Condition Based Maintenance

Summary:
The presentation provides an overview of Condition Based Maintenance research performed in the NASA Glenn Tribology and Mechanical Components Branch in support of the Subsonic Rotary Wing Project.

National Aeronautics and Space Administration

Fundamental Aeronautics Program

Subsonic Rotary Wing Project

CBM (Condition Based Maintenance)

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What is CBM?

Condition Based Maintenance:

Application & integration of processes, technologies & knowledge via a systems approach to improve aircraft reliability and maintenance effectiveness*

- » Reduce maintenance tasks
- » Increase aircraft availability
- » Improve flight safety
- » Reduce costs

**US Army ADS-79 HNDBK*

CBM Functions

Propulsion System Health

- Health monitoring of dynamic mechanical components
- Monitored by vibration signature analysis methods (condition indicators-CI) and oil condition

Structural Health

- Fatigue life management/component lifing based on actual usage & regime recognition

Exceedance Monitoring

- Aircraft operational/parametric data (torque, speed, temperature)

Engine Health

- Power assurance check/Power Management

Rotor Smoothing

- Automated track & balance of rotors to decrease vibrations

Fleet Maintenance

- Logging maintenance actions/CBM data

SRW CBM Focus - Propulsion

Propulsion System Health

- Improved detection techniques
- Improved diagnostic algorithms
  - Multi-sensor data fusion
  - Performance metrics
  - Damage magnitude assessment
- Validated methods – rotorcraft field verification
  - Test methods representative of fielded faults
- Future prognostic algorithms
  - Damage life prediction models – predict remaining useful life

Structural Health & Exceedance Monitoring

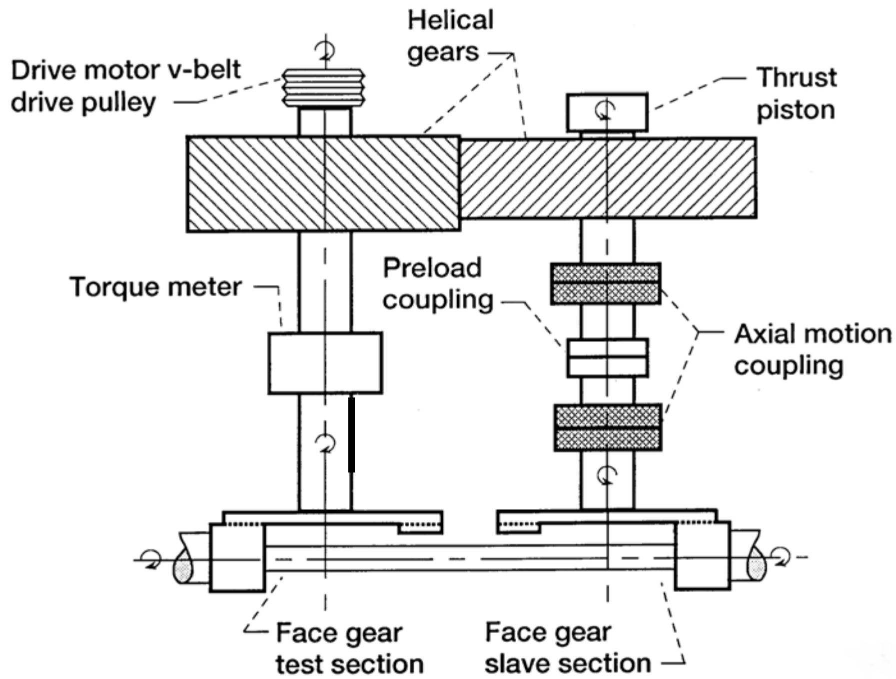
- Correlate aircraft operational parameters to component life.

Research enabled through Partnerships with the FAA and US Army

- FAA funded Space Act Agreements
- Access to > 2000 Army HUMS equipped helicopters

Propulsion System Health

Gear Fault Detection Effectiveness

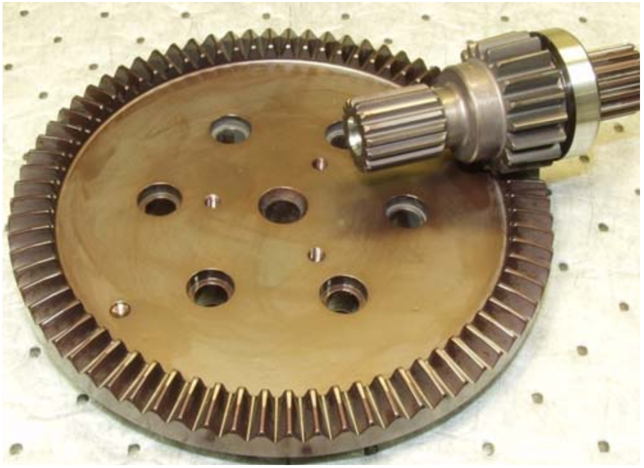


Objective:

- Evaluate gear tooth pitting fatigue fault detection effectiveness
- Evaluate repeatability of gear tooth fault detection methods
- Evaluate CI threshold values

