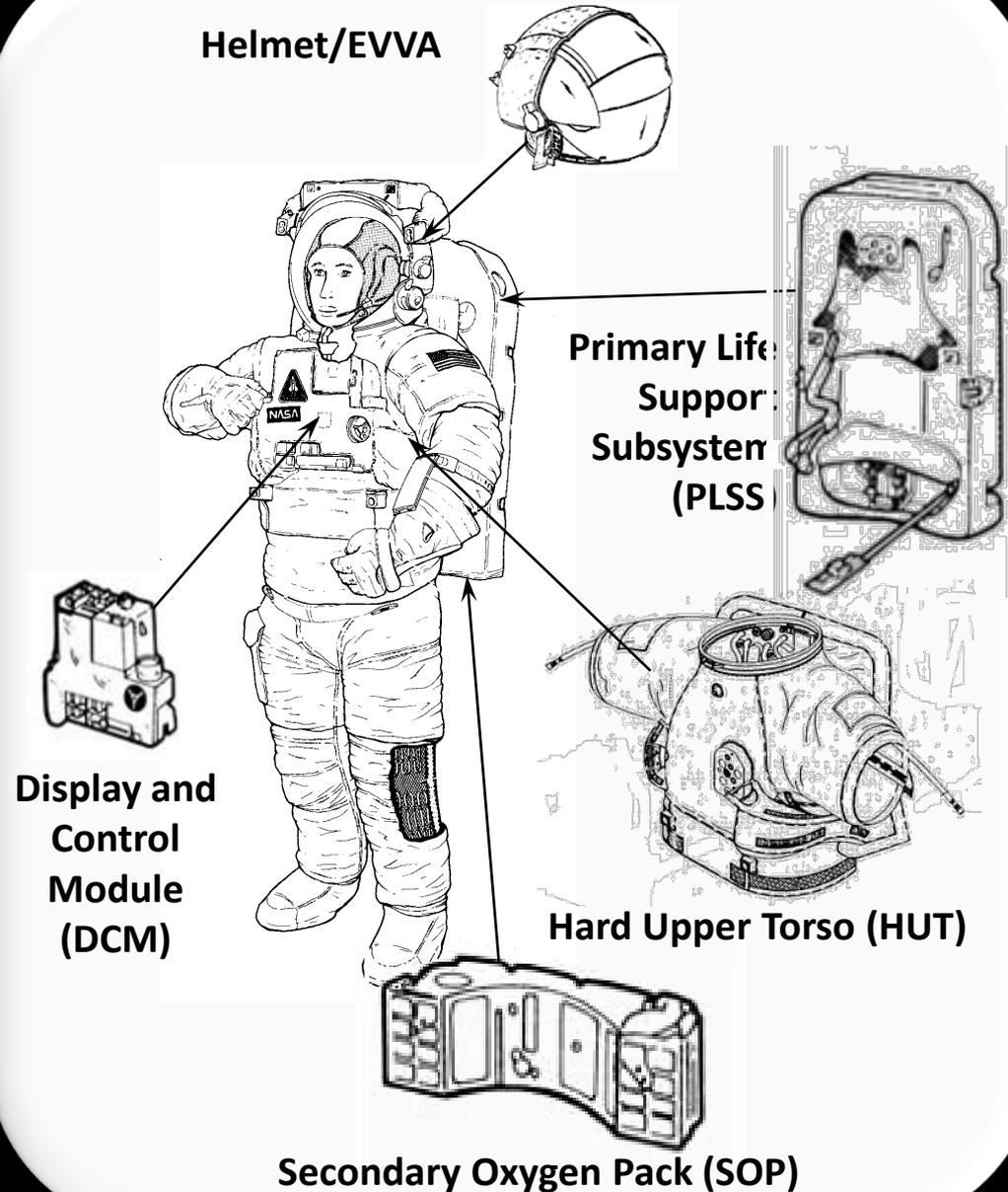


HRR Type 2 HTV Rack



EMU Hardware on HTV

- PLSS and or PLSS/SOP launched in a fixture to protect it from vehicle vibrations & launch loads.
- DCM, SOP, HUT, etc “soft-stowed” in bags.
- **Hardware re-assembled & checked out on-orbit.**
 - EMUs are currently launched integrated in Shuttle.

