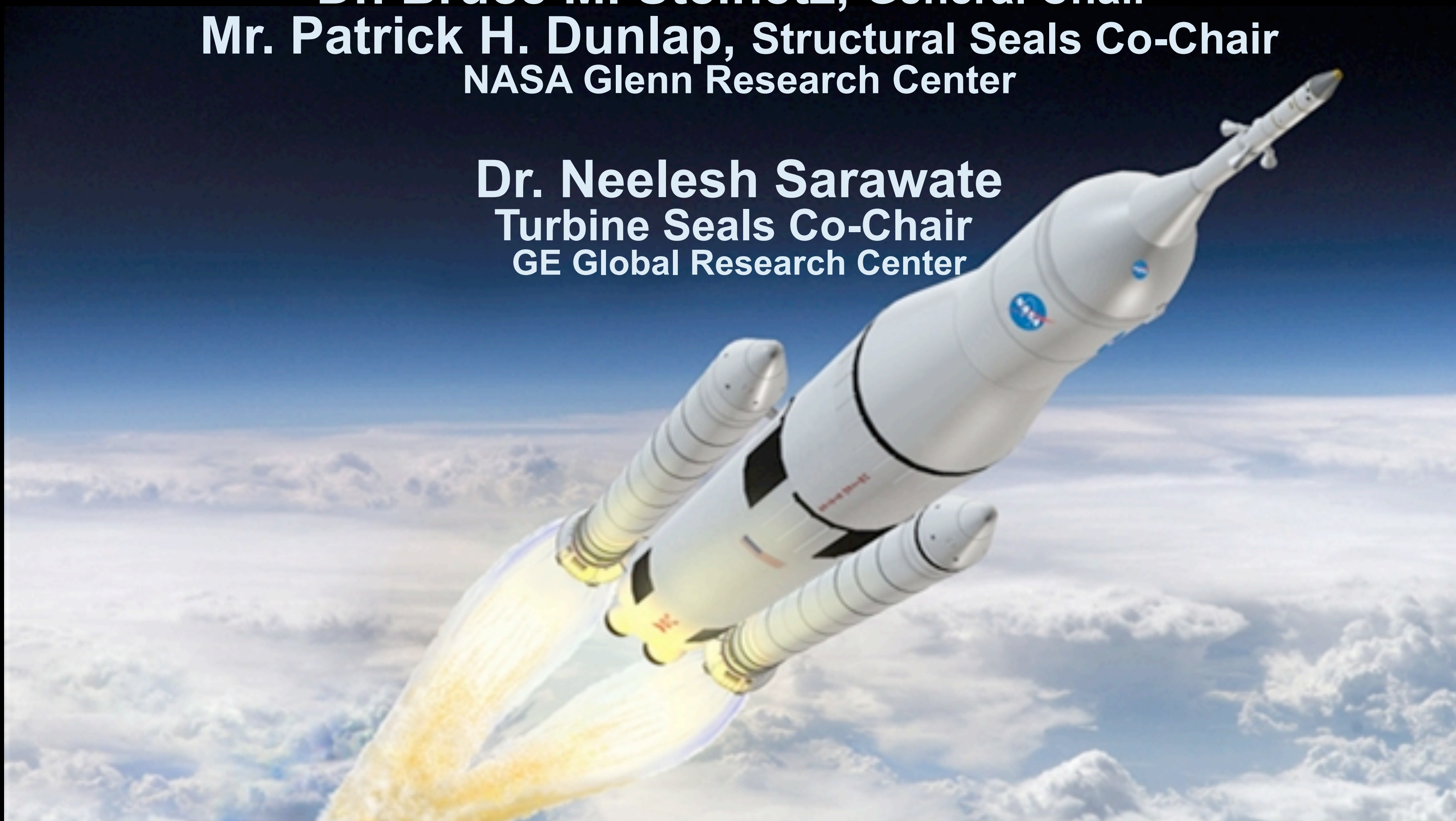
Advanced Seal Sessions I & II

Dr. Bruce M. Steinetz, General Chair
Mr. Patrick H. Dunlap, Structural Seals Co-Chair
NASA Glenn Research Center

Dr. Neelesh Sarawate
Turbine Seals Co-Chair
GE Global Research Center



49th AIAA/ASME/SAE/ASEE
Joint Propulsion Conference, San Jose, CA
July 16, 2013

Outline

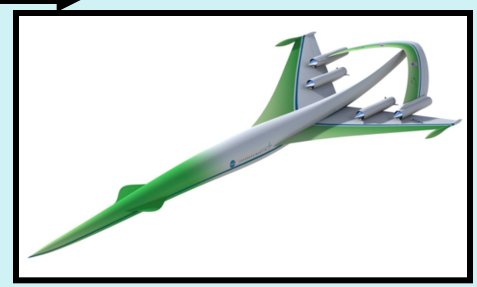
Turbine Seals

- Why work advanced seals?
  - NASA engine/propulsion technologies NASA N+3 Studies
  - Challenges
- Advanced concepts under development
  - NASA Glenn
  - GE Global Research

