Tribology & Mechanical Components Branch Overview

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Abstract:

An overview of NASA Glenn Research Center's Tribology & Mechanical Components Branch is provided. Work in space mechanisms, seals, oil-free turbomachinery, and mechanical components is presented. An overview of current research for these technology areas is contained in this overview.

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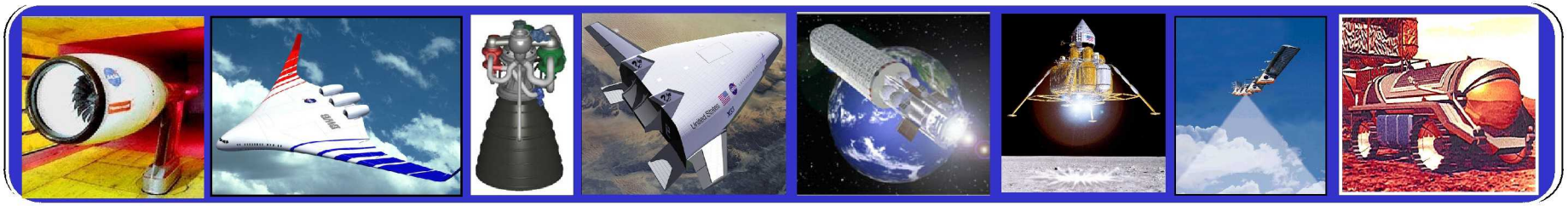
Topics

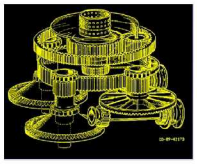
- View from 30,000 feet
- Structures and Materials Division
- Tribology & Mechanical Components Branch
- Branch teams
- Oil-free bearing research activities
- Tribology activities
- Seals Team activities
- Drive system activities
- Summary

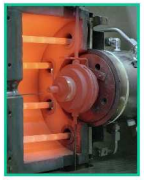
NASA Glenn Research Center

Materials and Structures Division

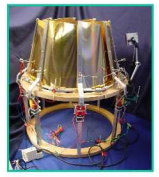


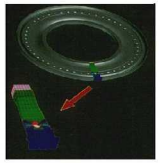
Propulsion and Power System Components

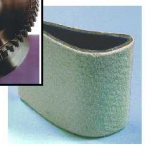


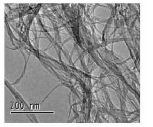


- Aeroshells
- TPS; Cooled strs.
- Cryogenic tanks
- Nacelles
- Combustors
- Engine fan system
- Mechanisms
- Oil-Free engines
- Injectors
- High-power motors
- Space lubricants
- Protective Coatings
- Sensors
- Thermoelectrics
- Surface mobility systems
- Nozzles
- In-space & on-surface modules
- Rotor discs and systems
- Turbine vanes
- Energy absorbing systems
- Mechanical drive systems
- Human health systems
- Thrusters
- Bearings and flywheels
- Solid oxide fuel cells, batteries
- High temp. and cryogenic seals
- Porous membranes
- BN nanotubes









Core R&T Capabilities

- Probabilistic methods
- Mechanical power transfer
- Impact dynamics
- Structural mechanics
- Material modeling
- Material characterization
- Functional materials
- Metallic alloys
- Computational materials
- Surface science
- Materials science
- Matl. and strl. Concepts
- Health prognostics
- Blast mechanics
- Structural dynamics
- Joining technology
- Failure and damage growth
- Processing technologies
- Shape memory alloys
- Protective coatings
- Extreme environment effects
- High temperature chemistry
- Design technology
- Experimental methods
- Measurement technology
- Aeroelasticity
- Durability and life
- Fatigue and fracture
- High temp. and cryo seals
- Ceramic materials
- Multifunctional Materials
- Lubricant chemistry
- Friction and wear

Tribology & Mechanical Components Branch

"NASA's one-stop-shop for all its mechanisms & lubrication needs"

Branch Organization:

- **Oil-Free Turbomachinery – Dr. Chris DellaCorte**
- **Space Mechanisms & Lubrication – Dr. Phil Abel**
- **Aerospace Seals – Dr. Bruce Steinetz**
- **Aero Drive Systems – Dr. Robert Handschuh**

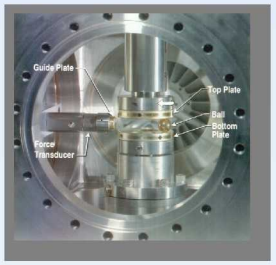
Tribology & Mechanical Components Branch

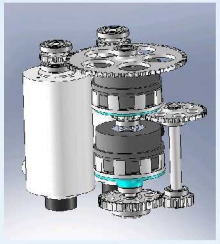
Oil-Free Turbomachinery

From basic research to application

- Aero / Space application
- World-leading bearing experts
- Advanced modeling methods
- Foil bearing predictive design

Space Mechanisms & Lubrication

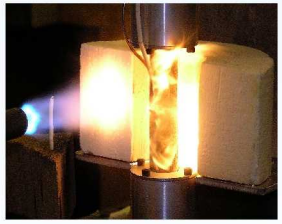


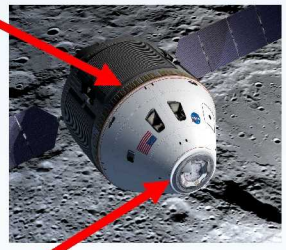


- Accelerated space lubricant life testing under vacuum
- New mechanism concepts for planetary environment
- New space lubricant development
- Terramechanics modeling & testing for efficient wheels

Aerospace Seals Research

Heat Shield Interface Seal

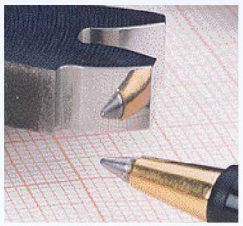


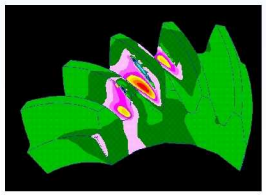


Docking Seal

- Space habitat seals for extreme environments
- Structural / thermal protection seals
- Non-contacting turbine seals

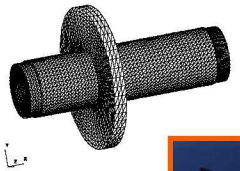
Aero Drive Systems



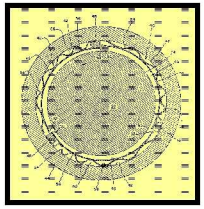


- Gear fatigue research
- High speed gear lubrication
- Drive system diagnostics
- Fatigue crack modeling
- Dynamic mechanical components
- Rotorcraft transmission systems
- Advanced rolling element and wave bearing technologies

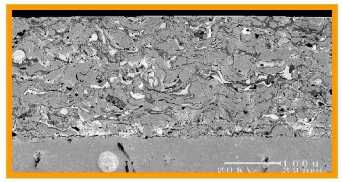
Oil-Free Turbomachinery



CAD



Foil air bearings



PS304

For cryogenic to 800C sliding contacts

Oil-Free enabling technologies

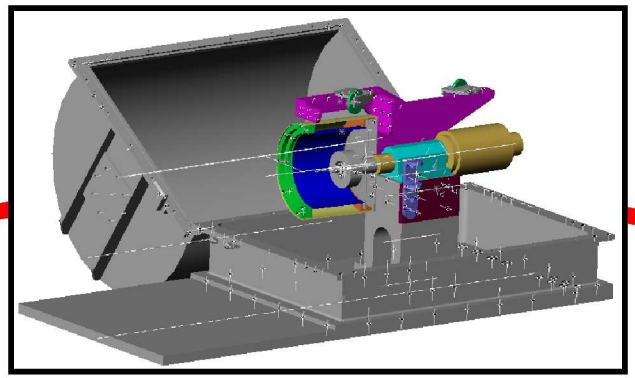
TGIR Award for Level I Milestone:
"Core Hot Bearing Tests" (OFTET)

?

