
NASA
Welcome

# A little about the speaker…Tim Hall

- Born & raised in West Virginia
- Graduate of West Virginia University (WVU)School of Engineering with a BS Mechanical Engineering

*Lets Go Mountaineers!!*

- Been involved in the space industry for 18+ years

- Space career includes working 30+ Space Shuttle and International Space Station (ISS) Missions in the Mission Control Center
- Currently Chief of the Extravehicular Activity (EVA) Operations Branch

National Aeronautics and Space Administration

# What's Going On Now At NASA?

www.nasa.gov/exploration

# *Human Spaceflight….*

Expedition 46

SpaceX Dragon

BEAM (Bigelow Expandable Activity Module) Install



Orbital Sciences ATK Cygnus

Expedition 47

# Commercial Resupply Services 2 (**CRS2**) Awarded

- Prime suppliers of cargo  to ISS
- 3 companies awarded for 2nd round
  - Orbital Sciences Cygnus
  - SpaceX Dragon
  - Sierra Nevada Dream Chaser


Dream Chaser

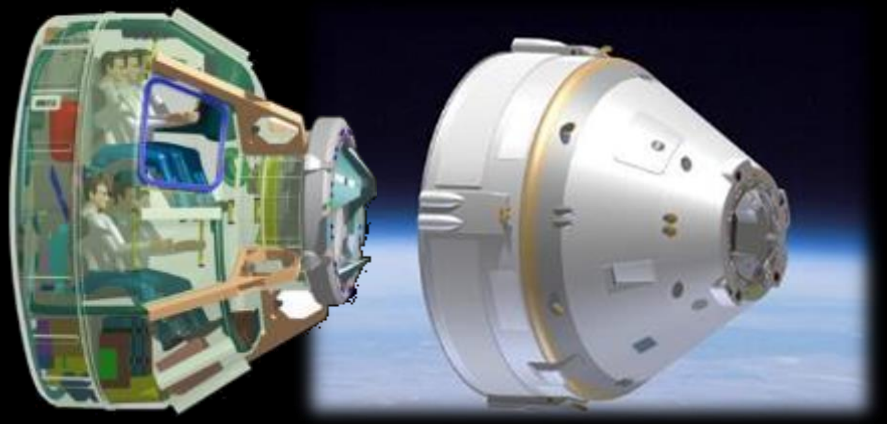

Dragon


Cygnus

# Commercial Crew

1. SpaceX
2. Boeing

Atlas V



Boeing CST-100

SpaceX Dragon Capsule

Dragon Interior

Falcon 9 Rocket

# EFT-1 = Exploration Flight Test -1 Success!

- 1st mission (unmanned) for Orion (MPCV)
- Tested heat shield at high entry velocity
- Used Delta IV Heavy rocket

# MPCV – Multi-Purpose Crew Vehicle “Orion”

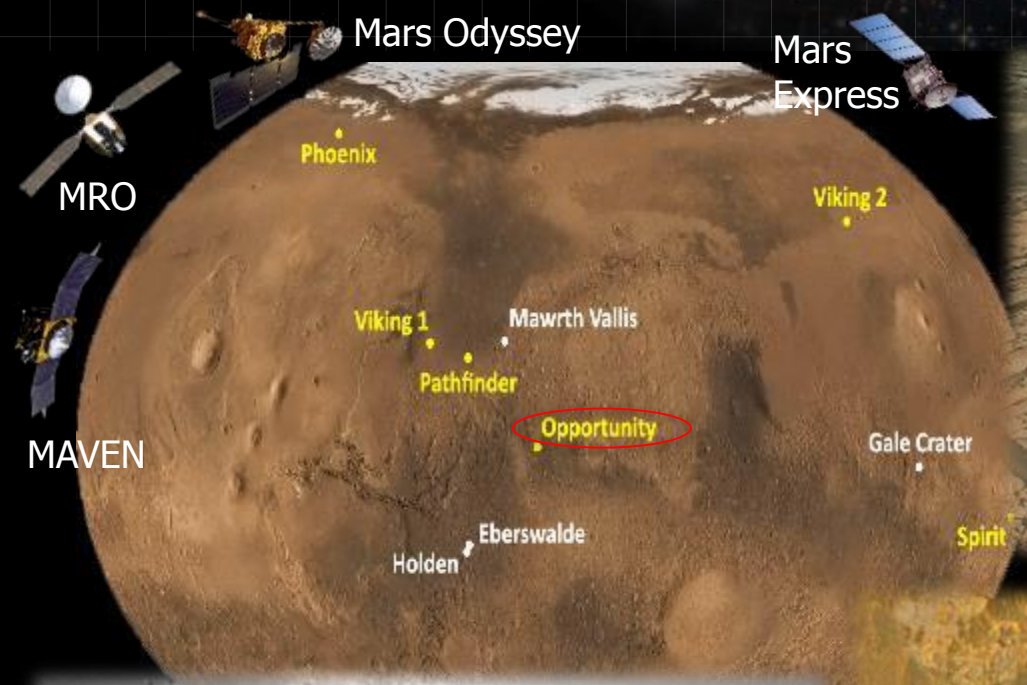
- Second test flight in 2018 (SLS)
- First Manned Mission 2021 (SLS)

# NASA Heavy Lift Vehicle - SLS

- SLS – Space Launch System
  - Estimated 80-120 metric tons capacity
  - First launch planned for 2017

Cargo and Crew Vehicle

# Planetary Missions, Mars is busy!…




MSL- Mars Science Laboratory "Curiosity"

MSL Selfie

MER Mars Exploration Rover– "Opportunity"

Mars Orbiter Views Curiosity Rover in 'Artist's Drive'

http://www.space.com/16874-where-did-nasa-spacecraft-land-on-mars-video.html

# Many, many other cool missions…

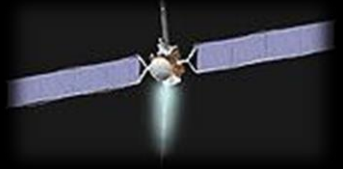
Just a few to mention…

Cassini

Saturn orbit, last year of operation

Dawn

Visiting Ceres (arrived March 6 2015)



Hubble

Still researching origins of the universe

Kepler

Planet Count

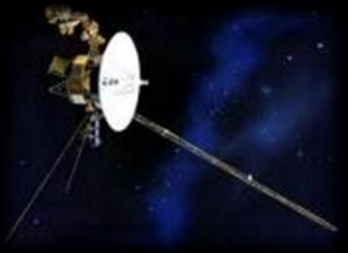
Confirmed Planets: 977

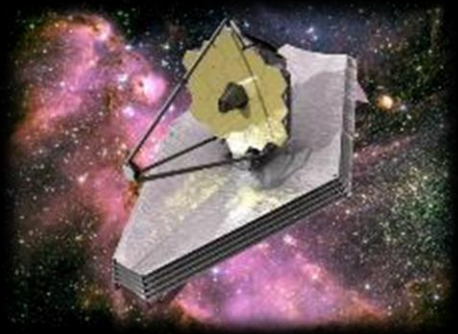
Planet Candidates: 4,234

Voyager 1

Has left the building…

Traveling interstellar space





James Webb Telescope

Launch in 2018

Eyes on the Solar System

http://eyes.nasa.gov/

# New Horizons @ Pluto!

- **New from NASA's New Horizons: Increasing Variety on Pluto's Close Approach Hemisphere, and a 'Dark Pole' on Charon**

NASA's New Horizons spacecraft doesn't pass Pluto until July 14 – but the mission team is making new discoveries as the piano-sized probe bears down on the Pluto system.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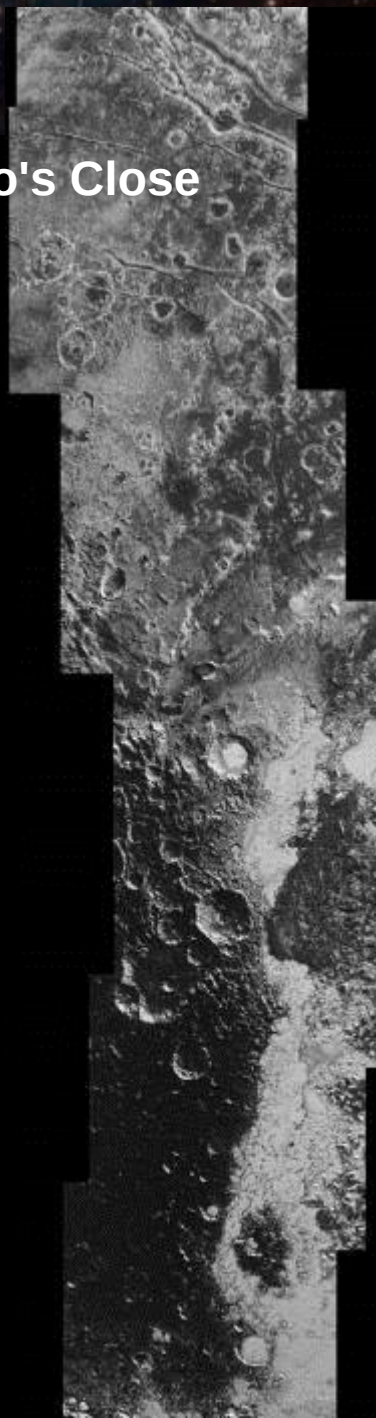
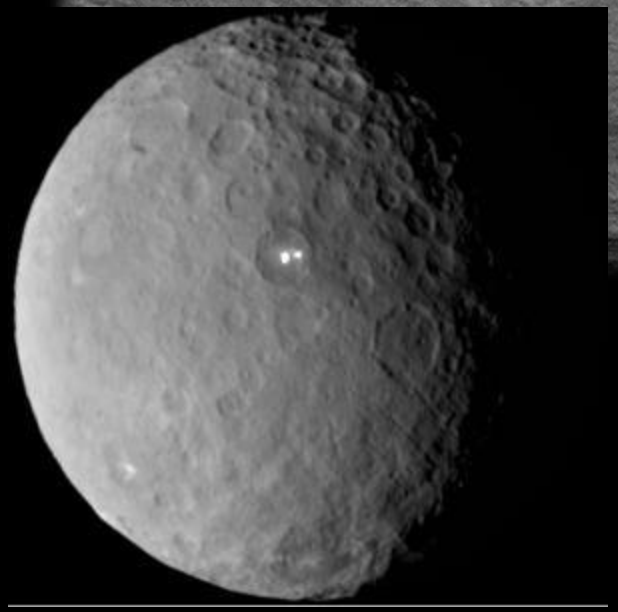


# Dawn Spacecraft @ Ceres

**Dawn** is continuing to unveil a **Ceres** of mysteries at the first dwarf planet discovered

**Dawn** spacecraft has found several more bright spots as well as a pyramid-like peak jutting out of the frigid world's surface



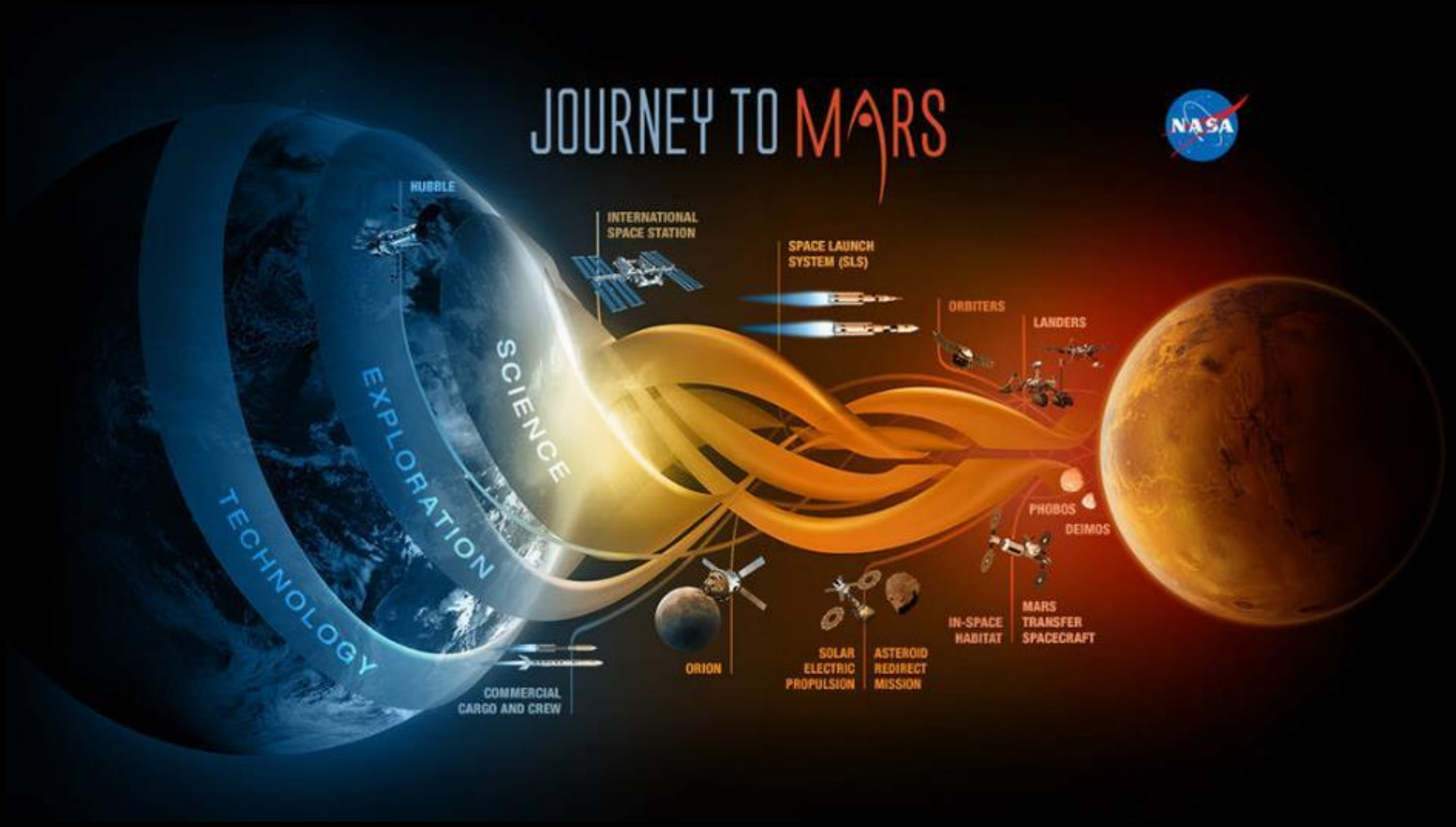
# Caltech Researchers Find Evidence of a Real Ninth Planet

- Caltech researchers have found evidence of a giant planet tracing a bizarre, highly elongated orbit in the outer solar system.
  - The object, which the researchers have nicknamed Planet Nine, has a mass about 10 times that of Earth
- Planets 9 may orbit about 20 times farther from the sun on average than does Neptune (which orbits the sun at an average distance of 2.8 billion miles).
  - In fact, it would take this new planet between 10,000 and 20,000 years to make just one full orbit around the sun
  - Source: https://www.caltech.edu/news/caltech-researchers-find-evidence-real-ninth-planet-49523

