Lunar Module ECS (Environmental Control System)
Design Considerations & Failure Modes
Part I
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
Oxygen Supply and Cabin Pressurization Section
Overview of LM ECS

- Oxygen Supply and Cabin Pressurization Section

Diagram showing the oxygen supply system with components such as oxygen supply, oxygen control module, oxygen demand regulator, oxygen repressurization valve, PLSS O2 hose, and interstage disconnect. The diagram also indicates the ascent and descent stages with respective oxygen tanks and valves.
Overview of LM ECS

- Oxygen Supply and Cabin Pressurization Section

Diagram showing the flow of oxygen supply and pressurization, including stages, tanks, valves, and regulators.
Overview of LM ECS

- Oxygen Supply and Cabin Pressurization Section

![Diagram showing oxygen supply and cabin pressurization section](image.png)
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

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Atmosphere Revitalization Section Simplified Schematic
Overview of LM ECS

Atmosphere Revitalization section

Atmosphere Revitalization Section Simplified Schematic
Water Management Section
Overview of LM ECS

Water Management Section

- Ascent H2O tanks
- Shutoff valves (5)
- H2O hose
- PSS refill
- Drinking
- Food preparation
- Fire extinguisher
- Water tank selector valve
- Pressure regulator
- Water control module
- R denotes redundant component

- Reclaimed metabolic H2O
- Pressure regulator
- Secondary coolant H2O sublimator
- Suit-circuit H2O sublimator
- Primary coolant H2O sublimator

Ascent stage

Descent H2O tank

Guillotine

Descent stage

Water Management Section
Overview of LM ECS

Water Management Section

- Ascent H2O tanks
- Reclaimed metabolic H2O
- Pressure regulator
- Secondary coolant H2O sublimator
- Suit-circuit H2O sublimator
- Primary coolant H2O sublimator
- Water tank selector valve
- Pressure regulator
- Water control module

- H2O hose:
  - PLESS refill
  - Drinking
  - Food preparation
  - Fire extinguisher

- Shutoff valves (5)

- Ascent stage
- Descent stage
- Guillotine

R denotes redundant component.
Heat Transport Section

- Coolant recirculator assembly
- Pump
- Low-temperature electronics
- Aft equipment bay electronics
- Suit heat exchanger
- Suit water cooling assembly
- Suit regenerative heat exchanger
- Primary sublimator
- Secondary sublimator
- Ascent batteries
- Descent batteries
- Coolant accumulator
- To coolant recirculator assembly

R denotes redundant component
Heat Transport Section

- Coolant recirculator assembly
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Heat Transport Section
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R denotes redundant component

Heat Transport Section
Generic Design Considerations

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

◆ Reliability
Generic Design Considerations -- Reliability

“Perfect” is the enemy of “good enough”
“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

Aldrin
Generic Design Considerations -- Reliability

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

→ Failure reporting
Generic Design Considerations – Flight Instrumentation

- Reliability
- Flight Instrumentation
Generic Design Considerations - Flight Instrumentation

◆ Minimum needed to monitor performance
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
Generic Design Considerations – Flight Instrumentation

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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
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  - Difficult to install
Generic Design Considerations - Modularization

- Reliability
- Flight Instrumentation
- Modularization
Generic Design Considerations - Modularization

→ Modularized by subsystem
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

→ Change to high pressure oxygen vs. LOX
- 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)
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
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

Ascent stage

Descent stage

Original design of interstage disconnect
Poppet seal was on the ascent stage portion.
Generic Design Considerations - Original QDs

Exterior leak path seal was on the descent stage portion.
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

Redundant seal used on coolant loop disconnects for LM-3 through LM-6 vehicles

Poppet seal

Ascent stage

Descent stage

Exterior leak path seal

Original design of interstage disconnect
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
Built in redundancy
Generic Design Considerations - Final QDs

Built in redundancy

Final design of interstage disconnect
Built in redundancy
- Highly resistant to installation damage

The poppet seals are protected behind metal.
Better protection to the sealing surfaces

Exterior leak path seals embedded in grooves
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

◆ Feasibility
General Testing -- Feasibility

- Feasibility
  - Original concept to use pre-production hardware
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

- Feasibility
  - Design verification
General Testing - Design Verification

- Design verification
  ➔ Performance
General Testing - Design Verification

◆ Design verification
  ➢ Performance
  ➢ Structural
General Testing - Design Verification

- Design verification
  - Performance
  - Structural
  - Leakage/stability
General Testing - Design Verification

- Design verification
  - Performance
  - Structural
  - Leakage/stability
  - Endurance
General Testing -- Qualification

- Feasibility
- Design verification
- Qualification
General Testing -- Qualification

- Qualification
  - Design limit testing
General Testing -- Qualification

- Qualification
  - Design limit testing
  - EMI
General Testing -- Qualification

◆ Qualification
  ➢ Design limit testing
  ➢ EMI
  ➢ Vibration
General Testing -- Qualification

- Qualification
  - Design limit testing
  - EMI
  - Vibration
  - Functional
General Testing -- Qualification

- Qualification
  - Design limit testing
  - EMI
  - Vibration
  - Functional
  - Endurance
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.
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