Transforming the NextGen Test Environment: Integrating Fused ADS-B and TIS-B NextGen Data

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Purpose

The goal of this project was to develop a prototype capability to read and store the internet-based Exelis commercial NextGen fused data stream to support ongoing NextGen and Unmanned Aircraft System (UAS) integration into the National Airspace System (NAS) Project research efforts across the Agency. The Exelis NextGen commercial data set contains detailed information on participating instrument flight rules (IFR) and visual flight rules (VFR) aircraft as well as airport ground movement, providing a more complete and accurate set of air traffic information than is currently available to NASA. Access to more realistic and robust air traffic data within the NAS modeling and simulation environment will enable researchers to generate more credible results.

Background

The NASA Ames Research Center has historically relied upon Center-TRACON Automation System (CTAS) data feeds (low fidelity primary and secondary radar data) to calculate 4D-trajectories, perform analysis, and generate realistic traffic scenarios to support its simulations. These feeds are limited to state and flight plan data for IFR and only VFR aircraft that have requested air traffic control (ATC) services. NASA research is 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. Obtaining access to ADS-B/TIS-B data for non-participating aircraft operating under VFR has become a critical element for assessing pivotal see/sense-and-avoid issues, an area normally not assessed during previous manned aircraft studies utilizing the existing data feeds. Obtaining access to commercially available fused traffic information with representative location accuracy, data conformity, and data rates will improve the fidelity of the NextGen and UAS test environment. Integrating a realistic and reliable NextGen data source is critical to NASA research.

Exelis generates the NextGen data by processing NAS surveillance data from radars, multilateration systems and ADS-B through multi-sensor trackers. The fused tracks and flight plans from Host Air Traffic Management Data Distribution System (HADDS) are filtered and sent through a one-way diode across the Security Content Automation Protocol (SCAP) Boundary into the commercial domain. The filtered data stream is merged with Aircraft Situational Display to Industry (ASDI) data, and undergoes fusion processes to correlate flight plans to tracks, eliminate duplicates and populate with metadata from HADDS and ASDI. The result is an integrated track for each flight in the NAS with real-time updating. To summarize, Exelis' NextGen data is a "multi-sensor based" solution that aggregates all available data sources, including: FAA terminal and en route radars FAA ASDE-X systems Exelis' national ADS-B system Flight plan data ASDI data. Benefits and features of incorporating NextGen data include:

- Fused multi-sensor surveillance – failure of one surveillance source does not mean a complete loss of data
- Geo-referenced data – all surveillance sources are calibrated after fusion to provide more accurate positions.
- As more aircraft become ADS-B equipped, the surveillance accuracy and update rates will improve, as will the quality of the data: the nationwide installation of the initial 634 ground stations was completed in April 2014.
- Real-time data is publicly available and not subject to FAA MOA requirements
- The data does not include aircraft without operating transponders and aircraft with transponders that are not reporting a Mode C altitude

Products, Deliverables, and Schedule:

Table 1 contains the products and deliverables of the project in accordance with the proposal submitted for this study. The first step was to record ADS-B and TIS-B traffic and associated HOST ATM Data Distribution System (HADDS) flight plan data for inclusion in the NASA scenario source data portfolio. The next progression was to enhance UAS scenario development by supporting insertion of real traffic, sourced from NextGen data sources into pre-existing traffic scenarios. The final enhancement, not included in the set of deliverables, was enabling live NextGen data to be part of a scenario source data portfolio that allows live test aircraft to interact with previously constructed simulated traffic. Due to the inherent incongruities of the data provided by Exelis, this final capability was not realized during Phase I, and was subsequently moved to the Phase II effort.