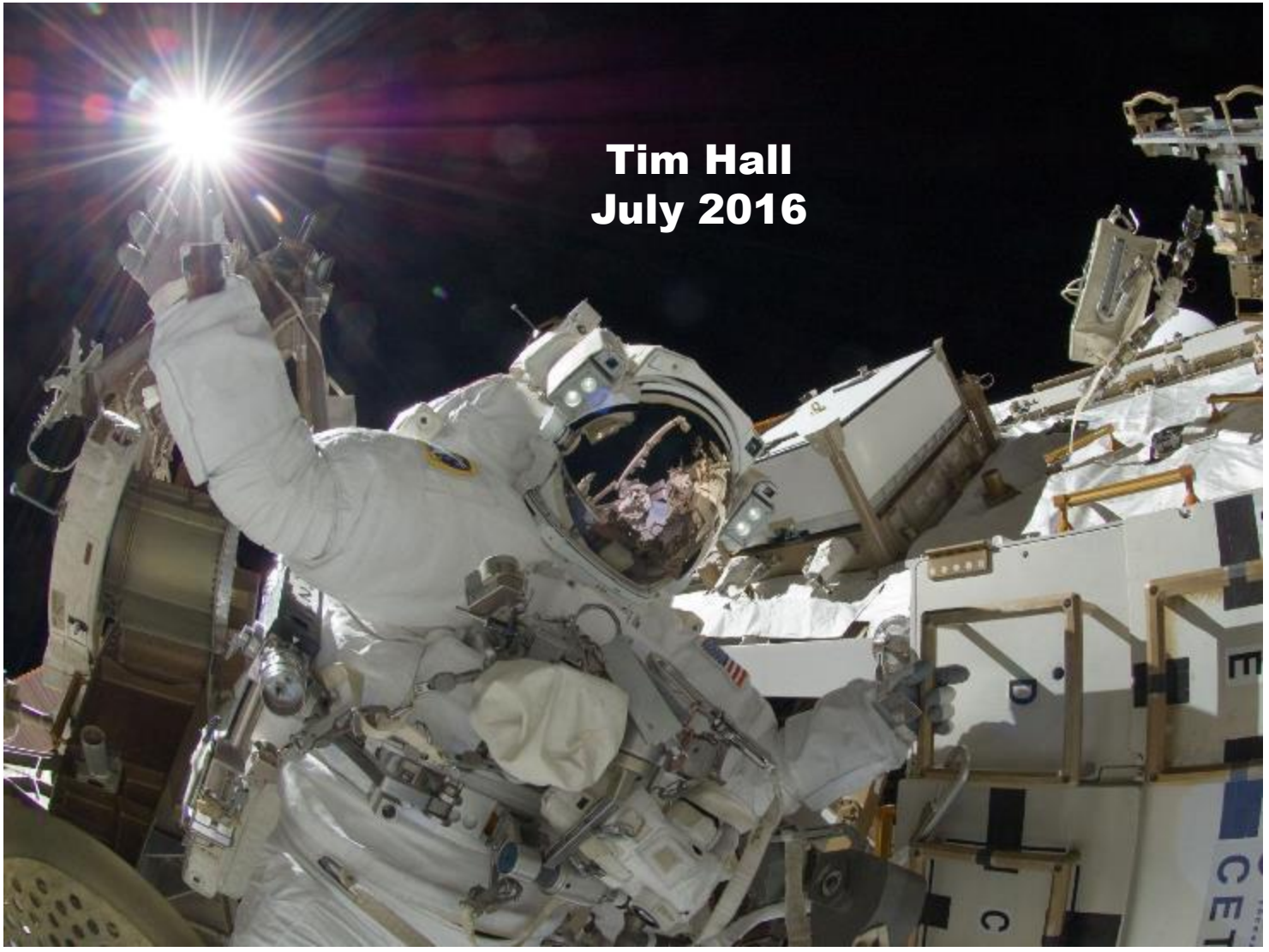
# NASA's Kepler Discovers First Earth-Size Planet In The 'Habitable Zone' of Another Star

- NASA's Kepler mission has now confirmed the first near-Earth-size planet in the “habitable zone” around a sun very similar to our star.
- For more information about this latest discovery, visit: NASA’s Kepler Mission Discovers Bigger, Older Cousin to Earth.

# NASA Journey to Mars

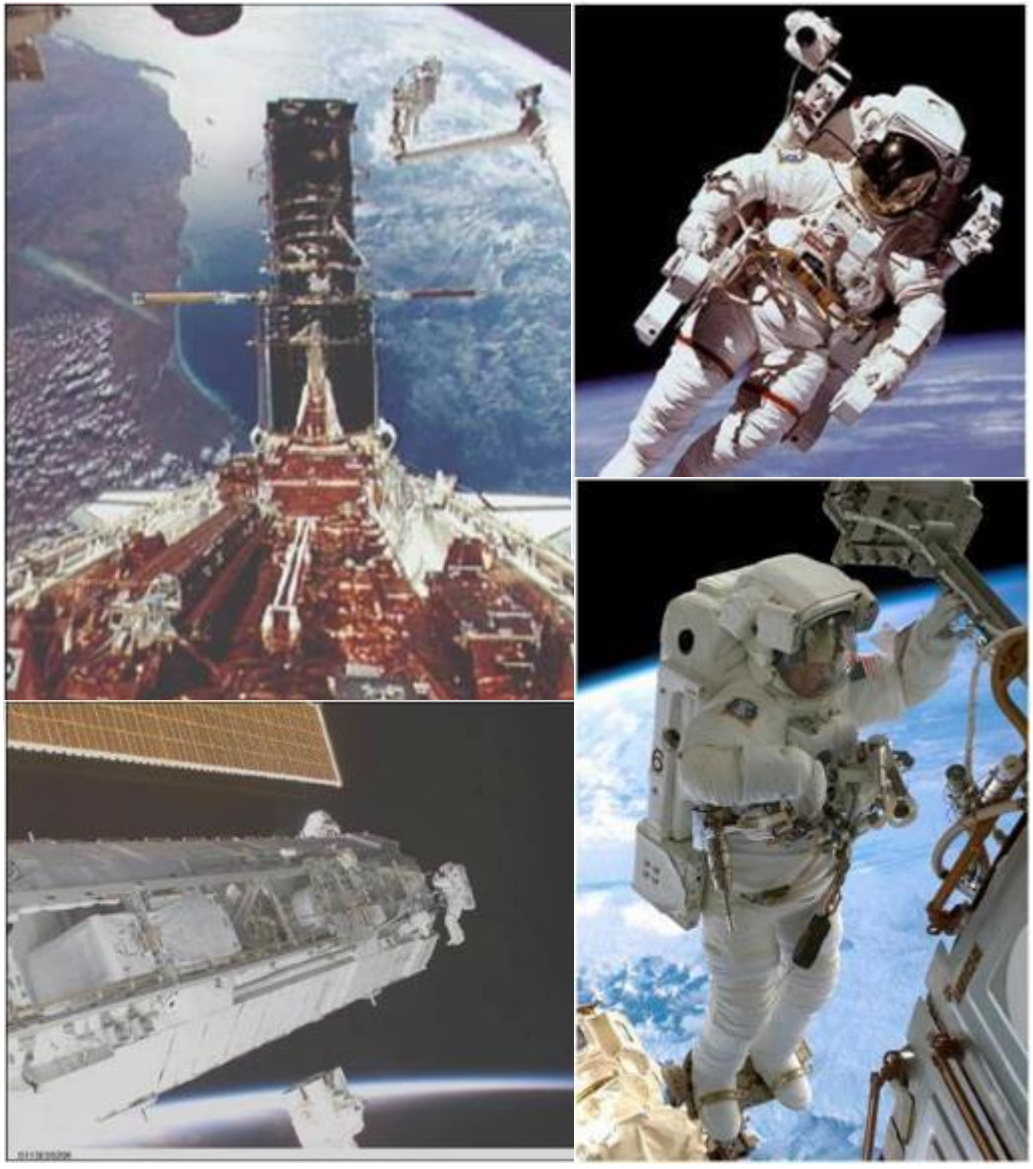


# Extravehicular Activity (EVA) Hardware & Operations Overview



# Definition of EVA

- Extravehicular Activity (EVA)
  - Definition: Crewmember leaves the protective environment of a pressurized spacecraft cabin and ventures out into vacuum of space wearing an extravehicular spacesuit.
  - Purpose
    - Contingency or Mission Success Repairs
    - Experiments or Testing
    - Spacecraft Servicing
    - Space Structure Construction [e.g., International Space Station (ISS)]



# Definition of Spacesuits

- Spacesuits
  - Typically, 2 types of pressurized "spacesuits' have been constructed to support our space programs

    - Launch, entry, and abort (LEA) spacesuit
      - Used to protect crewmembers from launch, ascent, abort, landing and other dynamic loading
      - Capable of providing protection from loss of cabin pressure and crew rescue following landing.

Launch/Entry Suit

    - Extravehicular Activity (EVA) spacesuit
      - Used to allow crewmembers to work effectively in the harsh external space environment (provides protection from vacuum, thermal, mircrometeoroids, radiation, etc.).

EVA Suit

# Historical Overview

- First EVA was conducted by USSR/Alexi Leonov on March 18, 1965.
  - Many EVAs have since been accomplished by the Soviet Union & Russia continuing into the International Space Station era.

•http://images.search.yahoo.com/search/images;_ylt=A2KJkPo2y.xPWkgAsWOJzbkF?p=voskhod+airlock&fr=yfp-t-701&ei=utf-8&n=30&x=wrt

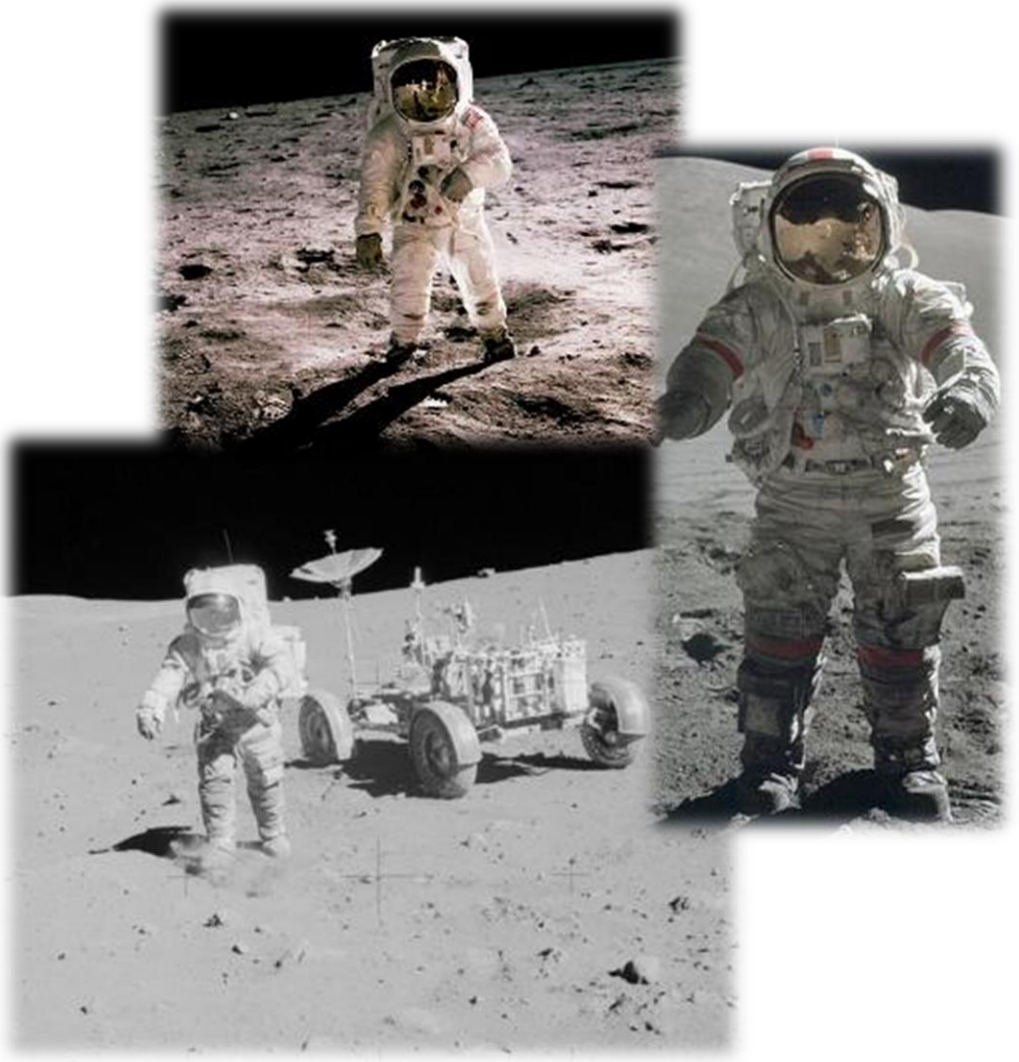
# Historical Overview

U.S. EVA Experience

- Gemini EVA Experience -
  - Astronaut Edward White II performed first U.S. EVA during Gemini IV June 3, 1965 (22 min).
  - Term “Spacewalk” coined
  - Start of EVA program was excursion to perform a special set of procedures in a new and hostile environment.
  - Proved EVA to be a viable technique for operations outside the spacecraft crew compartment.
  - Problems encountered: helmet fogging, overheating due to high metabolic activity (primarily due to suit constraints and lack of training).
  - Gemini Extravehicular Spacesuit and Life Support
    - 5-layer Gemini spacesuit was intended primarily for Intravehicular Activity (IVA).
    - 2 additional layers were added for EVA (making 7 layers total).
    - An umbilical was used to tether the EVA crewmember to the spacecraft and to supply breathing oxygen.
  - 5 Gemini missions involved nine EVAs for a total of **12 hours and 22 minutes** of EVA.

