

National Aeronautics and Space Administration



# Durability Testing of Docking System Seals for Space Applications

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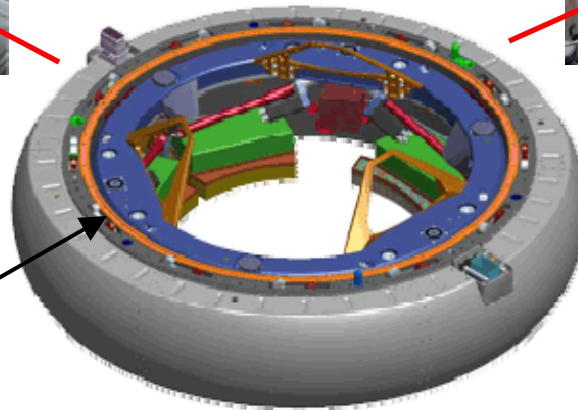
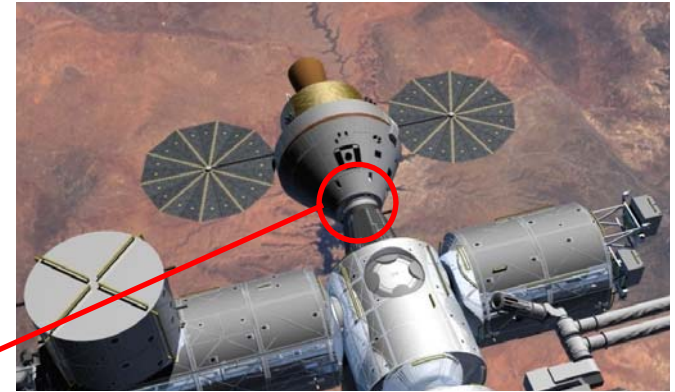
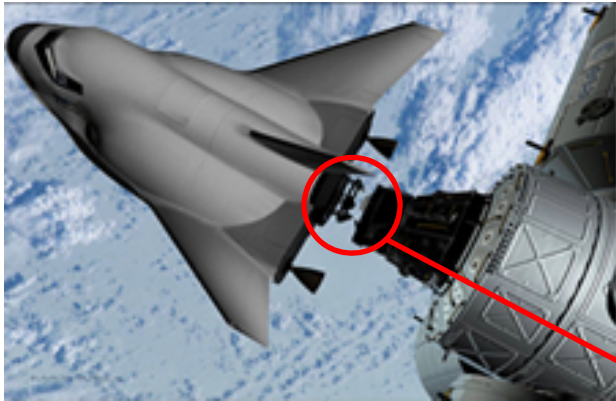
NASA Glenn Research Center, Cleveland, OH

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# Introduction

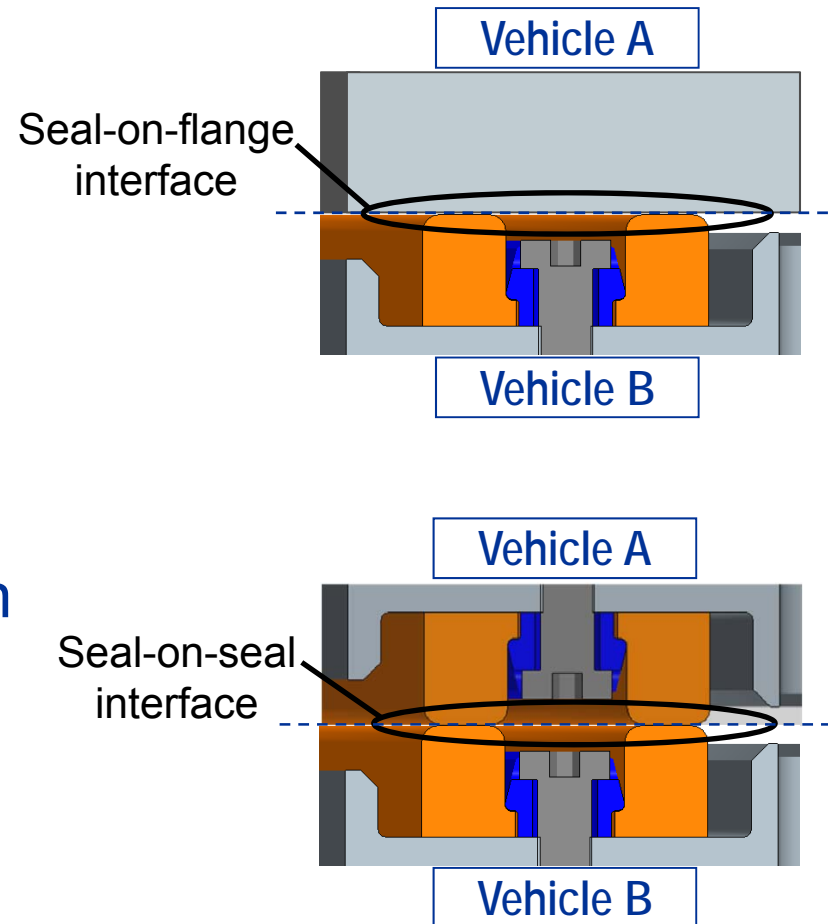


Docking interface seal

- NASA is developing advanced space-rated vacuum seals for future space exploration missions to International Space Station and beyond
- Used to seal interfaces between docked or mated vehicles and structures

