Overview of LIDS Docking Seals Development

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2008 NASA Seal/Secondary Air System Research Symposium
November 18, 2008

NASA is developing a new docking system to support future space exploration missions to low-Earth orbit, the Moon, and Mars. This mechanism, called the Low Impact Docking System (LIDS), is designed to connect pressurized space vehicles and structures including the Crew Exploration Vehicle, International Space Station, and lunar lander. NASA Glenn Research Center (GRC) is playing a key role in developing the main interface seal for this new docking system. These seals will be approximately 147 cm (58 in.) in diameter. GRC is evaluating the performance of candidate seal designs under simulated operating conditions at both sub-scale and full-scale levels. GRC is ultimately responsible for delivering flight hardware seals to NASA Johnson Space Center around 2013 for integration into LIDS flight units.

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NASA GRC LIDS Seal Development Team

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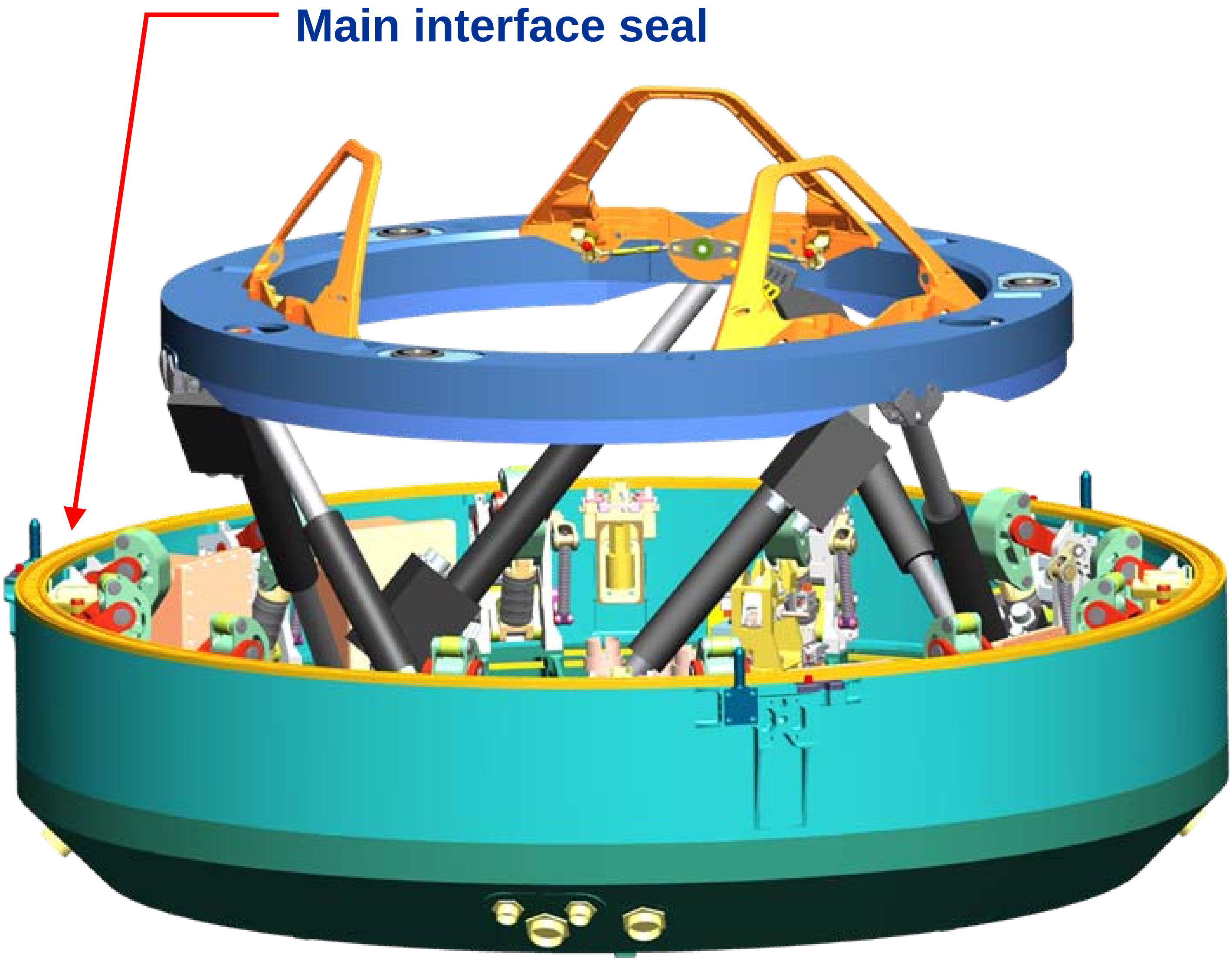
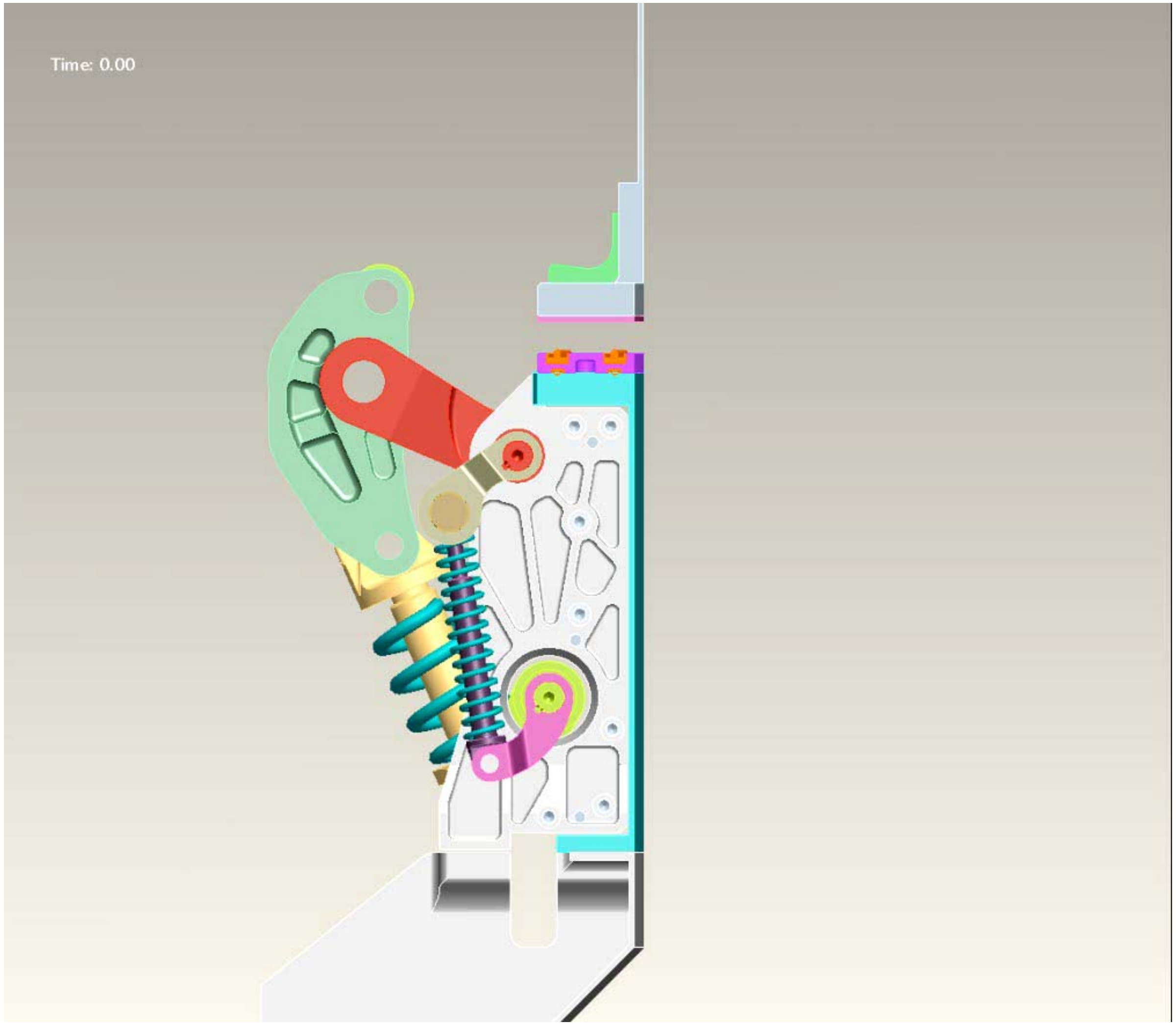
LIDS Main Interface Seal Location



