Identifying and Utilizing Precursors

From Data to Products … Revisiting Key Concepts
Scope

● Sharing observations and lessons-learned:
  - Issues and perspectives in identifying and using precursors

● Sharing resources (Appendix 1 thru 3):
  - Incidents/accidents, safety models, operating assumptions, risk factors, precursors, defenses/controls
Objective

- Elicit questions and answers:
  - How does this apply to my company / organization / operation?
  - How do we achieve this objective, in a similar or equivalent manner?
  - Where and how could we do more in identifying, analyzing and using precursors?
Prevention ... a Shared Challenge

Safety = Aircraft + Operation + Operating Environment

Manufacturer + Airline + State

Design Manufacturing Operations Maintenance + Regulatory Compliance Quality & Safety Management + Regulations Regulatory Oversight Infrastructures Air Traffic Management
Prevention … in a Nutshell

- Awareness of hazards and risks (severity / probability)
- Identification of hazard-related risk factors (threats)
- Understanding of causal sequences / causality chains:
  - Causes of known types of event
  - Precursors of potential types of event
- Development and deployment of hazard-related interventions:
  - Defenses (prevention)
  - Controls (detection / recovery / mitigation)
Risk Reduction … a Multi-Facet Effort

● Operational risks :
  - Hazard-related risks (permanent risk factors / threats)
  - Risk level variation with changing conditions

● Systemic risks :
  - Cross-boundary risks (owned, shared, incurred)
  - Change-induced risks
Defining Precursors

- Precursors (weak signals, early warnings, tremors …) of incidents / accidents may be found in:
  - Uneventful occurrences, that might have a more severe outcome
  - Inconsequencial deviations from flight path or procedures, that might result in undesired conditions

- Context and circumstances are critical pre-conditions

- Precursors usually are:
  - Known but … so far … ignored conditions
  - Unknown conditions, not detected by past analysis
<table>
<thead>
<tr>
<th>Incidents Accidents</th>
<th>Precursors</th>
<th>Risk Factors</th>
<th>Defenses / Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazards (Risk Domains)</td>
<td>Occurrences (Uneventful Events)</td>
<td>Deviations (Procedural / Flight Path)</td>
<td>Throats</td>
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<tr>
<td>Runway Excursion or Overrun (Takeoff)</td>
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<tr>
<td>Takeoff from taxiway</td>
<td>Excessive taxi speed</td>
<td>Industry prevention strategies and best practices (Note 2)</td>
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<tr>
<td>Runway confusion</td>
<td>Inadequate technique for line-up or 180-degree turn on runway</td>
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<td>Inappropriate intersection takeoff or takeoff from incorrect intersection</td>
<td>Inadequate engine stand-up technique</td>
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<tr>
<td>Line-up events</td>
<td>Gross error in takeoff weight entry or and/or in $V_{\text{1}} / V_{\text{N}}$ speeds assessment</td>
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<tr>
<td>Rejected takeoff (whether initiated below or above 100 kts)</td>
<td>Incorrect stab-trim setting</td>
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<tr>
<td>Tire burst</td>
<td>Undetected incorrect takeoff configuration</td>
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<tr>
<td>Aircraft swerve / lateral excursion during takeoff roll</td>
<td>Late rejected takeoff decision / initiation</td>
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<tr>
<td>Cautions / warnings (genuine or spurious) that may lead to a low-speed or high-speed rejected takeoff</td>
<td>Premature rotation (\text{(i.e., below } V_{N}\text{)})</td>
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<td>Other cockpit effects / malfunctions (genuine or spurious) occurring during takeoff roll</td>
<td>Late rotation (\text{(i.e., above } V_{N}\text{)})</td>
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<tr>
<td>Runway incursion</td>
<td>Slow rotation (\text{(i.e., low pitch rate)})</td>
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<tr>
<td>Wildlife incursion</td>
<td>Low pitch attitude after lift-off</td>
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<td>Bird strike</td>
<td>Note 2</td>
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</table>

Note 2: Industry prevention strategies and best practices (Note 2)

Adherence to SOP's (task sharing, briefings, use of checklists, standard calls and excessive-deviation callouts, mutual crosscheck and backup)

Cross-check of takeoff data: weight-and-balance, stab-trim setting, fuel distribution, runway conditions, wind component, outside air temperature, corrections (QNH, air conditioning, anti-ice, ...), flaps setting, $V_{1} / V_{N}$ speeds, assumed temperature / reduced or full thrust setting, ...