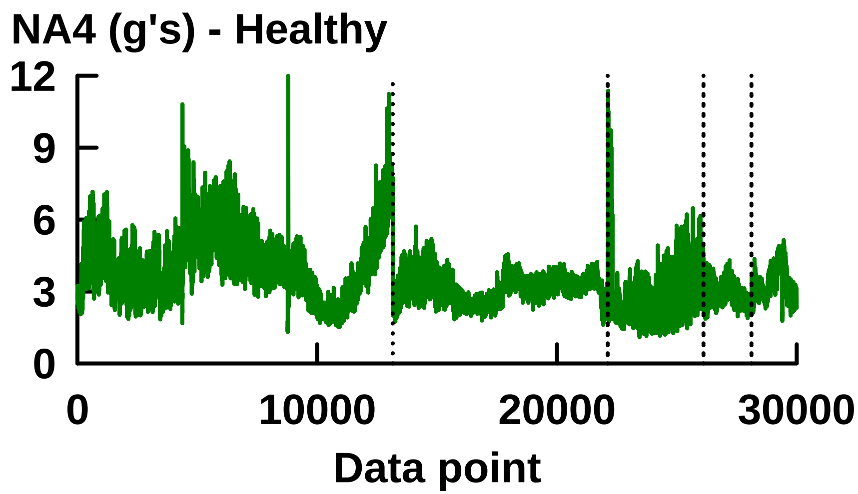
Approach:

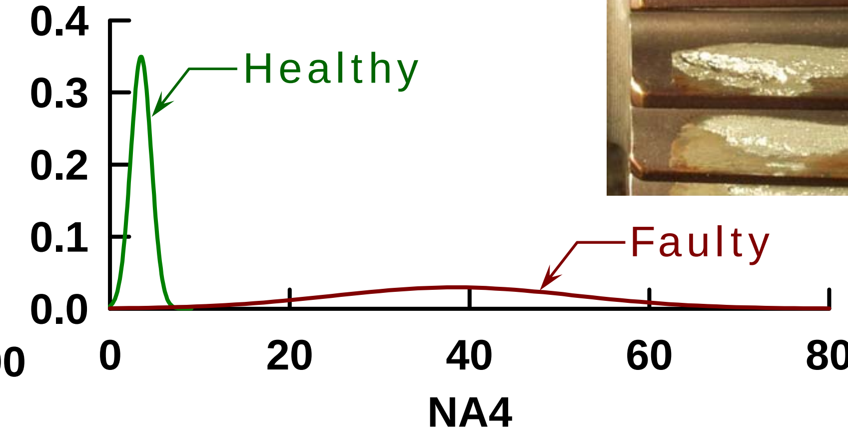
- Test gears: face gears with tapered involute pinions
- Vibration and oil debris monitoring during gear endurance testing
- Evaluate three common vibration CIs (RMS, FM4, NA4)

