Spacesuits

MAE 4160, 4161, 5160

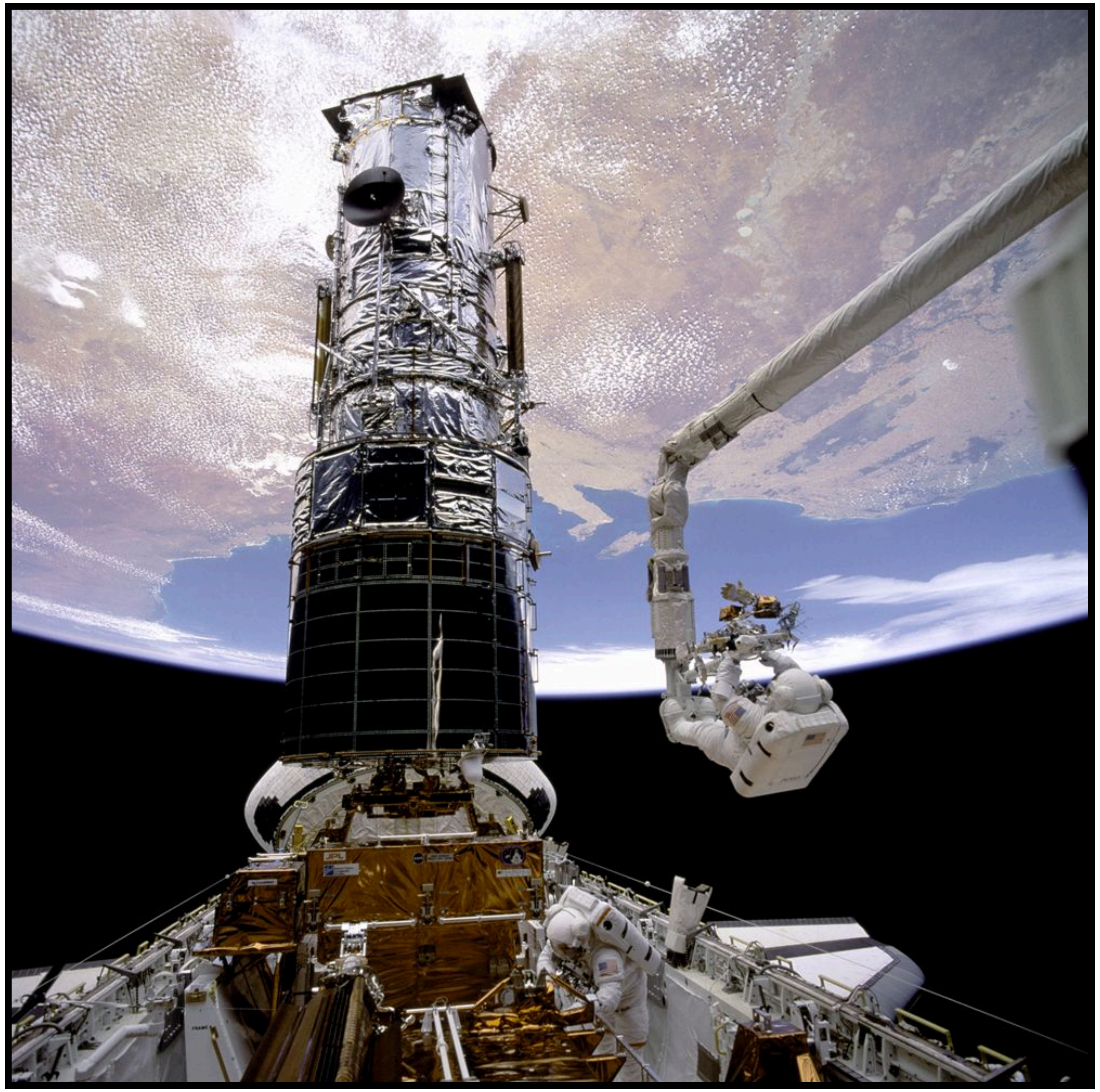
V. Hunter Adams, PhD

Today’s topics:

- What’s Extravehicular Activity?
- Why are we talking about spacesuits?
- Brief history of space walks
- The Extravehicular Mobility Unit
- EVA training
- Risks associated with EVA
- Mitigation strategies
- Spacesuits of the future

Extravehicular Activity (EVA)

- Any activity performed by a pressure-suited crewmember in unpressurized space environment
- Why perform an EVA?
  - Limitations on remote control
  - Limitations on perception, dexterity, and mobility
  - Time delays
- EVA's have facilitated
  - Repair and construction of satellites (e.g. Hubble)
  - Construction of the International Space Station
  - Exploration of the Moon



Musgrave and Hoffman repairing Hubble, 1993

Why are we talking about spacesuits?

A spacesuit is the smallest spacecraft that is capable of sustaining human life

- Oxygen
- CO_2 removal
- Pressure
- Thermal control
- Waste collection
- Power
- Water
- Communication
- Radiation protection
- (on at least one occasion) Attitude control

