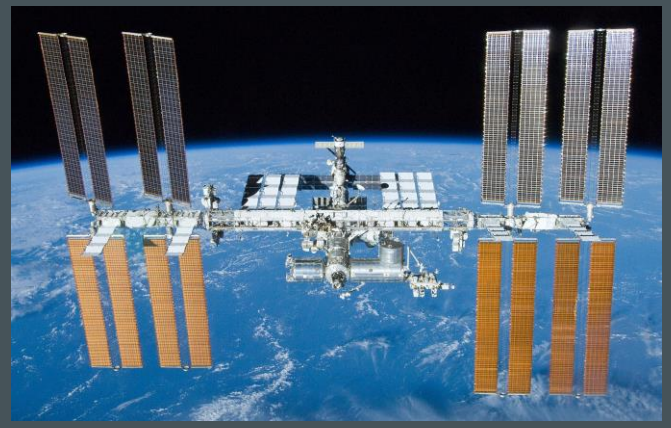
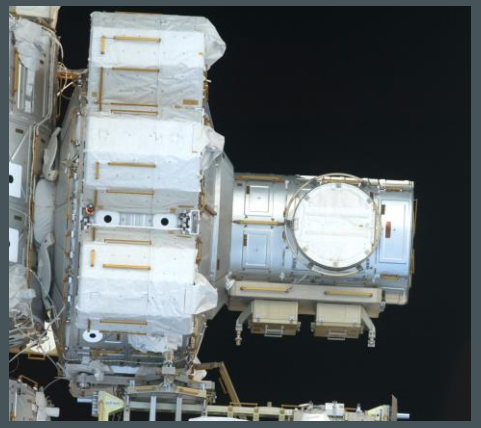
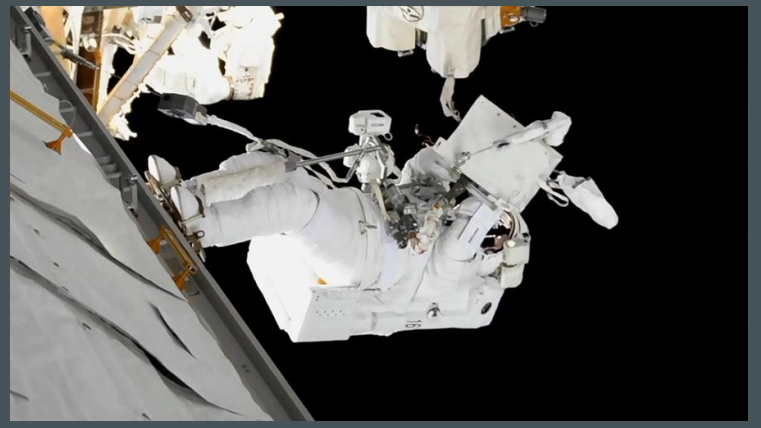
# ISS EVA OPERATIONS & THE EMU

GARY V STEPHENSON, 1/09/2021, PRESENTED TO NORTH HOUSTON NSS





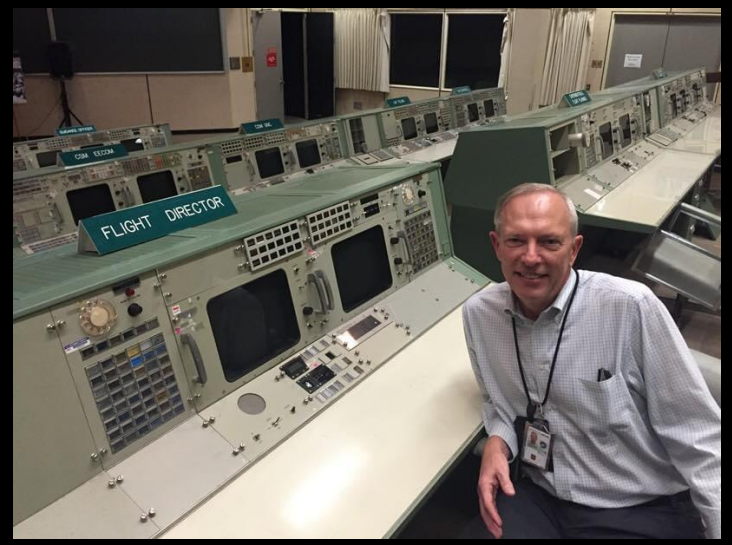


# PRESENTATION OUTLINE

- The First EVAs
- What's an EMU?
- How does an EMU work?
- How Does One Prepare for EVA?
- Quest Airlock
- What Happens During an EVA?
- EVAs: What Could Go Wrong?
- ISS 'EVA 23'
- EVA 23 Findings
- What Happens After an EVA?
- Return to the Moon: the xEMU
- How Will Spacesuits Need to Change To Work on Mars?
- Summary

# GARY'S EVA & EMU BACKGROUND

- I'm not an astronaut, and thus I've not been "out the door" on EVA, but….
- I did serve as EMU Systems Engineer and Houston Systems Engineering Manager for UTC / Collins from May 2015 to May 2019
- As the EMU Systems Engineer I was responsible for EMU performance for United Technologies / Collins prime contractor during EVAs
  - SE staff supported EVAs from JCS MER (Mission Evaluation Room, under Mission Control) and from factory (Windsor Locks, CT)
  - Supported Expeditions 45 – 59, ISS EVAs 189 – 216 (Wikipedia EVA numbering), including 23 US EVAs
  - Responsible for engineering support of sustaining EMU hardware components (spare parts)
- As the Houston Systems Engineering Manager I was responsible for systems engineering support for new NASA equipment
  - Redesigned UIA (umbilical interface assy) & FPU (fluid pumping unit)
  - Redesigned UWMS (space toilet) for ISS & cislunar missions
  - Conceptual design of TCPS (space trash compactor) for cislunar and interplanetary missions

