Model-Based service volume engineering development using CORE software

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Abstract

Automatic Dependent Surveillance-Broadcast (ADS-B) system is considered the cornerstone of the Next Generation Air Transportation (NextGen) System that would transform today's aviation and ensure increased safety and capacity in our NAS.

One of the most important design aspects of the ADS-B system is the design of the terrestrial radio station infrastructure throughout United States. Service Volume Engineering (SVE) is responsible for the technical design of such infrastructure that would meet all system requirements. This paper presents the model based engineering approach adopted to support the majority of SVE design activities culminating with the development of a complex Geospatial / Radio Frequency entity-relationship engineering model. CORE software environment was selected for the development of such model based engineering environment.

Introduction

Automatic Dependent Surveillance-Broadcast (ADS-B) system is considered the cornerstone of the Next Generation Air Transportation (NextGen) System that would transform today's aviation and ensure increased safety and capacity in our NAS.

The first building block of the NextGen system is the implementation of the Automatic Dependent Surveillance-Broadcast (ADS-B) system. One of the most important design aspects of the ADS-B program is the design of the terrestrial radio station infrastructure. This design must determine the layout of the terrestrial radio stations throughout the US optimized to meet system performance, safety and security. Enabled by the Global Positioning System (GPS) satellite system and a nationwide radio stations terrestrial infrastructure, ADS-B will enhance surveillance capabilities and improve aviation safety and capacity in US. ADS-B services in the United States are based upon two non-interoperable data link technologies: (Bruno & Dyer, 2008)

- 1090 MHz Extended Squitter (1090ES)
- 978 MHz Universal Access Transceiver (UAT): this data link operates at 978 MHz.

These two data link technologies will enable the following four ADS-B services that are required within NAS. (Gilbert & Bruno, 2009)

- ADS-B - Surveillance of 1090ES and UAT aircraft to FAA Air Traffic Control is a service that receives position broadcasts from ADS-B equipped aircraft and distributes this information to ATC automation systems for providing separation assurance and traffic flow management.
- ADS-R - ADS-B Rebroadcast is a service that receives ADS-B position broadcasts, and rebroadcasts the same information to near-by aircraft that are equipped with a different ADS-B data link.
- TIS-B - Traffic Information Services Broadcast is a surveillance service that derives traffic information from radar/sensor sources and uplinks this traffic information to ADS-B equipped aircraft.
- FIS-B - Flight Information Service Broadcast is an uplink service that provides aeronautical and flight information such as textual and graphical weather reports and Notice to Airmen (NOTAM).

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Document-centric vs Model-Centric SVE Design Approach

In the very early stages of ADS-B system design, the SVE design team was faced with a very challenging task of how to efficiently capture, maintain and distribute the RF design artifacts and/or data sets. Below we list a subset of stakeholders (external and/or internal) of the SVE RF design data.

1. External stakeholders
    a. FAA
    b. FAA Spectrum

2. Internal stakeholders
    a. SVE design team itself
    b. Systems Engineering team
    c. Implementation Acquisition team
    d. Implementation Construction team
    e. Flight Testing Design team
    f. System Configuration team
    g. Network Design team

A document-centric approach would have required the maintenance of several documents to satisfy the need of all stakeholders. Rather than following the document-centric path, SVE design team adopted the approach taken by the ADS-B System Engineering (SE) design team that used the model-centric approach for the ADS-B system design. The SE design team utilized CORE software for the requirement management and ADS-B system design. CORE software is a collaborative model based system engineering tool that provides an end-to-end system development from requirements to V&V. Model based system engineering schema is an integrated part of CORE software. The integrated schema can be tailored, that is augmented and/or modified based on the users' needs. Taking this one step further, CORE software can be used to build any model that relies on an entity-relationship-attribute (ERA) concept. Hence two main aspects of CORE software made this tool the preferred choice for SVE design team

1. Collaboration
2. ERA development capability

The concept of ERA data modeling was first introduced by Chen (Chen, 1983). The ERA model, according to Chen, adopts a more natural view of the real world. Furthermore, the ERA modeling can be efficient if used to model a physical system where one can identify with "ease" the entities and relationships governing the system. We applied the ERA model approach to SVE. The SVE primary tasks are to design the radio stations siting and configuration including but not limited to the number and types of antennas, RF channels and RF parameters associated with each radio station. This design must meet all requirements for each FAA's defined three dimensional service volumes where ADS-B services are offered (E. Boci, 2009; E. S. Boci, Sarkani, & Mazzuchi, 2010).

