SpaceOps Conferences
28 May - 1 June 2018, Marseille, France
2018 SpaceOps Conference

10.2514/6.2018-2403

Ground Enterprise Evolution at NESDIS

Steven R. Petersen[1]
National Ocenaic and Atmospheric Administration, Silver Spring, MD, 20910

This paper describes major changes in the architecture and capability of the Ground Enterprise that operates and sustains the National Oceanic and Atmospheric Administration's (NOAA's) weather satellites. Operated by NOAA's National Environmental Satellite Data and Information Service (NESDIS), the Ground Enterprise supports satellite systems in both polar and geosynchronous orbits. These include the legacy Polar Operational Environmental Satellite (POES) and Geostationary Operational Environmental Satellite (GOES) systems as well as the new Geostationary Operational Environmental Satellite Series R (GOES-R) and Joint Polar Satellite System (JPSS) systems. Additionally NESDIS participates with domestic and international partners in satellite operations, product generation, and distribution involving a variety of platforms. Analysis over the last three years defined an evolved architecture for the Ground Enterprise that integrates its elements together for greater effectiveness and efficiency. Based on common services, the evolved architecture complements the strengths of the new GOES-R and JPSS Ground systems with investments to modernize the remainder of the existing infrastructure. These changes will enable the Ground Enterprise to process and distribute new sources of data with greater agility, flexibility, and efficiency at reduced cost. They also provides economies of scale across the entire enterprise. This paper describes the translation of the architecture analysis into time-phased investment plans. These plans address the migration to a set of Enterprise Algorithms based on common physics implementations, a modernized data archive potentially leveraging the cloud, shared Product Generation and Distribution Services for more efficient operations, and a Mission Science Network to promote greater collaboration across the science community. The paper also describes the status of initial investments in mission support tools.

I. Background

The National Environmental Satellite Data and Information Service (NESDIS) acquires, operates, and sustains geosynchronous and polar weather satellites for the National Oceanic and Atmospheric Administration[1]. These platforms provide key observations for the National Weather Service and a variety of other US users and international partners. Historically, due to partnerships and acquisition strategies, NOAA's satellite missions have been developed as stovepipe systems. Over the last two years NESDIS launched the first two satellites in the new Geostationary Operational Environmental Satellite Series R (GOES-R)[2], now known as GOES-16 and GOES-17, as well as the first satellite of the new Joint Polar Satellite System (JPSS)[3], now known as NOAA-20. With these launches NESDIS began full operation of the two new ground segments developed to support them. These systems joined the infrastructure previously fielded to support legacy Geostationary Operational Environmental Satellite (GOES) and Polar Operational Environmental Satellite (POES) systems, which are still operating and forecast to flyout in the 2020s, as well as other NESDIS and partner missions. NOAA's stovepipe architectures supporting the legacy GOES and POES satellites provide limited sharing of common standards, services or functionality. These systems generally use dedicated component resources crafted to perform solely one mission. While these legacy designs are well-thought out and generally perform their intended functions well, they frequently lack provisions for sharing with other missions that need similar services. This has led to high acquisition costs in the aggregate due to redundant functionality with each new program and high operations and maintenance costs. The two new ground systems offer improved architectures that leverage some common services; however, they have been fielded as mostly stand-alone capabilities that do not interface with each other nor fully share common support infrastructures.

[1] Director, Office of Satellite Ground Services, NESDIS, 1315 East-West Highway, AIAA Senior Member.

II. Organization

In January 2015 NESDIS activated the Office of Satellite Ground Services (OSGS)[4]. OSGS was created to centralize development and sustainment of NESDIS satellite ground capabilities. OSGS leads the transition to an Integrated Ground Enterprise (IGE) that offers cost-effective, secure, agile, and sustainable support for NESDIS missions. The IGE consists of the new GOES-R and JPSS ground segments, elements of the legacy capability, and targeted new investments. The ultimate goal is to never again buy an entire new ground system for future satellite constellations. The remainder of this paper describes how OSGS and the other NESDIS offices are executing this transition. The role of the Concept of Operations[5] and the process used to create the Enterprise Architecture are illustrated in some detail, as these items can be employed by any organization seeking to transform itself. When fully developed the IGE will provide a suite of common ground services enabling (1) reduction of mission ground systems costs and (2) accelerated deployment of capabilities. In the process NESDIS will position itself as a data provider or data engine that leverages an IT-centric approach echoing modern IT concepts more closely aligned with Silicon Valley constructs than traditional Aerospace industry solutions.

III. Top-Level Objectives and Approach

Mission ground system costs will be reduced and deployment speed will be improved by 1) Eliminating redundant acquisition and development of common ground system functionality; 2) Sharing common but underutilized infrastructure resources across satellite programs and implementing standards for future development; and 3) Streamlining ground operations by eliminating redundant operations and embracing automation to require fewer support staff.

Planning for the transition to the IGE is accomplished through three sets of activities: 1) Development of an overarching IGE Concept of Operations and a set of Level 1 requirements (completed); 2) Development of an Enterprise Architecture describing the current and to-be IGE states (95% complete), and 3) Development and implementation of investment plans to transform the enterprise from its current state to the full IGE (in work). Figure 1 below illustrates the NESDIS Ground Enterprise.

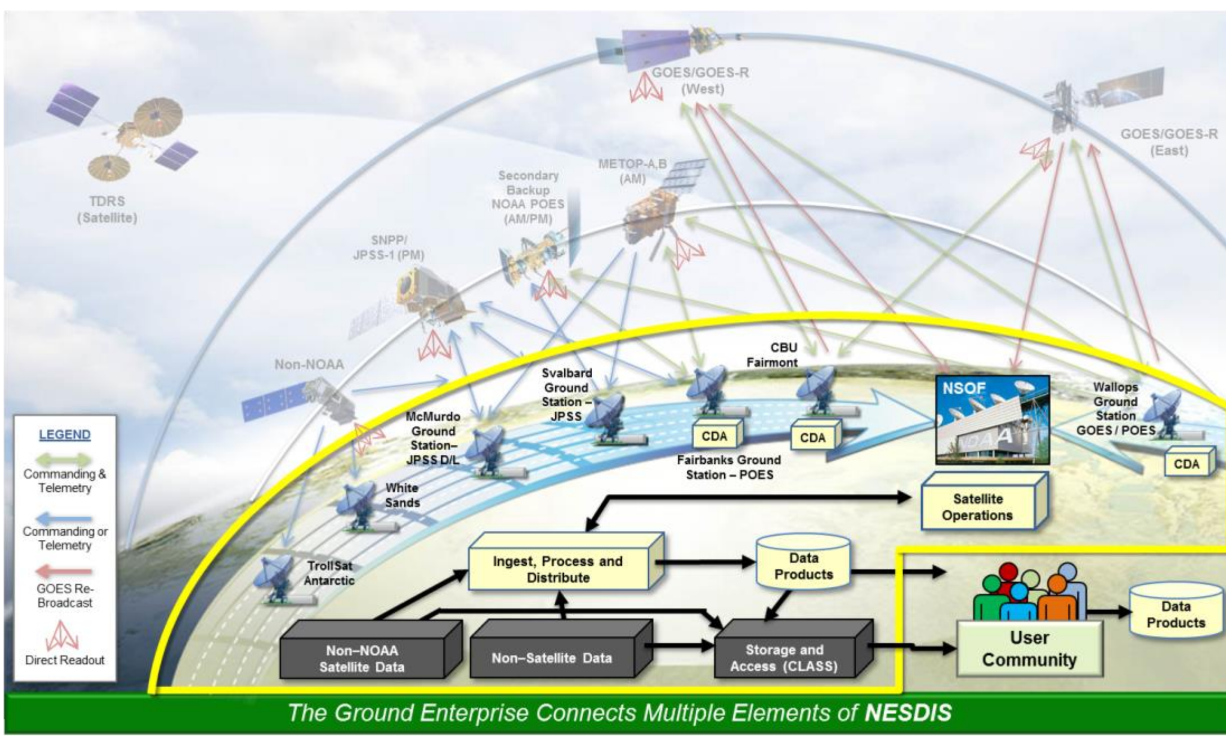

Figure 1. The NESDIS Ground Enterprise[6].

