

**Monitoring the health of the F-22A  
airframe during full scale ground testing**

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# Monitoring the health of the F-22A airframe during full scale ground testing



## Abstract

F-22A full-scale ground testing necessitated monitoring the health of the airframe. An enormous quantity of load, strain and deflection data was generated in a short period of time and needed to be effectively analyzed. A suite of software tools was developed to satisfy these demands. The software had to allow real-time monitoring or post test review and analysis.

During static testing approximately 4000 channels of loads, strains, deflections and other measurements were monitored for article health. Data monitoring schemes included tabular, graphical and diagram related methods. Various calculations are done during the test to alert the user if deflections or strains are approaching preset flag values. Data was sent over a private internet to program partners allowing offsite monitoring of tests.

During cyclic testing approximately 1500 channels of loads, strains and deflections are continuously monitored. Various mathematical methods are employed to analyze the data, searching for changes in deflection or strain which may signal problems with the structure. Defects were discovered earlier during the test and repaired. This averted more costly repairs or in the worst case catastrophic failure of the airframe.

# F-22A Static test article in test fixture



# Monitoring parameters

## Static test article

~4000 strain gages, 60 deflections, 220 load rams

-55 full aircraft limit load tests

-23 full aircraft ultimate load tests

## Fatigue test article

~1400 strain gages, 22 deflections, 220 load rams

-2.68 lifetimes of data at approx 1,000,000 points per lifetime

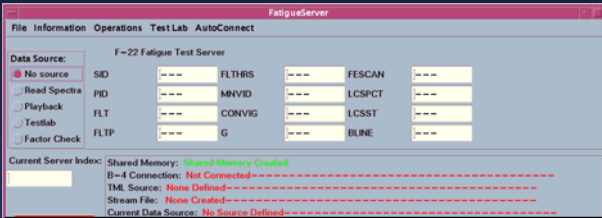
# Topics

## On Subject

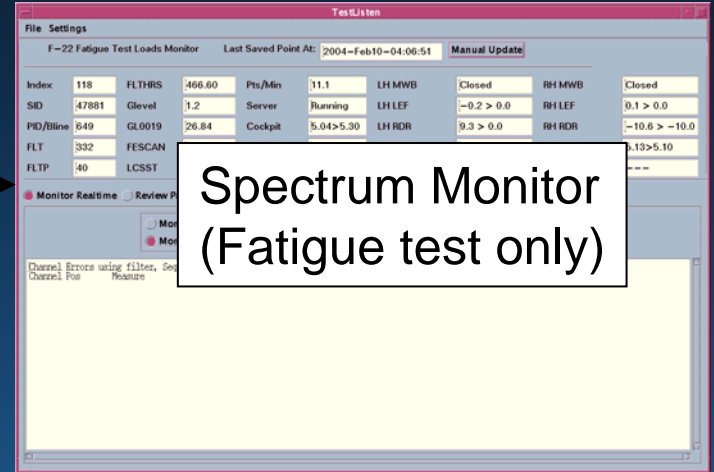
- Computer aided tools that monitor strains, deflections and loads, monitor changes in values which signal possible problems
- Monitoring often enough to catch problems which may lead to catastrophic failure of airframe.
- Maximizing lifetimes for a finite budget. Catastrophic failure tends to ruin your budget.

## Off Subject

- Using strain/load values as an input to any real time/near-real time durability or damage tolerance analysis
- Specific airframe related anomalies found during testing



**Main Server**  
 -Connects to data acquisition server at test site

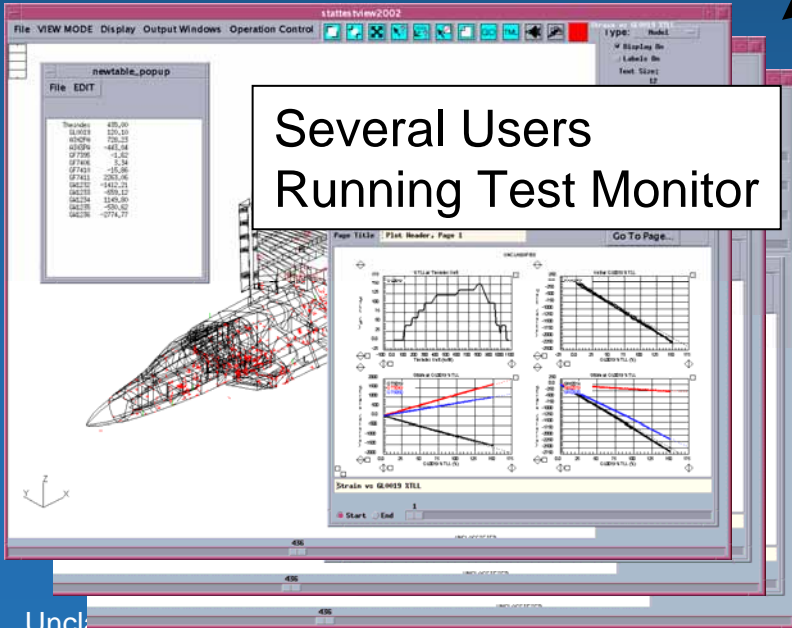


**Spectrum Monitor (Fatigue test only)**

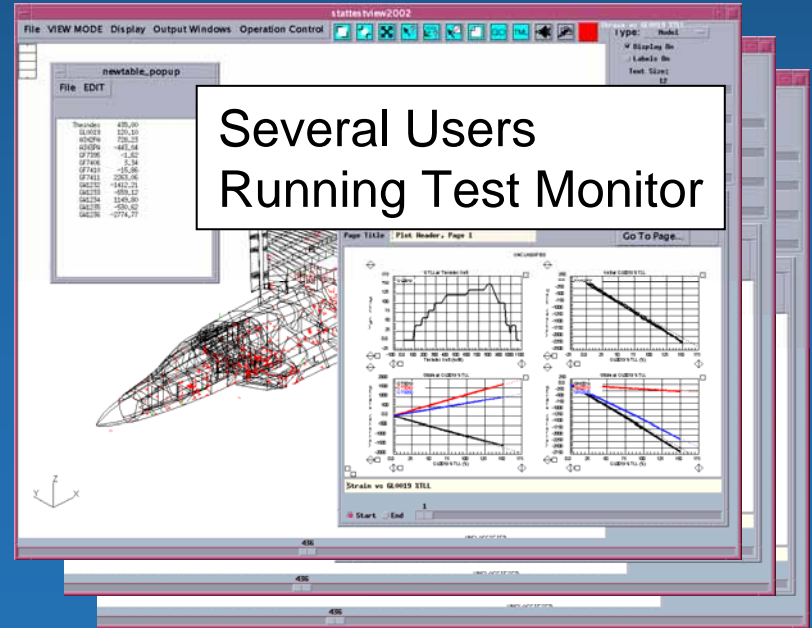
**Private Internet**

Geographic Site Marietta Ga

Other Geographic Site(Static Test)



**Several Users Running Test Monitor**



**Several Users Running Test Monitor**

## Monitoring Static Tests

- More real-time monitoring on test data
- Comparisons to FEM predictions important
- Broad overview of data important



The screenshot displays the 'stavesview2002Fs13' software interface with three main data visualization windows:

- Diagram:** A 3D wireframe model of an aircraft structure with red and green markers indicating data points. A label 'Diagram' is overlaid on the model.
- Tabular:** A table window titled 'newtab' showing a list of data points with columns for 'Theindex', numerical values, and alphanumeric codes. A label 'Tabular' is overlaid on the table.
- X-Y plot:** A window titled 'Plot\_popup' containing two line graphs. The left graph is titled 'Strain vs GL0019 %TLL' and the right graph is titled 'Strain vs GL0019 %TLL'. Both graphs show strain values on the y-axis and percentage of TLL on the x-axis. A label 'X-Y plot' is overlaid on the graphs.

