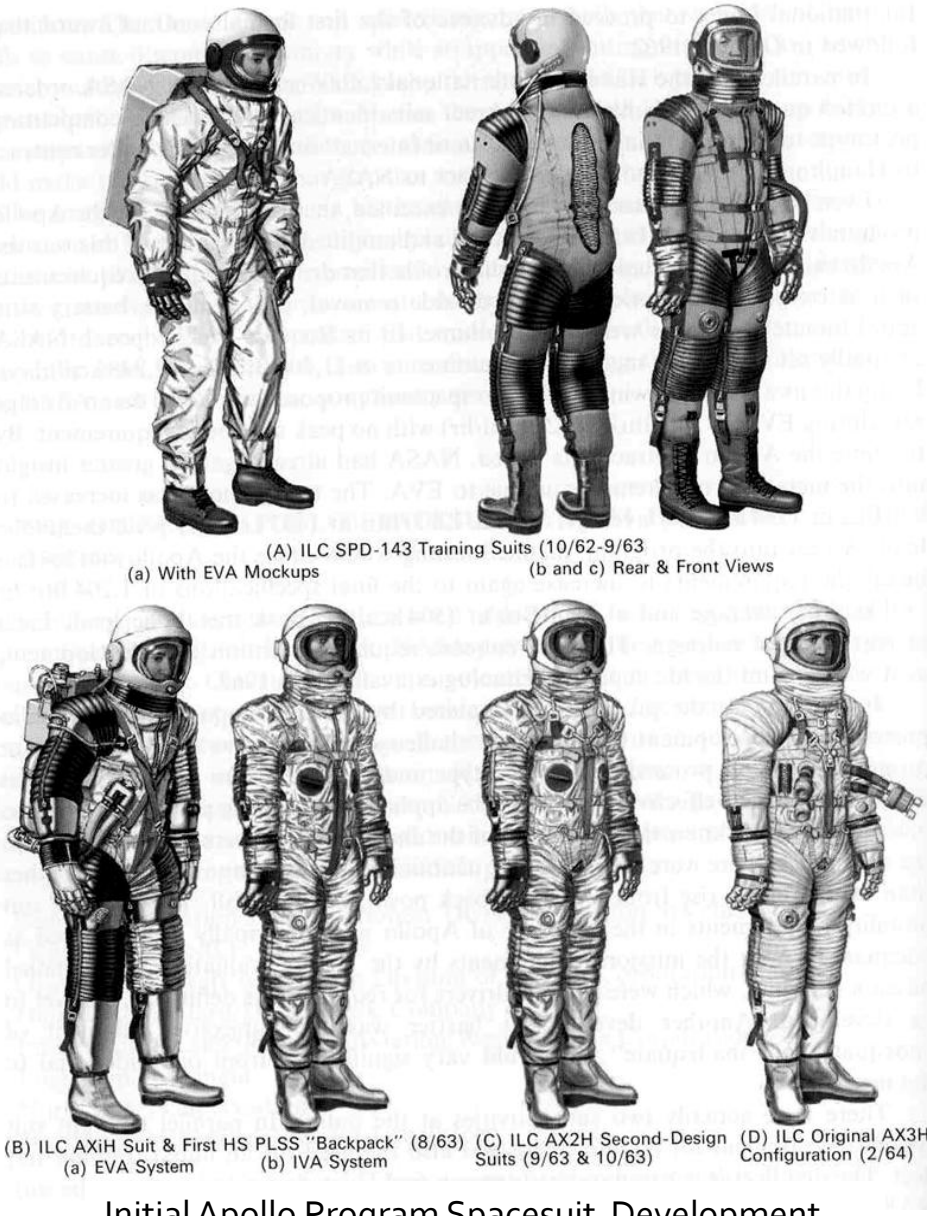
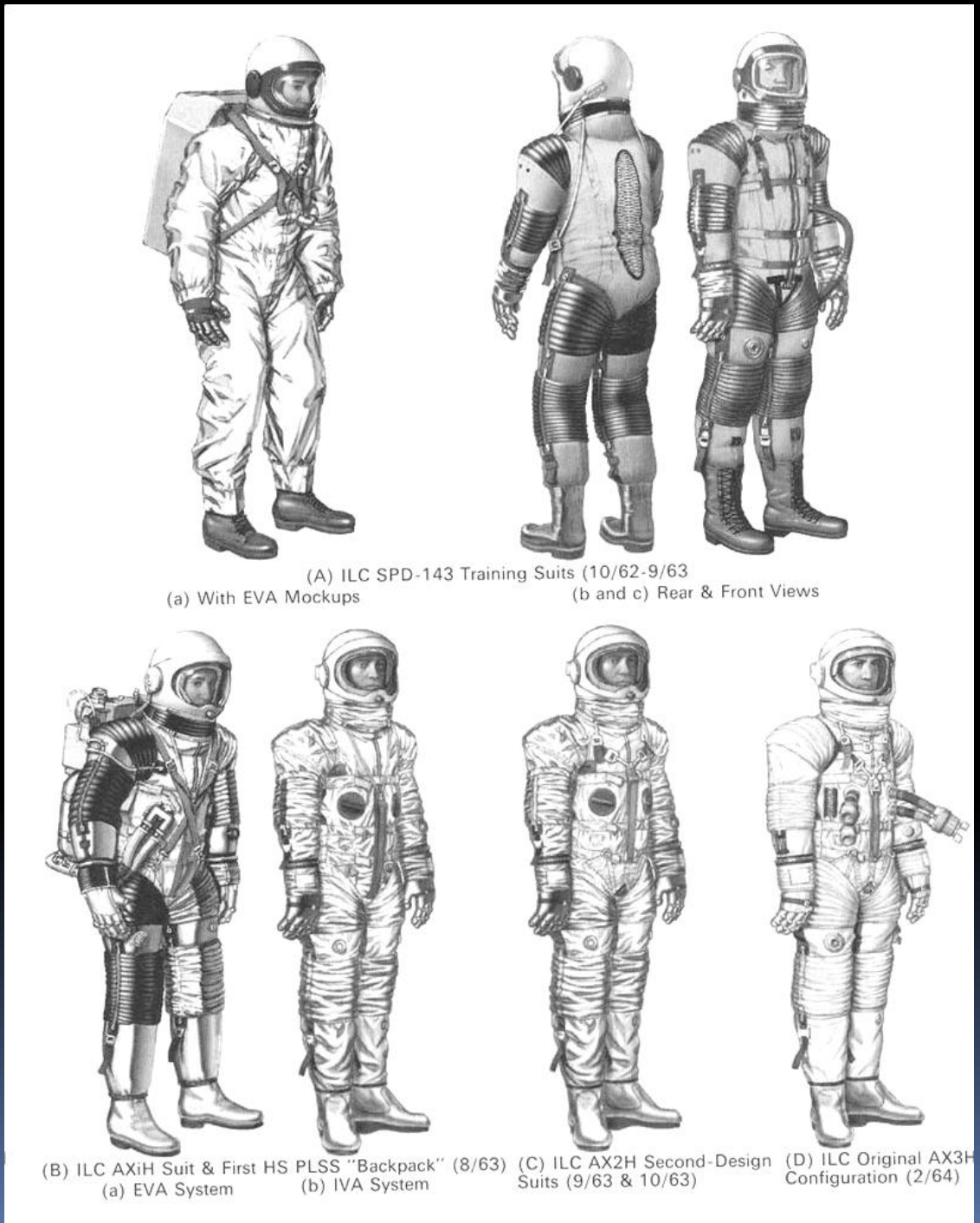
Apollo
ILC Hamilton Standard
A7Lb
Extravehicular
Mobility
Unit
(EMU)

