Extravehicular Activity 1

- Full pressure suits and high-altitude aviation
- Early human space program
- Operational suits

Spacesuit Functional Requirements

A suit has to

- Provide thermal control
- Provide a breathable atmosphere
- Hold its shape
- Move with the wearer
- Protect against external threats
- Provide communications and data interactions

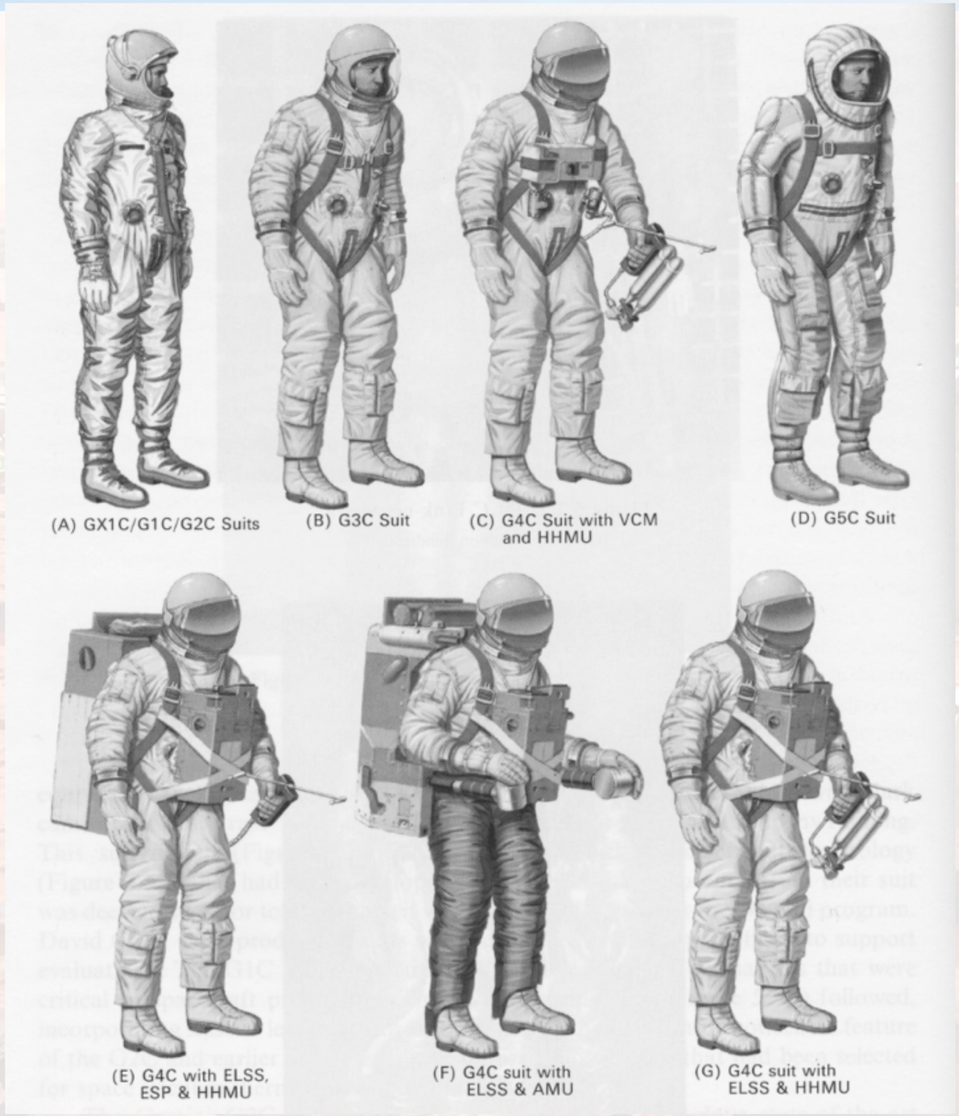
Wiley Post - B. F. Goodrich, 1934

“Tomato Worm” Suits - c. 1940

XMC-2 Full Pressure Suit (ILC - 1955)

Mercury Space Suits

Gemini Pressure Suits



Grumman Lunar Suit Concept - 1962

JHU Suit Concept (1964)