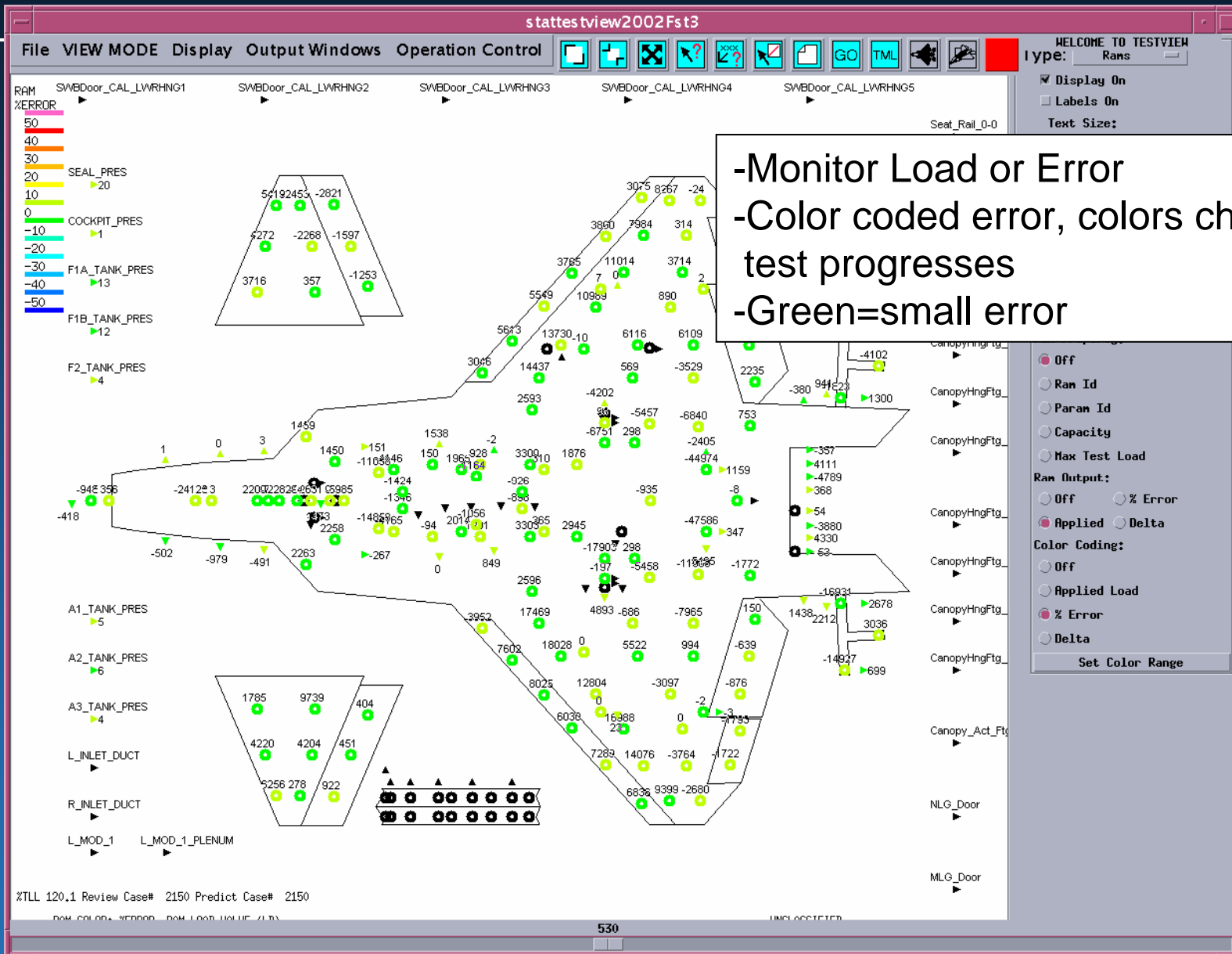
Theindex	Value	Code
Theindex	435.00	SF7411
GL0019	120.10	SF7652
AIH2PA	728.23	SF7656
AIH3PA	-443.04	SF7657
GF7395	-1.62	SF7658
GF7406	3.34	SF7659
GF7410	-15.86	SF7661
GF7411	2263.06	SF7663
GW1232	-1412.21	SF7667
GW1233	-659.10	SF7668
GW1234	1149.80	SW0212
GW1235	-530.80	SW0213
GW1236	-2774.10	SW0302
GW1240	1196.53	SW0306
GW1918	132.17	
GW1919	-66.52	
GW7004	-3764.28	
GW7006	9.91	
SF7310	232.34	
SF7312	-276.92	
SF7402	-964.49	
SF7406	459.62	
SF7409	558.40	

