



Smart Data Selection (SDS)

Mark Wigent
Laulima Systems

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Outline



- Project Description
- SDS ConOps
- System Description
- Bandwidth Efficient Algorithm
- PCM Compression Enhancement
- Benefits to T&E



Project Description

“The dominant inherent nature to TM in DoD testing is sampled time-history data from an ultimately analog world, (which) is not going to change drastically regardless of how data is transmitted to ground. A factor that could change that fact most is the degree to which answers instead of data are obtained on board the test vehicle”

iNET Concept of Operations, v. 2007.1

•SDS seeks to change this inherent nature of telemetry in DoD testing by:

- Developing an on-board capability to monitor and analyze test data in order to reduce the amount of data sent to the ground
- Employing bandwidth efficient algorithms to reduce bandwidth requirements
- Developing the capability to notify operators when data demonstrate abnormal behavior

Results in Significant Savings in Spectrum and Increased Operator Awareness



SDS ConOps

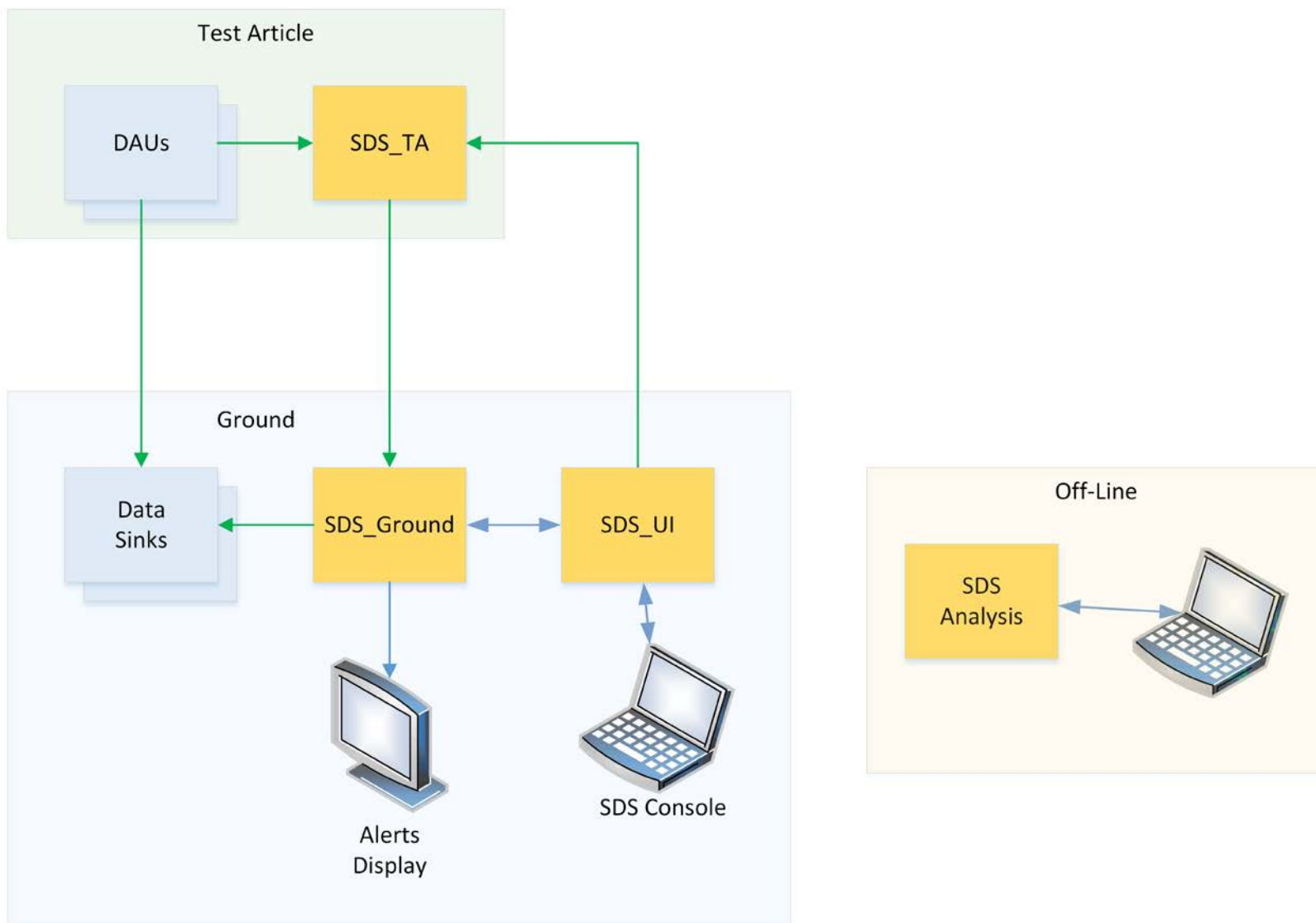
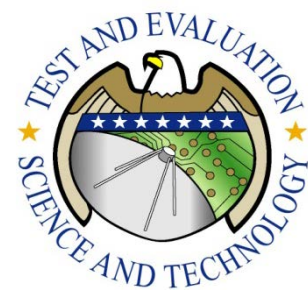