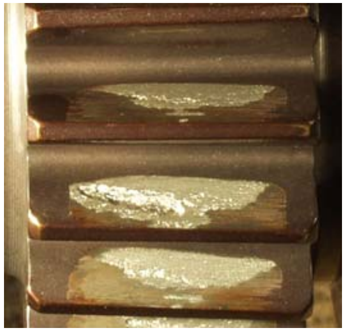


Propulsion System Health

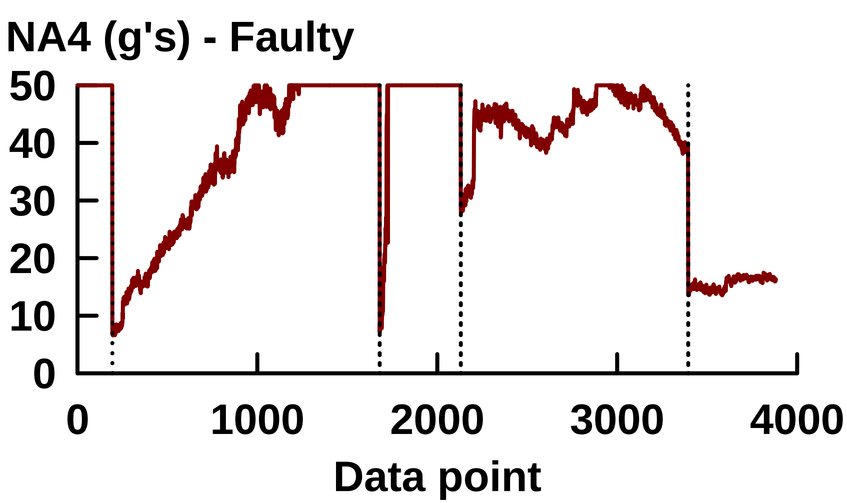
Gear Fault Detection Effectiveness

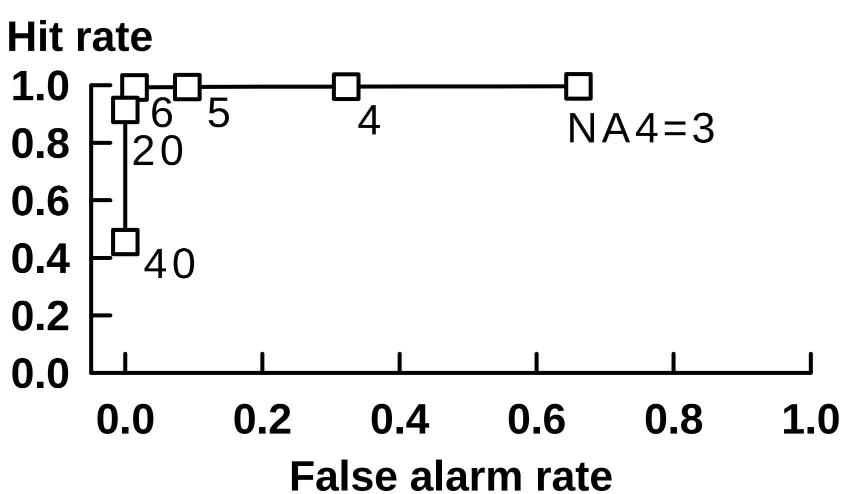






CI: NA4, Macro-Pitting, Single/Few Teeth





Propulsion System Health

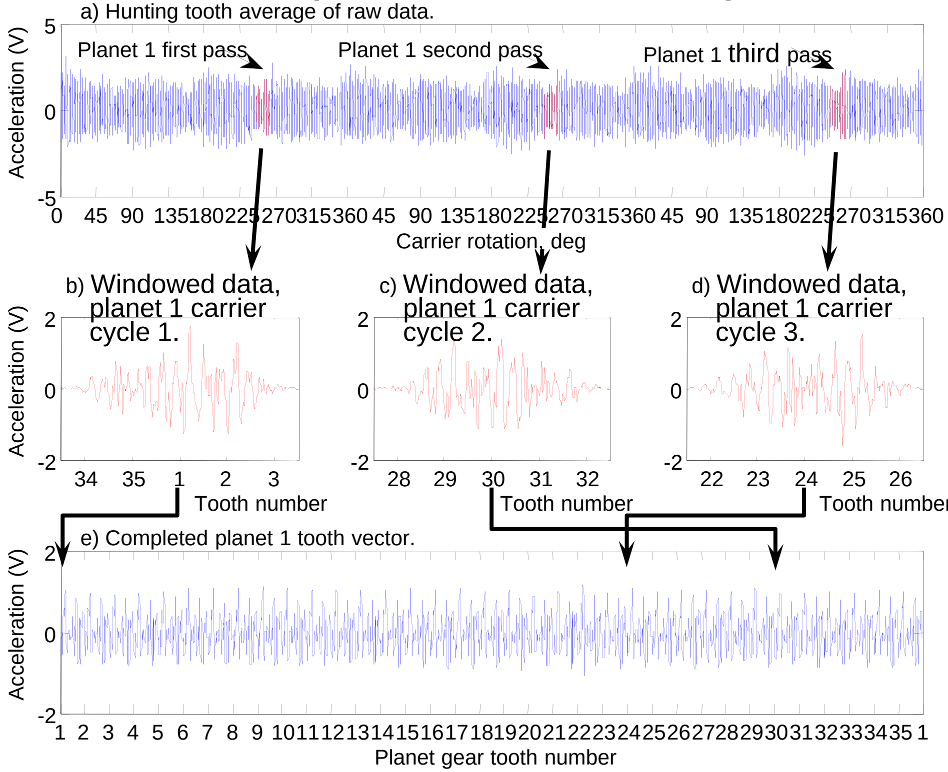
Planetary Fault Detection

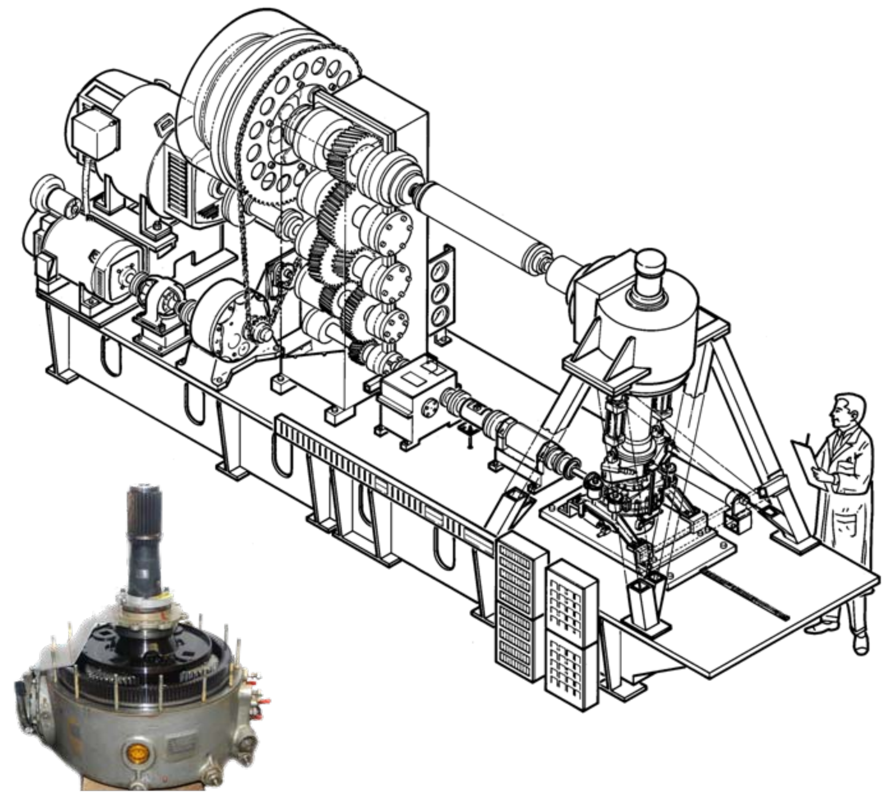
Objective:

Demonstrate diagnostics to detect gear and bearing planetary system faults in main-rotor gearbox

Approach

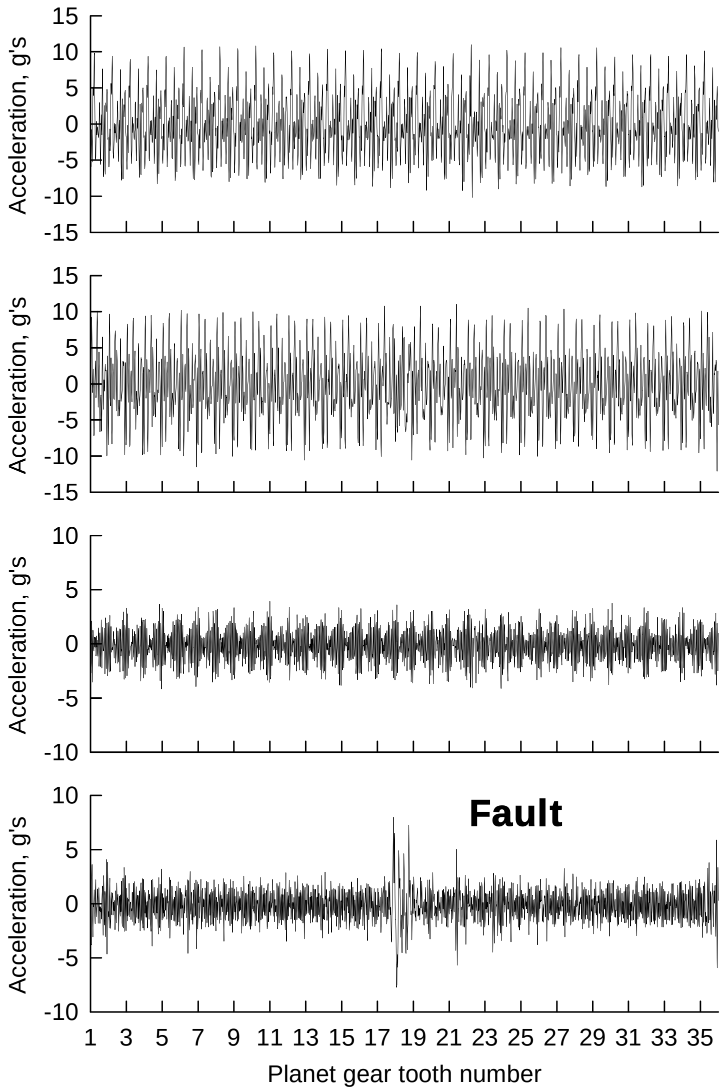
Develop algorithms from seeded fault tests on the OH-58 main-rotor transmission (AATD/Bell OSST)