-Same program used during real-time testing and post test data analysis





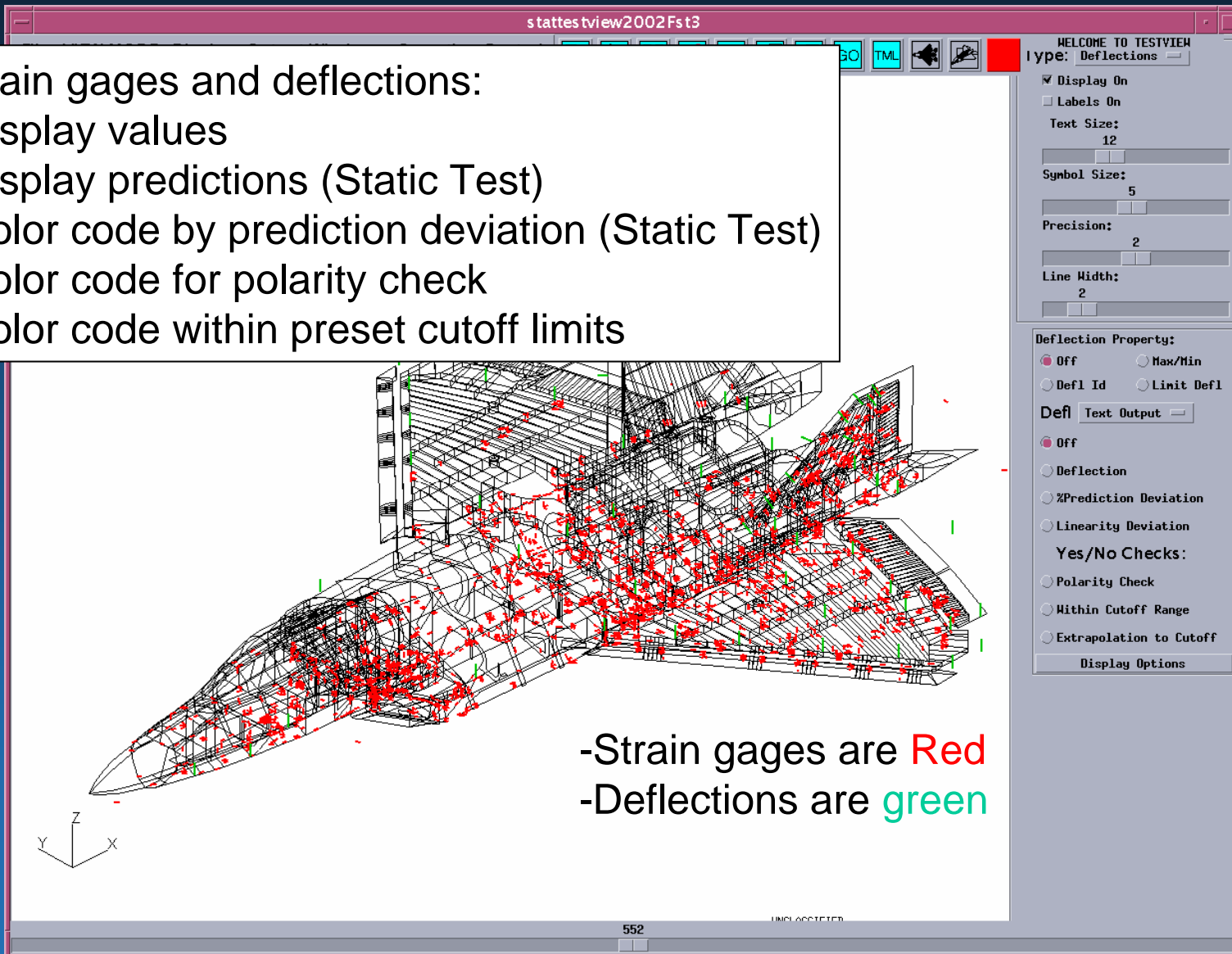
# Diagram Test Monitor For Load Rams during Static Test



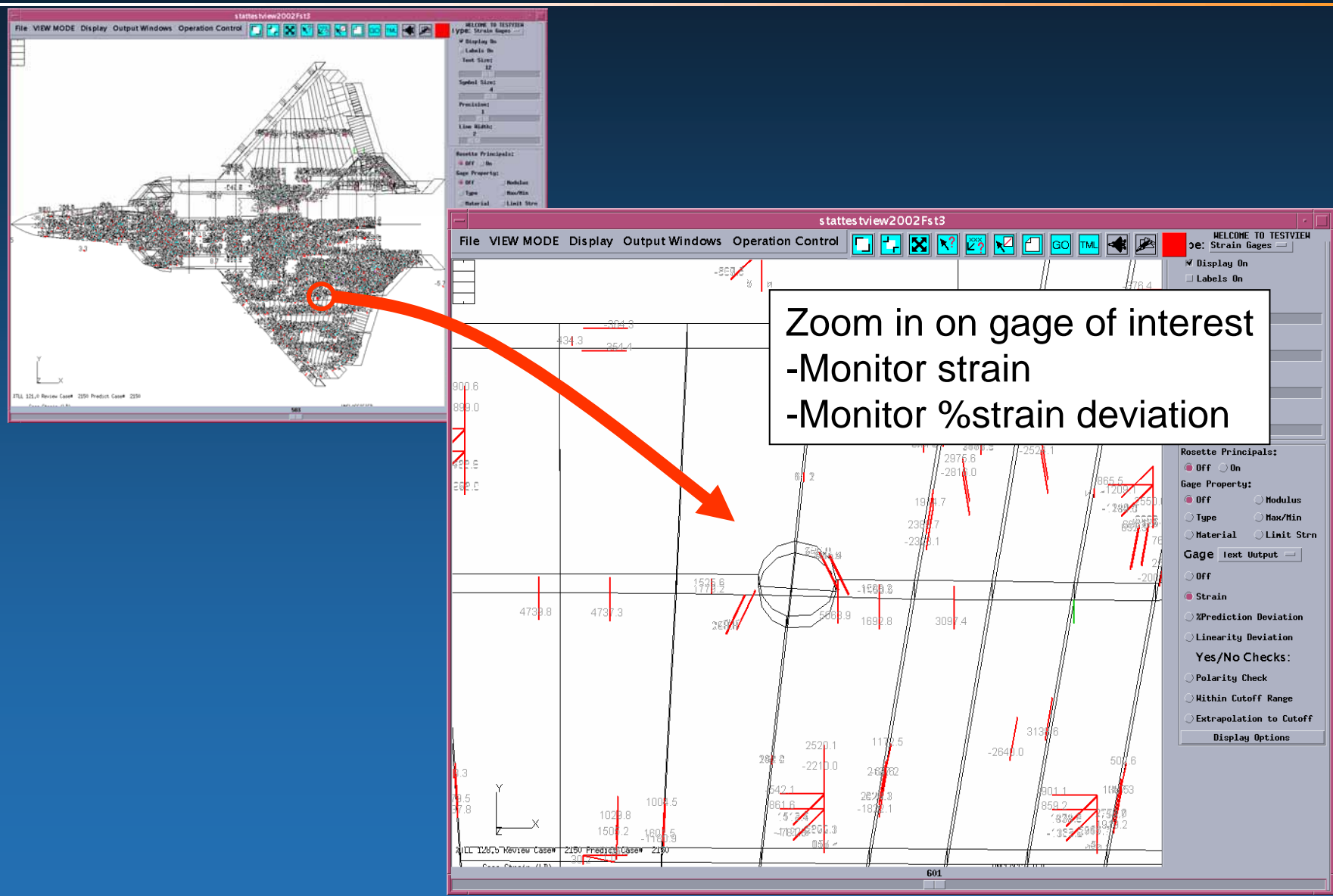


## Strain gages and deflections:

- Display values
- Display predictions (Static Test)
- Color code by prediction deviation (Static Test)
- Color code for polarity check
- Color code within preset cutoff limits



