



USING GENERIC TELEMETRY PROGNOSTIC ALGORITHMS FOR LAUNCH VEHICLE AND SPACECRAFT INDEPENDENT FAILURE ANALYSIS



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USING GENERIC TELEMETRY PROGNOSTIC ALGORITHMS FOR INDEPENDENT LAUNCH VEHICLE AND SPACECRAFT FAILURE ANALYSIS

- **Problem: It is Near to Impossible to Complete an Accurate Failure Analysis on Vehicles Produced by Another Company**
- Failure analysis now possible on any vehicle by completing a prognostic analysis
 - A prognostic analysis uses equipment telemetry to identify accelerated aging which precedes equipment failures by up to one year in advance
 - Uses data-driven telemetry prognostic algorithms to identify accelerated aging in equipment that has failed
 - Accurate for equipment with full design margins and has telemetry available
 - Encourage putting telemetry on all functional equipment



Prognostic Process

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○ Identifies Launch Vehicle and Satellite Infant Mortality Failure Liability

- Liability is currently on:
 - Space vehicle insurance providers are asking for relief
 - American tax payers are liable for civil NASA and military missions
- Contractors are not liable as long as they use their “best effort”
 - Indefinable
 - Unprovable



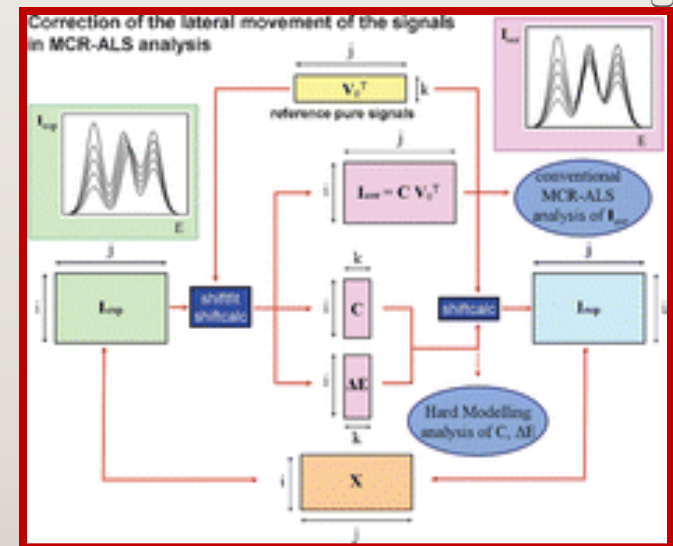
Establishes Contractor Legal Liability

- Using prognostic algorithms, the equipment that is going to fail prematurely and has already failed can be identified
- Vehicle builders can greatly influence future equipment reliability on-orbit

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○ Prognostic Algorithms

- Data-driven algorithms were developed after model-based algorithms were developed from failure models from high volume products
- The next logical step in raising equipment reliability to 100%
- Identifies equipment that has failed and is going to fail prematurely
- Already used across many industries including (computer, aircraft, nuclear power, HVAC)
- Developed from obtaining an intimacy with equipment's operational behavior seldom obtainable
- Is used, post failure, identifies equipment that should have been replaced before use

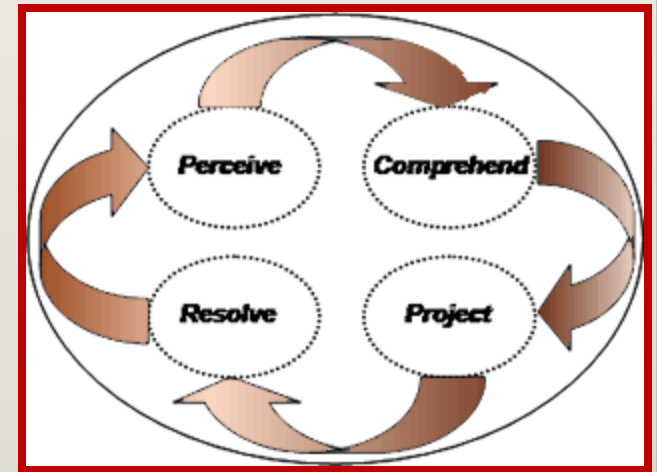


Prognostic Algorithm

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○ Telemetry Prognostic Technology

