BUILDING THE DATA-CENTRIC AIR TRAFFIC MANAGEMENT SYSTEM OF THE FUTURE

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The current ATC system manages 5,000 manned aircraft a day, a number that is expected to rise to 50,000 with the integration of unmanned aircraft.

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Today's ATM systems are challenged by a growing demand to support unmanned aircraft into the existing infrastructure designed for commercial airlines, private operators, and military aircraft. With technologies like FAA NextGen and Europe's SESAR, air traffic controllers are integrating relatively simple ground-to-air and air-to-air communications and situational awareness improvements, primarily for manned aircraft, with a focus on commercial airline safety. However, looming on the horizon is the growing challenge to safely integrate tens of thousands to millions of new air vehicles. These range from small unmanned aircraft systems (sUAS) to flying taxi services to air package delivery vehicles in a wide range of sizes and weights.

Global ATC systems are making progress in updating their legacy radio beacon, voice- and radar-controlled systems into modern platforms using low error rate digital data. Modernization programs like NextGen and SESAR, which deploy new capabilities like Automatic Dependent Surveillance-Broadcast (ADS-B), SWIM, and Collaborative Air Traffic Management Technologies (CATMT), are advancing the march to a more collaborative, reliable, and semi-autonomous airspace control for manned aircraft.

However, the emerging tidal wave of new airspace entrants will soon overwhelm these control systems. The current ATC system handles about 5,000 manned planes per hour during peak travel times. This number will be dwarfed by a large volume of new unmanned vehicles needing to enter controlled airspace. The numbers are staggering: up to 50,000 or more vehicles, performing air taxi, package delivery, and emergency response, plus a wide range of commercial and private delivery systems, all of which require monitoring. This influx of new entrants is driving the demand for a new dimension to the existing ATC system, one that drives autonomous, non-line-of-sight flight control and separation, and can rapidly scale as UAS operations increase. In the US, the FAA and NASA are working on new UAS control systems, such as UTM, which should address the first wave of new unmanned entrants into controlled airspace.

These incremental improvements to airspace are useful, but they cannot address this challenge by themselves. The pace of innovation of autonomous systems, robotics, computer vision, radars, and other sensing systems simply outpace the ability to create and deploy new federal airspace infrastructure programs. A new approach to distributed software architecture is needed. Data-centric software offers a decentralized "data everywhere" abstraction, easing integration while providing the scalability, performance, and security needed for future control of the national airspace.

Scalability Through a Data-Centric Architecture

Data-centric software makes strongly typed data the interface between applications rather than messages or protocols. Producers and consumers discover each other dynamically and are decoupled in time, location, and flow. This allows easy federation of systems that naturally follows the control structure of ATC. Each data flow can be configured independently outside of the application code, giving each its own quality of service and security. The Data Distribution Service (DDS) standard provides a data-centric connectivity framework, called a databus, that runs over 1,200 large-scale real-time systems.

Creating a truly safe and secure airspace management system requires an overarching architecture that integrates data from national infrastructure as well as from the wide range of sensing systems on the ground and in the air. Data must be collected in real-time and available as required to authorized flight controllers and aircraft systems. As ATC systems have modernized the voice-centric control system to one that relies on the real-time flow of data, the foundation has been laid for a new data-centric architecture that can readily adapt to new airspace entrants with new sensing and control technologies.

The US military has faced this integration challenge for decades, where they need to track UAS operations and all flight levels, coupled with manned air systems and soldiers on the ground. Airborne Identification Friend or Foe (IFF), a radar/transponder system for identifying friendly and hostile aircraft, and Blue Force Tracker (BFT) are two examples of command and control in hostile military environments. Commercial airspace will need to prepare for scenarios where far more "unfriendly" operations will enter the traditional "friendly" airspace with the inclusion of future unmanned systems.

Leading the Way Through an Open, Secure Architecture

Over 1,200 commercial aerospace and defense systems already use a data-centric communications framework to integrate a wide range of sensor data and control information. These data-centric platforms are based upon the DDS open standard managed by the Object Management Group® (OMG). DDS is proven to meet the necessary interoperability and security requirements for cross-service,

