ELASTOMERIC SEAL DEVELOPMENT FOR ADVANCED DOCKING/BERTHING SYSTEM

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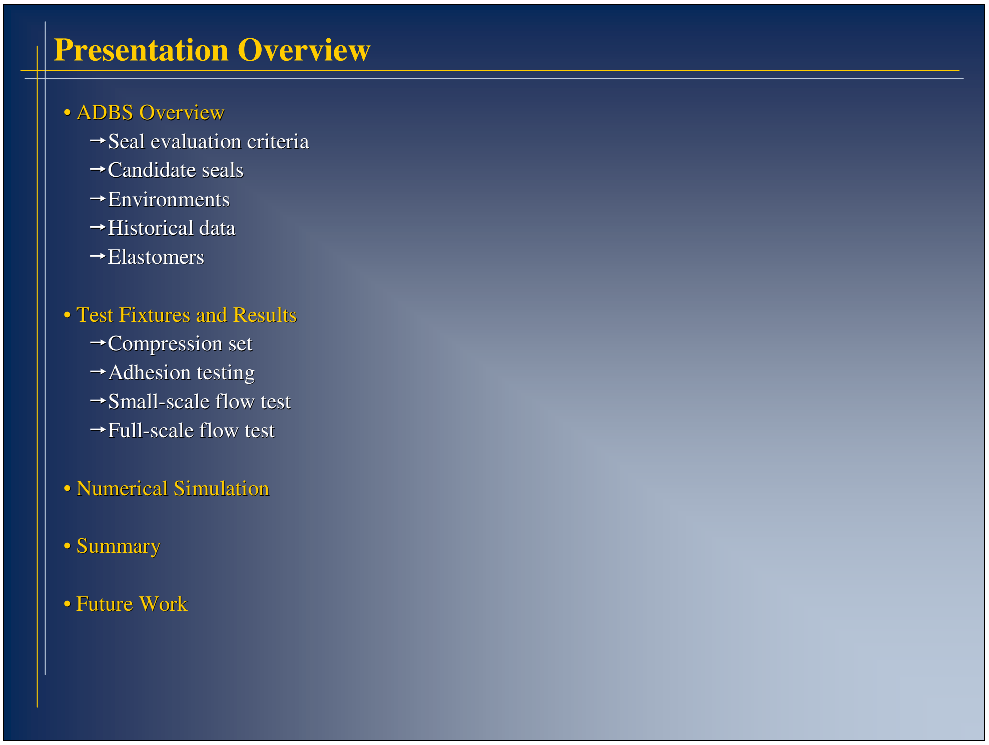
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Brief ADBS System Overview

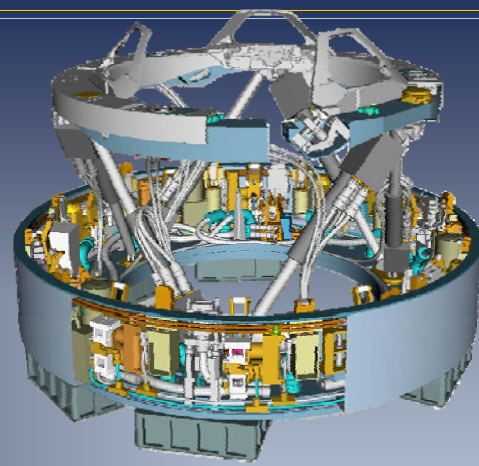
What is the ADBS?

System under development by Johnson Space Center (JSC) to:

- Provide androgynous pressurized interface permitting autonomous docking/berthing between space vehicles and structures
- Reduce impact loads between two mating space craft.
- Become new Agency standard for docking/berthing systems.

What are the Sealing Challenges?

