Integrated Space Asset Management Database and Modeling

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ABSTRACT

Effective Space Asset Management is one key to addressing the ever-growing issue of space congestion. It is imperative that agencies around the world have access to data regarding the numerous active assets and pieces of space junk currently tracked in orbit around the Earth. At the center of this issues is the effective management of data of many types related to orbiting objects. As the population of tracked objects grows, so too should the data management structure used to catalog technical specifications, orbital information, and metadata related to those populations.

Marshall Space Flight Center's Space Asset Management Database (SAM-D) was implemented in order to effectively catalog a broad set of data related to known objects in space by ingesting information from a variety of database and processing that data into useful technical information. Using the universal NORAD number as a unique identifier, the SAM-D processes two-line element data into orbital characteristics and cross-references this technical data with metadata related to functional status, country of ownership, and application category. The SAM-D began as an Excel spreadsheet and was later upgraded to an Access database. While SAM-D performs its task very well, it is limited by its current platform and is not available outside of the local user base. Further, while modeling and simulation can be powerful tools to exploit the information contained in SAM-D, the current system does not allow proper integration options for combining the data with both legacy and new M&S tools.

This paper provides a summary of SAM-D development efforts to date and outlines a proposed data management infrastructure that extends SAM-D to support the larger data sets to be generated. A service-oriented architecture model using an information sharing platform named SIMON will allow it to easily expand to incorporate new capabilities, including advanced analytics, M&S tools, fusion techniques and user interface for visualizations. In addition, tight control of information sharing policy will increase confidence in the system, which would encourage industry partners to provide commercial data. Combined with the integration of new and legacy M&S tools, a SIMON-based architecture will provide a robust environment that can be extended and expanded indefinitely.

1. INTRODUCTION

Space situational awareness (SSA) and the dissemination of an accurate space picture is recognized as an important capability for all actors in the Earth orbit environment. As populations continue to expand, the orbital space of the Earth is becoming more cluttered and this escalated congestion represents an ever-increasing risk to space-based assets. Knowing position, velocity, and various types of metadata about current orbiting bodies provides valuable information for mission planners and supports more accurate representations of the risks to critical space-based infrastructure. Also, as NASA plans to expand human exploration beyond the International Space Station, a more complete understanding of the Earth orbit environment improves human spaceflight safety. There are numerous systems that are tracking objects and developing pieces of the total SSA picture, but these efforts are fragmented and stove-piped within various organizations. There is a need for a sophisticated data processing and analysis system

that can provide an encompassing, accurate SSA picture to first, the national space-faring community, and ultimately, the global community. This paper presents a NASA/MSFC technical approach that will provide such a system.

2.   SPACE ASSET MANAGEMENT DATABASE (SAM-D) BACKGROUND

Several years ago, MSFC began to investigate the various issues related to orbital debris and space situational awareness as part of a series of spacecraft concept studies. It quickly became apparent to the analysts involved that, while the general idea of the orbital debris threat was known, any group interested in advancing technologies designed to address the various SSA issues required a certain level of understanding of the demographics and technical data that describes the populations of objects in Earth space. A large component of any SSA mission concept is the education of the audience on matters of debris populations, population centers at various orbits, the status and importance of active orbital assets, as well as international policy and law. Research into available data related to the orbital population revealed that, while both technical information and metadata of orbital objects are available, compiling the data requires the survey of many different resources and the completeness and validity of the data is varied.

To support these concept studies, the first version of the SAM-D was created. In its initial instantiation, the SAM-D was constructed in Excel. The center of the SAM-D was the publically available catalog of tracked objects maintained by the Joint Space Operations Command (JSpOC).[1] The JSpOC Catalog is freely available through the web site Space-Track.org, which was used as the source for the SAM-D. A Visual Basic for Applications (VBA) macro was written to convert the Two-Line Elements (TLEs) found in the catalog into single row database entries housed in a worksheet within the Excel file. Using the orbital characteristic data found in the TLE, the Semi-Major Axis, and Perigee and Apogee Altitudes were computed. The TLE also provided the satellite number, also knowns as the NORAD number, which serves in the SAM-D as the unique identifier for each entry in the database. With apogee and perigee defined and inclination provided directly from the TLE, the database immediately supported the binning of tracked orbital elements by orbit.

Several other public sources of information were tapped to provide other technical specifications and metadata. The Satellite Catalog (SATCAT) Database [2] provides a significant amount of supplemental information. The SATCAT database is a historical database of Earth satellite information maintained by the Center for Space Standards and Innovation (CSSI) at Analytical Graphics, Inc., makers of Satellite Tool Kit (STK). One unique aspect of the SATCAT database is that it holds a record of all assets launched since the beginning of space flight, over 39,000 entries. This information becomes extremely useful in establishing historical trends and separates the SATCAT database from the JSpOC catalog, the latter of which only keeps a running record of objects currently in orbit. The SATCAT database was the chief source for radar cross-section data, a key data element for spacecraft orbital life calculations. Additionally, historical data about orbital objects found in the SATCAT database, including launch site, country of origin, and operational status, were used to create metadata for the satellites in the catalog.

The database maintained by the Union of Concerned Scientists (UCS) provided additional data regarding operational status.[3] This data supplemented data found in the SATCAT database. The UCS database was also a source of mass data tracked objects, as was data maintained in the STK software itself. Mass data for the SAM-D from these two sources was supplemented by ad hoc searches completed using several web resources including Gunter's Space Page[4], Encyclopedia Astronautica[5], and the NASA Space Science Data Center (NSSDC)[6]. The data from these various sources were integrated with the TLE data, adding to the single-line database entry, via lookup functions based on NORAD number and, in the case of the ad hoc mass data, manually.