LIDS Hard Capture Latch Mechanism Compresses Seals



Top Level Seal Requirements

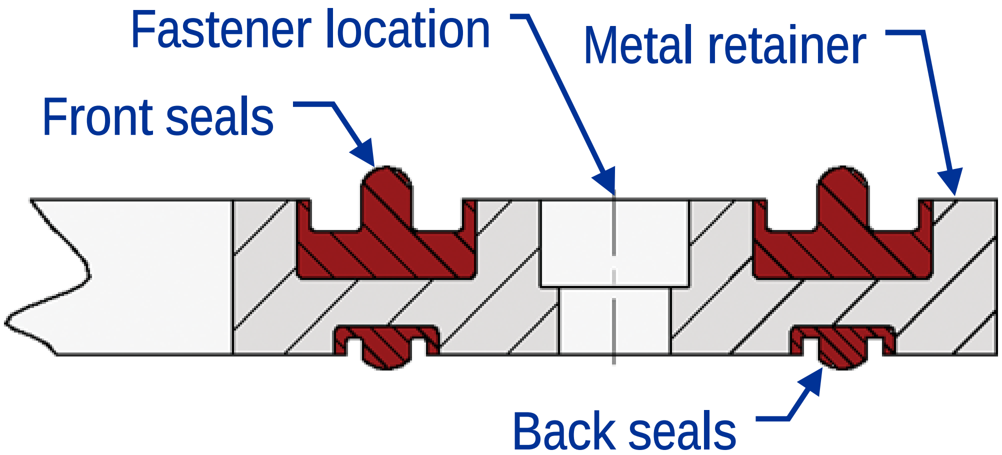
- Extremely low leak rates (≤0.0025 lbm/day) at 14.8 psia to minimize overall LIDS leakage
- Temperature ranges:
  - Operating: -30°C to +50°C (-22 °F to +122 °F)
  - Non-operating: -70°C to +100°C (-94 °F to +212 °F)
  - Ranges subject to change as additional thermal analyses and tests are performed
- <u>Max compression loads:</u> 140 lbf/in. (70 lbf/in. per seal bulb)
- <u>Max load to separate seals during undocking:</u> 300 lbf

Top Level Seal Requirements (cont.)