# Key Seal Requirements

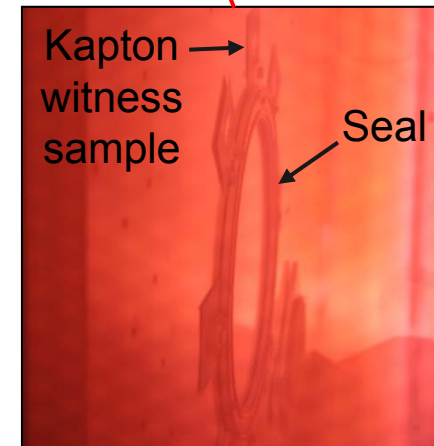
- Large seals: Up to 50 in. (127 cm) in diameter
- Seal-on-flange or seal-on-seal mating
- Extremely low leak rates to ensure that astronauts have sufficient breathable air for extended missions
- Compression and adhesion loads must stay below prescribed thresholds
  - High adhesion loads could restrict undocking and/or damage seals



# Adhesion Mitigation

- Adhesion loads for untreated silicone seals exceed capabilities of docking system separation mechanisms
- Pre-treatment of seals with low doses of atomic oxygen (AO) drastically reduces seal adhesion loads
  - Oxidizes silicone and passivates seal surfaces
  - Little effect on seal compression loads or leak rates
- Previous studies demonstrated low adhesion loads after multiple compression cycles (simulated docking and undocking)
- However, seals can also be subjected to lateral, scrubbing movements due to:
  - Mechanical alignment of docking systems after initial engagement
  - Thermal equilibration after mating has completed