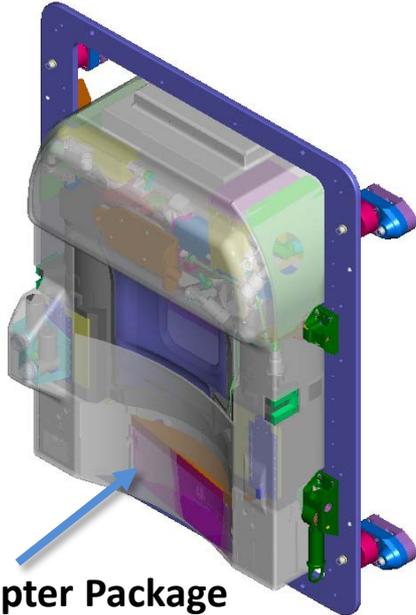




HTV Resupply Rack (HRR)

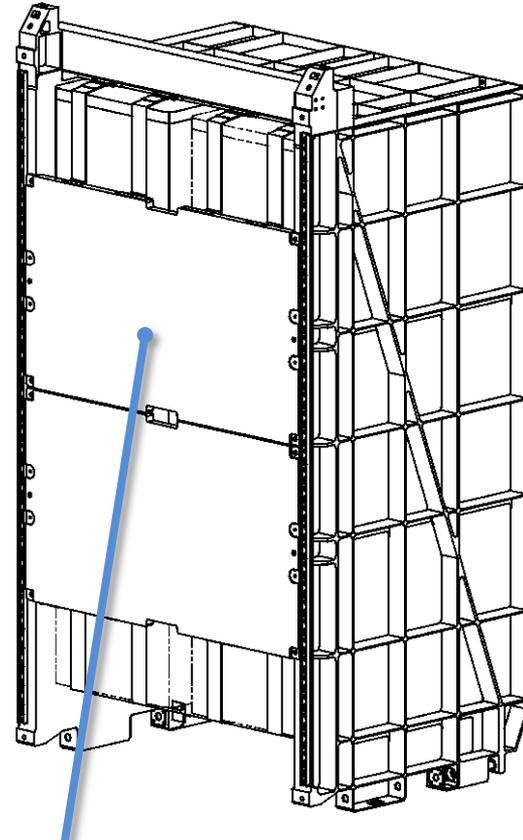
PLSS/SOP Launch Fixture

- PLSS launched attached to adapter plate bolted to HTV rack.



Launch Adapter Package

Cargo (inside HRR)