ADS-B Geospatial / RF design ERA Model

Figure 1 shows the ER model schema that we developed in support of SVE. The 12 new classes are defined under the RadioSiteElement abstract class following the object-oriented perspective and class organization in CORE software.

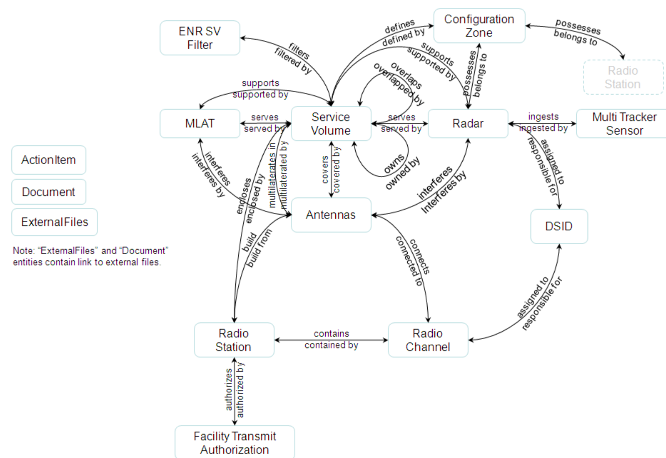

Figure 1. ADS-B Geospatial / RF design ERA model schema

The new ER schema development in CORE software started in 2007 with the creation of the first two classes: "RadioStation" and "Antenna". At the time, these two classes where sufficient to capture important SVE radio site design parameters and it greatly facilitated the data distribution of such data to several other ADS-B design teams. As the benefits of using such model based approach became evident, the ER schema continued to evolve. The next major model based development effort was to include the system requirements into the model schema. The following classes where specifically designed to capture the SVE design requirements

1. ServiceVolume
    a. 40 En Route SVs
    b. 236 Terminal SVs
    c. 35 Surface SVs
2. Radar
    a. En Route radars
    b. Terminal radars
3. MLAT
    a. Multilateration set of radio units deployed in each of the Surface SVs for which interference levels should be met

The current ER schema contains 14 new classes and 21 relationships. The ER diagram for "ServiceVolume", "Radar" and "MLAT" classes are shown in Figure 2, Figure 3 and Figure 4 respectively.

