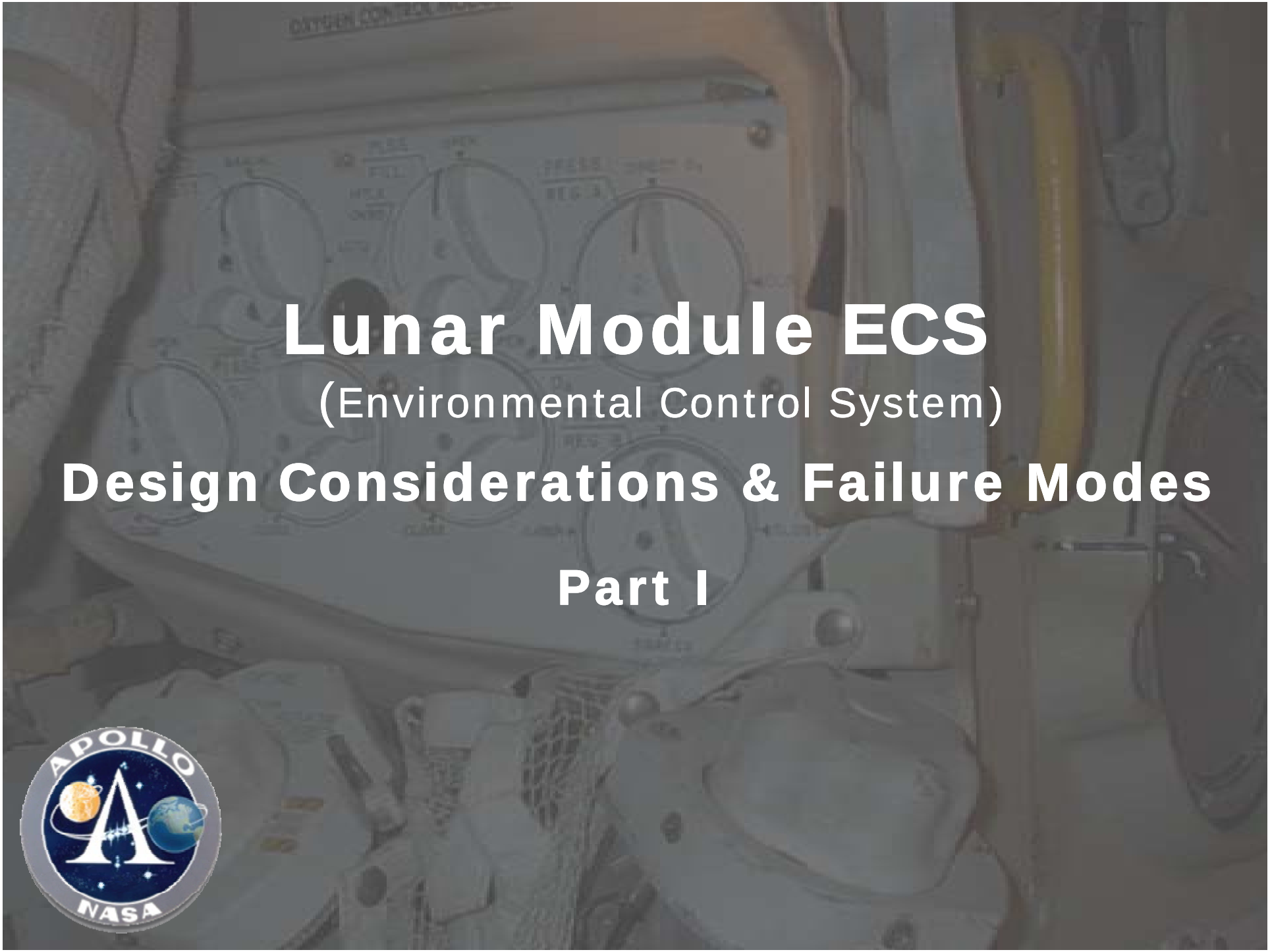


Lunar Module ECS

(Environmental Control System)

Design Considerations & Failure Modes

Part I

Objectives

Upon completion of the lesson, the student will be able to:

- Describe the Lunar Module (LM) Environmental Control System (ECS) generic design considerations philosophy.
- Summarize the LM ECS general testing regime.

Prerequisite

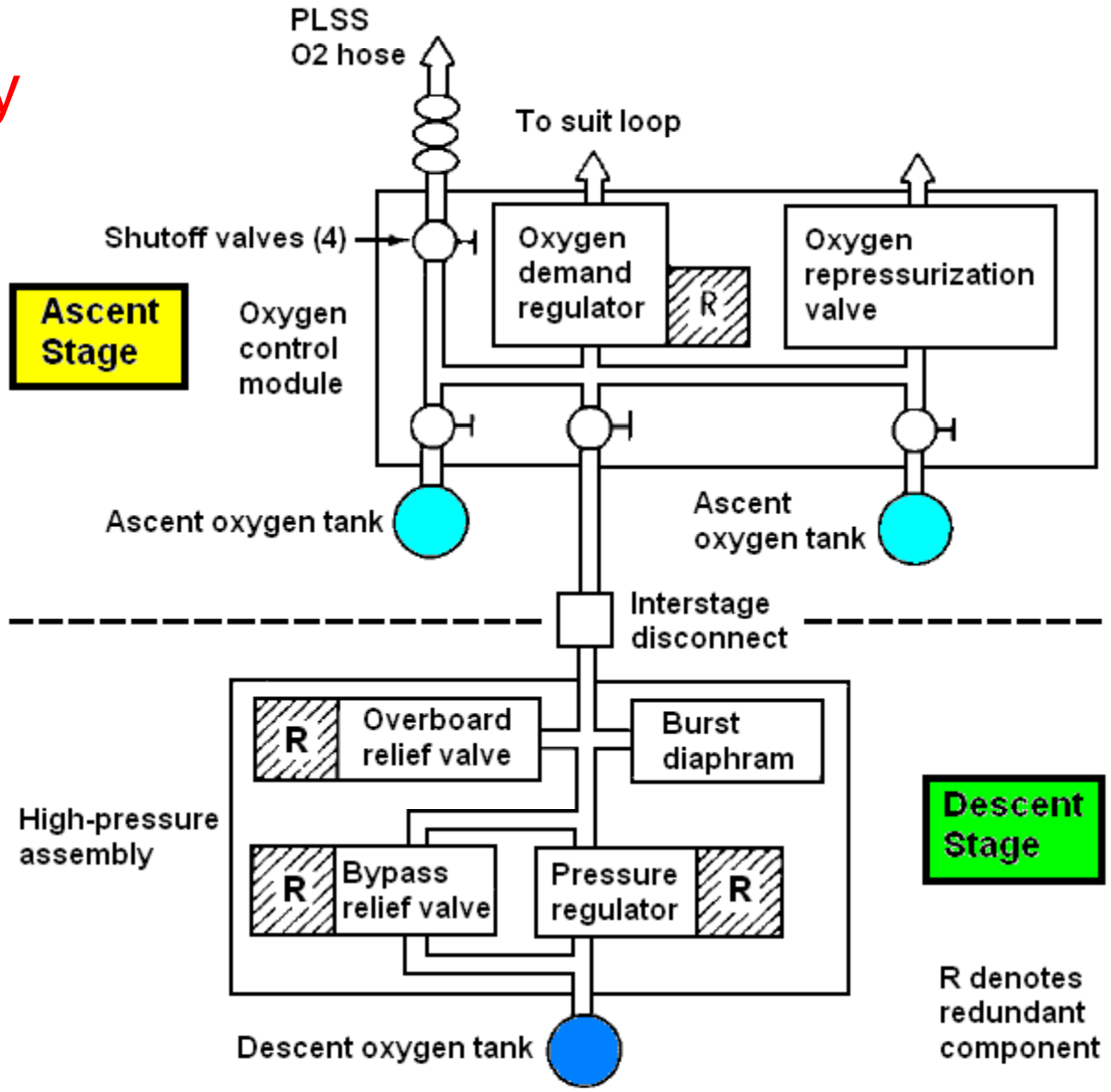
- For the best understanding of this material, the student should have viewed the Lunar Module (LM) Environmental Control System (ECS) Familiarization lesson prior to viewing this lesson.

Overview of LM ECS

- Oxygen Supply and Cabin Pressurization Section
- Atmosphere Revitalization Section
- Water Management Section
- Heat Transport Section

Overview of LM ECS

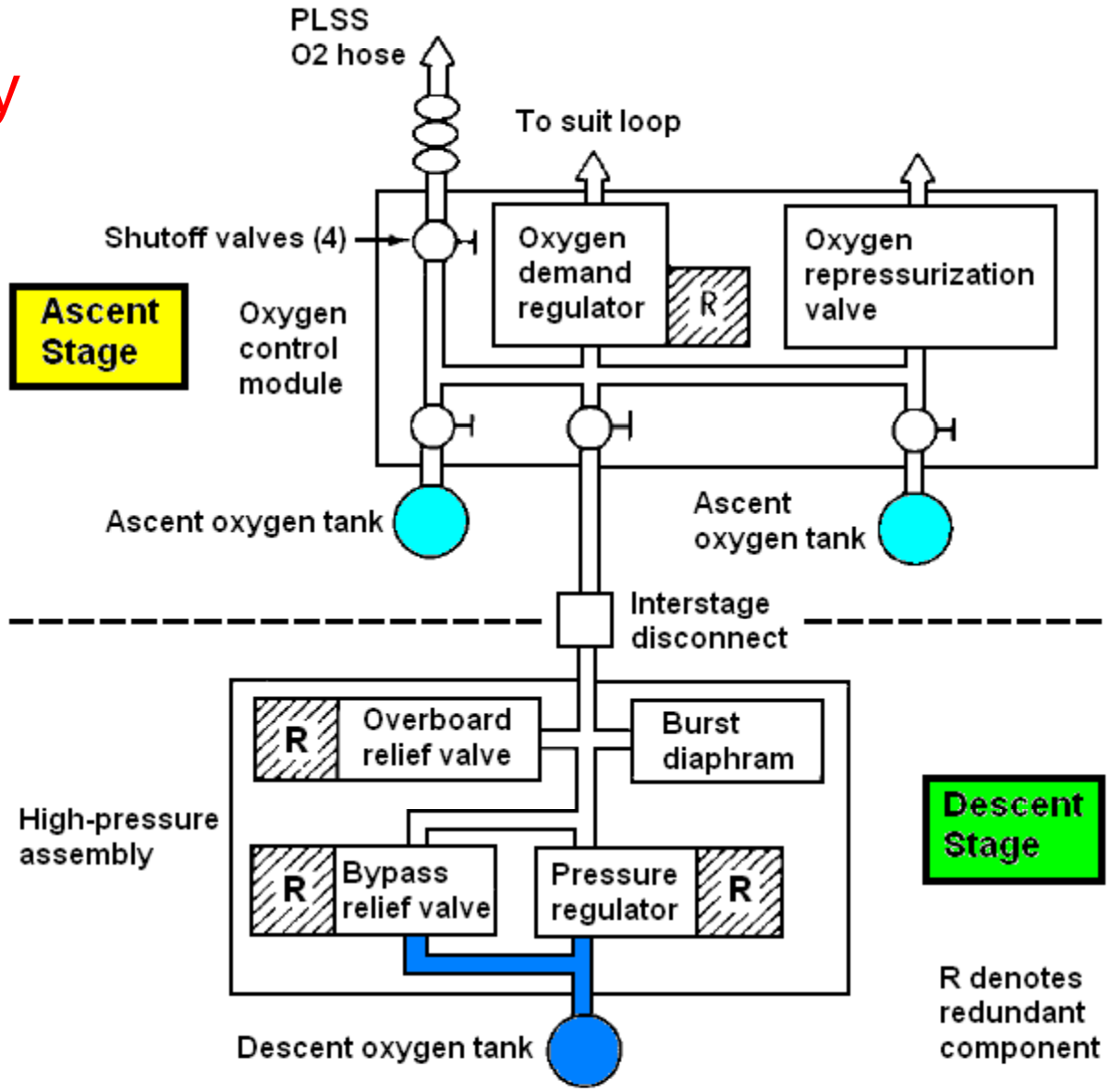
- Oxygen Supply and Cabin Pressurization Section



Oxygen Supply and Cabin Pressurization Section

Overview of LM ECS

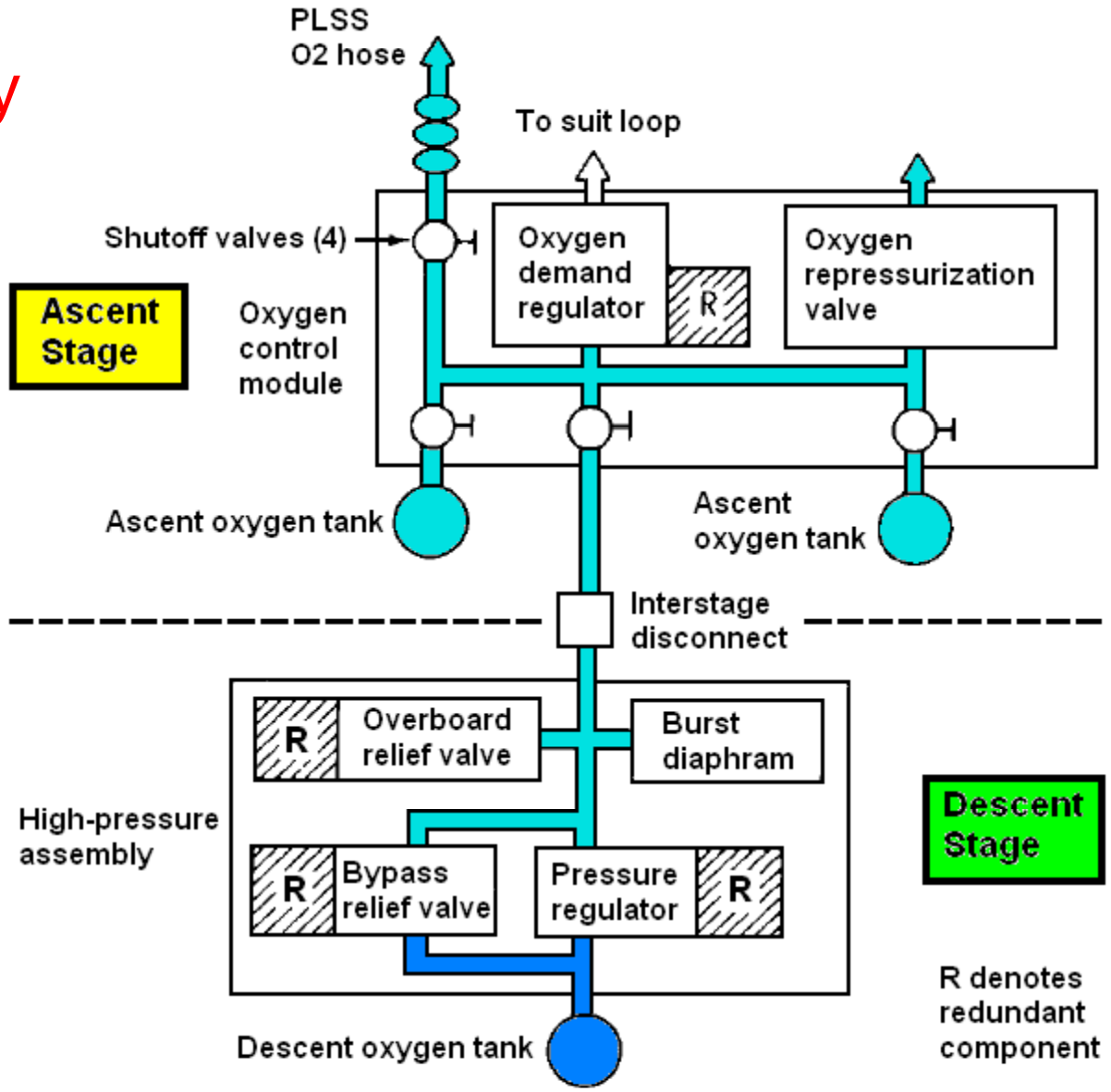
- Oxygen Supply and Cabin Pressurization Section



Oxygen Supply and Cabin Pressurization Section

Overview of LM ECS

- Oxygen Supply and Cabin Pressurization Section



Oxygen Supply and Cabin Pressurization Section

Overview of LM ECS

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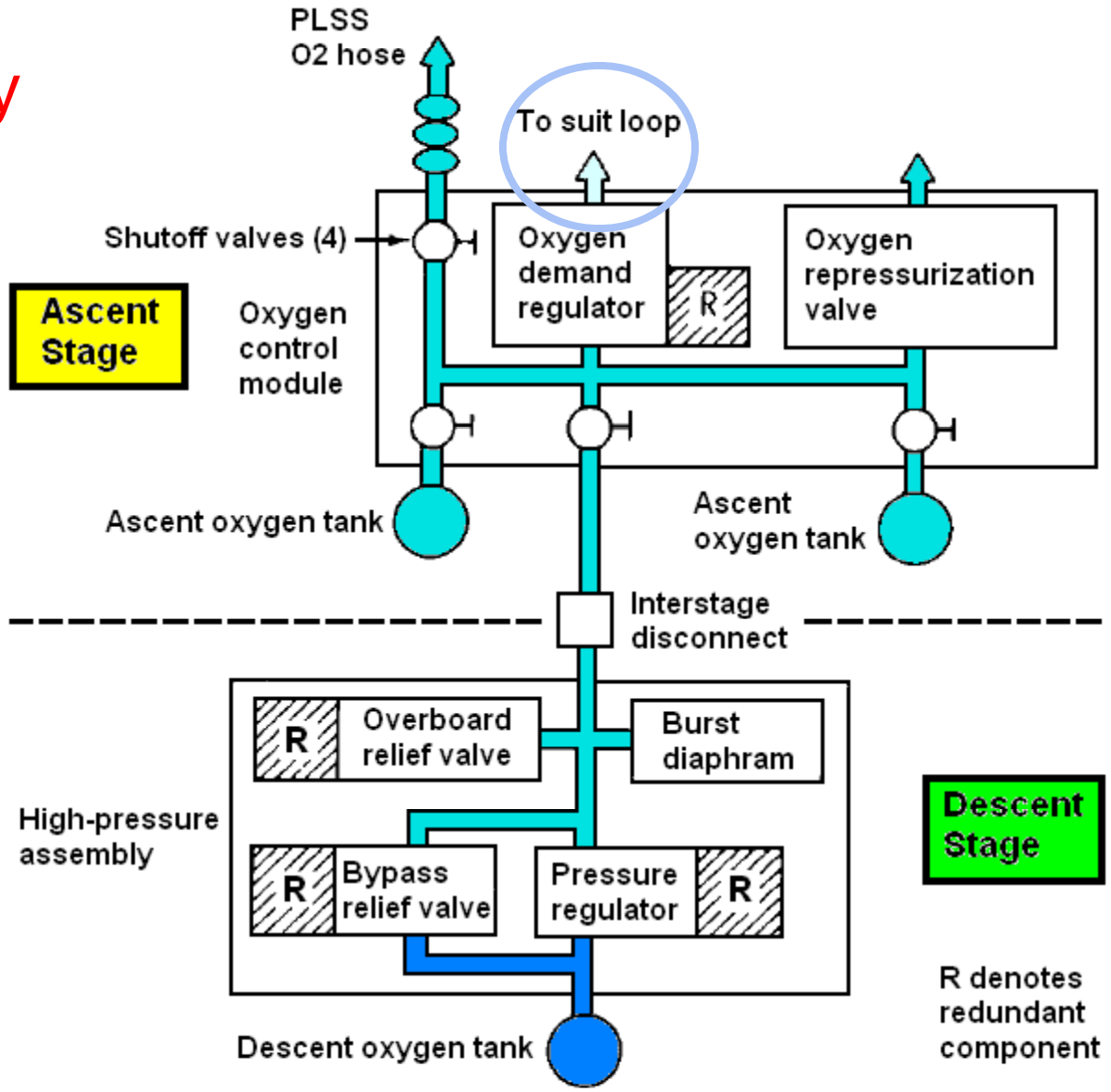
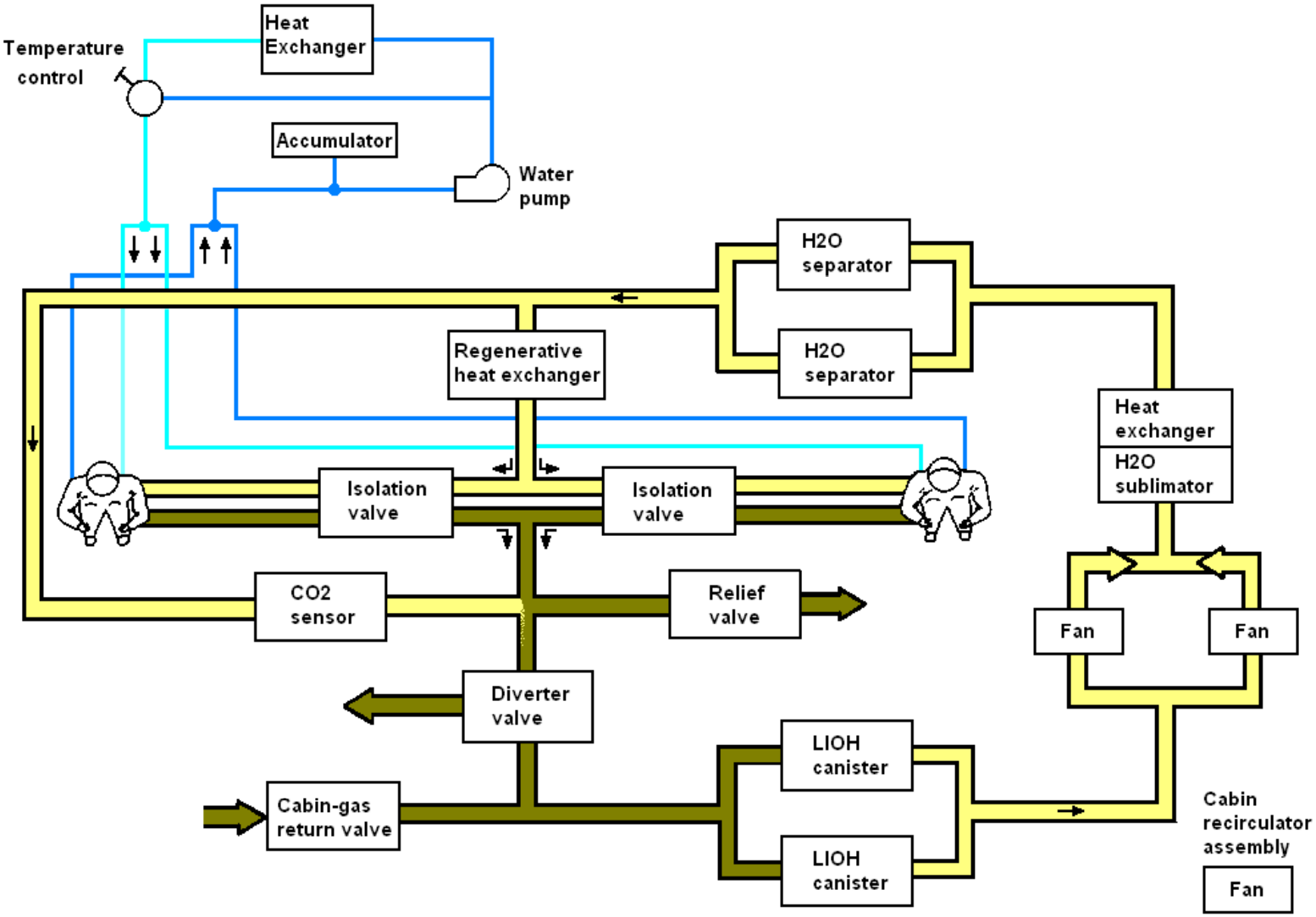