PM304 bushings for
industrial furnaces
and valves

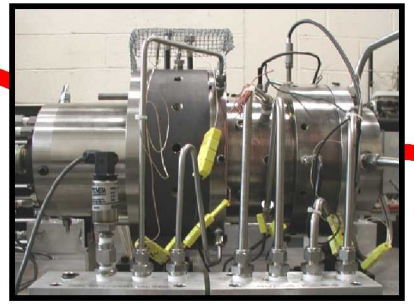
Oil-Free Key Facilities & Capabilities

Coating deposition research facility

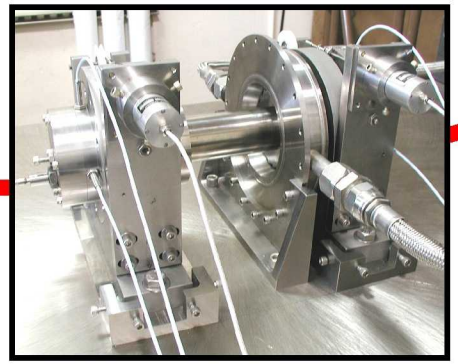


Foil bearing ambient pressure test rig

Capstone MicroTurbine proof-of-concept & environmental durability test facility

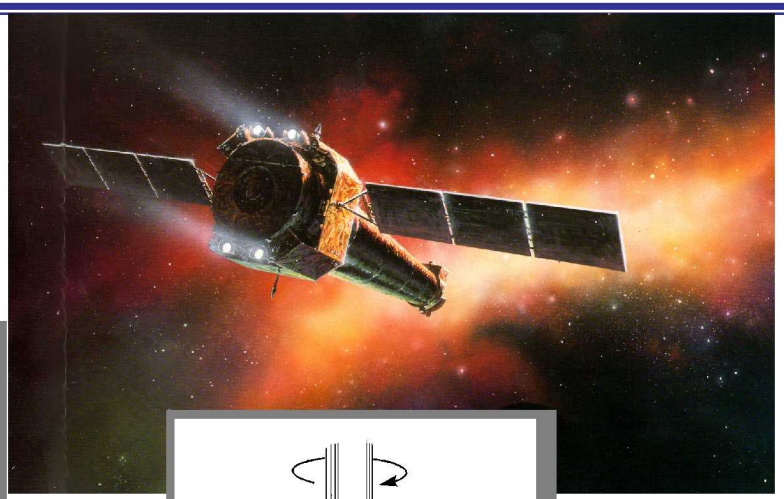


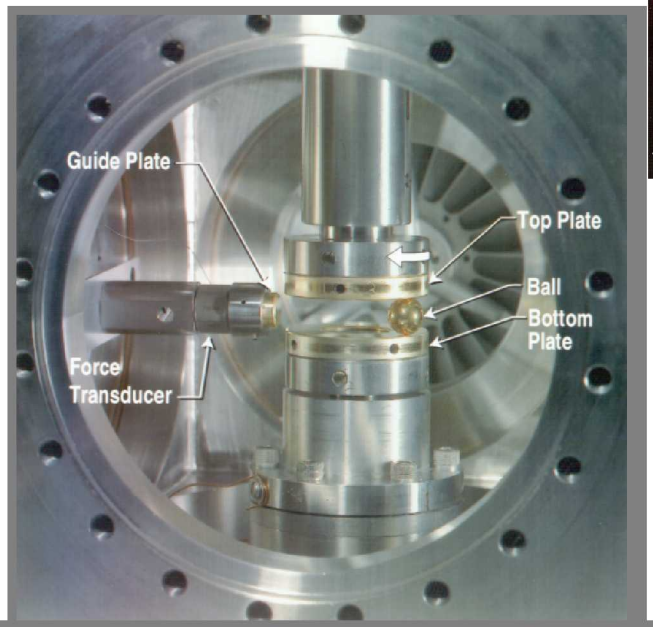
Hot high-speed thrust foil bearing rig



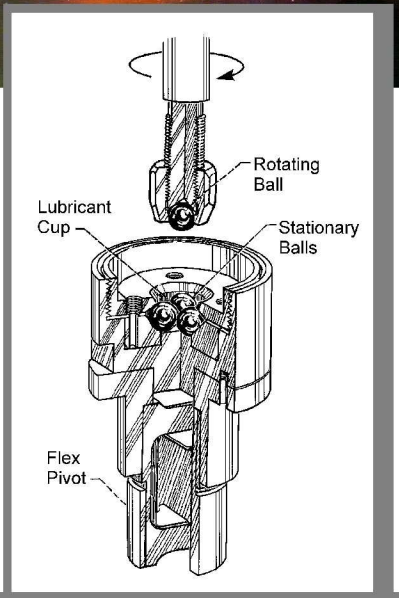
Shaft rotordynamic simulator test facility

Space Tribology & Materials

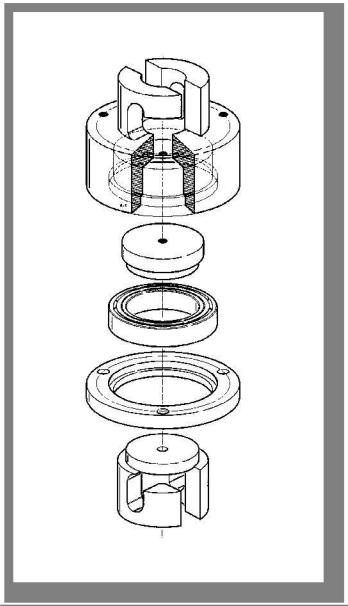




SPIRAL ORBIT TRIBOMETER
Accelerated Lubricant Life Testing Under Realistic Conditions



VACUUM 4-BALL
Accelerated Bulk Property Testing of Lubricants

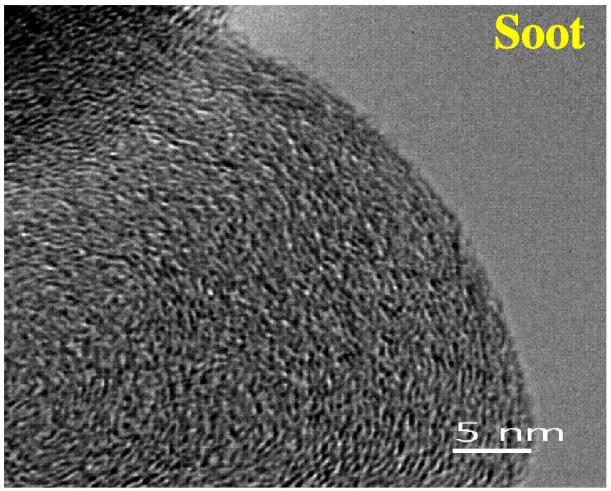


BEARING RIG
Full Scale Bearing Tests

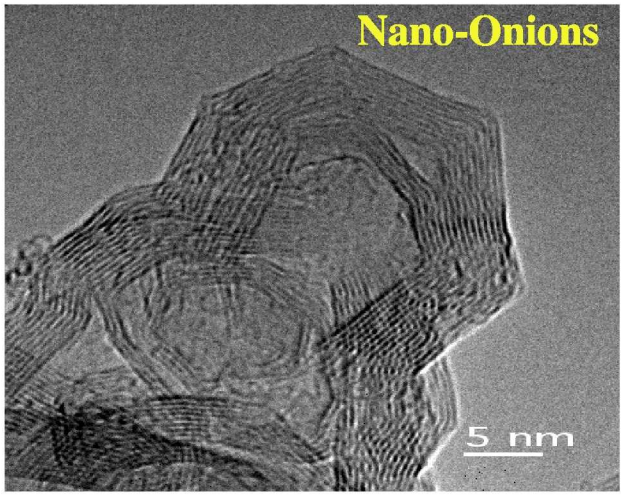
Other Facilities:
- Vapor Pressure of Fluids
- Radiation Damage of Polymers

Nano-Structured Lubricants for Tribology

Carbon nanostructure transformation by industrially scalable GRC developed process

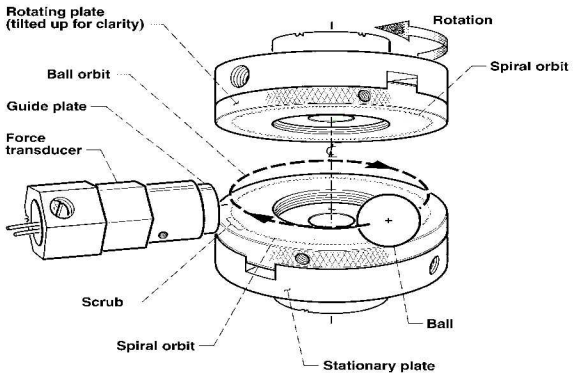


Heating soot to high temperatures in an inert atmosphere graphitizes the carbon to form nano-onions.



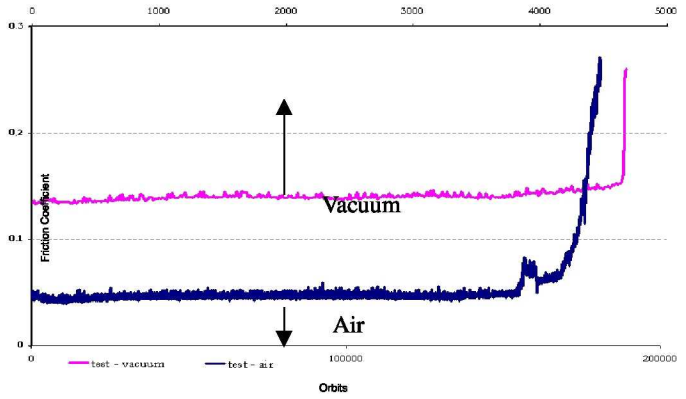
Addition of a small amount of nano-onions to oil improved the lifetime by a factor of 8x while decreasing the friction by a factor of 2.6

Spiral Orbit Tribometer (SOT)



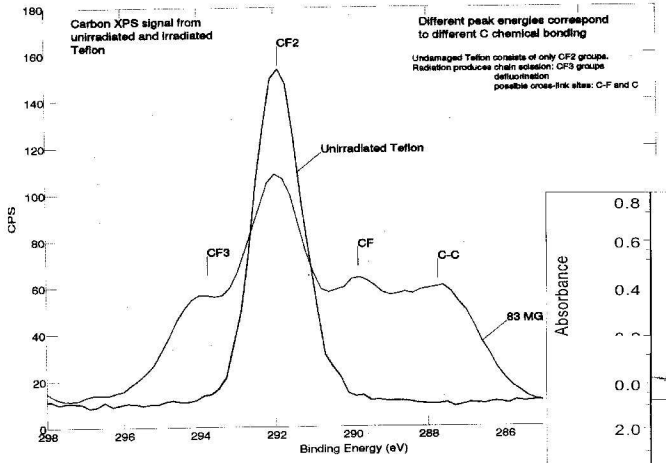
Nano-onions mixed with oil (Krytox 143AB) form a nano-grease. When tested in the SOT, which mimics the motion of a ball bearing, significant friction and lifetime improvements in air are realized.

