Lightweight Surveillance and Target Acquisition Radar Characterization For High Density Vertiplex Beyond Visual Line of Sight Operations

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ABSTRACT

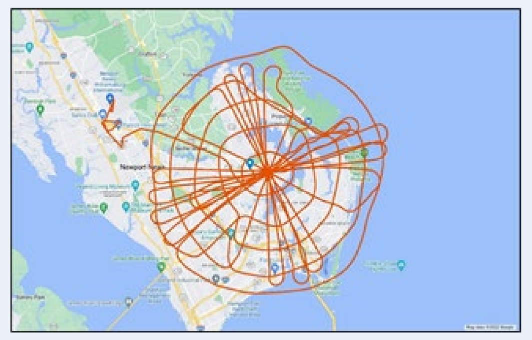
With the growth of the National Aeronautics and Space Administration (NASA) National Campaign, it is becoming increasingly important for government and enforcement agencies to be able to monitor and safely track urban air traffic that will take place in the coming years. The performance of the Lightweight Surveillance and Target Acquisition Radar (LSTAR) is investigated and statistically characterized. The compact LSTAR is mounted on a building at NASA Langley Research Center (LaRC) and operated to track a SR-22 aircraft. Performance data of the LSTAR tracking is presented by comparing the LSTAR-tracked flight against the on-board flight records and statistical characteristics are presented. Implications of findings to operations within High Density Vertiplex (HDV) at LaRC are discussed. The LSTAR ultimately proves to be a compact method to safely track and monitor small aircraft and other unmanned aerial vehicles.

INTRODUCTION

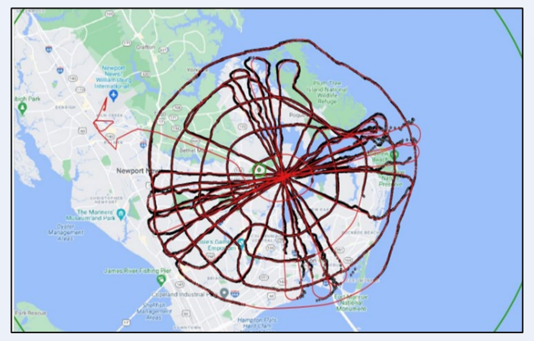
- The HDV sub-project within NASA's AAM Campaign is endeavoring to perform rapid prototyping assessment of an Urban Air Mobility (UAM) ecosystem using small unmanned aerial systems (sUAS) as surrogates for UAM vehicles such as air taxis.
- It is critical for researchers to be able to perform safe Beyond Visual Line of Sight operations (BVLOS), which necessitates the ability to track all participating and non-participating air-traffic in the area
- Ground based radars will be used to generate tracking data for these aircraft, which will be routed to sUAS vehicles operating within the LaRC test range for detect and avoid maneuvers, as well as to remote operations teams for monitoring
- The work presented here evaluated the ability of the LSTAR system to perform this tracking function for the HDV project.

FLIGHT TEST

- LSTAR performance was evaluated by tracking an SR-22 aircraft over a known flightpath, and comparing the recorded LSTAR positional data to the aircrafts recorded ADS-B flight path.
- One advantage of using the SR-22 was it's composite structure, which is similar to that of the planned surrogate sUAS, and provides a more significant challenge to track with radar
- The flight path flown by the SR-22 (shown below) was flown at an altitude of 305 meters, +/- 30 meters over the course of 2.2 hours.
- It flew a combination of inbound and outbound radials as well as circles of varying diameter in order to fully exercise the required range of the LSTAR.