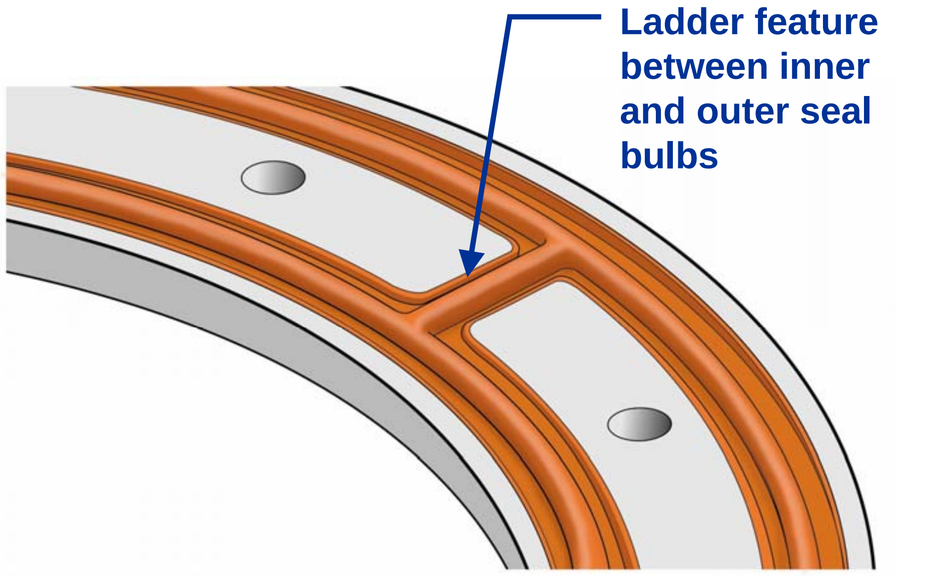
- Long mating periods (216 days) and repeated docking
- Withstand exposure to space environments (e.g., atomic oxygen (AO), UV radiation, micro-meteoroids and orbital debris (MMOD)) without excessive damage or loss of sealing ability
- Include redundant sealing features (i.e., two seals or two seal beads) and provisions to verify each seal prior to launch
- Materials must meet low outgassing requirements of total mass loss (TML) <1% and collected volatile condensable materials (CVCM) <0.10% using ASTM E595

LIDS Main Interface Seals

- Leading candidate is Gask-O-Seal™ design (Parker Hannifin)
  - Used on Common Berthing Mechanism (CBM) & other locations on ISS
  - S0383-70 silicone elastomer bulbs vacuum molded into 6061-T651 aluminum retainer
  - Dual bulbs on top & bottom of retainer
  - May include ladder features to create multiple zones between inner and outer seals for added reliability
- Dimensions:
  - EDU 58 (Engineering Demonstration Unit) & flight units:
    - ~58 in. outer diameter
    - ~1.5 in. face width
    - 0.300 in. retainer thickness
  - EDU 54 (early LIDS prototype):
    - 54 in. outer diameter
    - 1.125 in. face width
    - 0.200 in. retainer thickness



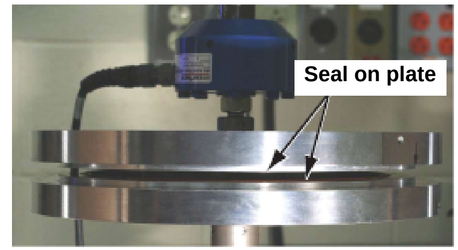
Cross section through Gask-O-Seal



Seal Development Approach

Small Scale Seal Development (0.83 in. dia.) (compression set, adhesion, flow, space environment exposure)

Medium Scale Seal Development (12 in. dia.) (compression, adhesion, flow)



Full Scale Seal Development (54 to 60 in. dia.) (compression, adhesion, flow)

