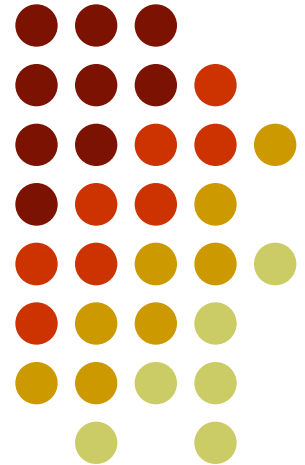


FA *Failure Analysis*

Engineering Services & Technology Licensing



Presents
Prognostic Technology
by Len Losik



Failure Analysis

Engineering Services



- *Company Information*

- *Founded in 2006 to market Telemetry Prognostic technology*
- *Located in Salinas California, 70 miles south of NASA Ames Research Center, at the Creek Bridge Commercial Office Complex, near Silicon Valley*
- *Small Business*
 - *8 Employees and volunteers*
 - *1500 ft² office*
- *Creator of and world leader in Failure Prediction™ technology*



Failure Analysis

Engineering Services

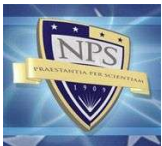


- *Experience*

- *Failure Analysis serves commercial, military, government and civilian customers worldwide*
- *30+ years in Satellite, Launch Vehicle, Missile and Aircraft Telemetry & Command and Communications Subsystem and System Design & Test*
- *5 years high-rel computer design*
- *Over 29 years in Telemetry Prognostics creation, research, development and use*



NASA ARES Launch Vehicle



Failure Analysis

Engineering Services Program Experience



Launch Vehicles/

Missiles

Ariane
Atlas
Titan
Delta
EELV
Sea Launch
Space Shuttle
Orbital Sciences
Trident D5

Customers

NASA
DOD
US Air Force
NASDA
KARI
NTT
SCC
NEC
NRL
DARPA
FEMA

Mission

Control

NASA GSFC
SUPERBIRD
AFSCN
STC
CSOC
UC Berkeley

Satellites

GPS
DMSP
DSCS
MILSTAR
GOES Next
EUVE
Lunar Prospector
Coldsat
TDRSS
Superbird
ANIK E
INTELSAT
HESSI
NSTAR
GMS
Space Station
KOMPSAT
A2100
FS 1300
HS 601
HS 702
ARABSAT
INSAT

Factories

Boeing Commercial
Boeing Military
Lockheed Martin
Commercial
Lockheed Martin
Military
Space Systems/Loral
AeroAstro
Ball Aerospace
Orbital Sciences
Fairchild Aerospace

Telemetry

Diagnostics & Prognostics

GPS
EUVE
GOES Next
Superbird
INTELSAT 7
INTELSAT 7A

Ground Stations

AFSCN
TDRSS
TMGS
M³
SMGS
ICO
PANAMSAT
GLOBALSTAR
DSN
JPL
GPS
DMSP
Svalbard
INTELSAT
SCC
IONDS
TELESAT
KOMPSAT

High Rel Server Design

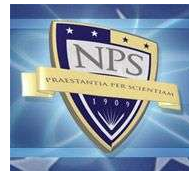
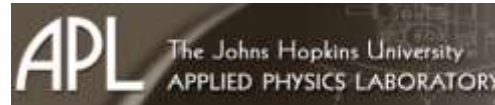
Force, Sun, HP, PC



Failure Analysis

Current Contacts

Engineering Services



1/14/2014



ITT

Failure Analysis

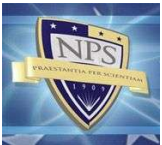
Engineering Services



- *Telemetry Prognostics Applications*
 - *Satellites*
 - *Launch Vehicles*
 - *Missiles*
 - *Ground Stations*
 - *Aircraft*
 - *Helicopters*
 - *High Rel Computers*
 - *Automotive*
 - *Medical*
 - *Nuclear Reactors*



Army UAV



Failure Analysis

Engineering Services



- *Reason for visit to NPS*
 - *Discuss failure prediction (prognostics) technology and the many paybacks which allows for upgrading aerospace equipment design, manufacturing and test process and replaces costly routine maintenance programs with condition-based-maintenance (CBM)*

Failure Analysis

Engineering Services



● *Prognostics*

- *Lowers equipment production costs*
- *Shortens equipment production schedule*
- *Increases equipment reliability*
- *Increases equipment usable life*
- *Replaces routine maintenance programs with CBM*

Failure Analysis

Engineering Services



- *Lowering equipment production costs*
 - *Prognostics allows for*
 - *Identifying equipment that has failed, is failing and will fail in the future*
 - *Lowering costs by*
 - *Shortening testing schedules*
 - *Shortening delivery schedule*

Failure Analysis

Engineering Services



- *Prognostics increases equipment reliability*
 - *Identifies equipment that has failed*
 - *Identifies equipment that is failing*
 - *Identifies equipment that will fail in the field*
 - *Stops infant mortality failures in the field*
 - *Identifies when and what equipment will fail*

Failure Analysis

Engineering Services



- *Increases equipment usable life*
 - *When equipment that will fail in the field are replaced with reliable equipment, the mean-usable-life is extended across a population of equipment*

Failure Analysis

Engineering Services



- *Contributions in reducing vehicle production costs & schedule using Prognostics*



***Equipment
Manufacturing***

Up to 10%



Vehicle I&T

Up to 40%



Deployment

Up to 20%

Failure Analysis

Engineering Services



- *Contribution to increasing equipment/vehicle reliability using Telemetry Prognostics*



***Equipment
Manufacturing***

Up to 20%



Vehicle I&T

Up to 20%



Deployment

Up to 30%

Failure Analysis

Engineering Services



- *History of Telemetry Prognostics*
 - *Created out of the desire by the Air Force to receive full funding for the Global Positioning System in 1978*
 - *TIMATION & TRANSIT Navy satellite based navigational systems already existed and well liked*
 - *Air Force wanted a satellite based navigation system to support multi-service navigation needs*
 - *Air Force funded the GPS Block I satellite contractor to provide an engineering team determine peak payload performance times to conduct critical multi-service system testing to get the highest system performance possible to obtain future program funding*
 - *The Air Force asked the GPS engineering team to be able to predict future atomic clock failures*
 - *No limit budget*
 - *No limit on resources needed*

Failure Analysis

Engineering Services



- *As a consequence of research in developing the ability to predict failures, in 1978 an equipment failure gets redefined*
 - *In analyzing rubidium and cesium atomic clock behavior, failure precursors are discovered many days, weeks and months before catastrophic failure occurs*
 - *The analytical tools and processes necessary to identify the failure precursors were developed by GPS engineering team*
 - *After GPS program was fully funded, Failure Prediction technology was abandoned in 1984*

Failure Analysis

Engineering Services



- *What stopped the creation of prognostics technology before 1978?*
 - *Beginning in the 1930's, with Hitler developing the most advanced military weapons, the US military began a program of preparedness by purchasing from US industry all the weapons systems that could be produced regardless of initial performance*
 - *After WWII was over, as a consequence of Russia's Stalin deploying a nuclear bomb and the first ICBM that could reach the US, the US military continued to purchase excessive numbers of weapons systems in the contract awards for missiles in 1955 regardless of missile performance undermining the contracts efforts to improve system reliability*
 - *The number of missiles purchased in a contract was determined by the number of missiles it took to hit a target successfully during missile development programs eliminating need to improve reliability*
 - *In the late 1950's, telemetry systems and remote ground stations were created in response to test pilots dying during aircraft flight tests at Dryden Air Force Base and the test crew could not be able to retrieve vital aircraft performance test data*
 - *Expensive telemetry systems were added on to already built missiles to collect launch test performance data (telemetry was not used during missile development) as overhead costs which threatened to decrease the number of systems purchased by the military on future contracts*
 - *Telemetry began to be used in meeting final acceptance testing criteria at the factory to increase reliability*
 - *With huge stockpiles of (unreliable) US military purchased missiles in storage, the same telemetry instrumented missiles became rockets in 1961 and continued to suffer high number of launch failures*
 - *The same contractors which designed and built aircraft, missiles and rockets began to build satellites, bringing with them their bias against expensive telemetry systems and its limited use as an after the fact analysis resources.*