Ground Track of SR-22



Ground Track of SR-22 (red) and LSTAR tracking points (black

THE LSTAR SYSTEM

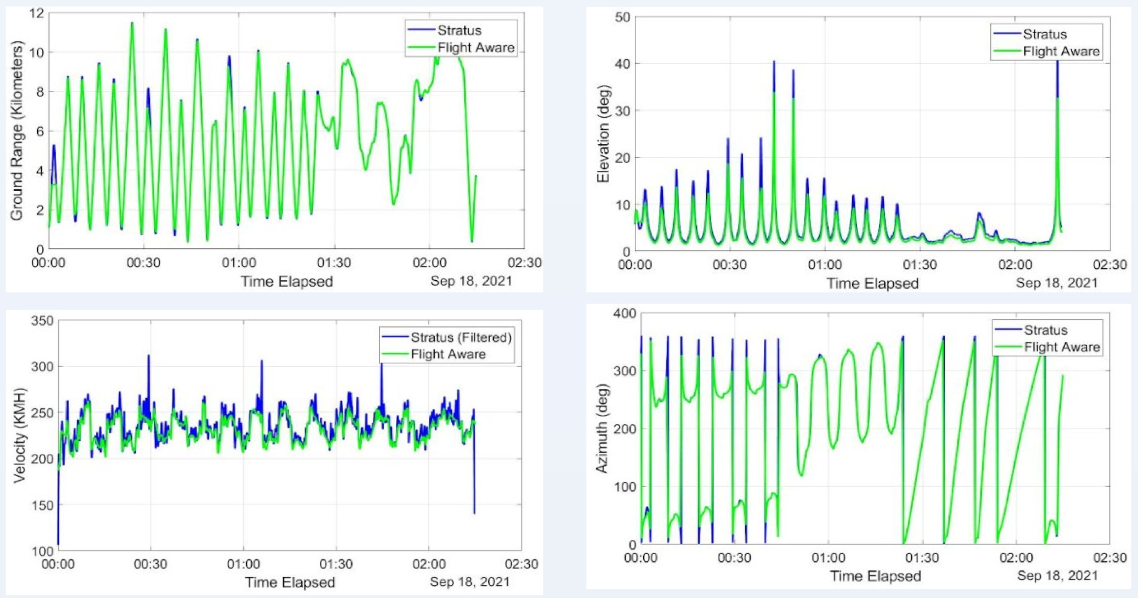
The primary system used for ground based tracking of non-participating air-traffic is the Lightweight Surveillance and Target Acquisition Radar or LSTAR.

- Range of 46.3 Kilometers
- 360° radial scanning up to 30° above the horizon.
- It was Installed on top of building 1230 at LaRC at ~15 meters above ground level (AGL) and stabilized by a custom-built wooden platform.
- Operates using between 1215 and 1390 MHz.

LSTAR on top of building 1230 at LaRC

ADS-B SOURCES

- FlightAware
  - Low sampling rate
  - Used for visual flight track comparisons
- Onboard Stratus 2S
  - ~1/sec sampling rate
  - Used GPS altitude
  - Not affected by barometric pressure changes
  - Recorded time, latitude, longitude and altitude at each point.
  - Significant noise in Velocity measurement,
  - Filtered using lowpass filter



ANALYSIS METHOD

- LSTAR tracking data
  - ~12,000 data points over 2.2 hour flight
  - LSTAR anomaly at 4 minutes removed from data
- Analysis method
  - Velocity, elevation, azimuth, range determined using MATLAB
  - Data filtered for LSTAR and Stratus points within 1 second
  - Total of 4430 data points for comparison
  - Mean and RMS errors determined

RESULTS

Tables showing statistics from Langley study as well as similar studies by other organizations:

TABLE 1

Langley Results		
Characteristics	***RMS Error***	***Average Error***
Azimuth (deg)	1.56	-0.12
Elevation (deg)	1.57	-1.27
Range (m)	65.22	-10.08
Velocity (Km/h)	30.09	3.99

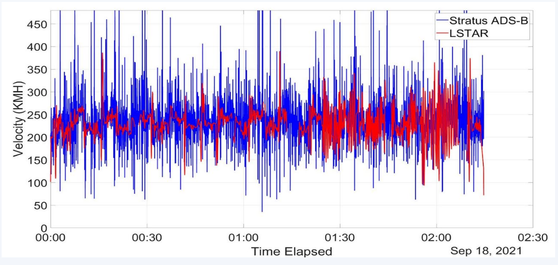
TABLE 2

Wallops Results		
Characteristics	***RMS Error***	***Average Error***
Azimuth (deg)	0.84	-1.08
Elevation (deg)	1.64	-0.33
Range (m)	5.90	2.63

