Researching UAS Capabilities for Three Dimensional Profiling of the Severe Weather Environment

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Environmental Profiling and Initiation of Convection (EPIC): Project Goal

Determine potential for a combination of UAS systems (various fixed-wing /rotary platforms, autopilot systems, and sensors) to provide detailed and accurate profiles of temperature, moisture, and winds frequently enough to capture important changes in the pre-convective severe storm boundary layer

Note: This study addresses the UAS Program Office objective to "evaluate options for UAS profiling of the lower atmosphere with applications for severe weather"

FY16 RFP; UAS PO Funding: $240.2 K

EPIC Project Objectives

- Develop small UAS (sUAS) capable of acquiring needed wind and thermodynamic profiles and transects of the Atmospheric Boundary Layer (ABL): one fixed-wing UAS operating in tandem with two profiling rotary UAS

- Adapt and test miniaturized, high-precision, and fast-response atmospheric sensors with high accuracy in strong winds characteristic of the pre-convective ABL in Oklahoma

- Conduct targeted short-duration experiments at the Southern Great Plains (SGP) site in northern Oklahoma concurrently with a second site to be chosen in "real-time" from the Oklahoma Mesonet in coordination with the NWS-Norman Forecast Office

- Gain experience in pursuit of NOAA's goals for determining the value of airborne, mobile observing systems for monitoring rapidly evolving high-impact severe weather conditions not observed with current operational systems

Collaborating Partners

Principle Investigator

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Co-Investigators

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Three Kinds of UAS Observations used in EPIC

Meteomatics Meteodrone

CU Fixed-wing TTwistor

OU CopterSonde

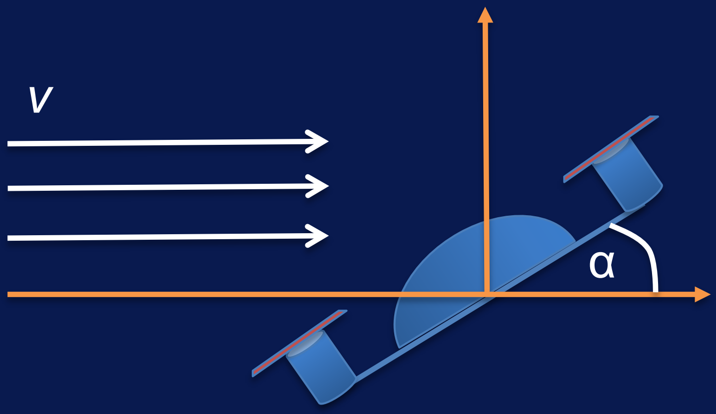
The three sUAS deployed for the EPIC intercomparison field experiment in October 2016.

Meteodrone is about 80% the size, but only 12% of the weight, of the CopterSonde.

TTwistor has a 10-ft wingspan – a dual-engine version of the Tempest used in VORTEX-2.

Meteomatics Meteodrone SSE Airframe

- Weight = 1.5 lb
- Dimensions = 2 ft x 2 ft
- Typical flight duration = 12min
- Max. altitude = 3,000 ft AGL
- Ascent/descent speed = 600 ft/min
- Max. operating wind speed = 40 kt
- White strobe (visible during daylight)
- Flies fully autonomously



Estimating wind vector from aircraft attitude (nick, roll, yaw angle)

Sensors are sheltered and mounted in the rotor downwash

Meteodrone SSE Sensor Specifications

Temperature:
- accuracy: ± 0.1 °C
- response time: 1 sec

Relative humidity:
- accuracy: ± 2 %
- response time: 4 sec

Wind speed & direction:
The aircraft compensates automatically for wind drag using autopilot to perform a "horizontal position hold":
- accuracy: ±1 m/s
- response time: 0.25 sec

OU CopterSonde

- An octo-rotor copter being developed by the University of Oklahoma based on a hashtag design
- Manual or autopilot (Pixhawk PX4) control with IMU and GPS
- CopterSonde equipped with differential GPS to improve accuracy of vehicle positioning (to 2 cm)
- Max wind speeds: 50 knots (anticipated)

Length	2.25 feet
Takeoff Weight	12.7 lb
Max Cruise Speed	95 knots
Endurance	25 minutes
Climb Rate	3,300 ft/min!

