FRIENDS AND PARTNERS IN AVIATION WEATHER

Low Altitude Weather

LOW ALTITUDE WEATHER

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LOW ALTITUDE WEATHER

What is Low Altitude Weather – A definition

- **Weather (temperature; dewpoint; wind direction/speed, visible moisture; precipitation and pressure) that is strongly influenced by interaction with the surface of the Earth and will adjust to surface forcings within a timescale of 1 hour or less**

LOW ALTITUDE WEATHER

Current sensing, analysis and forecasting capabilities

Ground-based In Situ Observations

- Surface Observations
  - Automated Surface Observing System and the Automated Weather Observing System
  - State Mesonets
  - Other third party surface observations of varying quality
- Ground-based Remote Observations
  - Radar
  - Lightning
  - Webcams
  - NY State Mesonet—Wind and Radiometric Profilers

Airborne In Situ Observations

- Rawinsonde
- Aircraft Observations

Satellite-based Observations (degrade in resolution, coverage, latency and accuracy in the boundary layer, depending on the specific satellite instrument)

LOW ALTITUDE WEATHER

Current sensing, analysis and forecasting capabilities

- Real-Time Mesoscale Analysis
- Multi Radar Multi Sensor Analysis
- Proprietary 3rd party Analyses supporting aviation clients
- National Weather Service Watches and Warning
- Terminal Aerodrome Forecast
- Localized Aviation MOS Program
- Graphical Forecast for Aviation
- Aviation Weather Hazard Guidance
- High-Resolution Rapid Refresh Numerical Weather Prediction
- Proprietary 3rd-party Prediction Products Supporting Aviation Clients

LOW ALTITUDE WEATHER

Developing Performance Based Weather Standards

- Working with ASTM F38 Wx Standards group
- Base standards on existing wx requirements
  - FMH-1
  - AWOS
  - ASOS
- Allows for analysis type data vs certified sensor data
- Looking to include 3 tiers of required data accuracy and confidence levels
- Operations under tiered data will be based on Acceptable Level of Risk (ALR)