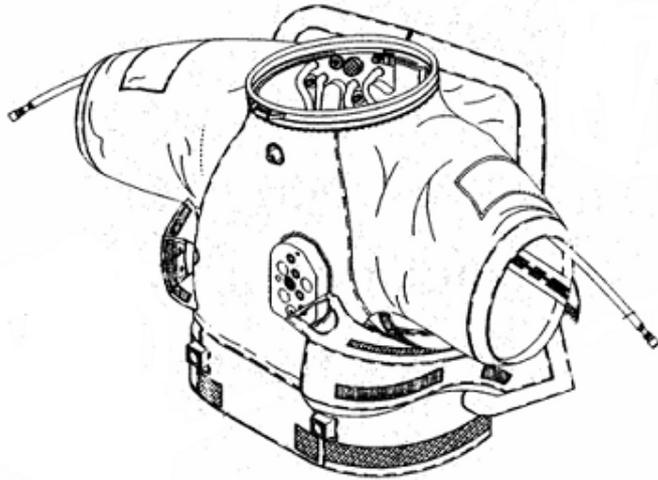


Front Panel



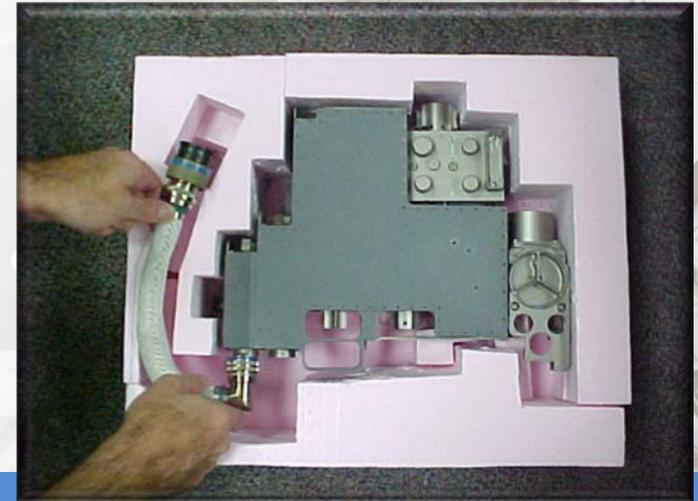
Example of Soft Stow Items

HUT set in Foam Box



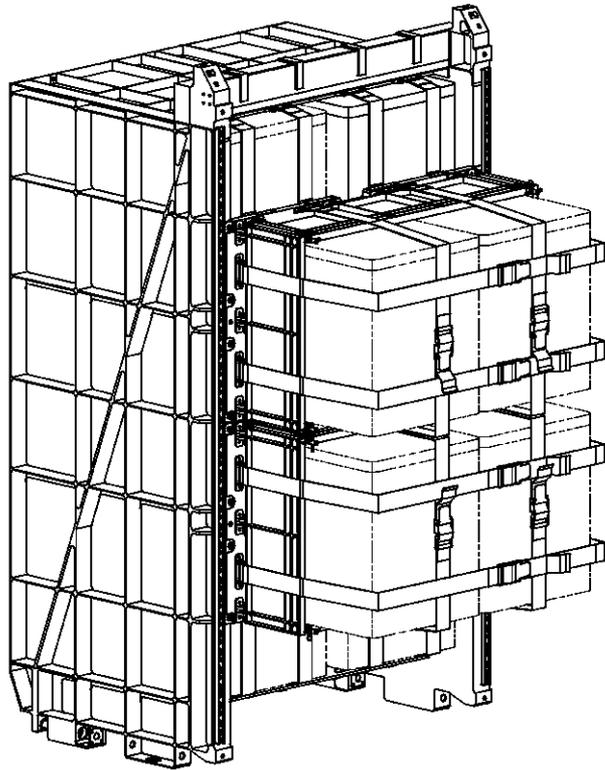
Hard Upper Torso (HUT)

Display Control Module (DCM)



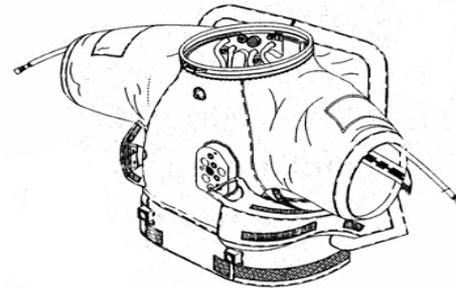


EVA Soft Stow Items: HRR



Cargo (Inside of HRR body)

Cargo
front panel)



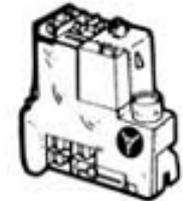
Hard Upper Torso
(HUT)



Helmet/E
VVA



Secondary Oxygen Pack
(SOP)



Display and Control
Module (DCM)



On-Orbit Troubleshooting & Repair

Ability of the ISS crew to troubleshoot suit issues and replace suit components is being developed by the EVA team.



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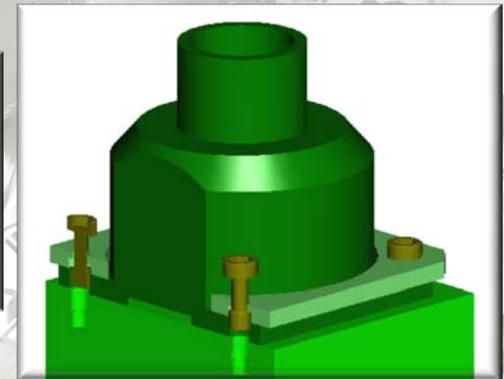
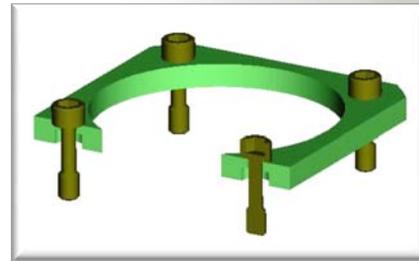
- **Following the Columbia accident, the on-orbit EMUs had several hardware anomalies that deemed them “No-Go” for use.**
 - Replacement h/w was delivered by Russian Progress and crew attempted to recover EMUs.
- **Lessons learned from that effort resulted in the development of RRUs.**



Repair Replacement Unit (RRU)

- **Components already designed for on orbit maintenance are known as Orbital Replacement Units or “ORUs”.**
 - ORU components typically incorporate captive fasteners as part of their design and are certified for removal and replacement.
 - Very few components in the EMU PLSS were designed for on-orbit maintenance.

