STPA Evaluation of Potential Conflicts Between Large Commercial Air Traffic and Small Uncrewed Aircraft Systems in the Terminal Airspace

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Overview

- Background
  - Small UAS (sUAS) and emerging hazards
  - Goals, scope and assumptions
  - Literature review

- STPA Details and Observations
  - Control Structure
  - Overview of losses, hazards, UCAs, loss scenarios

- Enabling Communication of STPA Results
  - Refinement and allocation of requirements to system components
  - Validation & verification of requirements
  - Distillation to key recommendations

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Background

- FAA estimates ~1.5M recreational/hobby sUAS in use by 2025
  - Additional 800k commercial sUAS estimated
  - Similar growth expected worldwide

- Current mitigations to avoid collisions are primarily procedural
  - UAS Operator must be aware of and abide by limitations
  - Some built-in geofencing for sUAS

- Some related losses have already been realized
  - Disruptive UAS operations (or reported operations) near airports
  - Collisions and near-collisions with aircraft

Total Recreation/Model Fleet (Million sUAS Units)

Fiscal Year	Low	Base	High
Historical			
2020	1.4365	1.4365	1.4365
Forecast			
2021	1.4544	1.5022	1.5417
2022	1.4668	1.5303	1.5935
2023	1.4708	1.5415	1.6157
2024	1.4719	1.5455	1.6237
2025	1.4724	1.5510	1.6347

FAA Aerospace Forecast Fiscal Years 2021–2041

NTSB News Release

NTSB Investigating Collision Between Drone, U.S. Army Helicopter

https://www.ntsb.gov/news/press-releases/Pages/PR20171005.aspx

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Background

- Goals
  - Provide an analytical basis for engagement with other stakeholders
    - Traditional engagements
      - Airspace & Airport Regulators, Air Navigation Service Providers, Airlines, Airport Operators
    - Emerging stakeholders
      - Public Safety Agencies, UAS Flight Approval Providers, UAS Operators

- Scope & Assumptions
  - Small mass-produced UAS
    - Most common UAS in use
  - Current state
    - Technology, regulation, operations, etc.
  - Terminal Airspace
    - Commercial airplanes at low altitude
  - Single airport, airplane, and UAS

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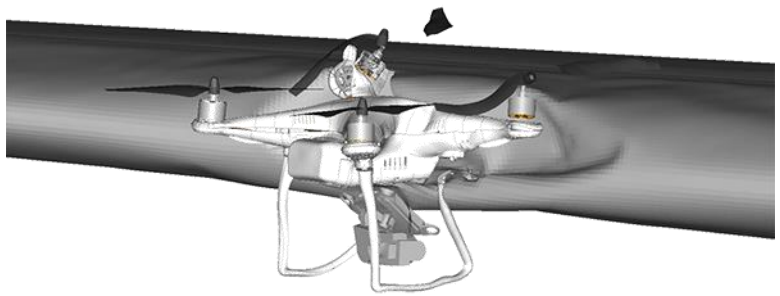
Literature Review

- Extensive research has shown that an sUAS collision could cause significant damage to airplane structure
  - FAA ASSURE UAS Airborne Collision Severity Evaluation
  - EASA Research Project: Vulnerability of Manned Aircraft to Drone Strikes



FAA Assure: Volume II –UAS Airborne Collision Severity Evaluation –Quadcopter

- "Detect and avoid" solutions for small UAS are in development
  - Electro-optical, radar, acoustic, cooperative (ACAS sXu)

- Emerging guidance to standardize response after detection of sUAS in restricted airspace near airports
  - EASA's "Drone Incident Management at Aerodromes" manual

- Limited published research regarding potential causes of sUAS incursions into terminal airspace or effective mitigations to deter and prevent such incursions