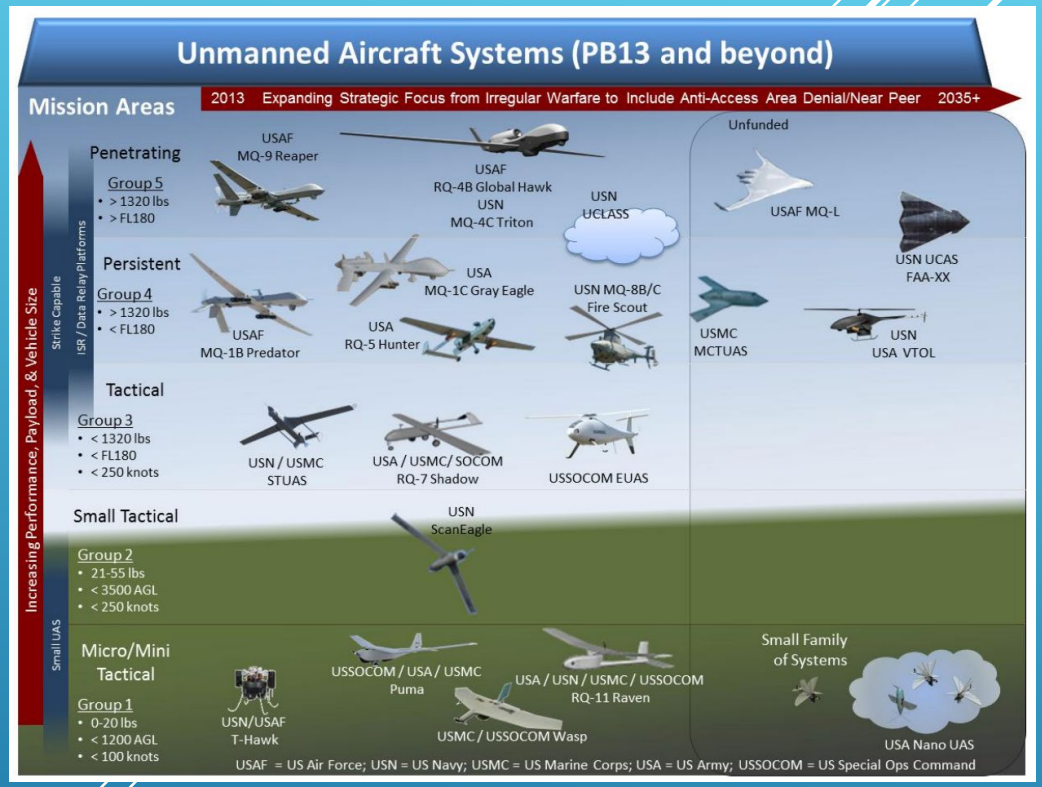
LOW ALTITUDE WEATHER

Local Influences on Low Altitude Weather

- Natural Terrain—winds, turbulence, inversions, low-level wind shear, local fog and low ceilings
- Urban Terrain—Venturi winds, turbulence, heat island
- Sea Breeze Fronts—rapid wind shifts, pop up showers/thunderstorms
- Differential heating—updrafts and downdrafts
- Moisture sources (fog, stratus, lake effect snow, etc.)

LL UAS Challenges

- **Some UAS operate beyond Line of Sight**
- **Data Gaps**
  - Validation of numerical weather model performance in UAS domains
  - Wind aloft forecasts lack precision and winds aloft observations
  - Sparse network of airport observations for ceiling, visibility, and wind
  - Convective weather products lack precision at long forecast horizons; need better confidence data to support operations
  - Icing models do not account for ‘cold soak’ effect
  - Lack of validated stratospheric and low-altitude turbulence information
- **Airframe Weather Sensitivities**
  - Icing
  - Turbulence
  - Ceilings
  - Visibility
  - Wind direction



LOW ALTITUDE WEATHER: AAM/EVTOLS

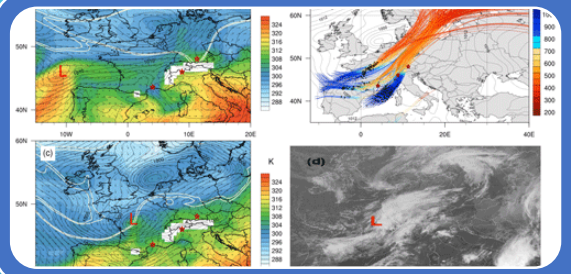
- What are the gaps in weather capabilities for low level operations?
- Who will provide weather services?
- How are eVTOL/AAM/SVO aircraft equipped to manage weather ?

- How will pilots/aviators on-board, off-board, autonomous operate VLOS and BVLOS?
- What are current tools available for pilots/aviators?
- Does current policy/regulation impede progress?

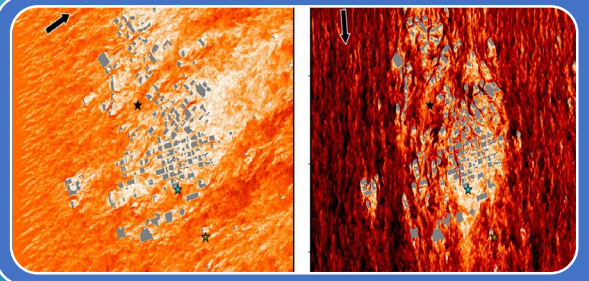
- Will Government and Industry collaborate to create new predictability capabilities?
- Will non-traditional data enable safe and efficient operations?
- Could AI, CFD, modeling, digital twins enable safe operations?

- Could road traffic cameras enable weather recognition?
- What is needed in the new operational environment, Vertiports, congested airspace?
- Will new entrant aircraft have anti-icing, de-icing, IFR capability?