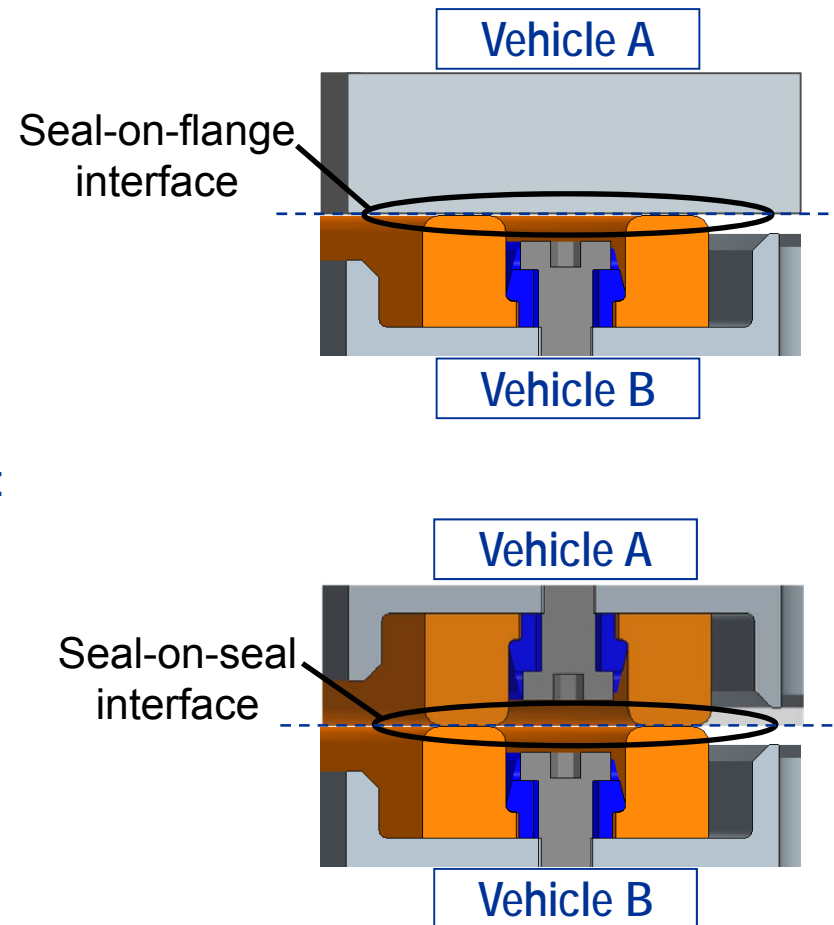
NASA GRC Tank 9 vacuum chamber facility



Seals being exposed to AO plasma

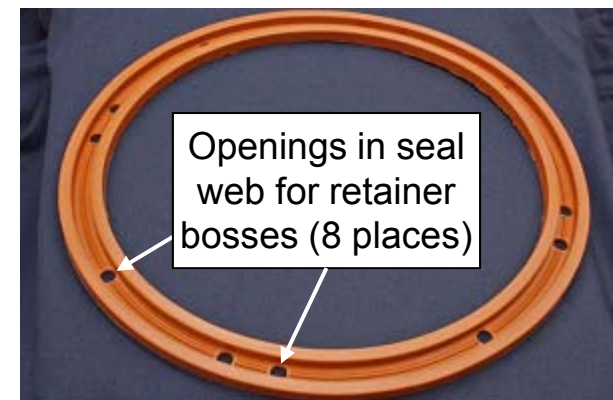
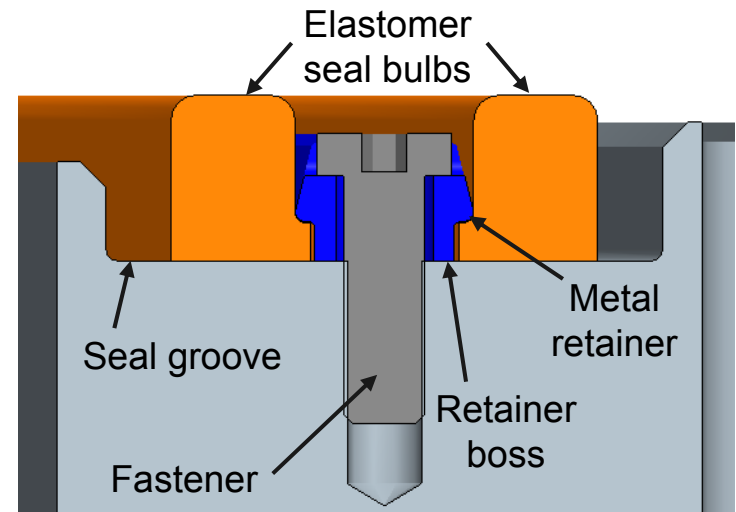
# Goal & Approach for Study

- Goal:
  - Evaluate effects of lateral scrubbing on seal performance by comparing leak rates and adhesion loads of AO pre-treated seals before and after scrubbing
- Approach:
  - Due to limited number of test specimens, performed durability (scrub) tests on seals made of two materials under anticipated worst-case conditions:
    - Seal-on-flange configuration
    - Warm operating temp. of 142°F (61°C)
    - High compression level (near full compression)
  - Performed room temperature leak tests and adhesion tests before and after durability tests to evaluate effects of scrubbing



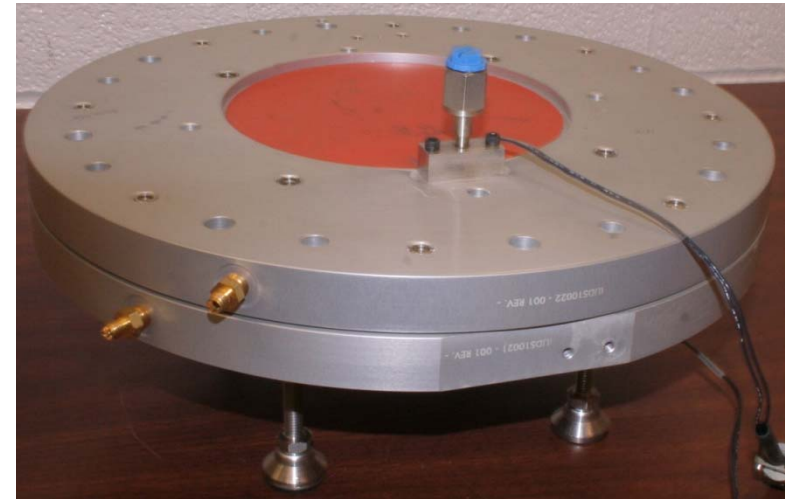
# Test Specimens

- Test specimens were subscale versions (~12 in. dia.) of candidate full-scale seal design
  - Elastomer seals made from two different silicone compounds:
    - 40 durometer material (XS3088-02)
    - 70 durometer material (S0383-70)
  - Retainers fabricated out of 6061-T651 aluminum
  - Eight #8-32 fasteners made of A286
- Test specimens were pre-treated to AO fluence level of approximately  $1 \times 10^{20}$  atoms/cm<sup>2</sup> prior to testing