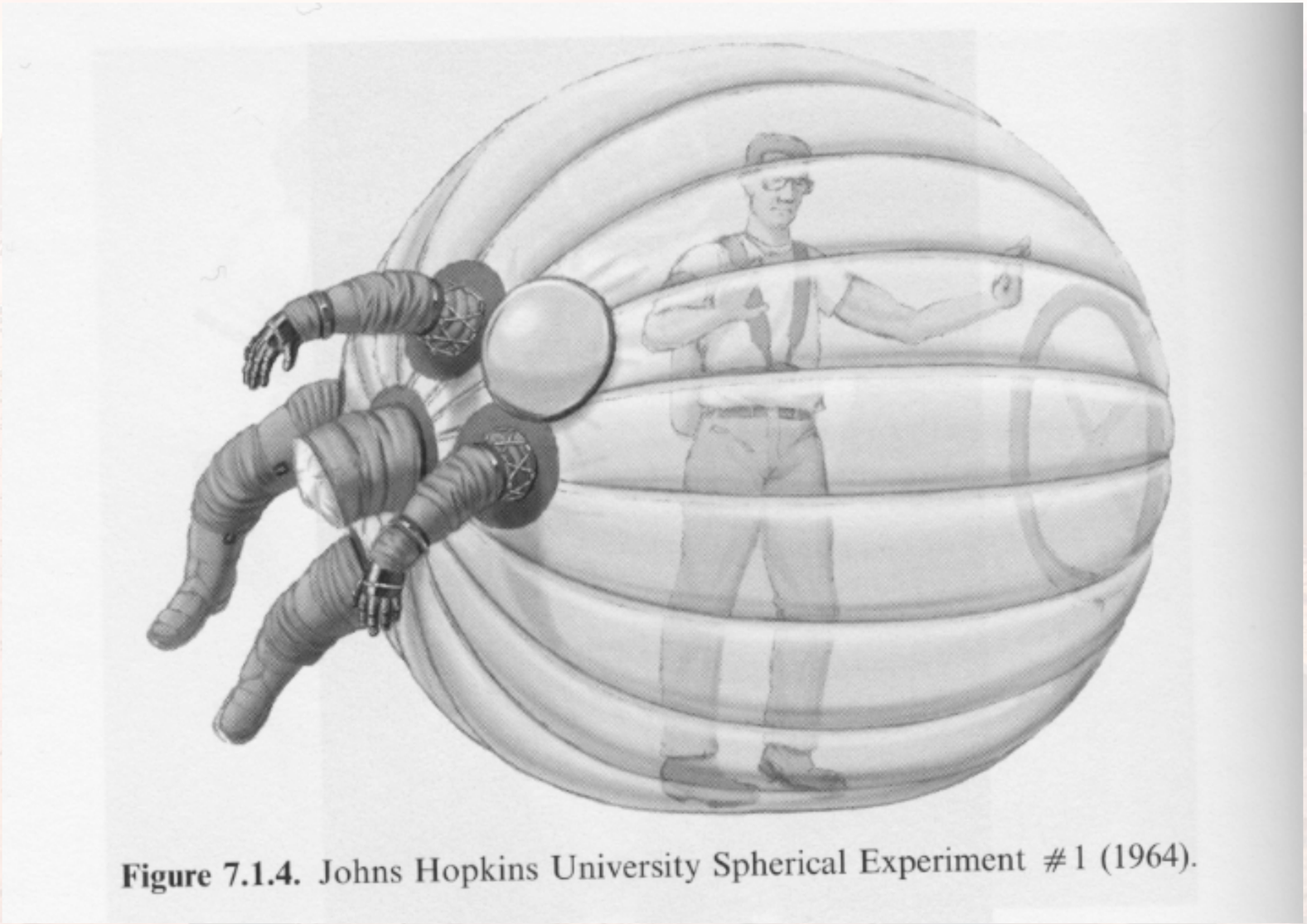
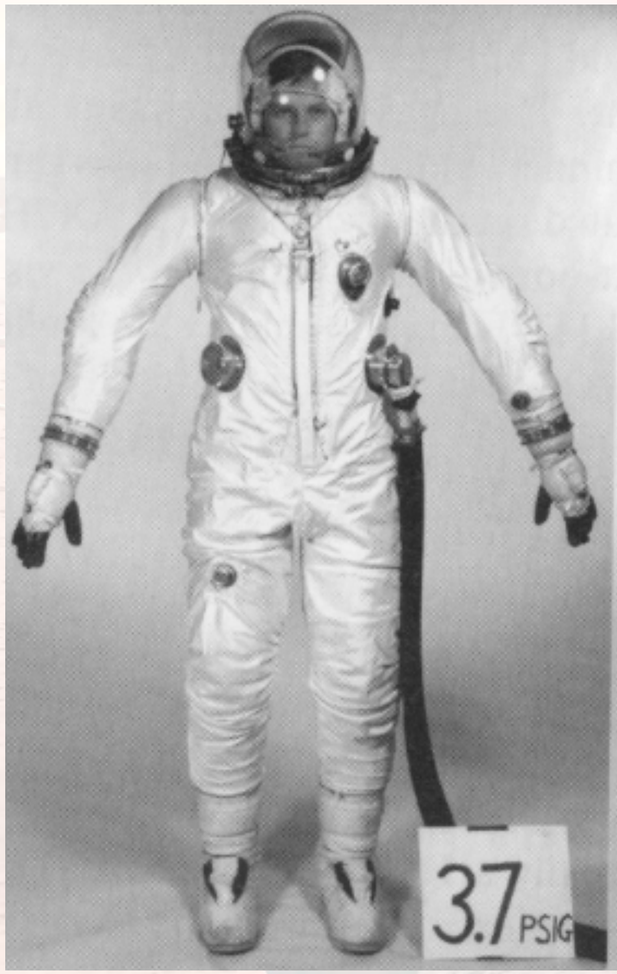