OPPORTUNITIES TO ENABLE CHANGE

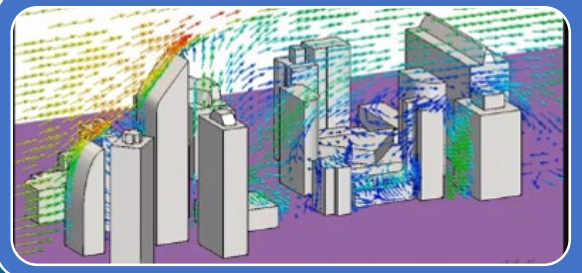


- Smaller and shorter-range radars installed on rooftops and cell towers to fill low altitude gaps
- Massachusetts-based Center for Collaborative Adaptive Sensing of the Atmosphere (CASA), created a network for emergency weather warnings with a range of 40-100 km. Data is fed to the NWS, which sends warnings to users via a phone app



- Crowdsourcing using internet connected cameras and sensors
- Change emphasis away from certifying weather instruments to standards for weather information
- Micronets spread across cities with thermometer, hygrometer, anemometer mounted on poles

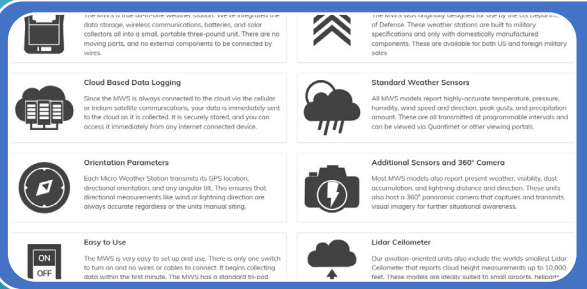
- Weather drones that carry sensors like those required for commercial aircraft (WMA AMDAR)
- NASA-sponsored project Weather Intelligent Navigation Data and Models for Aviation Planning (WINDMAP) studying how AAM aircraft could improve weather observations and forecasting by carrying weather sensors and data-sharing



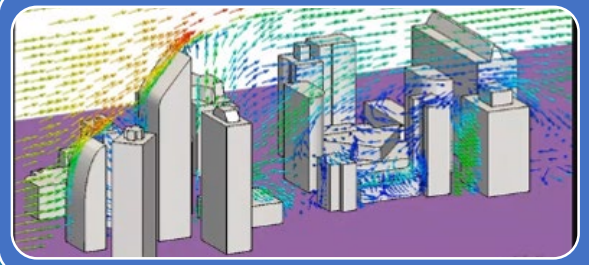
- Modeling and simulation – algorithms and CFD predicting every few minutes at a few meters resolution
- FastEddy with GPU-based computing power to create simulations of urban environments

OPPORTUNITIES TO ENABLE CHANGE

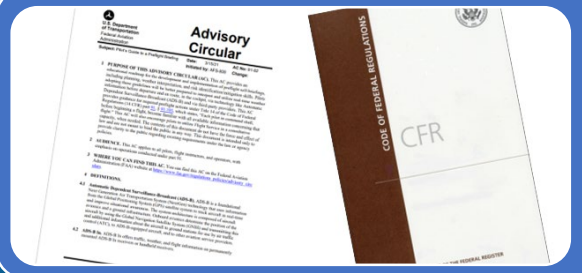
- Expand the FAA Wx Cam program (only 3% of the CONUS covered)
- Allow independent Wx Service Providers to support the industry
- Create a network utilizing personal micro weather stations
- Expand Automated Weather Observations System (AWOS) beyond airports



- Integrate Wx sensors onboard aircraft for: temperature, wind speed and direction, PA, turbulence
- Incorporate multi-function atmospheric sensor on aircraft
- Utilize Satellite link for upload/download of weather



- Computational Fluid Dynamics/Large Eddy Simulation (CFD/LES) to enable Vertiport Safety
- Enable an “EREP” integrated system
- Digital Twin, integrated data from different sources to enable a computerized wx “picture”



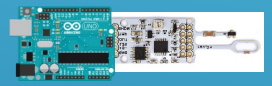
- Regulators and stakeholders should work toward change in policy to allow wx forecasting/nowcasting by service suppliers (other than NWS)
- Determine a “silver” standard if NWS is not the “approved” wx provider

eREP-DRIVEN, REAL-TIME, BOUNDARY LAYER WEATHER

Short-term (proof-of-concept)

1. WIND SENSOR HARDWARE
Arduino based wind speed sensor + parts + labor

2. SENSOR SOFTWARE



Long-term

Open-spec*, free-connectivity so that every UAS can participate, yet use any sensor or computation they want (*not susceptible to drone movement/prop wash, send data in same format, etc.)

