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Demonstration of an Adaptable NextGen Interface for the UAS Ground Control Station

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Presently a significant number of unmanned aircraft are not included in the National Airspace System surveillance system. This is due to many reasons including an inability to carry Automatic Dependent Surveillance Broadcast equipment for weight or power consumption deficiencies, legacy equipment usage, and the experimental nature of unmanned aircraft. In addition, pilots on the ground do not have the same situation awareness of proximal aircraft that pilots in the cockpit have. However, many unmanned aircraft utilize a command and control link between the aircraft and ground control station that includes periodic updates of the aircraft position. The focus of this effort was to determine the feasibility of leveraging these existing communication links to provide the location of the aircraft to the national surveillance system, as well as provide the pilot with a display of aircraft in the vicinity of the unmanned aircraft. A prototype system was developed and new technologies were integrated into several NASA and GA-ASI activities. That prototype and resulting data from the demonstrations are the focus of this paper. Using these same technologies, live national traffic data have been integrated into a research test environment and displayed to a ground pilot of an unmanned aircraft. NASA and its partners have conducted three demonstrations of these technologies during the testing of unmanned and remotely piloted aircraft. A discussion of the data collected and some timing results are provided.

Nomenclature

ADS-B	=	Automatic Dependent Surveillance - Broadcast
ATC	=	Air Traffic Control
DAA	=	Detect and Avoid
GA-ASI	=	General Atomics Aeronautical Systems Inc.
GCS	=	Ground Control Station
GPS	=	Global Positioning System
IFR	=	Instrument Flight Rules
INS	=	Inertial Navigation System
LVC	=	Live, Virtual, Constructive (describing the simulation environment)
MTS	=	Mission Tool Suite
NAS	=	National Airspace System
SIERRA	=	Sensor Integrated Environmental Remote Research Aircraft
TCAS	=	Traffic Alert and Collision Avoidance System
TOA	=	Time of Applicability
UAS	=	Unmanned Aircraft System
UTM	=	Unmanned Traffic Management
VFR	=	Visual Flight Rules

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I. Introduction

THERE is an increased interest in the ability to fly unmanned aircraft and coupled with that interest is a need to integrate those aircraft into the National Airspace System (NAS).[1] NextGen surveillance data are a key component of the NAS, providing position reports of aircraft in controlled airspace to air traffic control (ATC) and a view of surrounding aircraft to a pilot through services like Automatic Dependent Surveillance Broadcast (ADS-B) and Traffic Information Services-Broadcast.[2] However the Unmanned Aircraft System (UAS) ground control station (GCS) command and control element adds a new data interface potential that is not yet fully accounted for in the NextGen data service architecture. The existing NextGen data service delivery point is focused on aircraft, not the GCS. Full participation requires unmanned aircraft to carry transponders and ADS-B equipment onboard to receive the same services and similar situational awareness to the pilot as manned aircraft. Larger UAS will be able to comply with such requirements, but small and very small UAS (those under 55 pounds) may not have the payload or power capacity to support the additional equipment. In addition, even for larger aircraft, data links supporting UAS command and control functions may still lack the bandwidth required to send traffic information from ADS-B equipped UAS to the operator at the GCS. Small UAS vehicles face additional challenges in reporting their locations to air traffic controllers and other airspace users (pilots). Low radar cross-sections combined with no on-board transponder make them difficult to detect by traditional ATC surveillance systems. When operating at low altitudes detection is even more problematic. The ADS-B system was designed for coverage across the NAS at an altitude of 1,500ft and above, so surveillance data on ADS-B equipped UAS flying below this altitude may not be ingested into the NextGen system.

The National Aeronautics and Space Administration (NASA) at Ames Research Center, along with partners Harris Inc. (formally known as Exelis[**]) and General Atomics Aeronautical Systems Inc. (GA-ASI), developed an experimental capability to introduce Harris Commercial NextGen traffic data into a UAS GCS. This provides the UAS operator with increased situation awareness of aircraft within close proximity to an unmanned vehicle. In addition, using self-reported data already sent from the aircraft to the GCS, NASA developed technologies to send UAS own-state (position and velocity) data into the Harris Commercial NextGen traffic data service. Both of these efforts were accomplished by leveraging NASA's existing live-virtual-constructive[3,4] (LVC) distribution infrastructure to develop a new, real-time NextGen air traffic data delivery method between the existing Harris Commercial NextGen surveillance data and the GCS. This capability is intended enable a UAS not equipped with ADS-B to provide its own state information into the NextGen data system via a connection from the Harris Commercial services to the GCS. Through this connection to the GCS, Harris is able to provide UAS operators with a display of aircraft within close proximity to the unmanned vehicle. Since the NASA LVC system would provide the underlying message passing system infrastructure, these technologies would be readily available for use during LVC simulation and flight testing.