Oxygen Supply and Cabin Pressurization Section

Overview of LM ECS

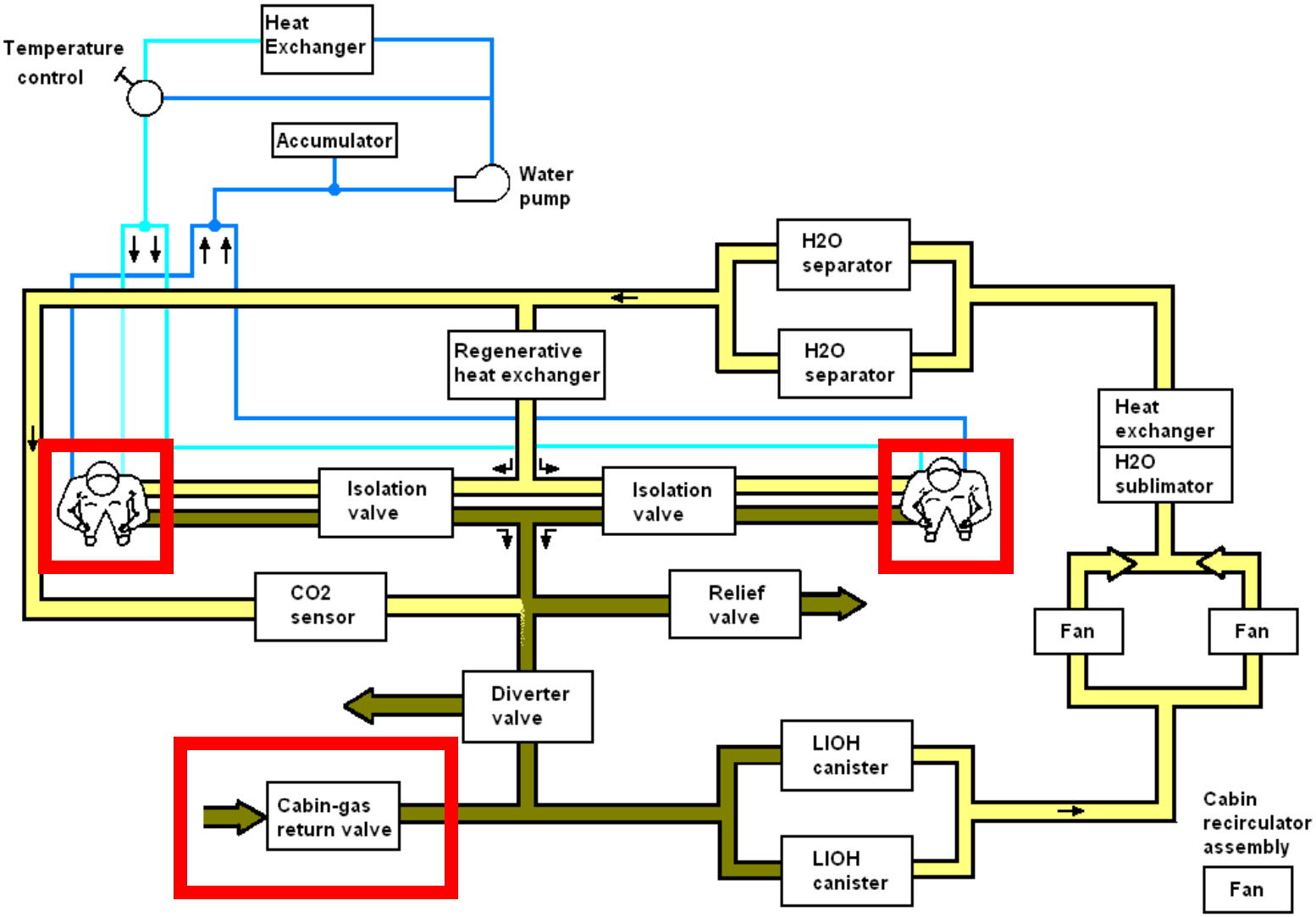
- Atmosphere Revitalization section



Atmosphere Revitalization Section Simplified Schematic

Overview of LM ECS

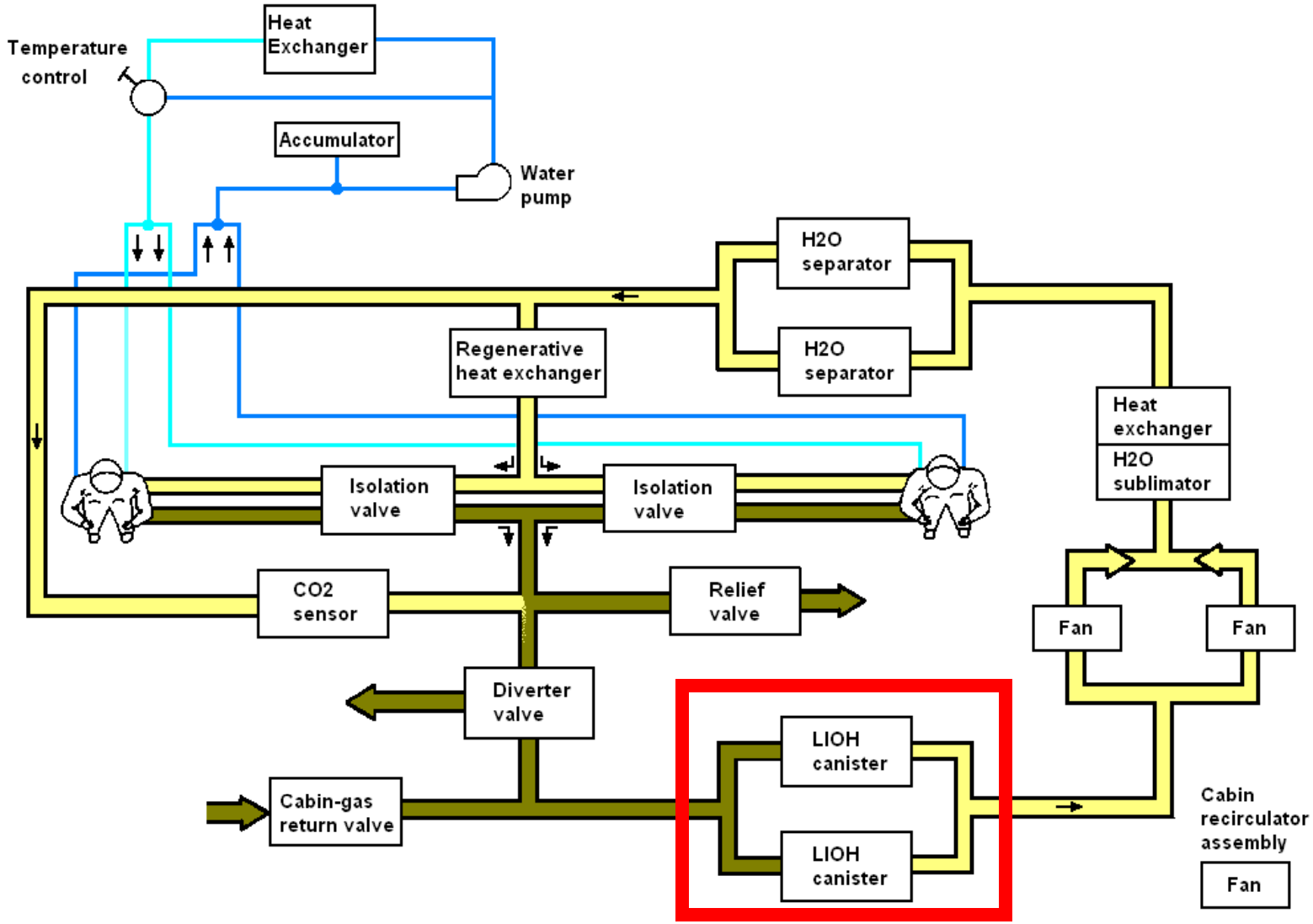
- Atmosphere Revitalization section



Atmosphere Revitalization Section Simplified Schematic

Overview of LM ECS

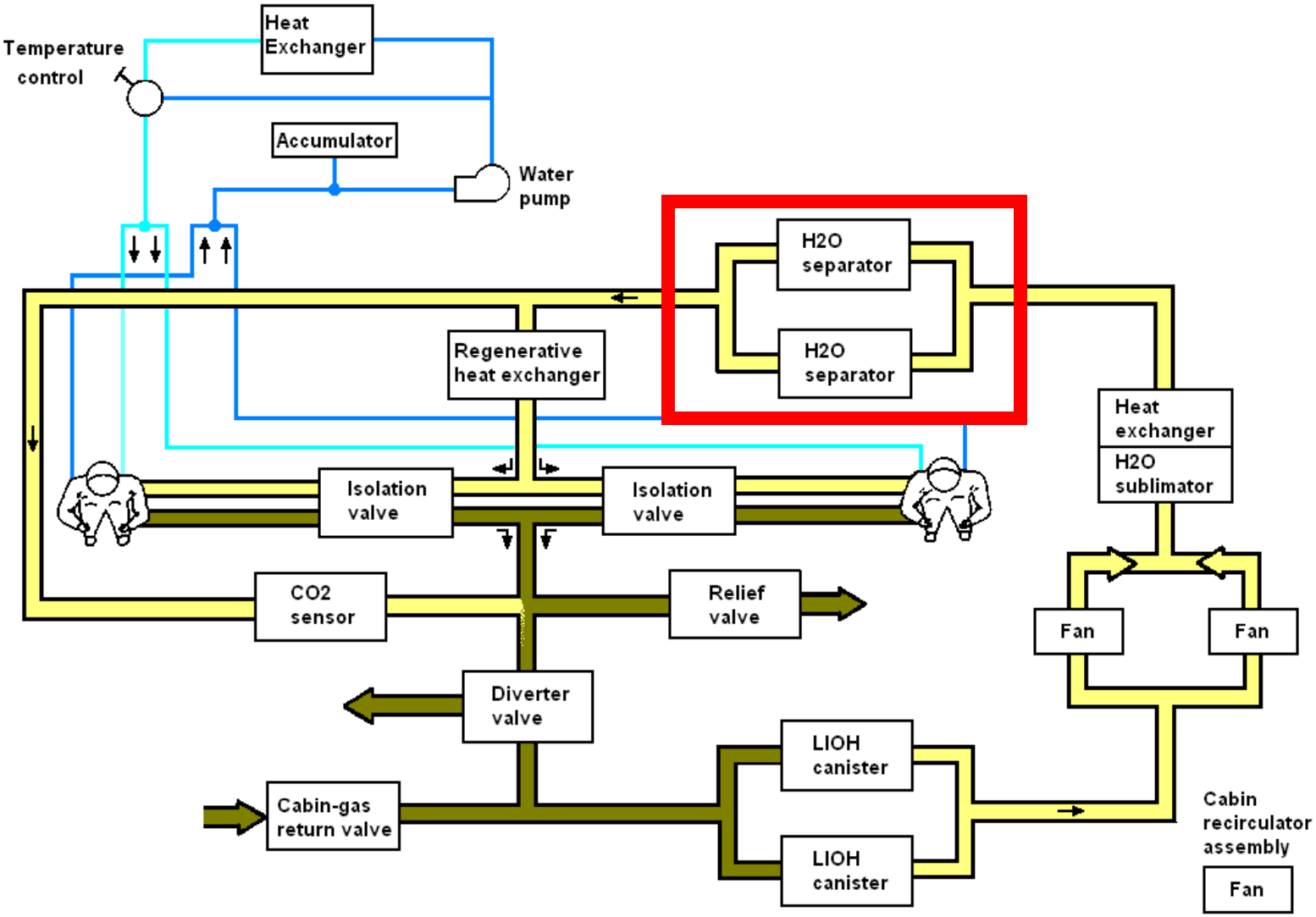
- Atmosphere Revitalization section



Atmosphere Revitalization Section Simplified Schematic

Overview of LM ECS

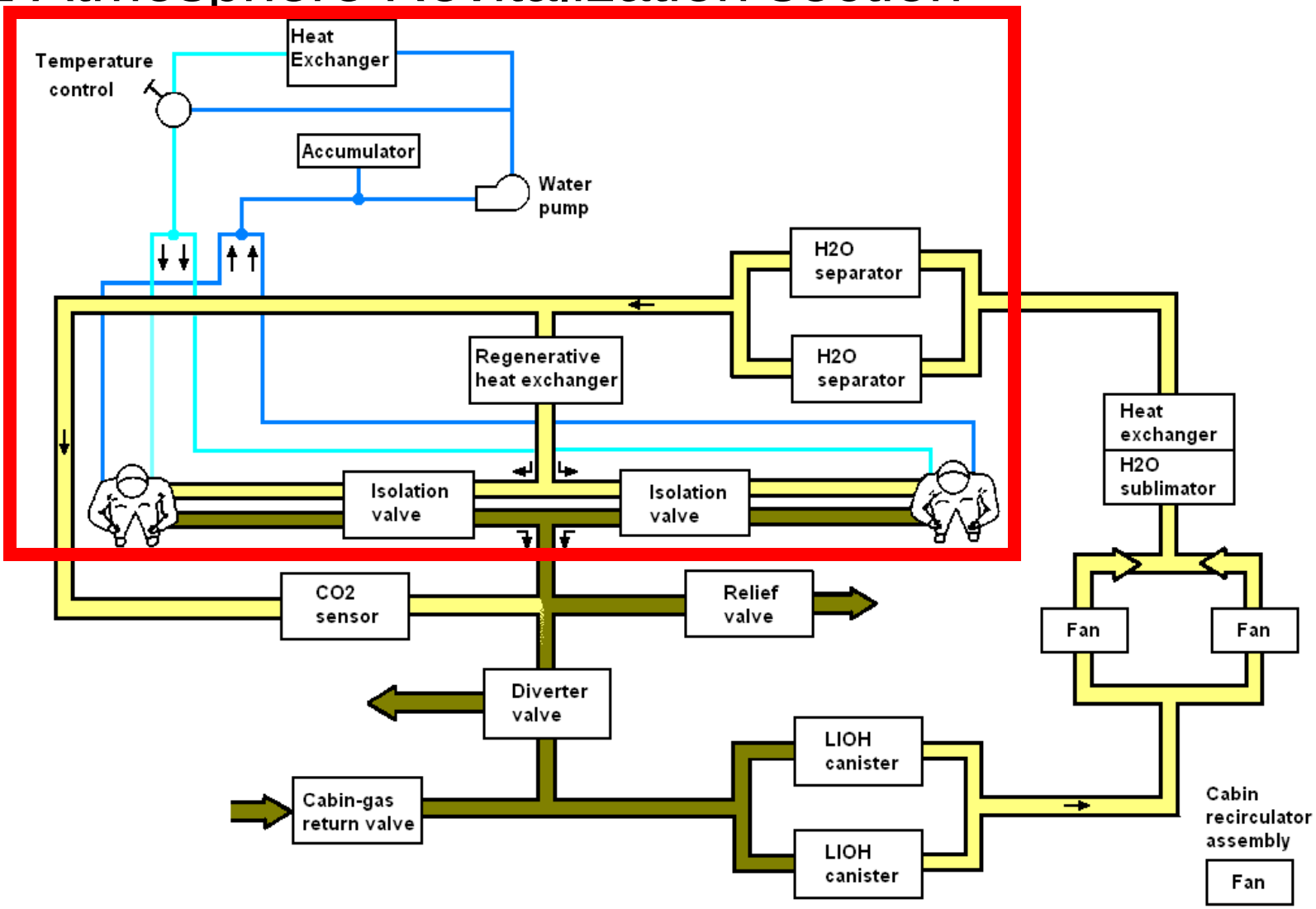
- Atmosphere Revitalization section



Atmosphere Revitalization Section Simplified Schematic

Overview of LM ECS

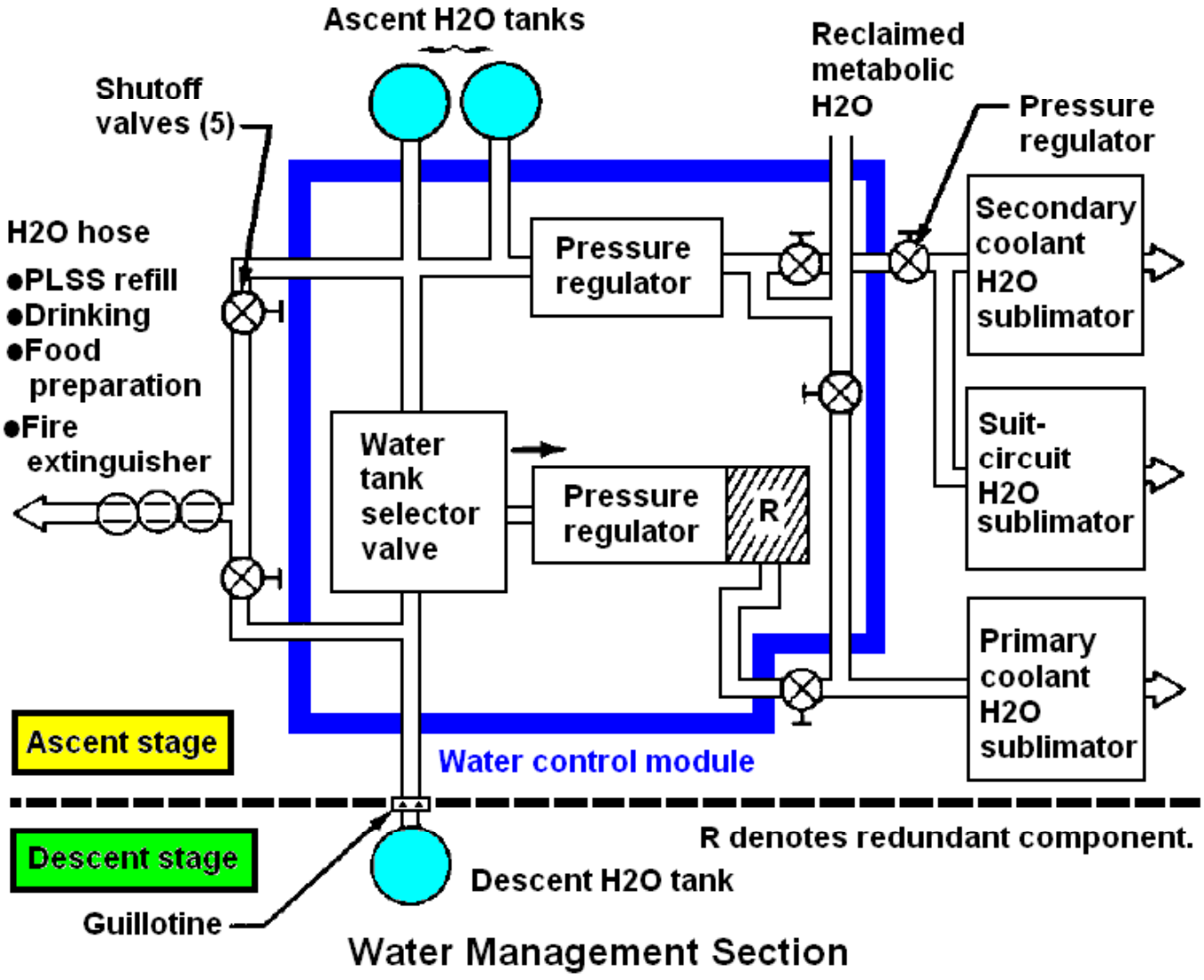
- Atmosphere Revitalization section



Atmosphere Revitalization Section Simplified Schematic

Overview of LM ECS

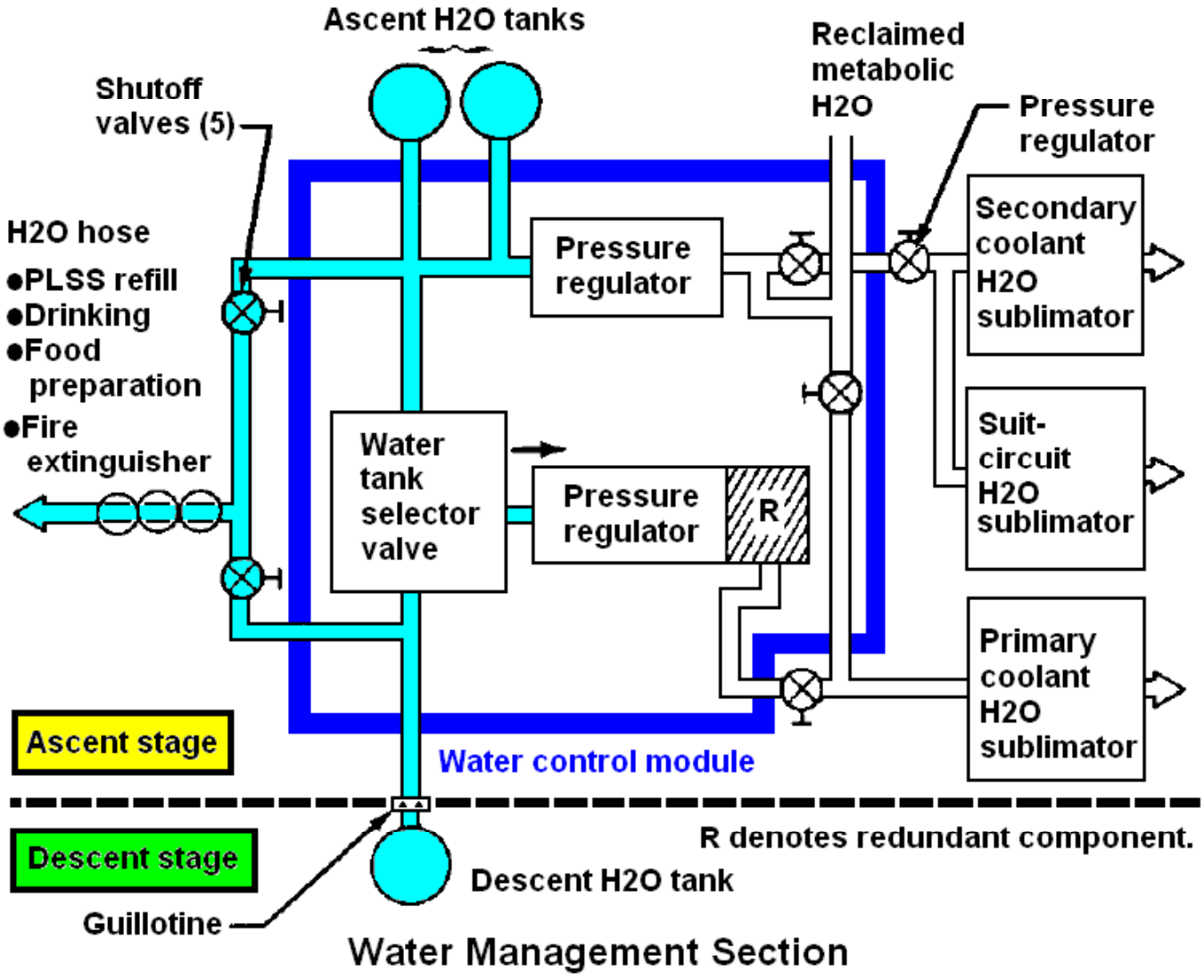
- Water Management Section



Water Management Section

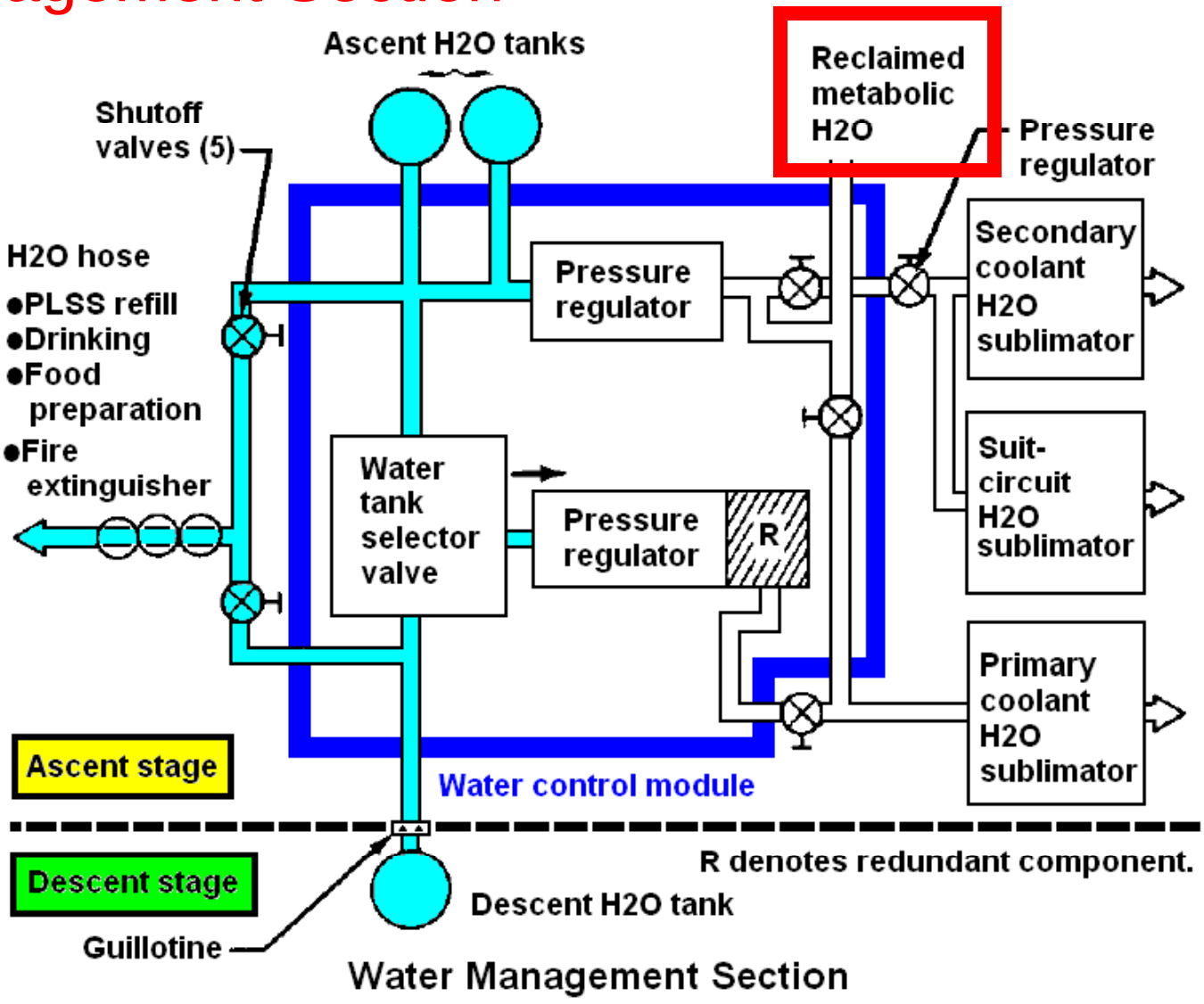
Overview of LM ECS

- Water Management Section



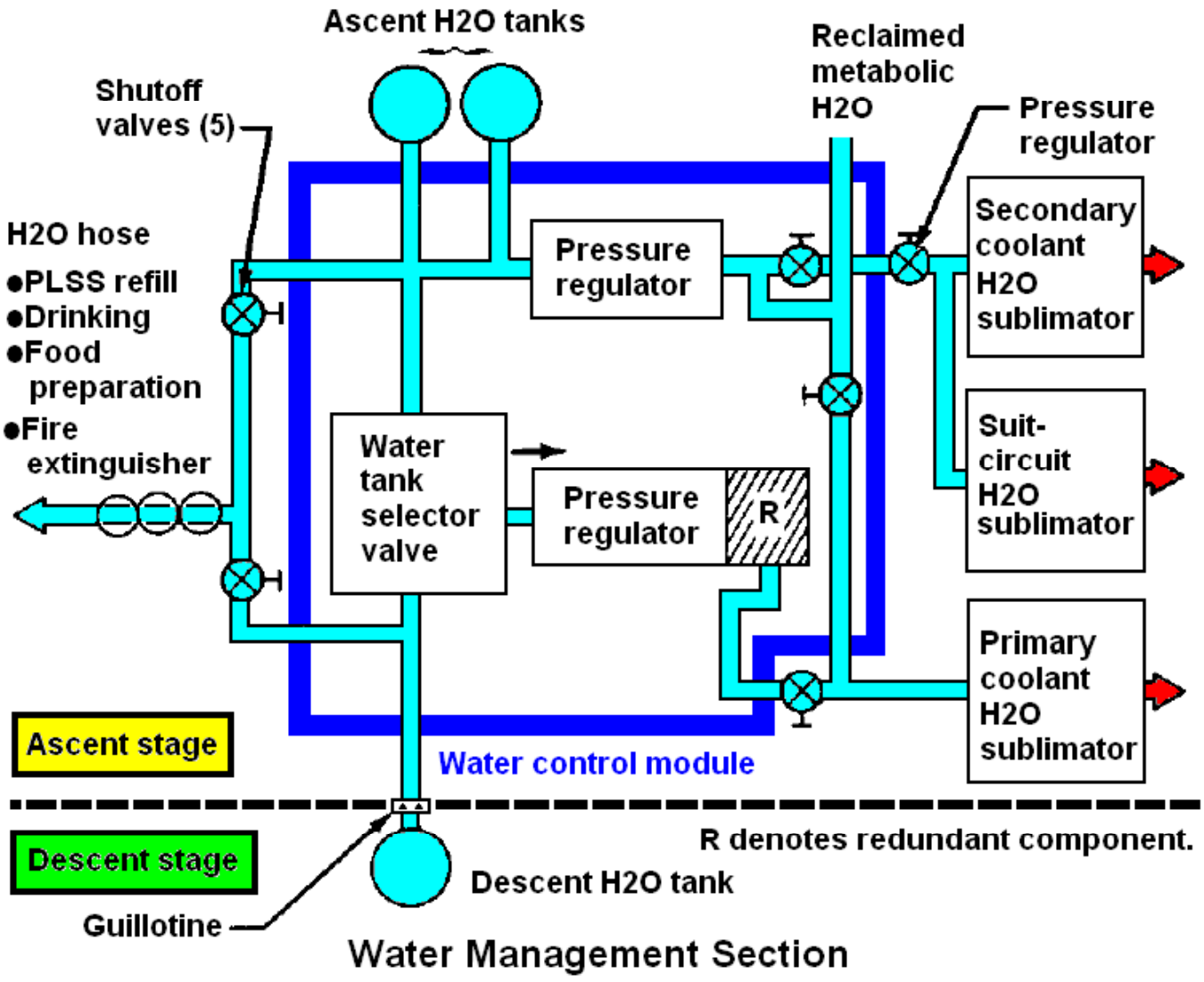
Overview of LM ECS

- Water Management Section



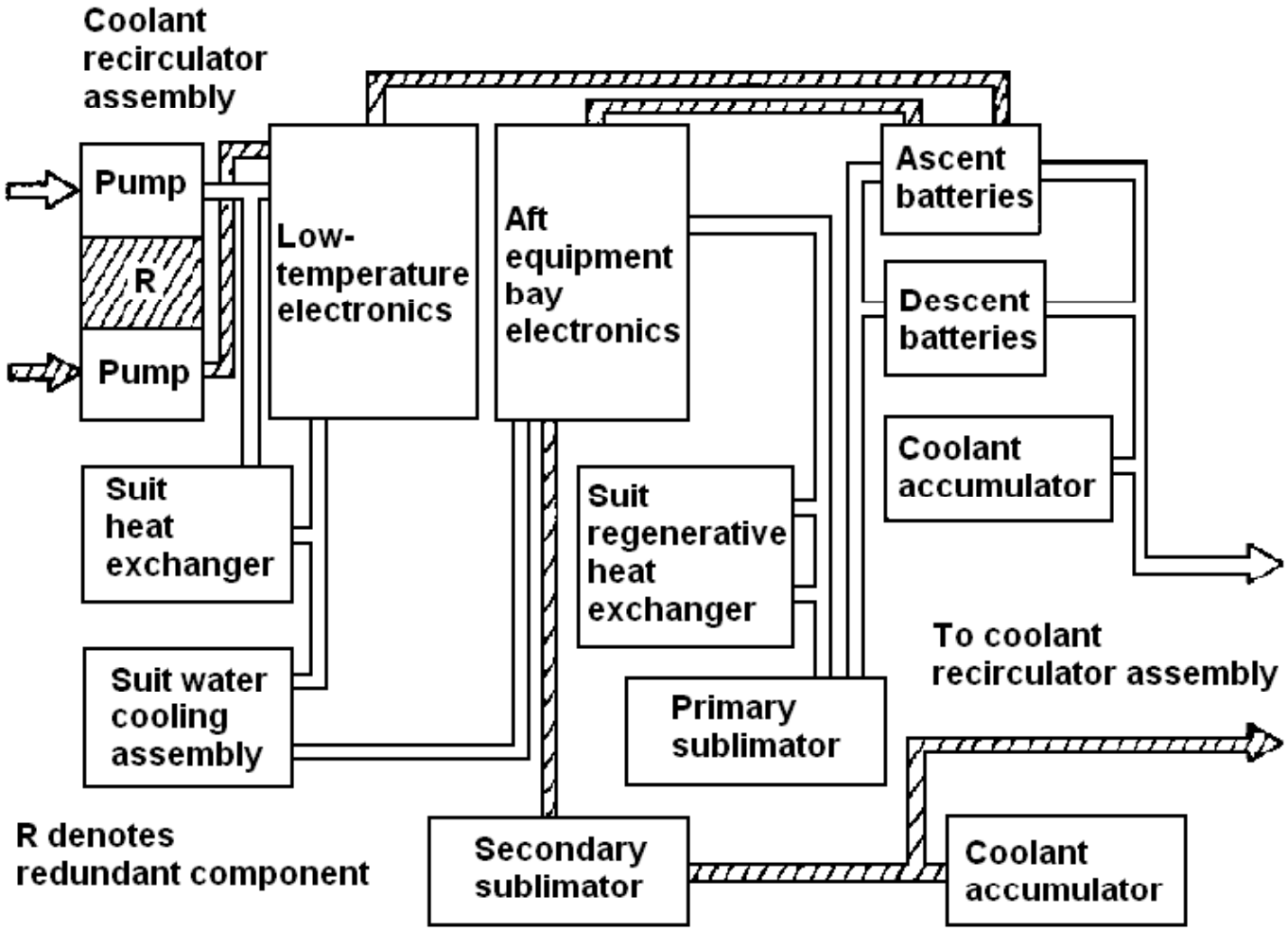
Overview of LM ECS

- Water Management Section



Overview of LM ECS

❑ Heat Transport Section



Heat Transport Section

Overview of LM ECS

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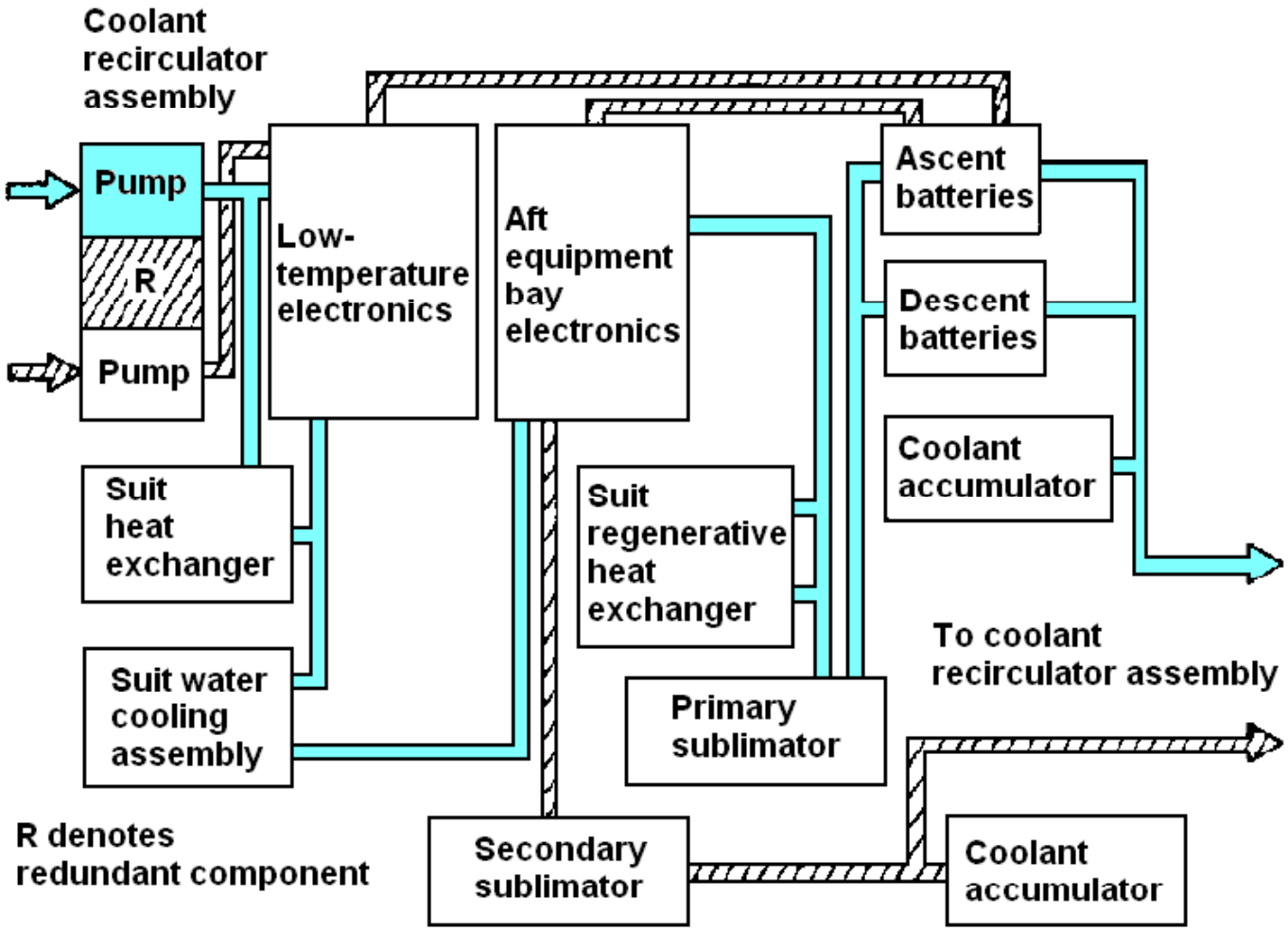

Heat Transport Section

Overview of LM ECS

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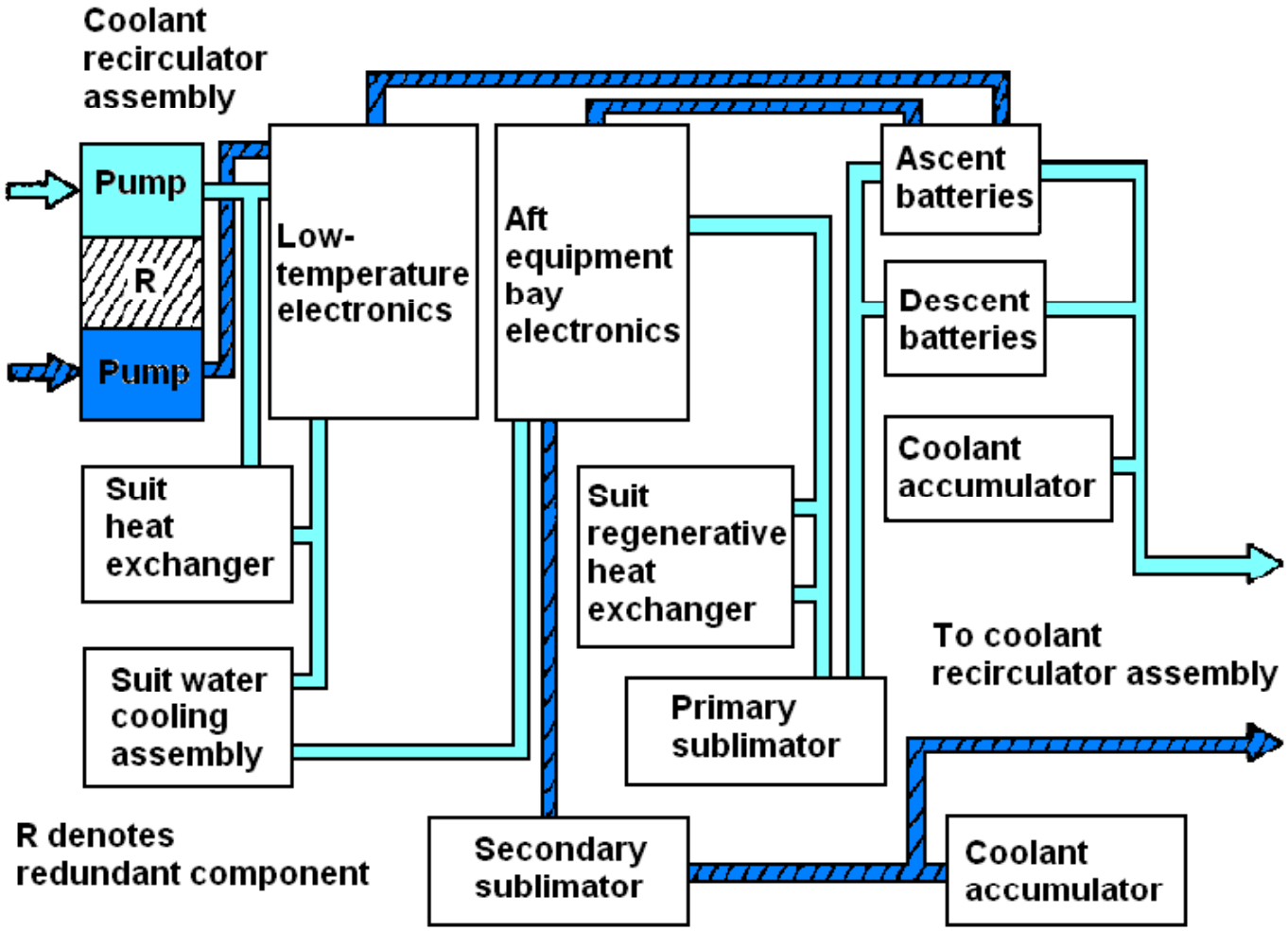

