Update of Weather Technology in the Cockpit (WTIC) Program Rotorcraft Related Research

US Helicopter Safety Team Meeting

Gary Pokodner
February 23, 2021
NTSB Accident Analysis

• Analysis by industry:
  
  – **Flight hours** by industry
    (FAA GA survey)

  – **Events** by industry
    (NTSB database)

*Note that low hour industries typically have higher accident rates than high hour industries*
NTSB Accident Analysis

- Type of weather linked to events:

- Most impactful weather events on these accidents are wind and visibility

* Events can have multiple types of weather associated (you cannot sum ceiling/vis/precip and light conditions)
NTSB Accident Analysis

- **Wind events:**

  - Phase of flight
  - Occurrence
  - Flight purpose

- **Visibility events (ceiling/vis/precip or light conditions):**

  - Phase of flight
  - Occurrence
  - Flight purpose

*NTSB defining event = phase of flight + occurrence. One per event.*
Pilot Survey Results

- **197 rotorcraft pilots answered:**
  - 69% have HAA experience
  - 58% of HAA pilots also have military experience

- **Weather tools:**
  - **Preflight:** 92% use online weather tools, 77% use mobile or tablet application
    - 31% explicitly mention the HEMS Tool (only 6.5% of those did not have HAA experience)
    - 80% listed 3 or more types of tools (average 3.6 types of tool)
  - **Enroute:** 91% use radio reports, 92% have access to graphical weather display
    - Pilots listed an average of 2.8 types of tool

- **Weather opinion:**
  - 71% think the tools they have are sufficient for safe operations
    - Most common reproach is sparseness of information in some areas
  - 38% think latency can be a hindrance to safe operations

- **Training:**
  - 97% reported receiving IIMC training
    - 90% within the last year
    - 69% within the last 6 months
  - 56% reported being rotorcraft IFR current
    - 63% of HAA pilots are current
    - 43% of non-HAA pilots are current

*Inadvertent entry into IMC (IIMC)*
Pilot Interviews Takeaways

• **Key Themes:**
  • Coarse/missing weather information
  • Failure of weather technology
  • Overreliance on weather technology
  • Willingness to self-assess and use decision gates for weather in-flight and post-flight
  • Reliance on local/tribal weather knowledge
  • Effect of external pressures on weather-related decision making
## Identified Gaps

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training</strong></td>
<td></td>
</tr>
<tr>
<td>Risk Assessment</td>
<td></td>
</tr>
<tr>
<td>Risk Assessment</td>
<td><a href="https://www.govinfo.gov/content/pkg/CG-2017-06-01/pdf/JM-2017-06-01-0105-1.pdf">TSA 25.67T</a>, but is not mandatory for other type of operations (ANC13GA038, EPA03FA537).</td>
</tr>
<tr>
<td>Risk Assessment</td>
<td>Risk Assessment tools can fail to capture risk. Risk Assessment Tools returned low risk for missions that ended with multiple fatalities (CEN20FA008, CEN30FA086, EPA15FA273) or in an accident (TSA16LA003). The FAA FRAT risk available is tailored for fixed wing.</td>
</tr>
<tr>
<td>Risk Assessment</td>
<td>Risk assessment tends to be reevaluated even if conditions have significantly</td>
</tr>
<tr>
<td>Skills and Abilities</td>
<td>pilots that are both trained and aware of risk can still fail to recognize the impending emergency (EPA03FA537).</td>
</tr>
<tr>
<td>Weather Technology</td>
<td>There can be a lack of information along a route of flight (VFR16FA037). Some adverse weather conditions that affect helicopters can be very localized (Pinckel plot interviews, p.52). As demonstrated by the Matt Split Analysis, linear interpolation between weather stations is inappropriate to estimate conditions between observations. Emergency responders or hospital personnel are at the site but are not trained to provide good weather information to helicopter pilots.</td>
</tr>
<tr>
<td>Weather Technology</td>
<td>many weather products are tailored for fixed-wing operations and are not adequate for the scale, altitude and time of weather that matter for helicopter operations.</td>
</tr>
<tr>
<td>Weather Technology</td>
<td>Weather avionics (such as ADS-B IN) or contact with ATC or OCC are not mandatory and can be lost due to terrain. Electronic wind indicators not mandatory.</td>
</tr>
<tr>
<td>Weather Technology</td>
<td>Delay in radar data. Weather can change quickly. There can be 15 minutes before the pilots are aware that there has been a change in forecast, observation along its route (Sax Alexander interview).</td>
</tr>
<tr>
<td>Weather Technology</td>
<td>Data available to pilots in cockpit is limited, e.g., HEMS Tool data is not available in the cockpit.</td>
</tr>
<tr>
<td>Human-Weather Interface</td>
<td>In many accidents pilots did not call a weather brief prior to their flight. Pilots favor electronic tools.</td>
</tr>
<tr>
<td>Human-Weather Interface</td>
<td>Workload can be high and a synthetic image of the weather is difficult to get in the cockpit (Sax Alexander interview).</td>
</tr>
</tbody>
</table>