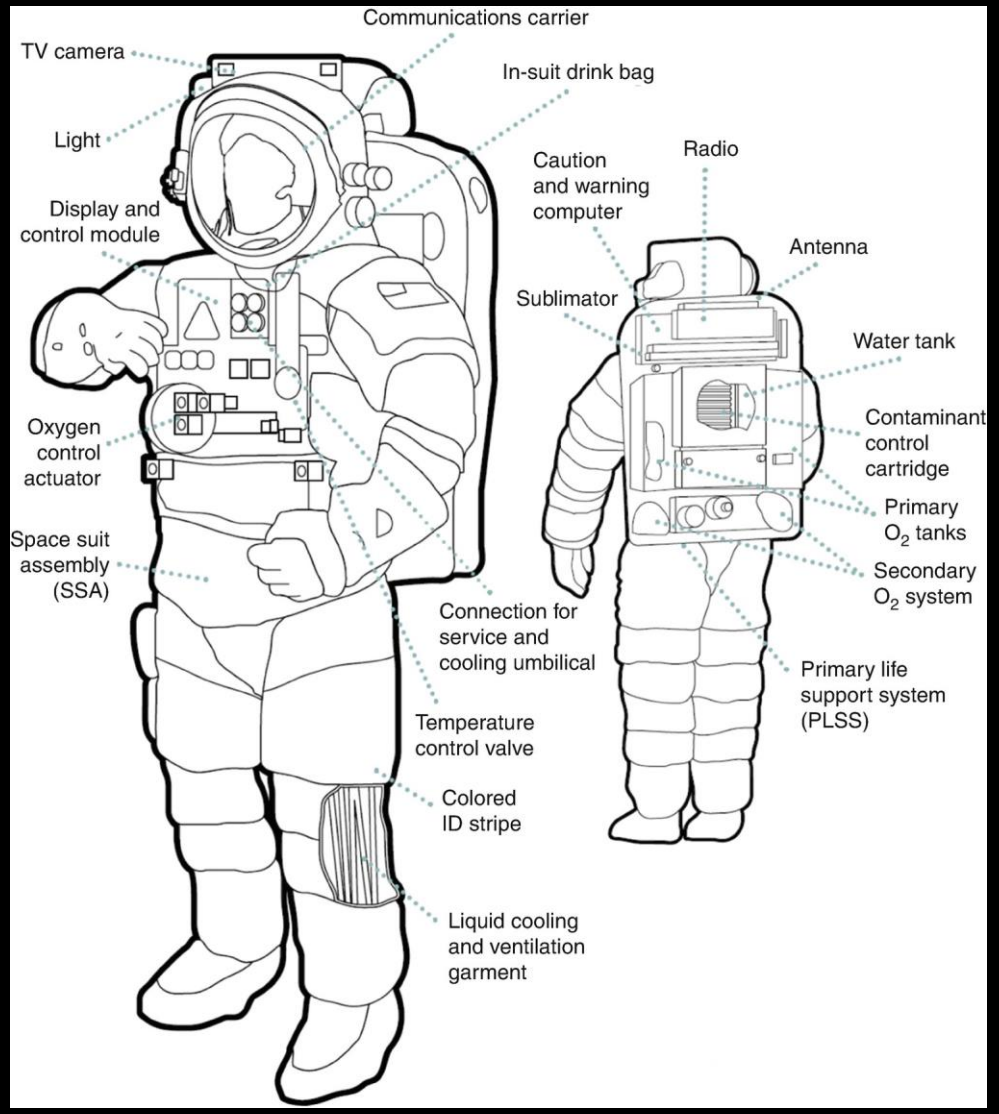



# THE FIRST EVAs, OR 'EXTRAVEHICULAR ACTIVITIES'

- First EVA was on 3/18/1965, by Cosmonaut Alexei Leonov
  - Umbilical only; not a self-contained life support system
  - Suit stiffening caused serious difficulties during space walk and while trying to get back into spacecraft
  - Suit overheating was an issue
- Second EVA (first US EVA) was on 6/03/1965, by Astronaut Ed White
  - Umbilical only; not a self-contained life support system
  - Troubles getting hatch open and closed
  - No external provisions for hand or foot holds on S/C
  - Maneuvering unit only lasted for 20 seconds
  - Suit overheating was an issue