- Androgynous configuration requires seal-on-seal mating at the interface between systems
- Seals must survive exposure to space environment



Criteria for evaluating candidate seals

- Environmental and operating temperature compatibility
  - → Environment: -100 to 100°C
  - → Operation: -50 to 50°C
- Compatibility to vacuum environment (low outgassing)
  - → Total mass loss (TML): <1%
  - → Collected volatile condensable materials (CVCM): < 0.1%
- Material stability when exposed to Atomic Oxygen (AO) and Ultraviolet radiation (UV)
- Compression force required to produce adequate seal
  - → Less than 100 lbf / linear inch
- Leak rate
  - → Less than 0.044 lbm / day
- Resistance to mechanical damage / ability to seal after damage
  - → Debris
  - → Micrometeoroids

Types of Candidate Seals

Two types of seals are being considered:

	Elastomeric Seals	Metallic Seals
		
Ability to form adequate seal	Excellent	Good
Long term resistivity to space environments AO / UV Micrometeroids	 TBD TBD	 Excellent TBD
Compression load required	TBD: initially low / expected to rise	TBD
Ability to perform under gapping / misalignment	TBD	TBD
Space application experience	<30 days on Shuttle / ISS	None known
Adhesion	Some expected	None expected

Environmental Exposures

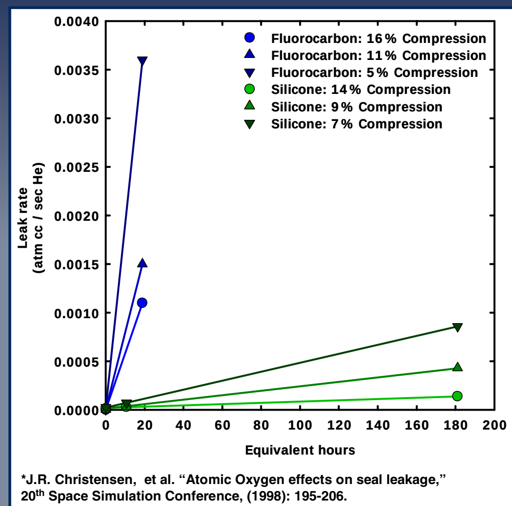
- As the Agency standard for docking systems, the ADBS is expected to operate
  - →In low Earth orbit (LEO)
  - →On Moon
  - →On Mars

Low Earth Orbit	Moon	• Mars
• Atomic Oxygen	• Ultraviolet radiation	• Ultraviolet radiation
• Ultraviolet radiation	• Vacuum	• Near vacuum
• Vacuum	• Micrometeroids	• Micrometeroids
• Micrometeroids	• Dust	• Dust / Debris
	• Temperature (-233 to 123°C)	• Temperature (27 to -128°C)

- To determine the effects of AO and UV, elastomer samples will be tested
  - →As-received
  - →After AO exposure
  - →After AO + UV exposure

Historical Data

- Material evaluation completed for the Common Berthing Mechanism (CBM) / International Space Station (ISS)
- Fluorocarbon elastomers are unacceptable for use in environments where Atomic Oxygen (AO) and Ultraviolet radiation (UV) are present
- Leakage from silicone elastomer seals increased linearly when exposed for up to 181 hours of AO and UV.
- Leakage increased up to 3200% for Silicone seals exposed to 181 equivalent hours.



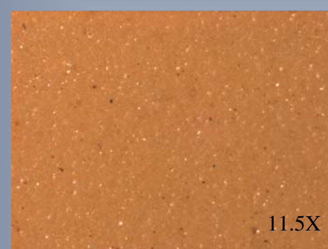
Candidate Elastomers

Three candidate elastomers are under consideration:

- Parker Hannifin S383-70
- Parker Hannifin S899-50
- Esterline Kirkhill-TA XELA-SA-401

Optical micrograph of Parker Hannifin S383-70

Optical micrograph of Parker Hannifin S899-50



Optical micrograph of Esterline Kirkhill-TA XELA-SA-401.

All three are silicone rubber. The PH S383-70 has a durometer of 70; the PH S899-50 has a durometer of 50; the EK is the softest material having a durometer of 38.