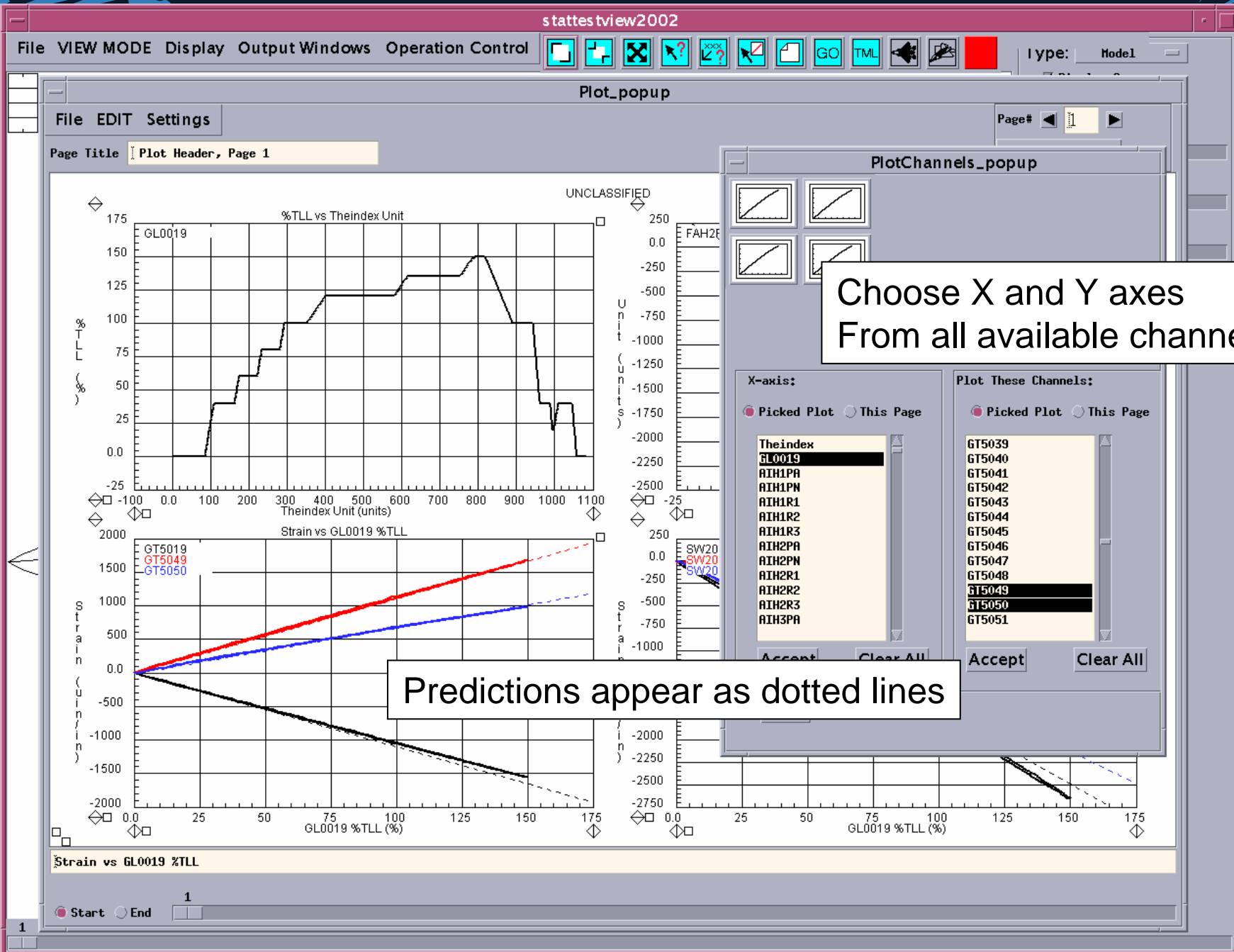
-Strain gages are Red  
-Deflections are green



The screenshot shows the 's tattes tview2002Fst3' application window. At the top, there is a menu bar with 'File', 'VIEW MODE', 'Display', 'Output Windows', and 'Operation Control'. Below the menu is a toolbar with various icons. A 'PlotTables\_popup' window is open, displaying a list of channel names under 'Channel Name:'. A callout box points to this list with the text 'Pick channels from a table or From diagram'. Below the list are buttons for 'Accept', 'Clear All', 'Cancel/Reset', 'Pick All Channels(Takes Time!)', and 'Close'. To the right, a 'Display On' panel has options for 'Labels On', 'Text Size: 12', 'Symbol Size: 5', 'Precision: 2', and 'Line Width: 2'. The main window displays a wireframe model of an aircraft with numerous red markers. A callout box points to the model with the text 'Monitor strain/deflection/load And corresponding prediction'. At the bottom right, a data table is visible, showing columns for 'TheIndex', numerical values, and channel names.

TheIndex	Value 1	Value 2	Channel Name	Value 3	Value 4
GL0019	600.0	No Predict	GT7457	3246.8	3229.26
GL0019	128.5	No Predict	GW0911	1476.3	1461.19
AIH2R2	1210.9	1083.67	GW0913	1386.8	1723.35
AIH3R2	1103.7	1199.24	GW0917	3424.1	3021.33
FAH1PA	-2565.5	-2864.16	SW0401	2418.0	2586.96
FAH1R1	-3745.3	-4146.75	SW2083	1858.5	1944.39
FAH2R3	-1900.5	-1763.17	SW2086	2468.1	2541.98
FAH3PN	1622.5	1526.68	SW2089	608.4	813.48
FAH3R2	-1622.5	-1526.68	SW2090	-951.5	-514.05
FAH4PN	-2428.9	-2536.75	SW2092	1466.1	1440.63
GF3185	-35.9	-52.69	SW2095	2692.9	2987.92
GF3204	1183.8	1035.81	SW2098	1494.9	1492.03
GF3211	-886.8	-610.43	SW2101	2131.3	2070.34
GF3213	458.3	457.50	SW2104	2047.6	2039.49
GF5252	-584.5	-534.61	SW2107	1849.6	1684.80
GF5255	-24.2	-17.99	SW3002	-932.2	-916.29
GF5257	-52.2	-56.55			
GF5259	-241.1	-331.56			
GF7255	3535.2	3545.66			
GF7265	-1429.0	-1426.49			
GT5019	-1338.2	-1425.20			
GT5048	-394.1	-224.90			
GT5050	847.1	875.17			
GT5053	772.4	868.74			
GT5058	1035.3	1080.79			
GT5059	853.3	975.41			
GT7454	-18112.3	-18060.76			