Product / Deliverable	Format	Schedule
Archiving and retrieval solution for ADS-B traffic data	Database	Start + 1 month
Symphony® OpsVue™ data viewing and integrated collaborative decision making tool for air traffic management	One software license for one year, and associated user training.	Start + 1 month
ADS-B traffic data playback integrated with MACS scenario	Demonstration (part-task simulation)	Start + 4 months
Conversion of ADS-B data files into MACS scenario files.	"Playable" scenario file, viewable in MACS (DSR) and CSD applications, Demonstration (part-task simulation).	Start + 7 months
Playback of ADS-B traffic in the LVC environment as a separate traffic generator.	HITL simulation event with ADS-B, MACS, and federate traffic generators.	Start + 10 months
Lessons learned analysis and report.	Document and presentation.	Completion + 1 month

Table 1. Milestones Schedule

Approach

The project was broken down into three steps:

- Analyze the suitability of the stored data for replicating NAS traffic for supporting simulation and research
- Construct a searchable database scheme to store the data and make it accessible to researchers in CmSim File, HLA CSV File, Track Only CSV file, and Google Earth KML file. These are file formats used by ATM research tools and real-time simulation software)
- Once an HLA interface is configured based on the known data content, test a real-time feed of live data into HLA

The initial effort to make Exelis data available to users was divided into five distinct phases (see Figure 1):

1. Collecting the live TCP/IP stream data and saving the data into one-minute-compressed files.
2. Extracting the hybrid XML-CSV data from the compressed files and saving the extracted data into an Oracle database.
3. Analyzing the extracted data and identifying any duplicated data and any other data issues.
4. Transforming the raw extracted data and performing data de-duplication and normalization.
5. Creating a web form to allow users to specify query criteria and to export the cleansed data into various data formats.

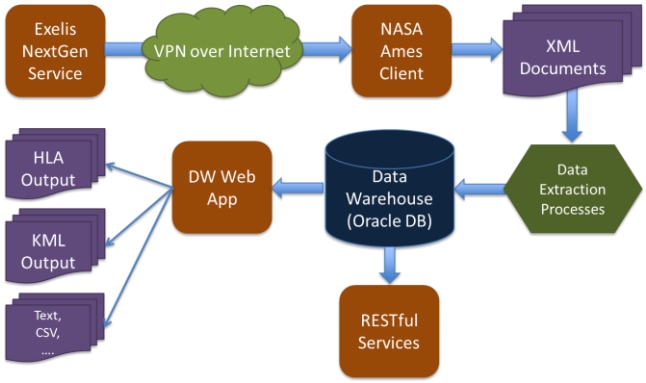

Figure 1. Exelis Data Processing

During **Phase 1 Data Collection**, Exelis Flight, FlightInfo and Track XML records were saved into one-minute-compressed files.

During **Phase 2 Data Extraction**, it was discovered that the VAS Gateway Interface Control Document provided by Exelis was incomplete and contained some errors. Much flight-diversion related data was not documented. The FlightInfo and Track data sources, previously described as the "Dual-Equipped" data source, turned out to be the "ASDE-X" data source.

During **Phase 3 Data Analysis**, the Flight and FlightInfo records were analyzed, duplicates removed, and inconsistent data cleansed. Two important observations were made during the analysis:

1. Exelis does not handle the situation when there are two flights with the same callsign but have distinct departure-arrival pairs. Flight plan and track data from these two flights get mixed up.
2. An Exelis flight record does not always represent a gate-to-gate flight. For example, if an aircraft stops at a gate between two flights with different callsigns and its transponder is not turned off at the gate, both flights are associated with the same Exelis Flight record. Without a clear start and end time of each flight, further temporal and spatial analysis of track records must be performed in order to associate track records with the correct corresponding flight or callsign.

Following these observations and further analysis of the Flight and FlightInfo records, software was developed to perform **Phase 4 Data Transformation**. Cleansed and normalized Exelis Flight, FlightInfo, and Track records were saved into the following seven database tables:

1. EXELIS_FLIGHTS to store only distinct Exelis Flight record.
2. EXELIS_FLIGHT_DVRSN_LOG to store, for a given Exelis Flight record, any flight-diversion related data.

3. EXELIS_FLIGHT_GROUND_LOG to store, for a given Exelis Flight record, in-airport related data.
4. EXELIS_FLIGHT_ROUTE_LOG to store, for a given Exelis Flight record, flight plan related data.
5. EXELIS_FLIGHT_TAXI_LOG to store, for a given Exelis Flight record, taxiing related data.
6. EXELIS_FLIGHT_TIME_LOG to store, for a given Exelis Flight record, departure and arrival time data.
7. EXELIS_TRACKS to store, for a given Exelis Flight record, any track related data.