Apollo A7L
Moonsuit
1967

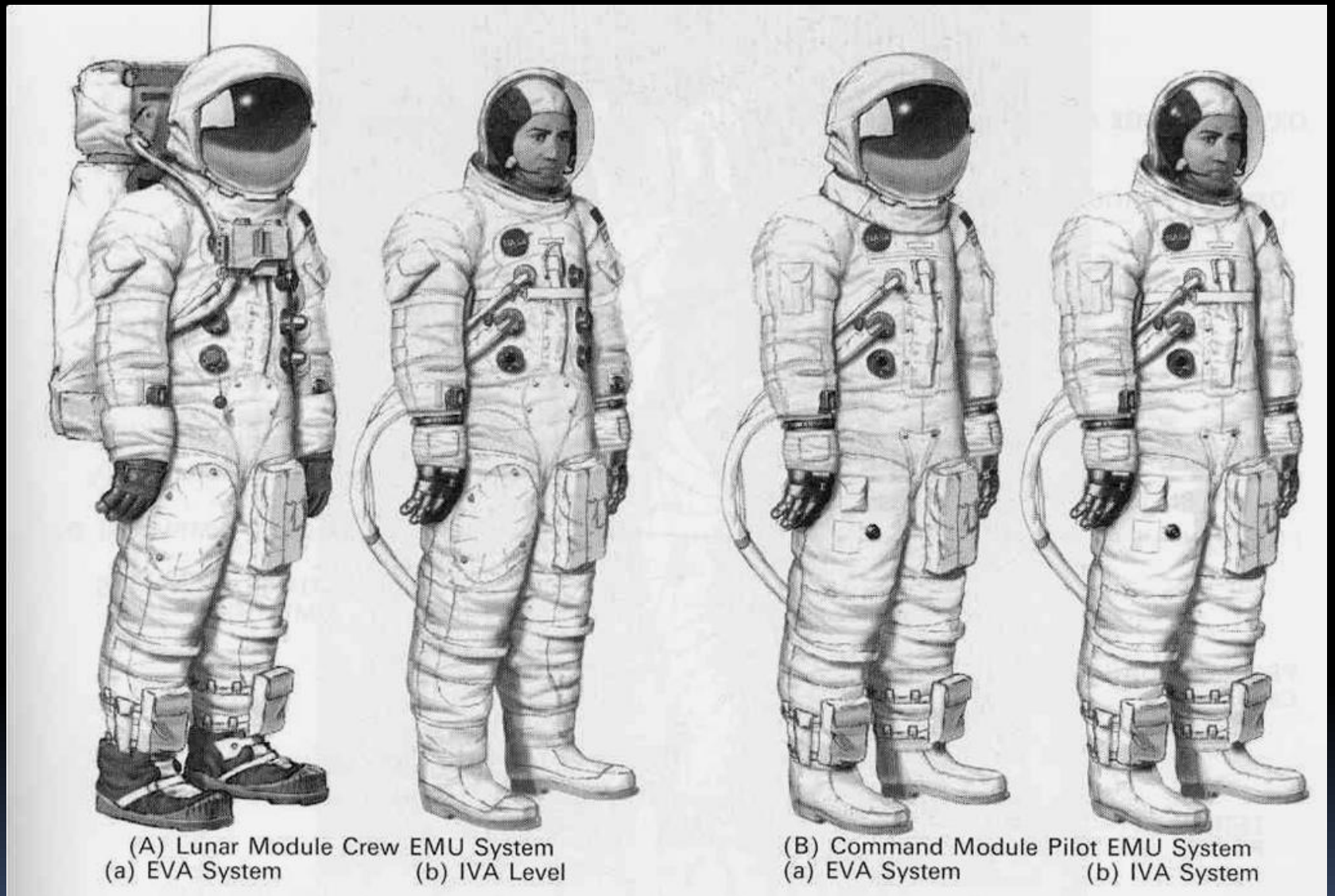
Moon suit concepts early 1960s



Initial Apollo Program Spacesuit Development

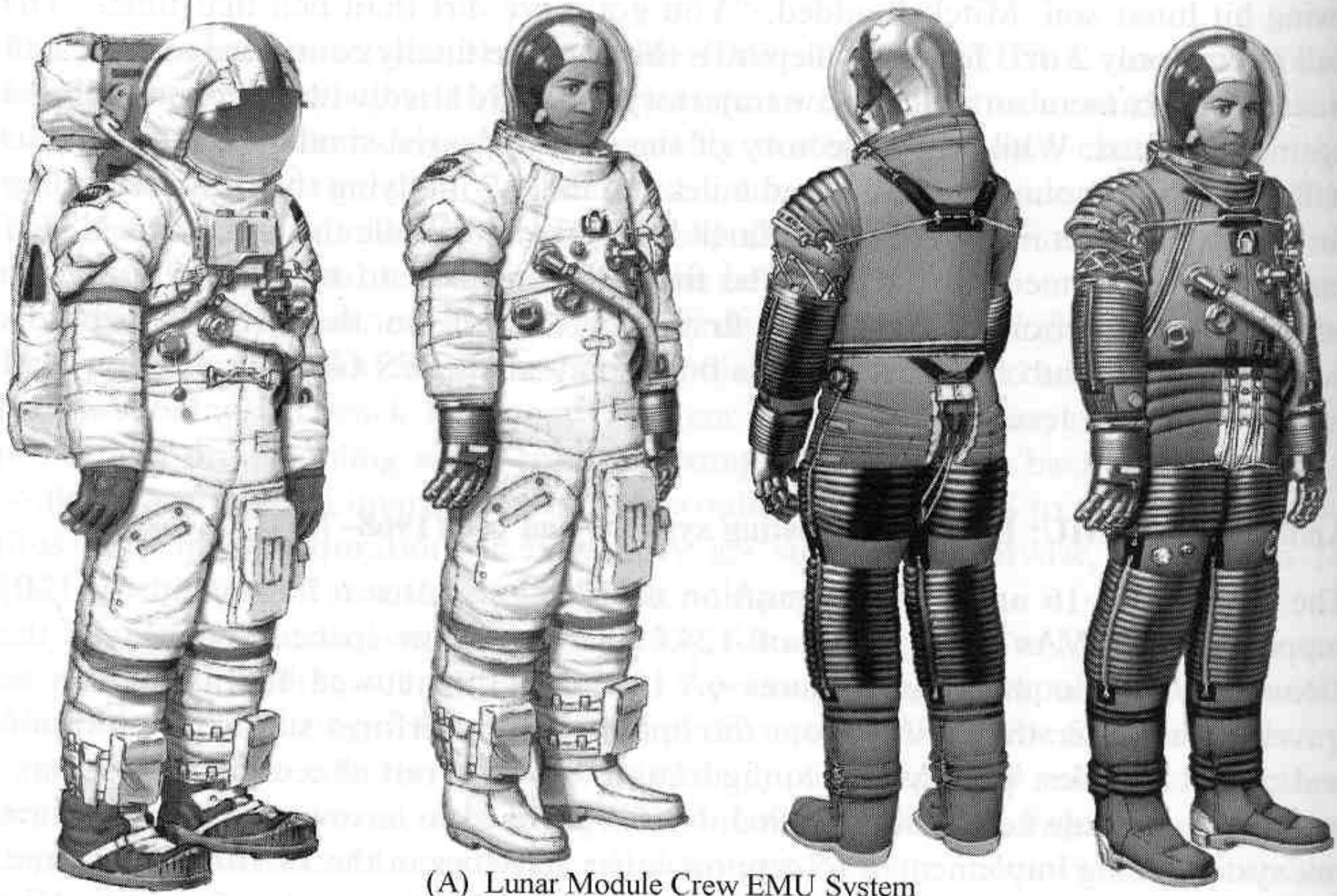


Initial Apollo Development Suits
1963-64



Apollo 11-13 EMU Configurations

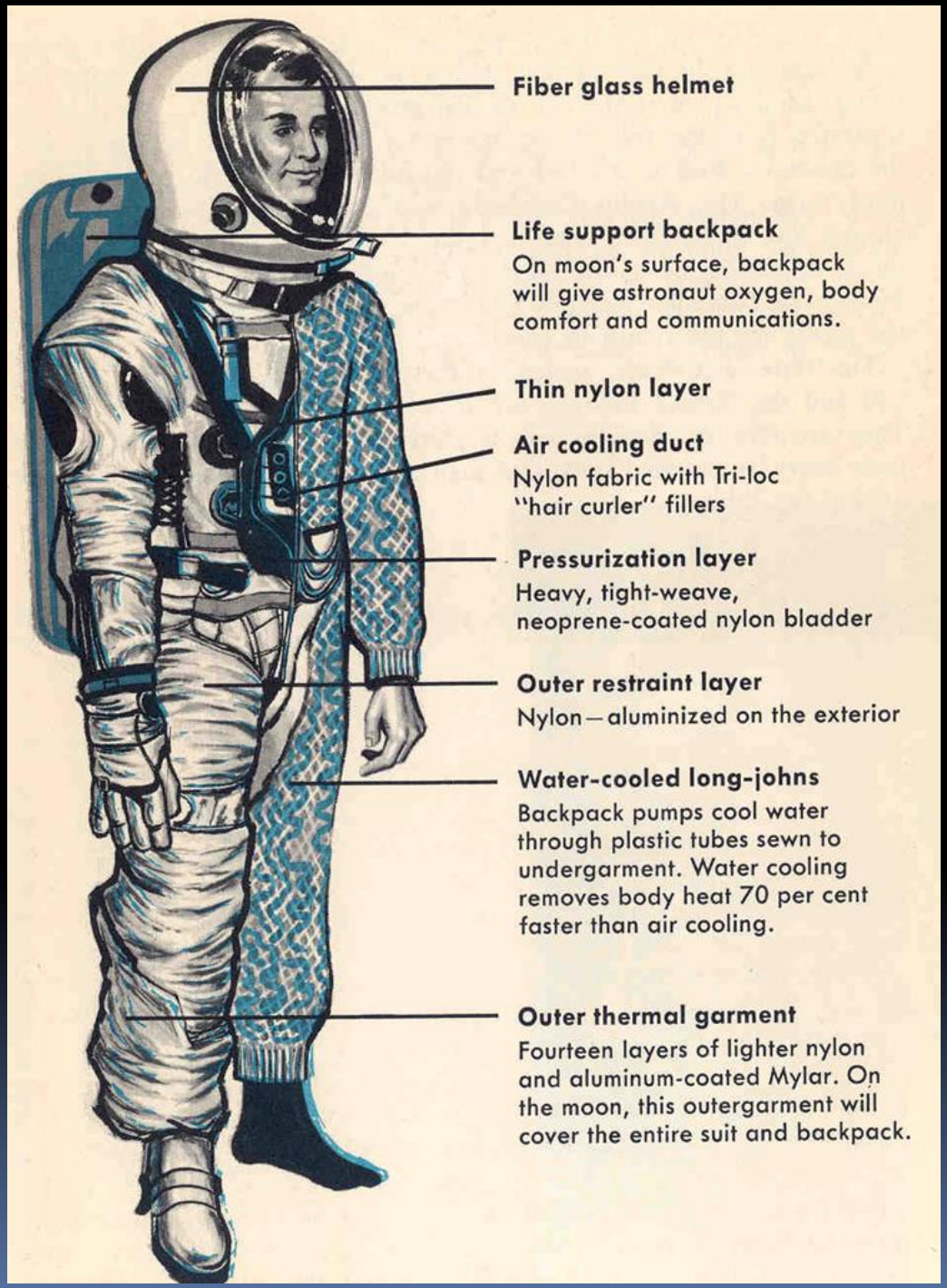
A7Lb used on Apollo 15-17



(A) Lunar Module Crew EMU System

(a) EVA System (b) IVA Level (c & d) Without Covers (rear & front)

A7L Suit with outer cover layers removed



1965 Apollo Moon Suit

THE 21-LAYER SPACE SUIT

Nature designed man to inhabit the earth, but his will to know drives him to explore other environments, such as the moon. The lunar environment is a hostile one, and in order to survive there, man requires special protective clothing. Science and technology have worked together to develop a suit (known technically as the Lunar Extravehicular Mobility Unit) which enables man to walk about the moon. This poster explains the complex layers of material from which the space suit is made.

Du Pont, the world's largest chemical corporation, developed materials used in 20 of the 21 layers in the space suit, although it did not make the suit itself. (ILC Industries makes the suits.) But none of these materials were developed with the moon in mind. Some were new materials, like "Kapton" film. Others, such as nylon, were discovered more than thirty years ago by scientists who had no idea of the distance the results of their research would travel some day. But achievements in science are often put to use in unexpected places. In the case of the space suit, materials which Du Pont had developed for use on earth ultimately found a place on the moon. We can expect to see them used, too, as man strikes out for outer space and farther planets.

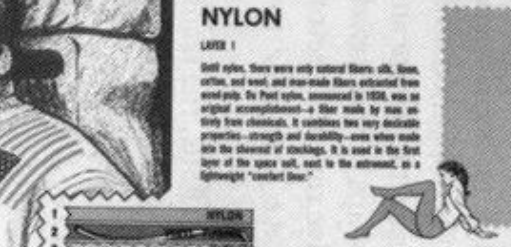
DU PONT

Du Pont materials in Apollo moon suits were originally developed for earthbound use . . .

NYLON

LAYER 1

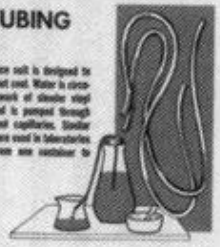
Until nylon, there were only natural fibers: silk, linen, cotton, and wool, and man-made fibers extracted from wood-pulp. Du Pont nylon, announced in 1938, was an original accomplishment—a fiber made by man entirely from chemicals. It combines two very desirable properties—strength and durability—even when made into the sheerest of stockings. It is used in the first layer of the space suit, next to the astronaut, as a lightweight "comfort liner."



VINYL TUBING

LAYER 2

This layer of the space suit is designed to help keep the astronaut cool. Water is circulated through a network of slender vinyl tubes, much as blood is pumped through your body's veins and capillaries. Similar kinds of vinyl tubing are used in laboratories to transfer fluids from one container to another.



LYCRA®

LAYER 3

"LYCRA" SPANDEX FIBER

"Lycra", invented by Du Pont, is a man-made fiber that has all the elastic qualities of natural rubber. It is stronger than natural elastic thread, but weighs one-third less and wears much longer. "Lycra's" flexibility and strength make it a good choice for a material to hold the cooling tubes close to the astronaut's body. You will find it most often in women's swim suits and undergarments.

NOMEX®

LAYER 4

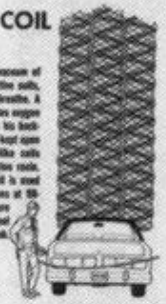
"NOMEX" NYLON YARNS

Du Pont scientists learned to make many types of nylon. "Nomex" is a high temperature resistant nylon. It cannot be melted or ignited even by burning gasoline. Its resistance to burning is built into the fiber itself and will not wear out or wash out. "Nomex" nylon is also used in racing drivers' suits, in clothing for people who may not be able to protect themselves in case of fire (such as children and mental patients), and in re-search ironing board covers.

NYLON COIL

LAYER 5

Closed off from the vacuum of space by their protective suits, the astronauts must breathe. A network of ducts carries oxygen to the astronaut from his backpack. These ducts are kept open and clear by spring-like coils made of a "Zytel" nylon resin. This type of nylon coil is used in gasoline pump hoses at filling stations, to assure unobstructed flow of fuel from pump to gas tank.



NEOPRENE-COATED NYLON

LAYERS 6, 8

Neoprene is a very special kind of synthetic rubber. It is not affected by heat, cold, oils, grease, oxygen, or ozone—and no liquid can seep or leak through it. In the space suit, used to coat nylon, it acts as a barrier layer to help keep oxygen loss to a minimum. The more common use of this fabric on earth is for tarpaulins that protect football and baseball fields, and for huge inflatable shelters.

NYLON

LAYER 7

As we have indicated, nylon can be produced in a variety of forms. In layer 7, because weight for weight it is stronger than steel wire, it is used as a restraint layer, to hold the many layers beneath it in shape. This same kind of nylon is used for seat belts in cars and airplanes.

MYLAR®

LAYERS 9, 11, 13, 15, 17

"MYLAR" POLYESTER FILM

Du Pont began producing super-strong "Mylar" in 1954. It takes a force of 25,000 lbs. per square inch to pull apart a sheet of "Mylar" only one one-thousandth of an inch thick. It is used as the base material in videotape, for packaging such items as poultry and frozen "boil-in-the-bag" foods, and as electric motor insulation. In the space suit, five layers of aluminum-coated "Mylar" help to block off radiant heat from the sun, and hold body heat in to protect against the cold of space.

DACRON®

LAYERS 10, 12, 14, 16

"DACRON" POLYESTER FIBER

"Dacron" is a man-made fiber, used extensively in apparel and home furnishings. Some of you might be wearing garments made of "Dacron" right now. In the space suit, four layers of strong yet flexible "Dacron" polyester are alternated with the layers of "Mylar" as a kind of insulating "sandwich" to protect the spacemen against heat and cold.

KAPTON®

LAYERS 18, 19

"KAPTON" POLYIMIDE FILM

Du Pont announced "Kapton" in 1964. Two aluminized layers protect the astronaut from extremes in temperatures, 530° F. in noon day to minus 250° F. in moon night. "Kapton" was chosen because it will not shrink, melt, or burn at high temperatures, even when as thin as one one-thousandth of an inch. It was also used in the moon landing space ship to insulate 14 miles of wire. On earth, "Kapton" is used to insulate motors for high-speed trains and wiring for aircraft.

TEFLON®-COATED GLASS FIBER

LAYER 20

"TEFLON" TFE-FLUOROCARBON FIBER

"Teflon" TFE-fluorocarbon resin finish, used for no-stick cookware, was a scientific serendipity, discovered by Du Pont scientists while at work on other research. In the command space ship, 15 miles of wiring are covered with "Teflon" resin. For the space suit, glass fibers are coated with "Teflon," then woven into a fabric. This layer was designed to provide fire protection and to guard against high speed dust particles.

TEFLON®

LAYER 21

"TEFLON" TFE-FLUOROCARBON FIBER

Here the "Teflon" TFE-fluorocarbon resin is made into fibers and woven into a fabric of "Teflon." On earth, because it is almost totally friction-free, you'll find this fabric used in grease-less bearings. On the moon, it is used on the outermost layer to cover hard-wear parts of the astronaut's suit, such as the elbows, knees, and shoulders, to provide an abrasion-resistant surface. About 30% of the space suit is covered with this special fabric.