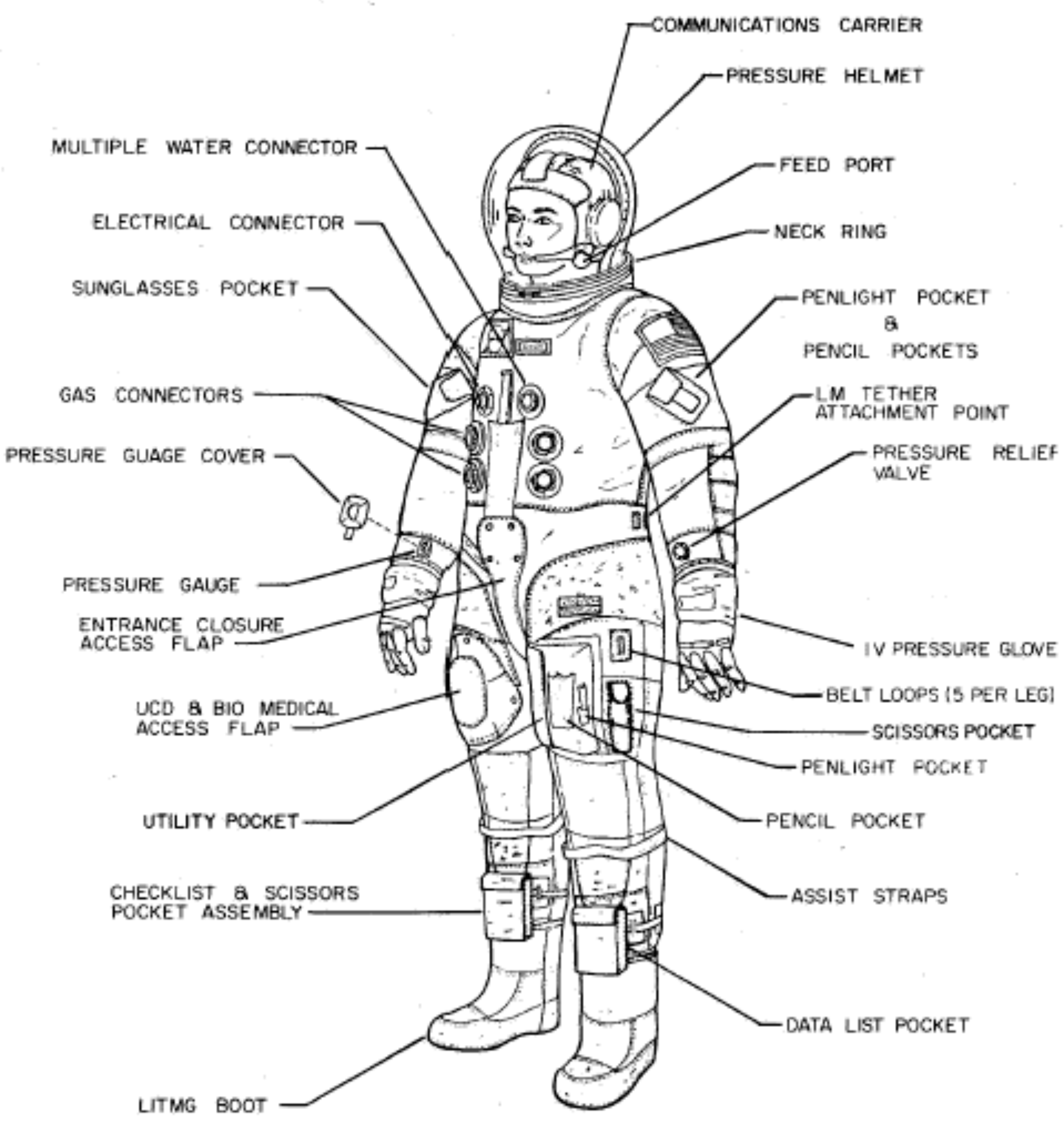


Figure I-5. - Extravehicular pressure garment assembly with arm bearing.

A (very) brief history of spacewalks

First spacewalk:

Alexei Leonov (March, 1965)

- Lasted for 12 minutes
- Suit was so stiff that it inhibited mobility
- Had difficulty fitting back into the spacecraft. Had to vent air from the suit in order to bend back into the capsule
- Depressurization caused the beginnings of decompression sickness (pins/needles)
- Capsule then malfunctioned after an emergency landing, and landed in a remote area of the Ural mountains
- The two crewmen survived two nights before rescue
- Capsule had a pistol onboard to ward off bears/wolves
- Skied to a waiting helicopter after the second night

Triple-barrel cosmonaut survival pistol

A (very) brief history of spacewalks

First American spacewalk:
Ed White (June, 1965)

- Lasted 20 minutes
- Also experienced mobility difficulty
- Tethered life support
- Despite extraordinary physical fitness, the experience left White exhausted

Ed White touching the void

A (very) brief history of spacewalks

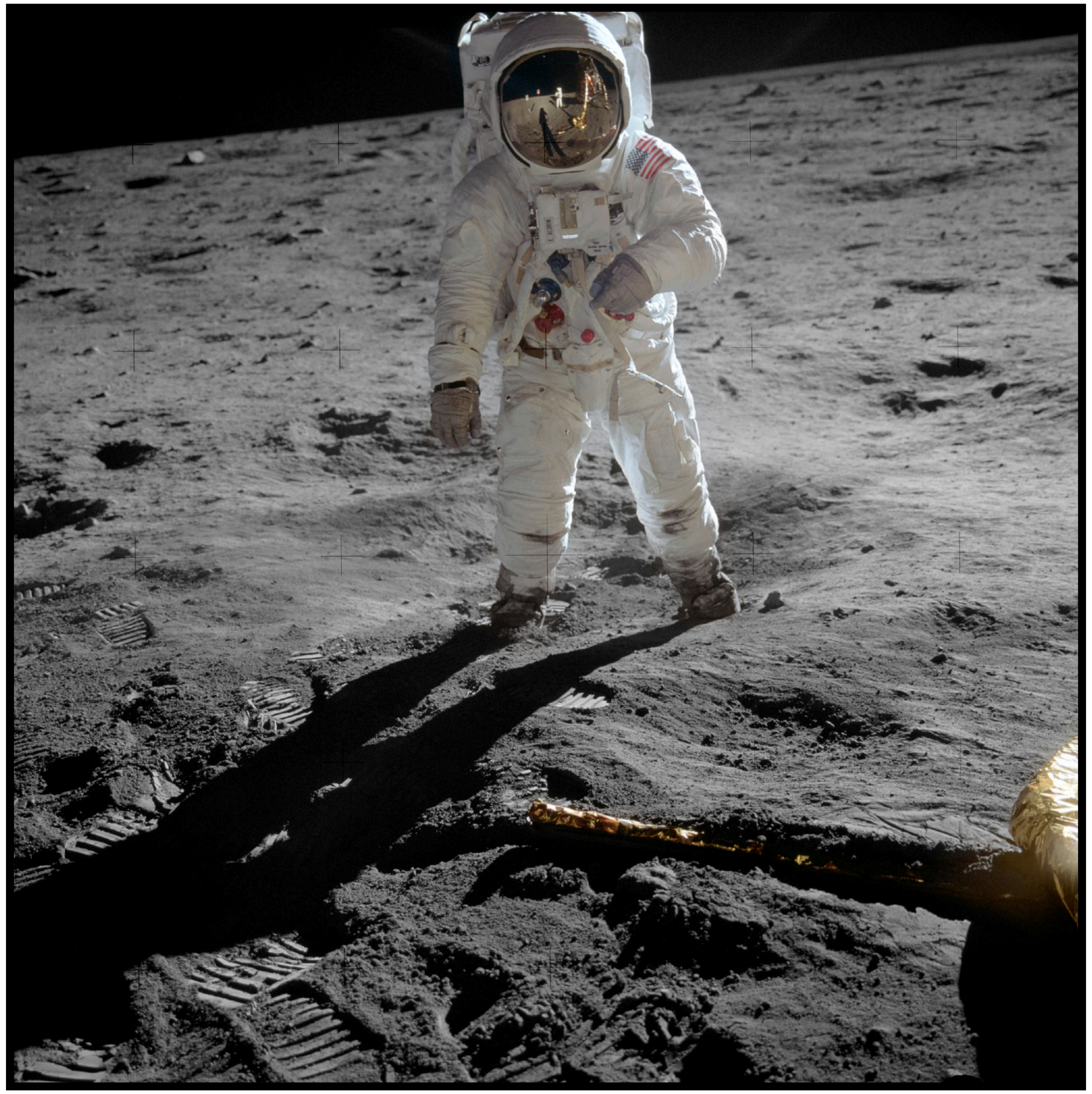
First EVA without umbilical:
Apollo 9

Russell Schweickart

A (very) brief history of spacewalks

First steps on another world:
Neil Armstrong/Buzz Aldrin (1969)

