“Adventure is just bad planning.”
– Roald Amundsen

Safety Plans

18-642 / Fall 2020

These tutorials are a simplified introduction, and are not sufficient on their own to achieve system safety. You are responsible for the safety of your system.
Safety Plan: The Big Picture for Safety

- Anti-Patterns for Safety Plans:
  - It’s just a pile of unrelated documents
  - It doesn’t address software integrity
  - You don’t link to a relevant safety standard
  - It doesn’t link to a security plan

- Safety Plan:
  - Safety Standard: pick a suitable standard
  - Hazards & Risks: hazard log, criticality analysis
  - Goals: safety strategy, safety requirements
  - Mitigation & Analysis: HAZOP, FMEA, FTA, ETA, reliability, ...
  - Safety Case: safety argument
Usually “functional safety” (safety functions)
- IEC 61508 is a generic starting point
- Many domains have specific standards
  - ISO 26262, EN-50126/8/9, MIL-STD-882, IEC 60730, DO-178, ...

Key elements of a safety standard:
- Method for determining risk
  - Usually Safety Integrity Level (SIL)
- SIL determines engineering rigor
  - Analysis techniques
  - Mitigation techniques
- Life-cycle approach to safety
Safety Goals & Safety Requirements

Safety Goal: top level definition of “safe”
- Example: vehicle speed control
  - Hazard: unintended vehicle acceleration
  - Goal: engine power proportional to accel. pedal position
- Safety strategy: how you plan to achieve goal
  - Example: correct computation AND engine shutdown if unintended acceleration

Safety Requirements:
- Goals at system level; requirements provide supporting detail
- Supporting requirements generally allocated to subsystems
  - Might include functionality and fail-safe mitigation requirements
- Examples:
  - Engine torque shall match accelerator position torque curve
  - Pedal/torque mismatch shall result in engine shutdown
Idea: Start with component failure; analyze results; identify hazards

<table>
<thead>
<tr>
<th>Component</th>
<th>Potential Failure Mode</th>
<th>Failure Effects</th>
<th>Recommended Action</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor R2</td>
<td>Open</td>
<td>Triggers Shutdown</td>
<td>Use Industrial spec. component</td>
<td>Done</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>Over-current/potential Fire</td>
<td>Circuit Redesign</td>
<td>Open</td>
</tr>
<tr>
<td>Capacitor C7</td>
<td>Explodes</td>
<td>Potential Fire</td>
<td>Select different component</td>
<td>Open</td>
</tr>
</tbody>
</table>

Significant limitations for generating hazards

- “Complex component” failures are not well behaved
  - Software fails however it wants to fail
  - Integrated circuits are usually highly coupled internally
- Poor at representing correlated and accumulated faults
  - E.g., exploding capacitor damaging several nearby components
HAZard and Operability Analysis (HAZOP)

- Hazard structured brainstorming
  - For each system requirement:
    - Modify with a guide word
    - Does the result suggest a hazard?
  - Effective starting point, but not guaranteed to find all hazards

- Examples
  - When pressure exceeds 6000 psig, relief valve shall **NOT** actuate.
  - System shall come to a complete stop within **AFTER** 5 seconds when emergency stop is activated.
    - Alternately: System shall come to a complete stop within 5 seconds **LATE** when emergency stop is activated.

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Guide Word  | Meaning
---|---
NO OR NOT | Complete negation of the design intent
MORE | Quantitative increase
LESS | Quantitative decrease
AS WELL AS | Qualitative modification/increase
PART OF | Qualitative modification/decrease
REVERSE | Logical opposite of the design intent
OTHER THAN / INSTEAD | Complete substitution
EARLY | Relative to the clock time
LATE | Relative to the clock time
BEFORE | Relating to order or sequence
AFTER | Relating to order or sequence

https://goo.gl/KTer9C
Hazard: a potential source of injury or damage
- A potential cause of a mishap or loss event (people, property, financial)

Hazard log
- Captures hazards for a system
- HAZOP generates some hazards
- Others are legacy & experience

Risk evaluation
- Risk = Probability * Consequence
  - Typically determined via a risk table
- Risk must be reduced to acceptable levels
  - Risk determines required SIL (e.g. “Very High” → SIL 4)
Safety Analysis & Mitigation

- **Failure Mode Effects Analysis (FMEA)**
  - Work forward from fault to mishap

- **Fault Tree Analysis (FTA)**
  - Work backward from hazard to causes
  - *Strategy:* HAZOP identifies fault tree roots

- **Avoid single points of failure**
  - If component breaks, is system unsafe?
  - Computational elements fail in worst way

- **Life-critical systems require redundancy**
  - Also avoid correlated faults
  - High-SIL software techniques to avoid SW defects
This system is safe because:
- structured argument + evidence

Incorporates safety plan topics:
- Methodical identification of hazards
- Each hazard evaluated for risk
- Mitigation rigor determined by risk (e.g., SIL)
- Analysis rigor determined by risk (e.g., SIL)
- Safety requirements appropriately cover all hazards
  - Including both accidental faults & malicious faults

Example techniques
- Goal Structuring Notation (GSN)  
- Systems-Theoretic Process Analysis (STPA / Leveson)
A written Safety Plan including:

- Hazards + risks
- Safety goals + requirements
- Safety analysis + Mitigation
- Following a safety standard
- Resulting in a written safety case
- Independent audit of safety case

Pitfalls:

- Software safety usually stems from rigorous SIL engineering
- FMEA can miss correlated & multipoint faults – must use FTA
- Need to include safety caused by security attacks
DANGERS

Indexed by the number of Google results for "Died in a ____ Accident"

<table>
<thead>
<tr>
<th>Type of Accident</th>
<th>Google Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skydiving</td>
<td>710</td>
</tr>
<tr>
<td>Elevator</td>
<td>575</td>
</tr>
<tr>
<td>Surfing</td>
<td>496</td>
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<tr>
<td>Skateboarding</td>
<td>473</td>
</tr>
<tr>
<td>Camping</td>
<td>166</td>
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<td>Gardening</td>
<td>100</td>
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<tr>
<td>Ice Skating</td>
<td>94</td>
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<tr>
<td>Knitting</td>
<td>7</td>
</tr>
<tr>
<td>Blogging</td>
<td>12</td>
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