IV. Concept of Operations and Use Cases

The IGE Concept of Operations was completed in February 2015. It describes the capabilities and attributes that the future Integrated Ground Enterprise (IGE) will possess and illustrates the application of these capabilities and attributes across 12 use cases. It provides the fundamental rationale for creating the IGE. Table 1 below describes the capabilities and attributes of the IGE.

Table 1. Capabilities and Attributes of the IGE Concept of Operations[7]

Capability / Attribute	Description
Enterprise Governance	IGE is a shared resource that stretches across all of NESDIS and is governed as an enterprise resource; all stakeholders have a voice.
Enterprise Management	Capabilities include situational awareness (health and status) and the ability to move resources from one use to another.
Enterprise Funding	All using organizations provide baseline IGE requirements and NESDIS requests the necessary funding.
Shared Infrastructure	An infrastructure of network, compute, storage and software resources are shared and dynamically managed to meet NESDIS requirements. This maximizes resource utilization, improves operational flexibility, & reduces O&M costs through standardization.
Ubiquitous Data Access	IGE provides a MetaData Registry describing available data and how to access it. The IGE data access architecture includes data from non-NOAA satellites, data from non-satellite sensors (e.g., in-situ sensors), as well as external data.
End-to-End Lifecycle Data Management	Data management includes acquisition, quality control, validation, reprocessing, storage, retrieval, dissemination, and long-term preservation activities. IGE provides common services for many elements of the process.
Isolation of Impacts	IGE provides separations between the users of the shared resources. IGE also enforces isolation of impacts by use of controlled interfaces.
Hardware Agnostic	IGE supports infrastructure as a service (IaaS). This approach breaks the dependency between hardware and software.
Location Agnostic	IGE is a distributed system where functionality may be implemented anywhere and migrate to new locations without impact to the users. This improved resource management, continuity of operations (COOP) and failover functionality.
Acquisition Approach Agnostic	IGE enables a range of acquisition approaches for adding additional resources, capabilities or applications.
Service-Oriented Approach	In the IGE service-oriented architecture (SOA) every IT resource is accessible as a service. Each service is discrete and interacts with the enterprise through defined interfaces, so service implementations can be changed with limited impact to the enterprise.
Maximum Reuse of Common Services	Missions are incentivized to reuse existing services instead of creating redundant functionality, and common services are well documented in an enterprise registry. By policy and contract the Government will own full data rights for all IGE common services (except for Commercial Off The Shelf (COTS) components). This includes the full source code and unlimited rights for reuse at no cost.
Use of Standards	IGE resources, interfaces, data and metadata formats use non-proprietary standards, with preference for International or consortium-based standards that have broad deployment and proven success. This avoids expensive dependencies on single vendor solutions.
Support for Automation	IGE provides workflow automation, rules engines and other automation tools as common services.
Security as Infrastructure	IGE provides information security as an integral feature of the infrastructure and meets NIST security requirements.

Warehousing and Restoring	Warehousing saves the current state of a user's profile and resources to storage so that the resources can be freed for other users.

The twelve use cases in the Concept of Operations illustrate the benefits of the IGE approach to all major groups of stakeholders, from application developers to operators to end users. The goal is to socialize the benefits of the IGE and enable all stakeholders to see themselves within the new construct. Table 2 lists the use cases.

Table 2. Concept of Operations Use Cases[8]

Use Cases
Routine Satellite Operations
Integration of a New Satellite Mission
Transition of a NASA Research Satellite Mission to NOAA Operations
Integration of an External Data Source
New Data Product Requirement
New Algorithm Development
Algorithm Sustainment
Calibration and Validation (Cal/Val) Support
Governance of Common Services
Automation of a Ground system Function
Adding a New Common capability to IGE
Reprocessing

Compared to the existing stand-alone approach, the IGE Concept of Operations brings significant impacts to traditional approaches to design, development, sustainment, operations, security, and staffing. Table 3 lists some of these impacts.

Table 3. Impacts of Adopting the IGE Concept of Operations[9]

Impact	Description
Government Integrator and Infrastructure Provider	In a traditional acquisition a prime contractor provides an end-to-end system, integrating together its elements. With IGE the Government provides infrastructure resources and has greater responsibility for integration and end-to-end system requirements.
Staffing and Skills	The shared infrastructure introduces new tasks and challenges to the existing organization; staffing and skills need to evolve.
Shared Resources	Redundancy, testing, and other technical mitigations are needed to increase the reliability and availability of the shared resources.
Security	Capability provisioned across the enterprise reduces the need to implement a redundant set of controls within each application.
Satellite Ground System Architecture and Design	Each new satellite ground capability added to IGE must comply with enterprise architecture principles such as avoiding duplicative services, being location agnostic, using non-proprietary standards, adhere to standard, open interfaces in the enterprise, etc.
Mission Acquisition	Missions constitute incremental modifications and additions to the existing ground enterprise. New missions will be required to use IGE capabilities, and NESDIS will have to provide greater technical support to new mission developers.
Flight / Ground Integration	IGE provides a documented interface between flight & ground segments; new flight systems must integrate to these interfaces.
Development and Deployment of Ground Functionality	IGE will provide development, test and deployment resources to developers. This saves time and money by providing an environment that closely mimics the operational one, access to operational and test data, and common services. OSGS must make resources available to developers when needed. Use of common ground services and resources may increase the integration risk, requiring increased integration testing.

Mission Operations	Operators will interact with a single, common ground operator interface, resulting in lower training costs and better efficiency. Since IGE is (largely) location agnostic, there will be no dependency between location and tasking. Most ground system tasks will be executable from any ground system location.
Sustainment	In IGE there is a large pool of shared resources that are continually allocated to meet changing requirements. This enables a dynamic sustainment approach tied to IT resources rather than systems. Individual IT resources or classes of resources can be refreshed independent of the systems that use those resources. This enables capability refresh that can quickly leverage opportunities to adopt technologies that deliver benefits across the enterprise.
Requirements	The process of requirements flow down to the ground system will be revised to enable enterprise-level ground system solutions. Level 1 ground requirements will mandate use of IGE. Mission unique requirements not already supported by common ground services will be built and integrated into the IGE in an enterprise-like fashion, enabling their reuse by future missions.

As NESDIS moves to fully integrate the new ground systems into a shared services approach we are already experiencing some of these impacts, including challenges in end-to-end testing of segments that were intended to function together but were developed and validated in isolation of each other. As the IGE matures NESIDS will need an Integration and Test (I&T) environment that accurately mimics the full operational environment, so that changes can be adequately tested to confirm that they do not create negative impacts on any of the systems that use common services.

V. Level 1 Requirements

The Level 1 requirements describe the capabilities that the IGE must provide. These are listed in Table 4. During architecture development these requirements are allocated across nine functional segments in the Business Architecture and subsequently decomposed into Levels 2 and below.

Table 4. Level 1 Requirements for the NESDIS Enterprise[10]

Level 1 Requirements for the NESDIS Ground Enterprise
NGE_L1_2: The NGE shall be developed as an enterprise-level system based on an open, flexible, and adaptable Enterprise Architecture.
NGE_L1_3: The NGE shall support satellite and instrument operations of NOAA operated satellites.
NGE_L1_4: The NGE shall configure, monitor and control the ground network to support operations.
NGE_L1_5: The NGE shall support a suite of simulators that includes spacecraft, instrument, and ground-link simulators.
NGE_L1_6 The NGE shall acquire, process, store, and disseminate data.
NGE_L1_7: The NGE shall support real-time operational data processing and (multi) mission level reprocessing of older data simultaneously.
NGE_L1_8: The NGE shall provide an enterprise level capability to disseminate operational data and products to the user community.
NGE_L1_9: The NGE shall provide ground operations support for space based data relay, direct broadcast, and rebroadcast services provided by or administered by NOAA.
NGE_L1_10: The NGE shall support operational product development, refinement, and transition of science to operations.
NGE_L1_11: The NGE shall support collaboration and technology transfer with user communities.
NGE_L1_12: The NGE shall provide communication services for missions supported by NOAA.
NGE_L1_13: The NGE shall implement NESDIS required DHS and NIST security directives in a manner consistent with NOAA/NESDIS IT Security policies.

