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Operational Considerations of Small UAS in Urban Canyons

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There is an increasing demand for small UAS to be able to perform missions in urban areas. In particular, there are a number of potential use cases that might require operating directly in the so-called "urban canyon" where tall structures line city streets.

There is a general lack of in-situ data to confirm the capabilities of sUAS to operate in an environment where there are significant structures surrounding the flight path of the sUAS. As a prelude to the NASA UTM TCL4 testing to be conducted in downtown Corpus Christi, Texas, a series of experiments were performed to determine performance characteristics of key sUAS systems in the environment for the tests. Specifically, the performance of the sUAS GPS navigation and the GCS control and telemetry links to the sUAS were tested in-situ on the routes expected during the NASA tests.

The preliminary analysis of the data taken indicates that it is feasible for the sUAS to operate in the urban canyon. While performance is degraded relative to an "open air" baseline, it appears there is sufficient accuracy and reception of GPS navigation satellites to obtain a fix within acceptable error limits. In addition, the telemetry experiments indicated that loss of point-to-point RF links in the ISM band are likely when operating BVLOS from the GCS/launch point.

Nomenclature

ADS-B	=	Automatic Dependent Surveillance-Broadcast
BVLOS	=	Beyond Visual Line of Sight
GCS	=	Ground Control Station
GPS	=	Global Positioning System
IMU	=	Inertial Measurement Unit
sUAS	=	Small UAS, generally considered as under 55lbs.
UAS	=	Unmanned Aircraft System
TCL	=	Technical Capability Level
UTM	=	UAS Traffic Management
V/TOL	=	Vertical Take Off and Landing

I. Introduction

The integration of sUAS into the National Airspace System is desirable for a variety of reasons including economics, public safety, and enabling new missions. Many of the envisioned use cases involve not only

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BVLOS flights but also flights over people and operations in urban or downtown areas.
As parth of the NASA UTM TCL4 demonstration, Lone Star UAS Center of Excellence and Innovation was chosen to perform an extensive urban area operation demonstration. Before these flights within the so-called “urban canyon” could be accomplished, a set of experiments were conducted to ensure that the performance of key sUAS systems were within acceptable parameters. This include the GPS-aided navigation system, and the primary command, control, and telemetry link.

II. Test Apparatus

Initial testing of the navigation performance was characterized by the use of a “plywood Tarot”. This apparatus, shown in Figure 1, uses the same Pixhawk autopilot system as would be used on the actual aircraft. It contains the same autopilot, GPS units, telemetry, and radio-control links as the real aircraft.

