

## JSC Oral History Project

Discussions of the EMU fire incident are also discussed in the Harold Joseph McMann, Jr. transcripts which is publically released.

[http://www.jsc.nasa.gov/history/oral\\_histories/m-n.htm](http://www.jsc.nasa.gov/history/oral_histories/m-n.htm)

# Lessons Learned From The EMU Fire And How It Impacts CxP Suit Element Development & Testing

**Presenter: Terry Hill**

**Audience:**

**15 Sep 08**



We're not just making history

**WE'RE LEARNING FROM IT**

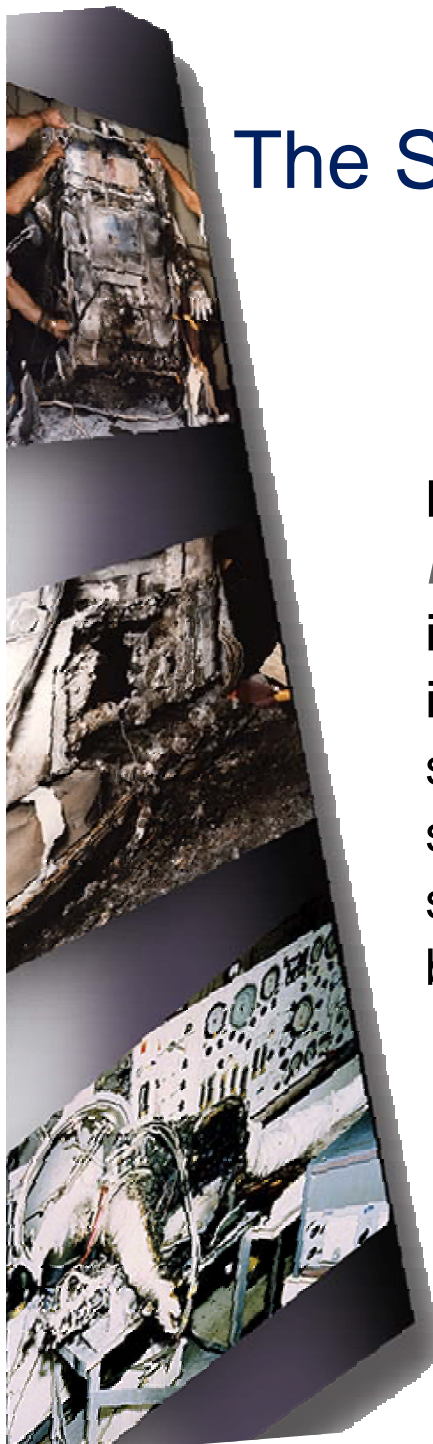




## The Story Line

A Space Shuttle Extravehicular Mobility Unit (*pressure garment and life-support backpack*) was destroyed in a flash fire during a functional test in the Johnson Space Center's crew systems laboratory. A technician standing next to the suit received second-degree burns over his upper body during the accident.

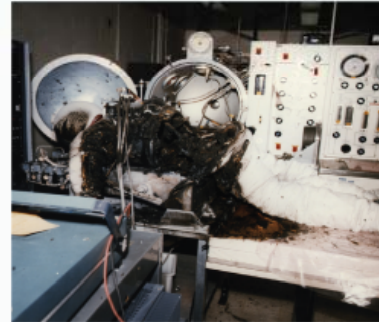
- What happened?
- Safety Message?
- Did we learn from our mistakes?
- Leveraging earned knowledge



# Excerpt From The Accident Investigation Report



On the afternoon of April 18, 1980, Hamilton Standard personnel were conducting an Extravehicular Mobility Unit (EMU) Performance Record Test in room 121 of building