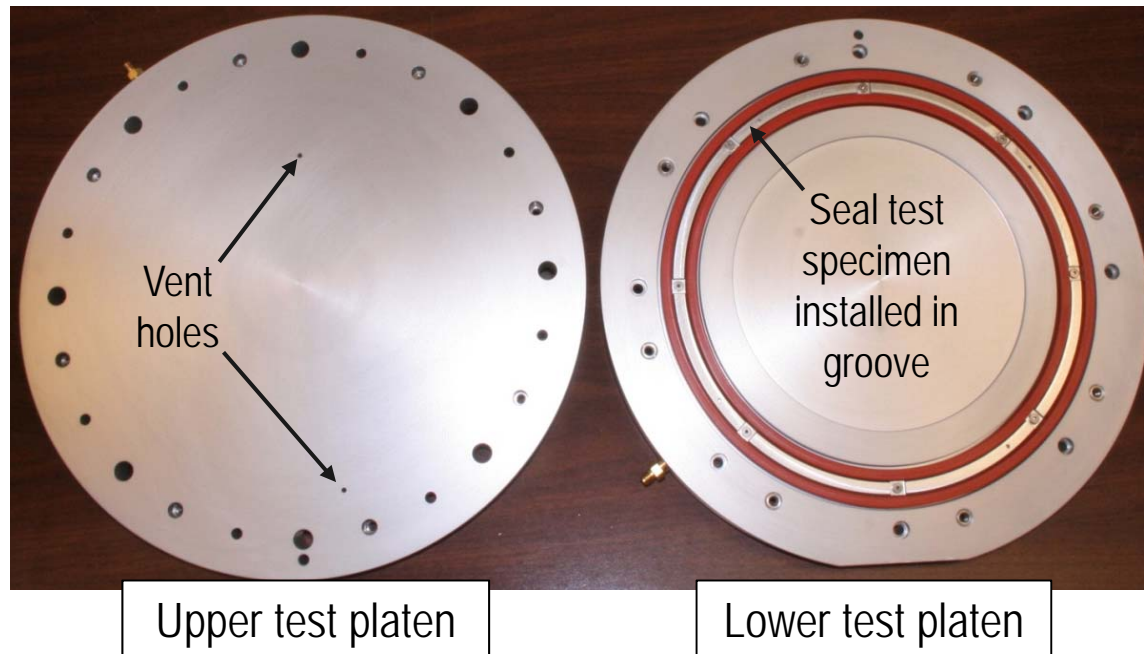
# Test Sequence

- Each test specimen was subjected to same test sequence:
  1. Room temperature adhesion test
  2. Room temperature leak test
  3. Durability test at anticipated warm operating temperature of 142°F (61°C)
  4. Room temperature leak test
  5. Room temperature adhesion test
- Seal test specimen remained installed in same test fixture as it was moved from test to test to minimize handling and disturbances of seal



Seal test fixture

# Test Fixture Details

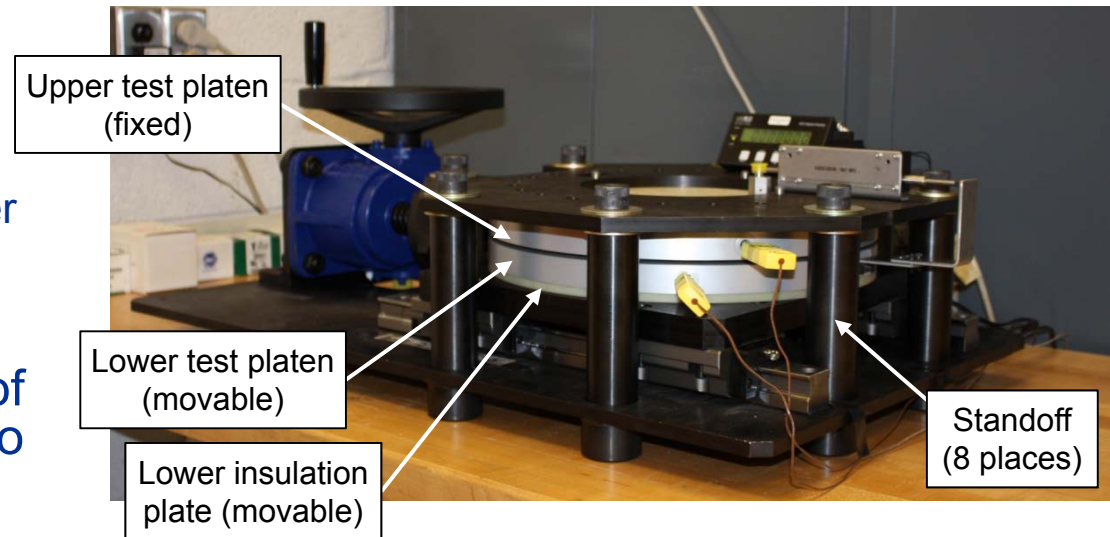
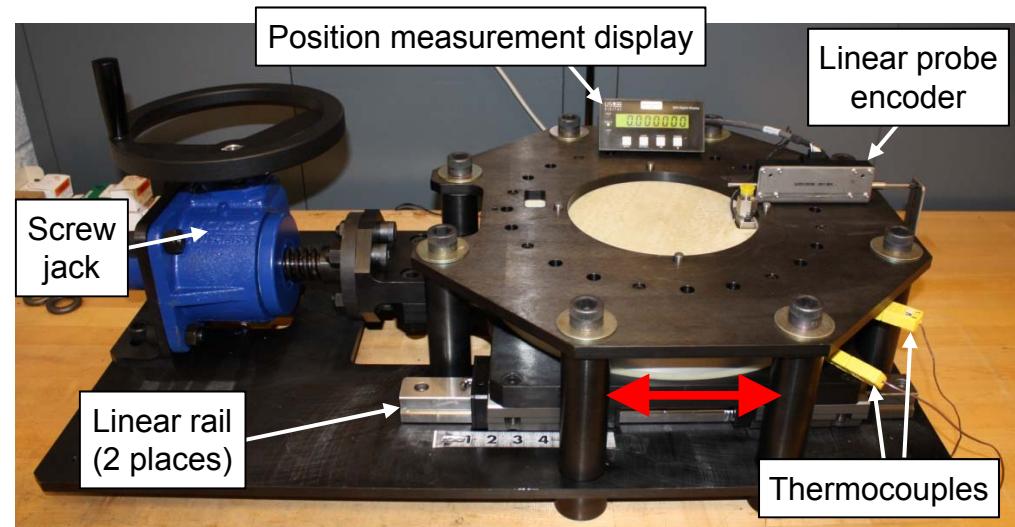


