OVERVIEW OF LIDS DOCKING AND BERTHING SYSTEM SEALS

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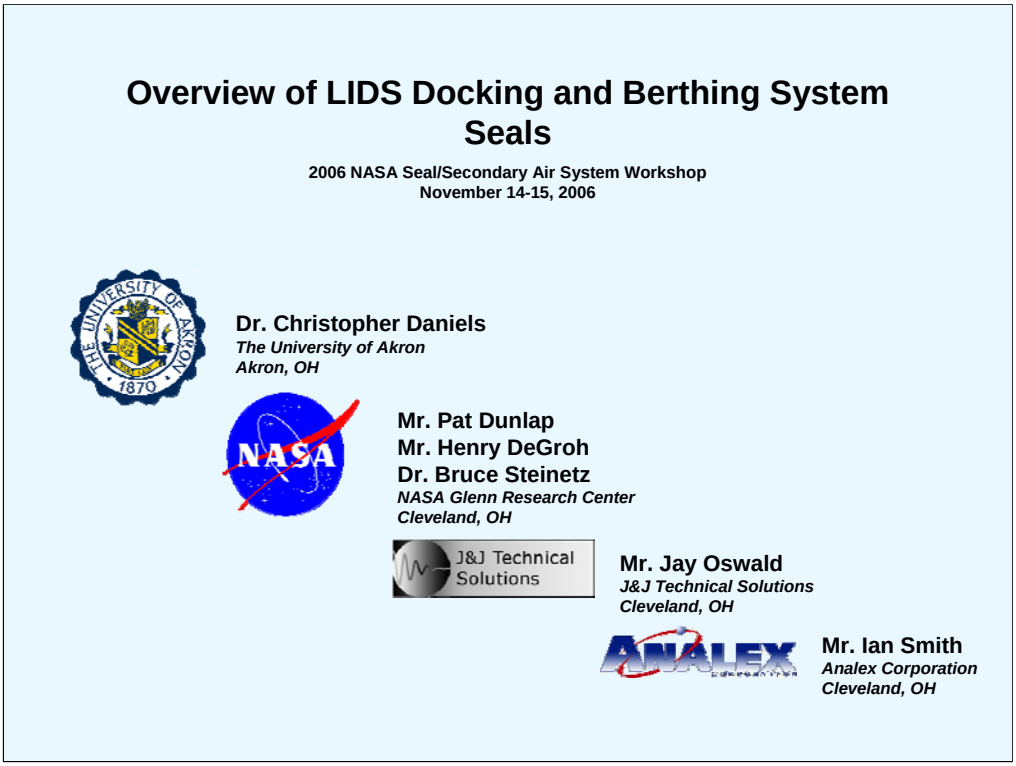
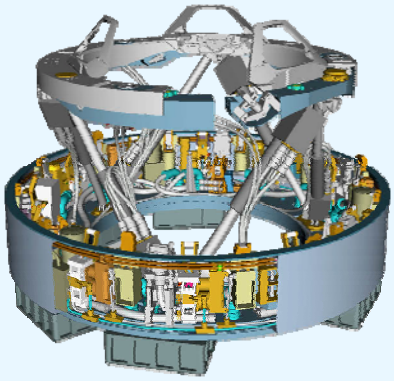


Description of the Application: Low Impact Docking System (LIDS)

- Low Impact Docking System (a.k.a. Advanced Docking Berthing System (ADBS))
- Next-generation space vehicle mating system
- Establishes a standard interface for mating spacecrafts that is:
  - compact
  - smart
  - lightweight
  - low impact
  - reduces the risks associated with mating spacecraft.
- Simplifies spacecraft docking operations by eliminating high-impact loads
- Supports autonomous docking and berthing operations
- Supports a wide range of spacecraft and mating operations.
  - Crew Exploration Vehicle
  - International Space Station