Failure Analysis

Engineering Services



● Telemetry Technology Evolution

Data Collection



Monitoring/Diagnostics



Prognostics

Schilling
1812

Konstantinov and Pouli
Takobi
1845

Olland
1874

Seismic Recording
1906

Marconi Wireless Communications
1907

Radiosonde
1930

Missile Technology
1946

Upper Atmosphere Monitoring
1947

Jet Aircraft
1953

Atlas Missile
1954

Thor/Delta Missile
Titan Missile
1955

Digital Telemetry
1957

Strip Chart Recorder
1958

NASA/JPL/DSN
1958

Titan Rocket
1961

Delta Rocket
1962

INTELSAT/COMSAT
1964

AFCSN
1969

GPS
1978

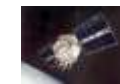
TDRSS
1978

PANAMSAT
Commercial Space
1985

AFCSOC
1986



las Rocket
1975



Failure Analysis

Engineering Services

● Failure Prediction™ Telemetry Prognostics Features

- Detects future failure in normal appearing telemetry*
- Detects future failures in high stressed operational environment*
- Observe individual component/circuit failure as it is occurring*
- Insensitive to quantity of telemetry*
- Insensitive to (quality) noisy or unreliable telemetry*
- Insensitive to amount of telemetry*
- Insensitive to LSB resolution*
- Insensitive to equipment/sensor aging effects*
- Flight proven*
- Platform independent*
- Developed for use on existing telemetry systems*



TITAN Launch Vehicle

Failure Analysis

Engineering Services



● *Prognostician*

- *An engineer that uses an array of imaging technologies to treat and diagnose latent, intermittent electrical component/circuit failure behavior*
 - *Requires 4 year technical degree in electronics and several years post graduate training.*
 - *Must understand and be experienced with linear and non linear DC circuit design, DC circuit troubleshooting, worse case circuit analysis, acceptance testing, electrical and mechanical layouts, thermal analysis, piece-part failure analysis and behavior, data analysis and presentation, mathematical modeling, telemetry system design.*

● *Radiologist*

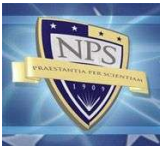
- *A physician that uses an array of imaging technologies (such as ultrasound, computed tomography (CT, X-rays) and magnetic resonance imaging (MRI) to diagnose or treat disease.*
 - *Requires 4 year medical degree and 5 years post graduate training.*
 - *Must understand and be experienced in nuclear medicine, physics of medical imaging, diagnostic imaging technology and be board certified.*

Failure Analysis

Engineering Services



- *Equipment Maintenance Options*
 - *Corrective Action programs*
 - *Let the equipment run until it fails and then fix it if possible or replace it*
 - *Preventive maintenance programs*
 - *Inspect and run maintenance on your components after a specific number of operating hours have passed, or after a certain number of months has passed since last inspection/maintenance*
 - *Condition Based Maintenance programs*
 - *Maintain and correct equipment at the right time*
 - *Uses real-time data to prioritize and optimize maintenance resources. Such a system will determine the equipment's health, and act only when maintenance is actually necessary. Condition based maintenance allows the maintenance personnel to do only the right things, minimizing spare parts cost, system downtime and time spent on maintenance.*



Failure Analysis

Engineering Services

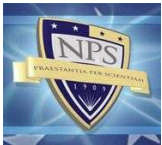


- *Equipment Maintenance (cont'd)*

- *A complete CBM system comprises a number of functional capabilities: sensing and data acquisition, signal processing, condition and health assessment, diagnostic, prognostics, and decision reasoning.*

- *Failure Prediction*

- *Take action prior to equipment failure, increasing reliability, operability, availability, serviceability*
 - *Uses real time instrumentation data to eliminate down time, reduces need for corrective maintenance*
 - *Act only when repair is actually necessary*
 - *Allows the maintenance personnel to do only the right things, minimizing spare parts cost, system downtime and time spent on maintenance.*



Failure Analysis

Engineering Services



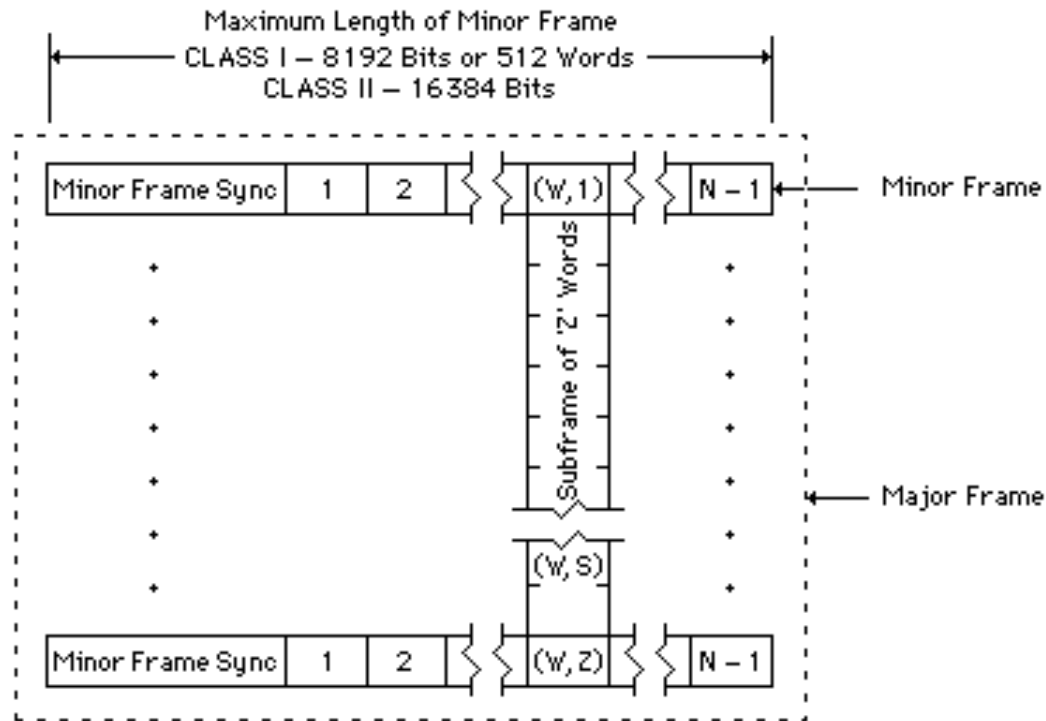
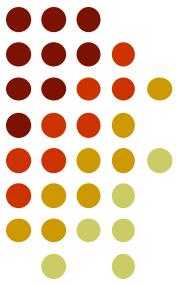
- *Telemetry Prognostics Description*
 - *Failure Prediction™ using Telemetry to identify equipment that has failed, is failing and is going to fail in the future using normal appearing telemetry*
 - *The next logical evolutionary step for telemetry diagnostics techniques*
 - *Created for use in a high signal noise, high stress environment with little telemetry available*
 - *For use in a dynamic environment when equipment is cycled randomly and non randomly effecting the telemetry behavior*
 - *Determines root cause of failure by Change Analysis and Baseline Analysis*
 - *Can predict remaining usable life and day of failure*



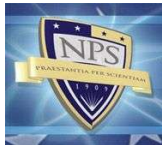
Failure Analysis

Engineering Services

● Telemetry Description



- By definition a major frame contains $N \times Z$ words, where
"Z" is the number of words in longest subframe (max. 256)
"N" is the number of words in minor frame.
"B" is the number of bits in minor frame
- Minor frame sync is considered one word, regardless of length.
- "W" is the word position in the minor frame
- "S" is the word position in the subframe

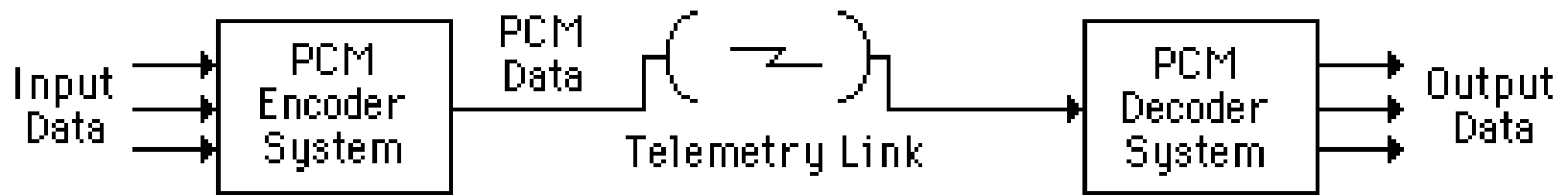


Failure Analysis

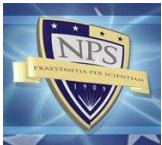
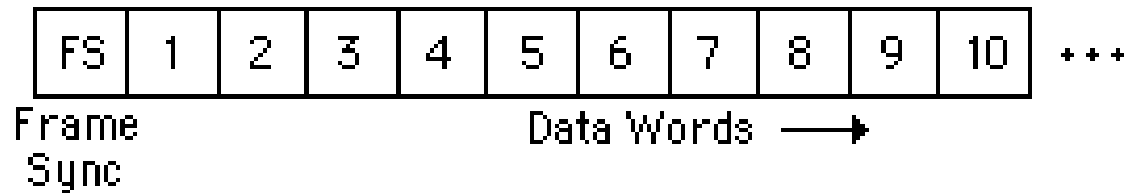
Engineering Services