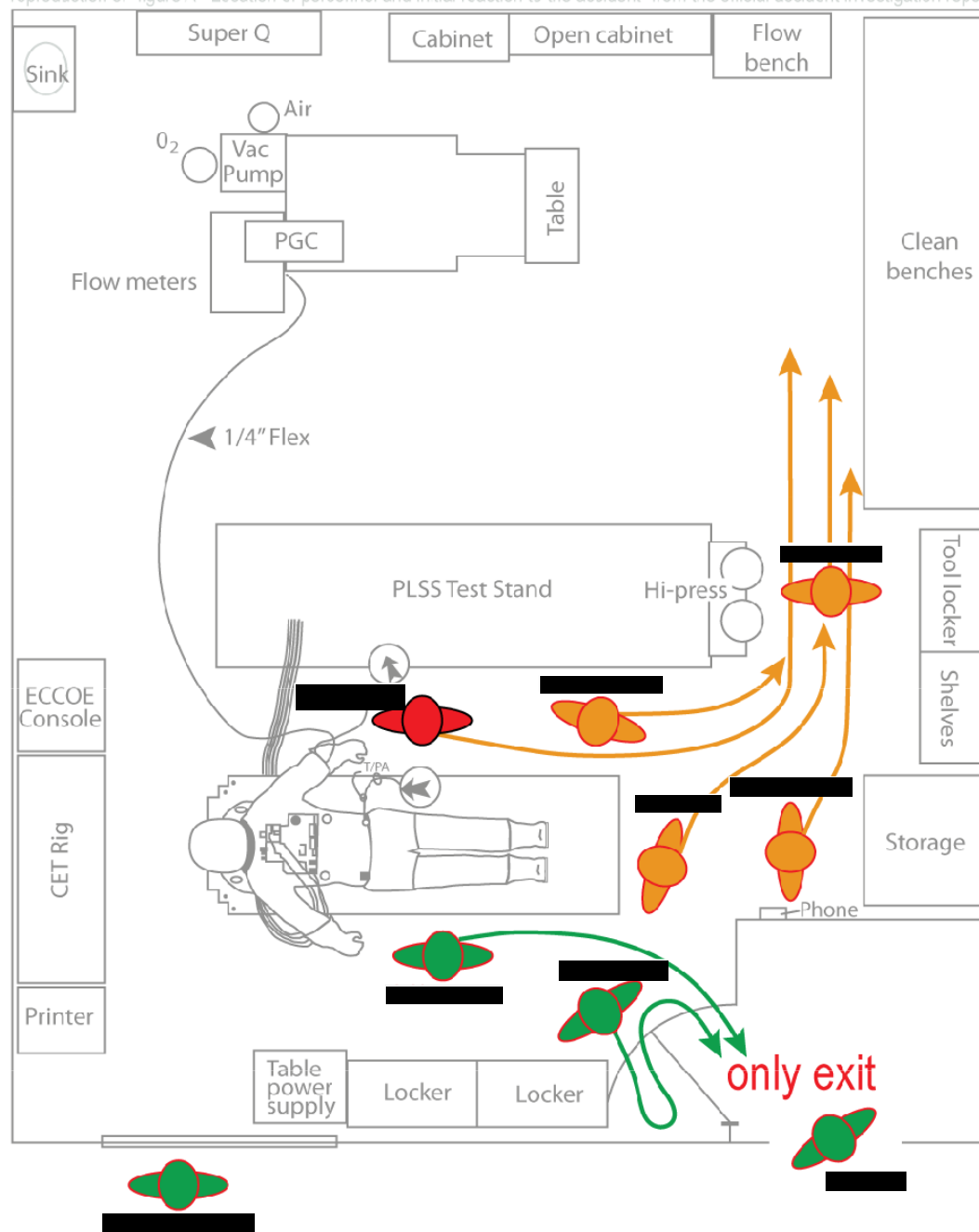





7. The test involved the use of 900 psi O<sub>2</sub> and 6200 psi O<sub>2</sub>. At 1:22 p.m., a flash fire occurred. One technician suffered first and second degree burns over 32% of his body and was taken to the hospital. Another technician got his hand burned, requiring first aid. The fire actuated an overhead sprinkler; two CO<sub>2</sub> extinguishers were used. The Houston fire department responded and assured the extinction of the fire. ■

- Regulator vaporized in less than 1 second
- O<sub>2</sub> availability allowed for metal to burn
- O<sub>2</sub> depress less than 2 seconds
- Softgoods burned until extinguished - ~1-2 minutes

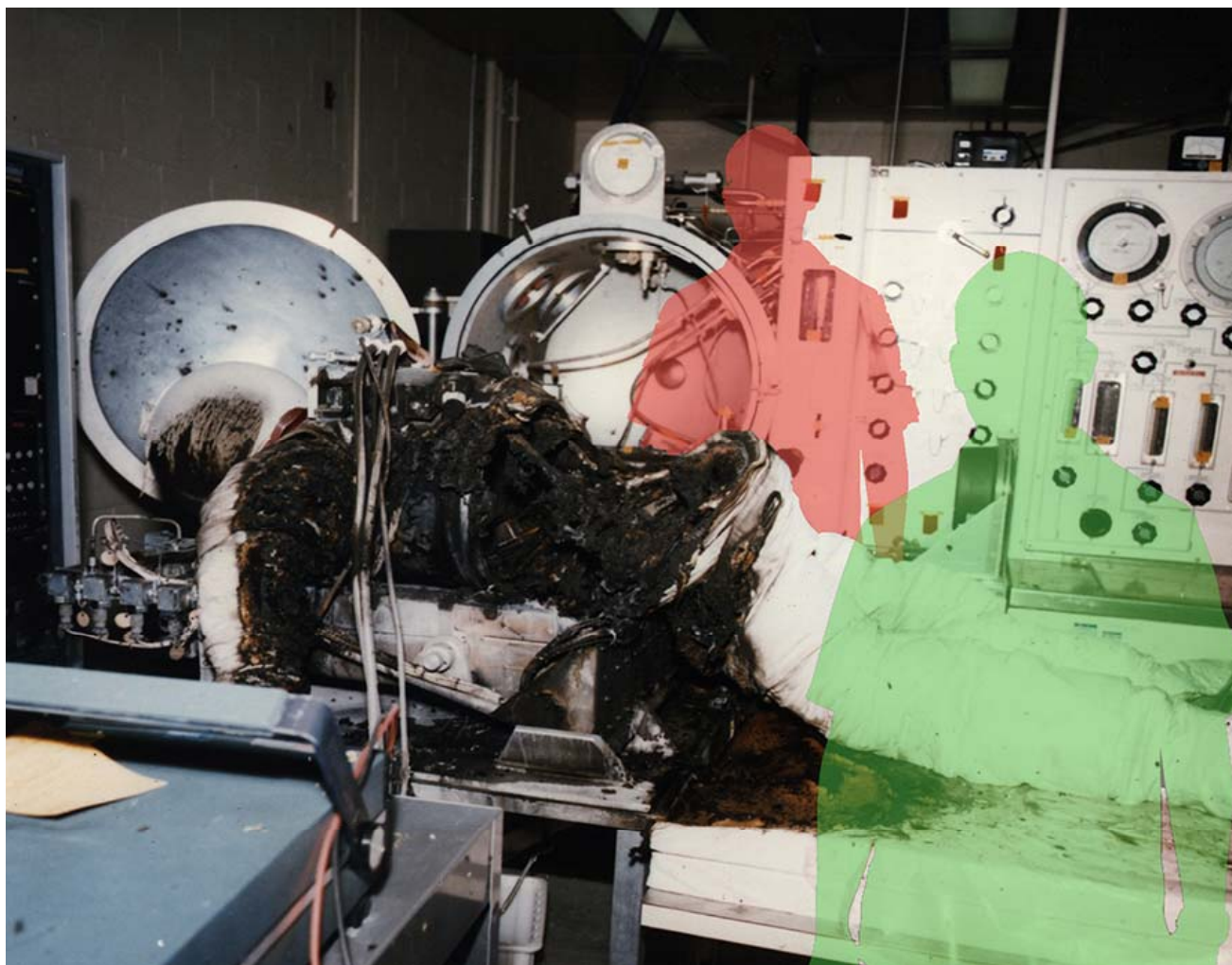


reproduction of "figure A - Location of personnel and initial reaction to the accident" from the official accident investigation report