This paper describes the design of the NASA system used to demonstrate the feasibility of a two-way connection between three research UAS (or UAS surrogate) and the Harris Commercial surveillance system. Data collection and timing results of sending data from the aircraft to the Commercial NextGen system during two flights tests are presented to illustrate the issues and viability of these connections. This research distinctly targets the Commercial NextGen data service, and not the operational NextGen surveillance data (also maintained by Harris) used by the Federal Aviation Administration (FAA). For convenience, unless explicitly noted, NextGen will refer to the Commercial NextGen system.

II. Background

Accurate and reliable data are required to conduct research and develop tools to aid air traffic controllers and managers. NASA has historically utilized the Center-TRACON Automation System data feeds (low fidelity primary and secondary radar data) to calculate 4D-trajectories, perform analysis, and generate realistic traffic scenarios to support its simulations.[5] These feeds are limited to state and flight plan data for instrument flight rules (IFR) and visual flight rules (VFR) aircraft that have requested ATC services.[6] However, NASA research was increasingly focused on the study of manned and unmanned aircraft integration throughout the entire NAS operating in the NextGen environment, including Class E airspace containing a greater mix of cooperative and non-cooperative VFR aircraft.[7] In 2013, NASA partnered with Harris (the developers of the FAA's operational NextGen surveillance system) to obtain access to fused traffic information with representative location accuracy, data conformity, and data rates.[8]

[**] Exelis was acquired by Harris during the partnership. To avoid confusion they will be referred to as Harris throughout the paper.

One outcome of that effort was 42 days of data, stored in a data warehouse, and made available to NASA researchers who require a more realistic NAS representation of traffic information for local or national air traffic analysis. The data included NAS-wide IFR, VFR and ground traffic data integrated from FAA radar and fused with ADS-B data sources. Though suitable for tracking of aircraft on a local level, it was found that the data required additional filtering and processing in order to store it as a single national dataset.[8] The data anomalies uncovered during this processing effort were reported back to Harris to permanently address data matching problems.

An initial consumer of the recorded NextGen data was the team at NASA that developed the distributed LVC infrastructure for human in the loop simulations and flight tests for UAS aircraft.[9] An LVC environment provides the underlying infrastructure to support localized and distributed simulation and flight-testing by integrating simulated aircraft (virtual and constructive) with live assets.[10] During the preparation for NASA detect and avoid flight test activities, the LVC development team started looking beyond archiving and into live connection to the NextGen data feed. The effort had three primary objectives:

- Interface the real-time NextGen traffic data with the LVC distributed test environment, providing enhanced data for UAS and other Air Traffic Management research.
- Provide a potential solution for small non-equipped UAS to "publish" aircraft state data to the NextGen system through the GCS.
- Deliver real-time NextGen traffic data to the UAS operator.

A prototype system was developed to meet each of these three objectives and instances of those technologies were integrated into several NASA and GA-ASI activities to demonstrate their feasibility. Those prototypes and resulting data from the demonstrations are the focus of this paper.

III. System Design and Demonstration

The prototype connection system was developed in three distinct phases and aligned to support different aspects of the objectives. First, the connection between the NASA LVC infrastructure and the Harris systems to support the ingestion of live NextGen surveillance data into the LVC system was enabled. Then, connections between the NASA LVC and the candidate demonstration aircraft via their respective ground control infrastructure were developed. Finally, a mechanism to display aircraft in the vicinity of the UAS (or surrogate) to the pilot in the GCS was created. At each phase, the development team leveraged existing research or flight activities to demonstrate the capabilities and when possible, collect data to evaluate the utility of the connection.

A. Development of the NextGen/LVC Connection

The first step was to identify the interfaces between the NASA LVC and the NextGen system in order to investigate a two-way data flow between them. For this initial effort, all interfaces were developed between the LVC and the Commercial NextGen system. The operational NextGen system that provides surveillance data to the NAS was not part of these tests. The NextGen system was configured to send aircraft flight state and flight plan information to the LVC, while the LVC sent only ownship flight state data back to the NextGen system. Both the NextGen system and the LVC had existing data structures that supported this data exchange. The effort focused primarily on the connection between the systems, parsing of the NextGen and LVC data formats, and mapping of the data from one format to the other.

