

# Real-time Early Warning Techniques

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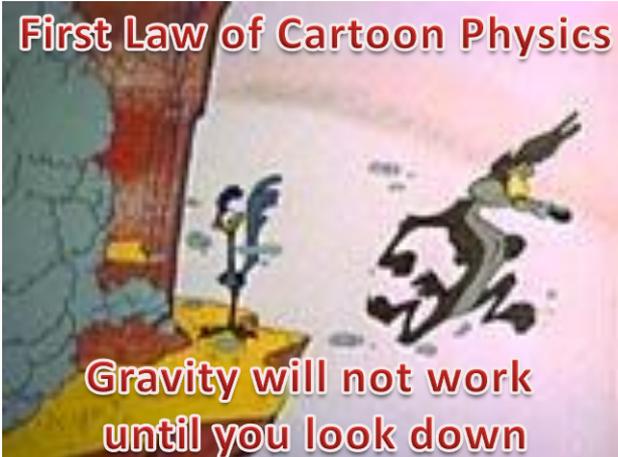
Integrity - Service - Excellence



# Contemporary System Health Management



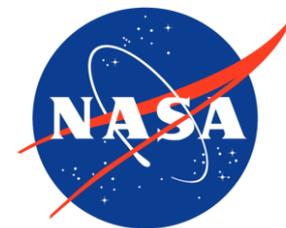
- Existing methods
  - Rely heavily on thresholds
  - Compromise between early warning and false alarms
  - “One-sensor, one-indicator” paradigm
  - Automation often reduces info displayed to the operator



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



# Example 1: Columbia Disaster

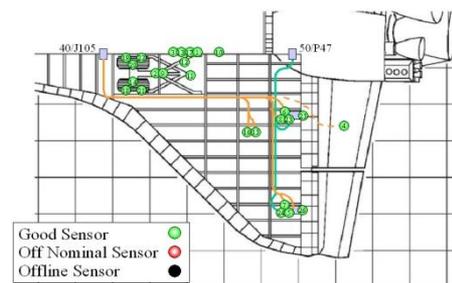


- Columbia summary
  - Space shuttle mission STS-107 catastrophic breakup on reentry
  - Caused by foam impact to left wing leading edge 82 seconds into ascent which compromised thermal protection



- Retrospective Temperature Sensor Analysis

- Left wing temperatures were within limits
- Temperature data could have been used to raise alarm earlier
- Served as an early test case of the Inductive Monitoring System (IMS)