# Test Monitor for X-Y plotting capability during static test

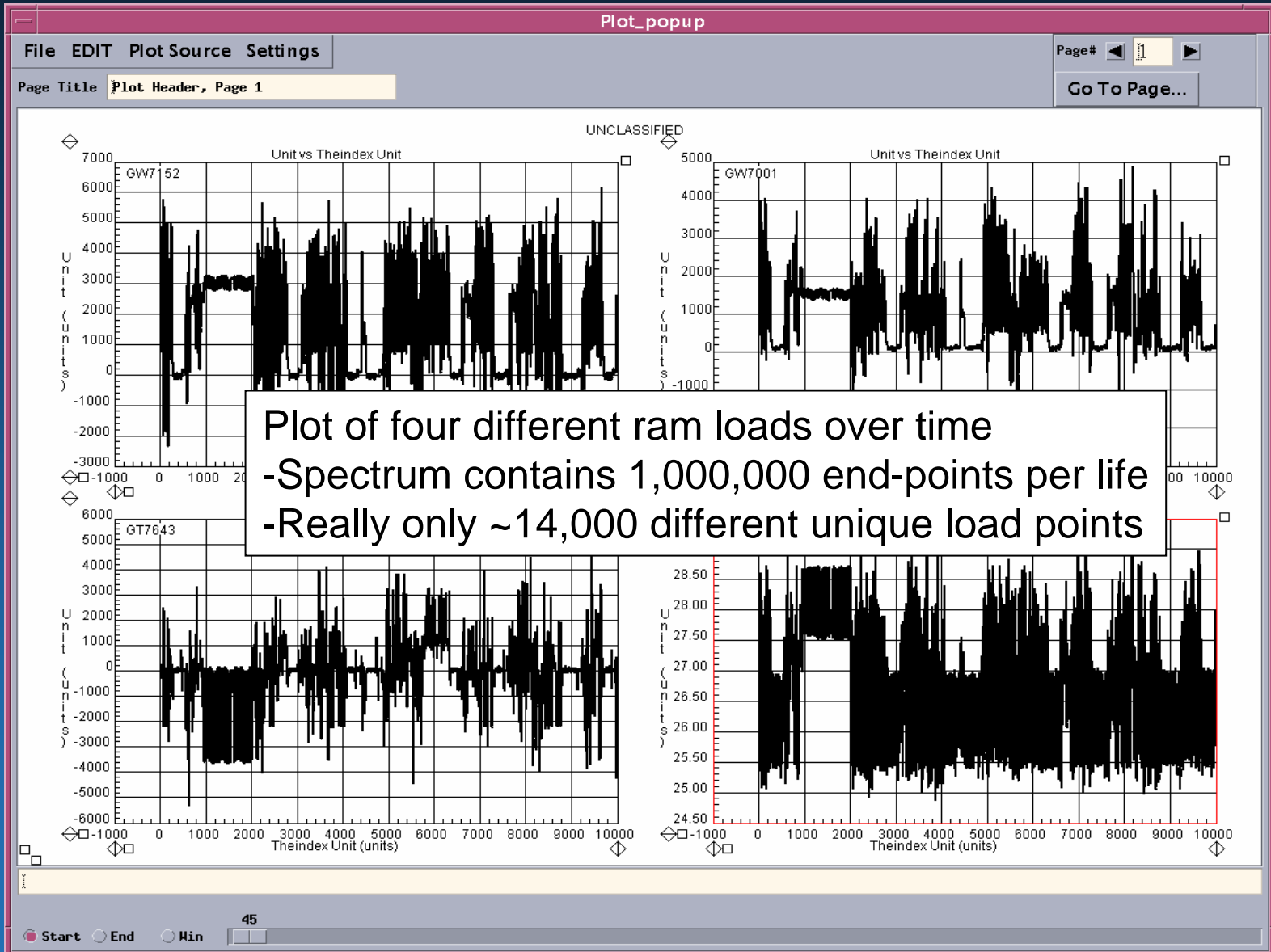




# Unique problems with durability testing

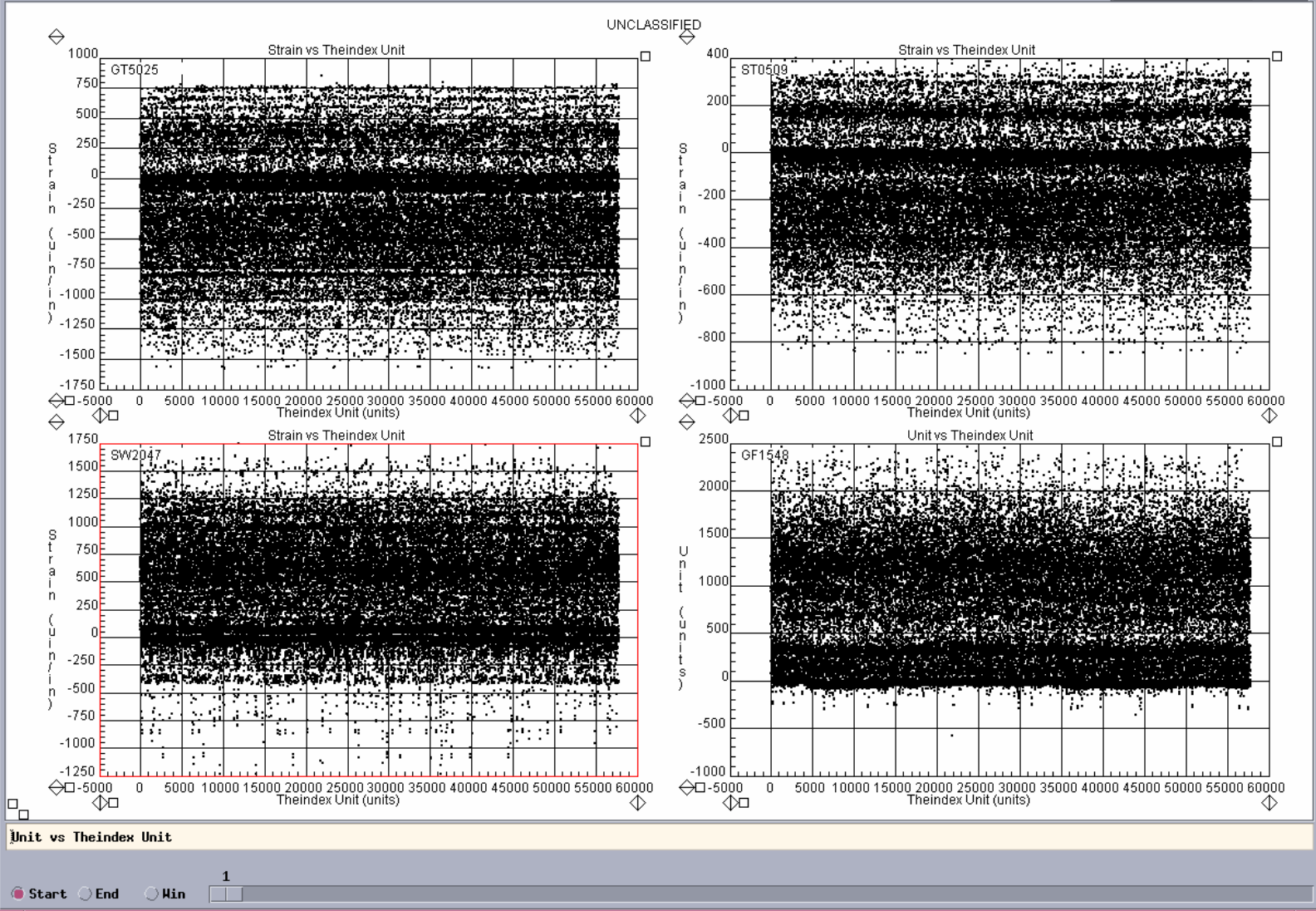


- Testing 24/7
- Little manual monitoring of strain/deflection data
- Emphasis on automated monitoring schemes
- Data trends become important