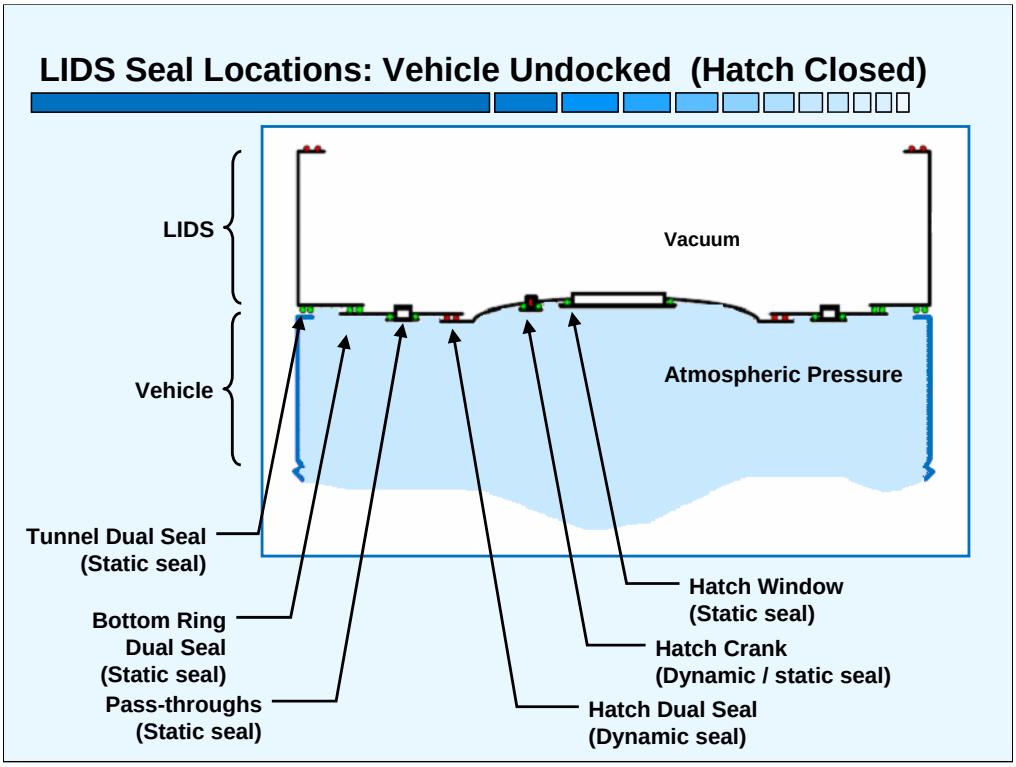
Graphic of the Low Impact Docking System.

+ The Advanced Docking Berthing System shown on the right is under development at Johnson Space Center. The future for the system is to become the agency's standard mating system going forward through the Constellation Program.

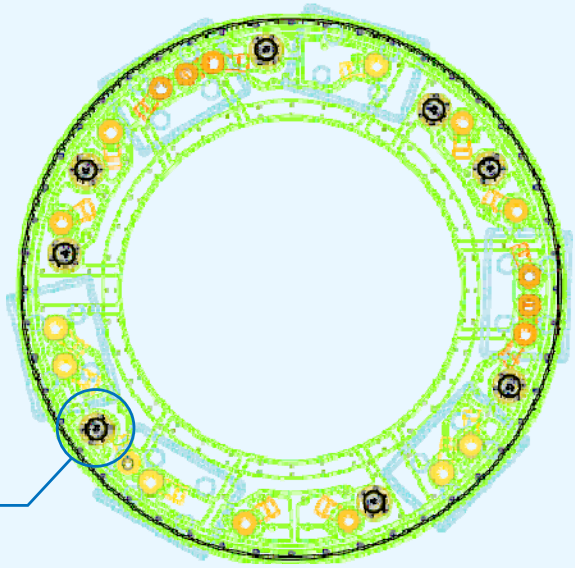
+ The system offers several advantages over the current Russian built system. Most importantly, it reduces the risks associated with mating.

+ It does this by mating with very low impact, and by offering system redundancy.

+ The system is redundant on every level because it is androgynous. Each joint is a mate between two identical systems.

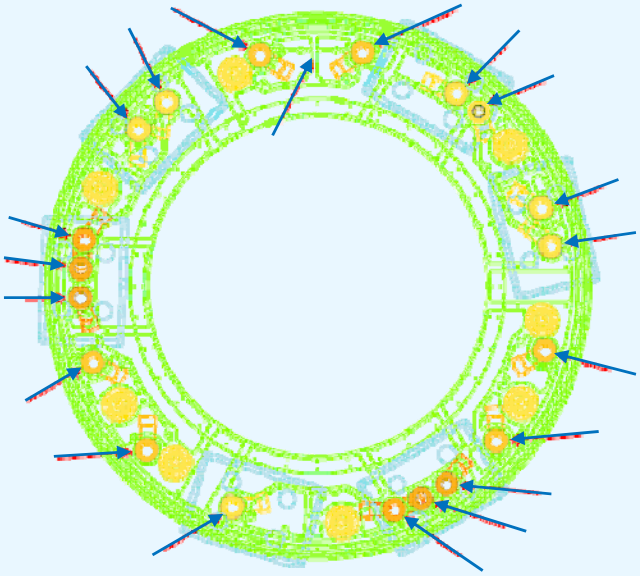

LIDS Seal Locations: Vehicle Undocked (Hatch Closed)
LIDS
Vehicle
Vacuum
Atmospheric Pressure
Tunnel Dual Seal
(Static seal)
Bottom Ring
Dual Seal
(Static seal)
Pass-throughs
(Static seal)
Hatch Window
(Static seal)
Hatch Crank
(Dynamic / static seal)
Hatch Dual Seal
(Dynamic seal)