- Seals were tested in seal-on-flange configuration:
  - Installed in groove in lower platen
  - Compressed against flat, smooth (16  $\mu\text{m}$ . (0.4  $\mu\text{m}$ )) sealing surface on upper platen
- Vent holes included in platens to prevent air entrapment that could otherwise:
  - Be measured as load during compression testing
  - Help separate platens during adhesion testing

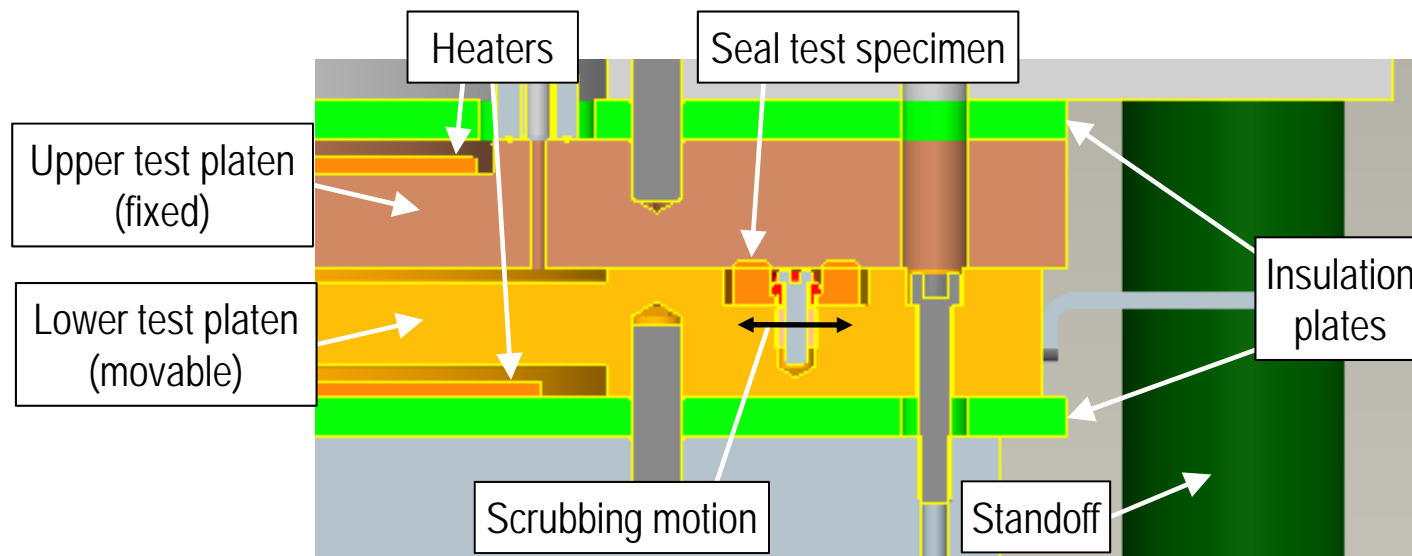


# Durability Testing

- Upper test platen with flat surface:
  - Secured to base of test apparatus through standoffs
  - Remained fixed during testing
- Lower test platen with seal:
  - Mounted on pair of linear rails connected to screw jack assembly
  - Moved back and forth during testing
- Amount of compression on seals controlled by precision metal shims installed on top of standoffs
  - Gap between upper and lower platens minimized ( $\sim 0.005$  in. (0.127 mm)) to nearly fully compress seals
- Heaters mounted on backs of platens warmed test fixture to  $142^{\circ}\text{F}$  ( $61^{\circ}\text{C}$ ) during testing