The SDS system:

- Analyzes pre-recorded data to identify behavioral trends
- Applies user-defined behavioral criteria
- Subscribes to all on-board parameters
- Determines what live data is of interest for real-time observation and analysis
- Applies bandwidth efficient algorithms to select measurements
- Generates specific messages to be sent to ground
- Provides alerts for data that demonstrate abnormal behavior
- Supports user feedback in response to alerts



System Description





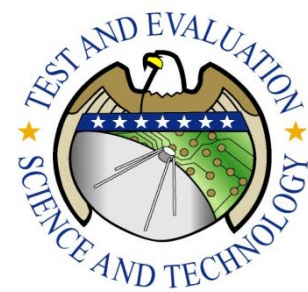
Data Compression



- Lossless compression (ZIP) is well known and has been widely used in situations where a reduction of the data sizes is desirable
- Not widely used in telemetry applications for the following reasons:
 - Increased processing requirements
 - Effective compression rate depends on the data being compressed
 - Compression works better for large blocks of data, but large blocks may increase latency
 - Single bit transmission errors may cause loss of a full block of data if ECC (Error Correction Code) is not used.



Enhanced Lossless Compression



- Takes advantage of telemetry data characteristics to improve the effectiveness of the ZIP compression
 - After the original measurement value only measurements deltas are transmitted
 - The bits of the deltas are reorganized to take advantage of the fact that the high order bits are much more stable than the low order bits
 - Limits block size to 255 bytes to reduce impact on latency
- Even with the overhead and ECC (13 bytes per 255 bytes block), tests with actual telemetry data showed an effective bandwidth gain of over 70%.



Bandwidth Efficient Algorithms



- SDS applies extrapolation algorithms to selected data
 - Allows for TA transmission of extrapolation parameters rather than individual measurement values
 - Ground calculates and publishes with required frequency
- TA monitors error between extrapolation values and actual measurements
- If error threshold exceeded, new parameters are calculated and applied



Bandwidth Savings



- Representative test results:
 - ~45,000 measurements at 98.04 Hz
- **Very small error threshold:**
 - Error $\leq 0.01\%$
 - SDS requires less than 7% of original bandwidth
- **Small error threshold:**
 - Error $\leq 0.02\%$
 - SDS requires less than 3% of original bandwidth