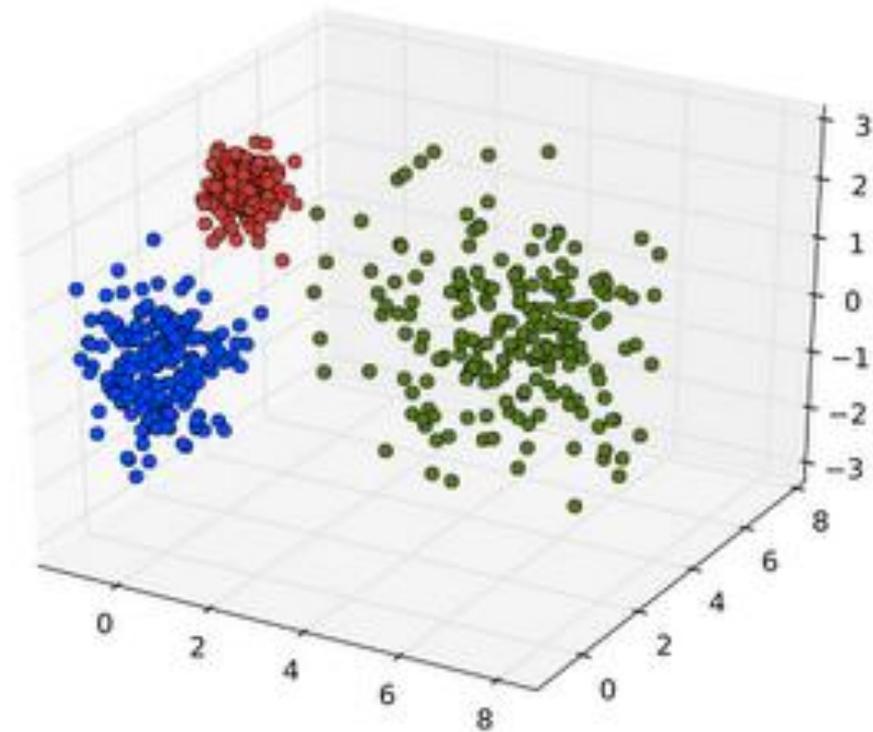




# Inductive Monitoring System (IMS)

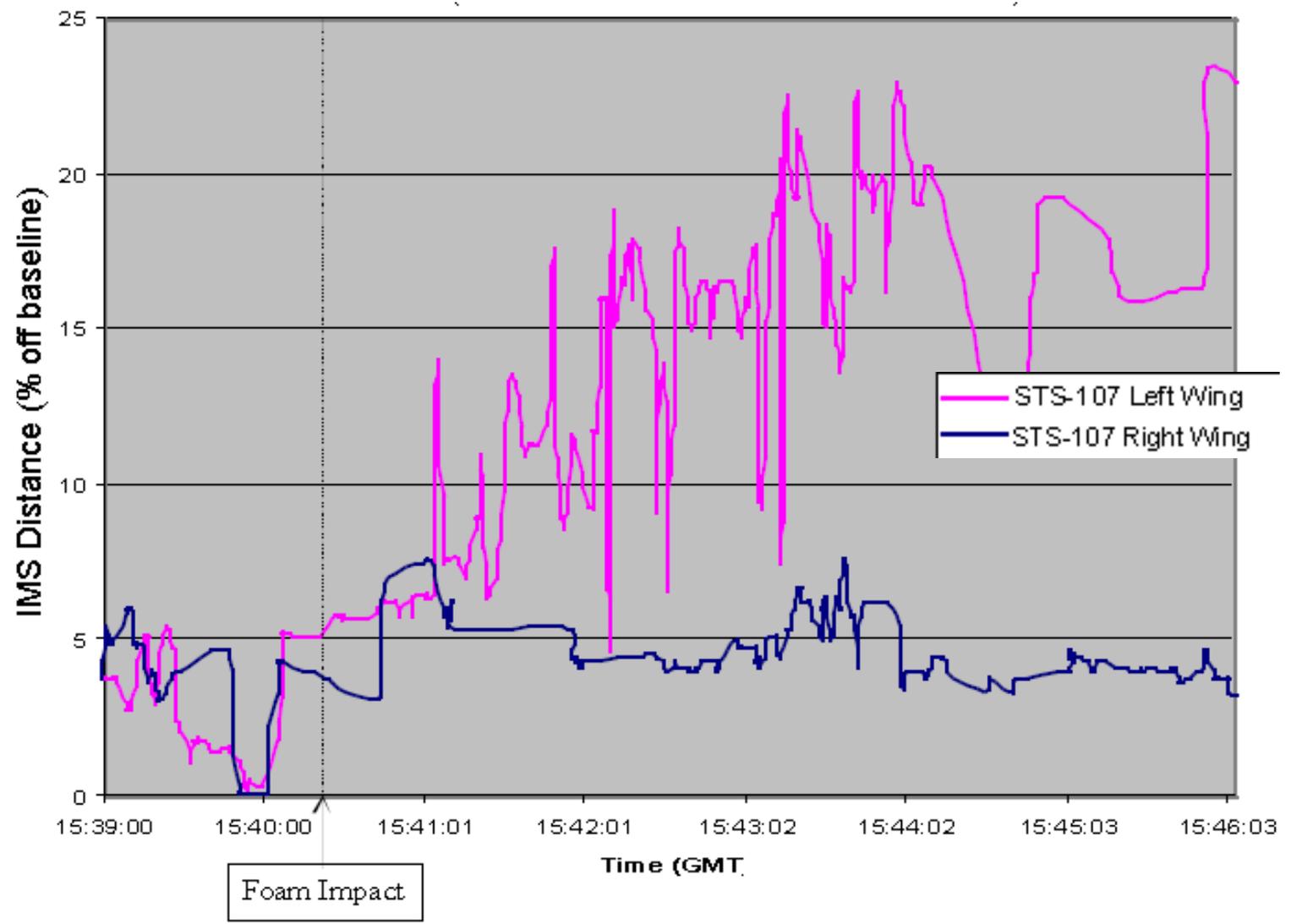


- Early warning option for systems with an established baseline
- IMS algorithm specifics
  - Compares real-time data to nominal archived data
  - Employs a hybrid of two clustering techniques
  - Indicates how far system behavior is from nominal
  - Useful for composite, or interrelated, parameters



