Reliability Improvement Projects (RIP)

Acknowledgements

- **Effort funded by the Government under Contract No. W911W6-07-D-0002**
- **Government: US Army**
  - ✓ **AMRDEC RAM Organization**

AH-64 Project Summary

RAM **Complete**
- Phase Kitting
- PIA Complet

RAM
- Improved Tail Rotor Blade
- GWOT/OMA

RAM **Complete**
- Main Rotor Blade Wedge Track & Balance
- PIA Complete

RAM **Complete**
- APU Mount
- AWCF

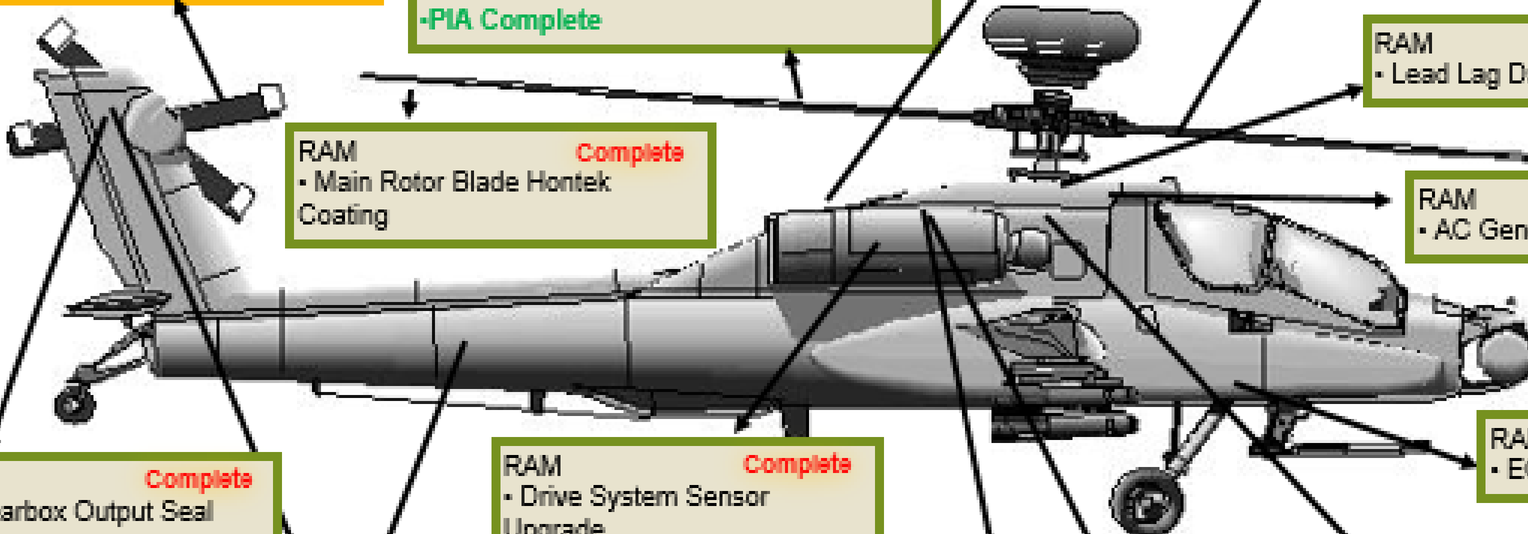
RAM **Complete**
- APU clutch
- PIA Complete

RAM **Complete**
- Inconel Leading Edge Project

RAM **Complete**
- Lead Lag Damper/Trunnion

RAM **Complete**
- Main Rotor Blade Hontek Coating

RAM **Complete**
- AC Generator Mag Seal



RAM **Complete**
- T/R Gearbox Output Seal

RAM **Complete**
- Drive System Sensor Upgrade

RAM **Complete**
- ECS Modulating

RAM
- Block III Drivetrain Vibration

RAM **Complete**
- Accessory Gearshaft Restoration

RAM **Complete**
- Sprag Clutch Prognostics/Diagnostics

RAM **Complete**
- Isotropic Super Finish Apache Drivetrain

RAM
- Formsprag Clutch

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

AH-64 Sprag Clutch Diagnostics

AMRDEC

Description

DLA

IMMC

Problem:

Establishment of dynamic foot-print of critical aircraft components and Condition Indication (CI) based on known data and seeded fault to support replacement of TBO philosophy with a CBM approach.

Solution:

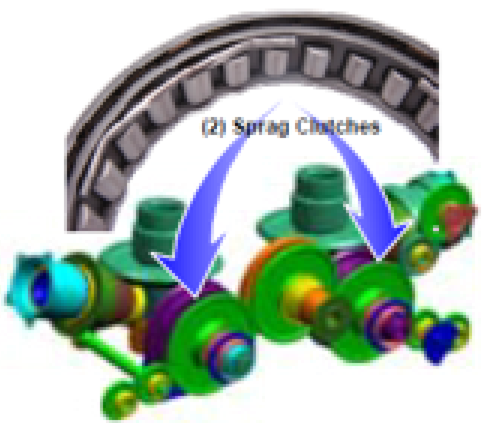
Use existing aircraft sensors to develop algorithms with the ability to detect impending failure of the AGB clutch long before it deteriorates to a condition likely to fail. Transition solution to a Condition Based Maintenance (CBM) environment supporting reduction of Operation and Support (O&S) cost for the Apache. Conducts prognostics development of CI and algorithms, and demonstrates through US Army's MPSU integration. Boeing CBMI program shall support Army Aviation on the CBM integration process.

Status

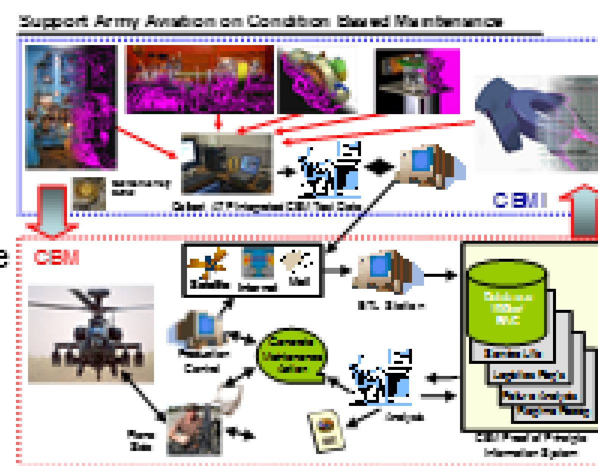
COMPLETE

- All technical work completed
- **Results increased RC from 1000 hours to 2000 hours**
- Refined Dynamic Model for AED to include pop and roll over condition indications
- Tore down over 30 Sprag Clutches from Fort Rucker and other testing to improve life
- **Innovative method was created and integrated into the MSPU to detect whether the accessories are being driven by the primary 85-tooth gear/clutch or the secondary 84-tooth gear/clutch.**
  - **Found several gearboxes with reversed install of these gears in the field.**

Technical Work Completed



Enabler for Army's Condition-Based Maintenance initiative



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Boeing Defense, Space & Security
Phantom Works

Condition Based Maintenance Integration Diagnostics/Prognostics of the AH-64 Main Transmission Accessory Sprag Clutch

Hieu Ngo, Richard Weisenburger, Douglas Knapp
Technology Department / Phantom Works
The Boeing Company, Mesa, Arizona

Damian Carr, Jeremy Partain
U.S. Army Apache Systems
RDMR & AMRDEC –AED, Huntsville, Alabama.

Presented at the American Helicopter Society 67th Annual Forum, Virginia Beach, Virginia, May 3-5, 2011

Outline

Introduction:

- CBMI
- Transmission/Clutch System Configuration

Approach:

- Analyze Available Data
- Modeling-Based
- Experimental-Based

Validation:

- Baseline
- Seeded fault

Conclusions / Plan Forward

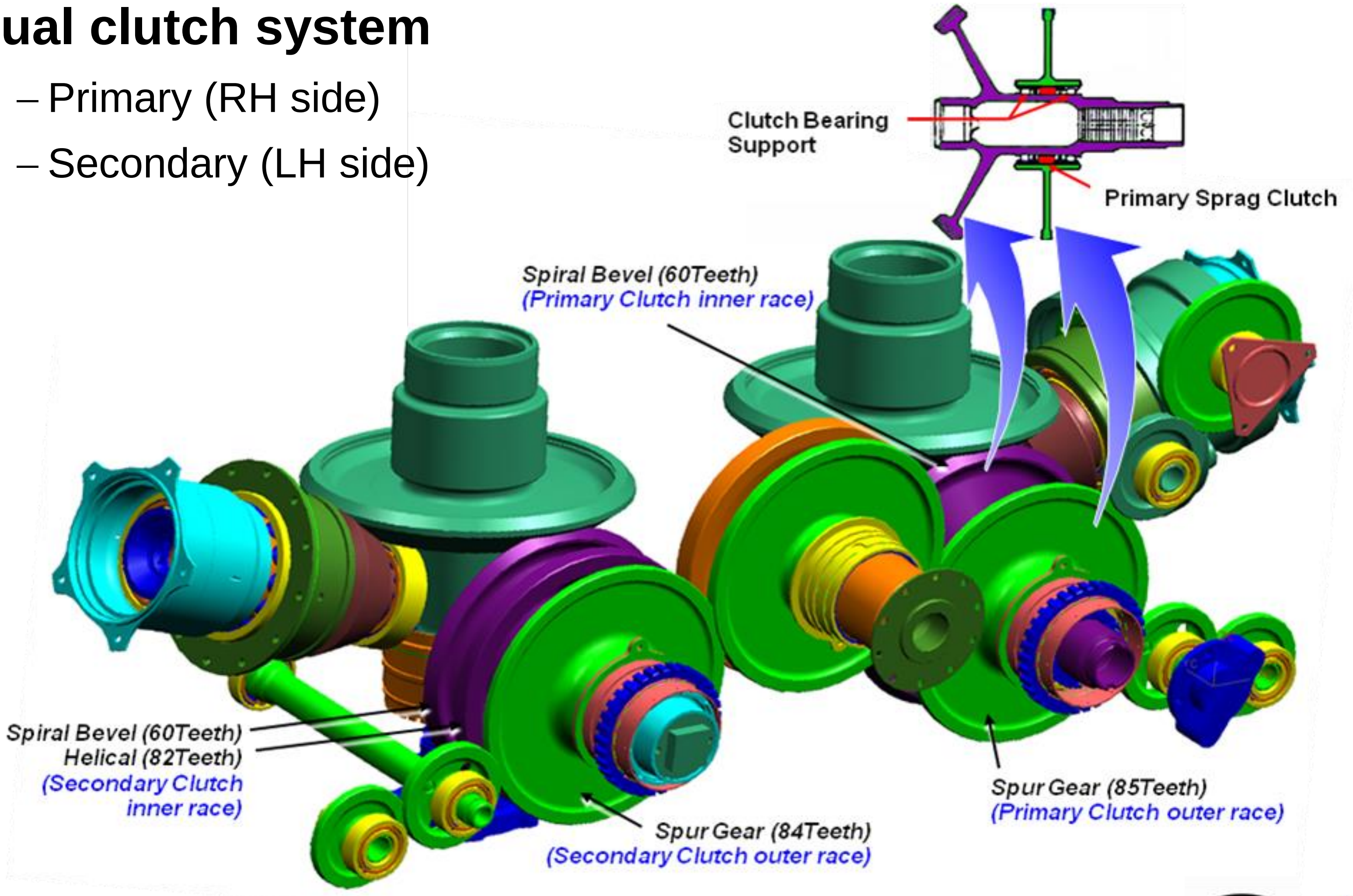
CBMI for AH64 Sprag Clutch

- **CBMI (Condition Based Maintenance Integration)**
  - Identify failure modes of critical aircraft components with degradation phenomenon, to define dynamic footprint
  - Existing Aircraft: provide dynamic footprint to identify effective seeded fault testing
  - New Aircraft: CBM data captured during design, developmental testing, qualification, and acceptance test phase

- **AH64 Sprag Clutch (Main Transmission Accessory Section)**
  - Objectives:
    - Characterize dynamic behavior of the sprag clutch at different states of clutch degradation
    - Obtain measured data during sprag clutch engagements to support the Army CBM program by developing a ***CI for clutch degradation algorithms***

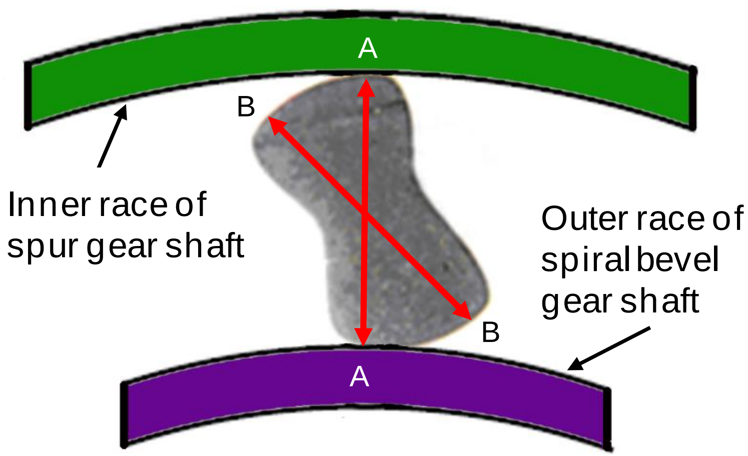
AH64 A/D Main Transmission Acc Section

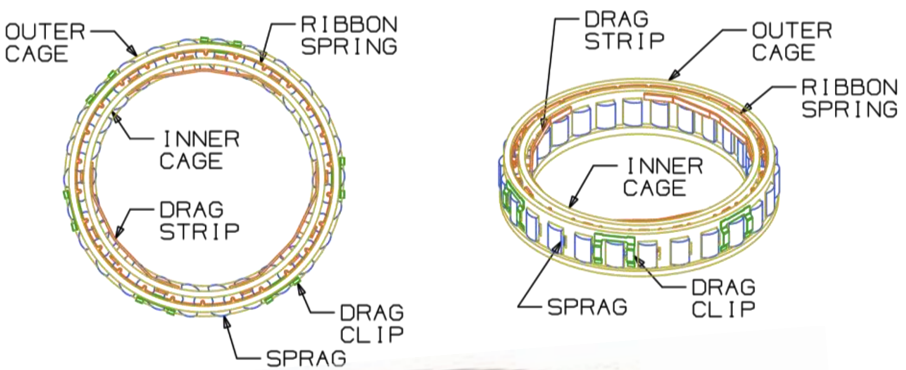
- **Dual clutch system**
  - Primary (RH side)
  - Secondary (LH side)



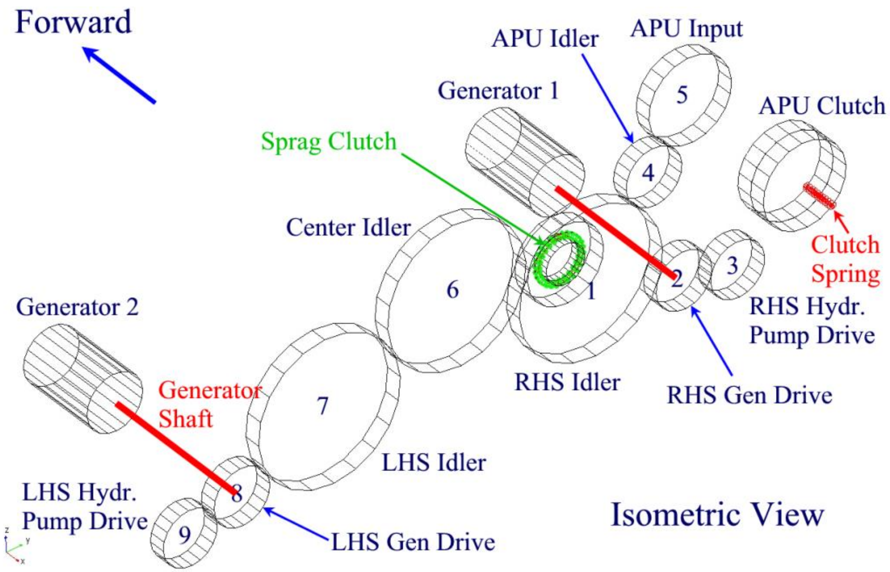
Sprag Clutch Design

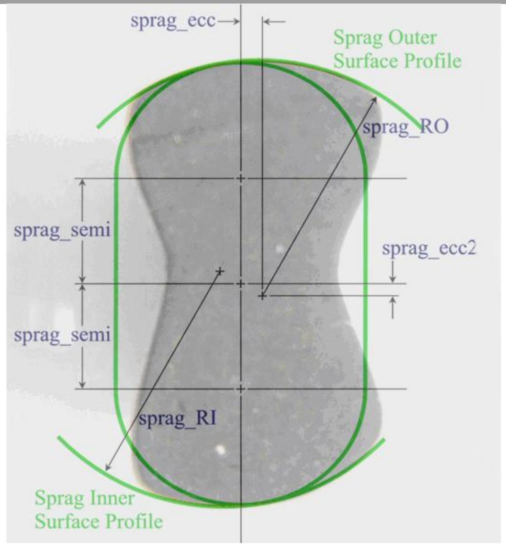
- **Engage/disengage based on relative speed inner/outer races**
  - Disengage position “slips”
  - Engaged position transmits torque between races