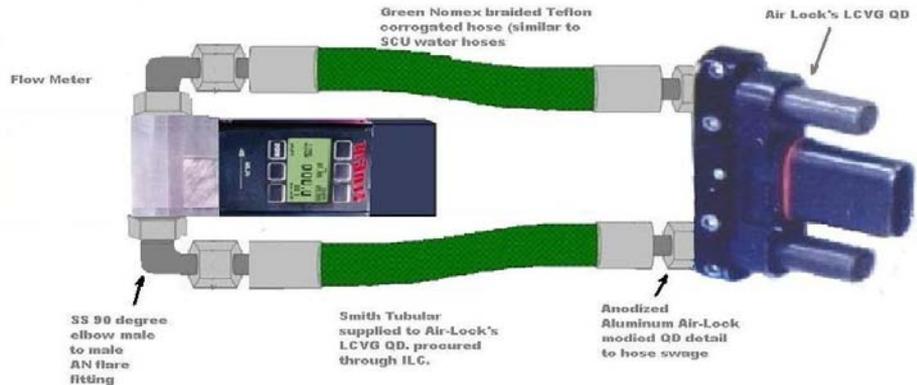
- **RRU is a component that is not already designed for on-orbit removal and replacement.**
 - Custom captive fasteners and yoke plates allow for replacement of small components in the EMU PLSS.



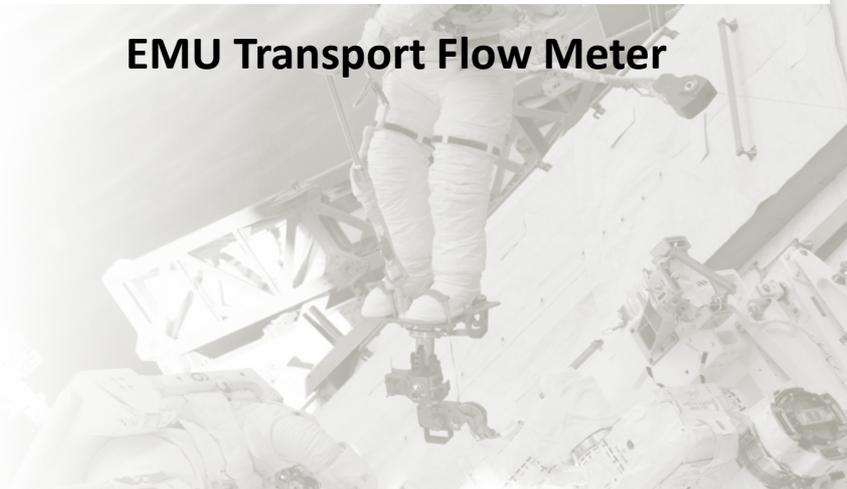


Diagnostic Tool Kit

- Diagnostic Kit is being developed to facilitate the return to service of an EMU after servicing or repair and for monitoring the health of the EMU.
- The diagnostic tooling includes:
 - Hardware to monitor the health of the EMU transport loop flow.
 - Sublimator Flange Leak Detection Strips
 - Vent loop leak detection fixture
 - Cabling to download the software from the EMU Electronic Caution and Warning System (ECWS) and the retrieval of diagnostic and trending data while on ISS.