SOT Nano-grease Friction Traces

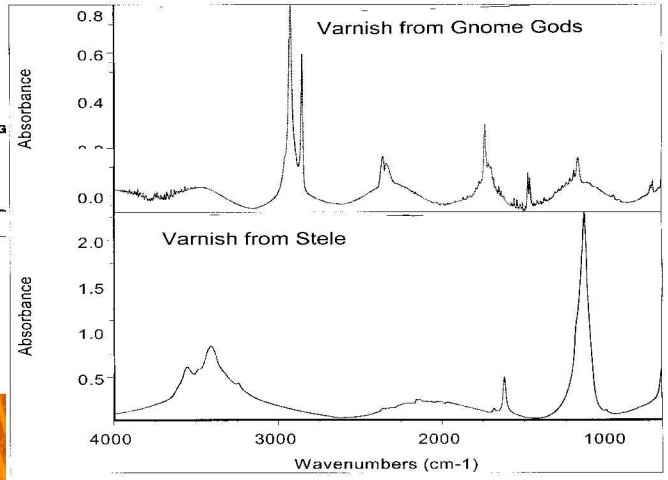


Surface Science Tools

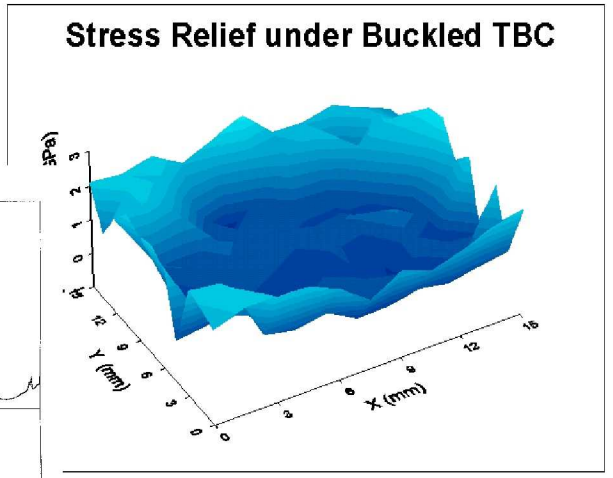
XPS

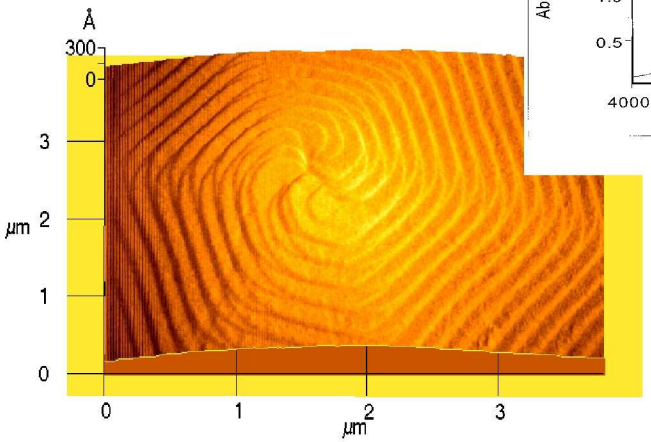


FT-IR

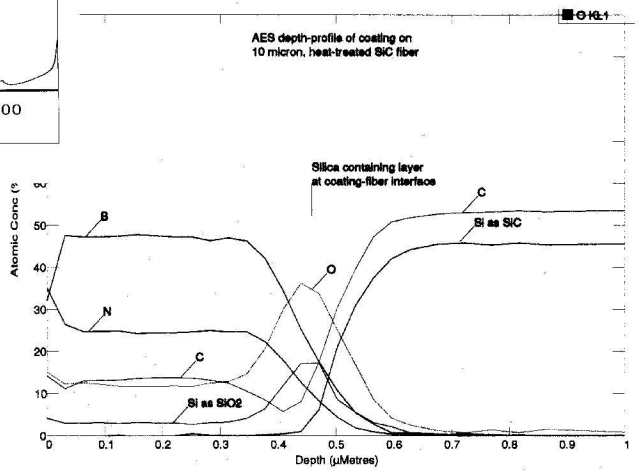


Raman





AFM

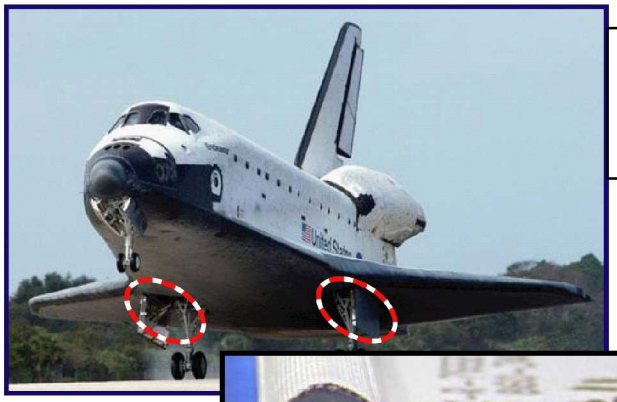


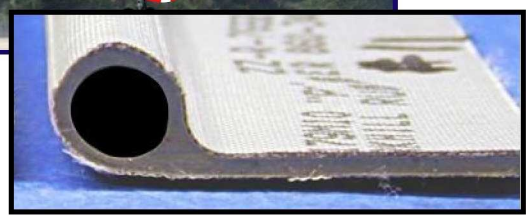
Auger

NASA GRC Seal Team

NASA GRC Seal Team contributions have influenced several flight projects:

- **Shuttle main landing gear door environmental seals**
- **Thermal barrier (braided carbon fiber rope) for nozzle joints of Shuttle and Atlas V SRM's**



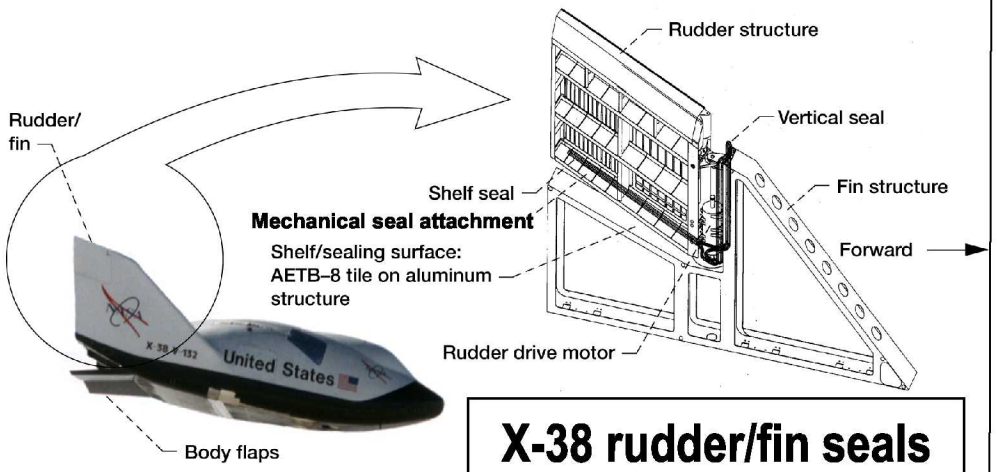


Shuttle MLG door seals

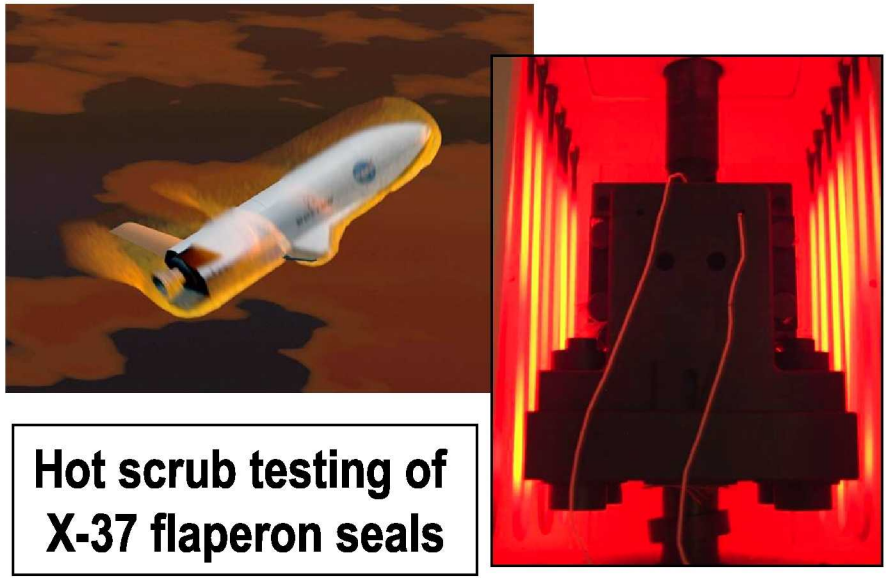
Thermal barrier for Shuttle and Atlas V SRM nozzle joints

NASA GRC Seal Team Overview

- **NASA GRC Seal Team contributions have influenced several flight projects:**
  - **X-38 rudder/fin seals**
  - **X-37 flaperon seals**



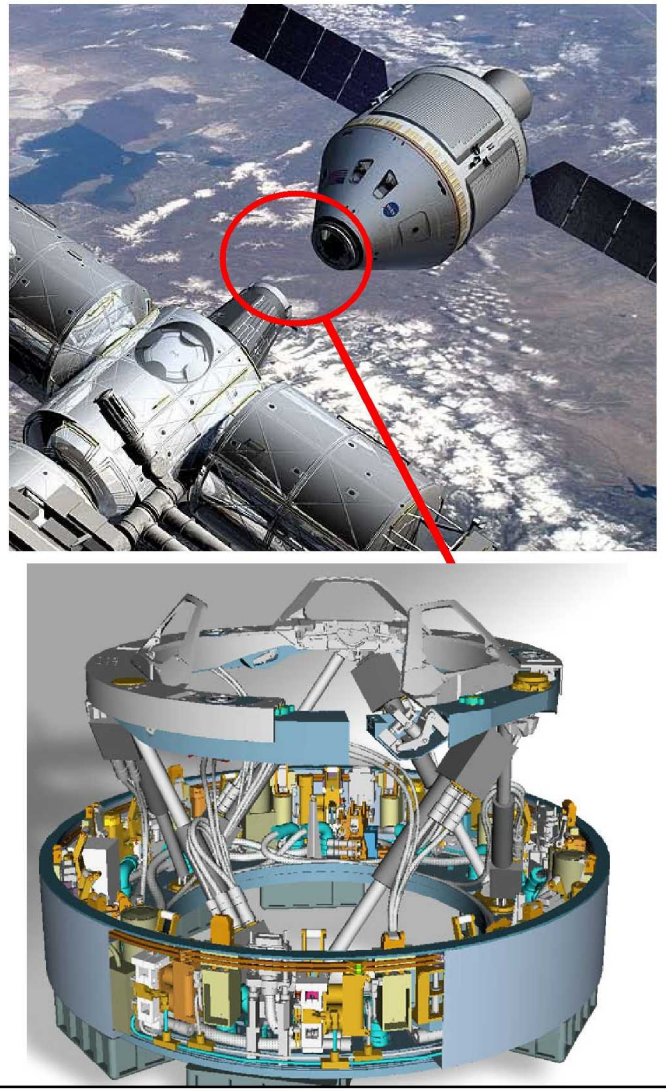
X-38 rudder/fin seals



Hot scrub testing of X-37 flaperon seals

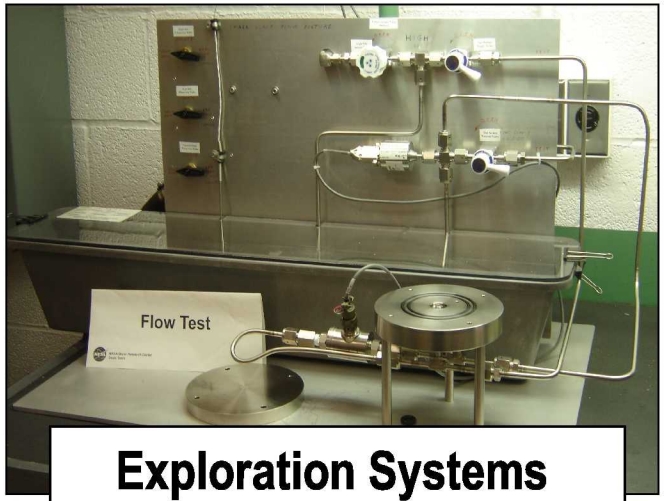
Low Impact Docking System (LIDS)

- LIDS is a system under development by NASA JSC designed to:
  - Provide gender-neutral (androgynous) interface permitting docking and berthing between any two space vehicles
  - Reduce impact loads between two mating space craft
  - Become new Agency standard for docking/berthing systems



Low Impact Docking System (LIDS)

