Verification of Collaborative Autonomous Systems for Multi Domain Operations Using a DevSecOps Model

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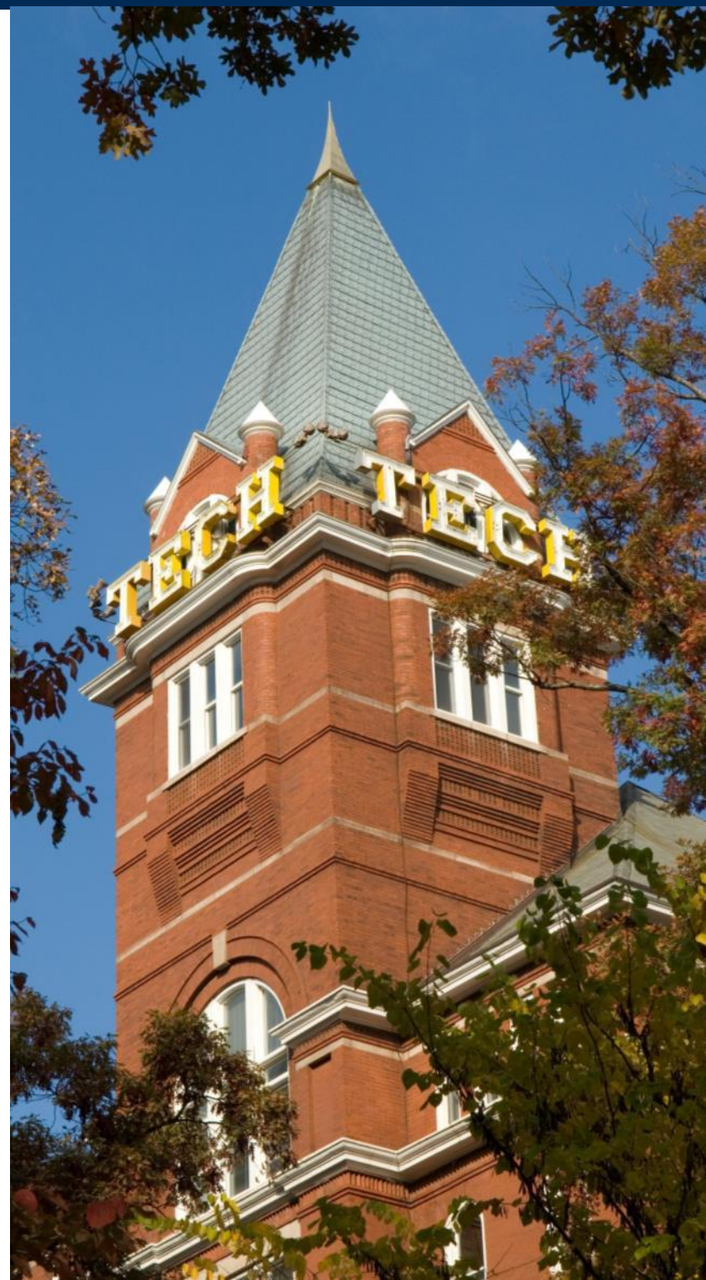


Outline

- Distributed Multi-Domain Warfare
- Digital Advanced Battle Management System (ABMS) and the Electromagnetic Spectrum (ES) “Domain”
- Autonomy As a Means to Gain ES Dominance
- Concepts of DevSecOps
- Autonomy Software Factory
- Continuous Testing





Terms of Multi-Domain

- **Domain**. [1]

  "*Maneuver in a domain is often a unique, defining feature that separates domains from one another.*"

  Domain: "*A critical maneuver space whose access or control is vital to the freedom of action and superiority required by the mission.*" Traditionally DoD domains are air, space, land and sea. Cyber has recently been added to the list and sometimes generalized to Electromagnetic Spectrum.