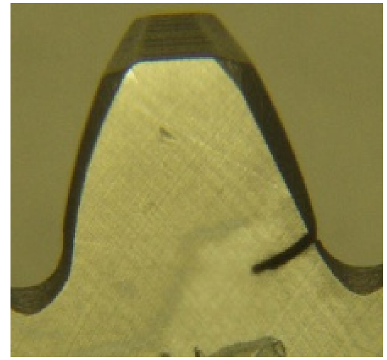


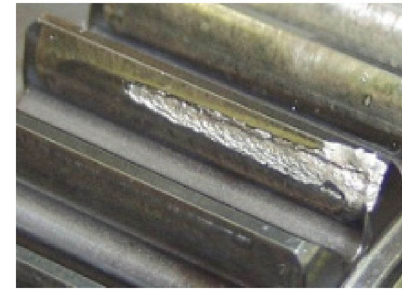


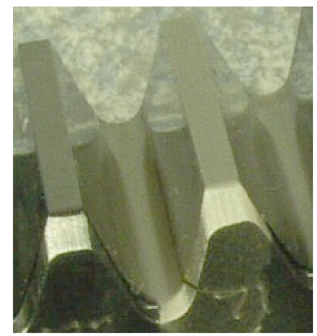
Propulsion System Health

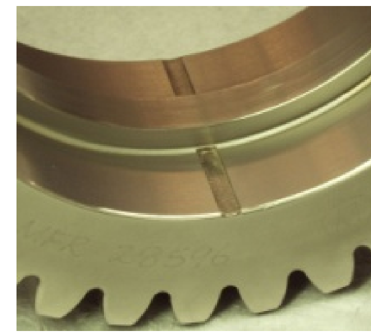
Planetary Fault Detection

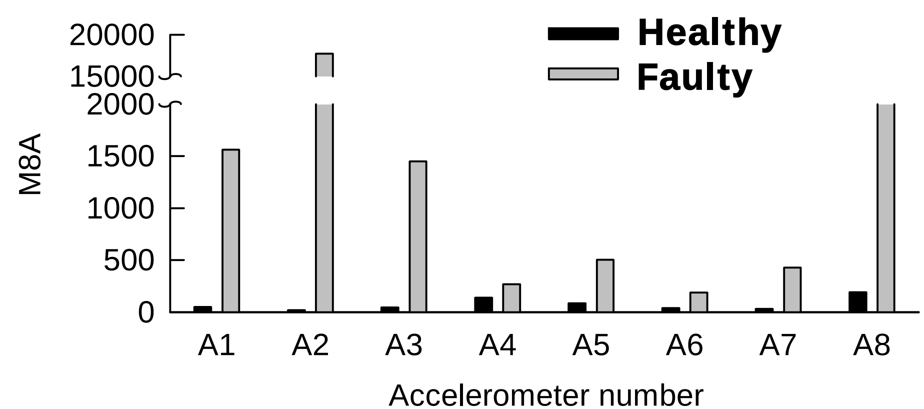








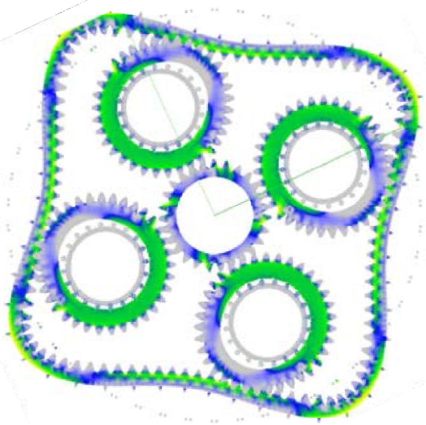




Propulsion System Health

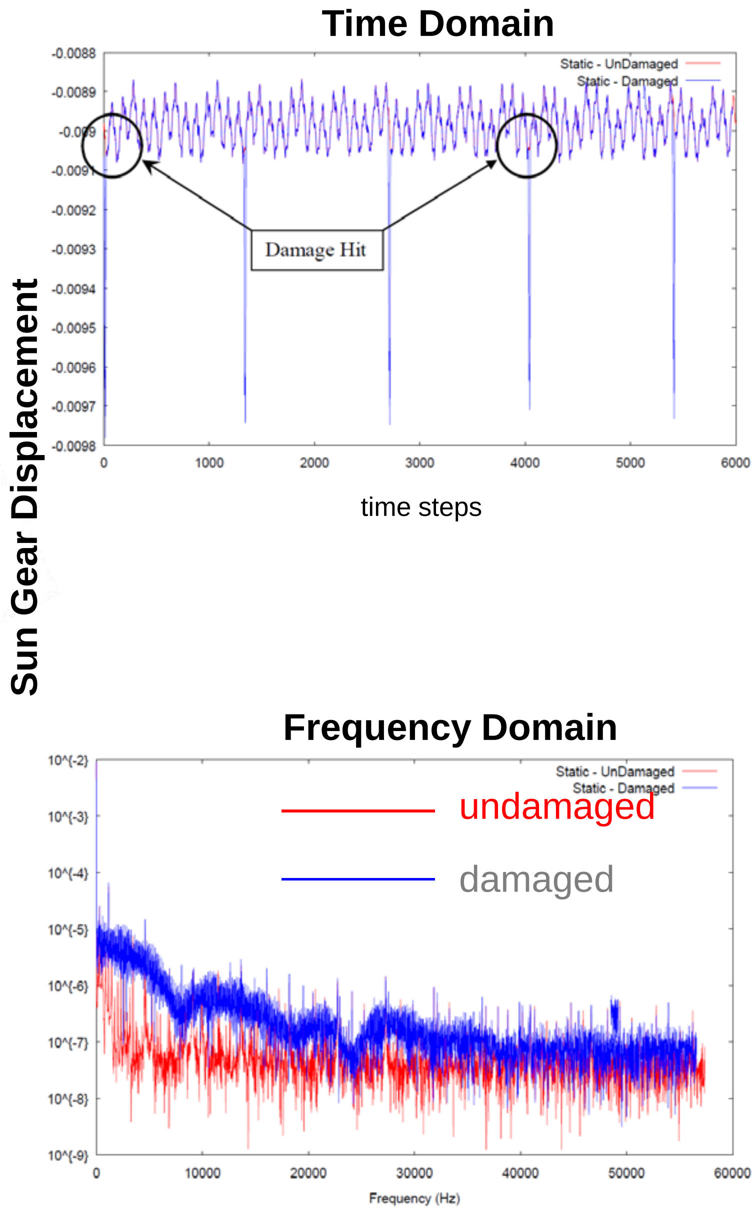
Objective:

Develop analysis method to simulate dynamic response of gear or bearing surfaces with damage



Approach:

- Defect geometries defined by actual measurements
- Forces between components calculated via contact mechanics
- Deformations and vibration responses calculated via finite element



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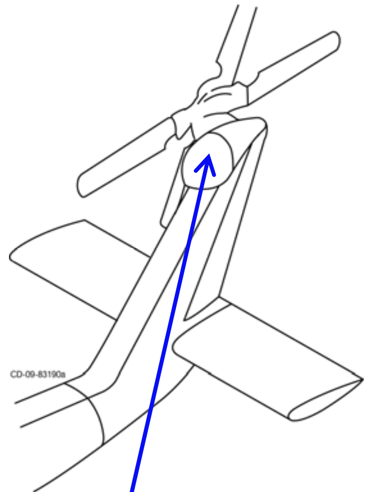
Propulsion System Health