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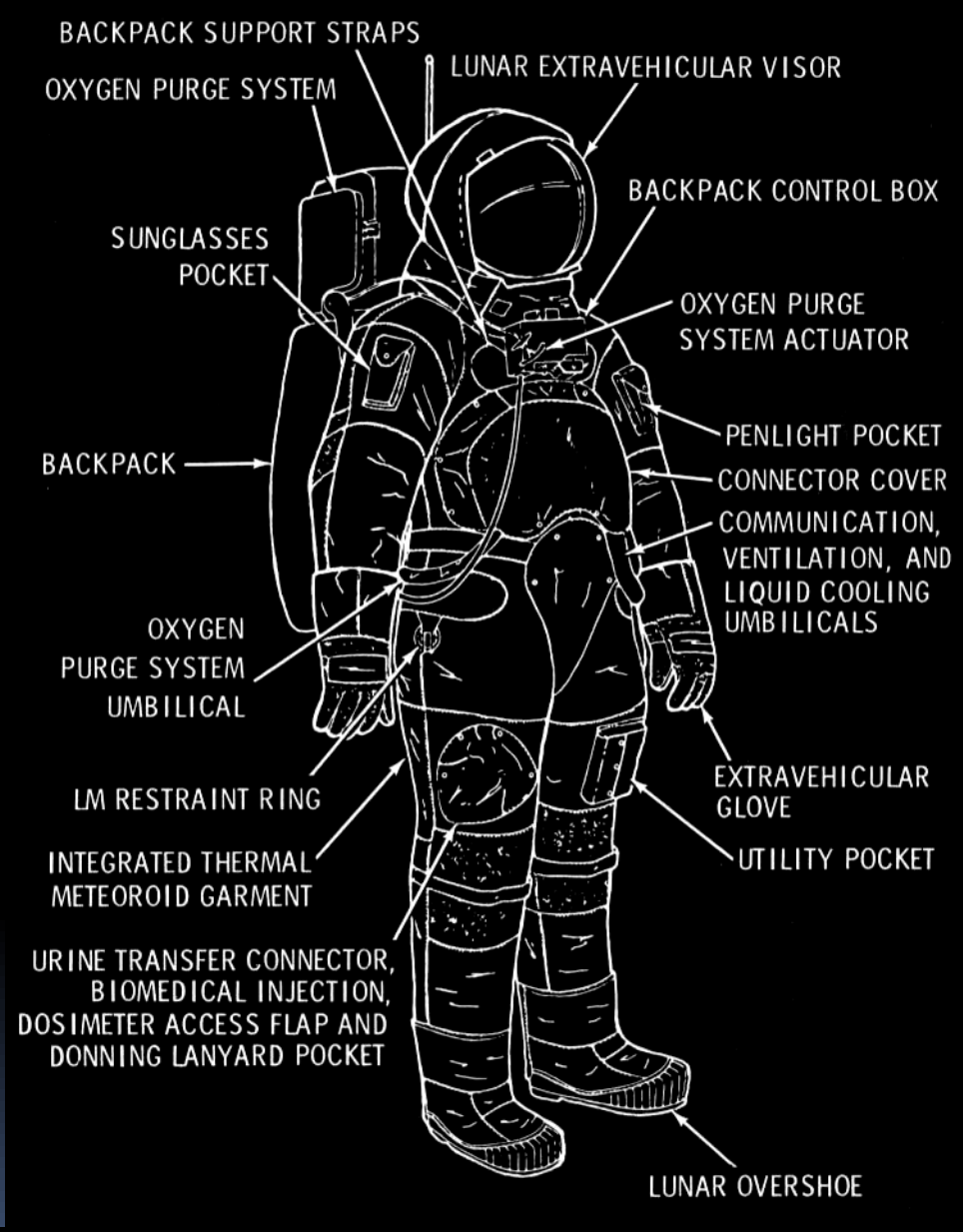
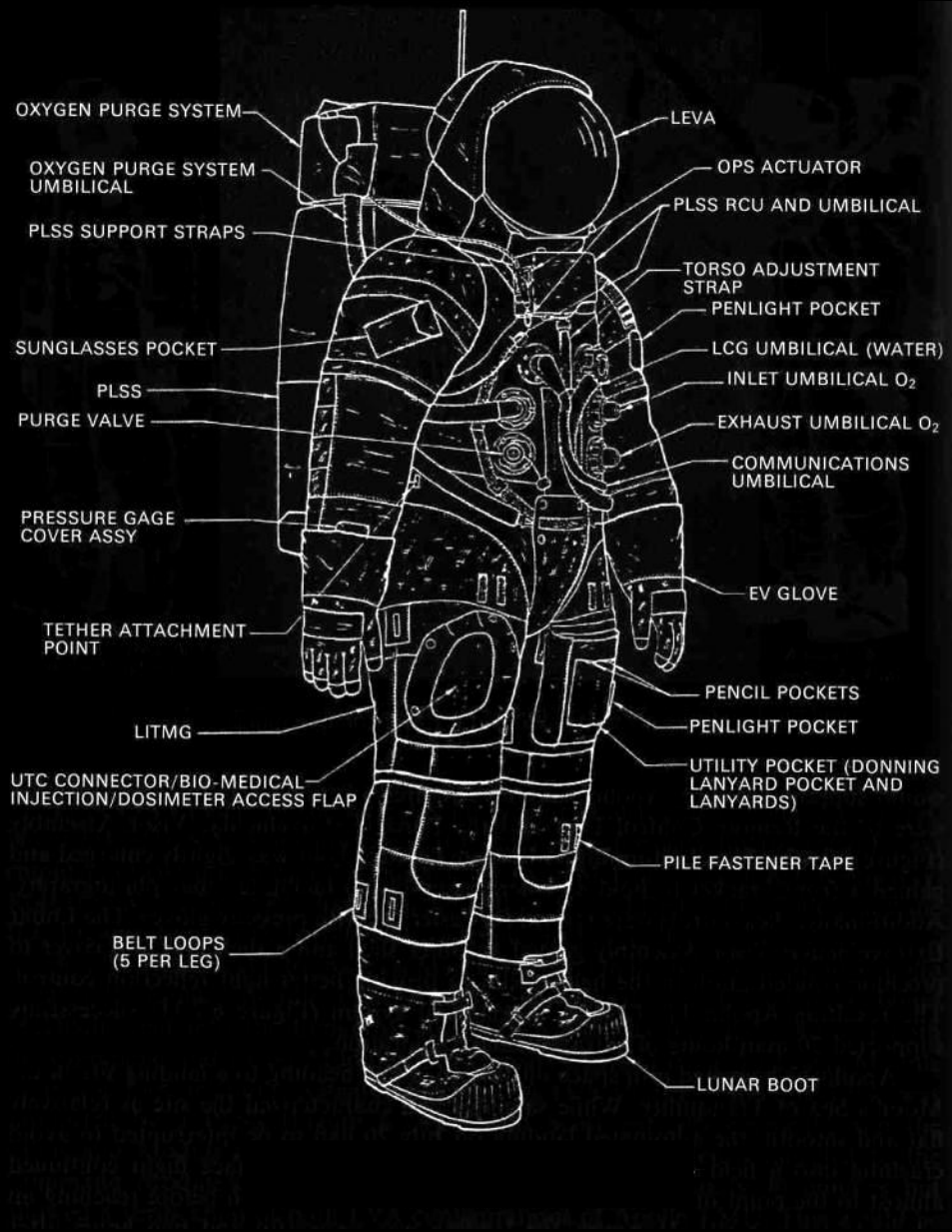
Apollo A7L Materials

Layer*	Material	Function
	Extravehicular (EV) Suit (rear entry zipper)	
1	Teflon cloth	Abrasion/flame resistance
2	Beta cloth (Teflon-coated silica fiber)	Fire protection (non-flammable in oxygen atmosphere)
3,5	Aluminized gridded Kapton	Reflective insulation
4,6	Beta marquisette (Teflon-coated silica fiber, laminated to Kapton)	Spacer between reflective surfaces
7,9,11,13,15	Aluminized Mylar	Reflective insulation
8,10,12,14	Nonwoven Dacron	Spacer
16	Neoprene-coated nylon	Inner liner
17	Nylon	Restraint layer for pressurized bladder
18	Neoprene-coated nylon	Bladder material serving as an impermeable layer containing suit-pressurization oxygen
19	Neoprene convolute	Pressure-retaining flexible joints
20	Knit jersey laminate	Abrasion protection
21	Lightweight Nomex cloth	Comfort
	Liquid Cooling Garment (LCG)	
22	Nylon spandex	Holds tubing close to skin
23	Vinyl tubing	Water distribution for cooling
24	Porous lightweight nylon	Comfort
	Intravehicular (IV) Suit	
1	Teflon-coated Beta cloth	Fire protection (non-flammable in oxygen atmosphere)
2	Nomex cloth	Snag/fire protection
3	Nylon	Restraint layer for pressurized bladder
4	Neoprene-coated nylon	Bladder material serving as an impermeable layer containing suit-pressurization oxygen
5	Lightweight Nomex cloth	Comfort
	Constant Wear Garment (CWG)	
1	Cotton	Comfort

*Materials are listed from outside to inside.