Spacecraft Seals

- Habitable volume seals
- Thermal Barrier seals

Turbine Seals



190
3

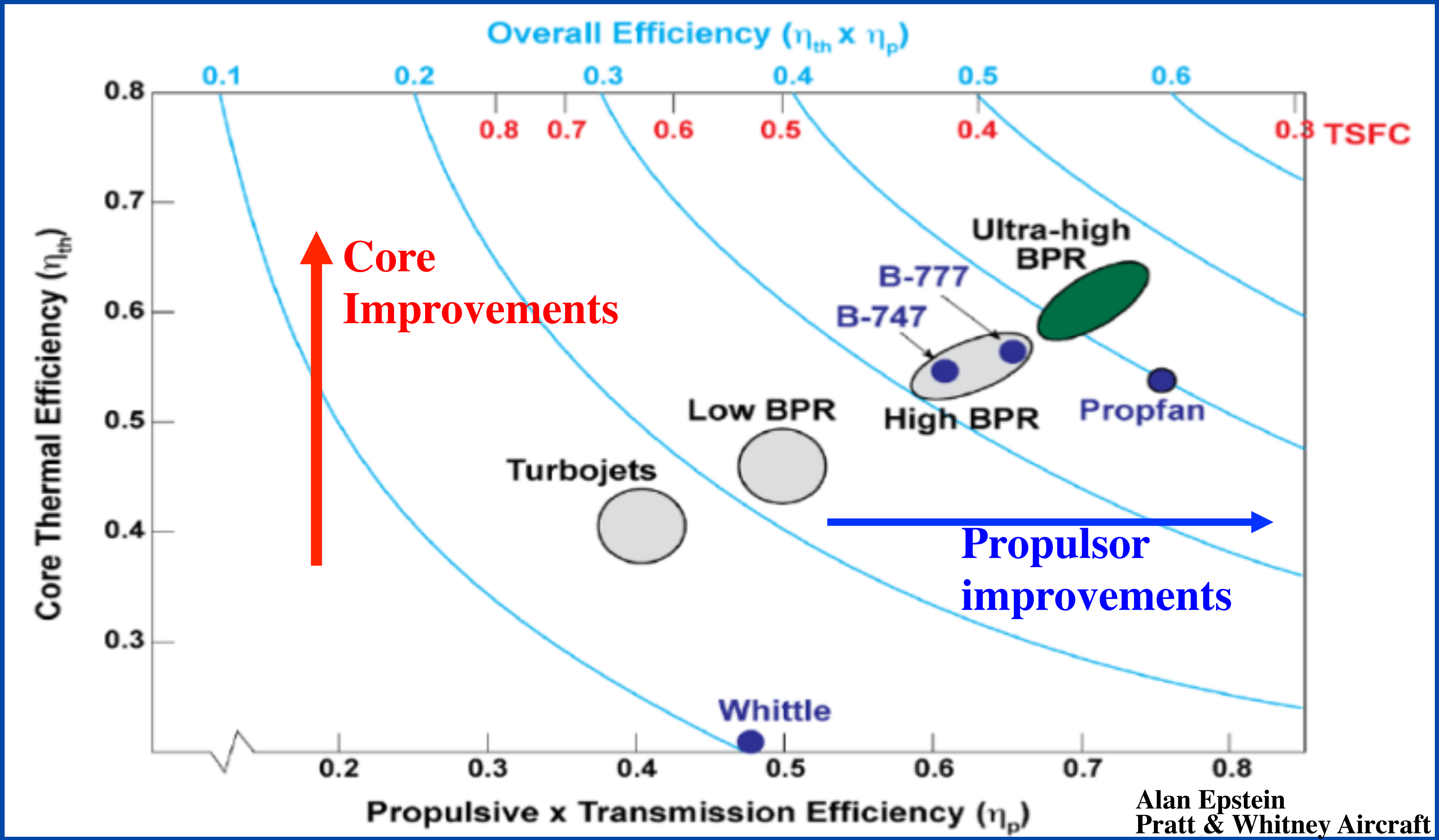
1930s

1950s

2000s

Aircraft Timeline

Turbine Engine Improvement Map



- **System improvements require advances in propulsor and core technologies**
- **Core technologies:**
  - improved internal aerodynamic
  - higher operating temperature
  - **control of parasitic losses**

Why Seals?

NASA Study Results: Expected Seal Technology Payoffs

Seal Technology	Study Engine/Co.	System Benefits
Large diameter aspirating seals (mult. locations)	GE90-Transport/GE	–1.86% SFC –0.69% DOC + I
Interstage seals (mult. locations)	GE90-Transport/GE	–1.25% SFC –0.36% DOC + I
Film riding seals (Turbine inter-stage seals, mult. locations)	Regional-AE3007/ Allison-RR	> –0.9% SFC > –0.89% DOC+ I
Advanced finger seals (mult. locations)	Regional/Honeywell	–1.4% SFC –0.7% DOC + I

NASA Subsonic Transport System Goals

Baseline: 2005

Target	Fuel Burn	Cruise NOx Emissions
N+1: 2015	-33%	-55%
N+2: 2020	-50%	-70%
N+3: 2025	-60%	-80%

- **Seals provide high return on technology $ investment**
- **Same performance goals possible through modest investment in the technology development**
  - **Example: 1/5th to 1/4th cost of obtaining same performance improvements of re-designing/re-qualifying the compressor**

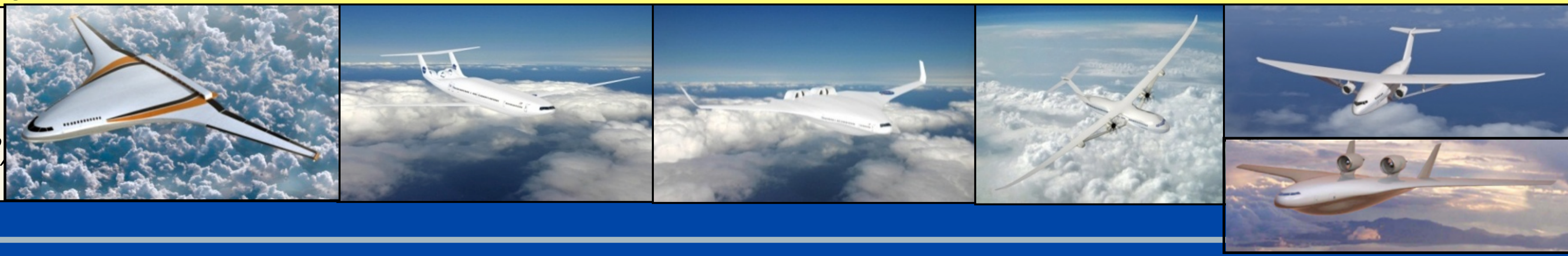
Advanced Seal Technology: An Important Player