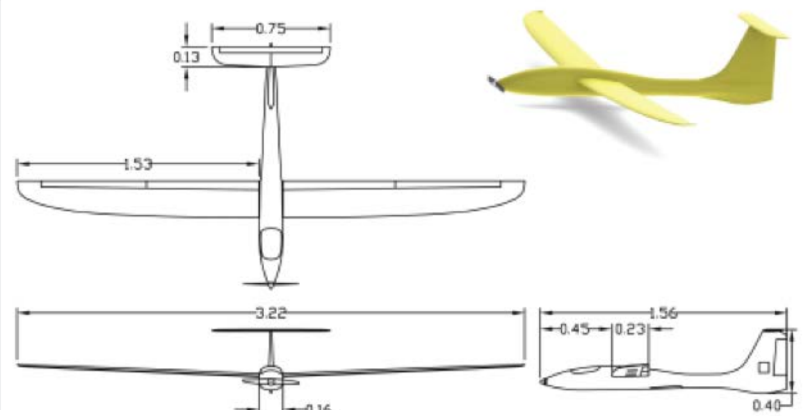
Control Calibration Chamber:

iMet sensors sampled every second taken from -60C to +40C over a period of 10h meet NOAA's accuracy and response time specs

CU Tempest/TTwistor

Aspect	Value
Gross weight (lb)	14
Payload capacity (lb)	5
Wingspan / Length (feet)	10.5 / 5.1
Autopilot	Piccolo SL, Pixhawk, Swiftpilot Pro
Max speed (knots)	83
Loiter speed (knots)	43
Endurance (hours)	2 – 3

TTwistor is twin-engine variant of Tempest



Dimensions in meters

Validation of UAS measurements using intercomparisons with independent observing systems in the field

Multiple independent systems used to validate UAS measurements at two “waypoints” (DOE Southern Great Plains (SGP) Lamont and Medford sites)

NSSL AERI, DWL, & sondes


NSSL Soundings


SGP AERI Spectrometer


SGP instrumented tower


SGP Doppler Wind Lidar (DWL)