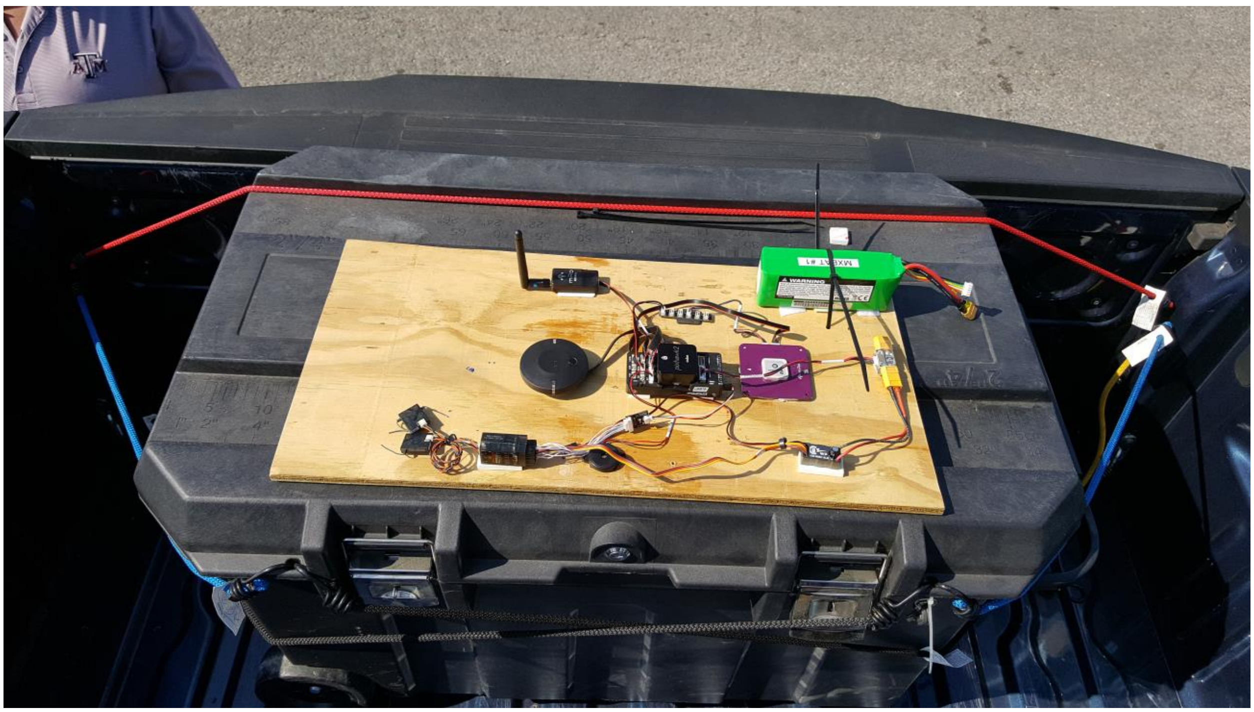

Figure 1 - Plywood "Tarot" test apparatus

The GPS units both contain a U-Blox Neo-N8M chipset with one of the units using a larger ground plane than the other. This test board was placed on a large case such that the GPS units would be above the truck bed height to eliminate satellite blocking from the truck.

The unit was then energized, a GPS lock was obtained, and the unit was then driven on several routes envisioned for the TCL4 tests. Figure 2 shows some of the routes used in and around the downtown area. Figure 3 shows the truck used parked on one of the downtown streets used during the experiment.