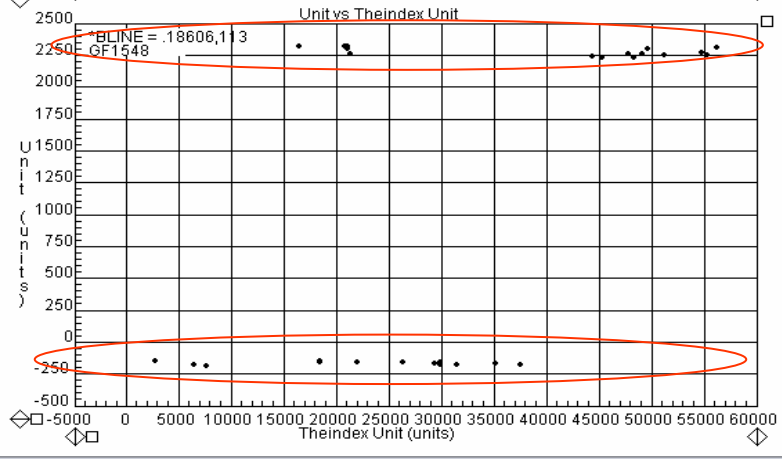
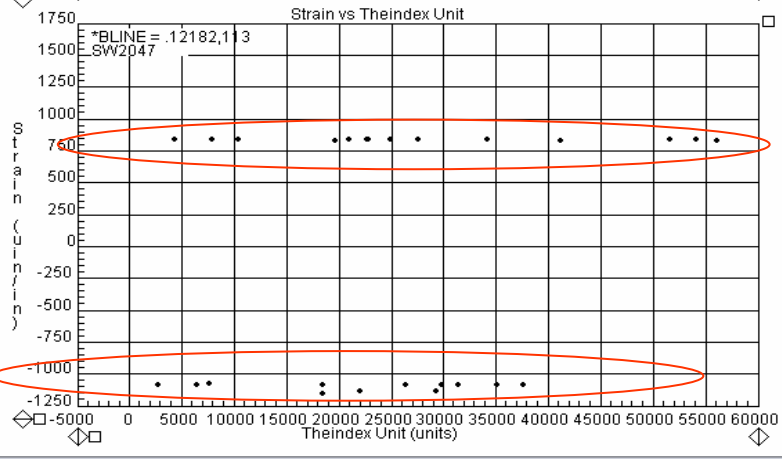
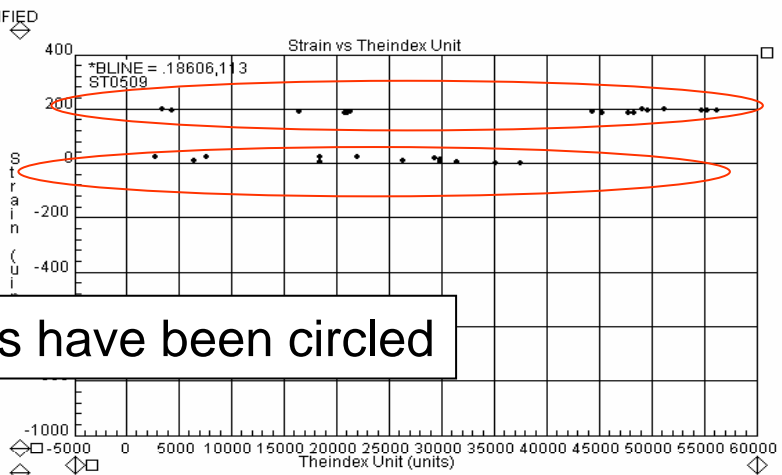
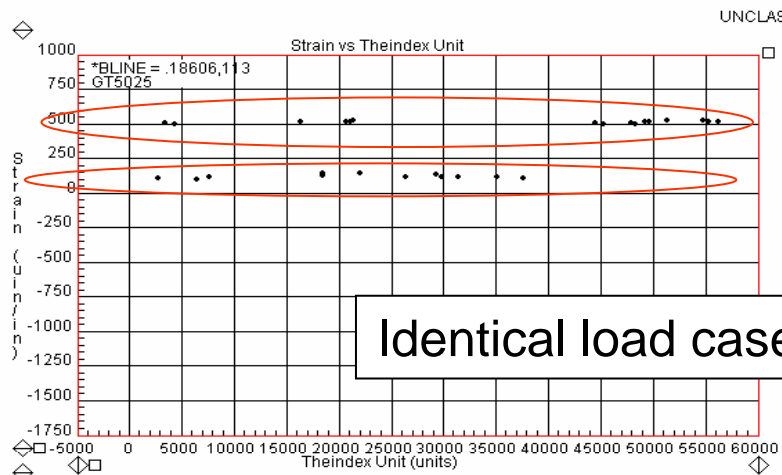
-Consistent uniform repeating strains signify good behavior







