The Ultimate Big Data Enterprise Initiative: Defining Functional Capabilities for an International Information System (IIS) for Orbital Space Data (OSD)

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ABSTRACT

Global collaboration in support of an International Information System (IIS) for Orbital Space Data (OSD) literally requires a global enterprise. As with many information technology enterprise initiatives attempting to coral the desires of business with the budgets and limitations of technology, Space Situational Awareness (SSA) includes many of the same challenges: 1) Adaptive / Intuitive Dash Board that facilitates User Experience Design for a variety of users. 2) Asset Management of hundreds of thousands of objects moving at thousands of miles per hour hundreds of miles in space. 3) Normalization and integration of diverse data in various languages, possibly hidden or protected from easy access. 4) Expectations of near real-time information availability coupled with predictive analysis to affect decisions before critical points of no return, such as Space Object Conjunction Assessment (CA). 5) Data Ownership, management, taxonomy, and accuracy. 6) Integrated metrics and easily modified algorithms for "what if" analysis. This paper proposes an approach to define the functional capabilities for an IIS for OSD. These functional capabilities not only address previously identified gaps in current systems but incorporate lessons learned from other big data, enterprise, and agile information technology initiatives that correlate to the space domain. Viewing the IIS as the "data service provider" allows adoption of existing information technology processes which strengthen governance and ensure service consumers certain levels of service dependability and accuracy.

1. INTRODUCTION

Multiple sources have documented the need and challenges of an International Information System (IIS) for Situational Awareness (SA) of Orbital Space Data (OSD) for orbital awareness objects [1][2][3][27]. Some of those needs and challenges involve the political and legal requirements to share data [4]. Enterprise Information Technology (IT) systems used for delivering services to customers face many complex challenges as well when scaled beyond a singular organization that has fiduciary responsibility for the "enterprise [5]."

When the primary service being delivered is data, an entirely new set of challenges exist as well [6]. This paper explores a novel approach to applying IT Service Management (ITSM) and other popular framework concepts to a big data system in support of the consortium concerned with OSD. The concept takes lessons observed if not learned from various large scale IT initiatives and begins where most meet the critical issues, sustainment. Large systems that spend the majority of effort and money designing and building complex systems without a solid plan and processes to maintain, operate, and enhance the system, inevitably reach critical mass where the system can't be maintained or enhancements can't rapidly be deployed.

The Open Systems Interconnection model (OSI model) is a conceptual model that characterizes and standardizes the communication functions of a telecommunication or computing system without regard to their underlying internal structure and technology [7].

Layer 1: Physical Layer
Layer 2: Data Link Layer
Layer 3: Network Layer
Layer 4: Transport Layer
Layer 5: Session Layer
Layer 6: Presentation Layer
Layer 7: Application Layer

Using the analogy of the OSI model, a layered approach to the enterprise architecture for delivery of IT Data Services will be defined.

Layer 1 - Core System Sustainment: IT Infrastructure Library (ITIL) (Service Strategy, Service Design, Service Transition, Service Operation, Continual Service Improvement) [8]

Layer 2 - Big Data: NIST Big Data Reference Architecture (NBDRA) and SSA Ontology / Taxonomy

Layer 3 - Cloud Service Provider (Physical Layer, Data Link Layer, Network Layer, Transport Layer, Session Layer, Presentation Layer, Application Layer)

Layer 4 - Data Provider (Data Link Layer)

Layer 5 - Data Life Cycle: NOAA baseline

Layer 6 - Agile Development: Scaled Agile Framework (SAFe), Microservices DevOps (Data Link Layer, Presentation Layer, Application Layer)

Layer 7 - Data Consumer (Data Link Layer, Presentation Layer, Application Layer)

2. CORE SYSTEM SUSTAINMENT

The benefits of following the ITSM framework most popularly recognized as ITIL processes identified within ISO 20000 has matured over the last decade [9]. That maturation has evolved into an integrated set of best practices and processes tuned to the business and technical life cycles for delivering and supporting services to customers. The Achilles heel of this framework is scaling beyond a singular enterprise. The generally accepted definitions of enterprise are: *1): a project or undertaking that is especially difficult, complicated, or risky; 2) readiness to engage in daring or difficult action: initiative showed great enterprise in dealing with the crisis; 3a)* ***a unit of economic organization or activity****; especially: a business organization 3b: a systematic purposeful activity: agriculture is the main economic enterprise among these people* [10].