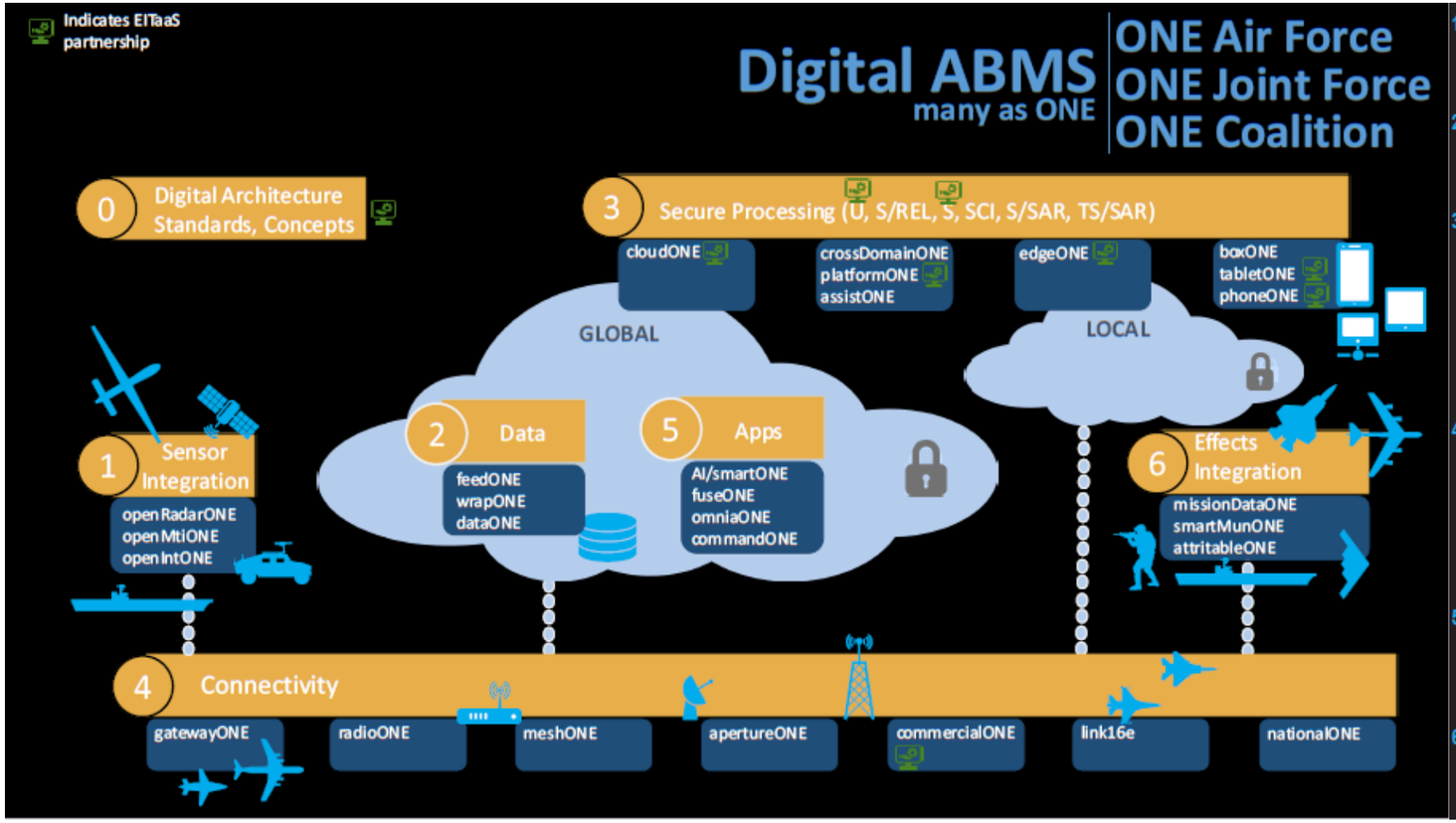
- **Multi-Domain Operations (MDO)**.2

  MDO is more than systems in one domain supporting operations in another domain (necessary but not sufficient). MDO are high velocity, operationally agile operations that present multiple dilemmas for an adversary at an operational tempo they cannot match.

  Multi-Domain Command and Control (MDC2). Seamless, dynamic and continuous integration of capabilities generating effects in and from all domains

1. Jared Donnelly and Jon Farley, Defining the Domain in Multi-Domain, Sep 17 2018, othjournal, https://othjournal.com/2018/09/17/defining-the-domain-in-multi-domain.
2. Brig Gen Chance "Salty" Saltzman, MDC2 Overview, 2018 C2 Summit,

Digital Advanced Battle Management System (ABMS)