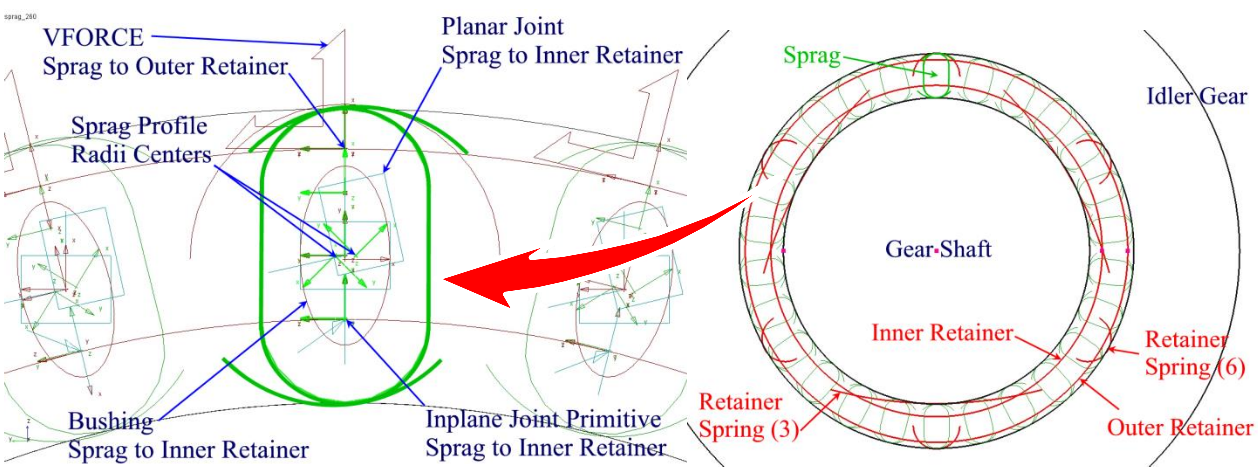




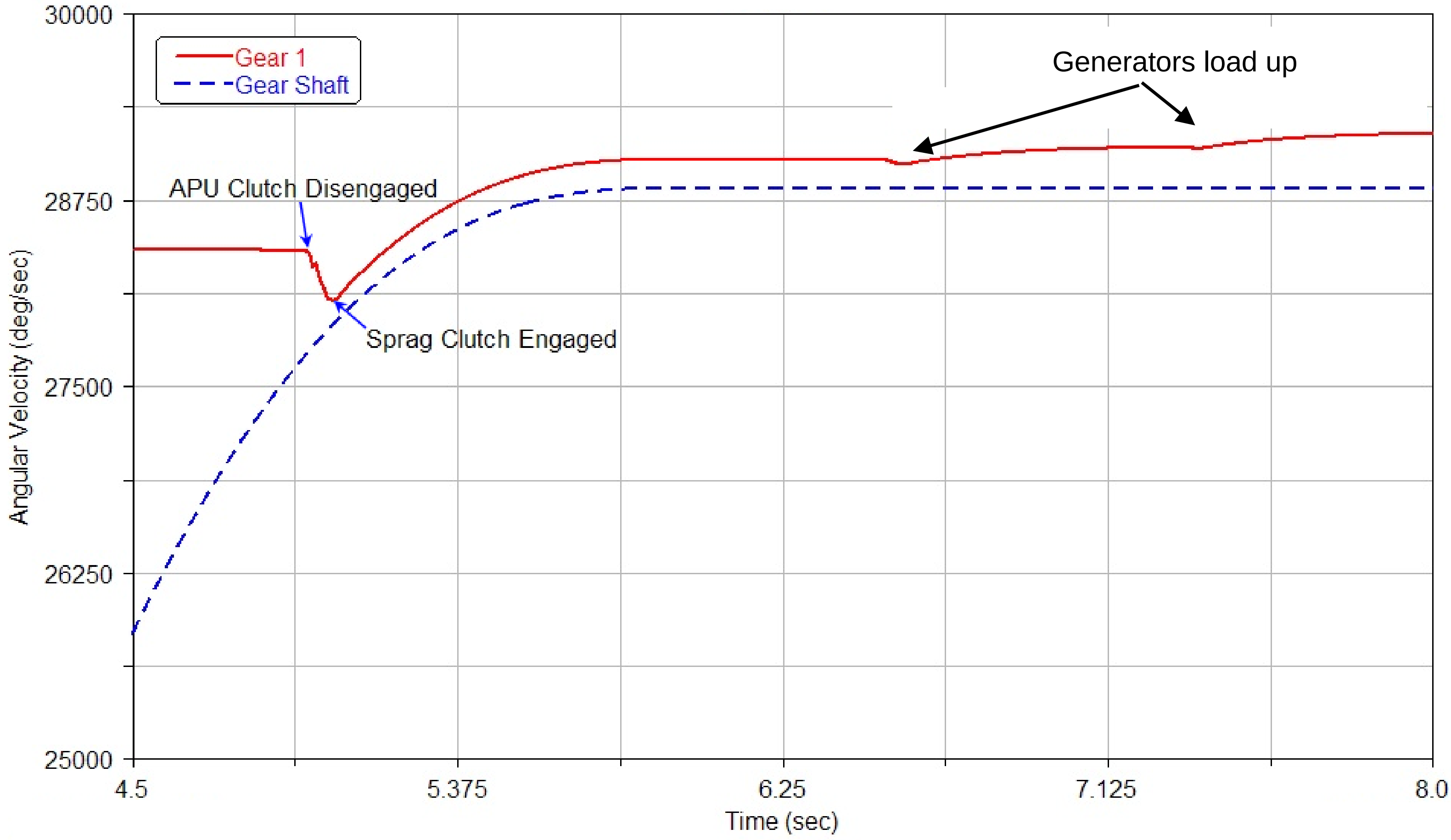
ADAMS Model


Forward
APU Idler
APU Input
Generator 1
5
APU Clutch
Sprag Clutch
4
Center Idler
Clutch
Spring
6
1
2
3
Generator 2
RHS Hydr.
Pump Drive
Generator
Shaft
7
RHS Idler
RHS Gen Drive
LHS Idler
LHS Hydr.
Pump Drive
8
9
LHS Gen Drive
Isometric View


sprag_ecc
Sprag Outer
Surface Profile
sprag_RO
sprag_semi
sprag_ecc2
sprag_semi
sprag_RI
Sprag Inner
Surface Profile


VFORCE
Sprag to Outer Retainer
Planar Joint
Sprag to Inner Retainer
Sprag
Idler Gear
Sprag Profile
Radii Centers
Gear Shaft
Inner Retainer
Retainer
Spring (6)
Retainer
Spring (3)
Outer Retainer
Bushing
Sprag to Inner Retainer
Inplane Joint Primitive
Sprag to Inner Retainer

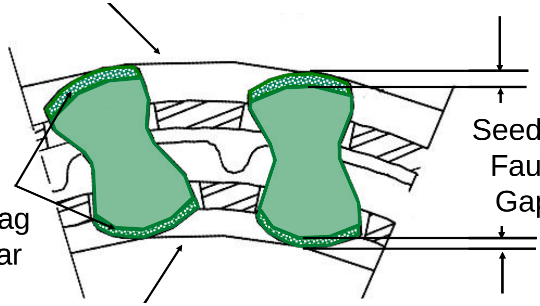
Model Results (Baseline)

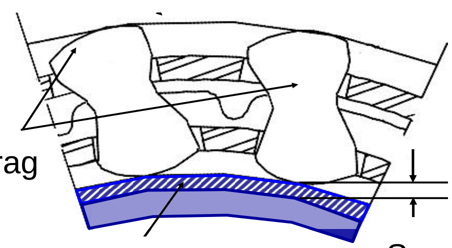


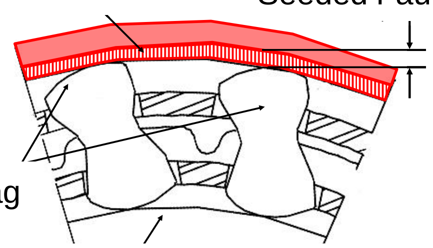
Inner and Outer Races of the Sprag Clutch speed During Normal Clutch Engagement

- **Access Select Analyze and Present flight test database**

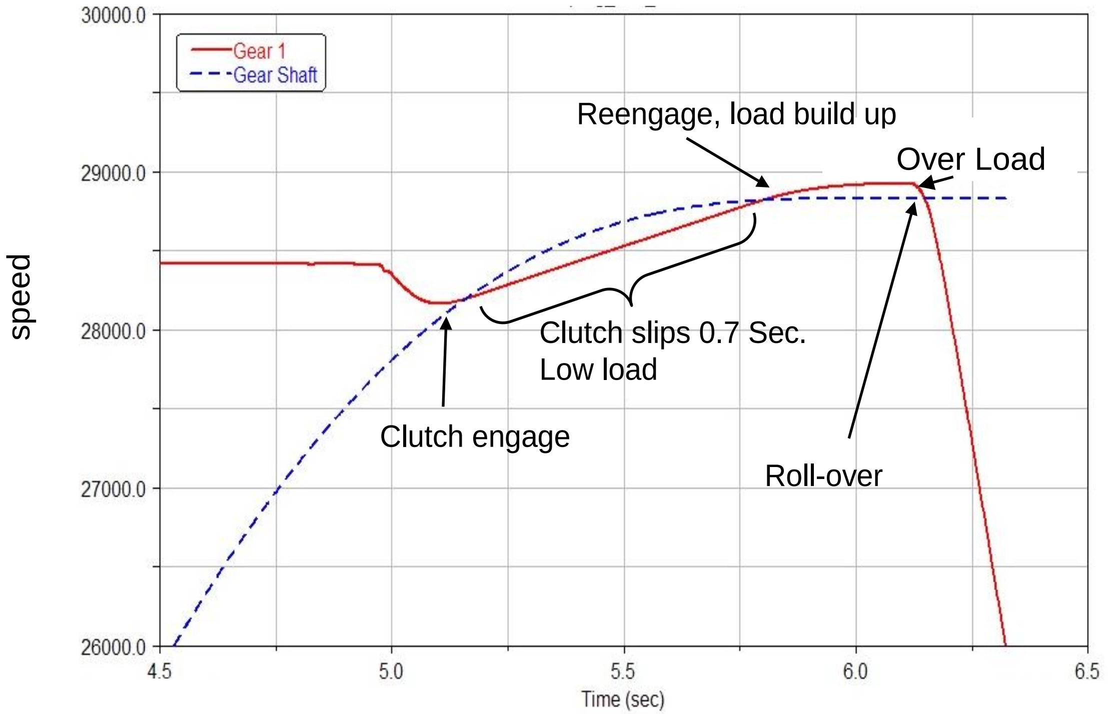
Model Results (Wear Seeded Faults)





