RAM 6 Update from RFAL

Dr. Rodrigo Teixeira
Principal Scientist
University of Alabama Huntsville
(256) 479-6664
rodrigo.teixeira@uah.edu

Mr. Chris Sautter
Associate Director
University of Alabama Huntsville
(256) 824-6147
chris.sautter@uah.edu

Mr. Daniel Sillivant
Reliability Engineer
University of Alabama Huntsville
(256) 824-5770
daniel.sillivant@uah.edu
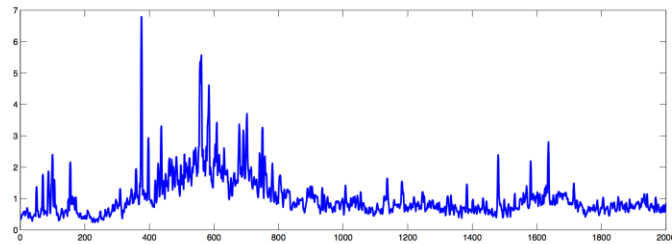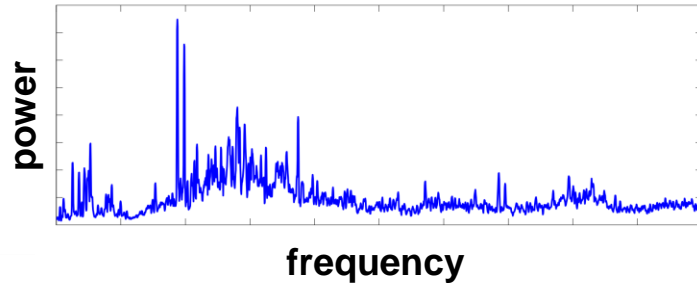
Overview of RFAL approach
Latest results for Chinook and Kiowa

Today

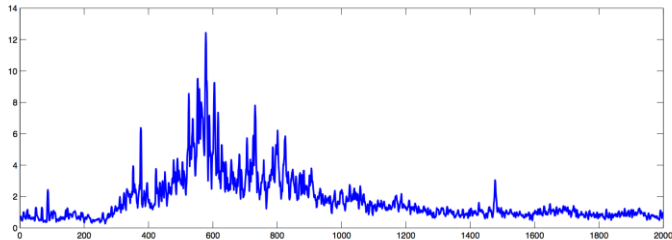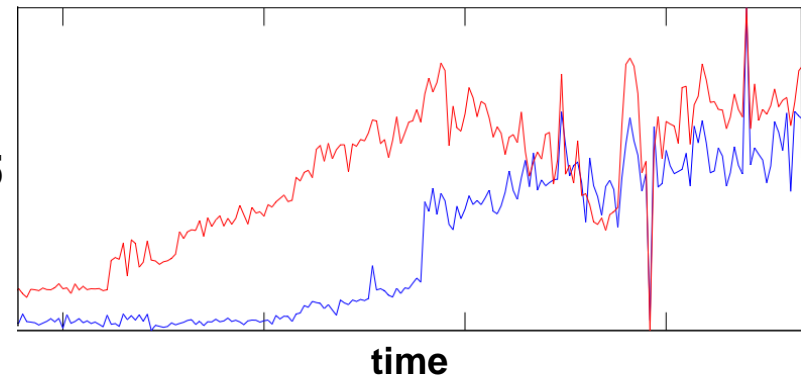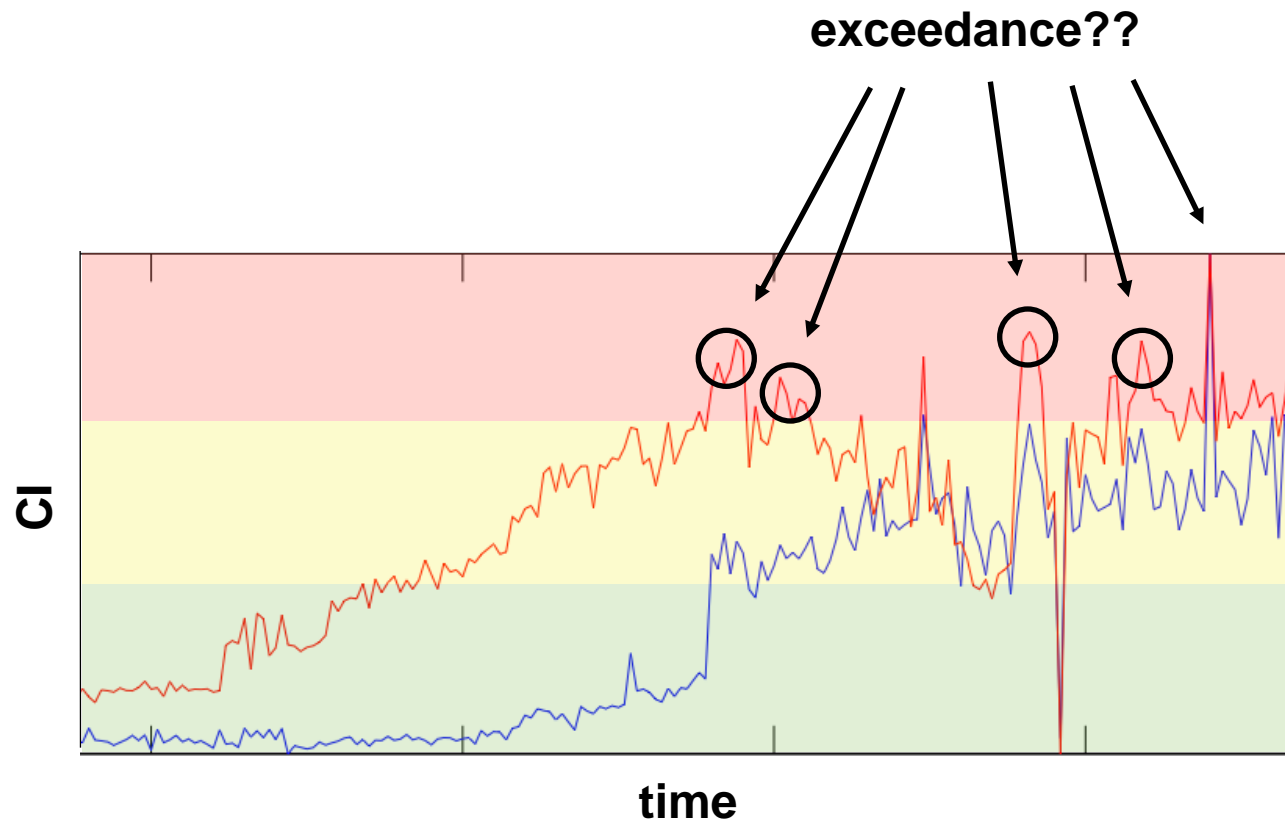# HUMS Analysis: Current CI Approach

