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

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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
Event Sequence Diagram (ESD):

Success flows up and to the right
Failure flows down

Payload in habitable volume

No Non-Standard Stowage in Module

OK

No Ignition Sources in Module

OK

Flammable items are kept the minimum operational distance from ignition sources

OK

No Ignition Occurs

OK

Fire

Fire Response Model

OK

Payload in habitable volume → No Non-Standard Stowage in Module → OK → No Ignition Sources in Module → OK → Flammable items are kept the minimum operational distance from ignition sources → OK → No Ignition Occurs → OK → Fire → Fire Response Model → OK

Kellie Anton 281-244-1973
Qualitative Fire Analysis

- Use counts, utilization, age

Define factors
- Weighted products of parameters

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<th>Module</th>
<th>Quantity</th>
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<th>Age (1-5)</th>
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SAMPLE NUMBERS, NOT ACTUAL
Qualitative Fire Analysis

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|            | 15A    | 1%  | 7%  | 9%  | 0%  | 5%  | 6%  | 26%  |
|            | 20A    | 1%  | 6%  | 8%  | 0%  | 4%  | 6%  | 11%  | 23% |

- Develop indices
  - % of overall fire risk

- Convert to quantitative factor
  - Ignition source index

**SAMPLE NUMBERS, NOT ACTUAL**
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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<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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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