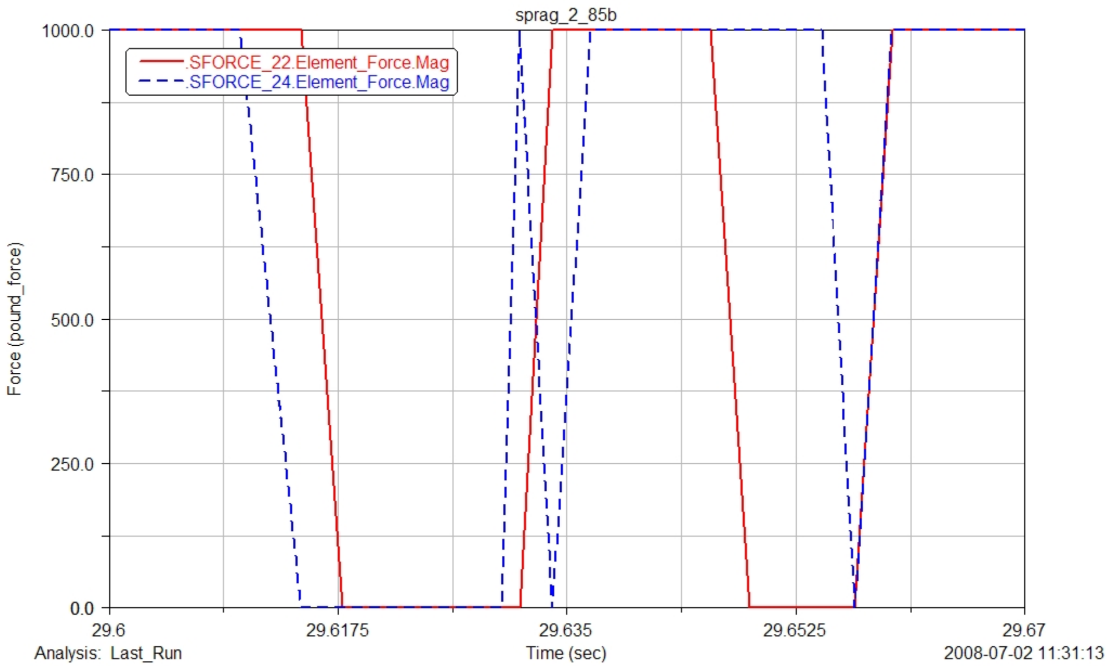


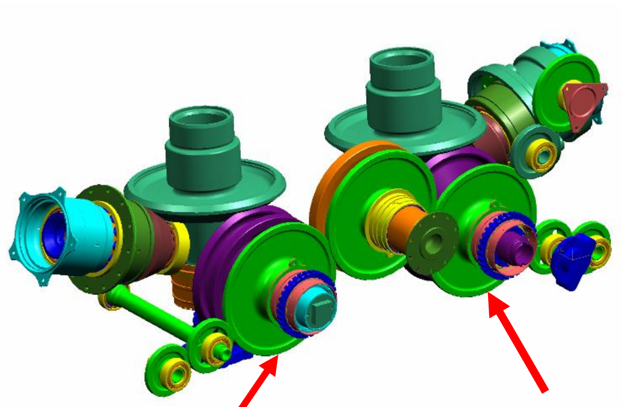
- **Clutch failure due to the simulated sprag wear**



Model Result (Chatter with Identical Gears)

- **Extreme condition (shaft speeds same), Primary/Secondary clutches "fight" for engagement**
- **Model predicted chatter**



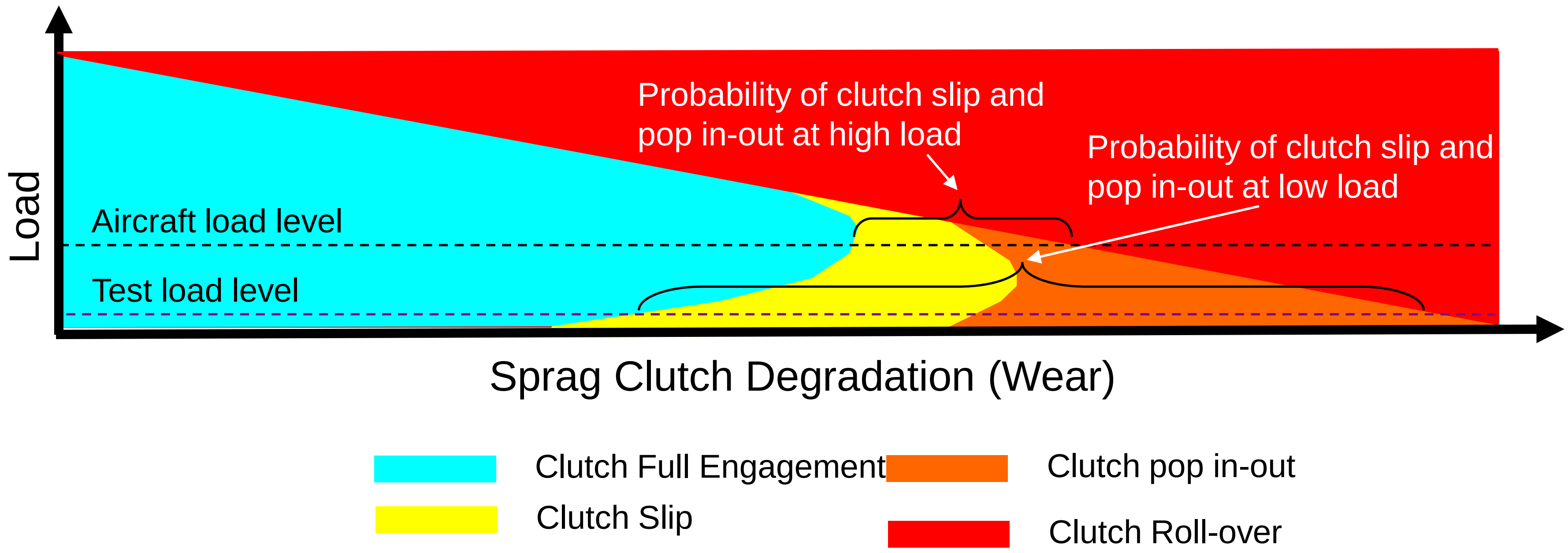


Spur Gear (85 Teeth)

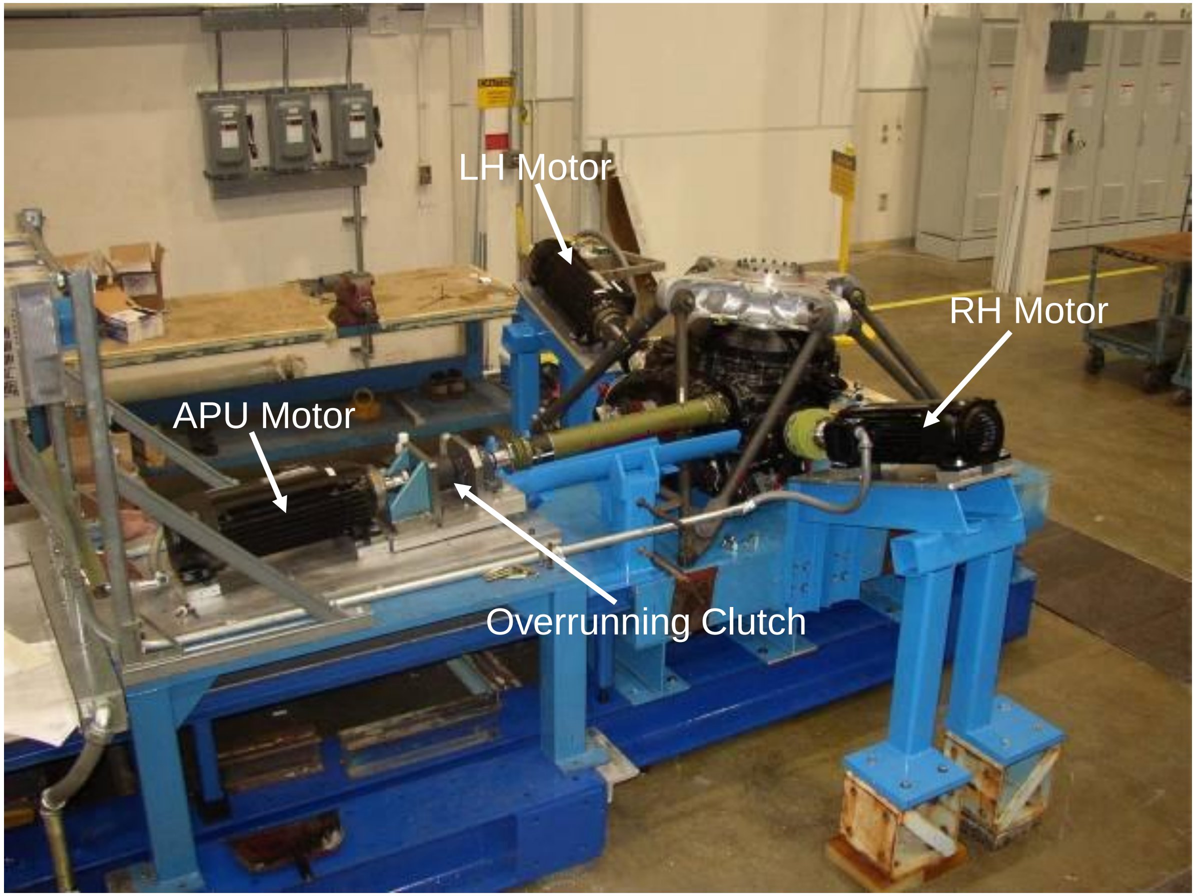
Spur Gear (84 Teeth)

