Aerospace Digital Engineering Ecosystem: Architecture and Implementation

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No SBU label required

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Briefer Bio

- **Erin T. Ryan, PhD**
  - *26 years active duty with U.S. Air Force*
    - Space architecture, space systems acquisition, launch, and ops
  - *5.5 years with Aerospace*
    - 4 years supporting space enterprise architecture for HQ AFSPC
    - 1.5 years leading DE ecosystem architecture within Aerospace
  - *Education*
    - BS in electrical engineering (Univ of Wash)
    - MA in national security (New Mexico State Univ)
    - PhD in systems engineering (Air Force Institute of Tech)
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Erin contemplating the deep mysteries of digital engineering

Agenda

- **Background / Context**
  - *Corporate strategy*
  - *Notional roadmap*
  - *Governance*
- **Aerospace DE Ecosystem**
  - *What is a DE ecosystem?*
  - *The traditional top-down architecture approach (and the revector)*
  - *Service-based approach => functional architecture*
  - *Enterprise Engineering Ecosystem (E3) = physical architecture*
- **Current Status**
  - *Progress to date and current challenges*

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Mission Statement

Aerospace DE Strategy

Balanced investment approach to enable the transformation of <u>both</u> Aerospace and our customers

- **<u>DE Transformation of Aerospace</u>**
  - *Ensures that the corporation remains relevant in the Digital Age*
  - *Ensures that the corporation keeps pace with and fosters digital fluency in modern engineering methods, processes, and tools*
  - *Modernizes the corporation's IT infrastructure and environment to serve as the corporation's DE ecosystem*
  - *Modernizes corporate modeling, simulation, and analysis capabilities to operate within a DE environment*

- **<u>DE Transformation of Customers</u>**
  - *Delivers near-term capabilities to meet immediate customer needs and solve their hardest problems*
  - *Provides guidance and support to our customers' DE transformation efforts*
  - *Supports the establishment of customer DE ecosystems that can be used to support acquisition and operations*
  - *Ensures that Aerospace serves a key tenant and user within our customers' DE environments*

Aerospace must fully commit to the digital transformation of its own enterprise to make itself more competitive, to enable it to become the premier integrator of the space enterprise, and to give it the necessary knowledge, experience, and legitimacy to effectively advise its customers on their own digital transformations

High-Level Digital Transformation Approach

Strategy

Corporate Vision
DE Strategy
M&S Strategy
Capability Framework
Transition Strategy
Data Strategy

Governance

Org Stand-Up
LOE Leads
Charters, IPT Structure
Research Alignment
Cost Accounting

Resources

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People / Culture

Digital Fluency Initiative
Learning Paths
Outreach / Expos
Migration Handbook

Mission Needs

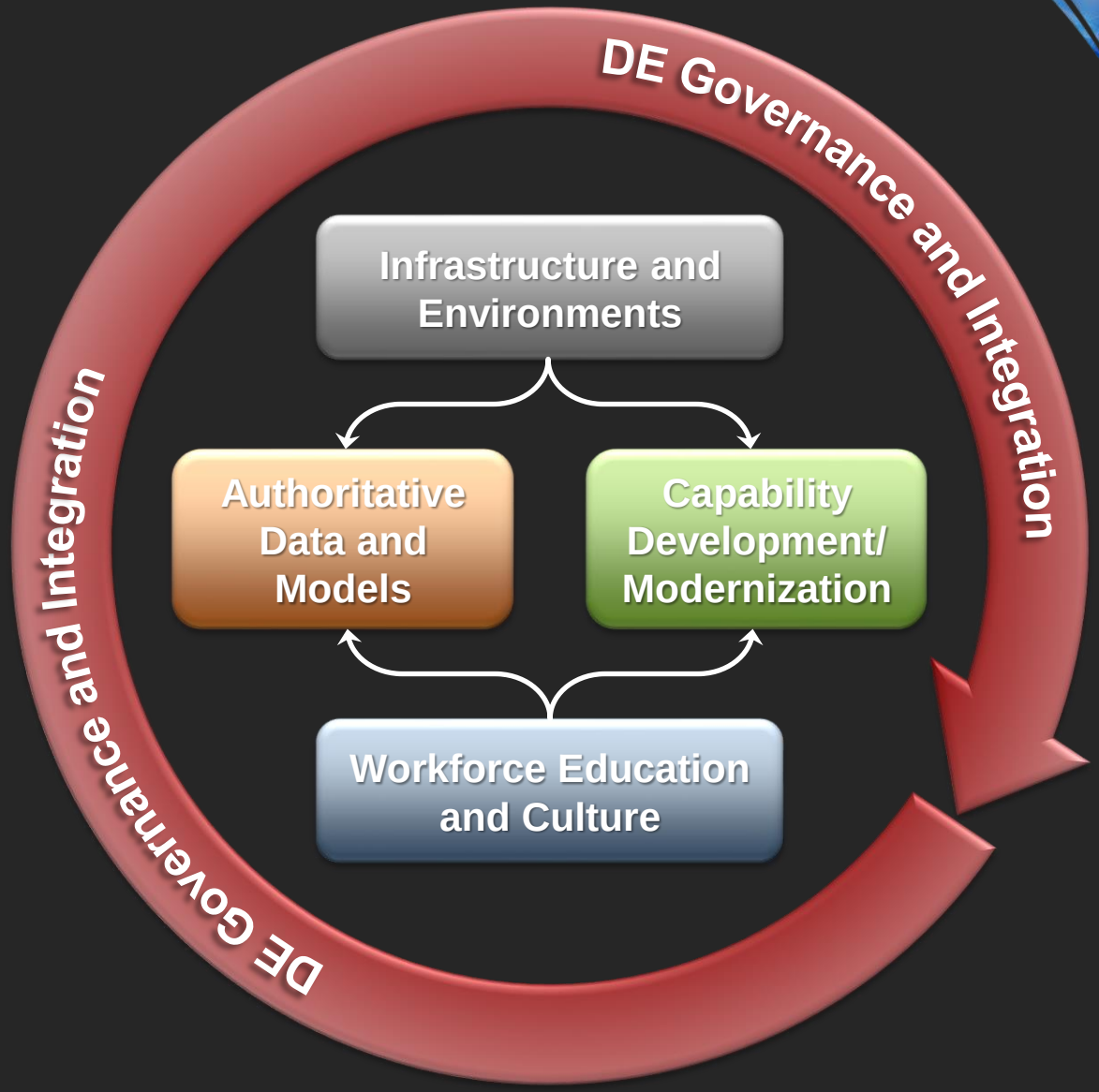
Stakeholder Framework
Data / Models Catalog
User Stories / Workflows
Digital Twins
Digital Sandboxes
App Store

Ecosystem Architecture

Digital Testbeds
On-Prem Cloud IOC
CONOPs
Services Framework
Digital Storefront
Off-Prem Cloud Pilots

Aerospace Digital Engineering Lines of Effort (LOEs)

- **LOE #1: Governance and Integration**
  - *Strategic planning, governance, and integration of DE activities across the Corporation and across all customer sets*
- **LOE #2: Infrastructure and Environments**
  - *Development and modernization of the Corporation's DE infrastructure and environment and the interoperability of the Aerospace DE ecosystem with customer DE ecosystems*
- **LOE #3: Authoritative Data and Models**
  - *Greater sharing of information and baselines to accelerate learning, facilitate knowledge management, and improve the accuracy, validity, and responsiveness of analyses*
- **LOE #4: Capability Development/Modernization**
  - *Development of capabilities required to implement DE processes and workflows and the modernization of legacy capabilities, including M&S, to be executable in a DE environment*
- **LOE #5: Workforce Education and Culture**
  - *Training and education of the Aerospace workforce to operate intuitively and effectively across the digital workspace and to champion the digital transformation of our customers*



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What Is a Digital Engineering Ecosystem?

The interconnected infrastructure, environment, and methodology (process, methods, and tools) used to store, access, analyze, and visualize evolving systems' data and models to address the needs of the stakeholders.

—Defense Acquisition University

The interconnected infrastructure, environment, and methodology (process, methods, and tools) used to store, access, analyze, and visualize data and models to address the needs of stakeholders.