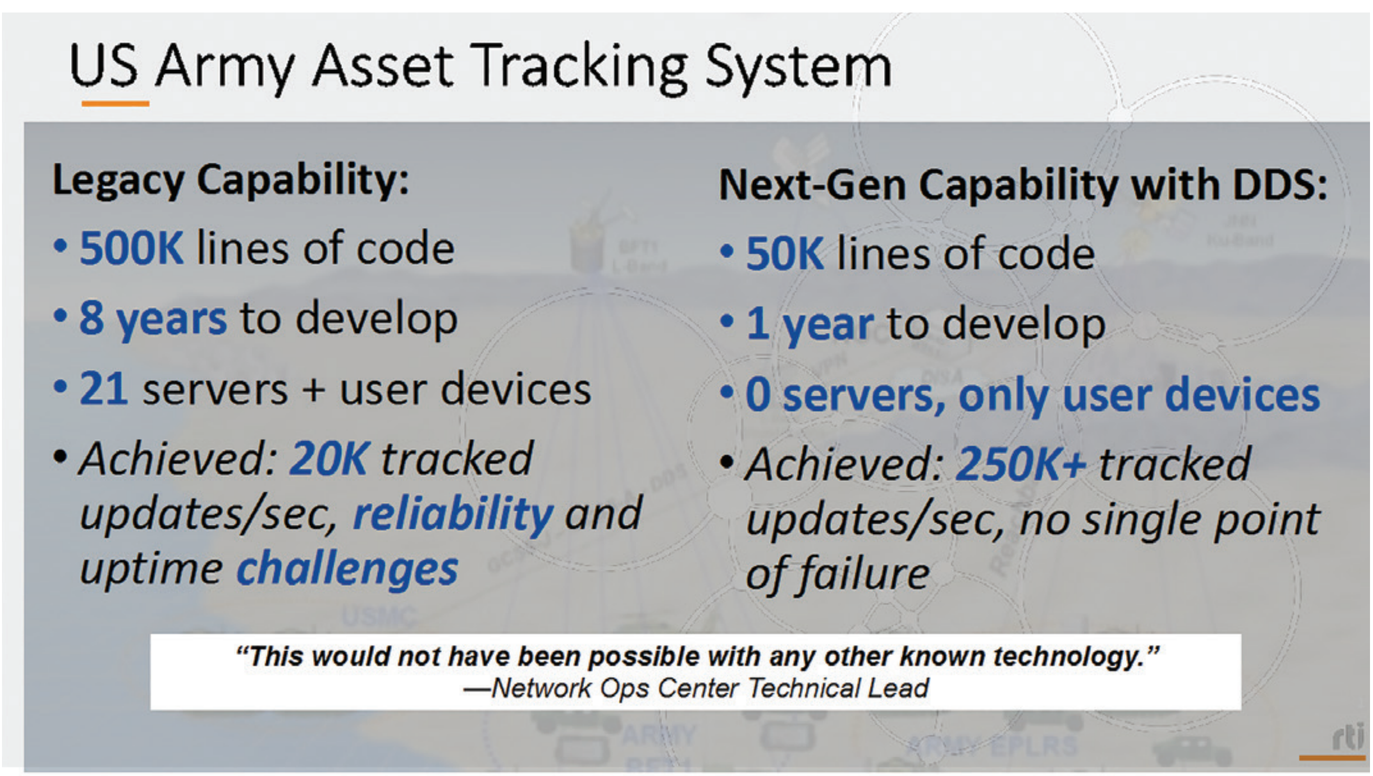

Figure 1. US Army Asset Tracking System.

cross-supplier, and cross-ally integration of a technology-driven operations environment. DDS is ideal for integrating a wide range of disparate systems, making it a low-risk choice for integrating the operations and control data from SESAR and NextGen ADS-B, SWIM, CATMT, UTM, and any other system that augments manned and unmanned flight operations, today and in the future.