Engine/Propulsion Technologies from NASA N+3 Studies

- **High OPR, high T4 cycle**
  - CMC Turbine Blades/Vanes
  - high temp disk material
  - **improved seal design**
  - intercooled compressor
- **High Efficiency Small Cores**
  - **mitigate efficiency decrement**
  - **active clearance control**
  - flow control

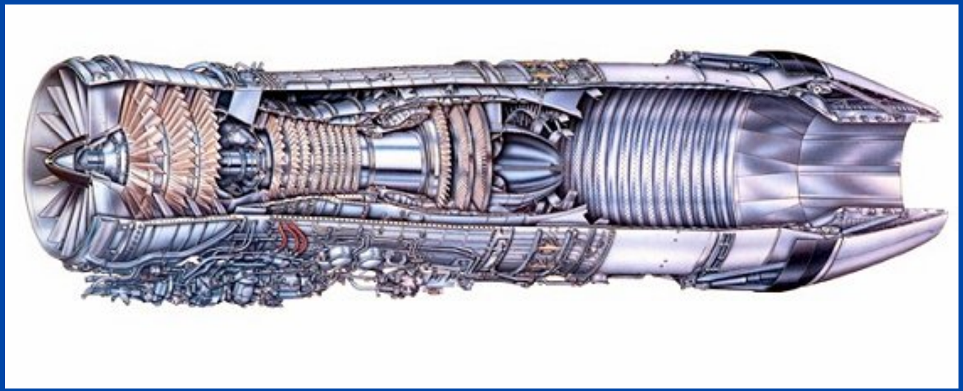
Goals *Metrics (N+3)*	*Noise* *Stage 4 – 52 dB cum*	*Emissions (LTO)* *CAEP6 – 80%*	*Emissions (cruise)* *2005 best – 80%*	*Energy Consumption* *2005 best – 60%*

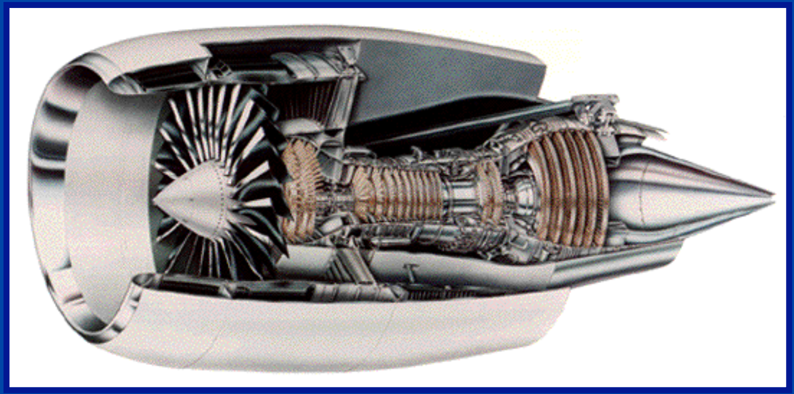
Goal-Driven Advanced Concepts *(N+3)*



Turbine Seals: Challenges

- Minimize leakage to enable: reduced fuel consumption and emissions
- High temperatures: 1200 to 1500°F
- Minimize heat generation
- High speeds 1000 to 1500 fps
- Moderate pressure 250 psi
- Operate with little or no wear for long life $\geq$20,000 hrs
- Occupy small "footprint"