- *Simple Telemetry System*



PCM Frame



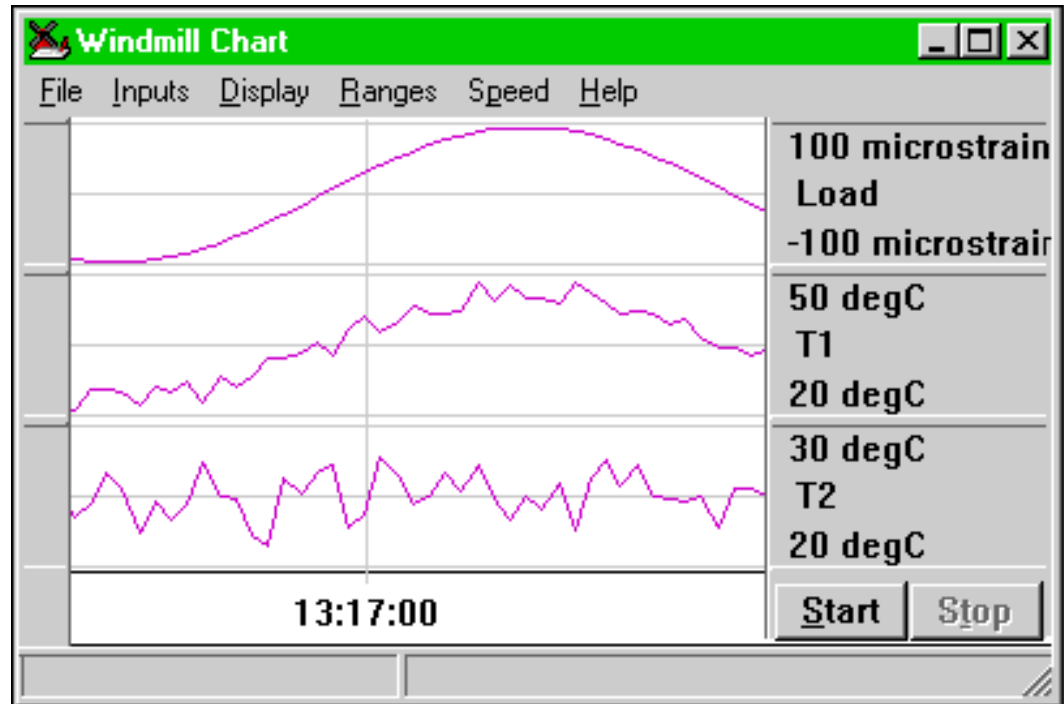
Failure Analysis

Engineering Services



- *Examples of Analog Telemetry Measurements*

- *Position*
- *Position error*
- *Resistance*
- *Pressure*
- *Accelerations*
- *Rotation angles*
- *Rotation speed*
- *Temperature*
- *Current*
- *Voltage*
- *Distance*
- *Phase*
- *Frequency*
- *Signal Strength*
- *Torque*
- *Momentum*

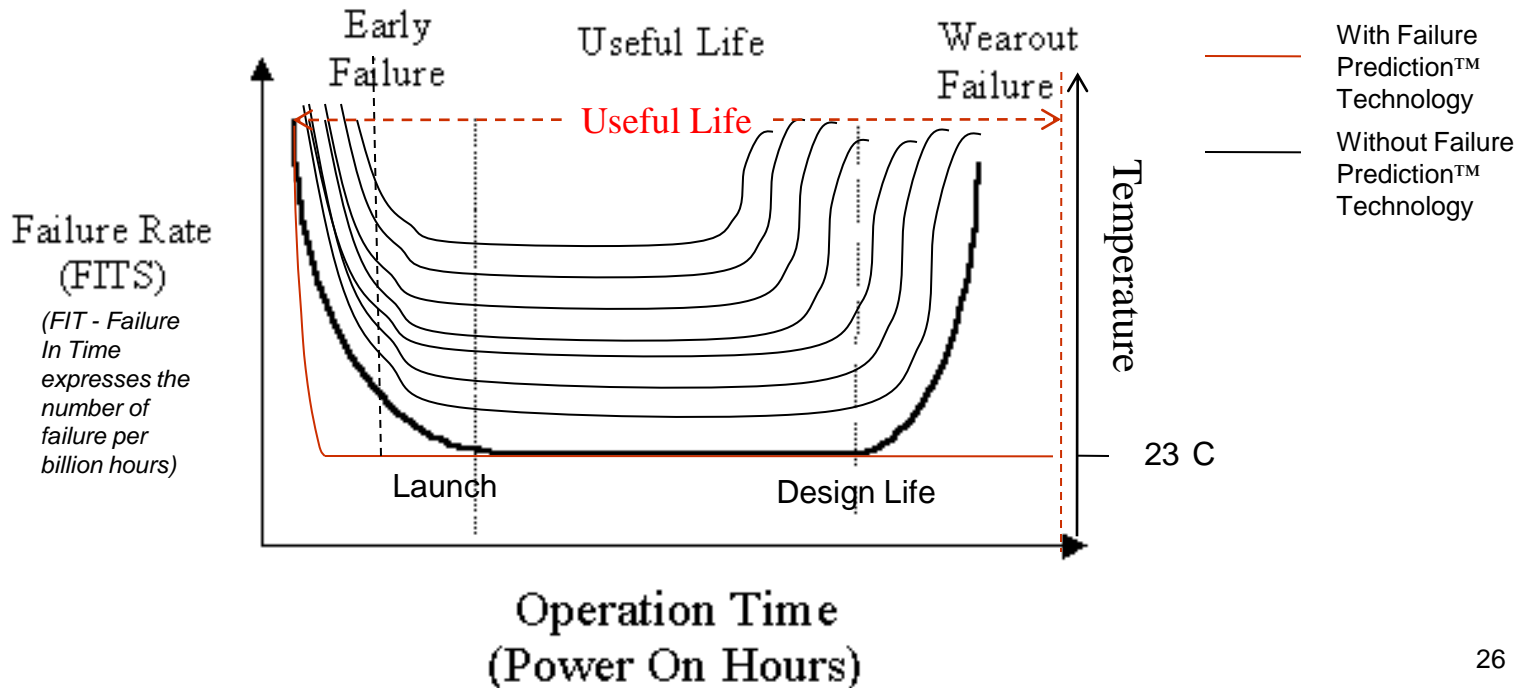


Failure Analysis

Engineering Services



- *Improves the Traditional Bath-Tub Equipment Failure Curve*
 - *Redefines the failure rate of a system*
 - *No infant mortalities*
 - *Increases and Extends operating and mission life*



Failure Analysis

Engineering Services



- *Examples of Equipment Failures*
 - *Open circuit*
 - *Short circuit*
 - *Piece part component wear out*
 - *Propellant/oxidizer/pressurant leaks*
 - *Lubricant dry up*
 - *Bearing wear out*
 - *Switch failure*
 - *Contact wear out*

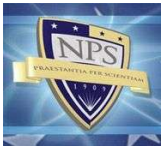


Failure Analysis

Engineering Services



- *Failure Prediction™ redefines reliability prediction analysis*
 - *Increased Mean Time Between Failures*
 - *MTBF = Average Life/Number of Failures*
 - *Number of failures approaches 0, MTBF gets very large*
 - *Expects replacement of parts*
 - *Increases Mean Time To Failure*
 - *MTTF = Is the amount of time the product should last*
 - *Decreases Mean Time To Repair*
 - *MTTR = Is the average time to repair equipment back to acceptable operating conditions. Once the equipment breaks down, the actual time spent on detecting a failure has occurred, arranging spares, resources, planning and executing the tasks and then bringing it back to operating condition.*