1. SENSOR INTEGRATION (indicates EITaas partnership)
   - openRadarONE..... Government-owned open architecture radar system & test bed
   - openMtiONE..... Mode to enable air & ground moving target indication on any open RadarONE radar
   - openIntONE..... Common open sensor architectures across domains (e.g. GEOINT, MASINT, etc.)
2. DATA
   - feedONE ..... Cloud-based data feeds from government and non-government sources
   - wrapONE ..... CloudONE hosted automated artificial intelligence meta data wrapper for analytics, algorithms & fusion
   - dataONE ..... Cloud-based & discoverable data library & data manager
3. SECURE PROCESSING
   - cloudONE..... Multi-level security cloud at U,S/REL,S,SCI,S/SAR,TS/SAR for development, data & applications
   - crossDomainONE..... Secure solution to move data up & down security levels
   - platformONE..... Cloud-based interoperable software development environment
   - edgeONE..... Edge based cloudONE for local processing data & apps even when disconnected from global cloudONE
   - boxONE..... Edge workstation that seamlessly accesses multi-level secure cloudONE or edgeONE network; zeroized option
   - tabletONE..... Tablet that seamlessly accesses multi-level secure cloudONE or edgeONE network; zeroized option
   - phoneONE..... Smart phone that seamlessly accesses multi-level secure cloudONE or edgeONE network; zeroized option
   - assistONE ..... Rapid deployment & configuration team for secure processing & user devices
4. CONNECTIVITY
   - gatewayONE ..... Government-owned open system enabling translation & communication across platforms
   - radioONE..... Government-owned open software-defined radio
   - meshONE ..... Government-owned open software-defined mesh network
   - apertureONE ..... Government-owned apertures capable of multiple functions (e.g. communications, radar, & electronic warfare)
   - commercialONE..... Robust classified capabilities over commercial communication networks
   - nationalONE..... Robust connectivity of data & intelligence between the IC & tactical edge
   - link16e ..... Enhanced legacy link 16 for resilient performance
5. APPS
   - AI/smartONE ..... Cloud-based algorithm development environment & library
   - fuseONE..... Cloud-based multi-domain intelligence & information fusion environment, enabled by cloudONE
   - omniaONE ..... Cloud-based multi-domain common operating picture, enabled by fuseONE
   - commandONE..... Cloud-based multi-domain battle management & machine-to-machine command & control
6. EFFECTS INTEGRATION
   - missionDataONE ..... Cloud-based real time update to mission data files
   - smartMunONE..... Networked smart weapons capable of dynamically retasking 3rd party sensor suites
   - attritableONE ..... Multi-role attritable capabilities

2019 Dr. Roper (SAF/AQ) appointed Preston Dunlap to be AF Chief Architect.

First order of business was to recast ABMS as Digital Solution for MDC2.

Approach: Build capability through 28 "thin" builds that complement one another.

How do we validate this system?

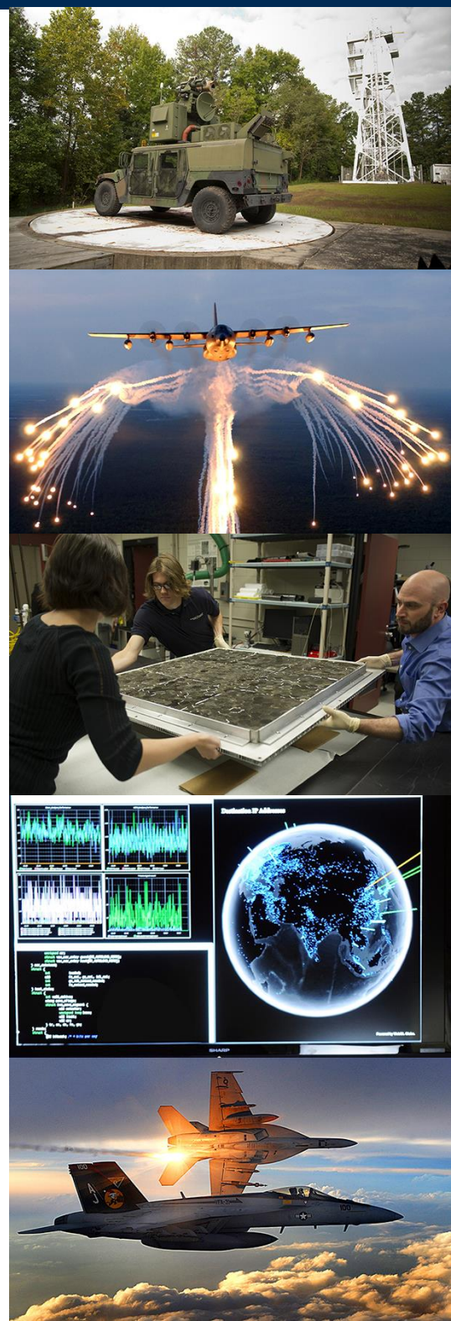
Expanded Ideas of 'Domain'

Electromagnetic Spectrum (ES) Domain.