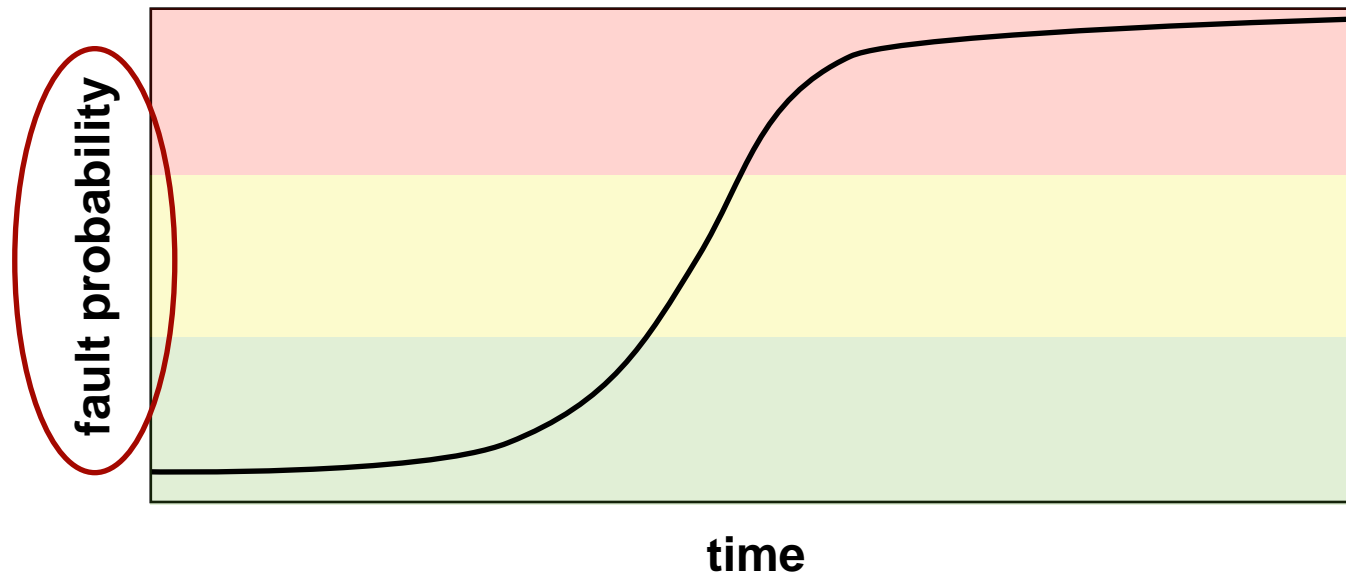**power spectra of component**

condition indicator

0.1

0.2

Typical CI Run

Actionable Information

Current CI Approach

Input Vibe Data

Tail 04-03740

transmission replaced due to chip light

"High Frequency Bearing Energy" and **"Bearing Energy"** CIs
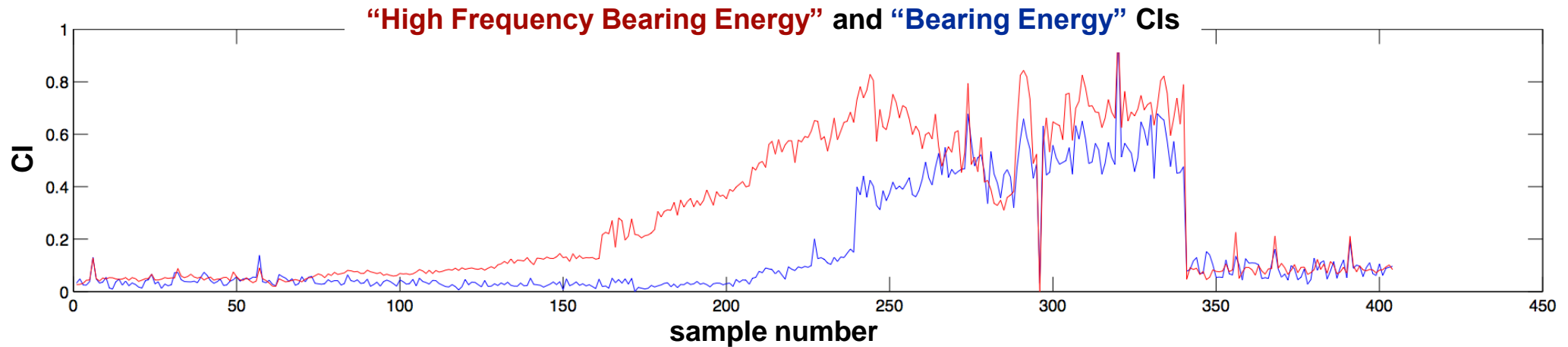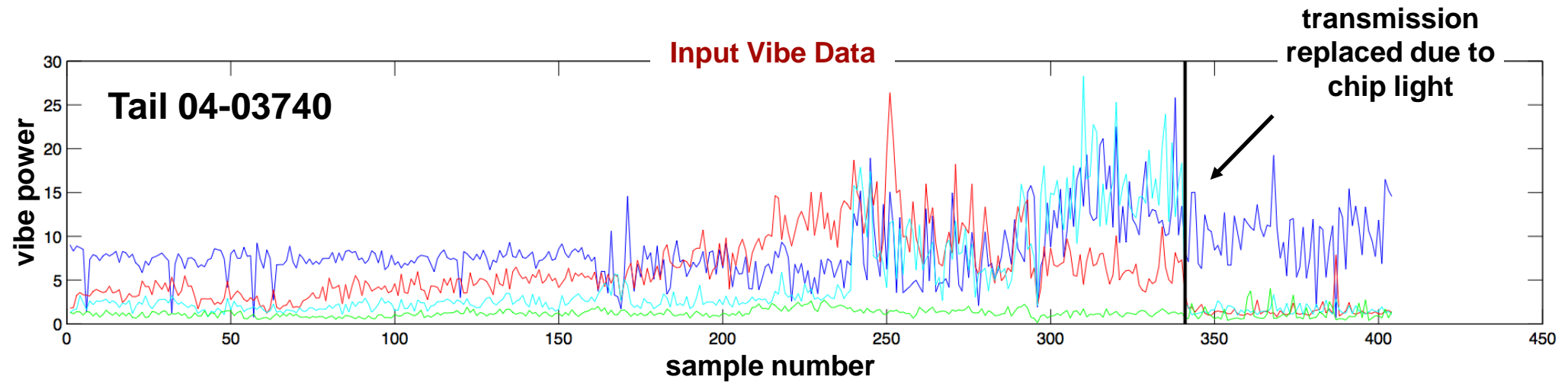
Bayesian Methods
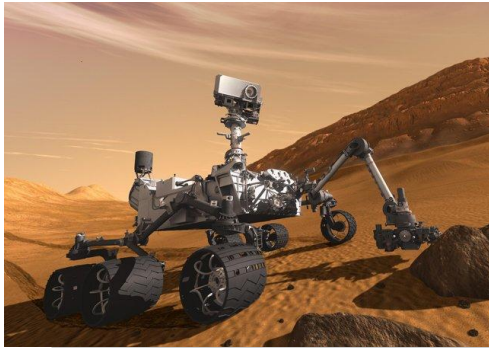
Curiosity rover (navigation)