Multi-UAS, real-time, networked-GUI is the goal/deliverable (not the sensor (left) which can be open-source)

4. UAS CONTROLLER TO SERVER SOFTWARE

3. UAS-SENSOR CONNECTIVITY SOFTWARE

5. SERVER COMMUNICATION

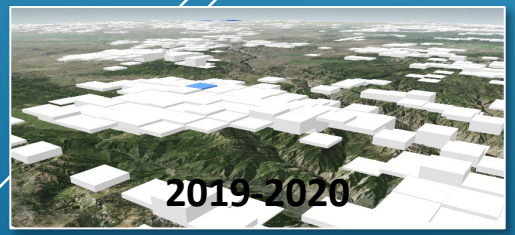
6. DATABASE

7. VISUAL USER INTERFACE

Boundary layer weather visualization driven by multi UREP inputs

8. PUBLIC AVAILABILITY

3D Weather developed since 2017 under FAA contract

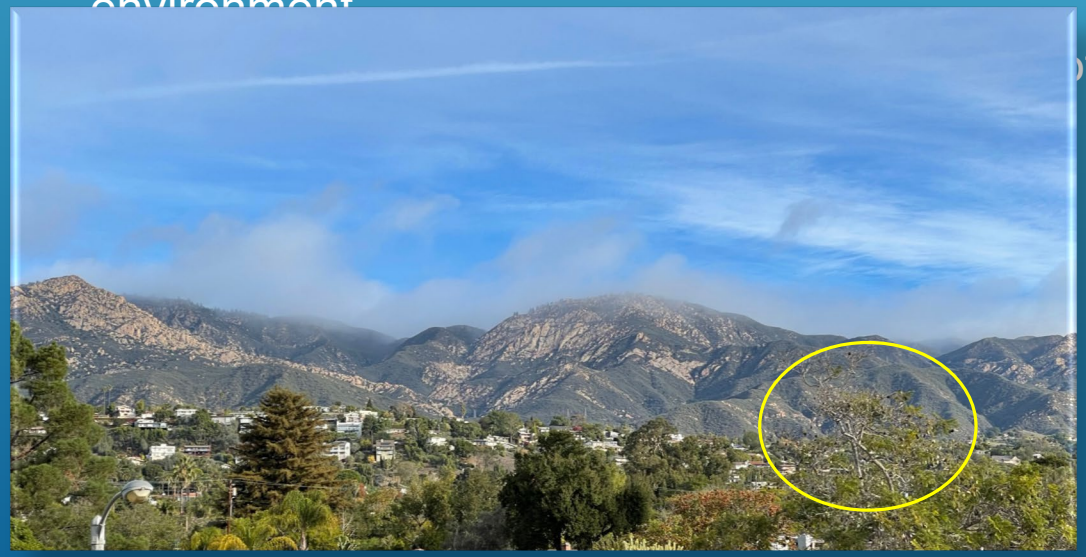


Boundary level detail

LOW ALTITUDE WEATHER

Helicopters

- **Weather Sensitivities** – obstructions to *visibility* (rain, snow, sleet, fog), *wind* direction and speed (turbulence, tail winds), *icing* conditions (low temp/high humidity)
- **Missions** – EMS, commercial, business, fire/LE, off-shore operations, training, tourism, private pilot, etc.
- **Safety** – According to a 2016 study by the International Helicopter Safety Team, 18% of commercial helicopter accidents are a result of a misjudgment of weather conditions
- **Current weather products** (off-airport) – HEMS (AWC), StormGeo, DTN, etc. (commercial products)
- **Rural vs. Urban operations** – wind shear/turbulence around buildings/urban canyons vs. natural environment



Weather can quickly change from good to bad. An aircraft returning from the other side of the ridgeline may have a report of good visibility but nothing about mountain obscuration.

