AIRCRAFT CERTIFICATION
ASSUMPTIONS AND STPA

MIT STAMP WORKSHOP 2024

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Credit also to Aaron Katz (NATCA)
• Secondary surveillance RADAR

• Provides primary flight details to ATC Controller

• Provides proximity alerts of other aircraft to flight crew

• Data based on aircraft systems and navigation trace
AIR TRAFFIC CONTROL (ATC) SCREEN VIEWS

Image ref: FAA.gov/air_traffic

Image ref: aviation.stackexchange.com
PILOT’S PRIMARY FLIGHT DISPLAY (PFD)

- Radio Altitude (RA) (appears below certain height)
- Barometric altitude
- Approach minimums for visual acquisition of runway (depends on approach category)
- QNH Setting
- ILS (Instrument Landing System) Glideslope

EXAMPLES FROM TRADITIONAL CERTIFICATION PROCESS
# Some Transponder Failure Conditions

<table>
<thead>
<tr>
<th>Failure Condition</th>
<th>Flight Phase</th>
<th>Env</th>
<th>Failure Effects</th>
<th>Class</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of transponder data to ATC</td>
<td>All phases</td>
<td>IFR</td>
<td>Loss of aircraft transponder data on ATC screen. Slight reduction in safety margins and increase in flight crew workload to maintain safe separation.</td>
<td>MIN</td>
<td>ATC and flight crew will recognize a loss of transponder data and revert to an existing procedure/primary radar.</td>
</tr>
<tr>
<td>Malfunction of transponder data to ATC</td>
<td>All phases</td>
<td>IFR</td>
<td>Incorrect aircraft transponder data displayed on ATC screen. Misleading position data presented to controller. Significant reduction in safety margins and increase in flight crew workload to maintain safe separation.</td>
<td>MAJ</td>
<td>ATC and flight crew conduct regular cross-check of assigned flightpaths/levels which will identify incorrect transponder data to the flight crew/ATC. This failure may significantly mislead the controller/flight crew or may take some time to be recognized (delayed awareness of failure).</td>
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The assumptions bound the failure effects, classifications and design level or rigor. **But are they valid?**

The overall assumption here is that the aircraft will not violate safe separation constraints!
TRADITIONAL REQUIREMENTS GENERATED

Reliability and level of rigor
- Loss of Transponder shall occur less than or equal to 1E-5 failures per flight hour
- Malfunction of Transponder shall occur less than or equal to 1E-5 failures per flight hour
- Transponder shall be developed to at least DAL C

Training and policy
- Flight manual instructions, likely to follow an established procedure in the event of loss/malfunction
- Regular simulator training requirement for flight crews to practice lost transponder scenarios
- Flight crew and ATCO readback of assigned squawk codes and instructions – to highlight errors

(1) The level of reliability, redundancy, and design rigor is reduced by the assumptions made in the failure condition assessment!
(2) There is absolutely nothing about the ATC controller, or their equipment in these requirements!
CAN STPA HELP?
STPA EXAMPLE...
### STPA STEP 1: LOSSES AND HAZARDS

<table>
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<tr>
<th>Loss Type</th>
<th>Hazard 1</th>
<th>Hazard 2</th>
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<tr>
<td>L1: Loss of life or serious injury to aircraft occupants</td>
<td>Aircraft violates minimum separation from other traffic.</td>
<td>Aircraft violates minimum separation from terrain.</td>
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<tr>
<td>L2: Destruction of/physical damage to aircraft structure</td>
<td>Aircraft violates minimum separation from other traffic.</td>
<td>Aircraft violates minimum separation from terrain.</td>
</tr>
<tr>
<td>L3: Monetary loss due to airspace infringement</td>
<td>Aircraft violates minimum separation from other traffic.</td>
<td>Aircraft violates minimum separation from terrain.</td>
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STPA STEP 2: CONTROL STRUCTURE

Focusing on QNH and altitude feedback for this example

ATC Operator
- Course Instructions
- Airspeed Instructions
- Altitude Instructions
- Emergency Instructions
- Squawk Code
- QNH (altitude calibration)
- Readback
- Fault Diagnosis
- Reported Altitude

Flight Crew
- Airspeed
- Altitude
- Mode Selection
- Status

Transponder
- Airspeed
- Altitude
- Status
- TCAS mode

Physical Aircraft
- Status
- TCAS mode
- Course
- Aircraft Data

Etc.
## STPA STEP 3: IDENTIFY UNSAFE CONTROL ACTIONS (UCAS)