Clutch Behavior (Non linear)

- **Clutch behavior differs (non linearly) as function of load and state of wear**
- **Clutch slip and pop more susceptible at low loads**

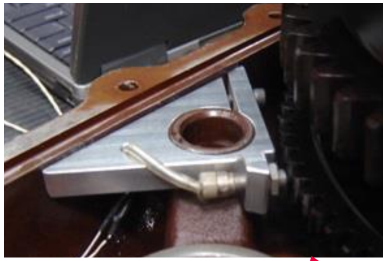


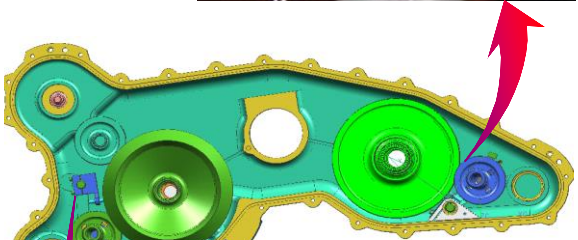
Test Rig (for Seeded Fault Testing)



CBMI Test Rig

Secondary sprag clutch
outer race speed sensor

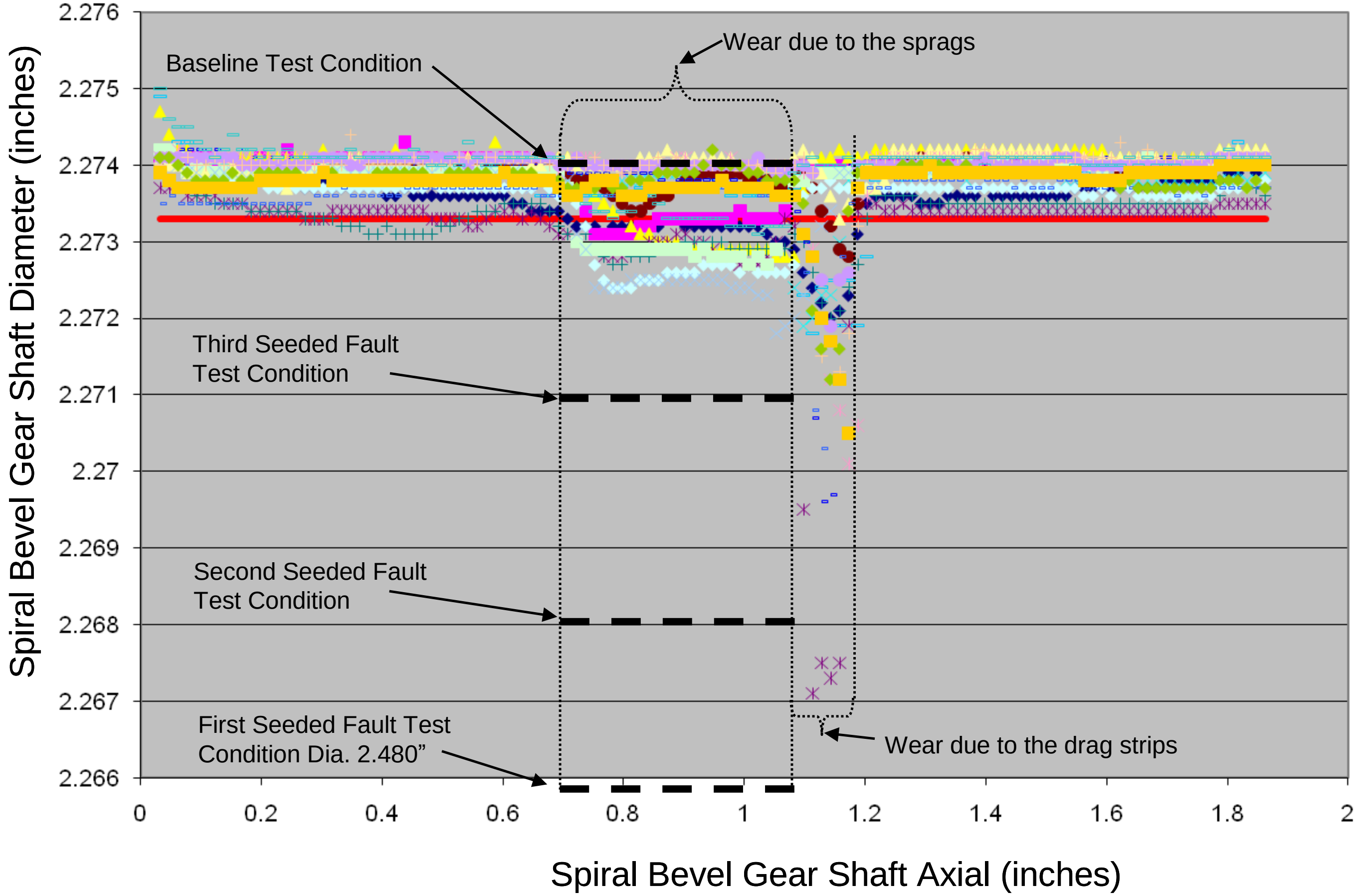




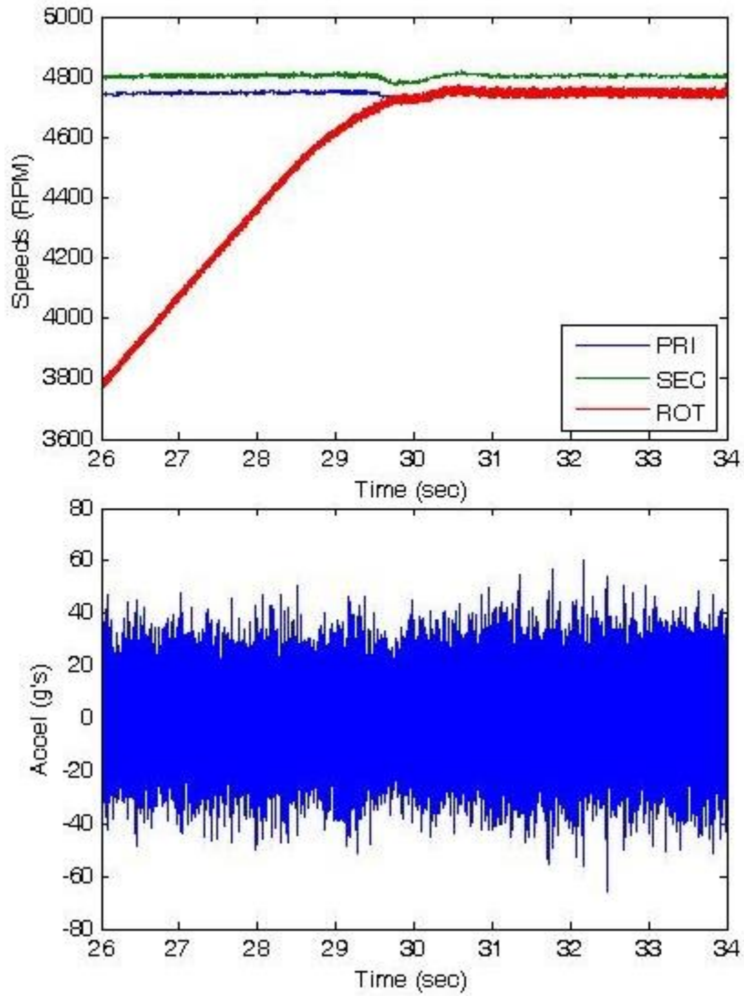
Primary sprag clutch
outer race speed sensor