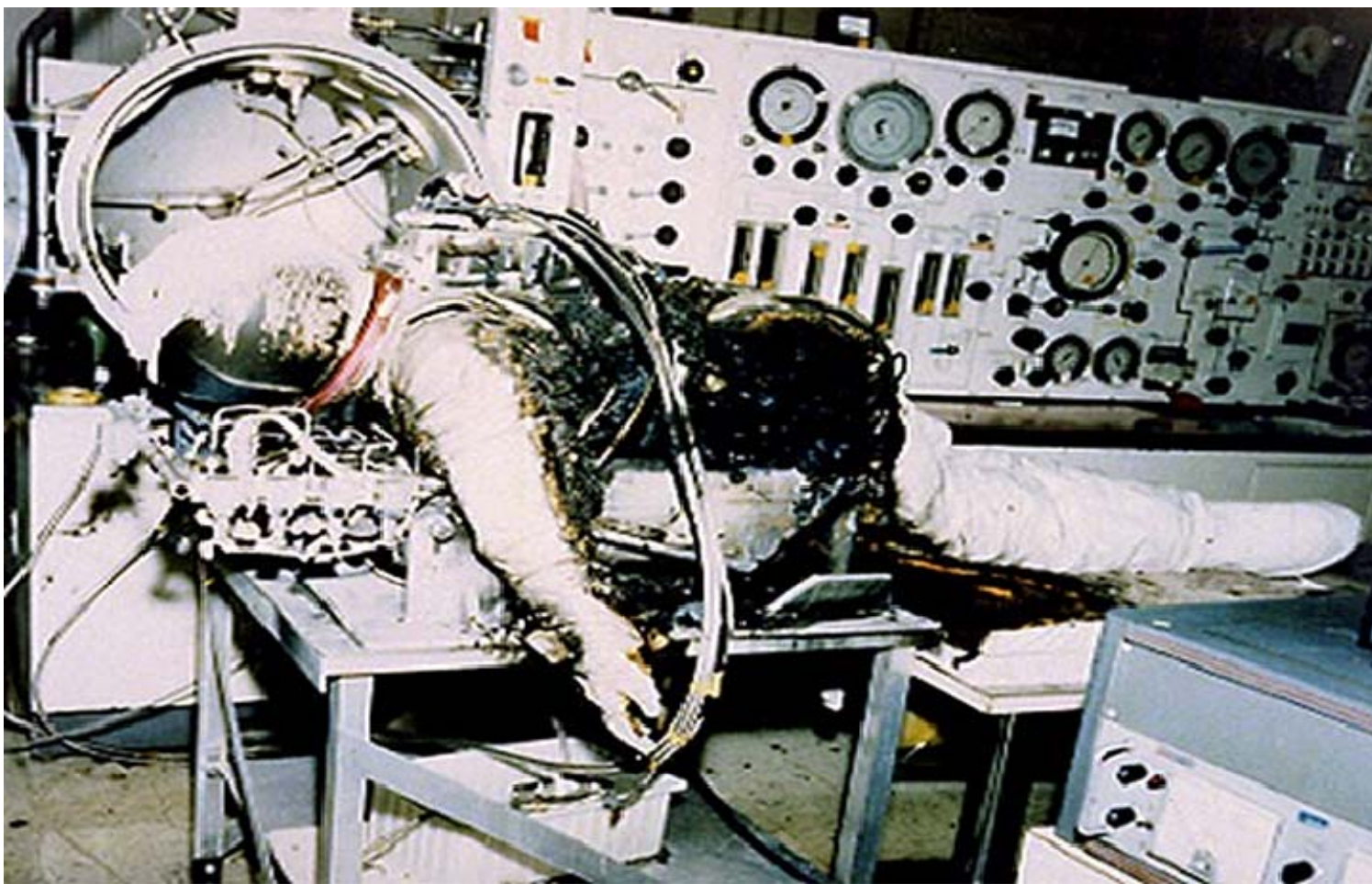


-  Suffered severe injuries - hospitalized
-  Improper reaction – could have resulted in injury or death
-  Proper reaction – individuals exited the room to safety





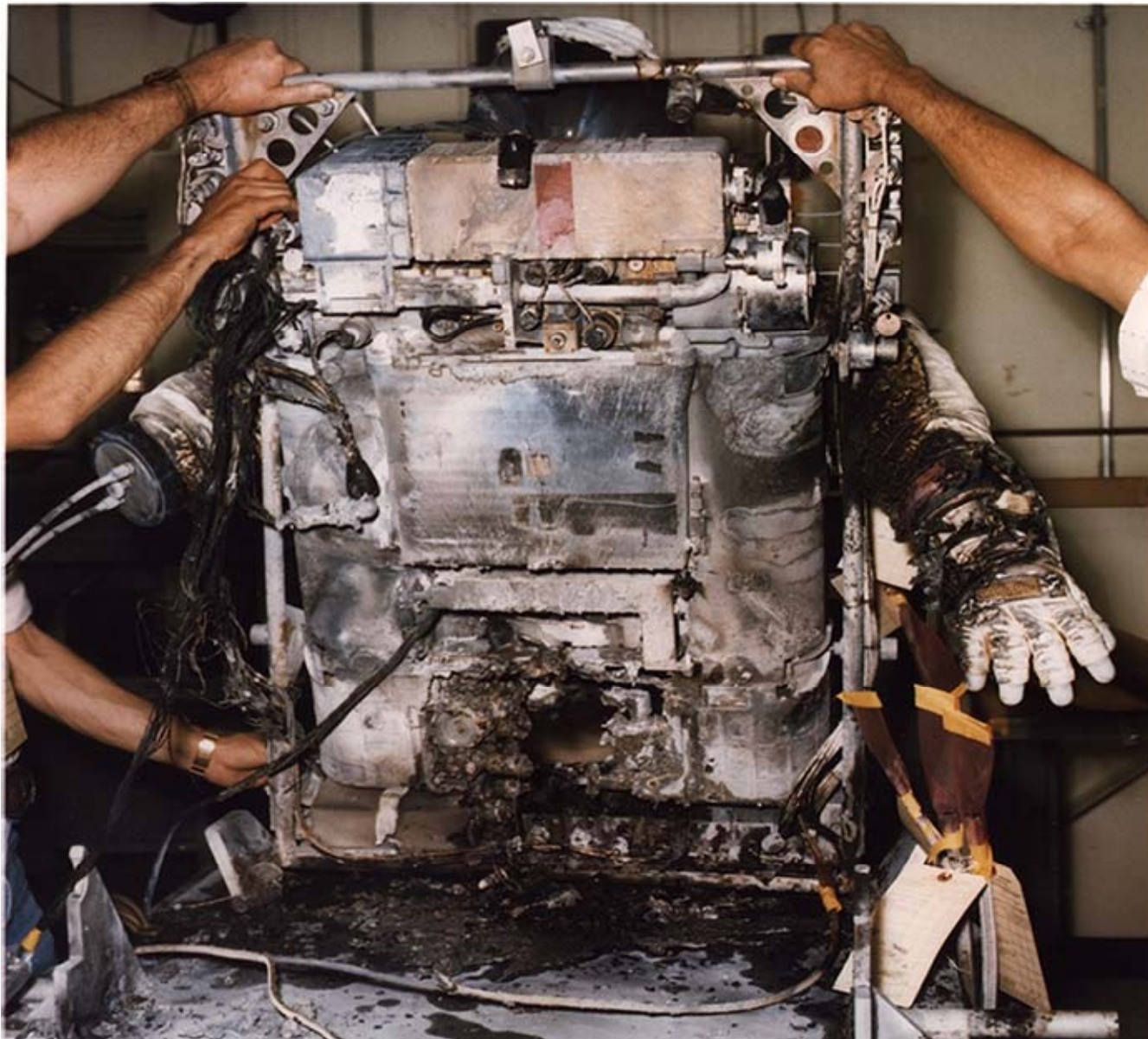
A technician was standing between the suit and test stand