Heat Transport Section

Overview of LM ECS

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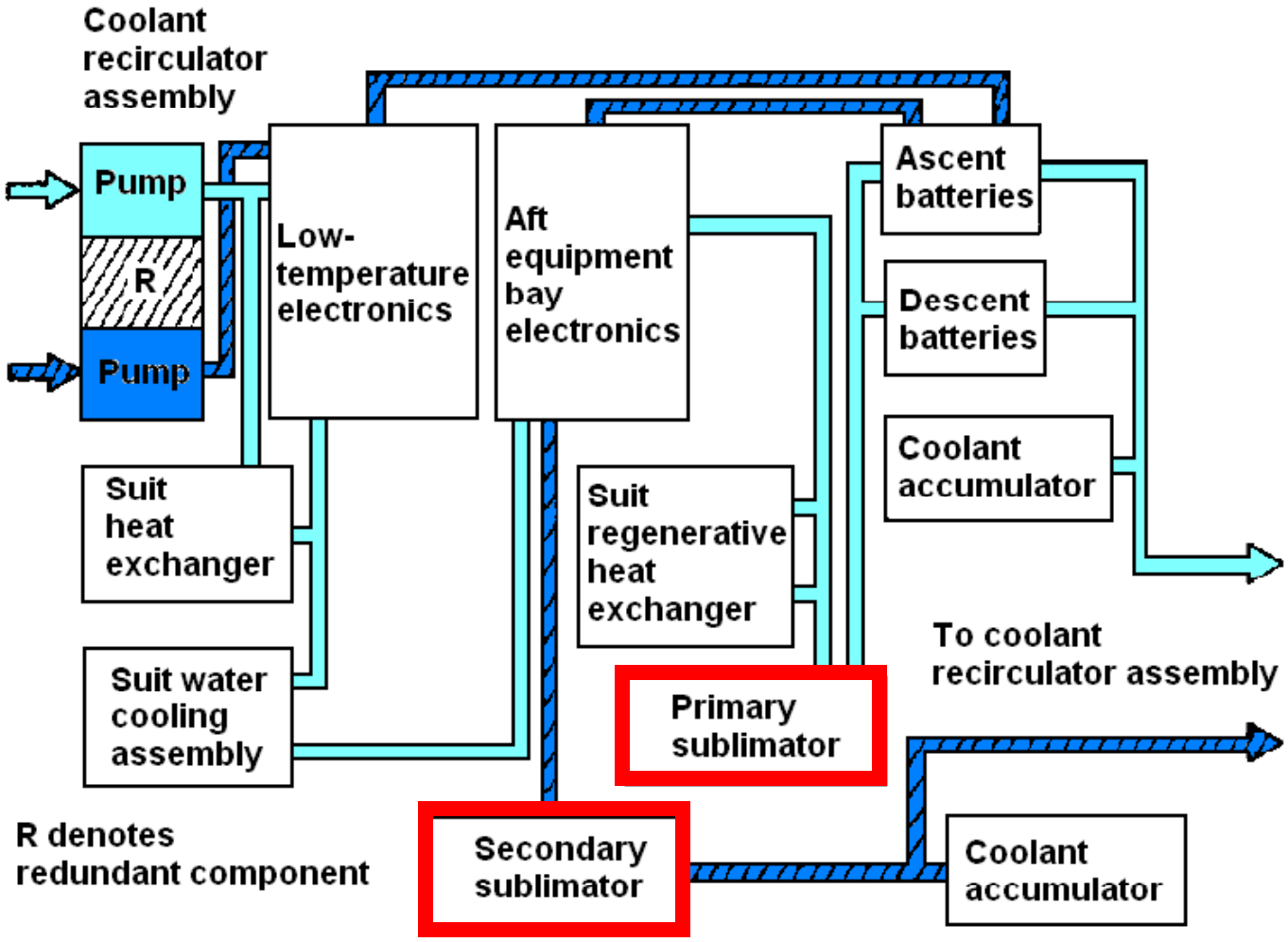
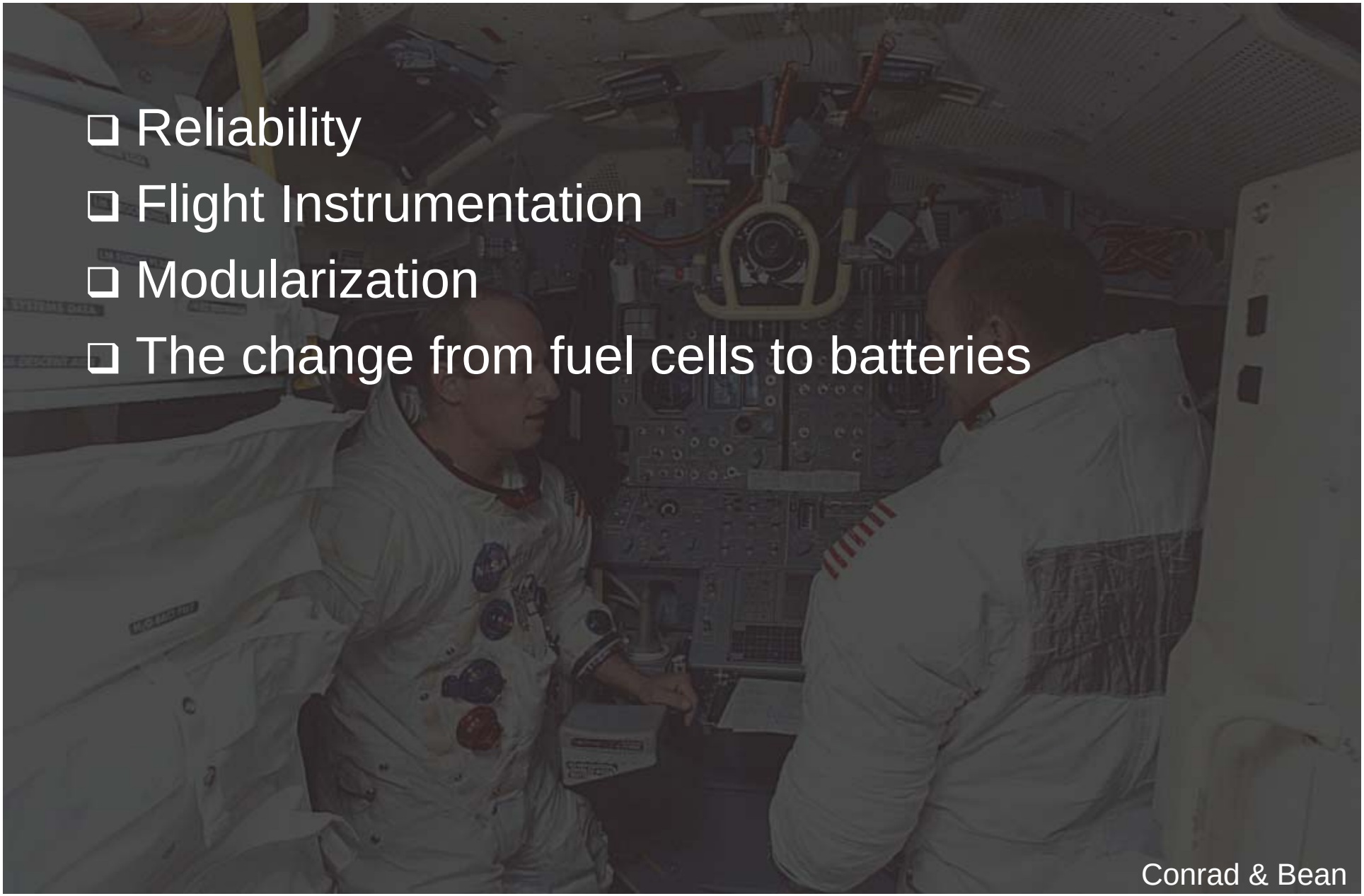


Heat Transport Section

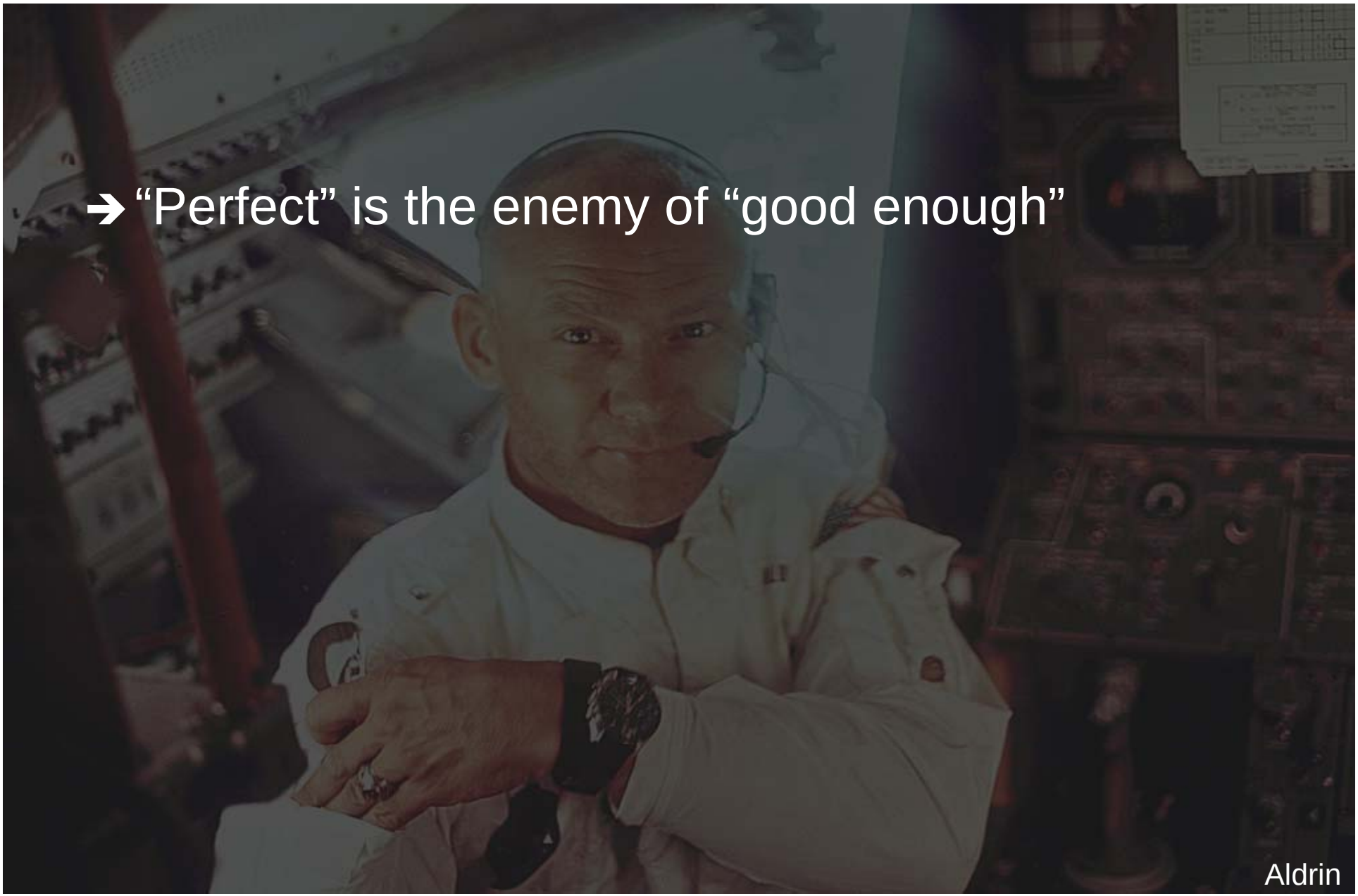
Generic Design Considerations



- Reliability
- Flight Instrumentation
- Modularization
- The change from fuel cells to batteries

Generic Design Considerations -- Reliability

Generic Design Considerations -- Reliability

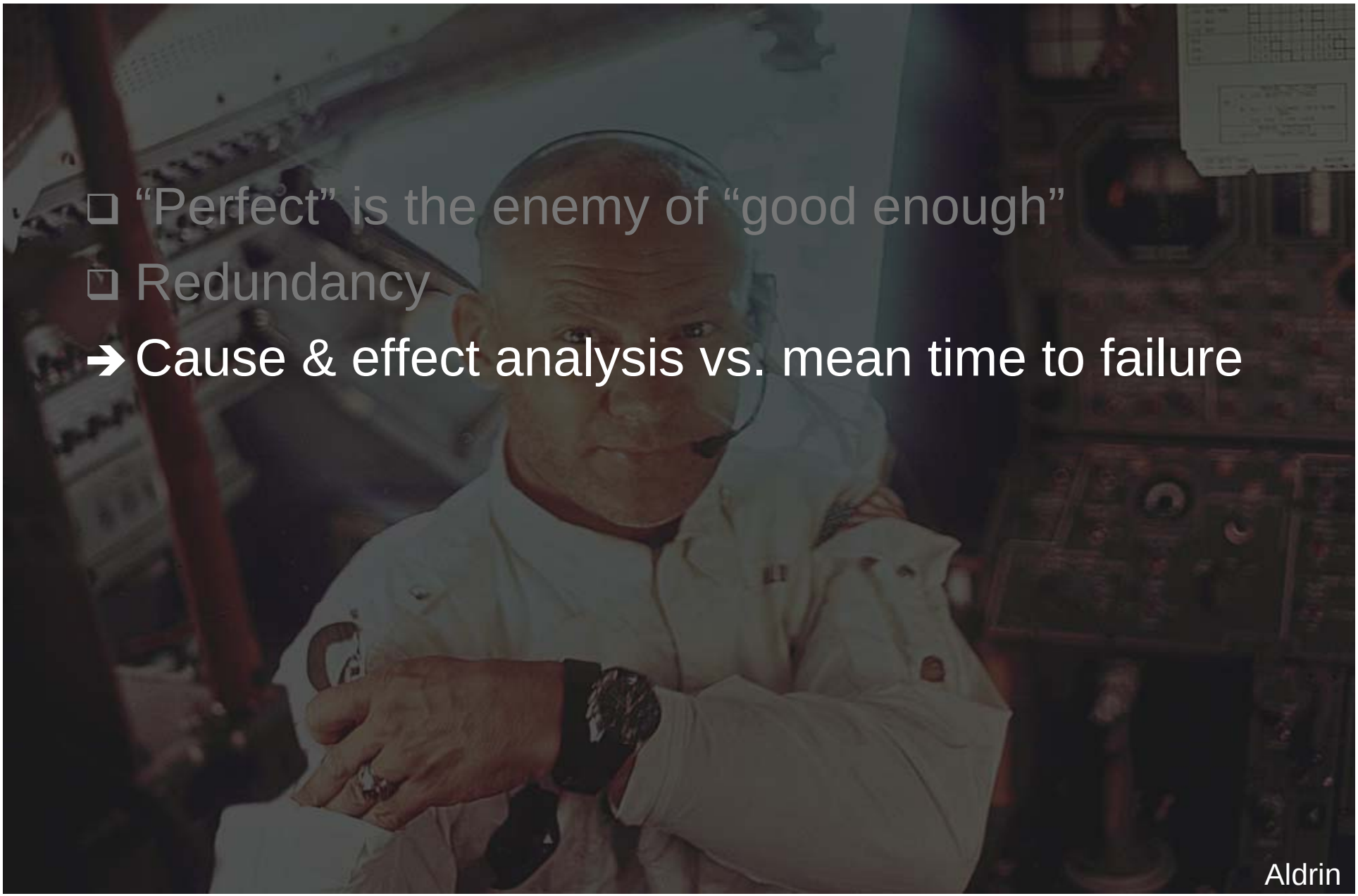


Generic Design Considerations -- Reliability

- "Perfect" is the enemy of "good enough"

➔ Redundancy

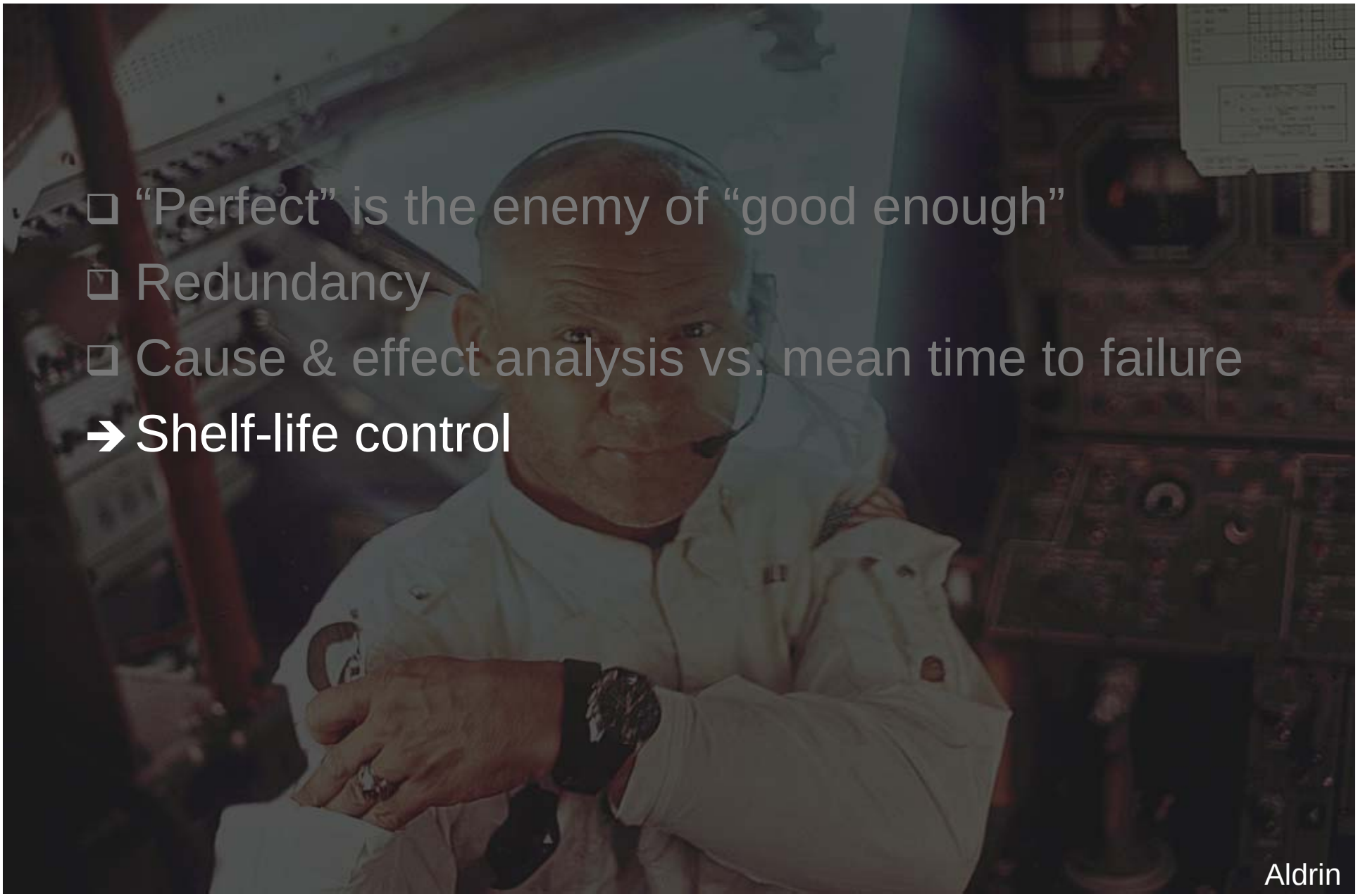
Generic Design Considerations -- Reliability



- "Perfect" is the enemy of "good enough"
- Redundancy

➔ Cause & effect analysis vs. mean time to failure

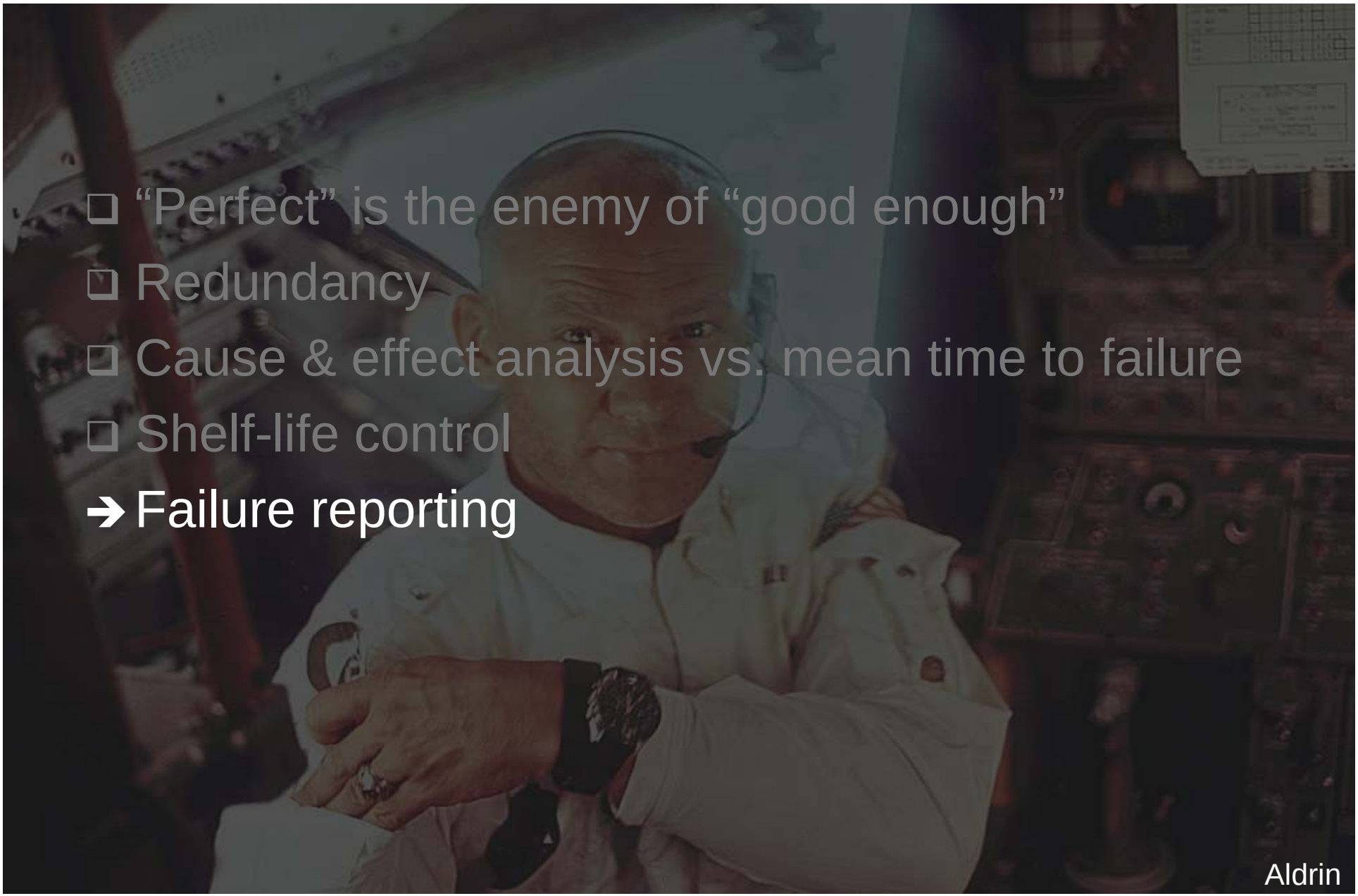
Generic Design Considerations -- Reliability



- "Perfect" is the enemy of "good enough"
- Redundancy
- Cause & effect analysis vs. mean time to failure

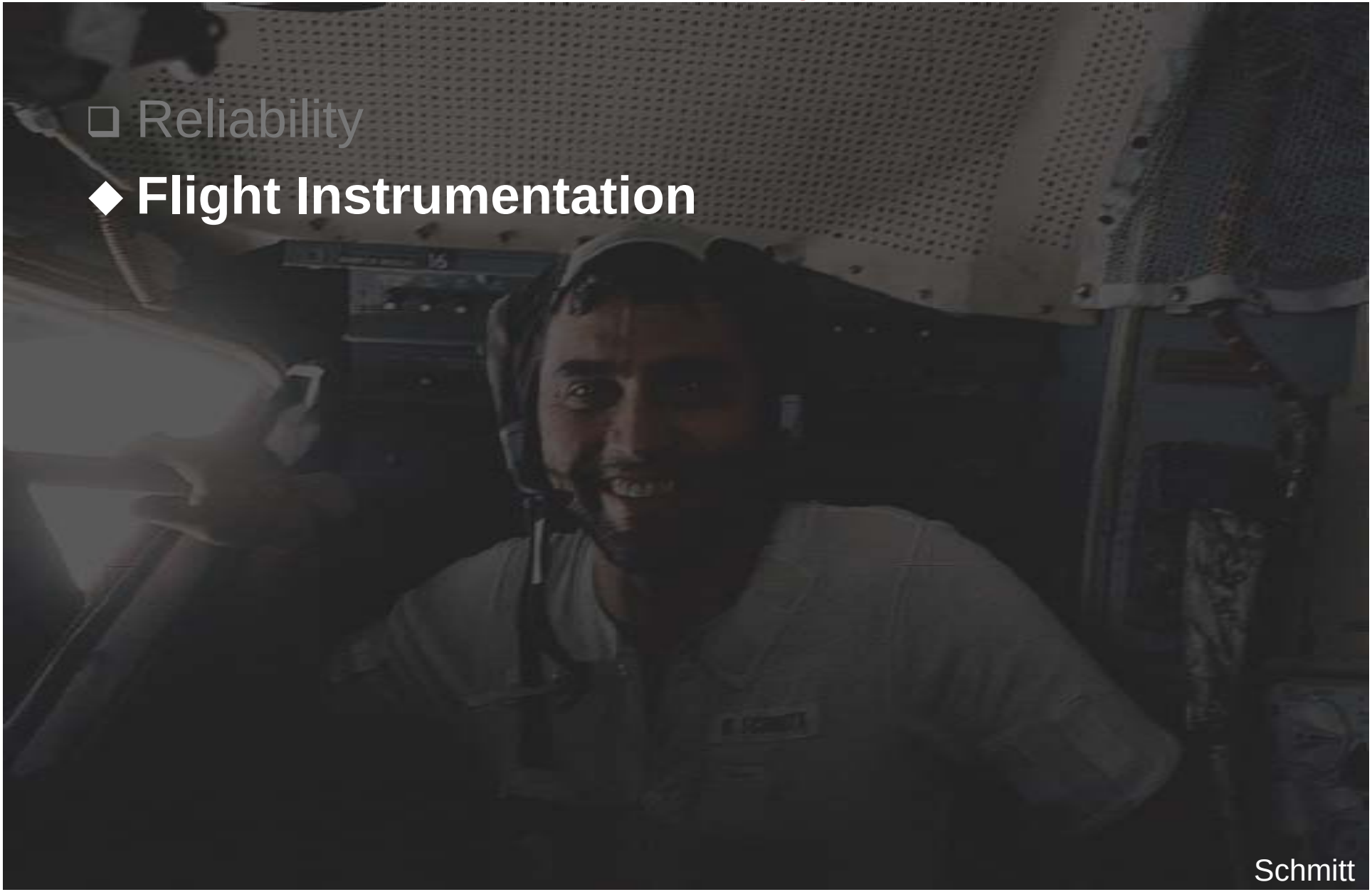
➔ Shelf-life control

Generic Design Considerations -- Reliability



- ❑ “Perfect” is the enemy of “good enough”
- ❑ Redundancy
- ❑ Cause & effect analysis vs. mean time to failure
- ❑ Shelf-life control
- ➔ Failure reporting

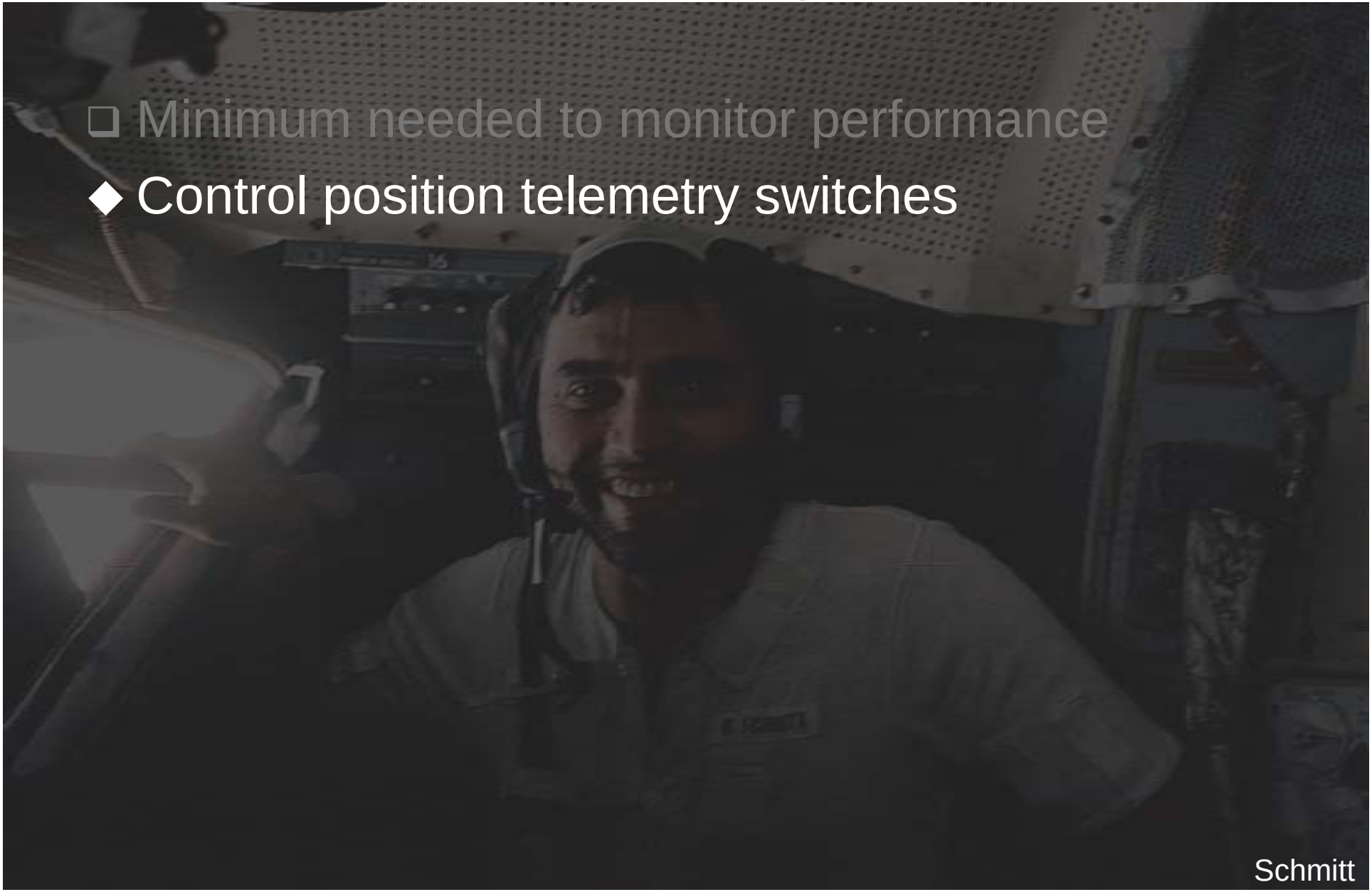
Generic Design Considerations – Flight Instrumentation



Generic Design Considerations – Flight Instrumentation

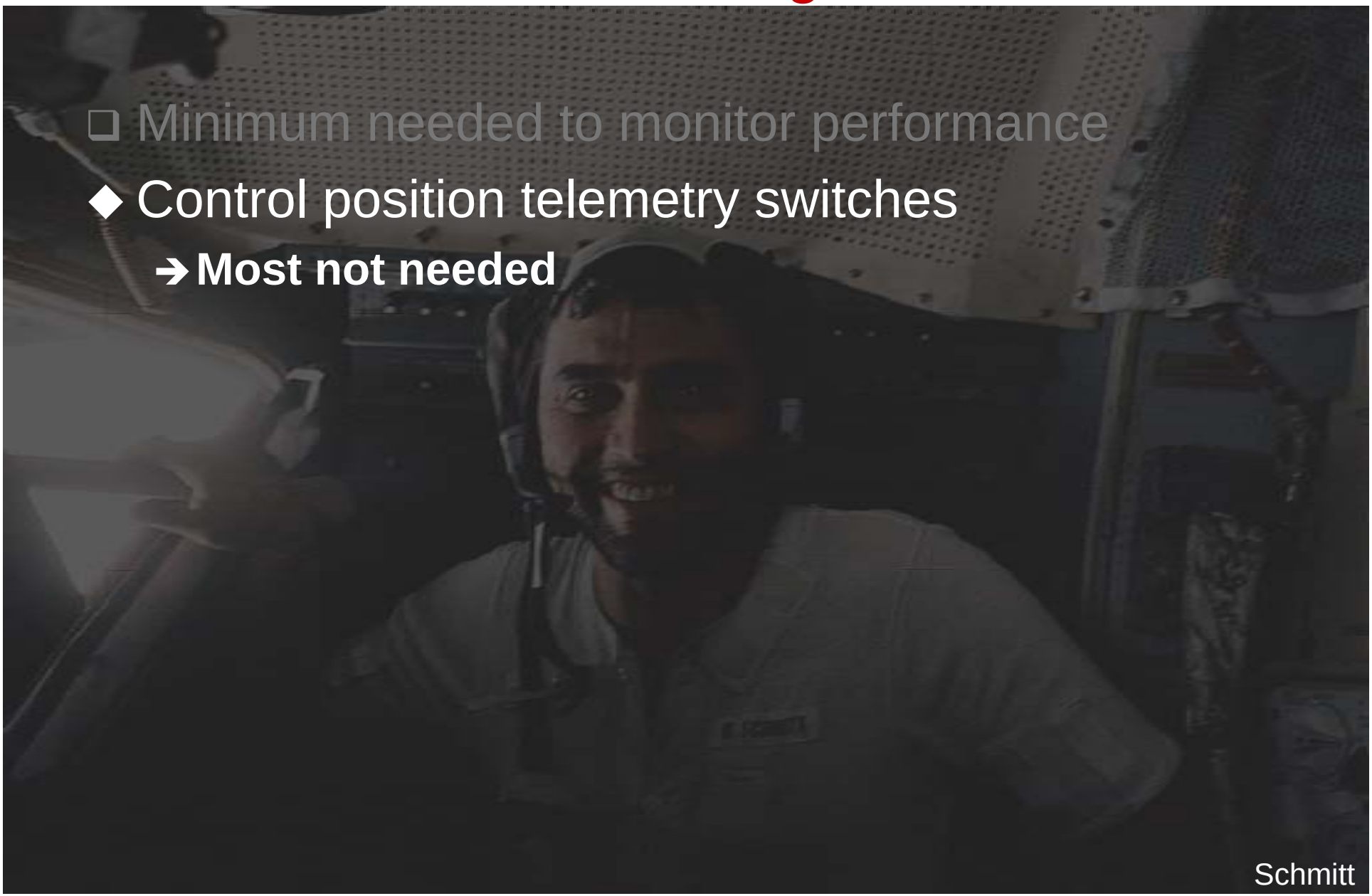
Generic Design Considerations – Flight Instrumentation