- 2.5-hour EVA
- Deployed Early Apollo Scientific Experimental Package
- Took a call from Nixon
- Collected rock/core samples
- Raised a flag
- Took pictures

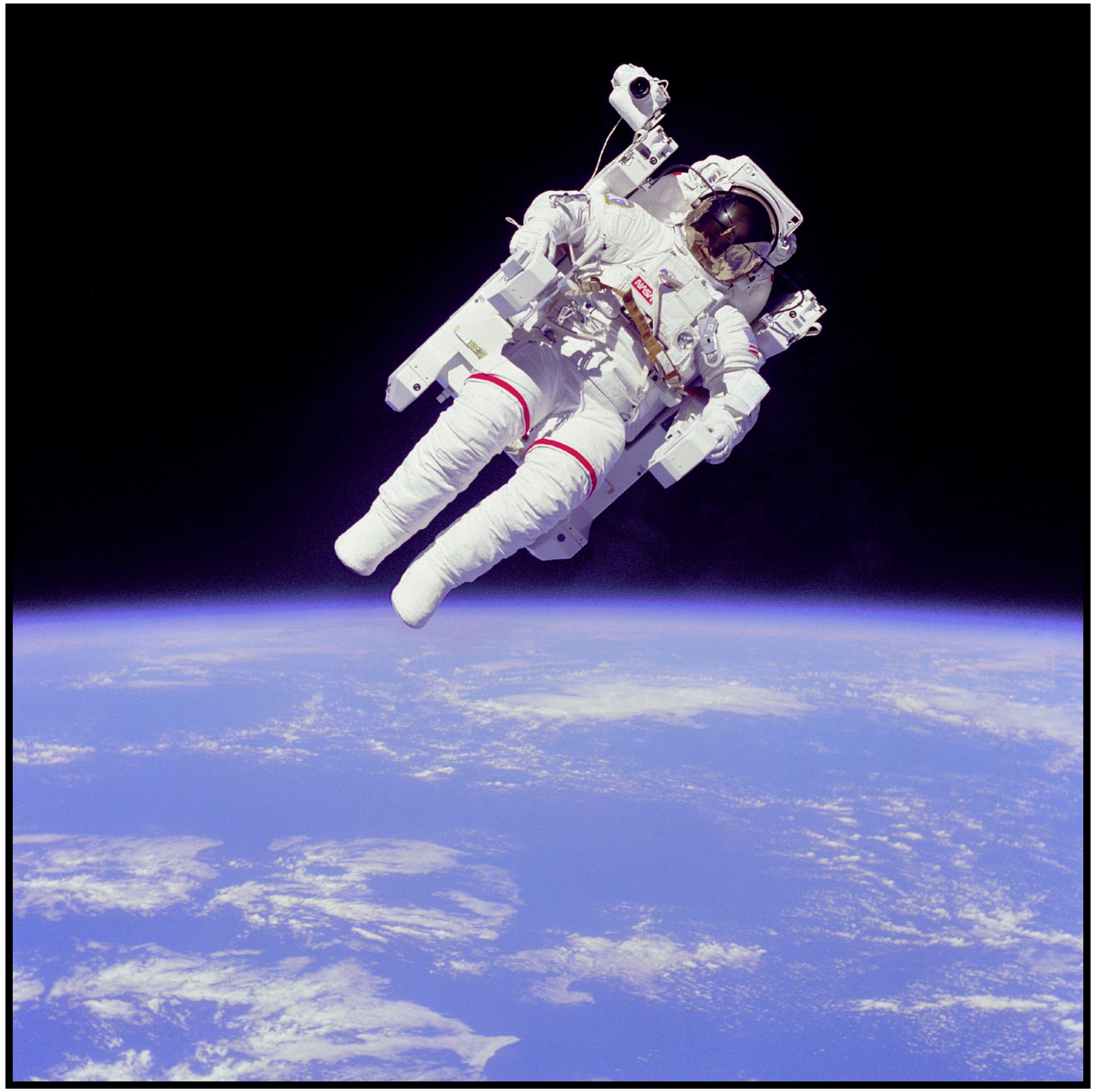


Aldrin

A (very) brief history of spacewalks

First untethered EVA:
McCandless and Stewart (1984)

- Test of the Manned Maneuvering Unit (MMU)
- Contained 24 nozzles for attitude and trajectory control, and reaction wheels for attitude stabilization (all contained in a backpack)
- Used on three shuttle missions, then deemed too dangerous



McCandless

Bruce McCandless

Dale Gardner retrieving Westar 6

The Extravehicular Mobility Unit (EMU)

Overview of the EMU

- One of two suit designs presently in use on the International Space Station (the other being the Russian Orlan Suit)
- Composed of . . .
    - Hard Upper Torso (HUT) assembly
    - Primary Life Support System
    - Arm sections
    - Gloves
    - Bubble helmet
    - Extravehicular visor assembly
    - Lower torso assembly
    - Maximum absorbency garment (underneath)
    - Liquid cooling and ventilation garment (underneath)