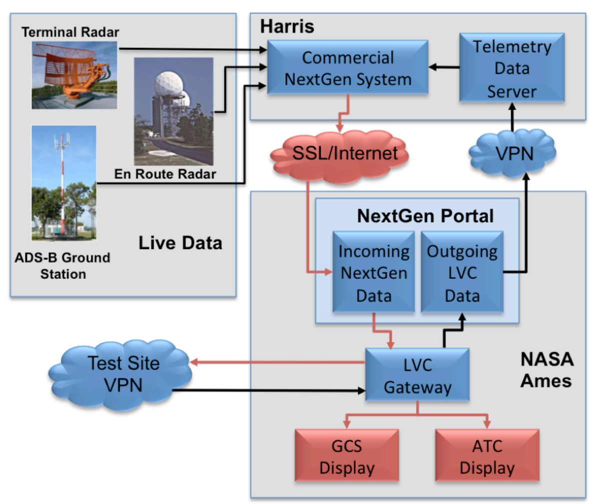

Figure 1. NextGen Portal Connection. *High level system architecture showing the main system components and the data flow between the Harris NextGen data and the NASA LVC.*

1. System Design

NASA developed the NextGen Portal process that runs on the NASA network and serves as a bridge between the NextGen and LVC systems. For data coming into the LVC system, the NextGen Portal is able to connect to the live Commercial NextGen feed via a Secure Socket Layer connection. It transforms the state and flight plan data into a format that complies with the LVC Gateway message format and publishes the data to the LVC Gateway. The NextGen data are made available to any LVC client that subscribes to state and flight plan data, including an ATC display, or a GCS traffic display (as shown in Figure 1).

To send ownship self-reported data from the LVC to the NextGen system, the NextGen Portal forwards aircraft state data to the Telemetry Data Server developed by Harris, which processes the data and forwards the state messages to the NextGen system.

The NextGen Portal application is comprised of the following internal components:

- **NextGen Data Parser:** This component receives and parses the aircraft state and flight plan information from the XML based NextGen data stream into internal data structures.
- **NextGen Data Mapper:** This component maps the NextGen data structures into the NASA LVC defined flight state and flight plan data structures.
- **Flight Plan and Flight State Encoder:** When data are ready to be sent to the LVC, this component packages the flight state and/or flight plan data and send it to the LVC Gateway via a client TCP/IP socket.
- **NextGen Data Handler:** This component supports the data to and from the NextGen system via a virtual private network tunnel. The tunnel is required for secure data transfer from NASA to the NextGen data server.
- **LVC Data Handler:** This component routes incoming and outgoing connections to the LVC Gateway.

2. Demonstration

The connection between the NASA LVC infrastructure and the Commercial NextGen data feed was demonstrated early in the development process to ensure the required fields in the state and flight plan data messages were complete and populated correctly. Figure 2 shows the first test of live data sent from the NextGen surveillance feed to an ATC display emulation through the NASA LVC system. The second line of the flight data block is of interest, showing "-9999" instead of the assigned altitude provided by the flight plan. Performing early testing of system the components allowed the integration team to identify these types of problems and fix them quickly. The missing assigned altitude field from the flight plan data was corrected in the NextGen Portal Data Mapper component.

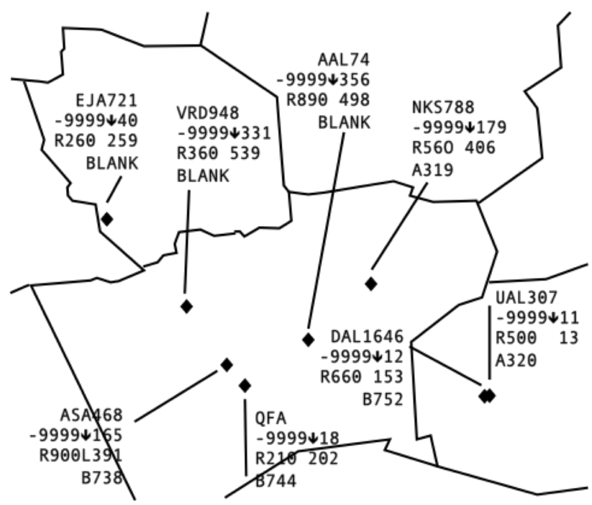

Figure 2. Live Traffic Display. *An emulation of an ATC display showing tracks from a live NextGen data feed integrated into the LVC environment. The diagram is shown in reverse video for clarity.*

B. Development of the LVC/GCS Connections

The purpose of this task was to develop the connection between selected aircraft ground systems and the NASA LVC. For this effort, three candidate aircraft with planned upcoming flight tests were identified to test the prototype data connection:

- Predator-B: GA-ASI
- T-34C (flown as a UAS surrogate): NASA
- Sensor Integrated Environmental Remote Research Aircraft (SIERRA): NASA

Table 1 describes the data collected during each of the tests, much of which was common to each. Since each aircraft had a unique connection to their associated ground station, their connection to the LVC is also unique and described in the following sections.

Table 1. Aircraft test data collection sources.