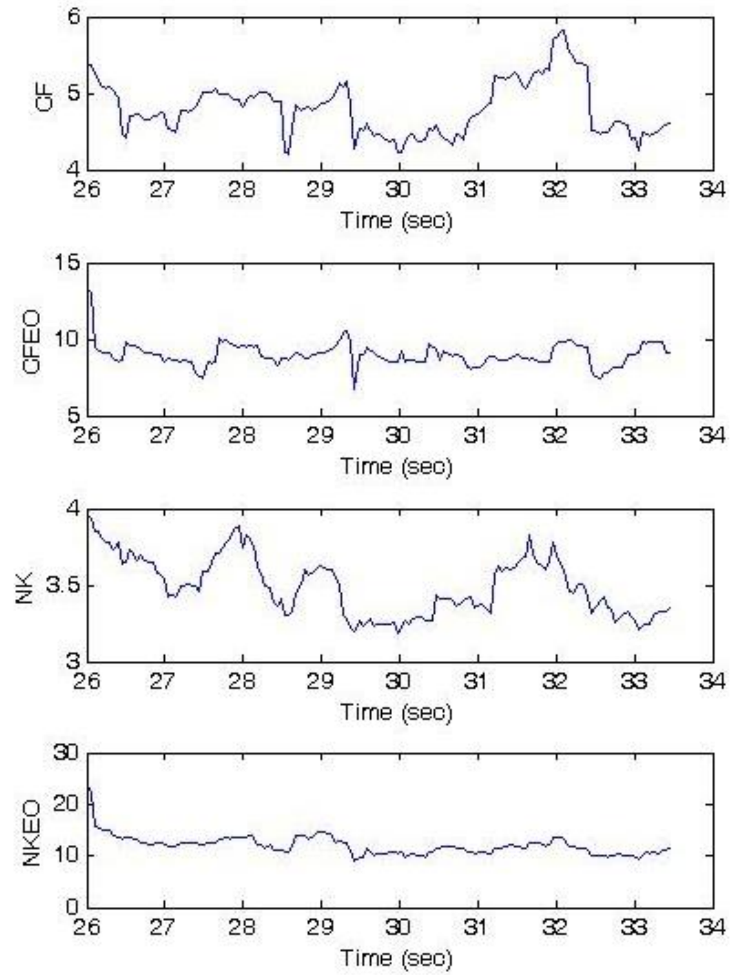
Wear Grooves from Field (Inner Race)

- **Inner race wear was measured from service parts**
- **Seeded faults were established based on wear measurements**

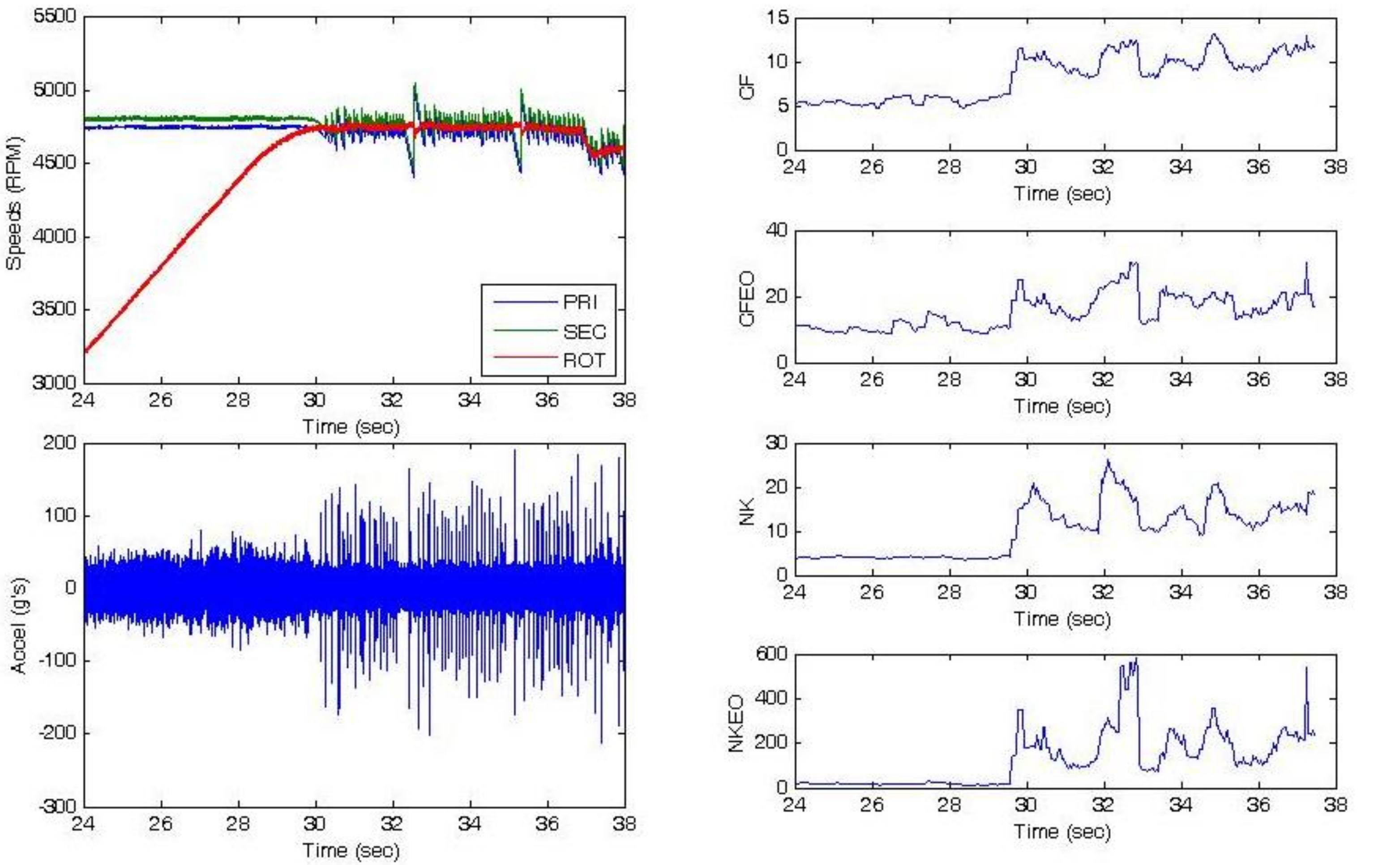


Baseline Test Result (Speed, Accel, CI)