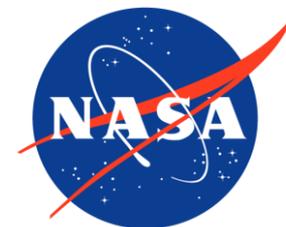


# Columbia Temperatures

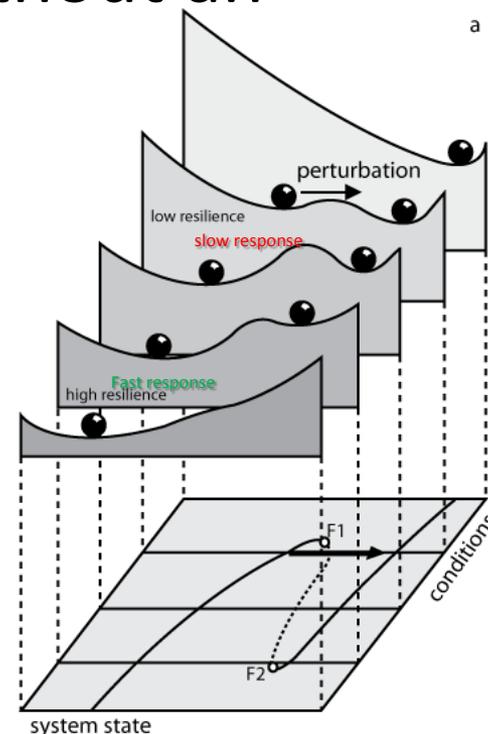




# Critical Slowing Down



- Early Warning option for systems without an established baseline
- Predict transition between contrasting dynamical regimes
- Exploit indications of critical slowing down
- Demonstrated in ferromagnets, seizures, etc.
- Handling Qualities, Stability, Flutter, etc.