NGE_L1_14: The NGE shall meet the continuity of operations requirements according to the Federal Continuity Directives FCD 1 and FCD 2.
NGE_L1_15 The NGE shall provide the IT infrastructure to support NGE life cycle activities.
NGE_L1_16: The NGE shall support mission-specific data latency and availability requirements.

VI. Enterprise Architecture (EA) Process

The Architecture Development activity leverages best practices such as those described in the Federal Enterprise Architecture Framework (FEAF)[11] and The Open Group Architecture Framework (TOGAF)[12]. The IGE Enterprise Architecture development follows the TOGAF development lifecycle process to conduct business mission and modeling first and then perform system architecture design, technical solution analysis, system development and/or acquisition. To provide more business, operation, and engineering details for TOGAF lifecycle process, DoDAF (DoD Architecture Framework) Enterprise Architecture Views are developed, especially for TOGAF's information system architecture.

TOGAF is a framework that provides an enterprise approach for designing, planning, implementing, and governing an enterprise information technology architecture, relying heavily on modularization, standardization, and existing, proven technologies and products. As of 2016, TOGAF was employed by 80% of Global 50 companies and 60% of Fortune 500 companies.

As shown in Figure 2 and summarized in Table 5, TOGAF EA is developed through a phased approach and process consisting of four iterative cycles: Architecture Context; Architecture Delivery; Transition Planning; and Architecture Governance. Each phase (from A to H) of the process is driven by the Requirements Management process to ensure every stage of a TOGAF-based project meets business requirements.

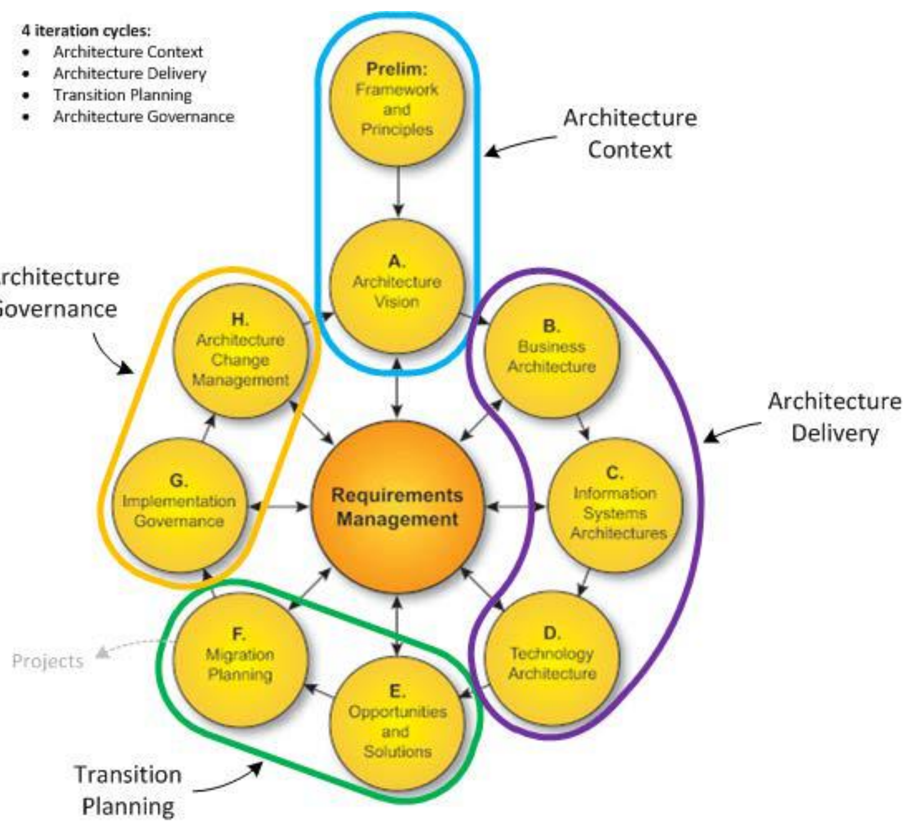

Figure 2. TOGAF's Phased Approach for EA Development[13]

Table 5. TOGAF's Architecture Development Phases

Phase	Purpose
A: Architecture Vision	Set the scope, constraints and expectations for a TOGAF-based project, create the Architecture Vision, validate the business context, and create the Statement of Architecture Work.
B: Business Architecture (BA)	Develop baseline and target architectures and analyze the business gaps.
C: Information Systems Architecture (ISA)	Develop baseline and target architectures and analyze the system gaps.
D: Technology Architecture (TA)	Develop baseline and target architectures and analyze the technology gaps.
E: Opportunities and Solutions	Perform initial implementation planning, conduct investment analysis, and identify major implementation projects.
F: Migration Planning	Analyze costs, benefits, and risks, and develop detailed implementation and migration plan.
G: Implementing Governance	Provide architectural oversight for the implementation, and ensure that the implementation project conforms to the architecture.
H: Architecture Change Management	Provide continual monitoring and a change management process to ensure that the architecture responds to the needs of the enterprise.

The Architecture Development Method (ADM)[14] is an iterative method over the whole process, between phases and within phases. Each iteration considers enterprise coverage, level of detail to be developed, time horizon, architecture asset re-use including previous ADM iterations, other frameworks, system models, industry models, etc. IGE EA development has completed the first-round of the four iterative cycles of TOGAF, with the exception of portions of Phases E & F, which are currently in work. and developed the following EA products for IGE design and planning.

A. Architecture Context Circle:
- IGE Concept of Operations, v.1.0 released in Dec. 2015, v1.2 released in May 2017
- IGE Requirements (NGE Level 2 requirements), v0.1 (Draft) in Dec. 2015 and v1.0 released in Oct. 2017

B. Architecture Delivery Circle:
- IGE Business Architecture Report, v3.0, Sep. 2016
- IGE EA Views Baseline Package, v1.0 released in May 2017
- IGE Technology Architecture (TA) document, v1.0, released in Dec. 2017

C. Transition Planning Circle:
- Transition & Sequence (T&S) Plan, v1.0 released in Sept. 2016
- Implementation Plan, under development (Target date: June 2018)

D. Architecture Governance Circle:
- EA Governance Document, v1.0 released in May 2017

VI. Three-Tier Results: BA, ISA, and TA

To develop a service-oriented and customer-focused Enterprise Architecture, the team developed the IGE EA through a descriptive model of the existing/legacy architecture which is used to make informed command decisions on operations, training, personnel, and acquisition to transition and sequence to a Target ("To-Be") Architecture.

TOGAF provides a top-down approach for EA development for its architecture delivery circle which includes three-tier enterprise architectures development. TOGAF starts from high-level business activities and ends at technology reference models for hardware and software standards and preferences. By following the three-tier TOGAF approach, the OSGS IGE EA team developed three enterprise architectures (BA, ISA, and TA). These architectures are described in the following sections. But since the IGE enterprise is very large and complex, comprising many separate but interlinked components within an overall collaborative business framework, the architecture development method used in IGE EA development was tailored accordingly.

A. Business Architecture (BA):

The BA defines the business strategy, governance, organization, and business processes. More specifically, the BA develops the target business architecture that describes how the enterprise operates to achieve the business goals, respond to the requests of strategic drivers, and solve the concerns of stakeholders. The BA also identifies architecture roadmap components based upon business gaps between the baseline and target architectures. During the BA development, in addition to the Business Architecture report DoDAF Operational Views (OVs) and Data & Information Views (DIVs) were developed to support the business description. The BA Report defines nine functional segments of the NESDIS Architecture. These functional segments are described in Table 6 below:

Table 6. IGE Business Architecture Functional Segments[15]

ID	Functional Segment	Description
MOP	Mission Operations	Plans, schedules and manages satellite flight and ground operations. This includes satellite and instrument commanding, maintaining situational awareness, operating antennas, allocating ground resources, managing flight software and verifying commands and flight software using simulations.
SCM	Satellite Communications	Provides space-ground communications and the routing of data received from the satellite to mission partners. This includes sending commands, product data for rebroadcast, memory loads and software updates to the satellite and receiving mission, rebroadcast, housekeeping and unique payload data from the satellite
DMS	Data Management Services	Provides product generation, product distribution and product-quality assessments for environmental data products. Product generation ingests data, and manages mission support data and production of data products. Product distribution disseminates data for exploitation by end-users & for permanent archival storage. Product quality monitors products, maintains metrics and generates alerts.
DSS	Data Stewarding Support	Supports data stewarding, which may include modifications to data (e.g., metadata updates, replacements, deletions, and/or removals) and access restrictions, by providing long-term storage, and catalog services as well as other IT infrastructure services. This includes ingesting submission information packages, ensuring permanent and supporting secure archival access.
SAS	Science Application Support	Provides infrastructure environments, and associated software, tools and data to support algorithm development and management and data product calibration and validation.
EMO	Enterprise Management & Operations	Manages the operation of the mission systems and services (processes, hardware, software, and data). Includes mission-based situational awareness, capacity management, integrated change control, configuration management and maintenance of the operational assets of the NGE. Enterprise operations include customer support (service desk), field terminal support, and I&T.
NES	NGE Engineering and Sustainment	Provides the planning, systems engineering, program and project management, and miscellaneous support functions that sustain each NGE Mission System.