- Minimum needed to monitor performance
  - Control position telemetry switches

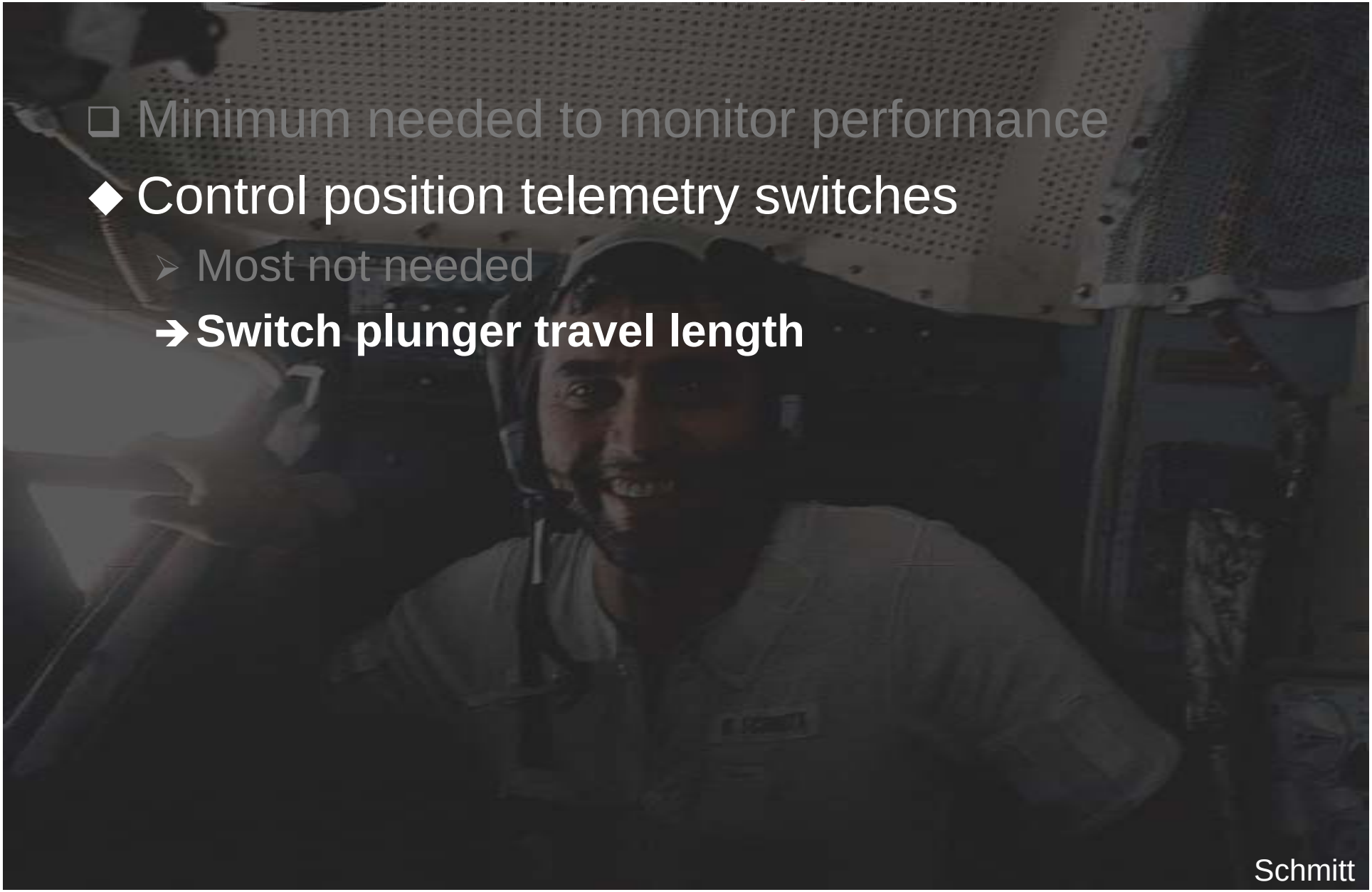


Generic Design Considerations – Flight Instrumentation

- Minimum needed to monitor performance
  - Control position telemetry switches
    - ➔ **Most not needed**



Generic Design Considerations – Flight Instrumentation

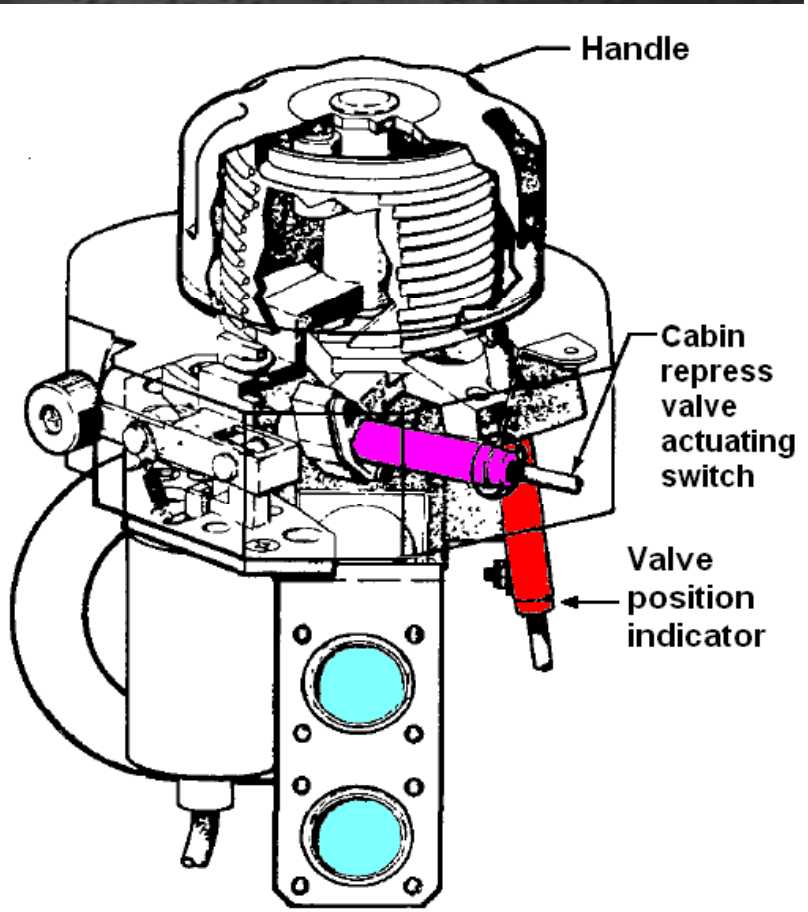


- Minimum needed to monitor performance
  - Control position telemetry switches
    - Most not needed
    - ➔ **Switch plunger travel length**

Schmitt

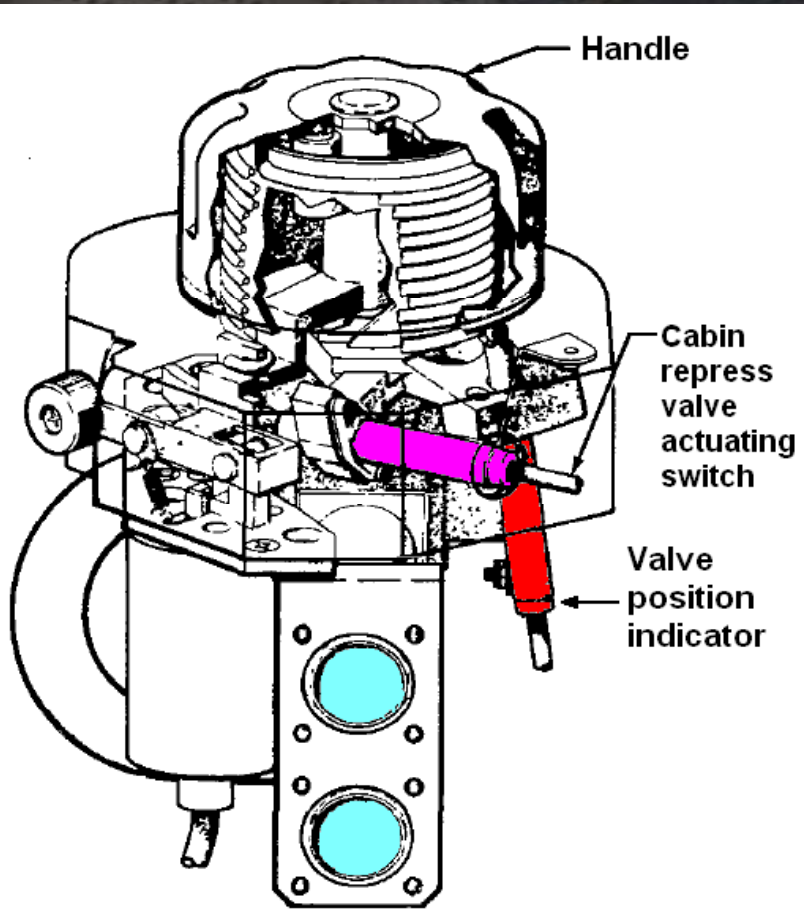
Generic Design Considerations – Flight Instrumentation

- Minimum needed to monitor performance
  - Control position telemetry switches
    - Most not needed
    - ➔ Switch plunger travel length



Generic Design Considerations – Flight Instrumentation

- Minimum needed to monitor performance
  - Control position telemetry switches
    - Most not needed
    - Switch plunger travel length
    - → **Difficult to install**



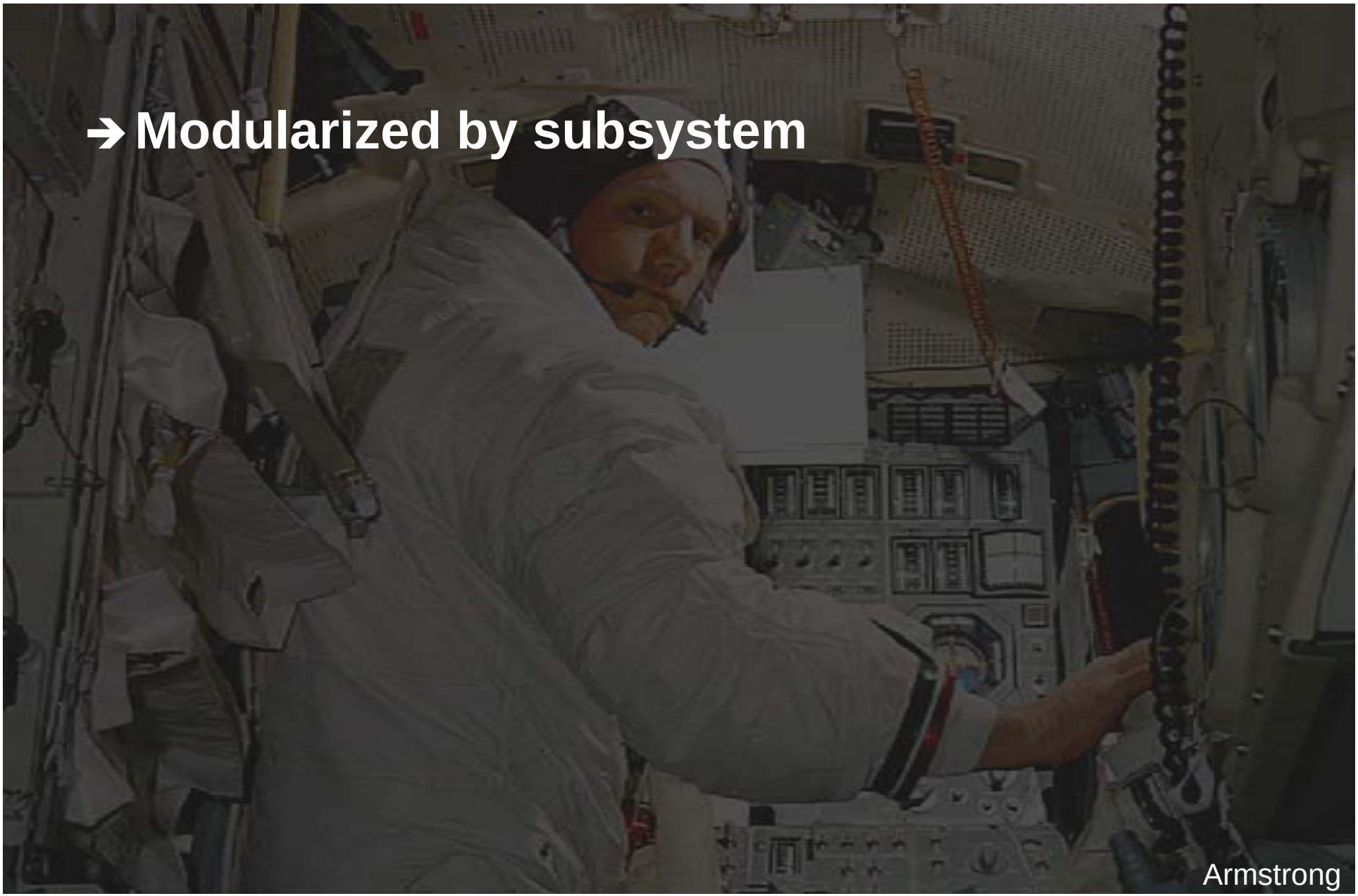
Generic Design Considerations – Flight Instrumentation

- Minimum needed to monitor performance
  - Control position telemetry switches
    - Most not needed
    - Switch plunger travel length
    - → Difficult to install

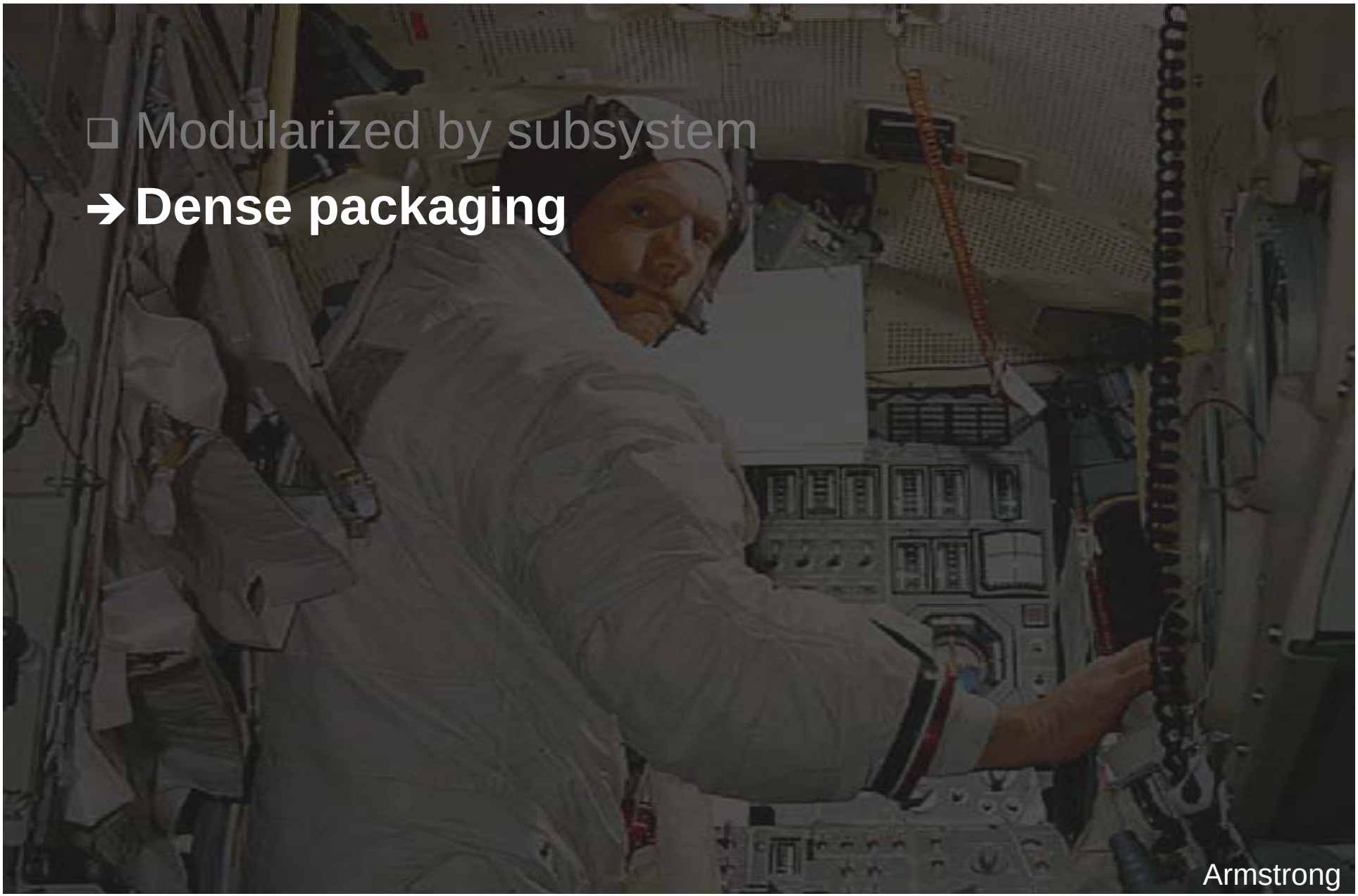
Generic Design Considerations – Modularization

- Reliability
- Flight Instrumentation
- **Modularization**

Generic Design Considerations – Modularization



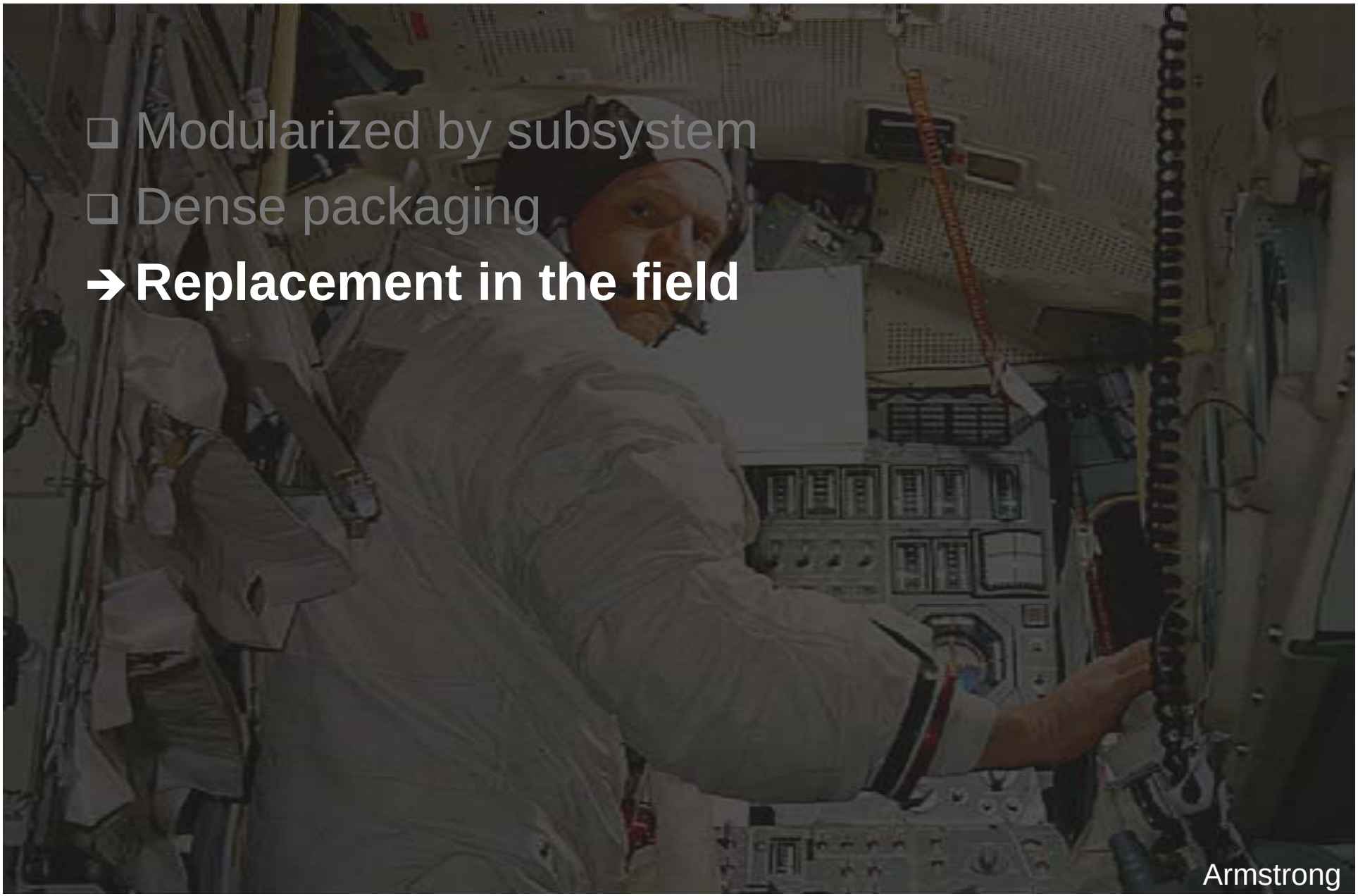
Generic Design Considerations – Modularization



- Modularized by subsystem

➔ **Dense packaging**

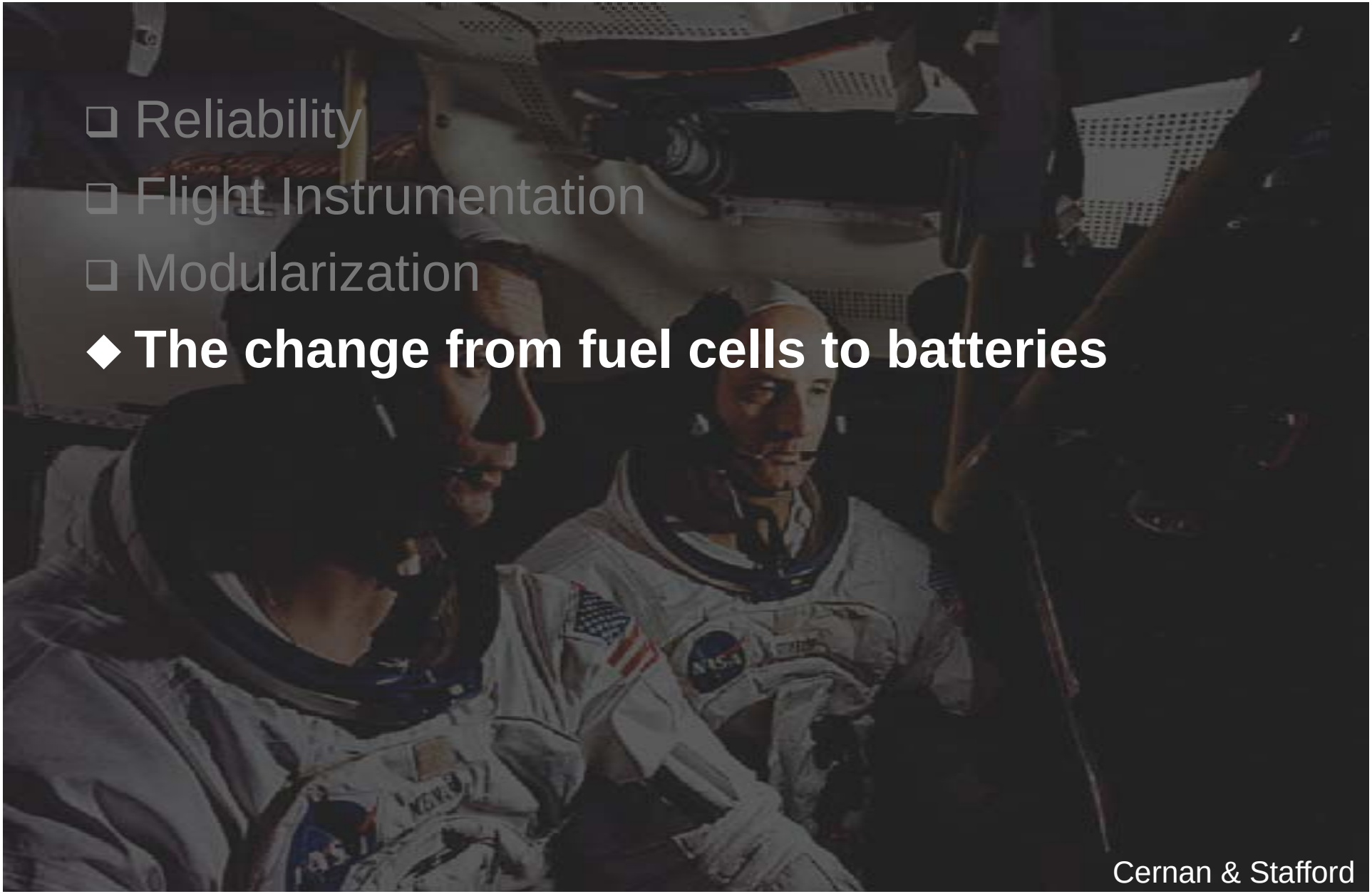
Generic Design Considerations – Modularization



- Modularized by subsystem
- Dense packaging

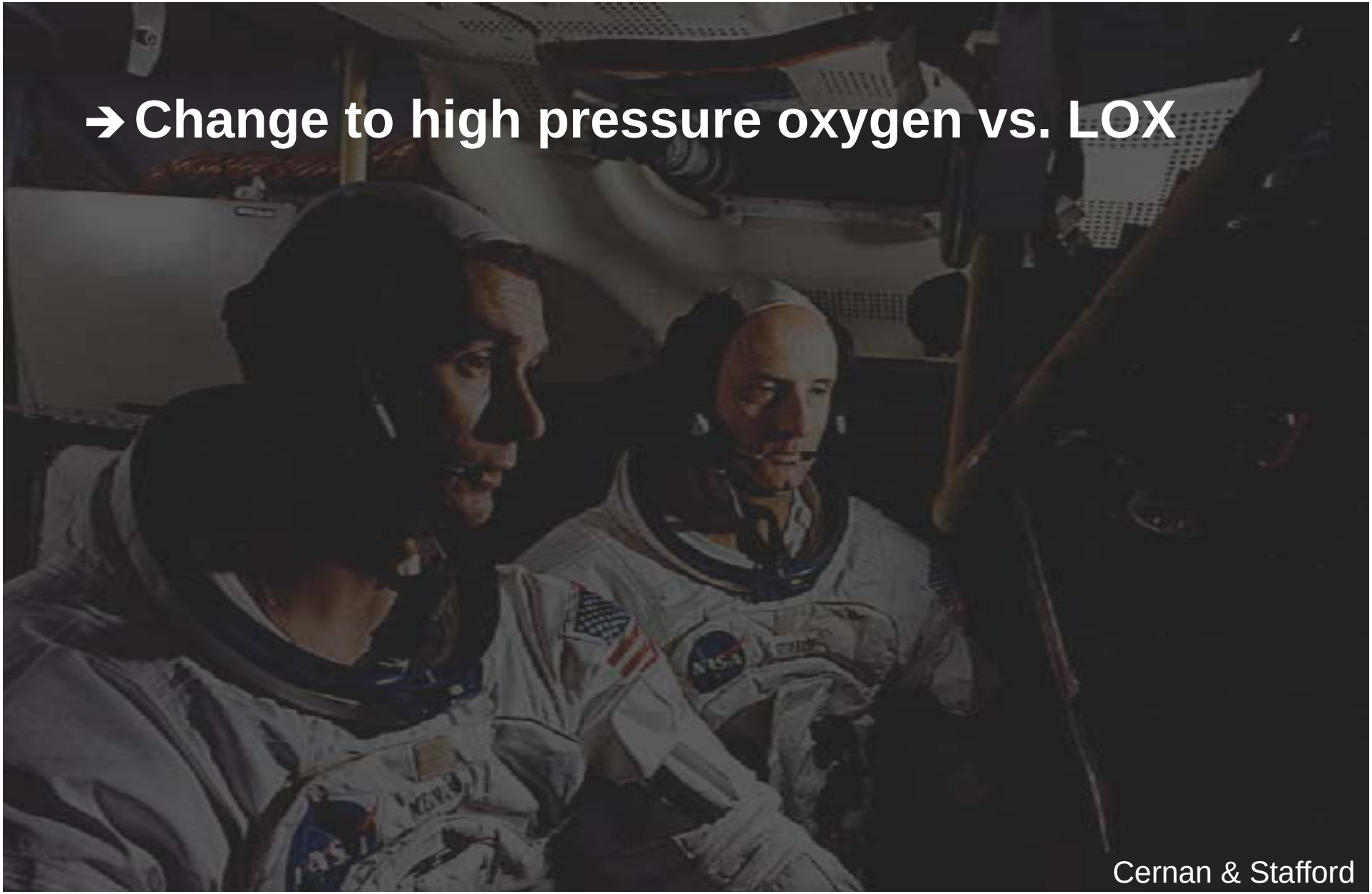
➔ **Replacement in the field**

Generic Design Considerations – The Change to Batteries

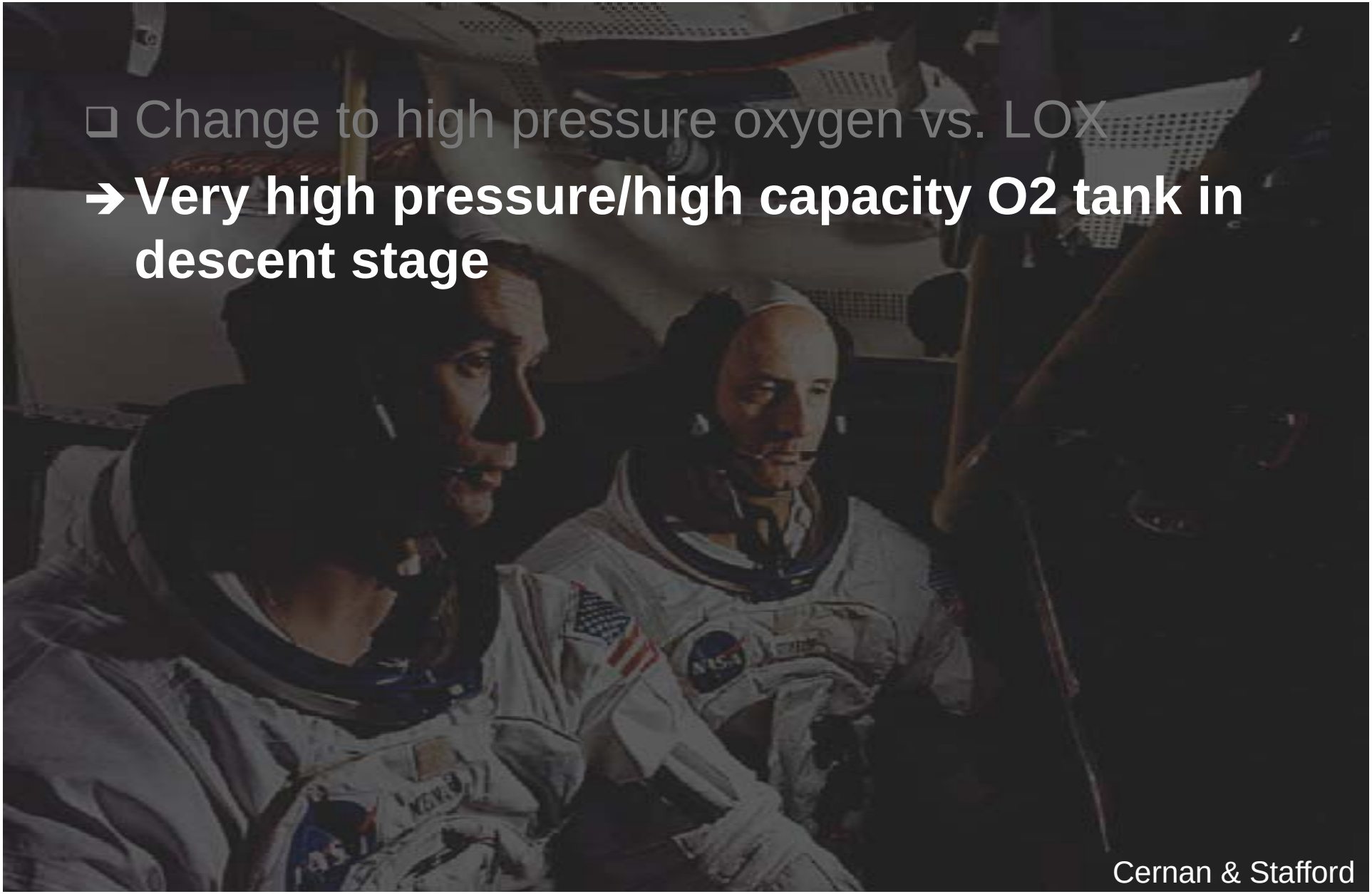


- Reliability
- Flight Instrumentation
- Modularization
- **The change from fuel cells to batteries**

Generic Design Considerations – The Change to Batteries



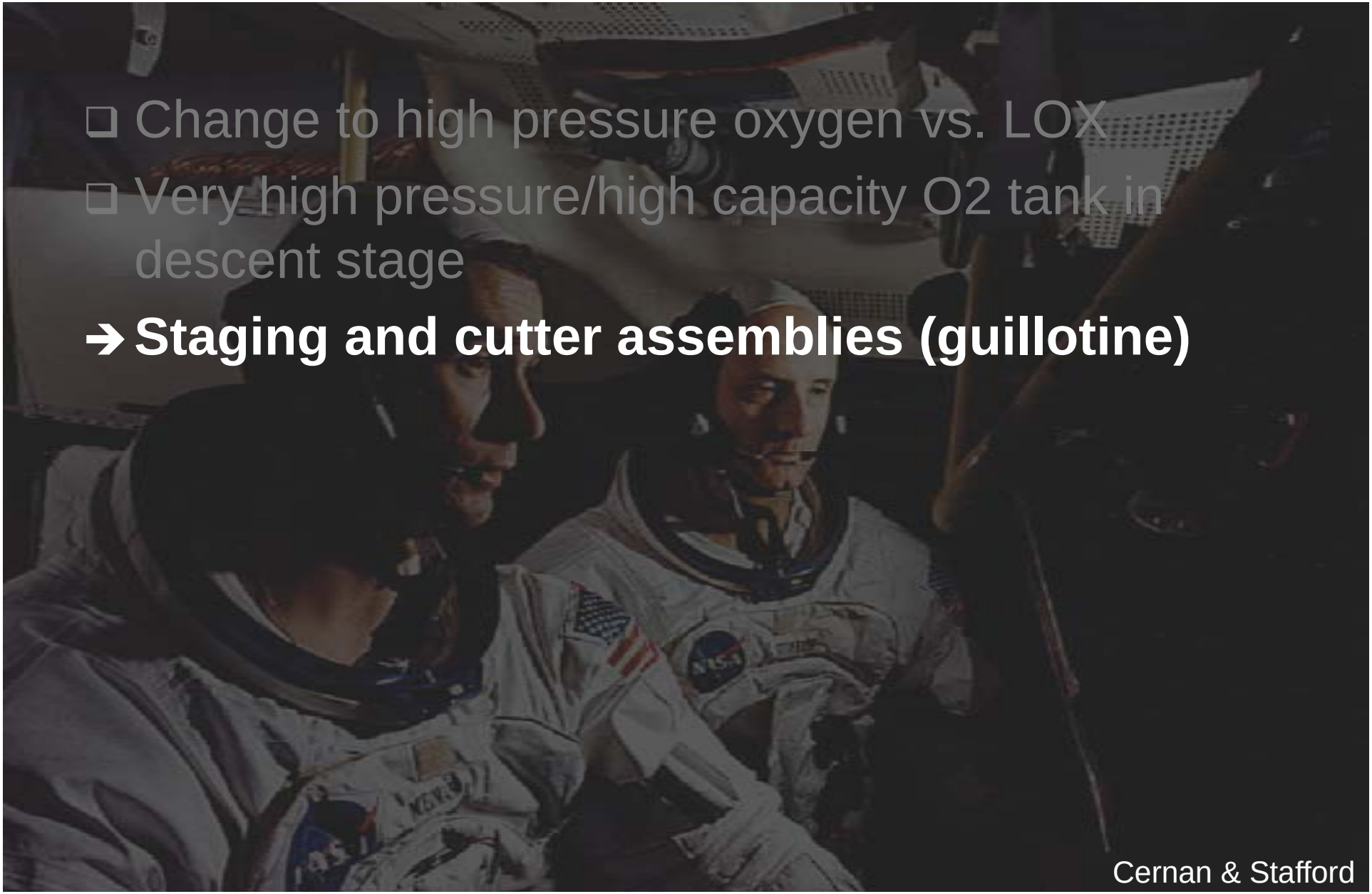
Generic Design Considerations – The Change to Batteries