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<tr>
<th>Controller</th>
<th>Control Actions</th>
<th>Not Providing Causes Hazard</th>
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<th>Too early, Too late, Out of order</th>
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<td>ATC</td>
<td>Provide QNH</td>
<td><strong>ATC does not provide updated QNH when FC is using outdated QNH</strong></td>
<td>ATC provides incorrect QNH that does not match environmental conditions</td>
<td>ATC provides QNH too late after crew executes maneuvers based on wrong QNH</td>
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<td>FC does not Set QNH when aircraft is using outdated QNH</td>
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<td>FC provide Course Change too late to after conflict with other traffic is irrecoverable. [H1, H2].</td>
<td>FC stops Course Change too soon leaving the aircraft on a conflicting flight path. [H1, H2].</td>
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UCA: ATC does not provide updated QNH when FC is using outdated QNH
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Procedure to detect altitude errors is to compare FC reported altitude with transponder reported altitude (Δ>300ft)
CHALLENGING ASSUMPTIONS

Traditional
- Transponder Loss / malfunction recognized by FC and ATC
- Existing procedures are adequate to maintain safe separation
- FC workload is manageable (nothing else is going on)
- Collision highly unlikely due to multiple layers: training, procedures, redundancy, etc.

STPA
- ATC may believe transponder output is correct. Relaying incorrect instructions to FC plausible.
- Multiple UCAs where unsafe actions may not be recognized by FC or ATC
- Multiple scenarios where workload is higher than expected (non-standard ops)
- Every UCA can be traced to a loss of separation
SO WHAT?

Remember our FHA hazard classifications?

- Would we consider driving up the severity with the loss / malfunction failure conditions? What would realistically be achieved?
- Could we introduce new functionality to provide better feedback?
- What would this new functionality be?
- Where in the traditional approach would we do this?
STPA RECOMMENDATIONS GENERATED

Aircraft Feedback to Flight Crew:
- Aircraft could provide alternate method for Flight Crew to validate QNH setting provided by ATC
- Aircraft could alert crew if QNH setting disagrees with alternate source of altitude (tricky without generating nuisance alerts)
**STPA RECOMMENDATIONS GENERATED**

**Aircraft-Aircraft Coordination:**
All aircraft operating in a terminal area should be using the same barometric ALT.
- Aircraft could cross check QNH setting with nearby aircraft and alert FC if discrepancy detected.

**Other aircraft**
STPA RECOMMENDATIONS GENERATED

Feedback to ATC:
- ATC could be provided enhanced feedback to determine if any aircraft are using an incorrect QNH
- Alert ATC if Aircraft-Aircraft check detects discrepancy
CAN STPA RESULTS HELP SUPPORT CERTIFICATION?
MEANS OF COMPLIANCE GUIDANCE (AC 25.1309-1B)

Advisory Circular

"...quantitative assessments of the probabilities of crew or maintenance errors are not currently considered feasible. If the failure indications are considered to be recognizable and the required actions do not cause an excessive workload, then for the purposes of the analysis, such corrective actions can be considered to be satisfactorily accomplished." (5-5)

"...Reasonable tasks are those that can be realistically anticipated to be performed correctly when they are required or scheduled." (8-1)

Questions STPA helps us consider:
- Recognizable to whom and with what training? Test pilot or line pilot?
- Excessive workload under what system conditions?
- How do we determine which tasks are reasonable? Are there situations in which tasks are not reasonable? (conflicting feedback, mental model flaws, etc)
- Realistic under which circumstances?
- What if tasks are not performed correctly?
MEANS OF COMPLIANCE GUIDANCE (AC 25.1309-1B)

Advisory Circular

"...meeting the $1 \times 10^{-9}$ per flight hour quantitative probability guidance alone is not sufficient to show compliance with the intent of the "extremely improbable" requirements of 25.1309(b) if relevant experience indicates the failure condition can occur." (A-2)

Are these failure conditions or a loss of functionality?

- Subsystem intentionally deactivated for maintenance (MMEL)
- Transponder configured incorrectly
- ATC provides incorrect QNH
- Flight crew enters incorrect QNH
- Poor visibility inhibits crew’s ability to visually confirm runway
- ILS down for maintenance
- ATC has no feedback to indicate QNH is incorrect

ATC SME comment on our UCAs: “I’ve seen all of these happen on a regular basis.”
IN CONCLUSION

System Design and Analysis for Safety
AC 25.1309

Flightcrew Human Factors Assessment
AC 25.1302
IN CONCLUSION

System Design and Analysis for Safety
AC 25.1309

Flightcrew Human Factors Assessment
AC 25.1302

Total Systems Approach with STPA
NOTE: The aviation system is very complex with many operational details and subtleties we didn’t have time to address today.