INF	Infrastructure	Procures and provides the compute, storage and network capabilities for each NGE Mission System.
SMT	Security Management	Develops and implements policies and procedures that protect NGE assets and operates security services that provide access control, incident management and IT security diagnostics and mitigation across the NGE.

The IGE BA Report identifies operational activities (and sub-activities) for each Functional Segment. Table 7 identifies the top-level operational activities for each Functional Segment.

Table 7. Operational Activities[16]

Functional Segment	Operational Activity	Description
Mission Operations (MOP)	Fleet Planning & Scheduling (FPS)	Long-range and intermediate planning and tactical scheduling of space and ground fleet assets.
	Flight Operations (FO)	24x7 support services for satellite operations.
	Ground Operations (GO)	24x7 support services for ground operations supporting satellite operations and Space-Ground Communications.
Satellite Communications (SCM)	Space-Ground Communications (SGC)	Provides the communications services between the Ground and Flight Segments.
	Data Routing (DR)	Relays raw data products to subscribing consumers.
Data Management Services (DMS)	Product Generation (PG)	Processes instrument detector samples (RDR/L0), performs radiometric calibration and geometric correction (SDR/TDR/L1b), assembles rebroadcast data sets and generates Higher Level Products (EDR/L2+). It uses algorithms developed and maintained by the instrument manufacturers and the science community.
	Product Distribution (PD)	Disseminates the real-time and near real-time NOAA data products. It includes user and subscription management.
	Product Quality (PQ)	Assesses and monitors products and production, assesses the quality of data products and manages data product consumer communications.
	Data Analytics (DA)	Analyzes data products, manually characterizes environmental information, provides discussion support analysis and distributes analysis products to consumers.
Data Stewarding Support (DSS)	Data Stewardship (DS)	Applies rigorous analyses and oversight to ensure that environmental data sets meet the needs of users. This includes documenting measurement practices and processing practices (metadata); providing feedback on observing system performance; inter-comparison of data sets for validation; reprocessing (incorporate new data, apply new algorithms, perform bias corrections, integrate/blend data sets from different sources or observing systems); and recommending corrective action for errant or non-optimal operations.

	Storage Support (SS)	Ensures permanent, secure archival of environmental data. It ingests data sets, provides archival storage and supports retrieval of archived data sets. It also administers storage support, provides common security, IT infrastructure and IT management services.
Science Application Support (SAS)	Science R2O (R2O)	Facilitates the transfer of satellite observations of the land, atmosphere, ocean, and climate from scientific research and development into routine operations, and offers state-of-the-art data, products, and services to decision-makers. Findings are shared with partners and stakeholders to promote creative thinking about methods that would use satellite data to obtain better information about the Earth and its environment.
	Algorithm Management (AM)	Develops deployable algorithm software and provides algorithm change management and testing. This service supports the development of both Mission Specific and Enterprise Science Algorithms.
	Data Product Cal/Val (CV)	Supports instrument calibration and data product validation activities.
Enterprise Management & Operations (EMO)	Enterprise Management (EM)	Manages the enterprise systems and services (processes, hardware, software, and data). It provides situational awareness, capacity

B. Information Systems Architecture (ISA):

The ISA develops data models and application systems/services structure. More specifically the ISA develops the target information systems (data and application) architecture to address business processes that are supported by IT and is the interface of IT-related process and non-IT related process. DoDAF DIVs, High-level Systems Views (SVs), and Services Views (SvcVs) were developed to provide ISA details through data modeling and application systems/services structure diagrams and description.

C. Technology Architecture (TA):

The TA describes the software and hardware capabilities that are required to support the deployment of IGE data and application services. More specifically the TA forms the basis for the EA implementation and establishes building blocks on functionality, standards, and interoperability. The key contents of the TA include the technologies, standards, specifications and protocols used in the enterprise. The TA tailored by the IGE EA team has two major parts, the Infrastructure Reference Model (IRM) and the Application Reference Model (ARM).

Infrastructure Reference Model (IRM): The IRM is the Taxonomy based reference model for categorizing IT infrastructure and the facilities and network that host the IT infrastructure. The IRM is developed to enable sharing and reuse of IT infrastructure to reduce costs, increase interoperability across the government and its partners, and guide the selection of service components for efficient acquisition and deployment. The IRM captures the IT infrastructure: the equipment, systems, software, and services used in common across the enterprise regardless of mission, program or project and the standards used by those infrastructure elements.

Application Reference Model (ARM): The ARM is the Taxonomy based reference model for categorizing software applications that support the delivery of service capabilities. The ARM is created to document the technologies, standards, specifications and protocols currently in use and to guide the selection of technologies, standards, specifications and protocols for future. The ARM captures the applications: mission, program or project specific software that resides upon the IT infrastructure and helps fulfill a business function, and the standards used by those applications.

Both the ARM and IRM Technology Profiles are highly matured in terms of data[17]. The Application and Interface Standards necessary to support Information Technology acquisitions are sufficiently usable in both the ARM and the IRM. The Usage Status is under development in the Standards View inclusive of ARM and IRM standards. The Standards View currently provides Usage Status recommendations and a standardized justification for 100 of 371 identified standards to date. A justification includes standardized assessments of technical maturity, availability, vulnerability, product implementation, among others, for any given standard.

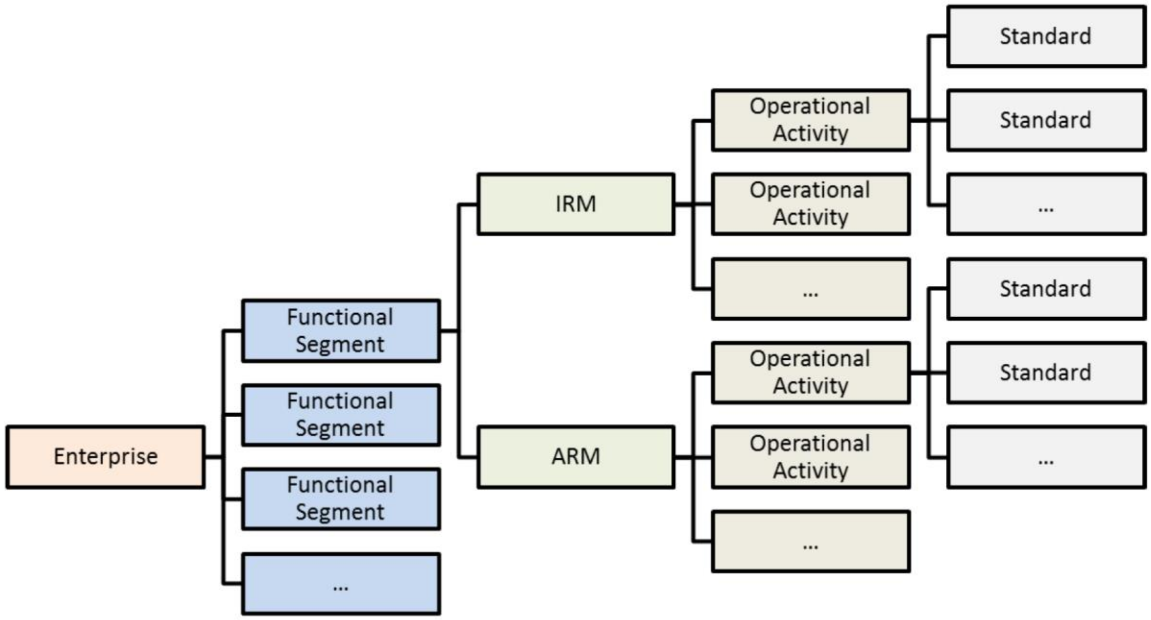

Figure 3 - Technical Architecture Organization[18]

In addition to the TA document which includes hardware & software technologies, standards, and usage status, DoDAF Low-level SVs were also developed to support the TA deployment (e.g., Level 3/4 SV-1s).