For a singular enterprise such as universities, hospitals, corporations, and minimally complex government agencies, the definitions above can apply. However, to truly maintain governance and maintain consistent delivery of new and updated services, the "unit of economic organization or activity" is fundamental and missing when attempting to apply the concepts to multiple enterprises combined for a common goal. Inevitably, without a single governing entity, the one with the money makes the rules and sets the priorities for what is funded, when it is funded, and how. Within the ITSM framework, this is exposed at the interface between service providers to service consumers (customers) which are defined within Service Level Agreements (SLAs). Following ITSM framework, the customer does not care what is required to deliver the service, only that the service they want is delivered consistently within an agreed set of measurable metrics to accomplish their objectives. When one of the service provider enterprises is also a customer of the services, it is easy to see where the broader customer base needs may take a back seat to the individual customer needs of that enterprise.

Three key artifacts lay the foundation for governance and sustainability of ITSM service delivery: Service Level Agreement (SLA), Organizational Level Agreement (OLA) and the Underpinning Contract (UC).

- SLA: *An agreement between an IT service provider and a customer. A service level agreement describes the IT service, documents service level targets, and specifies the responsibilities of the IT service provider and the customer. A single agreement may cover multiple IT services or multiple customers.*
- OLA: *An agreement between an IT service provider and another part of the same organization. It supports the IT service provider's delivery of IT services to customers and defines the goods or services to be provided and the responsibilities of both parties.*
- UC: *A contract between an IT service provider and a third party. The third party provides goods or services that support delivery of an IT service to a customer. The underpinning contract defines targets and responsibilities that are required to meet agreed service level targets in one or more service level agreements* [11].

The only contracts exist with third party entities required to support service delivery such as Verizon, AT&T, Amazon, Google, etc. These UCs assure a certain level of negotiated and measured performance. That is easier from a single enterprise of economic organization or activity. That is nearly impossible between two or more enterprises with different business models, funding streams, nationality, etc. Likewise, within a single enterprise, many OLAs are needed to support delivery of multiple services. One can see the compounded complexity of OLAs and UCs with two or more enterprises delivering services to varied customers.

What if the ITSM framework was adjusted to better fit the needs of a global customer base for an Enterprise IIS (EIIS)? The "system" itself would follow the true ITSM framework objectives and generalized definition of an enterprise where a singular economic organization performs the activities to assure service delivery and meeting customer SLAs within OLAs and UCs. This EIIS would require adjustments to traditional OLAs with data providers. Since the enterprise would only exist to deliver services and not be required to have the expensive infrastructure to support internal customers, there would be no traditional internal customers. Potentially a new System Usage Agreement (SUA) would be defined to govern behavior of privileged "individual customer" users of the EIIS related to standardization, data usage, configuration management, etc. The paradigm shift in this adjusted view on ITSM would be to introduce a Consortium perspective for what has been mislabeled as enterprise of enterprises. The OLA would need to be redefined for the Consortium (C-OLA). Adjusting the ITIL definition - *An agreement between an IT service provider (EIIS) and another part of the same* ***CONSORTIUM*** ~~organization~~.

3. CONSORTIUM

A generally accepted definition of consortium: *an agreement, combination, or group (as of companies) formed to* ***undertake an enterprise beyond the resources of any one member****. A consortium of researchers decoded the honeybee genome* [12]. The community of parties interested in an IIS for OSD would certainly fit the consortium definition. Separating organizational enterprises out of the constructs needed to maintain the EIIS life cycle aligns the governance and management processes for success. Defining a functional capability for the EIIS to provide all available data through a standard SLA for the controlled consortium user group would force C-OLAs to be written with language provided by data that will be available for consortium use. Should a provider of data to the consortium not want to share certain elements of the data set, it is upon the provider to not provide that data thus simplifying the EIIS access controls.

This new construct now opens opportunities for the EIIS consortium members to realize the cost effective and efficient delivery of IT services. SSA of OSD can require significant data storage and computing power. Researchers, owners, and other interested consortium members could be decoupled from the expensive commitment of IT infrastructure required to store and process large data sets. Leveraging cloud capabilities and enterprise tools, more energy could be applied to "what" the problems are and "how" to solve them, and less to "what" is needed to be acquired and maintained to support solving the problem along with associated infrastructure costs.