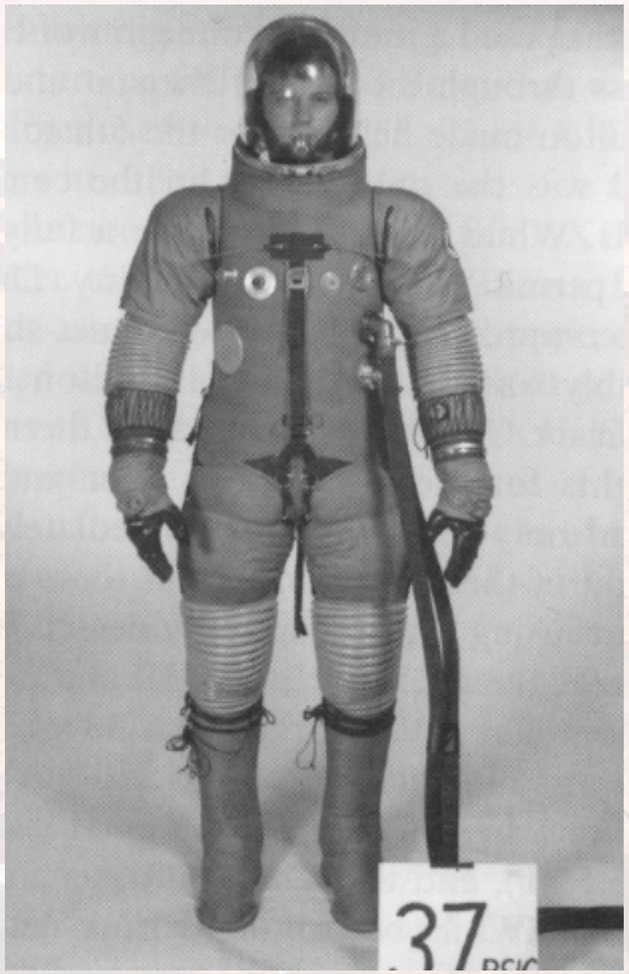
Figure 7.1.4. Johns Hopkins University Spherical Experiment #1 (1964).

Apollo Suit Contest



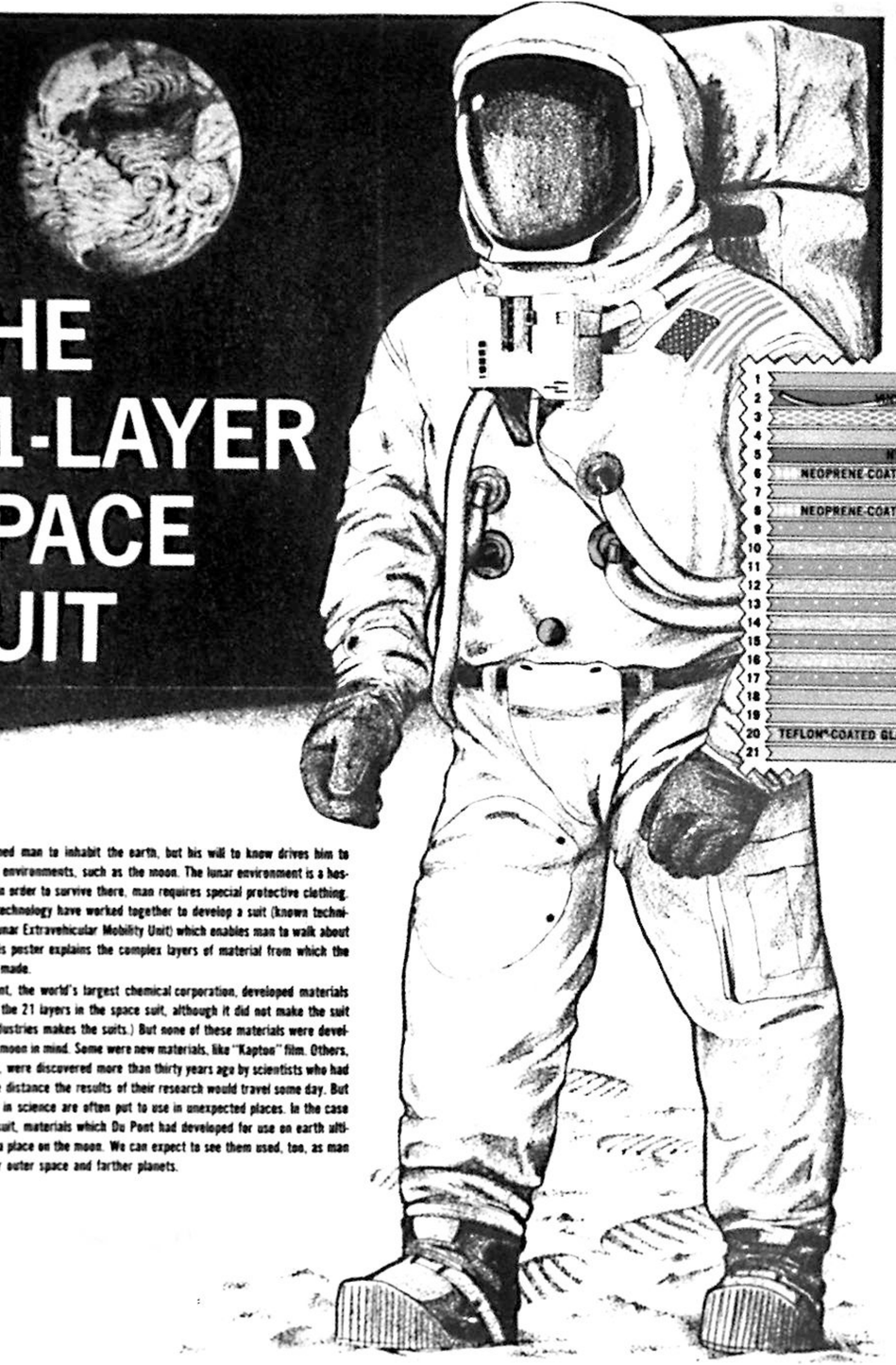
AX1C

AX6H



AX5L

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

NYLON

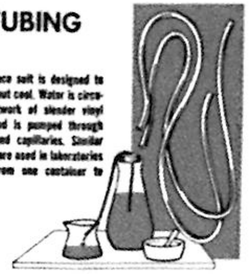
LAYER 1

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 made 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

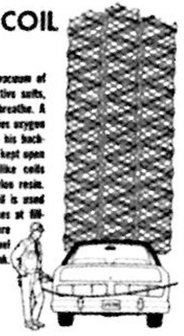
"NOMEX" NYLON YARNS

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 no-scorch 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 torpaulins that protect football and baseball fields, and for large 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 resistant 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 five layers of "Mylar" as a kind of insulating "sandwich" to protect the spacemen against heat and cold.