VII. Enterprise Architecture Views

A. DoDAF Views for IGE EA development.

Table 8. Enterprise Architecture View Categories[19]

View	Purpose
Data and Information View (DIV)	Describes current NGE from a data and information perspective. It identifies mission, security and support data elements at three abstraction levels and describes their aggregation.
Operational View (OV)	Describes the existing NGE from an operational and business perspective. It identifies the operational performers, roles, activities and requirements at multiple levels of abstraction and describes their aggregation. It identifies NGE data flows among the performers and activities, describes business processes and links requirements to the elements responsible for their satisfaction.
Systems View (SV)	Describes the current NGE from a systems perspective. It describes baseline "As-Is" NGE systems at three levels of abstraction and identifies the resource interaction among NGE systems at each level of abstraction.
Services View (SvcV)	Describes the desired "To-Be" services (future NGE) and their interaction. It identifies service access points, realized interfaces and the resource flow

	among the services.

IGE EA Views Baseline Package v1.0 (see Table 9 below) was prepared and released in May 2017 for NESDIS Ground Enterprise SEs and PMs for use in their system development and program/project management. The IGE EA Views, DIVs, OVs, and SVs were developed to baseline the current NGE ("As-Is") and only SvcVs were developed for the target NGE ("To-Be" or IGE). In the next version, more "To-Be" DIVs, OVs, SVs, and SvcVs will be developed and included.

Note that in the released baseline version (v1.0) "As-Is" Systems = FY2019; Target "To-Be" Services = FY2022+. In addition, a baseline package briefing was also developed and released together with the baseline package which includes 1) Introduction of IGE EA Baseline; 2) Introduction of EA Views; 3) Use of EA tool (a.k.a. MagicDraw); 4) Future work for the baseline release; and 5) Change Control Process.

Table 9: GEARS EA Views Baseline Package v1.0[20]

IGE EA Views	Descriptions
DIV-1: Conceptual Data Model	NGE high-level data concepts and their relationships are modeled in the views.
OV-2: Operational Resource Flow Description	A description of the NGE Data Flows exchanged between operational activities.
OV-5a: Operational Activity Decomposition Tree	NGE capabilities and activities (operational activities) are organized in different categories (service areas) and summarized in a hierarchal structure.
SV-1: Systems Interface Description	The identification of systems, system items, and their interconnections.
SV-3: Systems-Systems Matrix	The relationships (tabular summary) among systems in a given Architectural Description.
SvcV-1: Services Context Description	The identification of services, service items, and their interconnections in different levels of detail.
SvcV-2: Services Resource Flow Description	A description of Resource Flows exchanged between primary services.

B. Using EA Views for Analysis, Planning, and Development

The EA activity is an integral part of the overall Enterprise Engineering effort, that encompasses the systems architecting and systems engineering activities associated with the concept analysis, design, acquisition / implementation, and sustainment of the individual component systems and services that make up the Enterprise as shown in Figure 4.

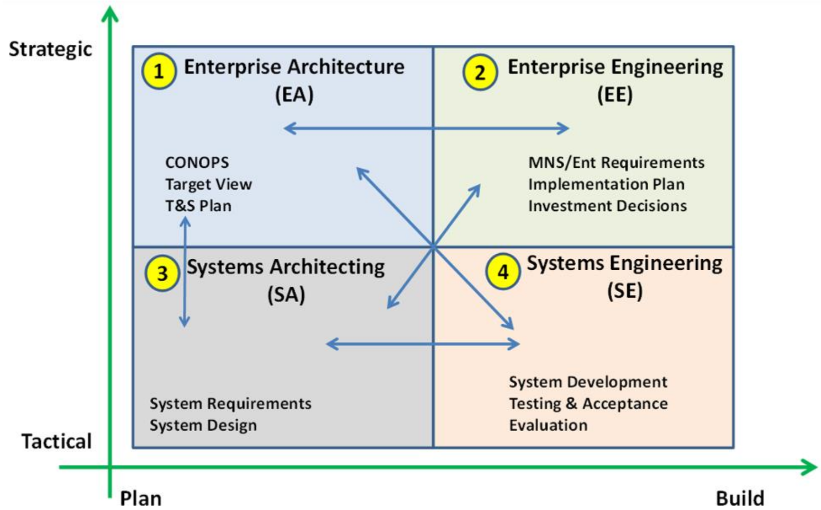

Figure 4. Architecture-to-Engineering[21]

As outlined in Figure 4, EA products (ConOps, EA Views, and T&S Plan) provide guidance and criteria for enterprise requirements finalization, implementation plan development, and investment analysis and decisions. Program/Project Managers and System Engineers follow enterprise requirements, implementation plan, and EA views for their system requirements development and system design. Both EA and SA products are followed during system development and used for system testing and acceptance evaluation. Program/Project Managers and System Engineers associated with NESDIS ground enterprise development are required to use the EA views directly for the following activities, but not limited to, 1) System Design, Development/Acquisition, and Sustainment; 2) System Configuration Management (SCM); 3) Analysis of Alternatives Studies; and 4) Impact Analyses.

C. Benefits of Using GEARS EA Views

IGE Views deliver direct and indirect contributions to the organization's goals and objectives. The EA Views provide a system development and operation analysis tool that facilitates better design and analysis to support all phases along the systems engineering life cycle and the acquisition life cycle of new and emerging technologies. Benefits exist in the following areas (useful not only at the enterprise level but also at the system/project level)

- Project/Program/Portfolio Analysis and Management
- System Configuration Management
- Requirements engineering
- Systems design, acquisition, development, and testing
- IT Management and Decision Making
- Reduction of IT Complexity and Redundancy
- Elimination of duplicative common services
- Promotion of Open, Responsive, Transparent IT functionality
- Risk reduction in project delivery, systems operations, and mission accomplishment
- Operational and Maintenance (O&M) cost reduction
- Ready availability & accessibility of enterprise design documentation
- Reduction of solution delivery time and associated development costs
- Ability to generate and maintain a common, accepted vision of the future
- Flexibility in expansion of the enterprise
- System acquisition Strategy and Planning
- Key Initiatives (pilots/demonstrations)
- Policy Definition and Refinement

VII. Harvesting Actionable Results from the Architecture

A. Development Principles

The IGE evolution from current NGE will meet all existing and envisioned future performance requirements by employing shared common services, implementing an evolutionary strategy changing small pieces at a time while continuing operations, fielding early enterprise elements to demonstrate the value of Common Services, and considering the Return on Investment; it may not be cost effective to migrate all the functions to shared common services. This approach maintains the integrity of existing operational systems while ensuring that sufficient return from investments is achieved along the way. In addition, there is the added advantage of adaptability to changing budgets and priorities, allowing NESDIS the flexibility to accelerate or delay aspects of the transition as needed.

More specifically, the GEARS development approach will take the following actions for IGE development as shown in Figure 5: 1) Decreasing the amount of mission-unique code to reduce overall maintenance and sustainment costs; 2) Creating shared common services to reduce time and cost of adding new products and missions; 3) Adopting common hardware standards to enable economies of scale in tech refresh and simpler security hygiene; and 4) Using the OSGS Infrastructure Reference Model (IRM) and Application Reference Model (ARM) as standards and guidance on software/hardware acquisition and/or development and sustainment efforts

The impact of increasing utilization of common services on sustainment costs in the evolution toward the IGE is illustrated in Figure 5. Duplicative functions or supporting applications in each mission will be collapsed into a set of common services using standardized interfaces. Any residual functions will be retained as Mission Unique Services based on mission-unique requirements and not encompassed by the overarching IGE mission requirements.