speech recognition
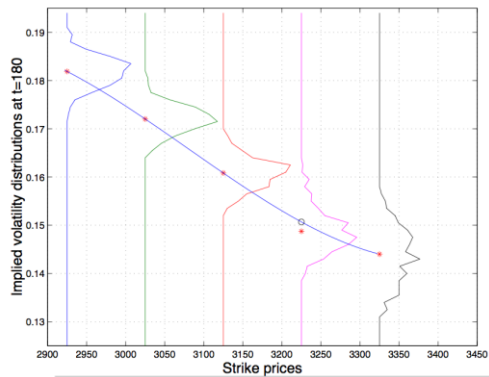
stock trading

reliability

?

Architecture

Top View

spectra

↓

RFAL
Algorithm

↓

**fault probability
metric**

Sequential Monte Carlo

spectra

Prior PDF

Posterior PDF

Bayesian update rule

probability

health state

probability

0

0

health state

Stochastic Model
(engineering physics)

fault probability

Stochastic Model
(engineering physics)

stress → **fault model** → **vibe model** → **sensor model** → **spectra**
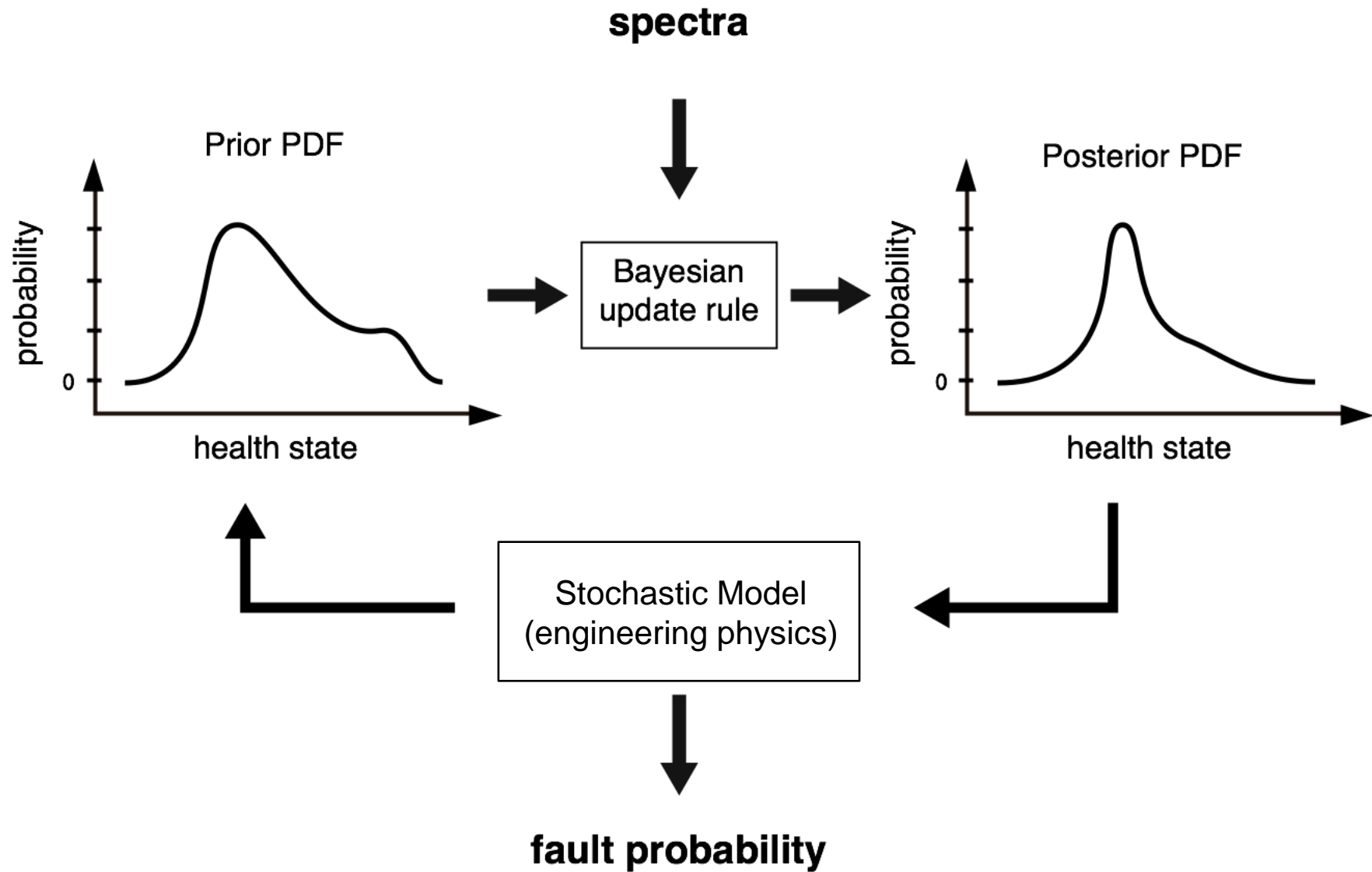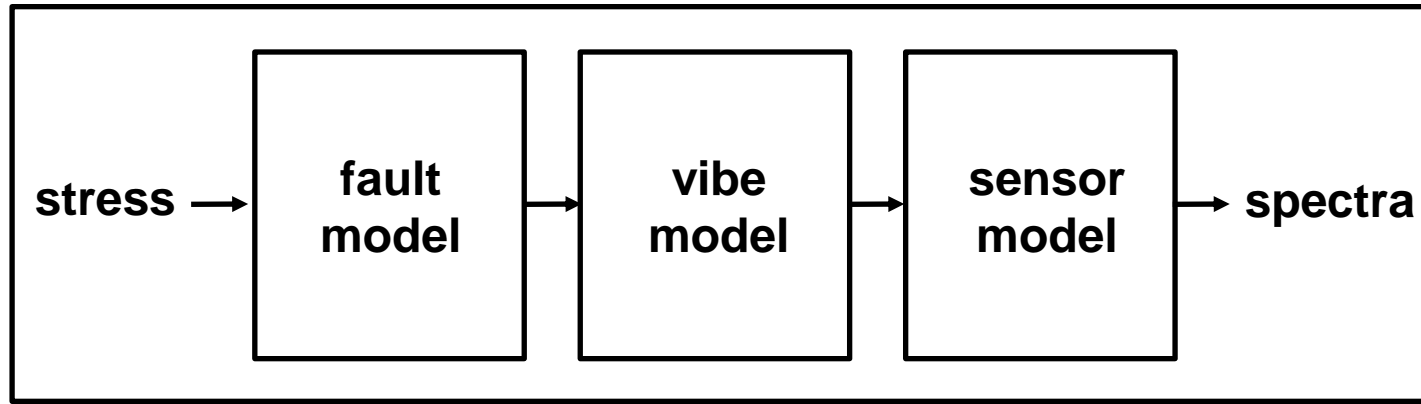
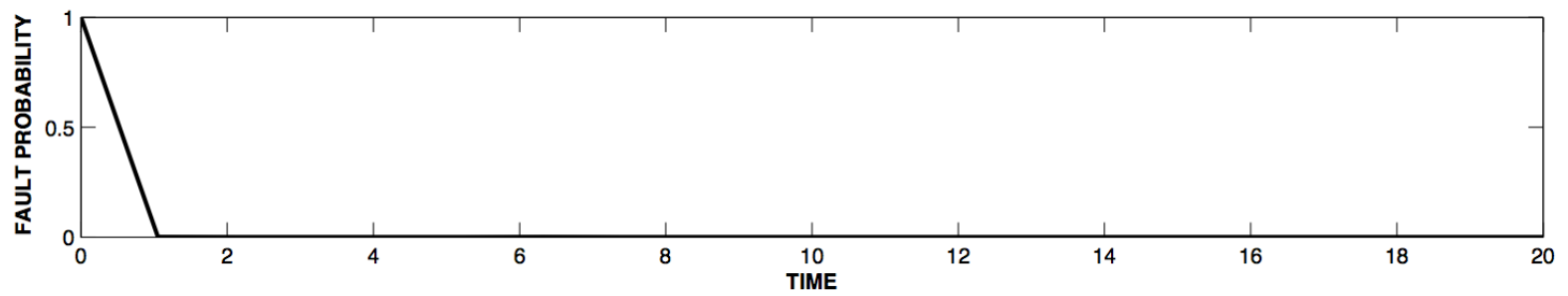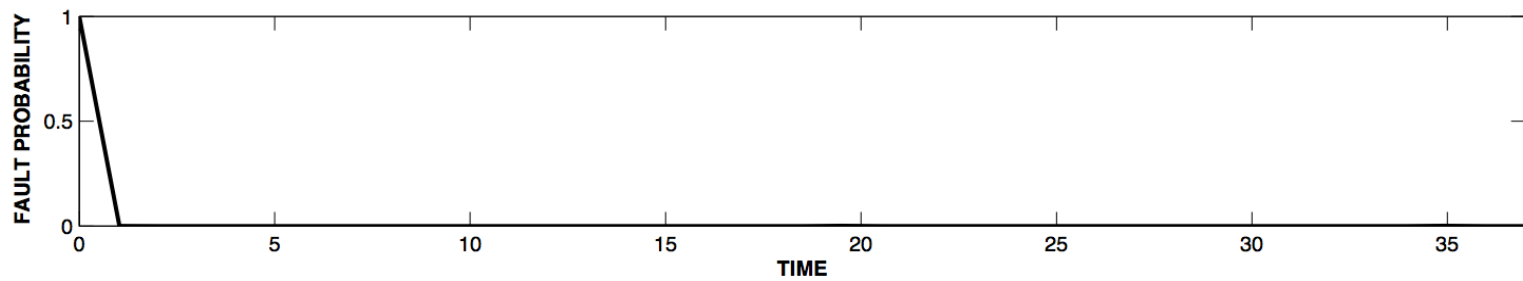# *Chinook*