—USSF Vision for a Digital Service, 2021

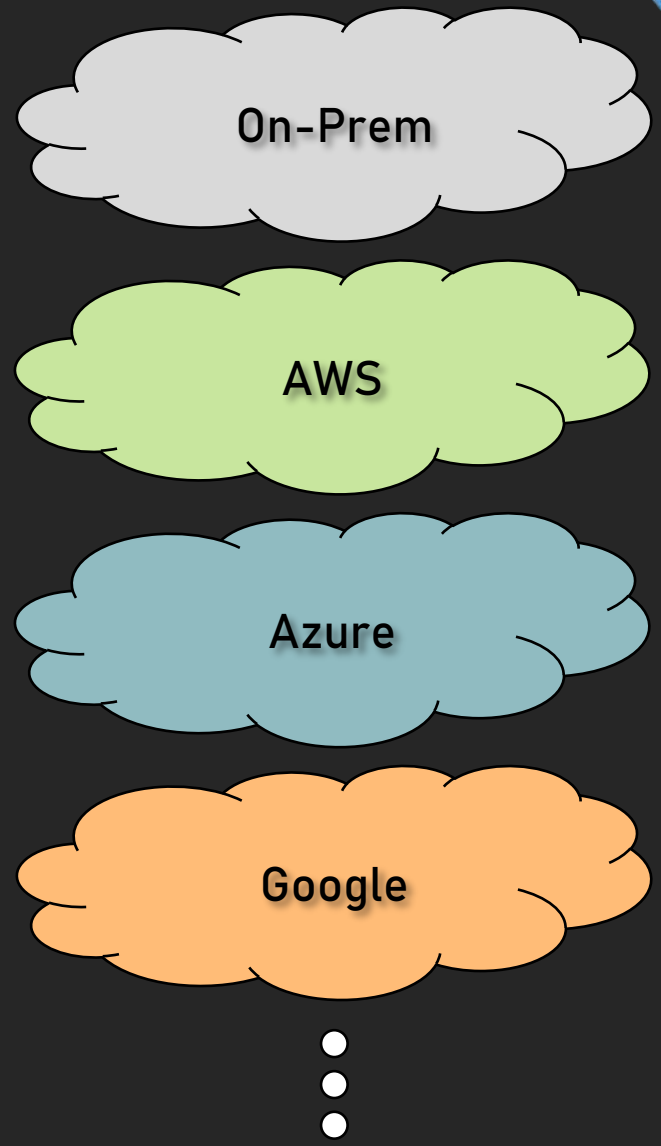
Improving and accelerating the capability lifecycle is heavily reliant on having a secure, revitalized, resilient digital infrastructure powered by a state-of-the-art, interoperable, low-latency network. On top of this foundational infrastructure, the USSF will establish the necessary tools, applications, and interfaces to allow users to produce and manipulate the data, models, and analysis, all of which comprise a fully federated Digital Engineering Ecosystem (DEE).

—USSF Vision for a Digital Service, 2021

- **Key Takeaways**
  - *DE ecosystem is interconnected and interoperable*
  - *Includes infrastructure, environments, and tools/apps (and users)*
  - *The technological foundation to enable DE to work as envisioned*
  - *A DE ecosystem helps users do what they need to do*

LOE #2: Infrastructure and Environments

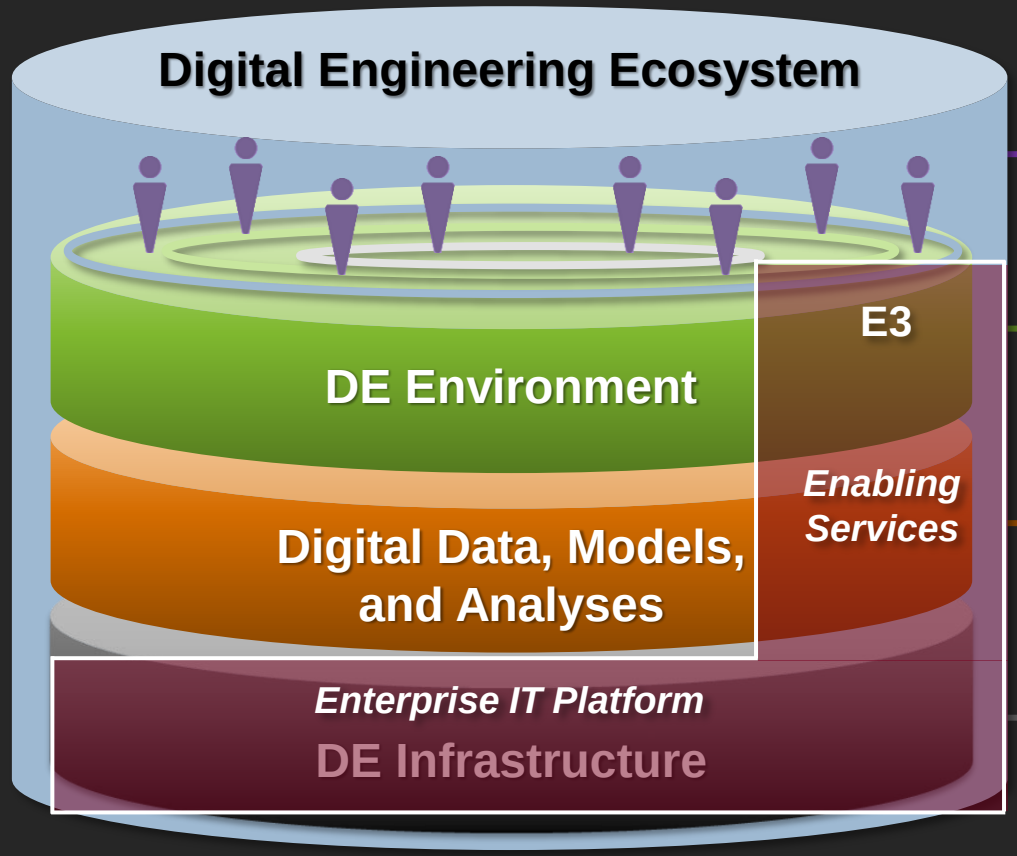
- **LOE #2 Definition/Scope**
  - *The development and modernization of the Corporation's DE infrastructure and environment and the interoperability of the Aerospace DE ecosystem with customer DE ecosystems*
- **Key Takeaways**
  - *The DE ecosystem serves as the technological foundation for enabling digital engineering across Aerospace and linkages to our customers*
  - *Knowledge management at this scale requires adoption of modern infrastructure, environment, and tools*
- **Ecosystem Implementation => Cloud Technologies**
  - *Clouds provide ability to readily access shared pools of configurable HW and SW resources that can be rapidly provisioned w/ minimal management*
    - Key Benefit: "Elasticity" and "democratization of IT"
  - *Clouds are typically accessed via the internet but can also be deployed on local networks as an "on-prem" (i.e., private cloud) solution*
  - *Clouds are service-oriented: Compute, store, software development, databasing, AI/machine learning, analytics, collaboration, etc.*
  - *Inherently involves architecture tradespace, transition strategies, and CONOPs*