Segmenting the OSD into "portfolios" would align SSA communities of interest with the ITIL activity of "Service Portfolio." *A Service Portfolio describes the services of a provider (internal, outsourced, etc.) in terms of value to the business.* The business of the EIIS would be to provide SSA data services. *The Service Portfolio covers 3 subsets* [13]:

- *Service Catalogue - The part of the Service Portfolio that is visible to Customers. It provides an overview of the services that are delivered by the service provider.*
- *Service Pipeline - Is made up of all services that are either under consideration or in development for a specific customer or market. This pipeline details the growth for the future.*
- *Retired Services - Services that are withdrawn or are to be phased out. Phasing out is part of Service Transition so there is overlap between the processes.*

Through establishment of an EIIS following ITSM best practices in support of the SSA Consortium, the IT would become utility allowing more effort to be focused on the Consortium level Big Data challenges.

4. BIG DATA

Big Data typically is characterized by data sets of terabyte size and above. The SSA Consortium truly has a Big Data challenge when defining EIIS requirements to handle 20,000 plus objects with multiple data sets for SSA of OSD. The ability to easily share and not transfer these data sets would be a functional requirement of the EIIS. Collaboration is significantly hampered if the data sets are too large to move from one members system to the collaborative partners system. The National Institute of Standards in Technology has produced a significant baseline of big data artifacts through their Big Data Public Working Group [14].

> ***Big Data*** *consists of extensive datasets - primarily in the characteristics of volume, variety, velocity, and/or variability - that require a scalable architecture for efficient storage, manipulation, and analysis.*

Big Data refers to the inability of traditional data architectures to efficiently handle the new datasets. Characteristics of Big Data that force new architectures are:

- *Volume (i.e., the size of the dataset);*
- *Variety (i.e., data from multiple repositories, domains, or types);*
- *Velocity (i.e., rate of flow); and*
- *Variability (i.e., the change in other characteristics)* [15].

The design of the EIIS could leverage the *NIST Big Data Interoperability Framework: Volume 6, Reference Architecture* to define functional and operational requirements [16].

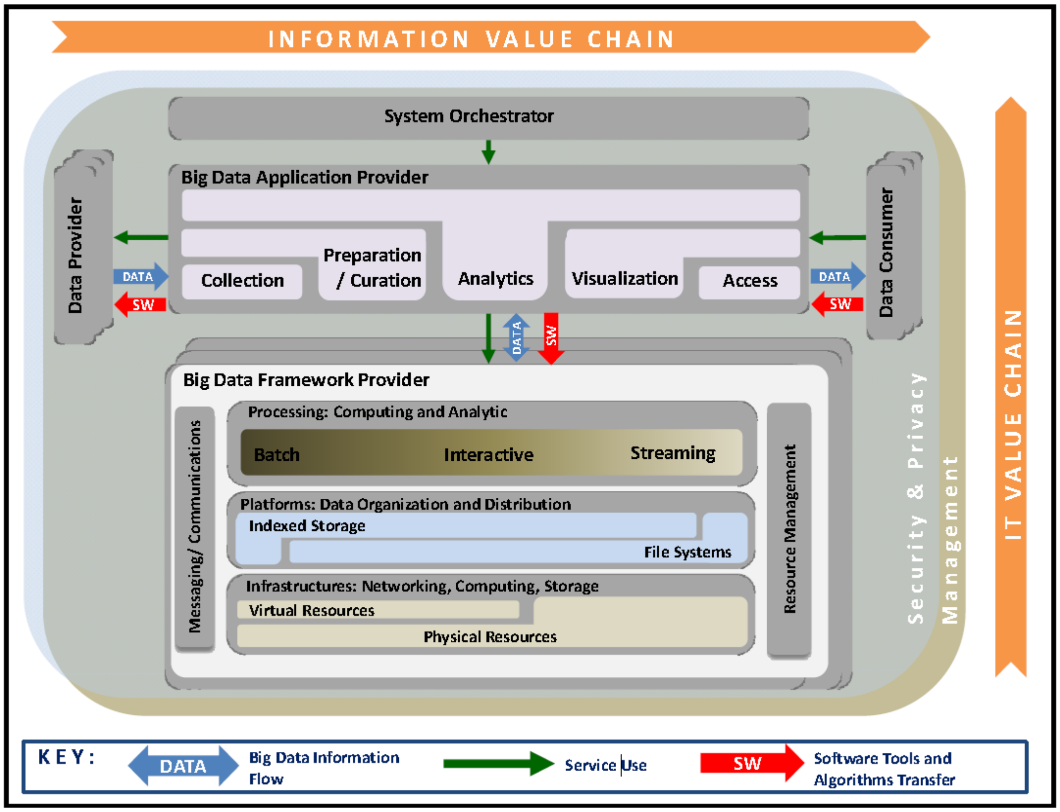

Fig. 1. NIST Big Data Reference Architecture (NBDRA) [16]