Preliminary Results

- *Known Removal*

- *Known Normal*

- *Known NEOF*

Known Normals
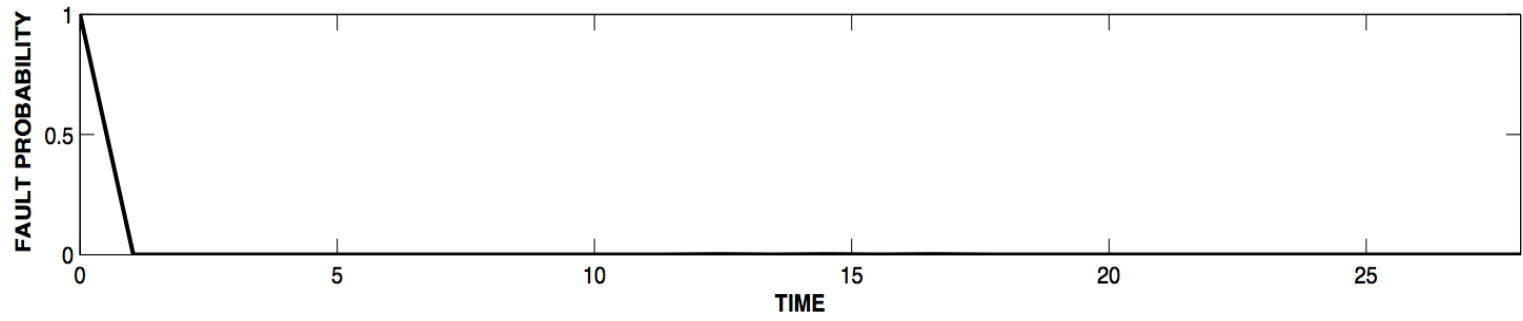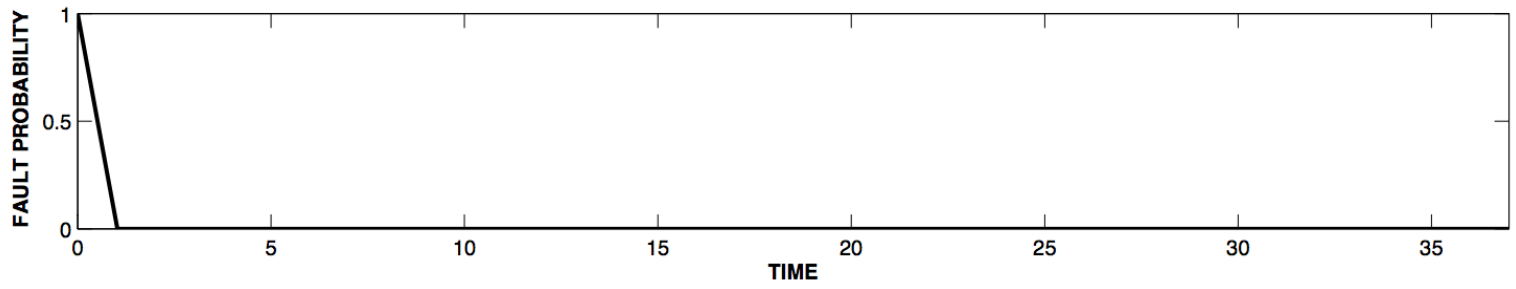
Known NEOF
Tail 08-3775
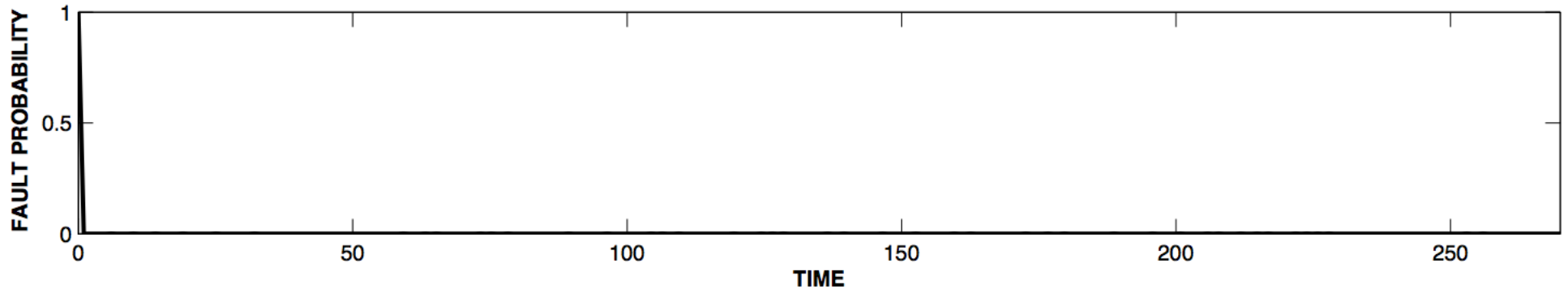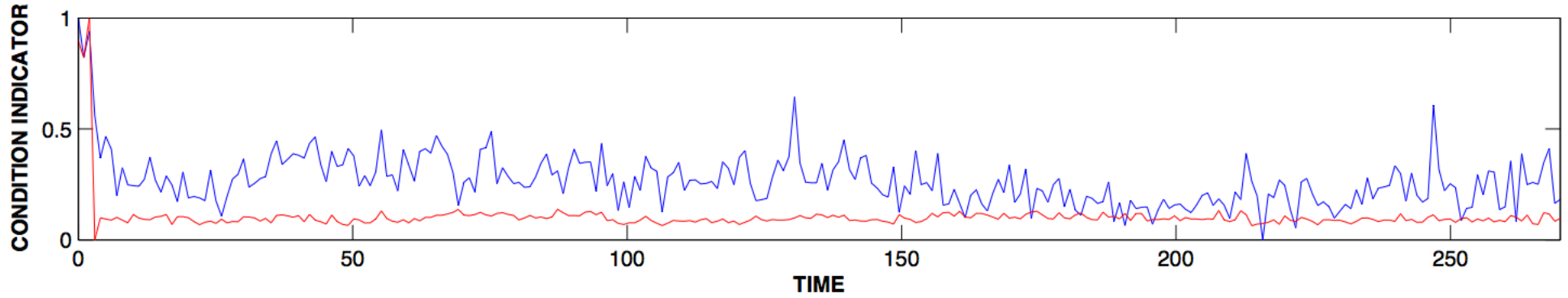
Known Removal
Tail 04-03740 (Chip Light)

Craft: MH-47 04-03740
Component: engine transmission
Part: #1 nose gearbox, single HUMS sensor
Action: transmission removed on May 2nd, 2012 for excessive metal contamination (chip light)
Inspection: shoulder to a bearing inner race broke in three places causing the rolling elements to degrade and a gear to become chipped.