LOE #2: DE Ecosystem on E3 Foundation

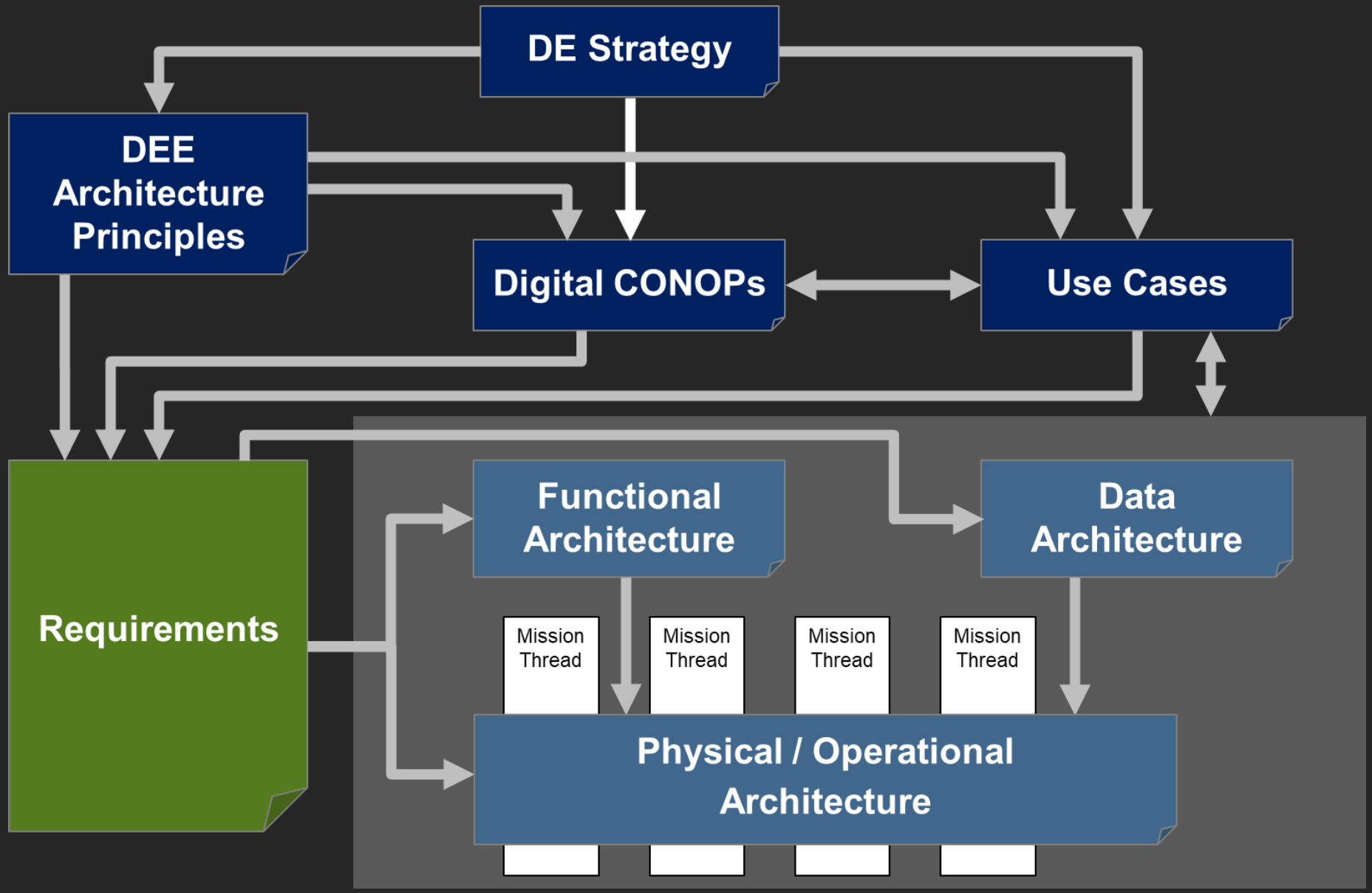
Digital Engineering Ecosystem (DEE): Serves as the common, integrated workspace for users to support and execute all technical functions

Enterprise Engineering Ecosystem (E3): Enables digital solutions by providing enterprise cloud services, associated provisioning across the DEE, and the intuitive interfaces for users to access what they need

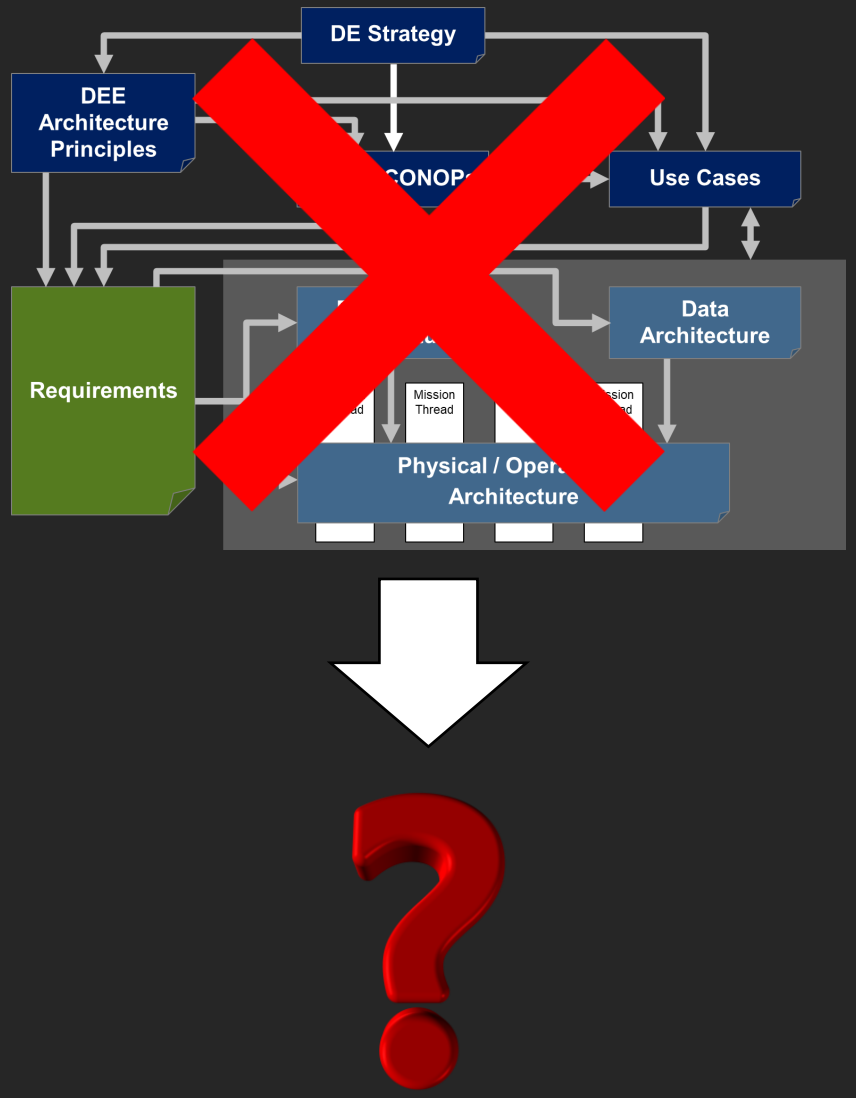


DE Ecosystem	Aerospace Examples
These are the people who interact with and govern the environment to directly deliver mission value	Analysts, engineers, developers, decision-makers
Provides the ability to access and manipulate the data layer, generally via application software, tools, user interfaces, workflows, etc.	Workflows, dashboards, M&S tools, collab tools, SW factory
The core "data layer" forming the heart of the corporate value proposition, supporting rapid capability development & data-centricity	ASOT models/datasets, database mgmnt, libraries, metadata
All of the foundational IT elements (e.g., core security, networks, virtualization, storage, & compute) that serve as the DEE "connective tissue"	AeroNet, ASENet, storage, compute, virtual machines

Original DE Ecosystem Implementation Approach



Several Factors Drove us to Revector



1. **Speed is Paramount**
   - *Must show value quickly to internal stakeholders; must learn quickly to credibly advise customers*

2. **Must Confront Cultural Barriers**
   - *Technical challenges hard, but people piece is harder—speed and results critical*

3. **DE is a Revolution**
   - *Today's use cases (rqmnts) are expected to be substantively different from tomorrow's use cases*

4. **Nature of Solution Known**
   - *We have a relatively firm understanding of rqmnts and architecture tradespace*

Aerospace DEE Implementation Approach

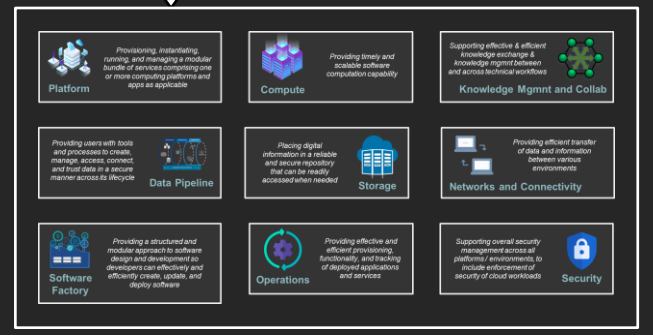
- **Pivoted to Agile/Incremental Approach**
  - *Establish basic principles for the DEE (vs. hard rqmnts)*