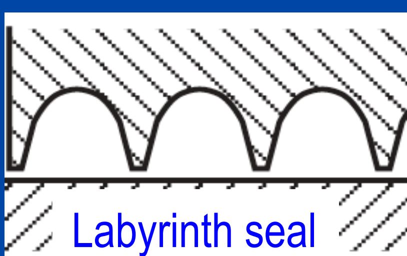


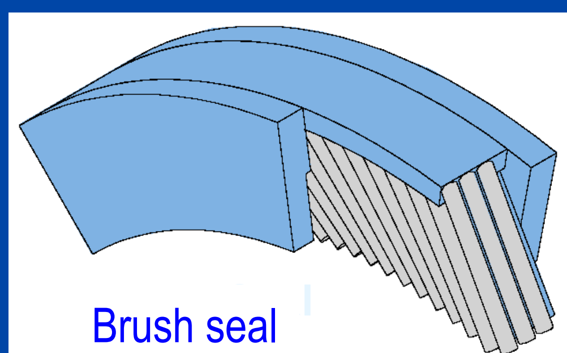


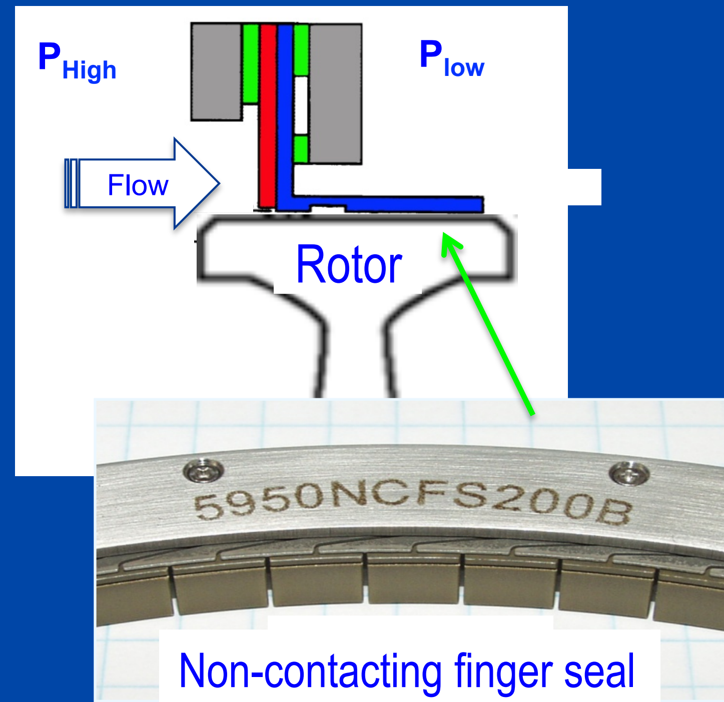
GRC Non-contacting Finger Seals

Key benefits are …

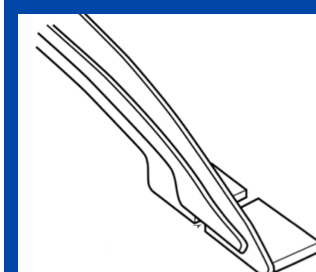
- **Avoids wearing out parts**: No contact avoids wear found in brush seals and labyrinth seals
- **Reduced flow**: <1/3 the flow of a straight tooth labyrinth seal and <1/2 the flow of a contacting brush seal
- **Comparable power loss**: Power loss is the same order of magnitude as brush and finger seals


Labyrinth seal


Brush seal



Non-contacting finger seal



GE Global Research

Neelesh Sarawate
GE Global Research

GE Global Research: Advanced Sealing Synergy

GE Global Research Center

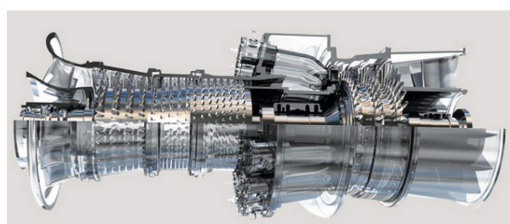
- First industrial R&D lab
- Established in 1900
- Nearly 180 research labs
- ~2,000 technologists, 2/3rd hold PhDs

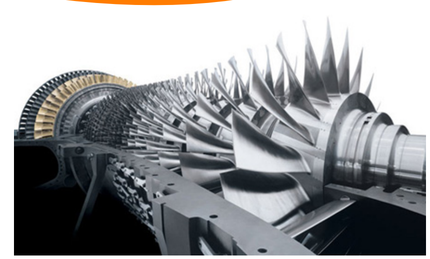
Aircraft engines
- High temp & creep
- Limited space
- High speed, swirl ratio
- Seal stability

GE Global Research
- Fundamental research
- Seal design & analysis
- Validation tests in custom rigs

Gas turbines
- Longer life
- Field installation, assembly
- Large interference

Steam turbines
- Rotor dynamics
- Short cycles
- Low-cost
- Rub tolerant



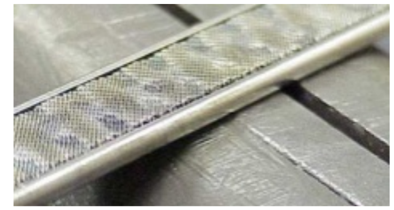


imagination at work

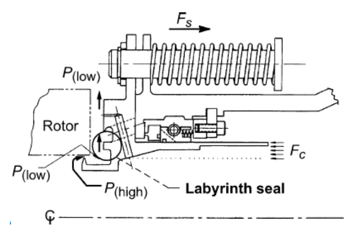
GE Sealing & Performance Technologies

- Brush seals
- Cloth seals
- Aspirating seals
- Abradable coatings
- Non-metallic brush seals
- Retractable seals
- Compliant plate seals