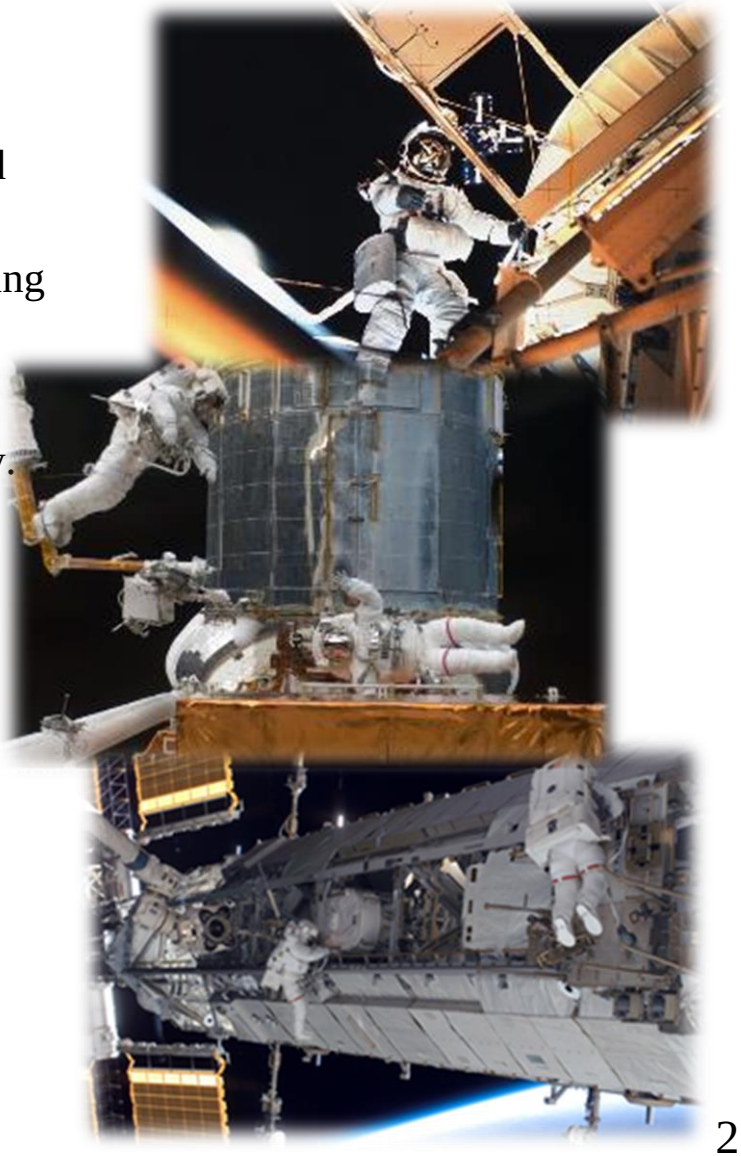
# Historical Overview

- Apollo EVA Experience
  - Spacesuit was redesigned to allow greater mobility.
  - Suit used for lunar and in-space EVAs.
  - Suit was configured with its own portable life support system providing:
    - Pressurization & Atmosphere
    - Communication
    - Ventilation
    - Cooling
    - Waste management system
  - 7 EVA missions totaling **170 hours** of EVA (15 on lunar surface, 5 outside Crew Module).
  - Last 3 Apollo missions (15, 16, & 17) utilized the lunar rover vehicle for greater range in lunar exploration.



# Historical Overview

- Skylab EVA Experience
  - Apollo-style suit used.
  - Umbilical replaced portable life support system and provided breathing oxygen, cooling, and served as a tethering device.
  - 10 EVAs were performed during the 3 Skylab missions totaling 82.5 hours.
- Space Shuttle EVA Experience
  - New space suit design for additional mobility and modularity.
  - Portable life support system designed for microgravity operation.
  - Increased operational capability from orbiter.
  - Accumulated 1000s of hours of EVA experience over 200+ EVAs.
- Space Station EVA Experience
  - EMU certified for extended duration on-orbit operations (25 EVAs).
  - Orbital Replacement Unit (ORU) capability added.
  - Accumulated 1000s of hours of EVA experience over 150+ EVAs.



# EVA Categories

## ISS & Shuttle Terminology

- Three basic categories of EVA:

1. Scheduled EVA:

   EVA planned and trained prior to launch and included in the mission timeline.

   - Both ‘skills-’ and ‘task-based’ training used

2. Unscheduled EVA:

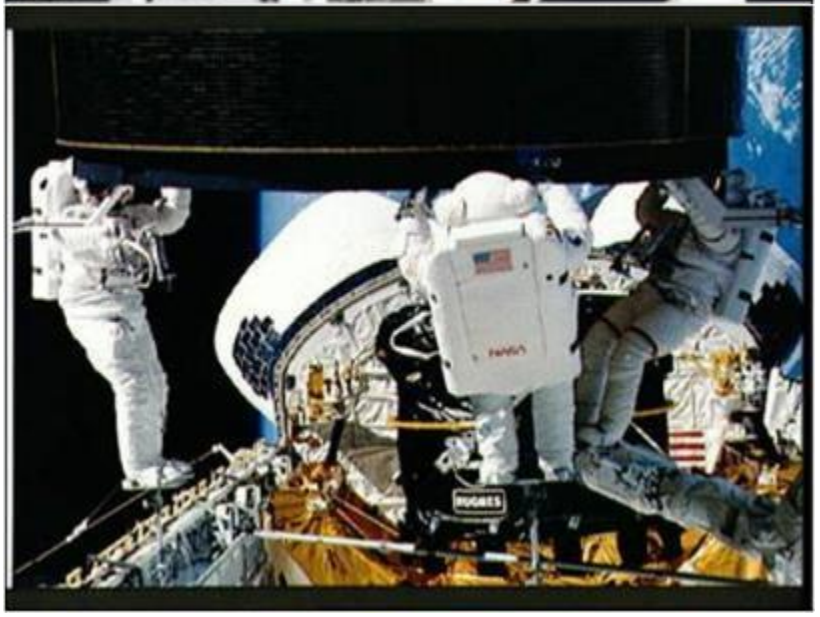
   EVA, although trained, not included in the scheduled mission activities, but which may be required to achieve mission or operational success.

   - Both ‘skills-’ and ‘task-based’ training used

3. Contingency EVA:

   EVA required to effect the safety of the crew and vehicle.

   -‘Skills-based’ training used



# US EVA Systems

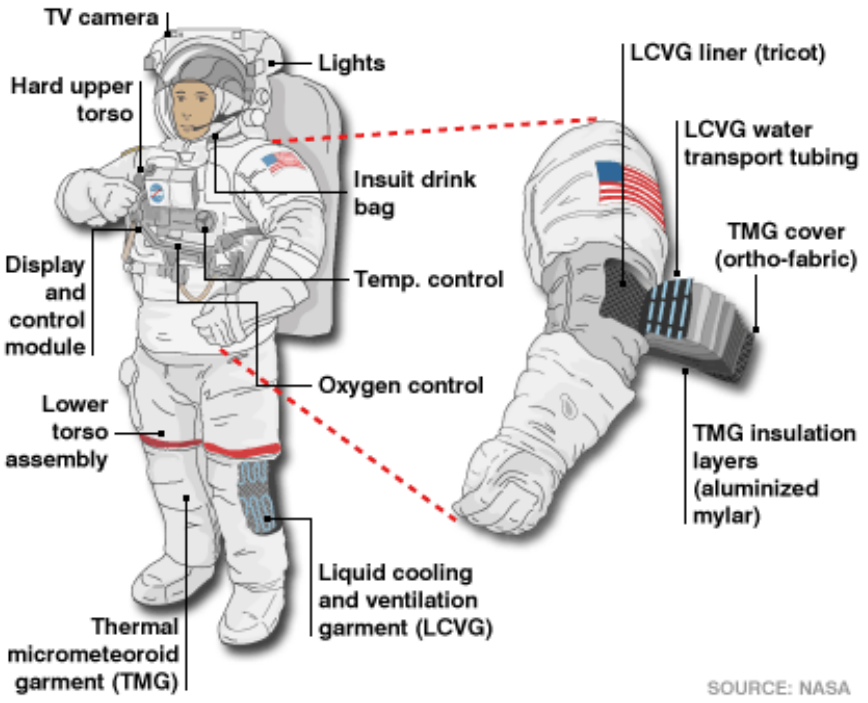
- Extravehicular Mobility Unit (EMU)
- ISS Joint Airlock
- Equipment & Tools (including Simplified Aid For EVA Rescue (SAFER))

# EVA Systems - EMU

• The EMU is an independent system that provides the crewmember with environmental protection, mobility, life support, and communications during EVA.

• EMU provides consumables to support an EVA of 7 hours maximum duration.
  - 15 minutes for egress
  - 6 hours for useful work
  - 15 minutes for ingress
  - 30 minutes for reserve

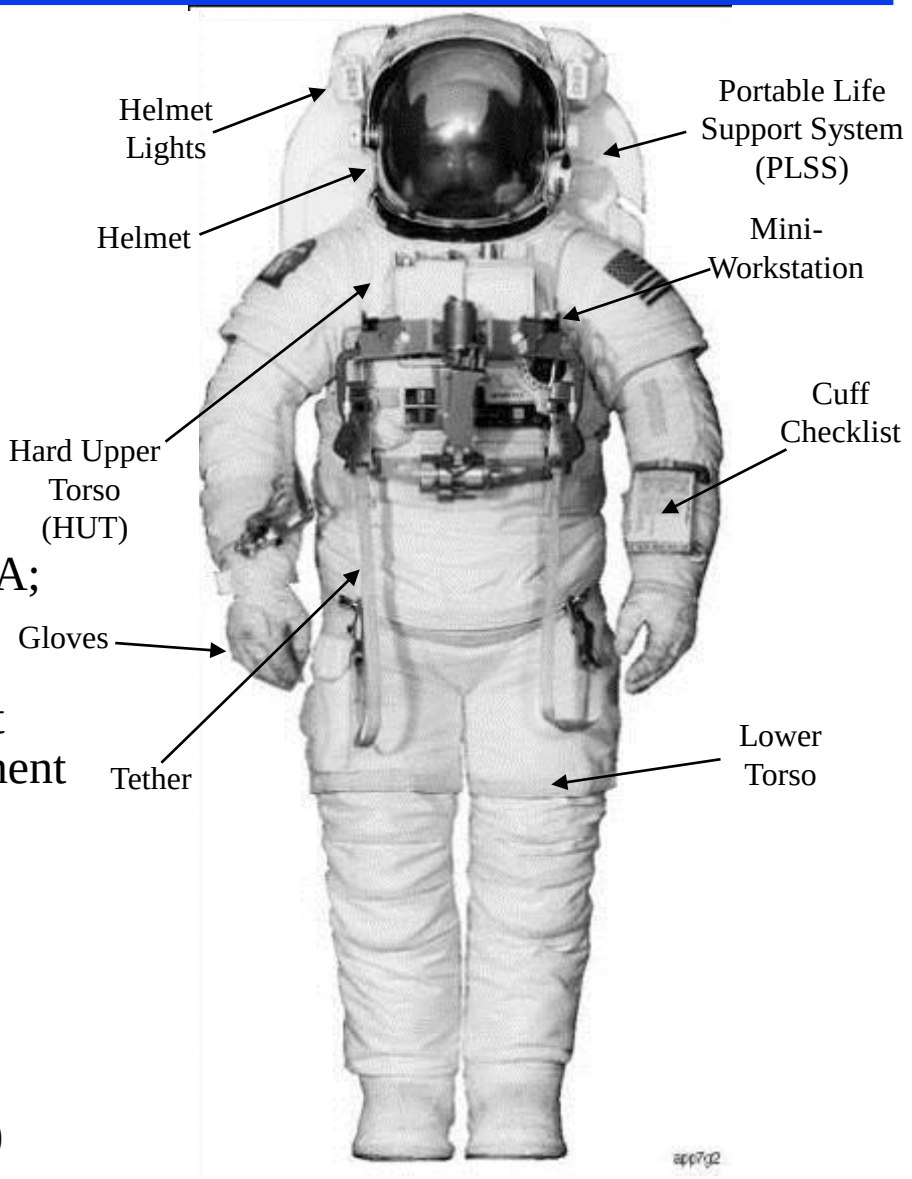
• EMU is an integrated system consisting of two subassemblies:
  - Space Suit Assembly (SSA)
  - Portable Life Support System (PLSS)



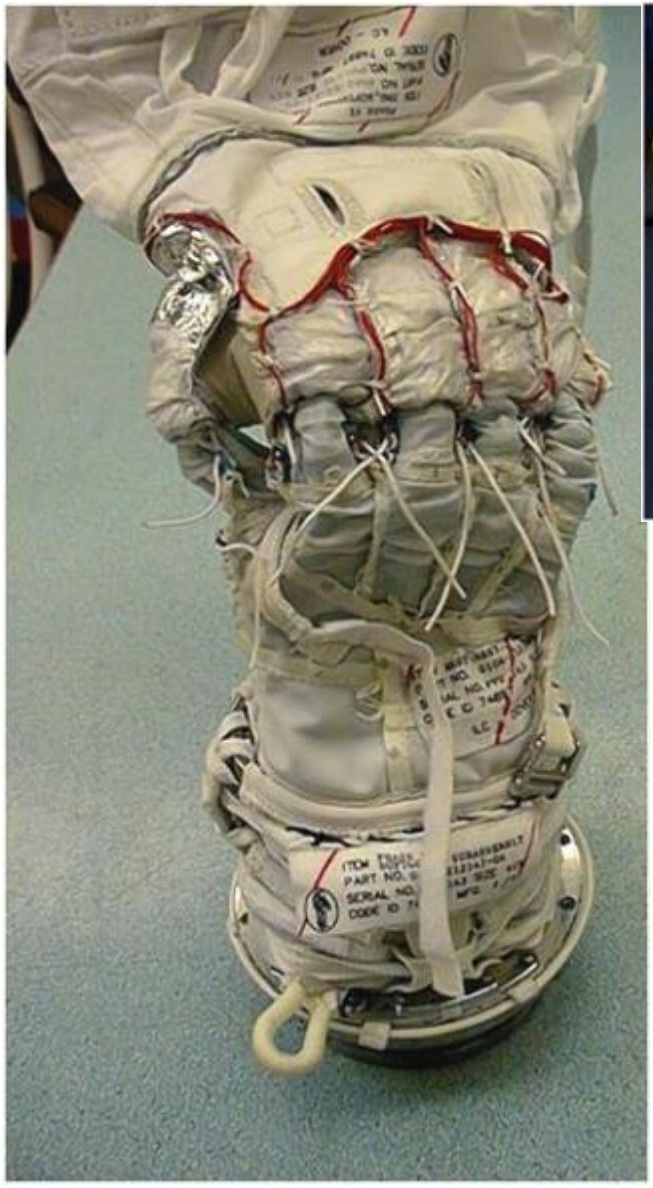

•orbiterchspacenews.blogspot.com

# EVA Systems – Space Suit Assembly

- Space Suit Assembly Components:
  - Hard Upper Torso (HUT)/arms
  - Lower Torso Assembly (LTA)
  - Extravehicular (EV) gloves
  - Helmet/Extravehicular Visor Assembly (EVVA)
  - Communications Carrier Assembly (CCA; Comm Cap)
  - Liquid Cooling and Ventilation Garment (LCVG) / Thermal Cooling Under-Garment (TCU)
  - Operational Bioinstrumentation System (EKG)
  - Disposable In-Suit Drink Bag (DIDB)
  - Maximum Absorption Garment (MAGs)



# EVA Systems – Space Suit Assembly

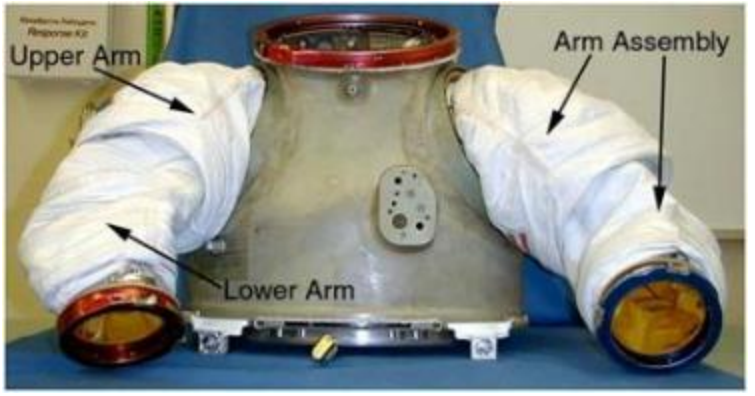


- Extravehicular (EV) gloves

- Extravehicular (EV) boots (and insert)