To ensure that only good quality data is extracted for research and playback, only Flights that had no more than one departure-arrival pair could be exported. In other words, multi-legged flights are excluded. If a flight record has associations with more than one tail number, or more than one aircraft type, or more than one ADS-B mode-S-code, it is excluded from being exported. If a flight has stationary tracks, it is also excluded. In summary, 20% of the original raw Flight records were excluded for export and 6% of the associated Track records were also excluded.

Detailed information on the information and findings gathered during this research was shared with Exelis development team. This NASA data analysis and feedback facilitated enhancements to Exelis NextGen data delivered to commercial users and researchers, making the end-product more useful to NASA.

During **Phase 5 Data Access**, a web form (see Figure 2) was created in the ATM NextGen Data Warehouse web application. This web page allows a user to enter query criteria and export the resulting flight and track data in various formats. Query criteria include date-range, track-boundary (area around an airport, Air Route Traffic Control Center, or Terminal Radar Approach Control Facility), IFR/VFR or both, ADS-B equipped aircraft, callsign, aircraft type, and minimal percentage of ADS-B tracks.

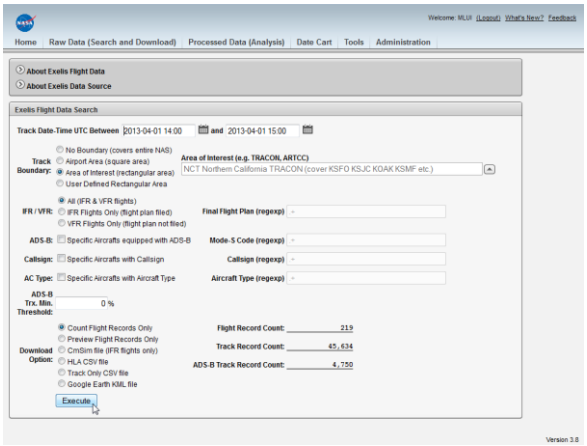

Figure 2. Exelis Flight Data web page from ATM NextGen Data Warehouse web application.

Data retrieved from the web queries can be exported in several formats: CmSim, HLA CSV, Track Only CSV, and Google Earth KML. Figures 3, 4, and 5 are screenshots of playbacks from a sample CmSim file, HLA CSV file, and Google Earth KML file respectively.

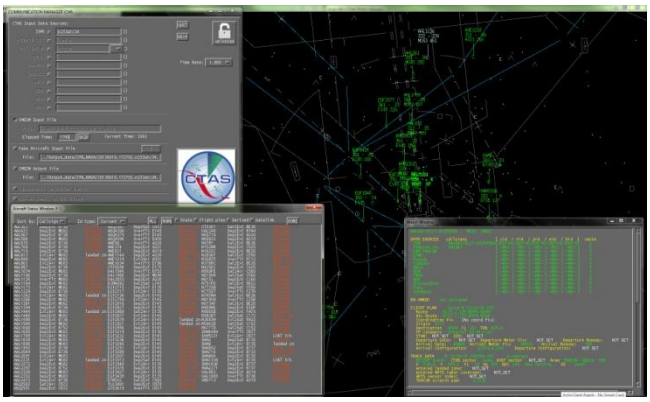

Figure 3. Playing back of a sample CmSim file in CTAS PGUI.