Compression Set Testing

- Determines the ability of elastomeric compounds to retain elastic properties after prolonged compression.
- Testing per ASTM Standards D395 (Test Method B) and D1414.
- Tests to be completed
  - → As-received ✓
  - → After exposure to AO
  - → After exposure to AO + UV

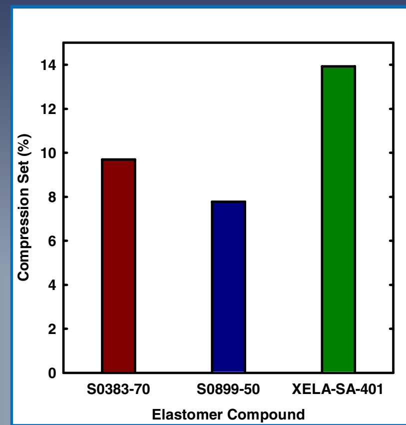
Photo of the Compression Set Fixture

Compression Set Results

- O-ring specimens have been tested per ASTM Standards D395 (Test Method B) and D1414.
  - →Parker-Hannifin silicone S0383-70
  - →Parker-Hannifin silicone S0899-50
  - →Esterline Kirkhill silicone XELA-SA-401

- The specimen were tested in the as-received condition and have not been exposed to atomic oxygen nor ultra-violet radiation.

- Test conditions
  - →25% Compression
  - →70 hours at room temperature
  - →Surfaces were unlubricated
  - →Compression set results (median)
    - S0383-70: $C_B = 9.7\%$
    - S0899-50: $C_B = 7.8\%$
    - XELA-SA-401: $C_B = 13.9\%$

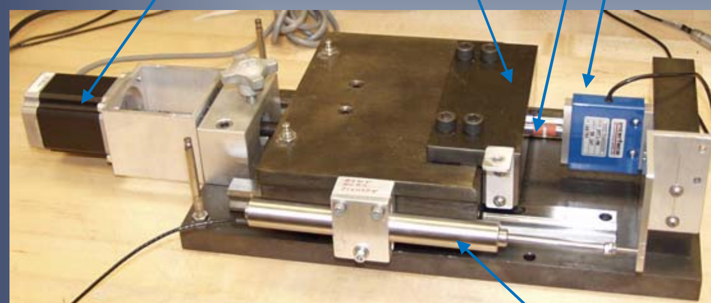


Compression set test results of o-ring specimen (AS 568A size 309) manufactured from Parker-Hannifin S0383-70, Parker-Hannifin S0899-50, and Esterline Kirkhill XELA-SA-401 compounds.

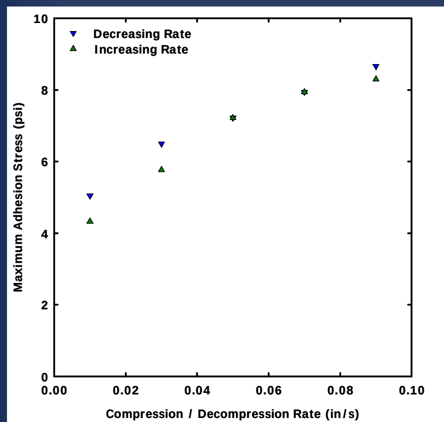
Adhesion Testing

- Quantify adhesion between two elastomeric samples before and after exposure to Atomic Oxygen and Ultraviolet radiation.

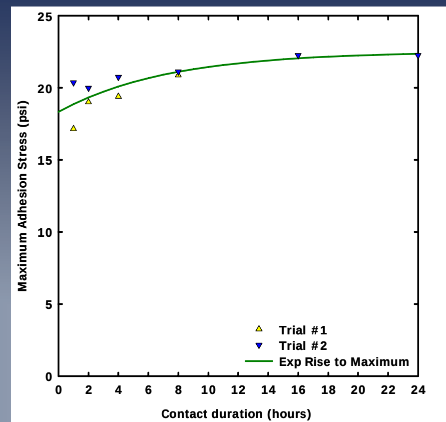
- Measures compression and adhesion forces as a function of displacement at a given compression / decompression rate



Sample Adhesion Test Results



Adhesion test results showing effects of compression / decompression rate on adhesion for XELA-SA-401.



Adhesion test results showing effects of contact period on adhesion for XELA-SA-401.

- Adhesion increases with increased compression / decompression rate
- Adhesion increases with increased contact duration, but levels off.