Using VBA macros, a search function was created to allow the Excel database to be queried. Sub-sets of tracked objects could be created by satellite name, orbital parameters (including inclination, perigee and apogee), or by metadata such as satellite owner. While this original SAM-D configuration served its purpose, it was significantly limited in its functionality and required significant computational resources, with file sizes as large at 45 MB. To improve the usability of the SAM-D, a new version was created in Microsoft Access. The goal of the new SAM-D was to improve access to a wide range of space object data, integrating several different sources into one easy-to-search database while retaining the integration of technical data and metadata supported by the original SAM-D. The Access database proved to be significantly more agile and user friendly. Queries could be executed on any of the data categories available in the database. Data could be updated at the click of a button with the SAM-D

programmed to seek file from web-based data resources such as Space-Track.org and the SATCAT database, and previous version of the database archived for future use in mapping the progression of the data over time. As shown in Figure 1, any individual data entry could be accesses and a "baseball card" of relevant information, including a graphic of the asset's orbit, would be provided. Finally, the feature of TLE exporting was added, which was a significant upgrade from the Excel-based database. With this new capability, users could query the database, generate a sub-set of relevant assets, and export their TLE data in the appropriate format to be included in any orbit propagation simulation. This made it possible to define a sub-set of elements and import them into high-fidelity simulations for detailed analyses, including orbital dynamics evaluation and conjunction assessments.
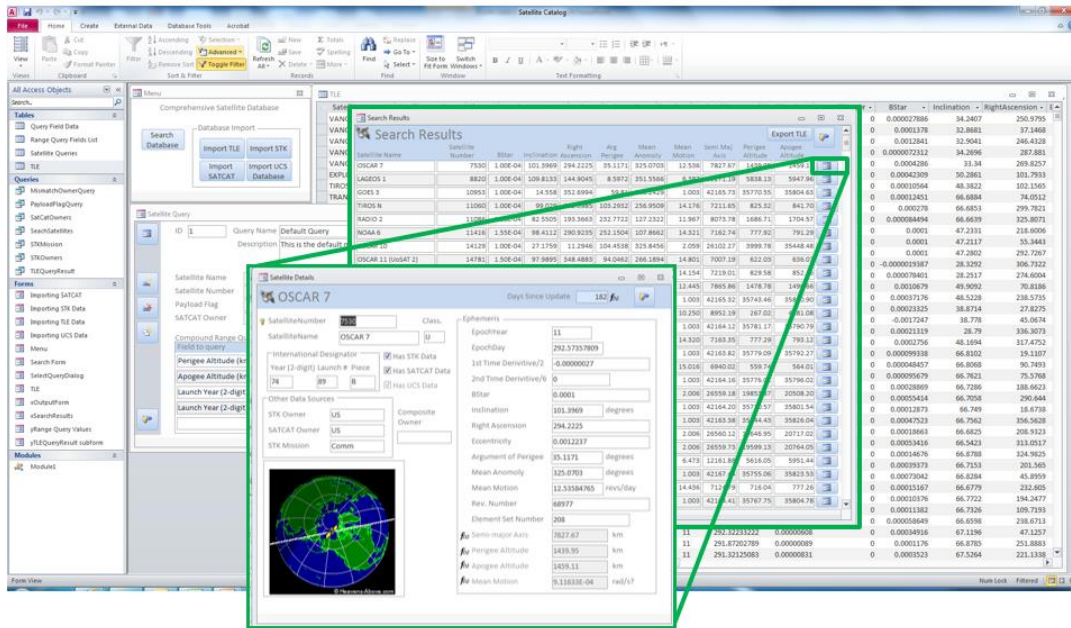

Fig. 1. The SAM-D Access Database

While the Access database provides some significant improvements, there remain limitations to its usefulness. The SSA community hopes to one day be able to track and assign unique identifiers to smaller objects in orbit. This population is significantly larger than the 39,000 objects cataloged to date. As the data set expands to include smaller objects, the size of the database will grow exponentially, and the Microsoft Access toolset is not scalable to that level. In addition, in order to encourage participation by a growing coalition of government and industry partners, the SAM-D must provide privacy protection in order to foster confidence that proprietary information will not be misused. Finally, in order to increase shared space situational awareness, SAM-D should be made available as a web service for use by a wide range of community partners.

For many problems in space situational awareness, making sense of the data requires complex calculation tools, including models and simulations that can be used to analyze and predict the behaviors of orbiting objects. Simulations and other computational models are essential to the effective use of space situational awareness data in predicting interactions between objects, and in developing launch and orbit maintenance plans for new and existing systems. In fact, modeling and simulation generally is the only strategy available to analyze and predict the behavior of N mutually interacting objects in a fluctuating gravitational and atmospheric environment. M&S provides a "virtual" representation of Earth space, and the objects moving through that space that can be used to augment our understanding of the data, and the future effects of additional changes to the situation. An improved SAM-D data architecture will support integration with various models and simulations to support these types of analyses. As new models and simulations are developed, both internally to NASA and by the global SSA community at large, they can be offered services deeply integrated into the SAM-D data architecture and available to all for enhancing the analysis capabilities for users. The remainder of this paper discusses the plans for creating just such a data architecture.