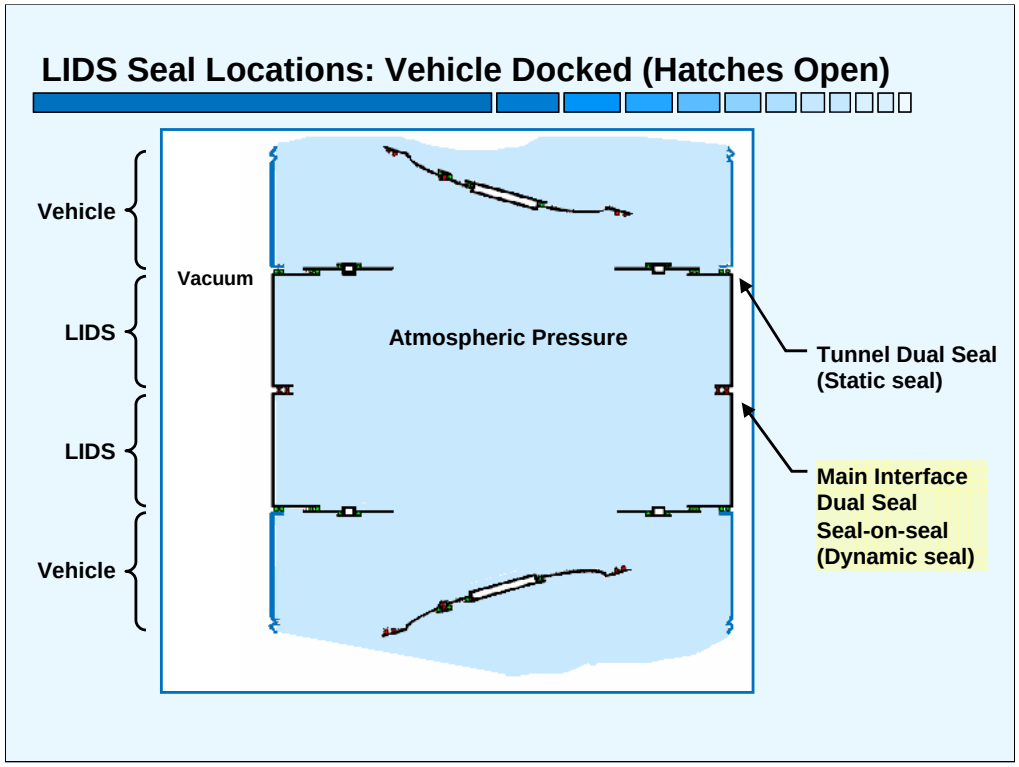
LIDS Seal Locations: Mechanical Pass Thru



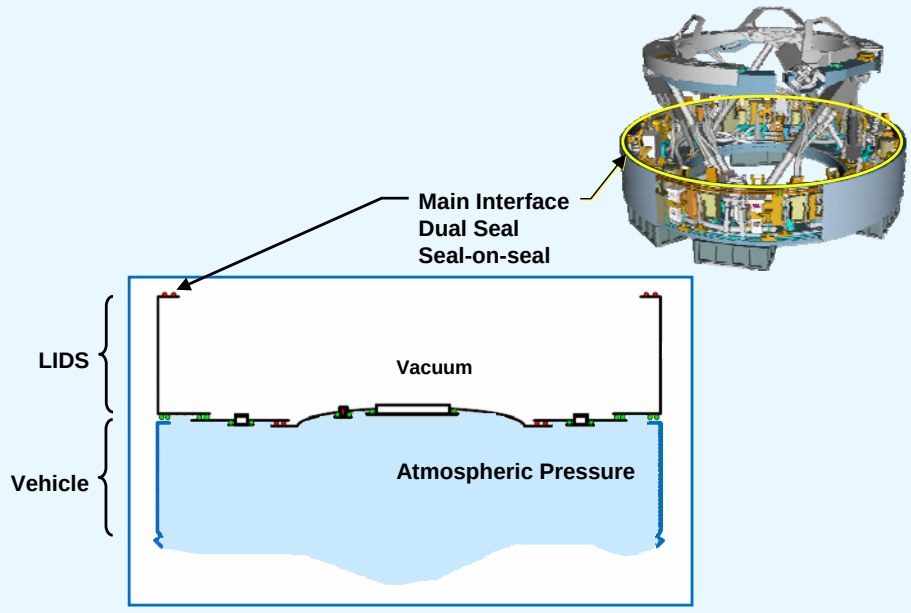
Mechanical
Pass-throughs
(8 places)