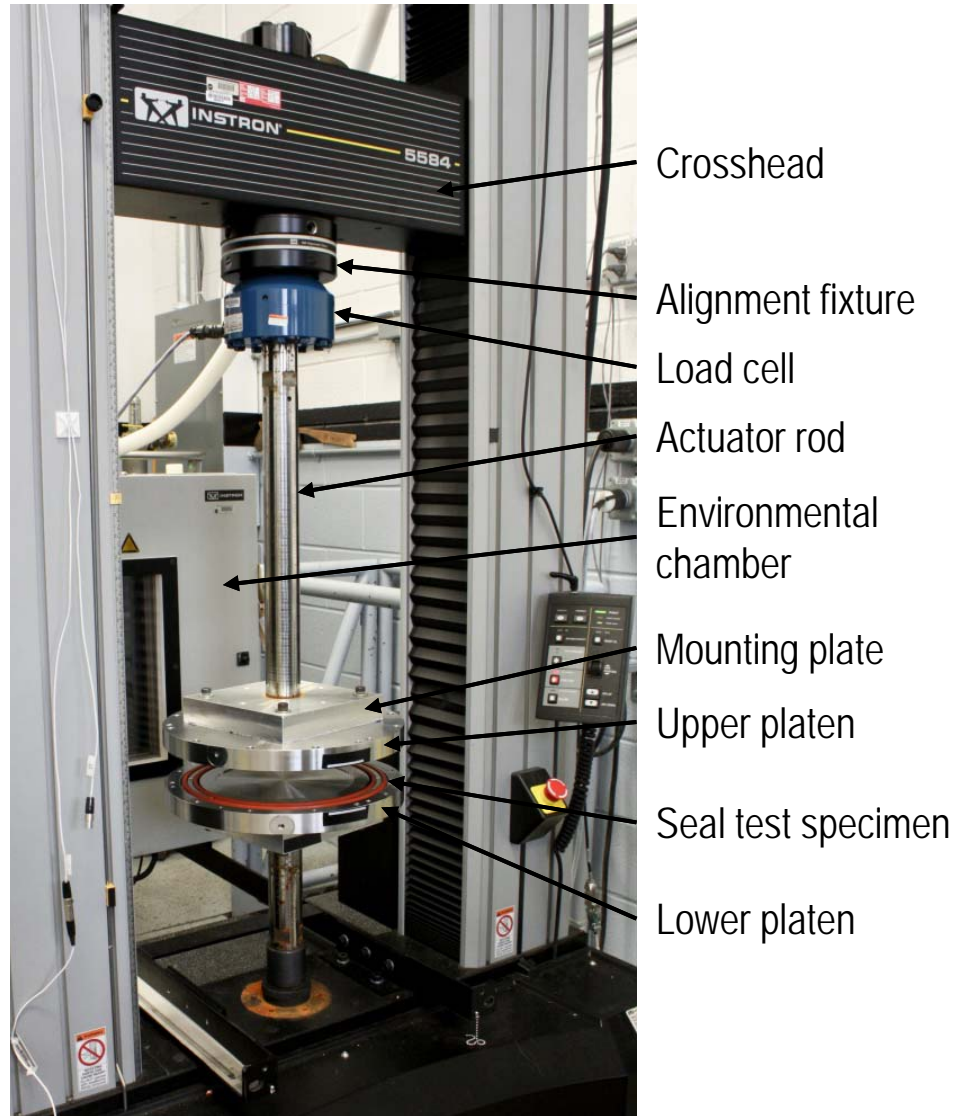
## Durability Testing (cont.)