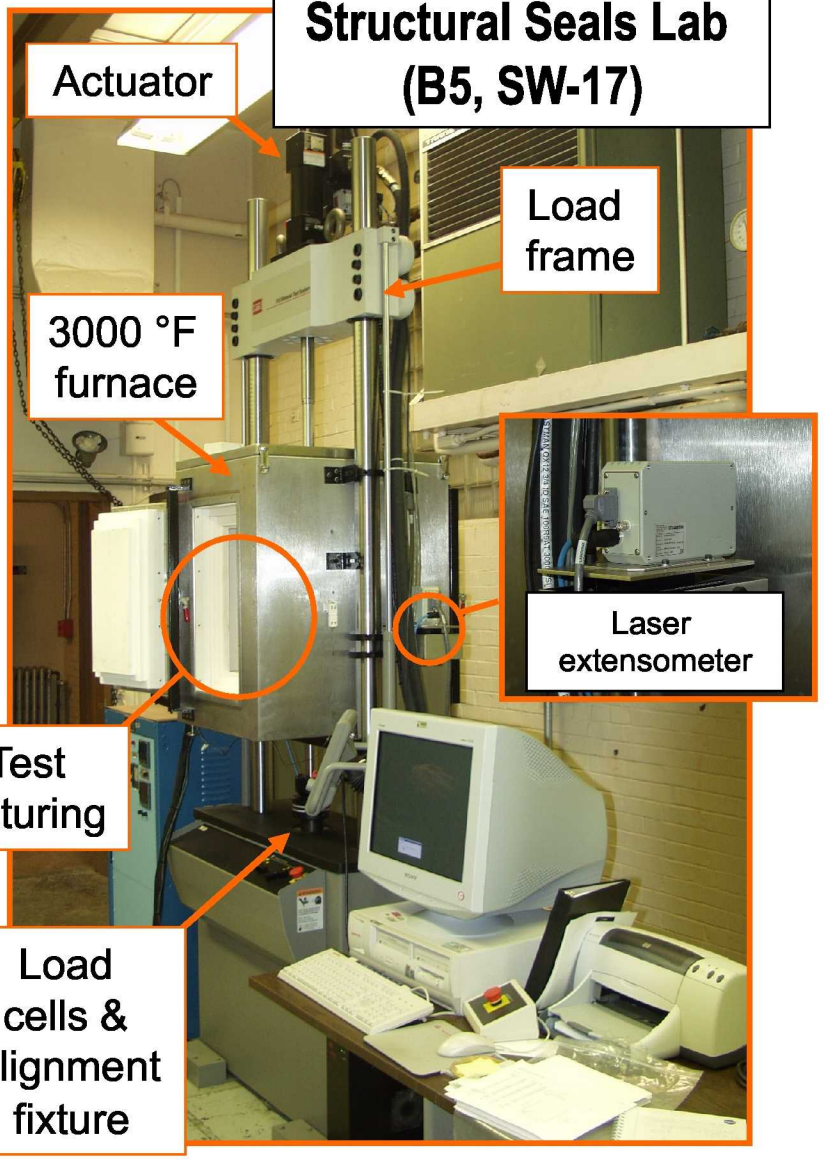
Seal Test Facilities



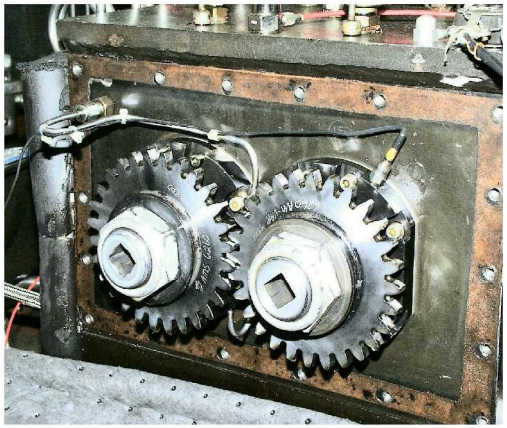
Exploration Systems Seals Lab (B5, C-9/SE-14)

New lab for full-scale LIDS seal testing in B63

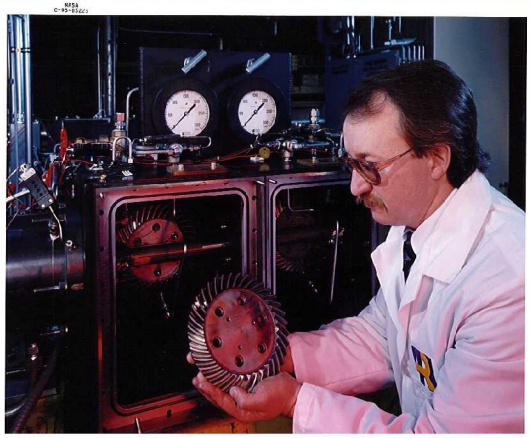
Structural Seals Lab (B5, SW-17)