Hard Upper Torso (HUT) assembly

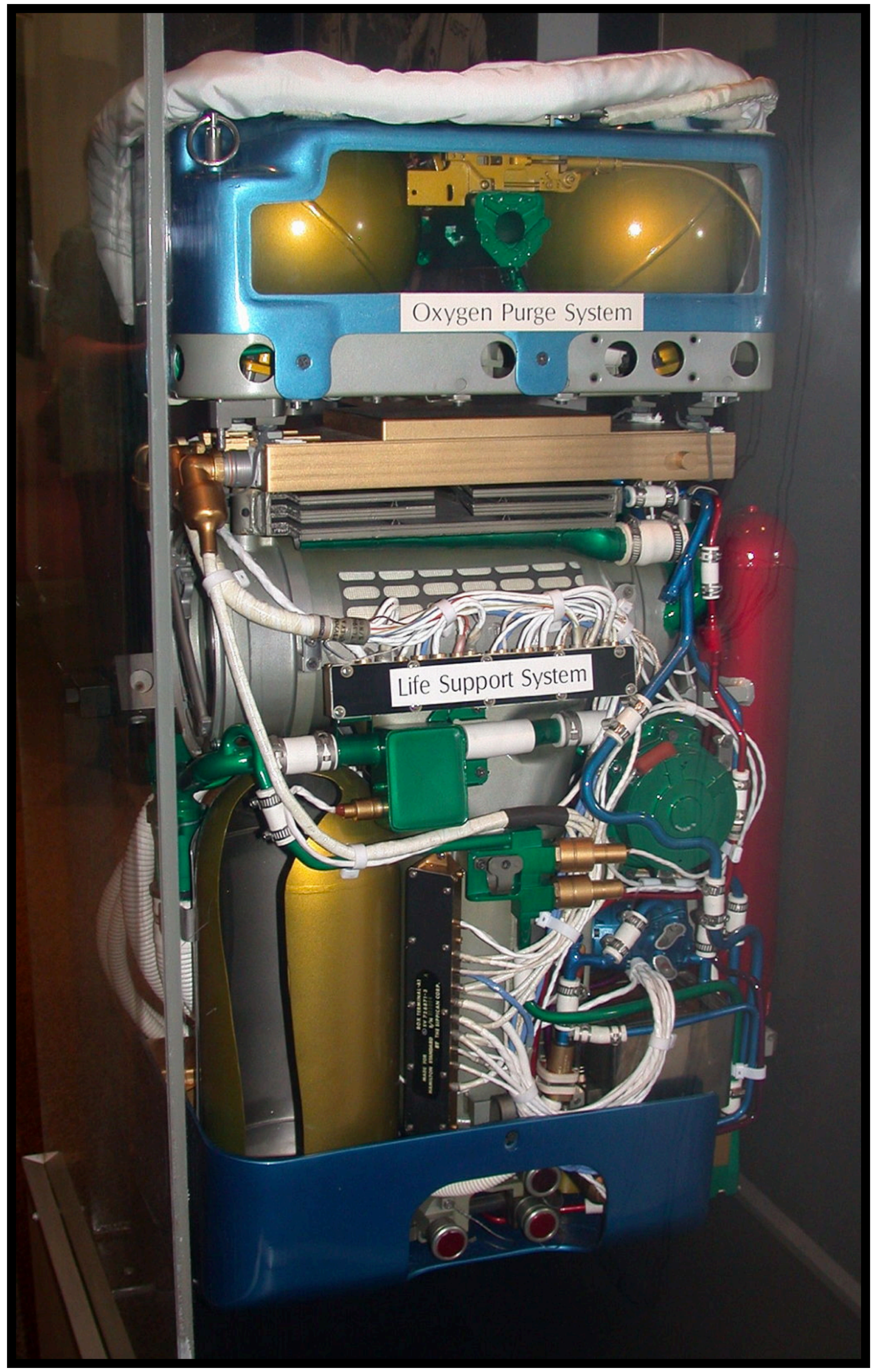
- Rigid fiberglass shell to which lower torso assembly, arms, helmet, chest-mounted display and controls module, and primary life support systems attach
- Available in 3 sizes, designed to accommodate body sizes in the 5th-95th percentile
- Includes an in-suit drink bag, with a straw extending into the helmet which allows the astronaut to stay hydrated

Gloves

- The only personalizable part of the suit
- Most important (and uncomfortable) part of the suit
- Pressurization makes the gloves difficult to squeeze (“Like squeezing a tennis ball”)
- Contain adjustable palm bar, rotating wrist bearings, tactility thimbles, and heating wires

Primary Life Support System

- Responsible for . . .
  - Regulating suit pressure (4.3 psi, 100% oxygen)
  - Providing breathable oxygen
  - Removing CO2, humidity, odors, and contaminants from internal atmosphere
  - Cooling and recirculating oxygen through the pressure garment, and water through the liquid cooling and ventilating garment
  - Two-way voice comms
  - Display telemetry of suit health parameters



Apollo-era PLSS

Helmet and snoopy cap

- Helmet connects to Hard Upper Torso (polycarbonate dome)
- Extravehicular visor assembly covers helmet and provides radiation protection to the astronaut
- Communication Carrier Assembly (snoopy cap)
- Air flows over the face to provide oxygen and prevent fogging

Armstrong in a snoopy cap

Visor assembly

Liquid cooling and ventilation garment

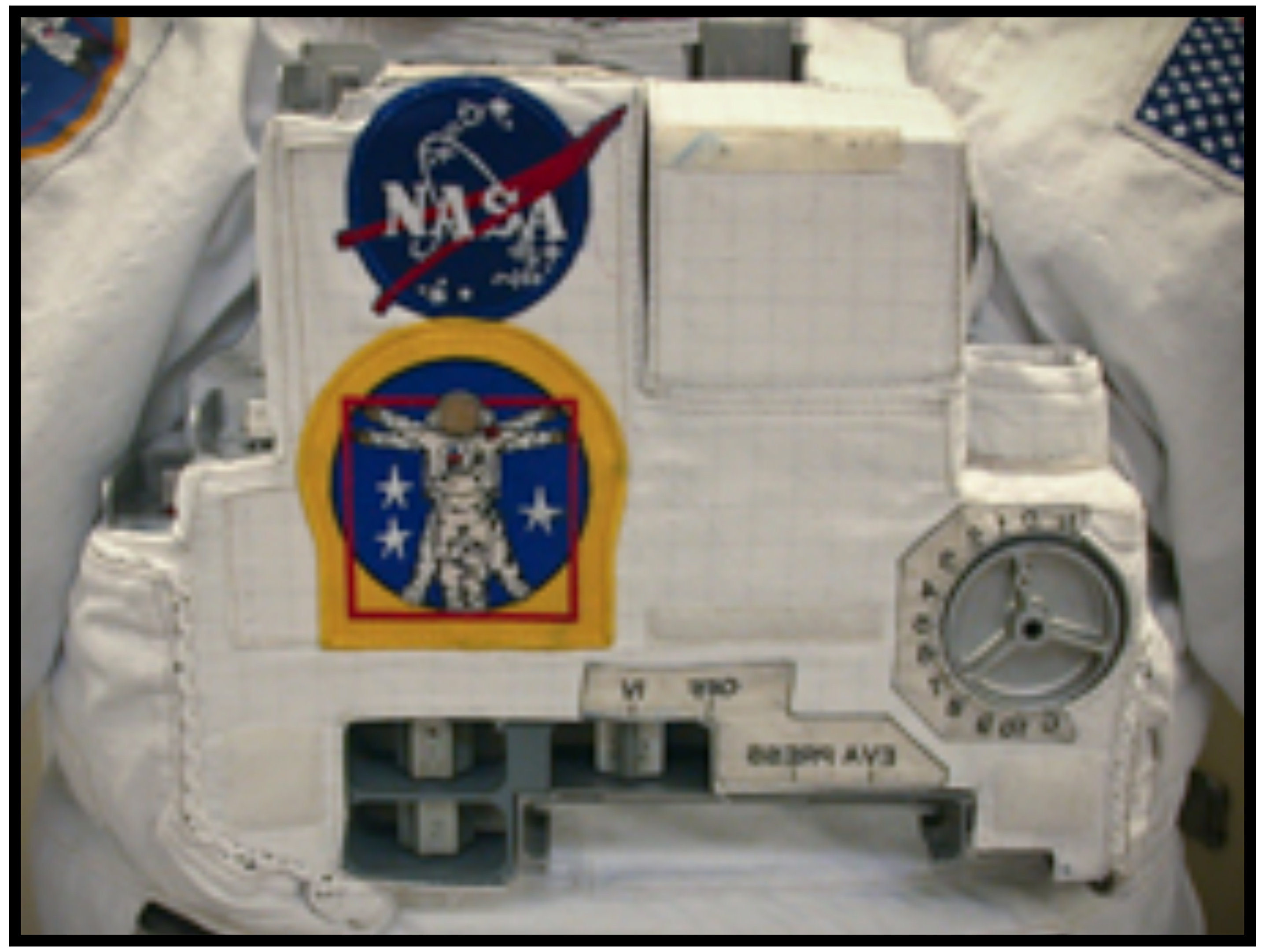
- 91.5m of tubing through which water is pumped to cool the astronaut
- Vents in the garment draw sweat away from the body
- Sweat is recycled in the water cooling system
- Oxygen pulled in at wrists and ankles to help circulation within the suit

