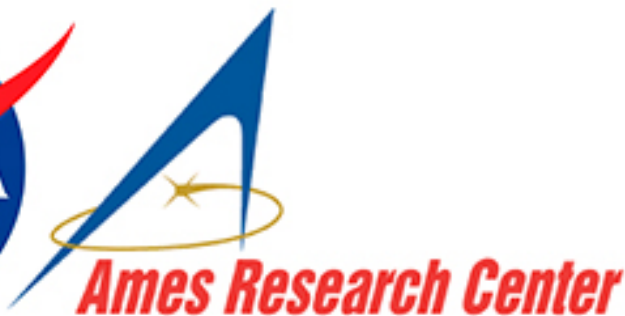


Real-time Early Warning Techniques



Dan “Animal” Javorsek

Immanuel Barshi



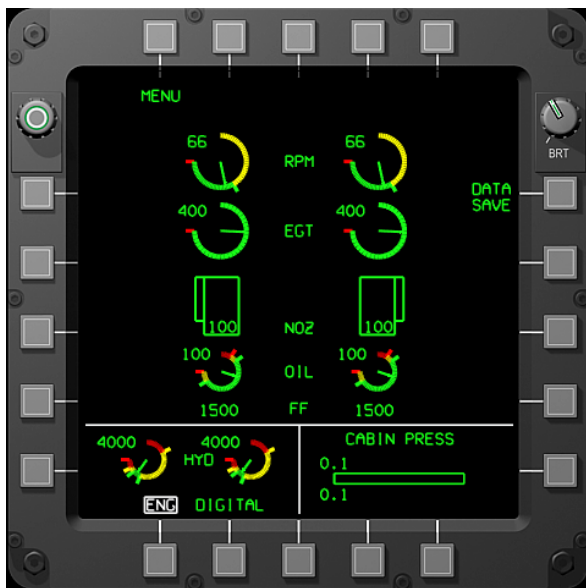
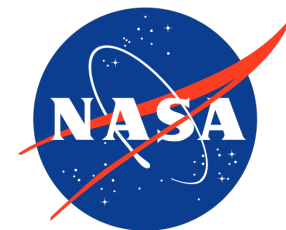
David Iverson

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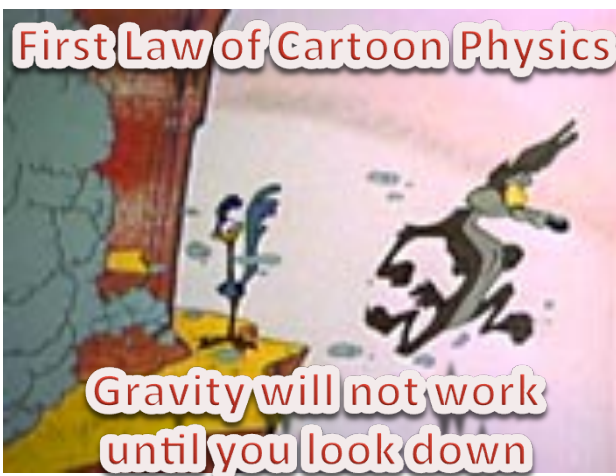
Integrity - Service - Excellence



Contemporary System Health Management



- Contemporary system health management
 - High reliance on thresholds
 - Compromise between early warning and false alarms
 - “One-sensor, one-indicator” paradigm
 - Automation often reduces info displayed to the operator



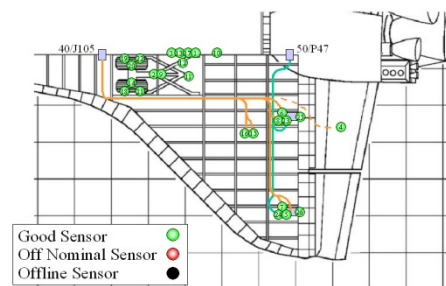
- Improve aerospace vehicle safety by monitoring for anomalous patterns of behavior