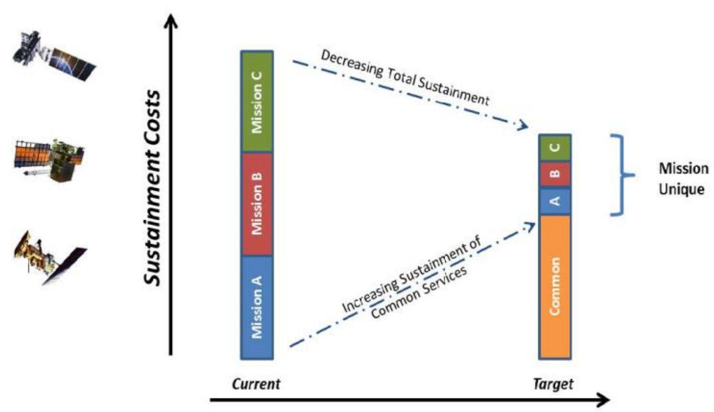

Figure 5. IGE Common Services[22]

One enterprise design employing a service-based architecture and shared resources, potentially structured in the layered building block approach, is shown in Figure 6 below:

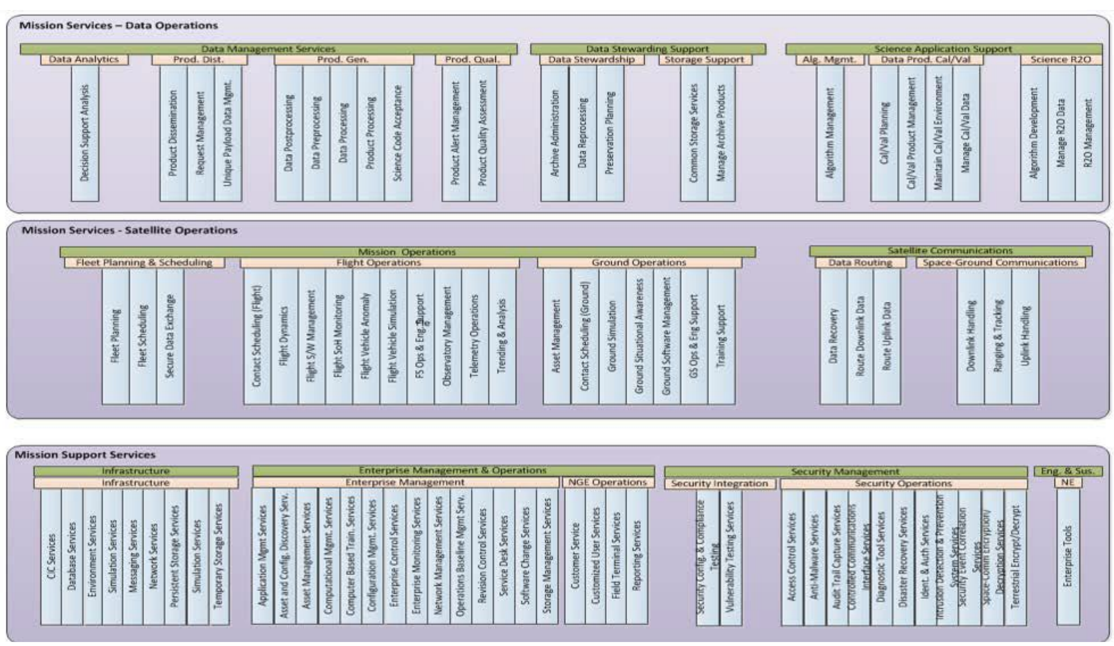

Figure 6. IGE Structured as a SOA-based Services Provider[23]

B. Results of the Business Architecture Analysis

The Business Architecture development effort and the associated Gap Analysis identified potential near-term and long-term investment opportunities on the path to transitioning to the desired end-state of the Target Enterprise Architecture. This includes new capabilities, existing mission-specific capabilities that should be combined and applied enterprise wide, existing capabilities that should be enhanced and applied across the enterprise and existing capabilities that are already appropriate for the Target Business Architecture. The following is a list of the candidate, business process migration opportunities ascertained during the development of the NGE Business Architecture:

- Infrastructure – Investment in enterprise infrastructure capabilities migrates mission-specific capabilities to the enterprise with attendant savings in acquisition, maintenance and sustainment.
- Algorithm R&D – Investment in enterprise algorithm research and development capabilities consolidates mission-focused algorithm sustainment and maintenance activities into an enterprise capability that supports algorithm research, development, deployment, maintenance and sustainment while reducing transition time from research to operations and reducing the number of algorithm versions that need to be supported.
- Product Generation – Investment in enterprise product generation capabilities consolidates mission-focused product generation into an enterprise-wide product generation capability, projected to be built on enterprise infrastructure services that reduce the costs of COTS licensing, system sustainment and maintenance.
- Enterprise Engineering – Investment in enterprise engineering capabilities consolidates mission-focused management activities into enterprise engineering services providing enterprise-level tools and processes for configuration management, requirements management, acquisition management, facility management, quality management and risk management with savings in engineering, licensing and system sustainment and maintenance.

C. Investment Priorities

Table 10 assesses the potential ROI by Mission Function. Mission Functions are a high-level classification of the functions carried out by the current Ground enterprise. The assessment is based on the degree to which a given system service is independent of mission-unique features. Downstream services (i.e., Archive & Distribution) which are independent of the original satellite mission data can be ranked High. Spacecraft/Instrument specific services (i.e., Command & Data Acquisition & L1/SDR data processing) are highly dependent on mission specific details and are ranked Low. Services such as Mission Operations, Ingest and Product Generation provide mission specific tailoring of capabilities that are common to all missions and are ranked Medium

Table 10. ROI Potential by Mission Function[24]

Mission Function	ROI
Mission Operations	Medium
Command & Data Acquisition	Low
Mission Data Routing	Medium
Data Ingest	Medium
Mission Data Pre-Processing	Low
Product Generation	Medium
Product Distribution	High
Archive	High

Table 11 below summarizes the analysis accomplished by the IGE implementation team and groups future investments into phases.

Table 11. IGE Investment Phases[25]

Enterprise Initative Group	Enterprise Initiative	Mission Unique	Investment Priority	Investment Phase
Enterprise Product Services	Data Processing Services	*Medium*	*1*	1
	Product Generation Services	*Low*	*2*	1
	Product User Services	*Low*	*3*	1
Enterprise Science Services	Environmental Information Services	*Low*	*1*	1
	Cal/Val Services	*Medium*	*2*	2
	Algorithm Services	*Medium*	*3*	2
Enterprise Operations Support Services	Ground Operations Support Services	*Medium*	*1*	1
	Planning & Scheduling Services	*Medium*	*2*	2
	Flight Operations Support Services	*Medium*	*3*	3
Enterprise Operations Services	Flight Operations Services	*High*	*1*	2
	Contact Services	*Medium*	*2*	3
	Common Operating Picture Services	*Medium*	*3*	3
Enterprise Data Relay Services	Sp/Gnd Comm Services	*High*	*1*	2
	Routing Services	*Low*	*2*	3

VIII. Investments in Migration to Service-Based Enterprise

The following sections describe ongoing and planned investments in the Product, Science, and Operations Support Services areas listed above. While these investment unfold NESDIS is preparing to make a strategic corporate decision in the near future regarding whether or not to move mission capabilities to a cloud (either private and/or public solutions). Commercial cloud solutions offer well-recognized benefits such as a continuous technology refresh conducted in a highly efficient fashion; spare capacity that can be accessed when needed but only paid for while actually in use; and common services that are well defined and documented. Constraints include concerns about security, reliability, and the cost of porting existing applications to a cloud environment. Individual assessments of the benefits and risks to specific mission functions are underway in the pilot experiments included below.

As NESDIS implements the projects described below it also has to make changes in the ways it integrates development and operations activities. Because the common services approach employs multiple services to simultaneously serve multiple missions, changes in a service will require testing that addresses end-to-end mission flows rather than just the impacts on one specific mission. The enterprise needs a fully capable set of Development and Integration and Test (I&T) environments along with the capacity to schedule the datat sources needed to drive them. This is fundamentally different than the way development and integration has been handled in the past.