LIDS Seal Locations: Electrical and Pyro Connectors




LIDS Seal Locations: Vehicle Docked (Hatches Open)
Vehicle
LIDS
LIDS
Vehicle
Vacuum
Atmospheric Pressure
Tunnel Dual Seal
(Static seal)
Main Interface
Dual Seal
Seal-on-seal
(Dynamic seal)

LIDS Seal Locations: Main Interface Seal



Main Interface Seal Challenges and Specifications

Vehicle to vehicle mating requires androgynous (gender neutral) interface

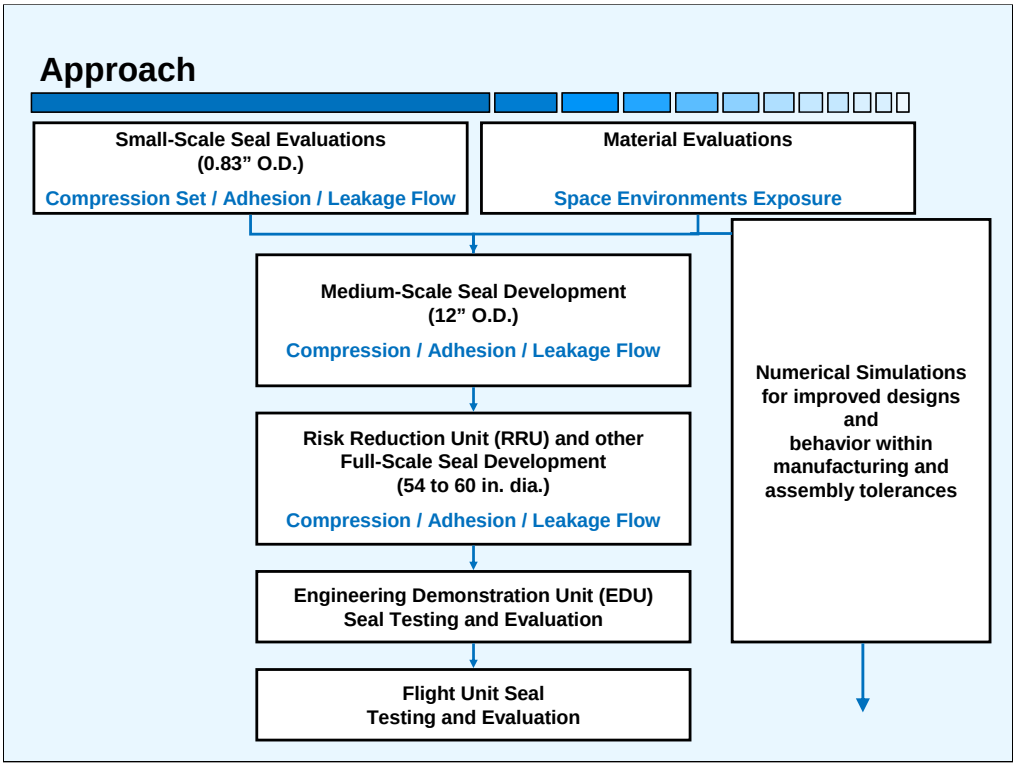
- Androgynous interface requires seal-on-seal configuration
- Seal must accommodate vehicle misalignments and manufacturing tolerances

Seal materials must withstand:

- Atomic oxygen in low Earth orbit
- Particle and ultraviolet radiation
- High number of mating cycles
- Micrometeoroid and orbital debris (MMOD)
- Long duration under vacuum
- Thermal gradients and transients
- Thermal environment: -100 to 100°C
- Operating temperature: -50 to 50°C
- Long periods under mating conditions

Seal specifications:

- Compression force < 100 lbf / linear inch / seal
- Adhesion force ~ 0 lbf
- Confined width and height requirements
- Leakage < 0.02 lbm_{AIR} / day under all conditions

