Committee on Assessing the Risks of Unmanned Aircraft Systems (UAS) Integration

Unmanned Systems Certification

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FAA Small Airplane Directorate
Guiding Principles

• FAA & Industry - Shared Responsibility For Safety & Innovation

• Collaboration With Industry To Manage Risks From UAS Integration, But a “Zero Risk” Is Not the Expectation

• Traditional Means Of Risk Assessment & Mitigation May Or May Not Be Appropriate For UAS – Design and Operational Risks
Fear, Risk, and Reward

• Fear (risk aversion) - Protection Mechanism
  – We fear what we cannot control or don’t understand

• Some risk taking is healthy – a means to grow, learn, improve society/technology
  – We learn by doing – calculated risk leads to growth
  – Olympic athletes, Apollo Program, etc.

• Can’t mitigate risks we don’t understand or know about
  – Companies new to aviation are less risk averse
  – Must learn the real risks they are creating/facing
Consider the “Total Safety Equation”

• Not only “what could go wrong”, but the net safety improvement from using UAS vs. manned aircraft

• Example: Infrastructure surveillance puts people at significant risk
Defining Risk For UAS

• Contributing Factors
  – Vehicle Design/Systems – What is it?
  – Operational Risk – How will it be used?
  – Area of Operation/Airspace – Where will it be flown?
  – Airspace – What’s its Separation Strategy?
  – Human vs. Automation – Have you Planned for Errors?

• We need a clear, documented Concept of Operation, and Operational Risk Assessment
  – Proposed Mission Drives Requirements and FAA Involvement
  – Main Issue is Safe Operational Integration
  – Level of Airworthiness Appropriate
Managing Risk for UAS

- Manage Design & Operational Risk to Public
  - Apply FAA Resources/Rigor Based on Risk

- Certification manages risk through “Safety Assurance”
  - Confidence a proposed product or action will meet FAA safety expectations to protect the public

- Safety Does not Rely on Luck
  - Requires Active Risk Management and Risk Based Decision Making
“Safety Assurance” Risk Controls

- **Airworthiness** – Condition for safe flight for its intended use
- **Design** – Verify design, engineering, construction, etc. meet applicable requirements in certification basis
- **Pilot** – Train for aircraft and level of risk
- **Maintenance** – Repair/replace prior to failure
- **Operation** – Limitations sufficient for the expected/acceptable level or risk
- **Airspace** – Level of Integration, Traffic Exposure, Controller Involvement, and Equipage
Challenges for Evolving UAS Integration

• Well Proven Design Techniques to Evaluate Risk for Manned Aircraft, but......
  – May Not Translate Well to UAS Design or Operational Risk
  – We don’t have models for UAS operational safety yet
  – Probabilistic analysis difficult due to accurate data on operational facets of the analysis & assumptions

• Key - Mitigate Reasonably Foreseeable Failures/Issues
  – Design, Operations, Pilot Error, Weather, Maintenance, Geographic Area, Airspace all influence safety
Combined UAS Risk Controls

- Systems, airspace, ops, maintenance, & pilot error all feed into operational safety
- Typically Apply System Safety Techniques “XX.1309” for aircraft systems
- Some try to fix top level targets with increasing $10^{-x}$ for system failures
- Not the right solution, we don’t have data to model pilots, weather, etc.
What’s Our Safety Target for UAS?

- Depends, but FAA Expectation Not the Same For All UAS, and $10^{-9}$ May Not Be the Default
- We don’t have one target for manned Aircraft
  - We have Scalable, Multi-Tiered Safety Targets
    - Experimental, Amateur Built, Part 23 fixed wing, and part 27 rotorcraft, Part 25 transports and part 29 rotorcraft
    - Also have Multiple levels of Operational Oversight
      - Part 91, 121, etc.
## Where Did $10^{-9}$ System Design Come From?