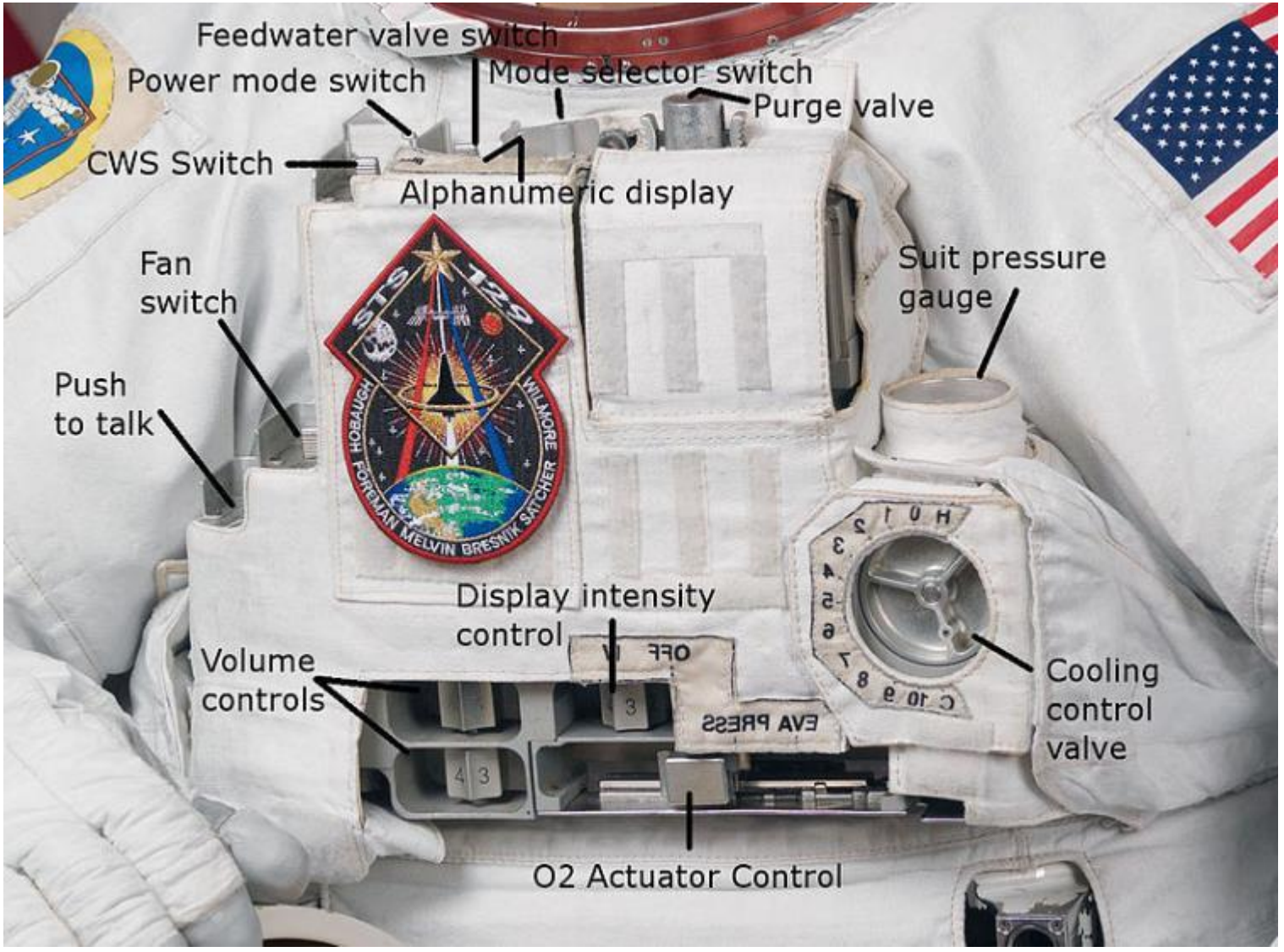
# EVA Systems – Life Support

- Life Support System Components:
  - Display and Control Module (DCM)
    - Provides Caution & Warning System (CWS) messages, EMU parameters, and EMU controls to crewmember





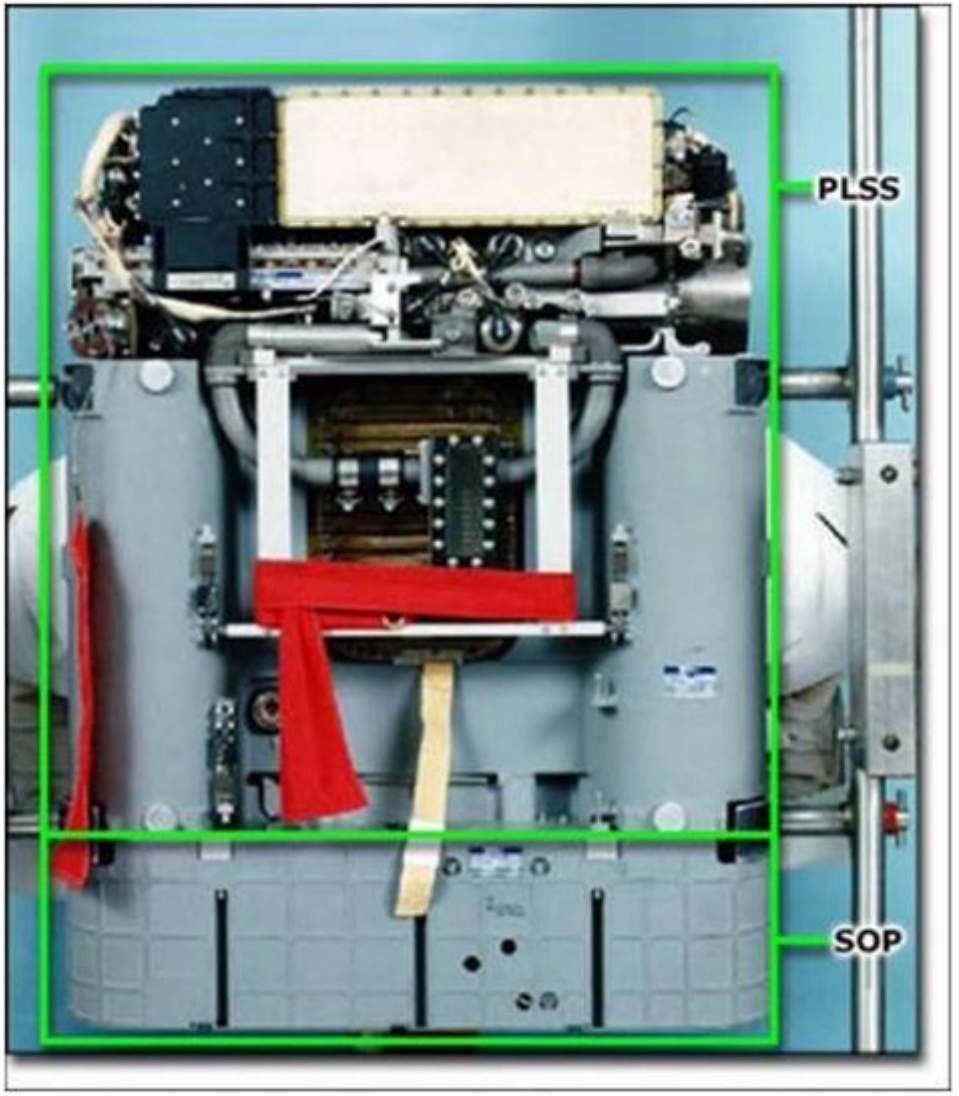

# Display Control Module




•http://en.wikipedia.org/wiki/File:Emu_spacesuit_control_module.jpg

# EVA Systems – Life Support

- Life Support System Components:
  - Portable Life Support Subsystem (PLSS)
    - Provides breathing $O_2$, electrical power, communications, cooling
    - Responsible for suit pressure control
    - Circulates $O_2$ and removes $CO_2$, humidity and trace contaminants
    - Controls thermal environment
  - Secondary Oxygen Package (SOP)
    - Provides a minimum of 30 minutes of emergency $O_2$ in open-loop purge mode
    - Activated automatically during EVA, if necessary

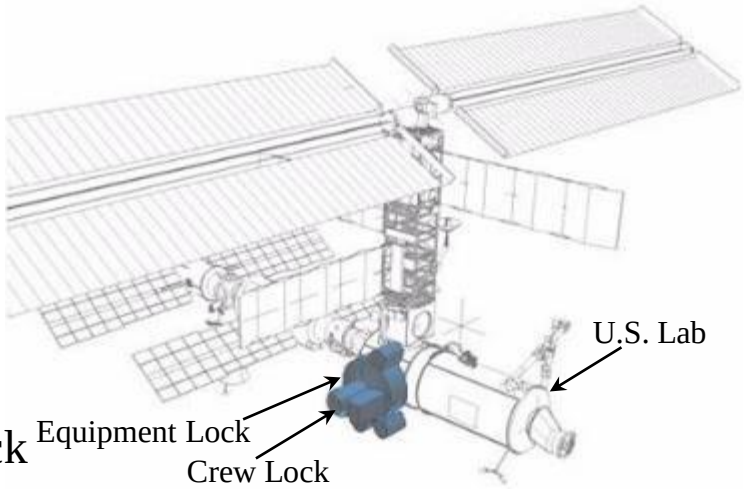


# EVA Systems - ISS Joint Airlock

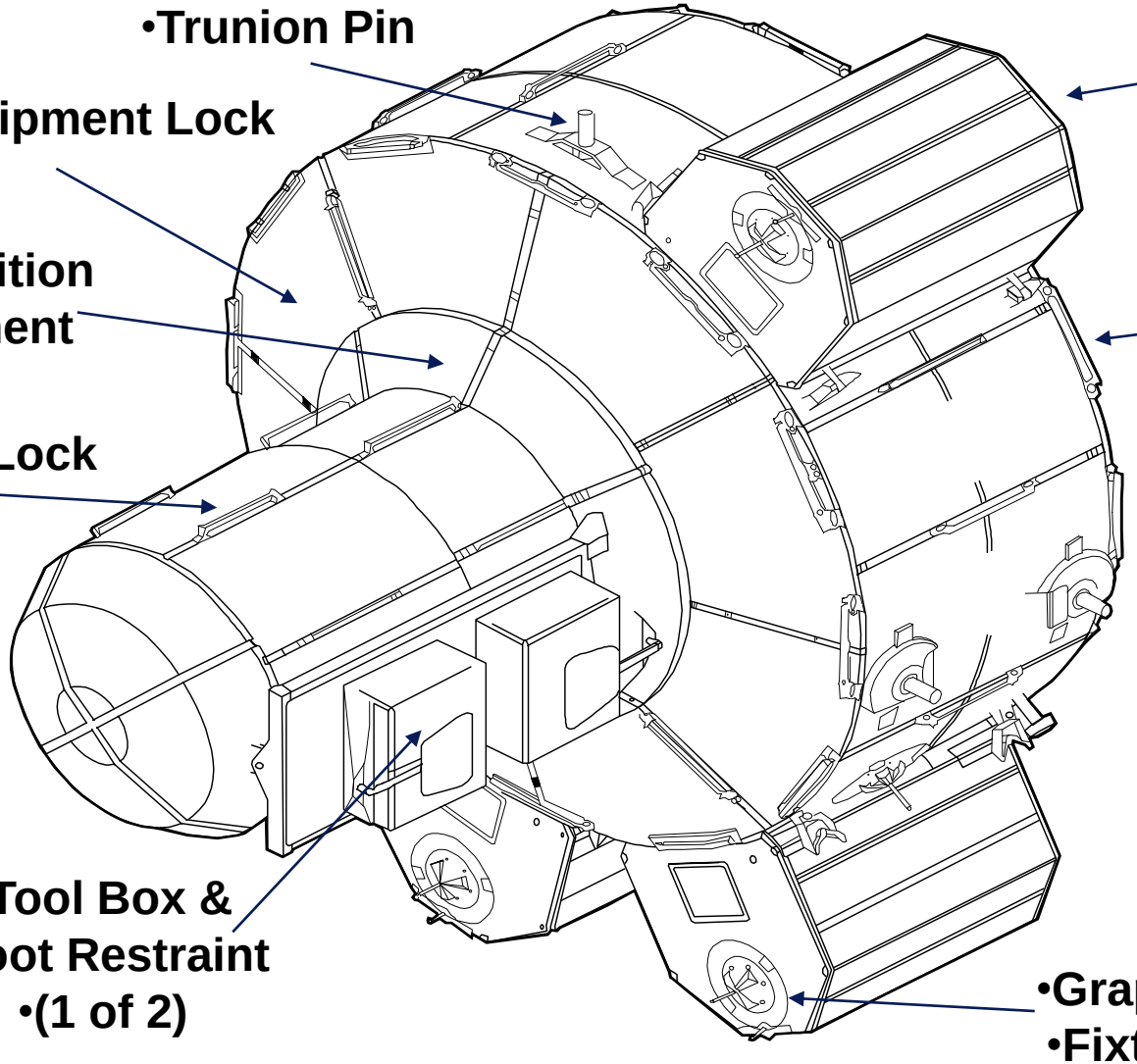
- ISS Joint Airlock:
  - Primary for U.S. ISS EVAs (both Orbiter and Station-based)
  - Compatible for use with Russian Orlans
  - Made up of two parts:

Crew Lock and Equipment Lock

  - – Equipment Lock is used for stowage, recharge and servicing of EMUs and to don/doff the EMUs
  - – Crewlock is the volume nominally depressed to vacuum for crew to go EVA