### Training

**Helicopter Technology**

- Helicopter pilots are not required to have received training for IMC recovery contrary to fixed wing pilots (14 CFR Part 61.103). Proper VFR into IMC recovery procedure is not tested as part of the emergency procedure during the practical test standards (Practical Test Standards: Private FAA-G-8081-15A and commercial FAA-G-8081-15B). Except for HEMS pilots, helicopter pilots can operate without having ever received any IFR training. IFR currency or recent IMC training is not mandatory for night operations.

- Military pilots are often used to having a copilot, but this is very rare for civilian operations in the United States.

**Skills and Abilities**

- Trained and warned pilots can still fail to recover from IMC emergencies due to safety requirements from the FAA FRAT-rated helicopters are expensive, most helicopters are VFR only and lack helpful avionics (artificial horizon, autopilot). 

- Tools like autopilot can be useful to lower pilots workload but can only be engaged in specific attitudes which can make them ineffective in IMC situation. In IMC the workload is very high.

**Helicopter Technology**

- VFR into IMC accidents are often fatal for everyone involved. The weather the pilots had access to was not recorded if a third-party briefing was used. This makes understanding the go/no-go decision more difficult to understand. The flight track shows what happened to the helicopter but not why. Flight Data Recording is not mandatory and is on the NTSB most wanted list.
Training Enhancements – Assess Effectiveness of Self Briefings

• Research Drivers
  • Recommendations for pilot training on performing a weather self-briefing
  • Understanding the implications of the shift from Flight Service Station (FSS) weather briefings to self-briefings
  • Identification of possible performance gaps in GA pilot weather self-briefings including the use of aviation apps
  • Recommendations for system design and instructions for weather self-briefing systems
Training Enhancements – Assess Effectiveness of Self Briefings

• **Research Areas**
  • Recommendations for pilot training on performing a weather self-briefing
  • Understanding the implications of the shift from Flight Service Station (FSS) weather briefings to self-briefings
  • Identification of possible performance gaps in GA pilot weather self-briefings including the use of aviation apps
  • Recommendations for system design and instructions for weather self-briefing systems
Training Enhancements – Assess Effectiveness of Self Briefings

• **Key Outputs/Outcomes Sought**
  • Comparison of performance of GA pilots conducting self-briefing and GA pilots using FSS for pre-flight weather briefings for flights in CONUS
  • Weather scenarios and performance measures adaptable for subsequent studies
  • Recommendations for self briefing system designs, instructions for self-briefings, and pilot training for using self briefings
Training Enhancements – Augmented Reality

• Developed augmented reality training app, WeatherXplore – available at Google and Apple stores

• Prototyped training using virtual reality models (interactive augmented reality) in the WeatherXplore App and evaluating its benefits

• Developed 10 mini-weather courses available on multiple websites and Youtube channel. Mini-course videos can be viewed at:
  https://www.youtube.com/playlist?list=PL72OJAPn9-hjTaJY3vMBmkd_qwflsOH6K
  or
  https://learn.fly8ma.com/courses/weatherxplore-course/
WeatherXplore Lessons

10 short weather lessons with real-world scenarios of weather you may encounter as a General Aviation pilot!