<table>
<thead>
<tr>
<th>Transport Category Airplanes</th>
<th>Small Single-engine Airplanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal accident rate at time of XX.1309 rule:</td>
<td>Fatal accident rate at time of XX.1309 rule (IN IMC):</td>
</tr>
<tr>
<td>10^{-6}</td>
<td>10^{-4}</td>
</tr>
<tr>
<td>+ Data showed $\sim$10% caused by system failures:</td>
<td>+ $\sim$10% caused by system failures:</td>
</tr>
<tr>
<td>10^{-1}</td>
<td>10^{-1}</td>
</tr>
<tr>
<td>+ Assume 100 catastrophic failure conditions:</td>
<td>+ Assume 10 catastrophic failure conditions:</td>
</tr>
<tr>
<td>10^{-2}</td>
<td>10^{-1}</td>
</tr>
<tr>
<td>Results in probability:</td>
<td>Results in probability:</td>
</tr>
<tr>
<td>10^{-9}</td>
<td>10^{-6}</td>
</tr>
</tbody>
</table>
## Tiered Risk Exposure Factors – Manned A/C

<table>
<thead>
<tr>
<th>Aircraft/Ops</th>
<th>Passengers</th>
<th>Complex Parts/Systems</th>
<th>Annual Hours Flown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Single /Recreational</td>
<td>1’s</td>
<td>10’s</td>
<td>10’s</td>
</tr>
<tr>
<td>Large Twin /Business Use</td>
<td>10’s</td>
<td>100’s</td>
<td>100’s</td>
</tr>
<tr>
<td>Airliner /Commercial</td>
<td>100’s</td>
<td>1000’s</td>
<td>1000’s</td>
</tr>
</tbody>
</table>

A Single Level of Safety for all Segments of Aviation Would Not Reflect Safety Continuum
### Resulting Logical System Safety Design Targets

<table>
<thead>
<tr>
<th>Aircraft/Ops</th>
<th>Passengers</th>
<th>Complex Parts/Systems</th>
<th>Annual Hours Flown</th>
<th>Theoretical Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Single /Recreational</td>
<td>1’s</td>
<td>10’s</td>
<td>10’s</td>
<td>10E-6</td>
</tr>
<tr>
<td>Large Twin /Business Use</td>
<td>10’s</td>
<td>100’s</td>
<td>100’s</td>
<td>10E-8</td>
</tr>
<tr>
<td>Airliner /Commercial</td>
<td>100’s</td>
<td>1000’s</td>
<td>1000’s</td>
<td>10E-9</td>
</tr>
</tbody>
</table>

Created Tiered Approach to Theoretical Probability of Catastrophic Failure from Manned System Design
Certification Focus on Net Safety Gain

• New Technology Introduces Risk with its Benefits
• Example: Capstone Program in Alaska
  – Glass Displays for GA - lower design assurance levels
  – Resulted in a 40% reduction in fatal accidents
  – Significant Initial resistance
• UAS
  – Will provide societal benefits
  – Risk-based, step-wise integration will manage risk
Safety Assurance By Regulatory Buildup

- Hobbyist/Recreational Operations
- Low Altitude Small UAS (Part 107)
  - In line of sight of operator
- Operations Over People (107 Expansion)
  - Working Regulation Now
- Beyond Visual Line Of Sight ( Permit to Fly)
  - Enable Low Risk, Small UAS First
- Integrated/Controlled UAS Ops (TC/PC)
  - Changes to ATM and Mature Technology
- Future Automation – “Pilotless” Ops
  - Only as ATM and Automation Allow

Future Rulemaking and Waivers
UAS Regulatory Structure
Risk Based Approach

Part 107, Small UAS
- Operating Limitations
  - Size / Energy

Part 21 “Permit to Fly”
Pending Rule
- Airworthiness Certification
- Industry Standards
- Operating Limitations
  - Size/Energy

14 CFR 21.17(b) Special Class Type Certification
- Airworthiness Certification
- Production Approval/PC
- Design Approval/TC
- Customized Standards
- Operating Limitations
  - Size/Energy

Increasing risk to public / mitigations / requirements
UAS System Safety Targets – Initially Energy Based