# •International Space Station (ISS) Joint Airlock



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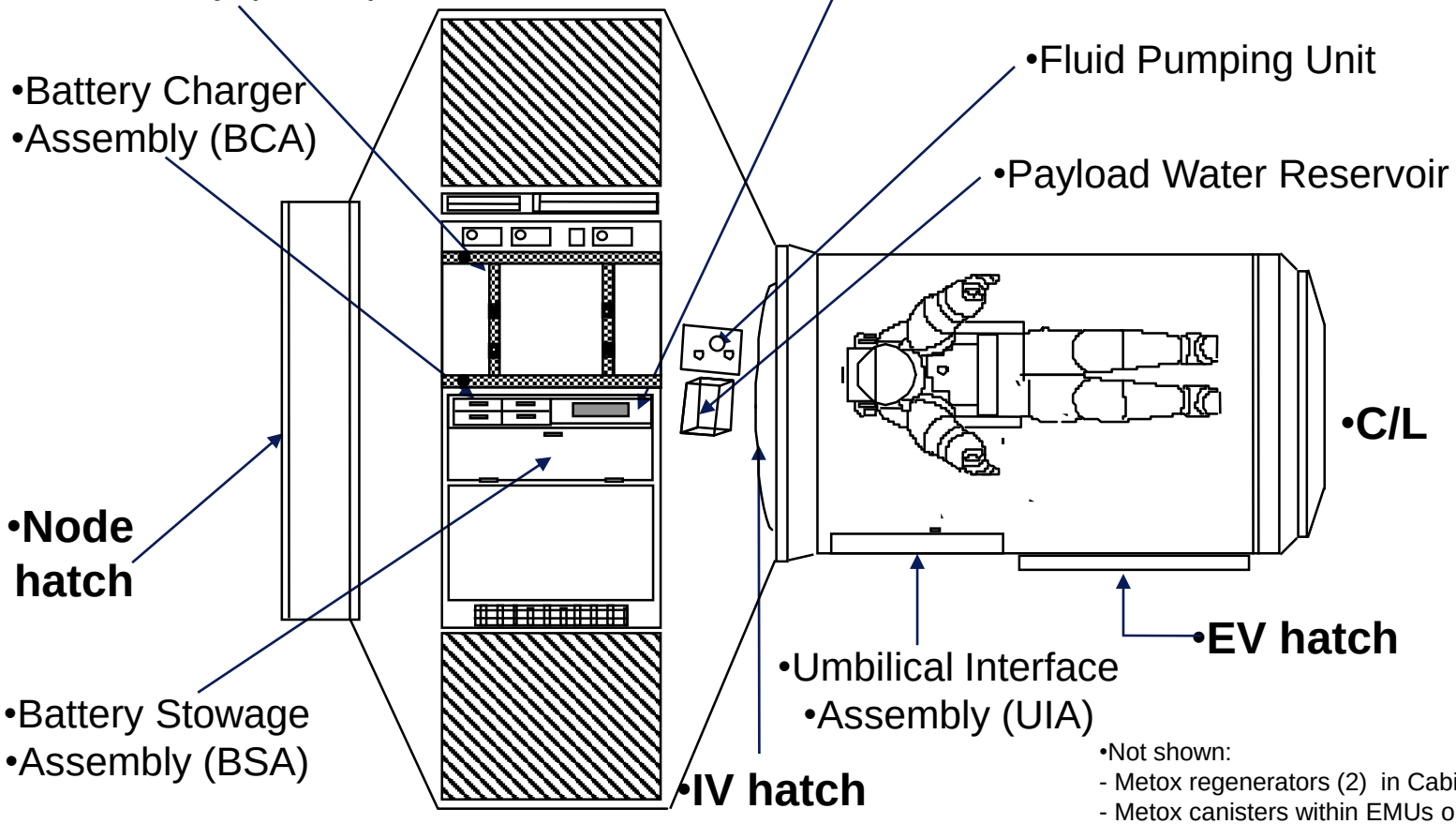



•Not shown:
- Metox regenerators (2) in Cabin Air Rack
- Metox canisters within EMUs or Metox
- regenerators
- Oxygen Recharge Compressor Assembly
- (ORCA) in overhead platform
- Russian Depressurization Pump

# EVA Systems - ISS Joint Airlock

## STS-104 / Flight 7A

**(Summer 2001)**

# EVA Systems - ISS Joint Airlock



PSA

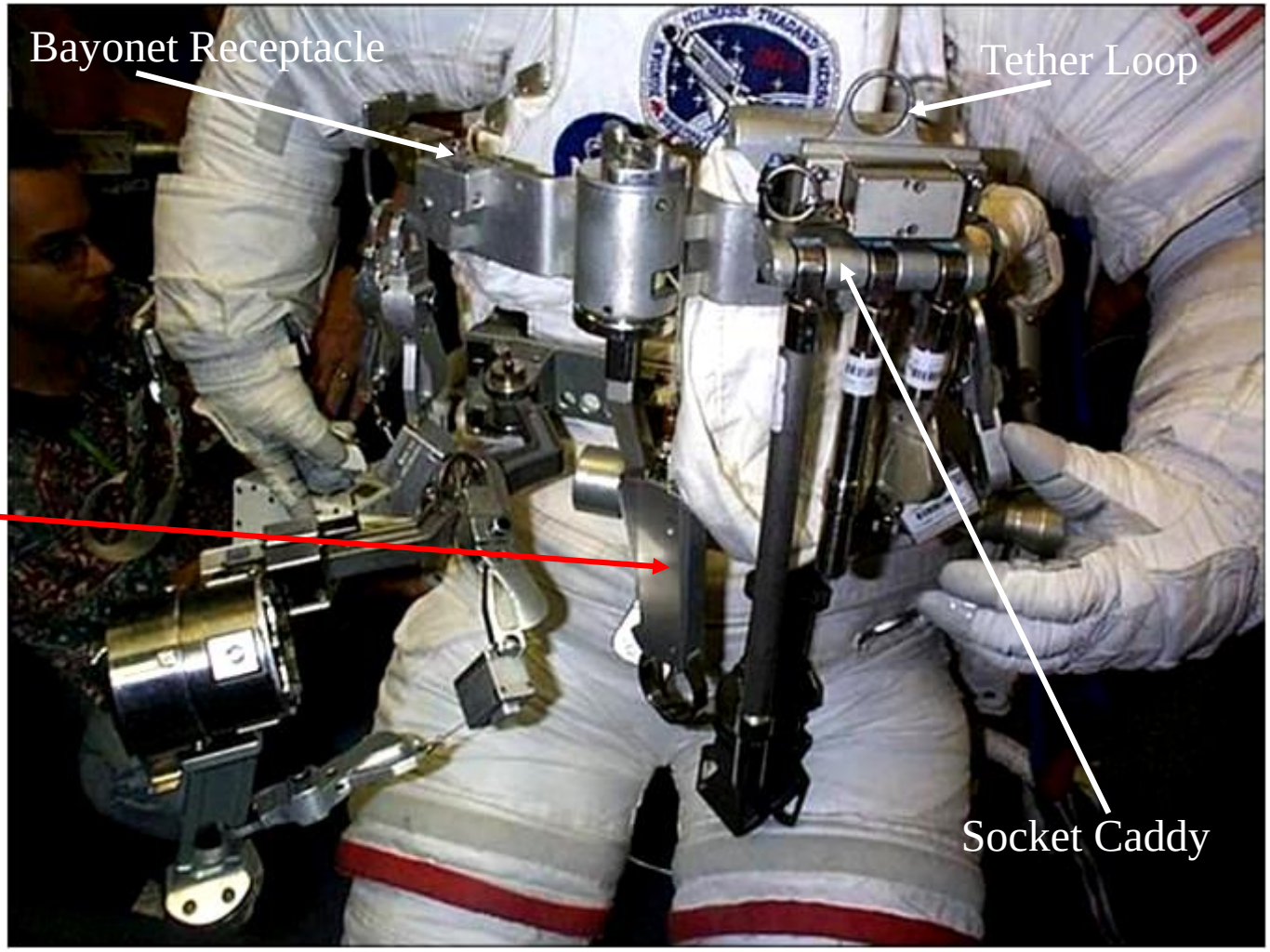
•Battery Charger
•EMU Battery

# EVA Equipment & Tools

- EMU-mounted tools & equipment
  - TV Camera
  - Lights
  - Mini-workstation
  - Waist tethers
  - EVA Cuff Checklist
  - Wrist mirror
  - Body Restraint Tether
  - Pistol Grip Tool (PGT)
  - ISS Small Trash Bag

# EVA Equipment & Tools

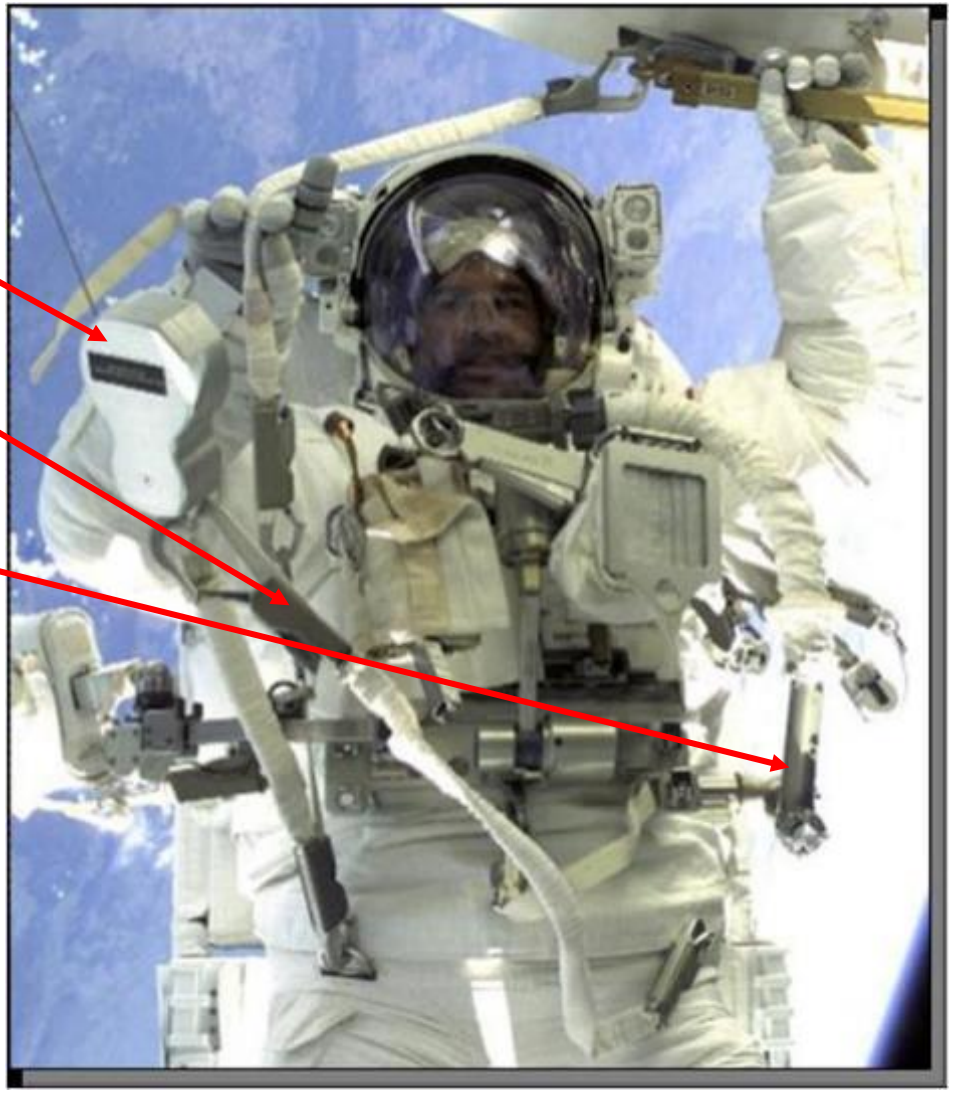
- Mini Work Station (MWS)
  - Attaches to front of the EMU
  - Used to carry small tools
  - Tools are secured via tether rings or via bayonet receptacles
  - MWS end-effector with retractable tether provides restraint to EVA Crewmember at worksite




- Note: "Drop-proof tether" PIP pins are used to secure certain items such as a socket onto a tool caddy.

# EVA Equipment & Tools

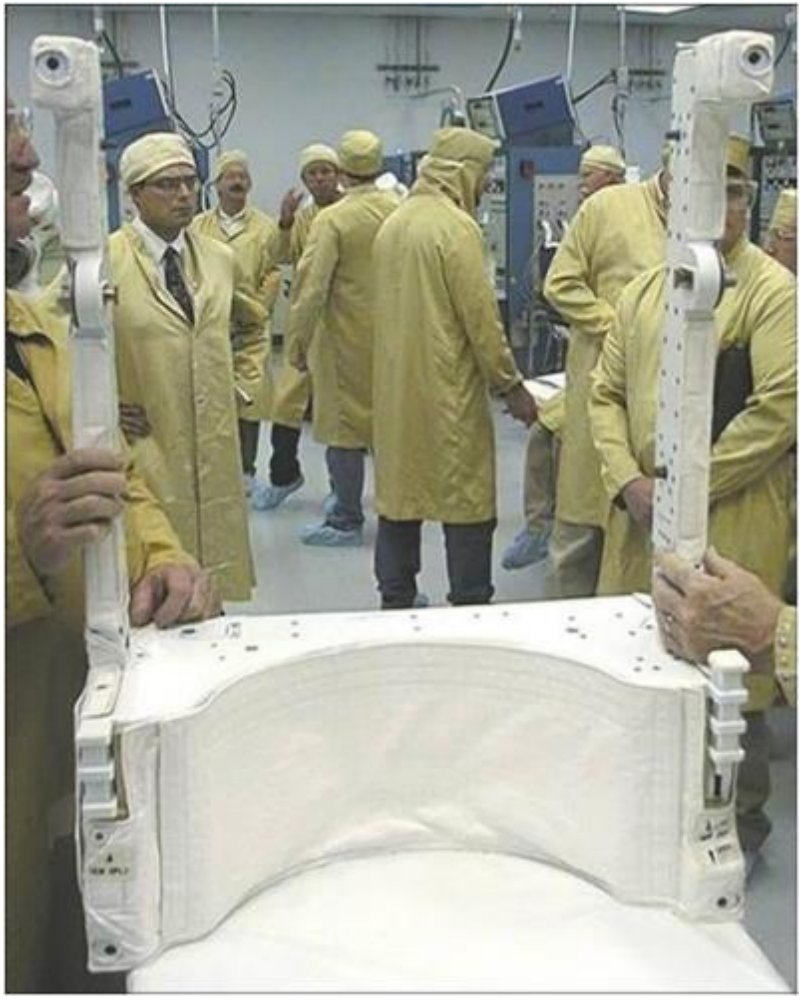
- Commonly Used Tethers
  - Safety Tether (55’ and 85’)
    - Used to secure the EVA crewmember to the vehicle
  - Suit tethers (Waist, Wrist)
    - Used to secure small items to the suit, usually for transfer
  - Retractable EVA Tether (RET)
    - Used to secure small items, usually while item is in use
  - Body Restraint Tether (BRT)
    - Attaches to the Mini-Work Station (MWS)
    - End-effector provides semi-rigid restraint to EVA crewmember at worksite via handrail (also used for translating small objects)
    - Requires less time than setting up a Portable Foot Restraint and is more stable than a MWS end effector
  - Note: EVA tether protocol is that crewmembers and equipment must be tethered at all times
    - **Always <u>make</u> a connection before you <u>break</u> a connection**.