Designing the operations of the EIIS to follow the ITIL processes, the Data Provider to the EIIS would have OLAs defining the data sets provided while SLAs would support the Data Consumers. Third party cloud support to the EIIS would use UCs to support those SLAs. Cloud providers could provide a multitude of "as a Service" capabilities to the EIIS Consortium users base such as Platform, Software, Infrastructure, etc. Some capabilities mapped into the NBDRA might be:

1) Visualization such as an Adaptive / Intuitive Dash Board that facilitates User Experience Design for a variety of users.
2) Collection for Asset Management of hundreds of thousands of objects.
3) Preparation and Curation for normalization and integration of diverse data possibly in various languages.
4) Big Data Framework Provider to meet expectations of near real-time information availability.
5) Analytics support to affect decisions before critical points of no return, such as Space Object Conjunction Assessment (CA).
6) System Orchestration governing data ownership, data management, taxonomy, and accuracy.
7) Big Data Application Provider providing integrated metrics and easily modified algorithms for "what if" analysis.

Research on the ontology and taxonomy of the space situational awareness domain provide functional capability considerations for both the big data architecture and data life cycles. It has been suggested the SSA domain is inclusive of, "the processes by which we achieve that awareness, such as observation, detection, identification, tracking, and prediction/propagation of space objects, their orbits and trajectories; as well as phenomena in the space environment [27]." The EIIS by contrast is the enterprise scoped by ***a unit of economic organization or activity***. The consortium owned and managed tools such as those used for observation, detection, and tracking would be data providers to the EIIS. The reference architecture allows for integration of consortium systems in addition to data provisioning where UCs could be reached. Some of those consortium owned and managed tools include [27]:

- International Scientific Optical Network (ISON)
- Canadian Space Surveillance System
- Russian Space Surveillance System
- Chinese Space Surveillance System
- Space Data Association

Managing user expectations of access and timeliness, some data could be pulled directly from the data provider and stored during analysis, or stored for longer periods of time to build larger data sets. Larger data providers could be integrated as Big Data Framework Providers within the EIIS, while maintaining the OLAs for usage, access and performance.

5. CLOUD SERVICE PROVIDER

Several established cloud providers are available globally to support an EIIS. *A cloud provider is a company that offers some component of cloud computing – typically Infrastructure as a Service (IaaS), Software as a Service (SaaS) or Platform as a Service (PaaS) – to other businesses or individuals. Cloud providers are sometimes referred to as cloud service providers or CSPs* [17]. Reliability and security are crucial requirements for the EIIS in the choice of CSP. Top CSP options in 2017 include: Amazon Web Services, Microsoft Azure, Google Cloud Platform, IBM Cloud, Rackspace, GoDaddy, VMware, Oracle Cloud, 1&1, and DigitalOcean [18]. Availability of Amazon Web Services for example, "The AWS Cloud operates 44 Availability Zones within 16 geographic Regions around the world [19]," could allow rapid operational capability to be deployed globally.

HADOOP could be a big data architecture deployed in support of the EIIS. Using CSPs for such an architecture would allow the physical system to expand and contract based on need without the dedicated financial commitment of a traditional data center solution. *The Apache Hadoop software library is a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models. It is designed to scale up from single servers to thousands of machines, each offering local computation and storage. Rather than rely on hardware to deliver high-availability, the library itself is designed to detect and handle failures at the application layer, so delivering a highly-available service on top of a cluster of computers, each of which may be prone to failures.* [26]

One can see the benefits of using a CSP over traditional data centers for a global SSA consortium of users and data providers when deploying new and enhanced capability to various locations around the world could happen within days or even hours. Structuring the EIIS as a standalone enterprise supporting the SSA consortium would further reduce the time required to manage requests from such a varied and geographically separated membership.