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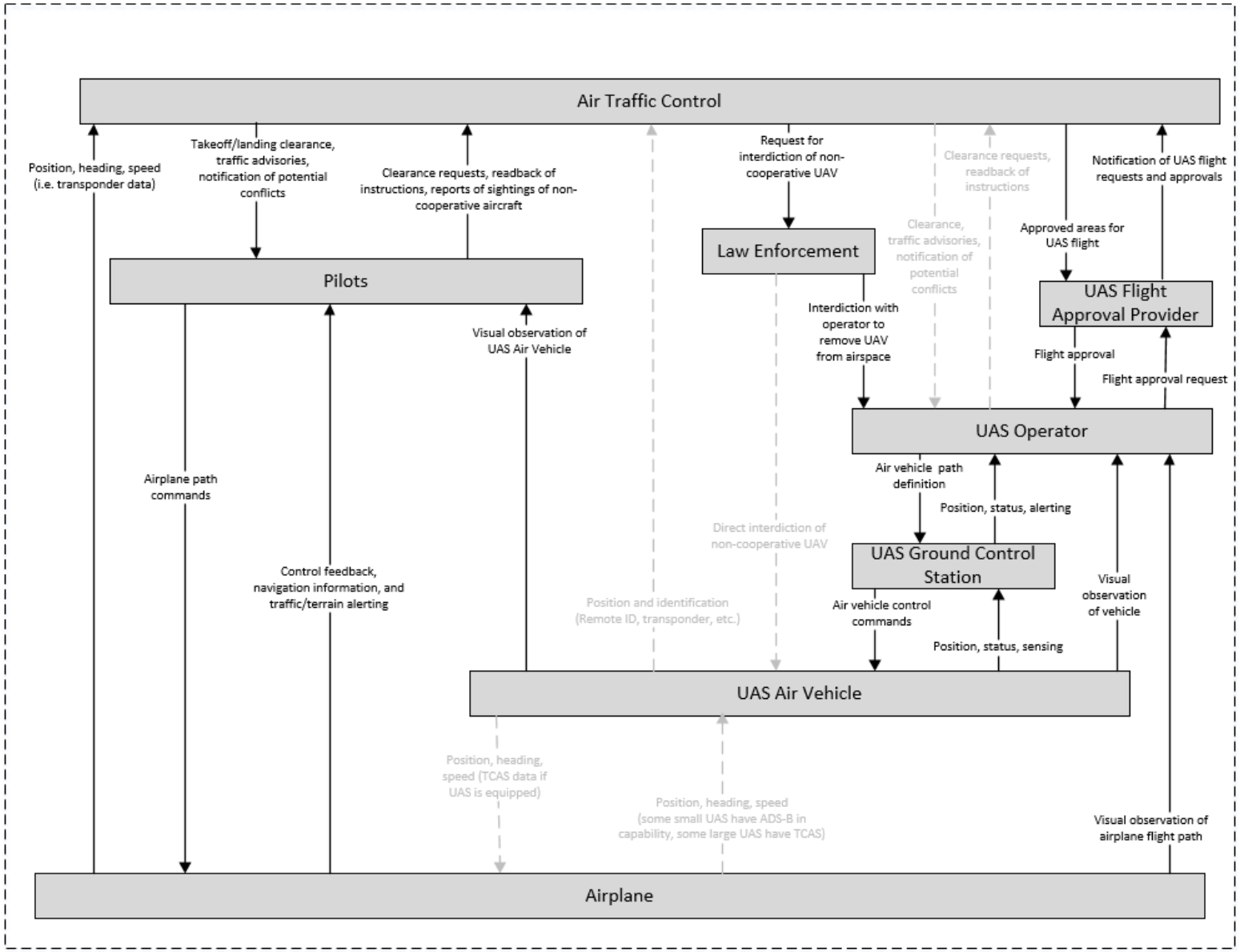
Control Structure Example