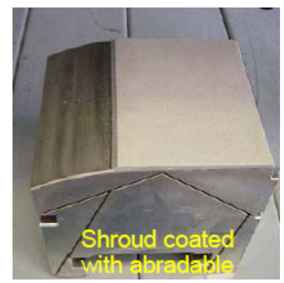
ST Brush seals
1990s-2000



Cloth Seals
AIAA 2001

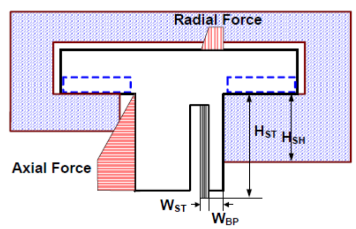


Aspirating seals
JPP 2006

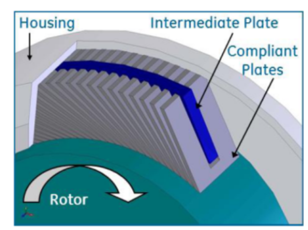


Abradable coatings
GT2004-53029

Non-metallic brush seals
AIAA-2010
GT2012-69329



Retractable seals
GT2011-45756



Compliant plate seals
GT2011-45756

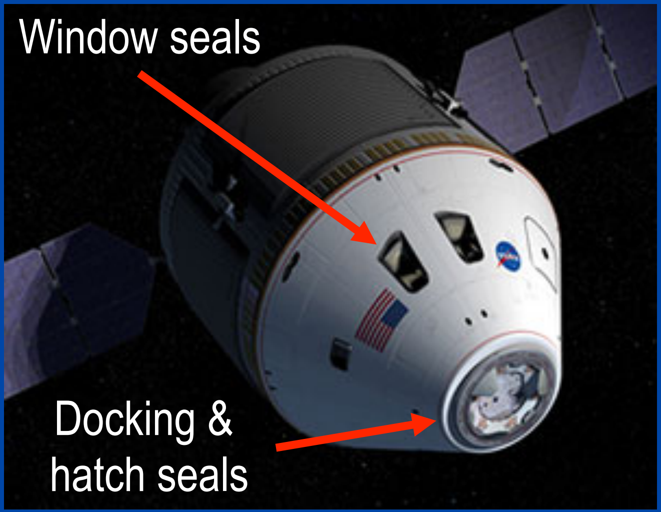
imagination at work

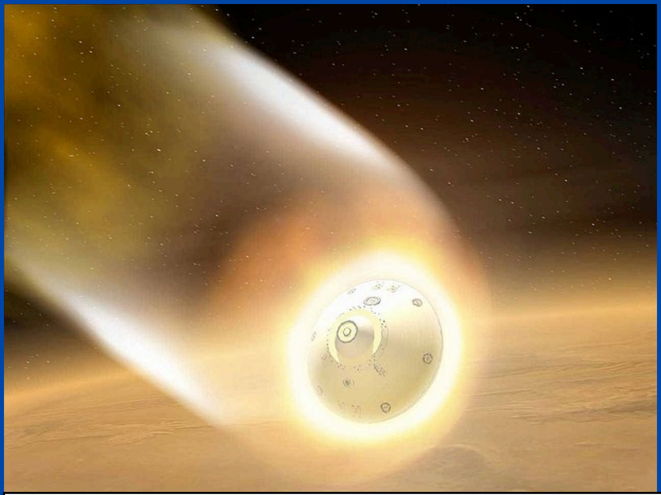
Spacecraft Seals

Pat Dunlap
NASA Glenn Research Center

Types of Seals

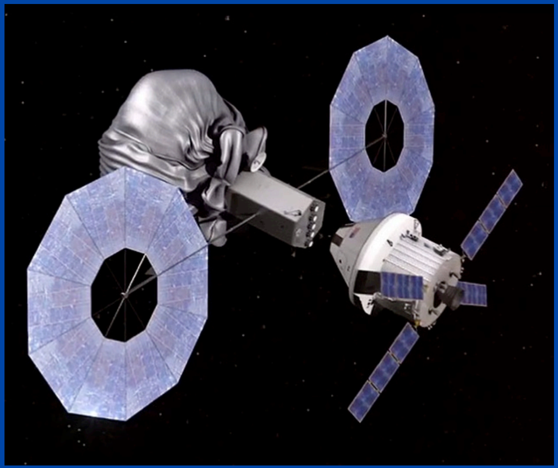
- Habitable volume seals
  - Seals for hatches, windows, docking interfaces, penetrations/ feed-throughs
  - Require extremely low leak rates to ensure that astronauts have sufficient breathable air for extended missions
  - Typically made of elastomer materials
- Thermal barrier seals
  - Seals for interfaces in vehicle thermal protection systems (TPS)
  - Must withstand extreme heating during re-entry
  - Typically made of high temperature fibers, wires, or insulating materials



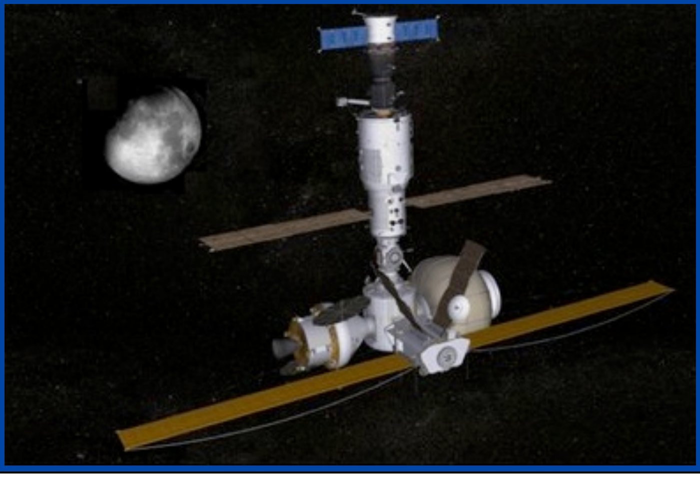


Thermal barrier seals for vehicle re-entry

Potential Missions



Asteroid retrieval mission



Future space station (e.g., cislunar)