MH-47G Aircraft 050375

CI Across Time
MH47G:05-03755 on or before 11/25/2012 08:59:17

Gearbox installed

Gearbox Replaced

Figure 1: High Frequency Energy CI indicating a healthy transmission

CI Across Time
MH47G:05-03755 on or before 11/25/2012 08:59:17

Gearbox installed

Gearbox Replaced

Figure 2: Bearing Energy CI indicating severe bearing damage

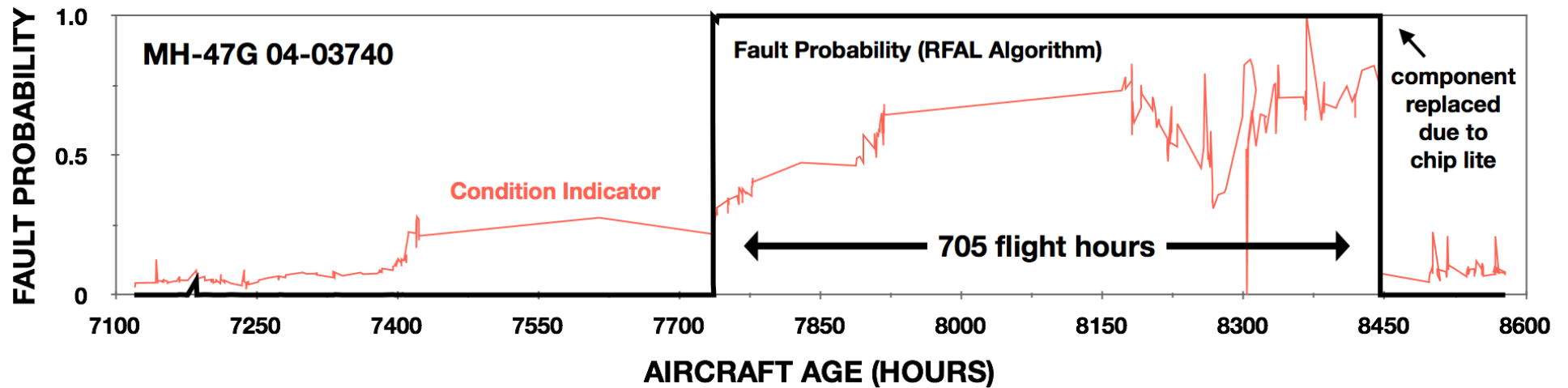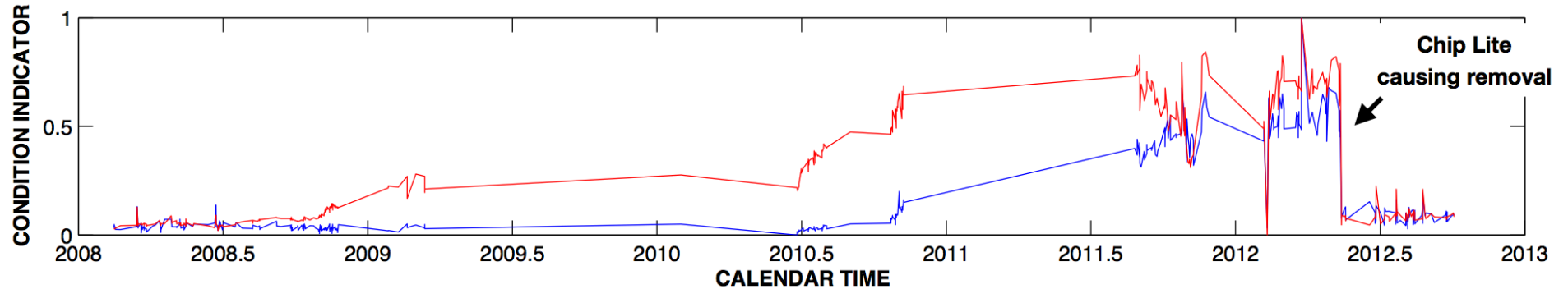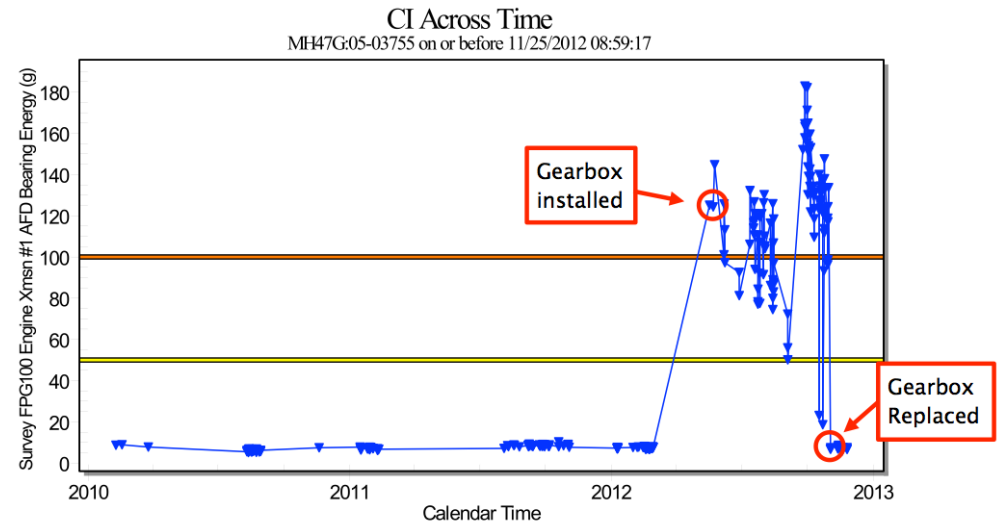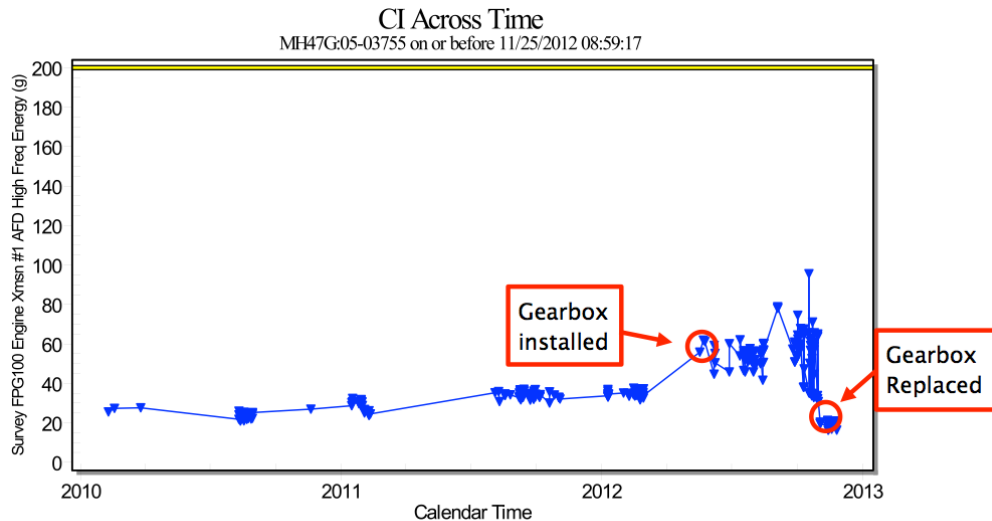**Excerpt from the report: "Review of Tear Down Analysis (TDA) of Engine Transmission Serial Number (SN): A11-083DRGI, Removed from MH-47G Aircraft 0503755 (TTS 117836A)"**

