



Application of Accident Precursor Analysis Techniques to NASA Missions

**Presentation to Bryan O'Connor, Chief
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What NASA Was Told

- **CAIB: Recommendation F7.4-5**
 - “Risk information and data from hazard analyses are not communicated effectively to the risk assessment and mission assurance processes. The Board could not find adequate application of a process, database, or metric analysis tool that took an integrated, systemic view of the entire Space Shuttle system.”
- **ASAP: Report on Leading Indicators (2003)**
 - “We could find no process for regularly tracking and assessing the performance and effectiveness of the agency’s leading indicators and safety information systems.”
- **NASA Exploration Safety Study (NESS): Recommendation R2.4.2**
 - “Establish an aggressive Accident Sequence Precursor (ASP) team to identify accident precursors for all remaining shuttle flights, and create an ASP program and data collection process for spaceflight programs.”



NASA Accident/Anomaly Precursor Analysis (APA) Program Approach

- **Review and learn from the Accident Precursor Analysis experience of the Nuclear Regulatory Commission (called Accident Sequence Precursors - ASP)**
- **Adapt the NRC methodology to NASA needs and make it compatible with available failure and anomaly data at NASA**
- **Initiate a pilot APA study to support “all remaining shuttle flights ... and data collection process for spaceflight programs”**
- **Select one or two Shuttle systems and test the NASA APA methodology**
- **Extend the methodology to all or most Shuttle systems**
- **Extend the methodology to all NASA human and robotic flight systems**
- **Use the methodology to develop failure and anomaly collection data to support safety assessment and enhancement of all NASA programs**
- **Use the APA methodology to support Probabilistic Risk Assessments**



Background of Precursor Analysis

- Precursor analysis is an accepted technical discipline for failure and risk assessment
- Precursor analysis has been implemented by many institutions including the U.S. Nuclear Regulatory Commission (NRC)
- The NRC has a dedicated group applying precursor analysis
- The National Academy of Engineering recently conducted a national workshop on precursor analysis*

*National Academy of Engineering, *Accident Precursor Analysis and Management: Reducing Technological Risk Through Diligence*, July 17-18, 2003.



Need to Extend NRC's Failure-Based Precursor Approaches

- **NASA's databases (PRACA, CARs, etc.) principally contain anomalies and not only failures**
- **NASA's PRAs are dominated by single failures**
- **Focusing on anomalies as well as failures provides maximum predictive risk information**
- **NRC's failure-based approaches thus were extended to analyze anomalies as precursors**



Definitions

- Anomaly** **A defect, fault, or other deviation;
In the extreme case, a failure.**
- Precursor** **An indication of a problem that could
recur with more severe consequences**



Key Points of Precursor Definition

- ***Indication of a problem-*** indicator of a problem in a process or design
- ***That could recur-*** the mechanism generating the anomaly could result in other anomalies
- ***More severe consequences-*** under different circumstances there could have been more severe consequences



Precursor Analysis

- Precursor analysis is an extrapolation of reality to events that could have happened
- The actual scenario is perturbed to identify possible, more severe failure scenarios
- Different perturbations produce different possible failure scenarios
- The likelihood of each failure scenario is constructed from the estimated probability of the perturbations occurring
- The likelihoods are formally conditional probability estimates based on the given occurrence



Examples of Precursors

1. A hydrazine leak that was indicative of a loose fitting which if not corrected could lead to a larger leak and a fire,
2. Foam damage to the Orbiter wing that was indicative of adhesion problems which if not corrected could lead to foam hitting a critical area
3. Corrosion in all three Auxiliary Power Units (APUs) which if not corrected could lead to a fire during a mission
4. Short circuiting of a cable that was indicative of more systematic damage in the cabling and wiring which if not corrected could lead to loss of control or fire



Examples of Precursors (Cont.)

5. Over-torquing of holddown bolts that could be indicative of systematic procedure deficiencies which if not corrected could lead to loss of crew and vehicle on launch.
6. Multiple workmanship problems occurring which can be indicative of process deficiencies which if occurring on critical equipment could result in loss of mission or loss of crew.
7. Inadvertent closure of a flapper valve associated with the 17-inch disconnect valve on the Shuttle which indicated stability problems with the valve which if not corrected and occurring during flight could result in major damage to the engines.
8. A high frequency of maintenance reworks indicating a deficiency in the maintenance process which if more severe and affecting critical equipment would result in loss of the equipment and possible loss of mission.