Data Files	Content	Source
LVC Gateway log	Aircraft state data, time of applicability (TOA) of the position, time the message was received	LVC Gateway (All aircraft)
ADS-B LVC log	Aircraft state data, TOA, time the message was received from the LVC	Harris Telemetry Data Server (All aircraft)
ADS-B data	Aircraft state data and TOA	ADS-B archive (Predator B and T-34C)
GPS log	Aircraft state data and TOA from independent GPS source	Aircraft GPS (Predator B only)
Internal aircraft system log	Aircraft state data and TOA, including the self-reported data and high resolution position updates from the Embedded GPS/Inertial Navigation System	Aircraft (Predator B only)

1. Connection to Predator B Class UAS

As partners in this effort, GA-ASI and the NASA LVC integration team worked closely to develop an interface between the LVC and General Atomics' Predator-B class capital asset (N308HK). This interface has been used extensively by NASA's UAS in the NAS project during their flight activities.

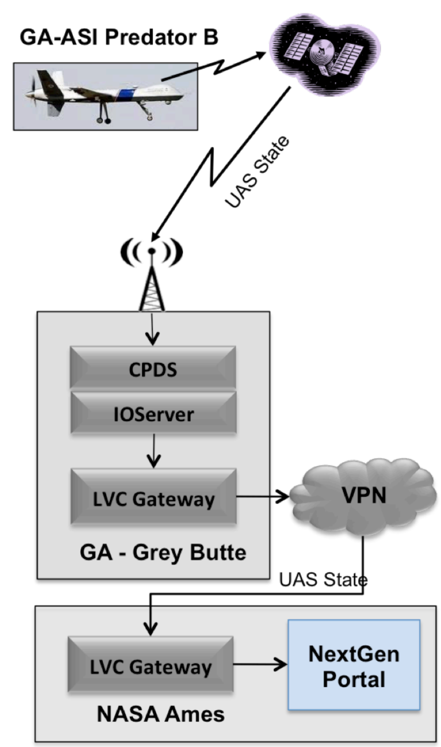

Figure 3. Connection to Predator B Class UAS. *The system diagram showing the connection between the General Atomics' Predator B capital asset and the NASA LVC infrastructure.*

System Design

The Predator-B aircraft was outfit with ADS-B and transmitted aircraft state data to the GCS via a Ku-band SatCom link and processed the data in the Conflict Prediction and Display System.[11] To send aircraft state and flight plan data from the GCS to external processes, GA-ASI developed the IOServer. The IOServer formatted and sent the data to the LVC Gateway, as shown in Figure 3. For ease of configuring the network, GA-ASI ran a local LVC Gateway (at Grey Butte), which communicated to an LVC Gateway at NASA Ames. The NASA gateway connected to the NextGen system as previously shown in Figure 1. As an independent data source, the Predator-B was outfit with ADS-B. Harris recorded these data per normal operations.

Demonstration

The Predator B flight tests were conducted on 12-13 October 2015 providing self-reported data into the NextGen test system through the GCS and LVC infrastructure. Over 4.5 hours of data the first day and 3 hours the second day were collected. This was the most complete test, with all of the data files from Table 1 collected. Due to the expanded data sources, extra analyses of the data timing were conducted after the demonstration of a data connection.

Figure 4 shows a plot of self-reported and ADS-B data recorded during a 13 October 2015 test run indicating both systems were reporting the aircraft's position properly. The self-reported data were sent from the ownship once per second, while the ADS-B data were recorded every five seconds from the surveillance feed.[††]

[††] Though ADS-B data have a nominal one-second update rate, the Harris Commercial ADS-B surveillance system only archives data at that rate when the aircraft is below 2000ft, otherwise data are archived at a five-second update rate.

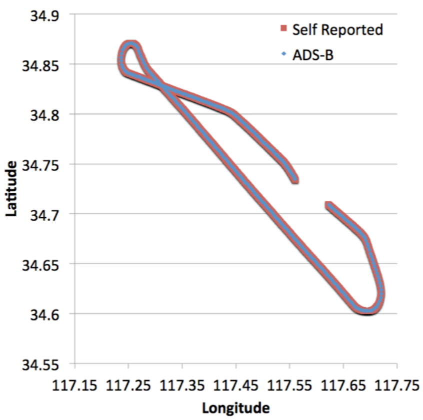

Figure 4. Predator B Track History. *Aircraft self-reported positions overlaid with the recorded ADS-B position of the aircraft.*

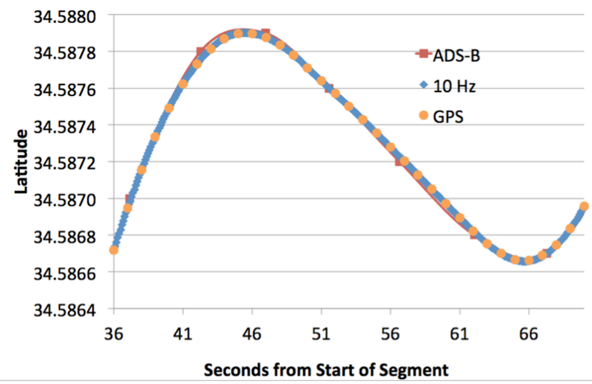

Figure 5. Predator B Position Data Smoothness. *The self-reported positions of the Predator B data shows good conformance with the ADS-B and GPS data.*