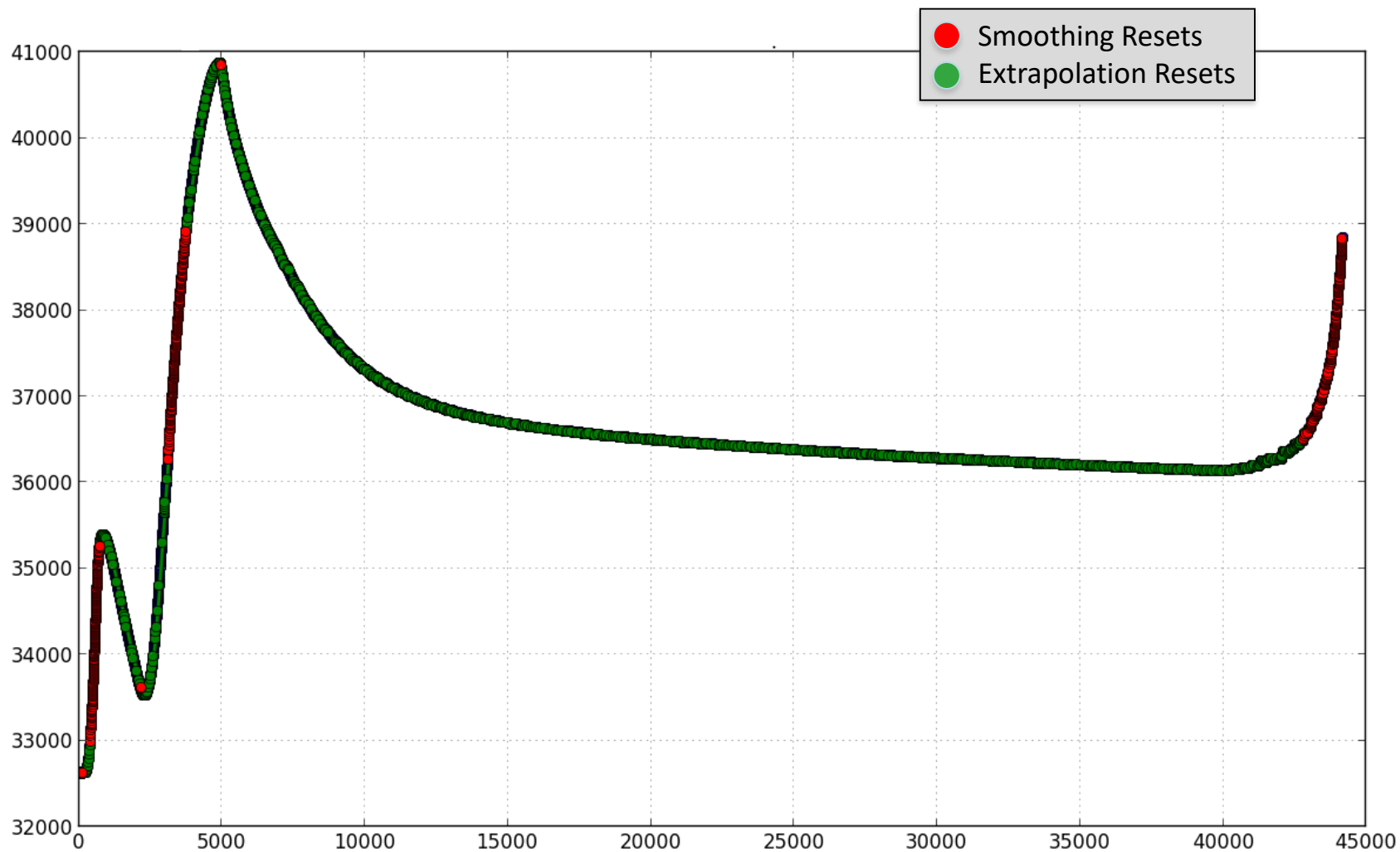
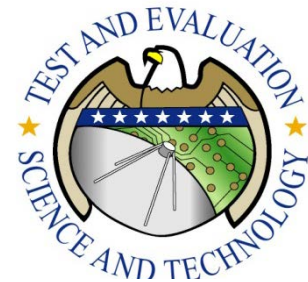
Bandwidth Efficient Algorithms



