ISS PRA:
Modeling Payload Stowage Impacts to Fire Risks On-board the International Space Station

April 8, 2010

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Purpose/Background

• **Purpose:** To determine the risks of fire on-board the ISS due to non-standard stowage

• **Background:**
  - ISS stowage is constantly being re-examined for optimality
  - Non-standard stowage involves stowing items outside of rack drawers
  - Fire risk is a key concern and is heavily mitigated
  - Methodology needed to account for fire risk due to non-standard stowage to capture the risk
Fire Risk Background

• Why is fire a concern on-board ISS?
  – Experience: Mir
  – Crew safety
    » Air quality
    » Injury
    » Death
  – Lead to other failures
General Assumptions

• Materials
  – Material selection
    » Control combustibility
    » Control fire propagation
    » Minimize fire risk
  – Propagation is mitigated in material selection
    » Tests for propagation to determine suitability

• Human factors
  – Processes are in place to minimize fire risk
    » Minimum distances between payloads and ignition sources
    » Personal effects stowage
  – Dependent on human adherence to the process

• Microgravity
  – Fire behaves differently
    » Hotter
    » Shape and movement
    » Oxygen sourcing
Modeling Techniques

- Qualitative
  - Payloads
    » Volume layouts
    » Flammability factors
  - Co-location
    » Human Error Probabilities (HEP)
    » Proximity likelihood
  - Fire
    » Modeling
    » Expert elicitation

- Quantitative
  - Basic events probabilities derived from qualitative analysis
    » Factor indices
  - SAPHIRE event tree and fault tree structure
Success flows up and to the right
Failure flows down

Event Sequence Diagram (ESD):

Payload in habitable volume

No Non-Standard Stowage in Module

No Ignition Sources in Module

Flammable items are kept the minimum operational distance from ignition sources

No Ignition Occurs

Fire

Fire Response Model
Qualitative Fire Analysis

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- Use counts, utilization, age

Define factors
  - Weighted products of parameters

SAMPLE NUMBERS, NOT ACTUAL
# Qualitative Fire Analysis

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**Develop indices**
- % of overall fire risk

**Convert to quantitative factor**
- Ignition source index

SAMPLE NUMBERS, NOT ACTUAL

Kellie Anton 281-244-1973
SAMPLE Qualitative Results for Fire Risk
Qualitative Stowage Analysis

Calculating the Stowage Factor

- **Volume**
  - Habitable volume
  - Stowage CTBEs
  - Table of high to low

- **Combustibility**
  - Level of flammability
  - Table of high to low

- Define factors
- Develop index value
- Quantitative factor

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<tr>
<th>Module</th>
<th>Stowage Density (Vol stow/habit vol)</th>
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Co-location factor to account for:

- Processes for minimum distance
- Human Error
  - CREAM or THERP analysis

Ignition factor to account for:

- Likelihood that fuel and ignition source will start fire
- Expert elicitation or fire modeling

SAMPLE NUMBERS, NOT ACTUAL

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SAMPLE Qualitative Results for Non-Standard Stowage
Quantitative Analysis
Basic Event Data

- **Ignition Likelihood**
  - Microgravity sensitive
  - Expert elicitation

- **Co-location**
  - Human error
  - Items are not placed according to established processes

- **Ignition Source**
  - Analysis of potential sources

- **Stowage**
  - Analysis of non-standard stowage

*All conditions have to come together simultaneously to have a fire.*
Conclusions

• Attempt to capture fire risk on-board station

• Placement of stowage and selection of materials is well mitigated
  – Mitigations in place
  – Materials testing
  – Human inclusion creates uncertainty
    » Follow processes
    » Personal effects

• New methodology
  » Utilizes qualitative analysis
  » Develop the quantitative factors from qualitative results and elicitation
Conclusions

- **Improve the fidelity of the current ISS PRA Fire Model**
  - Accounting of factors not currently modeled
  - Converge towards true fire risk

- **Heavily mitigated**
  - Materials and processes are designed to eliminate fire risk
  - Risk still remains
  - Personal effects add uncertainty
  - Human behavior is a contributor
  - Overall, risk likely to be low