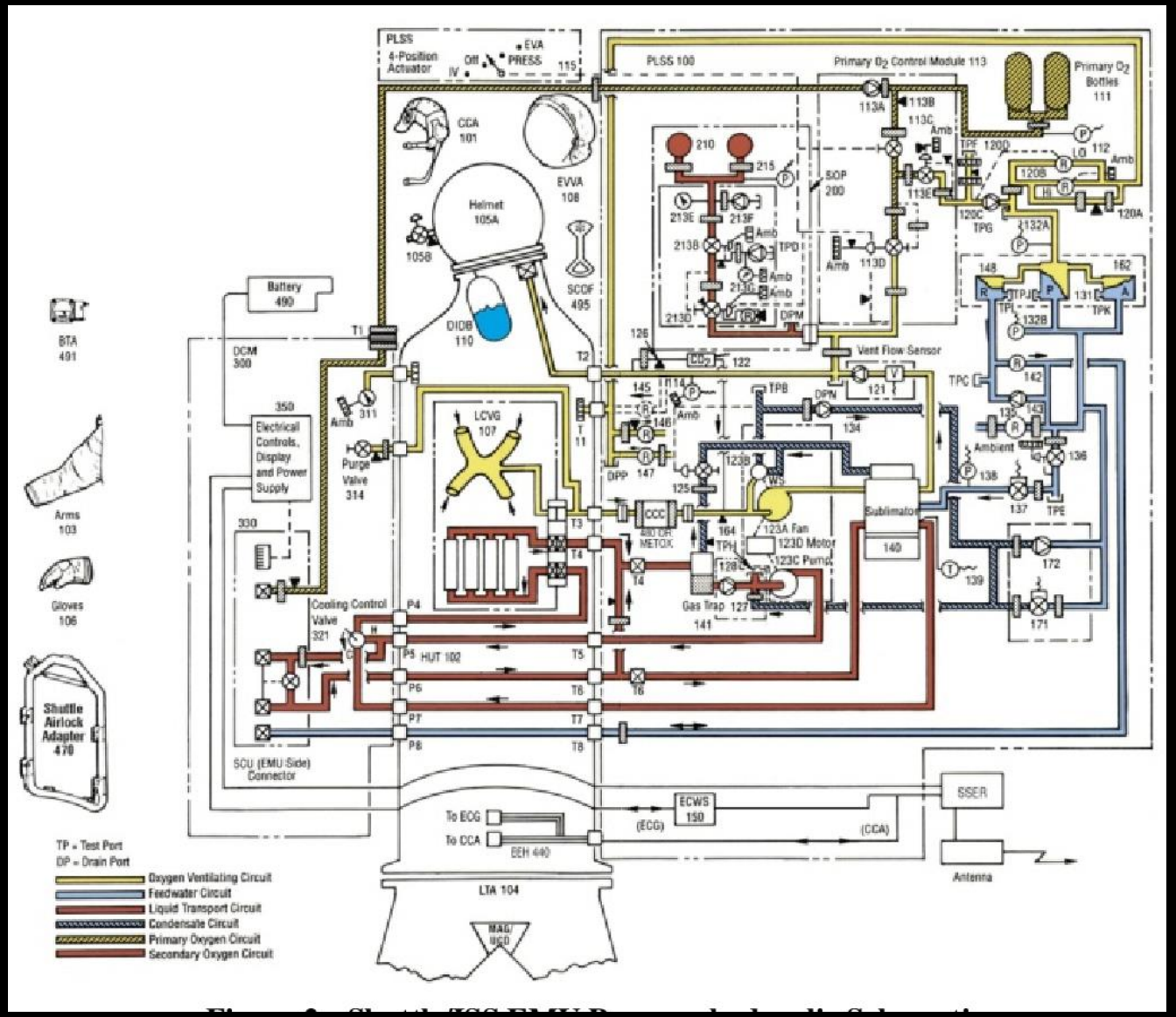
# WHAT'S AN EMU?

- EMU stands for Extravehicular Mobility Unit
- It's a spacesuit designed for micro-G spacewalks
- It can be thought of as a very small spacecraft
- Main subsystems consist of:
  - SSA, the Space Suit Assy
  - PLSS, portable life support system (backpack)
  - DCM, Display and Control Module (on front, which controls the PLSS)



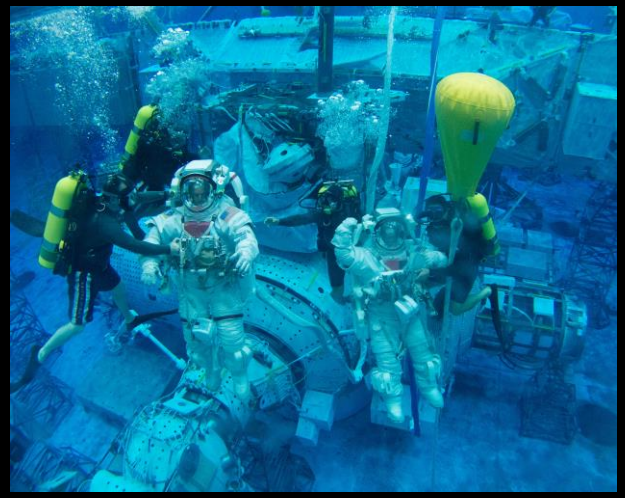
# HOW DOES AN EMU WORK?

- It’s a series of tubes, including
  - O2 supply
  - Vent loop
  - Feedwater supply
  - Cooling water loop
  - Condensate return



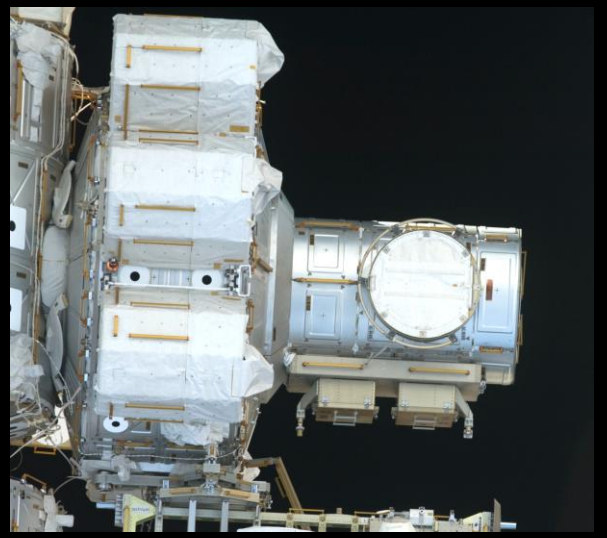
# HOW DOES ONE PREPARE FOR EVA?