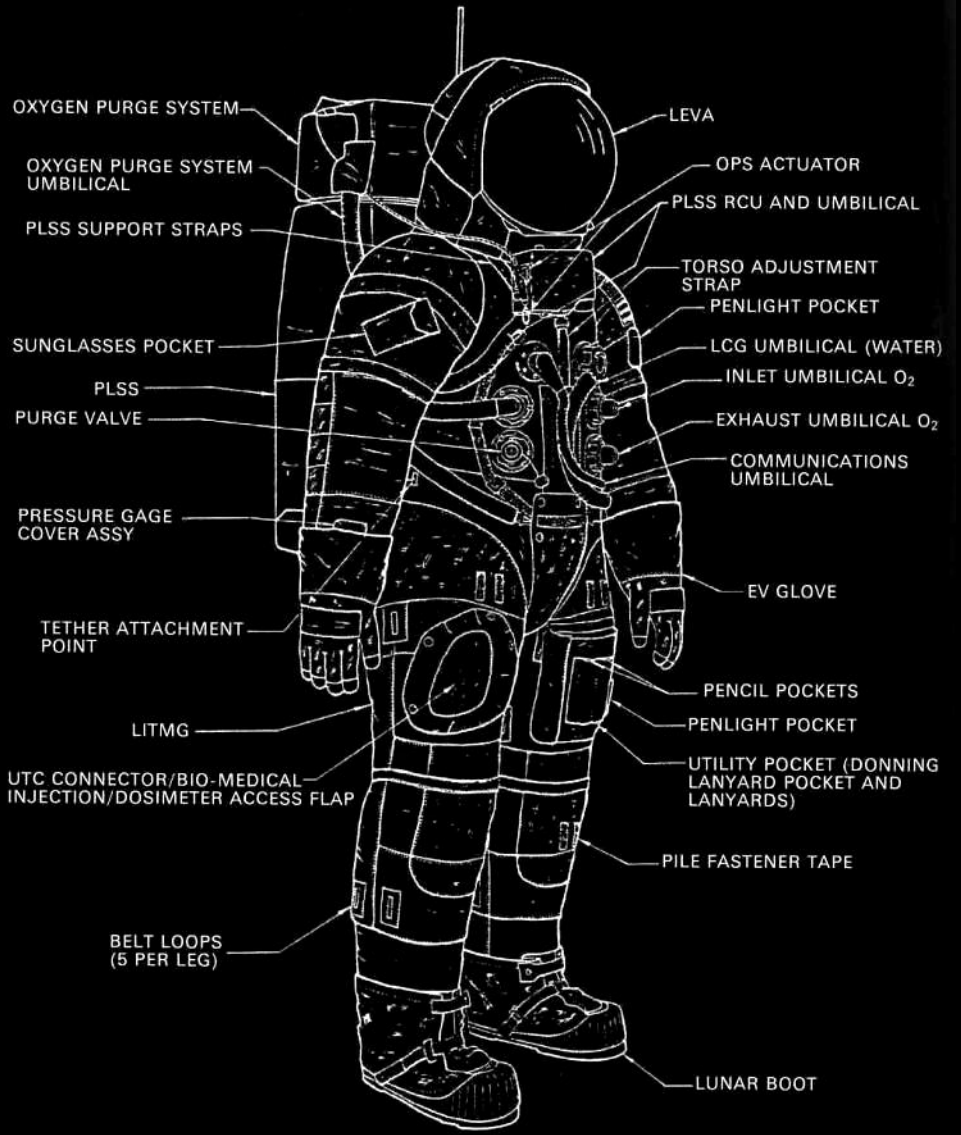


Pre-lunar mission design, note umbilical cover

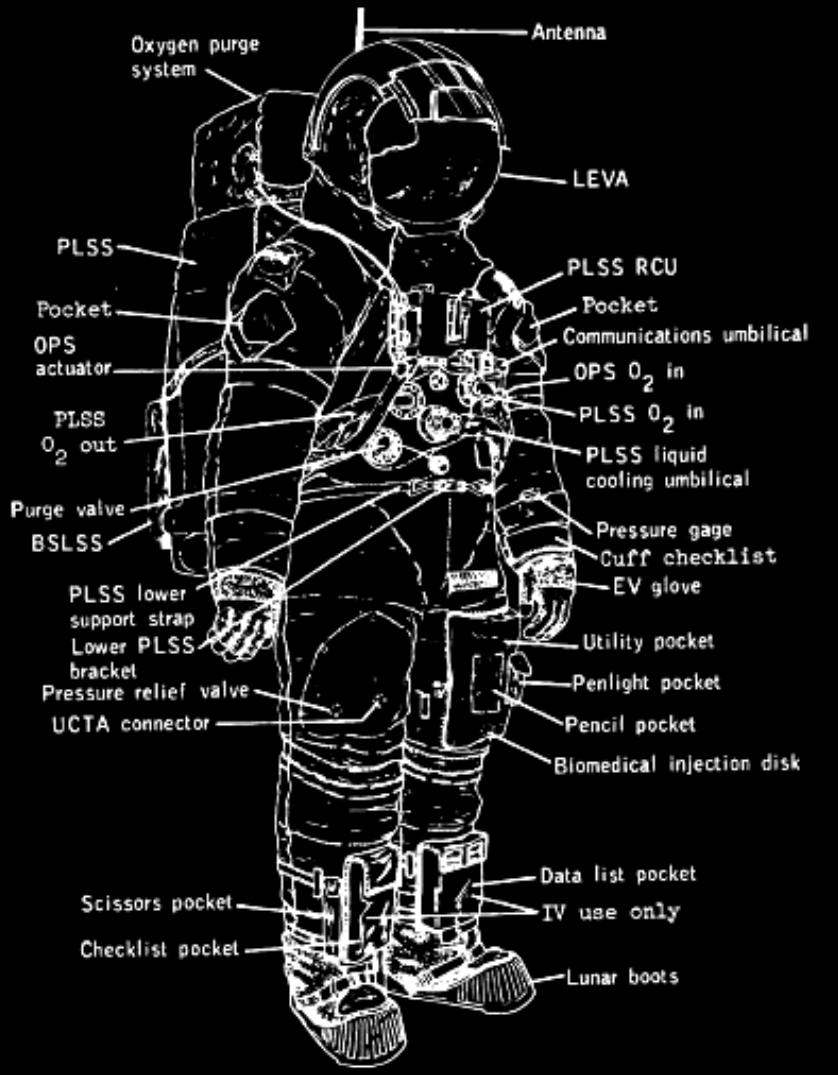


As flown on Apollo 11-14

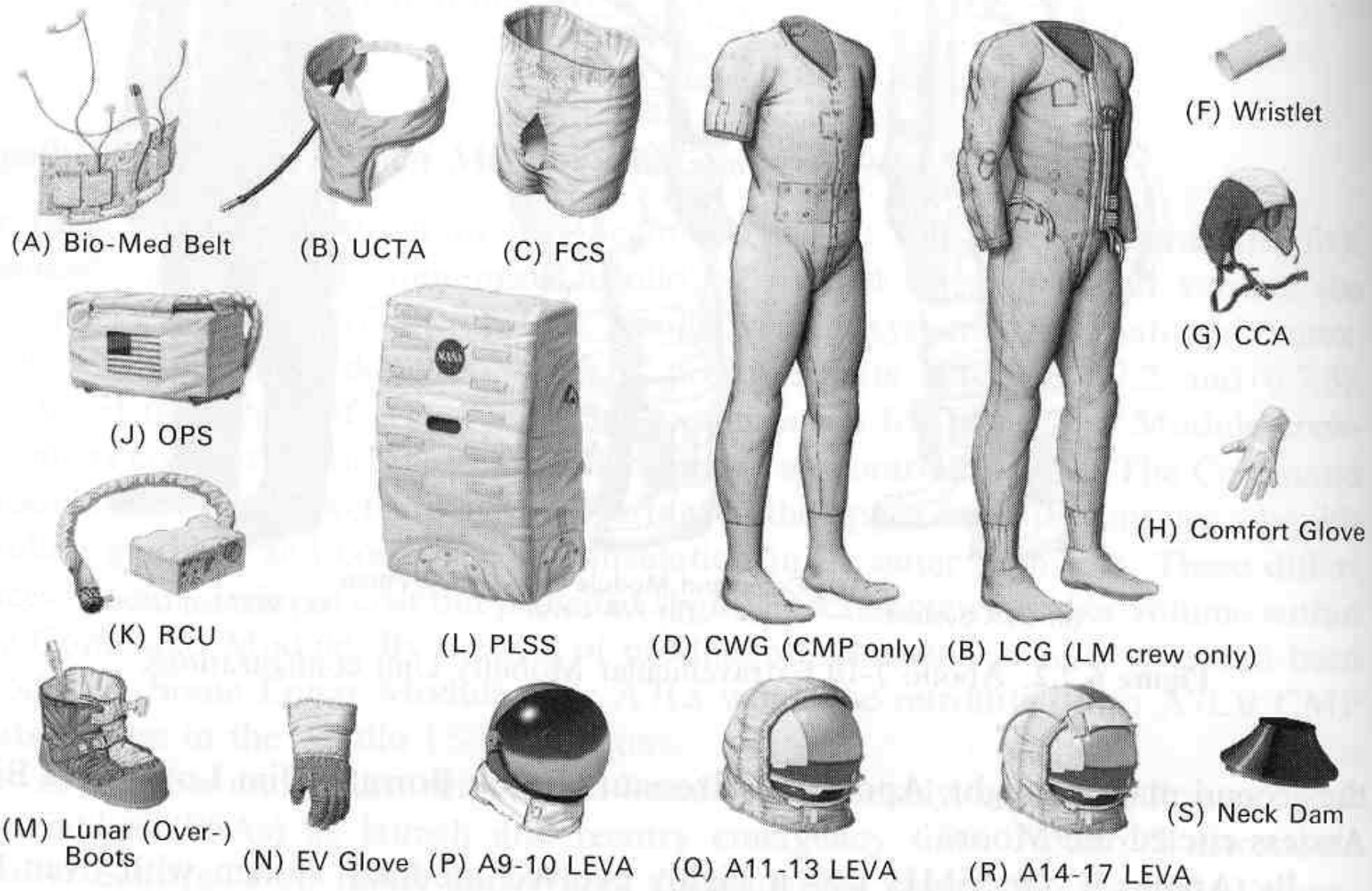
APOLLO EXTRAVEHICULAR MOBILITY UNIT



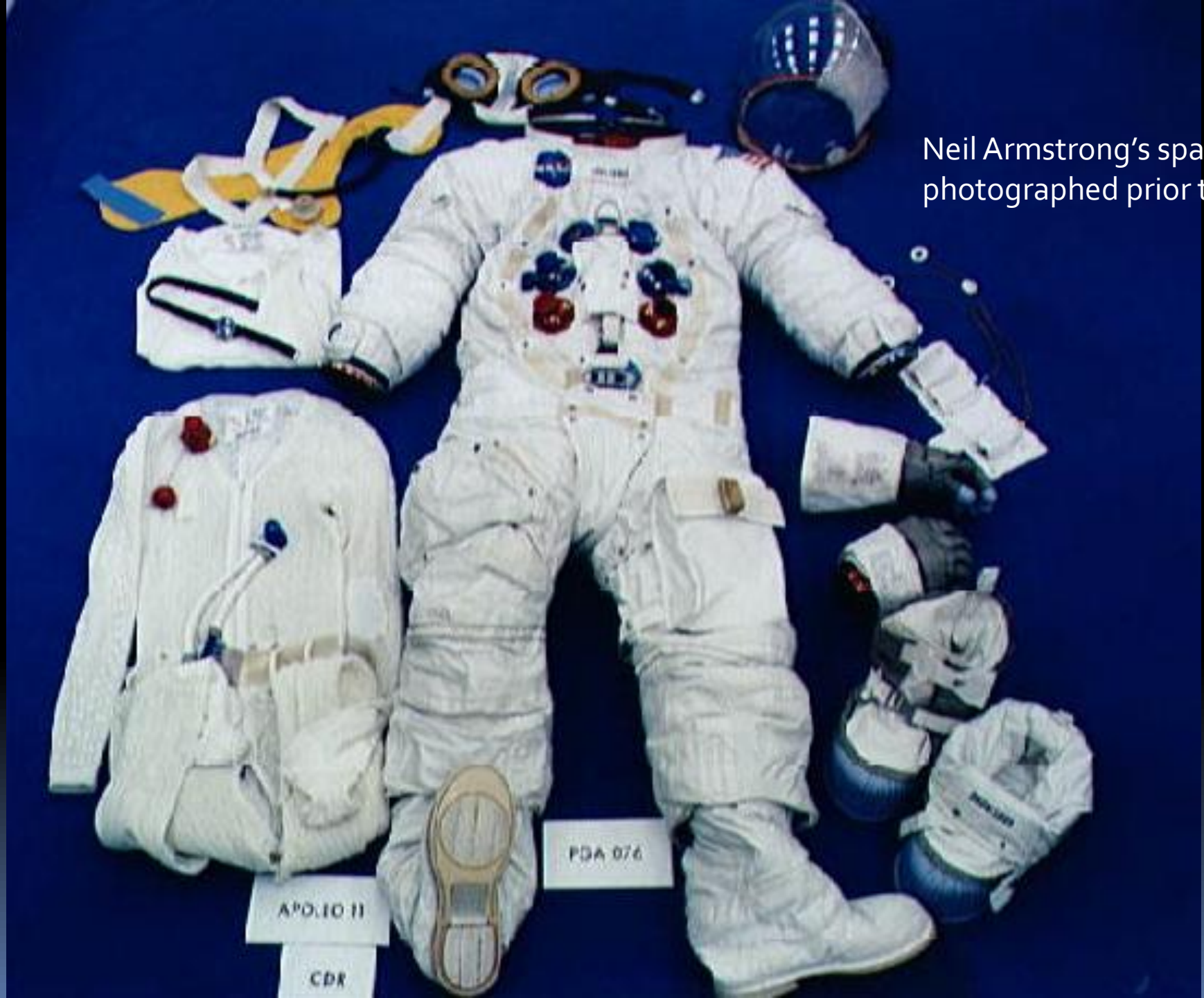
A7L As flown on Apollo 11-14



A7L b As flown on Apollo 15-17



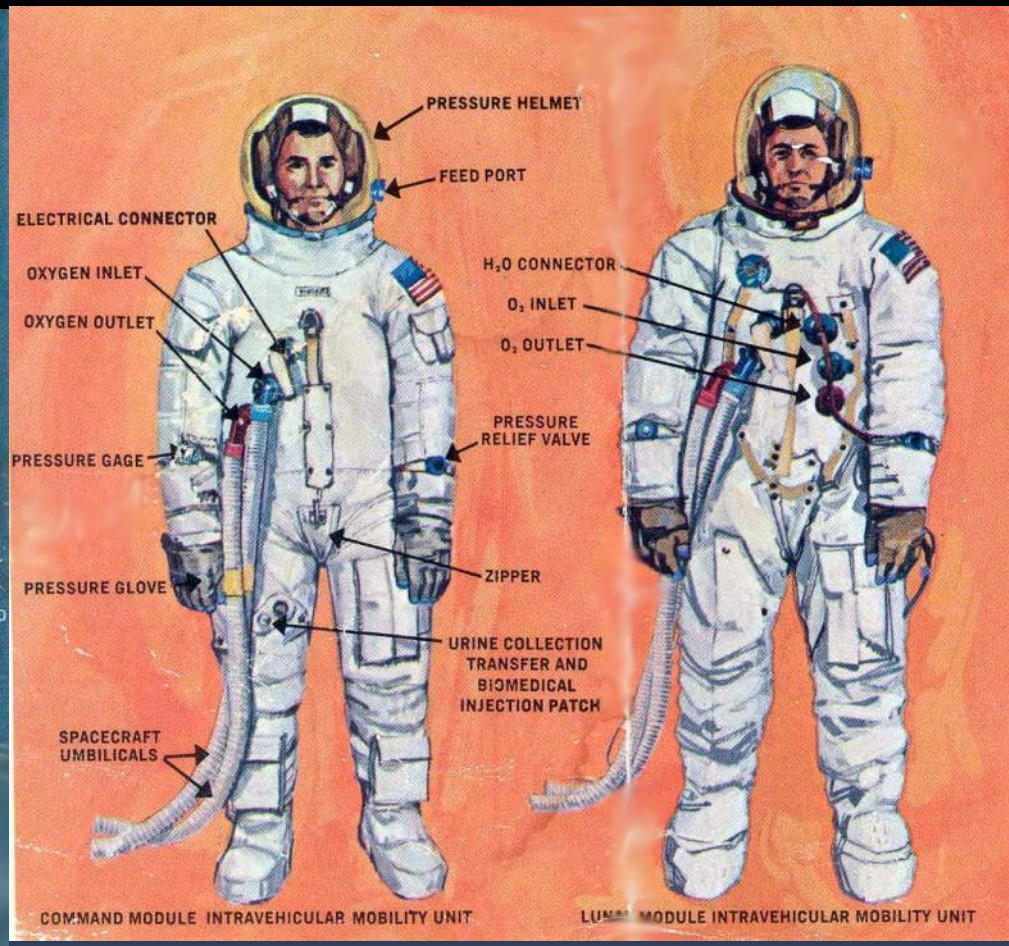
Components of the Apollo EMU System



Neil Armstrong's spacesuit photographed prior to flight

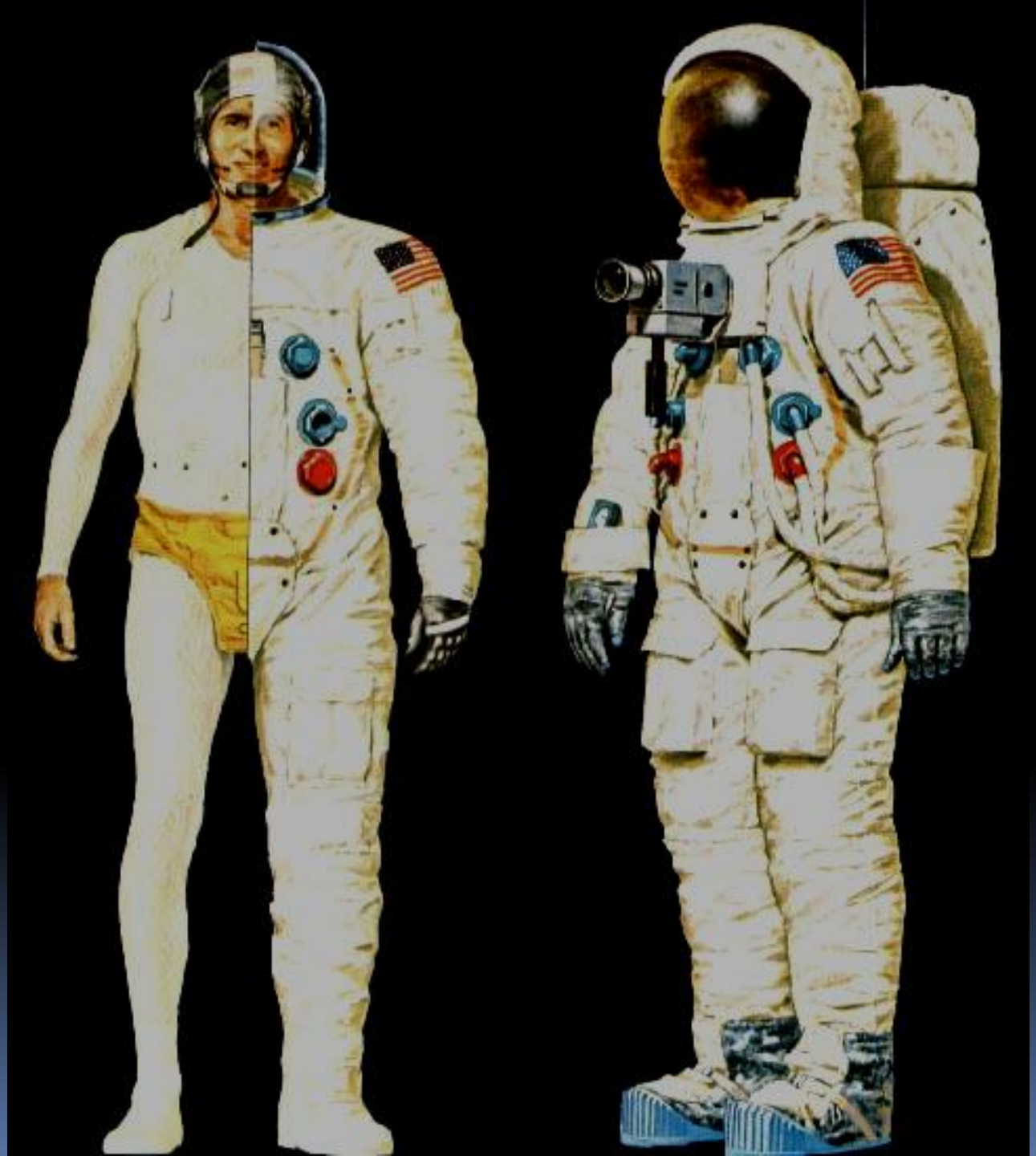
Normal intravehicular garment

Undergarments



Suit for intravehicular (Command Module Pilot) use

Suit for extravehicular ((lunar surface) use



Specification Requirements for the Apollo Lunar Surface EMU Portable Life Support System