3.   A NEW SAM-D

The plan for the next generation of the SAM-D is to develop a microservices-based Service Oriented Architecture (SOA) system to provide an Internet-accessible implementation of the SAM-D. This system will be built using a scalable Database Management System (DBMS) capable of handling the data size and scale anticipated as the catalog expands. Publicly available web services will be exposed to allow integration with the entire community. The system will be powered by the SIMON platform, a Government off the Shelf (GOTS) information sharing platform designed to federate data and capabilities across enclaves while providing fine grained control to data owners – allowing them to determine exactly how and when their data is shared. We propose to also augment the SIMON platform with integrated analysis services, including sophisticated modeling and simulation technologies, to provide SAM-D users capabilities to evaluate and understand the behaviors of objects orbiting in the vicinity of the Earth, and to estimate effects of the Earth orbit environment on potential new missions.

3.1   Microservice Architecture Overview

In computing, microservices is a software architecture design pattern, in which complex applications are composed of small, independent processes communicating with each other using language-agnostic APIs.[7] These services are small, highly decoupled and focus on doing a small task. The concept of microservices have been gaining market share with large scale computing entities in both government and industry. Amazon and Netflix have based their infrastructure around this concept, and SRI has been a thought leader in the government arena with their SIMON platform. Decomposing services into their smallest functional units provide the ability to dynamically recompose them into new applications, maximizing reuse. The secondary benefit is that this approach provides for greatly reduced transition time, as components are already designed to run in the target enterprise environment.

At the heart of the use case described for an enterprise SAM-D is an enterprise data processing infrastructure. Data is collected from various providers (asset source databases) using a set of agents. A generic architectural view for this pattern is shown in Figure 2. In this configuration, each agent along the top understands the data collection API for a particular data provider (e.g. NORAD, ESA, or NASA sensor and data systems).   A set of data processing, enrichment, fusion and normalization services is made available as a set of decoupled services, including access to modeling and simulation tools that can provide common analysis functions and capabilities based on a variety of new and existing software.

These services can then be sequenced together by workflows to produce meaningful input into the Space Asset Service, as illustrated in Figure 3. Source data is saved off to a metadata catalog where it can be accessed later for forensic and investigative purposed. Complex queries can be composed by one or more domain workflow services to be posed to the reasoning agent. The results are formatted by the domain workflow for simplified graphical representation when viewed by the operator via a componentized widget set.
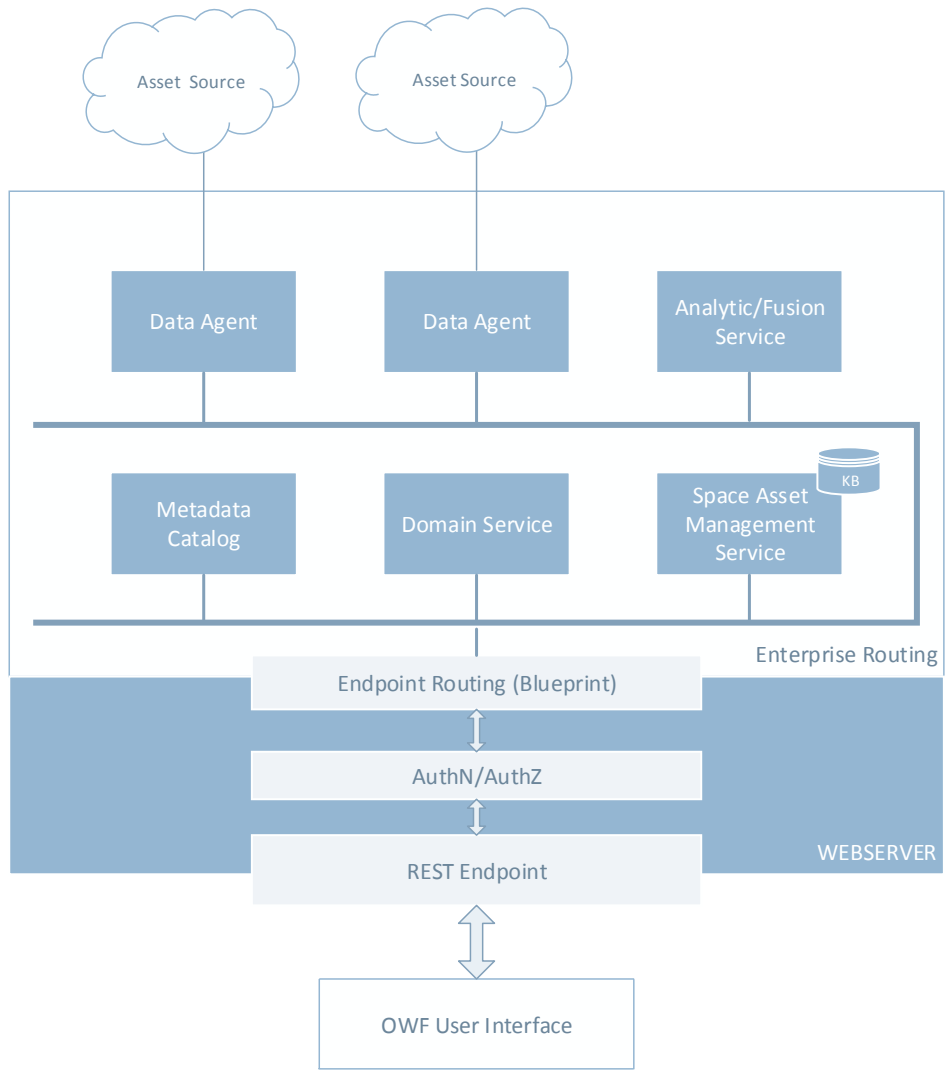
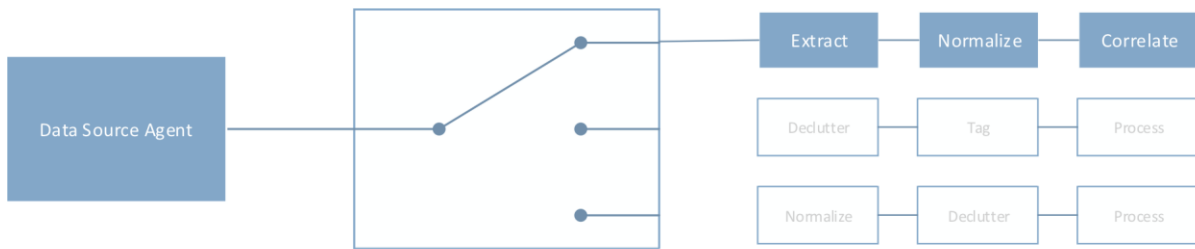Fig. 2. Microservice Architecture for Data Processing