Closer analysis of the timing of the position reports indicated a few system issues. First, the time associated with the position report (TOA) recorded for the aircraft was overwritten by the IOServer prior to it being sent to the LVC Gateway. This caused the system to reflect the time the aircraft message was received on the ground as the time associated with the aircraft position. In addition, the TOA was truncated to the nearest second. The impact was that the TOA recorded by the LVC Gateway and sent to the NextGen system was incorrect. To mitigate these issues for analysis, times for the self-reported position reports were instead derived from the Predator B internal system logs, which included higher resolution (10 Hz) updated position reports from the Embedded GPS/Inertial Navigation System (INS). As seen in Figure 5, which plots 30 seconds of the internal position data along with the independently recorded ADS-B and GPS data, the three independent sources are well aligned. The internal timing errors have been identified and corrected for future flights. For our analyses, the self-reported TOA has been corrected by applying the time from the internal higher resolution data at the same position (approximated by best fit).

Figure 6 shows the latency (and hence the applicability) of the self-reported data as received by the NextGen system for a 3-minute data sample. The latency is defined as the difference between the time the NextGen system received the position report and the position report TOA (corrected as described above). As can be seen, there is a clear bi-model distribution of latencies observed in the data. This is caused by the mechanism for sending and receiving the data between the NextGen Portal running at NASA and the Telemetry Data Server running at Harris, which caused the data to be parsed in bundles of multiple tracks, with a maximum latency of just over 2.0 seconds.

ADS-B has a 2.0 second maximum latency allowed for use by ATC.[12] Though not addressed in this initial prototyping phase, the cause of this bi-modal distribution of track latencies would need to be investigated and corrected to fully enable the use of these technologies.

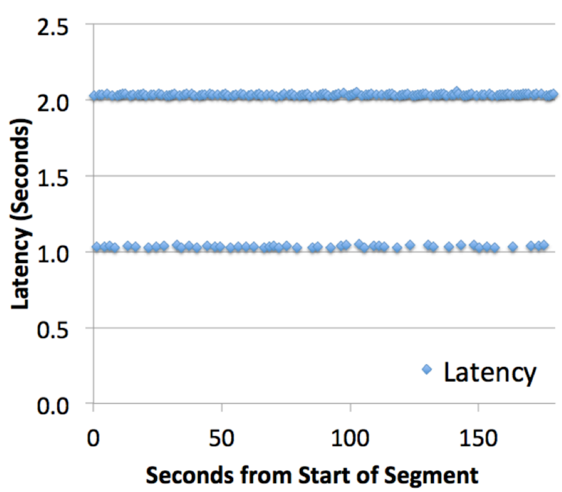

Figure 6. Aircraft to NextGen System Latency. *The difference between the time the position report was received by NextGen and the position TOA.*

2. Connection to Surrogate UAS (T-34C)

As part of NASA's UAS in the NAS Project, NASA Glenn Research Center developed a T-34C (NASA608) to serve as a surrogate UAS aircraft for Detect and Avoid research. The data collection was able to leverage the existing test LVC infrastructure to collect the appropriate data during one of those flight activities.

System Design

The T-34C aircraft transmitted aircraft state data to the research GCS via a prototype line-of-sight based communication system developed for the UAS in the NAS project. A process called the Vehicle Specific Module, running on the ground, processed and sent the data to the LVC Gateway, as shown in Figure 7. Since this effort leveraged the DAA test system, the local LVC Gateway connected to the UAS High Level Architecture[13] middleware and LVC Gateway running at NASA Ames. The NASA Ames gateway connected to the NextGen system as previously shown in Figure 1. For a detailed description of the overall flight test system, please refer to Murphy et. al.[14,15] As an independent data source, the T-34C was outfit with ADS-B. Harris recorded this data per normal operations.

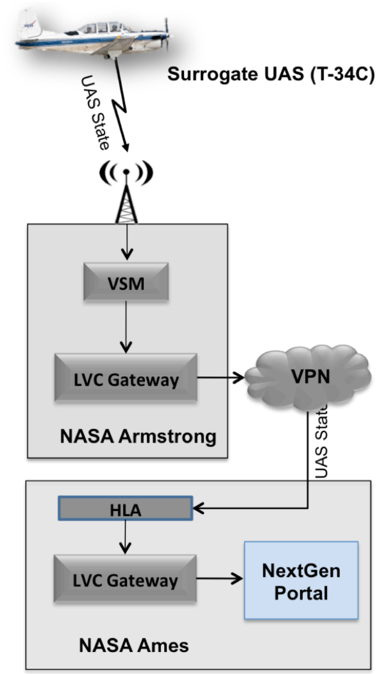

Figure 7. Connection of T-34C. *The system diagram showing the connection between the NASA T-34C surrogate aircraft and the NASA LVC infrastructure.*

Demonstration

The Detect and Avoid flight test that supported the NextGen connection and data collection was conducted on 12 August 2015 at NASA Armstrong. The T-34C provided self-reported data into the NextGen test system through the research GCS and LVC infrastructure for over 1.5 hours. The LVC Gateway log files, ADS-B archive, and the ADS-B LVC log files described in Table 1 (above) were collected.