LOW ALTITUDE WEATHER

Fixed Wing

- **Weather Sensitivities** – obstructions to *visibility* (rain, snow, sleet, fog), *wind* direction and speed (turbulence, tail winds), *icing* conditions (low temp/high humidity)
- **Accident/Incident Rates** – Average days between fatal accidents is 1.8 days (~200/year, 1,200 accidents total)
- **Missions** – Recreation, business, training, tourism, etc.
- **Current weather products** (for en route locations) – HEMS (97% of AOPA members were unaware of HEMS in 2018) GFA, Route Planning Tool (all from AWC), ForeFlight, Windy, CloudTopper, RadarScope (many commercial options)

ors,

General aviation fixed wing pilots generally takeoff and land at airports where weather can be obtained, but en route conditions can change quickly, and accurate information is scarce.

LOW ALTITUDE WEATHER

Transiting Aircraft

Transiting aircraft through Low Altitude Weather

- Applications: Small drones—light package delivery, surveillance, search and rescue, inspections and AG applications
- Applications: Advanced Air Mobility—cargo, people
- Urban challenges—Venturi winds, heat island effect
- Drones fly ubiquitously and generally not at airports where the best weather instrumentation is available
- Uncrewed aircraft loses the pilot sensing and reacting to rapidly changing micro-weather conditions
- Lost of onboard pilot heuristics means having to replace with better micro-weather detection and prediction systems in boundary layer