KAPTON®

LAYERS 18, 19

"KAPTON" POLYIMIDE FILM

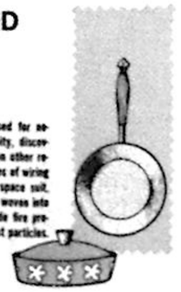
Du Pont announced "Kapton" in 1964. Two aluminized layers protect the astronaut from extremes in temperatures, 330° F. in moon day to minus 250° F. in moon night. "Kapton" was chosen because it will not shrink, melt, or burn at high temperatures, even when as thin as one one-thousandth of an inch. It 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 FINISH

"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 greaseless 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 50% of the space suit is covered with this special fabric.

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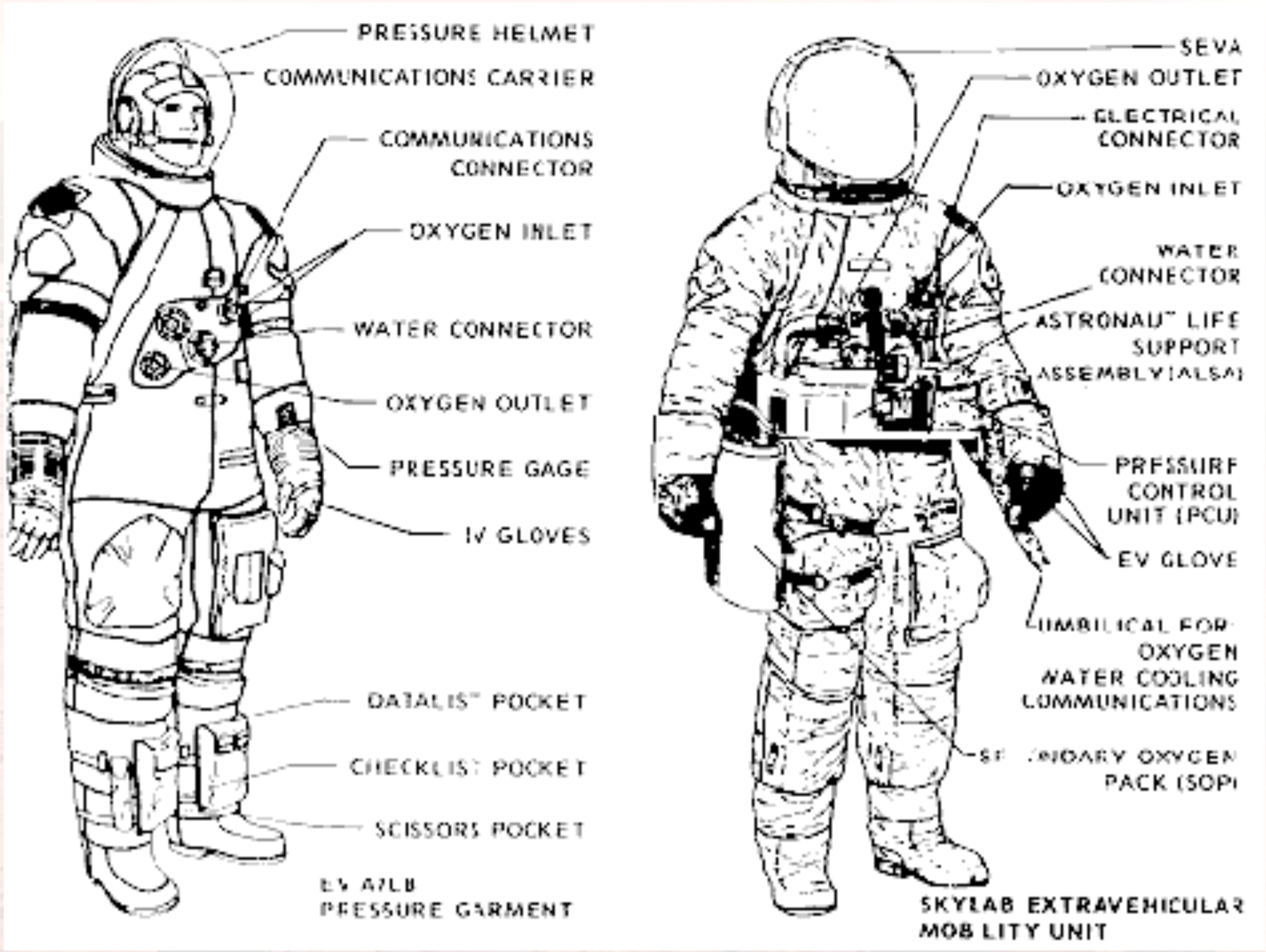
Skylab A7L-B


PRESSURE HELMET
COMMUNICATIONS CARRIER
COMMUNICATIONS CONNECTOR
OXYGEN INLET
WATER CONNECTOR
OXYGEN OUTLET
PRESSURE GAGE
IV GLOVES
DATALIST POCKET
CHECKLIST POCKET
SCISSORS POCKET
EVA A7LB PRESSURE GARMENT
SEVA
OXYGEN OUTLET
ELECTRICAL CONNECTOR
OXYGEN INLET
WATER CONNECTOR
ASTRONAUT LIFE SUPPORT ASSEMBLY (ALSA)
PRESSURE CONTROL UNIT (PCU)
EV GLOVE
OXYGEN
WATER COOLING
COMMUNICATIONS
PACK (SOP)
SKYLAB EXTRAVEHICULAR MOBILITY UNIT