Small Scale Flow Testing

- Quantify seal performance
  - →Of 2-309 size o-rings
  - →Leakage
  - →Before and after exposure to AO and UV
- Configuration
  - →Seal against flat metal plate
- Pressure boundary conditions
  - →Internal pressure
  - →External vacuum
- Temperature conditions
  - →Room temperature

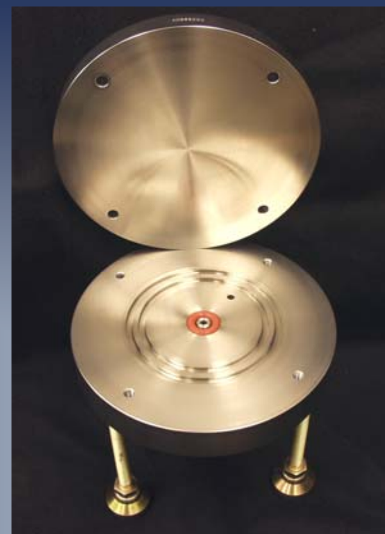
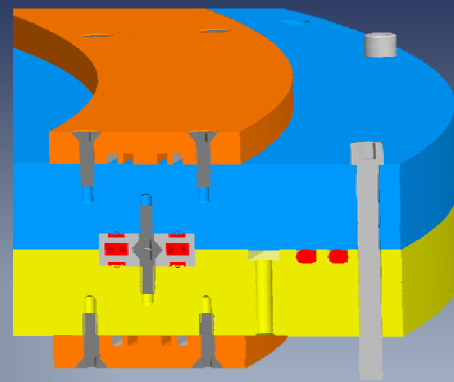


Photo of the Small-scale Flow Fixture with sample o-ring installed.

Full Scale Flow Testing

- Quantify seal performance
  - →Leakage
  - →Compressive load required
  - →Separation force required
- Under representative conditions
  - →Full-scale (ϕ54”) seal-on-seal configuration
  - →Pressure boundary conditions
    - Internal pressure
    - External vacuum
  - →Temperature conditions
    - Minimum temperature: -50C
    - Maximum temperature: 50C
    - Temperature gradients
  - →Seal-to-seal alignment
    - Up to 0.050 inch axial misalignment
    - Angular misalignment (gapping)



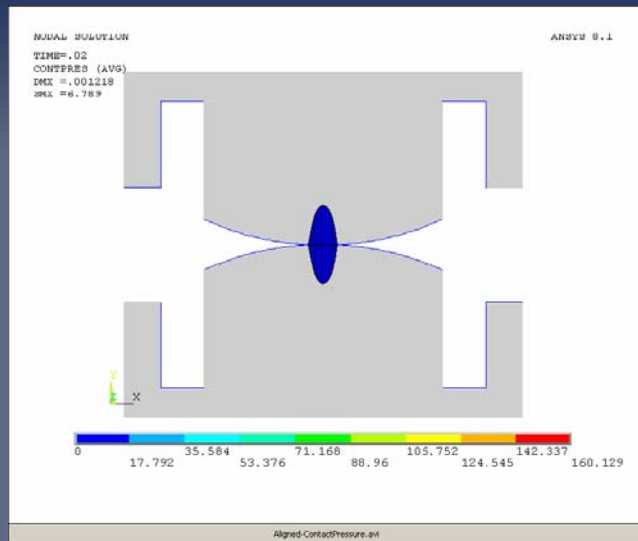
Full-scale Flow Fixture.

Numerical Modeling

- Preliminary model of contact pressure generated as the seal interacts with its replicate
- Model includes
  - → Properties obtained using adhesion test fixture
  - → Friction
  - → Misalignment of seals
- Many alternate configurations can be modeled as processing is fast (<60s) for 2-D cases
  - → Seal geometry
  - → Axial misalignments
- Model is linear elastic, not hyperelastic
  - → Does not support true incompressibility
  - → Difficult to converge
  - → Hyperelasticity most closely models rubber material
    - Close to ideally elastic
    - Strongly resists volume changes
    - Very compliant in shear
    - Shear response is strongly temperature dependent
- Planning to switch to hyperelastic model after obtaining needed material properties