Example 1: Columbia Disaster



- Columbia summary
 - Space shuttle mission STS-107 catastrophic breakup on reentry (1 Feb 03)
 - Caused by foam impact to left wing leading edge 82 seconds into ascent which compromised thermal protection
- Retrospective Temperature Sensor Analysis
 - Left wing temperatures were within limits
 - Anomalous left wing temperatures
 - Compared to right wing
 - Compared to prior flights
 - Temperature data could have been used to raise alarm earlier
 - Served as an early test case of the Inductive Monitoring System (IMS)

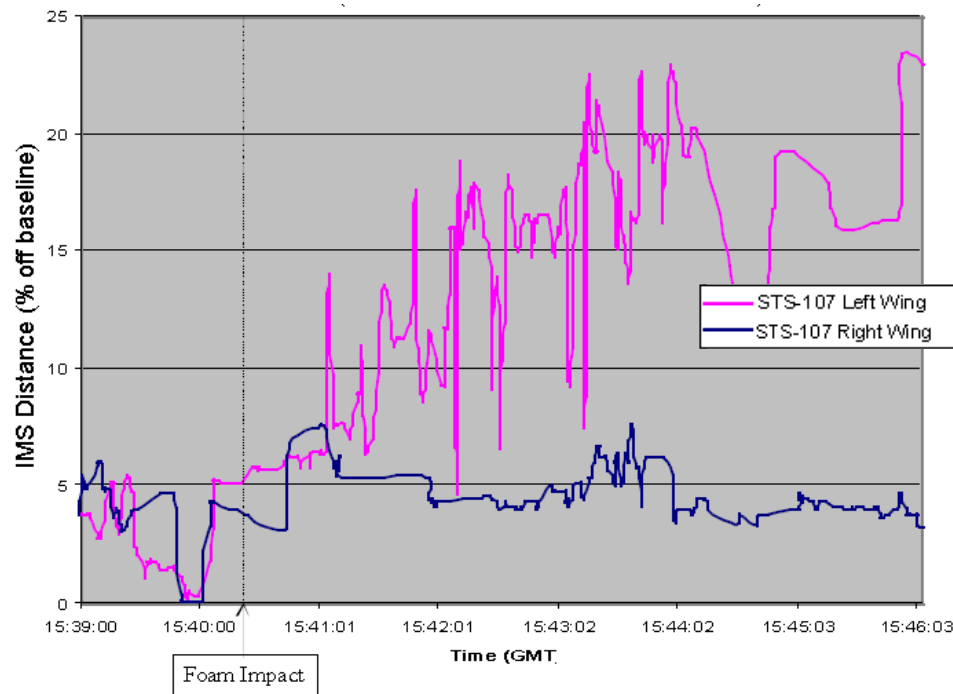




Inductive Monitoring System (IMS)

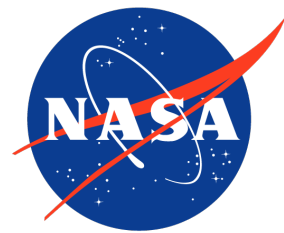


- Early warning option for systems with an established baseline
- IMS algorithm specifics
 - Compares real-time data to nominal archived data
 - Employs a hybrid of two clustering techniques
 - K-means clustering
 - Density-based spatial clustering
 - Creates a vector of parameter values for comparisons
 - Indicates how far system behavior is from nominal
 - Useful for composite, or interrelated, parameters
- Composite parameters
 - More sensitive to deviation from expected values
 - Can indicate an anomaly before manifestation in individual parameters
- In the Columbia Example, IMS would have indicated anomalies on ascent instead of just on reentry (17 days later)