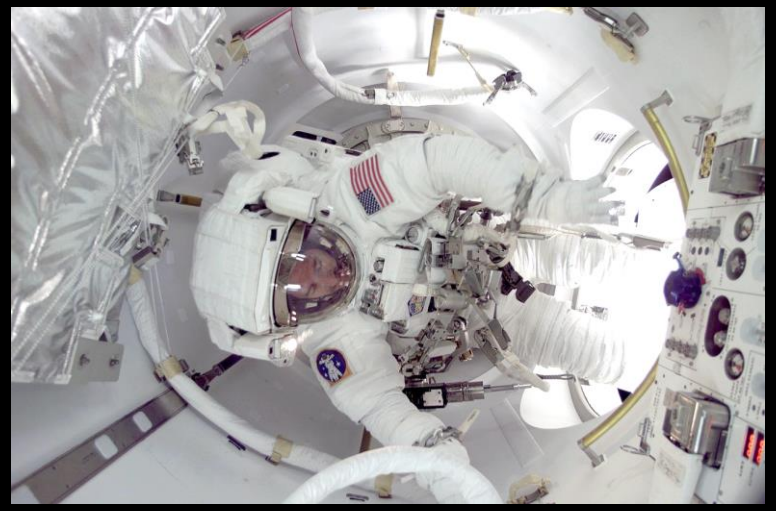
- The EMU has to be ready, and the astronaut has to be ready
- Test the EMU suit on the ground first in vacuum chambers, JSC Bldg 7
- Train the astronaut in a real EMU suit in vacuum chambers on the ground
- Train for mission at SVMF, Bldg 9
- Astronauts practice mission in NBL, Neutral Buoyancy Laboratory
- Day before, purge
- Day of, prebreathe $O_2$ several hours in EMU suits, on umbilical, to remove $N_2$ from blood



# THE QUEST AIRLOCK

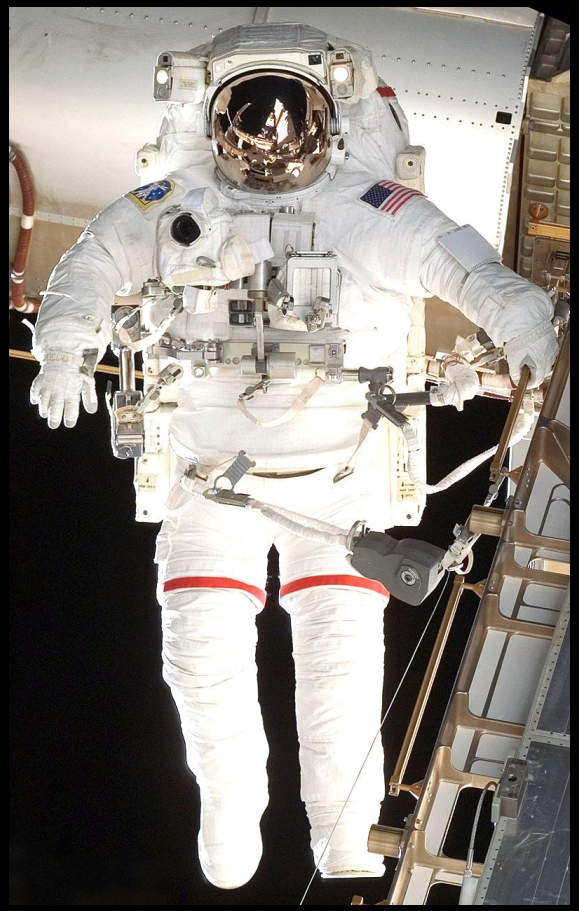
- Includes an equipment lock, that contains the EMU ‘Service Performance Checkout Equipment’ (SPCE), and the airlock used for EVA access
- Stores the 2 primary operational EMUs when they are not in use
- Designed for both US and Russian suits, but currently supports only US suits
- Airlock houses UIA for umbilical interface, air pump, hatches
- Equipment lock houses:
  - FPU for recharging suit water,
  - ALCLR (Airlock Cooling Loop Recharge) suit cleaning equipment,
  - 2 EDDAs to hang suits on,
  - Metox ovens for baking out $CO_2$
  - BCA battery chargers (for EMU batteries)
  - Power Supply Assy (PSA) to power all of the above





# WHAT HAPPENS DURING AN EVA?

- Two astronauts always go out on EVA together for safety
- Both astronauts are tethered to the ISS via cables, and their tools are tethered to their work belts, *at all times*
- Because of the short ISS orbital period (90 - 93 minutes) roughly half of every EVA is performed in the dark
- The astronaut with the red stripe on his/her EMU is the EVA commander
- An astronaut with EVA experience staffs the “EVA” position in Mission Control at Johnson Space Center (JSC) in Houston, TX
- Underneath Mission Control Center (MCC) in the Mission Evaluation Room (MER) there is a team of NASA and contractors monitoring suit performance, advising Mission Control as needed
- Via remote link the EMU factory in Windsor Locks, CT also monitors suit performance, advising the MER as needed