  - *Attack via middle-out design (vs. exclusively top-down)*
    - Service-centric (vs. requirement-centric)
    - Workflow creation w/ users (vs. use case satisfaction by architects)

  - *Rapid deployments of working capability*
    - Early, ongoing engagements with users
    - Heavy reliance on pilots/MVPs to create “beachheads” and learn
    - Extensible; libraries of modeled workflows and “service patterns”
    - Use BCAs for targeted transition points and strategies

Principles

Elastic
Service-Oriented
Secure
Frictionless
Collaborative
Data-Centric



Aerospace Service-Centric Approach: Top-Level ("Level 1") Services

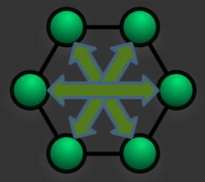
Platform

Provisioning, instantiating, running, and managing a modular bundle of services comprising one or more computing platforms and apps as applicable

Compute

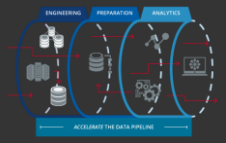
Providing timely and scalable software computation capability

Supporting effective & efficient knowledge exchange & knowledge mgmnt between and across technical workflows



Knowledge Mgmnt and Collab

Providing users with tools and processes to create, manage, access, connect, and trust data in a secure manner across its lifecycle



Data Pipeline

Placing digital information in a reliable and secure repository that can be readily accessed when needed

Storage

Providing efficient transfer of data and information between various environments

Networks and Connectivity

Software Factory

Providing a structured and modular approach to software design and development so developers can effectively and efficiently create, update, and deploy software

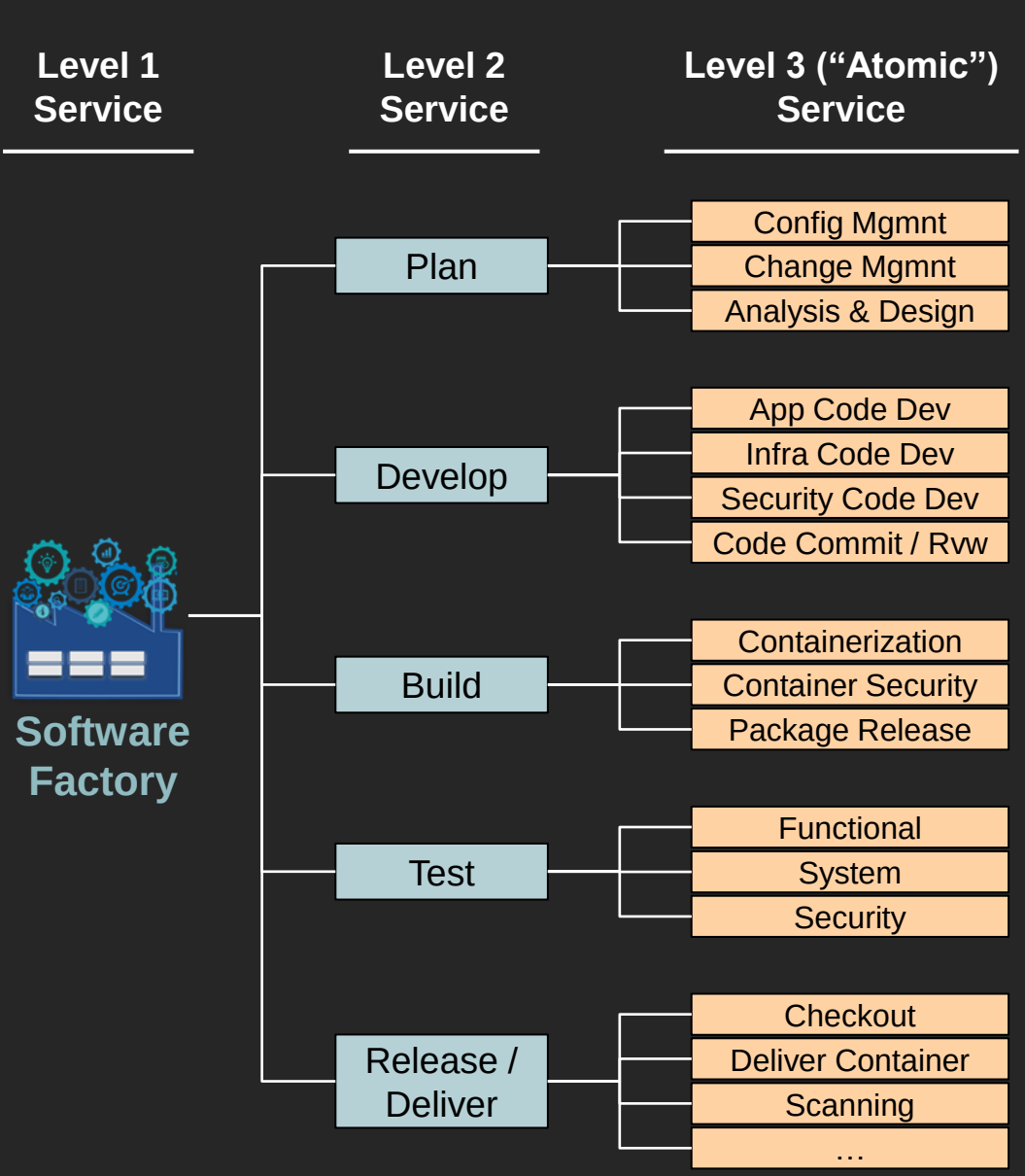
Operations

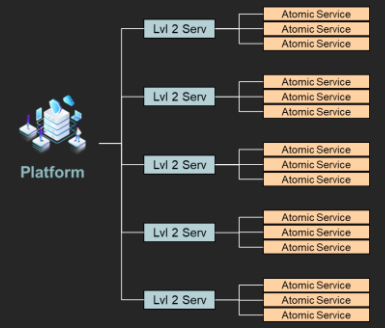
Providing effective and efficient provisioning, functionality, and tracking of deployed applications and services

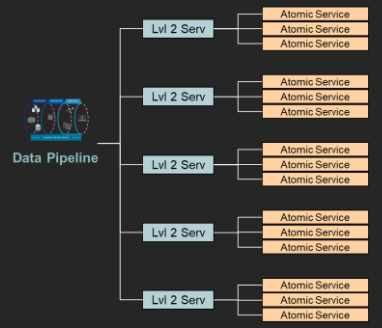
Supporting overall security management across all platforms / environments, to include enforcement of security of cloud workloads

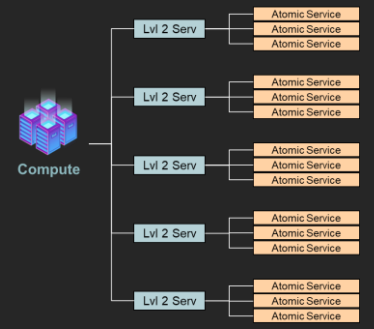
Security

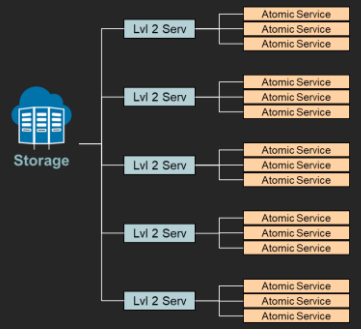
Aerospace DEE Functional / Logical Architecture