Maximum Absorption Garment

A diaper.

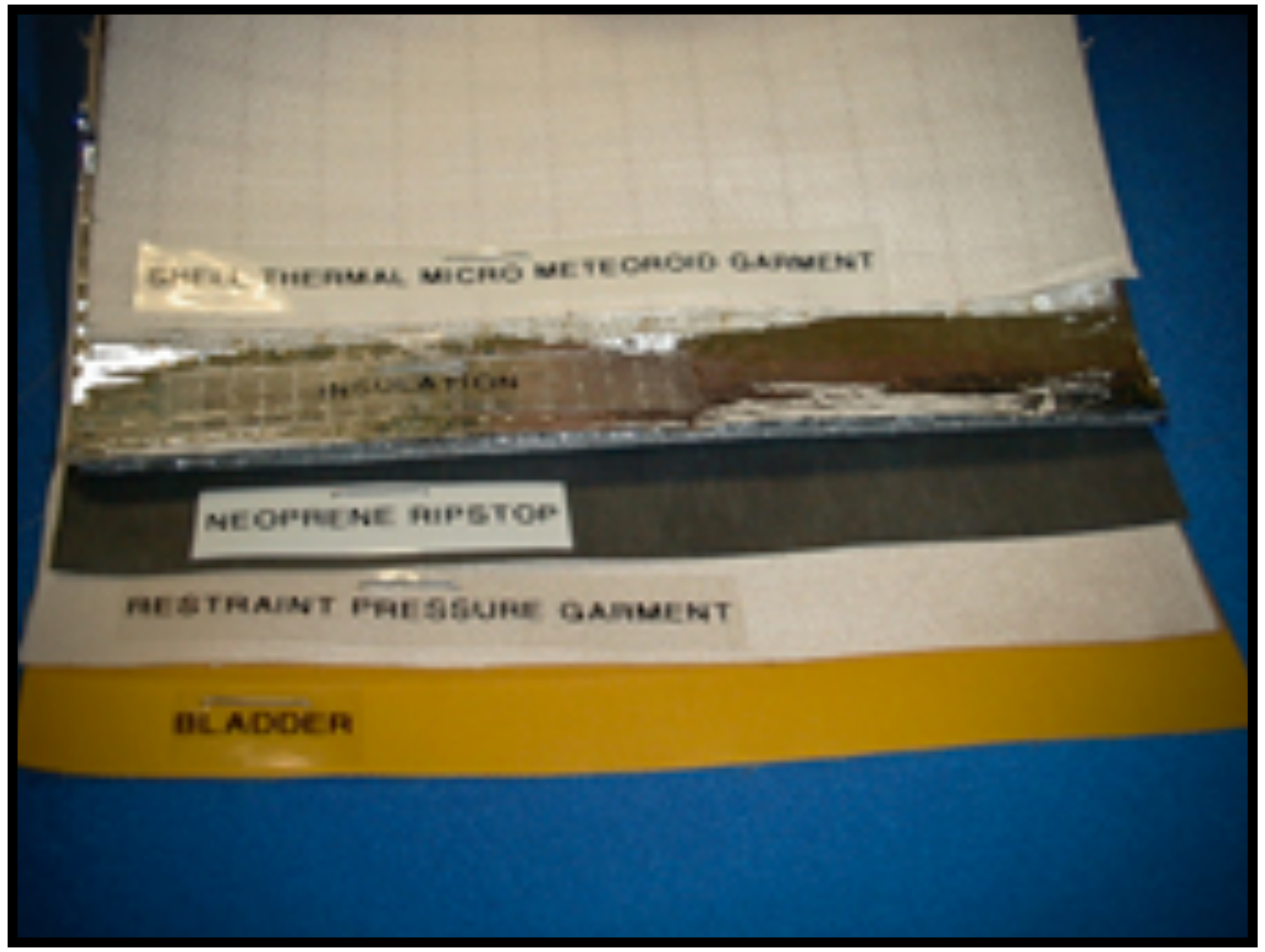
Display and controls module

- Control panel for the mini-spacecraft (spacesuit)
- Includes switches, controls, gauges, and electronic displays
- Allows the astronaut to control the life support subsystem
- Astronauts wear a wrist-mounted mirror to see the gauges on the front



Materials

- Suit is composed of 14 layers
- First three layers are the liquid cooling and ventilation garment
- Bladder layer next, which creates proper pressure for the body, and holds in oxygen for breathing
- Next layer is same material as camping tents, holds the bladder to the proper shape
- Rip-stop layer for tear resistance
- 7 layers of insulation
- Outer layer is mixture of 3 materials (waterproof, fire resistant, and puncture resistant)