Full-scale non-actuated rig

Engineering Demonstration Unit Seal Testing and Evaluation

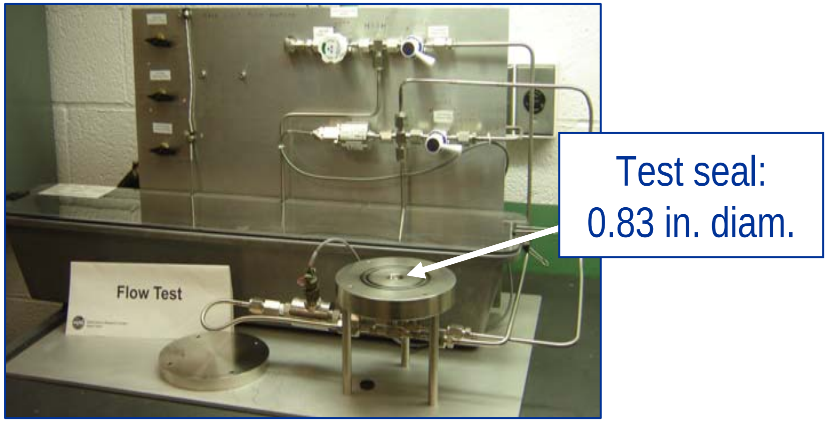
Full-scale actuated rig

Flight Unit Seal Testing and Evaluation

Small-Scale Seal Testing

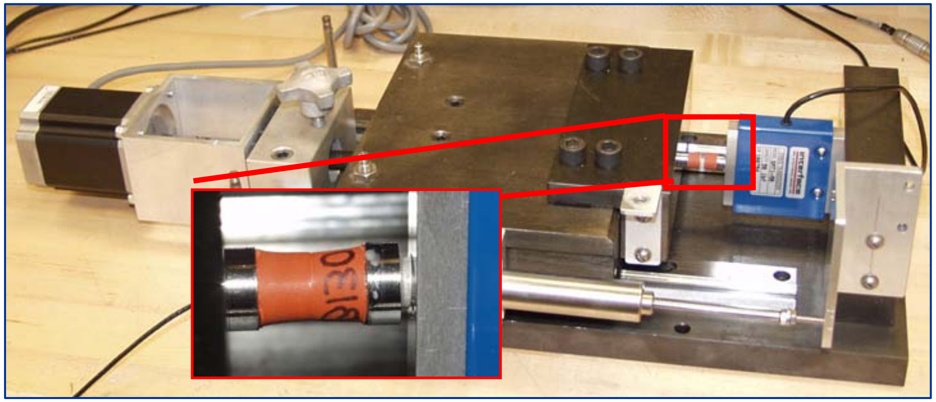
AO/UV/Ionizing Radiation Exposure:

Assess effects of space environment exposure on seal performance (flow, adhesion, compression set, etc.)



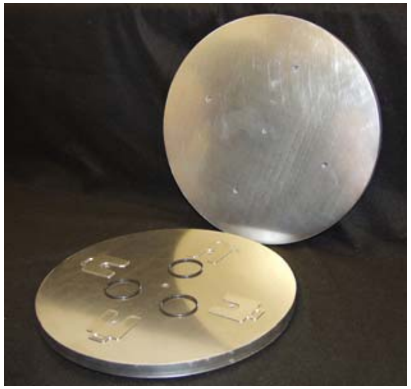
Small-Scale Leak Tests:

Assess seal leakage before and after environmental exposure (AO, UV, MMOD)



Small-Scale Adhesion Tests:

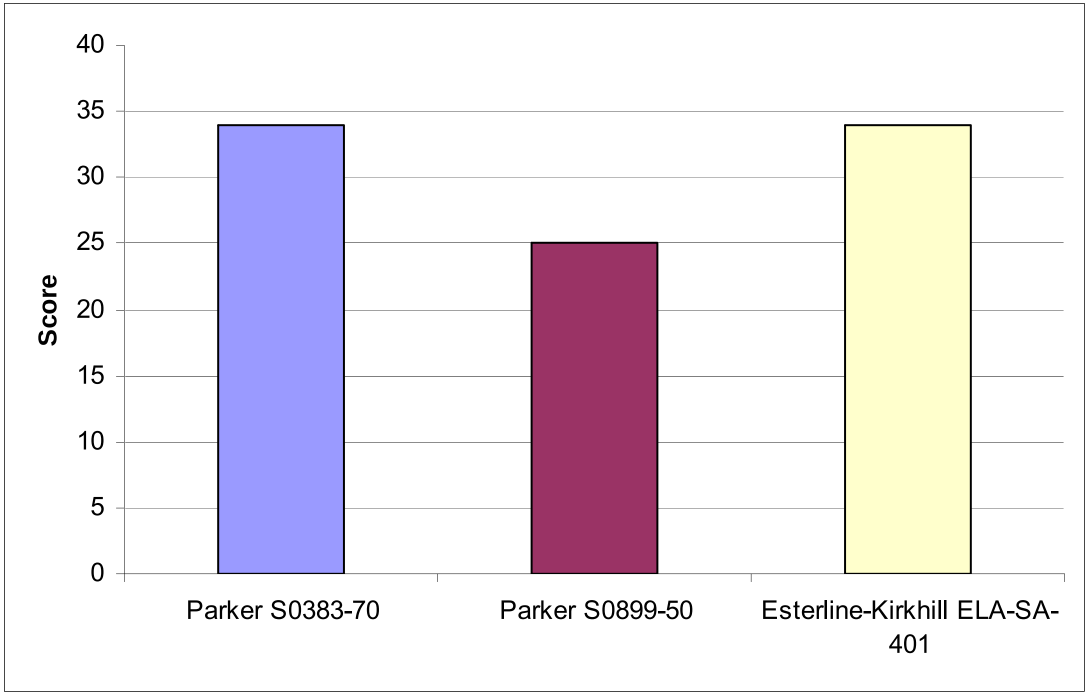
Assess effects of environmental exposure; evaluate mitigation techniques on seal adhesion