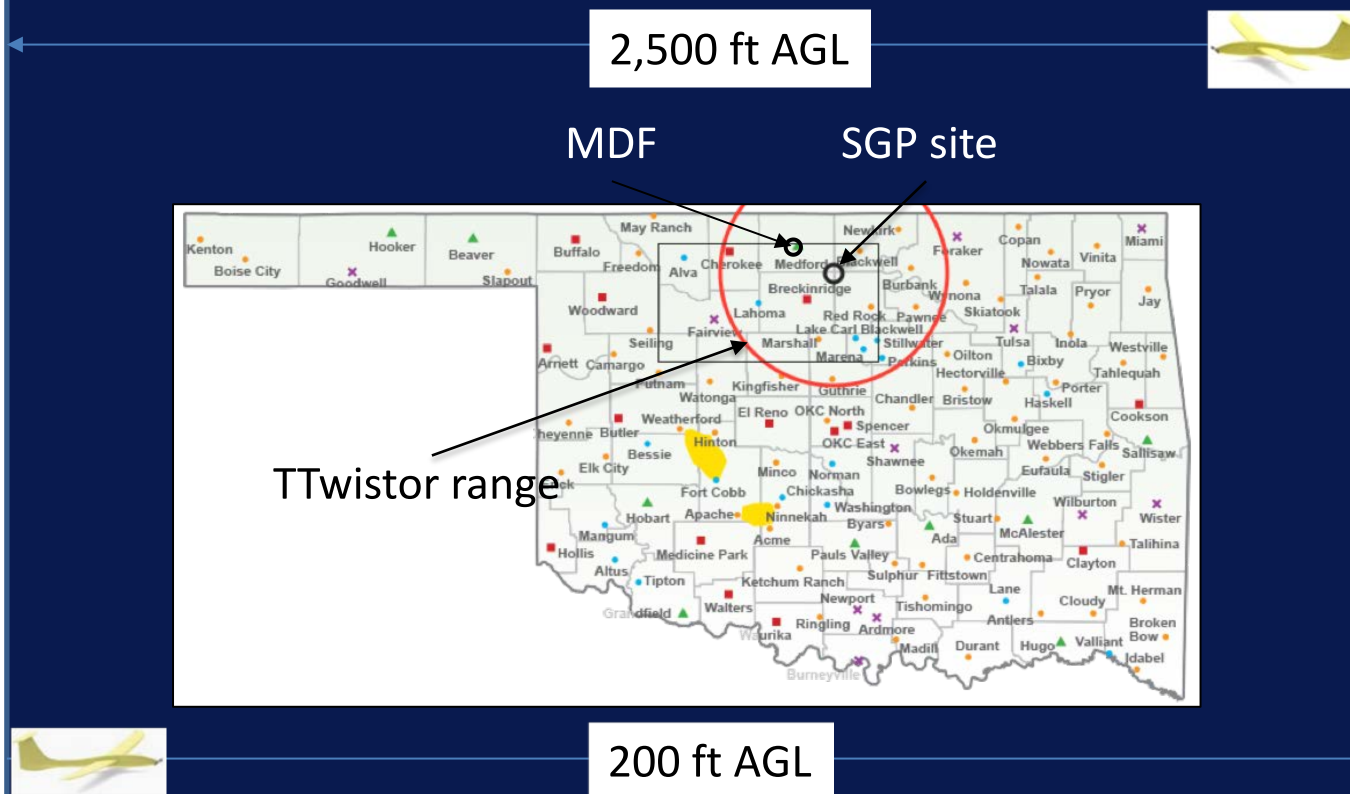
Milestones through Phase 1

- ✓ Oct 2016: Complete funding to OU/CIMMS and contract to Meteomatics
- ✓ Oct 2016: Complete alterations to OU CopterSonde (IntelinAir RD-100) to gain flightworthiness acceptance and sensor quality
- Oct 2016: Integrate the Differential GPS into the platform design
- Oct 2016: Obtain FAA Certificates of Authorization (COAs) to fly to desired 2,500 ft altitude at noted Mesonet locations for all three sUAS
- ✓ Nov 2016: Conduct Phase 1: calibration/validation exercise at SGP
- ✓ Jan 2017: Complete calibration/validation analysis of Phase 1 data
  - "Success" = finding an acceptable level of agreement between the airborne, SGP and NSSL remote sensing system observations
- Mar 2017: Determine the CONOPS for flying the three UAS in coordination with the NSSL mobile mesonet and remote sensing systems (CLAMPS) for Phase 2 exercise
  - "Success" = having a workable, quickly implementable operations plan

Future Milestones for Phase 2

- May 8 – 20, 2017: Conduct the real-time phase of the study (Phase 2) jointly with the NWS-Norman Forecast Office
  - "Success" = successfully executing the CONOPS for several severe weather events in Oklahoma with the engagement of NWS-Norman WFO
- July – September 2017: Conduct post-analysis of the collected data for quality control purposes, and engage NWS in a retrospective analysis of the value of the UAS data in being able to better determine the timing and probability of convection initiation
  - "Success" = determining that the data are of high quality and meet the objectives for better identifying the pre-convective environment.
- July 2017 – July 2018: Conduct all the research studies involving the graduate and undergraduate students, submit papers for publication, and complete the project final report to NOAA
  - "Success" = accomplishing all of this. Also, let us not forget that the ultimate measure of success of using sUAS is to show that the data are of significant usefulness in the forecast and warning process

EPIC Concept of Field Operations



Targeted short-duration experiments at the DOE Southern Great Plains (SGP) site concurrently with a second site to be chosen in “real-time” from the Oklahoma Mesonet in coordination with the NWS-Norman WFO.

Make vertical profiles to 2,500 ft every 30 minutes in coordination with TTwistor transects between the two sites. Data to be provided in real time to WFO for evaluation in Phase 2 (May 2017)

Quality and Performance Challenges

- All sUAS in this project are at ~TRL 6
- Goal is to raise the TRL for each UAS by one level within two years
- Must demonstrate ability for prototypes to provide accurate observations meeting standards of NWS rawinsondes
- Must demonstrate ability for prototypes to provide robust observations meeting standards of NWS of having data available for use by forecasters within 30 min of flight completion
- Must demonstrate ability for prototypes to make observations within stated window of 80 min (TTwistor) and 15 min (copters)
- Must demonstrate utility of these special real-time data in the NWS forecast and warning process – and training must also occur

Relevance to NWS Operations

- Determine the maximum altitude and vertical sampling interval needed to obtain sufficient resolution for capturing the strength of elevated inversions, moist layers, convective instability, and wind shear in the severe storm environment. Can UAS supplement or even replace rawinsondes?
- Determine the frequency of soundings from the fixed sites using the rotary systems needed to capture the temporal variability in these fields – is 30 minute sampling sufficient?
- Assess at what spatial density the soundings need to be made, vs. mapping out horizontal fields using fixed-wing UAS or balloons
- Assess the potential significance of having these data available in an NWS Forecast Office on the realization of severe weather warning and forecast improvements