- Change to high pressure oxygen vs. LOX

➔ **Very high pressure/high capacity O2 tank in descent stage**

Generic Design Considerations – The Change to Batteries

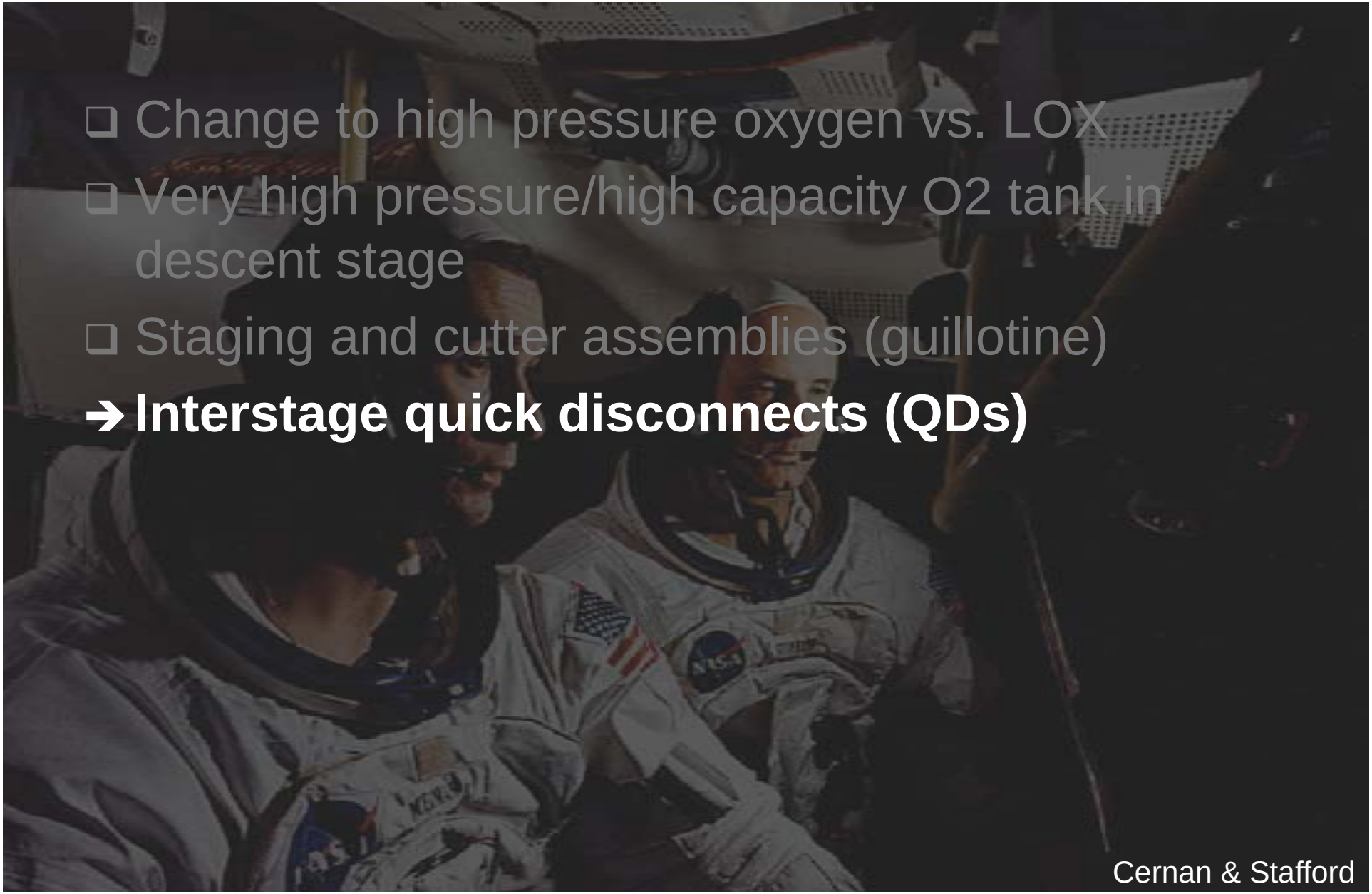


- Change to high pressure oxygen vs. LOX
- Very high pressure/high capacity O2 tank in descent stage

➔ **Staging and cutter assemblies (guillotine)**

Cernan & Stafford

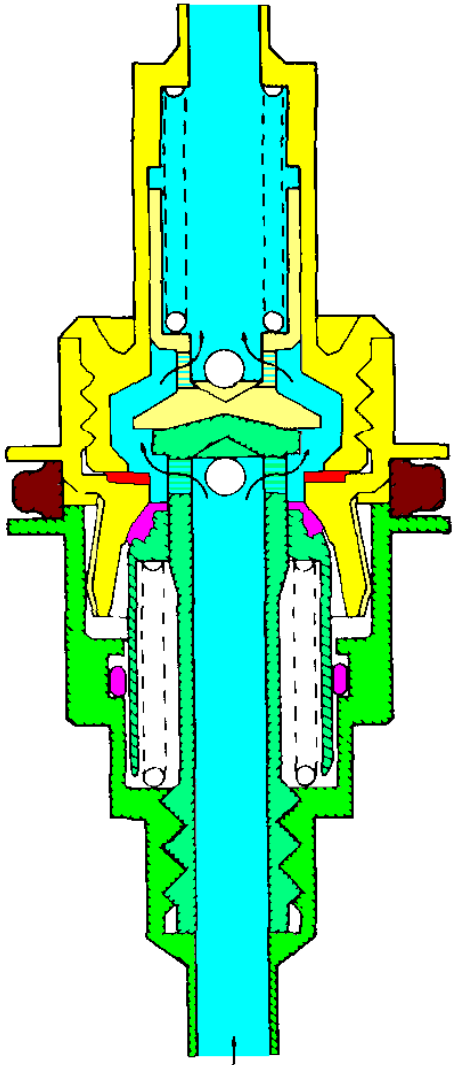
Generic Design Considerations – The Change to Batteries



- Change to high pressure oxygen vs. LOX
- Very high pressure/high capacity O2 tank in descent stage
- Staging and cutter assemblies (guillotine)

➔ **Interstage quick disconnects (QDs)**

Generic Design Considerations – QDs



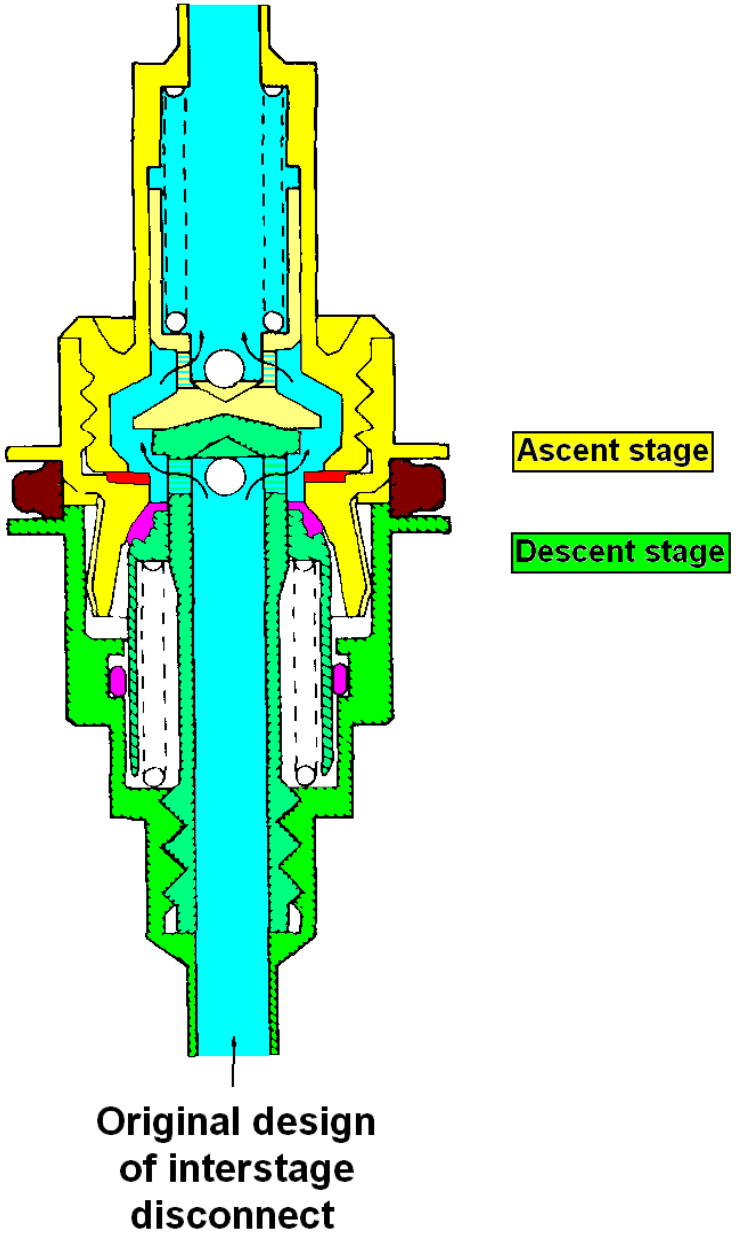
Ascent stage

Descent stage

Original design of interstage disconnect

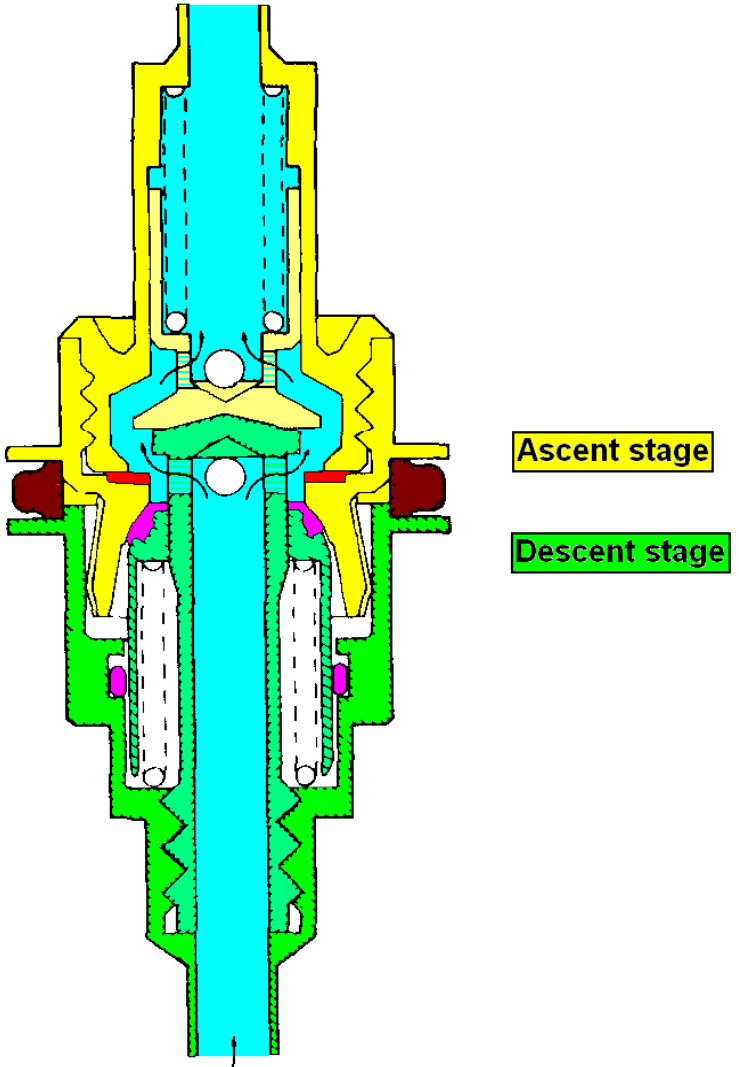
Generic Design Considerations – QDs

- Cutoff valves not needed, as will automatically seal



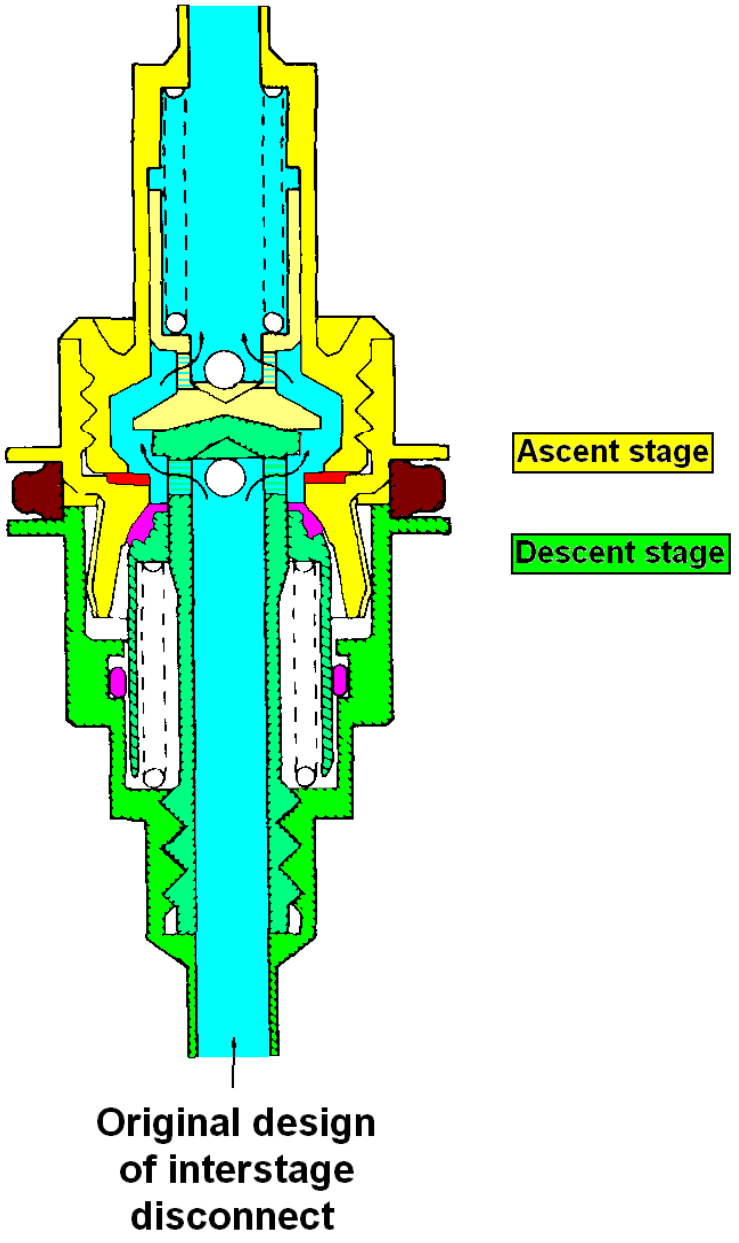
Generic Design Considerations – QDs

- Cutoff valves not needed, as will automatically seal
- No retention mechanism

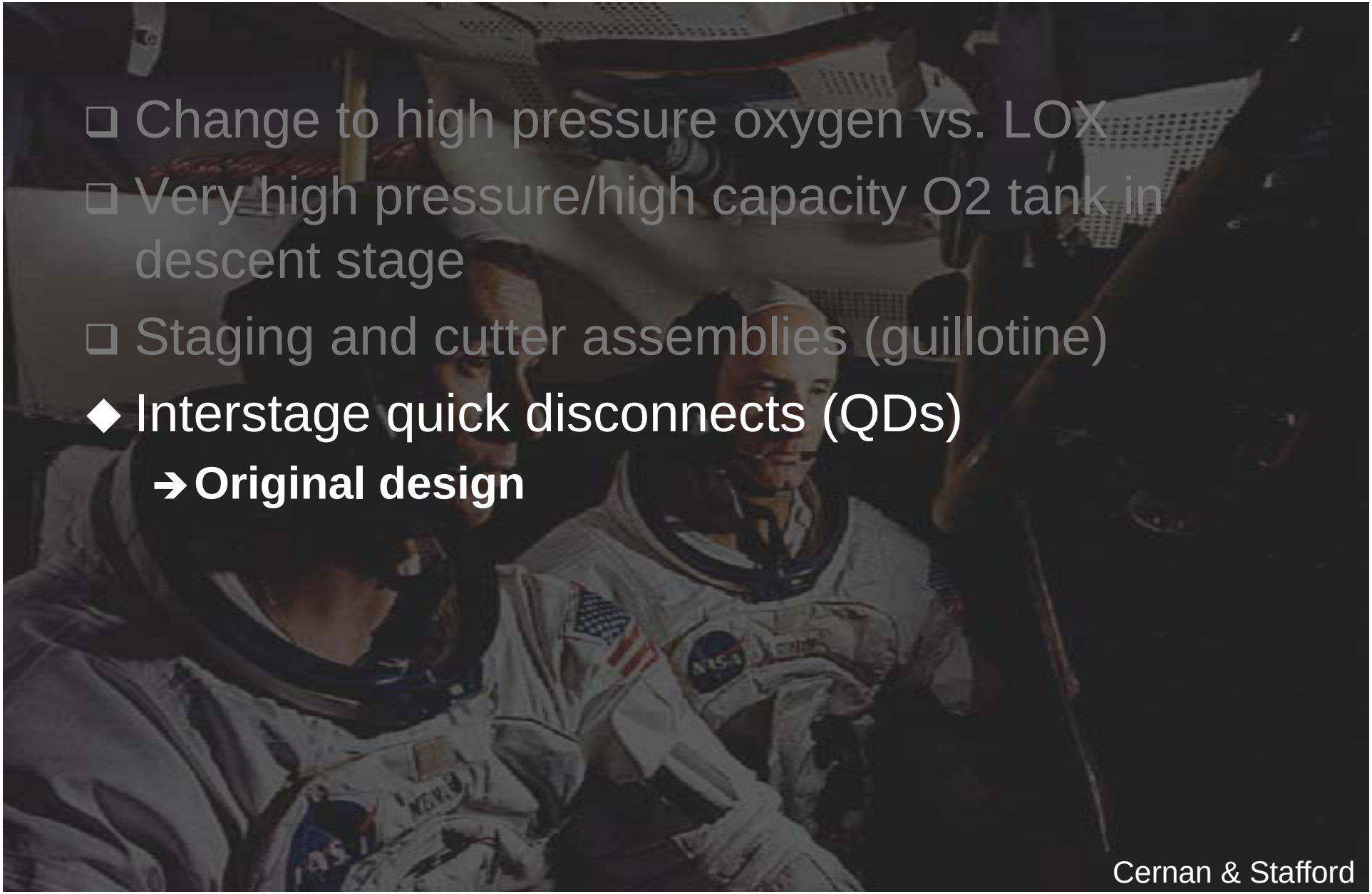


Generic Design Considerations – QDs

- Cutoff valves not needed, as will automatically seal
- No retention mechanism
- No risk of impact ignition

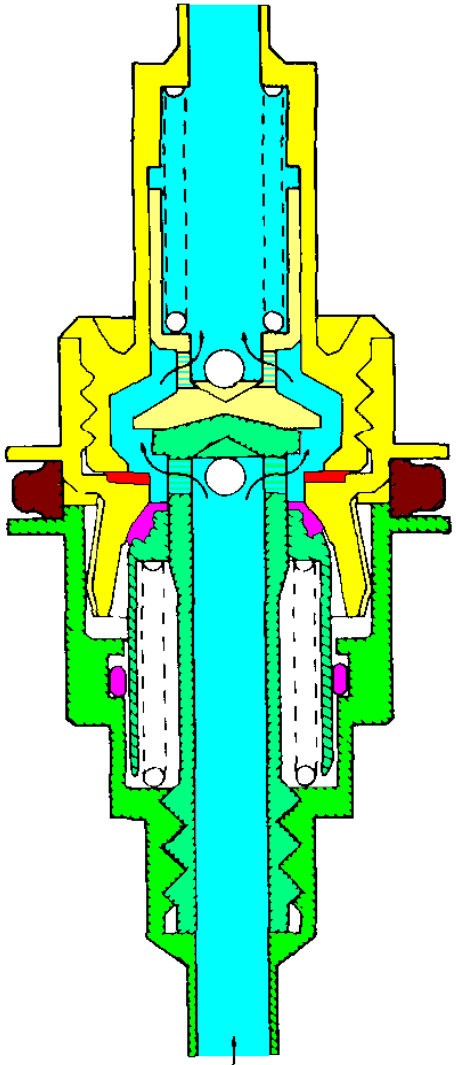


Generic Design Considerations – The Change to Batteries



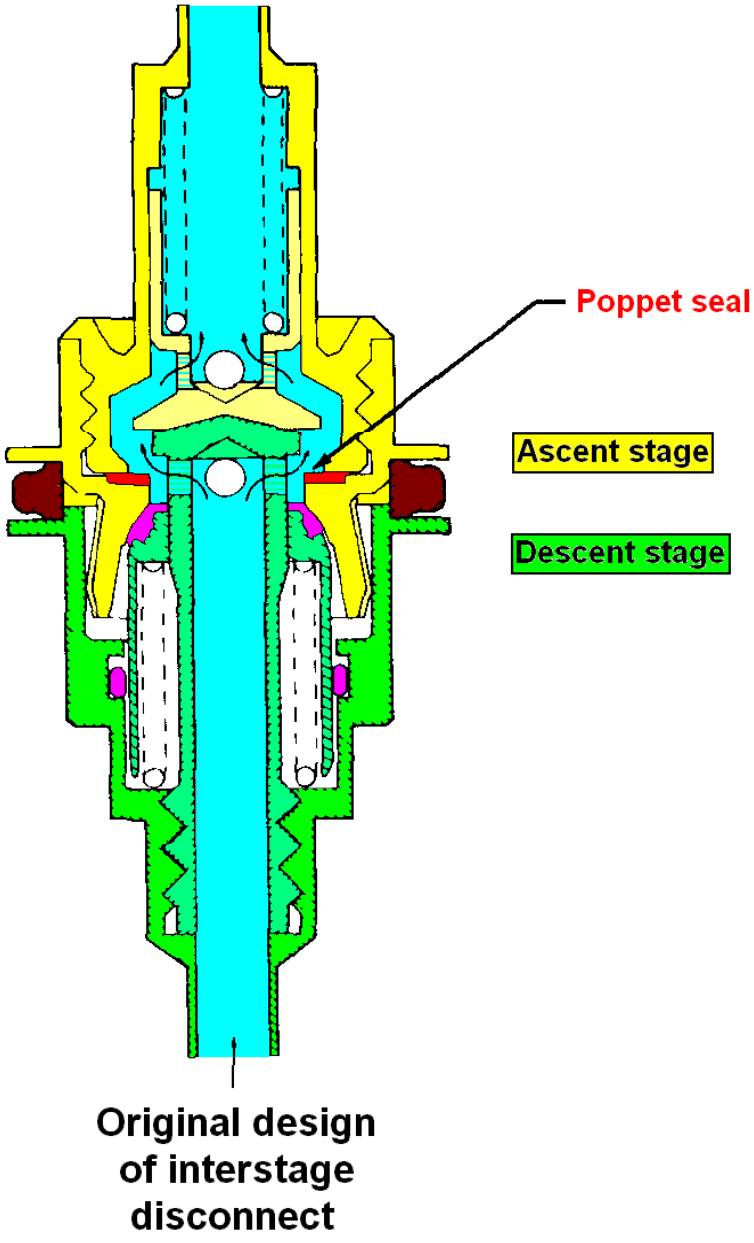
- Change to high pressure oxygen vs. LOX
- Very high pressure/high capacity O2 tank in descent stage
- Staging and cutter assemblies (guillotine)
- Interstage quick disconnects (QDs)
  - ➔ **Original design**

Generic Design Considerations – Original QDs



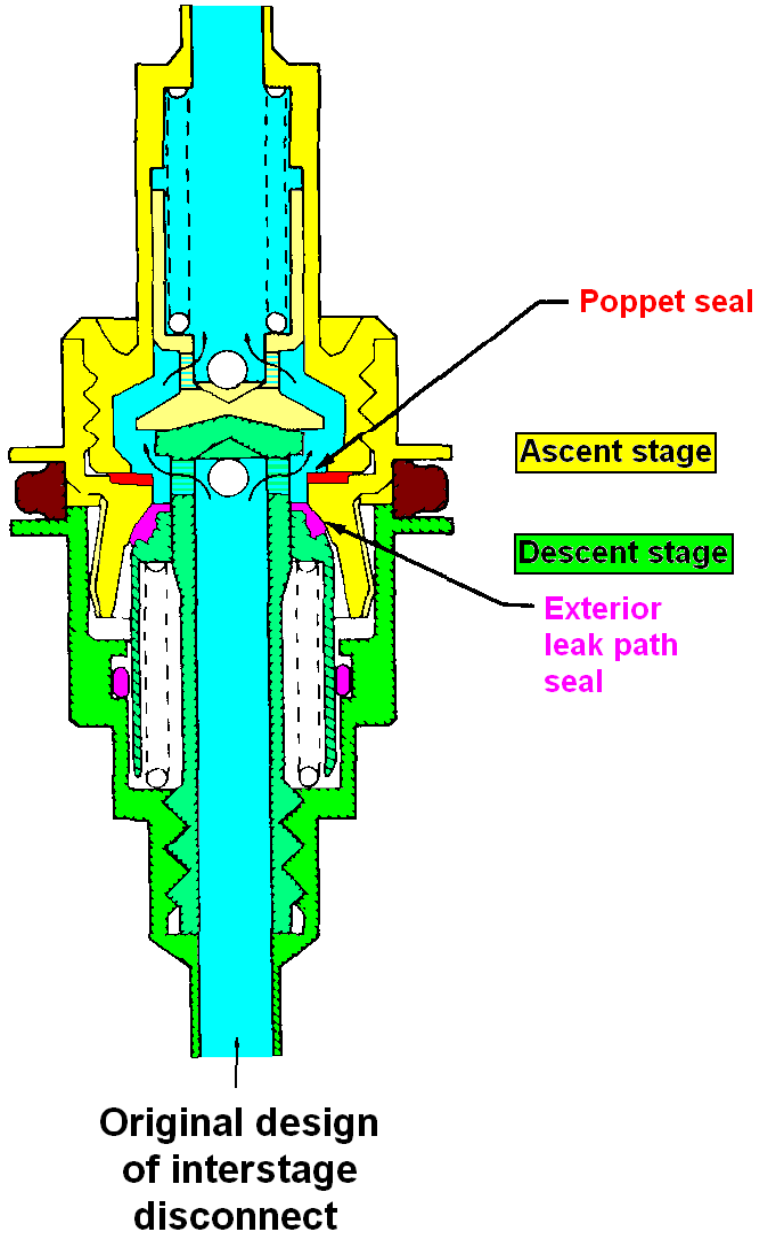
Generic Design Considerations – Original QDs

Poppet seal was on the ascent stage portion



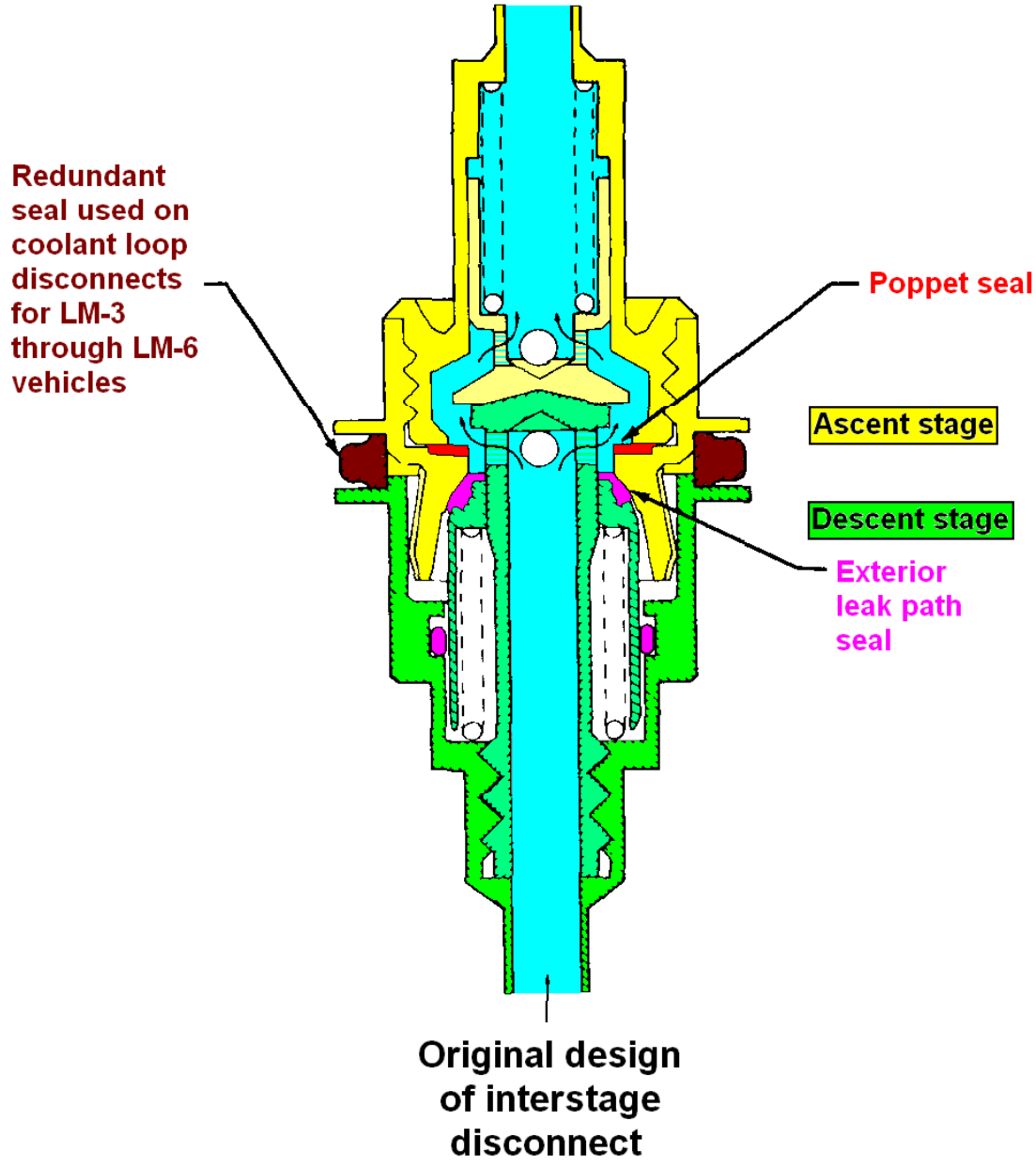
Generic Design Considerations – Original QDs

Exterior leak path seal was on the descent stage portion



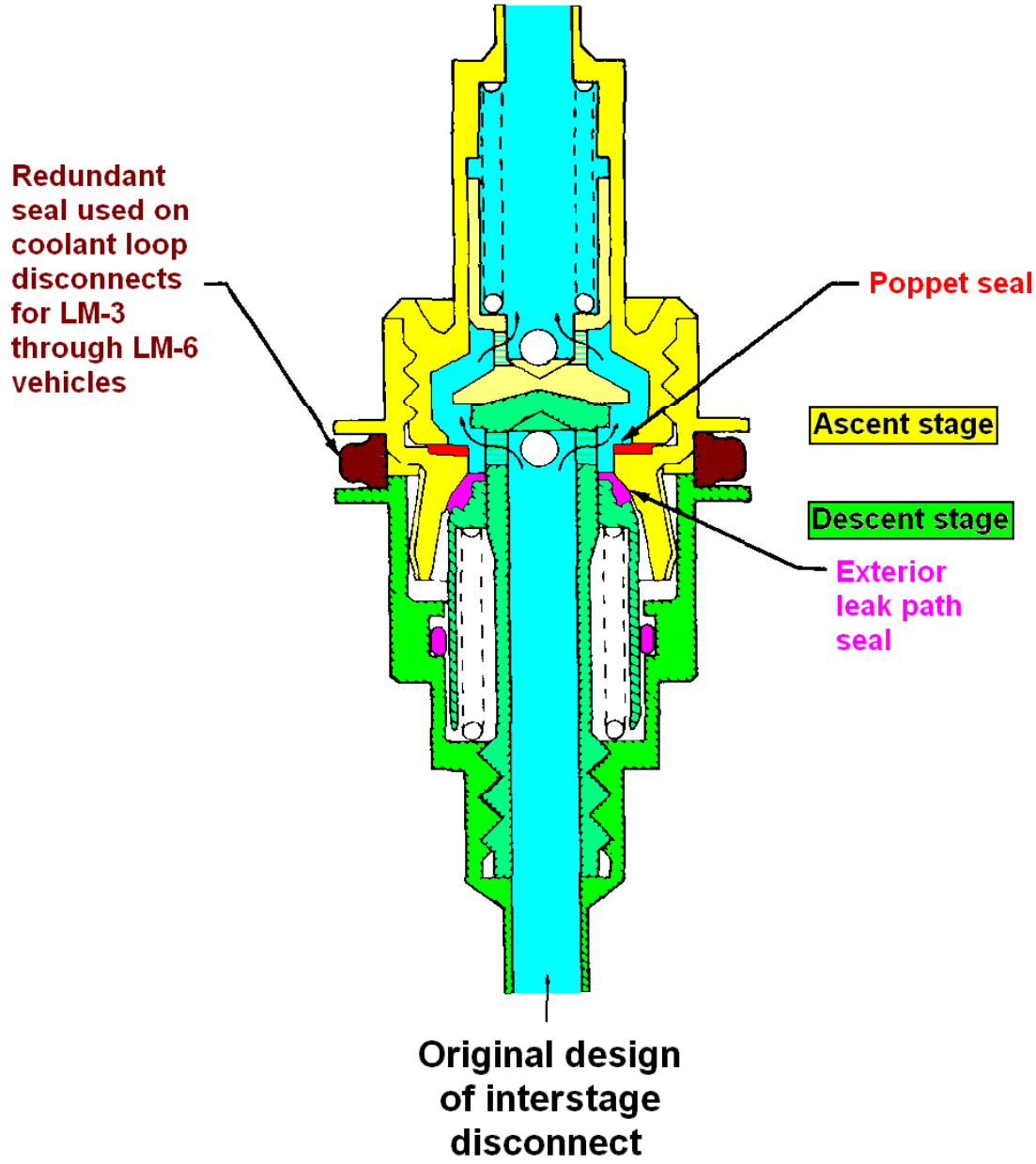
Generic Design Considerations – Original QDs