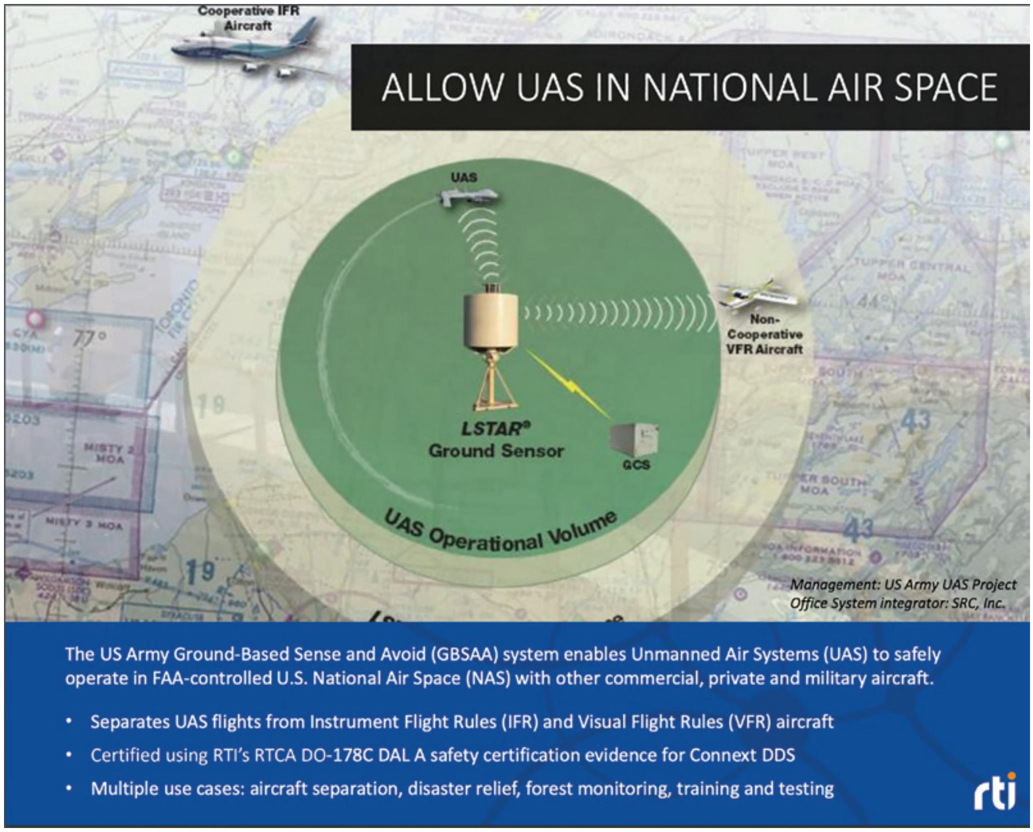

Figure 2. US Army GBSAA Benefits for UAS.

Real-Time Quality of Service

Cyber-physical systems like ATC require bounded response times. If messages or commands arrive too late, they are not relevant and can be dangerous. IT-based communications protocols and software are not built for real-time cyber-physical systems. NextGen systems, in addition to being built on data-centric technology, must also employ software that guarantees real-time contracts for data timeliness. DDS, as part of its standard, defines a rich set of Quality of Service (QoS) attributes that allow applications to enforce real-time constraints as part of their data exchange. In a DDS environment, an application offering data also advertises an offered QoS. Applications seeking to use that data will do so only if the advertised QoS meets or exceeds their local needs. Without QoS, all timing requirements are pushed into the application code, resulting in complex, brittle systems that are difficult to evolve and re-certify over time.

One Model for Integration: US Army Ground-Based Sense and Avoid

The US Army uses DDS for their Ground-Based Sense and Avoid (GBSAA) system that enables UAS to safely operate in the FAA-controlled NAS with other commercial, private, and military aircraft. The GBSAA system displays other aircraft near the unmanned aircraft and notifies the operator of potential hazards, while meeting federal requirements and eliminating the requirement of a chase plane or ground observer for UAS flights. This system can be used in many environments, including aircraft separation, disaster relief, forest monitoring, training, and testing. To accelerate FAA safety certification, RTI provided commercial-off-the-shelf (COTS) RTCA DO-178C DAL A certification evidence for this solution.

Multi-Supplier, Multi-Standard Simulation Integration

In systems built on DDS, the data is the interface between applications. All differences in underlying CPU architecture, operating system, and network connections are abstracted away. The real-time QoS settings ensure design capabilities are advertised at startup and enforced at run time. Multiple standards and protocols can be normalized to DDS to provide connectivity between disparate systems.

Most military and commercial aerospace customers and programs decline to publicly discuss their technology foundations. In 2019, RTI, the largest commercial supplier of DDS technologies, proved the unique capabilities of DDS to integrate a wide range of technologies, both standards-based and proprietary, at a public event. RTI integrated multiple competitive platforms for modeling, simulation, and training (MS&T) which included industry-leading platforms from L3Harris, VT MAK, Microsoft, National Instruments and SimBlocks.io. MS&T parallels the ATC environment, which integrates legacy, simulation, airborne, and new gaming platforms.

As Figure 3 depicts, RTI integrates platforms based upon the High-Level Architecture (HLA) simulation standard and the Distributed Interactive Simulation (DIS) standard, and combines these simulations with a Future Airborne Capability Environment (FACE™) standard avionics platform utilizing actual avionics hardware used in a hardware-in-the-loop (HIL) environment. The simulation engine from VT MAK and real avionics systems from L3Harris FliteScene were chosen for this challenge and were integrated with a non-HLA, non-DIS interactive simulation with a joystick and cockpit environment using Microsoft Flight Simulator. It also integrated a proven gaming platform, using SimBlocks.io One World SDK with the Unity Game Engine. The integration of the different simulation and HIL components is defined in Figure 3.

The ability to seamlessly mix live, virtual, and constructive elements into a simulation enables rapid development of new capabilities. In a similar way, a DDS-enabled mixed mode system could ingest live or recorded ATC data and share it with simulations to model and test new algorithms and methods for integrating UAS into the NAS.