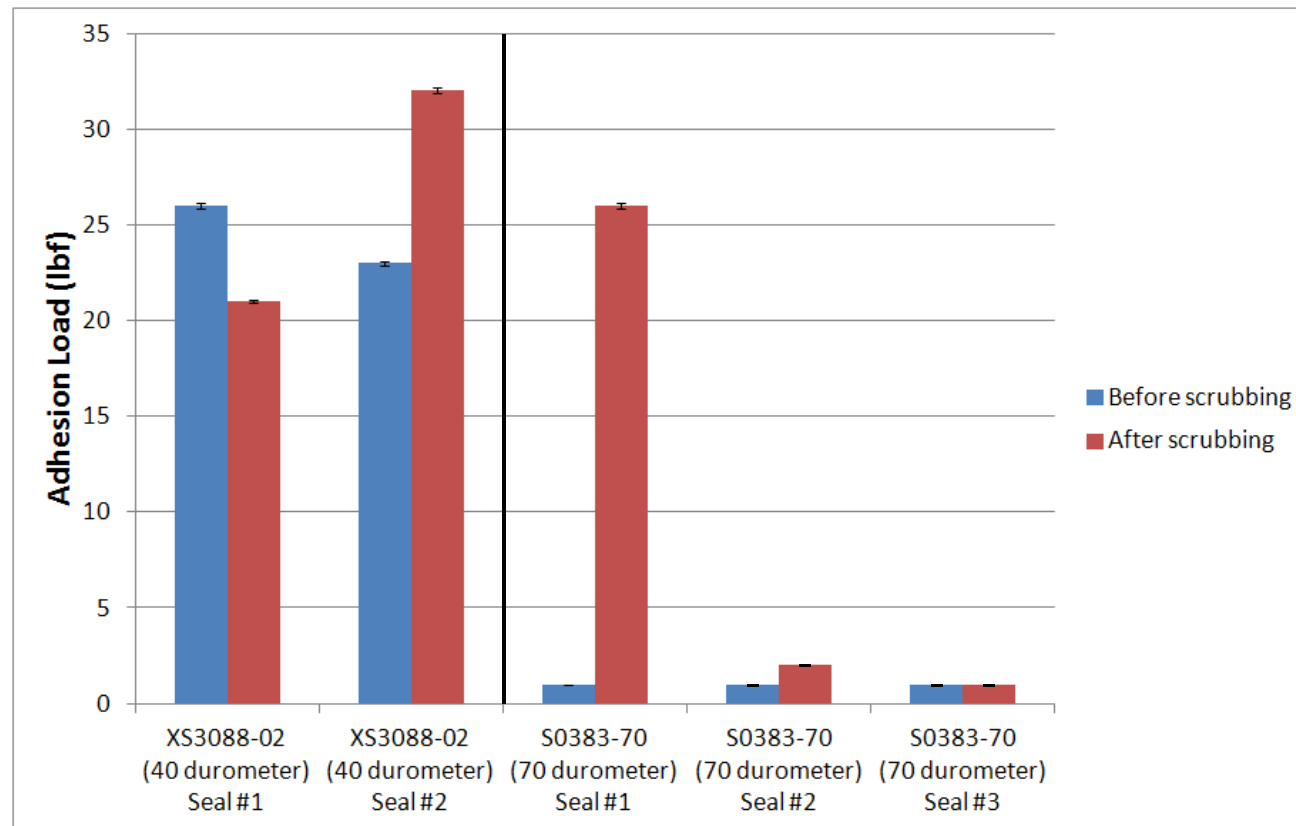
- Each seal subjected to 50 scrub cycles:
  - Each cycle consisted of a movement of 0.056 in. (1.42 mm) away from and back to original home position
  - Simulated amount of movement seal could experience during 50 missions

# Adhesion Testing

- Room temperature adhesion tests performed before and after durability tests
- Seals initially compressed in test fixture for 24 hrs at room temperature outside load frame
- Test fixture assembly then installed in load frame for adhesion test:
  - Upper platen raised according to specific displacement profile to simulate undocking sequence
  - Test was completed when seal was no longer in contact with mating surface
  - Maximum force required to separate seal from mating surface was reported as seal adhesion value



# Adhesion Test Results



- Before scrubbing, AO pre-treatment was more effective at reducing adhesion loads for seals made of S0383-70 than for seals made of XS3088-02
- Effects of scrubbing on adhesion loads were inconclusive:
  - For XS3088-02 seals, load increased after scrubbing for one seal and decreased for the other
  - For S0383-70 seals, load increased quite a bit for one seal but very little for other two seals; however, even max load was still lower than those for seals without AO pre-treatment