As before, the self-reported position reports were plotted against the ADS-B position data, showing good correlation between the two sources (see Figure 8). Unlike the Predator B, the T-34C was not equipped with an advanced Embedded GPS/INS, but relied solely on its INS to supply the position reports. Figure 9 plots the latitude of the position against the time and shows the inherent variability of the standalone INS as compared the ADS-B data (derived from GPS). The significance of the variability demonstrates the need to evaluate systems with different self-reporting accuracy to determine their inherent utility. A clear shift in the time of the self-reported position can also be seen in Figure 9, varying between 0.5 and 1-second delay.

As with the flight of the Predator B aircraft, the overall observed latency from the TOA of the position report to the time it was received by the NextGen system at Harris was investigated. Figure 10 shows a plot of these observed latencies. The parsing of tracks from the NextGen Portal is again in multiple track bundles by the Telemetry Data Server. However, the overall latency seems to be less than with the Predator B, with two rough bands at approximately 0.75 seconds and 0.25 seconds of latency. This decrease in overall latency can be linked to the T-

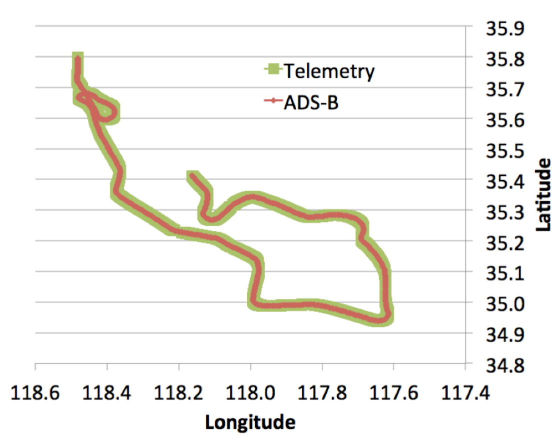

Figure 8. T-34C Flight Segment. *Aircraft self-reported position overlaid with the recorded ADS-B position of the aircraft.*

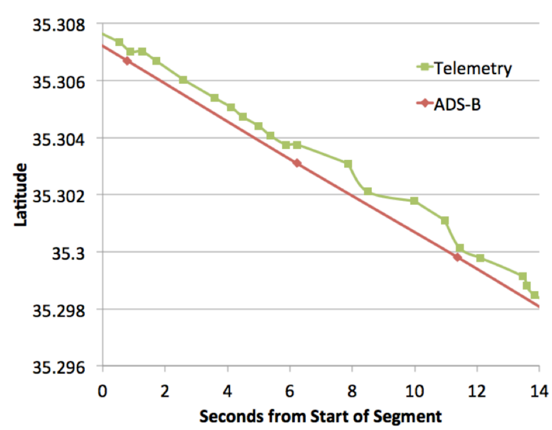

Figure 9. T-34C Track Latency. *The T-34C telemetry has a 0.5-1.0 second time shift and increased variability differences compared to ADS-B.*

34C's use of a line-of-sight data link instead of a SatCom data link. Increased variability in the data was also observed, most likely due to the on board system processing data as it is received as opposed to the regimented processing cycles on board the GA-ASI aircraft. Occurrences of negative latencies were also observed. This is seen when the TOA supplied from the T-34C is relatively later than expected. Whether this resulted from a problem in the system clock of the on board computer or in processing was not resolved. Utimately, this time uncertainty translates into relative uncertainty of the reported aircraft position.

3. Connection to NASA SIERRA UAS

The SIERRA is a UAS under development by NASA to support Earth Sciences flight activities. The objective of this connection is the support for a UAS flying in a remote location with limited Internet connectivity. The design and development for the connection to the SIERRA was conducted while a second SIERRA aircraft was constructed. The first suffered a mishap during a flight in Alaska.[16] The SIERRA did not have ADS-B installed.