- For Applicability of Airworthiness & Design Requirements
  - RC1 and RC2, Small UAS (Open, Part 107)
  - RC2 and RC3, Mid-Sized (Specific, PTF)
  - RC4 to RC6, Large UAS (Certified, Std. Cert)

- Does Not Set “Operational Safety” Target

Defining Scalable Safety Assurance Requirements
Resulting Risk-Classes Overlaid with Rules

Cert Basis Requirements Based on Risk

Cert Level

Top Down Risk Analysis §21.17(b)

Part 21 Permit To Fly *

Part 107 Expansions

No Airworthiness* Part 107

Bottom Up Risk Analysis “SORA”

Risk Class 6 (P25)

Risk Class 5 (P23 Twin)

Risk Class 4 (P23 Single)

Risk Class 3 (LSA)

Risk Class 2 (SUAS)

Risk Class 1 (Micro)

Hobby

Part 107

Part 21

Std. Certification* §23.1309

Risk to Public

* Dependent Upon Operational Integration
Risk-Based Operational Classification Strategy

- For Applicability of Operational Requirements - Address Operational Risk Exposure While Avoiding a “Zero-Risk” Mentality

Increasing Level of FAA Rigor

Operations Over People

Expanded Operations Beyond Visual Line of Sight

Small UAS Package Delivery Operations

Non-Segregated Operations

Routine/Scheduled Operations

Large Carrier Cargo Operations

Passenger Transport Operations

Increasing Level of Operational Integration
The Two Classifications Are Notionally Related

- “Typical Use-Case” Related to Size, Capability, & Performance
- Level of Integration sets Requirements, Level of FAA Oversight, and Involvement in Tactical Operation
Evolution of Safety Analysis

• Societal Expectations Have Changed
• Safety Requirements Have Evolved
  – 1938 CAR 3 – Does it work?
  – 1955 FAA – What if it fails?
    • Am I still safe? - Began evaluation of failures/malfunctions
  – 1968 FAA – Fail Safe Designs Required
    • Started Initial “1309” –Like Approach We Have Today
    • Mitigate Foreseeable Catastrophic Failures

• There are still no target probabilities in our regulations
• How can we safely enable UAS, and Future Transportation?
Risk Assessment Tools

- FAA SMS System
- Order 8040.4A – Overarching Safety Risk Management Policy
- Operational Safety Compliance Philosophy
- SAE Aerospace Recommended Practice (ARP) or best practices documents & AC 23.1309-1E
- JARUS SORA – “Bottom Up” Approach to Risk/Mitigation
- Many More......
Evaluating Risk Tolerance

- New Companies Will be Risk Takers or Risk Tolerant
  - Innovation/Market Advantage/Reward
- Established Companies Will be More Risk Averse or Cautious
  - Familiarity/Comfort/Established Process/Product
- Societies Behave Similarly
  - Look at how playgrounds/toys have evolved
- A Zero-risk, or risk-free society is a stagnant society
  - Uber Elevate concepts make UAS integration very important
Risk Analysis – Public Expectation

• The FAA is legally responsible for aviation safety – we have the safest system in the world
  – FAA must safely manage the airspace civil operations, per Title 49 U.S. Code § 40103(a)(1)

• The public depends on competent risk assessment and risk mitigation
  – When risks are overlooked--public skepticism abounds.

• Balance is important – overestimating risk can lead to high cost, complexity, and stagnation in innovation
  – New Transportation Concepts will challenge us all
Future Challenges for Risk Analysis

• UAS safely prototyping technology that will revolutionize flight
  – Automation & Flight Controls
  – Auto Collision Avoidance
  – Automation in Traffic Management

• Key to passenger carrying, highly-automated aircraft
  – Requires early collaboration
  – FAA, NASA, industry, academia, municipalities
Summary – Safety From Experience

• We have a history of finding ways to bring new technology into the National Airspace System safely
• We are already using a well-proven risk-based approach to safety
• Society Recognizes a need for balance regarding FAA Rigor vs. Safety Improvement – Drives cost, time for project
• UAS Certification will lead to future technology benefits for manned aviation
Managed Risk Will Enable Future Flight
Questions?
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