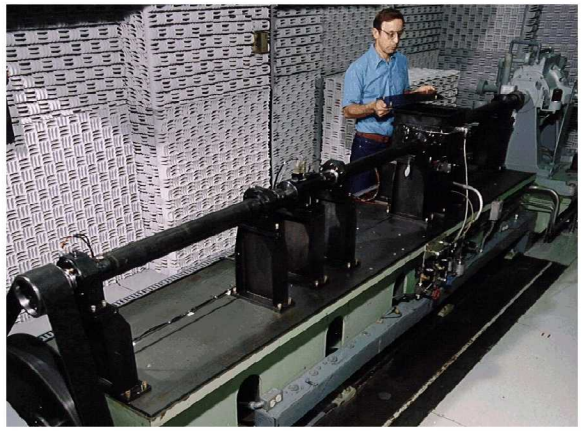
Drive System Test Facilities



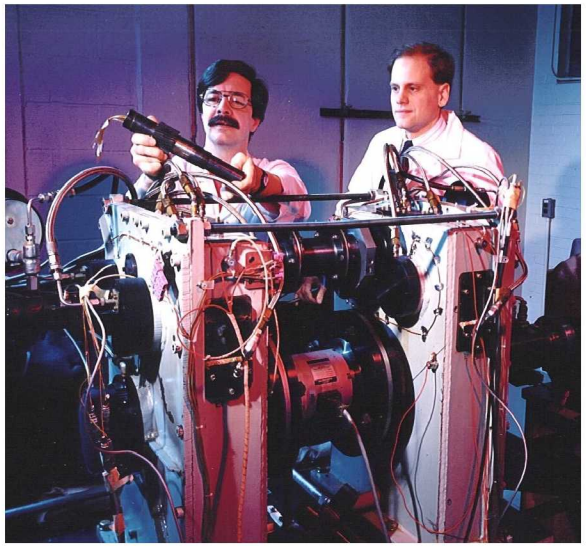
Spur Gear Fatigue Test Rigs



Spiral Bevel / Face Gear Test Facilities

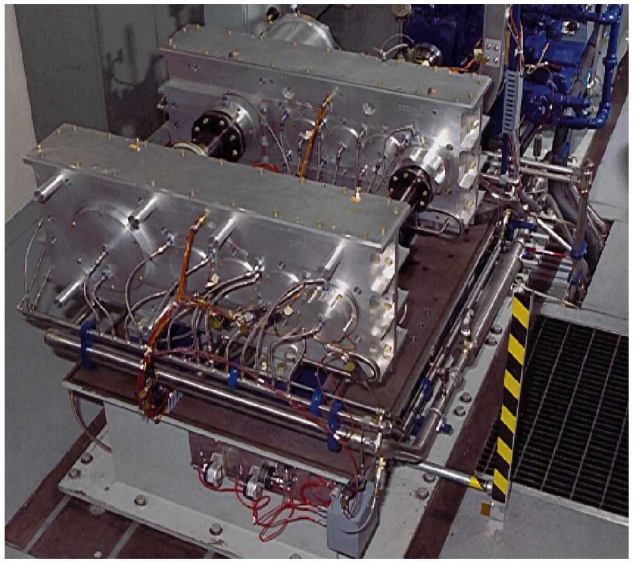


Gear Noise / Dynamics Test Facility



Split Torque Test Facility

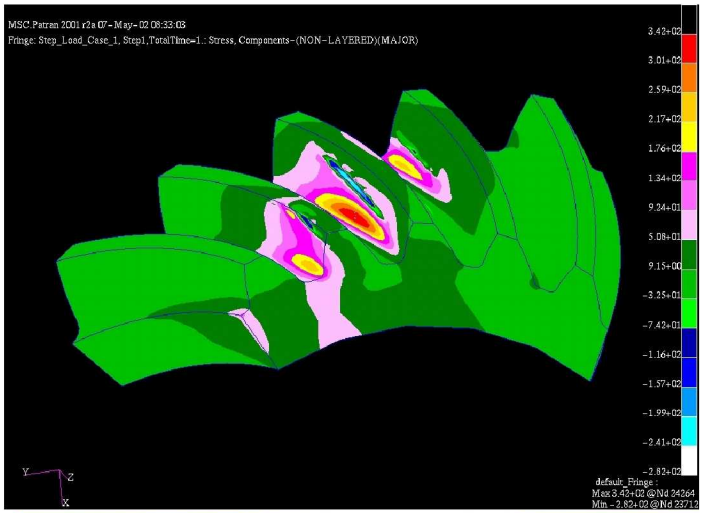
OH-58 Transmission Test Facility

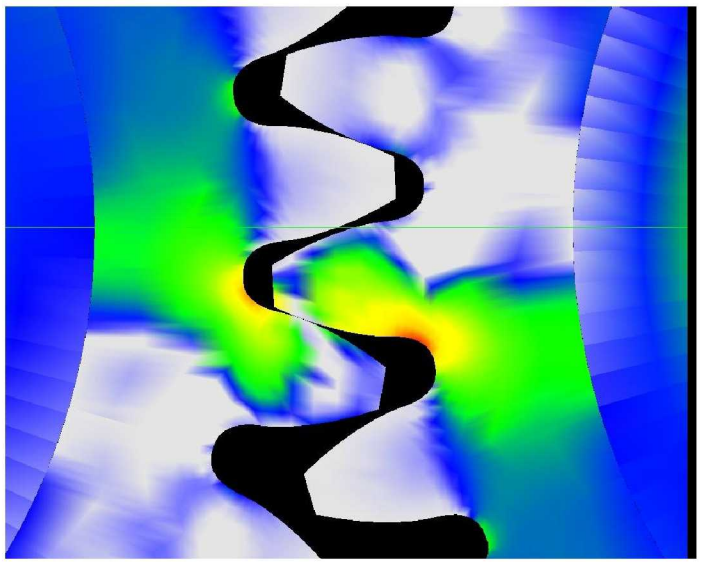


High Speed Helical Gear Train Facility

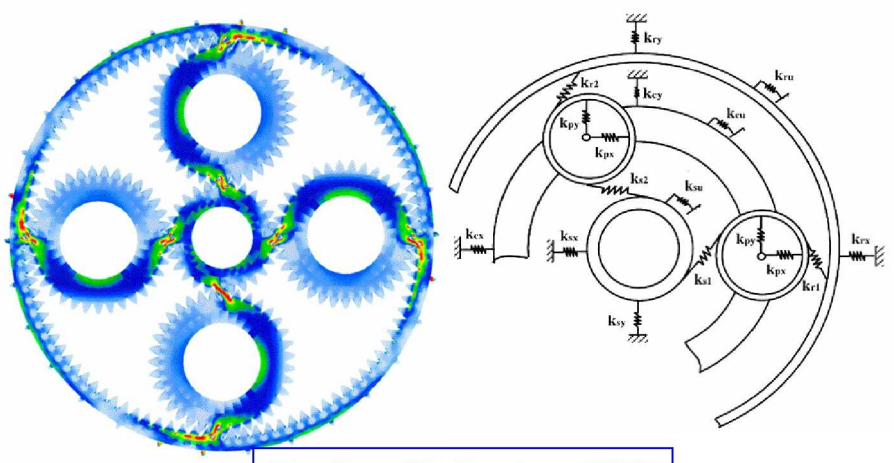
Drive System Analytical Capabilities

Finite Element Based
Structural - Thermal

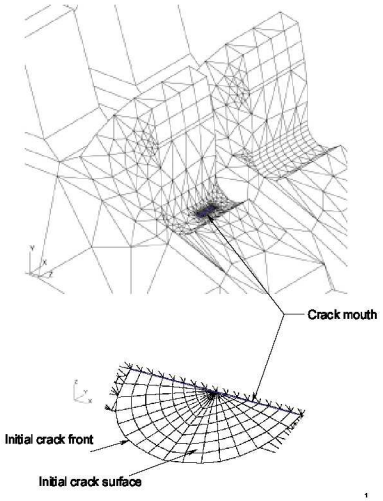




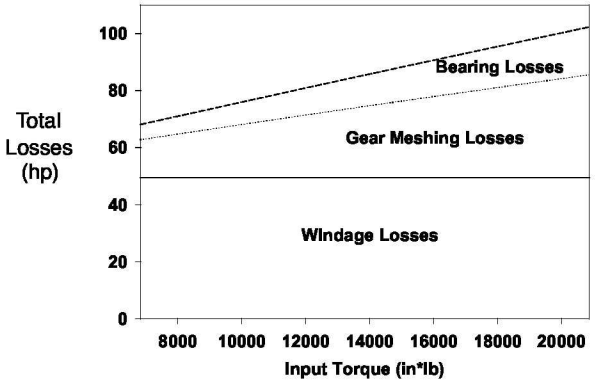
Planetary Gear Dynamics

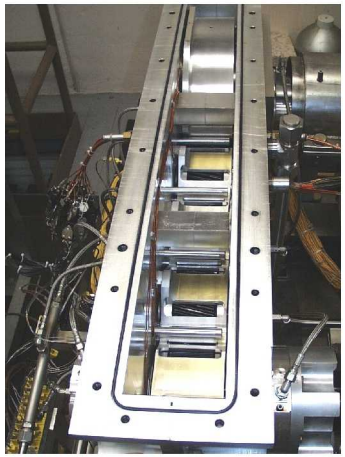


Fracture Mechanics - BEM

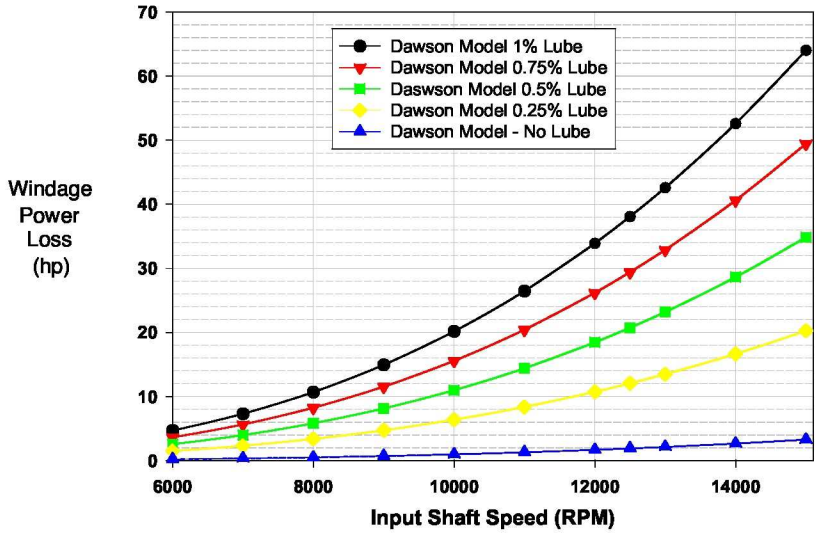


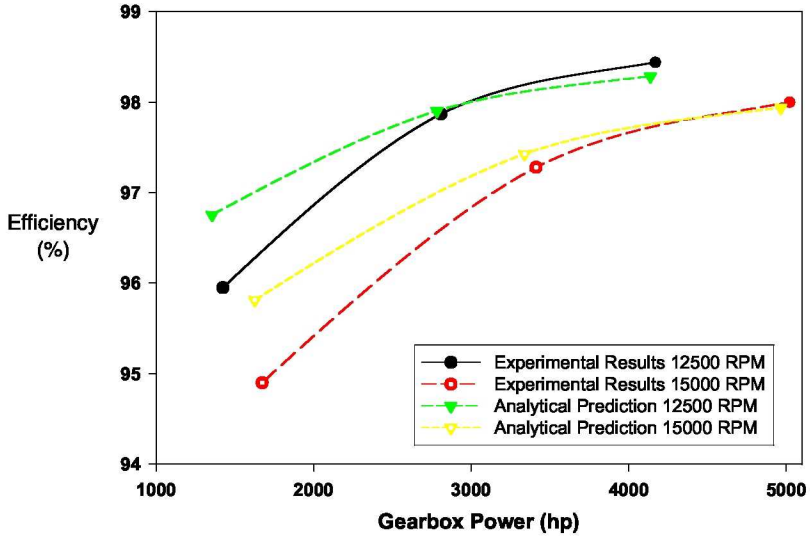
High Speed Gearing Results
NASA - ARL/VTD - Bell Helicopter





$$P_{Windage} = C_3 C' \rho N^{2.85} D^{4.7} \nu^{0.15} \lambda$$



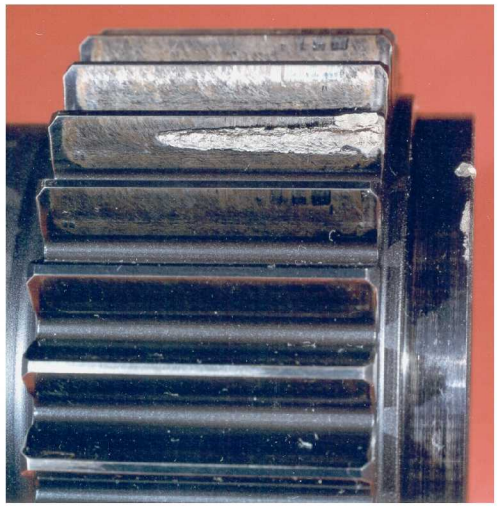


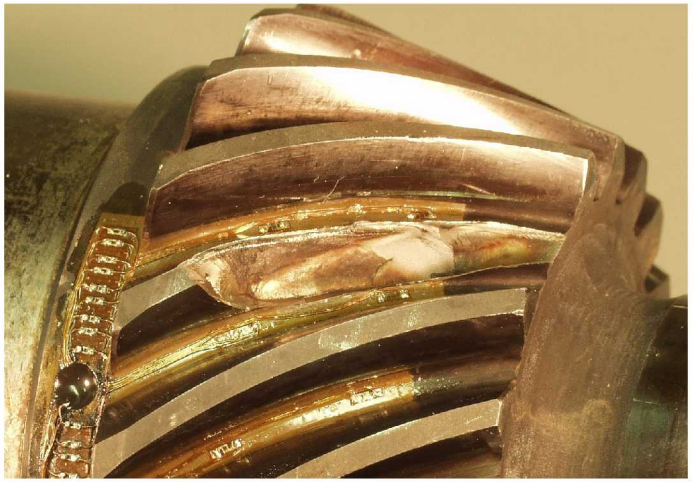
Condition Based Maintenance

Objectives: Increase reliability and decrease false alarms for mechanical component diagnostics. Demonstrate integration of oil debris and vibration based damage detection techniques results in improved capability.

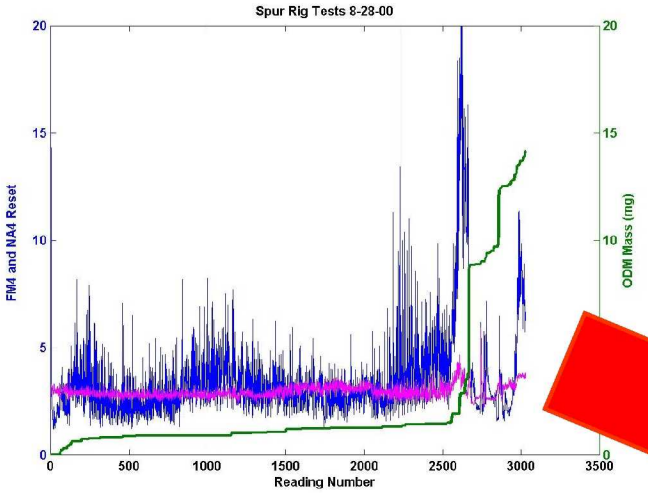
Approach:

Instrument and monitor all GRC gear fatigue test facilities and work with other govt. agencies, university, and industry



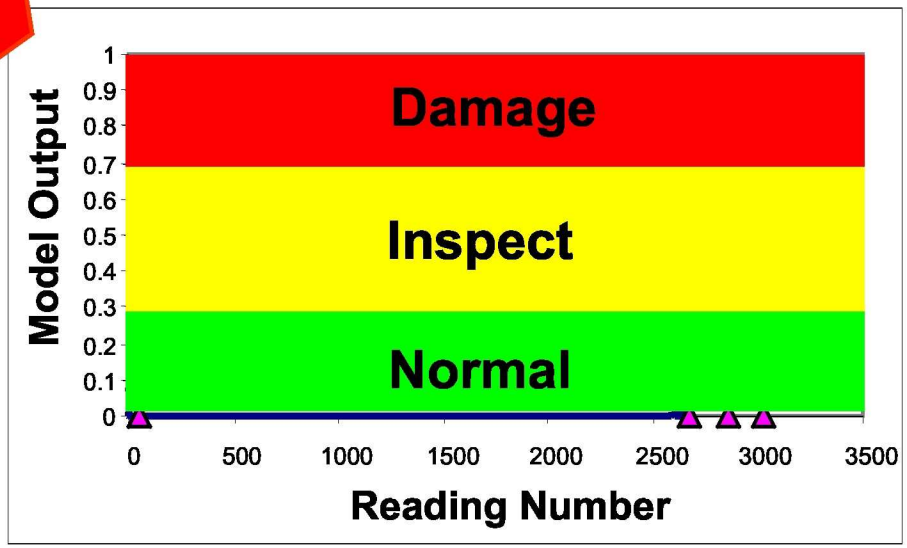


Condition Based Maintenance



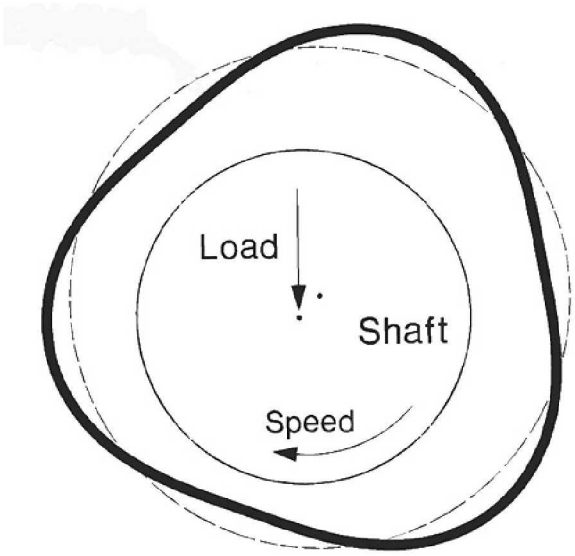
Vibration Techniques (FM4,NA4) and Oil Debris