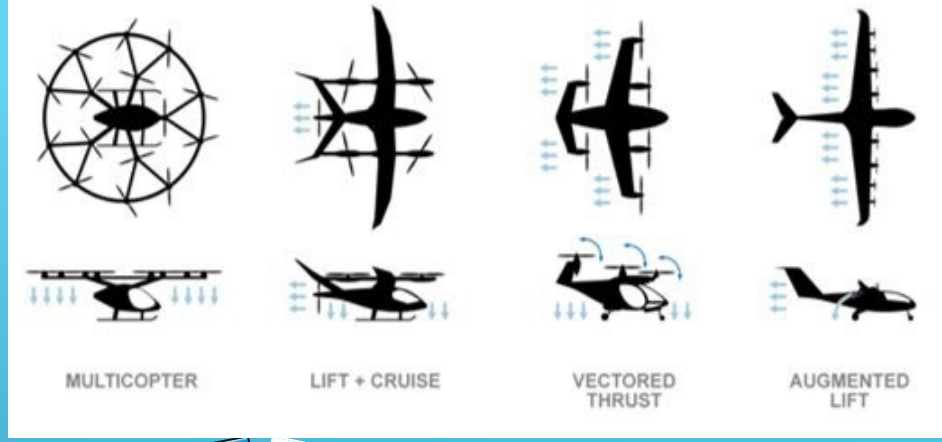
LOW ALTITUDE WEATHER

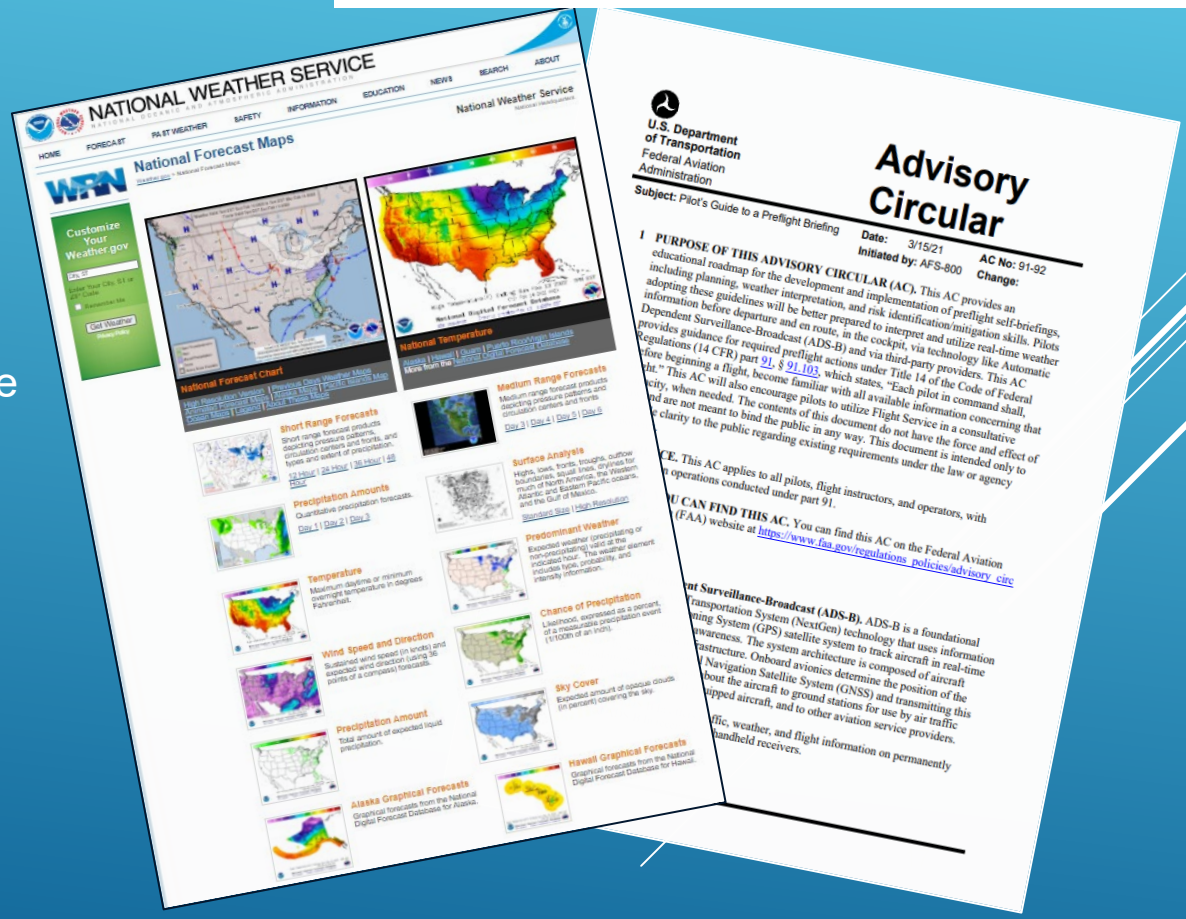
Vertiport Instrumentation

- **VFR only airfields often have little or no weather instruments relying on the pilot - often only a windsock is available.**
- **What do we need to measure**
  - Cloud Height
  - Visibility
  - Winds
  - Prefer full weather observation with all data
- **How often and how far is the data good for**
  - Data should be updated every 2 minutes and be valid for a distance of 5 SM
- **Cost effective sensors on a pole linked with satellite or cellular networks**
- **Technology exists today – we just need to use it**