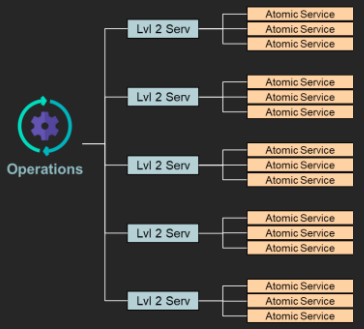


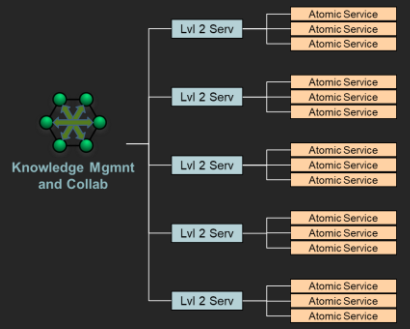


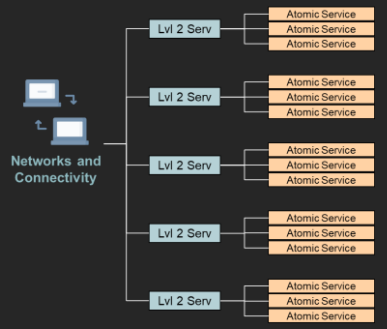


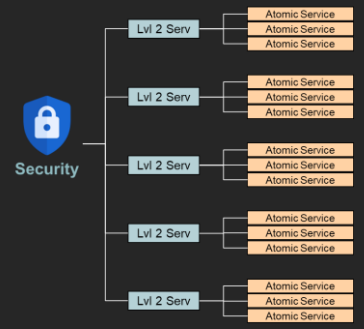






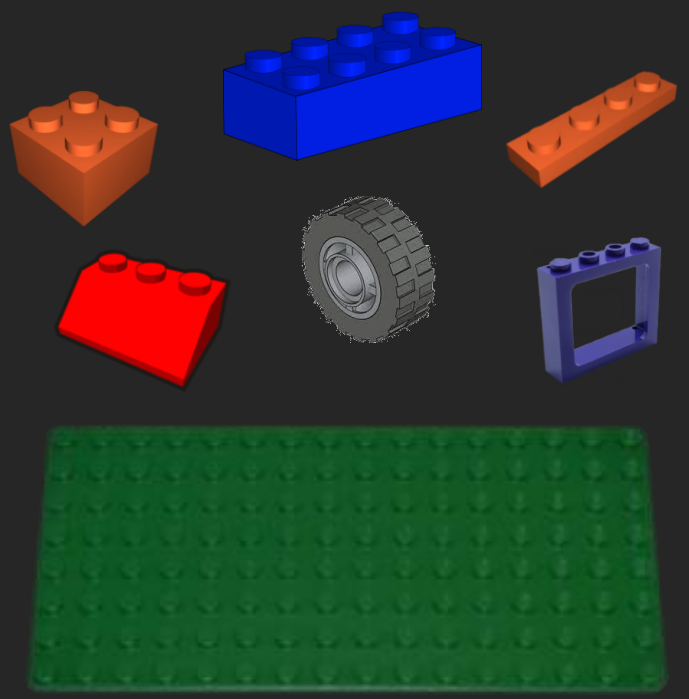






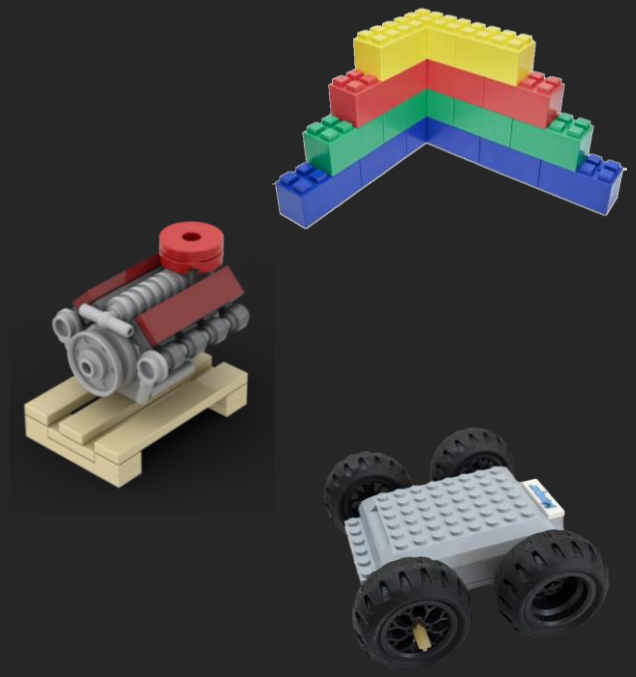
Legos Analogy

Lego Pieces



Atomic services that can be mixed and matched to satisfy user needs
(e.g., GPU, HPC, license mgmnt, databasing, versioning, archival, data tagging, web hosting, etc.)

Lego Modules

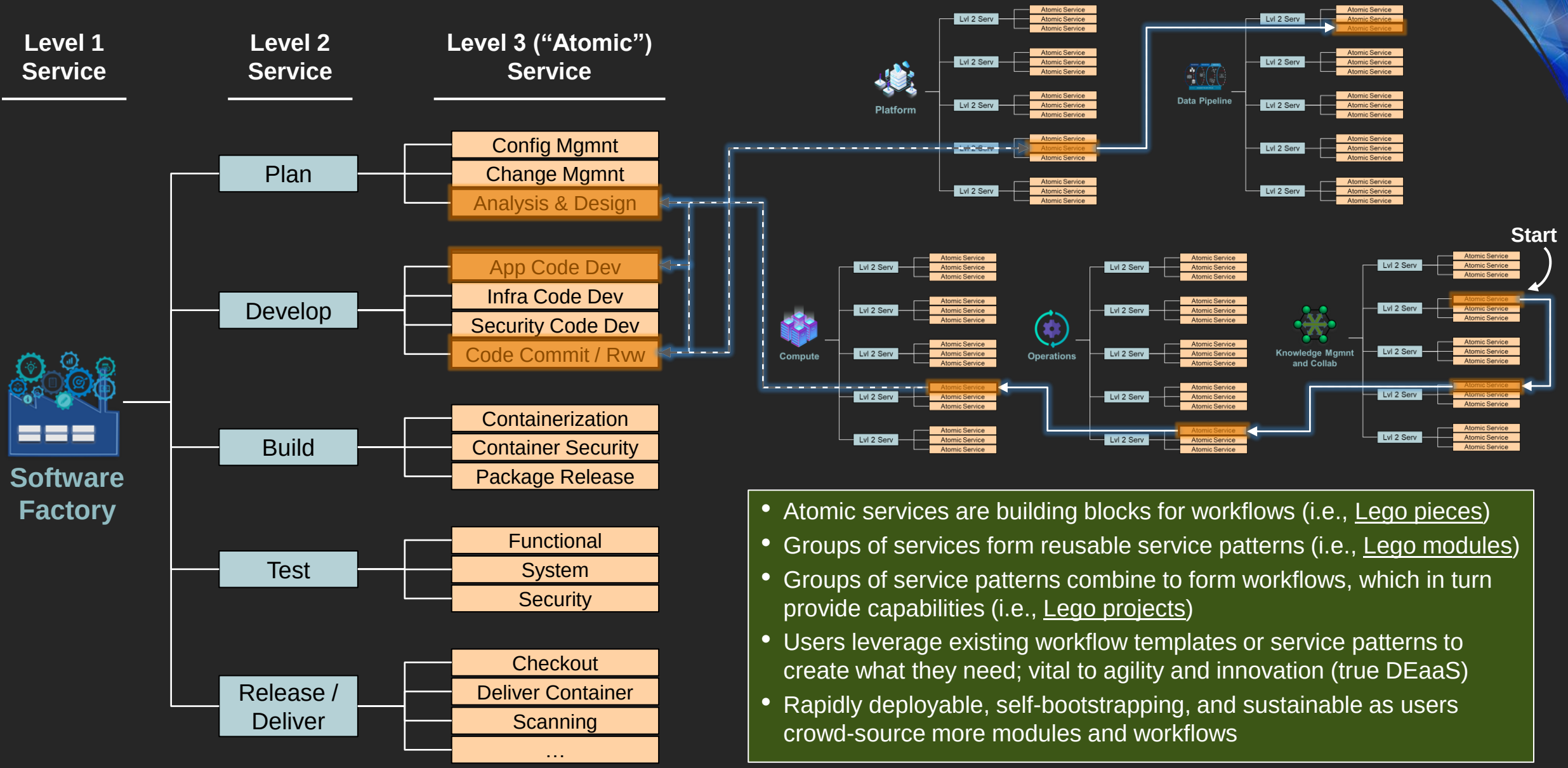


Common groupings of services (i.e., service patterns) that are readily reusable and extensible
(e.g., ETL, access controls, containerization, SW development)

Lego Project

Sequenced combination of services that satisfy user needs via an end-to-end workflow
(e.g., rqmnts mgmnt, survivability analysis, ICD development, etc.)