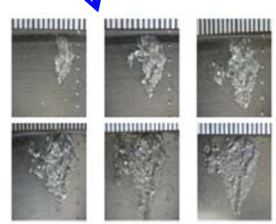
Objective:

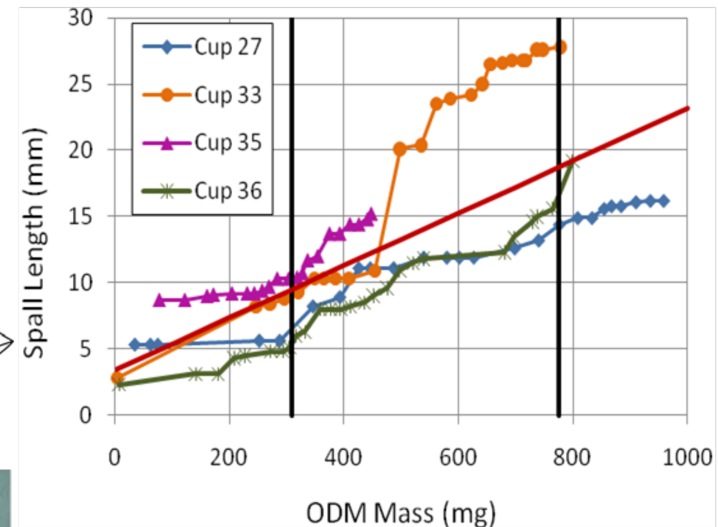
- Demonstrate (CI) responds to failure progression & correlates to remaining useful life

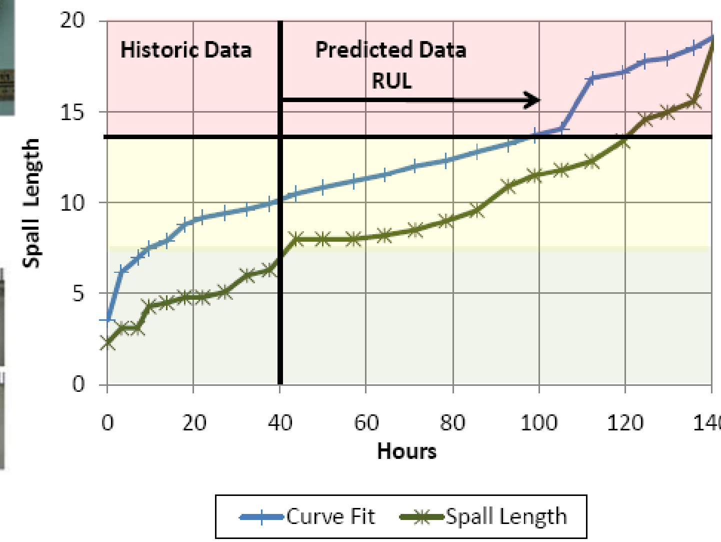
Approach:

- UH60 tail gearbox output shaft thrust bearings
- Removed from helicopters installed in test stand
- Periodic inspections to measure spall growth
- CI data mapped to the damage state did not perform well for magnitude assessment
- Oil debris sensor monitored debris generation & indicated progression & remaining life.









FAA Space Act Agreement

Validation & Demonstration of HUMS for Maintenance Credits,
modified inspection & removal criteria,
via FAA AC-29-2C, Section MG-15

Objectives:

- Develop CI validation methods in the lab that represent fielded faults
- Identify limitations of seeded fault data sets.
- Case Study: Component with naturally occurring faults in the field and test stand.
  - ✓ Spiral bevel gears in the Apache nose gearbox (NGB)
  - ✓ Spiral bevel gears tested in the Spiral Bevel Gear Fatigue Test Rig