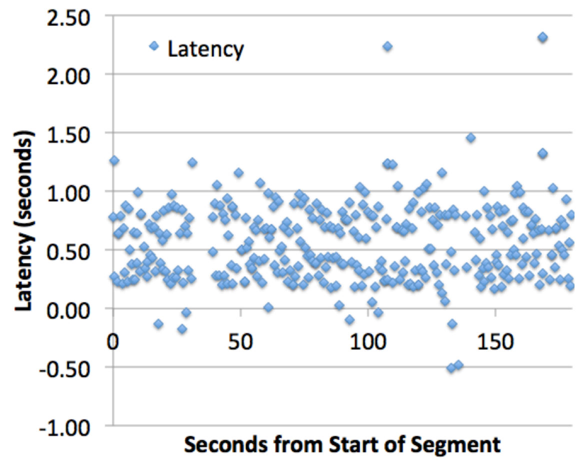

Figure 10. T-34C to NextGen System Latency. *The difference between the time the position report was received and the position TOA.*

System Design

The effort to integrate the SIERRA self-reported data into the LVC included development of a connector that processed the state data from the aircraft and sent it to the LVC Gateway as well as NASA's Mission Tool Suite (MTS). This process parses the data from the SIERRA and sends the data to the LVC via a 3G cellular connection. The LVC Gateway then sends the state data to the NextGen Portal, which is then forwarded directly to the Commercial NextGen system. On the NASA side, the MTS acts as an interface to the SIERRA Cloud Cap Piccolo autopilot. Although this capability will initially target SIERRA UAS flights, the MTS acts as a gateway to real-time aircraft self-reported data for every NASA Earth Sciences flight (see Figure 11).

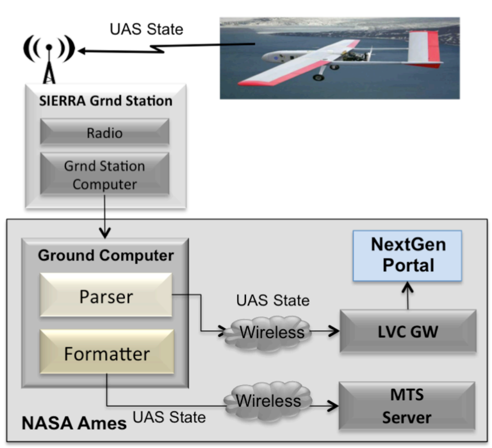

Figure 11. Connection of SIERRA. *The system diagram showing the connection between the NASA SIERRA UAS and the NASA LVC infrastructure.*

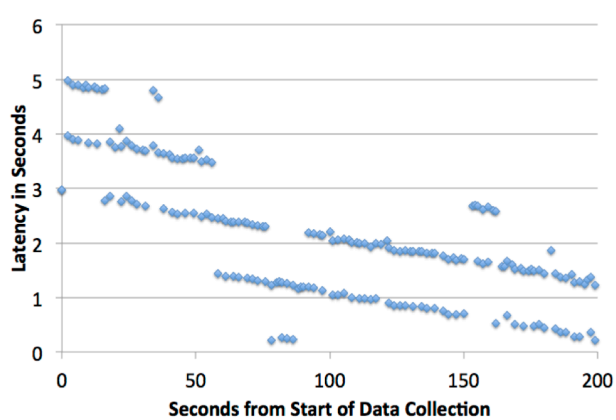

Figure 12. SIERRA to NextGen System Latency. *The difference between the time the position report was received and the position TOA.*

Demonstration

At the time of writing this paper, the SIERRA was still under development, however a successful connection test was performed during a ground test. The LVC Gateway log files, ADS-B archive, and the ADS-B LVC log files described in Table 1 (above) were collected for approximately three minutes during the test. The data analysis was minimal; however, the end-to-end latencies could be measured. A plot of the latencies is shown in Figure 12. The latencies once again have the bi-modal distribution, however, in this case the trend had a steady decrease in overall latency over time. The data stopped before the trend leveled out. In addition, several occurrences of shifted latency groups can be seen. Unfortunately, there were no additional opportunities to re-test in order to evaluate these phenomena. If consistent lower latencies can be achieved on a regular basis, the data stream could be a suitable source of position reports.

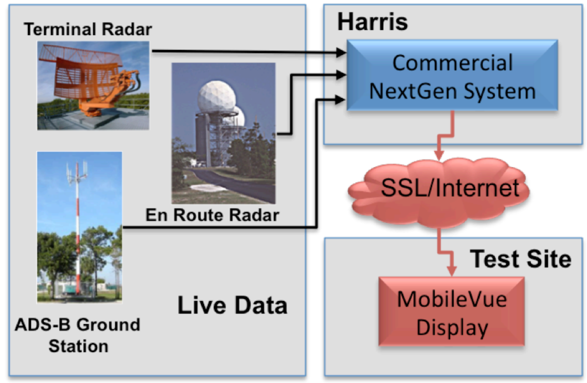

Figure 13. GCS Display Connection. *High level system architecture showing the connection between the NextGen system and the Harris MobileVue application.*

C. Display of Traffic to the Pilot on the Ground

The final objective of this work was to provide the pilot and other users on the ground a display of aircraft in the vicinity of the UAS. Based on the underlying infrastructure shown in Figure 1, an obvious mechanism to provide this functionality is to connect the GCS with a live data stream provided by the NextGen Portal fed from the Commercial NextGen System. A secondary mechanism to support GCSs that do not have access to a display that supports an LVC connection was developed by Harris and tested during a flight test of small UAS conducted by the Unmanned Traffic Management (UTM) project.