Lunar/Mars outpost

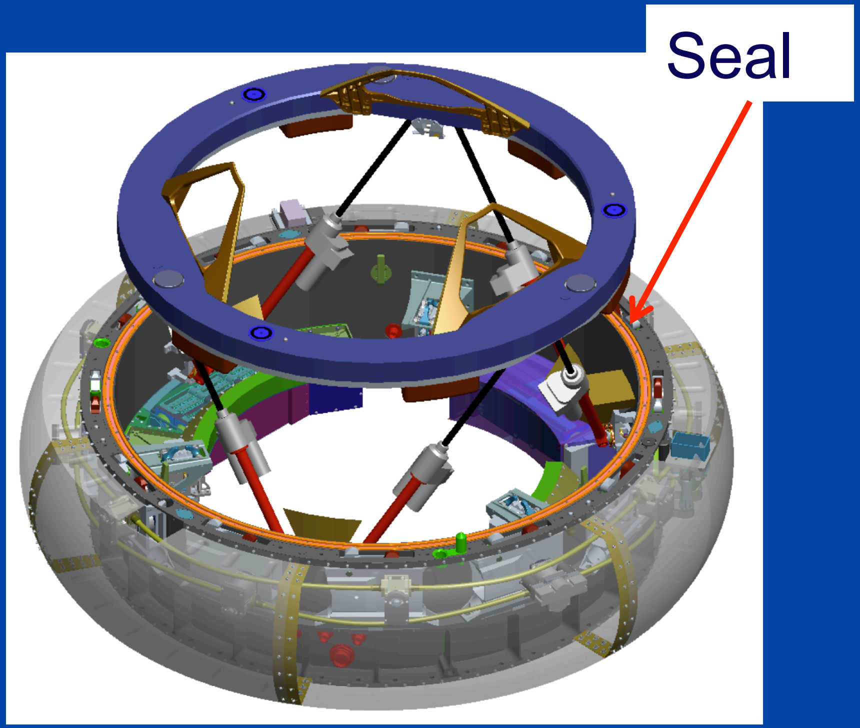
Habitable Volume Seals

Habitable Volume Seal Challenges

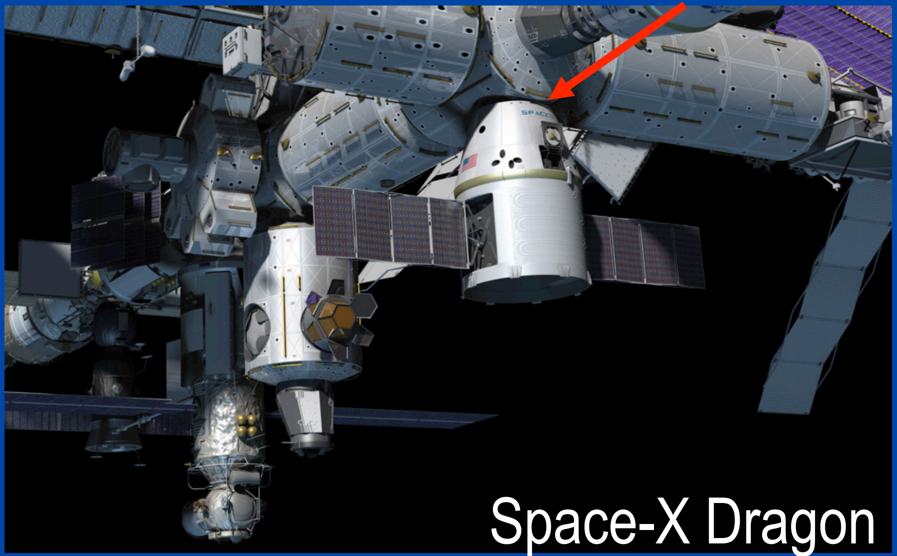
Low leakage	Near hermetic levels (~0.002 lb_m air/day)
Space environments	Resist damaging effects of atomic oxygen, UV radiation, ionizing radiation, MMOD
Resiliency	Exhibit acceptable compression set vs. cycling and re-mate after long term holds
Temperature	Survival: -65 to +100°C (-85 to +212°F) Operational: -50 to +75°C (-58 to +167°F)
Loads	Low compression and adhesion loads
Androgynous docking	Design for seal-on-seal operation for vehicle-to-vehicle craft emergency rescue
Fault tolerance	Include multiple seals/bulbs for redundancy
Surface operations	Exhibit robust operation in presence of dust, FOD, etc.

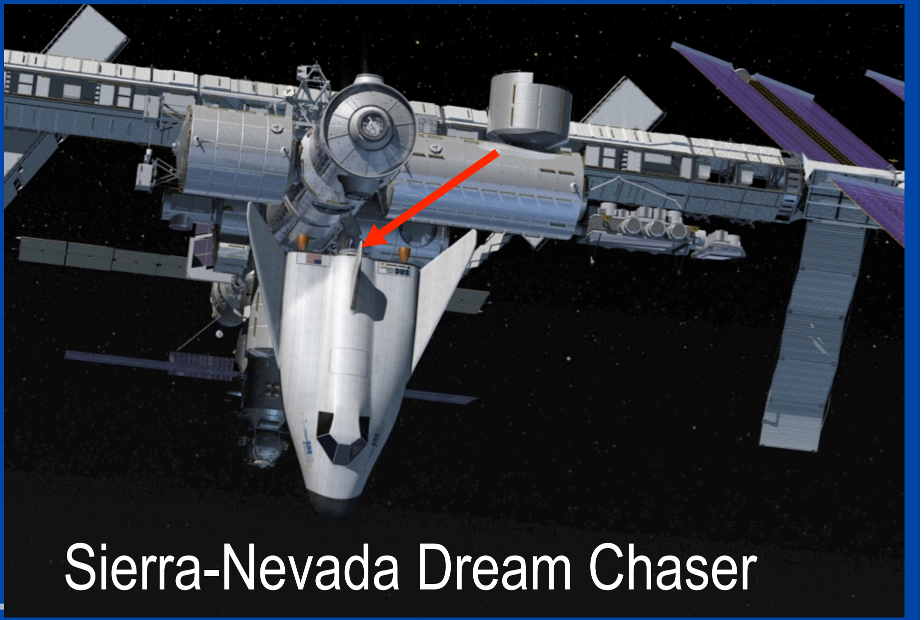
NASA Docking System

- NASA implementation of the International Docking System Standard (IDSS)
- Under development as a common docking system for a variety of host vehicles
- Requires a large (~51” diameter) near hermetic seal to prevent loss of cabin air
- Operate in either of following modes:
  - Seal-on-Flange
  - Seal-on-Seal (androgynous)