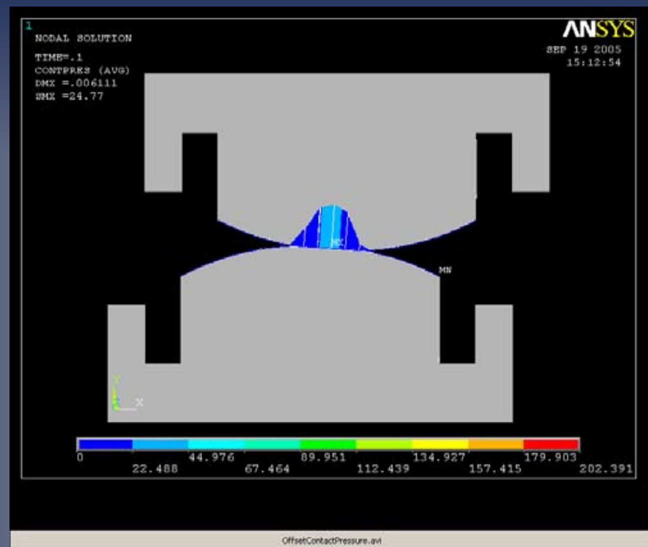
Common Berthing Mechanism: Numerical Simulation

- Configuration:
  Parker-Hannifin Gask-O-Seal
- Aligned
- Linear elastic model
  - → E = 230 psi
  - → ν = 0.4999
  - → μs = 0.8



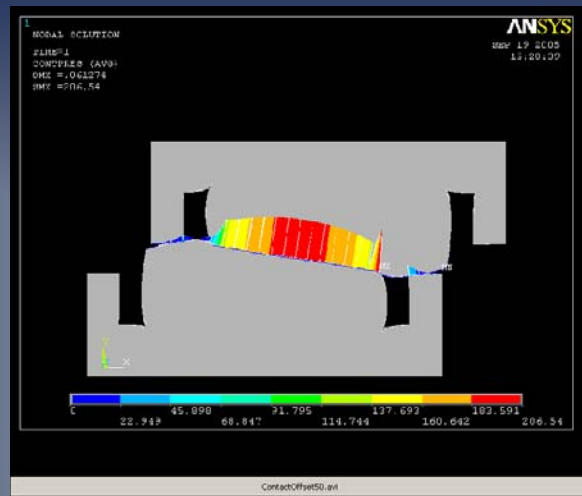
Common Berthing Mechanism: Numerical Simulation

- Configuration: Parker-Hannifin Gask-O-Seal
- Misaligned 0.025 inch
- Linear elastic model
  - → $E = 230$ psi
  - → $\nu = 0.4999$
  - → $\mu s = 0.8$



Common Berthing Mechanism: Numerical Simulation

- Configuration: Parker-Hannifin Gask-O-Seal
- Misaligned 0.050 inch
- Linear elastic model
  - → E = 230 psi
  - → ν = 0.4999
  - → μs = 0.8



Summary

- Elastomeric seals are being considered for application to the Advanced Docking / Berthing System.
- Currently, three candidate elastomers are being evaluated.
- To meet the unique requirements of the ADBS, several test fixtures have been built to determine each elastomer's
  - →Environmental and operating temperature compatibility
  - →Material stability when exposed to Atomic Oxygen and Ultraviolet radiation
  - →Adhesion force required to separate
  - →Compression set
  - →Leak rate
- These results will be compared with those from the metallic seal development to determine the final seal design

Future Work

- Complete compression set, adhesion, and small-scale flow tests
  - →Baseline
  - →After Atomic Oxygen (AO) exposure
  - →After AO + Ultraviolet radiation (UV) exposure
- Down-select between competing concepts and materials based on requirements.
- Perform full-scale flow tests to assess:
  - →Full scale seal-on-seal leakage
  - →Temperature effects
  - →Effects of axial offset
  - →Effects of seal-to-seal gapping (angular misalignment)
- Perform numerical simulations to predict seal leakage
  - →Seal geometries
  - →Misalignments