Duration (maximum)	4 hours
Metabolic rate:	
Average (3 hours)	1,600 Btu/hr (403 kcal/hr)
Average (4 hours)	1,200 Btu/hr (302 kcal/hr)
Average (6 hours)	930 Btu/hr (234 kcal/hr)
Peak	2,000 + Btu/hr (504 + kcal/hr)
Total useful heat removal capability	5,550 Btu (1,399 kcal)
Gas flow rate	6 CFM 170 litres/min)
Liquid flow rate	4 lb (1.8 kg) per minute
Weight	50 lb (22.7 kg)
Overall dimensions	8.4 × 16.6 × 27.2 in. (213 × 422 × 691 mm)
Power source: Battery	33 watts, rechargeable silver-zinc
Expendables:	
O_2 storage pressure	850 psi (57.8 atm)
O_2 storage quantity (recharge)	1.0 lb (0.5 kg)
Water storage quantity (recharge)	7.5 lb (3.4 kg)
LiOH quantity	2.7 lb (1.2 kg)
Contaminant control cartridge wt	4.5 lb (2.0 kg)

Table 6.7.1. Lunar Module crew extravehicular suit materials.

Material	Function
Teflon-coated yarn Beta fiberglass fabric	Fire protection (completely nonflammable in oxygen atmosphere)
Aluminized Kapton/Beta marquisette (super-insulation)	Aluminized Kapton for reflective insulation. Beta fiberglass serves as spacer separating reflective surfaces.
Aluminized Mylar film	Reflective insulation
Non-woven Dacron	Spacer material
Neoprene-coated nylon	Inner liner of the thermal outer garment
Nylon fabric	Restraint (outer) layer of the pressure suit
Neoprene-coated nylon	Bladder material serves as an impermeable layer containing suit pressurization oxygen
Lightweight Nomex fabric	Comfort liner

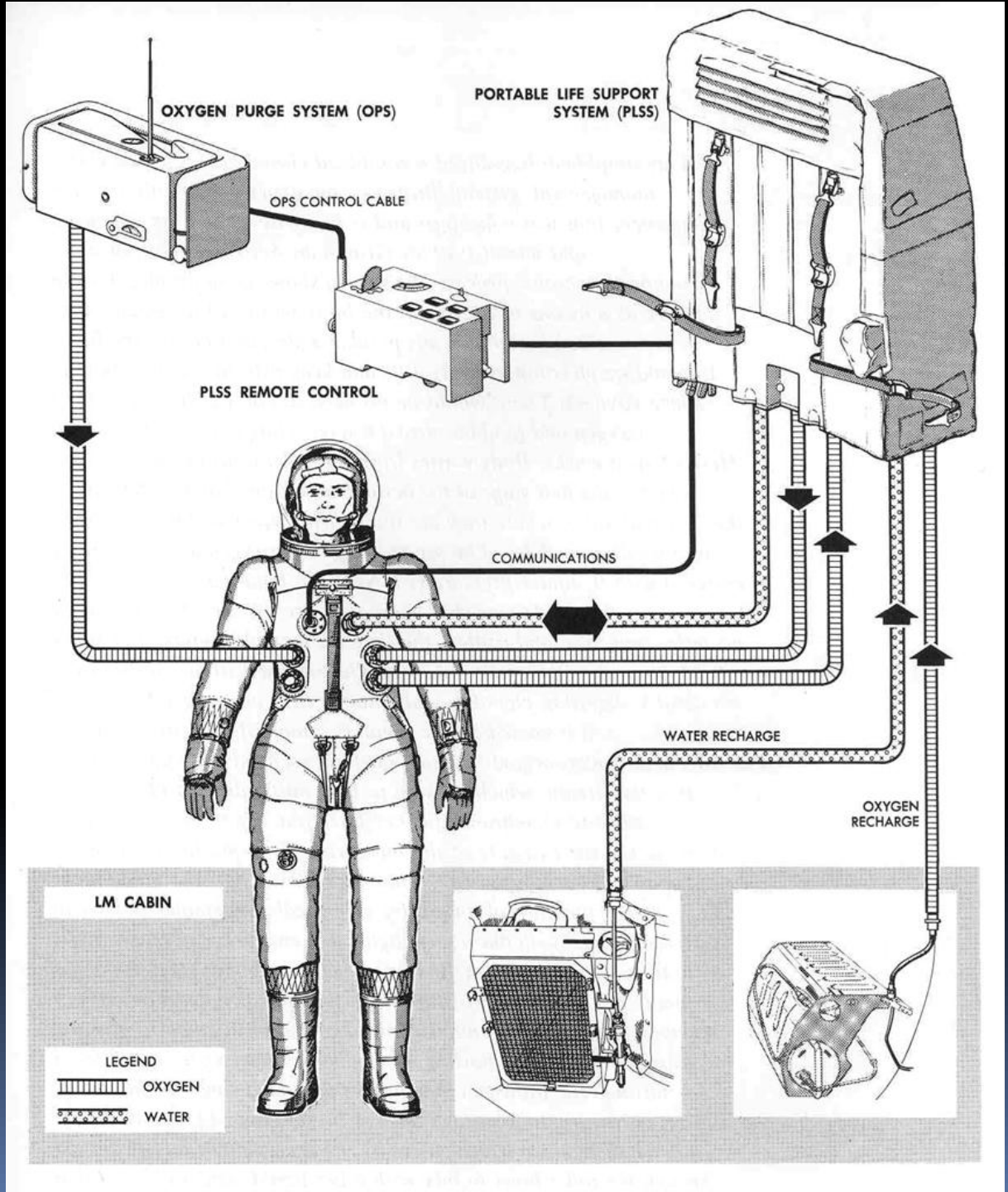
Table 6.7.2. Liquid-cooled garment materials.

Material	Function
Nylon Spandex Mesh	Retains tubing close to skin
Polyvinyl chloride (PVC) tubing*	Water distribution for cooling
Porous lightweight nylon	Comfort layer

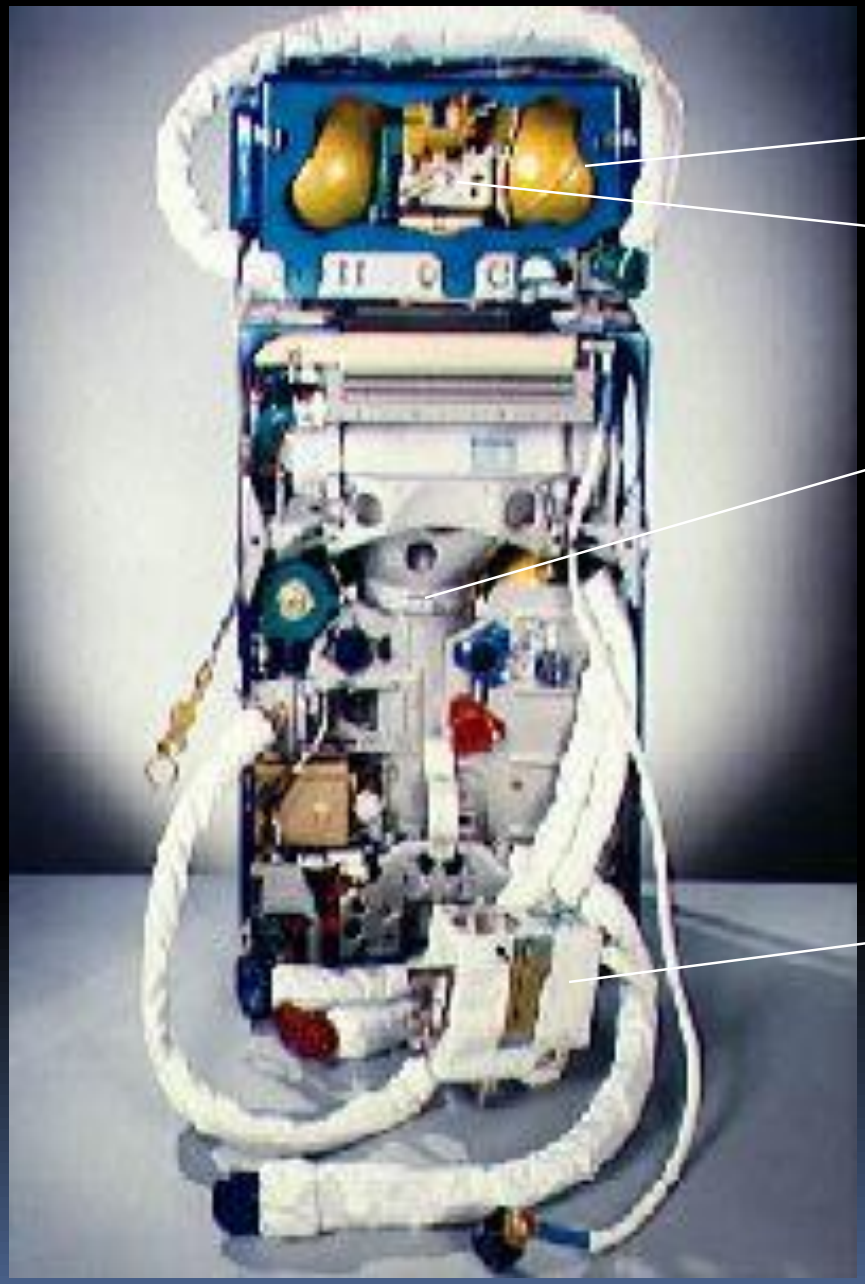
* The PVC tubing in the Apollo liquid-cooling garments was a PVC that contained a plasticizer to make the tubing soft enough to bend. While this worked well for the Apollo program, the plasticizer caused filter clogging in the Shuttle EMU program and posed problems for long-term preservation of Apollo spacesuits and components as historical artifacts.

Table 6.7.3. Command Module Pilot's suit materials.

Material	Function
Teflon-coated yarn Beta fiberglass fabric	Fire protection (completely nonflammable in oxygen atmosphere)
Nomex (high-temperature nylon)	Snag and fire protection
Aluminized Kapton/Beta marquisette (super-insulation)	Aluminized Kapton for reflective insulation. Beta fiberglass serves as spacer separating reflective surfaces
Aluminized Mylar film	Reflective insulation
Non-woven Dacron	Spacer material
Neoprene-coated nylon	Inner liner of the thermal outer garment
Nylon fabric	Restraint (outer) layer of the pressure suit
Neoprene-coated nylon	Bladder material serves as an impermeable layer containing suit pressurization oxygen
Lightweight Nomex fabric	Comfort liner


OXYGEN PURGE SYSTEM (OPS)
PORTABLE LIFE SUPPORT SYSTEM (PLSS)
OPS CONTROL CABLE
PLSS REMOTE CONTROL
COMMUNICATIONS
WATER RECHARGE
OXYGEN RECHARGE
LM CABIN
LEGEND
OXYGEN
WATER