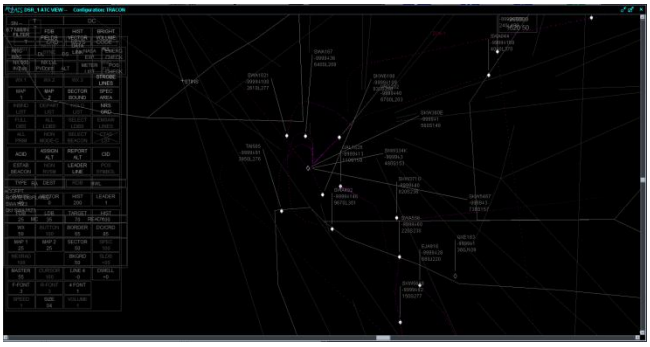

Figure 4. Playback of a sample HLA CSV file in MACS

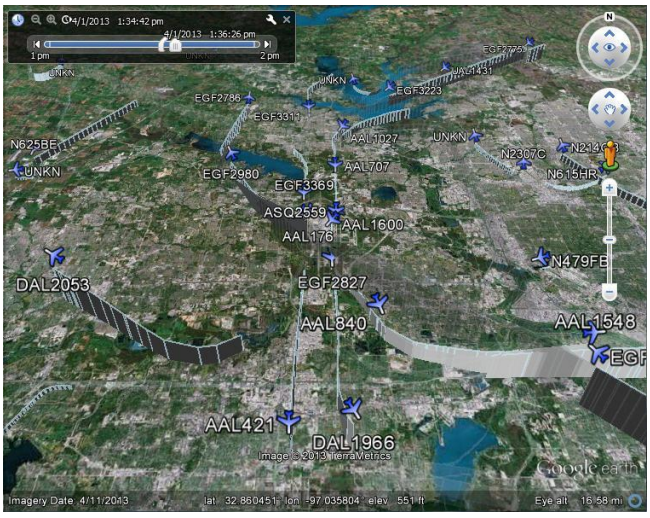

Figure 5. Playback of a sample Google Earth KML file in Google Earth

Accomplishments

NASA collected 42 days of ITT Exelis data that included NAS-wide IFR, VFR and ground traffic data. The track data included radar and ADS-B sources, when available. The recorded data was split into multiple one-minute-compressed files, which were stored in the network

attached storage system /home/data/exelis. The files were subsequently parsed, duplicates removed, and cleansed in the Code AF ATM Data Warehouse (80% of the original 7.7 million flight records and 94% of the original 2.7 billion track records were screened for quality). The data are now available for download by NASA researchers.

The completeness of the data set now available to commercial customers and researchers can be seen in the statistics generated from the collected data: 68% of flights collected were non-participating VFR aircraft, which had not been previously included in the NAS data archives collected by NASA to date. Figure 6 provides a graphic depiction of the volume of VFR aircraft active in the NAS on any given day in the San Francisco area.

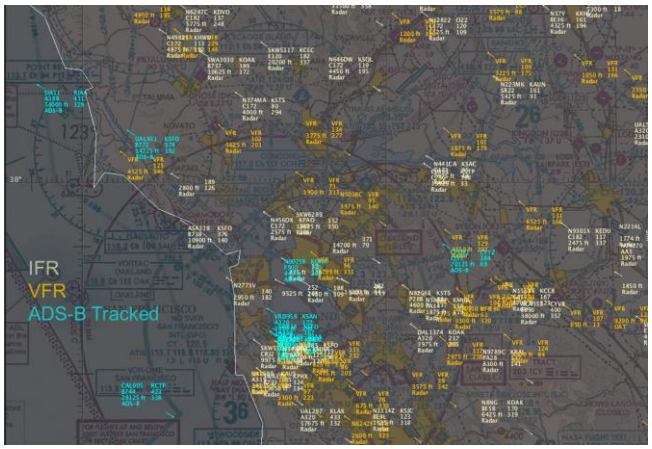

Figure 6. NextGen Data Coverage

Statistics on ADS-B equipage are also available for any given subset of the data. Overall, 19% of aircraft were ADS-B equipped, and 16% were both IFR and ADS-B equipped.

The Data Warehouse now contains these 42 days of enhanced data, available to NASA researchers who require a more realistic NAS representation of traffic information for any type of local or national air traffic analysis. The new data set fills a critical gap in NAS research data set.

The project has achieved all milestones on schedule, including capturing, analyzing, and storing the NextGen data in the Data Warehouse, and developing a database from which CmSim files can be created for playback as MACS scenario files. The Data Warehouse also supports the creation of files for playback through HLA. An HLA Toolbox, which will enabled playback directly into the HLA environment, was developed and successfully tested using a CSV file generated using the Data Warehouse web application. Significant additional work with Exelis will be required to read live NextGen data directly into the HLA environment in real-time, and was included in the project's Phase II proposal.

As a proof of concept, the project developed a prototype of a NextGen data display. The team utilized a mobile device running Exelis' OpsVue Mobile ® app and provided NASA's Dragoneye small unmanned aircraft operators with real-time ADS-B/TIS-B traffic awareness during flight operations at Lawrence M. Livermore Site 300 test site. The display is shown in Figure 7.