Fig. 3. Content-based workflow for Incoming Data

3.2   Content Processing in a Microservice Architecture

Decoupled services implemented as described in the previous section are inherently composable since they perform a single function. A simple workflow can be utilized to sequence processing steps based on any number of scenarios, from the content of the incoming data to the destination point of the resultant set. Processing steps can

include anything from entity extraction, event detection and geo-tagging to high level fusion, integration and correlation algorithms. Implementing these workflows as a set of declarative assertions, or blueprints, allows for a highly dynamic processing infrastructure created from common enterprise toolsets.

If enterprise routes are configured to process incoming data and update the Space Asset Management Service's knowledge base, a simple domain service can be utilized to compose an end user application out of the set of complex queries available from the Space Asset Management Service. The pattern used here will be to model the user interface elements first from the operators view based on the scenario. This answers the questions 'What information needs to be on screen?' and 'How will the operator interact with that information?' These items will be identified and mocked in an iterative process between developer and subject matter expert. The service contract (or API) for the domain service can easily be derived from the UI mock-ups. This allows for the minimal set of business logic to be implemented in the domain service while still satisfying operator requirements. In order to fulfill the requirements of the SAM-D migration, the following set of components will be required.

> **Data Agents:** Responsible for the automatic collection of data from the source system. Collected data would be normalized and then placed onto the asynchronous messaging bus for further processing.

> **Fusion Service**: Responsible for the task of fusing (correlating) entities from multiple sources into single entities.

> **Analytic Services**: Services that would provide advanced analytic capabilities, including a variety of models and simulations that have been developed over the years, ranging from simple orbital analysis, to complex N-body problems, and sophisticated physics models incorporating high altitude atmospheric effects, ionospheric effects, effects on look-down sensors due to the environment, motion, and interactions with other objects. Note that many of these simulations require complex computer architectures and are often prohibitively expensive in time and resources to acquire and maintain over time. By providing these tools as part of the service architecture we are proposing, these advanced analysis tools can be made widely available to the user community at a reasonable cost per user. Integration of modeling and simulation services into the proposed SAM-D architecture is further explored in succeeding sections of this paper.

> **Space Asset Management Service**: Responsible for cataloging incoming assets and updates as well as for formulating responses to user initiated queries. Exposing a rich query set for user interactions, this is the primary service responsible for providing Space Situational Awareness.

3.3   Building an Information Sharing Community with SIMON

SIMON is a Government off the Shelf (GOTS) information sharing platform designed to federate data and capabilities across enclaves while providing fine grained control to data owners, allowing them to determine exactly how and when their data is shared. SIMON has been used to build operational situational awareness systems for US SOUTHCOM, DHS, the Naval Research Lab and others. It is also included as a part of DISA's Unclassified Information Sharing (UIS) portfolio. As such, it is uniquely positioned to fill this need as an information sharing platform with a proven track record of successful situational awareness system deployments.

When building a sharing eco-system within a given community of interest, partners are often reluctant to join out of concern for how their data is handled. A primary feature of the SIMON platform it that data owners maintain complete control of how their data is shared with other partners using policy based access control. This increases partner confidence that the data they contribute to the system will only be distributed based on their policy. Policy can be dynamically adjusted, which allows for rapid response to emerging threats, natural events or political alignments. This allows policy administrators to set standing policy and rapidly activate policy in response to changing conditions and sharing environments. Much of the data being handled in modern systems are governed by legal distribution and centralized sharing policy enforcement allows for strict auditing and control. This provides assurances to partners that sharing is being conducted in accordance with pertinent legal policy.

SIMON is a highly componentized framework created from microservices and built for rapid response. The modular nature of this approach allows for low cost integration into existing infrastructure. SIMON is a fully featured enterprise environment and can run as a stand-alone enterprise node. It has built-in identity management, access control, service hosting to allow it to run stand-alone or as a part of an existing enterprise. Built on industry and government community of interest approved data exchange and security standards, SIMON can easily connect to existing information providers. As a highly flexible microservices implementation, it is also easy to add new capabilities in response to emerging events. SIMON also runs in distributed mode, which makes it easy to construct deployable expeditionary systems for mobile situational awareness.

3.4   Modeling and Simulation in a SIMON Architecture

Modeling and Simulation (M&S) tools can greatly enhance the functionality and the utility of the SAM-D system for users of near-Earth space situational awareness data. With tools such as orbit generators and collision detectors, physical effects tools, mission planning tools, and other analytical services, the nuances of the data being collected as part of the space situational awareness data gathering activities can be appreciated and the value of the data to the SSA user enhanced. The SIMON architecture is well-suited to support the integration of M&S tools into the overall SAM-D architecture is a manner which is useful to potential users.

