NOAA Cloud Strategy

Maximizing the Value of NOAA's Cloud Services

National Oceanic and Atmospheric Administration
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NOAA Science & Technology Focus Areas:

Uncrewed Systems ▪ Artificial Intelligence ▪ 'Omics ▪ Cloud ▪ Citizen Science ▪ Data   July 2020

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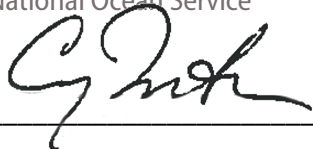Performing the Duties of Under Secretary of Commerce for
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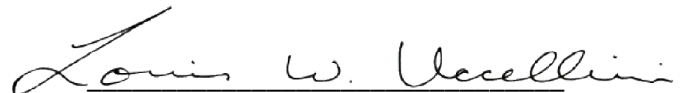Deputy NOAA Administrator

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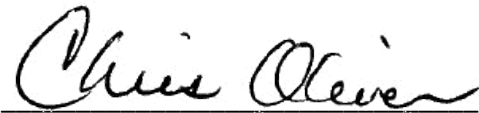and Information Service

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Purpose and Scope

This document defines a strategy to guide NOAA's adoption and utilization of cloud services. The strategy assumes change and requires a new mindset for modernizing NOAA's IT environment. Traditionally, modernization initiatives have started with the legacy architecture, followed by an evaluation of architectural alternatives for meeting the requirements. The strategy requires a fundamentally different and opposite approach—one that starts with and presumes an end-state architecture (specifically, a multi-vendor, multi-tenant commercial cloud environment), followed by a requirements and business case analysis to determine the suitability of cloud for the requirements, and if suitable then determine the best permutation of this architecture (e.g., private, hybrid, public) for the requirements. Whereas the traditional approach is incremental and tends to perpetuate legacy stove-piped infrastructure, the new approach embraces change and creates significant opportunities for collaboration and sharing of assets (both infrastructure and data).

As a new and fundamentally different approach for NOAA, the strategy recognizes the inherent risks, including the risk of unintended consequences. For example, the risk profile for operational prediction models and computers differs from that of research and other applications, which the supporting IT infrastructure needs to account for. To mitigate this and similar risks, the strategy calls for strong cloud governance to establish and manage change to the technical baseline, and a smart migration that includes a thorough and objective evaluation of viable architectural alternatives from a cost, schedule and performance perspective. Additionally, careful and deliberate consideration of other factors that could introduce unintended consequences is critical.

The strategy establishes a default architectural end-state for NOAA's cloud services, provides a unified approach to migrating to the cloud, promotes a smart transition based on requirements, business cases and best practices, and enables broad sharing of solutions.

The scope encompasses the full continuum of cloud deployment models (e.g., private, community, hybrid, public) and cloud service models (i.e., IaaS, PaaS, and SaaS) from a strategic perspective.[1] The strategy provides a consensus-based approach to guide decisions in the subsequent planning and implementation phases, without constraining or prescribing "how" to implement the vision, as shown below:

Strategy & Vision → Planning → Implementation

In Scope

The detailed planning and context-specific decisions necessary to implement the vision are not in the scope of this document but will be addressed in the subsequent phases. For example, the specific architectural alternatives and guidance for selecting the most appropriate alternative for a given set of requirements will be scheduled in the Cloud Implementation Plan and developed in the planning phase. The strategy recognizes that early adopters have made interim architectural decisions, and seeks to build on and replicate proven approaches. Early adopters are encouraged to develop architectures that are flexible enough to map to the Cloud Implementation Plan as it is developed. Likewise, existing operational capabilities such as NOAA's Cloud Utility Contract vehicle and the Big Data Project's public-private partnership provide a foundational platform and target to inform and shape the Cloud Implementation Plan. Crucially, the Cloud Implementation Plan will support the implementation plans of the other NOAA Science and Technology Strategies (i.e., Artificial Intelligence, 'Omics, UxS) to maximize coordination and promote synergies across the strategies. The strategy aligns with the emerging Federal Data Strategy and leverages the principles, mandates, and best practices of the Federal Cloud Computing Strategy.

Dr. Neil Jacobs, NOAA's leader, addressed over 300 stakeholders in August 2019 at the University of Colorado Boulder on NOAA's flagship Earth Prediction Innovation Center (EPIC). NOAA's Cloud Strategy is an essential foundation for EPIC because high-performance cloud computing architecture enables external research partners to develop, test, and provide constructive feedback to accelerate Earth-system modeling improvements.