~2 million dollars worth of damage



# SEMU 3002 /PLSS 1002

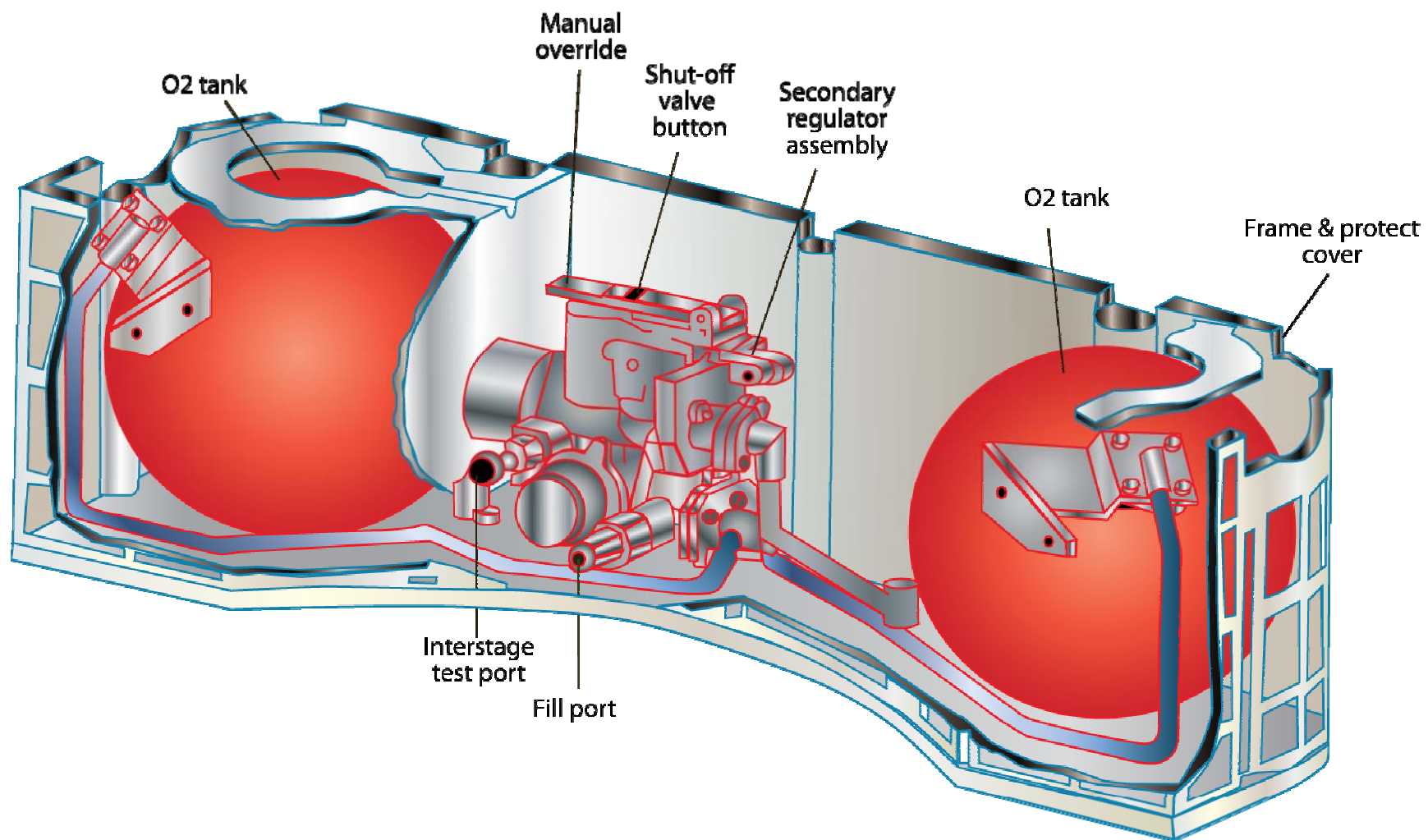




# Rear View of SOP/PLSS Regulators







# Not Much Left!







# Probable Causes

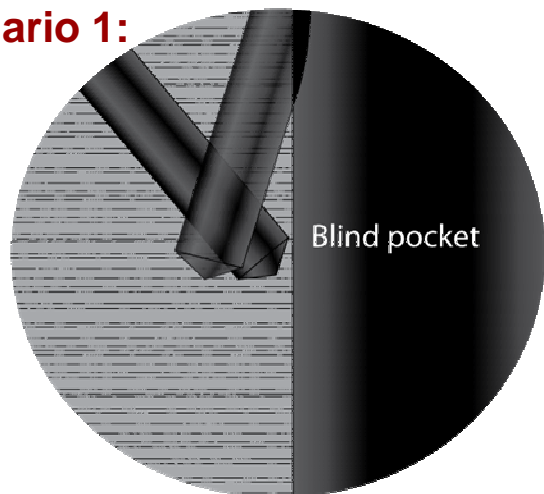
- The fire originated in an aluminum bodied regulator and valve assembly when 6000-psi oxygen was released through the valve into the regulator. It was postulated that the fire was probably caused by one or combination of the following:
  - the rupture of a thin, internal section of the aluminum body
  - the ignition of a silicone O-ring by compression heating of the oxygen, or
  - particle impact

As a result of the post fire investigation, the regulator and valve assembly was redesigned, and the aluminum in this assembly was replaced with Monel®