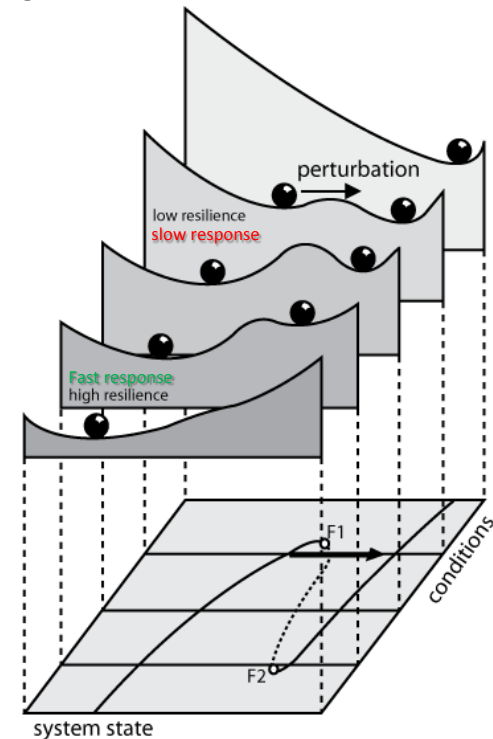




Critical Slowing Down

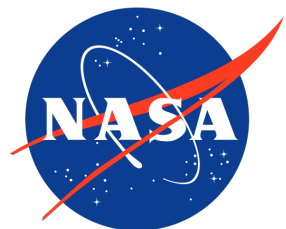


- Early Warning option for systems without an established baseline
- Goal: Predict transition between contrasting dynamical regimes
- Method: Exploit indications of critical slowing down
 - Increasing auto-correlation
 - Slower recovery from perturbations
 - Increasing variance (conditional heteroscedasticity)
 - Fluctuation asymmetries (skewness/kurtosis/flickering)
- Demonstrated: ferromagnets, siezures, etc.
- Handling Qualities, Stability, Flutter, etc.

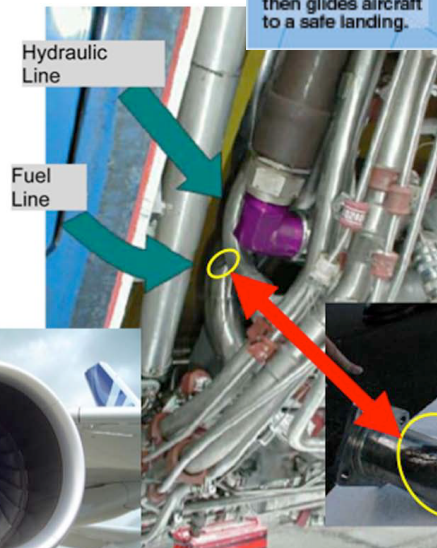




Example 2: Air Transat Flight 236

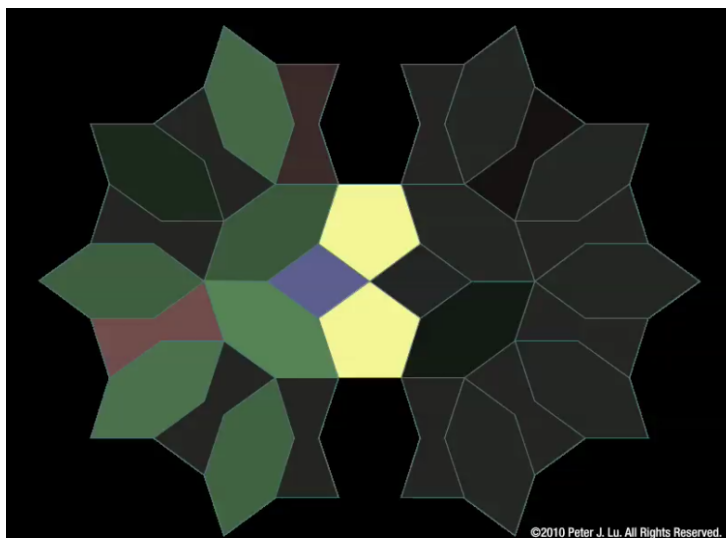
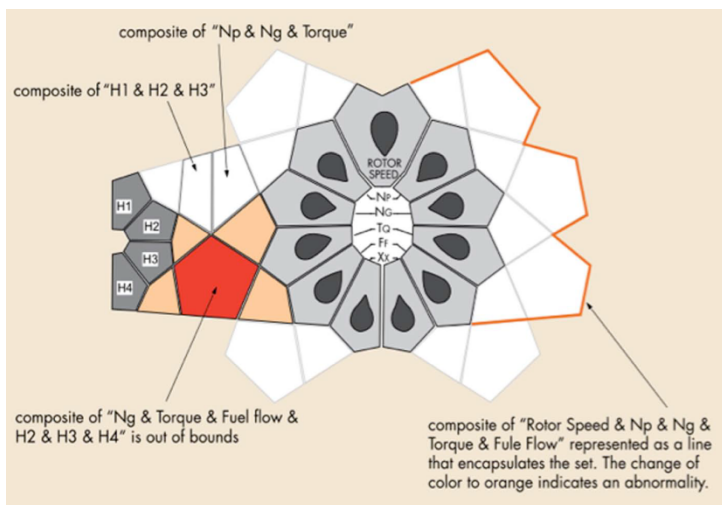