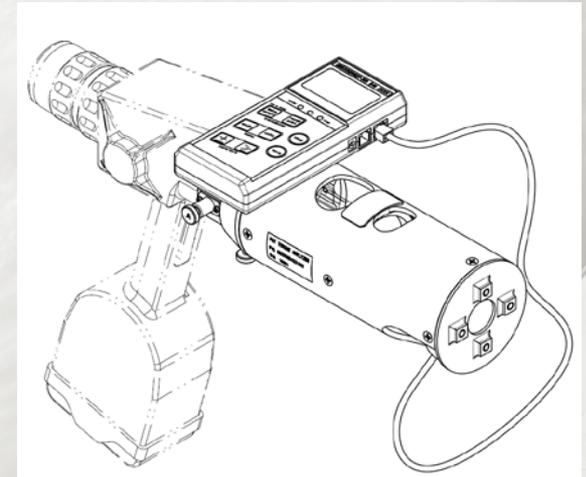
EMU Transport Flow Meter





EVA Tools: PGT Torque Analyzer Kit

- Effort underway to extend on-orbit life for EVA Tools.
- **EVA Pistol Grip Tool (PGT) is a battery-operated, programmable tool used to tighten and loosen various types of nuts, bolts, and other fasteners.**
 - Torque values can be programmed between 0.5-25.5 ft-lb.
 - Current on-orbit life is 2 years then returned to the ground for calibration.
- **On-orbit Torque Analyzer Kit will allow crew to calibration PGT on-orbit.**
 - The objective of the PGT TAK is to certify an upgraded torque analyzer system that can be used to verify, with confidence, the accuracy of the PGT torque output such that PGT calibration can be extended to 5 years