-Consistent uniform repeating strains signify good behavior

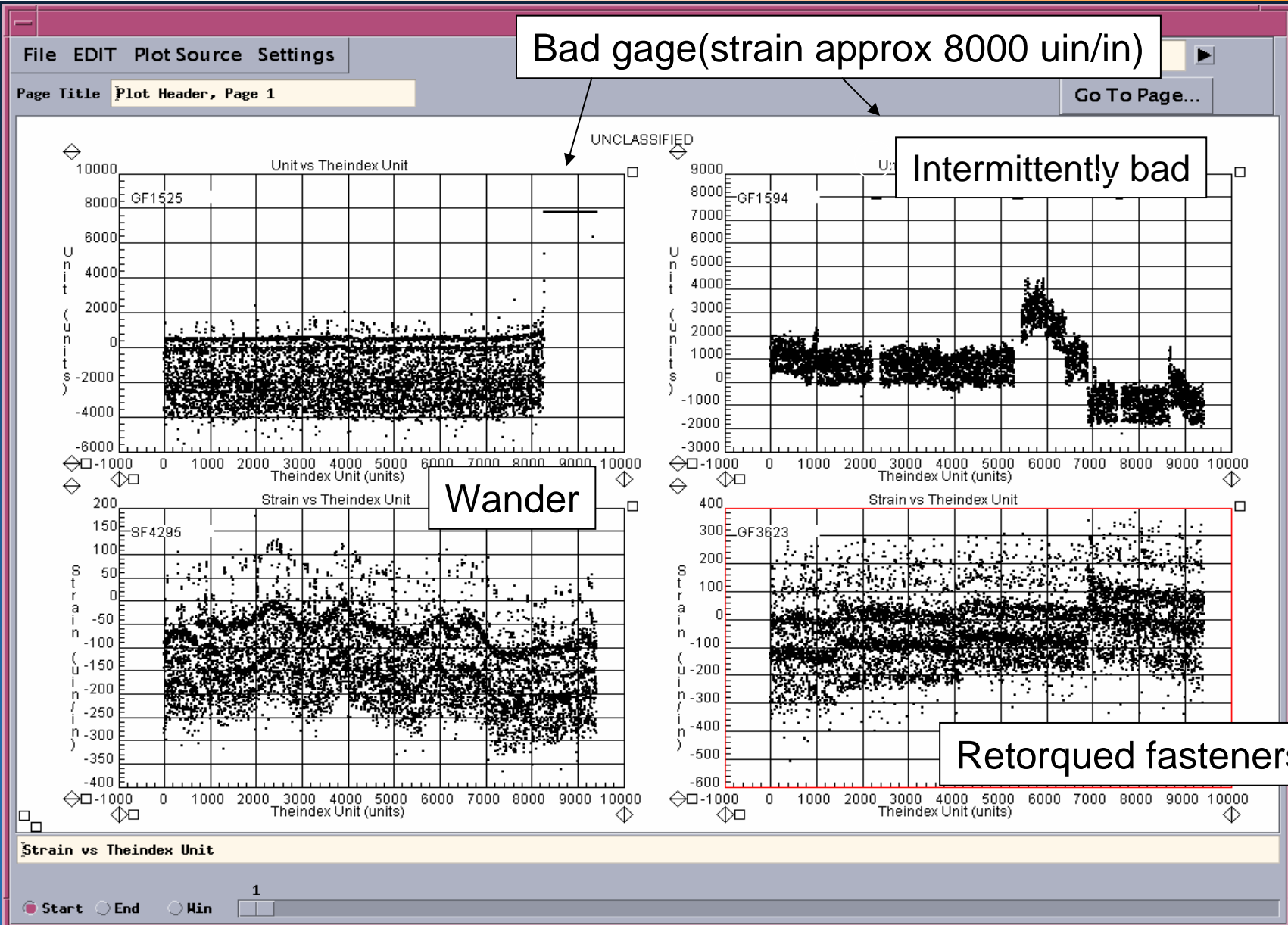


Identical load cases have been circled

Strain vs Theindex Unit

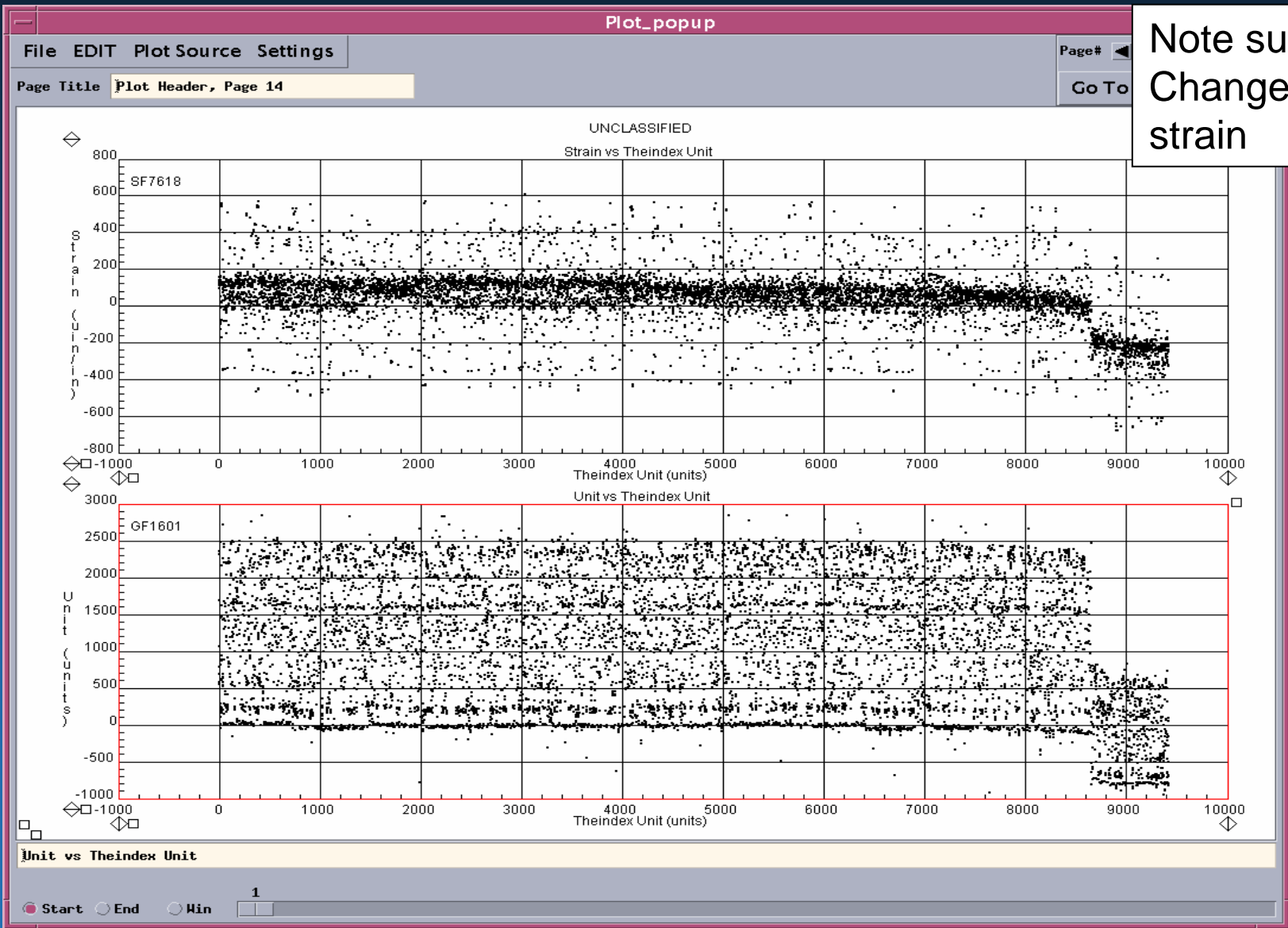
1

Start End Min



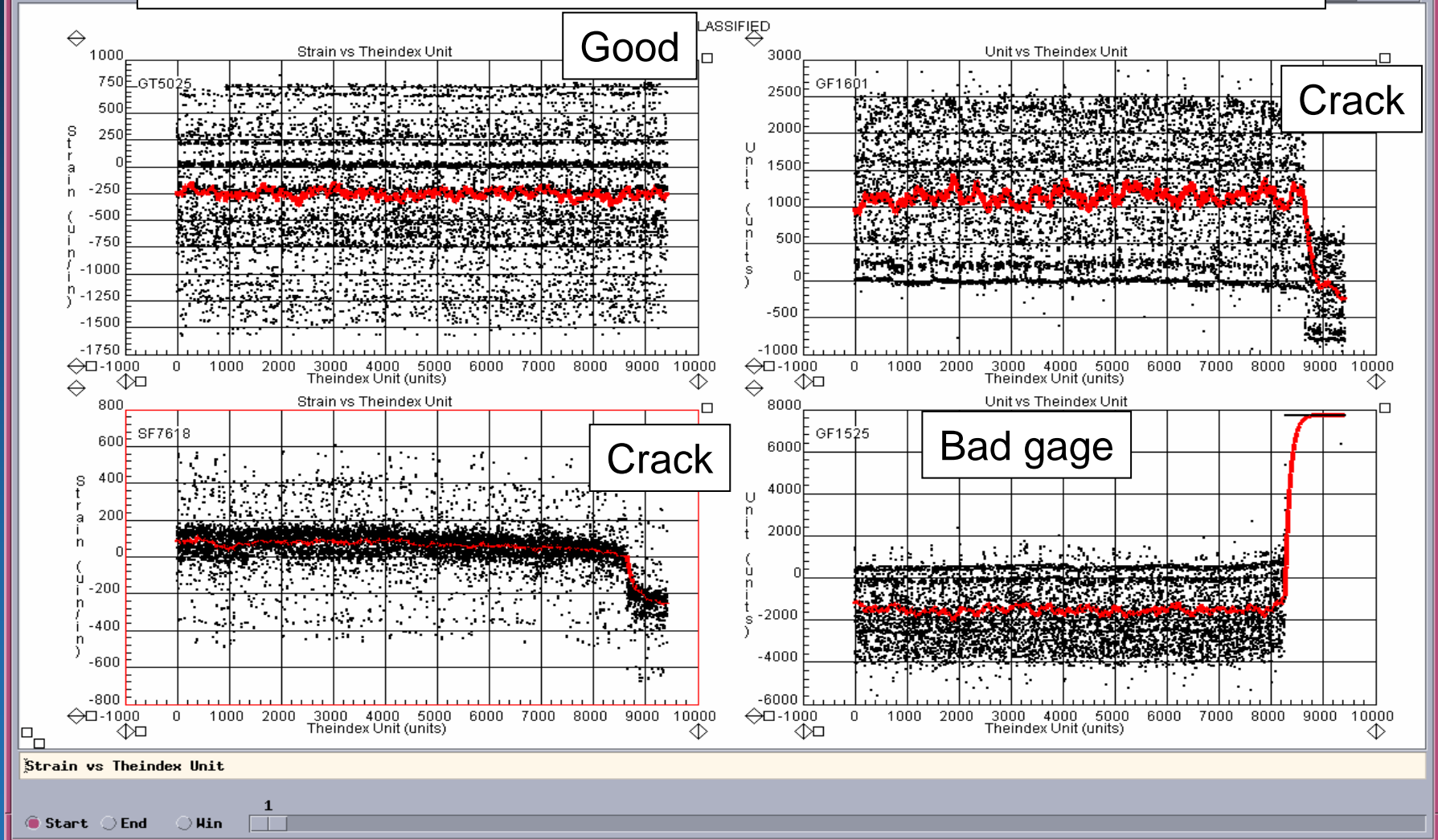


Note sudden  
Change in  
strain



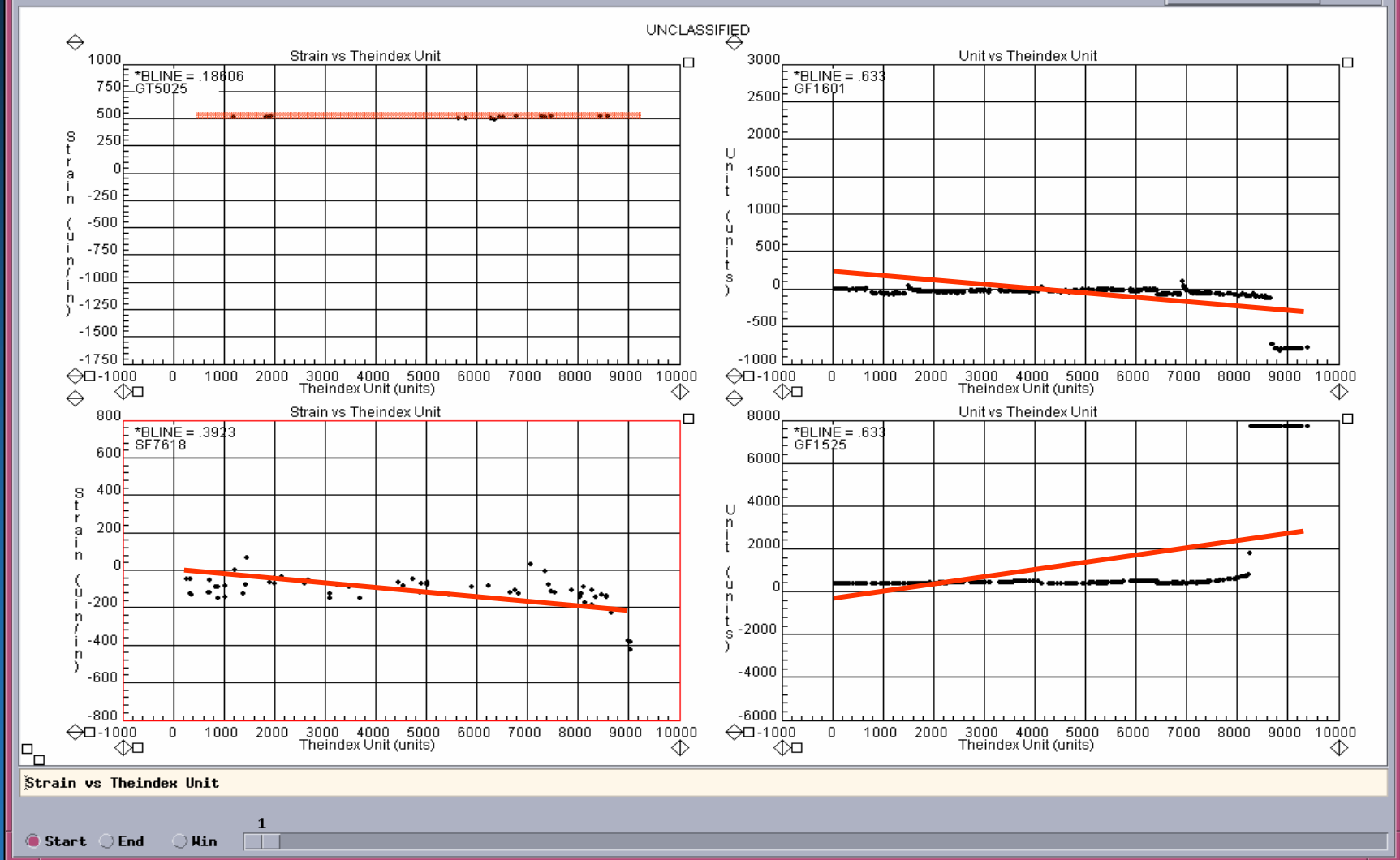


Method (1) Use 100-point moving average using all gage data, look for change above predetermined threshold





Method (2) Use single loadcase, do regression analysis on data, look for slope, change in scatter



## Summary

- F-22 employed a sophisticated array of automated means to monitor strain gages and deflections during full-scale static and durability testing.
- Real-time comparisons to predictions and preset error limits allowed closer observation of critical data channels.
- Fatigue test monitoring employed a variety of methods to examine strain and deflection data. A variety of real-time and near real-time methods were employed to flag problems with the instrumentation/airframe