- Allows the identification of electronic circuits and mechanical systems future failures by prognosticians
- Created and used on the Boeing/Air Force Global Positioning System (GPS) satellites and Atlas F launch vehicles
- Uses existing telemetry systems
- Over 30 years of use on many satellites and launch vehicles at the factory, in-orbit and on launch pad including: GOES Next (I-M), INTELSAT, GPS I, II IIA, DMSP, ATLAS, TITAN III, TRIDENT, SUPERBIRD, LS-1300,



Prognosis Process

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○ Telemetry Prognostic Algorithms

- Illustrates transient behavior in telemetry which prognosticians use to predict equipment failures during design, manufacture, test, integration, launch and on-orbit
 - Identifies space vehicle equipment/circuits and electro-mechanical systems that failed for up to one year in advance for all equipment that has analog type telemetry
- Post failure analysis includes review of factory test telemetry to identify failure behavior present during factory test missed:
 - Didn't know what to look for
 - Didn't know how to look
 - Didn't know when to look

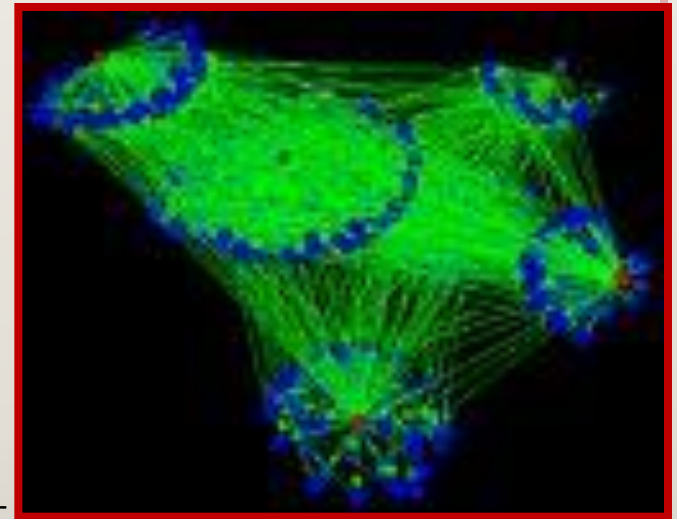


**Typical Signal Transients
Misdiagnosed**

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○ Prognostic Algorithms Incorporates:

- 5-dimension analysis to illustrate information that indicates a failure process is occurring
 - Identify the start of the failure process
 - Identify where in the failure process
 - Identify the day-of-failure
- After an equipment failure has occurred, can identify from past test data, when and where the failure process began identifying supplier whose is liable for shipping equipment that is going to fail



5-D Telemetry Analysis

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o Generic Telemetry Prognostic Algorithms

Prognostic Algorithm	Equipment Factory	Satellite Factory	LV Factory	Launch Pad	Mission Control	Mission Control (CCSDS)
Data Integration	X	X	X	X	X	X
Baseline Analysis	X	X	X	X	X	X
Change Analysis		X	X	X	X	X
Comparison Analysis	X					
Data Mining		X	X	X	X	X
Day of Failure	X	X	X	X	X	X
Digital Processing					X	
Discrimination Analysis	X	X	X	X	X	X
Mathematical Modeling	X	X	X	X	X	X
Multi-variant Limit Analysis	X	X	X	X	X	X
Rate Change Analysis		X	X	X	X	X
Remaining Usable Life	X	X	X	X	X	X
Statistical Sampling		X	X	X	X	X
State Change Analysis		X	X	X	X	X
Super Impositioning		X	X	X	X	X
Data Integration	X	X	X	X	X	
Super Precision					X	
Telemetry Authentication					X	
Virtual Telemetry	X	X	X	X	X	X
Data Base Creation					X	