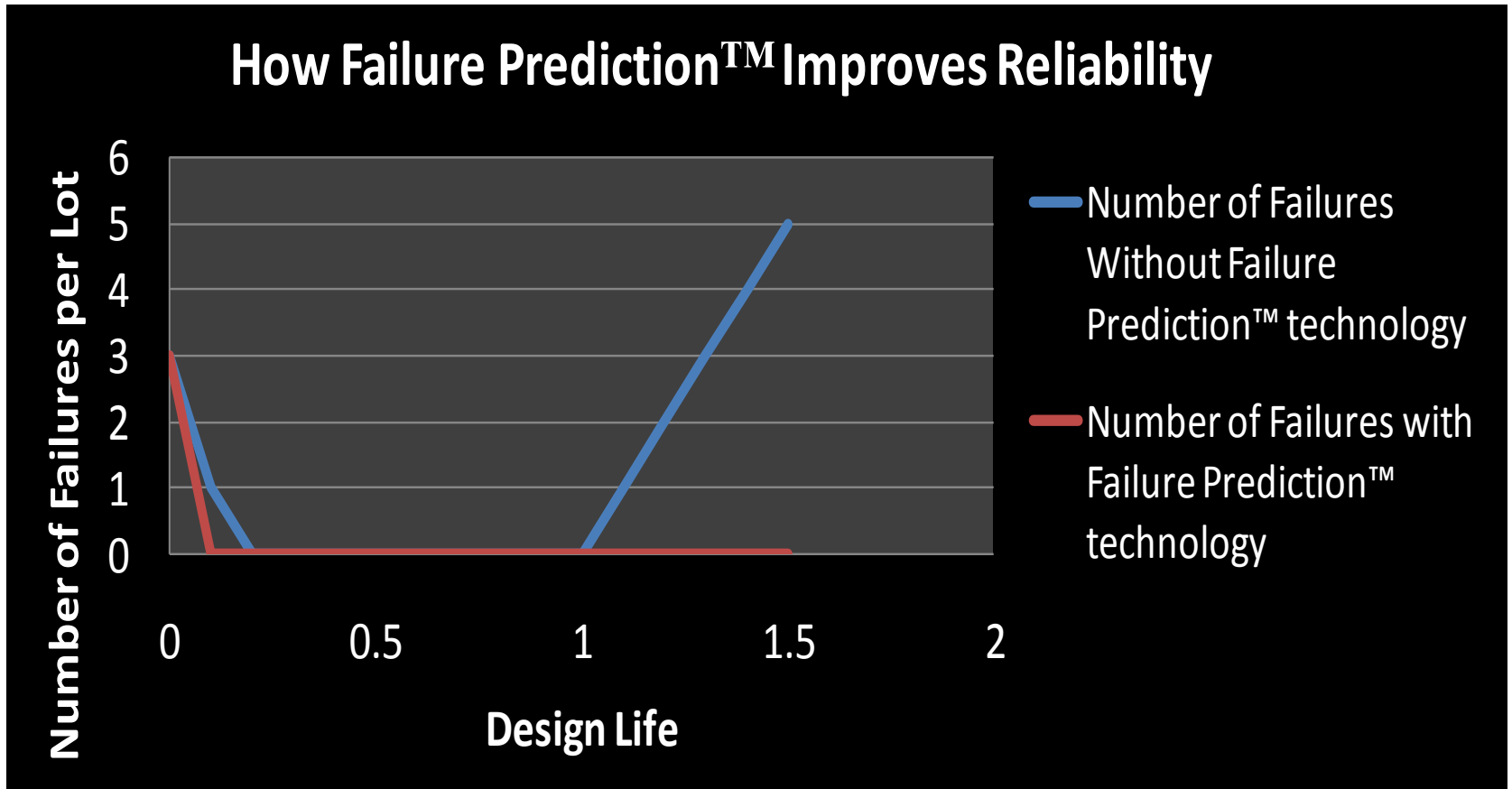


Failure Analysis

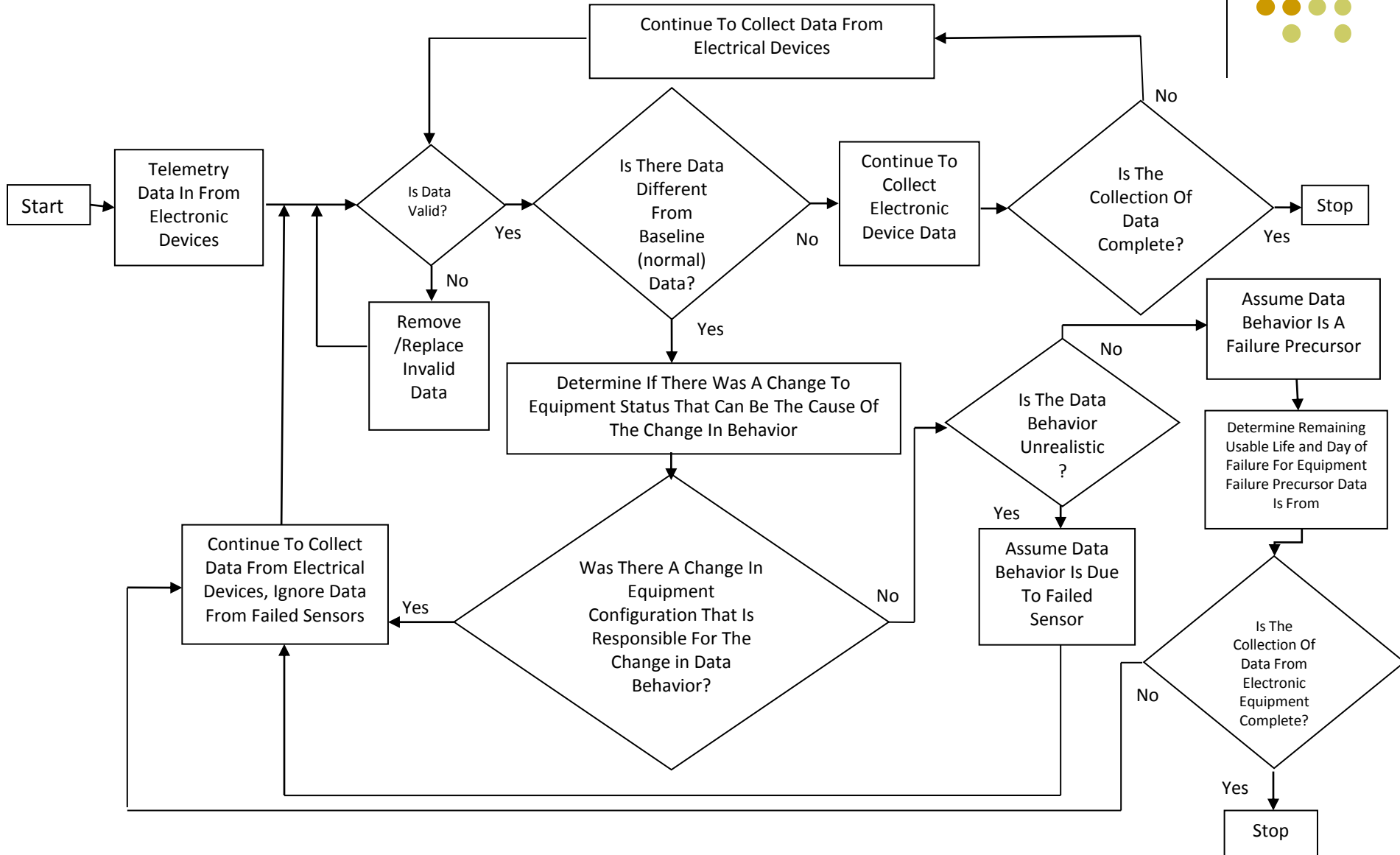
Engineering Services



- *Improves Equipment Piece Part Lot Wear Out Failure Rate*



Process for Identification of Failure Precursors in Telemetry



Failure Analysis

Engineering Services



Telemetry Prognostics Content Summary

| <i>Technology</i> | <i>Purpose/Objective</i> |
|-------------------------------------|---|
| <i>Active Reasoning</i> | <i>Takes passively monitored symptoms and returns fault diagnosis</i> |
| <i>Telemetry Authentication</i> | <i>To remove/replace unreliable telemetry</i> |
| <i>Rate Change Analysis</i> | <i>To identifies suspect telemetry for further analysis</i> |
| <i>State Change Analysis</i> | <i>To identify telemetry for further analysis</i> |
| <i>Multi-variant Limit Analysis</i> | <i>To identify suspect telemetry behavior</i> |
| <i>Statistical Sampling</i> | <i>To reduce size of telemetry database to analyze</i> |
| <i>Super Impositioning</i> | <i>To create virtual telemetry behavior</i> |
| <i>Mathematical Modeling</i> | <i>To generate predictive modeling functions</i> |
| <i>Digital Processing</i> | <i>To improve image resolution</i> |
| <i>Super Precision</i> | <i>To improve image resolution</i> |