6. DATA PROVIDER

***Data Provider**: Introduces new data or information feeds into the Big Data system* [16];

The EIIS would have a baseline set of data provider requirements identified within the NBDRA:
DATA PROVIDER REQUIREMENTS

- *DSR-1: Reliable, real-time, asynchronous, streaming, and batch processing to collect data from centralized, distributed, and cloud data sources, sensors, or instruments*
- *DSR-2: Slow, bursty, and high throughput data transmission between data sources and computing clusters*
- *DSR-3: Diversified data content ranging from structured and unstructured text, documents, graphs, websites, geospatial, compressed, timed, spatial, multimedia, simulation, and instrumental* (i.e., system managements and monitoring) data [16]

"The U.S. Air Force needs processed, commercial Space Situational Awareness (SSA) data for operational use," the Nov. 4 request for information said. "SSA data must originate from non-DoD sensors and be validated on commercial systems outside of the Department of Defense network. [20]*"*

Four of the seven data providers are networks that DARPA has developed to integrate SSA data from specific communities of interest:

- *StellarView, which uses optical telescopes and passive radio frequency (RF) telescopes at six academic institutions*
- *SpaceView, which uses privately owned optical telescopes*
- *EchoView, in which DARPA is developing the technology to leverage commercial and civil radars and passive RF telescopes*
- *The Low Inclined LEO Object (LILO) detection effort, which is deploying a suite of optical telescopes to Ascension Island in the South Atlantic Ocean to improve detection of space objects in equatorial orbits*

Three commercial and government networks are providing data on a fee-for-service basis:
- *ExoAnalytic Solutions, a commercial network of optical and passive RF telescopes*
- *Raven, a U.S. government network of small optical telescope systems composed of inexpensive commercial off-the-shelf (COTS) components under development at the Air Force Research Laboratory (AFRL)*
- *Rincon, a commercial network using passive RF telescopes* [21]

52 Nations Have Space Interests [22]

An EIIS would need to be consortium "owned" and managed by a single entity to ensure availability of data services to all members as well as transparent governance of the system and the data provided.

7. LIFE CYCLES

Key to the management of any IT system are clearly defined life cycles to properly plan, develop, manage configuration and change, operate, and meet various provider / consumer expectations. The EIIS set of life cycles will have to integrate and adapt with the life cycles of data providers and other dependent systems. The EIIS following the processes and life cycles of ITIL can establish the rhythm to maintain the "system" while a data life cycle would define the end services users would consume. That is to say the designed and operating EIIS would receive requests for change driven by new or enhanced data requirements from data consumers and providers. "Significant" changes would be those requiring change to the core EIIS while "Operational" changes would be those performed during normal operation. Designed properly, adding additional computing, and storage would be operational changes to meet temporary or long tern big data requirements. The ability to rapidly deploy a tool to perform analysis would be an operational change; adding additional frameworks would be a significant change. A functional requirement of the EIIS would be a capability to facilitate agile development and deployment of tools to connect with data sources and perform analysis.

The EIIS should adopt the functional requirement of following the NIST data life cycle management requirements [16].
- *LMR-1: Data quality curation, including preprocessing, data clustering, classification, reduction, and format transformation*
- *LMR-2: Dynamic updates on data, user profiles, and links*
- *LMR-3: Data life cycle and long-term preservation policy, including data provenance*
- *LMR-4: Data validation*
- *LMR-5: Human annotation for data validation*
- *LMR-6: Prevention of data loss or corruption*
- *LMR-7: Multisite (including cross-border, geographically dispersed) archives*
- *LMR-8: Persistent identifier and data traceability*
- *LMR-9: Standardization, aggregation, and normalization of data from disparate sources*

The National Oceanographic and Atmospheric Administration (NOAA) Environmental Data Management Framework data life cycle is an extension of the NIST data life cycle. Development of the EIIS life cycle could build from NOAA's as a baseline.