A. Enterprise Product Services: Environmental Satellite Processing and Distribution System (ESPDS)[26]

Over the past year ESPDS began product generation and distribution operations supporting the newly launched GOES-R and JPSS satellites. It also gained responsible for distributing products from the legacy satellites that had been distributed by the legacy Data Distribution System (DDS). ESPDS modernizes the existing Environmental Satellite Processing Center (ESPC), operated by the NESDIS Office of Satellite and Product Operations, with an enterprise solution that meets the needs of legacy, GOES-R, S-NPP/JPSS, and GCOM-W satellite programs, with scalability to support future environmental satellites. It includes modernization of the Product Generation (PG), Product Distribution (PD), and Infrastructure segments of the ESPC and provides environmental satellite data and services to a growing user community including the NOAA Line Offices (NWS, NMFS, NOS, NIC, NESDIS, etc.), DoD (AFWA, NAVO, etc.), and other U.S. and international users (government, universities, foreign partners, etc.). ESPDS provides a scalable and secure infrastructure as a foundational building block upon which all other system functions and services reside. It leverages common infrastructure and processing services, reducing redundancy and costs while simplifying operations, maintenance, monitoring, and security.

The ESPDS User Portal provides user self-service subscription and search capabilities across all NESDIS products, eliminating labor required with the current manual subscription method. Approved users can manage their data access details (product customization, selection and transfer method) and exercise greater data discovery (via the online catalog). ESPDS is built on a Service-Oriented Architecture (SOA) that provides the following benefits: 1) Extensibility: The loose coupling of services allows the ability to add new functionality to the system without impacting the existing capabilities; 2) Reusability: ESPDS services will be usable for future integration, benefitting future government systems; 3) Modularity: ESPDS services can be upgraded and replaced easily.

ESPDS is fielded at the primary and backup ESPC sites. The primary ESPC site is the NOAA Satellite Operations Facility (NSOF) in Suitland, MD; the new ESPC backup site is the Consolidated Back Up (CBU) facility in Fairmont, WV.

As part of internal planning to expand partner collaboration and data sharing, NESDIS is budgeting for significant increases in ESPDS product generation and distribution capacity. These will be implemented as part of the move to an IGE.

The ESPDS Program is conducting a pilot project entitled “NDE Proving Ground” to prototype candidate architectures for product generation as a service in a commercial (AWS) cloud environment. It is assessing cloud efficacy, performance, scalability, and maintainability, as well as the flexibility to execute multiple types of algorithms. The team also recognizes that even if the cloud proves unsuitable for operations, it may offer a viable approach for development, test, and collaborative research capabilities leveraging common frameworks.

B. Enterprise Product Services: Comprehensive Large Array-data Stewardship System (CLASS)[27]

CLASS provides long-term, secure storage of NOAA-approved data, information, and metadata, and enables access to these holdings through both human and machine-to-machine interfaces. Capabilities are provided in 3 primary functional areas as defined by the Open Archive Information System Reference Model (OAIS-RM): 1) Ingest - mechanisms by which data, information, and metadata are transferred to and organized within the storage system; 2) Archival Storage - common enterprise means for data, information, and metadata to be stored by the system and the capability to refresh, migrate, transform, update, and otherwise manage these holdings as part of the preservation process; 3) Access - common enterprise access capability enabling users to identify, find, and retrieve the data and information of particular interest to the user.

As an enterprise solution, CLASS reduces cost growth associated with storing environmental datasets by consolidating stove-pipe, legacy archival storage systems and relieving data owners of archival storage-related system development and operations issues. CLASS does not support near-real-time or mission-critical product delivery. CLASS consists of two full replicated storage nodes hosted by NOAA’s National Centers for Environmental Information (NCEI) located at Asheville, NC and Boulder, CO. Receipt nodes at located at the NOAA Satellite Operations Facility (NSOF) in Suitland, MD and the Consolidated Backup Facility (CBU) at Fairmont, WV.

The current capacity of the CLASS system is 20 PB, with projected growth to 53 PB by 2020. CLASS recently completed development and is currently in operation supporting the following users:

- NOAA Geostationary Operational Environmental Satellites Series R (GOES-R)
- NOAA Joint Polar Satellite System (JPSS)
- NOAA Polar-orbiting Operational Environmental Satellites (POES)
- US Department of Defense (DoD) polar orbiting satellites
- NOAA Geostationary Operational Environmental Satellites (GOES)
- Canadian Space Agency's Synthetic Aperture Radar Satellites (Radarsat)
- European Meteorological Operational Satellite (MetOp) Program
- Ocean Surface Topography Mission (OSTM) Jason-2 and Jason-3

Beginning in FY19 CLASS will implement changes designed to reduce costs and move the architecture closer to the common services approach of the IGE. Currently CLASS supports two fully capable storage nodes. Each can ingest data, which is then automatically replicated to the other node via custom software. Sustainment of this replication capability is costly. This new CLASS project changes the current architecture to a simpler one that limits ingest to a primary node only, with one-way data replication to a second node dedicated purely to backup. In addition to reducing costs this change paves the way for a future decision to move the second node to the cloud.

Future planned investments will also implement a more flexible approach to ingesting and stewarding data sets, opening the archive to broader adoption as a universal solution across NOAA.

C. Enterprise Product Services: Flexible Ingest

Currently the NGE ingests data through a variety of systems, each designed to accommodate a specific source in a fixed fashion. As part of the move to the IGE, NESDIS is planning a Flexible Ingest project that will provide data ingest as a service. This service will easily accommodate a variety of data sources, including non-satellite sources, and provide the data to product generation and distribution services. One key element of the project is an early evaluation of the feasibility of using cloud capabilities to implement this function.

D. Enterprise Science Services: Enterprise Algorithms[28]

As originally built and deployed as part of stand-alone ground processing systems, single-purpose algorithms produced satellite data products specific to an instrument type and mission. Multiple versions of algorithms & associated software created similar products. Since the single-purpose algorithms are developed for specific instruments and missions, these versions are generally run on different product generation systems. These algorithms were easy to develop, easy to test, and simple to deliver and maintain as individual algorithms. However as a group they were more expensive in the long run: more systems to maintain in operations; longer algorithm and system development time – more "from scratch" development, not much leveraging due to requirements; higher algorithm maintenance costs – each algorithm for each satellite type needs funding to be maintained; minimal software reuse; many sources of ancillary data required for the multiple algorithms – no standardization across algorithms. In light of these inefficiencies, NESDIS has chosen to move to enterprise algorithms.

An Enterprise algorithm uses the same scientific methodology (i.e., physical basis, including assumptions) and software base to create the same classification of product from differing input data (satellite, in-situ, or ancillary). Each time an unfamiliar observation / source is acquired, interfaces (metadata, data structures and formats) have to be written. But over time, as new observations are introduced into NOAA, the process of adding external sources of data will become easier because of the tools and interfaces already established.

Some of the benefits of this approach include: consistent products with similar characteristics and performance can be generated for different instruments to support end user operations; it aligns with the National Weather Service implementation strategy of multi-sensor algorithms and products; algorithms are independent of the satellite sensor input data; supports current and future NOAA operational satellites; same algorithm can process different resolutions of like sensors; eliminates the need to retrain users for continuity missions; sustains product calibration across continuity missions; requires fewer algorithms and processing systems to be installed and maintained; and streamlines transition to operations for new satellite missions.

This new approach brings some challenges of its own. These include: algorithm inter-dependencies; more rigorous testing requirements; a need for flexible systems and processes that accommodate new/updated requirements; alignment of algorithm delivery schedules across projects.

NESDIS has adopted a two phase strategy to instantiate Enterprise Algorithms within the IGE. The first phase, initiated in July 2017, focuses on algorithms that run on existing legacy product generation systems. By September 2020 all these algorithms will be converted to Enterprise Algorithms running on enterprise product generation systems, likely ESPDS, the GOES-R Ground Segment, and potentially the cloud. Evaluation of cloud suitability forms a key part of the early work and includes pilots specifically structured to address the concerns referenced above. At the end of Phase one the legacy product generation systems will be decommissioned. In Phase two all the Level 2 algorithms will be converted to algorithm services, consistent with the IGE architecture. Phase two will be completed by September 2025. Based on our analysis to date, Enterprise Algorithms will benefit the developers, operators, and the users

E. Enterprise Science Services: Mission Science Network (MSN)[29]

Development of the Mission Science Network began in 2016. MSN is an IT platform that will provide enterprise services addressing the following objectives:

- Deliver cost-effective, secure, cloud-based infrastructure to support research through operations
- Enable research and development of scientific data and applications
- Support operational availability for product generation
- Manage data through its full lifecycle from creation to preservation
- Provide access to NOAA's data, information and services.