# EVAs: WHAT COULD POSSIBLY GO WRONG?

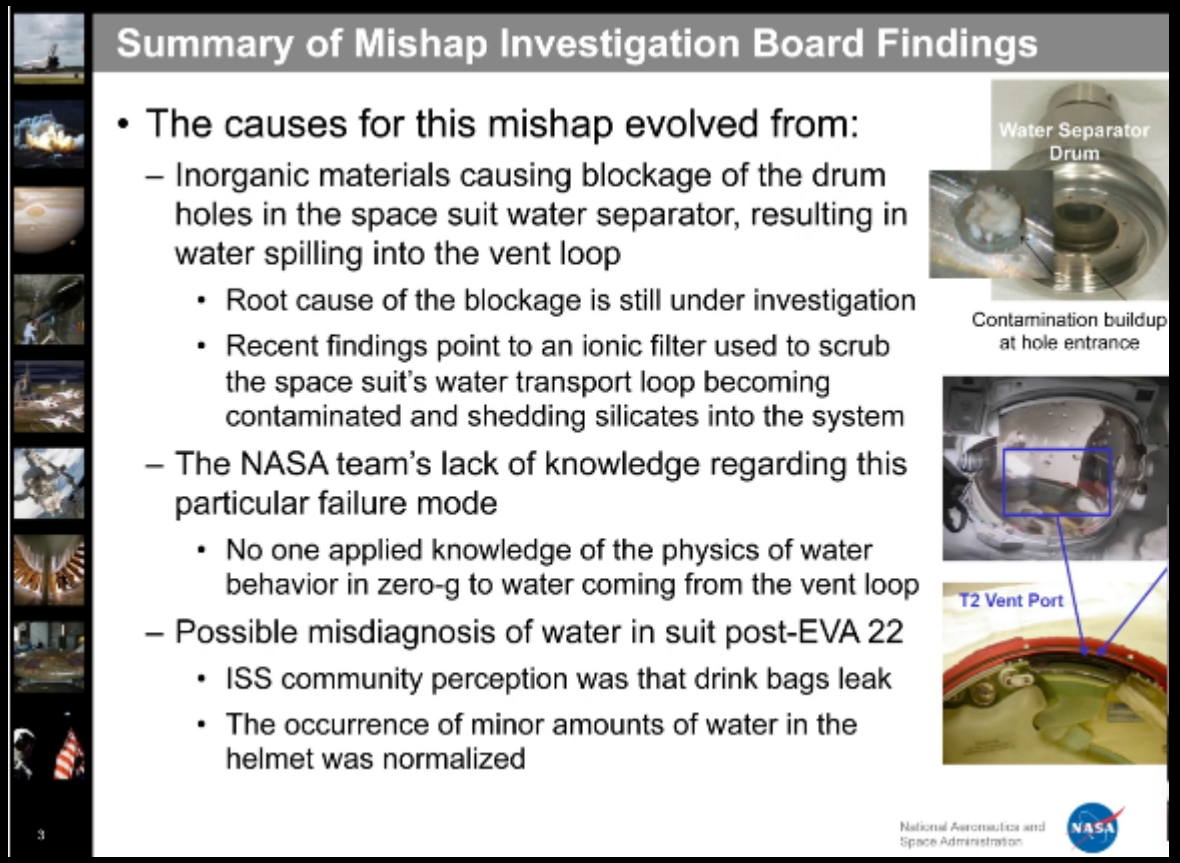
- The EMU uses pure $O_2$ inside the suit. One spark and there is a flash fire inside the suit, putting the astronaut's life very much at risk
- You can run out of $O_2$ or the primary $O_2$ can fail. There is a secondary $O_2$ system just in case, but that only lasts 15 - 20 minutes
- $CO_2$ build up can slowly poison an astronaut; there is spare capability in the Metox scrubber and $CO_2$ is monitored. If vent loop fails can RV purge
- To develop health problems while in the suit would be very dangerous; there is no opportunity to use a sickness bag
- It is possible to drown in a spacesuit when operating in a micro-G environment  if a leak develops
- You can break a tether or come off of a tether, and become lost in space
- A suit can develop an $O_2$ leak that is so fast it is not possible to make it back to the airlock in time
- A micrometeor strike could be fatal
- You can get the bends if decompression or recompression happens too fast and $N_2$ gets in the blood
- Suit can overheat if sublimator fails or clogs, or if water pump fails
- Suit can get too cold if bypass valve sticks; the only heaters in suit are in gloves; all other heat comes from astronaut's body heat

# ISS ‘EVA 23’

- Wikipedia EVA number 171, occurred July 2013
- Water in the helmet almost drown an astronaut (Luca Parmitano) during the EVA
- The situation was especially dangerous because the water in the helmet shorted out the voice com system in the helmet, which cutoff all communication with Luca
- When Luca’s EVA partner Christopher Cassidy and Mission Control noticed the lost com, Christopher helped seal Luca in the airlock
- More info:
  - https://www.youtube.com/watch?v=nMj7P8SB_g0
  - https://www.youtube.com/watch?v=bxFdfk35_K0