[1] The strategy encompasses the full range of applications, from email and website hosting to specialized High Performance Computing.

Strategic Imperative

Environmental data is foundational to NOAA, underpinning virtually all aspects of our mission. Consistent with key NOAA priorities such as reducing the impacts of extreme weather events and enabling the American Blue Economy, NOAA's data is also a vital national asset, serving the needs of myriad stakeholders in industry, academia, other government agencies, and the public. Aligning NOAA's capabilities with the constantly evolving needs of our stakeholders requires both collaboration and partnership (e.g., as piloted in NOAA's Big Data Project) to deliver data and services in a way that stakeholders expect to consume them.

NOAA's data holdings are also vast, complex, and distributed, reflecting the diversity and footprint of NOAA's mission. Likewise, the systems and infrastructure that process, store, and disseminate NOAA's data are complex, distributed and built to optimize separate missions. In the foreseeable future, the volume and velocity of our data are expected to increase exponentially with the advent of new observing system and data-acquisition capabilities, placing a premium on our capacity and wherewithal to scale the IT infrastructure and services to support this growth. Modernizing our infrastructure requires leveraging cloud services as a solution to meet future demand. Broad adoption of cloud services represents both a significant investment and a change management challenge. At the same time, cloud adoption is an opportunity, an inflection point, where NOAA can modernize data storage and dissemination instead of just shifting existing systems to the cloud. Applying the right architecture for the right situation is the imperative. While cloud services may not be the best solution for all requirements, all NOAA IT investment decisions should fully and credibly consider cloud as a potential alternative.

These realities present NOAA with both complex challenges and new opportunities, and many of those technical opportunities are manifest in "Cloud" computing services. NIST 800-145 defines cloud computing as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." Commercial cloud services that provide computing capability as services have matured, creating favorable circumstances and means to address our data growth and management challenges.

NOAA received a 2019 Government Innovation Award for its pioneering partnerships with commercial cloud providers, called the Big Data Project, successfully testing a new business model that incentivizes cloud providers to make more of NOAA's important datasets available for free. Receiving the award for NOAA were Jon O'Neil, Big Data Project Director (center-left), and Matthew "Chase" Long (center-right). Photo Credit: Zaid Hamid Photography 2019 | Government Innovation Awards

Strategic Imperative

NOAA's utilization of commercial cloud capabilities represents a unique, compelling and well-timed opportunity to support the fulfillment of NOAA's mission. A strategic, unified and collaborative approach is needed to take full advantage of this opportunity.

A continuum of commercially available solutions and service models are now available—including owned, leased, and collaborative public/private partnerships. Given the anticipated benefits and variety of cloud services, along with NOAA's growing scientific computing needs, it is crucial to consider how utilization of these services impacts limited budgets and resources. It is imperative to leverage both mature cloud capabilities as well as emerging technologies (e.g., big data analytics and artificial intelligence) to drive additional value from our data and better serve our customers, wherever there is a sound business case.
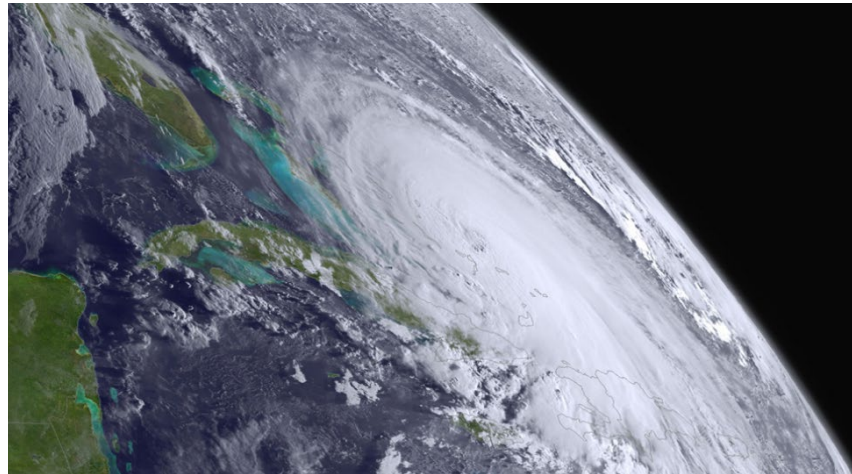
Future State, Vision, and Success Drivers

In the desired future state all NOAA IT services are hosted in a cloud, based on a deliberate decision process, which first considers application hosting in a brokered, multi-vendor, multi-cloud, multi-tenant FedRAMP certified commercial cloud computing environment, and chooses the migration target (multi-tenant, hybrid, private off-premise, etc.) based on cost-effectively meeting all mission requirements, including security, latency, workload variability, and the like.