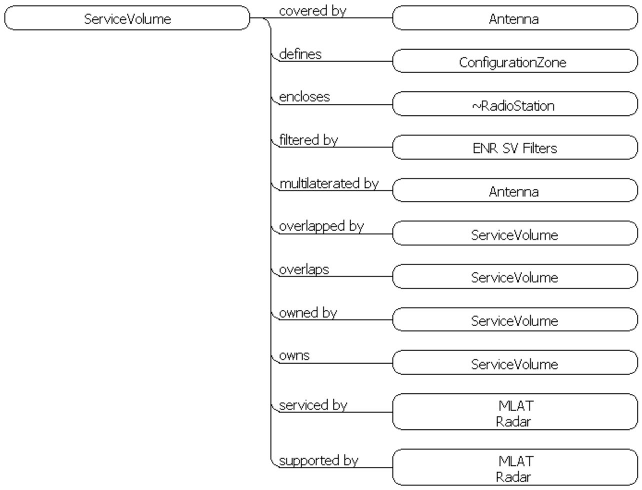

Figure 2. "ServiceVolume" class ER diagram

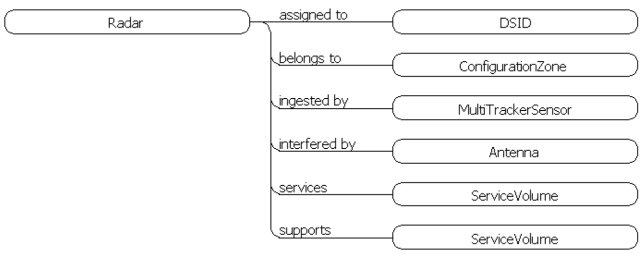

Figure 3. "Radar" class ER diagram

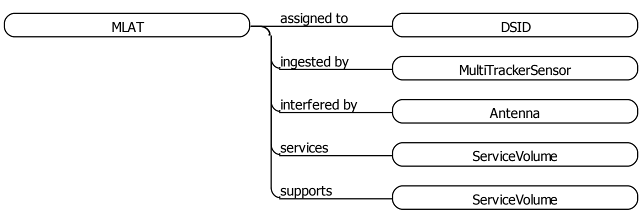

Figure 4. "MLAT" class ER diagram

The Extended Markup Language (XML) repository size history of the ADS-B Geospatial / RF design implemented in CORE software is shown in Figure 5. Leveraging on CORE software scalability feature, we were able to grow our model in two distinct ways. First, we enhanced our model by introducing new classes and relationships to support the stakeholders' needs. Secondly, we continued to capture the SVE design data and parameters thru element instantiations. The number of attributes for each class has also increased during the three year period of the model development. In addition, we have developed several CORE scripts to extract data in a format specifically requested by internal and or external stakeholders.

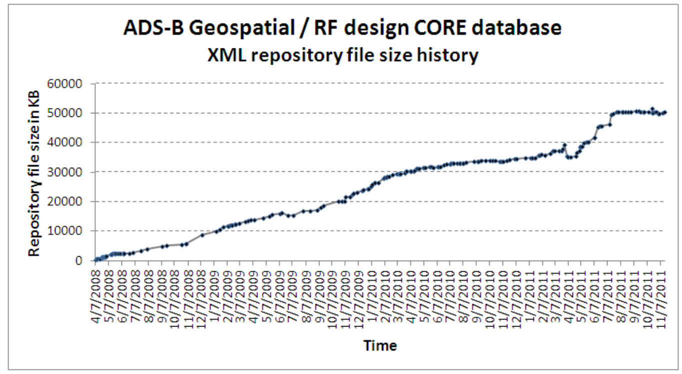

Figure 5. XML repository file size

Currently the ADS-B Geospatial / RF design CORE database contains more than 14,000 elements, 135,000 element attributes, 36,000 relationships and 12,000 non-empty relationship elements.

The CORE project data for the ADS-B Geospatial / RF design CORE project is maintained by extensive use of RDT imports. The RDT files are created using third party development tools and provide the necessary bridge that connect to and transfer from other development tools that SVE design team uses. For example the radio station data information is acquired using Open API from the RF software that SVE uses to design the radio stations. The necessary RDT file(s) are created capturing the radio station instances and attributes content for the "RadioStation" class. The last step in the process is to import the RDT file(s) and check the import results. Also we have experimented with creation of XML files to be used as the import engine to CORE software. From our perspective, the use of RDT and/or XML files closed some of the gaps that CORE software currently has on the data import/export capabilities. The introduction of Open API in GENESYS software will greatly facilitate the development of advanced algorithms that would synchronize CORE projects with other tools and greatly increase data exchange and integrity between CORE software and other tools.

Integration of ADS-B Geospatial / RF design model within ADS-B System

One of the most important features offered by CORE software is the generation of the project specific XML repository file. The XML format is used by CORE to import and/or export from selected CORE project. With the intent to eliminate the human in the loop interaction while transferring the ADS-B Geospatial / RF design CORE database data into other databases, we decided to use the XML file as the only interface mechanism between ADS-B Geospatial / RF design CORE database and other databases in need of RF design data.

As shown in Figure 6, the XML file is used as the interface to the Adaptation database for the ADS-B system configuration.