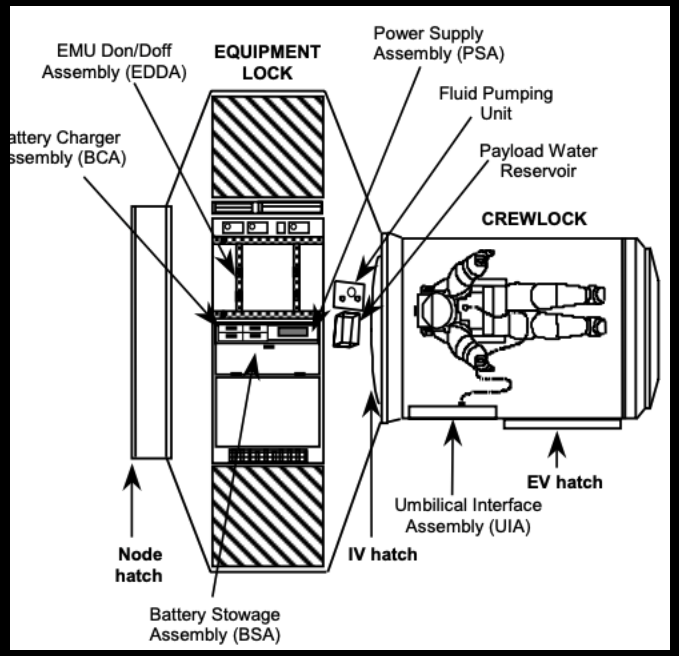
# EVA 23 FINDINGS

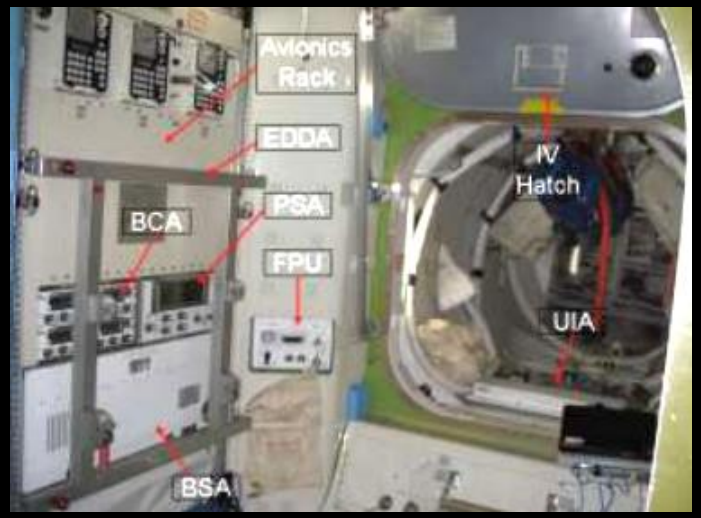
- Cause: a plugged water separator in EMU
- Why? Dirty water in suit
- Why? Dirty suit cleaning water filter
- Why? We sent up a filter that was already dirty
- Why? It got dirty during ground testing
- Why? We used plant water out of Clearlake to acceptance test the water filter, ruining it
- Fixes:
  - Developed a process for water filter acceptance testing on ground at JSC that does not pollute or ruin water filters
  - Expanded cleaning of suits during post EVA processing (ALCLR)
  - Expanded water cleanliness testing pre and post EVA on ISS
  - Added a High Absorbency Pad (HAP) to back of helmet near T2 vent port
  - Filter supply water before it is pumped into the EMU



# WHAT HAPPENS AFTER AN EVA?

- EMU suits are removed with the aid of other astronauts
- EMU suits are put back on umbilicals to recharge O2 supplies back up to 900 psi
- Batteries are changed out and recharged via BCA
- Suit water is cleaned via water filters in ALCLR system
- Feedwater is topped off via FPU pumping water from PWR
- Metox canisters are changed out, and is $CO_2$ baked out of the used ones in specialized ovens
- The astronauts not on the EVA are usually the ones performing these post EVA tasks

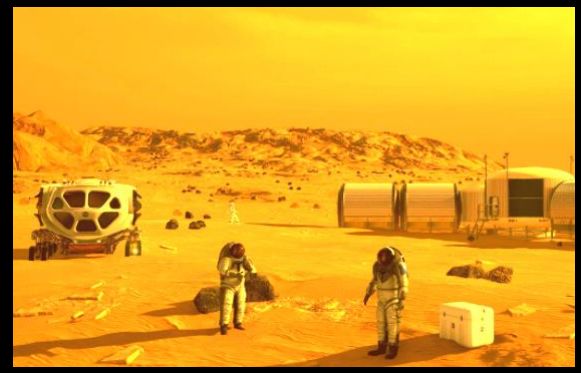


# RETURN TO THE MOON: THE xEMU

# HOW WILL SPACESUITS NEED TO CHANGE TO WORK ON MARS?

- They will need to be lighter, more flexible, and more reliable
- They will need to accommodate a wider range of motions
- They will need to be more serviceable remotely, on site
- They will need to work in Martian atmosphere
  - Sublimators used in a vacuum will not work in 5 Torr Martian atmospheric pressure, and thus SWMEs (suit water membrane evaporators) will need to be developed
- They will need to work in Martian soil
  - Needs to be abrasion resistant since contact with soil is inevitable
  - Needs to be easily cleaned since Martian soil can be toxic
- They do not exist yet, and prototype development still needs to be funded – pictured is the NASA Z-2, an early prototype