Apollo Portable Life Support System(PLSS) with outer cover removed

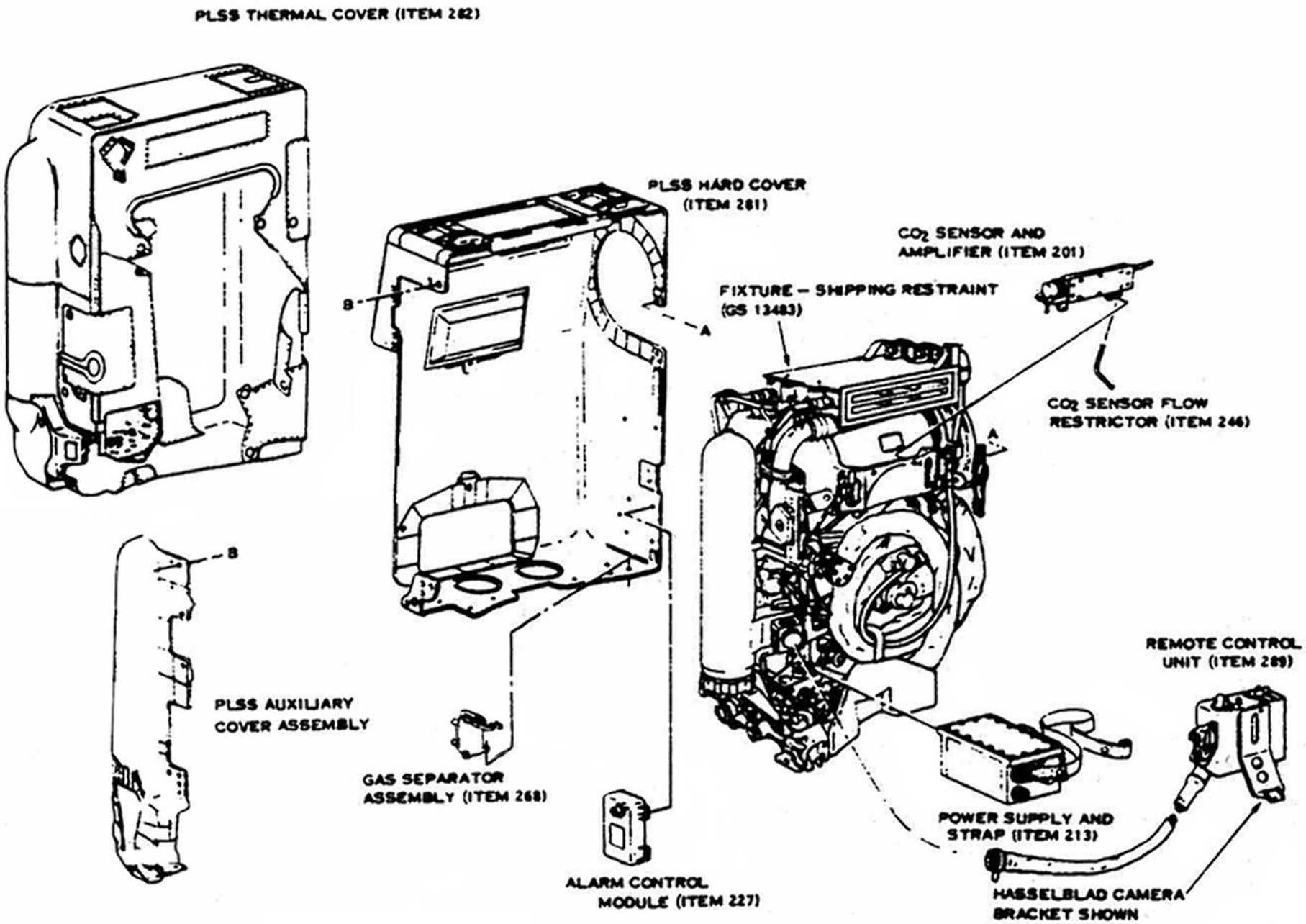


Oxygen Purge System (used for emergencies)