Figure 4 provides a notional SIMON architecture that illustrates the various data models and integration technologies that are inherent in the system. Of note are the two main sub-architectures integrated within the total SIMON environment: the Enterprise sub-architecture, and the Real-Time sub-architecture. The primary delineation (for purposes of the discussion with respect to M&S support in SAM-D) between the sub-architectures are the characteristics of the data communications implemented in each. The Enterprise sub-architecture is based on the classic client-server request/response model inherent in, among other technologies, web application and Service-Oriented Application (SOA) implementations. The Real-time sub-architecture is based on peer-to-peer streaming protocols and bi-directional data architectures. Both architectures provide capabilities that are needed to support a variety of modeling and simulation tools in multiple domains.
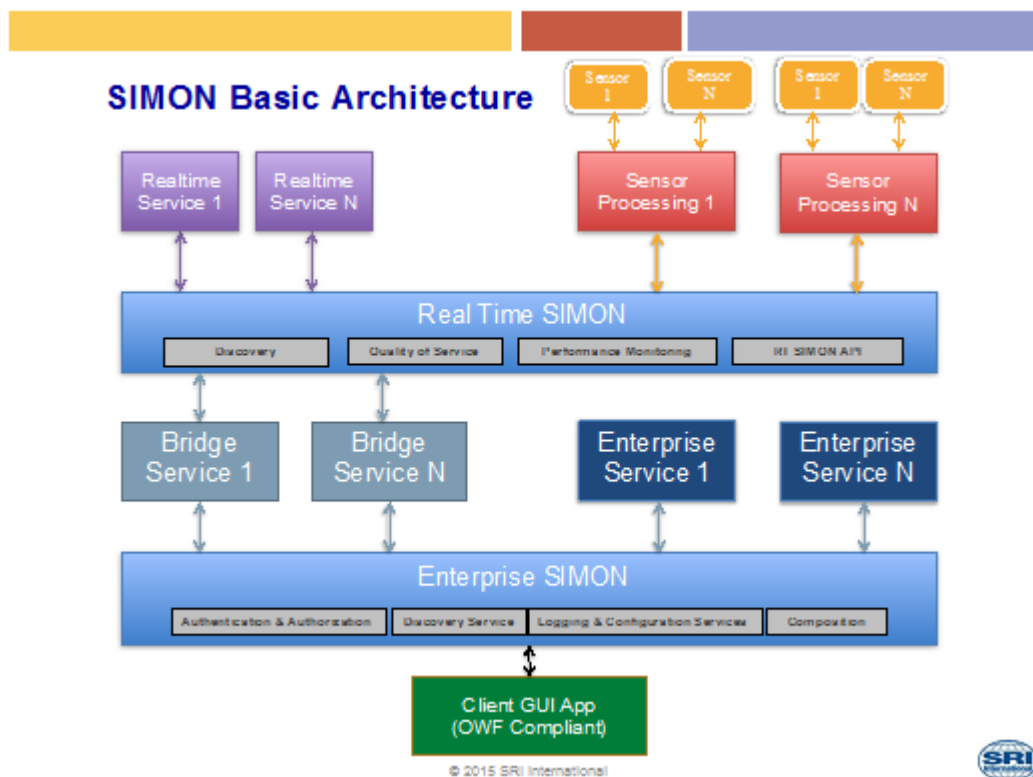

Fig. 4. A Notional SIMON Architecture

It should be noted the Enterprise sub-architecture does support a persistent connection protocol that is useful for connecting continuous data streams in some modeling and simulation tools with user-interface and other enterprise-oriented environments. These streaming protocols, such as the use of WebSockets and other web application protocols, model interactions that are primarily uni-directional, and are initiated by an initial request to a service provider with the architecture. The real-time protocols implemented within the Real-Time SIMON sub-architecture connect "peers" that do not necessarily require a request to initiate a response stream, but are oriented towards multiple bi-directional connections that allow continuous movement of data between cooperating processes.

Other notable features of the model outlined in Figure 4 include the bridge services that are used to connect the sub-architectures into a total integrated SIMON architecture. These bridge services play key roles in mediating data flowing through each of the separate environments implemented with SIMON. M&S bridge elements will play a key role in mediating access to simulation executions and the Enterprise and User-Interface applications that wish to interact with data streaming from the Real-Time sub-architecture.