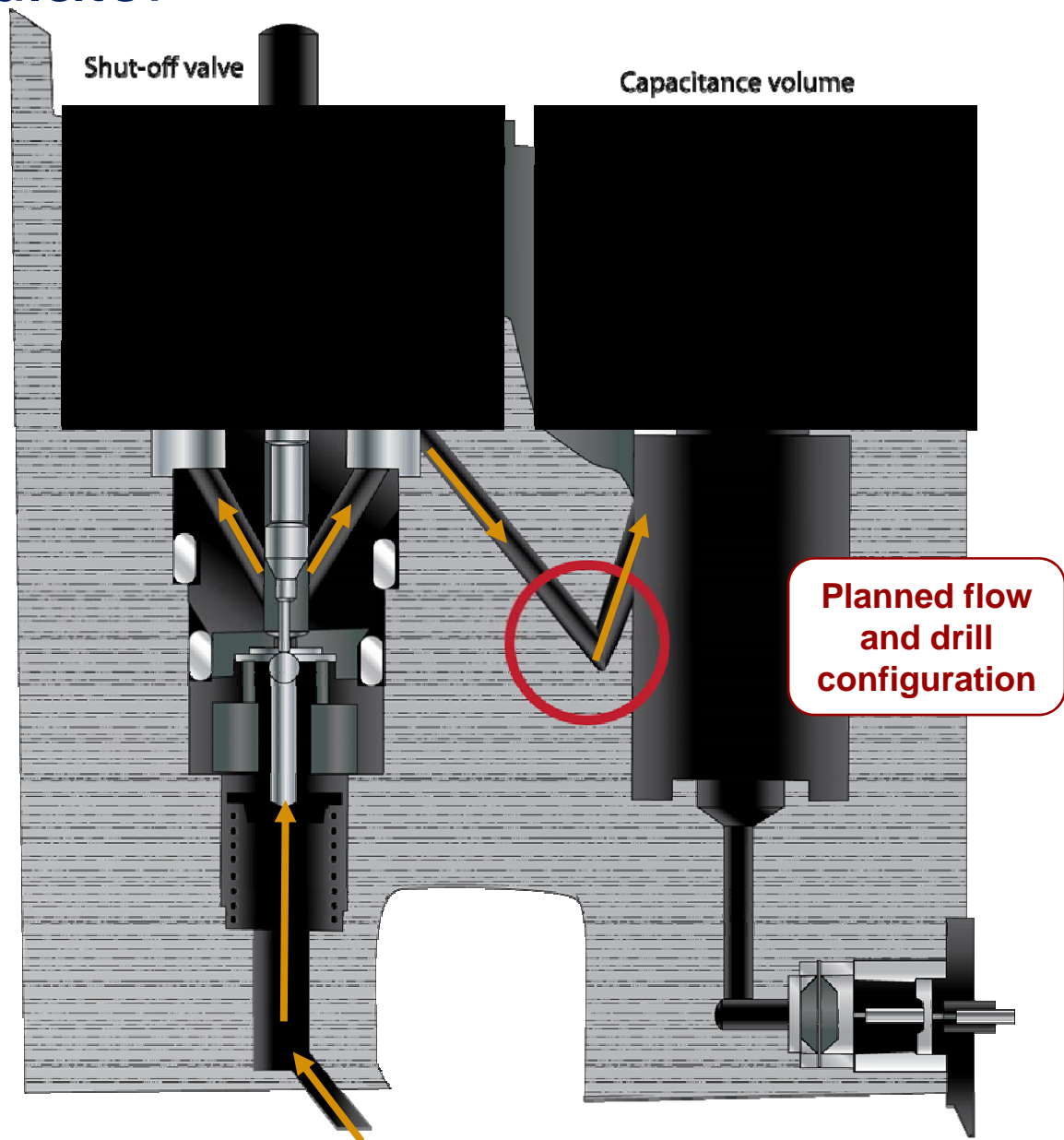
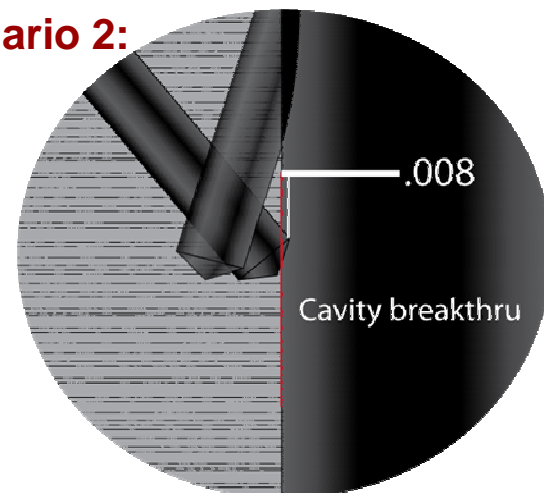
This change and several others were implemented in the version of the EMU suit that is in use today

# Secondary Regulator

## Scenario 1:



## Scenario 2:





# Accident Investigation Report Recommendations

1. Nylon smocks tend to melt into the skin with a fire. An alternate material should be worn (Durret/ Chemstat)
2. All test personnel were wearing safety glasses, a requirement when operating a high pressure O<sub>2</sub> system. This requirement protected the injured technician from serious eye damage. This regulation should be rigorously followed during testing
3. This accident highlights the necessity of proper procedures while working with equipment of this type. Specifically, safety glasses and the proper type of protective clothing should be worn. (*PPE*) Cleanliness rules should be followed and technicians should be familiar with all corrective measures indicated in case of a system failure

# Lessons Learned That Changed The Way We Do Business



- **Documentation**
- **Procedures**
- Proper **PPE** enforced, management held responsible to make sure it is available to everyone (VPP program)



# Lessons Learned That Changed The Way We Do Business: Documentation & Reviews



- TPS System was put into use, stopped working from service instructions
  - Warnings and Safety notes are on the TPS and a procedures **Hazard Analysis** is required
- Perform a **TRR** as required
- Hardware should be designed with safety in mind. Follow the **design requirements** and get the right people involved during PDR, CDR



# Lessons Learned That Changed The Way We Do Business: Procedures

- Procedures were written and a signature list developed
  - We now have a S.P. which includes a checklist review of all procedures
- **Restrict the number of people in the area**, set up a test area and only allow the test team members access
- Perform a **safety briefing** and all members should know how to secure and evacuate the area and set up test such that **safe and rapid evacuation is possible**
- Stress **Safety**, the person who will use the hardware; your friend or a co-worker's LIFE may depend on it