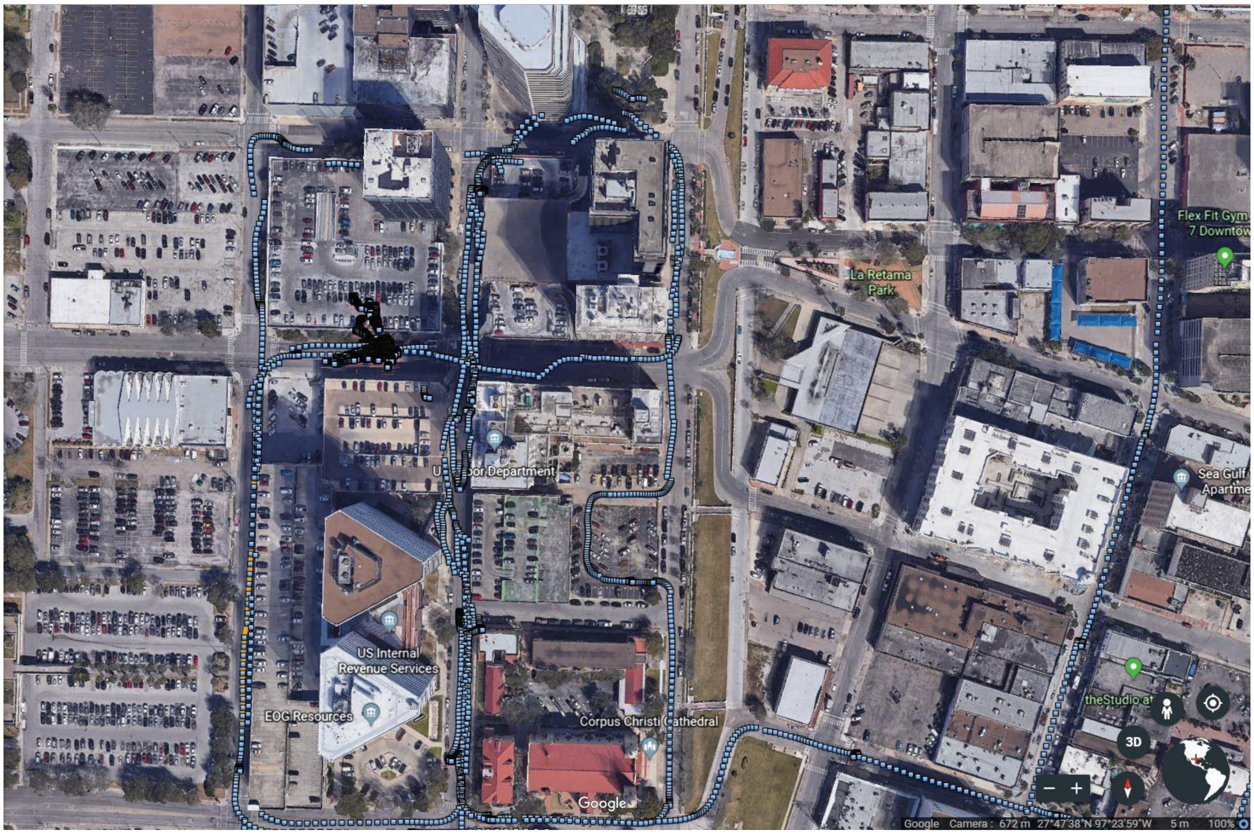

Figure 2 - Downtown routes for ground experiment


Figure 3 - Truck with plywood Tarot parked along street

The second test was conducted using an actual aircraft positioned similarly to the testboard. In this instance, the focus was on a route specifically in downtown where tall buildings exist on both sides of the city street. The GCS was set up in a parking lot along one of the streets. It remained fixed while the truck with the aircraft drove the route being examined.

III. Navigation Performance Assessment

During the first experiment, several of the routes expected to be used were driven to collect GPS satellite availability. Figure 4 shows the number of satellites seen by the autopilot during the experiment. The number of satellites seen ranged from a high of 21 satellites with the minimum observed being 7. Since the Pixhawk considers a minimum number of 6 satellites to be adequate for a GPS position fix to be valid, this was encouraging.

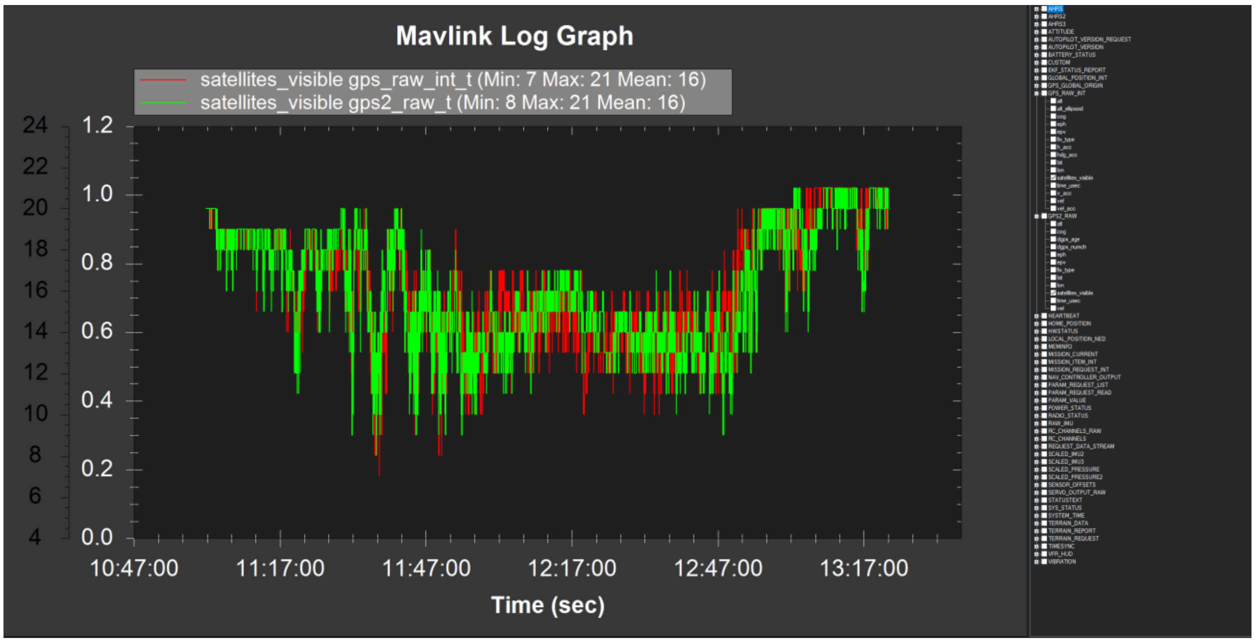

Figure 4 - Number of satellites for GPS receivers used in ground test

The ground observations taken during the first experiment represents a "worst case" scenario for GPS satellite visibility. This is simply a function of how many satellites are blocked from direct line of site to the GPS receiver because of buildings on one or both sides of the roadway.