0 out of 11 steps completed 0%

WeatherXplore Carb Ice
WeatherXplore Variable Wind / Sudden Wind Shift
WeatherXplore AIREP / PIREP
WeatherXplore Density Altitude
WeatherXplore Low Ceiling / Mountain Obscuration
WeatherXplore Thunder
Potential WTIC Training Enhancement Project – Virtual Reality (VR)

• Project objective is to decrease potential aircraft loss-of-control in IMC
  • Assess benefits of VR training to accomplish objective through experiential learning
• Loss of Control Inflight (LOCI) is the single largest cause of accidents and fatalities in General Aviation with VFR into IMC often identified as a causal factor
• Project to increase understanding of how VR training might improve pilot weather decision-making and situational awareness
• Use virtual reality (VR) training scenarios focused on weather hazards to assess if the recognition primed decision (RPD) model leads to adaptive behavior that reduces upsets and loss of control
  • Compare VR trained pilots to control group and use VR scenario to test RPD benefits
• VR Demo at: https://youtu.be/PvtO_ks1jVg
Relevant Standards Development Efforts

• ASTM F-38 7.02 WK73142
  • Define minimum performance-based standards for Weather Supplemental Data Service Provider (SDSP) data and services to UAS Service Suppliers/Providers (USS/USP) and Operators in a UAS Traffic Management (UTM) ecosystem
  • Weather Data Performance Standards
  • Weather Data Interface Standards

All 3 efforts began summer 2020 and looking to end Spring 2022

FAA Aviation Weather Division and Flight Standards are involved

https://www.astm.org/DATABASE.CART/WORKITEMS/WK73142.htm
Crowd Sourcing Visibility Information – Hybrid Configuration Update

- Hybrid configuration includes MIT/LL developed edge detection software and selective crowd workers to produce visibility information from camera images
- Used MIT/LL developed trigger to send camera images to the crowd along with accompanying edge detection assessment values
- Implemented change detection algorithm to reduce selective crowd workload
- Utilized findings from FAA Tech Center experiment to provide supplementary information to pilots compared to a single visibility value
  - Supplementary information included: sky conditions, snow covering runway/taxiway/ramp, inability to specify ceiling/cloud base height, problem with image
- Supplementary information also provided feedback to image processing
Crowd Sourcing Visibility Information – Hybrid Configuration Update

Findings Summary:

• Most sites show that the crowd identifies the same trends observed with ASOS
• The biggest difference is that the ASOS values are higher on average than both crowd and edge detection evaluations.
• Edge detection evaluations in these cases are lower than the crowd on average
• ASOS also shows more extreme rises and falls in its recorded values over time
• Assessment of individual cameras can provide a different visibility assessment from the overall site
• Cloud cover information was fairly accurate and potential enhancements identified
• Edge detection software can benefit by crowd assessment of snow cover
Crowd Sourcing Wind Information Update

Project Background

• Research to produce accurate surface wind information to enhance safety and efficiency at uncontrolled airports and other areas with significant flight operations and landings that lack certified weather observation stations, but currently have or could easily install a windsock.

• Objective is to assess the capability of existing artificial intelligence technology and its analytic capabilities to calculate wind speed and direction based on camera images of windsocks.

<table>
<thead>
<tr>
<th>Flight Purpose</th>
<th>Pilot Experience</th>
<th>Weather type</th>
<th>Helicopter type</th>
<th>Percent of all weather-events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerial Application or Observation</td>
<td>more than 1000 flight hours</td>
<td>Wind</td>
<td>single engine</td>
<td>6%</td>
</tr>
<tr>
<td>Instructional or Personal</td>
<td>more than 1000 flight hours</td>
<td>Wind</td>
<td>single engine</td>
<td>15%</td>
</tr>
<tr>
<td>Instructional or Personal</td>
<td>less than 1000 flight hours</td>
<td>Wind</td>
<td>single engine</td>
<td>9%</td>
</tr>
<tr>
<td>Instructional or Personal</td>
<td>less than 1000 flight hours</td>
<td>Bad Visibility</td>
<td>single engine</td>
<td>6%</td>
</tr>
<tr>
<td>Instructional or Personal</td>
<td>more than 1000 flight hours</td>
<td>Bad Visibility</td>
<td>single engine</td>
<td>3%</td>
</tr>
<tr>
<td>HAA</td>
<td>more than 1000 flight hours</td>
<td>Bad Visibility</td>
<td>single engine</td>
<td>7%</td>
</tr>
<tr>
<td>HAA</td>
<td>more than 1000 flight hours</td>
<td>Bad Visibility</td>
<td>twin engine</td>
<td>3%</td>
</tr>
</tbody>
</table>
A pirep-like sky condition (/SK) report