Skylab A7L-B

A Parting of the Ways

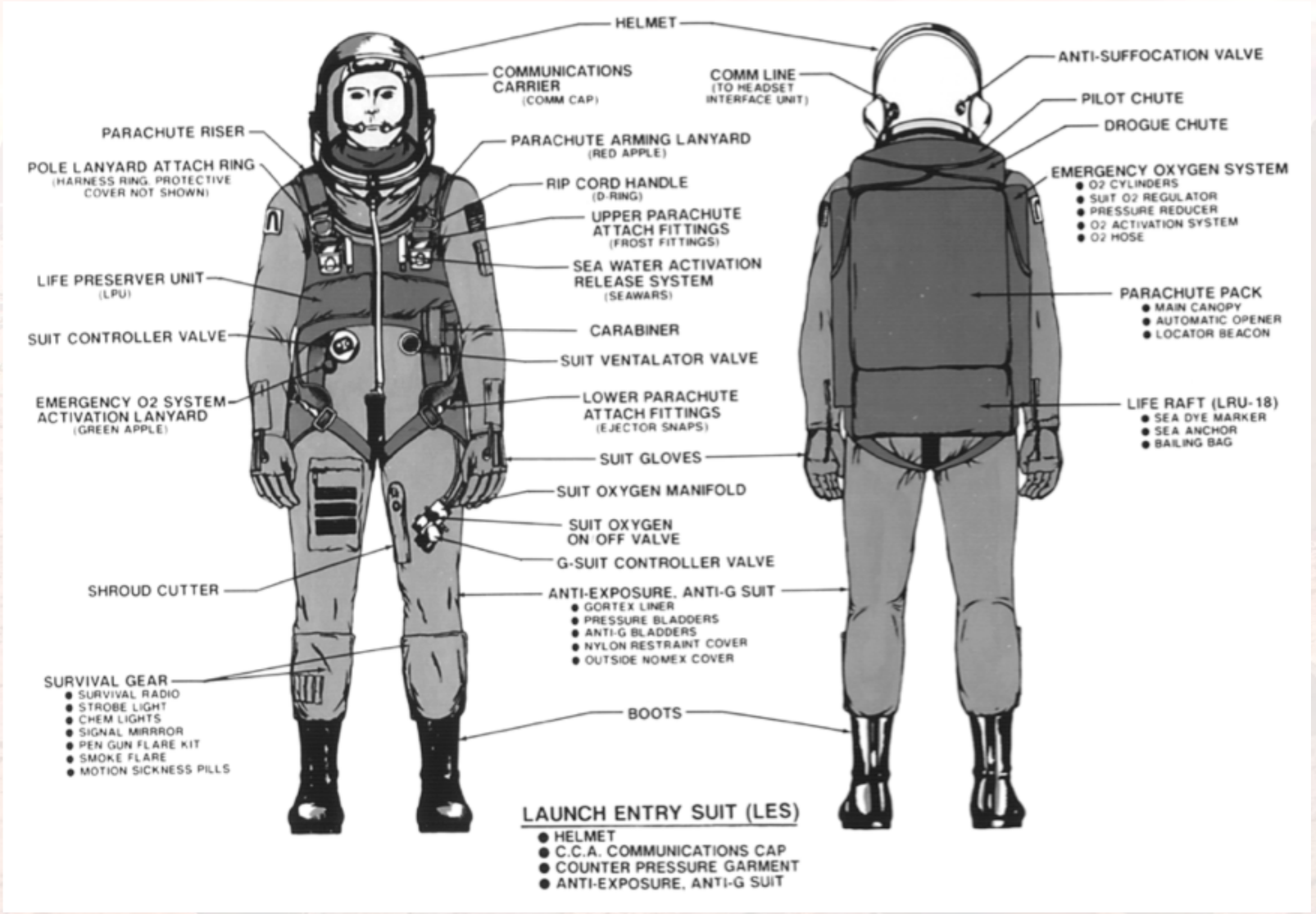
- Spacesuits through Apollo/Skylab did everything
- Shuttle onwards led to a bifurcation of suit types
  - Launch and entry suits (LES): used to protect the crew in the event of a cabin depressurization or emergency egress at launch pad; typically operated at “vent pressure” (small increment over ambient)
  - EVA suits: used for nominal external sorties in space or on planetary surfaces; have greater flexibility and protection against environmental hazards; frequently much heavier than LES

Russian Sokol Suit

Sokol Suit Entry

Advanced Crew Escape Suits (ACES)