Small-Scale Compression Set Tests:

Assess effects of thermal and environmental exposures on seal compression set (loss of resiliency)

Seal Elastomer Selection

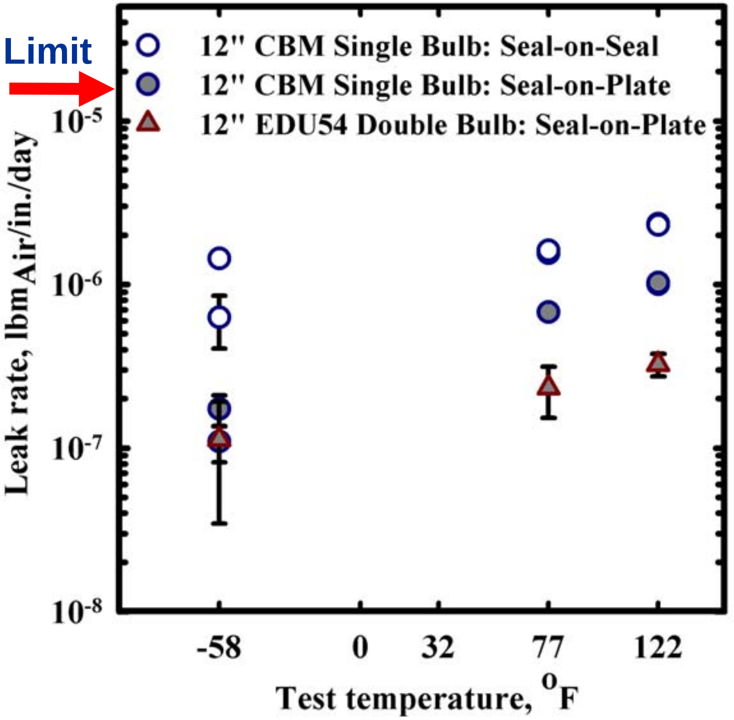


	Parker S0383-70	Parker S0899-50	Esterline-Kirkhill ELA-SA-401
Adhesion			
As-Received	2	1	3
AO Exposed	2	1	3
AO + UV	3	3	3
Particle Radiation	2	1	3
Compression Set			
As-Received	2	3	1
-50°C	2	1	3
25°C	1	2	3
50°C	2	1	3
125°C	1	2	3
AO Exposed	2	3	1
AO + UV	3	2	1
Particle Radiation	0	0	0
Leakage Rate			
As-Received	3	2	1
AO Exposed	3	1	2
AO + UV	3	1	2
Particle Radiation	3	1	2
Total	**34**	**25**	**34**

- Evaluated three elastomer materials for seals:
  - Parker S0383-70
  - Parker S0899-50
  - Esterline-Kirkhill ELA-SA-401
- Based on small-scale seal testing after space environment exposures:
  - Selected Parker S0383-70 as baseline material for Gask-O-Seal design
  - Pursuing ELA-SA-401 material with alternate seal design in parallel for risk reduction

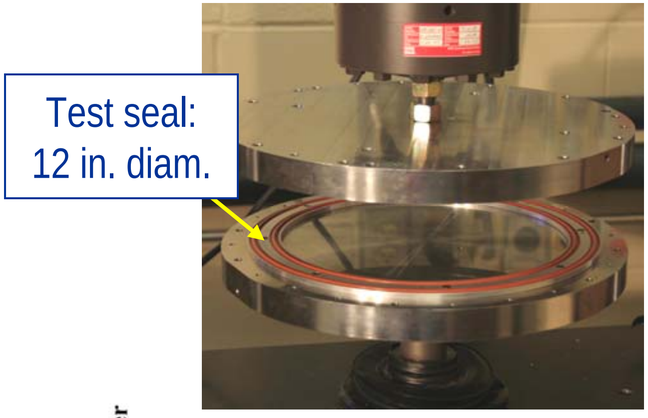
Medium-Scale Leak Tests

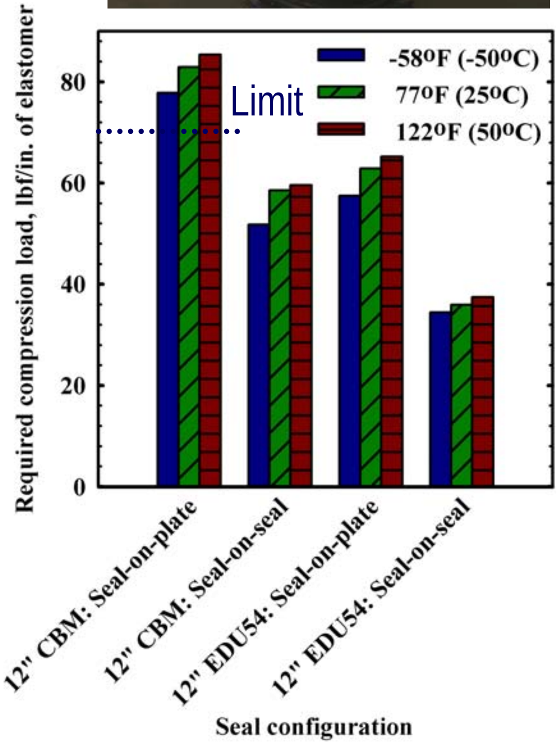
- Objective:
  - Measure leak rates for various:
    - Seal designs
    - Temperatures
    - Mating conditions
      - Seal-on-plate vs. seal-on-seal
      - Standoff
      - Misalignment
    - Pre-treat conditions (w. & w/o AO pre-treat)
- Key findings to-date:
  - Leak rates for EDU 54 and CBM seal designs fall below leakage threshold across operating temperature range
  - Back seal bulbs on CBM design leak more than front bulbs
- Future plans:
  - Complete leak tests on candidate designs for Gen 1 EDU 58 seals
  - Prepare candidate Gen 2 EDU 58 seal designs based on test results
    - Redesign back seal bulbs to reduce leakage