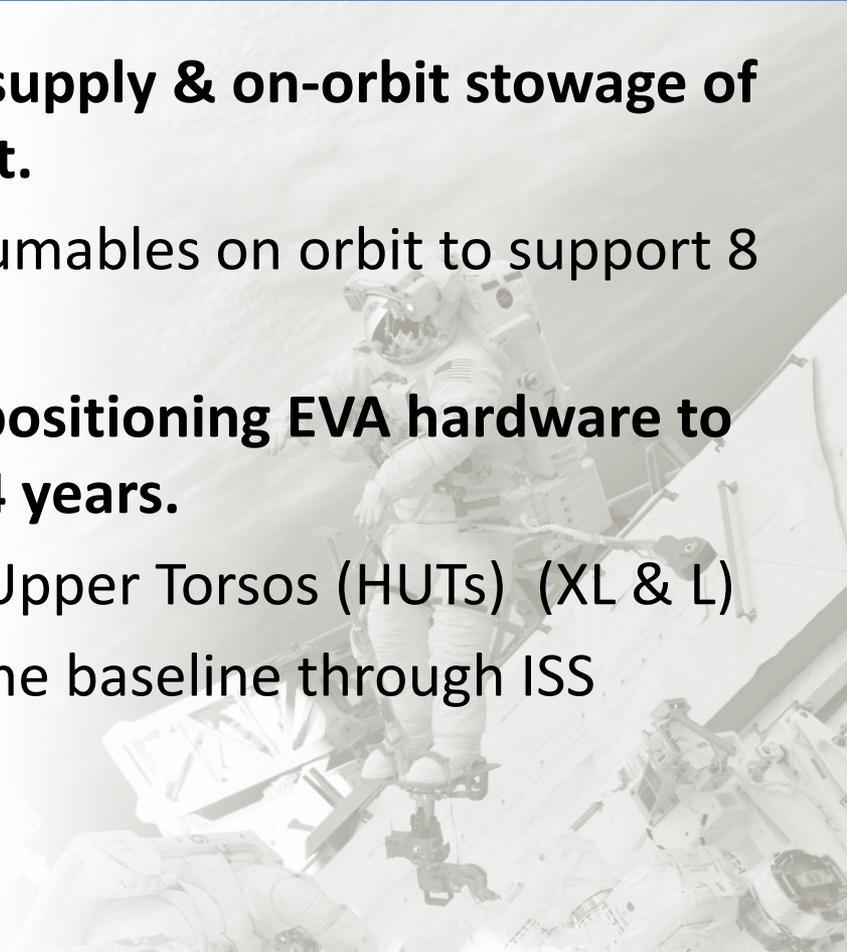
EMU Cooling Loop Feed Water

- **EMU cooling is provided by sublimating water to vacuum.**
 - Water is currently provided from the Shuttle Fuel Cell and stored on-board the ISS for later use with the EMU.
- **Two EMUs use on average 11 pounds of water per EVA**
- **Annually the tanks also need to be drained and filled to iodinate feed water and to expel any gas (9.2 lbs/EMU).**
 - Approximate water usage per year may be around 125 lbs for 4 EMUs/8 EVAS per year.
- **Sublimation can be sensitive to trace amount of contamination on the porous plate.**
 - Negative impact on EMU operations
 - Would require more frequent replacement of the EMU PLSS.
- **ISS EMUs have two options for water supply**
 - Launch water on expendable vehicles (additional upmass requirement to ISS)
 - Use ISS Water Processor Assembly (WPA) water
- **Early test of ground-WPA water identified issue with using WPA water with EMU.**
 - Further testing with samples of ISS produced WPA water inconclusive with ground WPA water.
 - Filter may need to be developed to allow WPA feed water to be used with EMU.



EVA Logistics & Stowage

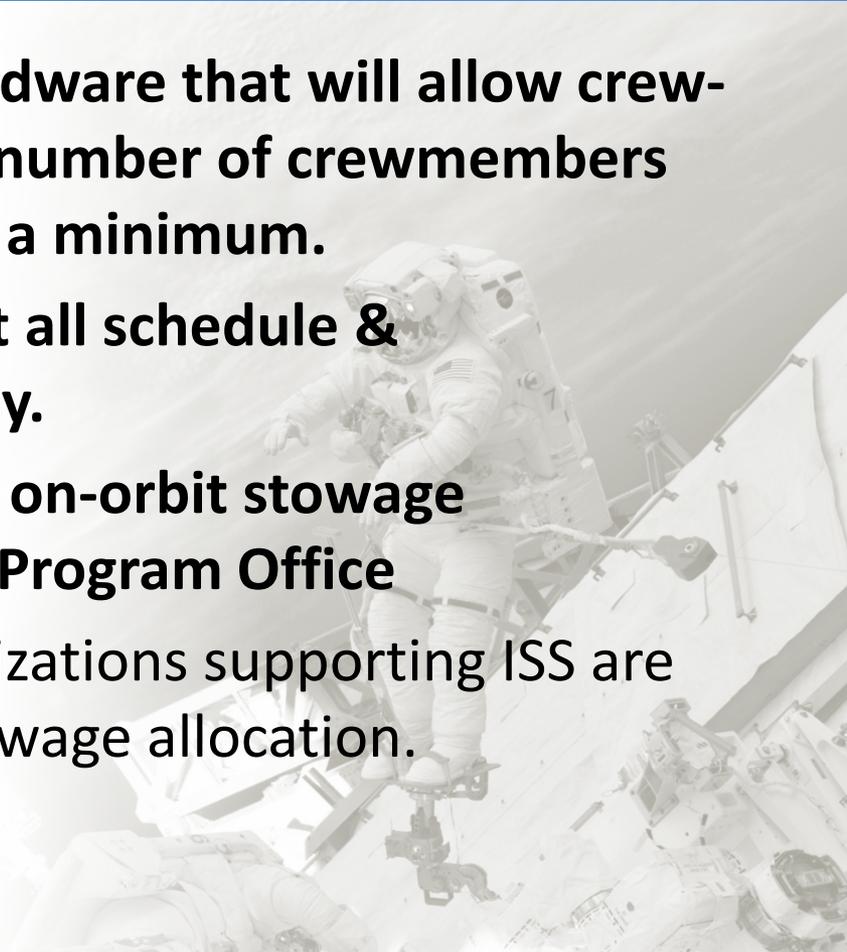
- **Shuttle retirement ⇒ Logistical resupply & on-orbit stowage of EVA hardware has to be re-thought.**
 - Goal: sufficient hardware & consumables on orbit to support 8 EVAs per year.
- **Remaining Shuttle flights are pre-positioning EVA hardware to minimize logistical resupply for 2-4 years.**
 - 4 EMUs (1 XL, 2 L, 1 M) + 2 Hard Upper Torsos (HUTs) (XL & L)
 - 3 EMUs & no HUTs have been the baseline through ISS assembly.