- Redundant seal was needed on the glycol loop because it leaked
- Not needed on the oxygen QD



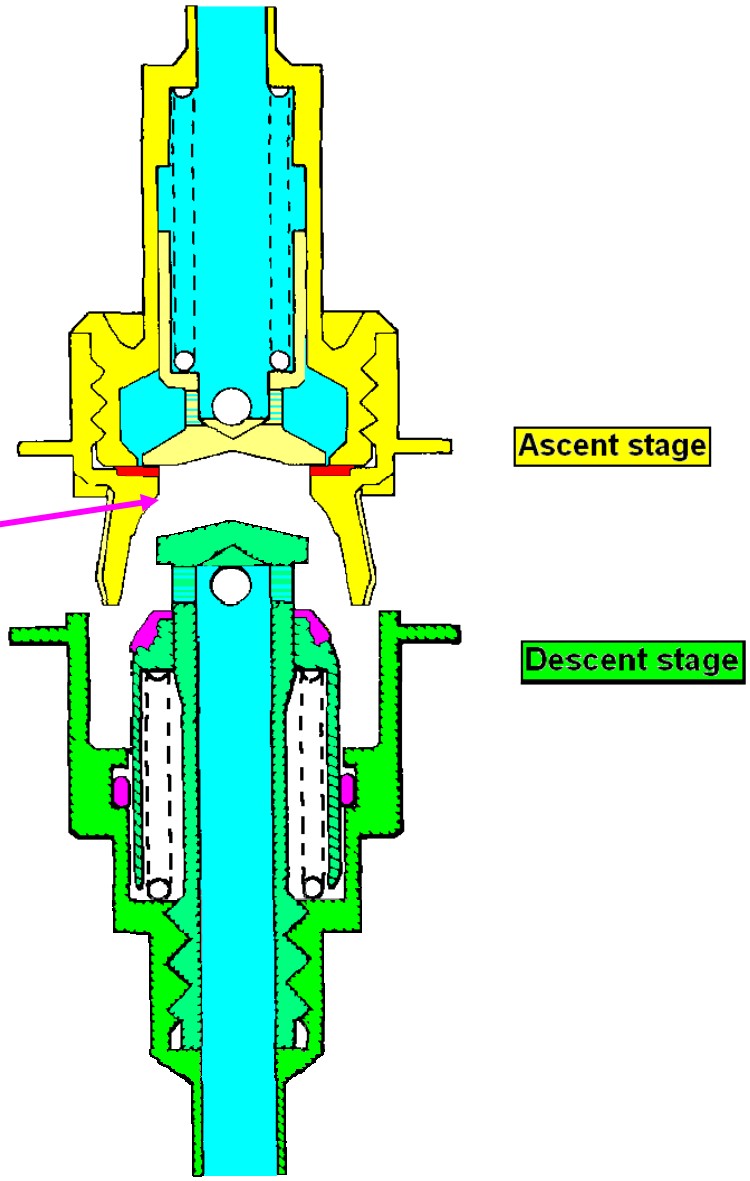
Generic Design Considerations – Original QDs

- Very susceptible to installation damage



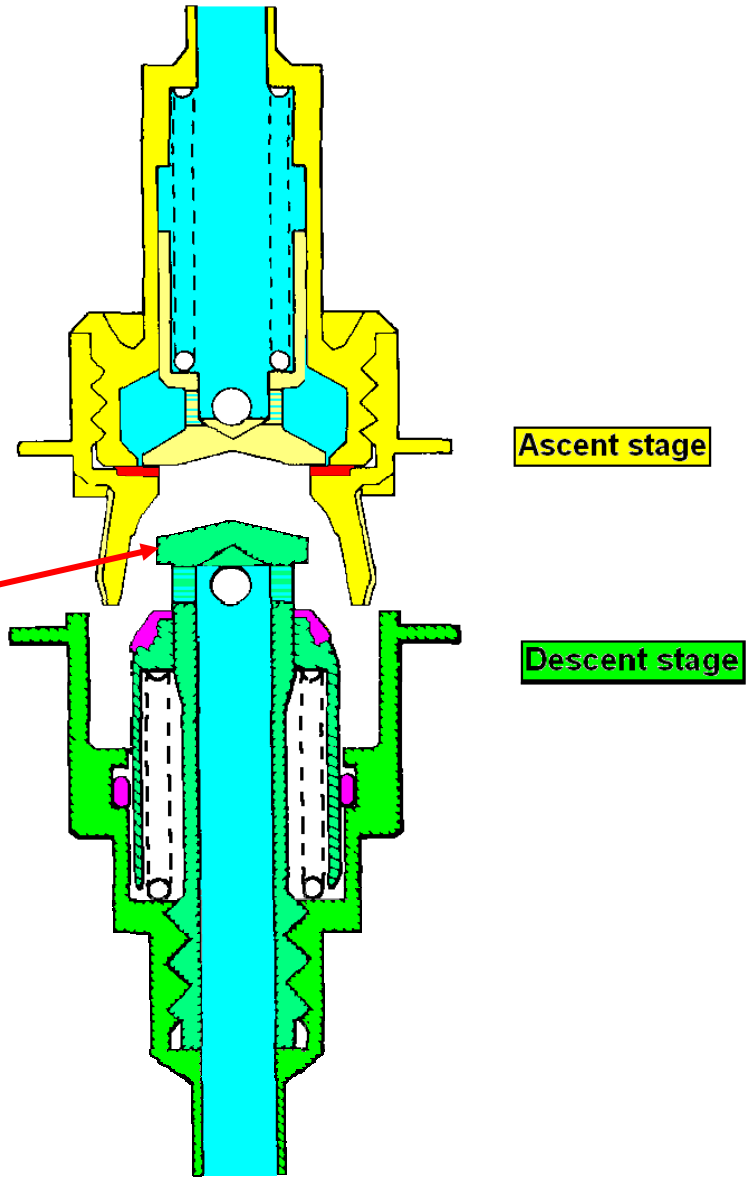
Generic Design Considerations – Original QDs

- Very susceptible to installation damage
- External leak path seal can impact here

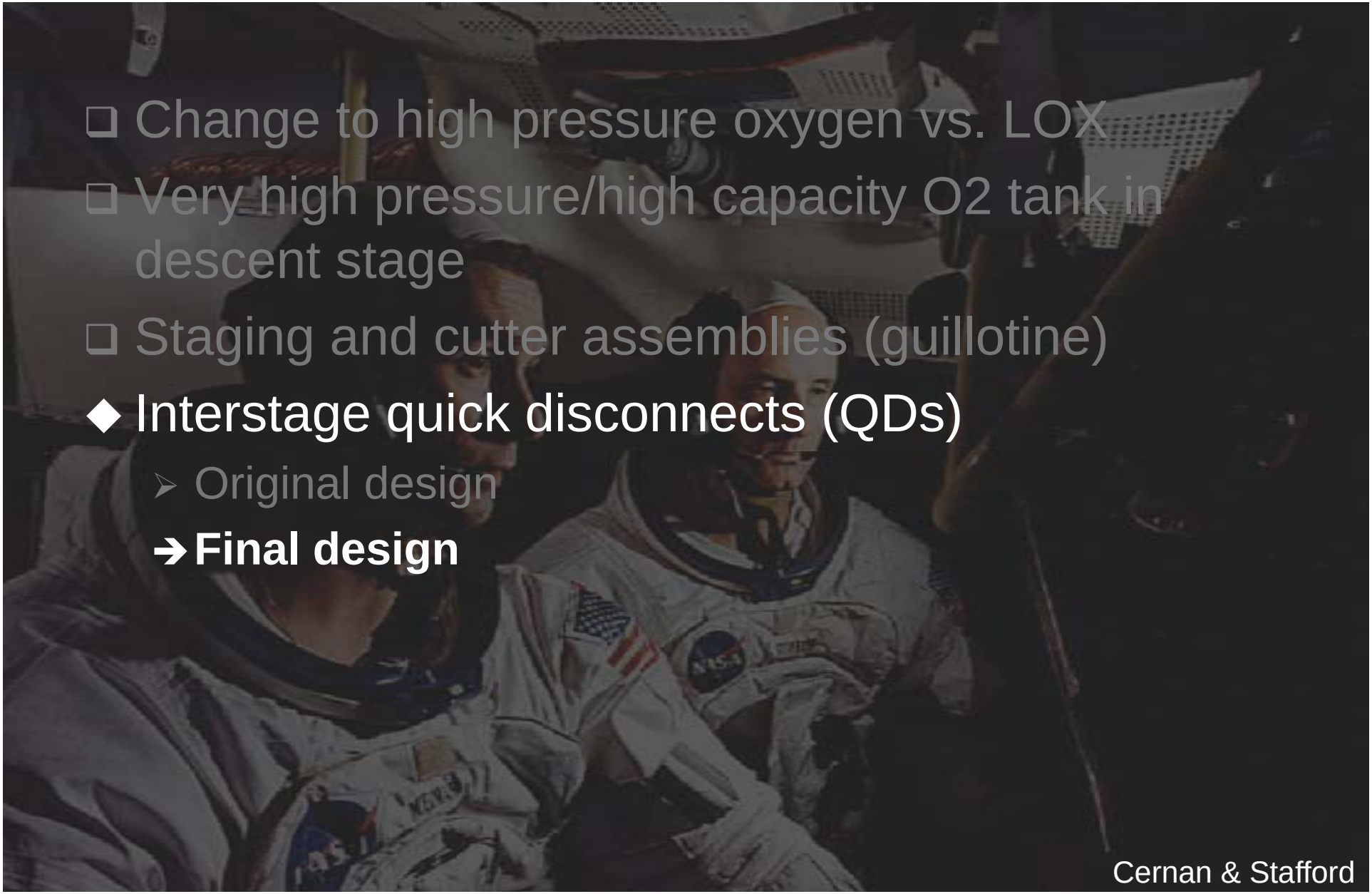


Generic Design Considerations – Original QDs

- Very susceptible to installation damage
- Poppet seal can be impacted by head of descent stage portion

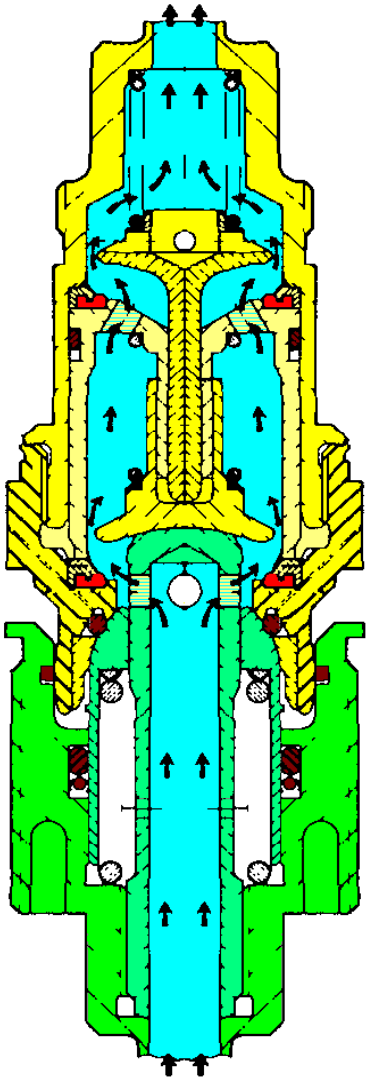


Generic Design Considerations – The Change to Batteries



- Change to high pressure oxygen vs. LOX
- Very high pressure/high capacity O2 tank in descent stage
- Staging and cutter assemblies (guillotine)
- Interstage quick disconnects (QDs)
  - Original design
  - **➔ Final design**

Generic Design Considerations – Final QDs



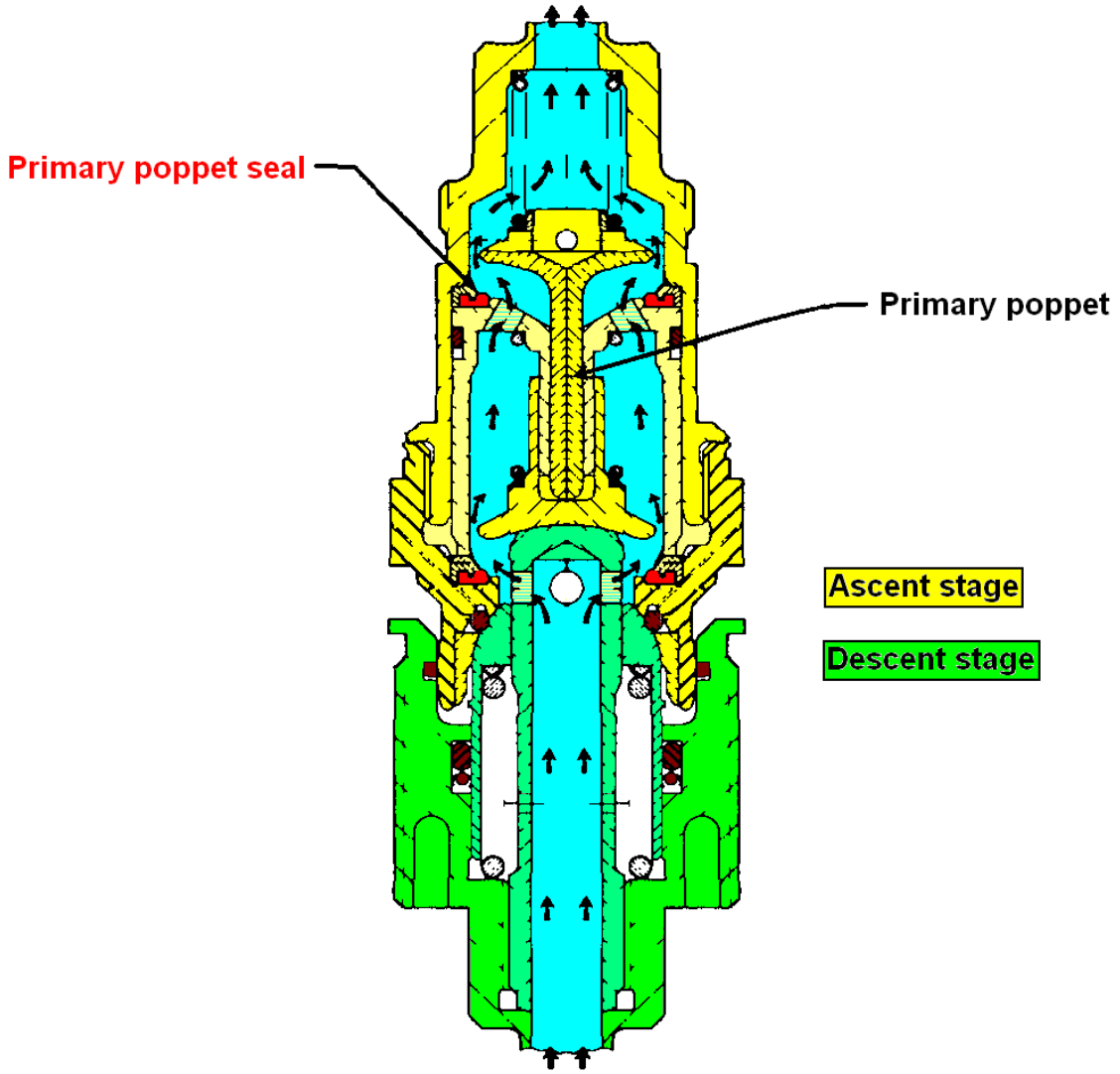
Ascent stage

Descent stage

Final design of interstage disconnect

Generic Design Considerations – Final QDs

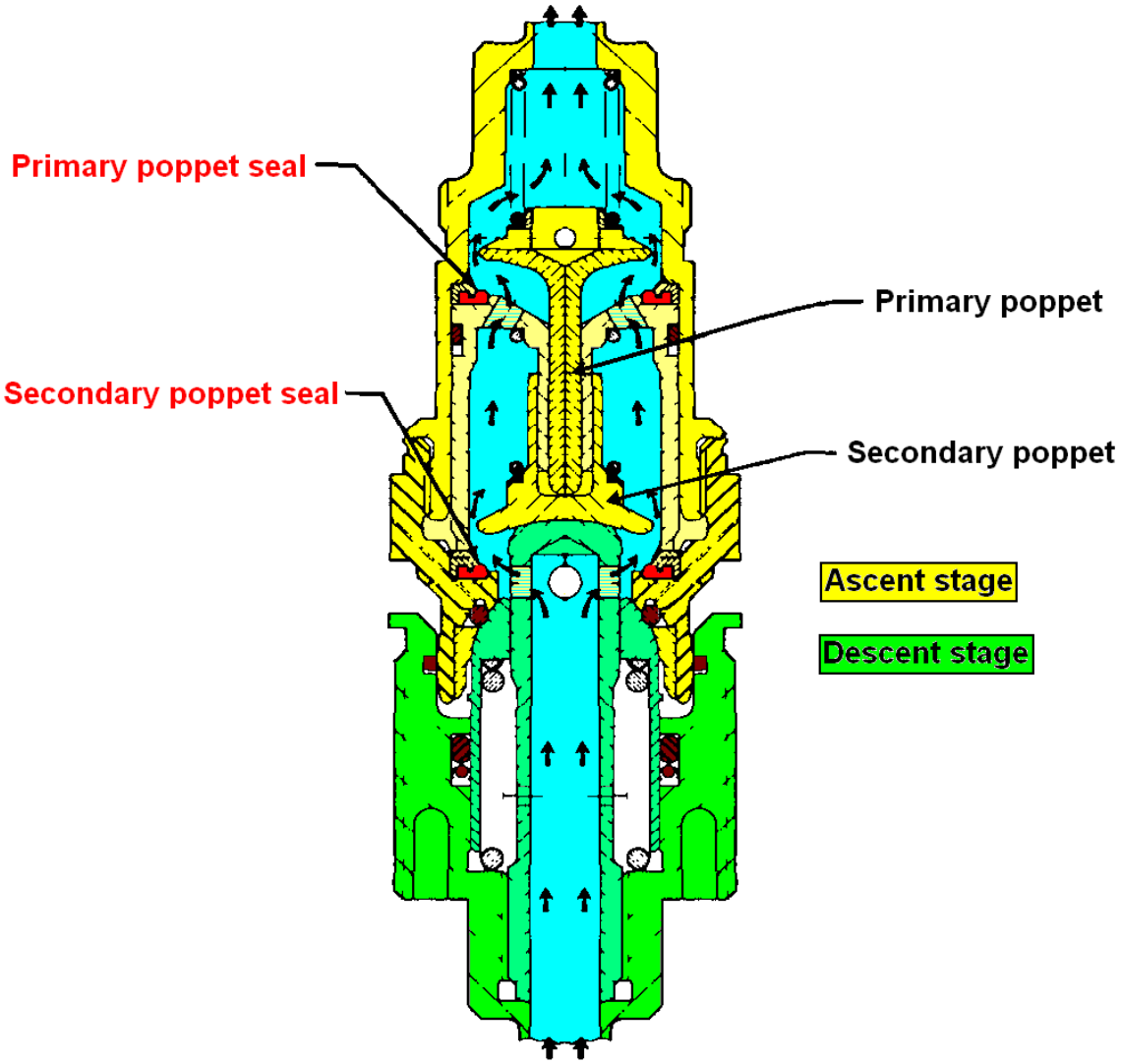
Built in redundancy



Final design of interstage disconnect

Generic Design Considerations – Final QDs

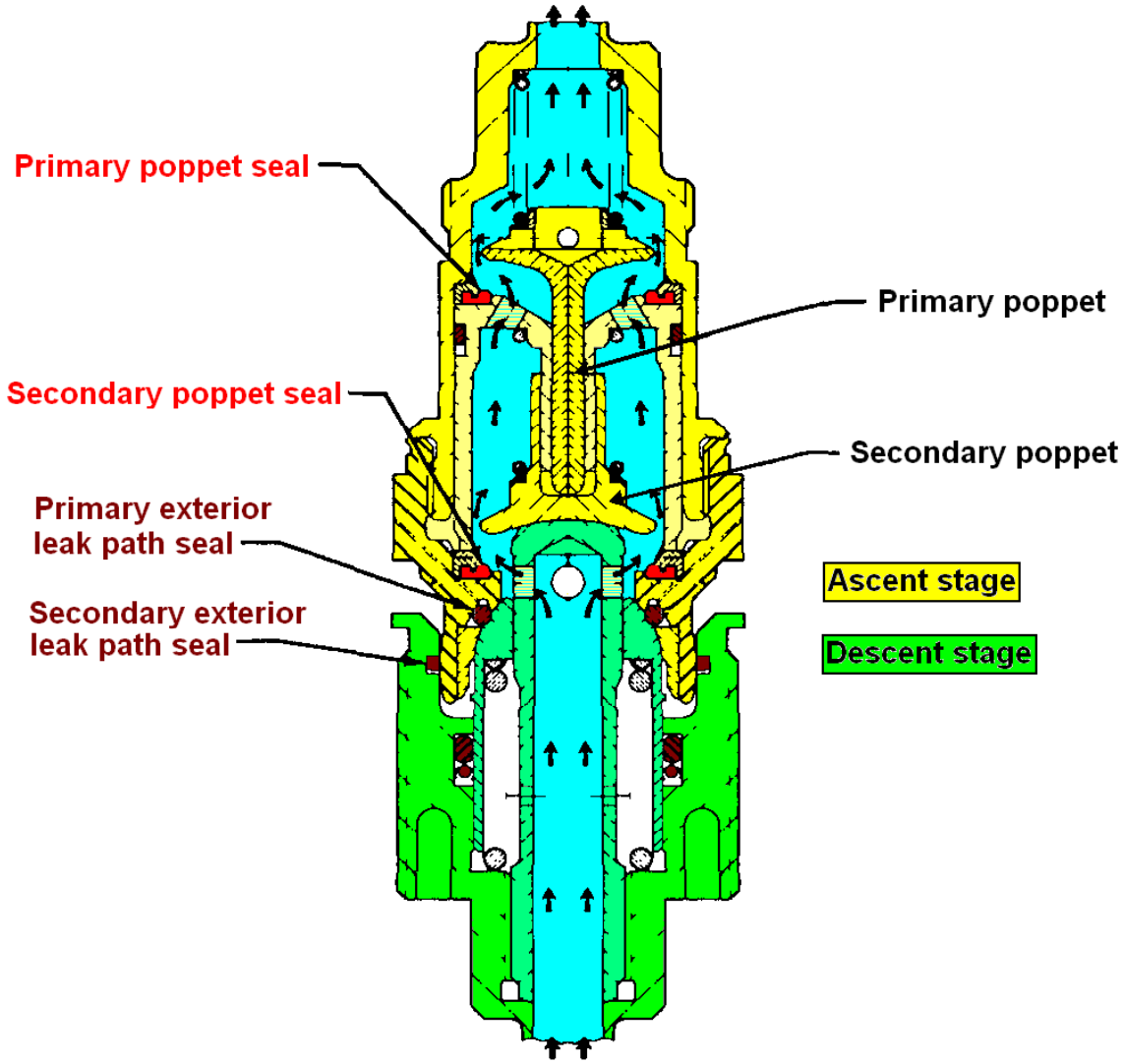
Built in redundancy



Final design of interstage disconnect

Generic Design Considerations – Final QDs

Built in redundancy

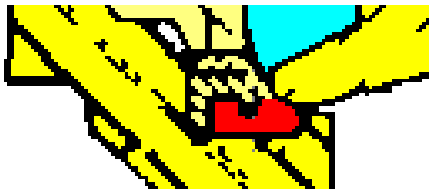


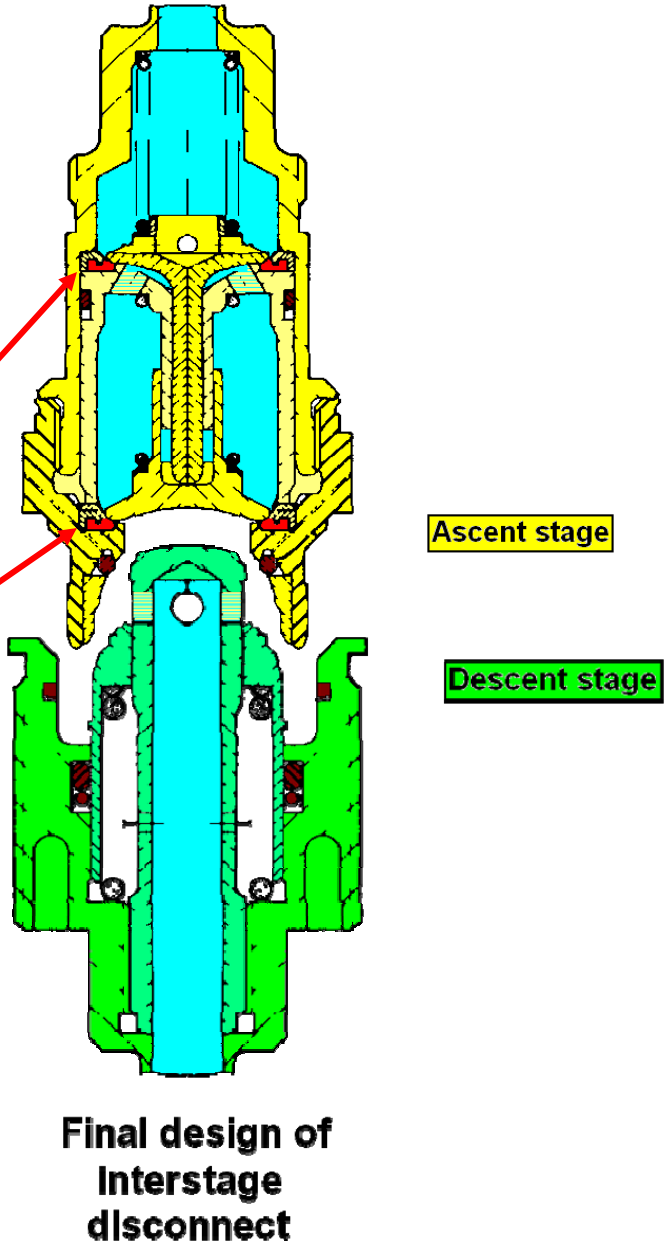
Final design of interstage disconnect

Generic Design Considerations – Final QDs

- Highly resistant to installation damage

The poppet seals are protected behind metal



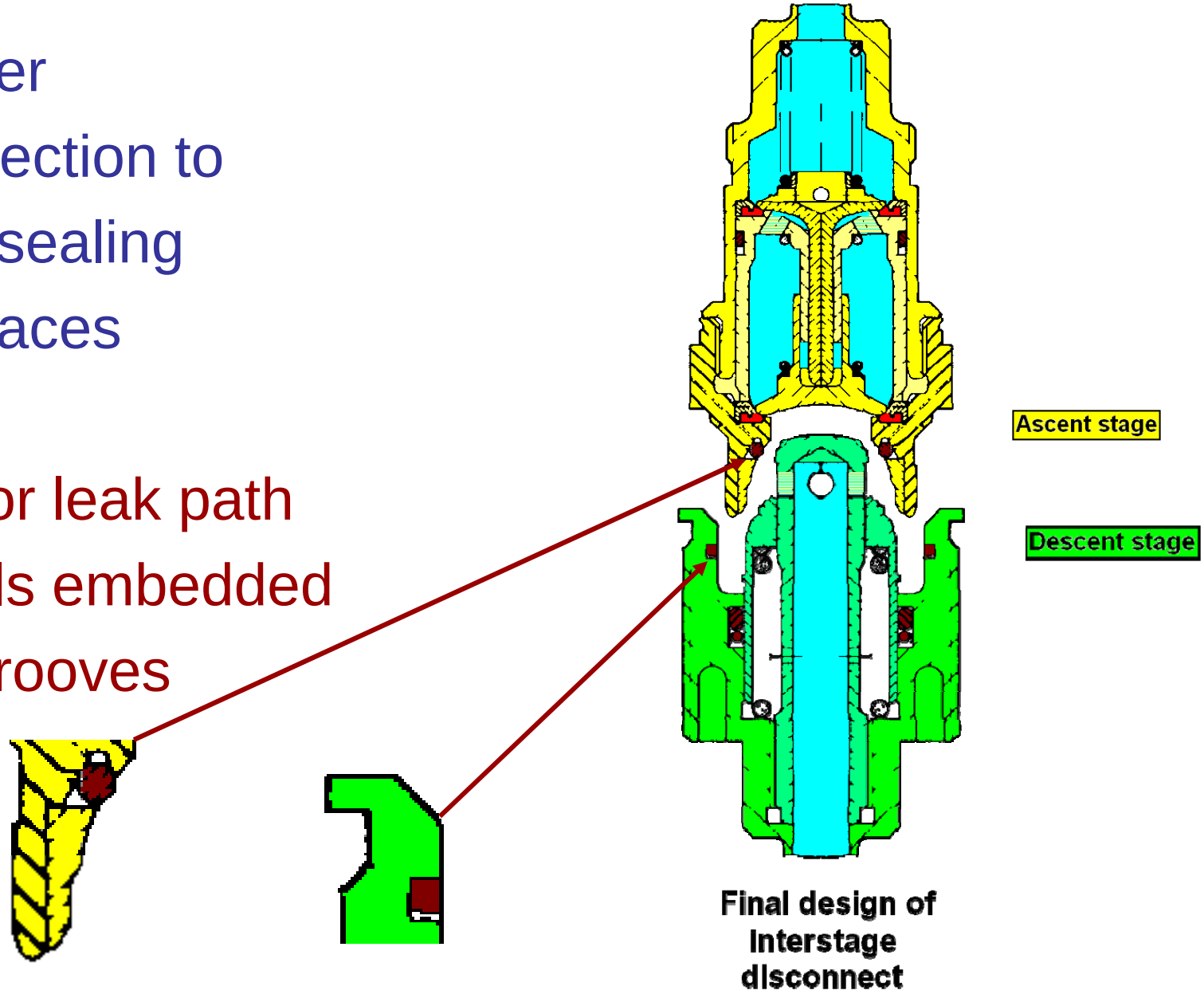


Final design of Interstage disconnect

Generic Design Considerations – Final QDs

- Better protection to the sealing surfaces

Exterior leak path seals embedded in grooves



Objectives

Upon completion of this part of the lesson, the student will be able to:

- Describe the Lunar Module (LM) Environmental Control System (ECS) generic design considerations philosophy.
- Summarize the LM ECS general testing regime.