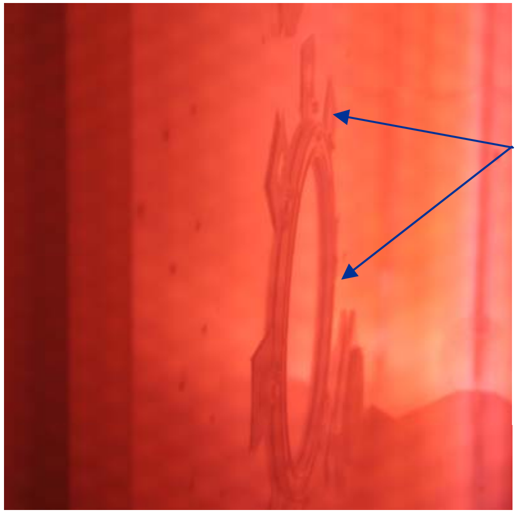
Medium-Scale Compression and Adhesion Tests

- Objective:
  - Measure compression and adhesion loads for various:
    - Seal designs
    - Temperatures
    - Mating conditions
      - Seal-on-plate vs. seal-on-seal
      - Standoff
      - Misalignment
    - Pre-treat conditions (w. & w/o AO pre-treat)
- Key findings to-date:
  - Compressive loads for EDU 54 seal design fall below load threshold across operating temperature range
- Future plans:
  - Complete compression and adhesion tests on candidate designs for Gen 1 EDU 58 seals
  - Fleet leader experiment
    - Evaluate seal leakage, adhesion, and compression set after compression under vacuum for 210 days

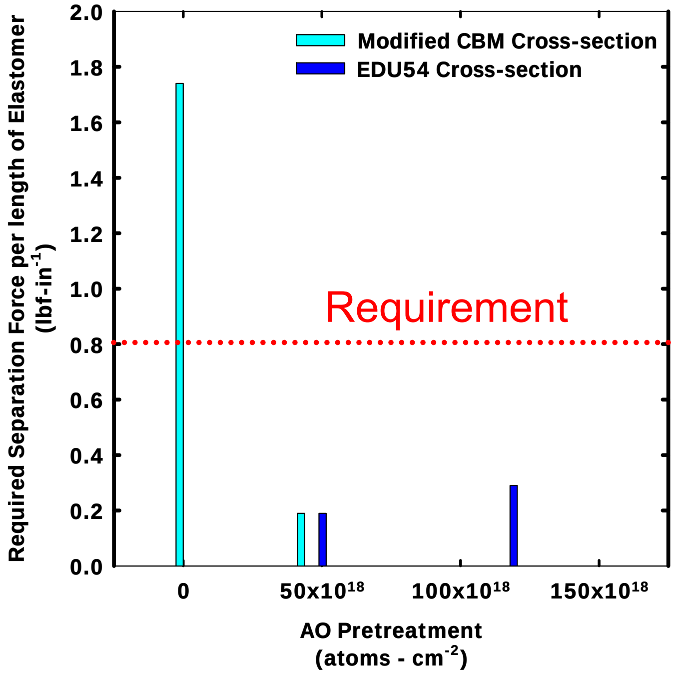




AO Pre-Treatment to Reduce Seal Adhesion



AO pre-treatment of sub-scale seals in GRC Tank 9 facility. Red color: AO plasma



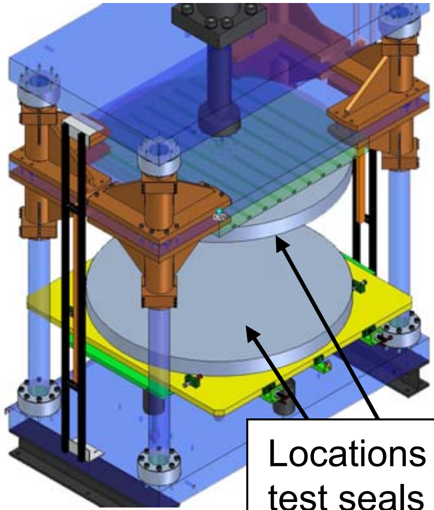
Seal-on-plate adhesion for 12-in. seals
(70 hr contact period)