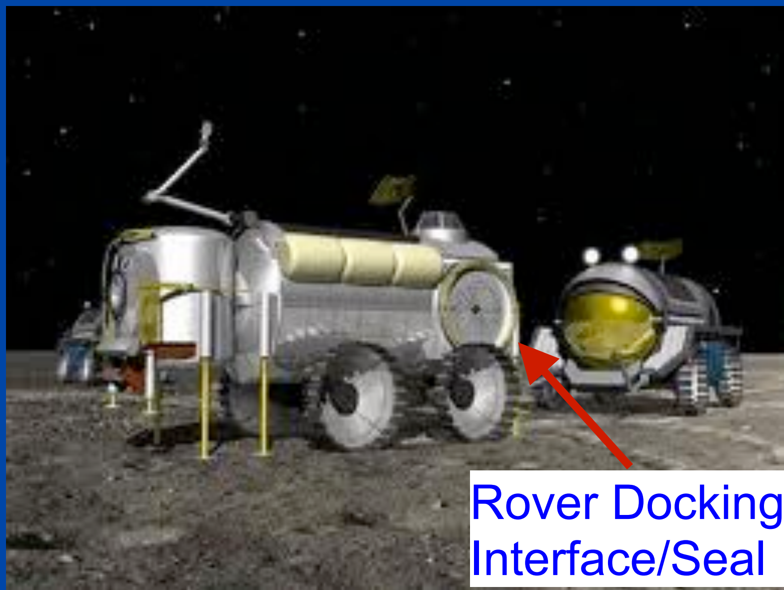


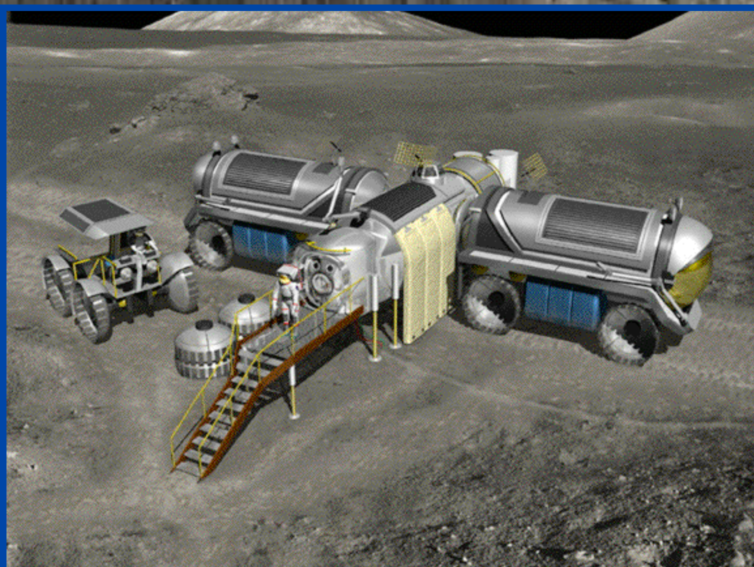
Potential NDS Applications



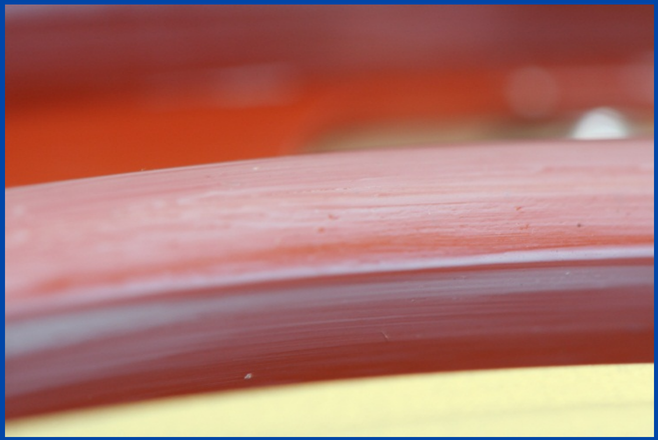


Advanced Habitat + Rover Seals

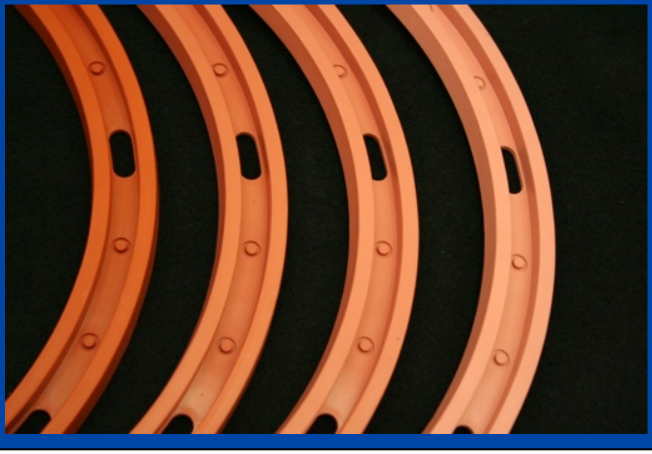




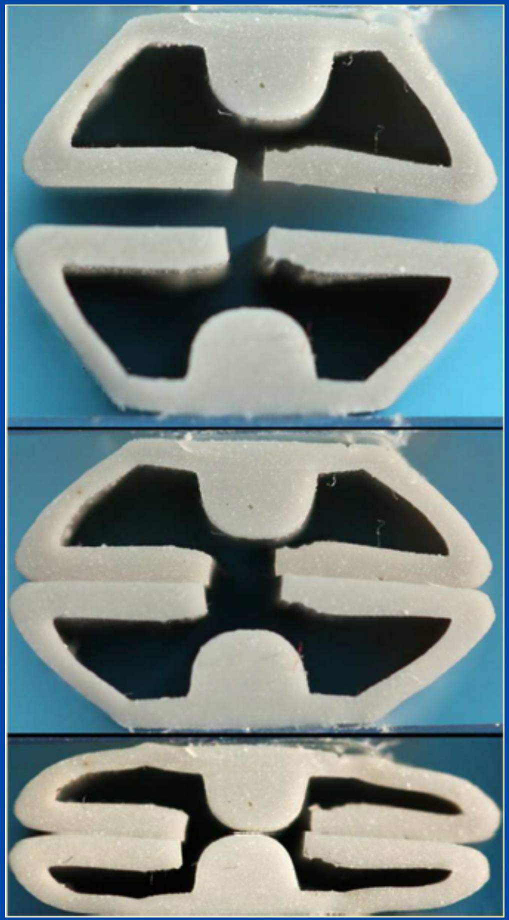
Advanced Habitable Volume Seals for Space Envrionments



Seals with UV-resistant coatings



Seals with additives for UV resistance



Seals with retractable “shrouds”

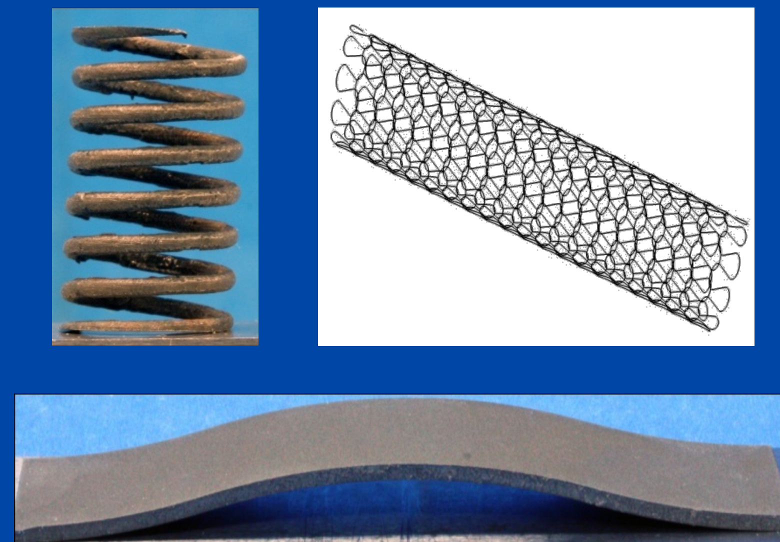
Thermal Barrier Seals

Thermal Barrier Seal Challenges

Temperature	Near term missions: 2600°F with short (<1 min.) exposures to 3200°F for single heating pulse Far term missions: 2600°F with longer (2-3 min.) exposures to 3200°F for multiple heating pulses (e.g., Mars re-entry/return)
Leakage	Prevent excessive heat flow to underlying structures
Space environments	Resist damaging effects of atomic oxygen, UV radiation, ionizing radiation, MMOD
Resiliency	Maintain contact with adjacent sealing surfaces; exhibit acceptable compression set vs. cycling
Loads	Exhibit light loads to prevent damage to TPS tile surfaces
Durability	For dynamic interfaces, tolerate scrubbing with minimal damage or loss of performance

Advanced Thermal Barrier Seals

Use of advanced high temperature fibers



Advanced seal preloaders for improved resiliency at high temperatures

Agenda Information

Advanced Seal Technology I

2013 AIAA Joint Propulsion Conf. – Session: SCP-03 Tuesday Morning, July 16, Room 210 G