Benefits of Precursor Analysis

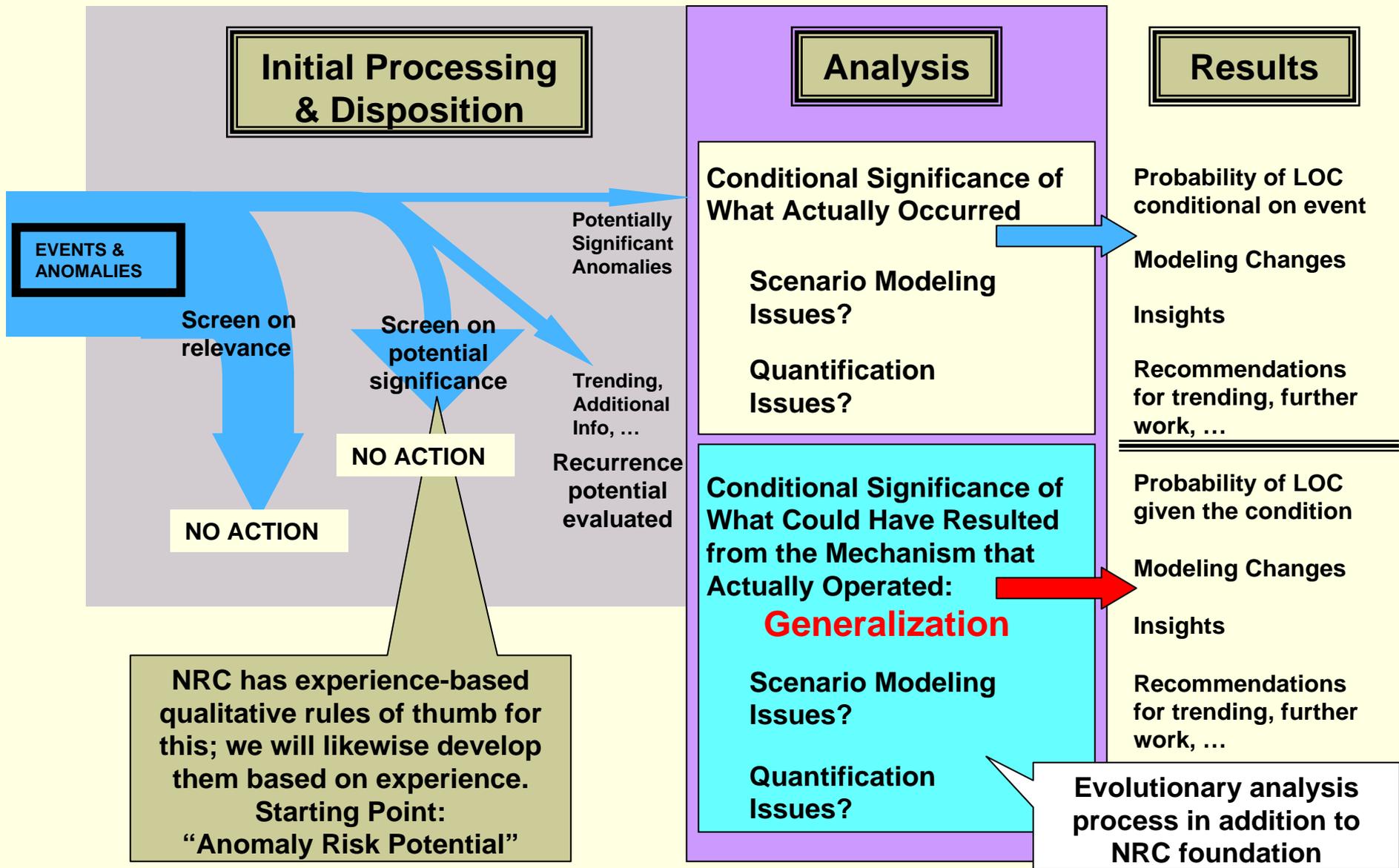
- Precursor analysis is unique in systematically assessing the risk implications of anomalies
- Failure scenario models are based on what occurred and what perturbations were needed for failure
- Precursor risk assessments are statistically valid risk estimates that can be aggregated and be tracked
- Risk models such as PRAs can be updated to be consistent with the failure scenarios identified and the assessed risks



Precursor Evaluation Steps

1. Characterize the anomaly in terms of its *mechanism* and *severity*
2. Assess the possible *failure scenarios* associated with the anomaly
3. Assess the *uncertainties* in the failure scenario descriptions
4. Assess the controls to *mitigate* the failure scenarios

Process Overview





Current APA Efforts

- **Pilot study with JSC (and ISL) on the Shuttle OMS RCS system**
 - This study will be discussed in this presentation
- **Pilot study with MSFC and ATK Thyokol on the Shuttle SRB system**
- **Pilot study with APL on APA application to the ISS**

Summary

- Precursor analysis has the potential to improve the safety basis model through a systematic process of learning from experience
- A NASA-oriented process is being developed for trial purposes
- JSC Exercise
 - Apply processing & dispositioning steps to OMS/RCS
- Next Steps after Exercise:
 - Investigation of events dispositioned for analysis
 - Refinement of Screening Process
 - Application of Revised Process to Other Systems