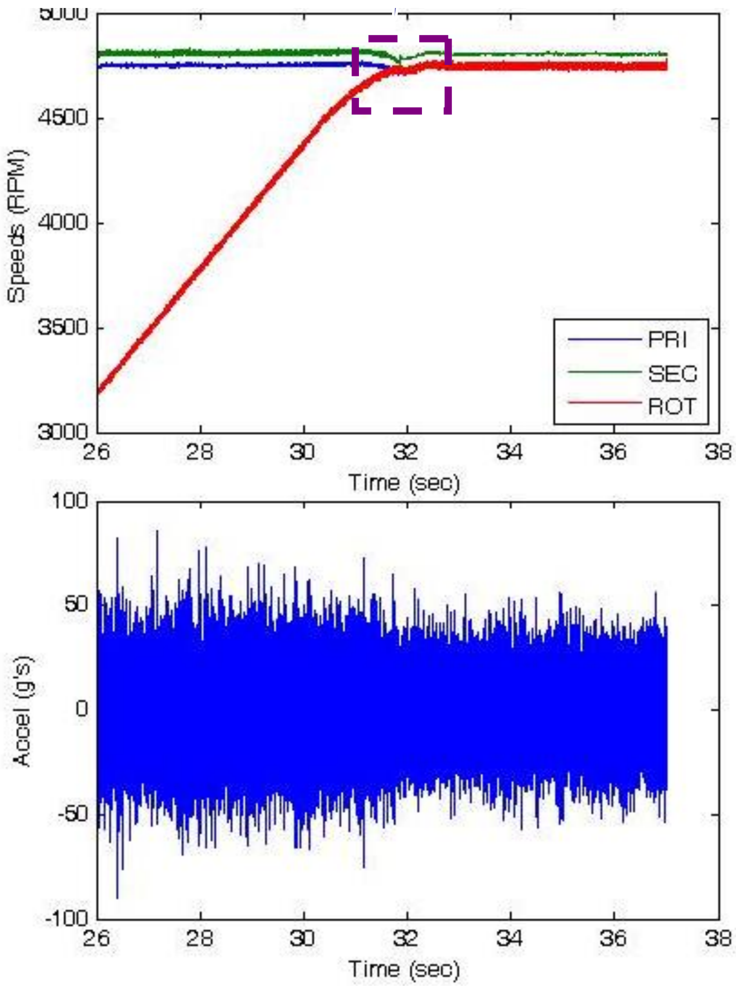


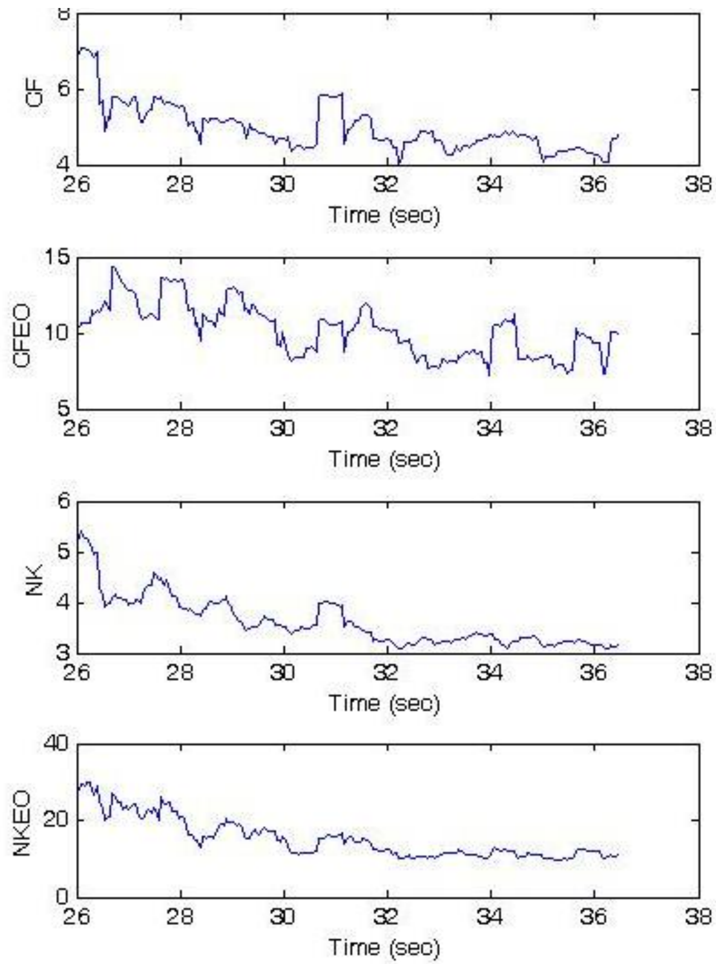


Seeded Fault Test Result (Speed, Accel, CI)



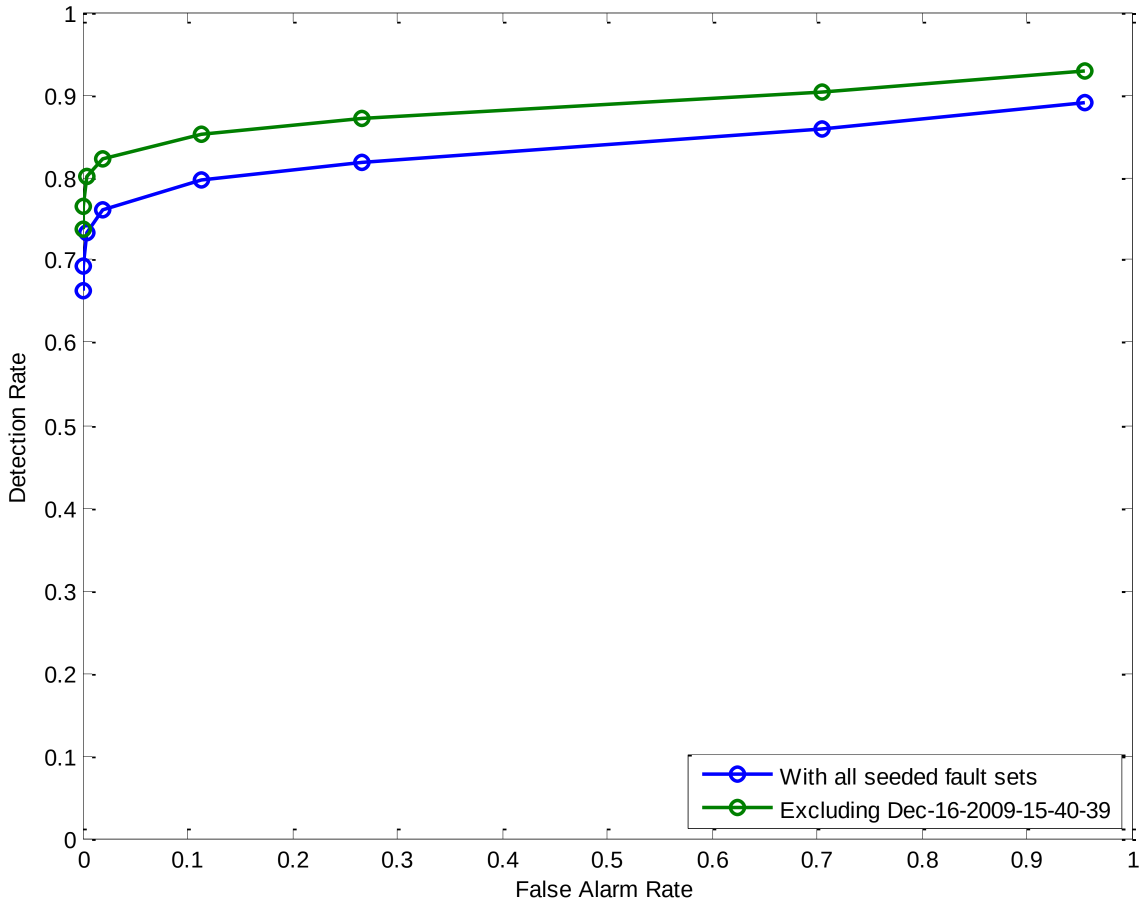
Seeded Fault Test Result (Speed, Accel, CI)





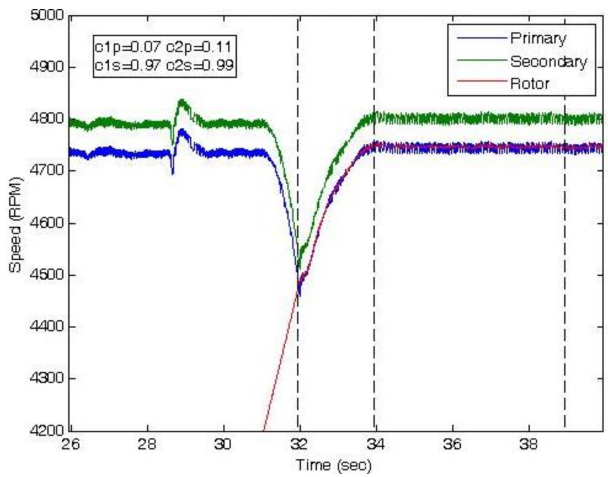
Accelerometer Inadequate for Detection

- **For Detection rate >90%, False Alarm rate > 70%**

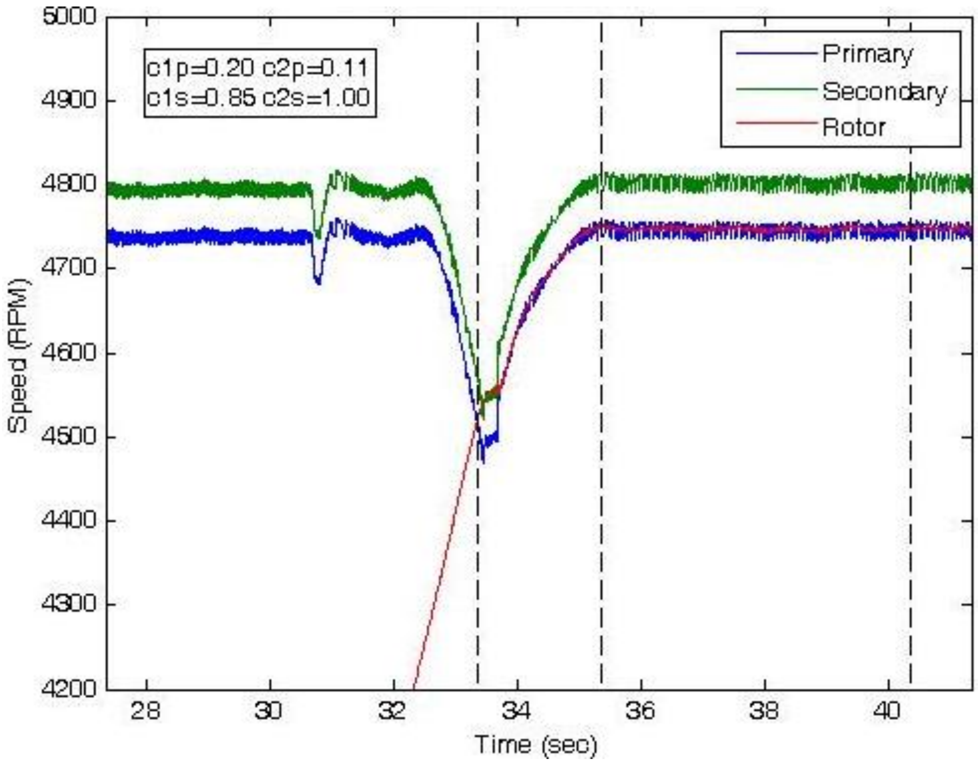


Seeded Fault Test Results (Speed)

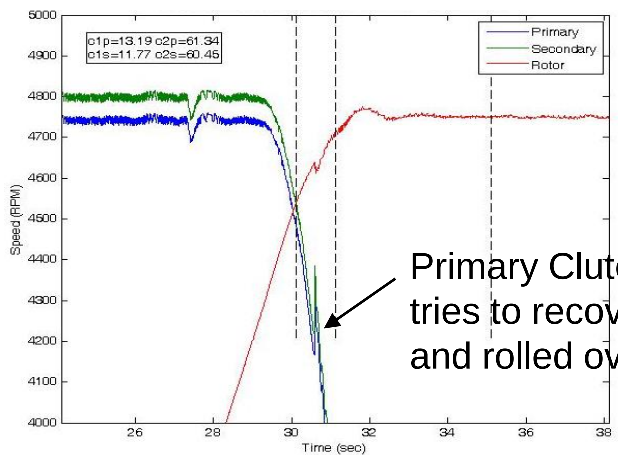
Baseline (normal engagement)