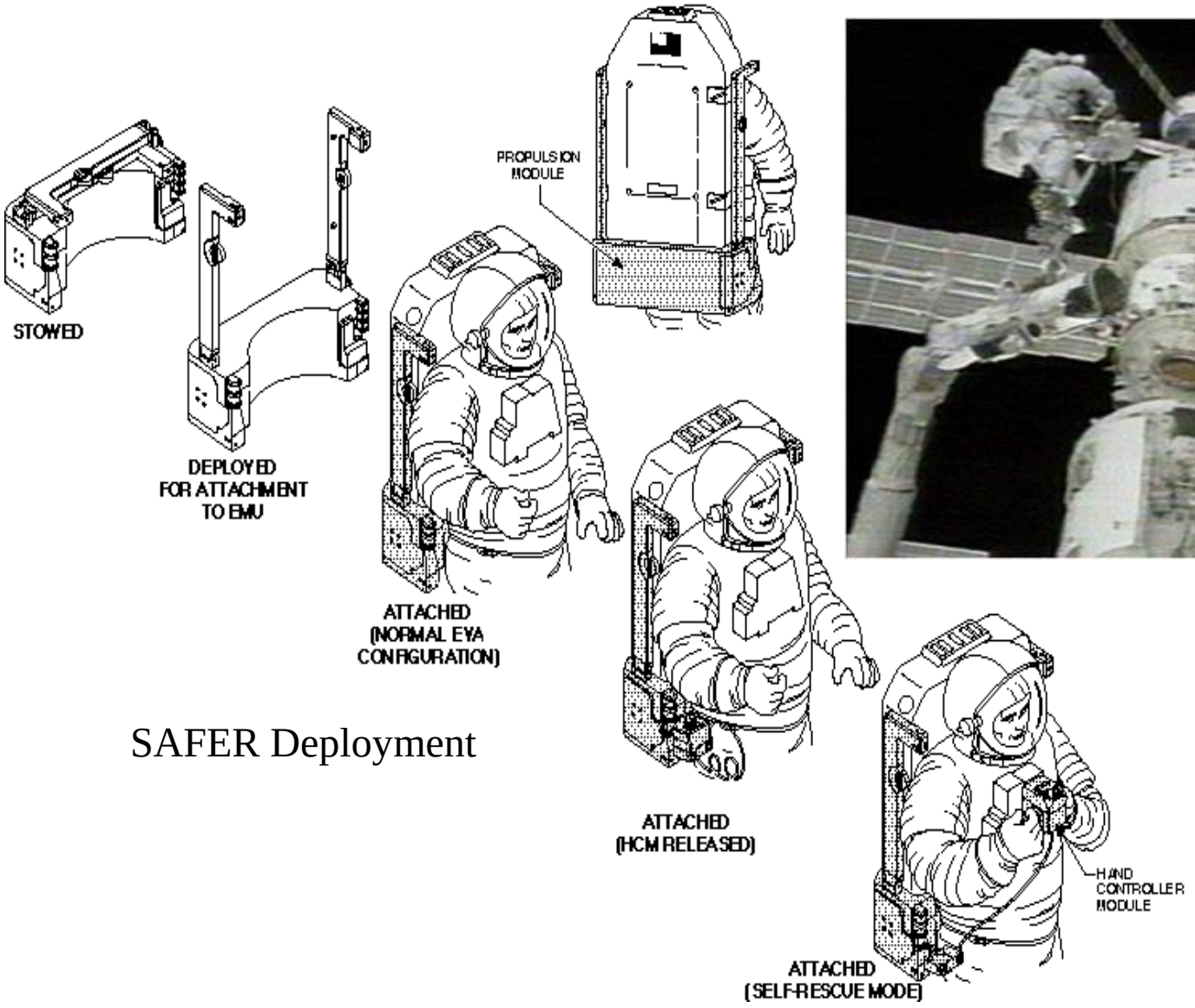
# EVA Systems - SAFER (Simplified Aid for EVA Rescue)

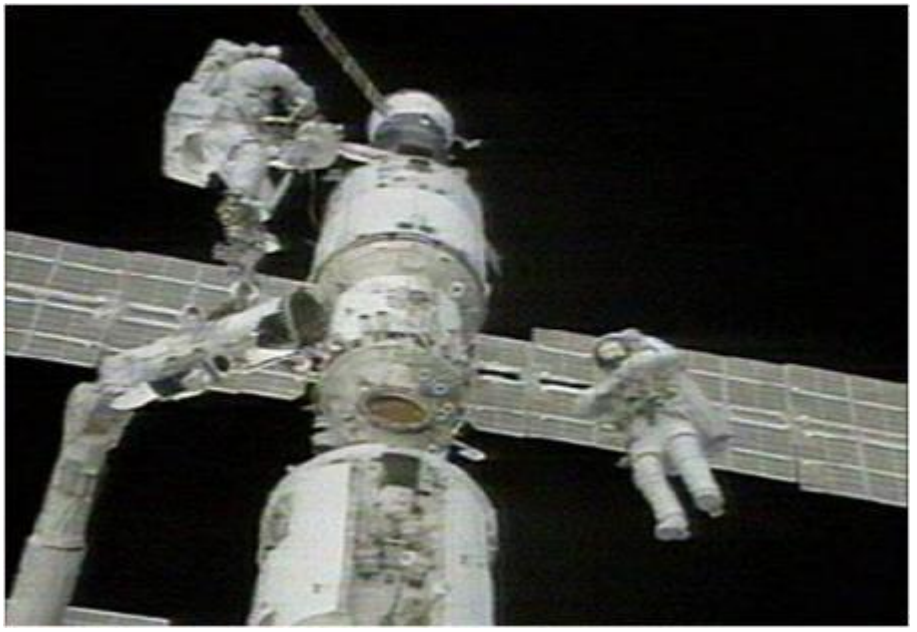
• SAFER is a self-contained, propulsive backpack self-rescue system that provides the EV crewmember with self-rescue capability when the orbiter is not present or cannot immediately perform EVA rescue.

- Propellant: Pressurized nitrogen gas
- Controlled by a single hand controller
- Stowed in ISS Airlock, used on ISS EVAs
- Sufficient propellant and power for one self-rescue (~13 min)
- Test flight on mission STS-64; self-rescue capability on STS-76
- Power up of production model SAFER on STS-86
- Tethered test flight of production model SAFER on Flights 2A and 3A



# EVA Systems - SAFER (Simplified Aid for EVA Rescue)



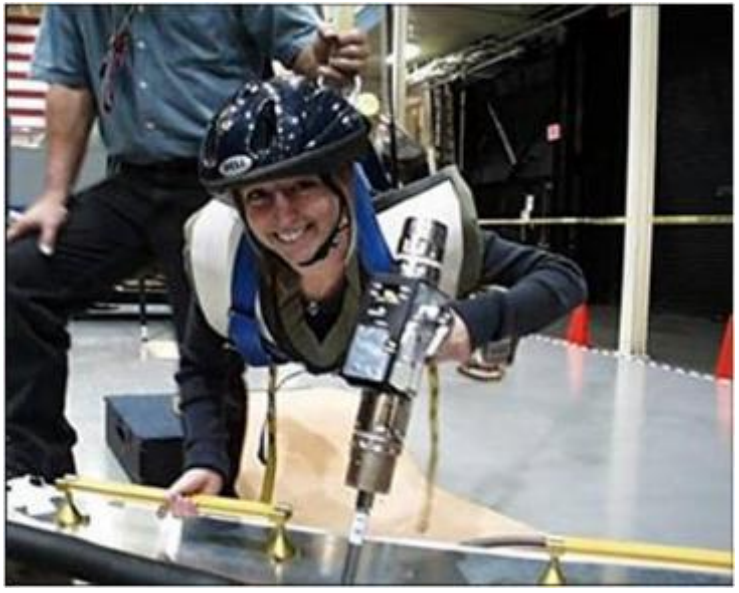



SAFER Deployment

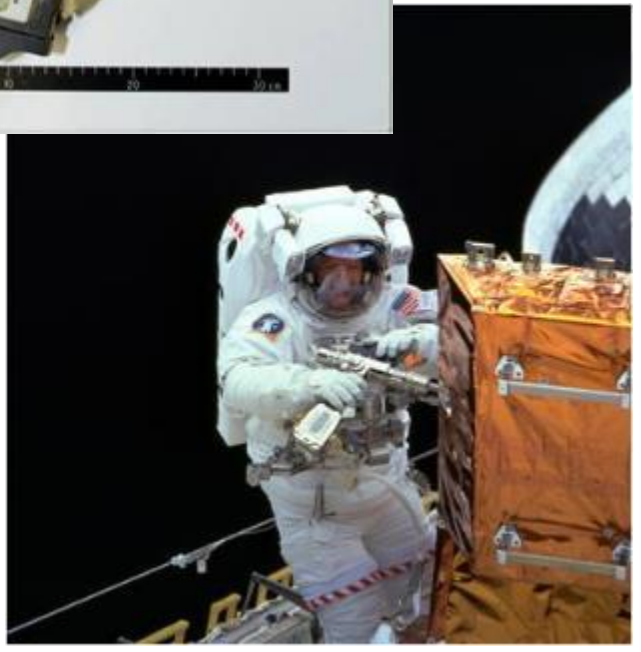
# EVA Equipment & Tools

- Pistol Grip Tool (PGT)

  - EVA torque wrench (i.e., a bolt turner)
    - Has a programmable torque limiter and turn limiter
    - Crewmember needs to be secured depending on amount of torque required
    - 2ft-lbs to 25ft-lbs of torque available
    - Generally used for ISS assembly missions and maintenance EVAs



← 1-G Testing of the PGT

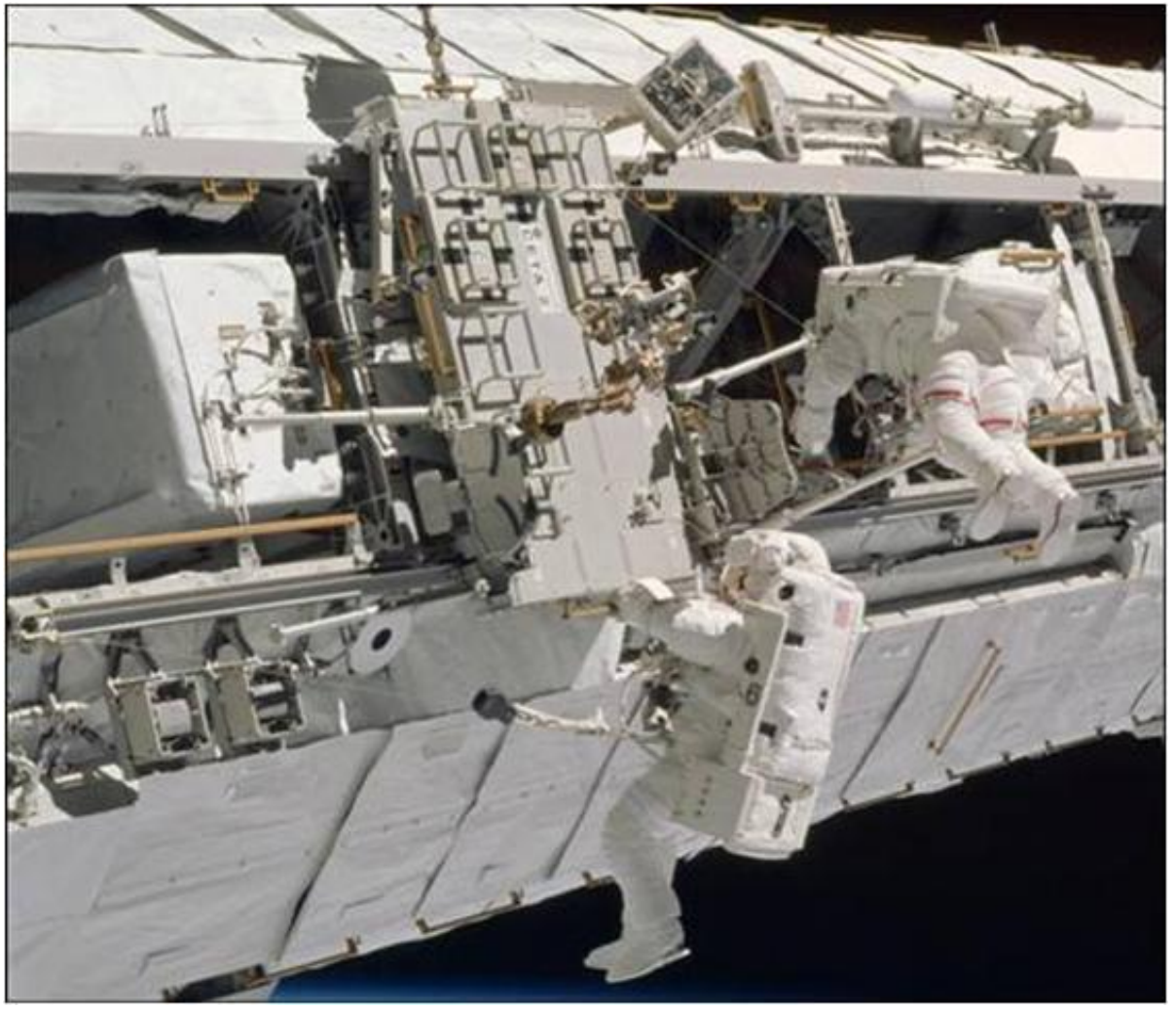


# EVA Equipment & Tools

- Foot Restraints
  - Attach to structure via a socket
  - Provides EVA crewmember rigid restraint at a worksite (Newton's 3rd Law)
  - Different types:
    - Portable foot restraint (PFR) *(Shuttle)*
    - Articulating PFR (APFR) *(U.S. ISS)*
    - Interoperable APFR (IAPFR) *(U.S. & Russian ISS)*

# EVA Equipment & Tools

- Crew and Equipment Translation Aid (CETA) Cart
  - Essentially an EVA equipment cart
  - Translates by CM manually pulling it along truss
  - Use brakes to stop and stay parked
  - Typical use: small ORU replacement on front truss face



# EVA Operations Overview

EVA operations can be divided into three phases:

Pre-EVA

EVA

Post-EVA

# EVA Operations: Overview of Typical EVA

| | |
|---|---|
| 30 min | Airlock depress |
| 15 min | Airlock egress |
| 6 hours | Worksite operations: Shuttle and ISS-based<br>– All Shuttle EVA crewmembers are trained to perform the following Orbiter contingency tasks (if necessary) for each flight:<br>• Failed airlock hatch latches or actuator tasks<br>• Failed Remote Manipulator System (RMS) tasks<br>• Manual stowage of radiators or Ku-band antenna<br>• Manual closure of payload bay doors<br>• Installation of payload bay door latch tools<br>• Manual separation of Shuttle from ISS (96 bolt task)<br>– EVA crewmembers assigned to a flight are also trained for scheduled, unscheduled, or contingency tasks. |
| 15 min | Airlock ingress |
| 30 min | Airlock repress |

# Comparison of Russian & U.S. EVAs

- Russian Orlan-M Spacesuit
- U.S. Extravehicular Mobility Unit (EMU)

# •Orlan-M Spacesuit

- Visors
- Helmet Lights
- Suit Pressure Gauge (УДСК)
- Electrical Control Panel (ПО-4МТ)
- Backpack Closure Strap
- Pneumo-Hydraulic Control Panel (ПГПУ-1М)
- Fluid Umbilical Connector (ОРК-19)
- Emergency $O_2$ Hose
- Orlan Safety Tether
- Electrical Umbilical

- Backpack
- LCG

**Back-Entry Orlan-M**

# •Suit Enclosure

- Helmet Assembly
- Upper Arms
- Lower Arms
- Umbilical Interface
- Gloves
- Orlan Safety Tethers
- Hard Upper Torso
- Backpack Closure Strap
- Suit Probe
- Leg Assembly
- Boots