- Exponential Smoothing
 - Single Exponential Smoothing
 - $sv[i] = a * m[i] + (1 - a) * sv[i-1]$
 - Extrapolation: $ev[i+n] = sv[i]$
 - Double Exponential Smoothing
 - $sv[i] = a * m[i] + (1 - a) * (sv[i-1] + t[i-1])$
 - $t[i] = b * (sv[i] - sv[i-1]) + (1 - b) * t[i-1]$
 - Extrapolation: $ev[i+n] = sv[i] + n * t[i]$



Thermocouple Example



~45000 measurements @ 98.04 Hz



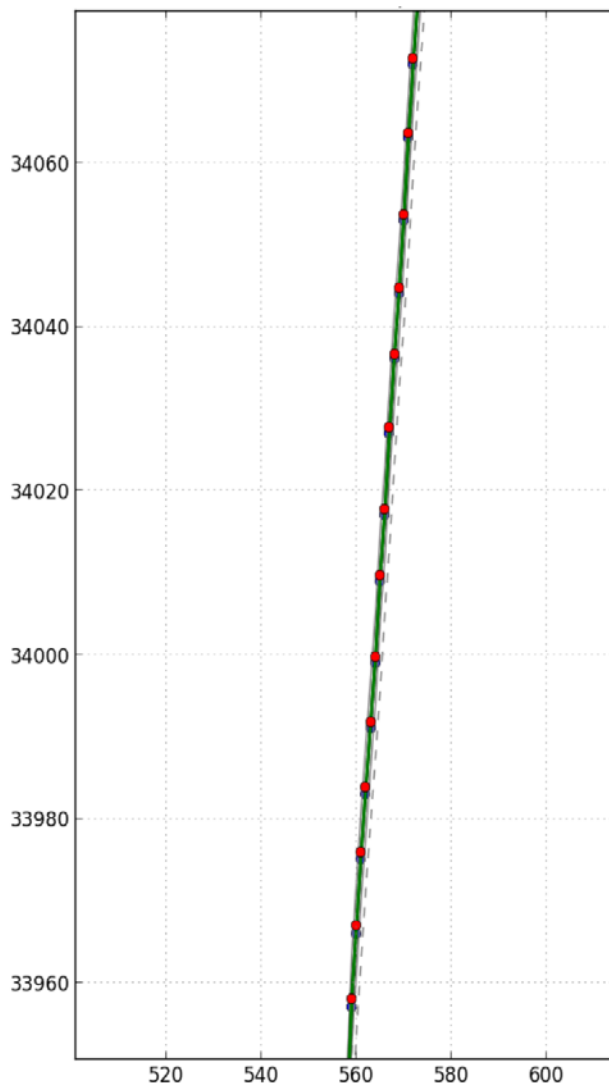
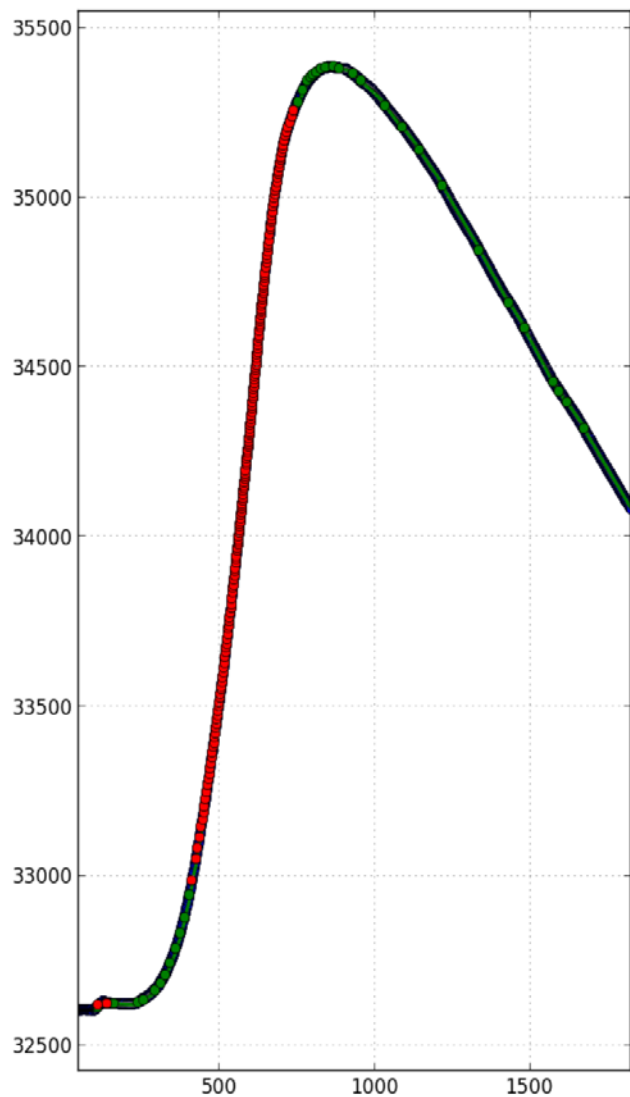
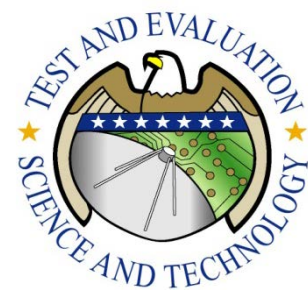
Bandwidth Savings