Failure Analysis

Engineering Services



Telemetry Prognostics Content Summary

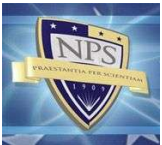
| <i>Technology</i> | <i>Purpose/Objective</i> |
|--------------------------------|---|
| <i>Data Mining</i> | <i>To identify suspect telemetry behavior in large databases of telemetry</i> |
| <i>Database Generation</i> | <i>To reduce the amount of telemetry to analyze</i> |
| <i>Baseline Analysis</i> | <i>To determine normal telemetry behavior</i> |
| <i>Change Analysis</i> | <i>To identify deviations from normal telemetry behavior</i> |
| <i>Discrimination Analysis</i> | <i>To be able to discriminate normal from failure precursors</i> |
| <i>Root Cause Analysis</i> | <i>To identify circuit/component failing</i> |
| <i>Remaining Usable Life</i> | <i>To determine remaining usable life of equipment</i> |
| <i>Day of Failure Analysis</i> | <i>To determine day of failure of unreliable equipment</i> |

Failure Analysis

Engineering Services



- *Telemetry Prognostics Description cont'd*
 - *Uses Mathematical Modeling*
 - *Regression Analysis /curve fitting*
 - *Harmonic Analysis is used to create sinusoidal functions for predicting future normal telemetry (virtual telemetry) behavior*
 - *Fourier Analysis is used to create mathematical functions for telemetry (virtual telemetry) behavior that are used to predict future normal behavior*
 - *Fourier Transforms are used to identify data for further analysis*
 - *Kalman Filtering is a mathematical process using time series data for predicting future behavior based on past behavior with real time updates included by modeling all known variables is used to create future telemetry (virtual telemetry) for predicting normal telemetry behavior*
 - *Neural Networks are used for predicting future telemetry (virtual telemetry) behavior for normal telemetry*



Failure Analysis

Engineering Services



- *Kalman Filtering*

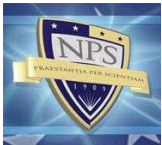
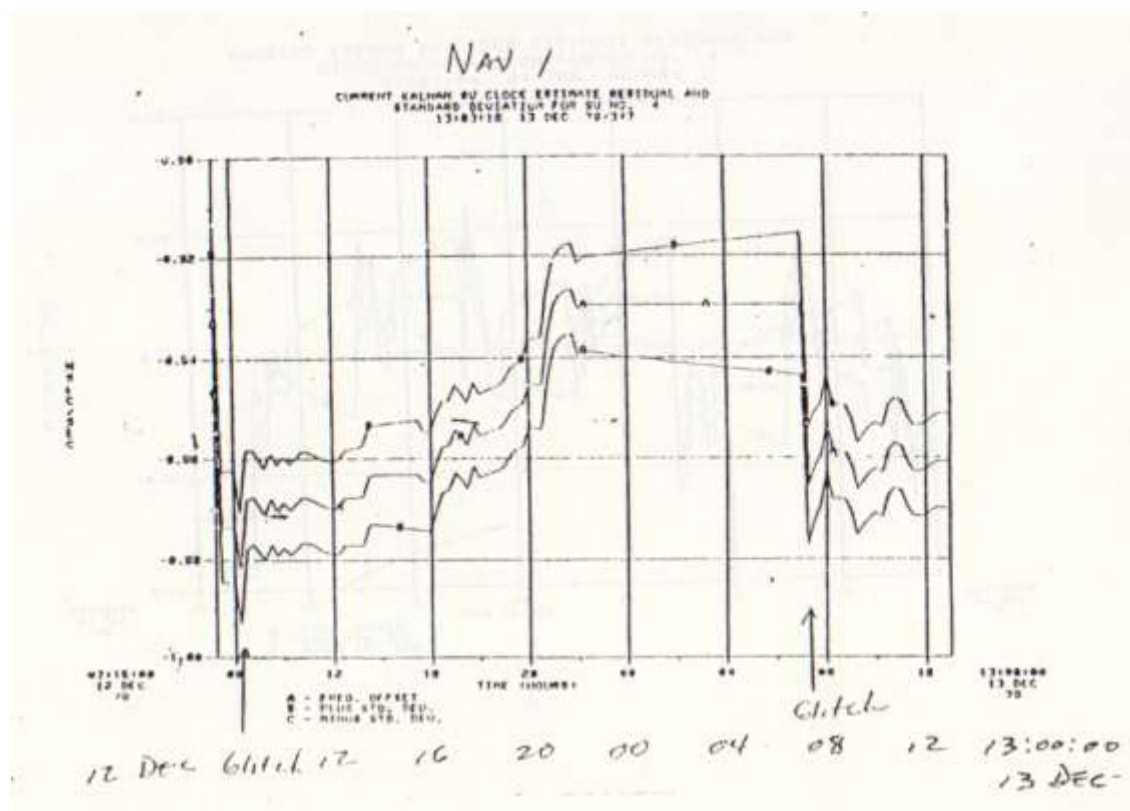
- *A non linear modeling technique that estimates by using a form of feedback control, the filter estimates the process state at some time and then obtains real-time feedback in the form of noisy measurements in the future*
 - *Equations are time series update equations and measurement update equations.*
- *The time series measurement update equations are responsible for the feedback, i.e. for incorporating a new measurements into the a priori estimate to obtain an improved a posteriori estimate.*
 - *The time series update equations can also be thought of as predictor equations*
 - *Measurement update equations can be thought of as corrector equations.*
- *The final estimation algorithm resembles that of a predictor-corrector algorithm for solving numerical problems.*

Failure Analysis

Engineering Services



- *Kalman Filtering*



Failure Analysis

Engineering Services



- *Neural Networks*
 - *Uses computational model for information processing based on a connectionist approach to computation*
 - *It is an adaptive system that changes its structure based on external or internal information that flows through the network.*
 - *Non-linear statistical data modeling or decision making tools*
 - *Used to model and predict complex relationships between inputs and outputs by finding patterns in data and modeling them*

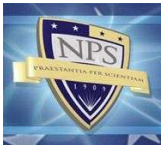
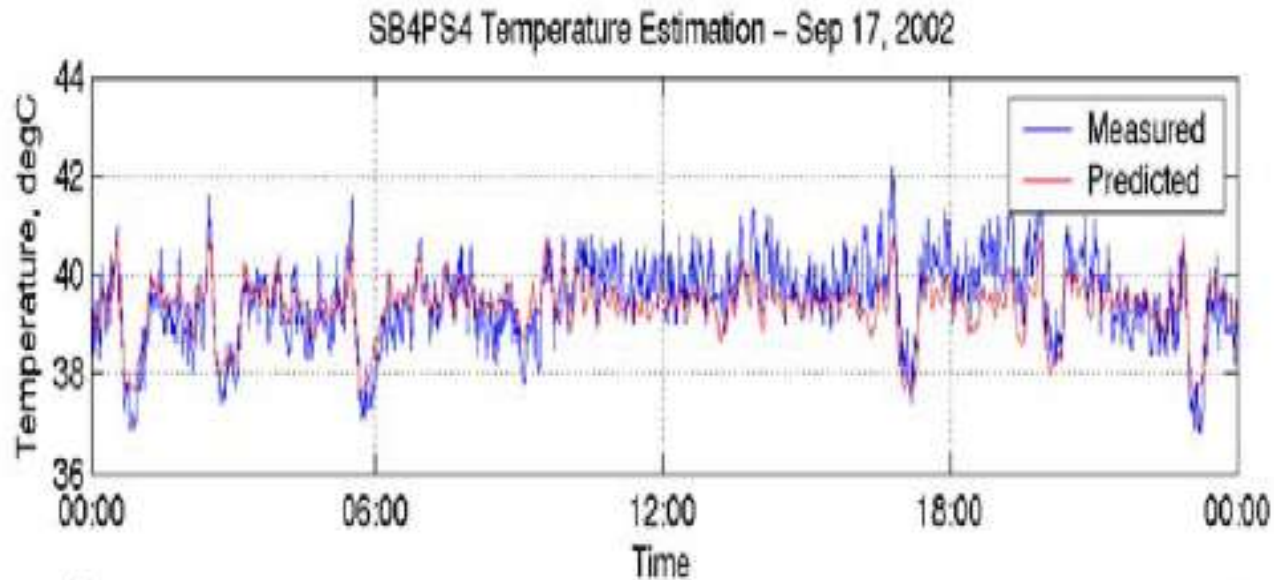