Output of Fuzzy Logic Model

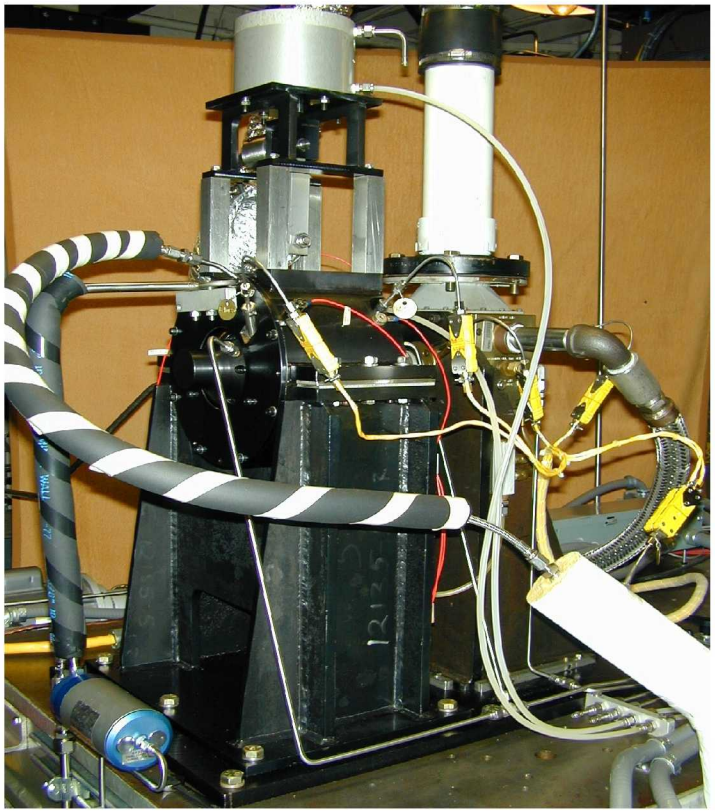


Wave Bearing Technology

Bearing Concept



Test Facility

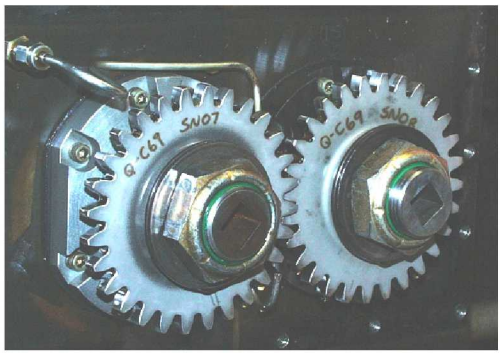


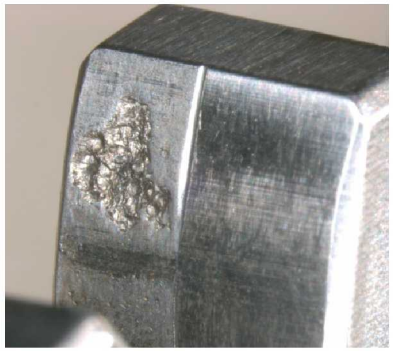
- Improved stability and cooling
- Ability to tailor stiffness and damping
- Use of hard sleeves

Advanced Gear Material

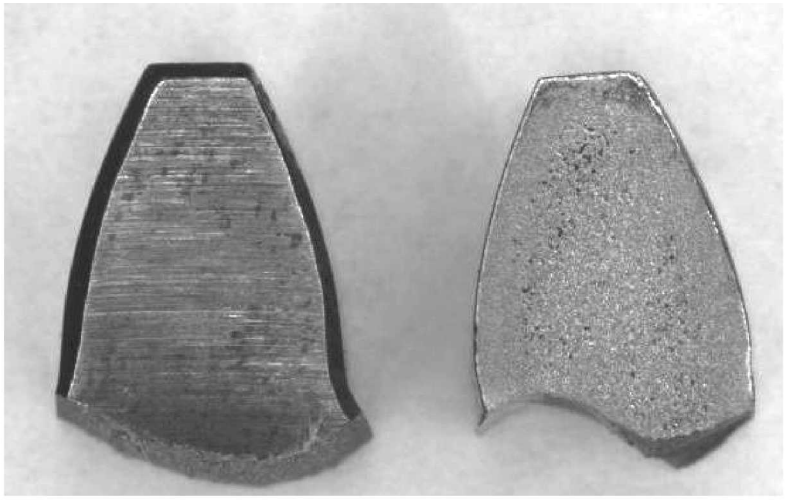
Surface Fatigue Results

Gear Material	Number of failures	Number of tests completed	Median life (million cycles)
AMS 6308B [Ref. 10]	15	21	134
AISI 9310 [Ref. 13]	25	33	200
Ferrium ® C69 [present study]	5	10	361