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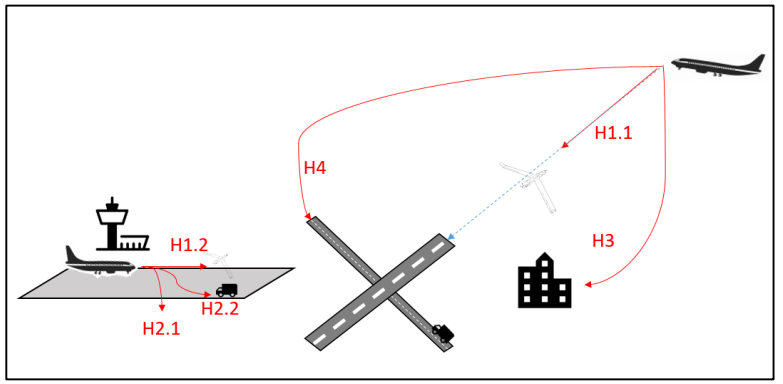
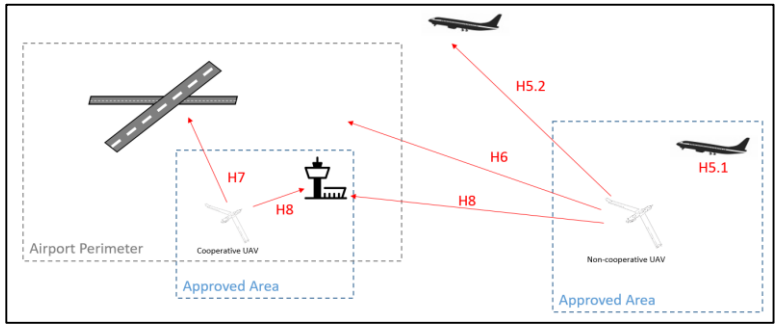
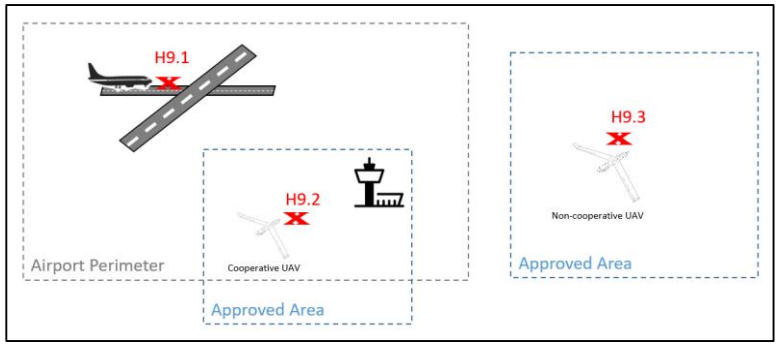
STPA Details & Observations

- Eight Losses
- Nine Hazards
  - Pictorial depiction of hazards helped supplement text
- 94 Unsafe Control Actions
- 400+ Loss Scenarios
  - Important to maintain structured approach to loss scenarios
    - Focused on maintaining connection and terminology related to inputs/feedback, process model, control algorithm, and controlled process
    - Aids consistent balance of generality/specificity, particularly for human controllers







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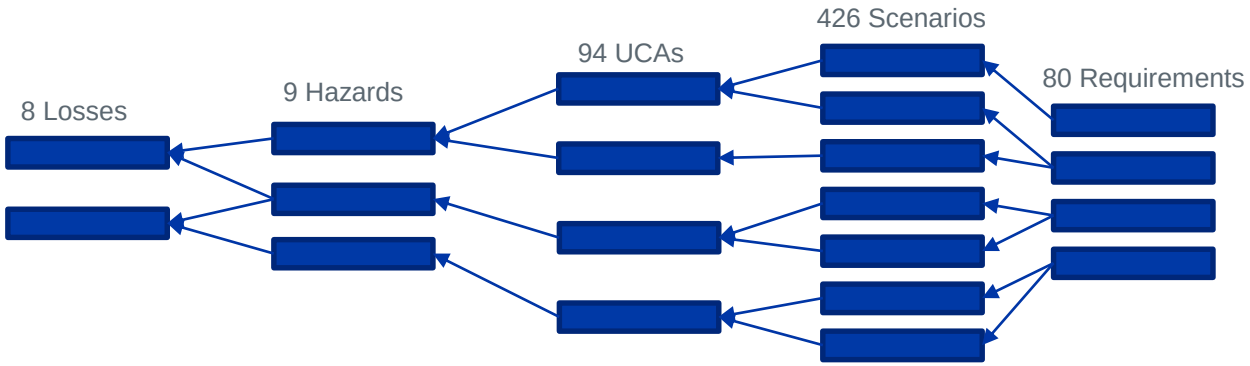
Refinement & Allocation of Requirements

- For each loss scenario, requirements identified and allocated to system elements
  - Engineering judgement needed to identify appropriate requirement and allocation
  - Supporting rationale recorded for each scenario to maintain traceability
  - A single requirement may help mitigate several loss scenarios
    - 80 requirements identified and allocated

- Alternate requirement proposals easily evaluated within STPA structure



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Evaluation of System Requirements