Table 1: NOAA Phases and Activities in the Data Life Cycle [23]

Planning and Production	Data Management	Data Usage
Requirements Definition	Collection	Discovery
Planning	Processing	Reception

Planning and Production	Data Management	Data Usage
Development	Quality Control	Understanding
Deployment	Documentation	Analysis
Operations	Cataloging	Value-Added Products
	Dissemination	User Feedback
	Preservation	Citation
	Stewardship	Tagging
	Usage Tracking	Gap Assessment
	Final Disposition	

It has been suggested that SSA data life cycle includes at least [27]:

A. Observation of the space environment,
B. Identification and Tracking of space objects in that environment,
C. Accumulation and analysis of Data, and
D. Knowledge discovery that ideally is actionable

Additionally, applying ontology to the SSA domain, additional functional requirements within the SSA data life cycle include [27].

- S1 - Identify
- S2 - Domain Research
- S3 - Demarcation
- S4 - Vocabulary/Terminology
- S5 – Definitions

One can see the development of the EIIS data life cycle following a reference architecture, application of the reference architecture, SSA domain specific requirements, and implementation specific operational requirements to meet consortium user capability needs.

8. AGILE DEVLEOPMENT

Agile "*…early delivery of business value. That involves early and regular delivery of working software, a focus on team communications, and close interaction with the users* [24]."

Agile software development evolved to incorporate the customer on the development team to build small capability releases in short time frames. That was the opposite of a waterfall development approach where one step had to be completed before the next could be executed. Requirements were the stumbling block in waterfall development. Often the majority of time and money were expended before any capability could be delivered. That is not to say Agile development does not design and build against requirements. Agile excels through the incorporation of the customer on the team to help work out the requirements, one capability at a time. Within an EIIS, designing into the core system the ability to execute Agile Development techniques, such as Scaled Agile Framework (SAFe) or DevOps, one could continuously design, build, test, and deploy new capability without affecting the core system.

Microservices are another example of an Agile Development capability. *Microservices - also known as the microservice architecture - is an architectural style that structures an application as a collection of loosely coupled services, which implement business capabilities. The microservice architecture enables the continuous delivery/ deployment of large, complex applications. It also enables an organization to evolve its technology stack* [25]. An example is a Java based microservice architecture with a simplified module reuse and / or design and execution by the trained user to connect data sources, perform analysis, and generate reports. Another example is to connect a set of modules to continuously run and report only when certain conditions were met.

Functional requirements of the EIIS would be infrastructure, applications, frameworks, and services to facilitate development in support of SSA data. (For example, Integrated Development Environments (IDE), software version control, test suites, and isolated development and test environments.)

9. DATA CONSUMER

> ***Data Consumer:*** *The Data Consumer receives the value output of the Big Data system. In many respects, it is the recipient of the same type of functional interfaces that the Data Provider exposes to the Big Data Application Provider. After the system adds value to the original data sources, the Big Data Application Provider then exposes that same type of functional interfaces to the Data Consumer* [16].

The EIIS would develop capability requirements form the data consumer requirements defined within the NBDRA as a baseline:

- *DCR-1: Fast searches from processed data with high relevancy, accuracy, and recall*
- *DCR-2: Diversified output file formats for visualization, rendering, and reporting*
- *DCR-3: Visual layout for results presentation*
- *DCR-4: Rich user interface for access using browser, visualization tools*
- *DCR-5: High-resolution, multidimensional layer of data visualization*
- *DCR-6: Streaming results to clients* [16]

10. CONCLUSIONS

The intent of this paper was to present the SSA community with a different perspective on the functional requirements and capabilities of an international information system providing OSD as a service. Focusing on the end service to the user, and the frameworks and architectures required to design and sustain the system has illustrated this is not a new problem. However, to manage the scale of the problem, it can be divided into manageable modules which have defined architectures, processes, and industry best practices to facilitate a solid SSA EIIS solution. Intentionally, the focus was on enterprise IT and data, not specific SSA domain detail and issues. Those details and issues are non-trivial and require further examination to formalize an SSA EIIS capability design document. Likewise, some issues are not technical; further examination is needed to consolidate the various constraints, laws, and other challenges of a political nature.

The layered approach presented suggests an ITIL framework that sustains the system as an enterprise servicing the SSA consortium, could adapt to the needs of the users. Leveraging the work of NIST for a Big Data Reference Architecture greatly reduces R&D of the final system design. Using cloud service providers greatly increases the speed at which a system could be deployed, changed, and enhanced. Further research is needed to explore the cost to benefit ratio of using cloud services for SSA data storage and processing needs. Designing the EIIS with separate core system management processes, while incorporating agile development activities at the user level, facilitates timely solutions to various user needs.

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