# Lessons Learned That Changed The Way We Do Business: PPE

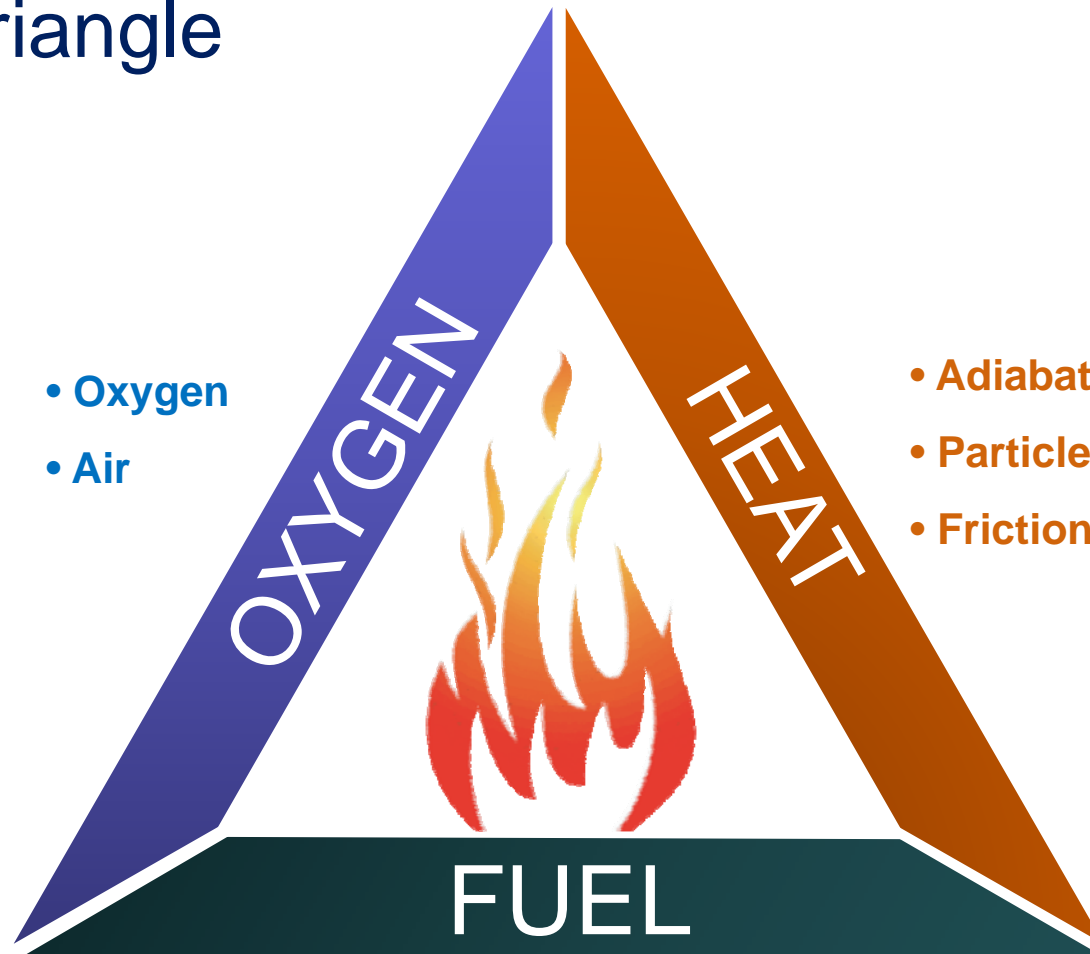


- PPE provided at entry of lab
- No one is allowed to enter without wearing the proper equipment





# Fire Triangle



- Oxygen
- Air

- Adiabatic Compression
- Particle Impact
- Frictional Heating

- System Components
- Non-metals
- Metals





# What Do We Do About It?

- The Constellation Space Suit will have all 3 hazards present
- Risk mitigation efforts
  - When possible lower potential activation energy sources
  - When possible pick materials with higher activation energy requirements that are not propagation promoters
  - Keep the system clean so that you do not get unwanted, “bad” materials
  - Mandatory training on oxygen system hazards and safety measures
- Use a systematic approach to identify and analyze the ignition mechanisms resulting in the safest design and operation of the system as possible



# Ignition Mechanisms



## Particle Impact

- Heat generated when small particles strike a material with sufficient velocity to ignite the particle and/or what it hits
- Most common ignition source in metallic systems

## Adiabatic Compression

- Heat generated when a gas is compressed from a low to a high pressure
- Most common when exposed non-metal close to a dead-end
- Most efficient direct igniter of non-metals and contaminants

## Flow Friction

- Oxygen leaking across a polymer in such a way that enough heat is generated within the polymer to cause ignition
- Requires a high pressure drop and an exposed non-metal in a flow path



# Ignition Mechanisms



## Galling, Friction, or Mechanical Impact

- Heat generated by the rubbing of two or more parts together
- Compressors, chattering RVs, check valve barely opening

## Promoted Ignition

- Heat from the ignition and combustion of a more flammable material igniting a less flammable material
- Contamination is a very common, unplanned start for this

## Static Discharge

- Accumulated static charge on a non-conducting surface discharging with enough energy to ignite the receiving material
- Most severe in a dry environment

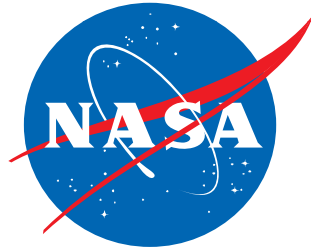
Electrical Arc

Resonance -  
Acoustic source



# Conclusion

- All Must be educated on the topic so that:
  - **Design** of systems both flight and ground with ignition mechanism mitigation incorporated
  - **Maintain** systems so that contaminants and leaks do not occur
  - **Operate** systems, both flight (*crew training and procedures*) and ground (*tech training and procedures*) to minimize risk by maintaining cleanliness thus mitigating adiabatic compression





# NASA News

National Aeronautics and  
Space Administration

**Lyndon B. Johnson Space Center**  
Houston, Texas 77058  
AC 713 483-5111

---

Terry White

For Release

RELEASE NO: 80-039

June 10, 1980

ALSO RELEASED AT NASA HEADQUARTERS

## INVESTIGATORS FILE REPORT ON CAUSE OF SPACESUIT BACKPACK FIRE

A NASA board investigating the April 18 flash fire in a spacesuit backpack found where the fire started and recommended 11 ways to improve safety and reliability of the system.

While the exact cause was not found, the four most probable causes of ignition were cited in the board's report to Johnson Space Center Director Christopher C. Kraft, Jr., after five weeks of engineering detective work that included more than 2,000 unsuccessful attempts to reproduce the fire.

The accident destroyed an unoccupied Space Shuttle spacesuit and life support backpack. A Hamilton Standard technician, Robert A. Mayfield, was severely burned but is recovering and has been released from the hospital.

- more -

These tests are conducted to assure that such malfunctions are discovered prior to flight, since such an accident during a mission might well cause serious injury or fatality, or require premature termination of the mission.

The fire apparently started when the technician switched the secondary oxygen pack to the "spacewalk" position during a performance test in a clean room in the Crew Systems Laboratory. The secondary pack is attached to the bottom of the main backpack and provides 30 minutes of emergency oxygen for breathing and to maintain suit pressure if the main oxygen source fails.