Aerospace DEE Operational / Capability Architecture (Notional)



- Atomic services are building blocks for workflows (i.e., Lego pieces)
- Groups of services form reusable service patterns (i.e., Lego modules)
- Groups of service patterns combine to form workflows, which in turn provide capabilities (i.e., Lego projects)
- Users leverage existing workflow templates or service patterns to create what they need; vital to agility and innovation (true DEaaS)
- Rapidly deployable, self-bootstrapping, and sustainable as users crowd-source more modules and workflows

Aerospace DEE Modeling Strategy

Discrete low-level service that is solution agnostic

Atomic Services

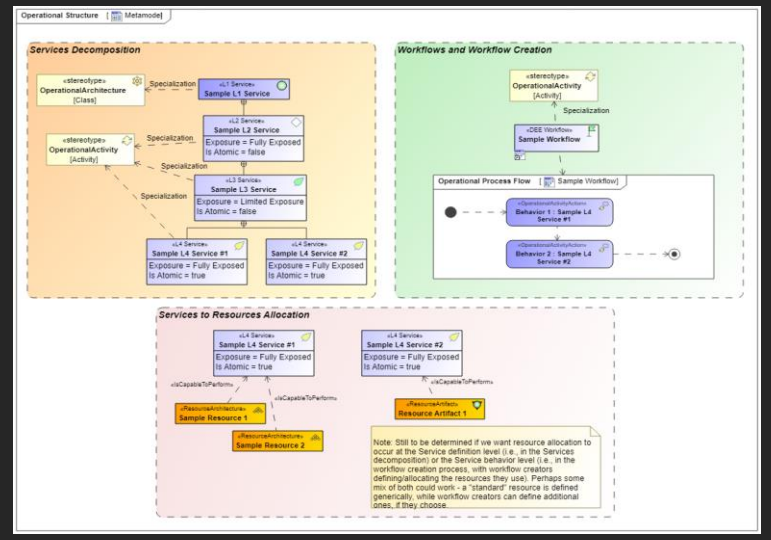
Frequently used (and reusable) combination of atomic services

Service Patterns

Sequenced collection of services that satisfies a recurring user process/task

Workflows

"Master" model with reference libraries accessible to all users

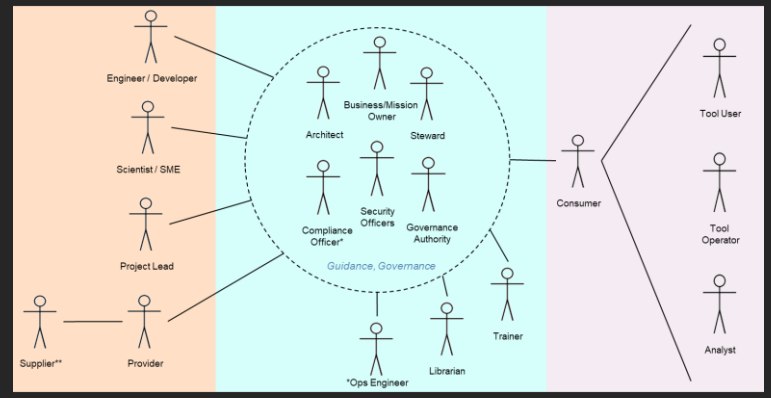


Users query for existing workflow and/or service pattern that is most like what they want to do; Stakeholder Framework

Workflow Creation

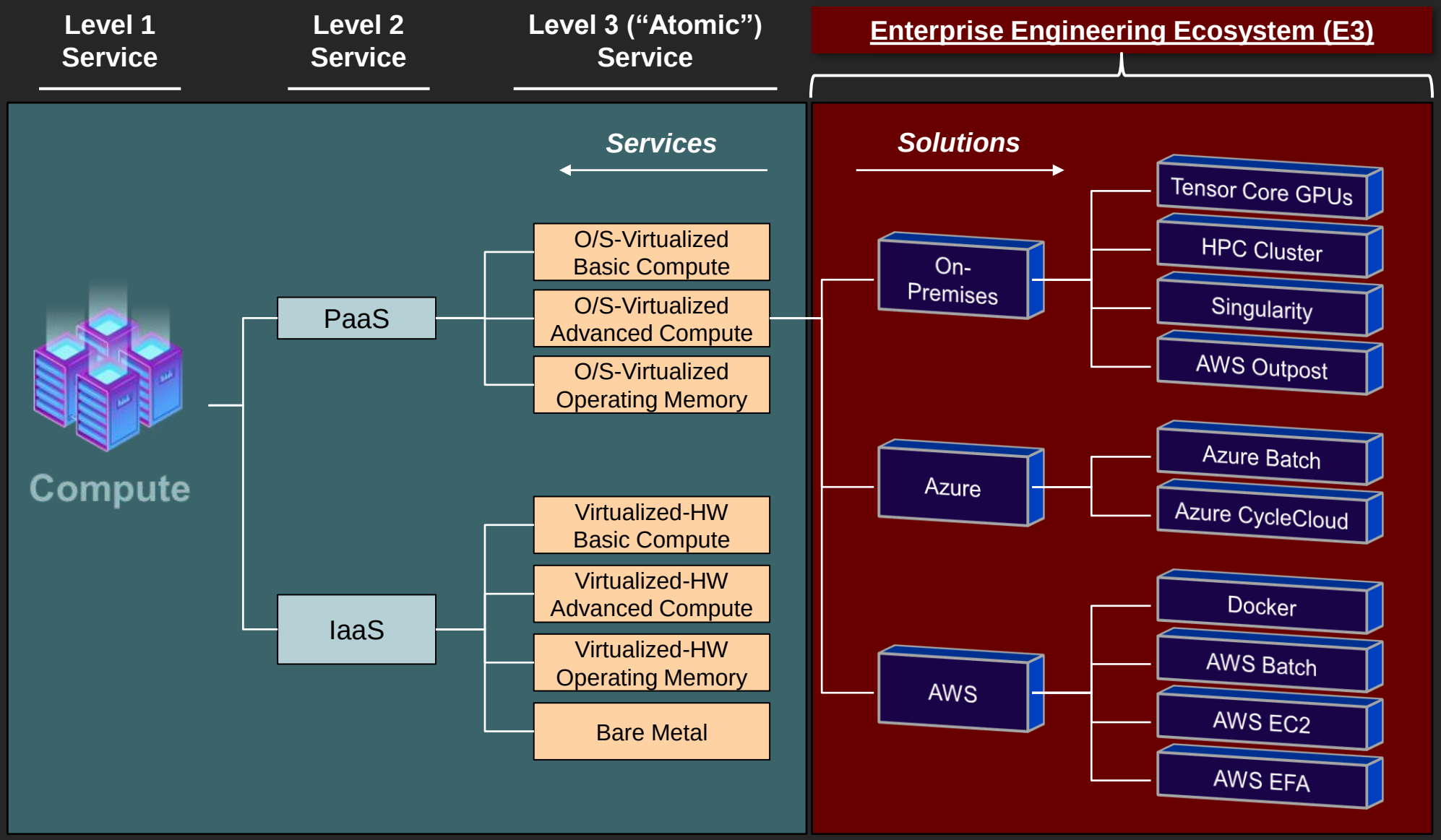
Users modify the workflow for their purposes, reordering services, pulling in additional atomic services

