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
- Cabin Pressurization Section

Diagram shows the flow of oxygen through the system, including control modules, tanks, and various valves and regulators.
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
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

![Diagram of Atmosphere Revitalization Section Simplified Schematic]
Overview of LM ECS

Atmosphere Revitalization section

Atmosphere Revitalization Section Simplified Schematic
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 control module
- R denotes redundant component
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
- Ascent H2O tank
- Descent stage
- Guillotine
- Water control module

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

R denotes redundant component.
Water Management Section

- Ascent H2O tanks
- Reclaimed metabolic H2O
- Pressure regulator
- Reclam H2O sublimator
- Suit-circuit H2O sublimator
- Primary coolant H2O sublimator

Components:
- Shutoff valves (5)
- H2O hose
  - PLS refill
  - Drinking
  - Food preparation
  - Fire extinguisher

Notations:
- Ascent stage
- Descent stage
- Water control module
- R denotes redundant component
- Descent H2O tank
- Guillotine

Overview of LM ECS
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
- Water control module
- R denotes redundant component.
Overview of LM ECS

Heat Transport Section

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

R denotes redundant component

To coolant recirculator assembly

Heat Transport Section
Overview of LM ECS

Heat Transport Section

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

R denotes redundant component

Heat Transport Section
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 regenerative heat exchanger
- Primary sublimator
- Secondary sublimator
- Suit water cooling assembly
- To coolant recirculator assembly

R denotes redundant component
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
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
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
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
Cutoff valves not needed, as will automatically seal
- 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

Cernan & Stafford
Generic Design Considerations - Original QDs

Original design of interstage disconnect
Generic Design Considerations - Original QDs

Poppet seal was on the ascent stage portion
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.
- 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
- 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

Cernan & Stafford
Generic Design Considerations - Final QDs

Final design of interstage disconnect

Ascent stage
Descent stage
Generic Design Considerations - Final QDs

Built in redundancy

Primary poppet seal
Primary 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 poppet
- Secondary poppet

Final design of interstage disconnect

Ascent stage
Descent stage
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
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
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