3.5   Realizations of a SAM-D M&S Capability within SIMON

A potential realization of the abstract SIMON architecture illustrated in Figure 4 that would undergird the SAM-D system is illustrated in Figure 5. The developers envision that a variety of services will be defined that provide a multitude of capabilities to ingest and process space situational awareness data to meet user analysis and design needs.
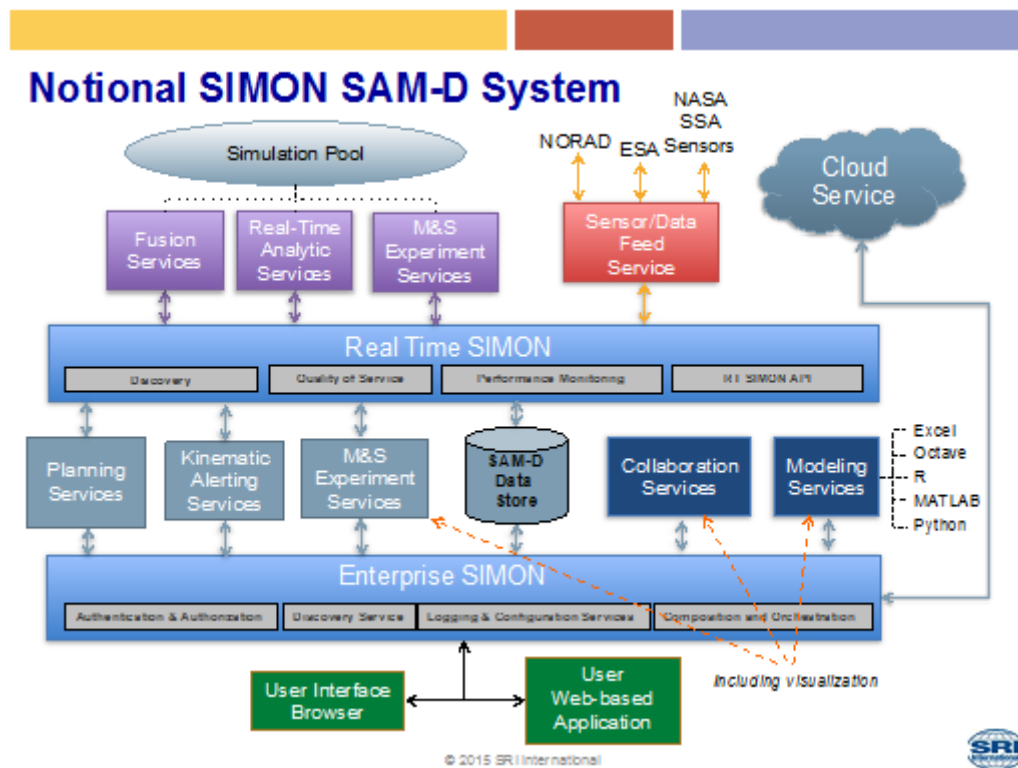

Fig. 5. Potential SIMON-Based SAM-D Architecture with Modeling & Simulation Additions

At the center of the architecture envisioned in Figure 5 is the SAM-D Data Store, which holds the archival data gathered from the data feeds, entered by users and other applications. Data ingested and generated within the environment will ultimately be stored in the Data Store. The Data Store is the primary data source for analytical, visualization, and collaboration services that are asked by the user. It is anticipated that there will be a variety of applications including planning services for mission planning, kinematic tracking and alerting services, and services that facilitate the development and execution of a variety of M&S-based experiments structures for use by the customer community to tailor a series of data-driven M&S-based experiments to address their specific analysis and synthesis needs. These services will need to bridge between the Real-Time and Enterprise sub-architectures in order

to provide access to the M&S data from simulation runs in combination with live data from the potential feeds and the information resident in the data store. The system must also provide a service interface to the Enterprise side for developing Enterprise applications using the data and an interface to the individual user.

Other key features the envisioned SAM-D architecture are the provisioning of an infrastructure that provides access to key information resources in the space situational awareness community, examples of which include NORAD, ESA, and organic NASA SSA sensors as they are developed and deployed. In addition, as shown in the figure, there are other data sources that are more amenable to access from the Internet ("cloud") that would be accessible from the Enterprise sub-architecture that could potentially provide additional characterization data for the orbiting components being tracked and analyzed by the SAM-D system.

As shown in Figure 5, there are two general characterizations of the models and simulations envisioned for support within the SAM-D architecture. These M&S tools allow for both quick, "back of the envelope" level calculations and data manipulation, as well as more sophisticated simulation capabilities that use expanded and higher-fidelity models of space object behaviors in the various regimes within the near-Earth environment to accurately calculate and illustrate the physical effects and subsequent behaviors of space objects under study.

The first set of models, shown in Figure 5 as "Modeling Services", use the SIMON Enterprise integration technologies to provide a series of capabilities to develop and use models. Actual capabilities will be defined by further interactions with potential clients, but this set of services includes the exposure of a variety of analysis tools already in use within the community (Excel, Octave, MATLAB, R, Python are examples). Since most of the most popular tools support a variety of user customizations, develop a standardized API package will be developed that can be used as the basis for development of SAM-D customizations for these tools to facilitate the interaction of the tool environments with the SAM-D data store, and other components of the SAM-D architecture, where it makes sense. Provision of these types of capabilities, implemented as micro-services using the SIMON architecture development process, will provide a wide variety of capabilities to the user to tailor their experiment and data analysis environment to address the problems under study.

The second set of simulations reside in the Simulation Pool and are comprised of a series of simulations that provide modeling of the complex environment of Earth orbit space, and the complicating factors that govern the behavior of the physical objects that are the subject of the space situational awareness collection and analysis activities. These simulations are characterized by the potentially large sets of resources required to complete the computations and potentially long computation times. Calculation of the space time evolution of the objects is one of the objectives of the analysis. The simulations in the Pool will be required to support both stand-alone and distributed simulation modes, depending on the requirements of the experiment. Infrastructures and data models based on the High Level Architecture (HLA) will be used as the integrating agent for bringing together simulation tools, run-time management tools, and run-time analytical tools into federations tailored to provide a variety of simulation architectures to meet a multitude of needs.

As shown in Figure 5, there will be SAM-D applications, as shown in the Fusion Service and Real-Time Analytical Services boxes that may need to use models and simulations as part of their processing. For example, a Fusion Service may need to decide if a new track or object introduced into the system could be a known object, with radically changed orbital elements, perhaps caused by a collision, or through a gravitational force exerted on the known object due to the introduction of a larger object into the space. The Fusion Service would most likely use existing data from the SAM-D store of objects, along with orbit calculation simulations, to determine if there is a correlation of new unknown to potential known objects.