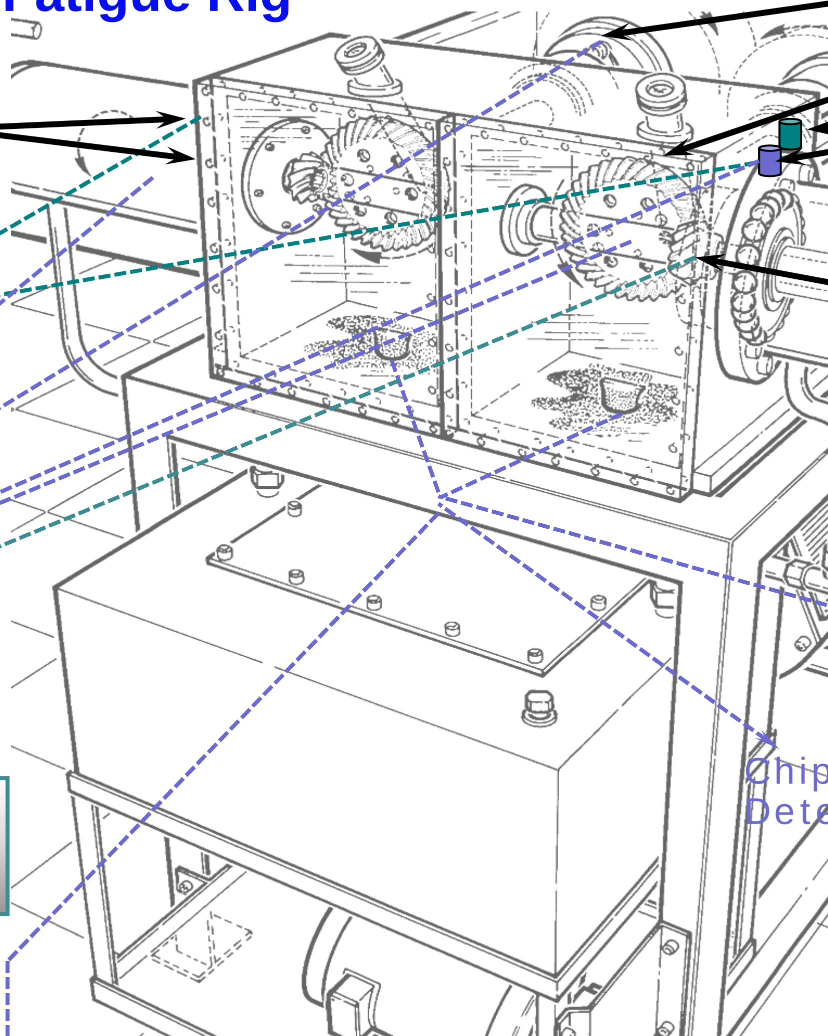
Approach

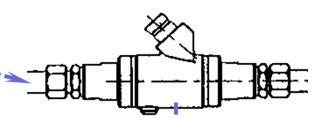
- Rig gears designed/tested with loads/speed scaled to NGB
- Field units studied for failure modes & operational environment
- Field/Rig data studied for CI performance
- Usage data studied to determine if failure can be correlated to usage

Collaborative Team Effort: FAA, US Army, NASA, Boeing

FAA Space Act Agreement

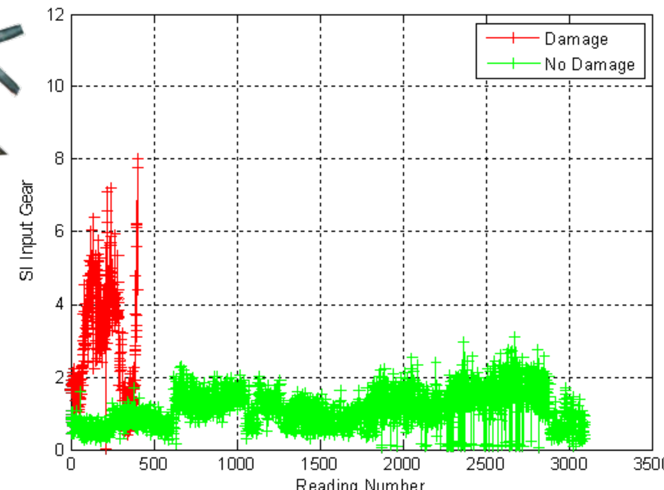
Spiral Bevel Gear Fatigue Rig



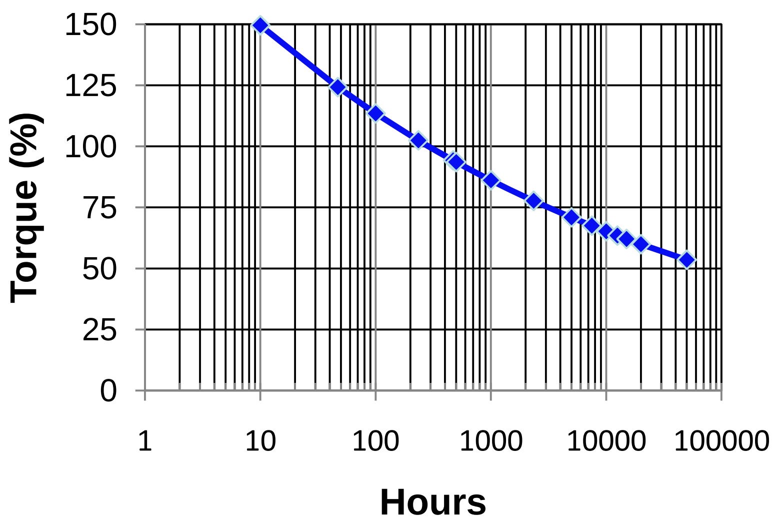


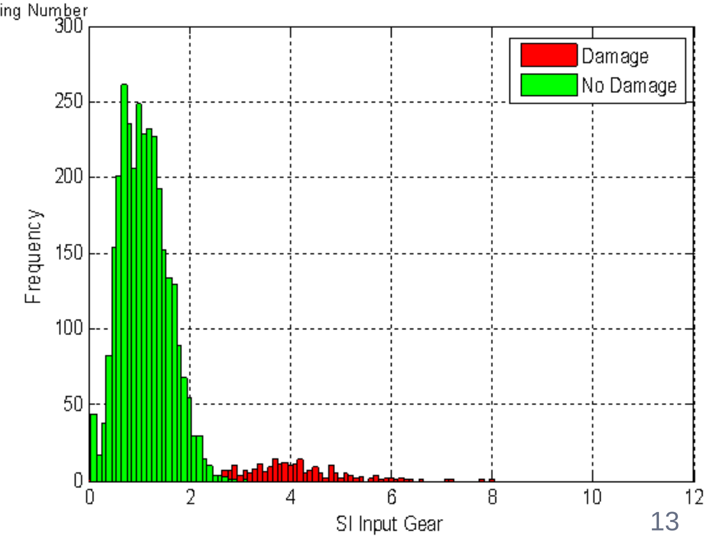
FAA Space Act Agreement

Assess CI performance from field & lab



Correlate usage to failures





SRW Phase II SBIR

Embedded Data Acquisition Tools for Rotorcraft HUMS (Ridgetop)