Awareness of prevailing takeoff performance-limiting factor (available acceleration-stop distance or other limitation)

Compliance with "minimum turn-around time", as applicable, to ensure adequate brakes energy

Takeoff briefing highlighting the specific / non-routine aspects of the takeoff

Line-up technique

Readiness for possible stop or go scenarios (being go-minded whenever warranted)
Identifying Precursors

First Precursor(s) → Reported Event → Potential Events
Looking Beyond Reported Events

**Passenger aircraft, Cruise altitude**
- Avionics Smoke + Cargo Compartment Fire warnings
- Heavy smoke in cockpit
- Crew sequence of actions?

**Freighter aircraft, Final approach**
- Avionics Smoke + Cargo Compartment Fire warnings
- Heavy smoke in cockpit
- No crew action, Landing continued
- Runway vacated and aircraft evacuated

**Reported Event**
( Prior - Precursor )

**Potential Event**
Analytical Tools - Dependency Models

- Establish hierarchy and relationships between risk factors, defenses and controls
- Describe causal sequences (causality links / chains) leading to given outcome
- Capture dependencies (inter-relationships) between causal sequences
- Measure robustness (effectiveness / reliability) of defenses and controls
- Generate automatic warnings on unanticipated combination of / interactions between « links / chains »
Analytical Tools - Classification Models

- Assist in encoding typology of individual occurrences:
  - Event / occurrence originator (trigger, root cause)
  - Operational consequences on flight conduct / continuation
  - Operational and human performance markers (including threat and error management)
  - Environmental factors and circumstances
  - Organizational / systemic factors
  - Challenged operating assumptions

- Enable statistical analysis of event data sets:
  - Focus on « big bars »
Functional Hazard Analysis (FHA)

- FHA is a generic concept using a variety of subject-matter-specific methods and tools

- Common features include:
  - Analysis workflow (from data to interventions)
  - Fault-tree analysis (fault, error)
  - Checklists / questionnaires (elicitation techniques)
  - Mapping / cartography (threats, hazards)
  - Matrix / radar scope / … (risk scoring)
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FHA is a look-ahead risk assessment approach.
Quantitative and Qualitative Analysis

- **Objective (quantitative, hard)** data establish facts and figures

- **Subjective (qualitative)** data add layers of:
  - Subject-matter-expertise (experience, insight and hindsight)
  - Engineering judgment (educated guess, correlation)

- Integrating objective and subjective data helps:
  - Painting a more comprehensive risk picture
  - Reaching more balanced and complete conclusions and recommendations
Implicit Safety Models

- Set of historical references defining the current paradigm of commercial aviation:
  - ICAO standards
  - National laws and regulations
  - Industry standards and best practices
  - Industry hazard prevention programs
  - Research contributions
  - [ ... ]
## Implicit Safety Models

<table>
<thead>
<tr>
<th>Risk Domains</th>
<th>Defenses / Controls</th>
<th>Safety Models - Sources</th>
</tr>
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</table>
| Altitude Deviation | Threat-related Prevention Strategies | **Eurocontrol - European Air Traffic Management Program**  
[http://www.eurocontrol.int/eatmp](http://www.eurocontrol.int/eatmp)  
and  
[http://www.eurocontrol.int/safety](http://www.eurocontrol.int/safety)  
Level Bust Safety Bulletins |
| Level Bust    |                     | **IATA / Eurocontrol - Level Bust Tool Kit**  
European Action Plan for the Prevention of Level Bust  
Level Bust Briefing Notes |
|              |                     | **FSF - ALAR Toolkit**  
ALAR Briefing Notes 3.1 and 3.2 |
Operating Assumptions