# EVA Training Facilities

- Space Station Mockup Training Facility (SSMTF) Airlock Mockup

# EVA Training Facilities

- EMU Caution and Warning System (ECWS) Trainer

# EVA Training Facilities

- Vacuum chambers
  - 11-foot chamber
  - Environmental Test Article (ETA) chamber
  - Space Environment Simulation Lab (SESL) chamber
  - Space Station Airlock Test Article (SSATA)

# EVA Training Facilities

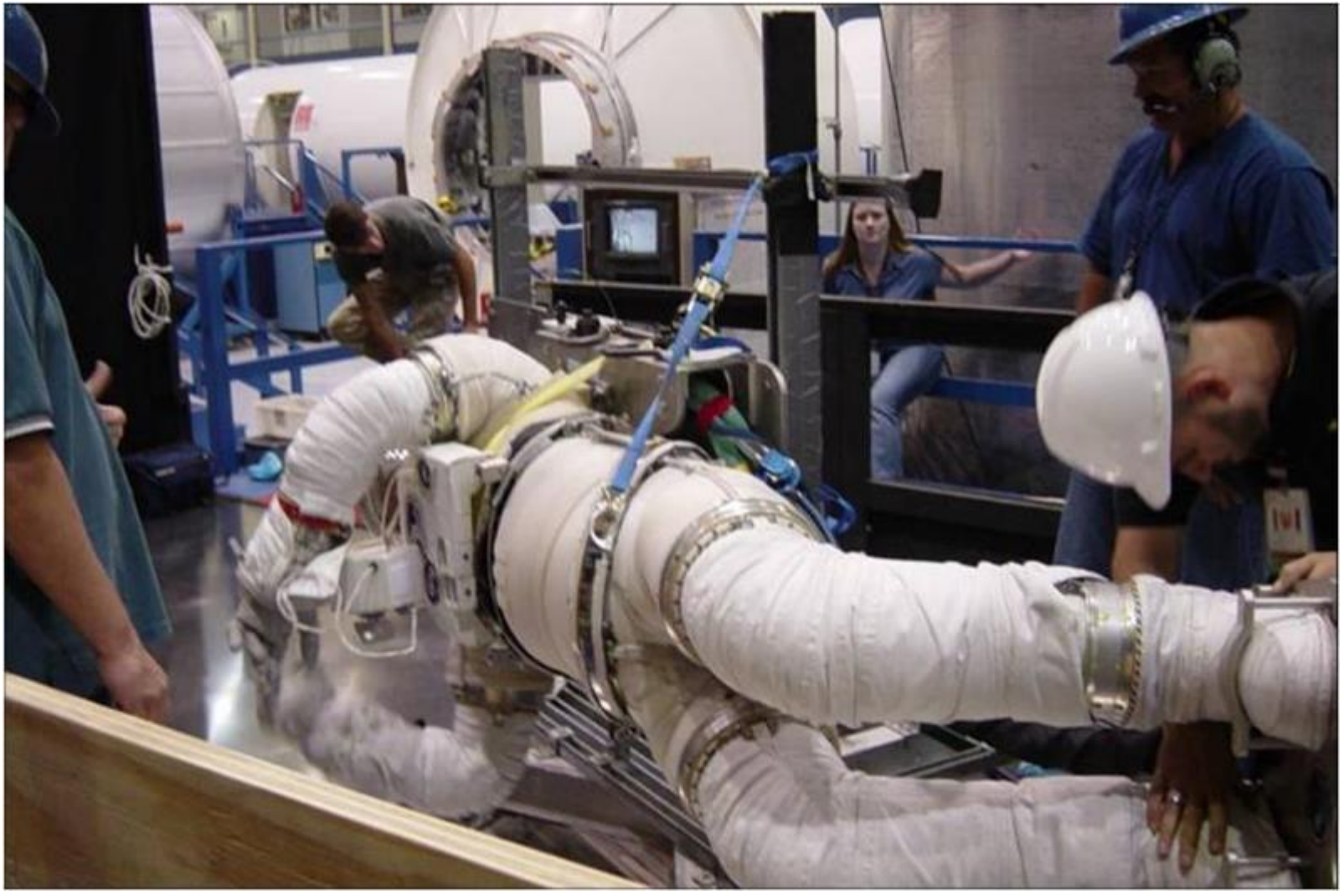
- Virtual Reality Lab

# EVA Training Facilities
# Charlotte for Low Gravity Mass Ops

Source : Osterlund, J. & Lawrence, B. 2012

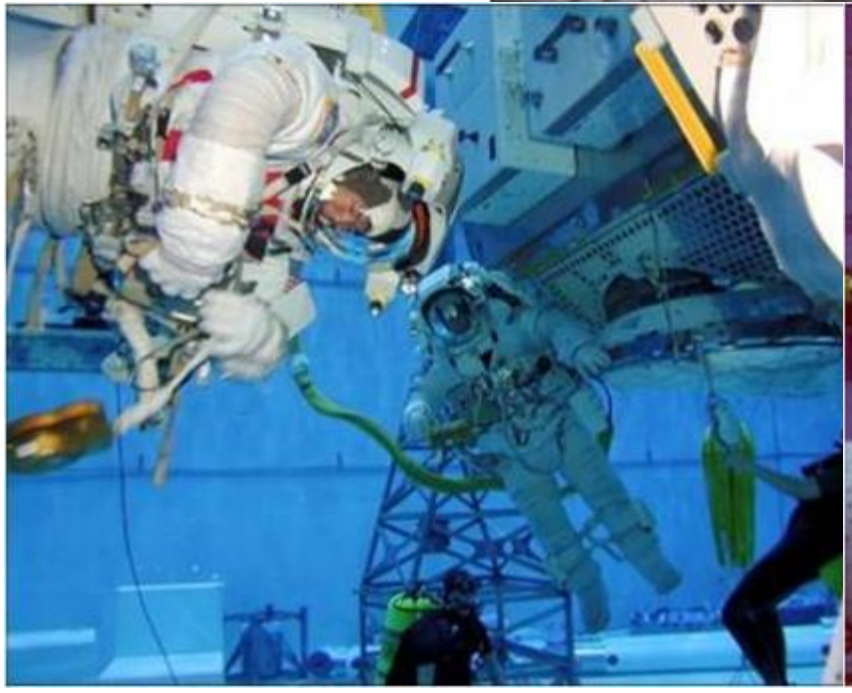
# EVA Training Facilities

- Precision Air-Bearing Floor (PABF)



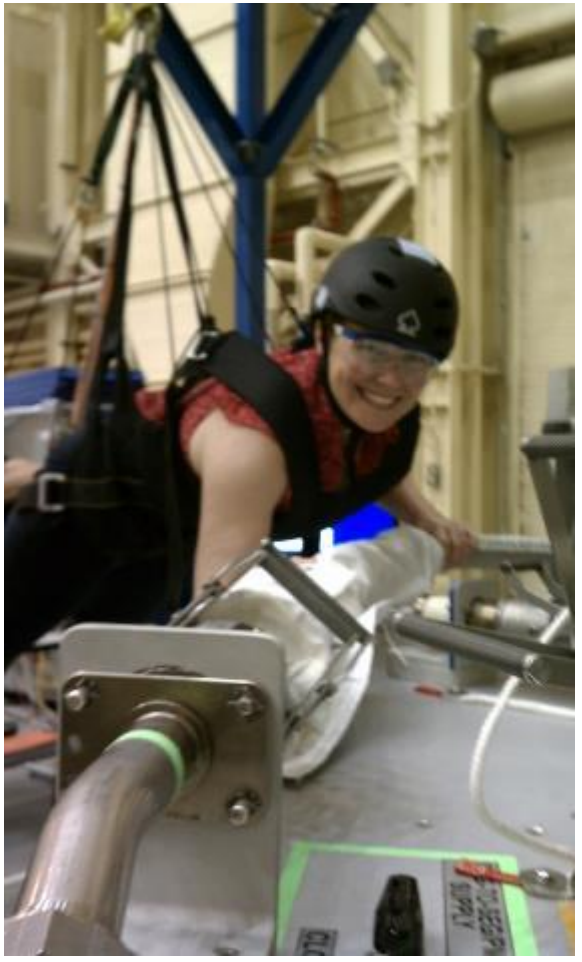
# EVA Training Facilities

- Neutral Buoyancy Laboratory (NBL)



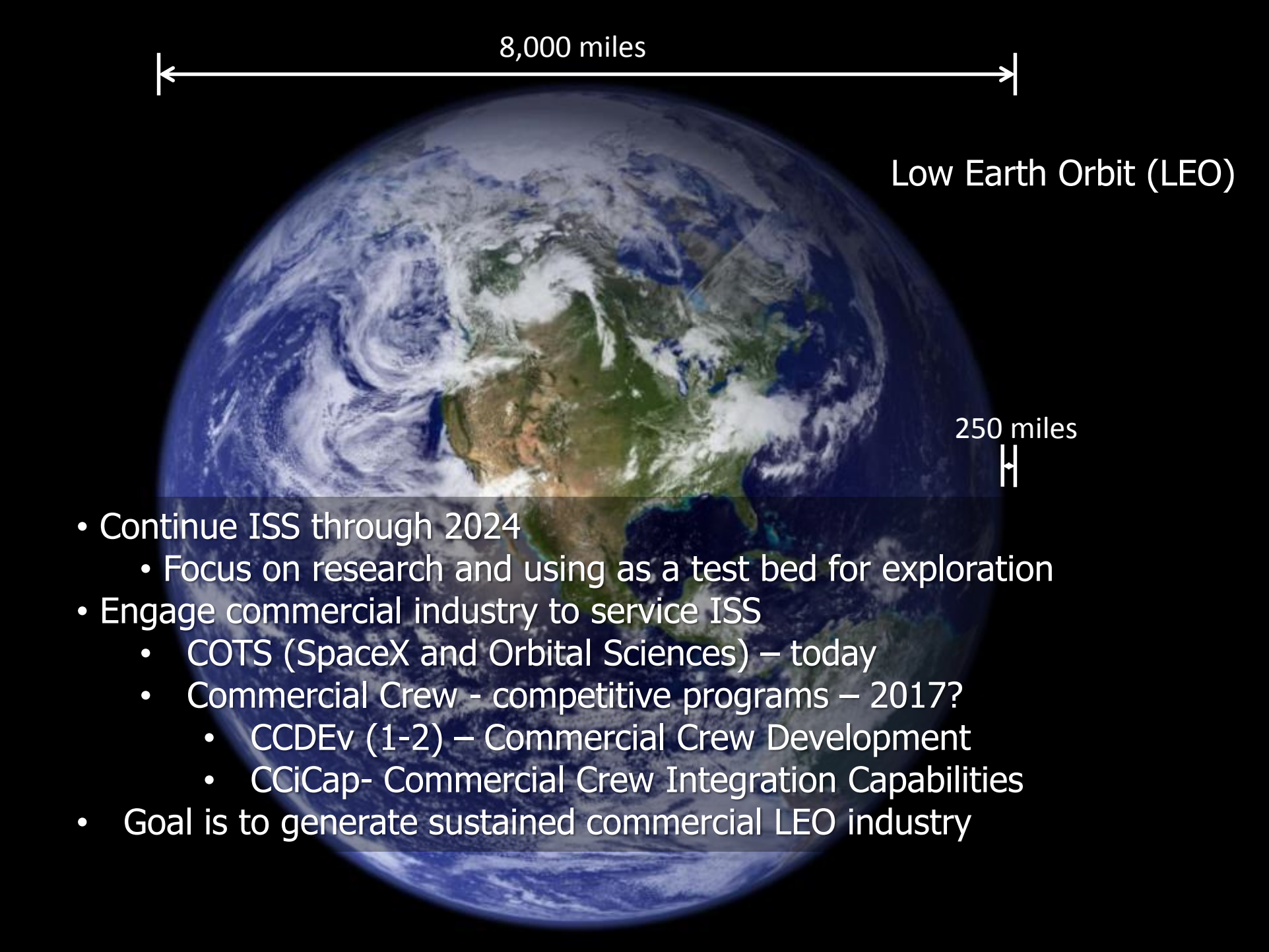
# EVA Training Facilities

## The Active Response Gravity Offload System (POGO/ARGOS)



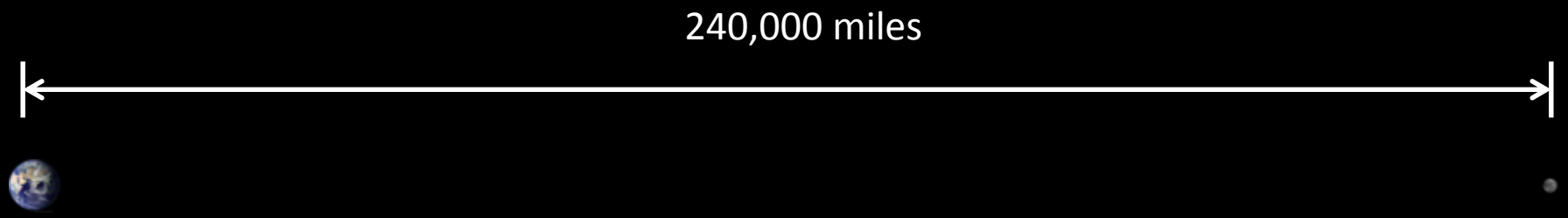
•POGO/ARGOS uses an inline load cell to continuously offload of a portion of a human or robotic subject's weight during all dynamic motions

# Backup…

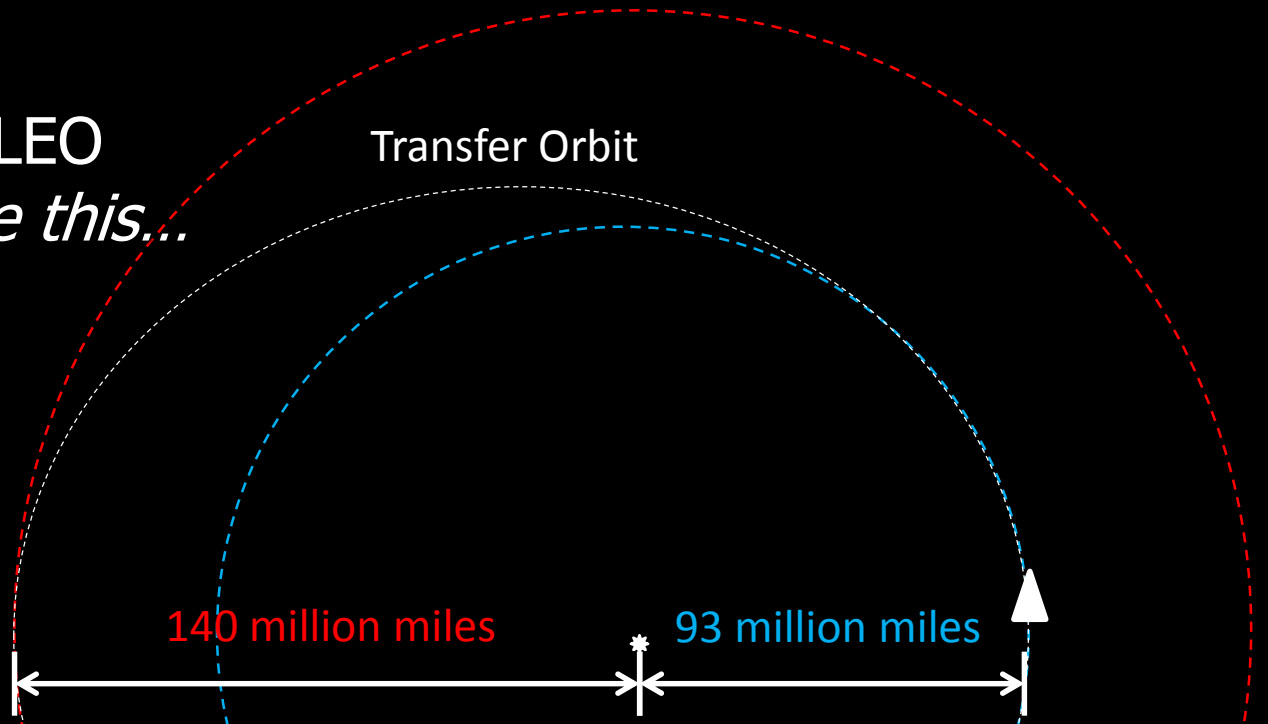



- Continue ISS through 2024
  - Focus on research and using as a test bed for exploration
- Engage commercial industry to service ISS
  - COTS (SpaceX and Orbital Sciences) – today
  - Commercial Crew - competitive programs – 2017?
    - CCDEv (1-2) – Commercial Crew Development
    - CCiCap- Commercial Crew Integration Capabilities
- Goal is to generate sustained commercial LEO industry

# Beyond LEO?



## Beyond LEO
*More like this…*




- Capabilities-Driven Approach for Exploration
  - NASA gathered community thoughts on technology needs for human exploration
  - Results (partial)
    - Crew vehicle capable of deep space travel
    - Heavy lift to manage required up mass
      - Leverage Constellation Program Concepts (Orion

# Space Exploration Challenges…

- Who would you need on a deep space mission?