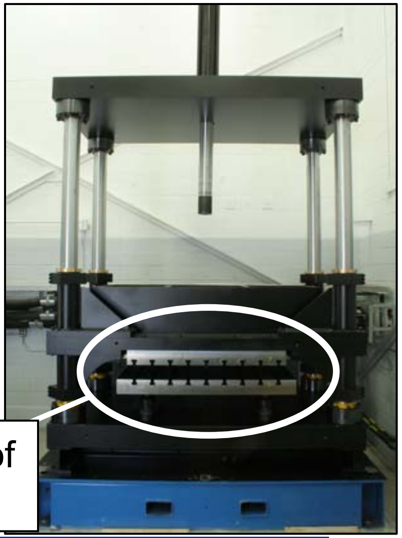
- Requirement: Seal separation force during undocking is to be <300 lbf (0.8 lbf/in. elastomer)
- Potential issue:
  - As-received silicone seals exhibit high levels of adhesion
  - If left untreated seals could adhere excessively to mating surfaces
- Solution:
  - GRC developed technique to pre-treat seals with moderate fluence levels of atomic oxygen (AO)
    - Reduces seal adhesion to acceptable level via formation of thin SiO_x layer on surface
    - Has negligible influence on leak rates

Full-Scale Seal Testing

- <u>Objective:</u>
  - Evaluate performance of candidate full-scale seals under anticipated operating conditions
- <u>Approach:</u>
  - Non-actuated test rig measures seal leak rates
  - Actuated test rig measures seal leak rates and loads
- <u>Capabilities:</u>
  - Seal-on-plate (primary) and seal-on-seal configurations
  - Seals of various designs and sizes:
    - Diameters: 52 to 60 in.
    - Various seal widths and thicknesses
  - Temperatures: -50 to +50°C (-58 to +122°F)
  - Pressure differentials across seals for:
    - Operating conditions in space
    - Pre-flight checkout conditions on ground
  - Aligned vs. misaligned conditions
  - Seal compressive & adhesive loads during docking & undocking (actuated rig only)