- Flameout Landing in the Azores on August 24, 2001
 - Airbus A330-200, 306 passengers/crew
 - Original flight plan: Toronto, Canada to Lisbon, Portugal
- Mishap timeline in UTC
 - 04:38 (3+46 into the flight) Right engine fuel leak began
 - High pressure line ruptured into a 3.5 x 1/8 inch crack
 - Resulted in a 60 gallons/min fuel flow overboard
 - 05:03 Aircrew observed abnormal oil T/P/Qty
 - All still within limits
 - Conference hotel did not offer an explanation
 - 05:33 Aircrew observed fuel imbalance
 - Crossfed IAW checklist
 - Made the situation worse
 - 05:45 Initiated divert to Lajes
 - 06:13 Right engine flamed out
 - 06:26 Left engine flamed out
 - 06:45 Safe landing at Lajes Air Base
- No indications the oil anomalies and fuel imbalance were related





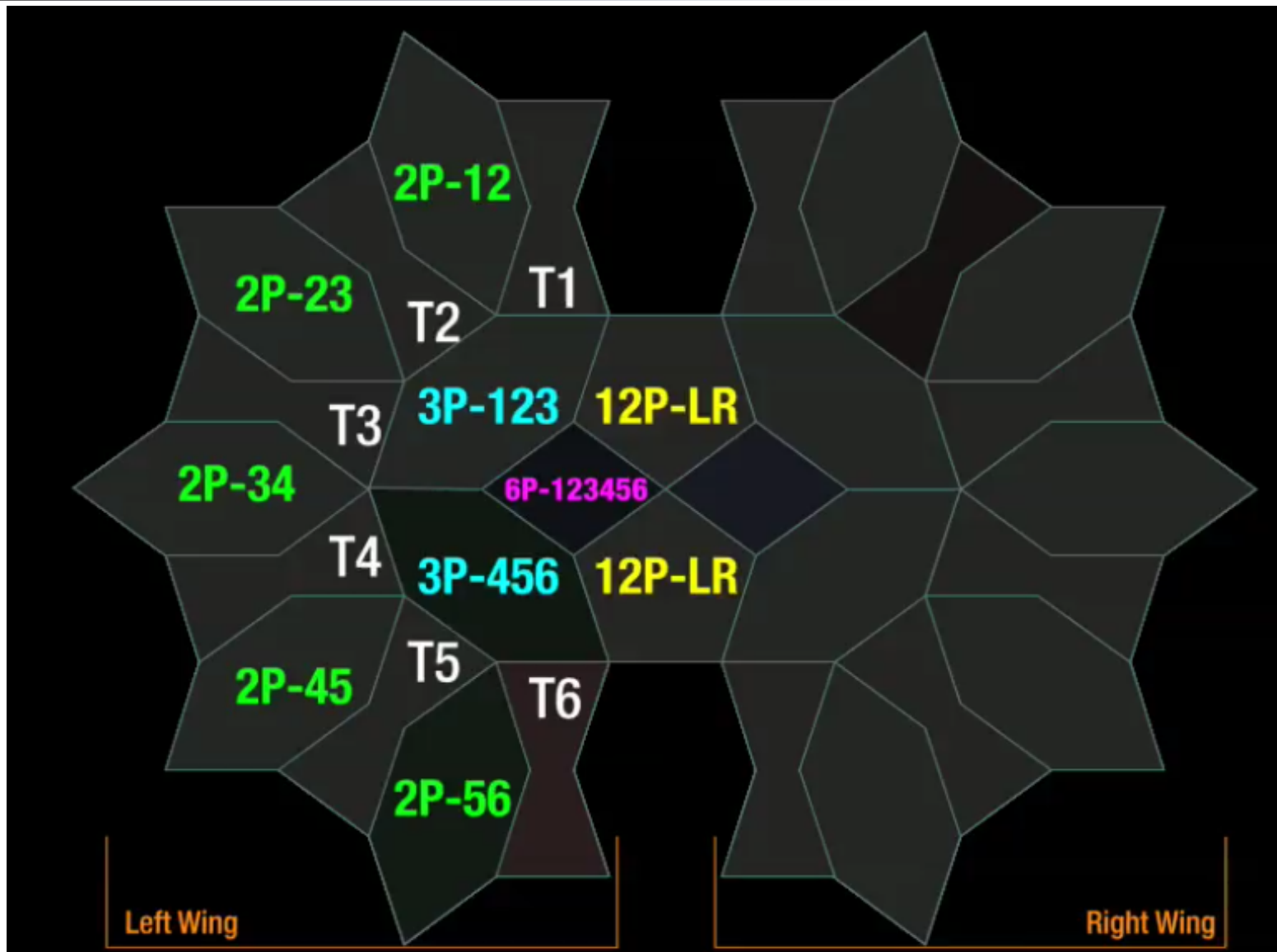
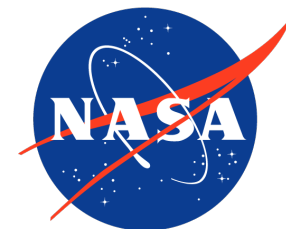
Composite Parameter Display