Vision for NOAA's Enterprise Cloud

NOAA uses an accessible, scalable, secure, flexible, agile, cost-effective, efficient, highly reliable, and integrated suite of cloud computing products and services to fulfill its mission. Cloud solutions are driven by requirements and the business case, with the default solution being a brokered commercial, multi-cloud, multi-tenant cloud.

Early NOAA cloud adopters and pilots have demonstrated the viability of cloud solutions for a wide range of mission requirements. The vision builds on this work and seeks to enable all NOAA stakeholders and programs to utilize a suite of enterprise-level cloud services to empower their mission, unless their specific requirement and business case analysis determines cloud is not the optimal solution. NOAA's desire to go multi-cloud, multi-vendor and/or cloud native may impact complexity and costs in some instances. This will need to be balanced and managed for maximum flexibility and choice, while maintaining best practices and open standards in meeting NOAA's diverse mission needs.

Key success drivers to implement this vision include:

- NOAA leadership support for accelerated transformation to the cloud
- Prioritized budgets and investments
- Efficient governance mechanisms
- Federal Cloud Computing Strategy alignment
- Internal and external customer inclusion
- A high-level, cloud native architecture
- Practical implementation guidance to inform cloud suitability, platform selection, and transition decisions
- Evolving a NOAA culture that embraces agility, learning, and innovation
- Effective approaches to optimize cloud costs and inter-cloud data migration obstacles
- Cloud-optimized security policies and toolsets
- Modern software development approaches
- Incorporating adaptive change management
- Close coordination across Line Offices in migrating to the cloud
- A motivated, well-trained, and agile workforce
- Best practices and standards
- A standard framework to estimate cloud migration costs, hosting costs and ROI, and best practices for preventing cost overruns
- A standard security framework that includes common tool sets, methods for deployment models, monitoring, and incident response

NOAA's Strategic Goals for Cloud

The cloud strategy incorporates five goals that collectively drive change and position NOAA to exploit the potential of cloud services to advance the mission.

1. Enable Innovation through Rapid Adoption of Cloud-Based Services

Leverage best practices and build partnerships to drive innovation that supports NOAA's mission and meet stakeholder needs. Innovation is particularly critical to sustain and evolve NOAA's world-class R&D and operational capabilities. Cloud computing services facilitate innovation at NOAA through capabilities such as rapid system provisioning and processing, automation of security and administration, ease of access to machine learning and analytic tools, data integration, leveraging cloud native capabilities, and pay-for-use costing models which reduce the investment risk of experimenting with new technologies.

Objective 1.1: Establish a capability for users with appropriate approvals to rapidly access or provision a secure exploratory cloud environment.

Objective 1.2: Identify opportunities to automate cloud management processes (e.g., provisioning, monitoring consumption, etc.) to accelerate timelines, achieve efficiencies and promote consistent implementation of policy.

Objective 1.3: Identify and promote novel approaches to encourage innovation using cloud technologies, to include leveraging agile principles and a continuous learning culture.

Objective 1.4: Establish best practices for developing cloud-native applications using DevSecOps approaches to accelerate Research to Operations (R2O).

2. Drive Smart Migration to the Cloud

Cloud migration decisions should be based on mission requirements and a sound business case, and informed by a suitability analysis to confirm that a cloud-based alternative is viable. Careful and thorough analyses are critical to validate and select the most appropriate platform for the requirements. Apply Federal Cloud Computing Strategy recommendations to develop a deliberate migration of cloud-appropriate resources and services in a cost-effective way. Capabilities should be evaluated for their suitability to cloud hosting prior to migration to the cloud. Carefully consider the strategy, implications and benefits of refactoring/optimizing legacy applications targeted for migration to the cloud. Therefore, NOAA

will leverage an accountable entity to oversee and facilitate an efficient implementation of cloud services.

Objective 2.1: Develop a NOAA cloud strategy implementation plan that promotes collaborative solutions and aligns with the other NOAA Science and Technology (S&T) and Data Strategy implementation plans.

Objective 2.2: Develop guidance and tools to facilitate cloud transition planning. Such guidance includes but is not limited to templates for cloud business cases, models to estimate migration and hosting costs, and best practices to prevent cost overruns.