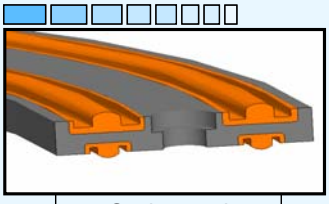

Approach
Small-Scale Seal Evaluations
(0.83" O.D.)
Compression Set / Adhesion / Leakage Flow
Material Evaluations
Space Environments Exposure
Medium-Scale Seal Development
(12" O.D.)
Compression / Adhesion / Leakage Flow
Risk Reduction Unit (RRU) and other
Full-Scale Seal Development
(54 to 60 in. dia.)
Compression / Adhesion / Leakage Flow
Engineering Demonstration Unit (EDU)
Seal Testing and Evaluation
Flight Unit Seal
Testing and Evaluation
Numerical Simulations
for improved designs
and
behavior within
manufacturing and
assembly tolerances

Seal Concepts Under Development/Evaluation

Elastomeric Seals

Gask-o-seal:

- Able to form near-hermetic seal
- Able to perform under gapping / misalignment conditions
- Currently flying as static berthing seal on Space Station: Common Berthing Module
- Concerns:
  - Long term space exposure
  - Seal-to-seal adhesion
  - Examining remedies.



Gask-o-seal

Gasket Seal:

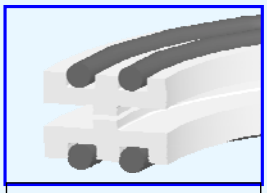
- Near Term Risk Reduction Unit (RRU) trial seal
- Using to check-out JSC and GRC test hardware

Gasket Seal

Metallic Seals

Metal Face Seal:

- Immune to UV, AO, IR effects
- No known adhesion issue
- Concerns:
  - Very low leakage
  - Large diameter, precision flat surfaces



Metallic Face Seal

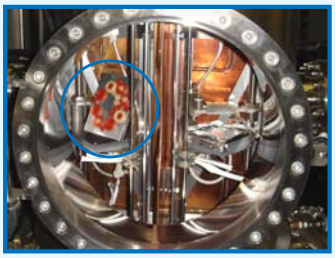
Elastomer Material Evaluations

Evaluation of relevant seal properties

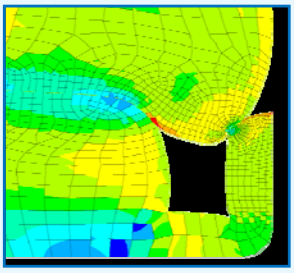
- Compression set
- Elastomer-to-elastomer adhesion
- Leakage rates

Space Environments Exposures

- Understanding / quantifying the effects of
  - Atomic oxygen
  - Ultraviolet and particle radiation
  - Micrometeroid / orbital debris impacts



Photograph of elastomer specimens in the UV exposure chamber



Numerical simulation of two misaligned Gask-o-seals in contact

Numerical predictions

- Mechanical properties of elastomers measured at various temperatures
- Compression load and deformation predicted

Details provided in the next two presentations

- Space Environments Effects on Candidate LIDS Seal Materials
- FEA Modeling of Elastomeric Seals for LIDS

Evaluation of Relevant Seal Properties

Compression Set

- Determines the ability of elastomeric compounds to retain elastic properties after prolonged compression per ASTM Standards

Photograph of an adhesion test in progress

Adhesion

- Quantifies adhesion between two elastomeric samples

Leakage Flow

- Measure leakage rate of air under vacuum conditions before and after space environments exposures to quantify degradation from AO, UV, ionizing radiation, and MMOD

Medium Scale Flow/Compression Fixture

- Measures leakage rate of candidate seal geometries and materials in nominal and off-nominal configurations
- Quantifies compression and adhesion forces required to mate and demate candidate seal geometries and materials

Medium-Scale (12”) Gask-O-Seal Compression Tests

Objectives:

- Determine maximum compressive load
- Characterize decay in maximum compressive load on seal
- Measure maximum adhesion on seal as a function of hold time and number of cycles
- Measure compression set

Procedures:

- Compression set test #1
  - Load and hold for 70 hours (using LIDS docking profile)
  - Unload
  - Wait 30 minutes
- Cyclic loading (Cycles 2-21):
  - Load and hold for 30 minutes
  - Unload
  - Wait 30 minutes
- Compression set test #2
  - Load and hold for 70 hours
  - Unload
  - Wait 30 minutes
- Load for 30 minutes (Cycle 22)

Cross-sections of the elastomer seal concepts with elliptical top (left) and flat top (right) sealing surfaces.