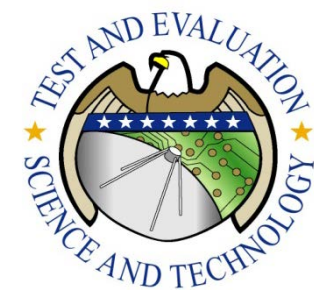
- 44091 Measurements
- Measurement Size = 2 bytes
- Error threshold of 0.01%
- 1001 EBE Resets
 - Transmission Cost = ~3 Measurements
- Extrapolated Data = $1001 \times 2 \times 3 = 6006$ bytes
- Raw Measurements = $44091 \times 2 = 88192$ bytes
- **SDS uses less than 7% of bandwidth required to send raw data**



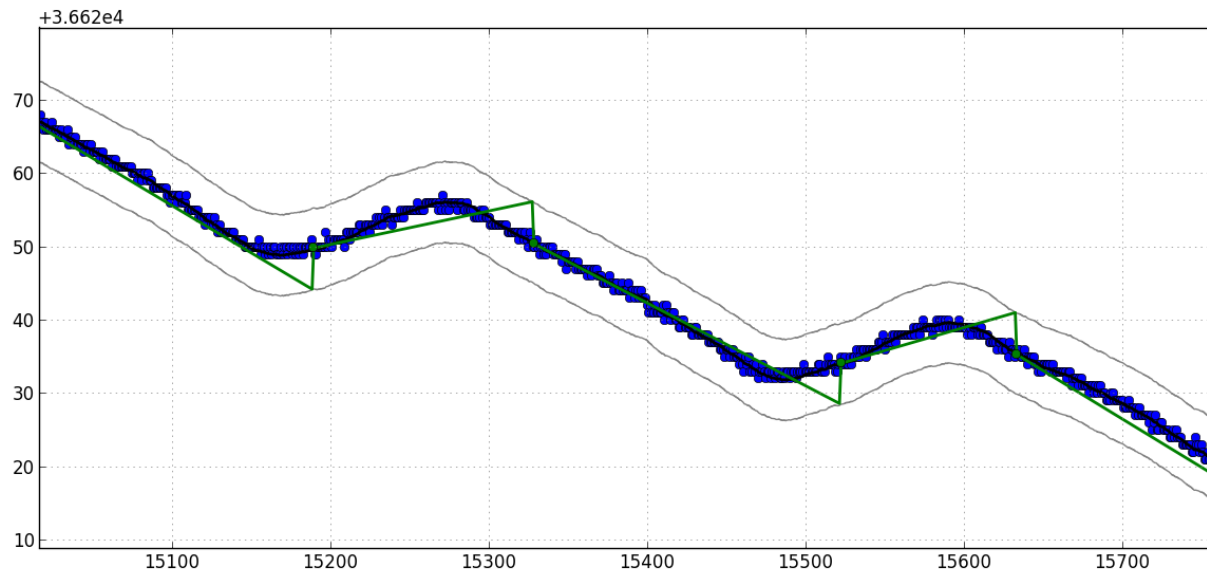
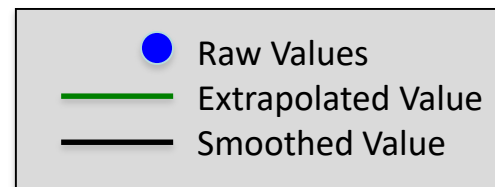
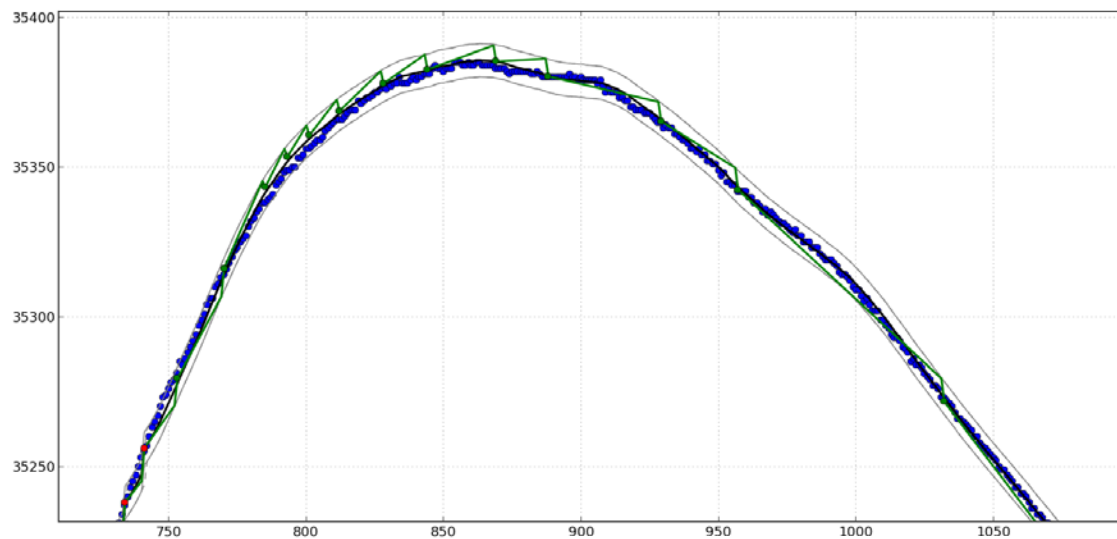
Enlarged View



- Smoothing Resets
- Extrapolation Resets



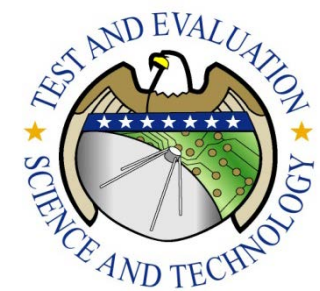
Enlarged View





Benefits to T&E

- **Bandwidth Savings/Increased Spectrum Efficiency**
 - For measurements that demonstrate a normal behavior, transmit to the ground only a representation rather than the entire data set
- **Simplified Pre-Test Configuration of Test Article Commutator**
 - Analysis of pre-recorded test data allows for determination of expected behaviors
 - Allows for automatic configuration of transmission rates
- **Enhanced Operator Awareness of Test Conditions**
 - Automatic operator notification when data values outside of normal range
 - Allows operators to focus on situations requiring immediate attention



QUESTIONS?