1. System Design

Similar to the secure socket connection between the Commercial NextGen System and the NextGen Portal that provides data to the LVC, Harris sends state and flight plan data directly from the NextGen system over the secure link across the Internet to a display application developed internally by Harris called Symphony MobileVue™ (MobileVue).[17] The MobileVue display provides the user with the basic state and fight plan information available for those aircraft. This includes call sign, position (latitude, longitude, altitude), speed, heading, flight path, and aircraft type. The only connection the computer running MobileVue requires is a 3G (minimum) cellular signal or network connection. The MobileVue application sends traffic to the application based on a predetermined location. Ultimately, the concept is that MobileVue will display aircraft surrounding a determined area of a registered ownship aircraft, updated dynamically as the aircraft flies. Figure 13 shows the connection of the MobileVue application.

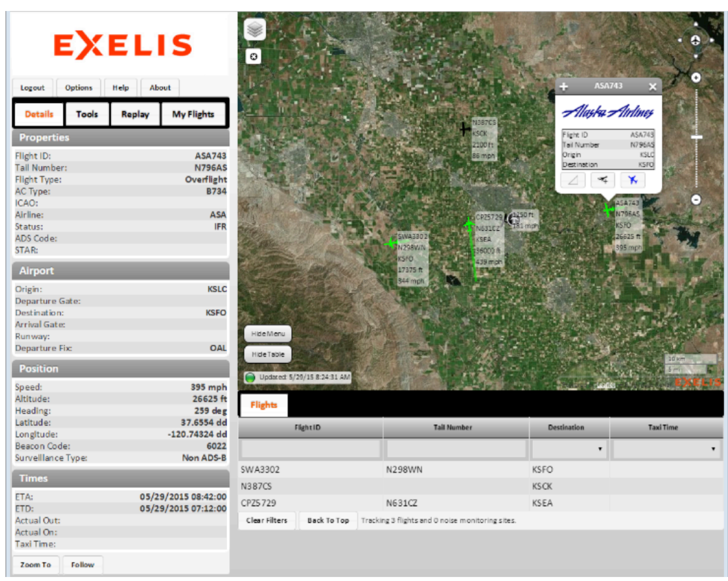

Figure 14. Display of Proximal Aircraft at the GCS. *Example of the Harris MobileVue aircraft display used to provide users a view of aircraft in the vicinity during a NASA test flight.*

2. Demonstration

The MobileVue display was demonstrated during a UTM flight on 29 May 2015 at Crow's Landing airport in Northern California. Using the display as shown in Figure 14, the UAS operator and other flight personnel on the ground were able to see aircraft in the vicinity of their UAS. This first demonstration of bringing NAS surveillance data to a remote pilot was successful, though the full potential of this concept had not yet been realized. Since the UAS under test during this flight was not equipped with ADS-B, nor was it self-reporting its location to the LVC, the UAS was position was not included in the data stream, so not included on the MobileVue display.

IV. Conclusions

Two different instances of sending data from a UAS aircraft into the Harris Commercial NextGen surveillance system were demonstrated in flight (with a third exercised during ground testing). The technologies were very early prototypes and though they showed promise in supporting the augmentation of surveillance data and UAS pilot situation awareness further development and analysis will be required.

The observed parsing for self-reported data in multiple track packages needs to be resolved before the system truly provides viable data. The concept would also benefit from the testing of additional UAS to gauge the relative accuracy and latency of sending data to the underlying LVC infrastructure over a broader sample of aircraft. Due to limitations of partner test schedules and development efforts, it was not feasible to conduct a fully end-to-end test of sending self-reported data into the NextGen system and at the same time present a mosaic of ownship and proximal traffic to the UAS pilot on a single display. As previously discussed, there are several mechanisms for doing this, depending on the equipage of the aircraft. Next steps in the development effort include exercising those different mechanisms.

The use of MobileVue to provide a display of proximal traffic to a remote UAS pilot is of interest. Though it has limitations when used standalone, primarily, not having the ownship UAS displayed (if not equipped by ADS-B or under FAA radar surveillance), it could be expanded to provide that utility if combined with the self-reported position technologies. The SIERRA aircraft is a candidate for this type of testing. Completion of the SIERRA testing, as well as further integration of the self-reported data into the NextGen data feed would be the next steps.

The connection between the NextGen and LVC systems offers not only a mechanism for reliably sending data to and from the surveillance network, but also a live data feed into the LVC system for flight test and simulation purposes. This connection provides research projects with an alternative source of live data, on a NAS-wide level, supporting situation awareness during flight-testing as well as the ability to exercise systems running in shadow mode.

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