- Requirements were evaluated through a lens of validation and verification maturity
  - Evaluation of current state, with intent to identify potential gaps in the system
  - Examples:
    - *(ATC-01): ATC shall have accurate indications of airplane location and path*
      - Standardized two-way communication protocols with worldwide implementation
      - Millions of commercial flights have been conducted in accordance with the established protocols and standards
      - Automatic components are designed to established standards and have effective error detection and alerting
      - Backup procedures are well established and proven to be effective
      - Observation: Requirement is well validated and implementation well verified
    - *(ATC-11): ATC shall be informed of sUAVs that could present an airspace conflict*
      - Related standards that could contribute (but not complete) implementation are emerging (e.g. Remote ID)
      - Implementations are not widespread or thoroughly validated
      - Backup procedures are not well defined
      - Observation: Validation of the requirement and verification of implementations are incomplete

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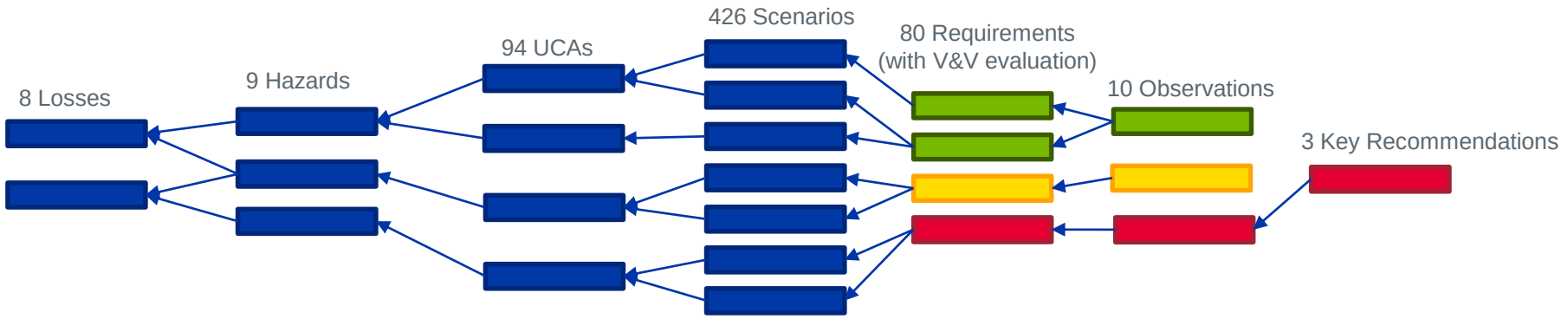
Distillation to key recommendations

- Ten observations based on V&V evaluation
- Three key recommendations to support prioritized stakeholder engagement
- All fully traceable throughout STPA documentation
  - Enables evaluation of alternate hazard mitigation strategies
  - Enables potential further research



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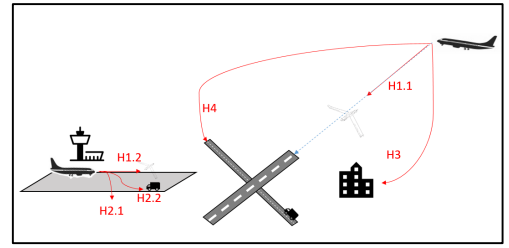
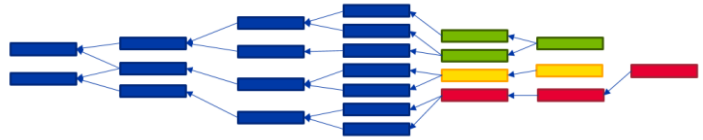
Conclusions

- STPA proved to be an effective analysis tool for this study
  - Complex interactions managed through relatively high level of abstraction
    - Allowed analysis of interactions without necessarily understanding internal details of each element
    - Hardware, software, and human elements
  - Generated insight and solid analytical basis for recommendations to stakeholders
  - Pictorial depiction of hazards aided organization and communication



- Allocation and evaluation of requirements helped distill results
  - Enabled focus on key recommendations
  - Facilitates communication with stakeholders
  - Full traceability maintained within STPA structure
    - Supports evaluation of alternate mitigation strategies
    - Supports further research expanding scope or increasing level of detail
    - Supports revision as “current state” evolves



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