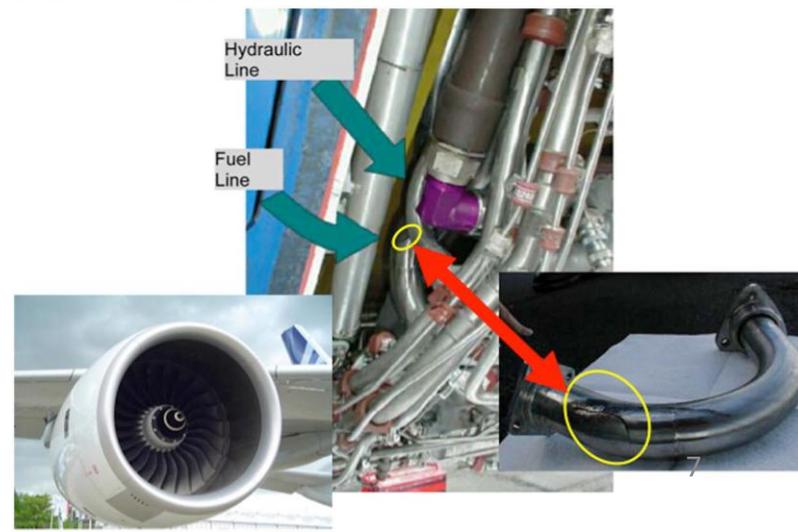




# Example 2: Air Transat Flight 236

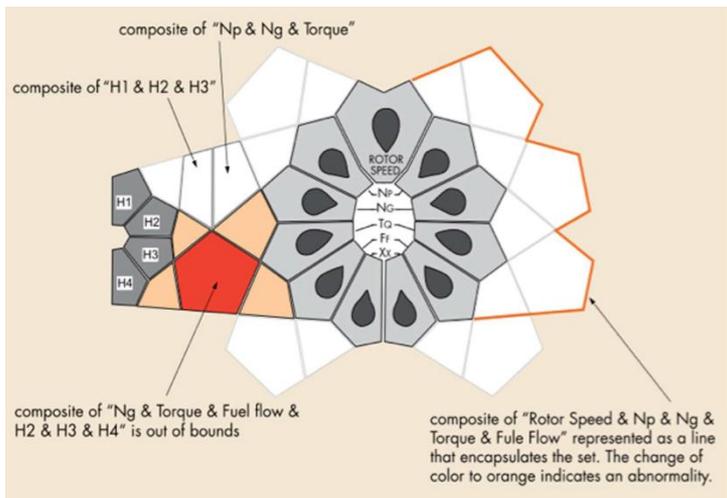


- Flameout Landing in the Azores on August 24, 2001
  - Airbus A330-200, 306 passengers/crew
  - Original flight plan: Toronto, Canada to Lisbon, Portugal
- Mishap timeline in UTC
  - 04:38 (3+46 into the flight) Right eng fuel leak
  - 05:03 Aircrew observed abnormal oil T/P/Qty
  - 05:33 Aircrew crosseded to correct fuel imbalance
  - 05:45 Initiated divert to Lajes
  - 06:13 Right engine flamed out
  - 06:26 Left engine flamed out
  - 06:45 Safe landing at Lajes AB
- No indications the oil anomalies and fuel imbalance were related