Failure Analysis

Engineering Services

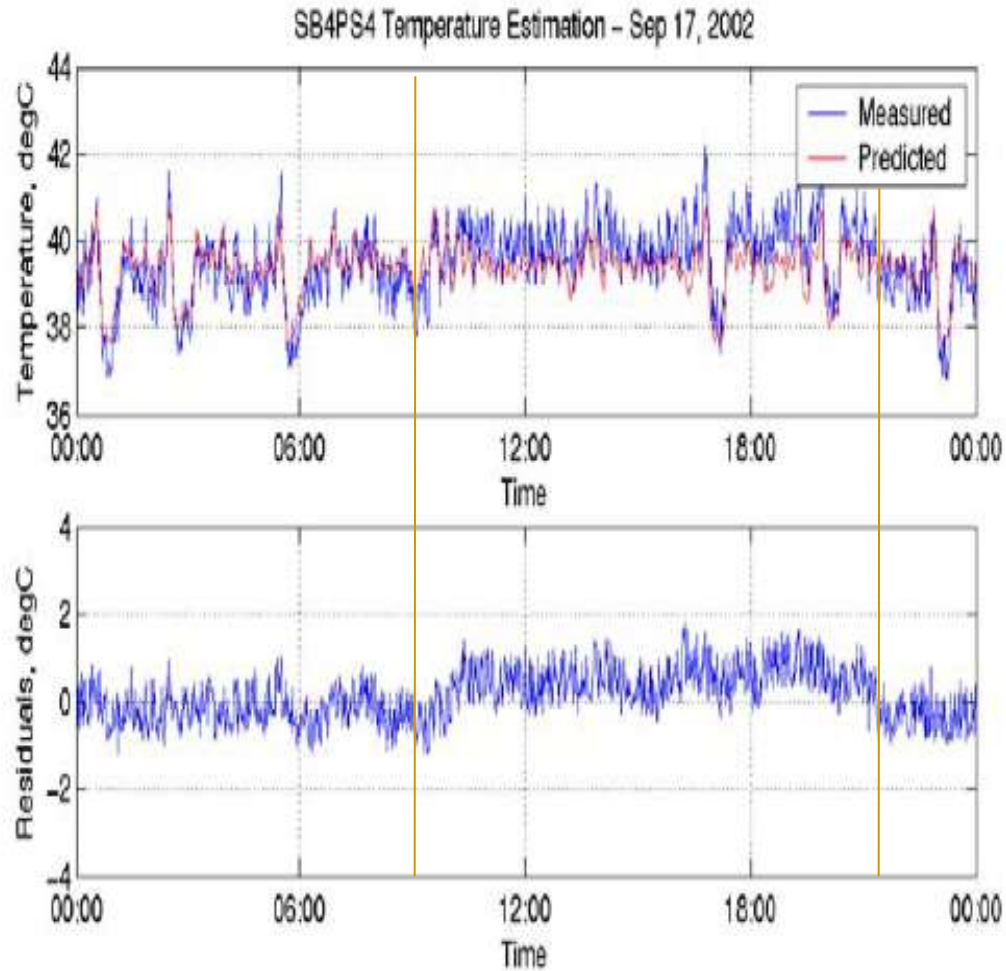


- *Neural Networks Signal Prediction for Creating Virtual Telemetry*



Failure Analysis

Engineering Services



Failure Analysis

Engineering Services



- *Telemetry Prognostics Description cont'd*
 - *Uses Tailored Statistical Sampling Techniques*
 - *When real-time engineering data is collected and stored, the sheer amount of data can be daunting even for low downlink rates.*
 - *Processing all the engineering data for a specific measurement overwhelms the resolution of the analysis tools and the products are of no value.*
 - *Statistical sampling techniques allow reducing the workload associated with processing large quantities of engineering data collected from telemetry and has been highly successful.*

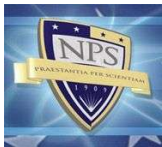


Failure Analysis

Engineering Services



- *Statistical Sampling Techniques cont'd*
 - *Failure Analysis uses flight proven statistical data sampling techniques created just for Telemetry Prognostics for reducing overall data size which allows latent behavior characteristics to become discernable in time series data*
 - *Synchronous, dynamic interval (SDI).*
 - *Non-synchronous, fixed interval (NFI).*
 - *Non-synchronous, dynamic interval (NDI).*
 - *Synchronous, fixed interval (SFI).*
 - *Using Failure Analysis' statistical sampling techniques can reduce the total data available for Prognostics by over 99.99% however, which data is valuable ahead of time is not known so all of it must be available for processing*



Failure Analysis

Engineering Services



- *Statistical Sampling Techniques cont'd*
 - *Final data sets are selected to maximize end product visual performance for pattern recognition in normal appearing telemetry.*
 - *Using both synchronous and non synchronous sampling increases the likelihood of detecting the start of a failure precursor but it isn't needed to determine the remaining usable life. Other factors such as least significant bit resolution and bit depth effect this calculation.*
 - *Linear negative extrapolation is used to determine starting point.*
- *Because of the variability of piece parts performance in circuit operations and temperature cycling influence on piece part failure, failure precursor signatures do not repeat even on identical piece parts, identical units and identical circuits*
- *Failure Precursor Pattern Recognition (FPPR) is accomplished by the Prognostic engineer using image analysis – No 2 failures are alike*

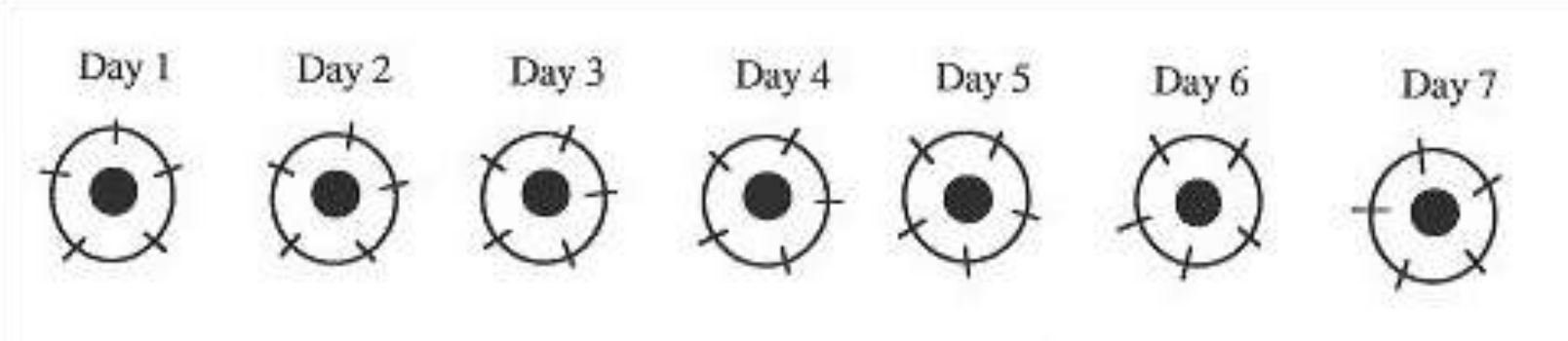


Failure Analysis

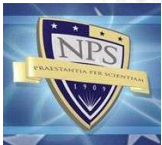
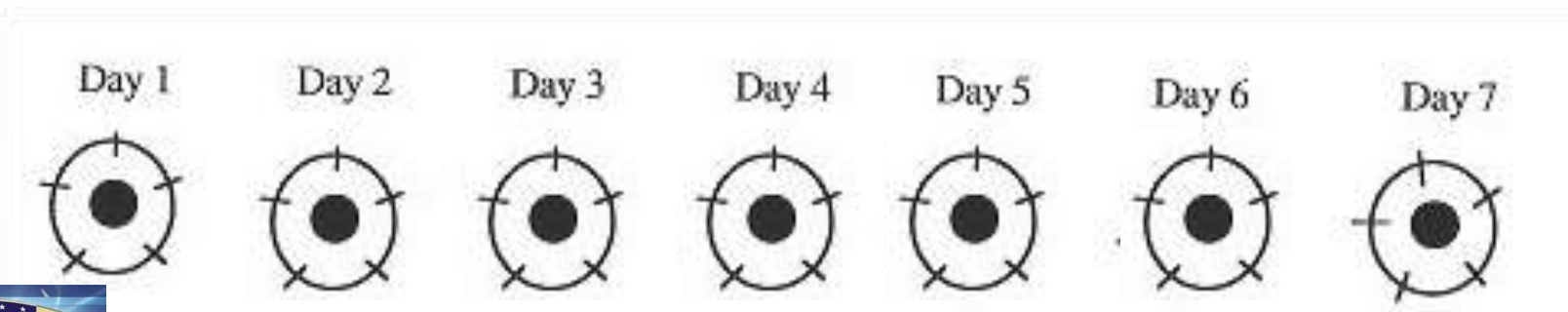
Engineering Services