Fracture Toughness

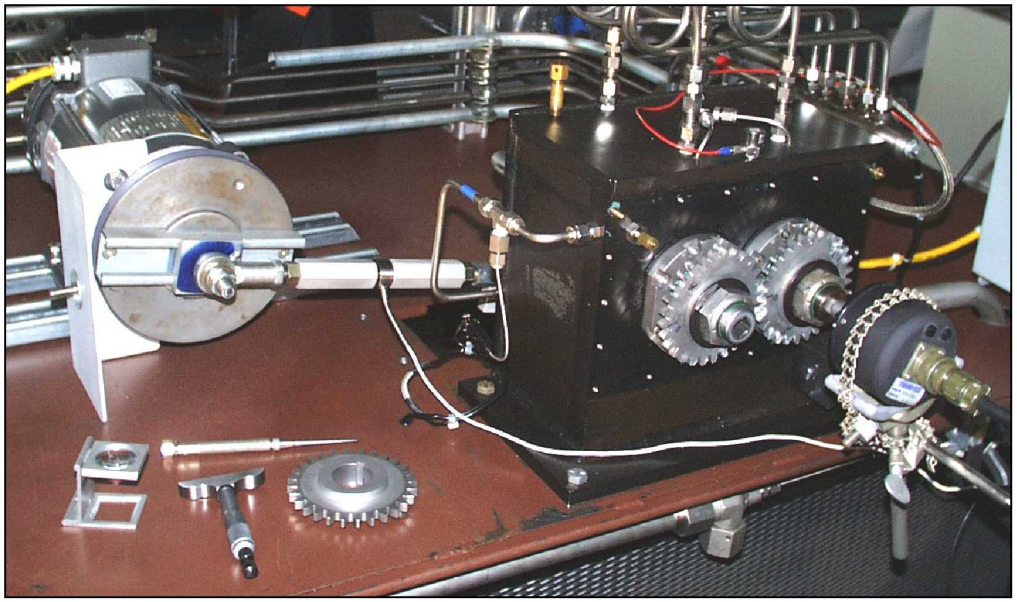


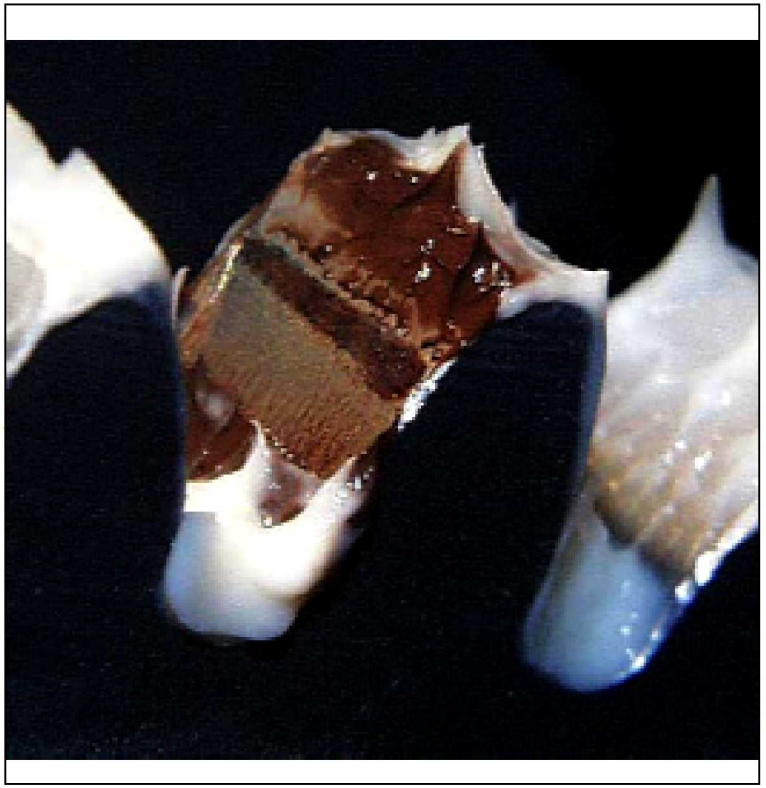
Ferrium® C69 AISI 9310

- Excellent Contact Fatigue
- Poor Fracture Toughness

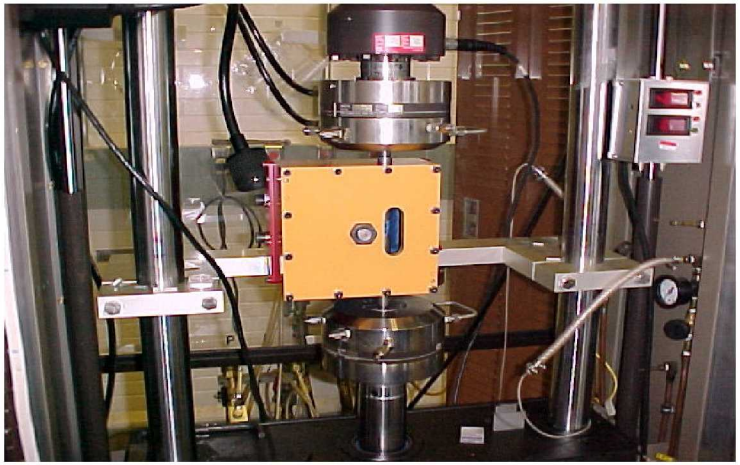
Space Mechanism Wear

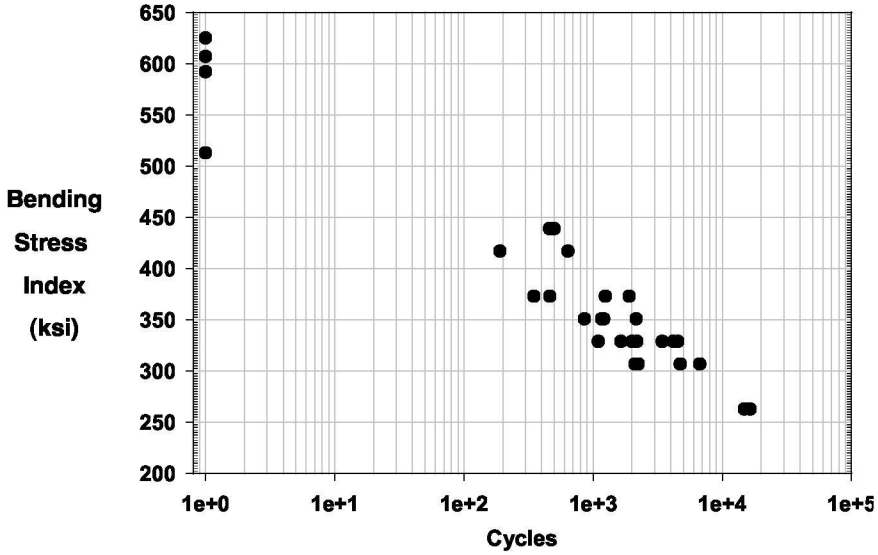
Dither Damage Assessment

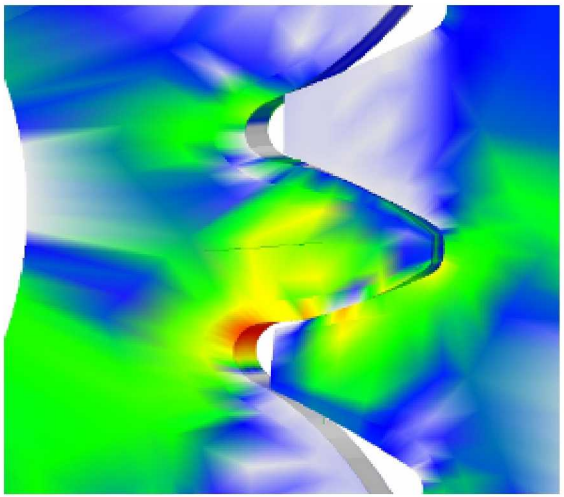




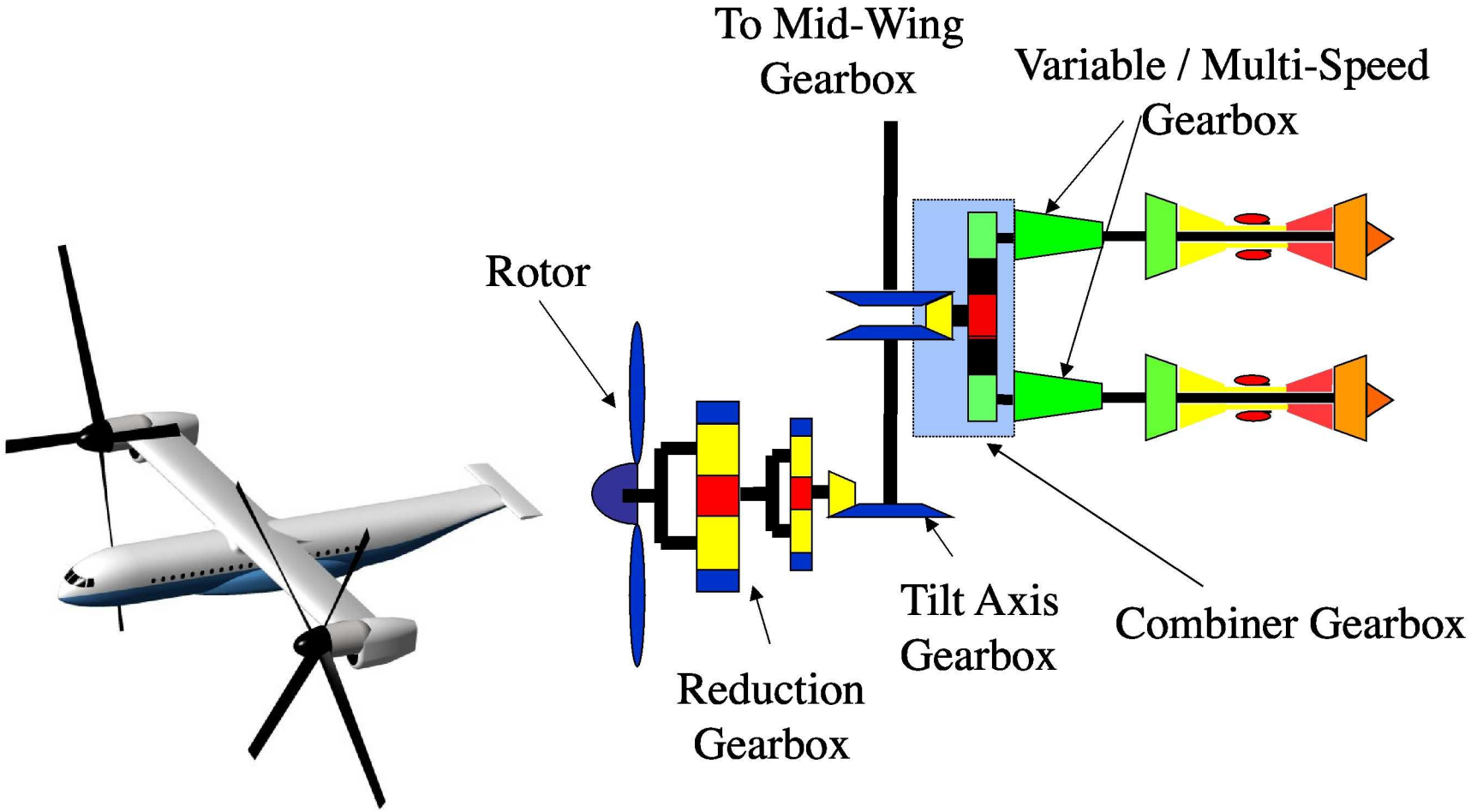
Low Cycle Bending Fatigue





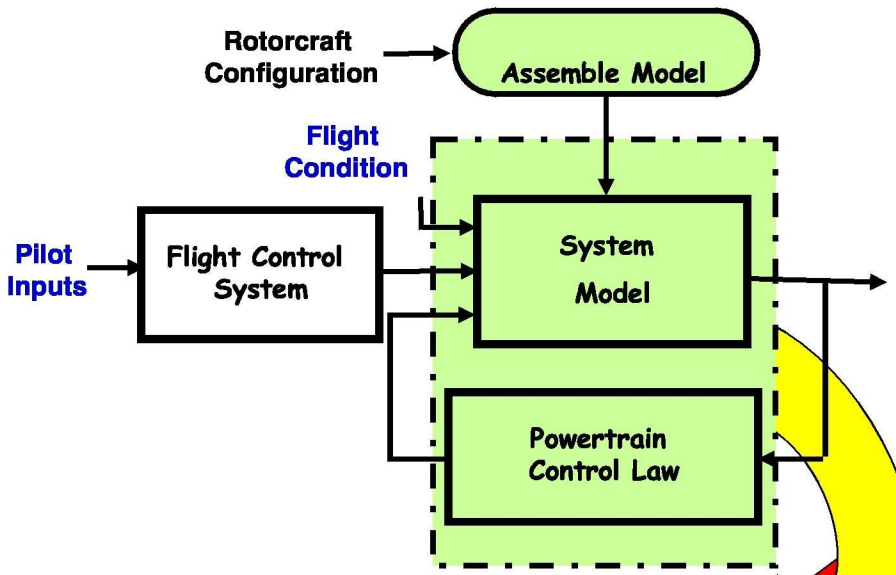


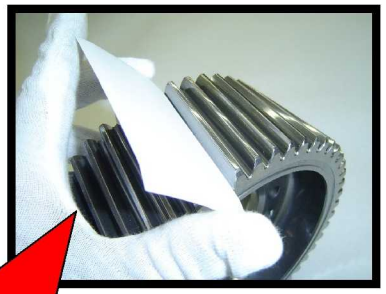
Civil Tiltrotor Drive System Configuration