Objective 2.3: Ensure enhanced transparency to promote trust and encourage collaboration on enterprise cloud solutions.

Objective 2.4: Leverage shared infrastructure and partnerships to reduce data dissemination and egress costs.

Objective 2.5: Establish Cloud Success Team(s) to assist NOAA programs with developing and executing cloud adoption/migration plans.

Objective 2.6: Engage other Federal agencies to identify and leverage best practices for cloud migration and lessons learned applicable to NOAA's use cases for the cloud.

3. Ensure Secure and Broad Access to Cloud Services

Expand access to NOAA's data to unleash its full value, while simultaneously improving the security of the information systems and data supporting NOAA's mission. Leverage, inherit and augment (as needed) FedRAMP-provided security controls to ensure the availability, integrity, and confidentiality of data, applications, and cloud services, with full consideration of national security, PII/BII, and trust concerns.

Objective 3.1: Identify and onboard NOAA Cloud Service Providers into a cloud access security platform.

Objective 3.2: Identify and implement advanced techniques (e.g., AI and ML) to improve detection and prevention of malicious and unauthorized behaviors.

Objective 3.3: Establish an accredited system boundary for SaaS applications used by NOAA.

Objective 3.4: Provide guidance for defining information system boundaries when programs are leveraging cloud services.

Objective 3.5: Identify and establish common services for cloud use. Common services include procurement, networking, authentication, configuration management, security assessment, and security monitoring.

4. Provide Effective Governance for Cloud Shared Services

Cloud governance, with substantial and multi-disciplinary NOAA-wide engagement, provides a strategic framework for cloud adoption and promotes consistency across implementations. Governance occurs at both the strategic level (e.g., policy, the selection of cloud vendors and brokerage models) and operational level (i.e., running the cloud). Governance also encourages cooperative behaviors, promotes best practices, establishes performance metrics, facilitates compliance, and centralizes communication and coordination of NOAA's cloud activities. Effective governance also provides management mechanisms to ensure that the use of on-demand cloud based computing services is conducted within NOAA's annual budgetary constraints. Cloud governance will be consistent with NOAA and Line Office policies. The primary entity to facilitate and coordinate cloud governance is the NOAA Cloud Committee, reporting to the CIO Council and including representatives from all Line Offices.

Objective 4.1: Develop and implement procedures to govern enterprise cloud services. Procedures ensure continuous and measurable customer experience improvements.

Objective 4.2: Establish a NOAA Cloud Committee to support governance and coordinate effective use of cloud services. The Committee will ensure alignment of planned cloud activities with the NOAA Cloud Strategy, as well as the NOAA Data and other S&T strategies.

Objective 4.3: Develop and implement cross Line Office procedures to seamlessly transition cloud-based services from Research to Operations (R2O).

5. Empower a Cloud-Ready Workforce

Ensure that the workforce has the skills, competencies, authority, and information needed to apply cloud technologies that support NOAA mission across all Line and Staff offices. Increase NOAA's competitiveness in the job market by utilizing technologies that top talent is looking for in the workplace. To attract, retain and grow talent, leverage the workforce recommendations outlined in Section IV (Workforce) of the Federal Cloud Computing Strategy.

Objective 5.1: Invest in and develop the full range of NOAA's cloud expertise, including cybersecurity in the cloud and other cloud-centric skillsets. Employ traditional and innovative development approaches and methods.

Objective 5.2: Establish a cloud Community of Interest (COI) to share cloud knowledge, lessons learned, and best practices NOAA-wide.

Objective 5.3: Expand NOAA's cloud talent pool by creating partnerships with other governmental organizations, academia, non-profit organizations, and the private sector, and by leveraging internship opportunities.

Objective 5.4: Attract a multi-generational cloud proficient IT workforce by creating an agile workplace that embraces technology allowing the flexibility to work from anywhere.

Objective 5.5: Streamline recruitment and hiring to bring on needed cloud talent quickly. Develop a cloud workforce pipeline. Use existing hiring authorities and incentives, and develop new ones. Expedite security checks.

Objective 5.6: Develop NOAA-wide competency based standards for cloud knowledge, skills, and abilities.