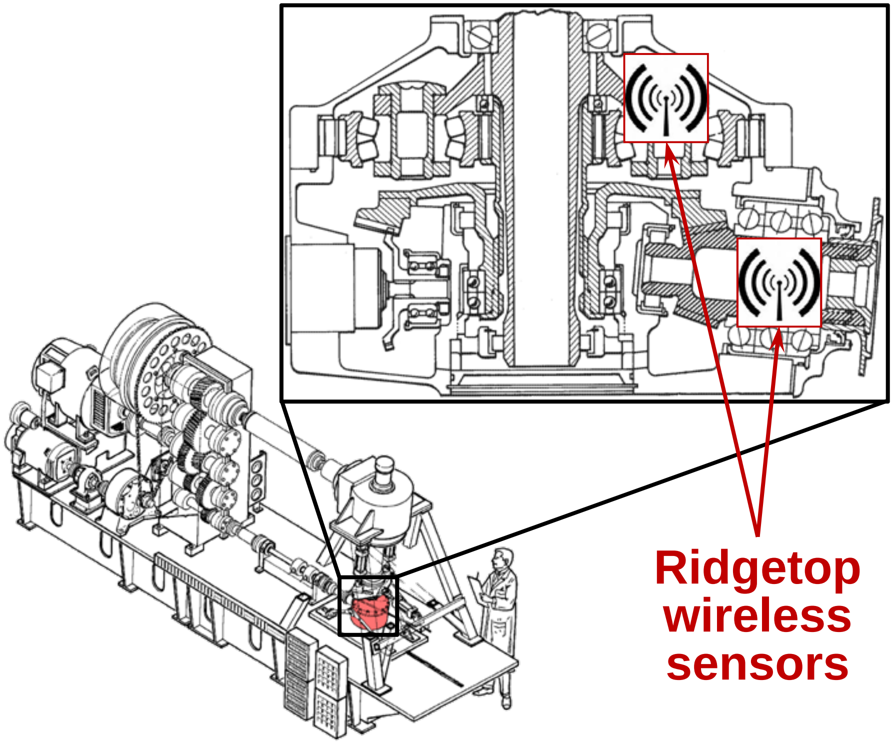
Objective:

Develop MEMS wireless sensor for fault detection in rotorcraft transmission applications

Approach:

- Develop MEMS vibration-monitoring accelerometer, microcontroller conditioner, wireless transmitter, and receiving unit for data collection.
- Mount directly on helicopter transmission component of interest to measure abnormalities and faults.

OH-58 main rotor transmission



NASA GRC 500-hp transmission test facility

SRW Phase I SBIR

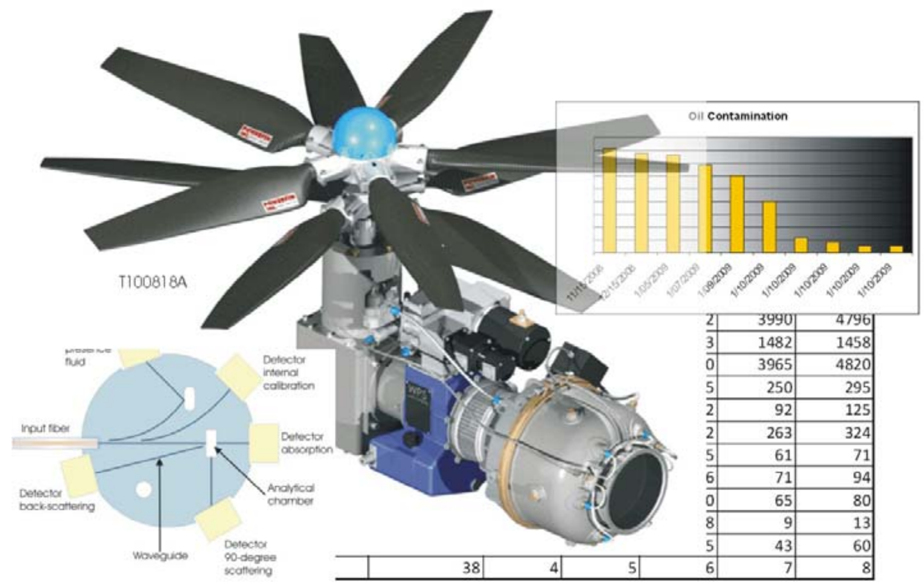
Optical oil-debris sensor for rotorcraft health monitoring (Translume)

Objective:

Develop an oil debris sensor to monitor rotorcraft power train oil.

Approach:

- Develop sensor to simultaneously detect both metallic and non-metallic debris
- Optimize sensor to detect, count and size particles
- Conduct a feasibility demonstration on a laboratory scale



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