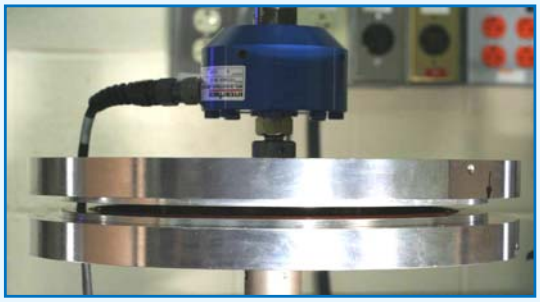
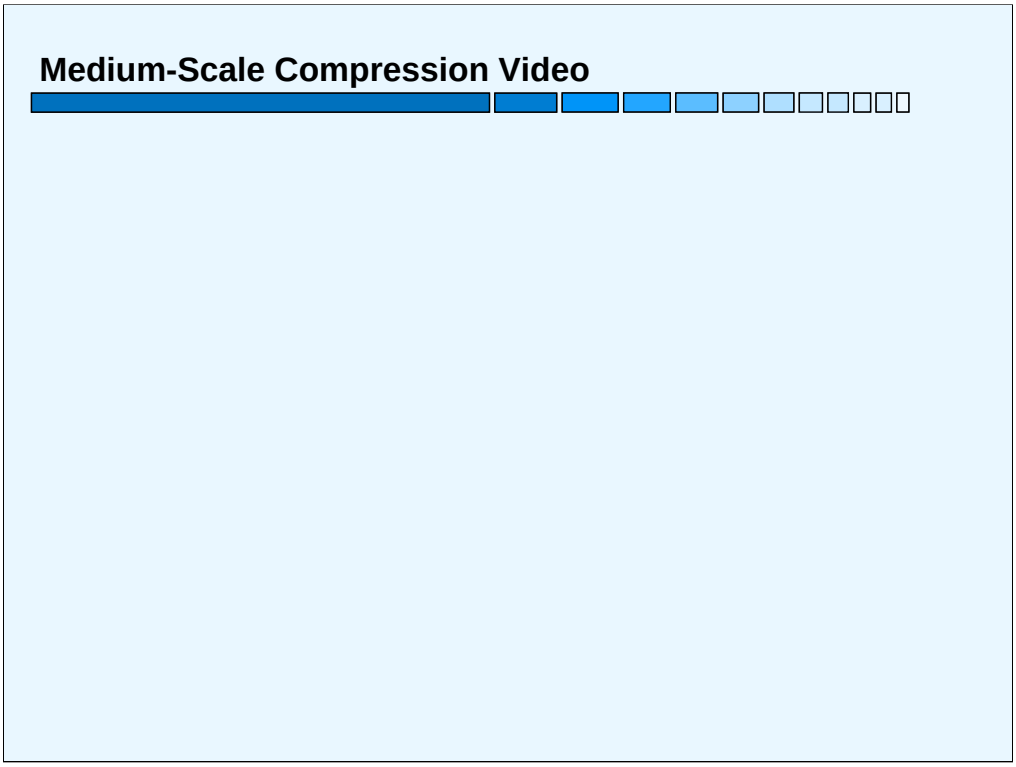


Photo of the compression testing of 12” Gask-o-seals in an axially aligned seal-on-seal configuration.


Medium-Scale Compression Video

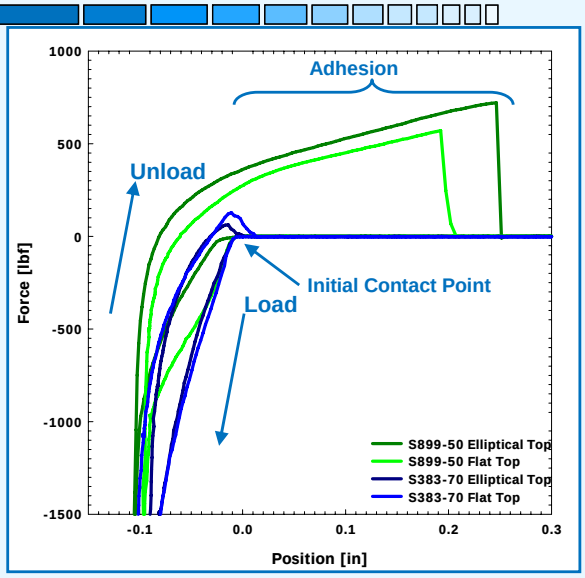
Medium-Scale Compression Results

Test specimens:

- Parker Hannifin Gask-o-seal
  - Common Berthing Mechanism (CBM) design
- Two compounds
  - S0383-70
  - S0899-50
- Two configurations
  - Elliptical top
  - Flat top

Results

- Both compounds showed adhesion before release
- During separation, the S0899-50 elastomer stretched 0.25 / 0.20 inch (elliptical / flat top) beyond the initial contact point
- Compression set results were masked by the high levels of adhesion of the S0899-50 compound

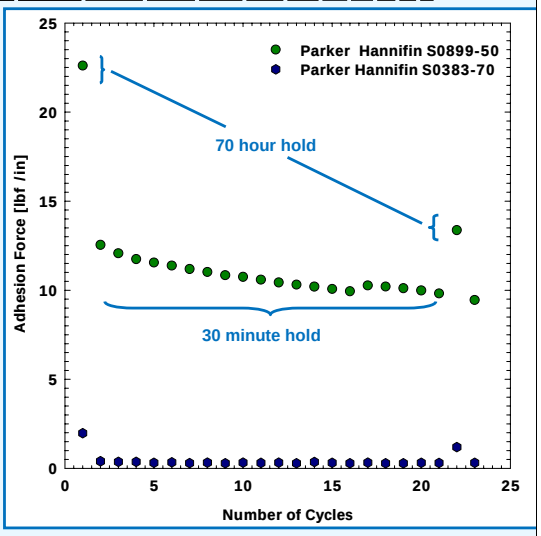


S1853-50 and S0899-50 are identical elastomer compounds with different designations from different divisions within Parker Hannifin. S0899-50 is used throughout this (and other) presentations for uniformity.

Adhesion Forces of Elliptical Top Gask-o-seals

Results

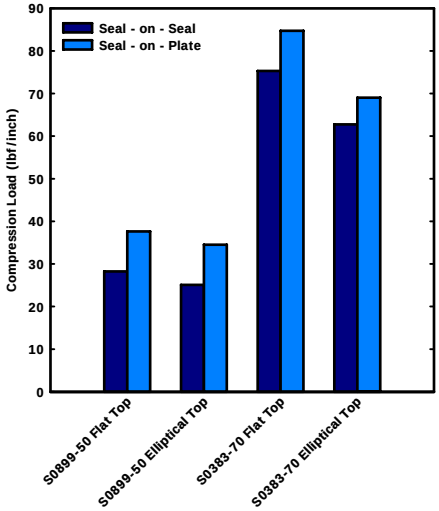
- Adhesion increases with contact duration (70 hrs versus 30 min)
- Adhesion generally decreases with number of mate cycles
- No trends were observed in the adhesion with sealing surface configuration (not shown)
- Adhesion levels of the S0383-70 elastomer seals were stable and lower than those for S0899-50



Medium-Scale Seals

Compression forces required for 58” dual-bead seal-on-seal is predicted to be:

- ~5100 lbf (S0899-50 / Elliptical top)
- ~4600 lbf (S0899-50 / Flat top)
- ~13700 lbf (S0383-70 / Elliptical top)
- ~11400 lbf (S0383-70 / Flat top)



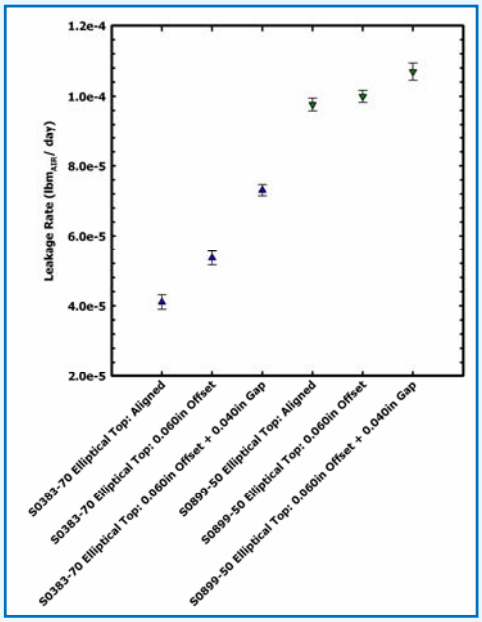
Medium-Scale Leakage Results: Effect of Configuration