The M&S Experiment Services, both in the bridge component, and in the real-time sub-architecture, are cooperating software components that are implemented to provide users with direct access to the simulation pool to design user experiment federations, initiate and manage federation executions, and to provide access to the results of the experimental runs. Figure 6 shows an expanded version of the SAM-D SIMON architecture, concentrating on the Simulation Pool and the associated exercise support components.

Potential SAM-D M&S Architecture
Separate HLA RTI
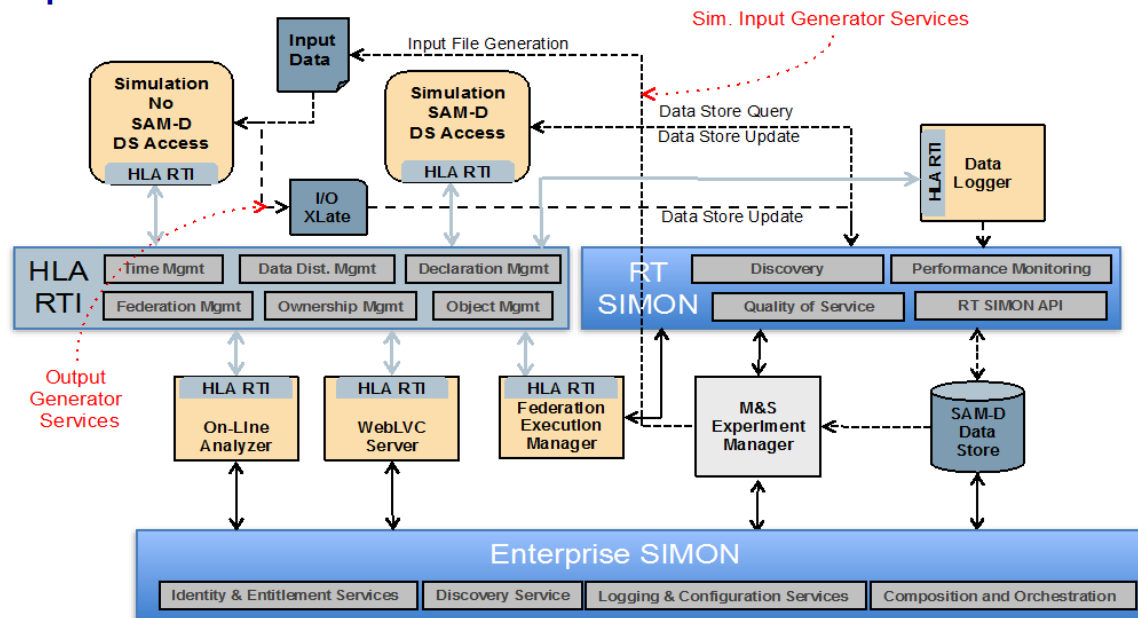
Fig. 6. SAM-D M&S with External RTI

In addition to the models and simulations that make up the simulation pool, the M&S Experiment services consists of the following services:

Experiment Management Service: A service designed to aid the user in developing an experiment design, and generating the artifacts necessary to carry out the experiment. The Experiment Management Service will help the user identify the data sets required from the SAM-D data store, as well as any other data sources such as the real-time data feeds needed for the experiments, as well as the data collection to be accomplished. The Service will also help identify the set of simulations and models needed to build the federation. The Service will generate a set of directives to be used by the Simulation Input Generator Service to generate appropriate input data sets where necessary from the data store, or to setup the necessary access queries for a specific simulation into the data store directly. The Experiment Management Service will also develop directives to the Output Collection Service to setup simulation data logging and post-processing activities to generate analysis output from the collected output. Finally, the Experiment Management Service will provide the directives required by the Federation Management Service to setup the federates comprising the experiment federation.

Simulation Input Generator Services: Services designed to generate input data sets for the simulations being used in an experiment. The Simulation Input Generator Services map the data contained in the SAM-D data store into the specific requirements for each simulation. This mapping is derived from the data models underlying the SAM-D data store, and Service plugins provided as part of each federate that does the actual data extraction and formatting for the subject simulation. The Simulations Input Generator Services host the plugins, and provide API access to the data store based on the data models for plugins to use to access data.

Output Collection Services: A service designed to generate output data sets that can be stored in the SAM-D data store architecture, as well as collect raw logs from simulation executions. Again,

using the SAM-D data store data models, the Output Collection Service uses plugins developed as part of the federates to extract required data from the output data sets and store them in the SAM-D data store. Federates could include simulations, and specialized run-time data loggers and analyzers that provide specialized in-line post-processing and analysis outputs.

Federation Management Service: A service to provide capabilities to automatically start up, monitor, and shutdown a federation of simulations and run-time tools. This service will initiate the HLA RTI infrastructure for a run (determine federation name, federate names, initialize the RTI, if required), or a set of runs, for instance to support a Monte Carlo set of replications; start the federates up; mediate the startup sequence, where required; and monitor the federation execution, providing status reports on progress, alerts if federates fail to behave as required, and other federation alert situations. A key requirement for the Federation Management Service will be to adjudicate and separate concurrently operating instances of different federations, and to maintain the mapping between individual experiments being conducted, and the federations that are being used to conduct each experiment.