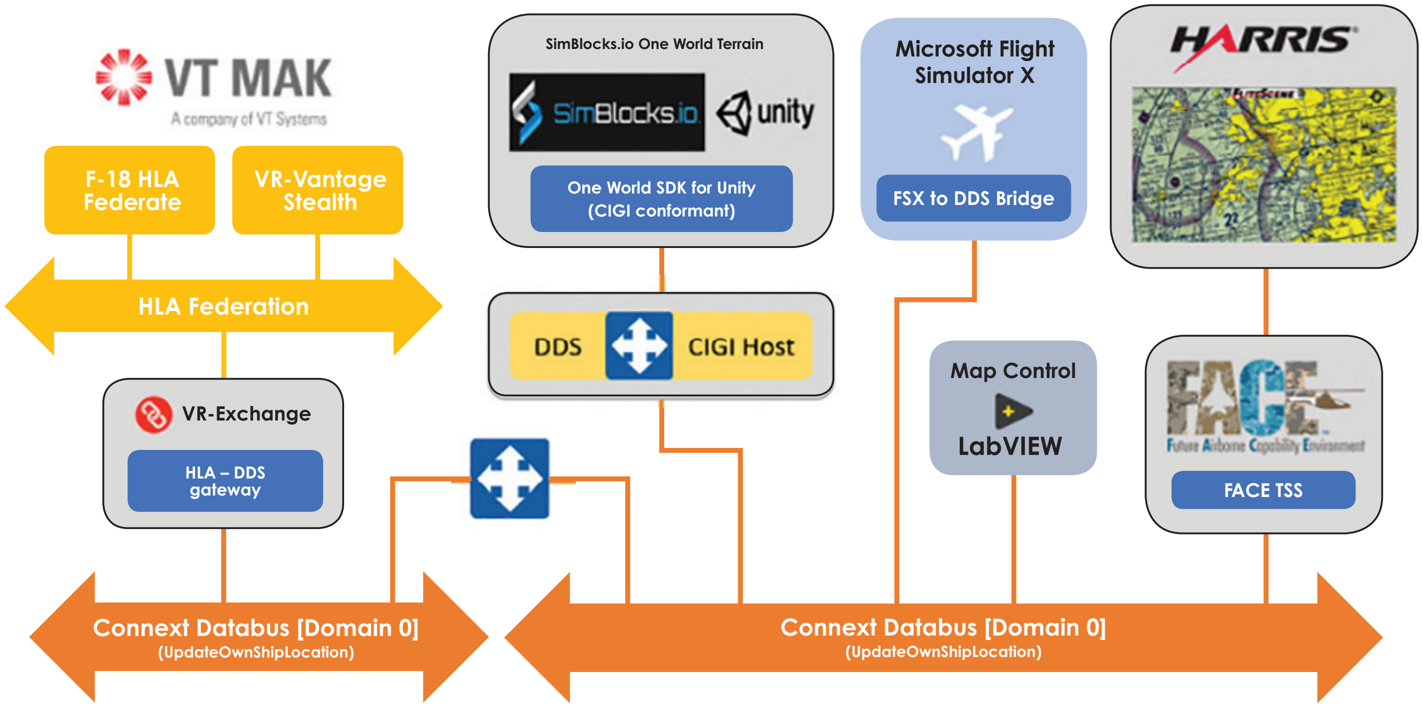

Figure 3. Integration of Different Simulation and HIL Components.

Autonomous Air Systems

The big unknown in future ATC systems is the wide range of future airborne vehicles that will need to share airspace. The biggest challenge facing these systems is safe, scalable, and efficient processing of the data to ensure safe operations. The volume of data in these platforms will resemble a gaming platform more than a traditional ATC system. Advanced autonomous systems are being built to accommodate the petabytes of connected data. There are currently more than 200 commercial, defense, and research autonomous vehicle programs being built on the RTI platform. One of these companies, Airbus Vahana, is developing the first certified, electric, self-piloted vertical take-off and landing (VTOL) passenger aircraft.

Enhanced Regional Situational Awareness (ERSA)

In the wake of the September 11 terrorist attacks on the Pentagon, the US Air Force Rapid Capability Office developed an integrated sensing and decision support system to enhance the situational awareness of decision makers responsible for protecting and responding to attacks from the complex airspace surrounding the National Capitol Region (NCR). Using DDS, ERSA fuses together data from government and non-government sources into a common air picture that automatically detects and highlights aircraft behaving in a suspicious manner. Real-time communications allow operators to control multiple cameras to assess threats and to instantly send visual warnings to pilots.

Conclusion

The global ATC environment is increasing in complexity faster than control and separation infrastructure can be built. Airspace must be able to rapidly, reliably, safely, and securely process data from new airspace entrants and integrate this data with current ATC control systems. The use of DDS in a wide range of critical platforms provides a network foundation that optimizes the flow of authenticated multi-domain data in real-time with millisecond precision. Future ATC platforms need this foundation to include future unmanned systems to enter controlled airspace with continued high safety and security.

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