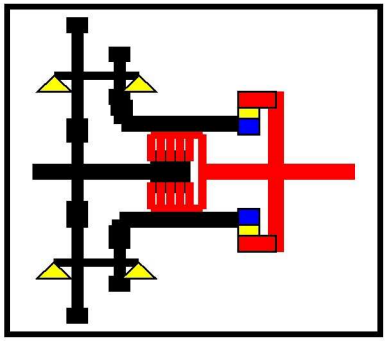


Hover Ratio 131.4 : 1 Forward Flight Ratio 243.6 : 1

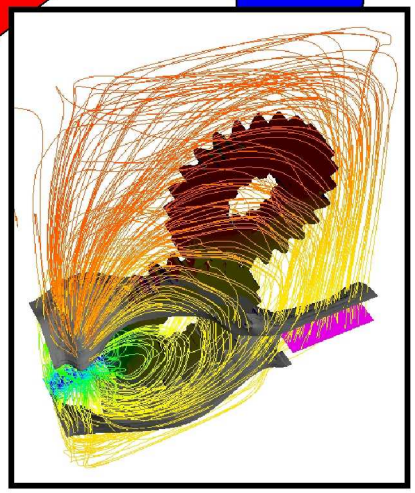
Penn State Univ. - NASA NRA R&D







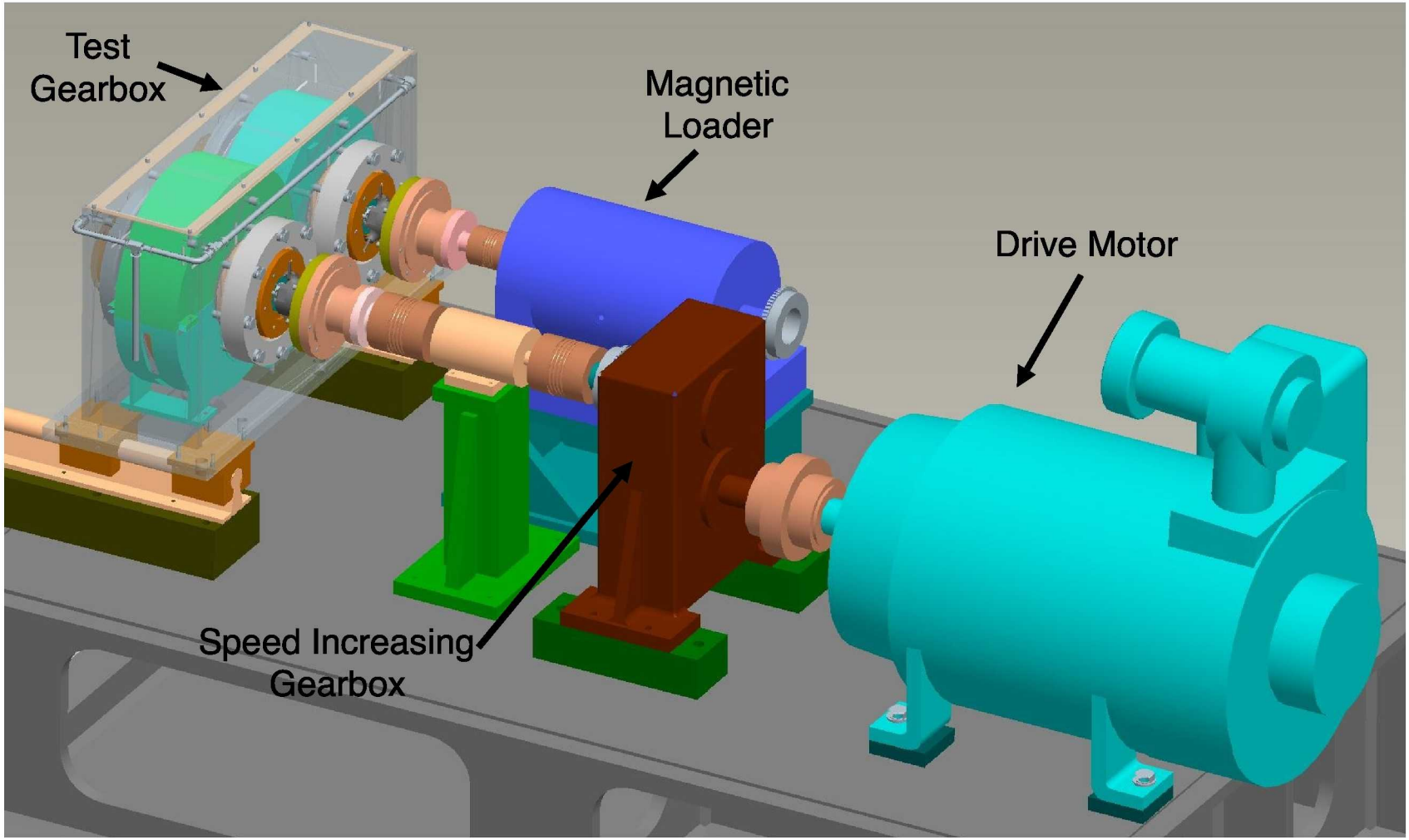
System Dynamics



Gear Performance

Subsonic Rotary Wing: High Fidelity Design Tools

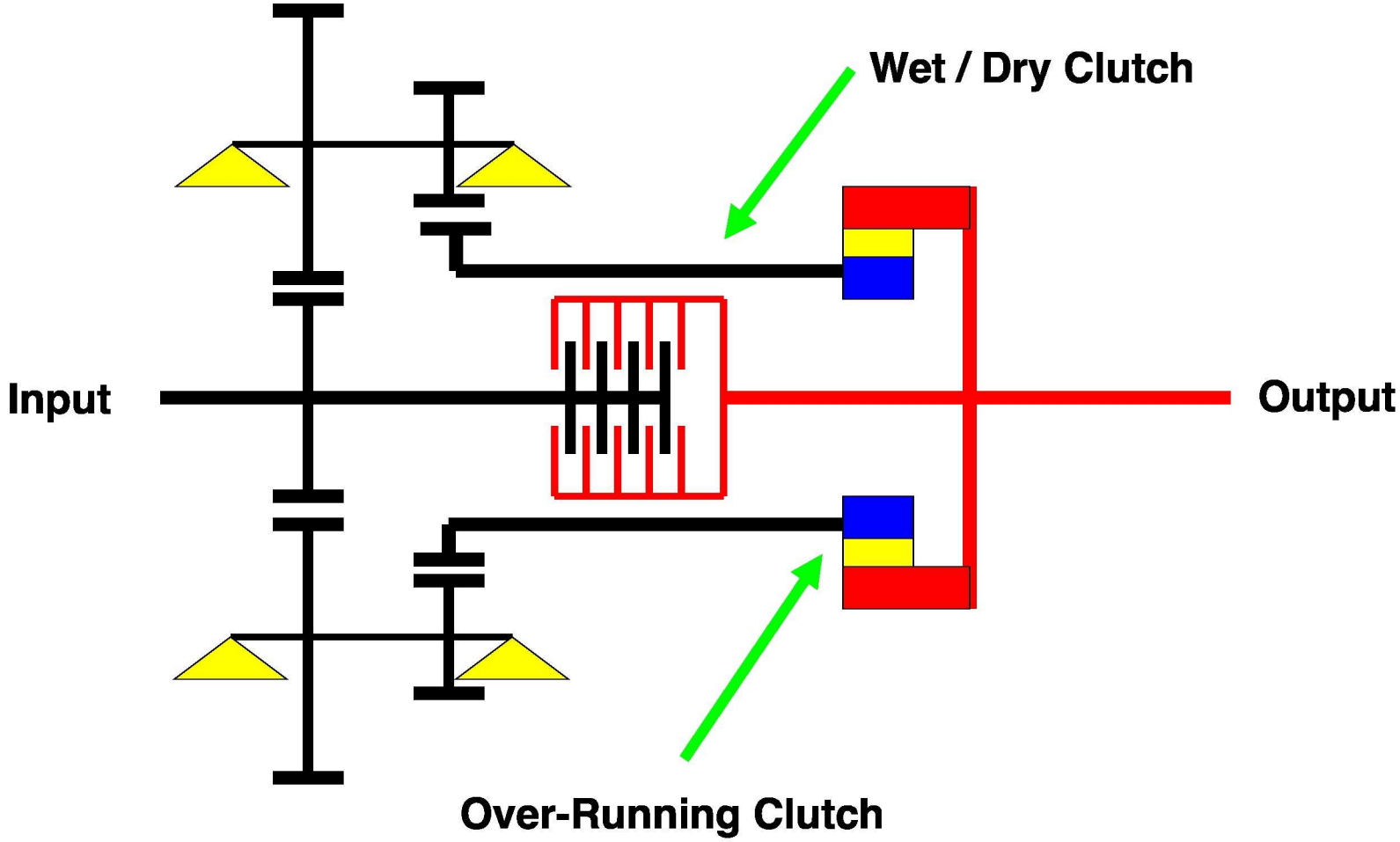
Windage Test Facility, NASA-GRC



Dr. Robert F. Handschuh, Army Research Lab, NASA - Glenn

Mark A. Stevens, NASA Glenn Research Center

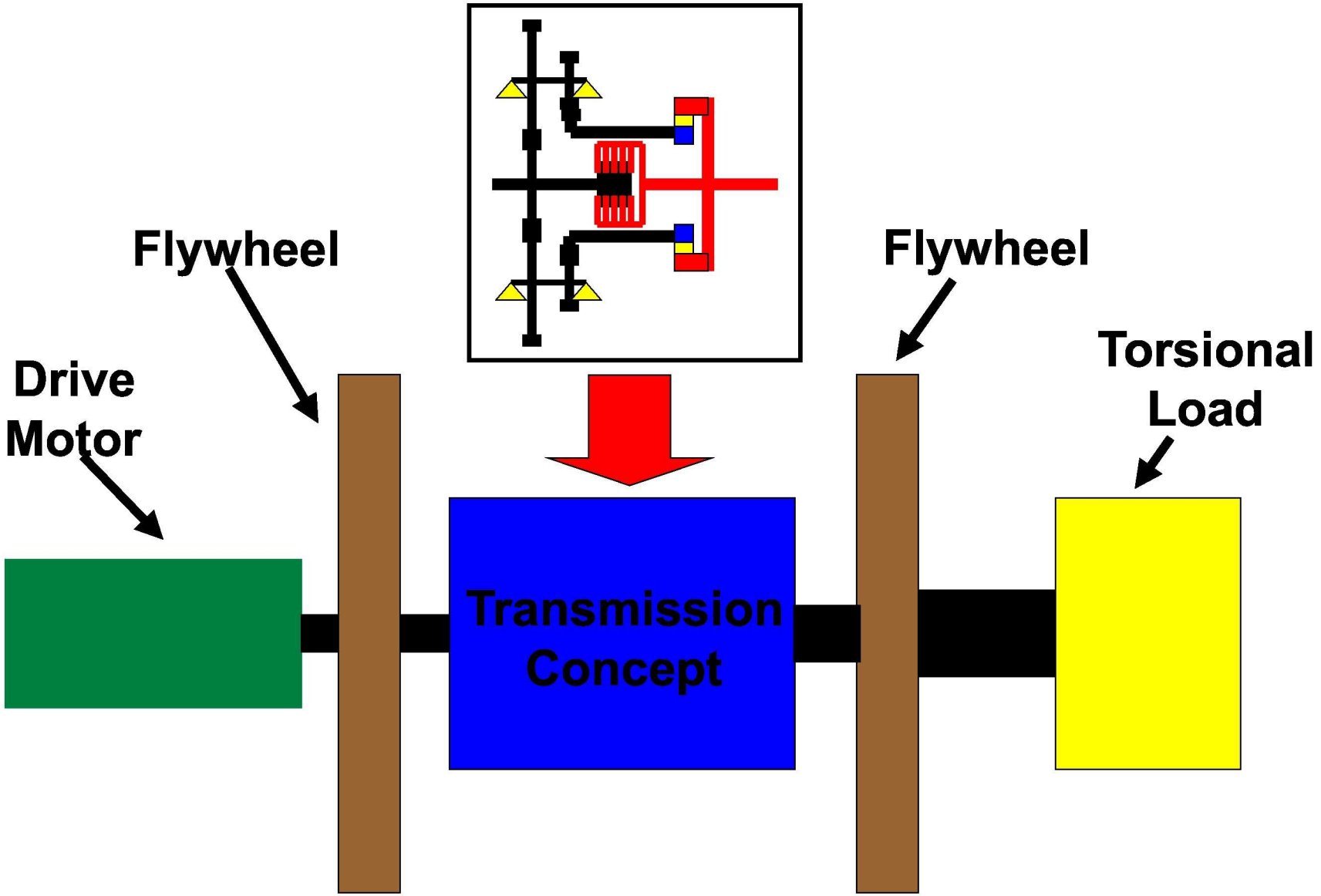
In-Line Two Speed Advanced RC Drive System



High Speed Operation (hover): Wet / Dry Clutch engaged, Over-Running Clutch over-running
Low Speed Operation (cruise): Wet / Dry Clutch disengaged, Over-Running Clutch driving

Dr. Robert F. Handschuh (October 2007)

Variable / Multi-Speed Drive Facility Concept



Summary

- Four main focus areas in the drive system area:
  - * Oil-Free Turbomachinery
  - * Tribology – Surface Science
  - * Seals – Static and Dynamic
  - * Drive System Technologies
- Currently conduct / manage research within our center as well as at contractor and university locations
- Involved in analytical and experimental developments
- Work closely with the space & aerospace industry, other government agencies / NASA centers, NESC….