General Testing -- Feasibility

General Testing -- Feasibility

- Feasibility
  - ➔ **Original concept to use pre-production hardware**

General Testing -- Feasibility

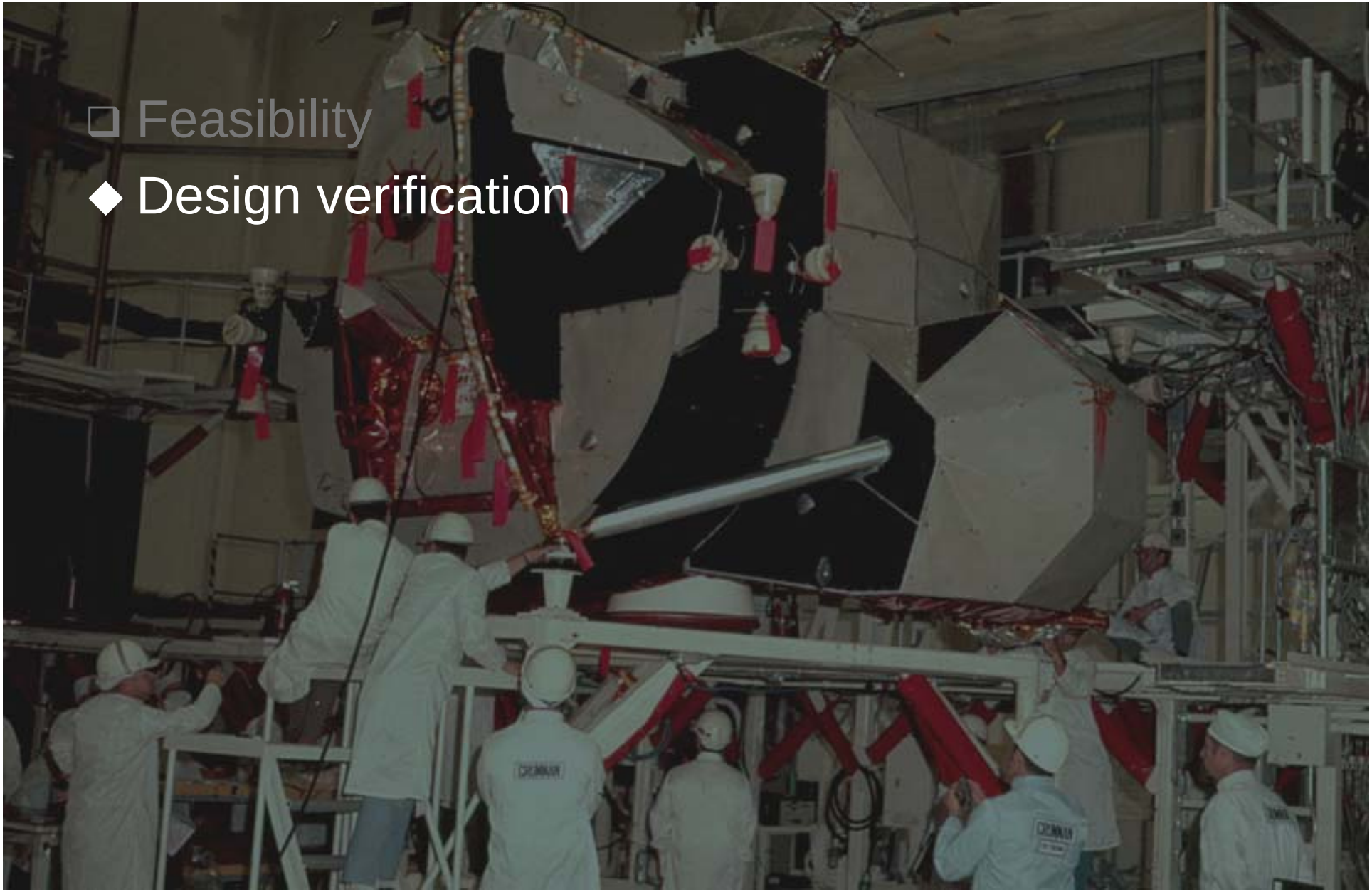
- Feasibility
  - Original concept to use pre-production hardware
  - ➔ **Tests conducted on component, logic group, and system levels**

General Testing -- Feasibility

- Feasibility
  - Original concept to use pre-production hardware
  - Tests conducted on component, logic group, and system levels

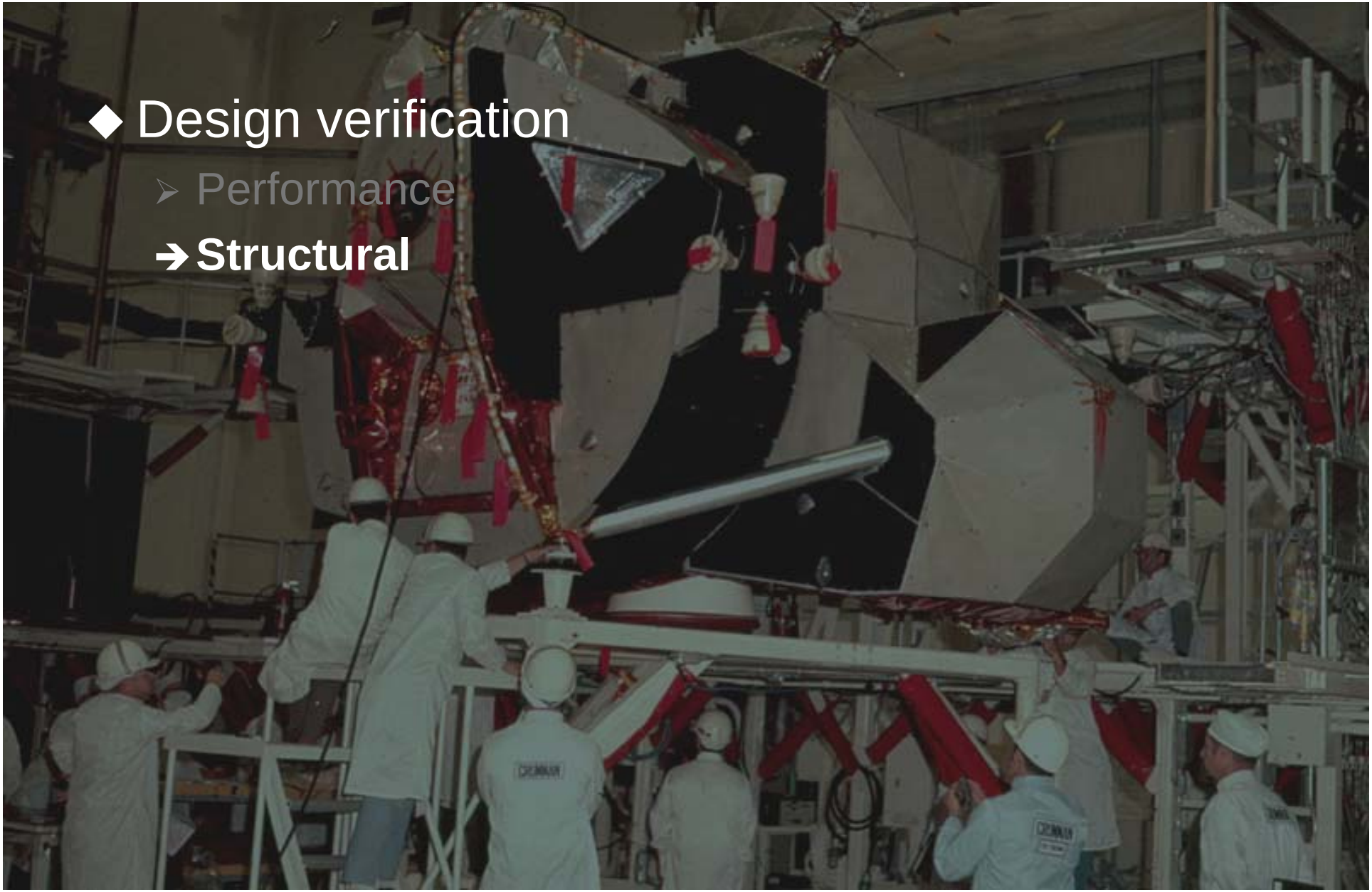
  → **Pre-production hardware very much resembled eventual production hardware, reducing the need for design verification testing**

General Testing – Design Verification



General Testing – Design Verification

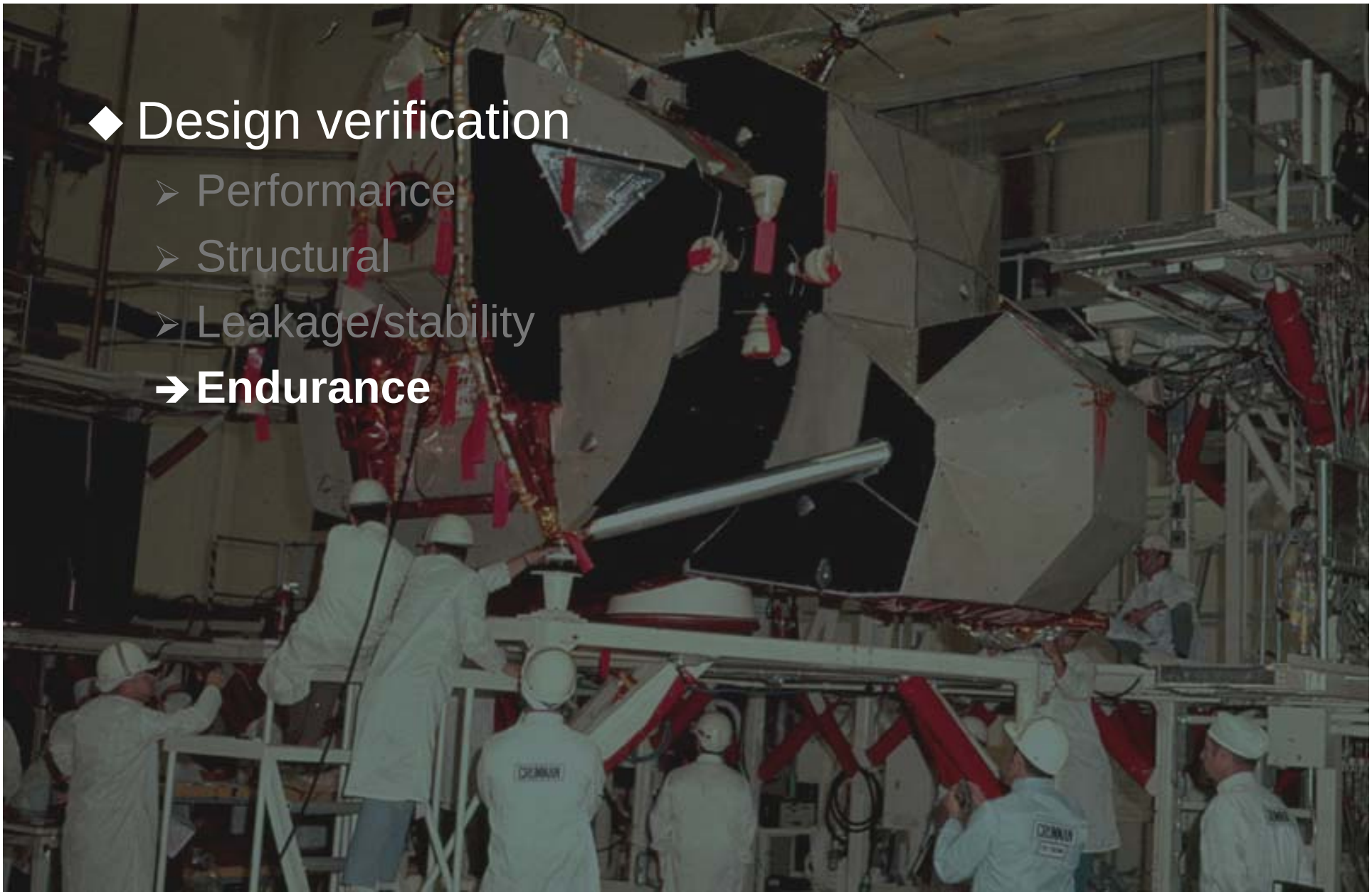
General Testing – Design Verification



General Testing – Design Verification

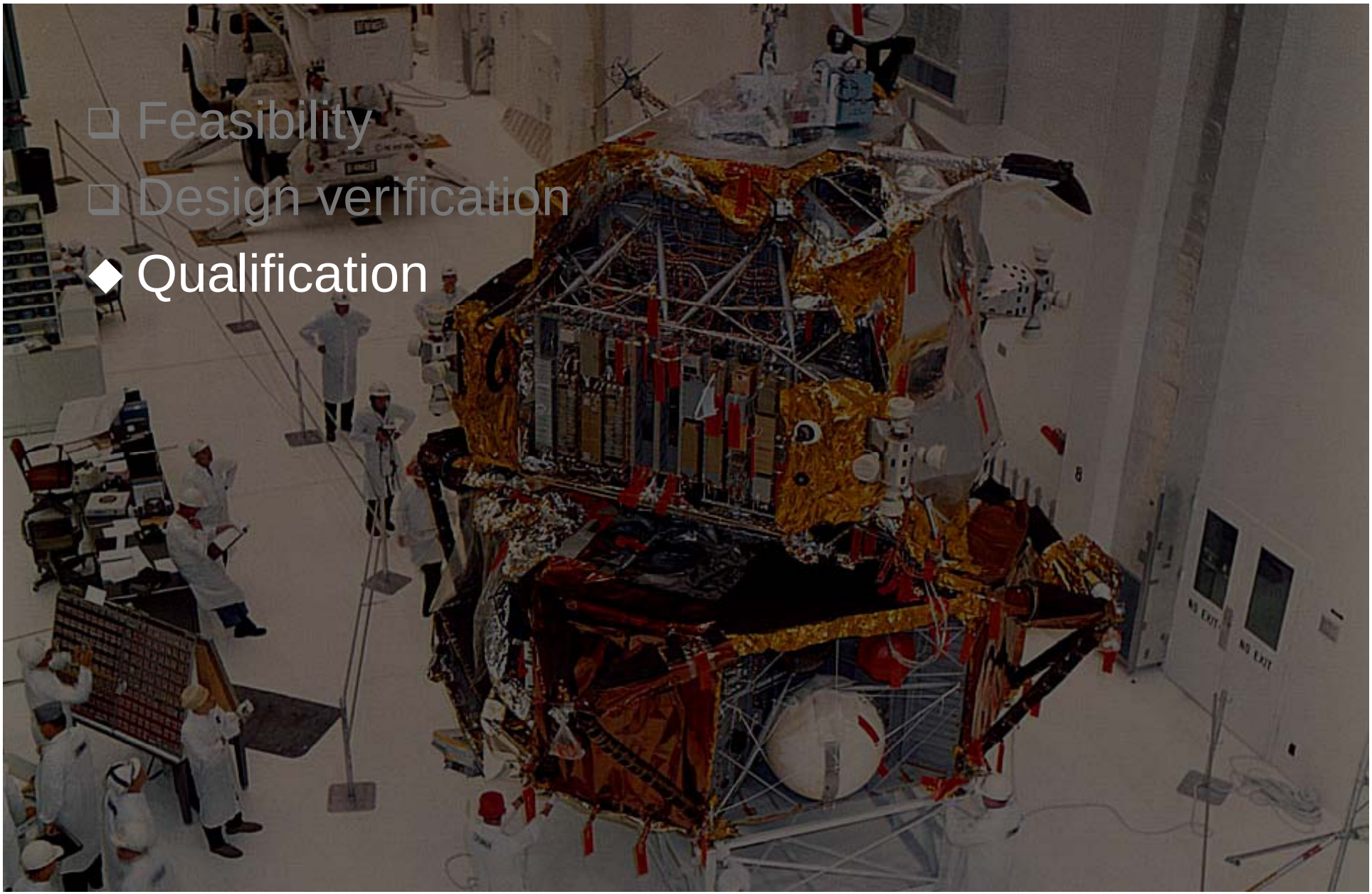
- Design verification
  - Performance
  - Structural
  - → **Leakage/stability**

General Testing – Design Verification

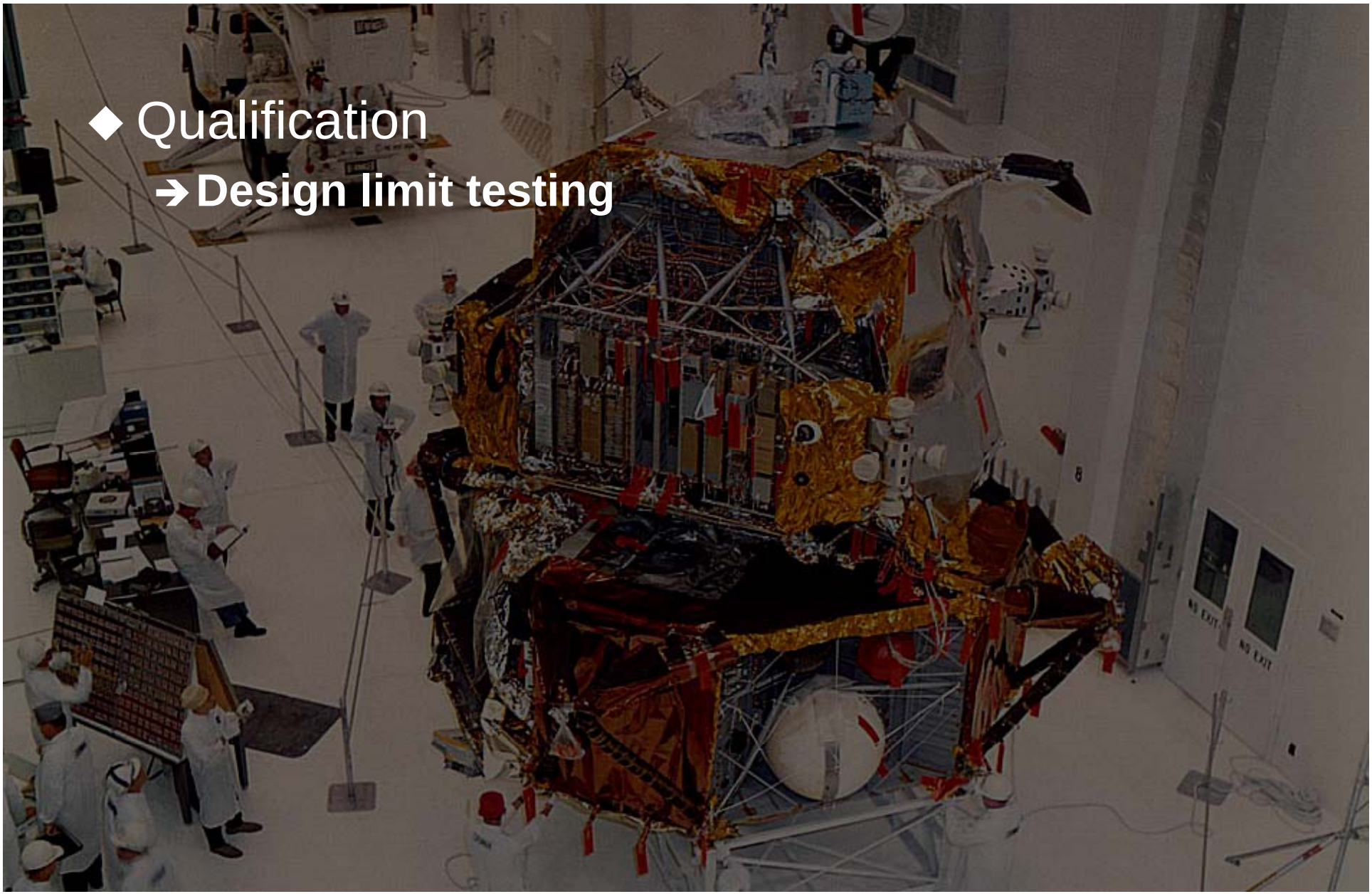


- Design verification
  - Performance
  - Structural
  - Leakage/stability
  - **➔ Endurance**