Ignition took place in a V-shaped passage which serves to restrict the flow of oxygen between a shut-off valve and a chamber in the pack's regulator module, the investigating board determined. It said the four most probable causes were:

1. Heating by compression or shock of a thin section of aluminum between the flow restrictor passage and the adjacent cavity.
2. Heating by compression or shock of contaminants in the flow restrictor.
3. Heating of internal surfaces through mechanical shock of incoming high-pressure oxygen, or heating of particles.
4. Similar heating of shut-off valve o-rings.

The board found that all procedures followed during the April 18 test were proper. The regulator module had 19 cycles with high-pressure oxygen prior to the accident.

Technicians were unable to duplicate the failure in tests at Johnson's White Sands Test Facility, Las Cruces, New Mexico. Four regulator modules of the same factory batch were cycled 2,228 times. Post-test disassembly revealed significant contamination within the modules.

A regulator module is machined from a single block of aluminum and is fitted with valves, a pressure gauge and two step-down regulators that reduce oxygen supply pressure from 6,000 to 3.5 pounds per square inch. The flow restrictor consists of two 1/16-inch diameter drilled passages that intersect. It is between the high pressure inlet and the first stage regulator.

After ignition on April 18, the regulator module burned through and an oxygen-rich jet of flame burned the lower torso of the attached spacesuit.

The board ruled out backpack and clean room electrical systems as ignition sources. It said all clean room support feed lines were pure.

The 11 recommendations of the board are:

° Redesign high pressure oxygen valves and regulators so that debris cannot be trapped and eliminate "stagnation points" where heating by compression and shock can occur.

° Redesign regulator modules to lessen chance of internal contamination, while improving manufacturing inspection techniques.

° Review the design of all Space Shuttle high pressure valves and regulators for debris traps and unprotected o-rings.

° Replace existing silicone o-rings with silicone o-rings having improved ignition resistance.

° Machining regulator module body from monel instead of aluminum would reduce ignition potential.

° Inspect completed regulator modules with X-rays.

° Consider using neutron radiography to confirm that o-rings and other non-metallic components with significant hydrogen content are properly installed.

° Machine a dummy regulator module body from a block of clear plastic to verify wall thicknesses and other passageway machining tolerances.

° Consider comparison impact ignition testing of Teflon or Kel-F backup rings as a means of reducing shock heating of silicone o-rings.

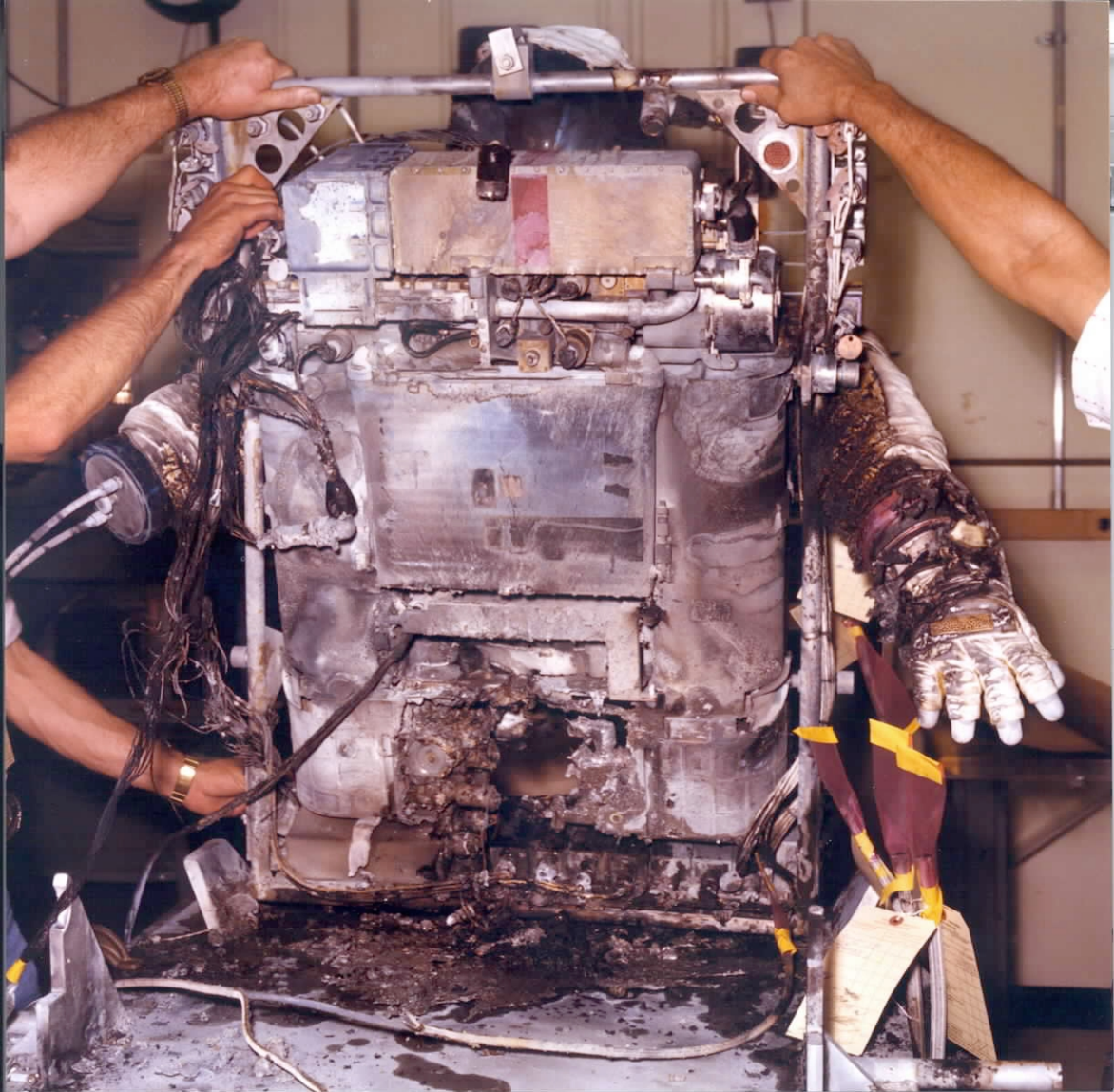
° Clarify internal NASA specifications.