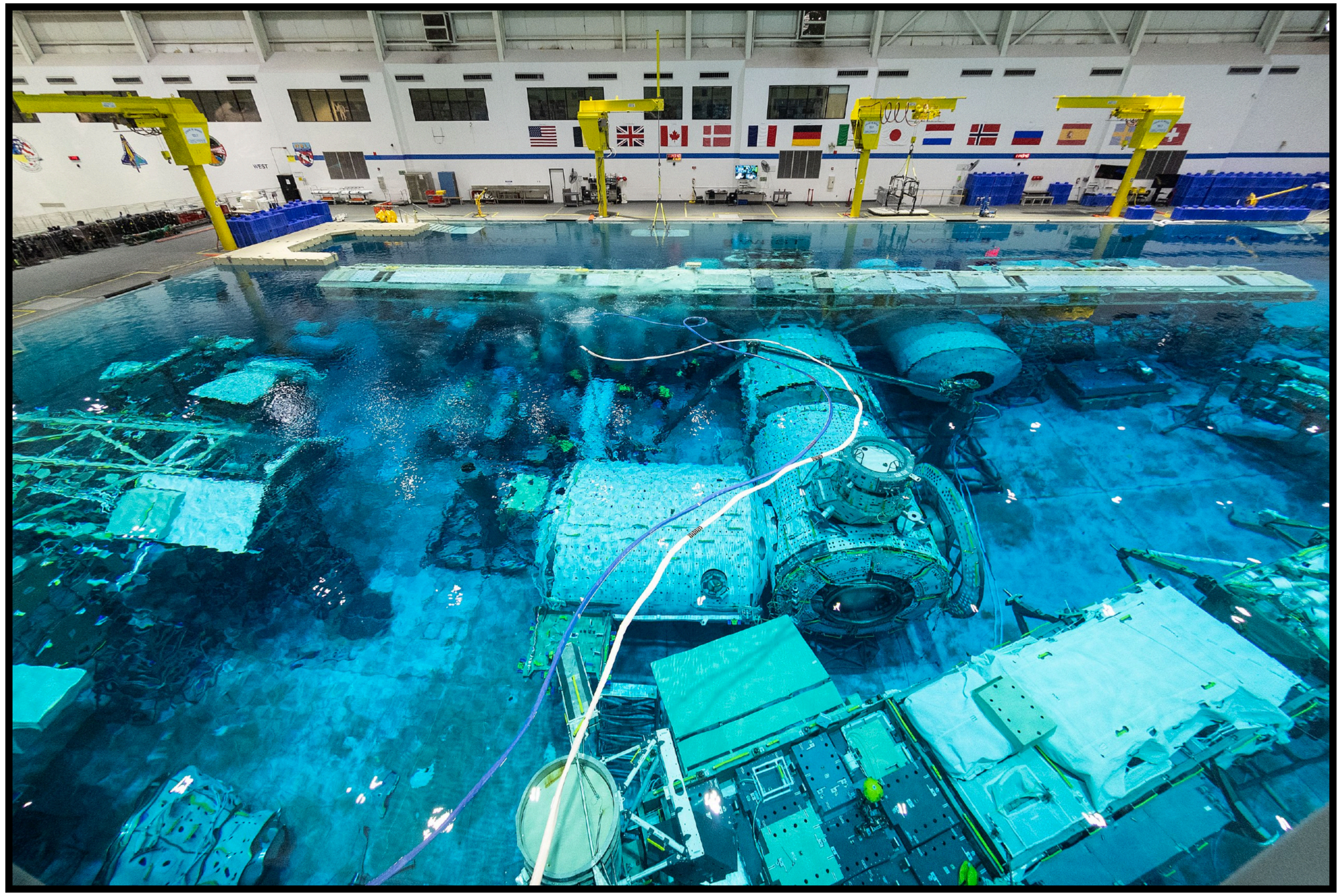
Today’s topics:

- What’s Extravehicular Activity?
- Why are we talking about spacesuits?
- Brief history of space walks
- The Extravehicular Mobility Unit
- EVA training
- Risks associated with EVA
- Mitigation strategies
- Spacesuits of the future

The Neutral Buoyancy Lab

At the **Sonny Carter Training Facility** near the Johnson Spaceflight Center

- Pool 202ft. long, 102ft. wide, and 40.5ft. deep
- Contains 6.2 million gallons of water, and full-scale mockups of ISS, Dragon, Cygnus, and other visiting vehicles
- Astronauts are lowered into the pool by a crane, and breathe nitrox during training
- Has the advantage of weightlessness for the suit (though not within the suit), drag effect mitigated by moving slowly



Risks associated with EVA

Risks include . . .

- Equipment failure
- Decompression sickness
- Suit injuries
- Fatigue/exhaustion
- Thermal stress
- Radiation exposure

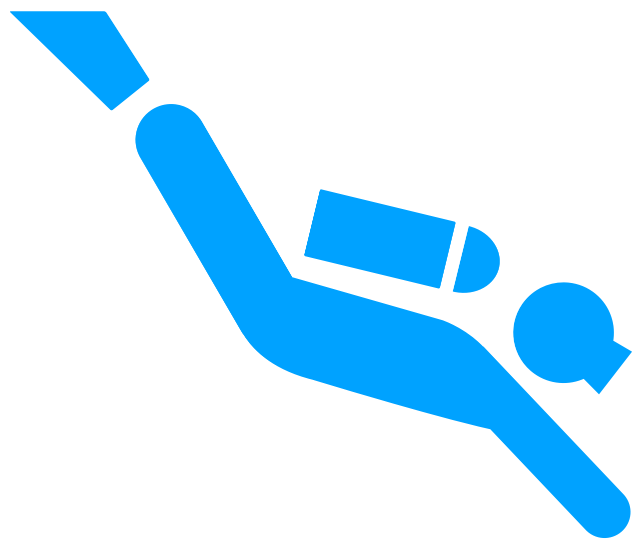
Equipment failure

- July 16, 2013
- Water flowed into astronaut Luca Parmitano's helmet
  - Estimated 1.5 liters
  - Intermittent communication loss
  - Impaired vision
  - Water entered nose
- EVA aborted

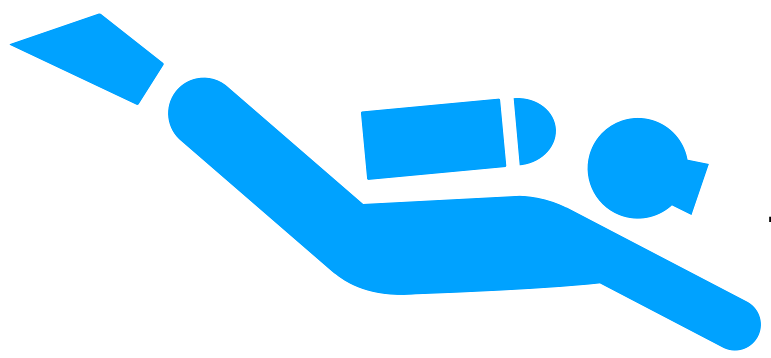
https://www.youtube.com/watch?v=q9ab1mkPh8A