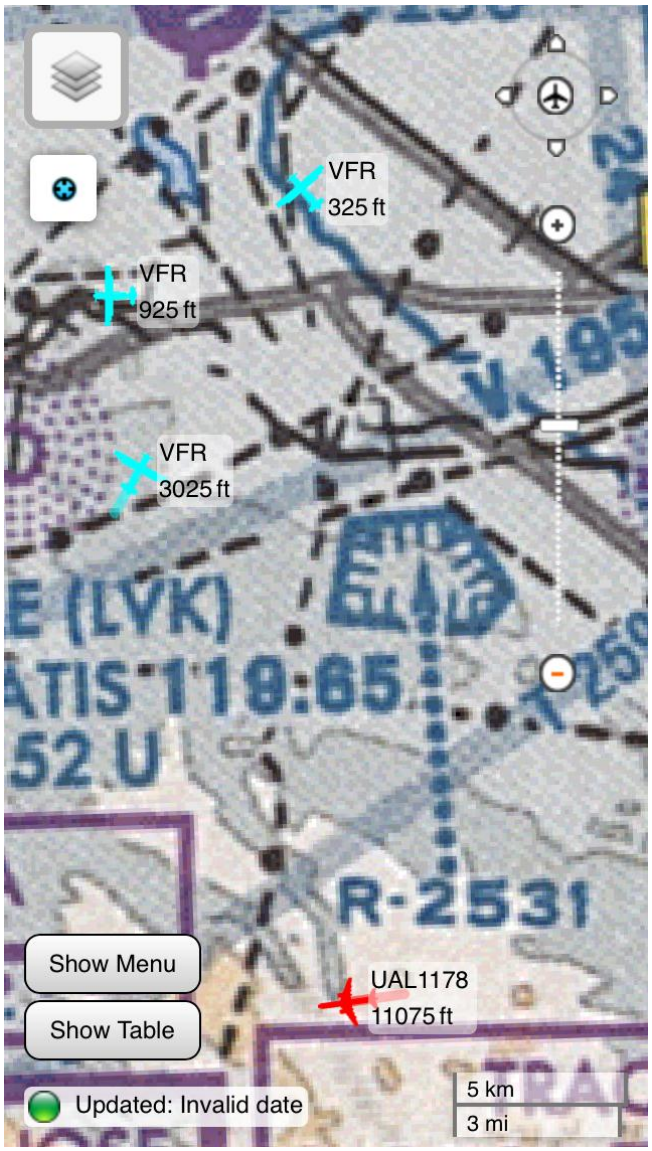

Figure 7. Prototype traffic awareness display demonstrating live NextGen data displayed to small UAS operators in the field over a cellular connection

Phase II research promises to further enable safe and effective integration of UAS into the NAS through two-way data sharing between the UAS ground control station and the NAS. The research will evaluate the feasibility and effectiveness of providing real-time NAS surveillance data to UAS operators and the NASA research environment while simultaneously inserting real-time ownship flight state information—for UAS of all sizes and equipage—into the NAS. Ultimately, it will assess the feasibility of UAS without transponders or NextGen equipment to see and be seen by other aircraft.

Current TRL: Technology Readiness Level 3: Analytical and experimental proof-of-concept has been demonstrated.

Applicable NASA Programs/Projects

The UAS-NAS Project has and will continue to benefit from this effort as realistic test scenarios that satisfy the requirements of Human Systems Integration and Separation Assurance/Sense-and-avoid Integration researchers are developed.

The Tactical Separation Assured Flight Environment (TSAFE) and Terminal TSAFE groups have also expressed interest in the data supplied by these technologies, but their usage requires that Exelis address some of the data issues uncovered by the primary analyses of the data.

Due to the ease of accessing ground data at several major airports on demand, this data feed may also be of interest to the Spot and Runway Departure Advisor (SARDA) group.

Publications and Patent Applications

A conference paper detailing the implementation and usage of the Data Warehouse, including storage of the NextGen data, will be presented at the Digital Avionics System Conference in October 2014:

Eshow, Michelle, M. Lui, and S. Ranjan, "Architecture and Capabilities of a Data Warehouse for ATM Research," 33rd Digital Avionics System Conference, Colorado Springs, October 2014.

Awards & Honors related to Seedling Research

None at this time.