- Design principles, operating procedures and training concepts reflect implicit / explicit operating assumptions about the intended « user »:
  - Airmanship / craftsmanship
  - Prior experience
  - Behavior (code of conduct)
  - Knowledge of systems operation and … of how to operate the systems
  - User’s « Always do » and « Never do »
  - Day-specific information availability
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Real world differs from implicit safety models
# Challenged Operating Assumptions

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<td>When selecting a system or when setting a target value, the flight crew ensures that the correct selector / control is used and is actuated in the intended manner</td>
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<td><strong>SOP's</strong></td>
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<td>Systems are always armed, engaged, used and monitored as per SOP's ( e.g., automation, ground spoilers, autobrake, thrust reversers, ...)</td>
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<td>Flight crew and cabin crew strictly adhere to the sterile cockpit rule, but cabin crew is aware of circumstances that warrant breaking this rule</td>
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<td>Flight crew maintains overall situation awareness during cruise by periodically reviewing systems operation on corresponding display unit</td>
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<td>Flight crew monitors FMS navigation, particularly during SID and STAR phases of flight</td>
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<td>Load-and-trim sheet is checked by both the dispatcher and the flight crew for possible gross errors</td>
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<td>Operating guidelines are available to support the flight crew's &quot;stop-or-go&quot; decision during the various phases of the takeoff roll ( i.e., below or above 100 kt )</td>
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We need to challenge our operating assumptions
Cross-boundary Risks

- Air Traffic Control
- Cabin Operations
- Flight Operations
- Regulations
- Maintenance
Cross-boundary Risks

Use of FHA to assess cross-boundary hazards / risks
Risk Variation with Changing Conditions

- Risk prevalence varies from flight to flight, e.g.:
  - Dispatch under MEL
  - Crew factors:
    - Experience on type / pairing
    - Route familiarization
    - Duty day
  - Weather conditions:
    - Enroute, at destination
  - NOTAM’s:
    - Unserviceable navaids / letdown aids
    - Work-in-progress
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Make use of “Risk Assessment Tools”
(Hazard-related or flight-phase-related RATs or TEM checklists)
Change-induced Risks

● Changes always are introduced for good reasons
● Changes carry their own risks
● Changes should be evaluated using subject-specific FHA methodologies:
  - Organization:
    ▪ Policies, processes, procedures
  - Products:
    ▪ Design, operations, maintenance, training
  - [ ... ]
Formulating Problem Statements

● Raising the problem:
  - Do we have a problem? ... or ... We have a problem!

● Formulating accurately the problem:
  - What went wrong, how and why?

● Quantifying the problem:
  - Why is this important?
  - What are the challenges?

● Evaluating the solutions:
  - What are the possible interventions?
## Identifying Interventions

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Technology</th>
<th>Operating Standards</th>
<th>Training Standards</th>
<th>Safety Awareness</th>
</tr>
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<tbody>
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<td>✔️</td>
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Deploying Interventions

- ICAO / European Union
- Civil Aviation Authorities / Agencies
- Operators / Manufacturers / Vendors
- Industry organizations
- Flight Safety Foundation
- Universities / Academies
Aviation Safety Enhancement Loop

Analytical Methods and Tools

Enhanced Technologies
Procedures / Training
Awareness Information

Event Analysis

Prevention Strategies and Interventions

Observed Deviations and Factors

Problem Statements
Lessons-learned

Consolidation with other Events

Operational and Human Factors Analysis
Quotes from our peers

« You cannot fix a category of accident, you can just fix the contributing factors »

Paul Russell - Boeing - US CAST - FSF

« Find the reasons, stop feeding the causes … and let the reasons starve »

Dr Robert O. Besco - American Airlines, retired

« Leave no stone unturned »

[ … ] - Accident Investigator - US NTSB