Decompression sickness

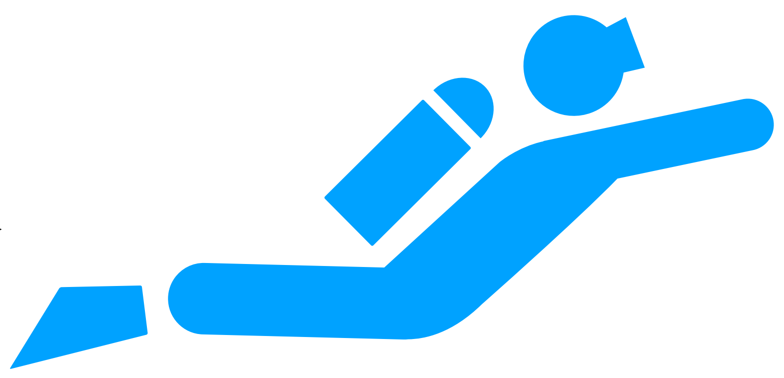
- Outgassing of inert gasses in the body, which form gas bubbles
- The amount of gas dissolved in a liquid is described by **Henry's Law**, which states that when the pressure of a gas in contact with a liquid decreases, the amount of that gas dissolved in the liquid will decrease proportionally
- If pressure is decreased slowly enough (how fast can you come up from a dive?), then off gassing occurs by gas exchange in the lungs
- Depressurize too quickly, and gas bubbles form in blood or tissue
- Symptoms can be mild or extremely severe



Moving to higher pressure, nitrogen moves from lungs to blood



At high pressure, nitrogen in higher concentration in solution in the blood and tissue



Depressurize slowly: nitrogen moves to lungs and is breathed out

Depressurize quickly: nitrogen comes out of solution in the blood/tissue

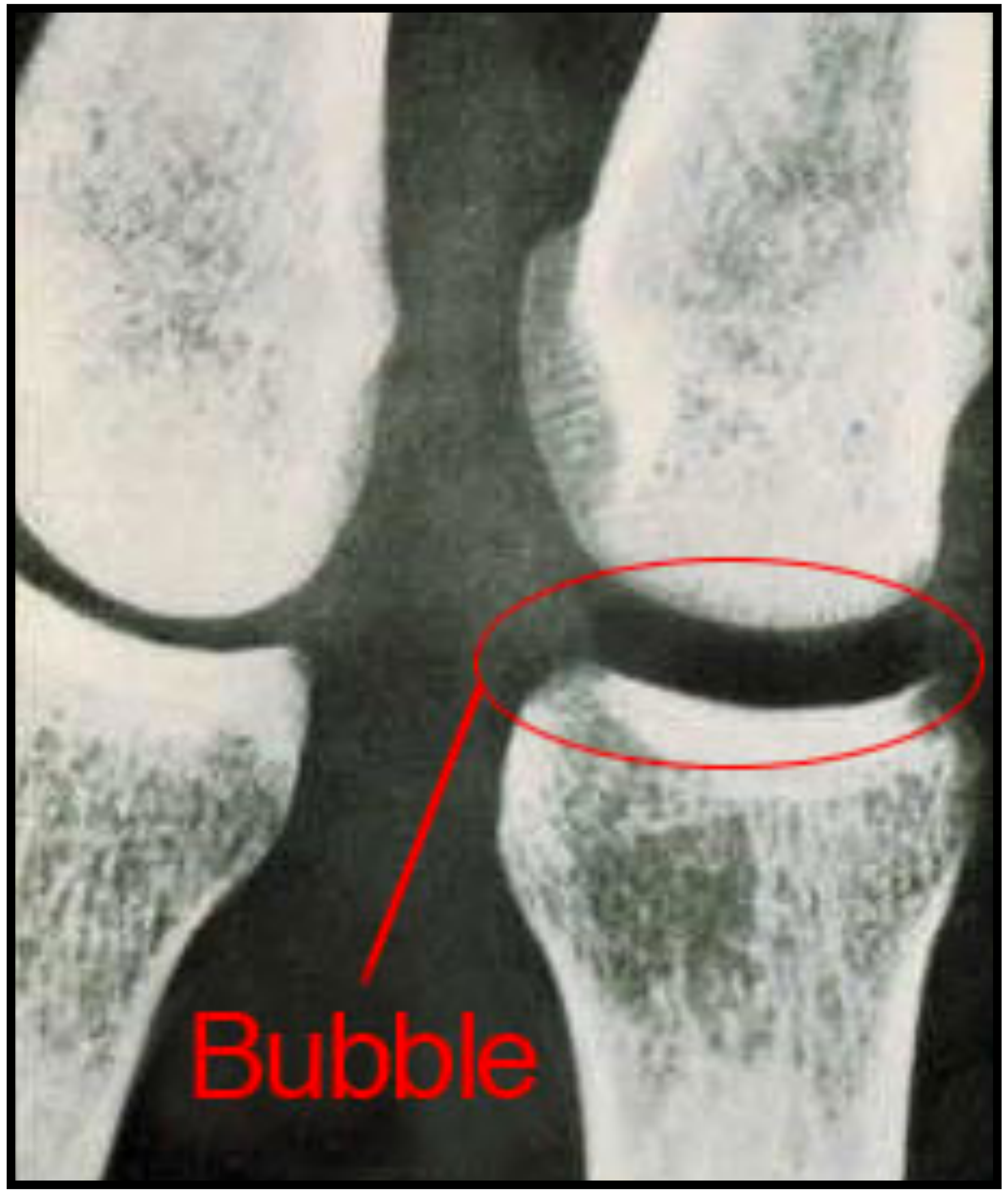
Decompression sickness symptoms

Type 1

- Most common
- Symptoms involving skin, musculoskeletal system, or lymphatic system
- Bubbles around joints cause pain

Type 2

- Bubbles in central nervous system
- Brain embolism, disruption of spinal cord, stroke, paralysis, unconsciousness, death
- Bubbles in pulmonary system
- Shortness of breath, cough, pain, cardiovascular collapse



Decompression in space

- Astronauts go from 101.7 KPa in ISS to 29.6 KPa in the EMU
  - Why not reduce cabin pressure for ISS?
  - Why not increase oxygen concentration?
- Option 1
  - Camp out in Quest Joint Airlock overnight (9h) at 10.2 psi - **reduces N2 concentration**
  - Spend 1 hour breathing pure O2 - **drop partial pressure of N2 to 0**
  - Suit up and perform EVA
- Option 2
  - Perform 4-hour pre-breathe of pure O2 prior to EVA - **drop partial pressure of N2 to 0**
- Option 3
  - High intensity exercise for 30 minutes
  - Perform 2-hour pre-breathe of pure O2