The MSN focuses primarily on the science needs of the Center for Satellite Applications and Research (STAR) and the National Centers for Environmental Information (NCEI). MSN will be implemented through the following tasks:

- Connection of existing systems between STAR and NCEI
- Harness existing N-Wave connectivity
- Consolidate systems in order to obtain efficiencies of scale and long-term cost savings
- Migrate data and applications, and shutdown systems in NCEI-MD and NCEI-MS
- Consolidate existing STAR systems into internal MSN clouds at STAR
- Deploy IT services that support entire science enterprise
- Determine best-of-breed capabilities between NCEI and STAR
- Leverage open source applications wherever possible
- Develop agile, scalable and secure architecture for future science mission
- Prepare NCEI and STAR systems for future migration into public cloud

Initial Operational Capability (IOC) is scheduled for September 2019 with Full Operational Capability (FOC) in September 2022.

F. Enterprise Operations Support Services: Enterprise Tools – Active Risk Manager (ARM), Enterprise Configuration Management Tool (ECMT)

OSGS has deployed two support tools to enable better management of NESDIS projects and operations. The first tool, Active Risk Manager (ARM), allows all Project Managers to document and manage their issues, risks, and opportunities. As currently configured it enables managers at all levels to gain enterprise views of the risks within their line of responsibility. It helps the organization prioritize and allocate resources to mitigate the risks and exploit the opportunities.

The Enterprise Configuration Management Tool is deployed at the NOAA Satellite Operatons Facility (NSOF) in Suitland, MD. ECMT was originally developed by the GOES-R project and now hosts configuration information on most of NESDIS satellite programs, with the exception of JPSS, which is expected tomgrate over the next few years.

IX. Managing Change

This paper has described technical and management activities across NESDIS focused on implementing the transition from stand-alone to integrated ground systems. As illustrated in the Concept of Operations, the use of shared infrastructure embedded in an Integrated Ground Enterprise brings change that impacts many elements of traditional system acquisition, operation, and sustainment. The good news is that the technologies to accomplish this transformation already exist (with the possible exception of some security aspects of cloud operations) and have been successfully applied to similarly complex problems in other industries – there are no known technical show stoppers. The NESDIS Office of System Architecture and Advanced Planning (OSAAP) established a Governance Process for the architecture and it is working well. OSAAP organized and chairs a weekly forum known as the NESDIS Enterprise Architecture Council (NEAC). The NEAC coordinates and provides awareness of IGE-related activities, and serves as an excellent conduit for information dissemination.

The biggest challenges associated with this transformation are its impacts on the people that develop and operate these capabilities. Team members across the spectrum of ground enterprise jobs have been successful for many years doing things the traditional way. Now we are asking them to recognize that the traditional way is no longer scalable or affordable, and to adopt new roles, job definitions, and tools. The transformation is about change management.

X. Towards the Future

OSGS is driving the development of a future Integrated Ground Enterprise that offers numerous advantages over the traditional stand-alone approach to system development and operation. Activities to realize the desired end state are well underway, including completion of a Concept of Operations and most of the Enterprise Architecture analyses. Complementing these activities, OSGS is fielding pioneering enterprise product generation, distribution, and archive systems that fully support the recently launched new generations of polar and geosynchronous environmental observation satellites. Supporting all these endeavors is a communication and outreach approach designed to address the challenges of change management.

Acknowledgments

Dr. Scott Turner (Aerospace Corporation) played an essential role in the development of the Concept of Operation. Mr. Mike Greico (Vencore) leads the Enterprise Architecture Team. The government Chief Architect is Xiaokun (Mark) Li (OSGS). The opinions expressed in this paper are entirely those of the author.

References

[1] "About NESDIS – NOAA's Satellite and Information Service". NESDIS.NOAA.gov. National Oceanic and Atmospheric Administration. 29 Feb 2016. Web. 24 Mar 2016. 873.

[2] "GOES-R Ground Segment Overview". GOES-R.gov. GOES-R Series Program Office. Web. 24 Mar 2016.

[3] "About JPSS – JPSS Ground System". JPSS.NOAA.gov. National Oceanic and Atmospheric Administration. Web. 24 Mar 2016.

[4] "NESDIS. Offices. NOAA OSGS – Office of Satellite Ground services". NESDIS.NOAA.gov. National Oceanic and Atmospheric Administration. Web. 24 Mar 2016.

[5] United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data and Information Service. Office of Satellite Ground Services. NESDIS Ground Enterprise Architecture Services (GEARS) Concept of Operations. Silver Spring, MD: NOAA. N.p.: Office of Satellite Ground Services, Feb 2015. Print.

[6] "NESDIS. Offices. NOAA OSGS – Office of Satellite Ground services. About OSGS". NESDIS.NOAA.gov. National Oceanic and Atmospheric Administration. Web. 24 Mar 2016.

[7] (GEARS) Concept of Operatios, pp 11-20.

[8] Ibid., pp 20-37.

[9] Ibid., pp 39-45.

[10] United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data and Information Service. Office of Satellite Ground Services. NESDIS Ground Enterprise Architecture Services (GEARS) Requirements. Silver Spring, MD: NOAA. N.p.: Office of Satellite Ground Services, Sep 2017. Print.

[11] United States, Office of Management and Budget. Federal Enterprise Architecture Framework Version 2. Washington DC. Jan 2013. Print.

[12] "TOGAF Version 9.1". OpenGroup.org. The Open Group. 2013. Web. 24 Mar 2016

[13] "TOGAF 9.1. Part II: Architecture Development Method. Introduction to the ADM." OpenGroup.org. The Open Group. 1999-2011. Web. 24 Mar 2016.

[14] United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data and Information Service. Office of Satellite Ground Services. Systems Engineering Division. NESDIS Ground Enterprise Architecture (EA) Views and Usage Document. Silver Spring, MD: NOAA. N.p.: Office of Satellite Ground Services, Nov 2017. Print.

[15] United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data and Information Service. Office of Satellite Ground Services. Systems Engineering Division. NESDIS Ground Enterprise Architecture Services (GEARS) Technology Architecture OSGS TA 5350.16A Version 1.5. Silver Spring, MD: NOAA. N.p.: Office of Satellite Ground Services, Mar 2018. Print. Pp 13-15.

[16] Ibid., pp 15-17.

[17] Ibid.

[18] GEARS Technology Architetcure, p 13.

[19] Ground Enterprise Architecture (EA) Views and Usage Document, p 19.

[20] Ibid., p 20.

[21] Ibid., p 21.

[22] Ibid., p 11.

[23] Ibid., p 9.

[24] United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data and Information Service. Office of Satellite Ground Services. Draft NESDIS Ground Enterprise Architecture Services (GEARS) Transition & Sequencing Plan: A Migration Strategy for the NESDIS Ground Enterprise (NGE). Page B-2. Silver Spring, MD: NOAA. N.p.: Office of Satellite Ground Services, December 2015. Print. P 42.

[25] United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data and Information Service. Office of Satellite Ground Services. Integrated Ground Enterprise (IGE) Implementation Plan (IGEIP) Version 1.0. Silver Spring, MD: NOAA. N.p.: Office of Satellite Ground Services, Dec 2017. Print. P 30.

[26] "NESDIS. Offices. NOAA OSGS – Office of Satellite Ground services. Sustain." NESDIS.NOAA.gov. National Oceanic and Atmospheric Administration. Web. 24 Mar 2016.

[27] Ibid.

[28] United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data and Information Service. NESDIS-TEC-6510.1 Enterprise Algorithms White Paper. Silver Spring, MD: NOAA. May 2017. Print.

[29] United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data and Information Service. 2Q FY18 Program Mnagement Review – Mission Science Network. Silver Spring, MD: NOAA. Mar 2018. Print.