- *Synchronous Dynamic Interval Sampling*



- *Synchronous Static Interval Sampling*



Failure Analysis

Engineering Services



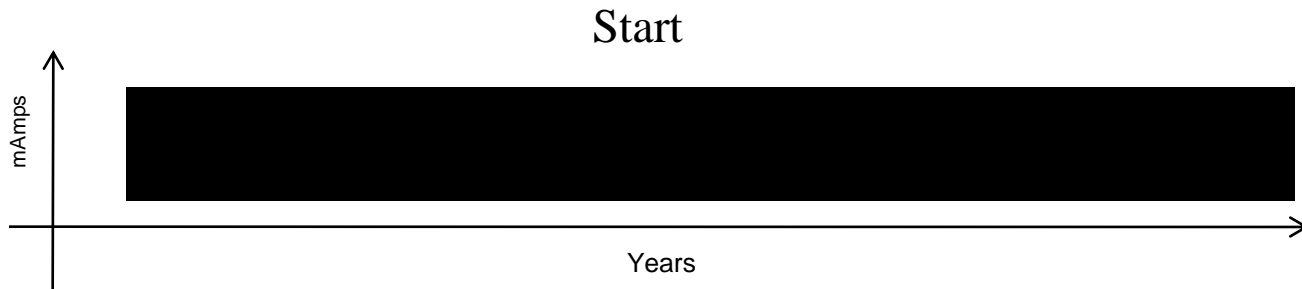
- *Calculating Remaining Usable Life (RUL)*
 - *Historically, high reliability flight equipment has demonstrated consistent behavior from the start of failure to complete failure.*
 - *RUL is shortened when equipment is subjected to high stress (acoustic, thermal, vibration, shock) environment*
 - *Resolving the start of the failure signature in normal appearing telemetry using discrimination analysis increases the accuracy of the RUL calculation.*
 - *Predict Day Equipment Will Fail*



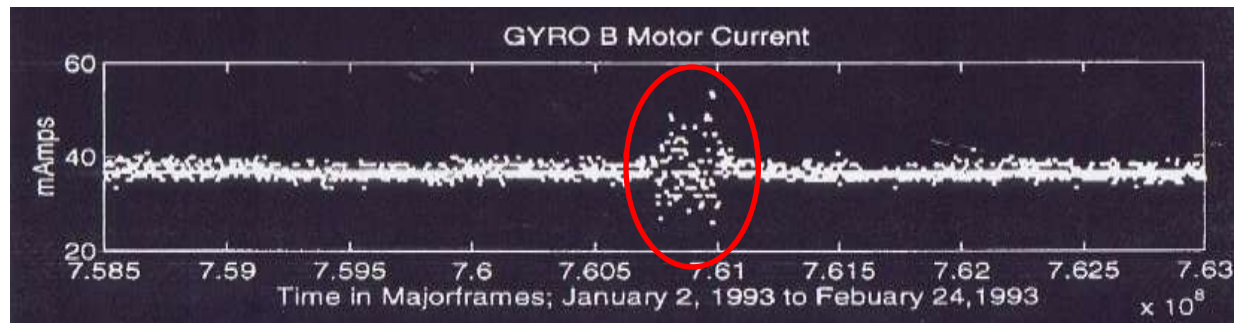
Failure Analysis

Engineering Services

- *Telemetry Prognostics Start*



Finish

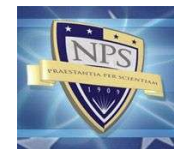


Failure Analysis

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- *Why Failure Analysis' Failure Prediction™ Telemetry Prognostics?*
 - *Responsible for the creation and use for 29 years*
 - *We know what to look for*
 - *Requires high level of expertise*
 - *No two failures look alike*
 - *Not suitable for pattern recognition software*
 - *We know when to look for it*
 - *We know how to look for it*
 - *We know where to look*
 - *We know why it works*