*Background: The subject component was removed for excessive vibration. Findings: Upon inspection, RTC found abnormal wear patterns on both the input pinion and output bevel gear teeth. The output bevel gear also showed abnormal staining on the inner race of bearing PN 145D603-3. RDMRAEP noted that bearing PN 145DS600-4 exhibited false brinelling on both raceways of its inner and outer races. **RDMR-AEP stated that "due to the lack of significant damage, and since the time horizon to maintenance is > 100 hours, the Component Condition for this Engine Transmission is Green."***

*Data Analysis: **The component condition does not align with the level of damage suggested by the MSPU**. There are two condition indicators (CIs) designed to detect bearing damage within the #1 engine transmission: Survey FPG100 Engine Xmsn #1 High Freq Energy and Survey FPG100 Engine Xmsn #1 Bearing Energy. While the former CI gave no indication of bearing damage, the latter implied severe damage to the output bevel gear bearings (Appendix A, Figures 1-2). (bolded for emphasis).*
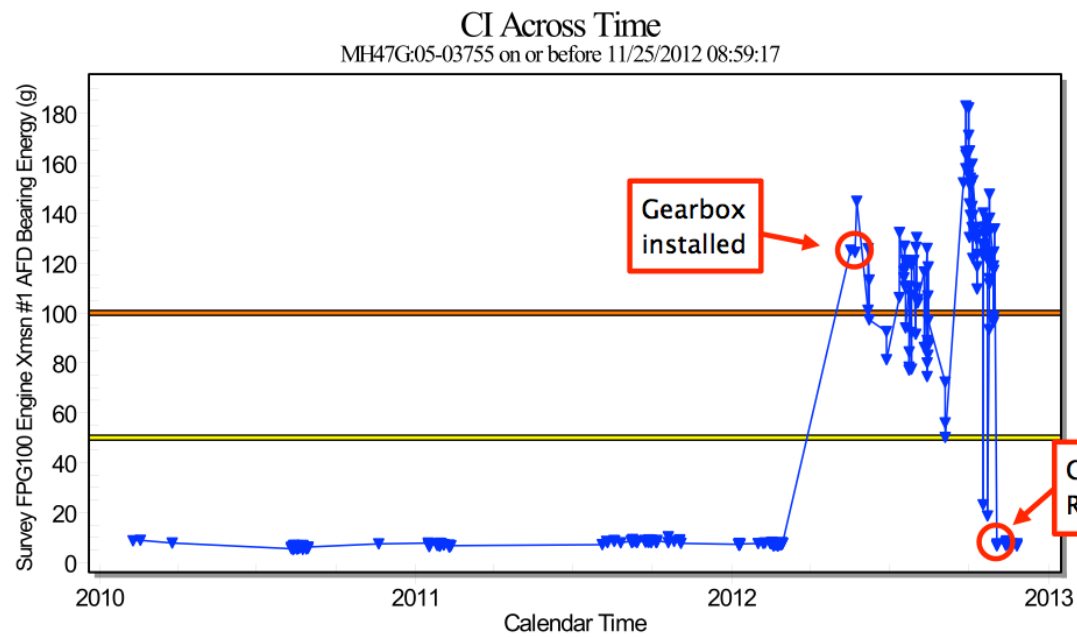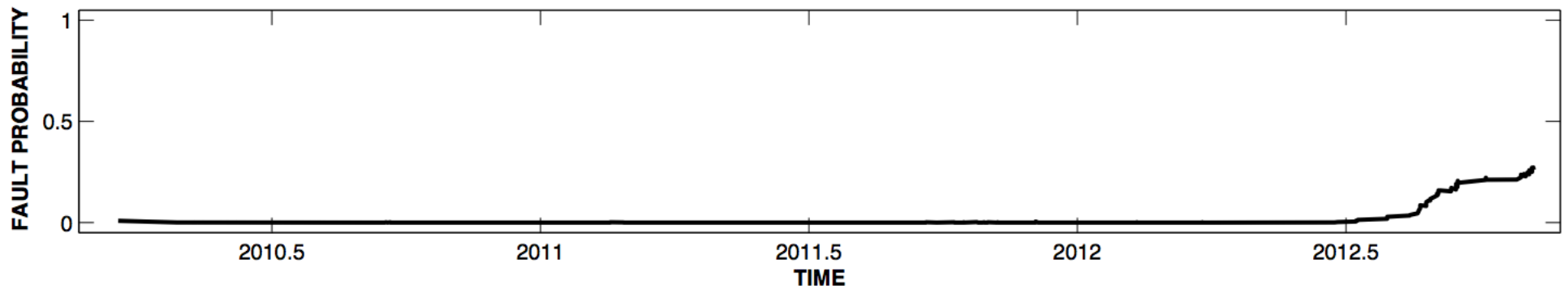
MH-47G Aircraft 050375