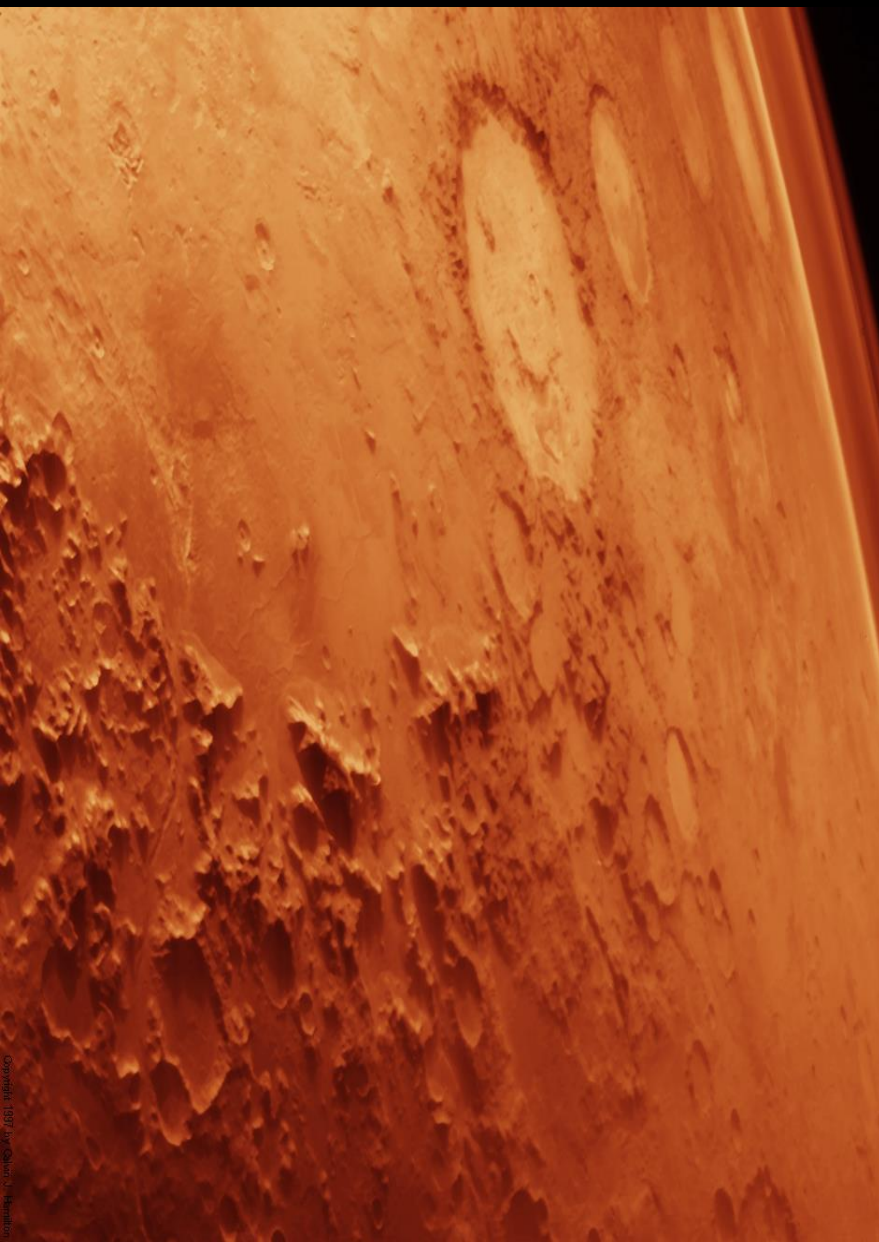
Standard for LEO today
- Pilot
- Scientist
- Engineer

Required Systems Experts for Exploration Missions
- Propulsion
- Navigation
- Communication
- Environmental (Plumber, AC, Heat)
- Power
- Stowage/Inventory

- Other crew, required?
  - Doctor
  - Dentist
  - Psychologist
  - Geologist
  - IT/Computer
  - Machinist
  - Handyman
  - Sheriff
  - Judge/Lawyer
  - Machinist

**20+ People???**

# Space Exploration Challenges…



- Up mass
  - Exploration Vehicle – est. 100 tons of material and supplies (ISS 420 tons)
- Propulsion
  - Chemical, Ion, Solar Electric
- Environmental Systems
  - Closed loop, Reliability, Redundancy
- Automation
  - Self maintaining systems
- Radiation Shielding
  - Crew and systems health
- Communication
  - Comm delays increase
- Long Range Human Health Affects
  - Bone health, eye damage, long term radiation exposure
- Stowage/Logistics


# Questions?

## Thank You!

# My favorites…

# My favorite sites and links…

- Heavens Above
  - http://heavens-above.com/
- NASA Spinoffs
  - http://spinoff.nasa.gov/
- Eyes on the Solar System
  - http://eyes.nasa.gov/
  - Youtube NASA Television
  - http://www.youtube.com/user/NASAtelevision
  - Youtube Earth Video
  - http://www.youtube.com/watch?v=Ip2ZGND1I9Q
  - ISS Tour by CDR/Suni Williams
  - http://www.youtube.com/watch?v=doN4t5NKW-k
  - Why Mars is Hard Stan Love
  - http://www.youtube.com/watch?v=fturU0u5KJo
- Perspectives

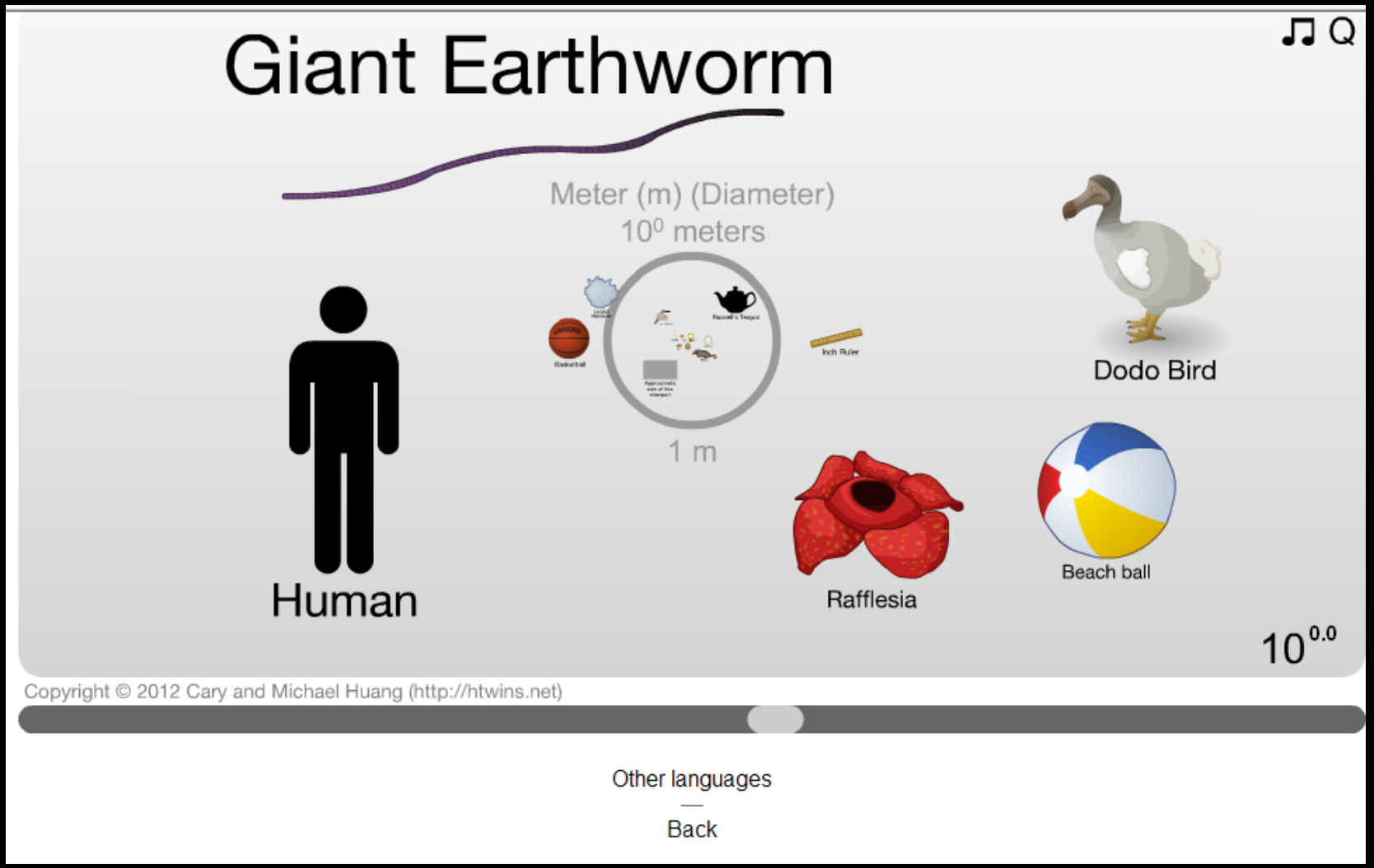
  http://htwins.net/scale2/?bordercolor=white
- ISSLive
  - http://spacestationlive.jsc.nasa.gov/
- Distance Learning Network
  - NASA DLN Website: http://www.nasa.gov/offices/education/programs/national/dln/index.html
  - Toolkit with Material and Templates: http://communications.nasa.gov/OCP/Communications%20Tool%20Kit/Presentation%20Templa

# JPL – Eyes on the Solar System


Eyes on the Solar System
http://eyes.nasa.gov/

# Perspective -

http://htwins.net/scale2/?bordercolor=white



# ISS*Live*

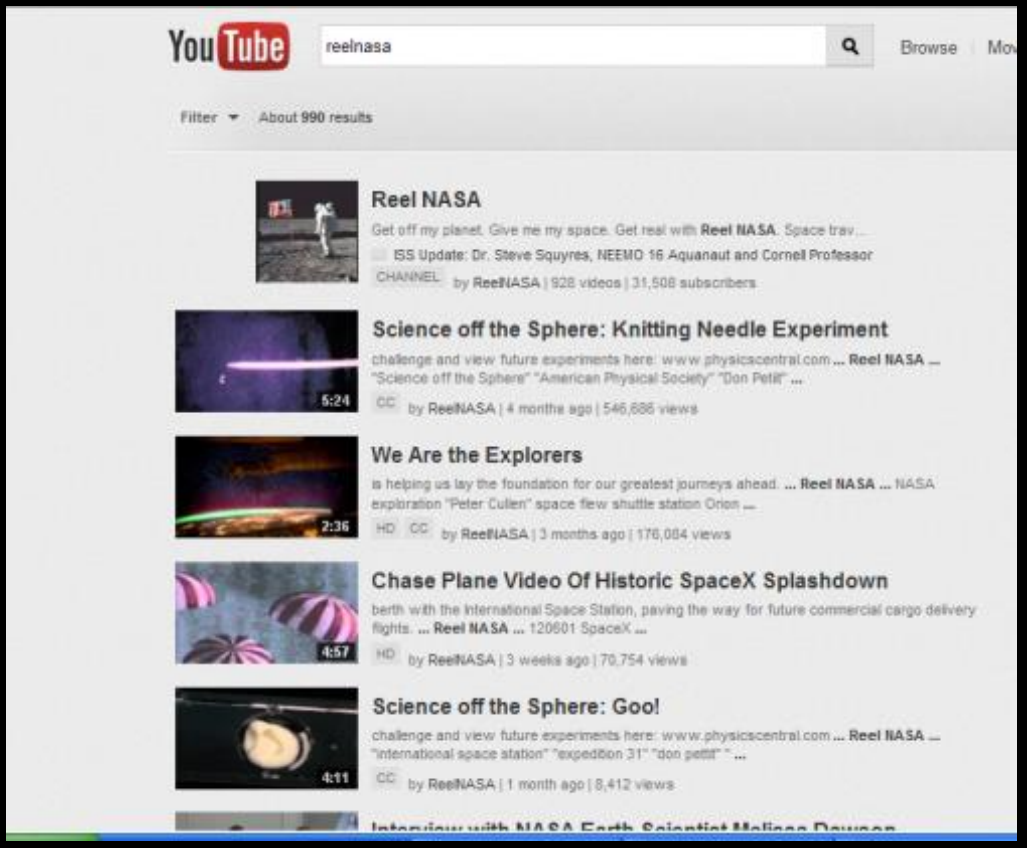
ISSLive

http://isslive.com/

# Youtube – REELNASA

ReelNASA

http://www.youtube.com/results?search_query=reelnasa&sa=X&spell=1&search=Search&oi=spell



# NASA Spinoffs

http://spinoff.nasa.gov/

# Heavens Above

http://heavens-above.com/

# NASA Distance Learning

NASA DLN Website: http://www.nasa.gov/offices/education/programs/national/dln/index.html

## See the Space Station fly over YOUR home!

Use “Skywatch” program or go to “sightings by city”

- **spaceflight.nasa.gov/realdata/sightings**

| SATELLITE | LOCAL DATE/TIME | DURATION (MIN) | MAX ELEV (DEG) | APPROACH (DEG-DIR) | DEPARTURE (DEG-DIR) |
|---|---|---|---|---|---|
| ISS | Tue Nov 14/06:22 AM | 4 | 66 | 10 above WSW | 31 above NE |