Decompression in space

- Interestingly, no DCS incident has ever been *reported* on US space missions
- However, ground studies predict higher rates of DCS
- Possible reasons
  - Difficult to discriminate between suit discomfort and DCS pain
  - Perhaps weightlessness somehow reduces DCS risk by changing gas dynamics and diffusion
  - Over-reporting in ground-based studies
  - Under-reporting of DCS by astronauts
  - DCS may resolve in the 100% O_2 environment

Spacecraft cabin atmosphere

- Must provide sufficient total pressure to prevent vaporization of body fluids (>6 KPa)
- Must provide sufficient oxygen partial pressure for adequate respiration
  - Determined by partial pressure of oxygen in the alveoli of the lung
  - Oxygen partial pressure must not be so great as to induce oxygen toxicity

Program	Cabin Pressure, kPa (psia)	Cabin Oxygen Concentration, volume %	EVA Suit Pressure, kPa (psia)[a]	EVA Prebreathe Time, min	EVA Prebreathe Conditions
Mercury	34.5 (5)	100	-	-	-
Gemini/Apollo	34.5 (5)	100	25.8 (3.75)	0	-
Skylab	34.5 (5)	70	25.8 (3.75)	0	-
Shuttle	70.3 (10.2)	26.5	29.6 (4.3)	40	In-suit (after 36 hours at 70.3 kPa)
	101.3 (14.7)	21	29.6 (4.3)	240[c]	In-suit
ISS/US	101.3 (14.7)	21	29.6 (4.3)	120-140	Mask and in-suit; staged w/exercise
				240[c]	In-suit
Salyut, Mir, ISS/Russian	101.3 (14.7)	21	40.0 (5.8)[b]	30	In-suit

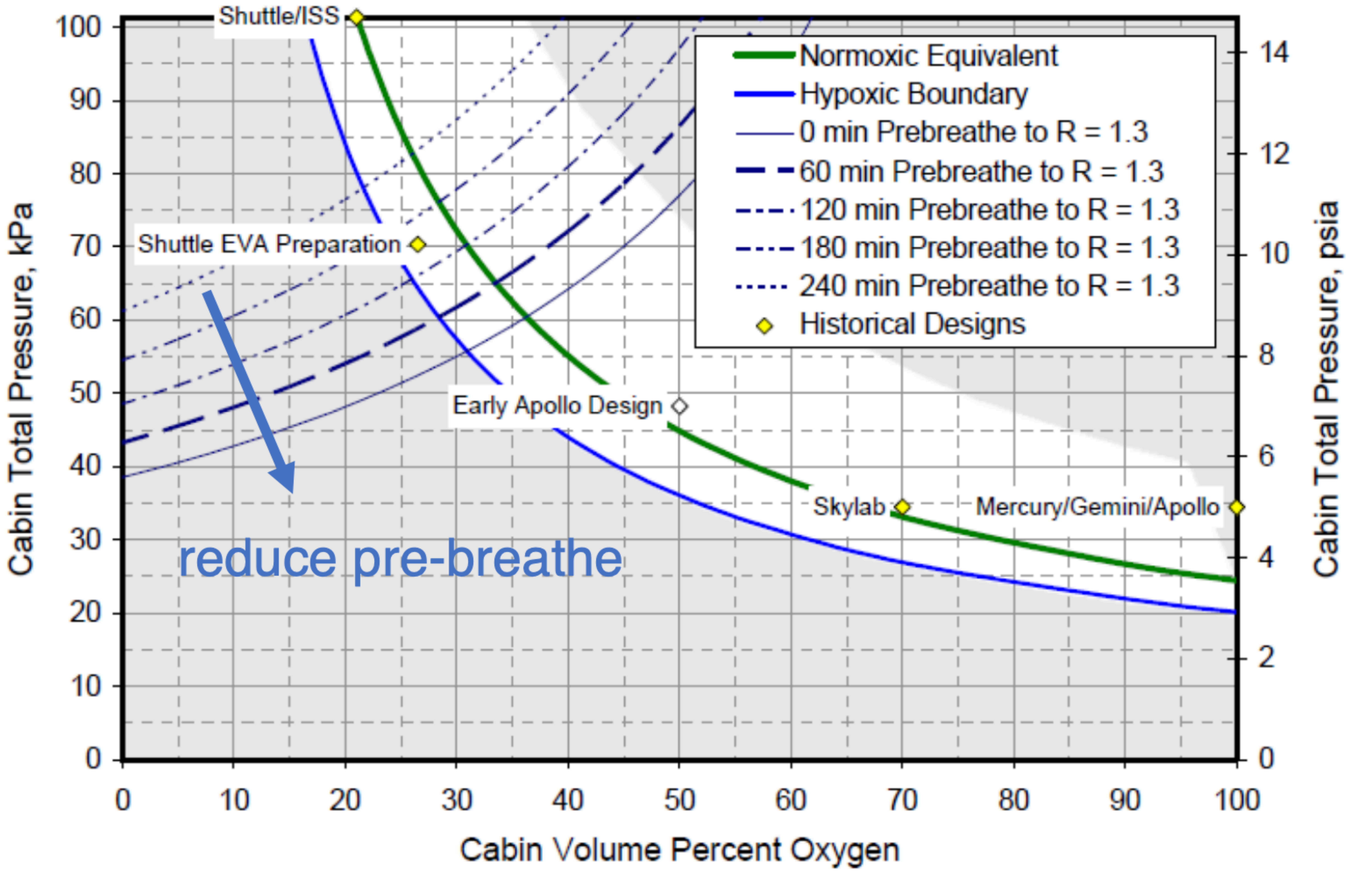
[a] At 100% oxygen.

[b] Can be reduced to 26.5 kPa (3.8 psia) for short-duration work regime.

[c] Under emergency conditions, a minimum of 150 minutes of unbroken prebreathe is recommended.

References: Carson (1975), McBarron (1993), Waligora (1993), NASA (2002), NASA (2003).

Lange 2005 *Bounding the Spacecraft Atmosphere Design Space for Future Exploration Missions*



Curves of constant EVA prebreathe time for a **29.6 KPa spacesuit** with a final **R-value of 1.3**

Lange 2005 *Bounding the Spacecraft Atmosphere Design Space for Future Exploration Missions*

Spacesuits of the future

Dava Newman

- “BioSuit”
- Provides necessary pressure mechanically (using shape-memory alloys) rather than using air
- Radically improves mobility
- Reduces risk of catastrophic decompression from rip or tear

SpaceX

- Not for EVA
- Custom-built for each astronaut
- 3D printed helmet
- Offers protection in event of depressurization
- Touchscreen-compatible gloves

Starliner

- Not for EVA
- Offers protection in event of depressurization
- Touchscreen-compatible gloves