Figure 2: Bearing Energy CI indicating severe bearing damage

Kiowa Blind Study

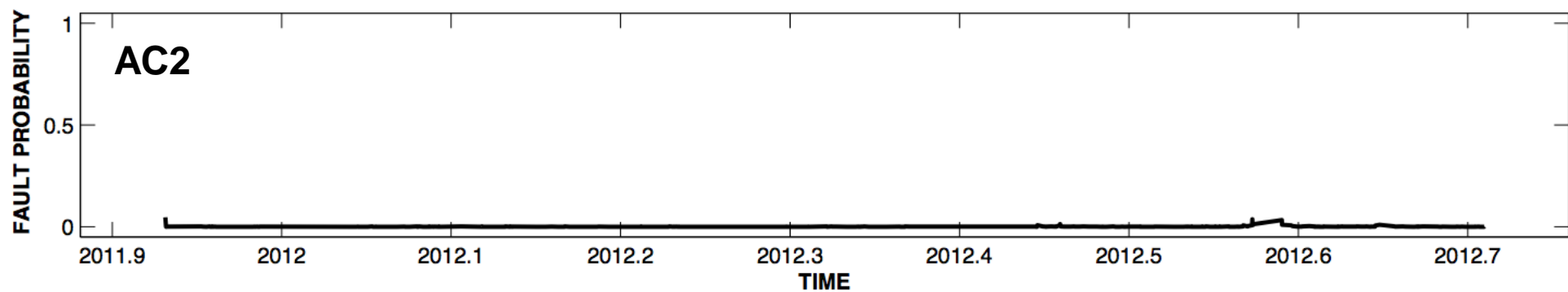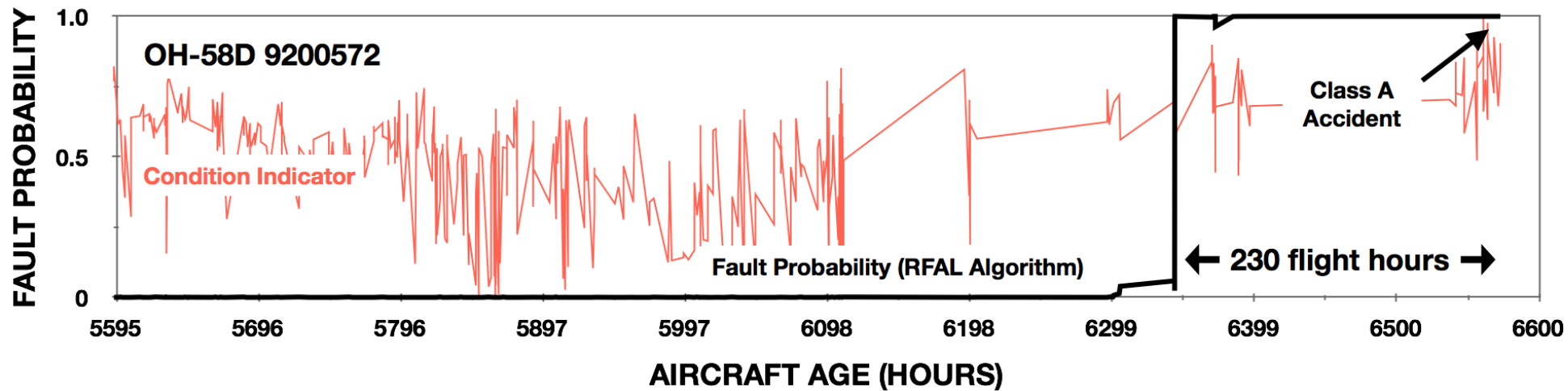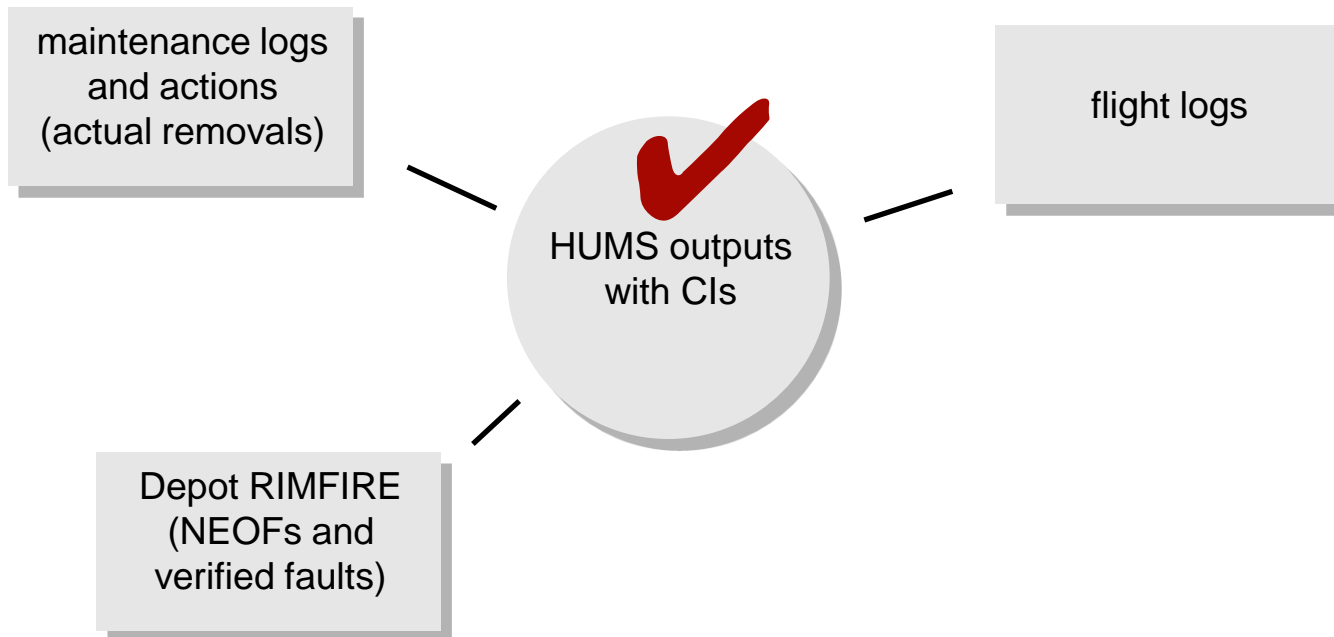**Problem**:

- Tail rotor gearbox sensor data
- Two datasets: one normal and one fatal accident
- No maintenance logs, actions, tear down analyses, CIs, or any indication of where the abnormality occurred
- Anecdotal evidence given that supported intermittency

Solution:

- Assumption of abnormal signature
- Same algorithm but "retrained" model parameters
- 12 frequencies used (previously 4)

Upper chart:

FAULT PROBABILITY (y-axis): 0, 0.5, 1.0

OH-58D 9200572

Condition Indicator

Fault Probability (RFAL Algorithm)

← 230 flight hours →

Class A Accident

AIRCRAFT AGE (HOURS) (x-axis): 5595, 5696, 5796, 5897, 5997, 6098, 6198, 6299, 6399, 6500, 6600

Lower chart:

FAULT PROBABILITY (y-axis): 0, 0.5, 1

AC2

TIME (x-axis): 2011.9, 2012, 2012.1, 2012.2, 2012.3, 2012.4, 2012.5, 2012.6, 2012.7

Consolidated Data Requirements

maintenance logs
and actions
(actual removals)

flight logs

HUMS outputs
with CIs

Depot RIMFIRE
(NEOFs and
verified faults)

End