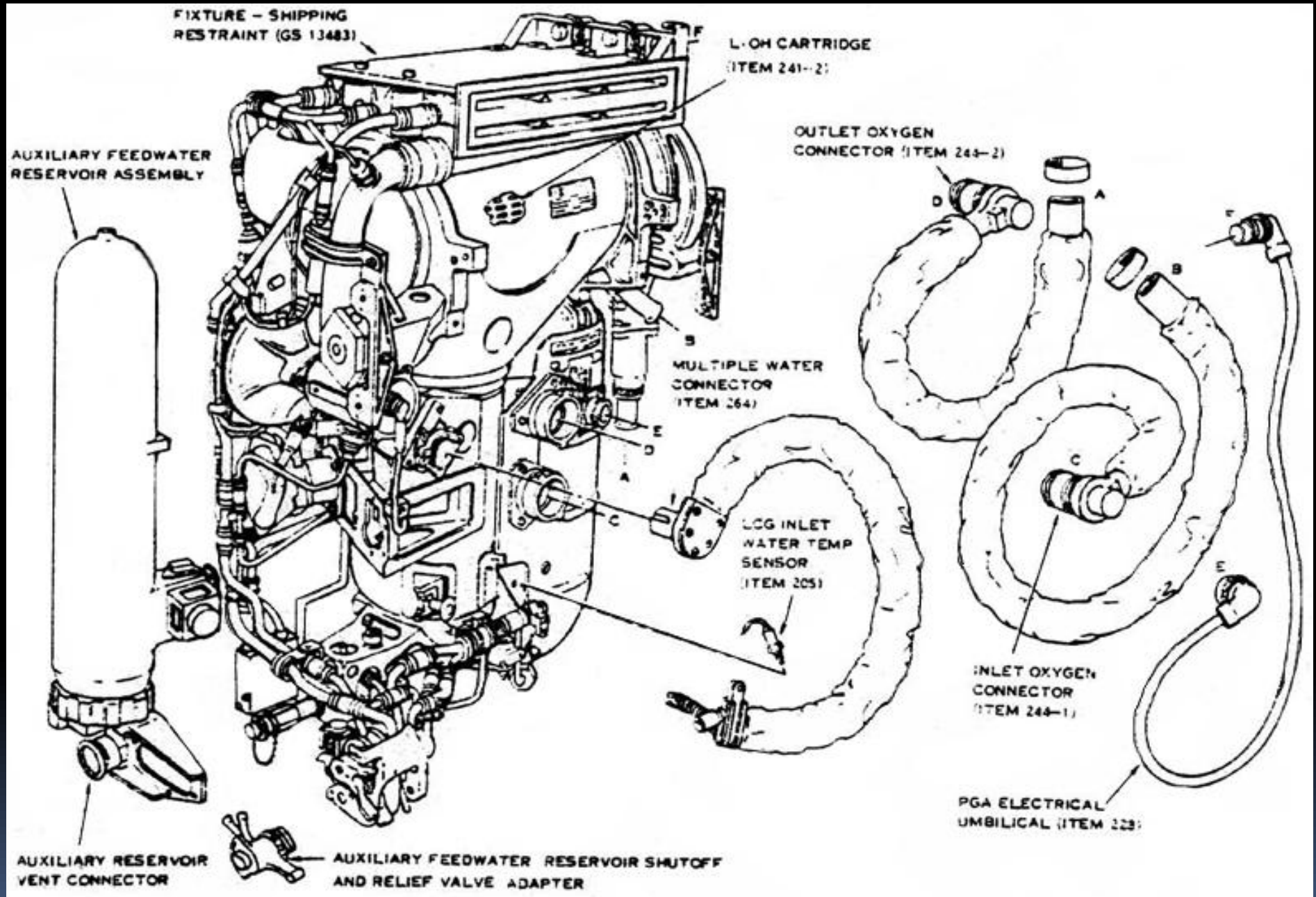
Radio/communications equipment

Primary oxygen system

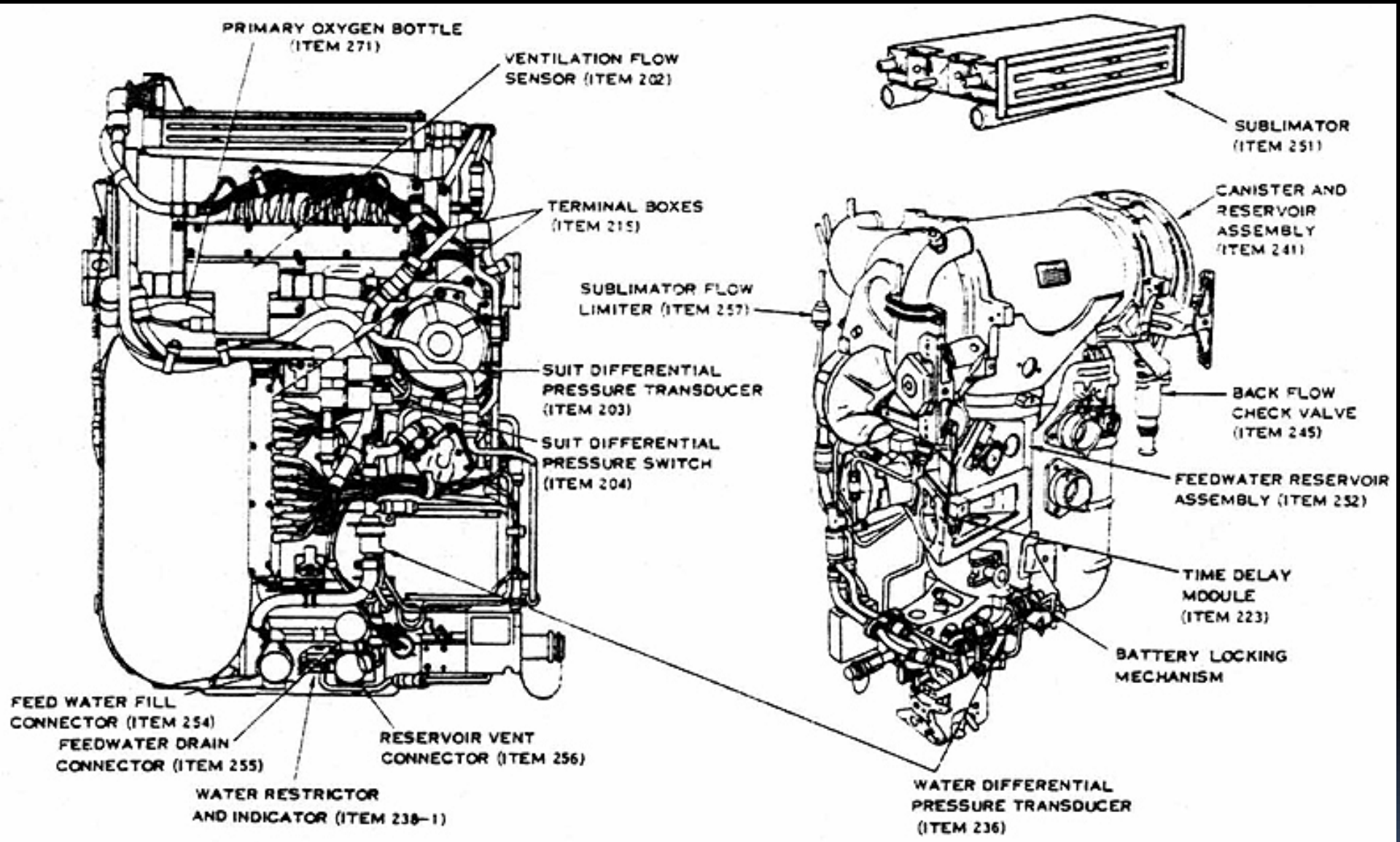
Remote Control Unit



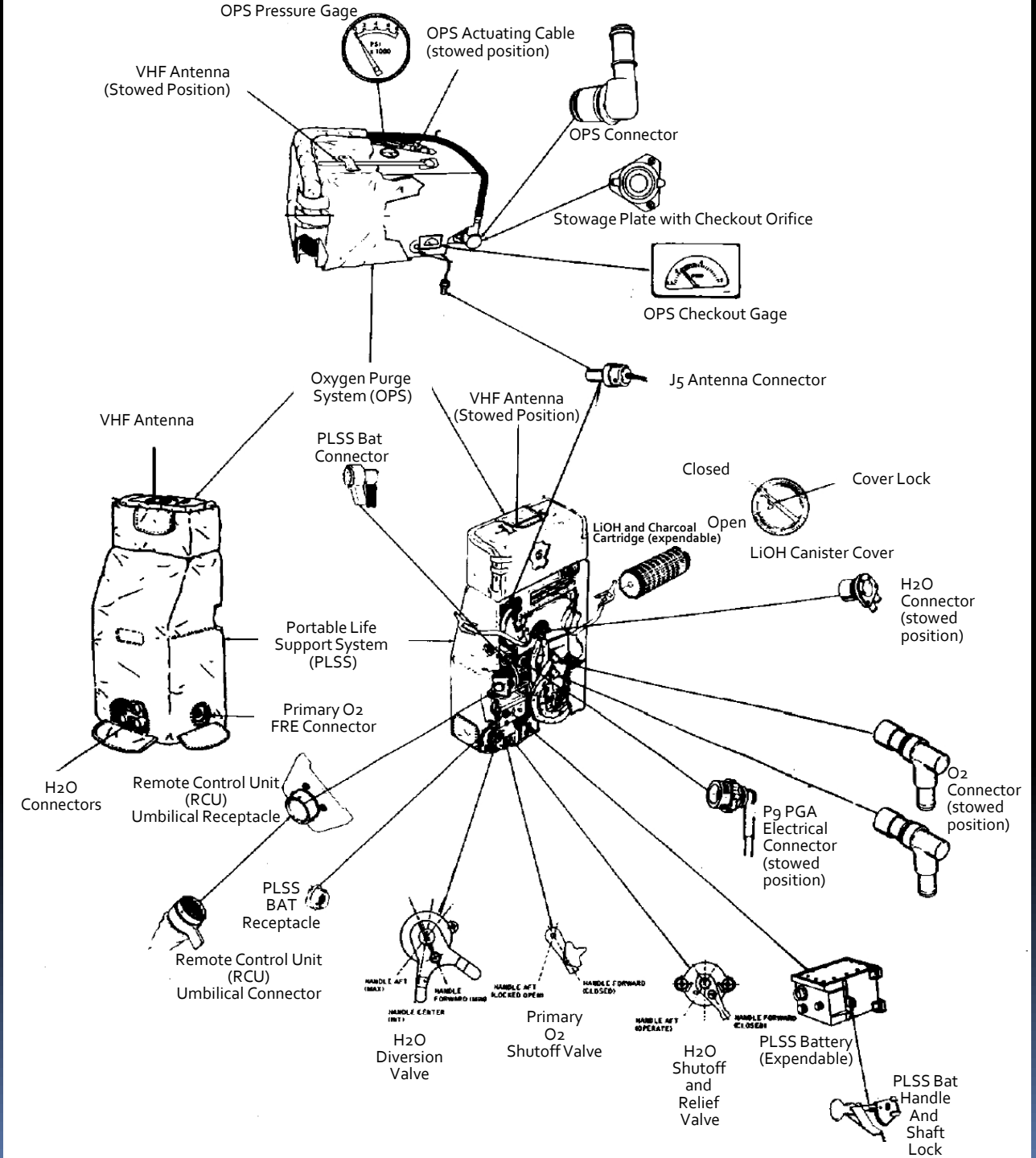
Apollo EMU PLSS Equipment

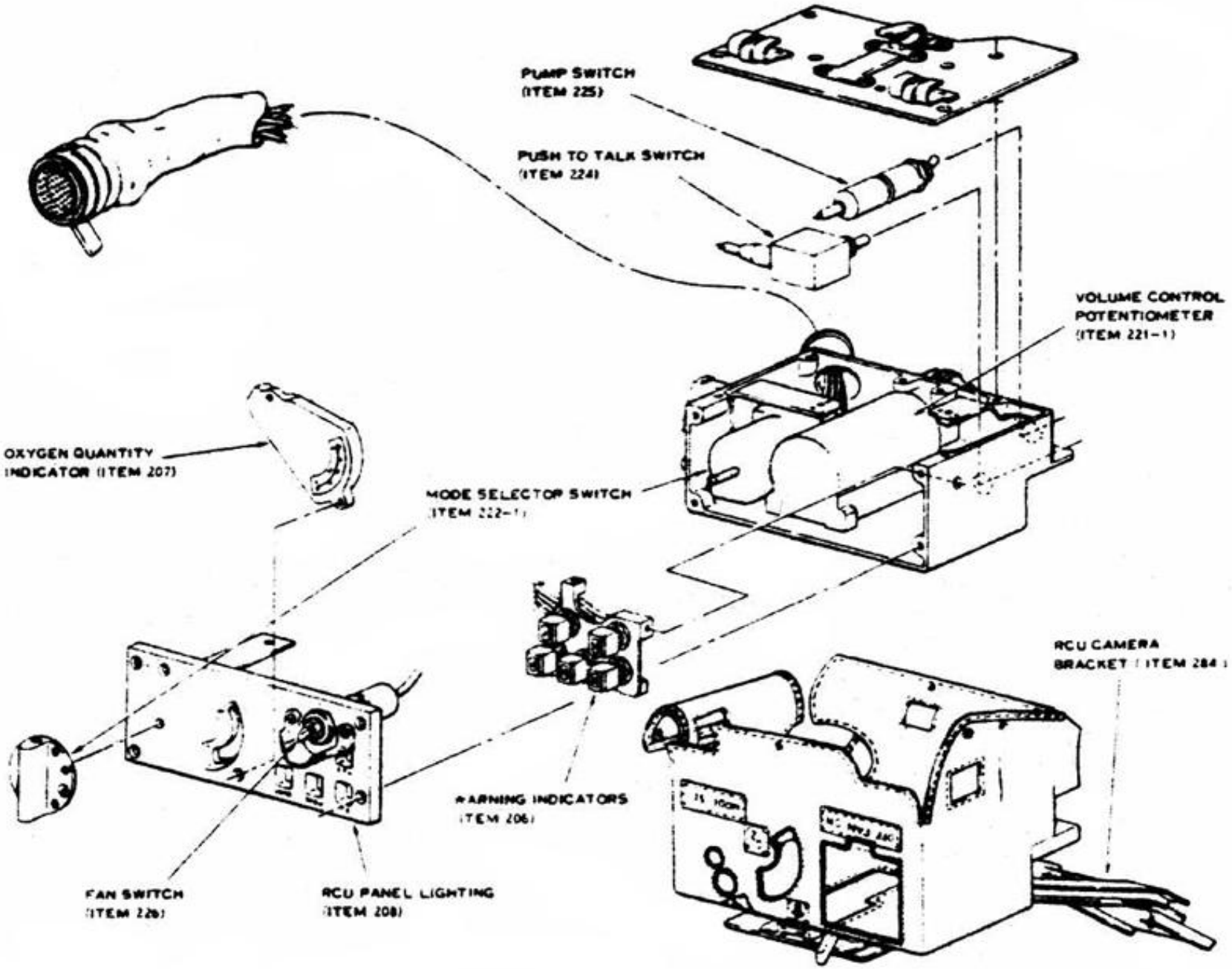


Apollo EMU PLSS Equipment

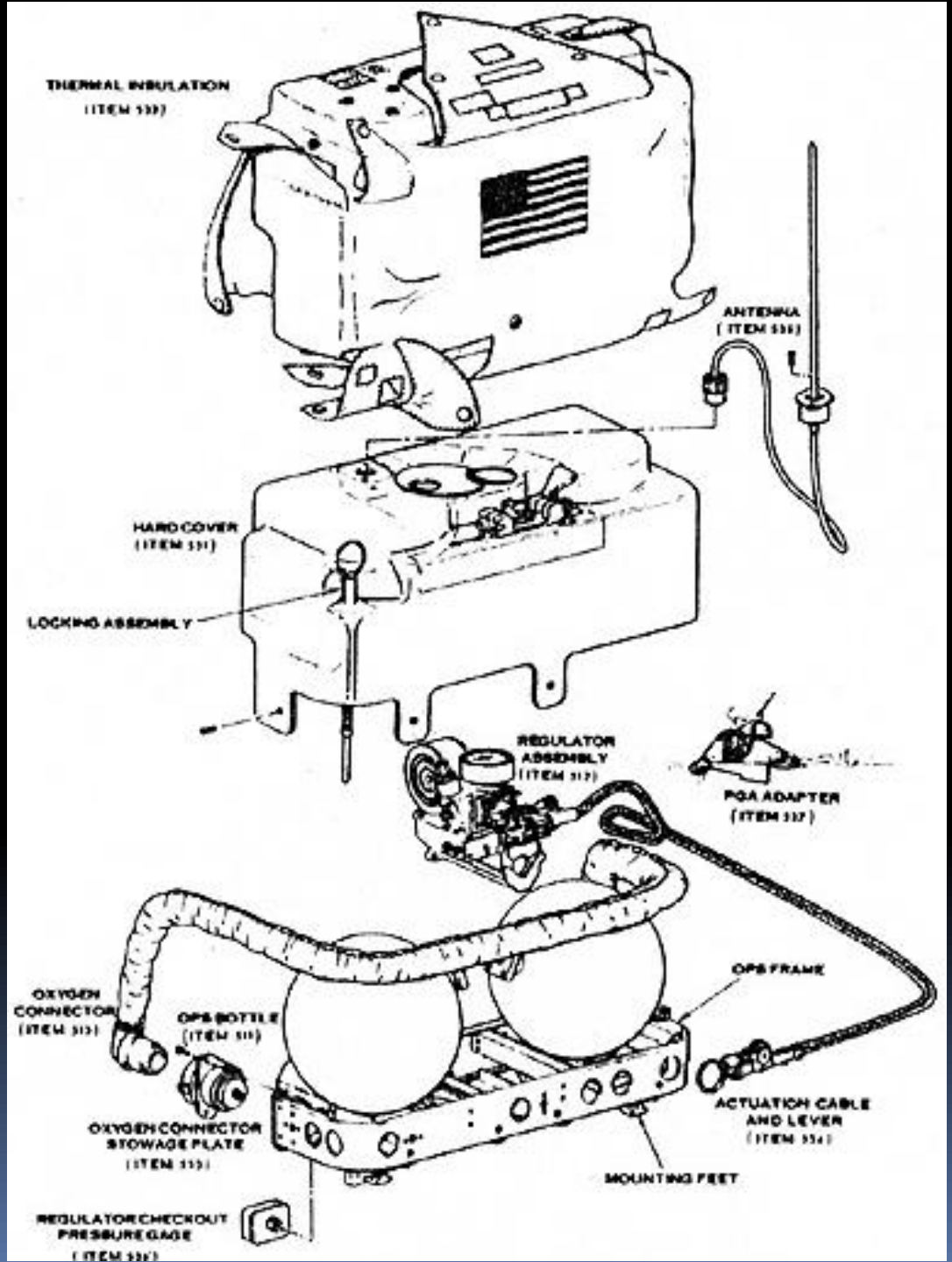


Apollo EMU PLSS Equipment

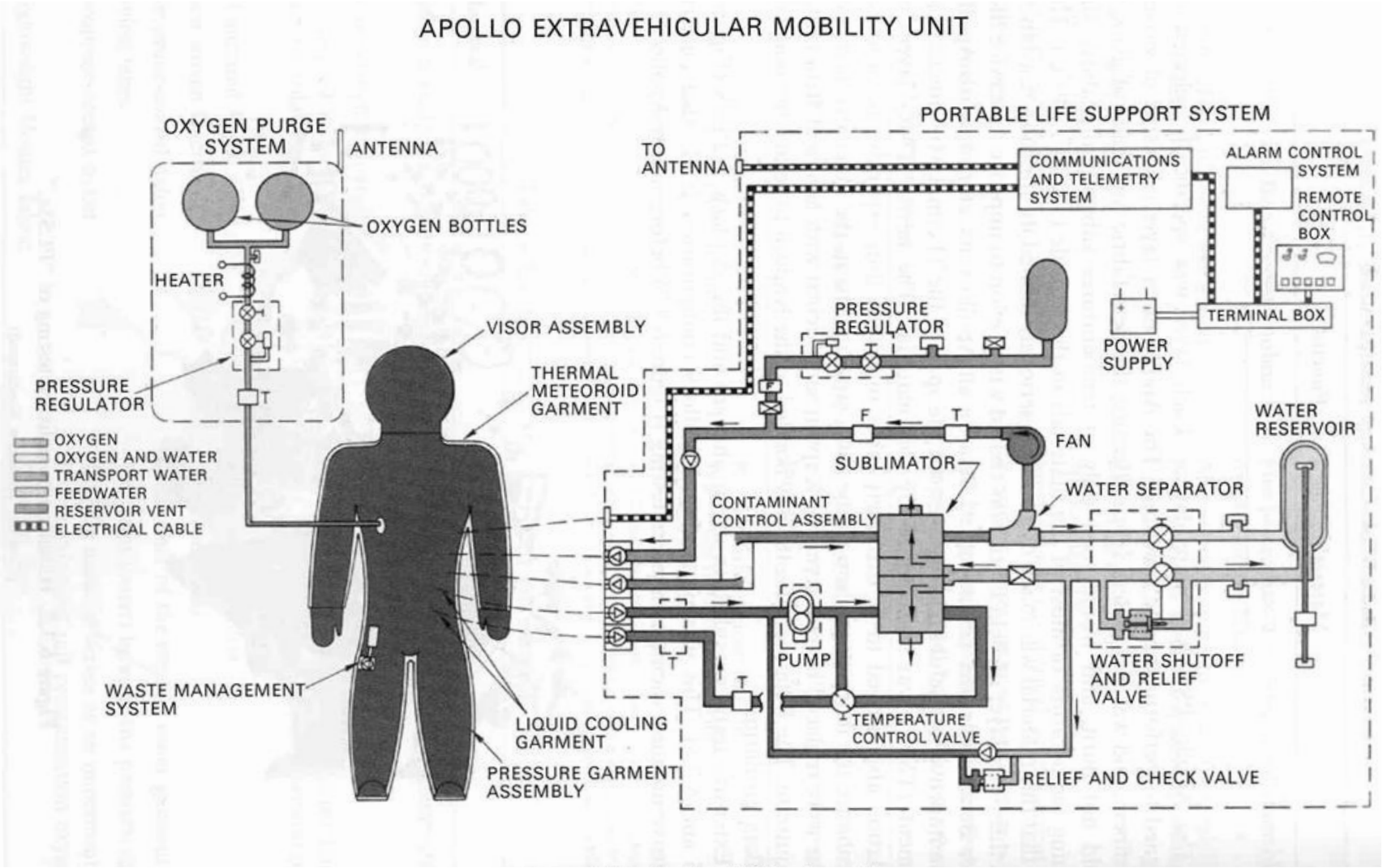

OPS Pressure Gage
OPS Actuating Cable (stowed position)
VHF Antenna (Stowed Position)
OPS Connector
Stowage Plate with Checkout Orifice
OPS Checkout Gage
Oxygen Purge System (OPS)
J5 Antenna Connector
VHF Antenna
VHF Antenna (Stowed Position)
PLSS Bat Connector
Closed
Cover Lock
Open
LiOH and Charcoal Cartridge (expendable)
LiOH Canister Cover
H2O Connector (stowed position)
Portable Life Support System (PLSS)
Primary O2 FRE Connector
H2O Connectors
Remote Control Unit (RCU) Umbilical Receptacle
O2 Connector (stowed position)
P9 PGA Electrical Connector (stowed position)
PLSS BAT Receptacle
Remote Control Unit (RCU) Umbilical Connector
H2O Diversion Valve
Primary O2 Shutoff Valve
H2O Shutoff and Relief Valve
PLSS Battery (Expendable)
PLSS Bat Handle And Shaft Lock