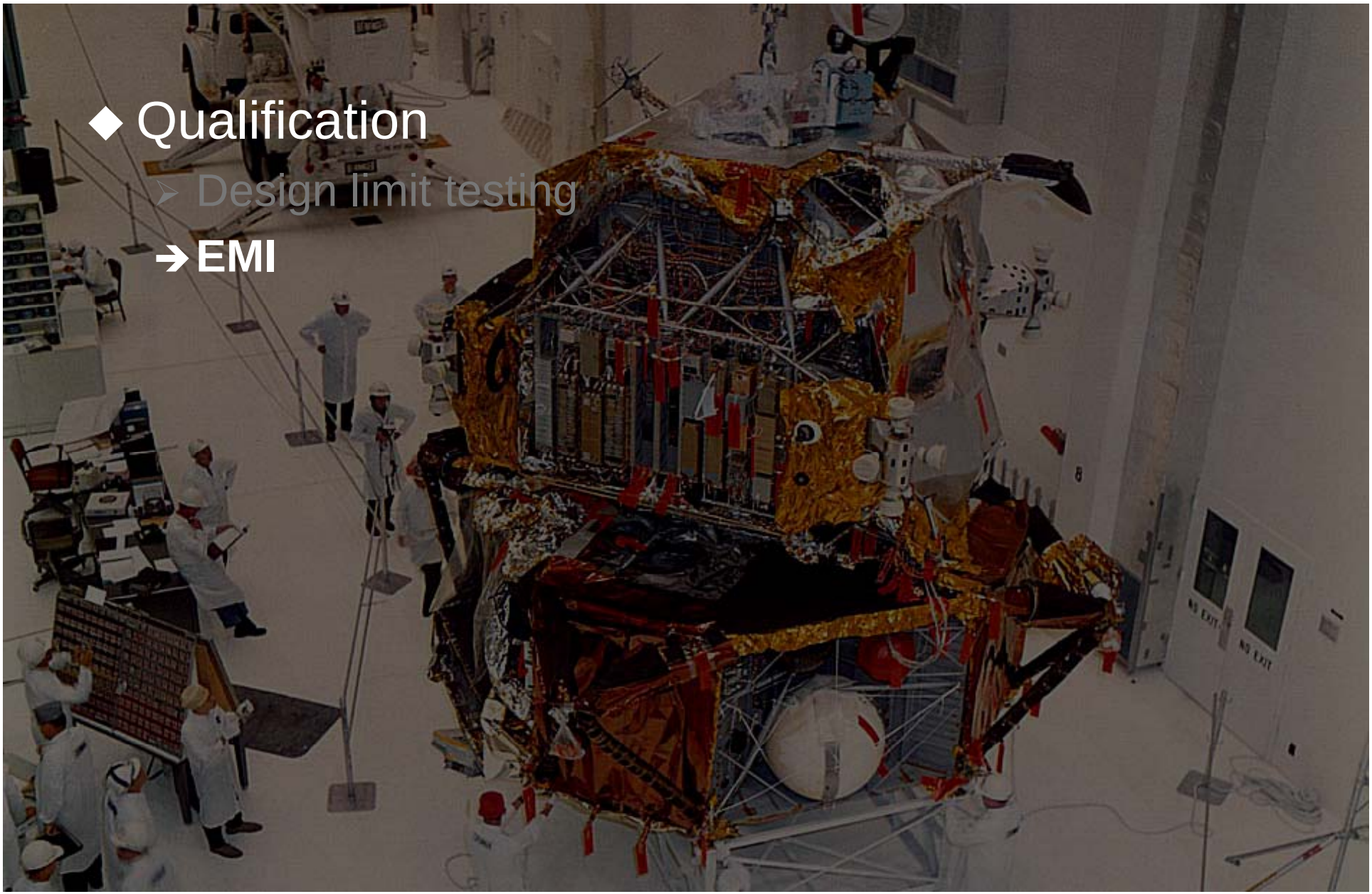
General Testing -- Qualification



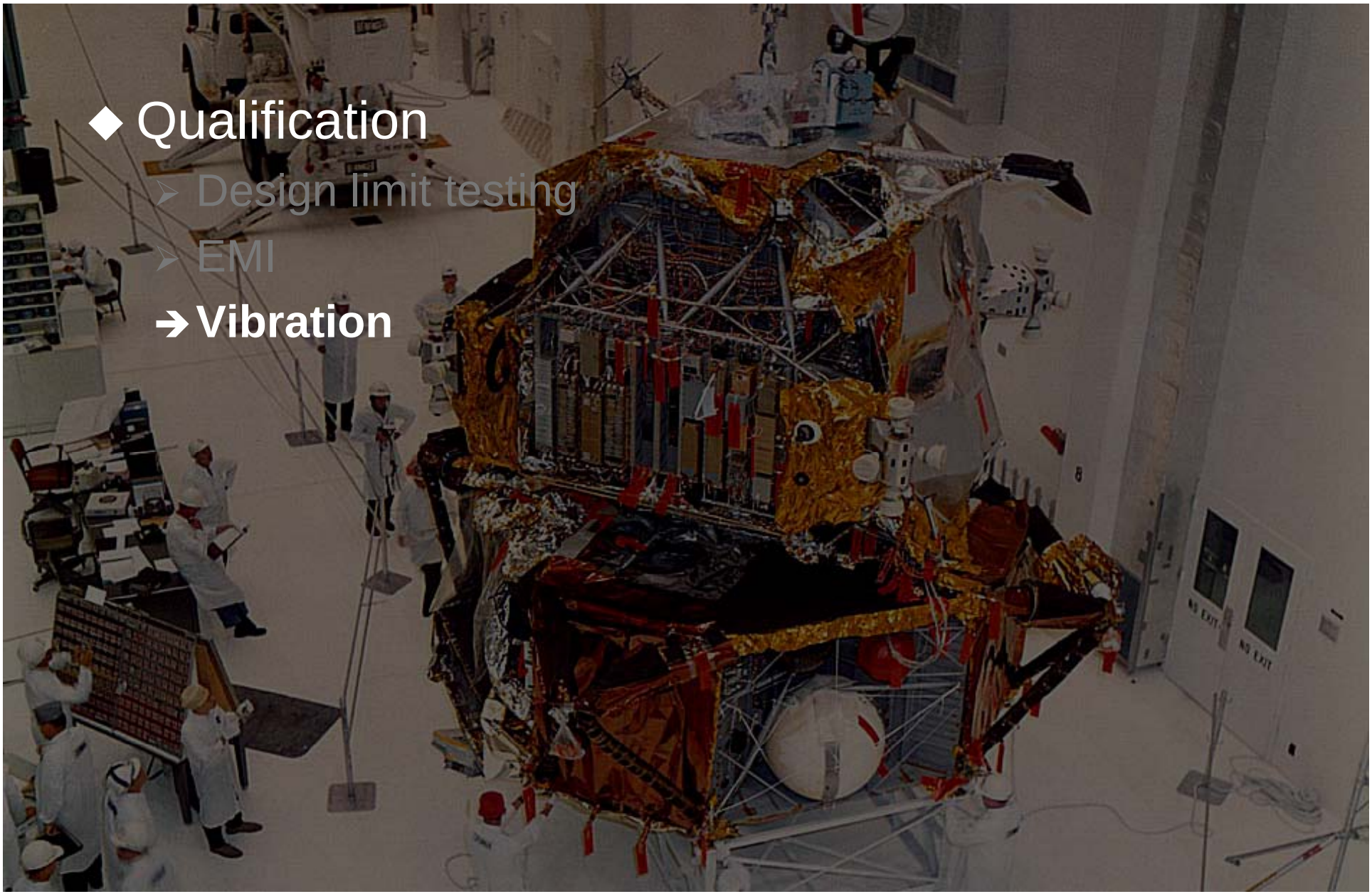
General Testing -- Qualification



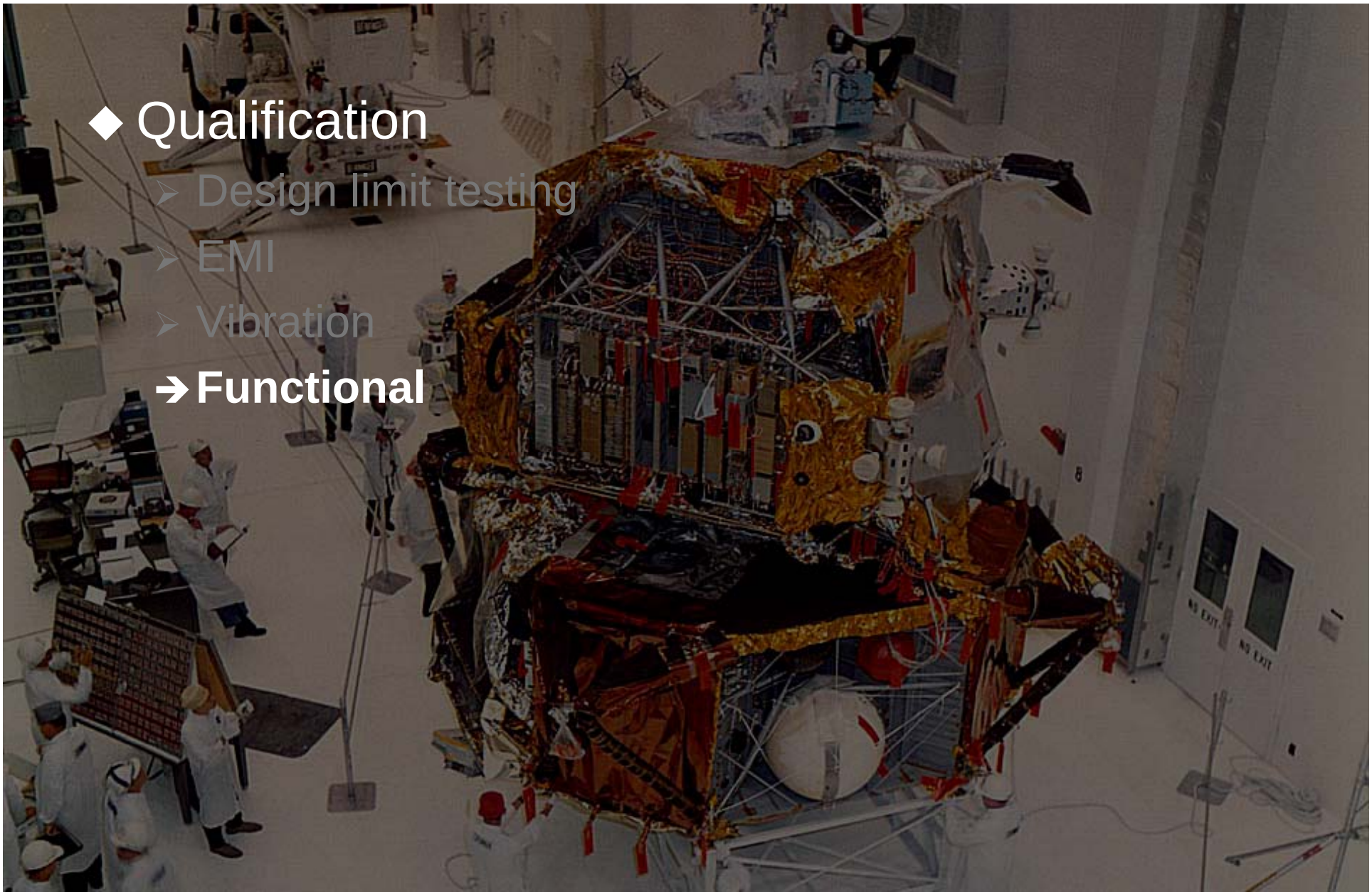
General Testing -- Qualification



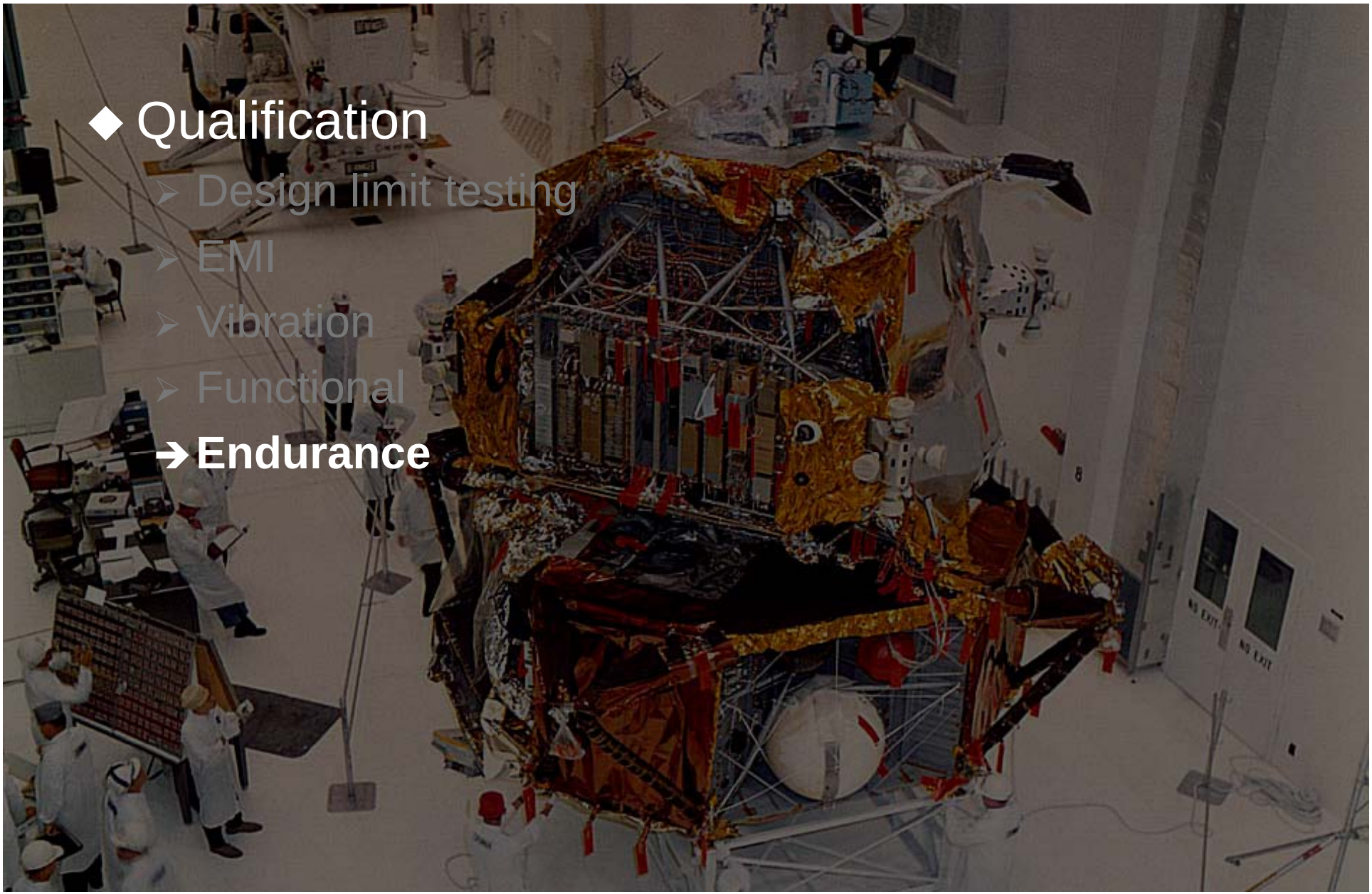
General Testing -- Qualification



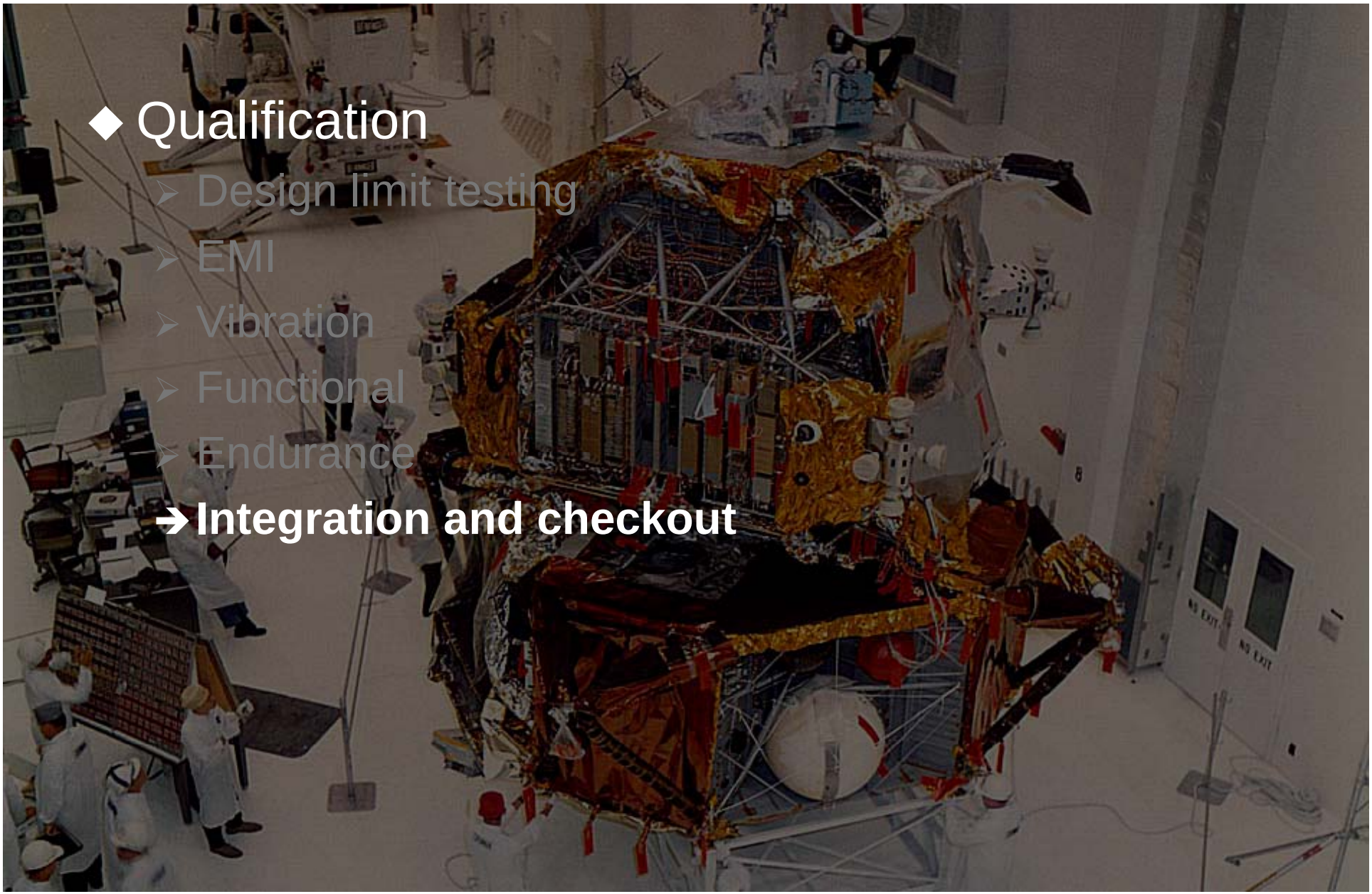
General Testing -- Qualification



General Testing -- Qualification

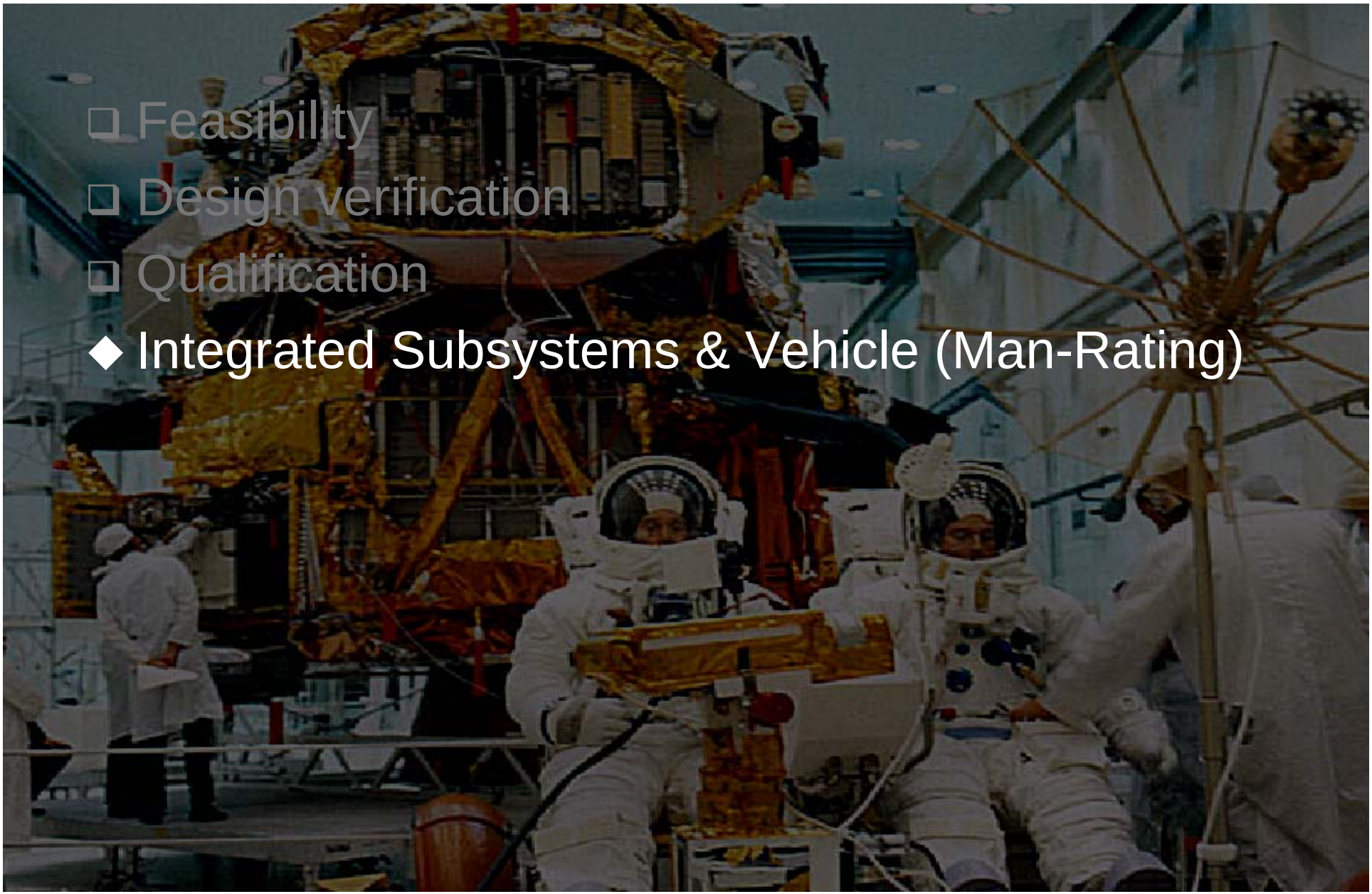


General Testing -- Qualification



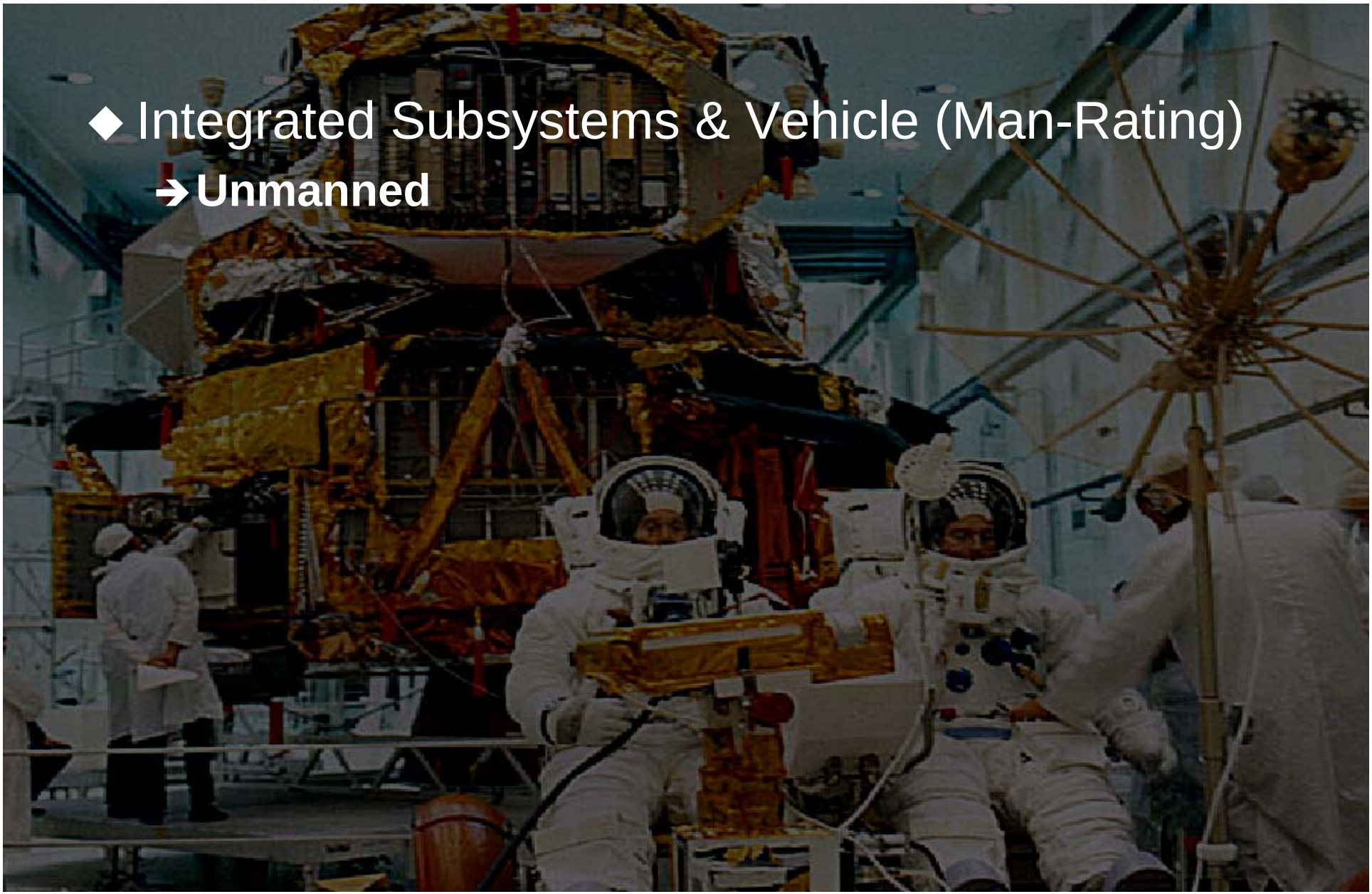
- Qualification
  - Design limit testing
  - EMI
  - Vibration
  - Functional
  - Endurance
  - **➔ Integration and checkout**

General Testing – Man Rating



- Feasibility
- Design verification
- Qualification
- **Integrated Subsystems & Vehicle (Man-Rating)**

General Testing – Man Rating

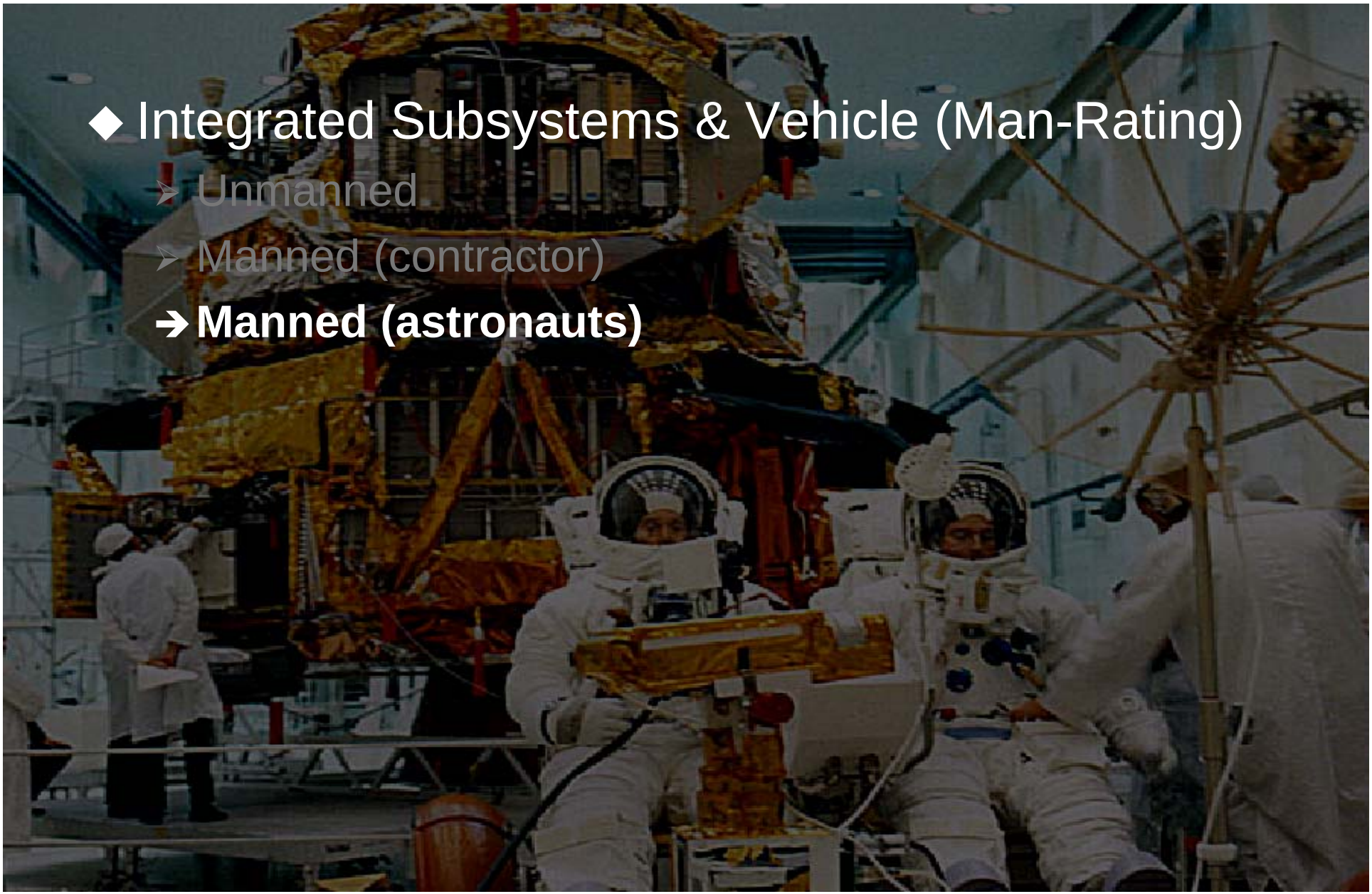


- Integrated Subsystems & Vehicle (Man-Rating)
  - → **Unmanned**

General Testing – Man Rating

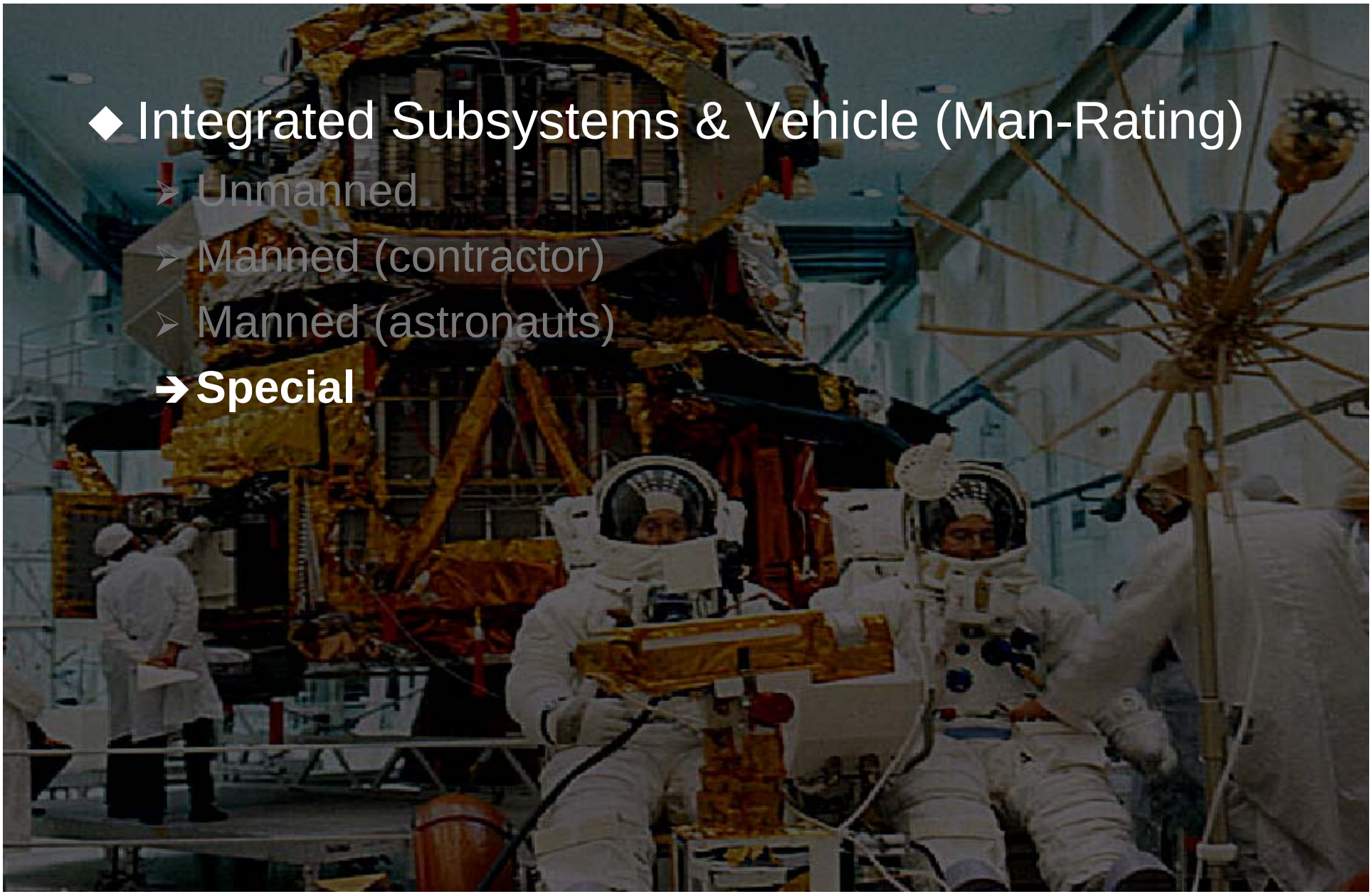
- Integrated Subsystems & Vehicle (Man-Rating)
  - Unmanned
  - **➔ Manned (contractor)**

General Testing – Man Rating



- Integrated Subsystems & Vehicle (Man-Rating)
  - Unmanned
  - Manned (contractor)
  - **➔ Manned (astronauts)**

General Testing – Man Rating



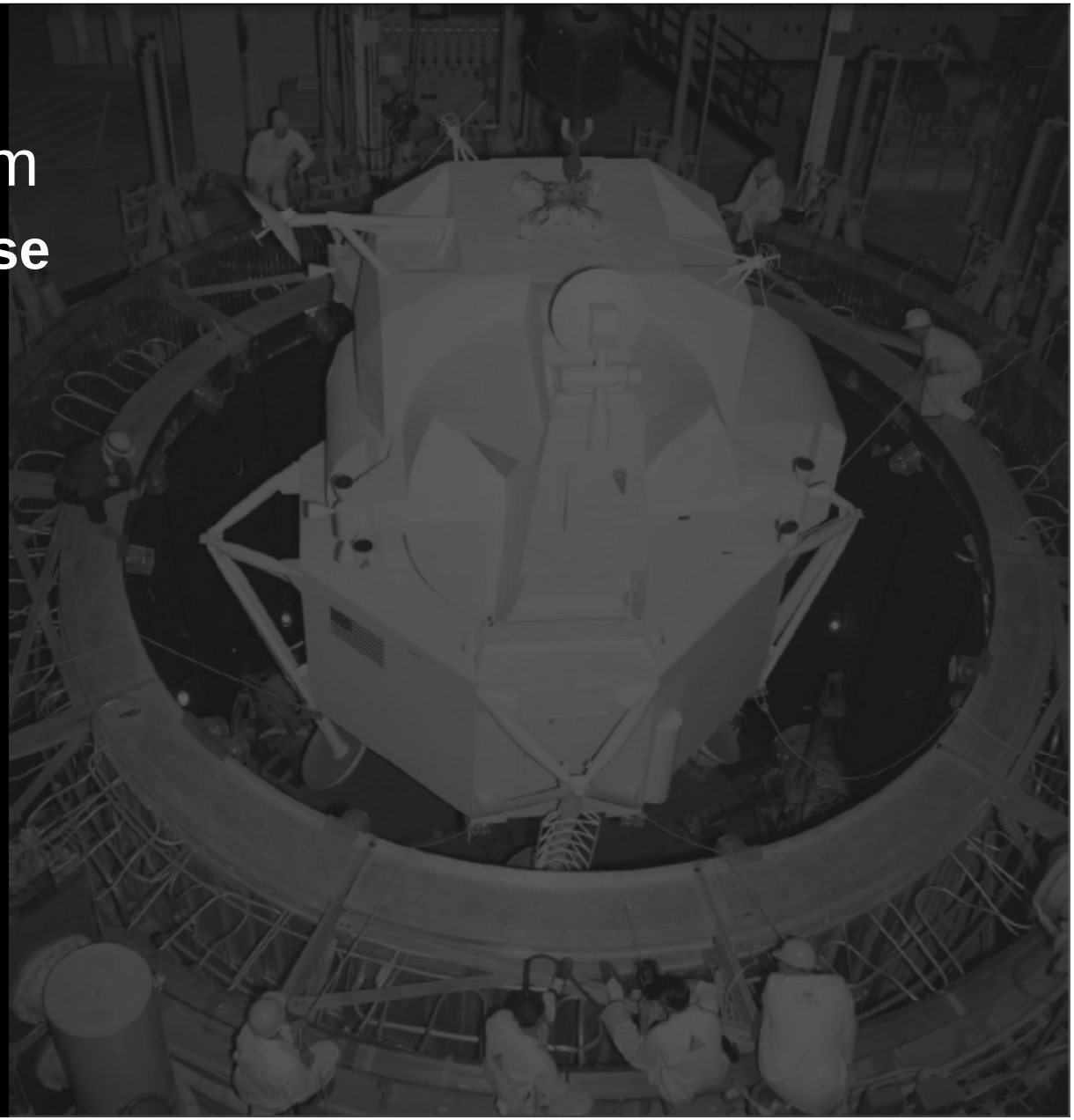
- Integrated Subsystems & Vehicle (Man-Rating)
  - Unmanned
  - Manned (contractor)
  - Manned (astronauts)
  - **→ Special**

General Testing – Thermal Vacuum

- Feasibility
- Design verification
- Qualification
- Integrated Subsystems & Vehicle (Man-Rating)
- **Thermal-vacuum**

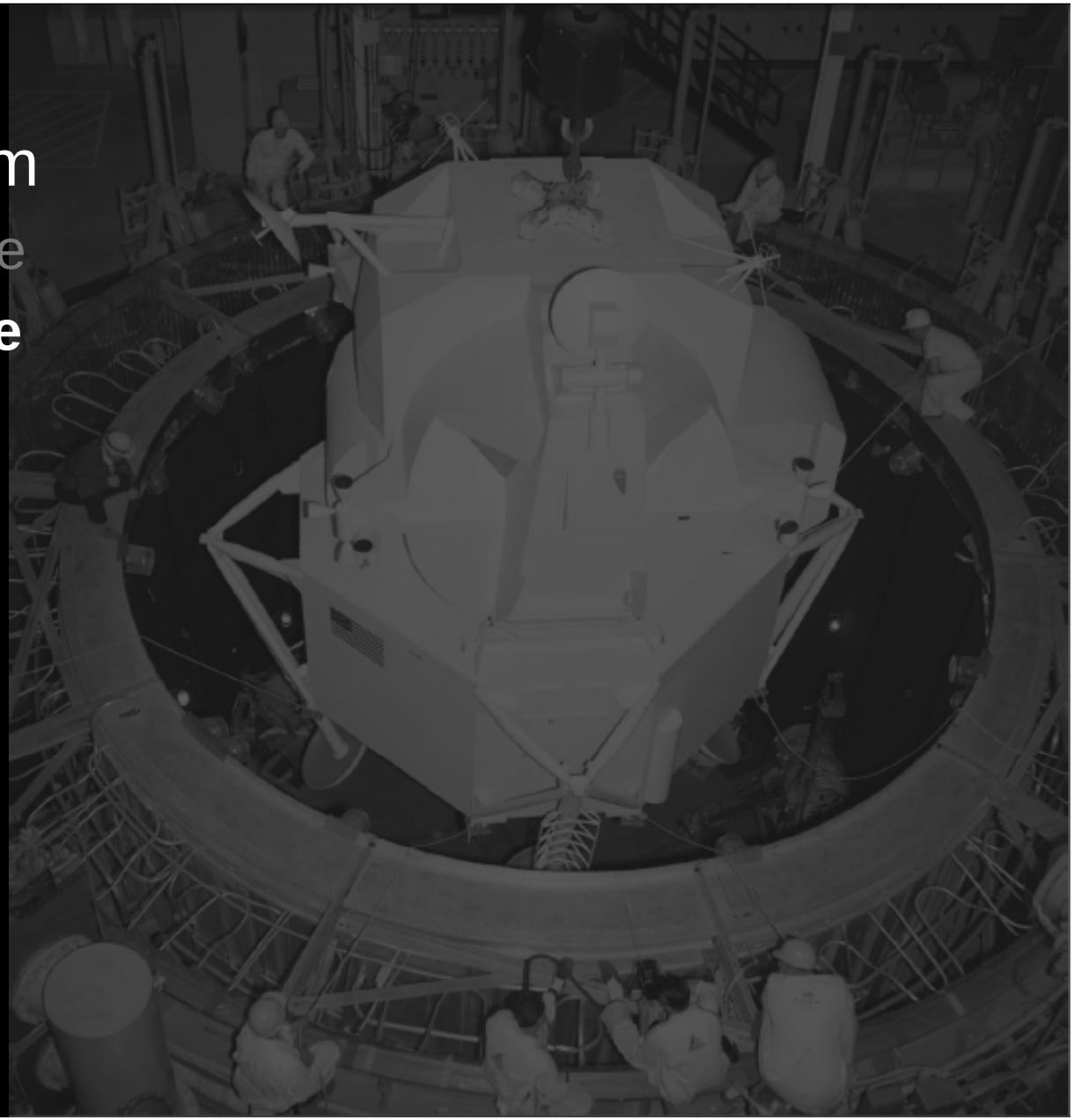
General Testing – Thermal Vacuum

- Thermal-vacuum
  - ➔ **LTA-8 cold case**



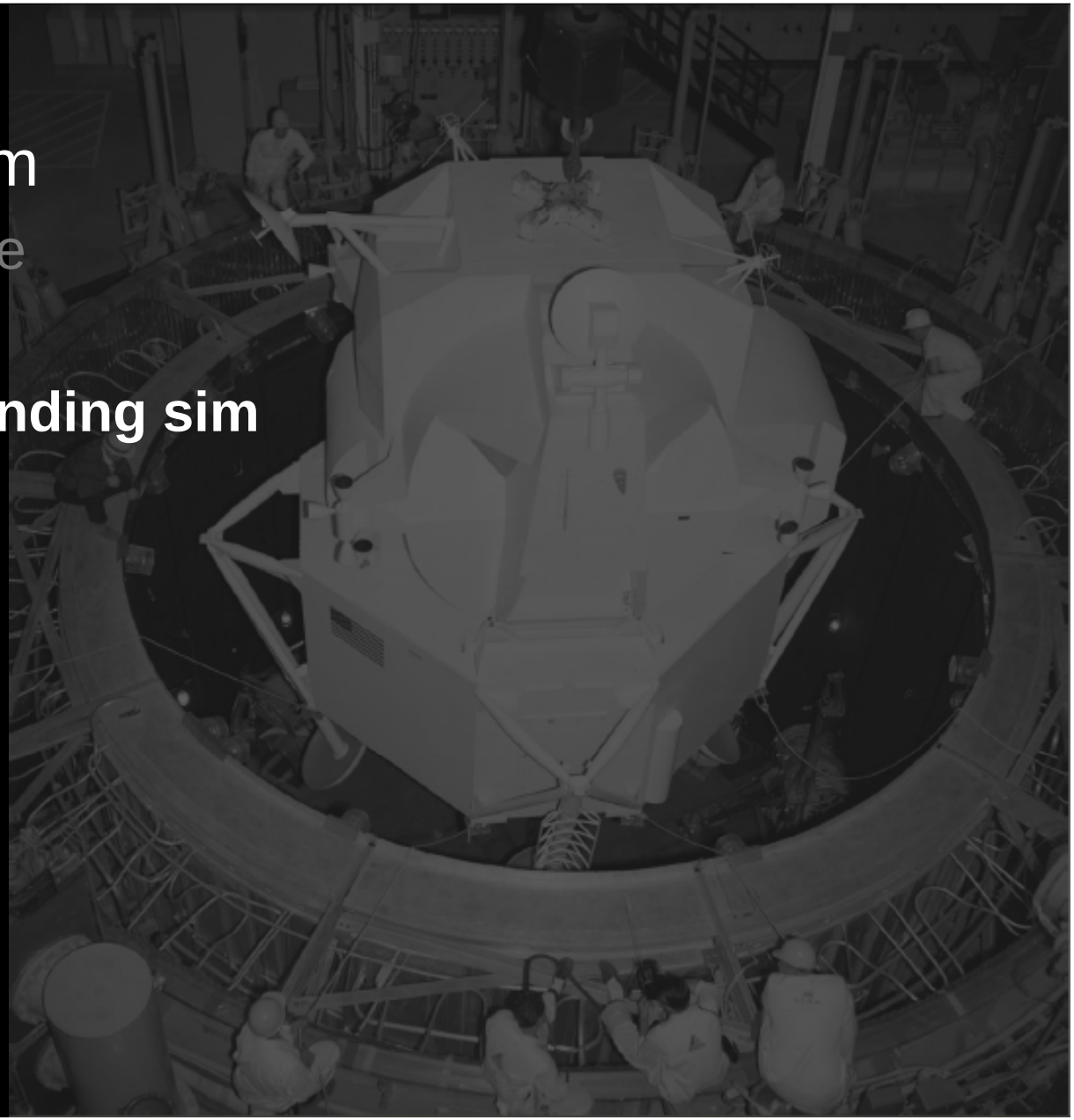
General Testing – Thermal Vacuum

- Thermal-vacuum
  - LTA-8 cold case
  - **➔LTA-8 hot case**

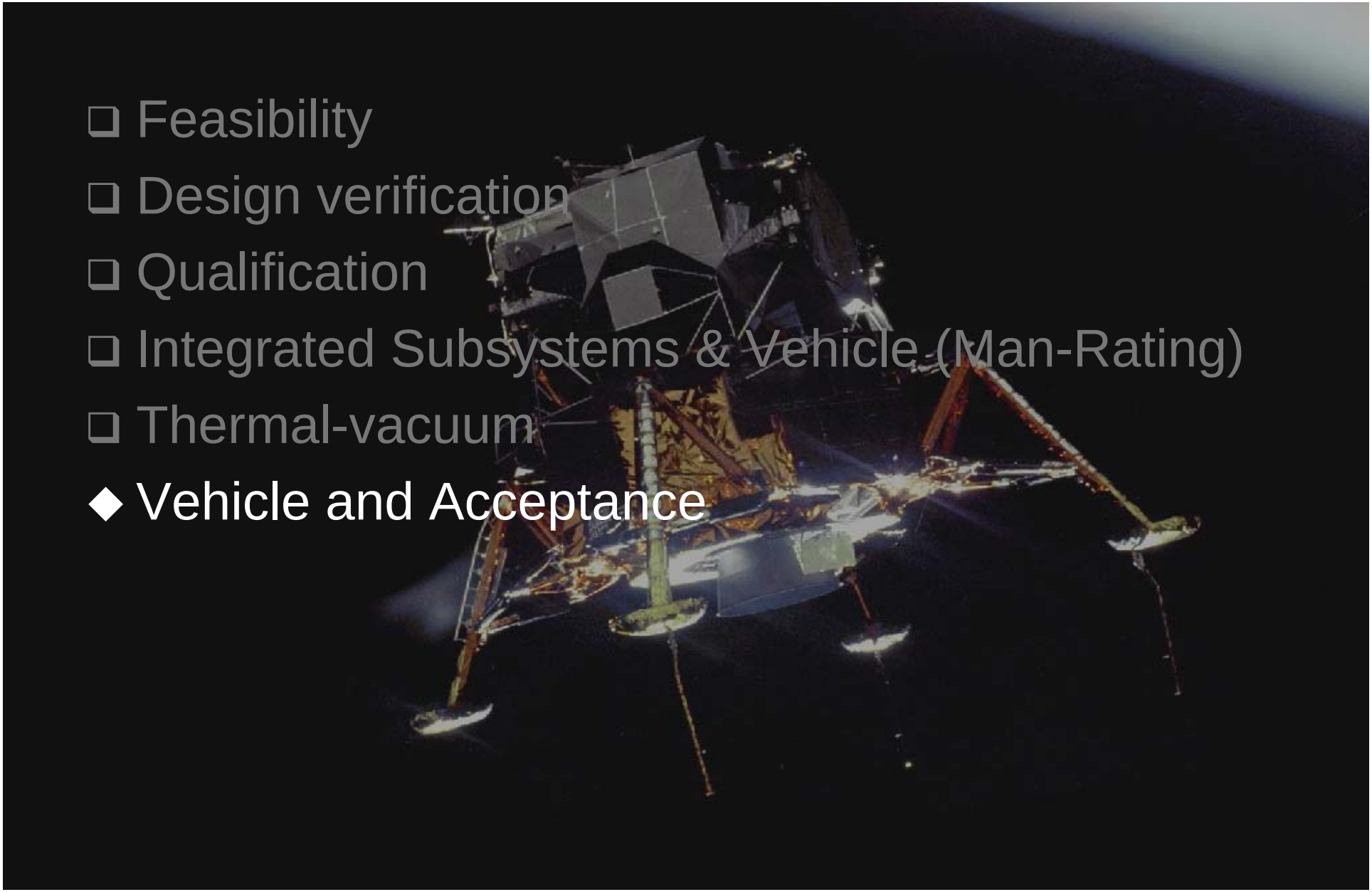


General Testing – Thermal Vacuum

- Thermal-vacuum
  - LTA-8 cold case
  - LTA-8 hot case
  - **➔LTA-8 lunar landing sim**



General Testing – Vehicle and Acceptance



- Feasibility
- Design verification
- Qualification
- Integrated Subsystems & Vehicle (Man-Rating)
- Thermal-vacuum
- **Vehicle and Acceptance**

Review of Objectives

- Describe the Lunar Module (LM) Environmental Control System (ECS) generic design considerations philosophy.
- Summarize the LM ECS general testing regime.

References

- Apollo Experience Report – Lunar Module Environmental Control Subsystem
- Wiki on this website: http://modspops.jsc.nasa.gov/mod/DA4/CxTraining/Apollo/Apollo%20Wiki/Home.aspx

More references found under link below