Model Based Risk Assessment: Foundations and Applications

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Definition of Risk

- Risk is usually associated with the uncertainty and undesirability of a potential situation or event

  \[ \text{Risk} = \text{Uncertainty} \text{ and Undesirability} \]

- In order to have a risk situation, both elements must be present

- Metrics

  \[ \text{Risk} = \text{Likelihood} \text{ and Severity} \]
Three Questions of Risk Analysis

- What can go wrong?
- What are the consequences?
- How likely are they?
Input to Decision Making

Hazard Category R1
Hazard Category R2
Hazard Category R3
Model-Based Approach

Socio-Economic Environment
Regulatory Environment
Physical Environment

System Characteristics

Integrated Causal Model

System 1
System 2
Initiating Event
Human Action
Risk Metrics
- Likelihood & Severity
- Hazard Ranking

Root Causes

Model - Based Approach
Anatomy of Scenario-Driven Risk Analysis

Event causing deviation from normal operation (initiating event)

Undesired Aircraft States

C

F (failure/accident)

Recovery

Normal Operation

Generic Scenario

ESD Model
Causal Details through Fault Trees and Influence Diagrams

Fault Tree

Influence Diagram (e.g., BBN)
Incorporating Soft Causal Factors (e.g., Safety Culture Factors)

Safety Culture

- OC: University of Illinois Approach
- OP
- FS
- IS

SV
SF
BC
CH
F
DI
S
TR
N
REP
FEE
PER
ACC
AUT
PIL
Application Areas

• Analysis of Hazards
  – Identification
  – Ranking

• Accident/Incident Analysis
  – Identifying common root causes

• Identification and Quantification of Safety Indicators
  – Calculation of conditional risk for various safety indicators

• Analysis of Precursor Events
Risk Analysis

Risk Model (Scenario Analysis)

Quantitative Ranking of Risks

<table>
<thead>
<tr>
<th>ET Scenario</th>
<th>Min Cut Sets</th>
<th>Prob./ Freq.</th>
<th>Cutset Freq.</th>
<th>Total Frequency</th>
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IRIS Hybrid Platform
Precursor and Event Assessments

- The risk level is calculated as
  \[ R = \Phi \cdot P(\text{Accident} | \text{Precursor}) \]

- \( \Phi \) is the frequency of the precursor event of a certain type

- If there are other precursors the total risk is calculated by summing over individual precursor risks
Precursor Event Assessment (1/2)
Precursor Event Assessment (2/2)

Precursor Frequency = 0.02
Crash Probability Given Precursor = 0.001

From Fault Tree
Selecting and Justifying Safety Performance Indicators

<table>
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<tr>
<th>Indicator</th>
<th>Frequency</th>
<th>“Risk Weight”</th>
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<td>2 SI-2</td>
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<td>0.01</td>
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<tr>
<td>N SI-N</td>
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<td>$P_N$</td>
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## Monitoring Safety Using Performance Indicators

<table>
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<th>Indicator</th>
<th>Freq.</th>
<th>“Risk Weight”</th>
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</thead>
<tbody>
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<tr>
<td>Hydraulic System Failure</td>
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<tr>
<td>Missed Approach</td>
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<td>0.01</td>
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<tr>
<td>……</td>
<td>0</td>
<td>0.5</td>
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</table>

**Select Indicators to Plot**

**Select Airline**

**Total Risk**
Applications

- **Nuclear**
  - PRA, Risk Monitor, Outage Planning, Precursor Analysis, Even Assessment, Regulatory Oversight

- **Aviation**
  - SASO, Risk Informed Inspection, Safety Indicators

- **Space**
  - Mission Assurance, QRA, Precursor, Upgrades, Operational Decisions, Design Trade Studies (Shuttle, ISS, ESA,...)

- **Petro-Chemical**
  - QRA, Safety Assessment, Precursor Analysis