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.
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 and cabin pressurization system with labeled components such as oxygen demand regulator, oxygen repressurization valve, shutoff valves, ascent and descent oxygen tanks, high-pressure assembly, and burst diaphragm.
Oxygen Supply and Cabin Pressurization Section

Overview of LM ECS
Overview of LM ECS

- Oxygen Supply and Cabin Pressurization Section

Key components:
- PLSS O2 hose
- Ascent Stage
- Oxygen control module
- Oxygen supply
- Oxygen demand regulator
- Oxygen repressurization valve
- Ascent oxygen tank
- Interstage disconnect
- Overboard relief valve
- Burst diaphragm
- Pressure regulator
- Descent Stage
- Descent oxygen tank

R denotes redundant component
Overview of LM ECS

Atmosphere Revitalization section

Atmosphere Revitalization Section Simplified Schematic
Overview of LM ECS

- Atmosphere Revitalization section
Overview of LM ECS

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

Atmosphere Revitalization section

- Temperature control
- Heat Exchanger
- Accumulator
- Water pump
- Regenerative heat exchanger
- Isolation valve
- CO2 sensor
- Relief valve
- Diverter valve
- Cabin-gas return valve
- LIOH canister
- LIOH canister
- H2O separator
- H2O separator
- H2O sublimator
- Heat exchanger
- Cabin recirculator assembly
- Fan

Atmosphere Revitalization Section Simplified Schematic
Overview of LM ECS

Water Management Section

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

H2O hose
- PLSS refill
- Drinking
- Food preparation
- Fire extinguisher

Water Management Section

R denotes redundant component.
Overview of LM ECS

- Water Management Section

- Ascent H2O tanks
  - Shutoff valves (5)
  - H2O hose
    - PLESS refill
    - Drinking
    - Food preparation
    - Fire extinguisher

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

- Water tank selector valve

- Water control module

- Ascent stage
- Descent stage
- Water Management Section
- R denotes redundant component

- Guillotine
- Descent H2O tank
Overview of LM ECS

Water Management Section

- Ascent H2O tanks
- Shutoff valves (5)
- H2O hose
  - PLESS refill
  - Drinking
  - Food preparation
  - Fire extinguisher
- Pressure regulator
- Reclaimed metabolic H2O
- Secondary coolant H2O sublimator
- Suit-circuit H2O sublimator
- Primary coolant H2O sublimator
- Water control module
- R denotes redundant component
- Ascent stage
- Descent stage
- Guillotine
- Water Management Section
Water Management Section

- Ascent H2O tanks
- Reclaimed metabolic H2O
- Pressure regulator
- Secondary coolant H2O sublimator
- Suit-circuit H2O sublimator
- Primary coolant H2O sublimator
- Pressure regulator
- Water tank selector valve
- Water control module
- Ascent stage
- Descent stage
- Descent H2O tank
- Guillotine
- R denotes redundant component.

Overview of LM ECS
Overview of LM ECS

Heat Transport Section

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

R denotes redundant component
Heat Transport Section

- Coolant recirculator assembly
- Pump
- Low-temperature electronics
- Aft equipment bay electronics
- Ascent batteries
- Descent batteries
- Coolant accumulator
- Coolant accumulator

R denotes redundant component

Heat Transport Section
Heat Transport Section

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Heat Transport Section

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- 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
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”
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

- 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

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

![Diagram of control system components: Handle, Cabin repress valve actuating switch, Valve position indicator.](image)
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

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
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)
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

Original design of interstage disconnect
Cutoff valves not needed, as will automatically seal.

**Generic Design Considerations - QDs**

- Ascent stage
- Descent stage

Original design of interstage disconnect
Cutoff valves not needed, as will automatically seal.

No retention mechanism.
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
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.
- Very susceptible to installation damage

**Generic Design Considerations - Original QDs**

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

**Ascent stage**

**Descent stage**

**Exterior leak path seal**

**Poppet seal**

**Original design of interstage disconnect**
Generic Design Considerations - Original QDs

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

- Primary poppet seal
- Primary poppet
- Ascent stage
- Descent stage
- Final design of interstage disconnect
Generic Design Considerations – Final QDs

Built in redundancy

- Primary poppet seal
- Secondary poppet seal
- Primary poppet
- Secondary poppet
- Ascent stage
- Descent stage

Final design of interstage disconnect
Built in redundancy

Generic Design Considerations - Final QDs

Primary poppet seal
Secondary poppet seal
Primary exterior leak path seal
Secondary exterior leak path seal

Ascent stage
Descent stage

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

Ascent stage

Descent stage
- Better protection to the sealing surfaces

Exterior leak path seals embedded in grooves

Final design of interstage disconnect
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
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

- 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