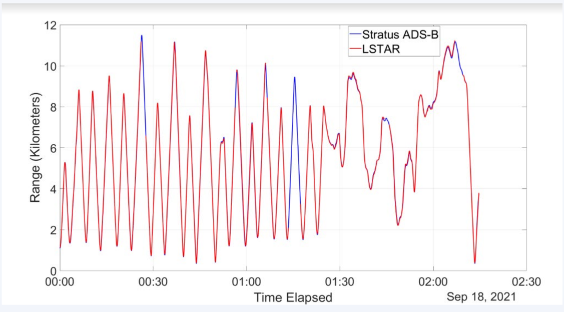
TABLE 3

SRC Advertised Values	
Characteristics	***Average Error***
Azimuth (deg)	0.8
Elevation (deg)	1.8
Range (m)	24.99

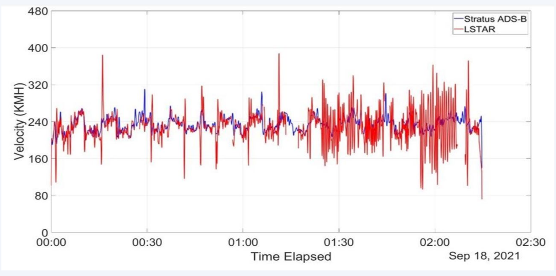
Graphs Depicting the accuracy of several Key parameters output by the LSTAR in real time:



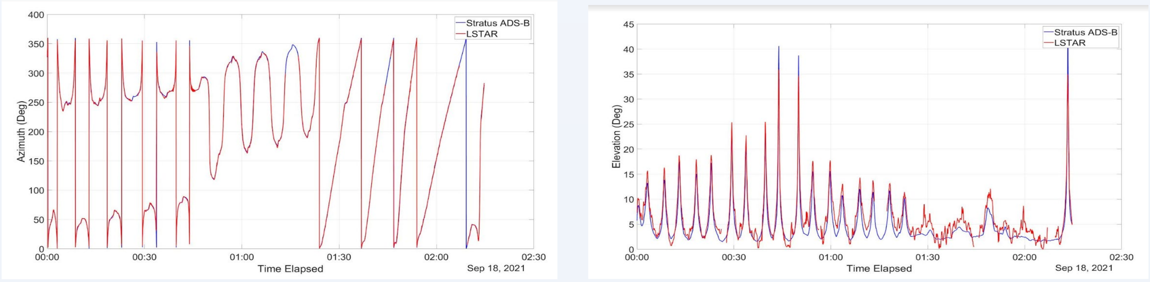
Velocity Before Filtering



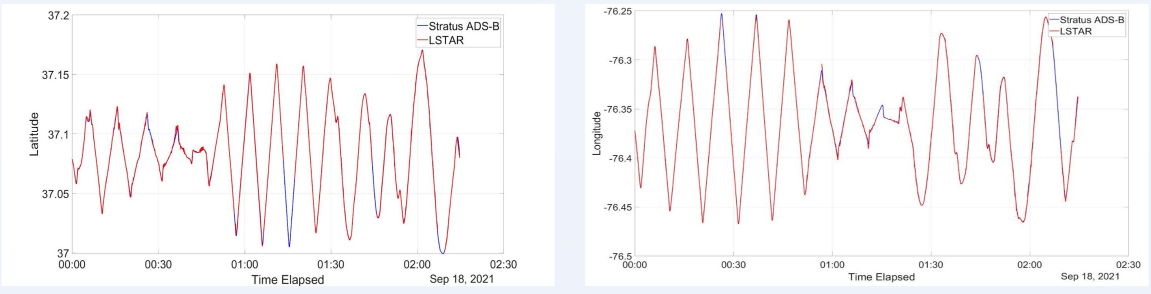
Range



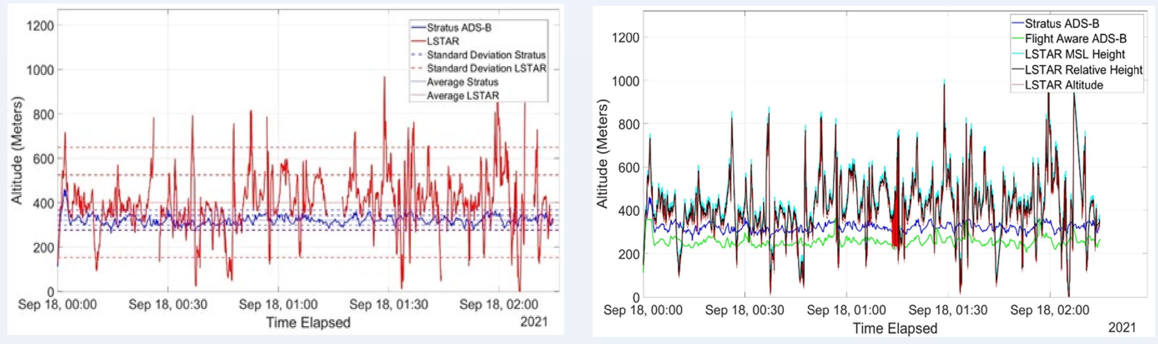
Velocity After Filtering



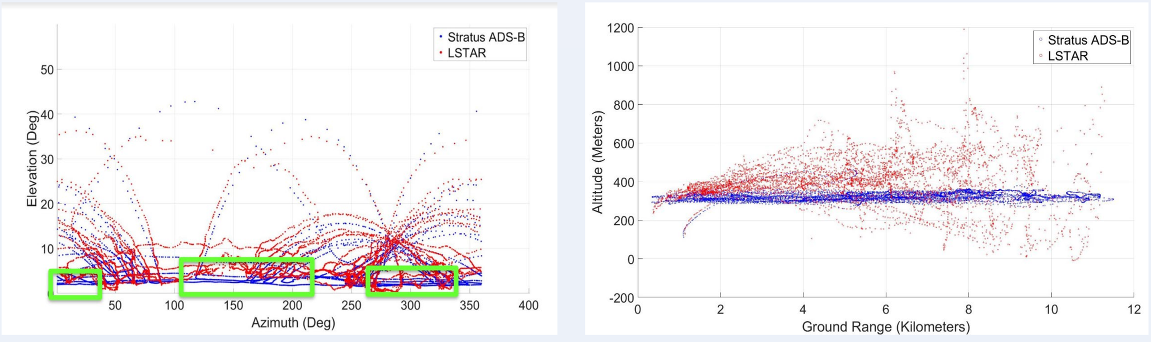
Azimuth and Elevation from Horizon Angles



Latitude and Longitude Data



Altitude Information Comparison and Key Relationships



Other Key Relationships, Elevation Vs. Azimuth and Altitude Vs. Range

DISCUSSION

- Flight test results overall showed close agreement between data from the Stratus ADS-B system and the LSTAR data.
- RMS and mean difference between select parameters were compared to those from similar tests of the LSTAR by different organizations and showed similar results.
- Significant noise was observed in the velocity measurement in the ADS-B truth data, causing large variation in this parameter. Some of the noise was filtered with a lowpass filter.
- Error in elevation angle measurement was found, especially at shallower angles. Likely sources of this error were misalignment of The LSTAR or seating on a non-level surface.
- Error in altitude measurement was also found, which is linked to the elevation error. Average altitudes were similar, with the LSTAR's values being shifted upward.
- LSTAR altitude standard deviation was ~150m, which fully Envelopes the stratus 2S altitude
- Operational considerations based on altitude:
  - Potential larger well clear altitudes needed for radar only targets (+/- 1 standard deviation)
  - Fusion with other radar inputs could mitigate
- The relationship between range and altitude measurement shows decrease in accuracy with increased range.
- Areas of poor radar coverage (drop out zones) were Identified.
- The largest area of drop out was from 120° to 220° and supports the results presented visually on the maps of the flightpath.
- Other dropout zones tend to occur below ~3°
- Plans include relocating LSTAR to a higher locations to see over obstructions

SUMMARY AND FUTURE WORK

- Demonstrated the ability of the LSTAR to track the location of a composite GA aircraft
- Errors in velocity measurement identified (possibly caused by GPS coordinate drift)
- Errors in altitude measurement may also necessitate operational restrictions for radar only targets
- Geographical locations of dropout zones identified
- Plans to relocate LSTAR to higher field of view
- Future tests planned that will attempt to fuse multiple radar sources
- Radar-2 Test recently took place (