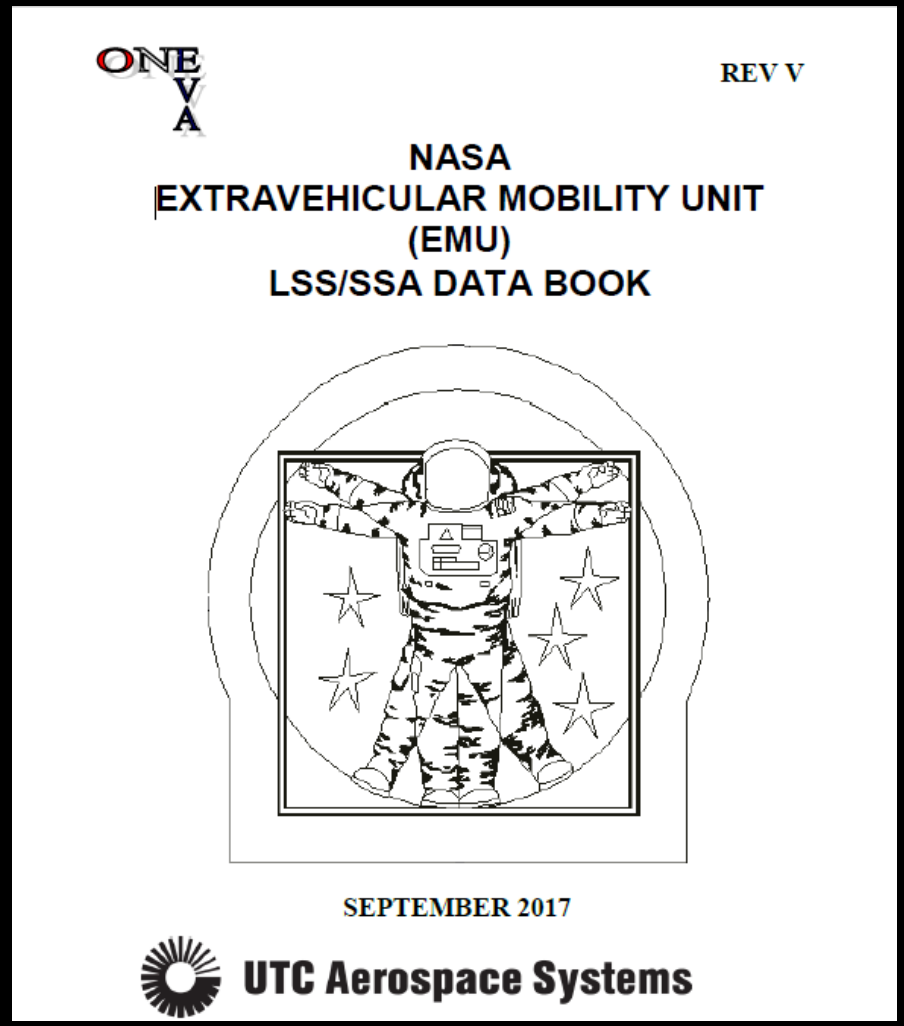
# SUMMARY

- EMUs need a lot of care and maintenance
- EMUs are only for EVA not for surface ops
- xEMUs are experimental and will only work on the Moon
- Martian suits will need to be a lot lighter and more reliable

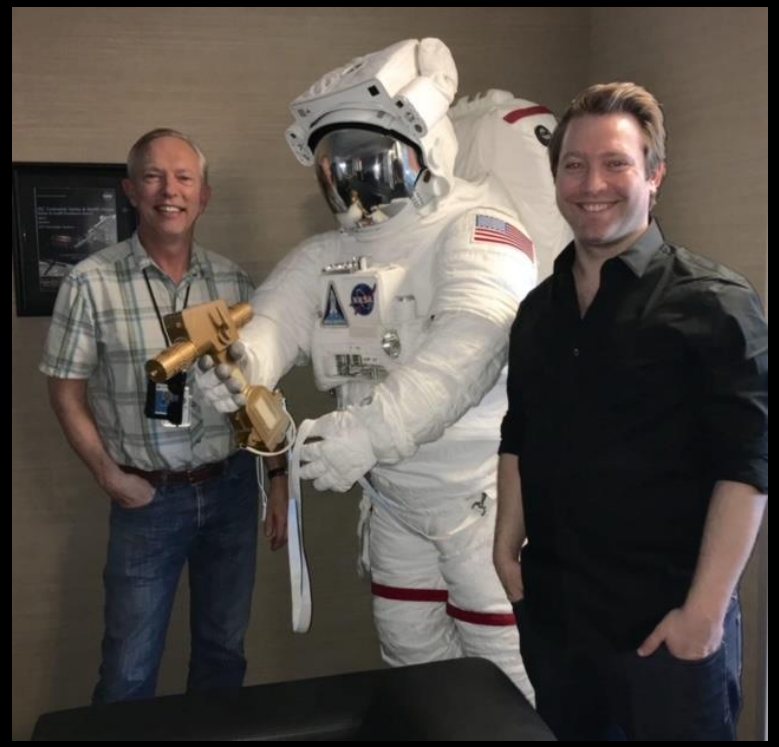
# REFERENCES

- EMU wiki article: https://en.wikipedia.org/wiki/Extravehicular_Mobility_Unit
- ISS EVAlist: list:https://en.wikipedia.org/wiki/List_of_International_Space_Station_spacewalks
- EMU Data Book: https://www.lpi.usra.edu/lunar/constellation/NASA-EMU-Data-Book-JSC-E-DAA-TN55224.pdf
- xEMU Conops: https://www.nasa.gov/sites/default/files/atoms/files/topic_1-_eva_lunar_surface_concept_of_operations.pdf
- SPCE equipment in airlock: https://spacecraft.ssl.umd.edu/design_lib/ICES02-2366.airlock.pdf

- Inputs and corrections from Ana Castaneda are gratefully acknowledged



# QUESTIONS?

# BACKUP CHARTS

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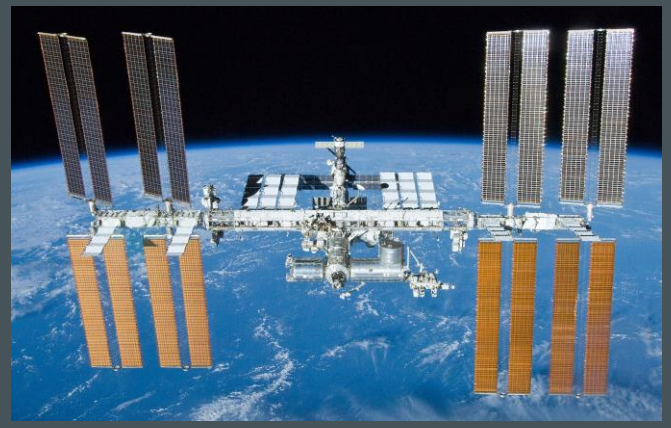
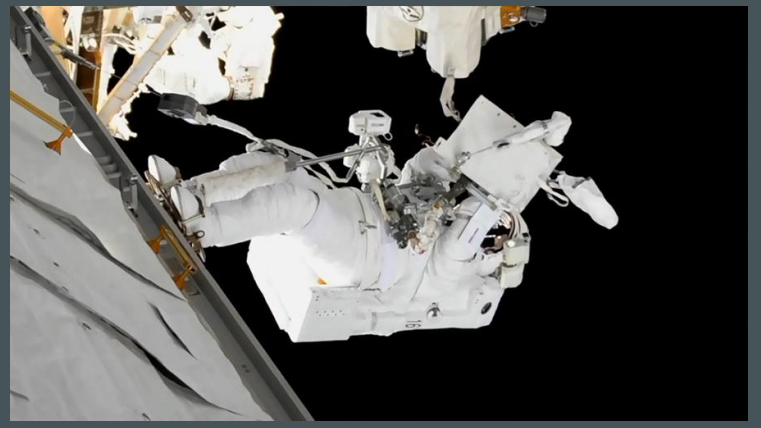
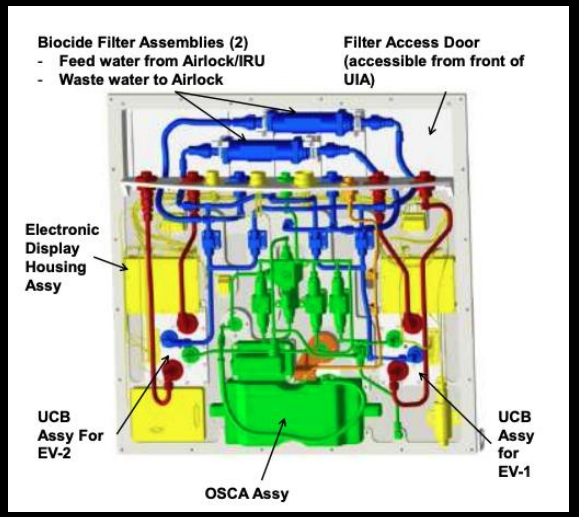