Full-scale non-actuated LIDS seal test rig

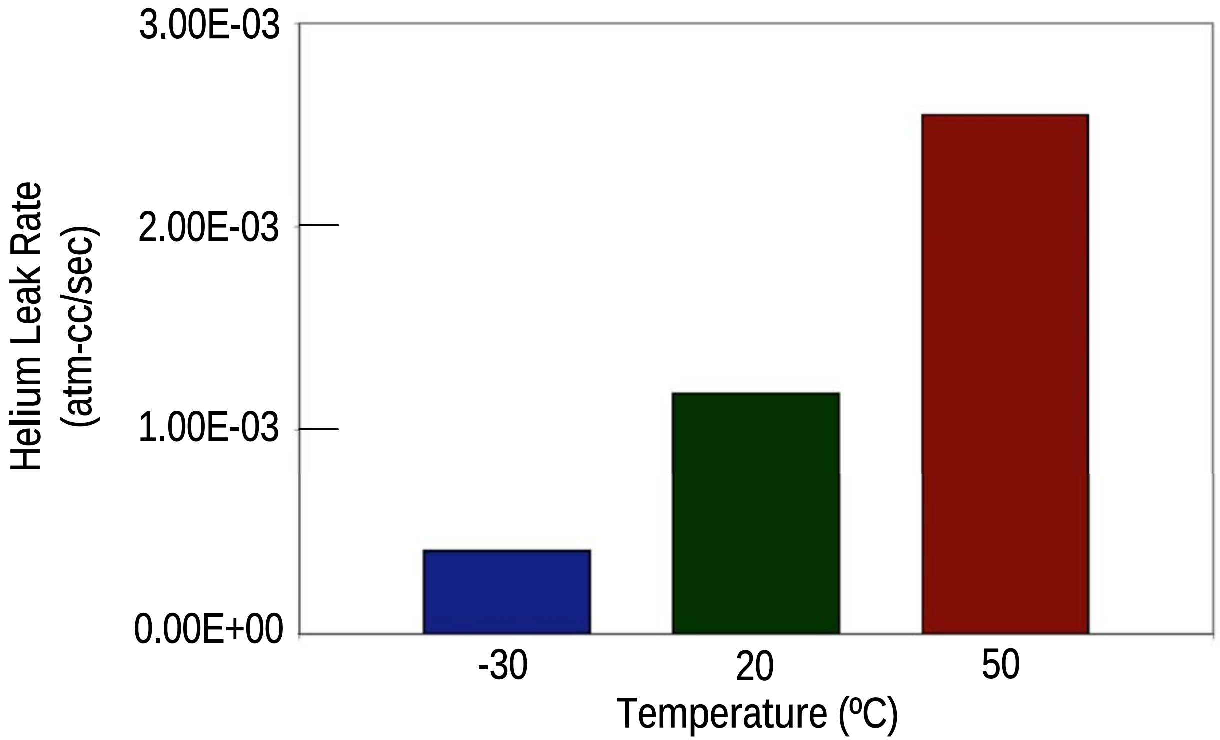




Locations of test seals

Full-scale actuated LIDS seal test rig

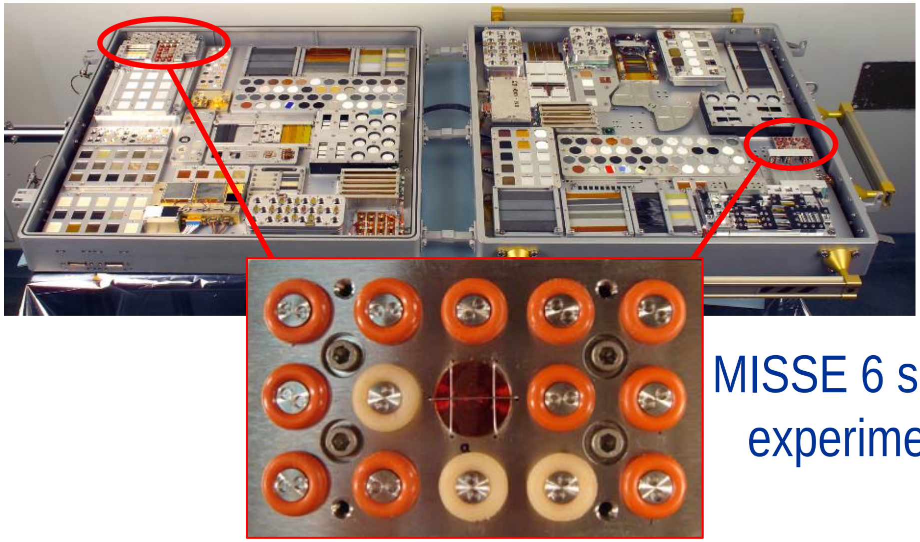
Full-Scale Leak Test Results (Preliminary)



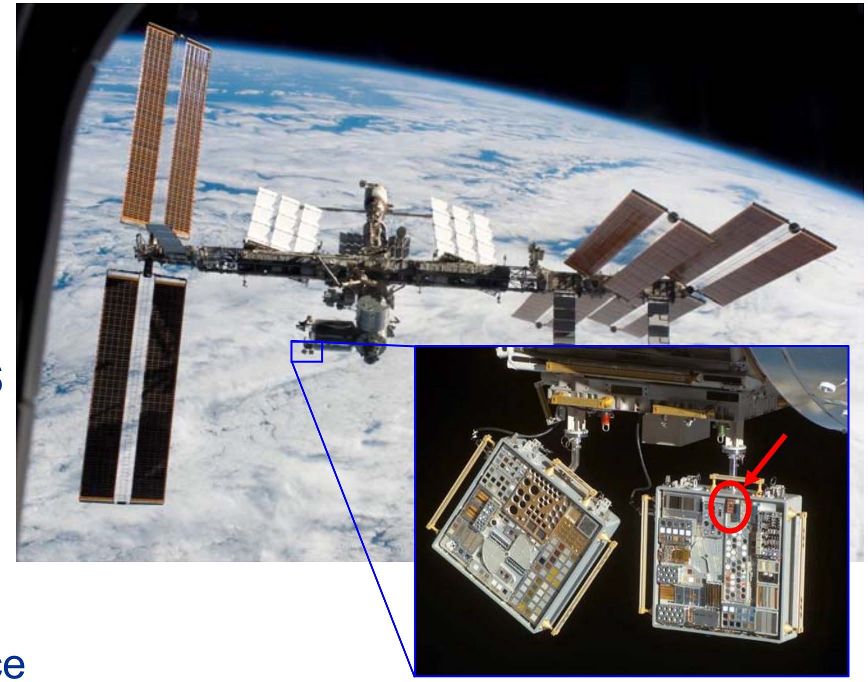
Seal-on-plate leak rates for full-scale EDU 54 seals

- Leak rates for full-scale EDU 54 seal in seal-on-plate configuration increased with temperature
- Pending agreement on leak rate conversion factor for helium to air, it is believed that EDU 54 seal leak rates are less than leak rate limit of 0.0025 lbm/day

MISSE 6 and 7 Seal Experiments



MISSE 6 seals experiment



- Objectives:
  - Expose candidate seal materials to LEO environment using Materials International Space Station Experiment (MISSE)
  - Evaluate effects on performance after experiments are retrieved from ISS
- Status:
  - MISSE 6:
    - Seal experiment launched aboard STS-123 on 3/11/08
    - Mounted on ISS Columbus module for 9-12 mos.
  - MISSE 7:
    - Launch to occur Oct. 2009 on STS-129
    - To be mounted on ISS EXPRESS Logistics Carrier 2 (ELC2) for ~1 yr.

MISSE 7 seals experiment

Summary

- GRC is supporting JSC by developing LIDS main interface seals
- Seal development and testing is occurring at both sub-scale and full-scale levels
  - Small-scale tests performed to define seal materials and evaluate exposure to space environments
  - Medium-scale testing:
    - Permits evaluation of candidate seal designs at faster pace than for full-scale seals
    - Leak rates and loads can be scaled up to full-scale for indication of seal performance
  - Full-scale test rigs used for seal development and flight qualification tests and to assess on-orbit anomalies if needed
- GRC responsible for delivering flight hardware seals to JSC ~2013 for integration into LIDS flight units