# Leak Testing

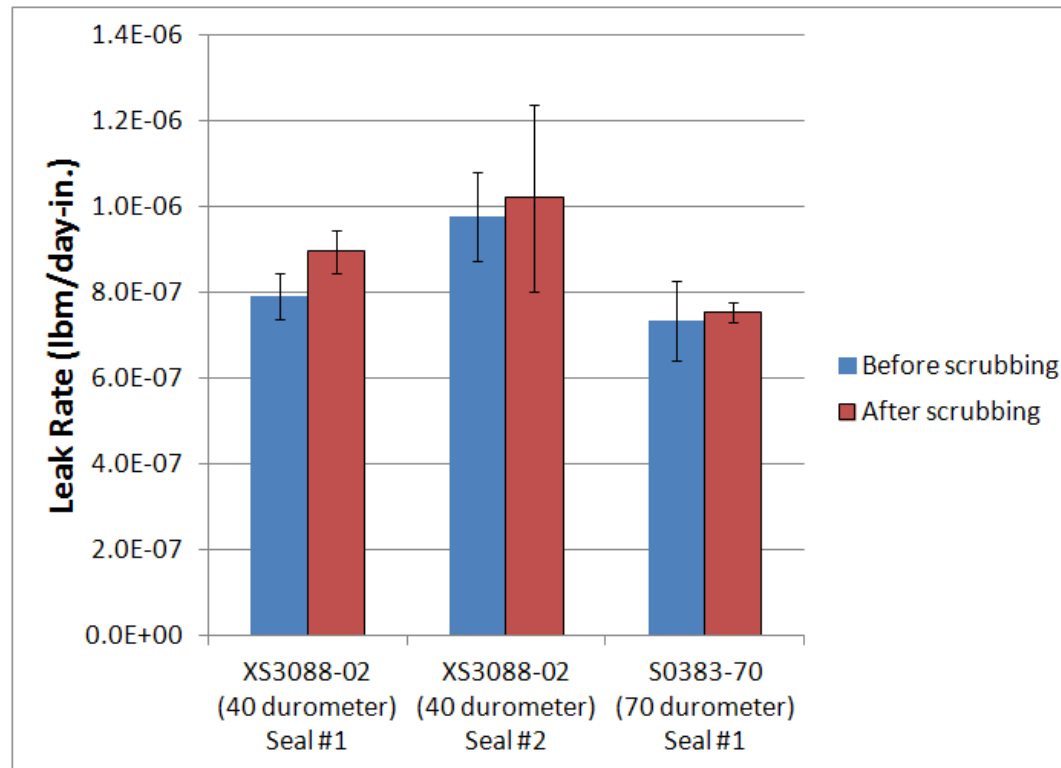
- Room temperature leak tests performed before and after durability tests
- Control volume inboard of inner seal bulb pressurized with dry air to create  $\Delta p$  across seal of 14.7 psid
- Measured pressure and temperature of volume as air permeated through seal
- After test was completed, utilized mass point leak rate method to quantify leak rate for inner seal bulb
- Calculated uncertainty for leak rate based on 95% confidence interval



Test fixture

Environmental chamber

# Leak Test Results



- Leak rate after scrubbing increased slightly compared to leak rate prior to scrubbing for each seal
- However, leak rates before and after scrubbing were deemed to be statistically equivalent since their confidence intervals overlap

# Summary & Conclusions

- Durability tests were performed on subscale seals under anticipated worst-case conditions to evaluate effects of lateral, scrubbing movements on performance of AO pre-treated seals
  - Testing revealed:
    - AO pre-treatment was more effective at reducing adhesion loads before scrubbing for seals made of S0383-70 than for seals made of XS3088-02 compound
    - Effects of scrubbing on seal adhesion loads were inconclusive; however, still lower than those for seals without AO pre-treatment
    - Potential increase in seal adhesion after scrubbing must be accounted for in future docking system seal designs
    - Scrubbing of S0383-70 and XS3088-02 seals did not cause statistically significant changes in seal leak rates
  - Additional tests and evaluations are warranted to confirm these findings since conclusions are based on limited number of tests
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# Acknowledgments

- International Low Impact Docking System (iLIDS) team from NASA JSC
- William Anderer (Sierra Lobo, Inc.) for technical contributions in performing tests
- Parker Hannifin Corporation's Composite Sealing Systems Division (San Diego, CA) for fabricating seal test specimens
- Henry de Groh (NASA GRC) and Bruce Banks (Alphaport) for completing AO pre-treatment of seal test specimens



# Appendix

# Leak Testing

- Room temperature leak tests performed before and after durability tests
- Control volume inboard of inner seal bulb pressurized with dry air to create  $\Delta p$  across of 14.7 psid
- Measured pressure and temperature of volume as air permeated through seal
- After test was completed, utilized mass point leak rate method to quantify leak rate for inner seal bulb:

- Calculated mass of air in test section at each time step using Ideal Gas Law:

$$m(t) = (pV)/(RT)$$

- Performed linear regression on population of mass sample points using Least Squares Method to yield:

$$m(t) = a_1 t + a_0$$

- Variable  $a_1$  was slope of curve and corresponded to leak rate for inner bulb of test seal
- Calculated uncertainty for leak rate based on 95% confidence interval



Test fixture

Environmental chamber

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