Guiding Principles

The following principles provide guidance to prioritize and optimize cloud transition, operations, and management decisions. These principles apply at all levels, from strategic to tactical implementation:

Accelerate the Mission	Mission First	Do no harm. Sustain mission performance in all cases, and enhance the mission wherever possible.
	Maximize the Value of NOAA Data Assets	Provide ubiquitous access to and cost-effective use of NOAA data and services to realize their full potential, including distribution to customers from centralized data. Leverage ongoing efforts to improve NOAA's data discovery and accelerate the initial work being done to explore cloud-ready data formats.
	Empower NOAA Stakeholders	Enable NOAA staff to explore and leverage the wide range of cloud based options to meet their needs.

Protect and Simplify Data Access and Use	Protect NOAA Data	Leverage cybersecurity expertise, tiered access methods, inheritable NOAA and FedRAMP controls, common enterprise security tools available in cloud environments, and a "zero-trust" model to ensure data security.
	Default to Industry and Community Best Practices	Implement standards, proven techniques, and automated testing, where appropriate, to increase system interoperability, security and enable more rapid deployments.
	Target Cloud-Optimized Systems	Build or re-architect toward cloud-native and cloud-optimized systems to take full advantage of cloud technologies and capabilities whenever practical.

Maximize Portability and Re-Use	Leverage Shared Services	Utilize common services for common requirements whenever practical, except where justified by a mission or business need.
	Replicate Success	Seek to scale proven solutions rather than invent new solutions.
	Design for Maximum Agility, Portability, and Choice	Design for multi-cloud portability management and integration across computing vendor platforms. Develop an exit strategy to mitigate vendor lock-in risk.

References

- **Statutes and Executive Mandates:**
    - o Federal Information Technology Acquisition Reform Act (FITARA)
    - o Foundation for Evidence-Based Policymaking Act (H.R.4174)
    - o White House Executive Order on Maintaining American Leadership in Artificial Intelligence (EO 13859)

- **Federal Initiatives:**
    - o Federal Cloud Computing Strategy (Cloud Smart)
    - o Federal Data Center Optimization Initiative (DCOI)
    - o Federal Risk and Authorization Management Program (FedRAMP)

- **NIST Guidance:**
    - o NIST Guidelines on Security and Privacy in Public Cloud Computing (SP 800-144)
    - o NIST Definition of Cloud Computing (SP 800-145)
    - o NIST Cloud Computing Standards Roadmap (SP 500-291)
    - o NIST Cloud Computing Reference Architecture (SP 500-292)
    - o NIST Big Data Interoperability Framework (NBDIFv2)

- **Leadership Strategies**:
    - o President's Management Agenda 2018
    - o Department of Commerce Strategic Plan (2018-2022)

Acknowledgements

Appendix A: Terminology

Artificial Intelligence
Refers to computational systems able to perform tasks that normally require human intelligence, but with increased efficiency, precision and objectivity.

Cloud Deployment Models
As identified in the NIST cloud computing definition, a cloud infrastructure may be operated in one of the following deployment models: public cloud, private cloud, community cloud, or hybrid cloud. [NIST SP-500-291 v2]

Cloud Native
An approach to building and running applications that exploits the advantages of the cloud computing delivery model. "Cloud-native" is about how applications are created and deployed, not where. It implies that the apps live in the public cloud, as opposed to an on-premises datacenter.

Community Cloud
The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.

Data Egress Costs
The cost associated with moving data off of a commercial cloud platform for use, processing, storage, or archiving on another system. (e.g., NOAA seeks to minimize costs associated with data egress through contractual agreements with Cloud Service Providers such as the Big Data Program).

Development, Security and Operations (DevSecOps)
An organizational philosophy that combines agile software development, security testing and tools for rapid delivery of applications and services.

FedRAMP
The Federal Risk and Authorization Management Program (FedRAMP) is a US government-wide program that provides a standardized approach to security assessment, authorization, and continuous monitoring for cloud products and services.

Hybrid Cloud
The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

Infrastructure As A Service (IaaS)
The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls).

Machine Learning (ML)
A subset of Artificial Intelligence (AI), Machine Learning (ML) refers to mathematical models able to perform a specific task without using explicit instructions, instead relying on patterns and inference gleaned from training data.

Multitenancy (Multi-tenant)

The existence of multiple clients sharing resources (services or applications) on distinct physical hardware. Due to the on-demand nature of cloud, most services are multitenant. Each customer is provided a separate, secure space for storing data and projects. Each user can only access its own stored information, based on the cloud provider's permissions.

Multi-Vendor

When an organization uses multiple cloud vendors.

Platform As A Service (PaaS)

The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.