- With more automation
 - More information is needed, not less
 - Flight 236 automatic trim tank transfers dumped additional 3.5 tons
 - Presentation matters
 - More dials is not the answer
- Aircraft systems are not federated but the displays are
- Challenge the current "one-sensor, one-indicator" paradigm
- Display that geometrically represents interrelationships
- UH-60 and Columbia examples

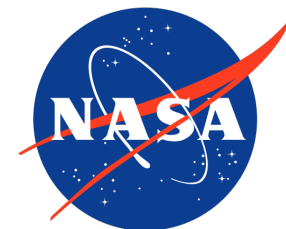


Sample Columbia Display

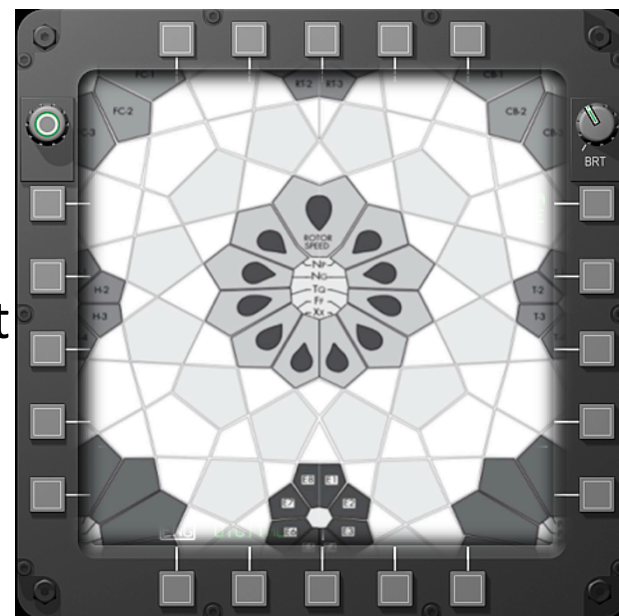




Bottom Line



- Aerospace vehicle system health management can be improved by:
 - Introducing methods beyond threshold exceedance
 - Monitoring for anomalous patterns of interaction to provide earlier warning
 - Monitoring for composite parameters to capitalize on interrelationships
 - Developing displays that represent the true complexity of aircraft subsystems
- Continuing work
 - Test Pilot School Test Management Project
 - Incorporation into the USAF Academy Flight Test Course
 - Applying these techniques to other fields (Big Data, geology, social science, etc)





Questions?





Clustering Backup