Splitt/bougeard/hernandez
Skyrep Prototype Overview

- Used imagery from the ALERTWildfire camera network in real-time with a focus on coastal Southern California stratus/fog events.
- Post-analysis of the imagery provided estimates of cloud base and height, by assessing the vertical continuity of obscurations (SKYREP).
- Comparison to available pilot reports (PIREPs) checked on the quality of the cloud layer estimates and indicated this prototype has potential to validate PIREP cloud base-top reports.
- May provide independent PIREP-like observations of clouds or other obscurations where camera observations are of sufficient density.
- SKYREPs could provide cloud base/top information for day and night operations, including regions where few PIREPs are available.
Motivation for the /SKYREP
- Southern California fog/stratus events
- Mountain obscuration and/or IFR conditions or advisories
- Cameras useful!
<table>
<thead>
<tr>
<th>Time of the day UTC</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (ft, MSL)</td>
<td>3200+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3000-3200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2800-3000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2400-2600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2200-2400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2000-2200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1800-2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1600-1800</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1400-1600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1200-1400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1000-1200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>800-1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>600-800</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>400-600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>200-400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

July 22, 2020 "June Gloom" Fog/Stratus Event
Skyrep Prototype

• Early results
  • Demonstrates detection of cloud layers for day and night conditions
  • Extends the typical PiREP temporal range

• Next steps
  • Database of clear sky images for both day/night conditions
    • Testing automated image detection
      • Route to automation or semi-automation of cloud layer reports
  • Additional fog/stratus events
    • Cool season
    • Leverage other camera networks (e.g. DOT).

• /SKYREP
  • Prototype report
    • Steps from images to cloud layers
      • Leverage other useful data (e.g. topography & visible imagery)?
    • What elements to report?
      • Base/top only, add coverage? (e.g. BKN, OVC)
  • Migration to operations?
    • Who might “own” generation of such reports?
    • How would users respond to such reports?
Planned Wx Information Representativeness and Projection (WIRP) Study

Objective:

• Provide minimum weather service recommendations, research data and demonstrations to industry regarding availability, consistency, and usability of weather information to address critical aspects of information representativeness affecting aircraft performance and pilot decision-making in complex meteorological environments
Planned Wx Information Representativeness and Projection (WIRP) Study

Overview:

• Gap analyses of indicate pilots are affected by operational uncertainty of weather information in potential VFR-IMC transition settings
• Unclear how pilot understanding, information representativeness, and temporal projections interact to affect pilot decision
• Traditional approaches to rational decision-making and risk determination is not a realistic model to project likely outcomes of pilot decisions in a complex, multivariate weather information environment.
• Prospect Theory and Real Options Theory may influence how factors of weather information representativeness affect pilot risk determinations in both general settings and specific scenarios
Planned Wx Information Representativeness and Projection (WIRP) Study

Project Tasks:

• Define variables, conditions, and availability of data affecting weather information representativeness and projection, including appropriate dimensions of uncertainty and time to contact factors affecting fixed wing and rotorcraft operational environments

• Perform research on pilot understanding, and relative influence, of WIRP variables, dimensions, and magnitudes affecting risk-related decisions associated with VFR-IMC transitions

• Utilize research data to develop pilot decision-making models and scenarios to operationally test pilot recognition of uncertain WIRP and risk factors in VFR-IMC transition-decisions in various flight regions
FAA Point of Contact

• Gary Pokodner – WTIC PM - Gary.Pokodner@faa.gov