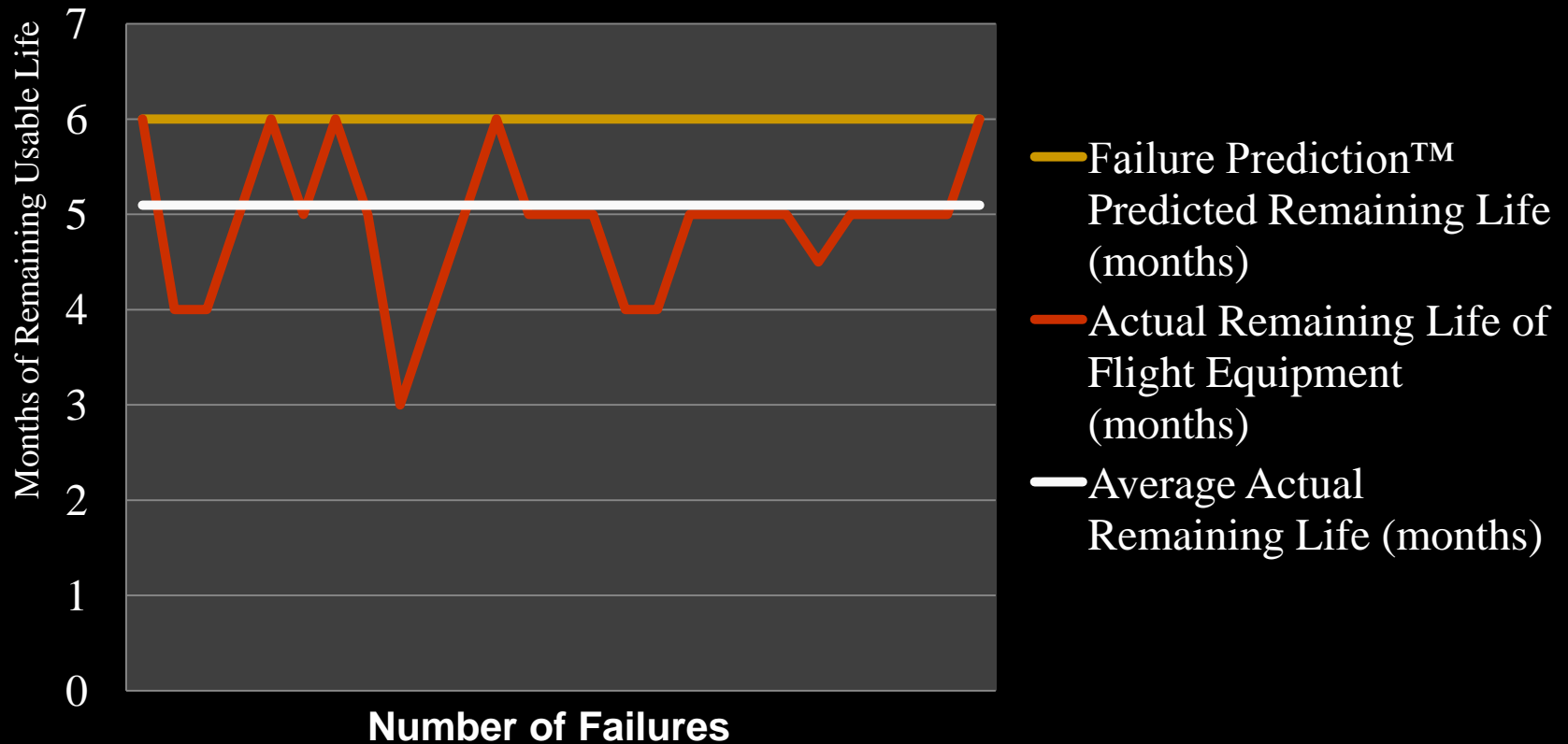
Failure Analysis

Engineering Services



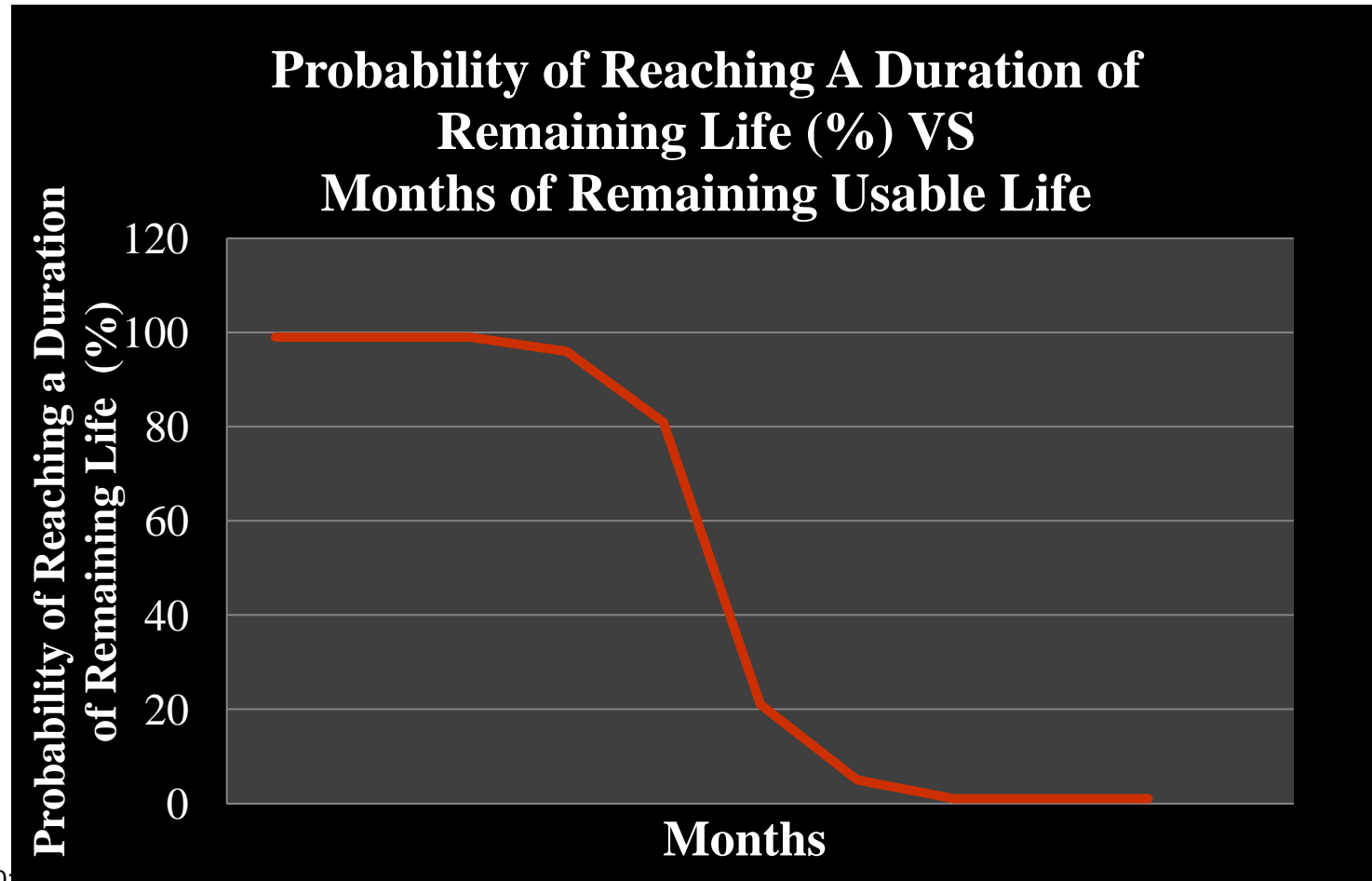
- *Actual Failure Prediction™ Performance*

**Comparison Between Failure Prediction™ RUL,
Actual RUL and Average Actual RUL**



Failure Analysis

Engineering Services



Failure Analysis

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- *NASA's Implementation of Telemetry Prognostics*
 - *NASA Ames Research Center*
 - *Huge Research & Development effort on-going for several years trying to become an expert in Telemetry Prognostics*
 - *2006 Small Business Innovation Research (SBIR) projects*
 - *Aeronautical systems - Aviation Safety*
 - *Integrated Vehicle Health Management*
 - *Prognosis technology for predicting aircraft failures*
 - *Exploration systems – Future spacecraft & launch vehicles*
 - *Integrated Vehicle Health Management*
 - *Prognostic technology for predicting vehicle failures*



Failure Analysis

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- *Funded NASA AMES SBIR Vehicle Telemetry Prognostics Technology Development Projects for 2006*



| NASA Subtopic | NASA Proposal Title | Research Firm | NASA Proposal # |
|--------------------------------------|--|----------------------------------|------------------------|
| Integrated Vehicle Health Management | Diagnostics and Prognostics for Space Applications | Global Technology Connection Inc | 06-IA1.07-8707 |
| Integrated Vehicle Health Management | Aircraft Electrical Power System Diagnostics and Health Management | Techno-Sciences, Inc. | 06-IA1.07-8798 |
| Integrated Vehicle Health Management | Real-Time Fault Contingency Management for Integrated Vehicle Health Management | Impact Technologies, LLC | 06-IA1.07-9303 |
| Integrated Vehicle Health Management | Real-Time Adaptive Algorithms for Flight Control Diagnostics and Prognostics | Barron Associates, Inc. | 06-IA1.07-9512 |
| Integrated Systems Health Management | Automated Fault Diagnostics, Prognostics, and Recovery in Spacecraft Power Systems | Qualtech Systems, Inc. | 06-IX2.01-8204 |
| Integrated Systems Health Management | Integrated Health Management for Space Flight Digital Systems | Ridgetop Group, Inc. | 06-IX2.01-9421 |

Failure Analysis

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- *Air Force & Navy Telemetry Prognostics Programs*
 - *Adding measurements on aircraft to stop failures and reduce maintenance for in-flight missions*
 - *Reduce the need for preventive maintenance*
 - *Only do what repair & replacement as required*



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- *Telemetry Prognostics Development in Other Industries*
 - *Nuclear Power Industry*
 - *Argonne National Laboratory*
 - *SPRT - Sequential Probability Ratio Test for static time varying sequences*
 - *MSET – Multi-variante State Estimation Technique*
 - *Commercial Computer Industry*
 - *Sun Microsystems*
 - *High Reliability (>99.999%) Computer Servers*
 - *Uses SPRT and MSET for Telemetry Prognostics*
 - *HP, Force Computers*
 - *High Reliability (>99.999%) computer servers*
 - *Uses in house proprietary technology*



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- Books and reference material available from Failure Analysis at www.failureanalysisco.com, info@failureanalysisco.com
 - *An Introduction to Predicting Failures & Measuring Remaining Usable Life for Highly Reliable Aerospace Equipment*, ISBN 0974135844, 400 pgs, \$99.95, available from Amazon.com, etc
 - *Predicting Failures & Measuring Remaining Usable Life for Highly Reliable Aerospace Equipment*, ISBN 097674919X, 325 pgs, \$149.95, available from Amazon.com etc.
 - *Failure Prediction Telemetry Prognostics for Satellite & Launch Vehicle Integration & Test Users Guide*, 200 pgs, available free
 - *Predicting Failures & Estimating Duration of Remaining Service Life from Satellite Telemetry*, paper published at ITC 1995, available free
 - *Predicting Hardware Failures and Estimating Remaining Usable Life from Telemetry* presentation, by Lockheed Martin Missiles & Space Company, presented in 1996, available free
 - *Stopping Launch Pad Delays, Launch Failures, Satellite Infant Mortalities and On orbit Satellite Failures Using Telemetry Prognostic Technology*, paper presented at ITC 2007, available free
 - Power Point presentation from the paper presented at ITC 2007 titled, *Stopping Launch Pad Delays, Launch Failures, Satellite Infant Mortalities and On orbit Satellite Failures Using Telemetry Prognostic Technology*, available free
 - *A Statistical Approach for the Development of the Failure Prediction Process (FPP)* published in 1995 by Lockheed Martin Space & Missiles Company, available free
 - *Telemetry Prognostic Technology* Power Point presentation, 200 pgs, available free

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Conclusions

- *Telemetry Prognostics*
 - *Lowers costs*
 - *Shortens delivery schedules*
 - *Simplifies maintenance program*
 - *Predicts failures*
 - *Determines remaining usable life*
 - *Increases equipment reliability*
 - *Increases equipment serviceability*
 - *Increases equipment availability*
 - *Increases usable remaining life*
 - *Uses proven techniques*
 - *Can be used across many types of vehicles*
 - *Highly reliable*
 - *Available today*