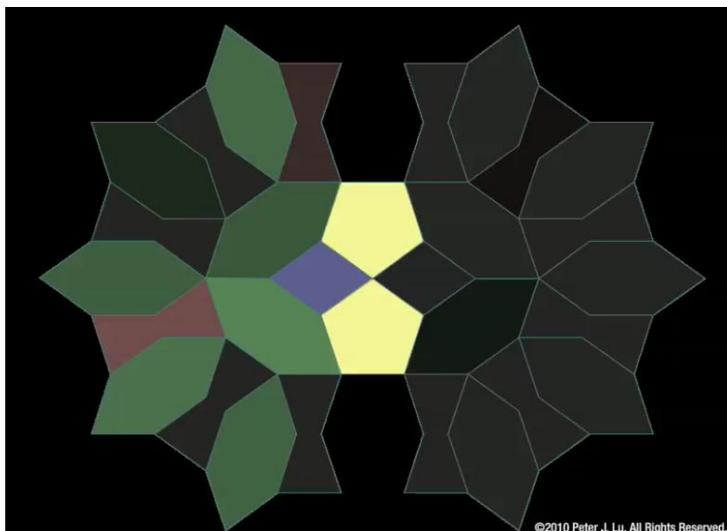




# Composite Parameter Display

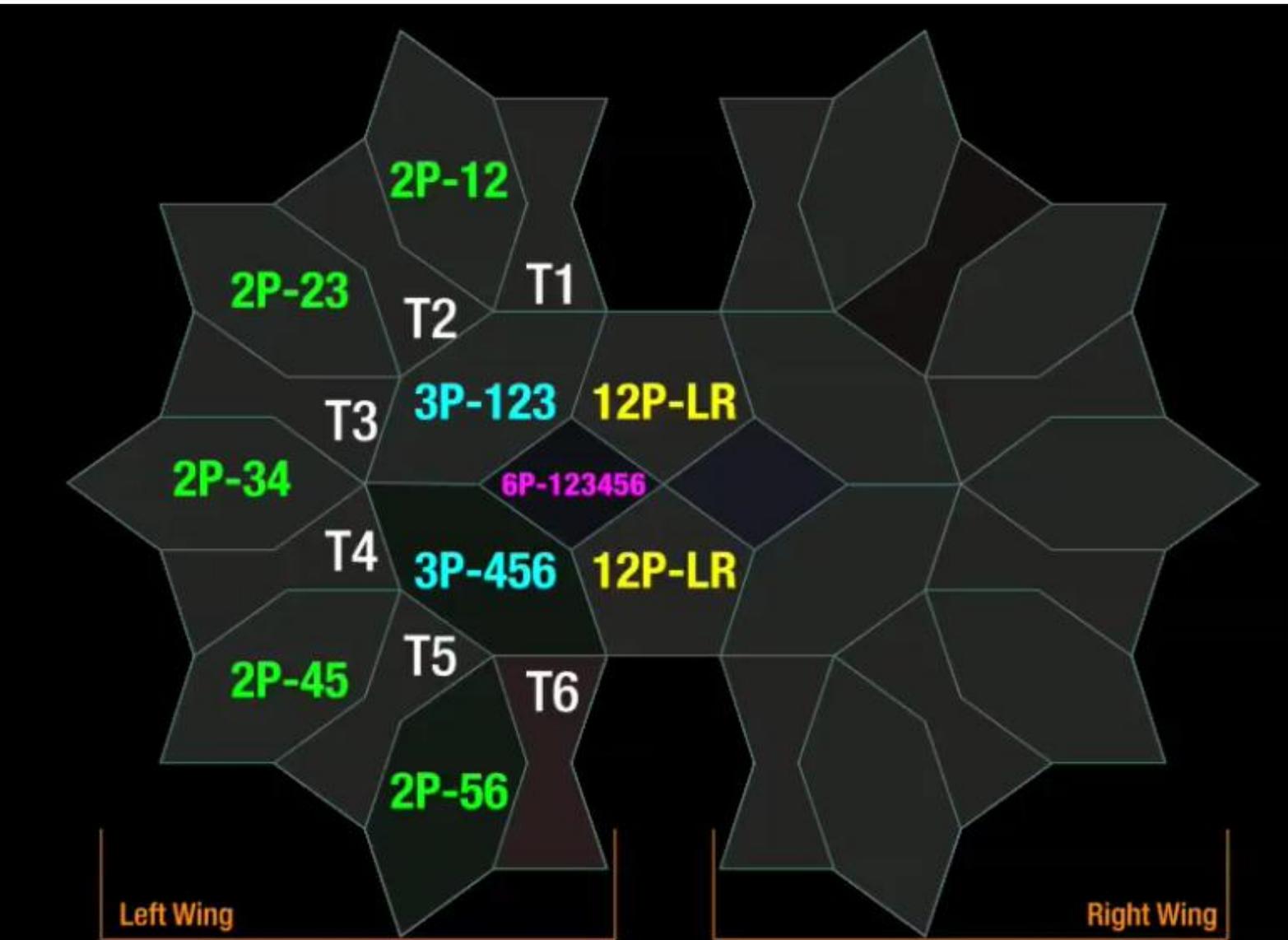


- Composite parameters
  - More sensitive to deviation from expected values
  - Can indicate an anomaly before manifestation in individual parameters
- With more automation
  - More information is needed, not less
  - Flight 236 automatic trim tank transfers dumped additional 3.5 tons
  - Presentation matters
- Display that geometrically represents interrelationships



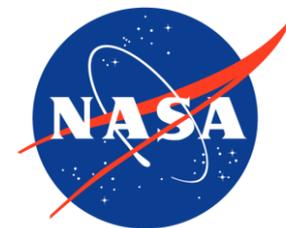


# Sample Columbia Display

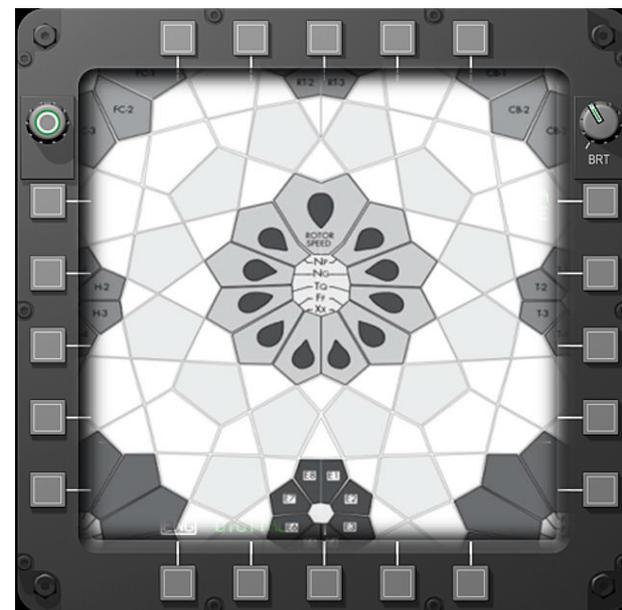




# Bottom Line



- 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
  - Apply these techniques to Military Flight Operations Quality Assurance Data
  - Test Pilot School Test Management Project
  - Applying these techniques to other fields (Big Data, geology, social science, etc)





# Questions?