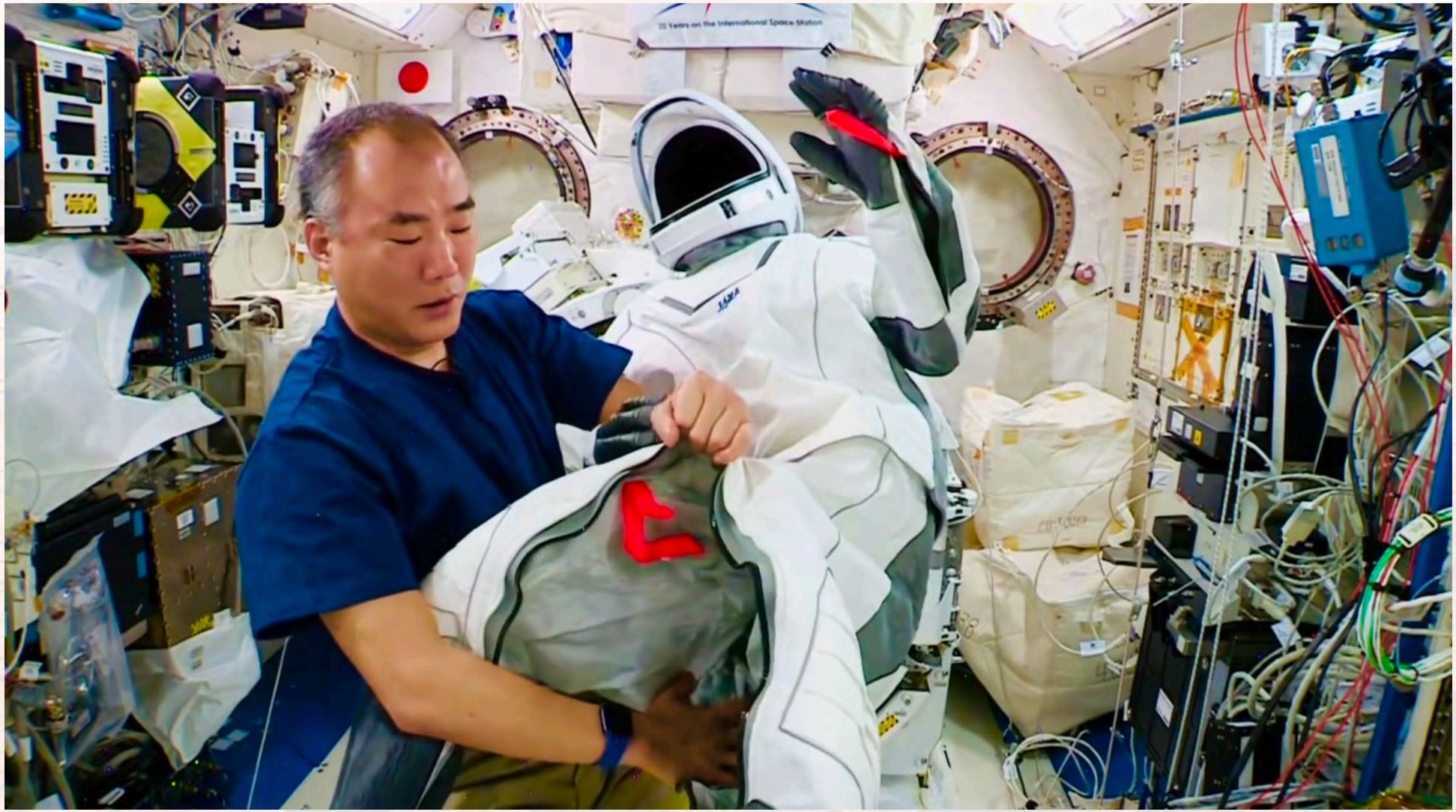
Shuttle Launch and Entry Suit (LES)



Boeing Starliner Launch & Entry Suit

SpaceX Launch & Entry Suits

SpaceX Suit Crotch Entry



SpaceX Glove Access

Extravehicular Mobility Unit (EMU)

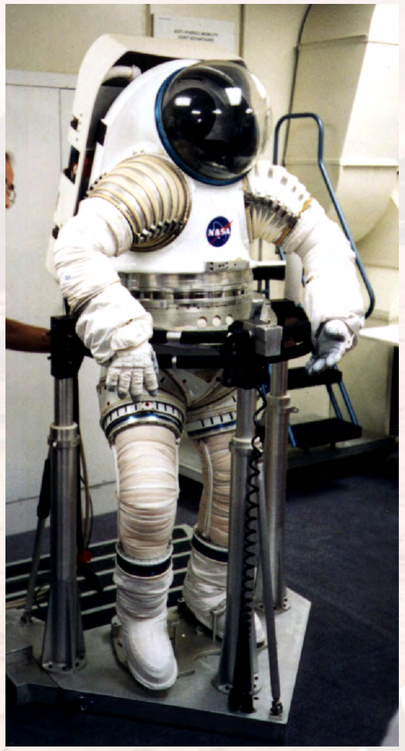
Existing Pressure Suits (c. 2000)