Because of this, it was expected that the system would perform better at the altitudes being used for the flight tests. This expectation was confirmed during flights in the actual urban canyon. Figure 5 shows the performance seen during a flight in the "urban canyon". In this instance, the flight was conducted at an altitude of 180ft. The large white building near the flight path was 225ft. tall.

In addition, a flight was conducted to compare the basic GPS position used by the Pixhawk autopilot to an RTK position solution. The flight path consisted of a takeoff and climb out, hover and two box patterns then landing. Figure 6 shows the 95% confidence level error band for the RTK solution unit along the flight path. The majority of the flight had a 95% confidence level of less than 2m. Figure 7 shows the position difference between the autopilot GPS position solution and the RTK position solution. Much of the flight path flown by the autopilot was within 5m of the "truth" position reported by the RTK unit. Some parts of the flight path showed less than 1m difference, and a few points near the takeoff and landing point that were 5m. It is surmised that the RTK corrections start becoming less effective the closer the rover unit is to the base station.

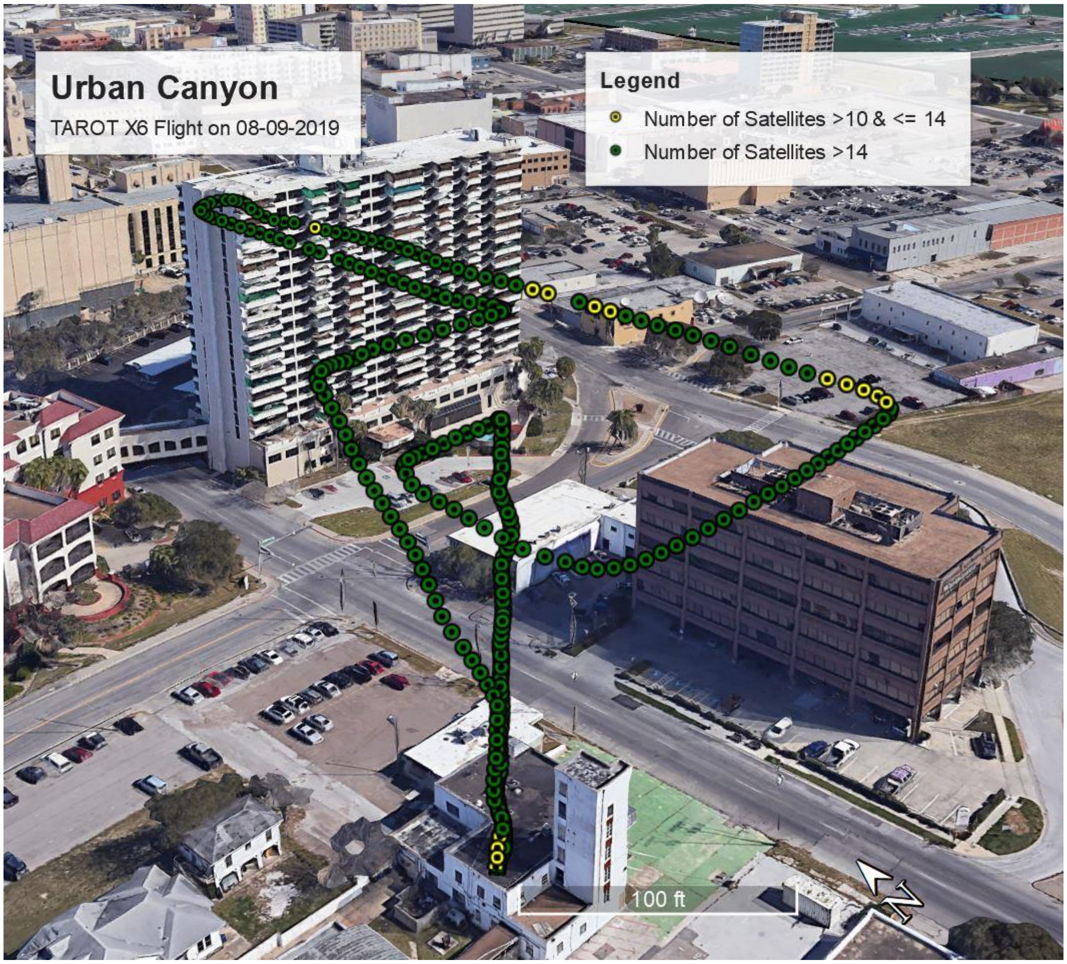

Figure 5 - Number of satellites seen during actual flight test in urban canyon