Test Specimens and Setup

- Parker Hannifin Gask-o-seals
  - CBM design
  - Elliptical top
- Two elastomer compounds
  - S0383-70
  - S0899-50
- Three configurations
  - Aligned seal-on-seal
  - Axial misalignment (0.060 inch)
  - Axial misalignment (0.060 inch) + Angular misalignment (0.040 inch)

Results

- The leakage of seals was greatest with both axial and angular misalignments
- When the seals were aligned, the leakage was the lowest
- S0899-50 seals leaked greater than S0383-70



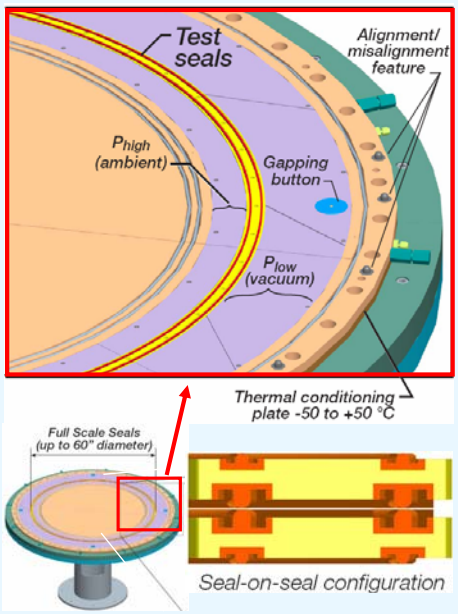
Full Scale LIDS Seal Test Rig Development

Goal: Evaluate full-scale seal leakage rates under anticipated thermal, vacuum, and engagement conditions

Features:

- Static seal-on-seal or seal-on-plate configurations
- Seal diameters:
  - Risk reduction unit.....54”
  - Engineering demonstration unit.....58”
  - Flight unit.....TBD
- Simulated environmental conditions
  - Thermal -50°C to +50°C (shade or sun)
- Pressure (ΔP)
  - Operational: Ambient pressure to vacuum
  - Pre-flight checkout: 15 psig to ambient
- Engagement conditions
  - Vehicle alignment/misalignment (±0.060”)
  - Gapping: Non-uniform clamping engagement (0.040”)

Future: An actuation system to bring seals together simulating docking



Materials International Space Station Experiment (MISSE 6A and 6B)

Goals and Objectives

- To expose three candidate elastomers to space environments in low-Earth orbit to evaluate their applicability as material for primary mating interface seal for LIDS
- Combined and simultaneous exposure to atomic oxygen, ultraviolet and ionizing radiation, MMOD, and temperature transients in a hard vacuum cannot be replicated in terrestrial laboratories.

Anticipated data

- Leakage rates of three candidate elastomers o-rings after
  - exposure to combined space environments (to be compared with as-received samples).
  - exposure to UV, ionizing radiation, and thermal cycling only under hard vacuum conditions.
- Leakage rate of S0383-70 elastomer o-ring after exposure to thermal cycling only under hard vacuum conditions.
- Leakage rate of S0383-70 with additional post-cure after exposure to combined space environments.
- Leakage rate of S383-70 with a UV/AO protective coating after exposure to combined space environments.
- Adhesion level of pairs of S0383, S0899, and XELA-SA-401 elastomer o-rings after exposure to thermal cycling under hard vacuum conditions (simulating docking conditions).

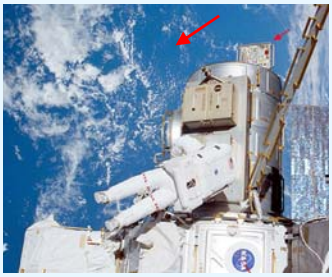


Photo of previous MISSE PEC taken during STS110

Diagram showing the MISSE 6A and 6B o-ring AO/UV exposure assembly

Schedule

Material Evaluations

- Atomic Oxygen, Ultraviolet and Particle Radiation, Micrometeoroid / Orbital Debris Impact
- Ongoing

Small-scale Seal Evaluations

- Elastomeric-seal concepts, metallic-seal concepts
- Ongoing

Medium-scale Seal Evaluations

- Seals showing promise after small-scale evaluation
- Through 2008

Full-scale Seal Evaluations (Static System)

- Rig fabrication out for bid
- Anticipate testing in Spring / Summer 2007

Full-scale Seal Evaluations (Actuated System)

- Actuation system out for bid
- Anticipate testing in Summer / Fall 2007

MISSE 6A and 6B

- Launch planned for Fall 2007

1st LIDS Flight

- Launch planned for 2012

Appendix

NASA GRC In-house Team

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