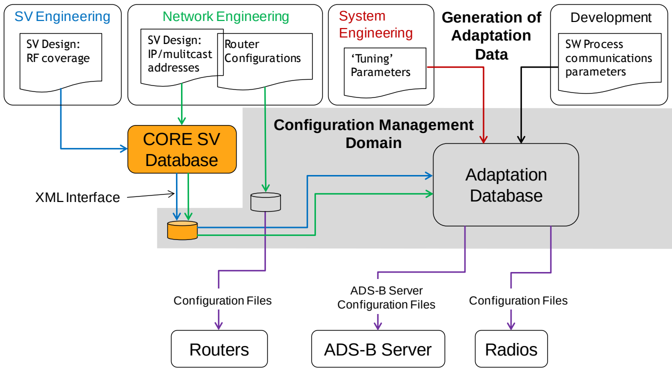

Figure 6. The adaptation data generation process for ADS-B system configuration

Furthermore, only the XML file generated by CORE software belongs to Configuration Management domain, thus it eliminates the need to maintain and generate documents that in a typical development environment will be part of the Configuration Management domain. The XML file is processed using custom developed parsers and the necessary data is retrieved and captured into the "Adaptation Database" as indicated in Figure 6. It is important to note that the approach taken to utilize the XML file as the interface between the ADS-B Geospatial / RF design CORE database and Adaptation database eliminates human in the loop factor thus drastically reduces number of errors that would have results otherwise. Furthermore, XML interface allows the communication among different data model implementations.

> XML is used to realize information communication between different process operation systems. The important thing here is to develop appropriate parsers. Once the parser is developed and put on different sub-systems, it is easy for the sub-system to read information from other sub-system. For different sub-systems, they can communicate without knowing the data style and data model. They only need to act as a messenger to send information. (Zhihui, JinSong, & Qian, 2010)

With the introduction of open architecture in GENESYS software, we envision to shift from the XML interface approach to the use of web services for project data extraction. This approach will further enhance the interface between ADS-B Geospatial / RF design CORE database and Adaptation database by eliminating the need for XML generation and XML parser development and maintenance.

In Lieu of a Conclusion

In this paper, we presented the development of a complex ADS-B Geospatial / RF design model in support of SVE design. One of the questions that one may ask is on the benefits that such model based development offers to not only the design teams but at the organization level.

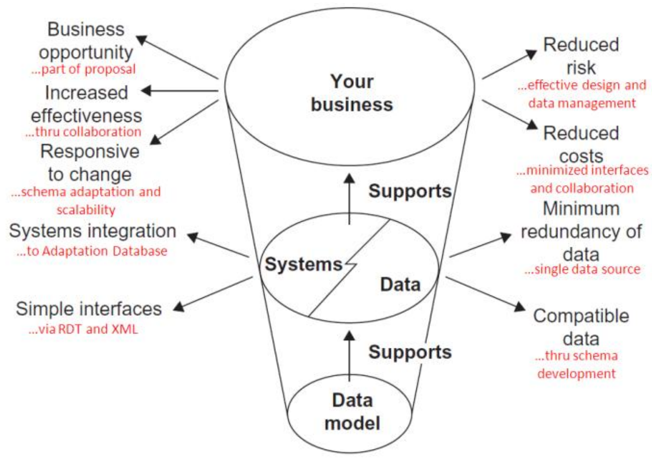

Figure 7. How data models deliver benefits (modified from (West, 2010, pp. 57))

Figure 7 shows the benefits delivered from (data) model based approach. The most important benefits realized by model based approach are the simplification of interfaces among systems that consume the data, the high level of integration and the increase in overall effectiveness. For each benefit shown in Figure 7, we have annotated how the benefit is realized thru the use of model based approach.

We will continue the development of our ADS-B Geospatial / RF design model by including additional classes into the schema in support of stakeholders' needs and requirements. The next most important step of our development effort would be the transition into the GENESYS software platform and the development of new VB scripts supported by GENESYS software.

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About the Author

Dr. Erton Boci holds a B.S. degree in Electrical Engineering from the University of Maryland, College Park, an M.S. in Electrical Engineering and a second M.S. in Systems Engineering from The George Washington University. In 2011, he received his Ph.D. in Engineering Management and Systems Engineering from The George Washington University. He joined ITT Corporation in 1998. Currently, he is leading the Service Volume Engineering design effort for the FAA’s ADS-B program.