New workflows (after some curation) get added to the Workflow Library



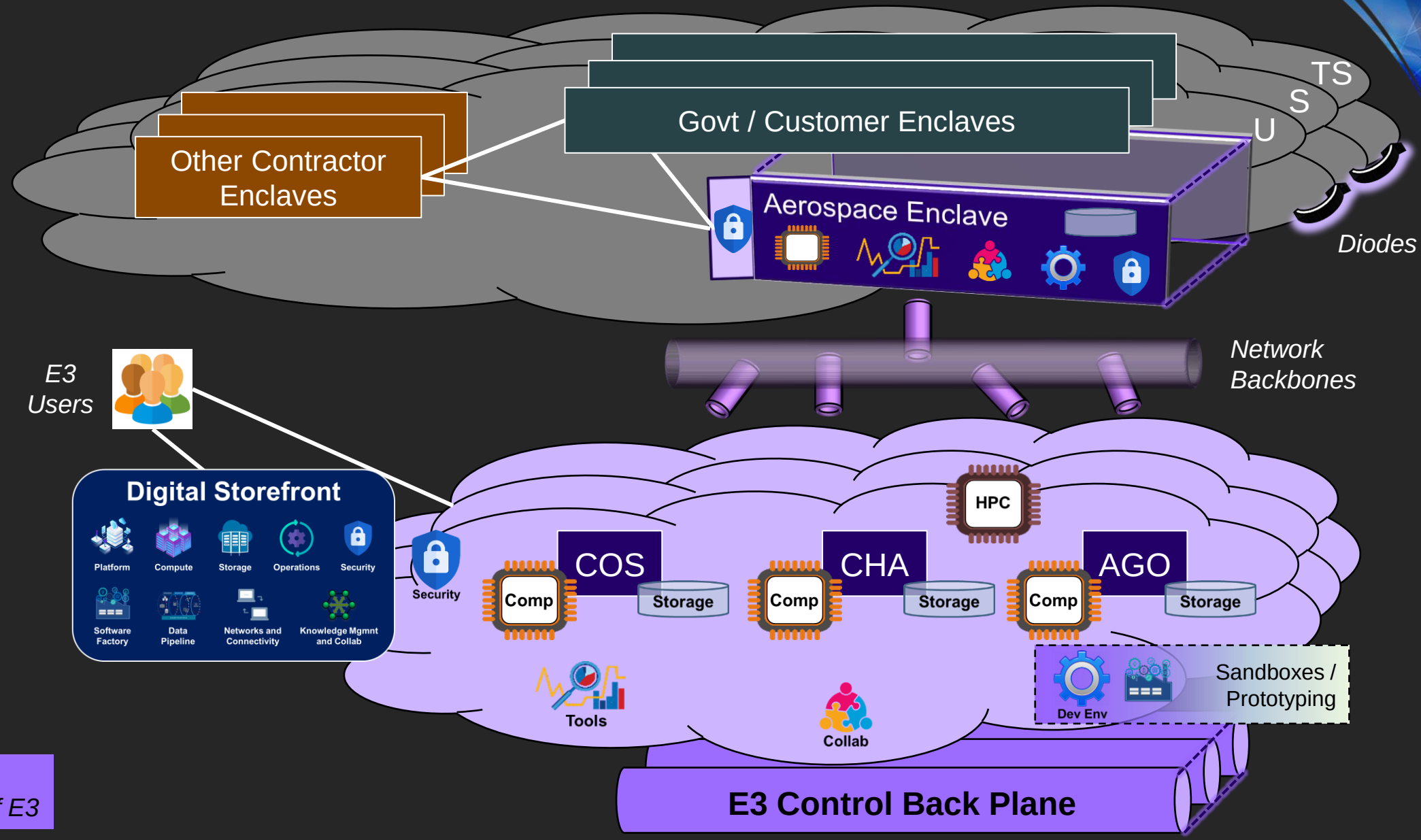
Stakeholder Framework: Role-based view of user needs and workflows

Aerospace DEE Physical / Solution Architecture



- Services are allocated down to specific resources
- CONOPS drives nature of solutions

E3 Multi-Cloud Architecture ("OV-1")



Shades of purple represent elements of E3

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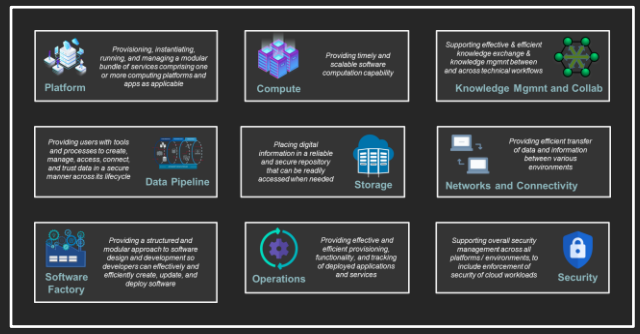
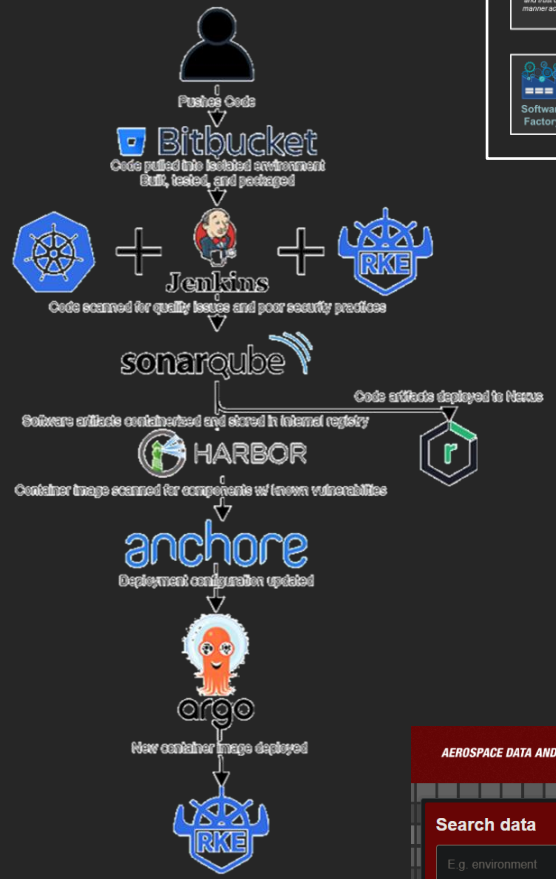
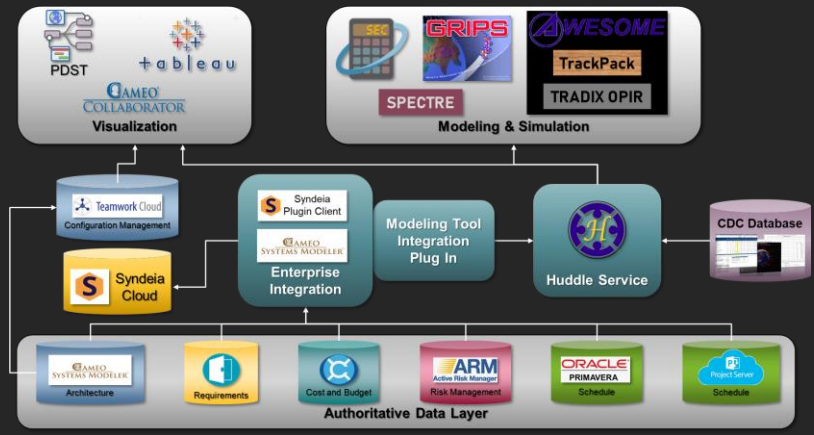
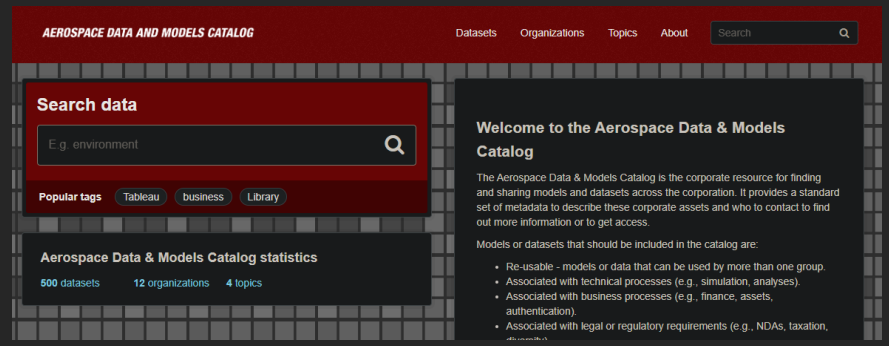
Current Status

- **Progress to Date**
  - *Functional Architecture*
    - Services framework 1.0 complete
    - All services captured in model (via UML)
    - Technical leads assigned
  - *Physical/Solution Architecture / E3*
    - AWS IL4 and IL5 connectivity
    - Compute and storage services
    - Cybersecurity services
    - Software factory services
    - Data and models Catalog
    - Hosting of digital sandboxes
    - Customers: Future STARS
  - *HPC Business Case Analysis*
  - *Pilots*
    - See next slide