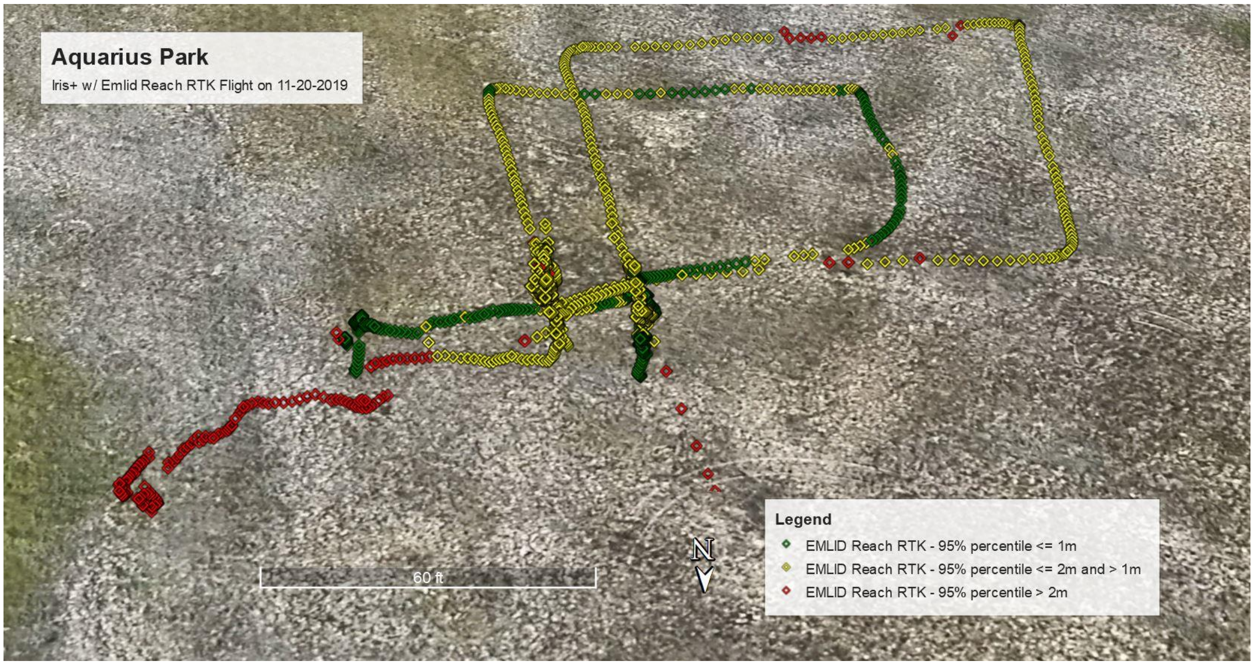

Figure 6 - RTK solution confidence level

Figure 7 - Difference between RTK and basic GPS solution

IV. Command, Control, and Telemetry Link Assessment

The first experiment did not look at telemetry specficially. The second test was conducted with the primary link using a typical 900Mhz ISM band telemetry serial data radio unit. It was anticipated that this point-to-point line-of-sight telemetry unit might not be able to stay connected during the route behind the large buildings. This turned out to be a correct assessment. Figure 8 shows the track of the vehicle in the downtown area. As can be seen, the telemetry unit lost connection shortly after the truck went behind the large building and recovered shortly after regaining line of sight. This again indicates a “worst case” scenario. However, there could be significant problems if during the period of time the sUAS is blocked from line-of-sight to the GCS and the sUAS needs to land in that region. A 433Mhz telemetry unit showed similar characteristics.

Possible mitigations for these phenomenon involve the creation of a reliable, redundant, multi-RF path communications link. This might include not just RF links in at least two different bands, but also cellular 4G/LTE and/or satellite communications links and/or mesh networks.