Remote Control Unit



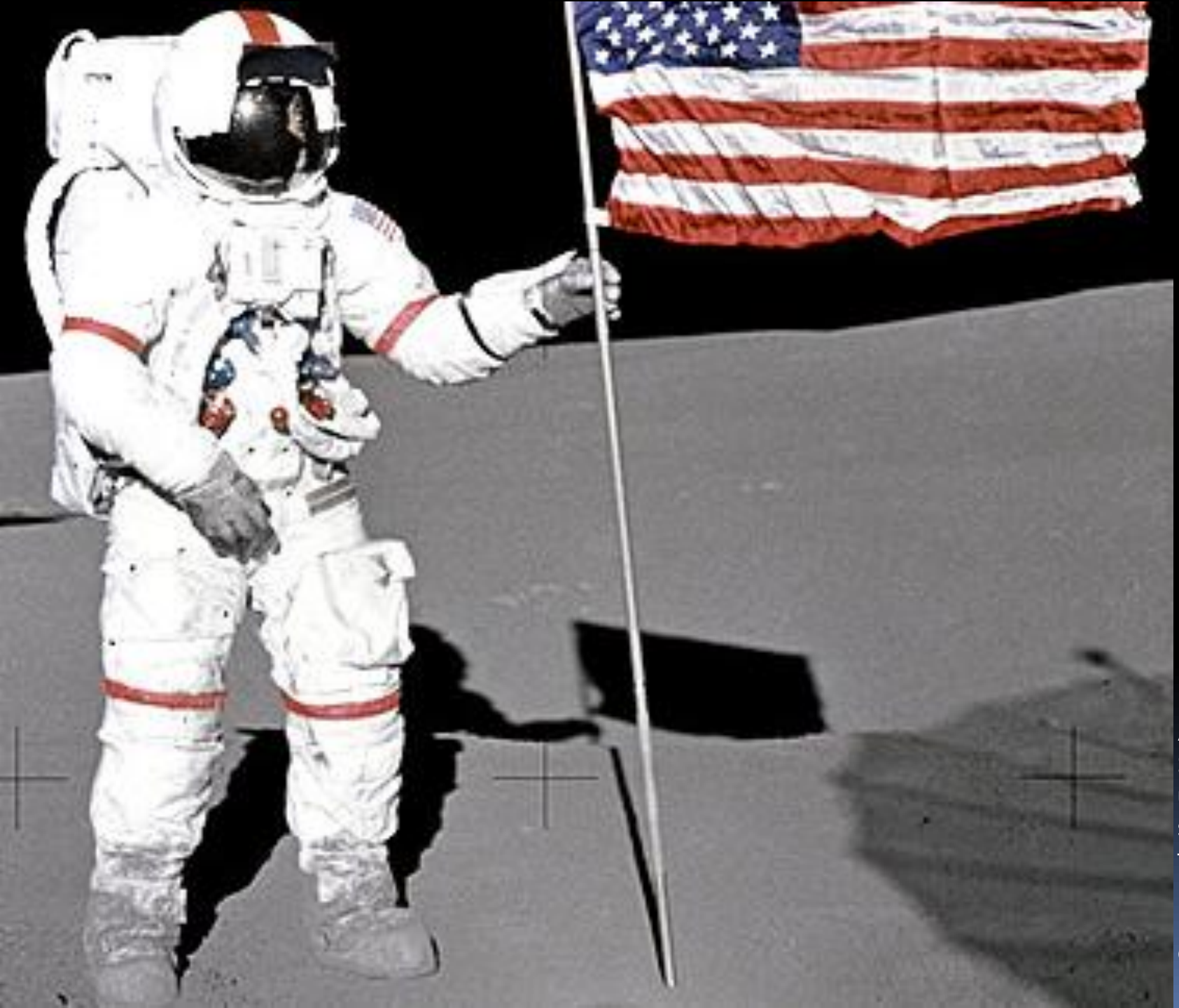
Oxygen Purge System



Apollo Portable Life Support System Schematic

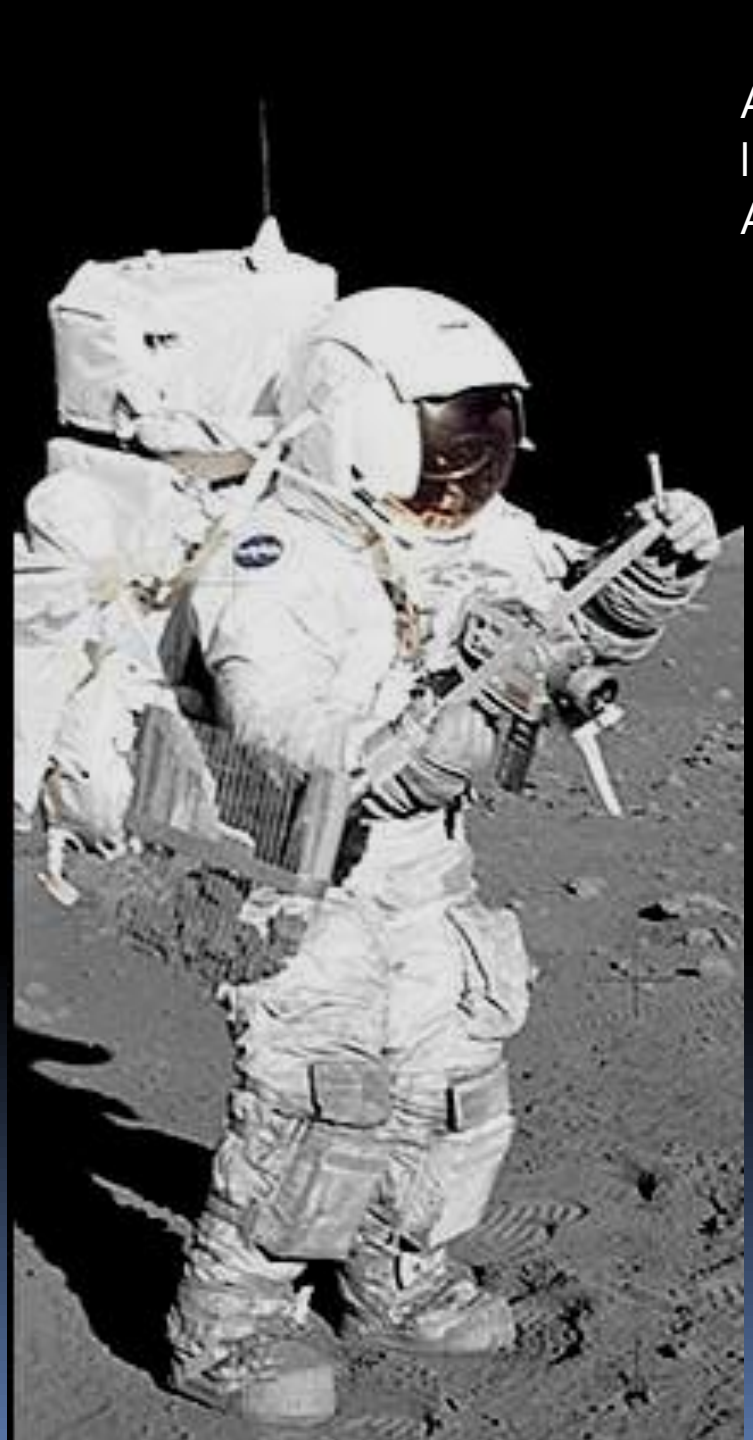
Pre-mission
Apollo 11 training

Apollo 11,
Aldrin



Apollo 14, Shepard, used A7L suit similar to Apollo 11-13 but with later A7Lb outer helmet layer

A7Lb suit on last lunar mission Apollo 17



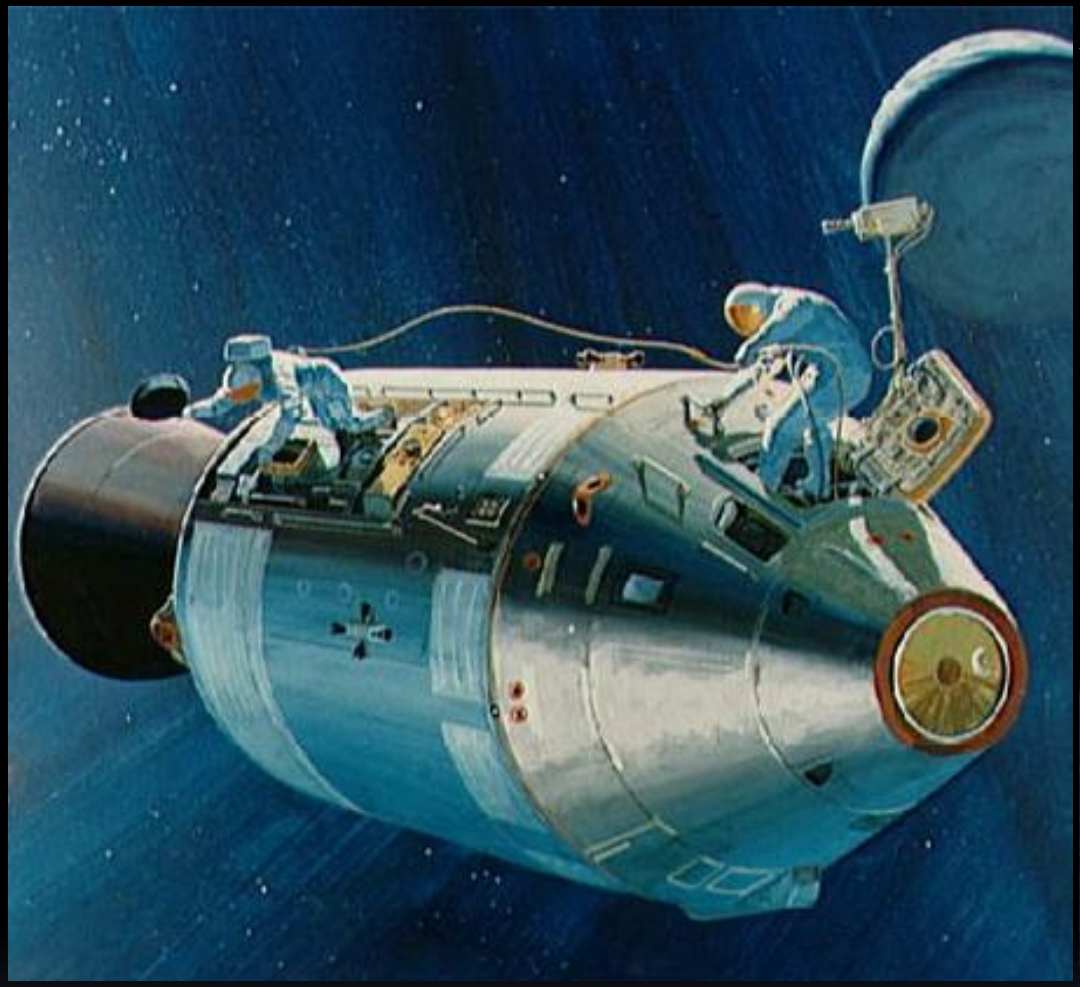
Schmitt

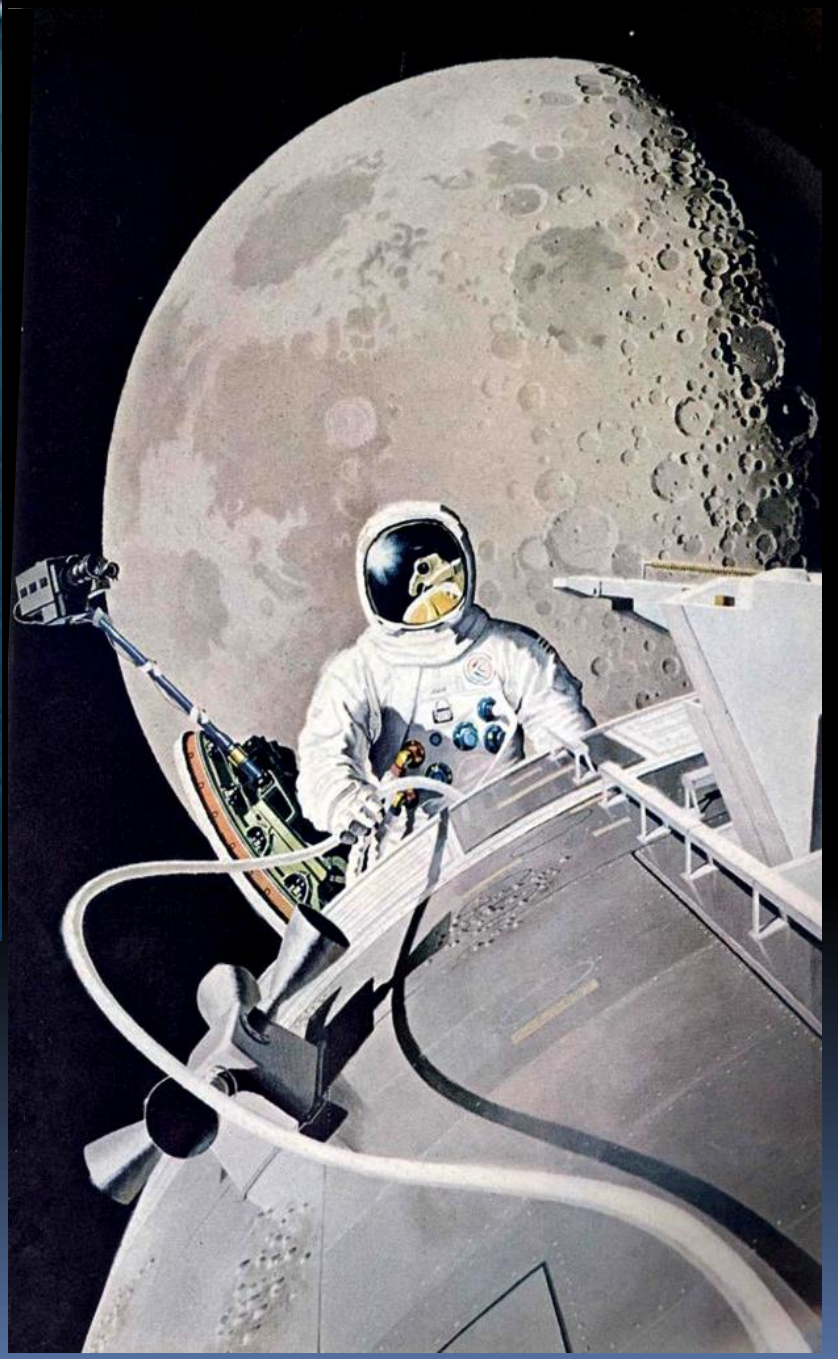
Cernan

Apollo 11
A7L
(Armstrong)

Apollo 15
A7Lb
(Scott)

Close up details and X-ray of Lunar EVA Gloves





Renderings,
Apollo 15 trans-earth EVA