Seeded Fault (primary slip)



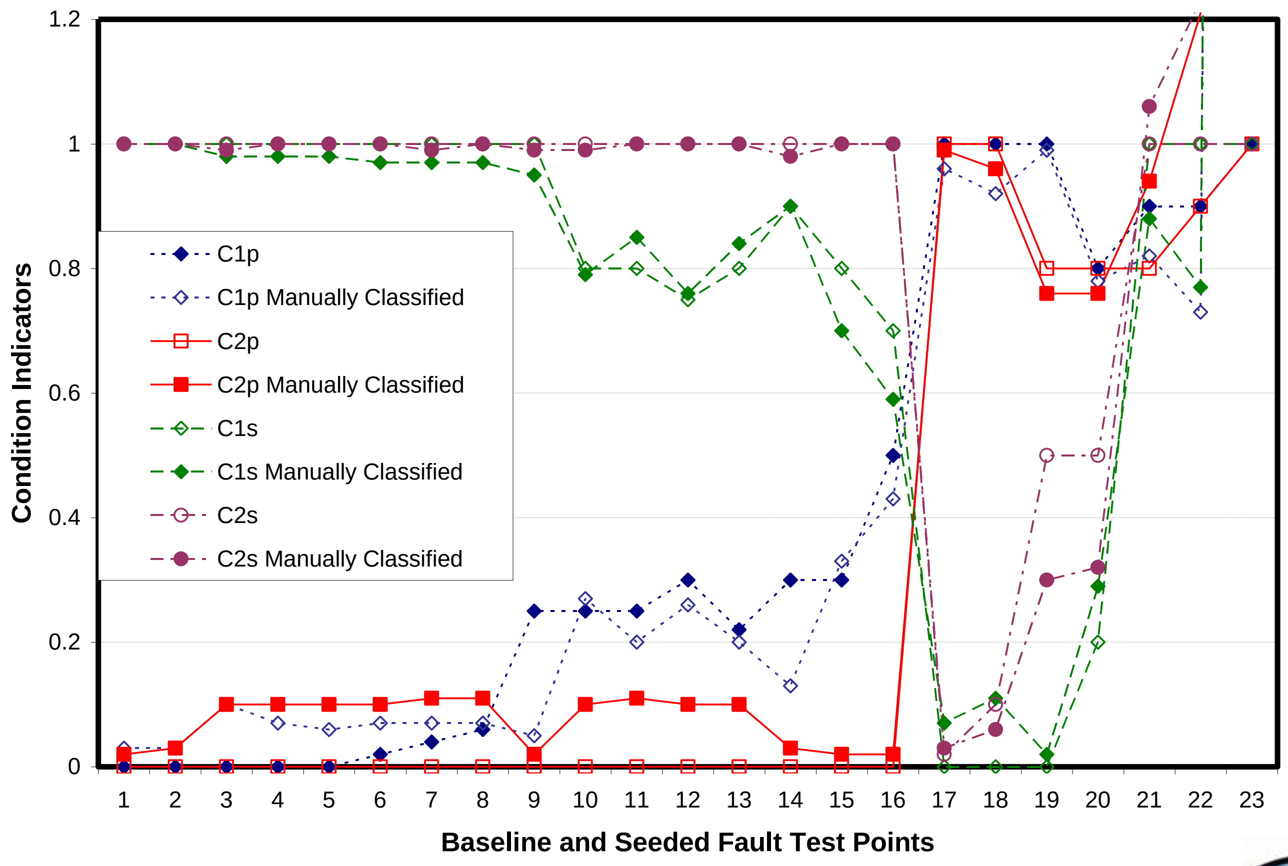
Seeded Fault (rollover)



Primary Clutch tries to recover and rolled over

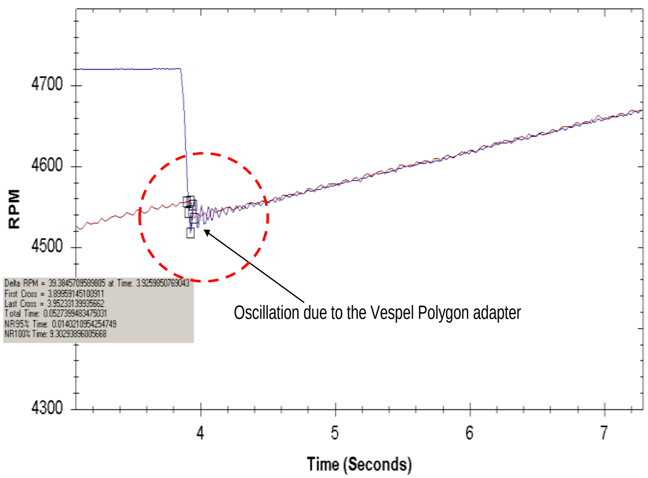
Speed Sensor Supports CI

- **All CI parameters trend closely for speed sensor**

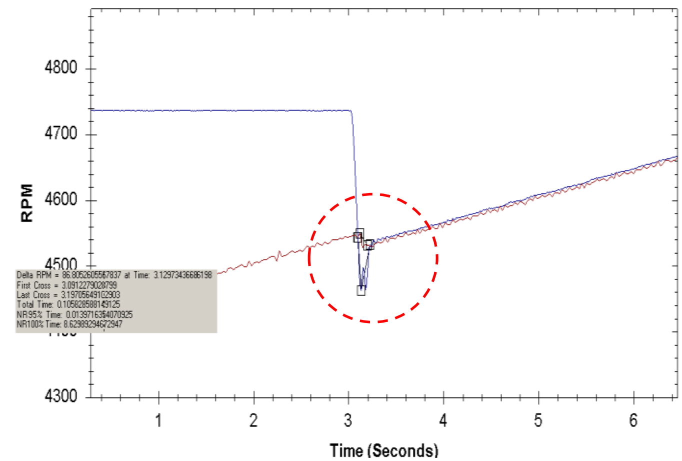


Validation Test Results (MSPU Format), Speed

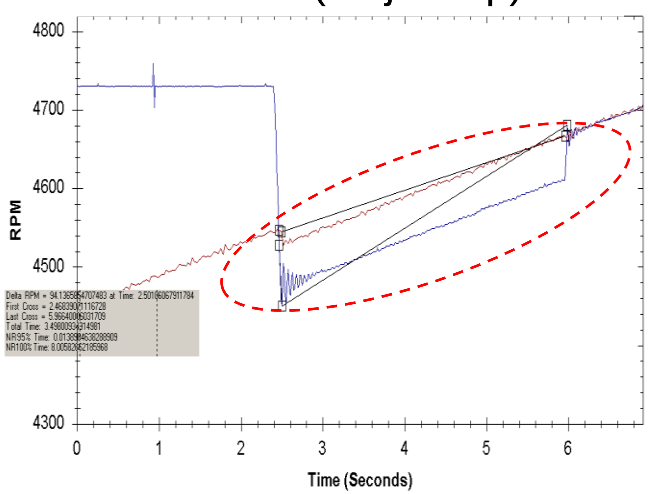
Baseline (normal engagement)



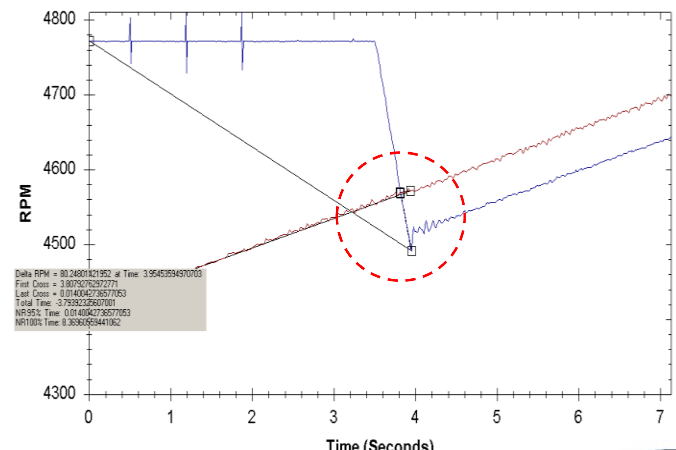
Seeded Fault (minor slip)



Seeded Fault (major slip)



Seeded Fault (2nd clutch engage)



Conclusions

- **MSPU proves it has the ability to detect minor clutch slippage and wear.**
- **Existing generator speed sensor could detect minor clutch slippage.**
- **For the double sprag clutch system, if the primary clutch slips the secondary clutch takes over.**
- **Using accelerometer sensor and a CF threshold of 5.5, the sprag clutch detection rate is 80% with less than 0.5% false alarm rate. Accelerometer sensor is not effective in detecting sprag clutch minor slip.**
- **Speed sensors successfully detect the sprag clutch full engagement, minor slip, pop – in and out, recovery cycle, and roll-over with high accuracy**

ASAP Database

- **Access Select Analyze and Present flight test database**