EVA Logistics & Stowage

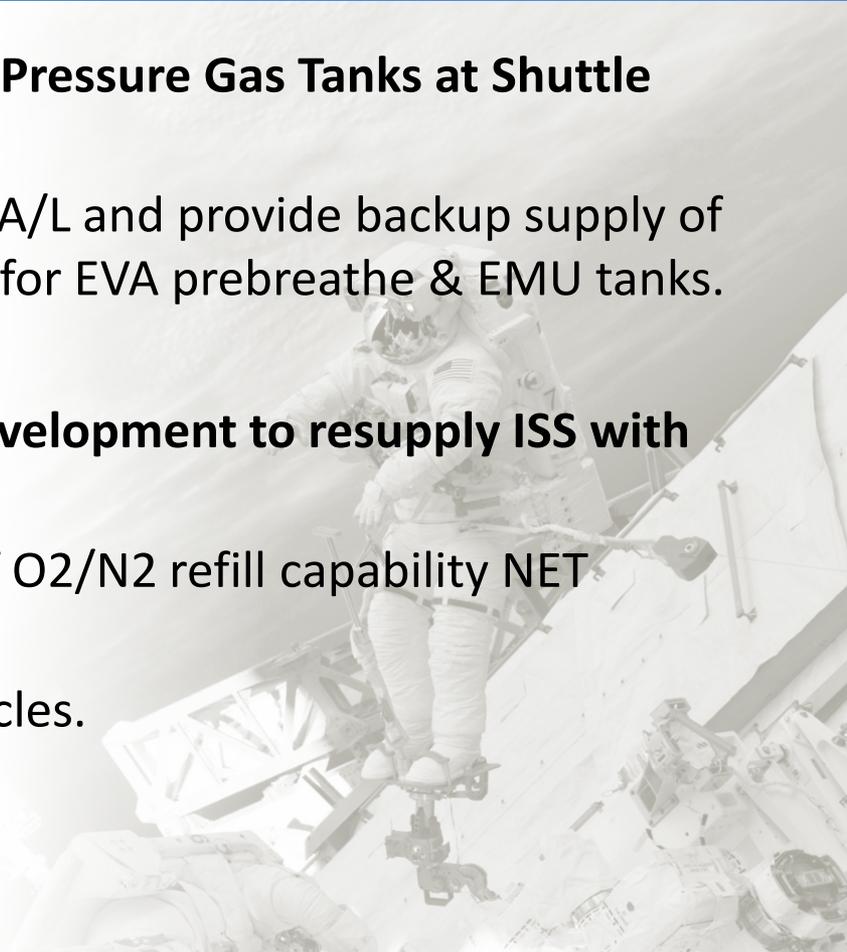
- **Pantry style approach for EMU hardware that will allow crew-sizing hardware for the maximum number of crewmembers while keeping on-orbit stowage to a minimum.**
- **Sufficient # of EVA tools to support all schedule & unscheduled EVAs with redundancy.**
- **Request to increase EVA hardware on-orbit stowage allocation by 21% made to the ISS Program Office**
 - This is a challenge as many organizations supporting ISS are also requesting an increase in stowage allocation.





Oxygen Resupply System Challenge

- **ISS Program goal to have full O₂/N₂ High Pressure Gas Tanks at Shuttle Retirement**
 - Tanks are located externally on the U.S. A/L and provide backup supply of O₂ for ISS as well as prime supply of O₂ for EVA prebreathe & EMU tanks.
- **N₂/O₂ Resupply System (NORS) under development to resupply ISS with both high-pressure N₂ & O₂**
 - Current NORS schedule shows launch of O₂/N₂ refill capability NET Spring 2013
 - Tanks will be launched by IP or CRS vehicles.