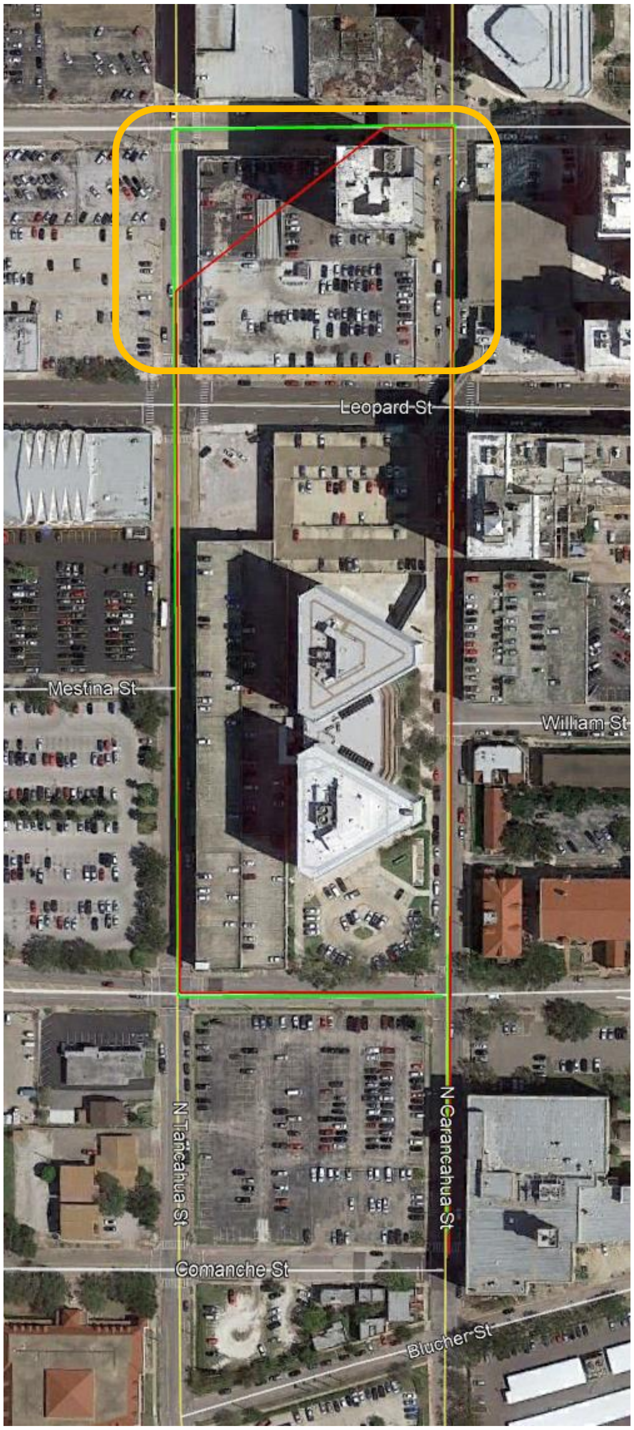

Figure 8 - Telemetry loss during ground experiment

V. Future work

Clearly, an important area for future research is the development of a highly reliable command and control link between operator and vehicle. Furthermore, for point-to-point RF links, a determination of a suitable "safety critical" RF spectrum band will be necessary. Additionally, work will be required to prioritize communication links such that deterministic selections can be made for which modality is the current link using under what circumstances.

Other future work should include alternative positioning system development such that the errors associated with GPS satellite signal blockage can be mitigated. This might include optical position systems, alternative ground-based geo-spatial positioning systems, cellular 5G positioning, and others.

If the density of urban operations is expected to be high, a system for sense-and-avoid will need to be developed that provides both a broadcast, ADS-B like capability that does not saturate the manned aviation ADS-B and an on-board system to detect, localize, and track non-cooperative aircraft.

VI. Conclusions

Many use cases for small UAS will require operation within an urban setting. It is important to consider the performance of key systems in the configuration of vehicles destined for this type of operation. Experiments were conducted to assess the performanc of GPS-aided navigation and RF telemetry links. Initial analysis indicates that operations within the so-called urban canyon appear feasible and within acceptable performance parameters. More study is required to evaluate different times-of-day and geometric configurations within the downtown area to ensure that the initial assessments continue to be valid for additional conditions. Further assessments will also be required to ensure that the performance error bands are within a reasonable tolerance for the downtown urban terrain. Data from the NASA UTM TCL4 demonstrations will be used to help define these performance requirement bounds.

References

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