Real-Time Federation Visualization and Data Analysis Services: A service that is a federate within a SAM-D federation that provides appropriate data to support a one-way transmission to user viewers, web browsers, and user-defined analysis software of selected data being maintained within a federation execution. These services sit between the HLA RTI messaging, and the Enterprise sub-architecture to provide a web stream of data to web applications and user browser sessions resident on the Enterprise sub-architecture. An example of a potential Federation Visualization Services, as shown in Figure 4, would be a WebLVC server that can operate as a HLA federate on one side, and convert the object updates and interactions into JSON packets that can be provided to web applications and web browsers via WebSockets for visualization using OWF-based browser visualization components. Also, as shown in Figure 4, on-line calculation services and data loggers that access federation data as HLA federates could also be developed using the interfaces to be provided as part of the SAM-D architecture.

Software that implements these types of services have been developed within the distributed simulation community. There are commercial implementations of many of these types of tools, and SRI personnel also have experience in developing these types of tools. The extent of the processing performed by these tools sets, especially the Experiment Management Service, and the level of interaction with the experimenter will need to be determined as the evolution of the SAM-D system proceeds.

Figure 6 illustrates a potential architecture for the simulation component of the SAM-D system that relies on the introduction of an external HLA RTI package as an adjunct to the Real-Time sub-architecture. If commercial RTI packages are considered for inclusion into the SAM-D system, this implementation methodology will be required since most, if not all, commercial implementations do not allow for substitution of the messaging level with the RTI implementation. However, as shown in Figure 7, using one of the several open-source RTI implementations, it is possible that the messaging layer within the RTI could be modified to use the SIMON Real-Time messaging protocols, and the RTI could be implemented with the SIMON architecture directly. This implementation approach would make the integration of all of the tools and services more direct, and total architecture would be less complicated in operation, since many of the SIMON services can be used as part of the execution services implementation.
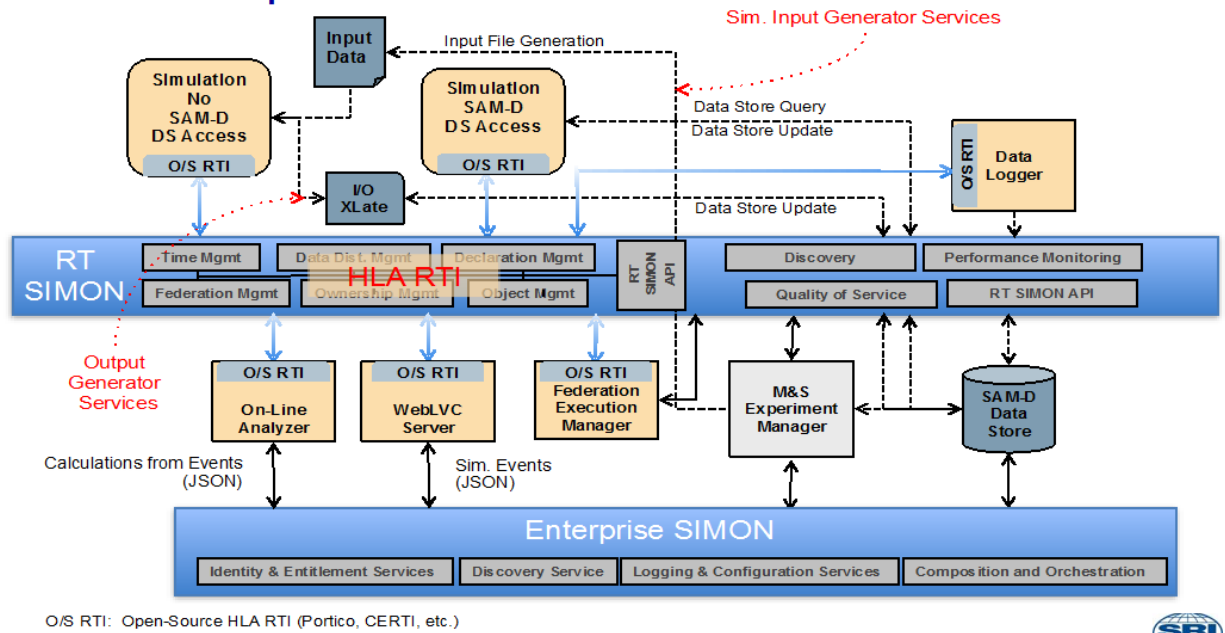
Fig. 7.   Open Source RTI using RT SIMON services

4. CONCLUSION

Access to a complete set of information related to the objects that orbit our planet is a key aspect of improving our current Space Situational Awareness. By combining several different data sources, the SAM-D has served as a one-stop-shop for tracked object technical information and metadata. In its initial and current forms, the SAM-D has provided a valuable service but it is recognized that the SAM-D is limited in its abilities and growth potential. Marshall Space Flight Center is continuing to pursue its goal of improving access to a wide range of space object data by integrating several different sources into one easy-to-search database. In order to realize that goal, a more capable data architecture must be implemented. A potential SAM-D architecture, based the SRI SIMON architecture, has been presented. This new data architecture incorporates a sophisticated modeling and simulation infrastructure that is consistent with the overall SIMON design philosophy and greatly expands the utility of the SAM-D. The new data architecture will also expand the capability to integrate data from many sources and will leverage policy-based access control to dynamically manage and protect data from this expanded community of interest. The envisioned set of capabilities will add significant value to the SAM-D system and will provide a level of analysis and synthesis capability that turns seemingly dissimilar information into a single, broad-reaching and understandable picture of space situational awareness for all interested parties.

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