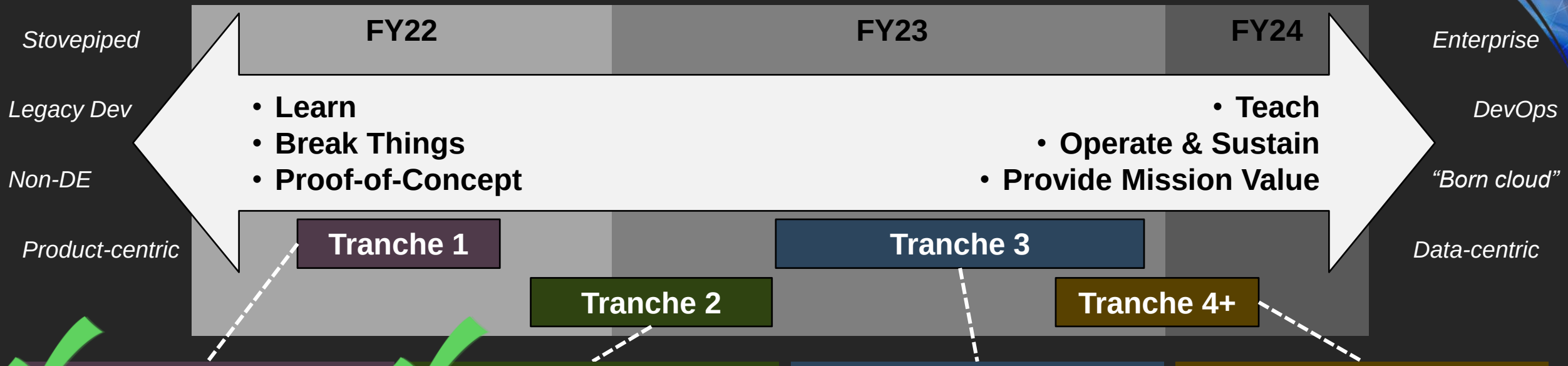








DEE Piloting



Characteristics of Tranche 1

- Simple, low risk; prove we can go fast and operate in cloud
- Track/understand actual costs and cost/performance trades
- Lift-and-shift candidates, i.e., mostly / entirely containerized
- Involve eager participants who have early-adopter mentality
- **Tools: DART, Informed, Magic, and Scout**

Characteristics of Tranche 2

- Moderate utility, including DE applications or key enablers
- Gain confidence in costing, sched, migration, & CONOPs
- Partially containerized; emulating E3 on AWS
- Exposing tool functionality across service boundaries to provide direct customer value
- **Tools: PDST and Huddle**

Characteristics of Tranche 3

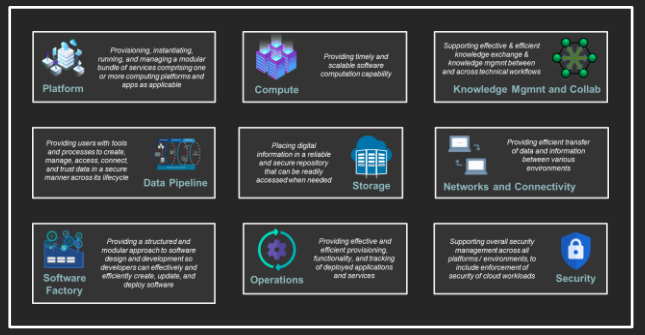
- Broader utility/scope, to include models and COTS tools
- Less containerization or more integration w/ cloud services
- Assessing data lineage approaches (e.g., CM, ASOT)
- Establishing sustained presence in cloud, to include prototyping and development
- **Cameo, ModelCenter, NNSA DE Workflow, HPC Pilots**

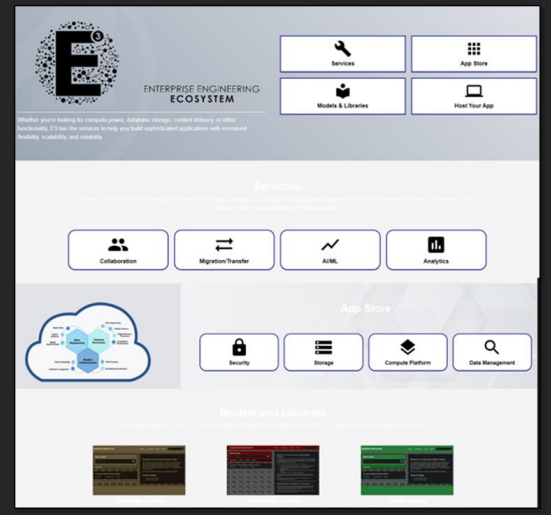
Characteristics of Tranche 4+

- Broader utility/scope to include models, data, and/or ASOTs
- Minimal or no containerization
- Hybrid workflows across cloud platforms (e.g., on-prem vs. public, AWS vs. Azure, exfil)
- Self-help workflows
- Multi-level security CONOPs
- HPC assessment
- TBD

Current Status

- **Ongoing Work**
  - *Services Framework*
    - Status of solutions/resources being assessed => gap analysis
    - Undergoing additional review w/ progress metrics being developed
  - *Workflows*
    - Working with users to “translate” their workflows into services framework
    - Identifying and establishing foundational design patterns
  - *E3*
    - Digital Storefront to access services and workflows, onboarding wizards
    - Expansion of services to classified levels
    - ANVIL to create first instance of E3 in collateral secret environment
  - *Broader business case analyses*
  - *Data Pipeline*
    - See next slide regarding Challenges



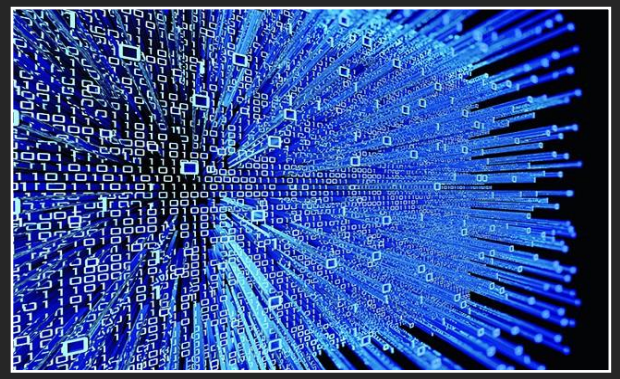


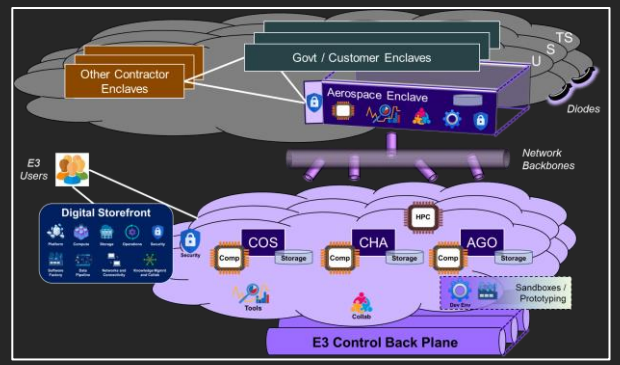
Biggest Near-Term Challenges

- **Data-Centricity**
  - *Data lineage, data tagging, standards, ontology, governance*
  - *“ASOTness” => fitness for purpose*
  - *Data CONOPs*

- **Multi-Cloud CONOPs**
  - *Hybrid workflows*
  - *Cross domain and multiple security levels*
  - *Synchronization, config mgmnt, interoperability*

- **Digital Transformation Blueprint**
  - *Proven strategies for our community*
  - *Ensure extensible / tailorable solutions*
  - *(Not just the DE ecosystem)*





Summary

- **Background / Context**
  - *Corporate strategy, roadmap, governance*
- **Aerospace DE Ecosystem**
  - *Definitions, scope, middle-out vs. top-down*
  - *Functional architecture, solution architecture (E3)*
- **Current Status**
  - *Progress to date and current challenges*
- **What's Next**
  - *Opportunities for collaboration?*