Co-Chairmen: Bruce M. Steinetz and Patrick H. Dunlap, NASA Glenn; Neelesh Sarawate, GE Global Research

10:00 am Oral Presentation: Overview of Advanced Seals Challenges and Opportunities

Bruce M. Steinetz and Patrick H. Dunlap, NASA Glenn Research Center; Neelesh Sarawate, GE Global Research Center

10:30 am Oral Presentation: Turbomachinery Sealing Technology- Survey of Past Success and Strategy for Future Development

Joel Kirk, GE Aviation

11:00 am: Design, Manufacture and Testing of Variable Bristle Diameter Brush Seals (AIAA- 2013-3859)

Xiaoqing Zheng, Mike Mack, Mehmed Demiroglu General Electric Co.; Deepak Trivedi, Binayak Roy, GE Global Research Center. *Presented by Neelesh Sarawate GE GRC*

11:30 am: A Novel Air/Oil Separator and Its Integration to a Prototype Miniature Jet Engine (AIAA- 2013-3860)

Emre Tan Topal, TUSAS Engine Industries Inc; Sercan Acarer, TEI TUSAS Engine Industries Inc. /Izmir Institute of Technology; Tuna Kirgiz, TEI TUSAS Engine Industries Inc.

1:00 pm Oral Presentation: Characterizing Multi-Scale Viscoelasticity of Polymers: A Transient Sealing Perspective

Azam Thatte, GE Global Research

1:30 pm: Transient Simulations of Rotordynamic Problems with Whirling Motion (AIAA- 2013-3914)

Chandrasekhar Kannepalli, Vineet Ahuja, and Ashvin Hosangadi, Combustion Research and Flow Technology, Inc. (CRAFT Tech)

2:00 pm: Use of VUV Radiation to Control Elastomer Seal Adhesion (AIAA- 2013-3915)

Henry C. de Groh III, Bernadette J. ("Sue") Puleo, and Deborah L. Waters, NASA Glenn Research; *Presented by Sue Puleo*