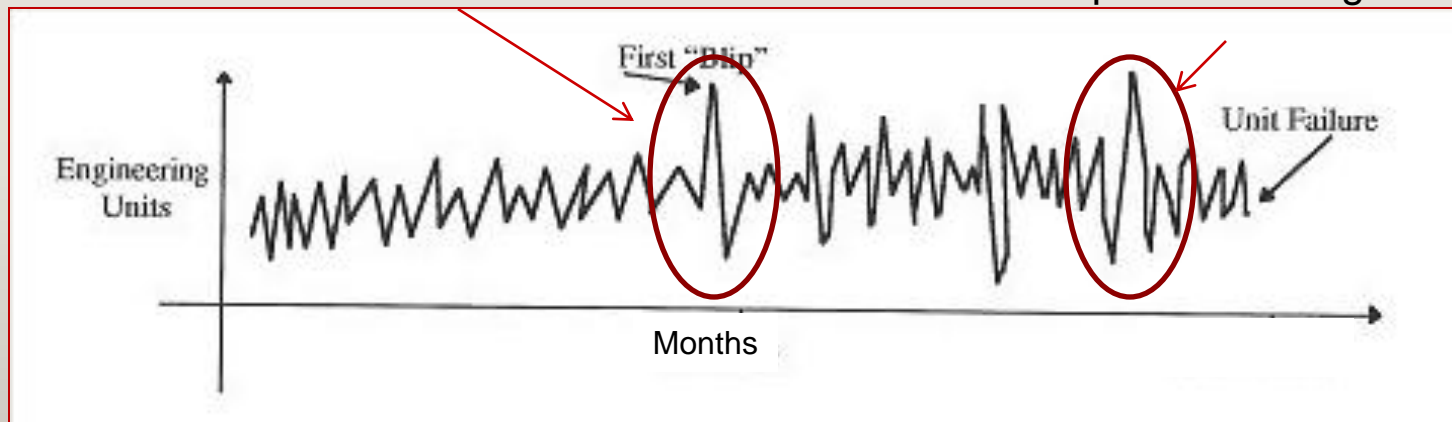
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○ Results Using Prognostic Algorithms

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May be present during factory test

Will be present during factory test



2-D Presentation

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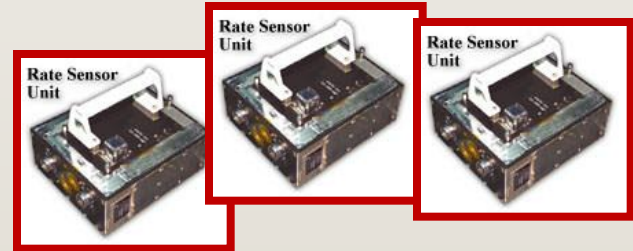
○ Flight History for Prediction Failure and Failure Analysis on space Equipment Completed

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- Air Force GPS
 - NAVSTAR 1
 - NAVSTAR 2
 - NAVSTAR 3
 - NAVSTAR 4
 - NAVSTAR 5
 - NAVSTAR 6
- NASA EUVE
- NASA GOES I
- SCC SUPERBIRD B



Rubidium Atomic Clocks



TT&C Equipment



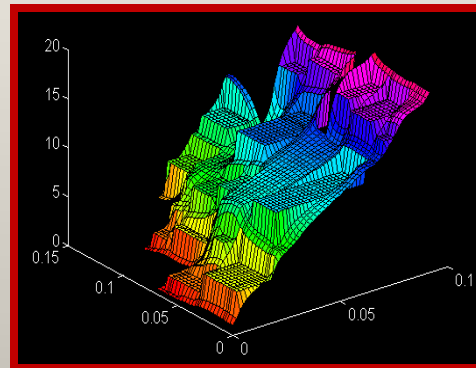
Batteries



Reaction wheel Assembly

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- **Independent Failure Analysis Service is:**
 - Independent of vehicle and vehicle manufacturer
 - Insensitive to amount of data available for analysis
 - Insensitive to resolution /accuracy of telemetry
 - Insensitive to noise in information
 - Available today
 - Any failure
 - Any place
 - Any time



4-D Telemetry Analysis



5-D Telemetry Analysis

We have no dog in the hunt!



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