EMU

Hamilton-Standard

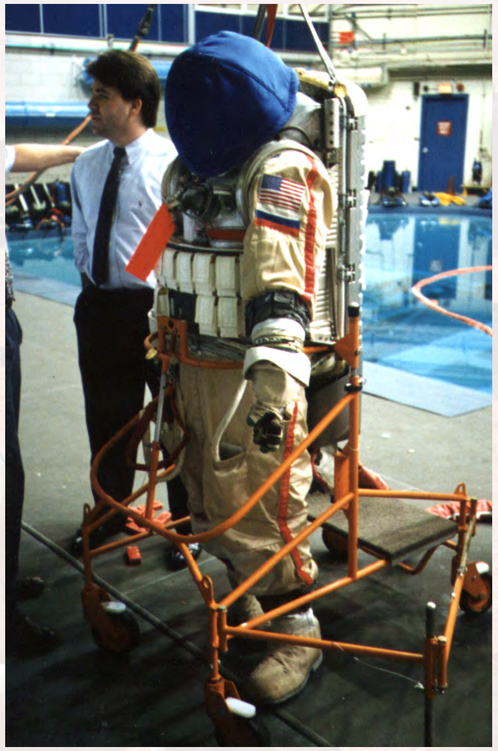
AX-5

NASA Ames



Mark III

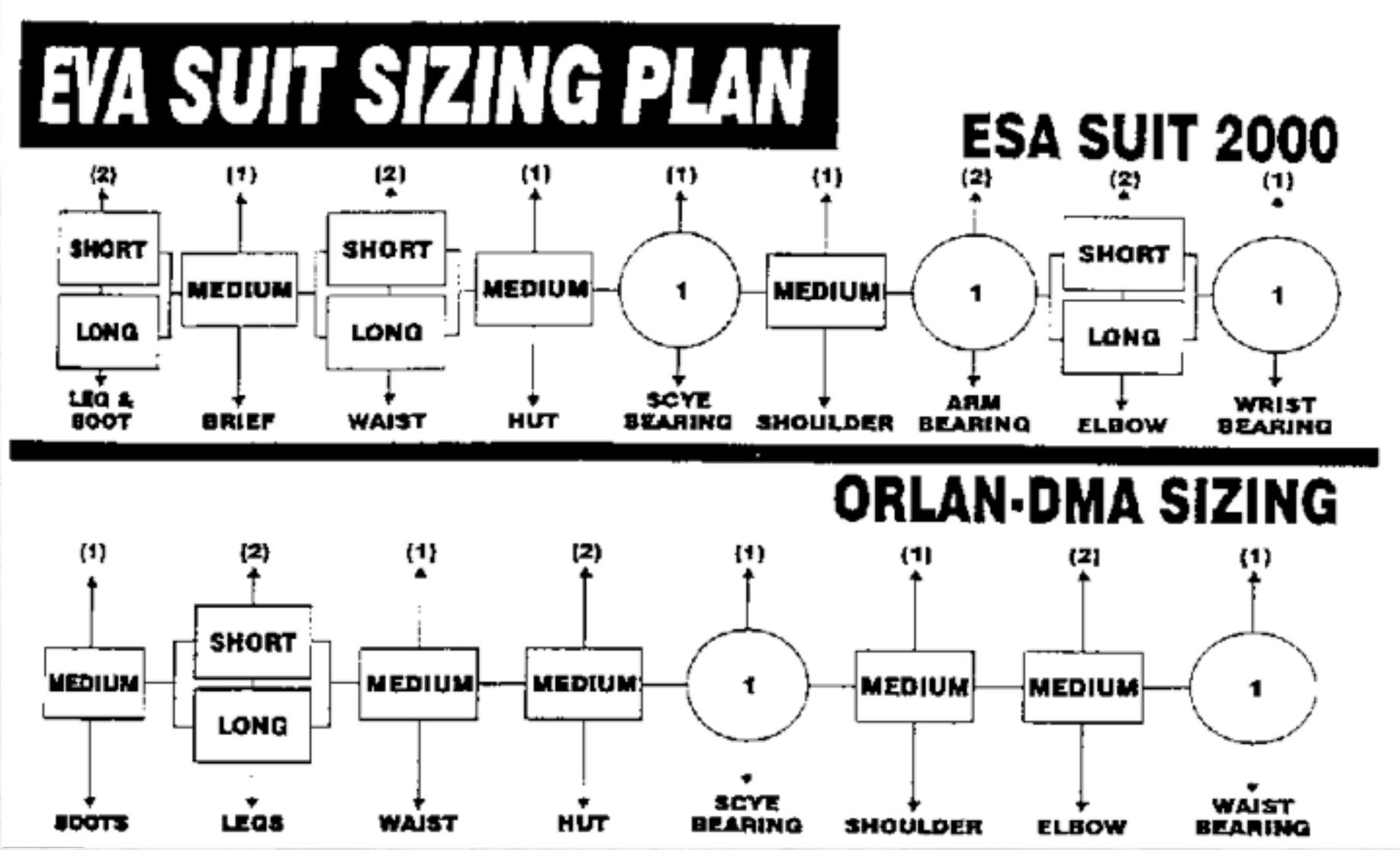
NASA JSC



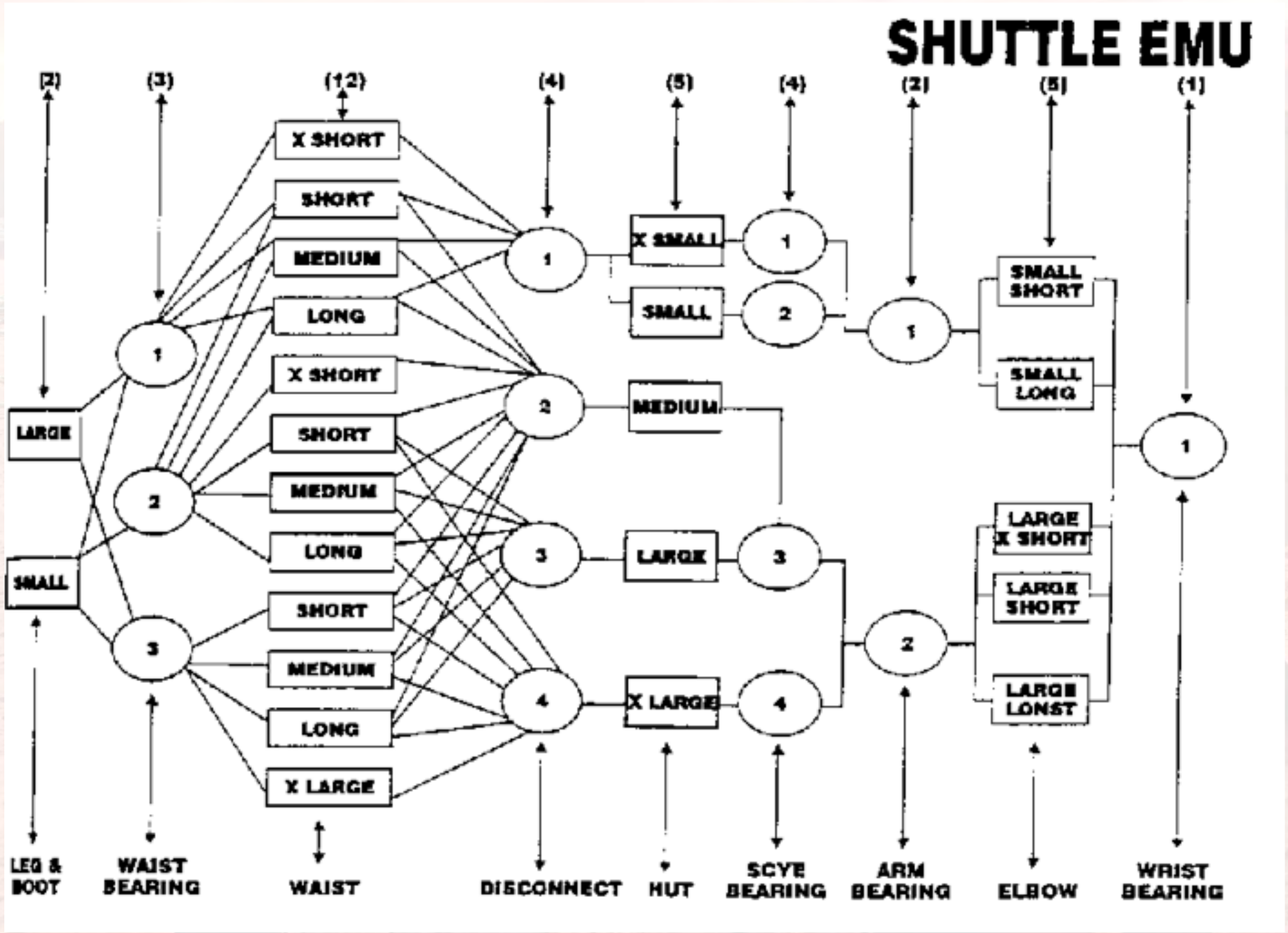
Orlan

Russia

ESA/Russian Suit Sizing



Shuttle EMU Sizing



Liquid Cooling Garment Designs

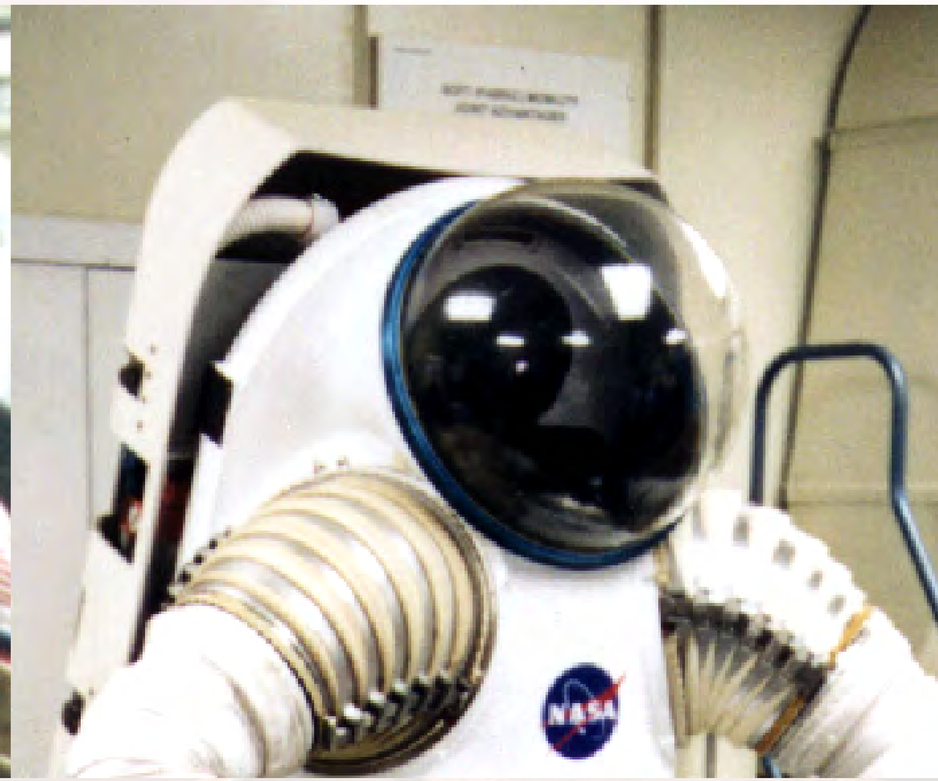
U.S. (ILC-Dover)

Russian

Pressure Suit Helmet Designs

Spherical Bubble with External Visor

Fixed Helmet with Faceplate



Hemispherical Bubble Helmet

Pressure Suit Entry Systems

Waist Entry

Rear Entry

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- Gary L. Harris, The Origins and Technology of the Advanced Extravehicular Space Suit - AAS History Series, Volume 24, American Astronautical Society, 2001