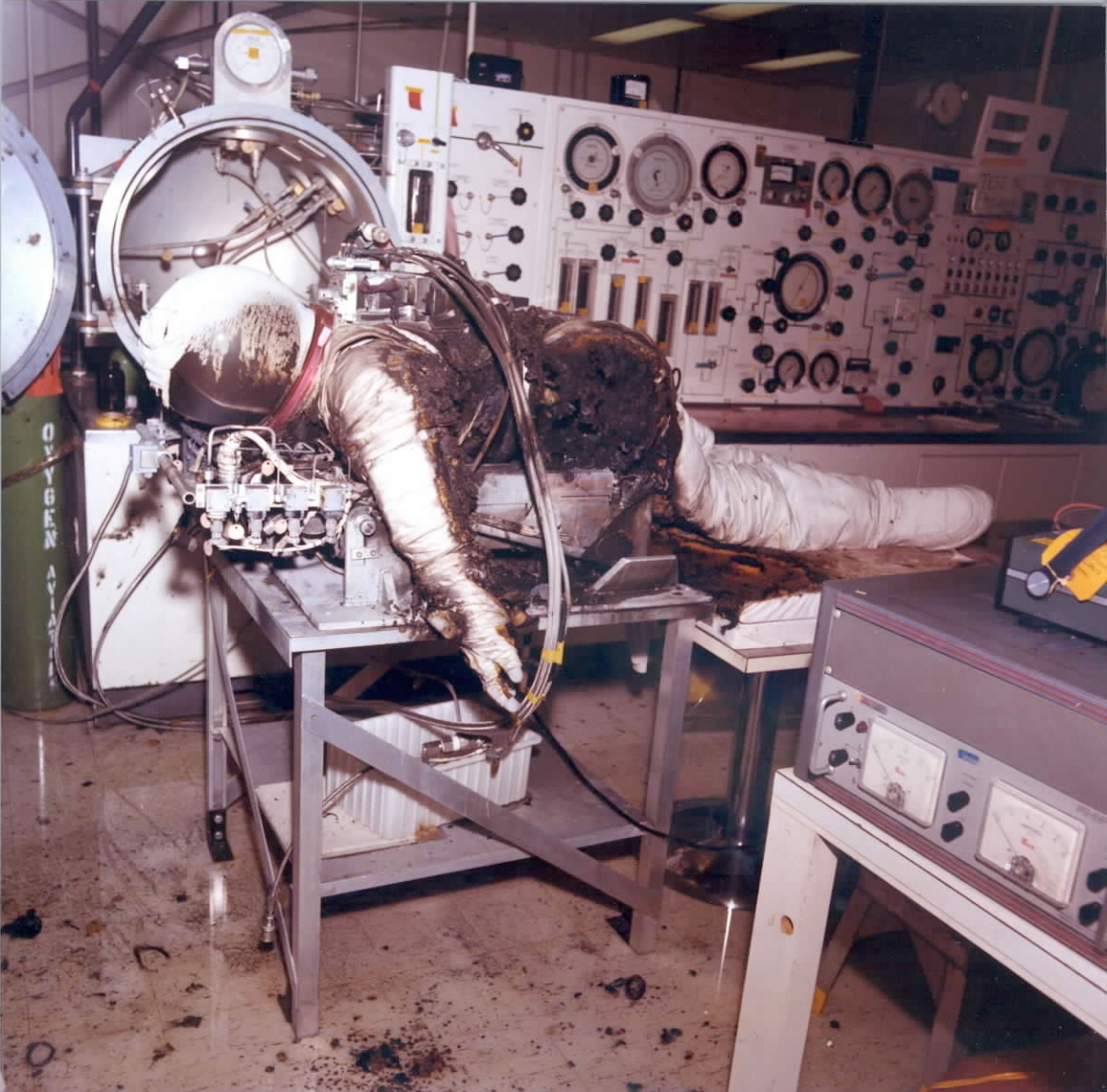
° Consider establishing a committee consisting of NASA and non-NASA personnel to collect existing high-pressure oxygen data, review and clarify existing design standards and requirements, recommend any necessary supplements to presently available information and publish a comprehensive standard for the design and use of high-pressure oxygen equipment used in the space program.

The investigating board was headed by Chester A. Vaughan, propulsion engineer. Members were: Noel Willis, Jr., crew systems engineer; George D. Nelson, astronaut; Joseph Degioanni, flight surgeon; and James B. Chappée, safety engineer. Andrew J. Hoffman of Hamilton Standard served as ex-officio member, and R. L. Johnston, materials engineer, served as advisor.

###











462

# Spacesuit flash-fire provokes minor alterations

NASA has revealed that an unoccupied astronaut's spacesuit was destroyed in a flash fire on April 18. The fire started during routine performance testing in the crew systems laboratory at Johnson Space Centre. A technician employed by Hamilton Standard, manufacturer of the Shuttle spacesuit, was badly burned in the incident, but has since left hospital.

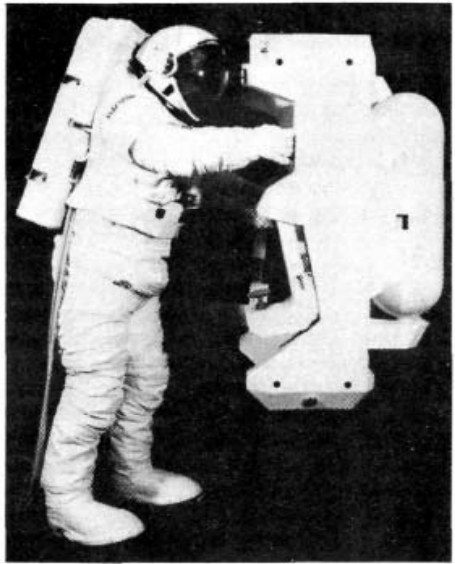
The flash fire started when the technician switched from the spacesuit's main oxygen supply to a 30min emergency supply. Ignition took place in a chamber between the high-pressure (200bar) oxygen supply and the regulator which reduces it to a breathable 240 millibar. The resulting fire burned through the regulator which is mounted in the backpack attached to the suit, as well as the lower torso of the spacesuit.

A review board was unable to

duplicate the flash fire in subsequent tests, or to pinpoint the cause of ignition. But it did list four probable causes, most of them involving shock-heating, in which the sudden flow of high-pressure gas against an obstruction rapidly raises its temperature.

To prevent a recurrence, the board made several recommendations. These included redesign of high-pressure oxygen valves and regulators to avoid stagnation zones and lessen the chances of internal contamination; replacement of silicone-rubber seals with a material of greater ignition-resistance and the clarification of Nasa specifications. The board also asked Nasa to consider making regulator bodies out of monel instead of the more easily ignited aluminium alloy, more detailed inspection during manufacture and further testing of the modified parts.

FLIGHT International, 28 June 1980



A spacesuited astronaut reaches for a manned manoeuvring unit. The back-pack on the spacesuit contains oxygen, cooling and other life-support systems

London D performance threatened