LOW ALTITUDE WEATHER: TRAINING

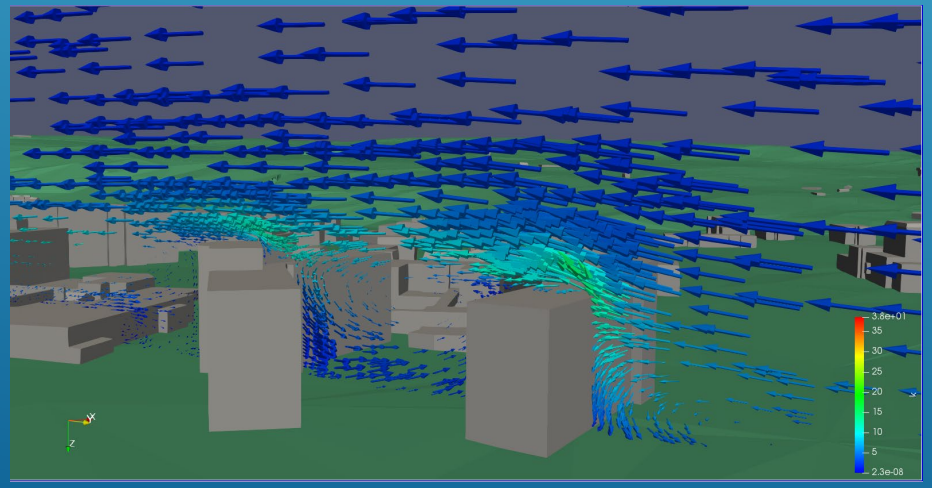
- Pilots are required to be knowledgeable in sources of weather information and effects of weather on performance
- Testing for all pilots includes weather, but it is the most failed area on all tests; private pilot to ATP
- NTSB finds the largest percent of fatal accidents has weather implications
- Pilots need to understand the resources available for decision-making to mitigate risk
- Low altitude operations pose new challenges where weather forecasting is not available; how do you train for the new environment?
- New operational environments like Vertiports will require more specific attention to low altitude operations
- What application should pilots use, third party apps often use different depictions of color, etc.
- Pilots aren't Mets, how can they prioritize and assimilate information critical to flight?
- CFIs may not transfer wx knowledge properly; CFIs may not be knowledgeable themselves
- Commercial operations (14 CFR part 135) demand a higher level of pilot qualification and wx requirements





PILOT TRAINING FOR LOW LEVEL OPERATIONS IN NEW ENVIRONMENTS

- Off-board pilots/aviators in uncrewed and BVLOS operations will need an emphasis on environment, to include weather knowledge in unique missions
- New technologies may enhance training for the pilot/aviator. AI, sense and avoid (SAA), detect and avoid (DAA) may enable the off-board pilot/aviator to “see” weather
- Pilots may learn to interpret computer generated data to identify weather hazards to flight
- Consider the implications to requirements for commercial operations (14 CFR part 135) training, re wx forecasts and how to comply if the “silver standard” is used



LOW ALTITUDE WEATHER

Performance Standards

Weather Supplemental Data Providers (SDSP) Data Performance Standards

- Data Performance Standards Versus Certifying Instruments
  - All data on the table…in-situ, remote sensor or derived
  - Data performance aggregated in tiers—risk-based performance standards
  - Data quantified for “goodness” and stamped with Tier Metadata
  - Guidance on remote sensing systems, and derived weather data sets requires further research and development
  - System for making data sets discoverable to UTM SS requires further research and development
  - Quantified data made available to UTM SS, operators as “approved data set” for mission risk profile
  - Tier 1 data equivalent to “ASOS” standard
  - Standards underdeveloped in ASTM F38 Weather Specification Group
    - Federal government, private sector and academia stakeholders
    - Recommendation for FAA consideration
    - Industry, NASA and FAA collect data to validate the standards
- FAA identifies and develops modified rules based on data submitted

LOW ALTITUDE WEATHER

Performance Standards

- **Weather SDSP aviation forecaster qualifications and EWINS**
  - Move responsibility from operator to Weather SDSP to meet EWINS
  - Should FAA set up mechanism to ensure Weather SDSP meet standards
  - UTM SS, operators can use any qualified Weather SDSP to receive forecaster developed products and weather briefings
- **Data Interface Standards**
  - Weather SDSPs translate “weather data formats” into JSON/GEOJSON data formats
  - JSON/GEOJSON is “data format” language of UTM SSs

LOW ALTITUDE WEATHER

- **Today**
  - Significant reliance on human operators in today's environment
  - Data sensing network only covers 3% of the CONUS
  - All data sources not effectively used
  - Policy limits data exploitation and places to much emphasis on human observers
- **Tomorrow**
  - Change Policy to increase use of available data
  - Fill gaps with non-traditional data sources and cost-effective weather sensors
  - Improved training for operators and decision makers
  - Provide data in usable formats
  - Increase supply of data providers

Thank You!