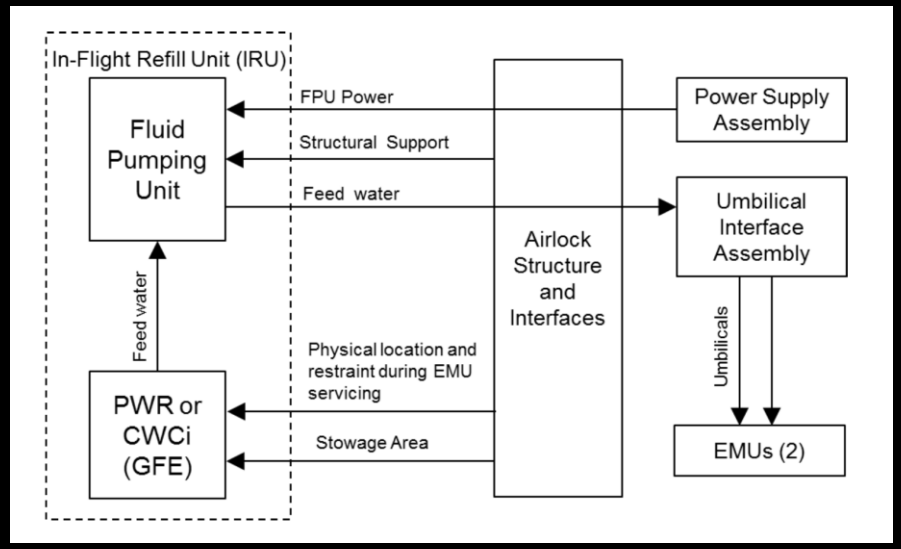
# UIA = UMBILICAL INTERFACE ASSEMBLY

- Ever wonder where the other end of an umbilical goes? To the UIA !
- Capable of supporting US (EMU) or Russian (Orlan) spacesuits
- Supplies and recharges 900 psi $O_2$ to EMU
- Supplies and biocide filters feedwater; also used for a dump and fill of suit water
- Provides cooling loop water heat exchanger since sublimator suit heat exchanger cooling does not work until in hard vacuum on EVA
- Supplies EMU power so as to save EMU batteries for EVA
- Supplies hardline com connections since RF com reception questionable in airlock

# FPU = FLUID PUMPING UNIT

- The FPU is used to recharge the feed water supply inside the EMU
- The FPU is a water pump that transfers clean water from the payload water reservoir (PWR) through the UIA and umbilicals to the EMU suits




FPU


PWR

# MOST COMMON EMU FAILURE: THE FAN PUMP SEPARATOR (FPS)

The fan drives the vent loop,

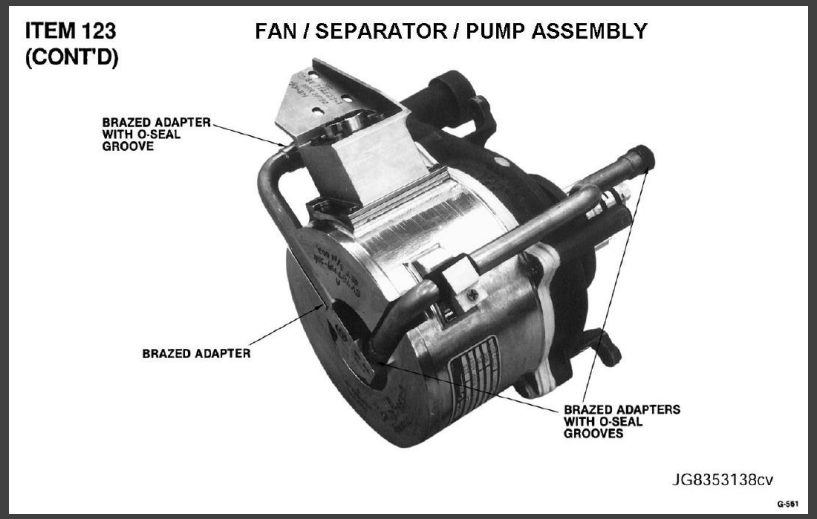
the pump drives the cooling water loop, and

the separator pulls water from the vent loop

A single electric motor is used to drive all 3 functions; if that motor fails, all 3 functions fail

Failure mechanisms include corrosion, bearing failure, and rotor binding derived from overheating and warping of parts

Item 123, FPS



# HOW DOES THE xEMU (LUNAR WALKING SUIT) WORK?