Oxygen Resupply System Challenge

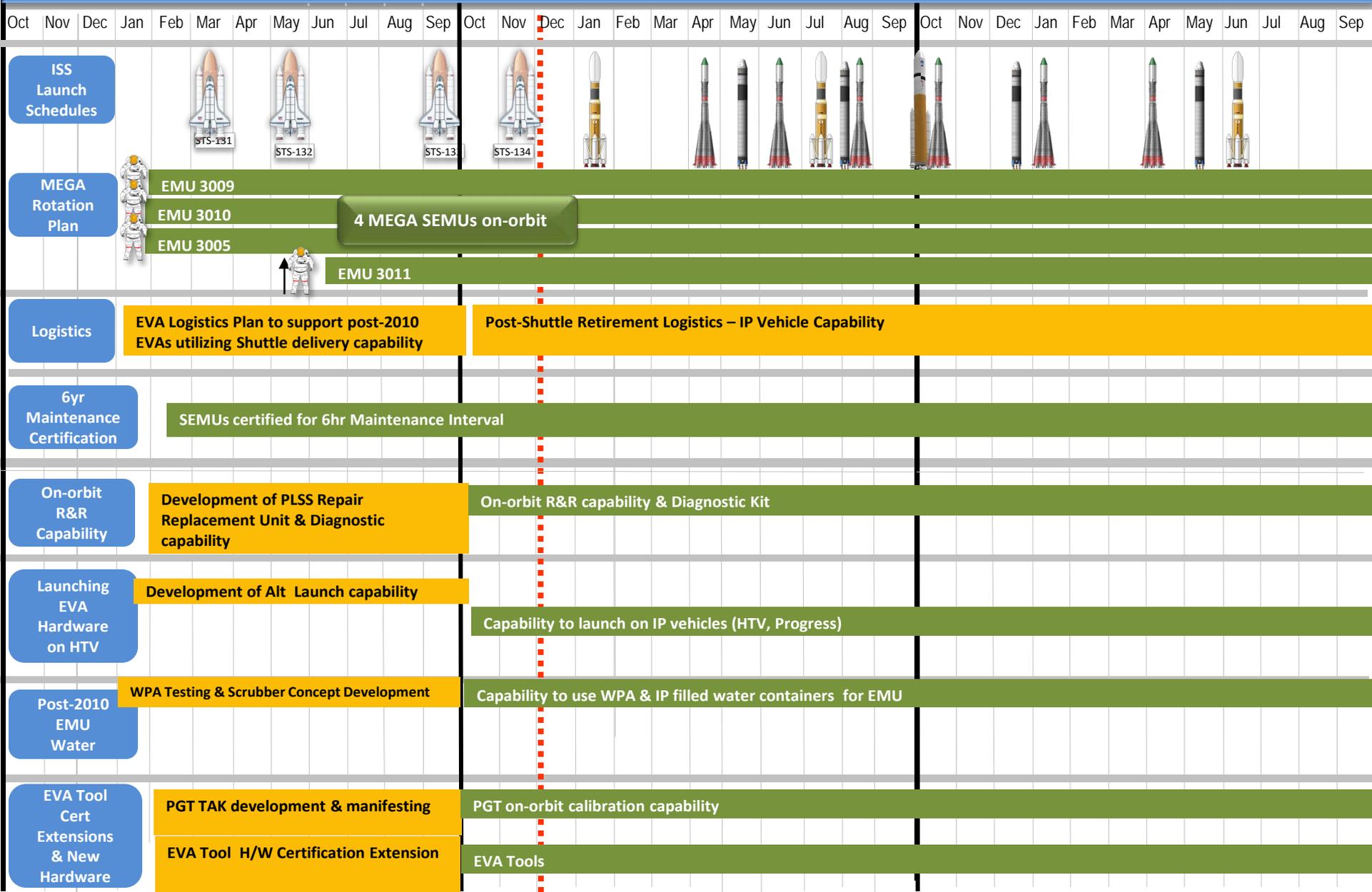
- **Consumables planning shows 13 total Campout Style EVAs available prior to NORS**
 - 13 EVAs in 3 years between Shuttle retirement and NORS on-orbit capability
 - Current ISSP requirement and consumables planning is for 8 EVAs per year
- **Total number of EVA's could be increased, but with shorter overall EVA time with In-Suit Prebreathe Protocol**
 - In-Suit Prebreathe uses 10 lbs O₂ vs 25 lbs O₂ for Campout protocol
 - Since crew is in the suit an additional 4 hrs during the prebreathe, EVA's are limited to 6:15 hrs due to crew day length

EVA2010 Integrated Schedule: FY10 – FY11

FY10

FY11

FY12





Conclusion

- **Retirement of the Shuttle + continued operation of the ISS until +2020 has forced the EVA community to change its operational philosophy.**
 - Limited resupply capability
 - Hardware becomes disposable
 - On-orbit replacement & testing by crewmembers
- **Opportunity for EVA to prepare for future missions beyond LEO**
 - Long-duration missions to other destinations will mirror this new operational philosophy.