- In 2011, the DoD recognized the strategic significance of managing the disparate missions of communication and control, strike, surveillance, navigation, and electronic warfare as a single, integrated ES "maneuver space" [3]
  - New strategic domain spans the traditional warfighting domains of air, space, land and sea, enabling Multi Domain Operations (MDO) and Command and Control (MDC2).
  - Managed across many platforms (manned and unmanned) with many unique ES enabled payloads across vast distances in land, sea, air and space.

- **Dominance in ES domain**: *Extending ES-enabled platforms some degree of autonomy and providing them with the ability to collaborate*.

Collaborative autonomous software services will form the backbone of Digital ABMS



3. Knowles, J., "Strategic Thinking?," Journal of Electronic Defense, SEPTEMBER 2011 • Vol. 34, No. 9

Autonomy Play Calling Concept

Provide a collaborative autonomous system of agents with flexibility to adapt to the environment, threats or changes in priorities but ensure they obey certain rules and are focused on achieving objectives.

- **Play calling** – A supervisory state machine evaluates information from the agent's sensors, avionics and network and based upon that information will call a play to be executed. The play is simply some predefined (parametric) behavior.

- **Collaborative Task Negotiation**. If a play requires multiple agents with prescribed roles, then the agent may negotiate with other agents to adopt the play and assume roles in the play. Often this is accomplished using a market based auction but could be any method including a state machine.

Benefits of a Playbook:

- Information used to trigger a play can be from anywhere and take any form.
- Plays can be restricted using constraints described in time, space, or state space.
- Plays can be called with humans (Man-Machine Teaming) or without (Machine-Machine Teaming).
- Task negotiation can be decentralized or hierarchical or a hybrid.

The DevSecOps Software Factory

Autonomy services are, in essence, *Software*.
So we should be looking for ideas that promote efficiencies in building and testing Software: **DevSecOps factories.**

- 2019 Nicolas Chaillan appointed to be AF Chief Software Officer by Dr. Roper (SAF/AQ)

- 2019 Dan Deasy appointed to be Chief Information Officer of OSD.
  - **In cooperation, AF and OSD immediately issued guidance on moving to a DevSecOps approach.[4]**
  - **AF created and staffed LevelUp and PlatformOne to assist programs in creating DevSecOps Software Factories**
  - **Software Factory methods now integrated with the Digital ABMS approach.**

- **Fielded Factories: Kessel Run (2017) Kobayashi Maru (2018) Space CAMP (2019), …**

What is DevSecOps?

A compound of development (Dev) security (Sec) and operations (Ops), DevSecOps is the union of people, process, and technology to continually provide secure software services.

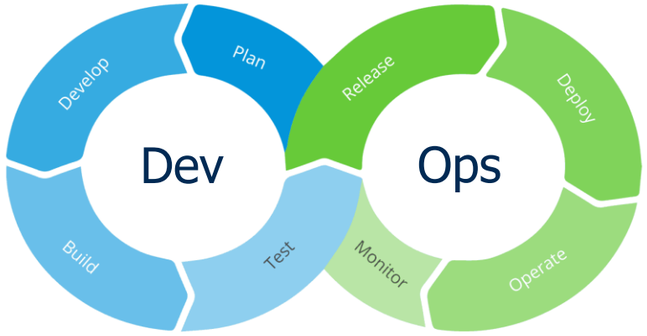
3 key ideas for autonomy software:

- Breaking down monolithic autonomous software services into multiple loosely coupled "microservices"
- Containerizing microservices for portability and baked in security
- Performing continuous integration, continuous testing, continuous delivery

4. Department of Defense (DoD) Chief Information Officer, "Enterprise DevSecOps Reference Design Version 1.0, 12 August 2019.

A Software Factory Approach for Multi-Domain Autonomy

- DevSecOps pipeline model provides products that naturally span multiple missions and then integrate in deployment
  1. Produce novel and innovative algorithms.
  2. Transforms these into production software.
- Services become domain (air, land, sea, space) agnostic thus naturally enabling MDC2



6 months – 3 years: S&T to create new behaviors

Hours to weeks: tune behaviors & triggers

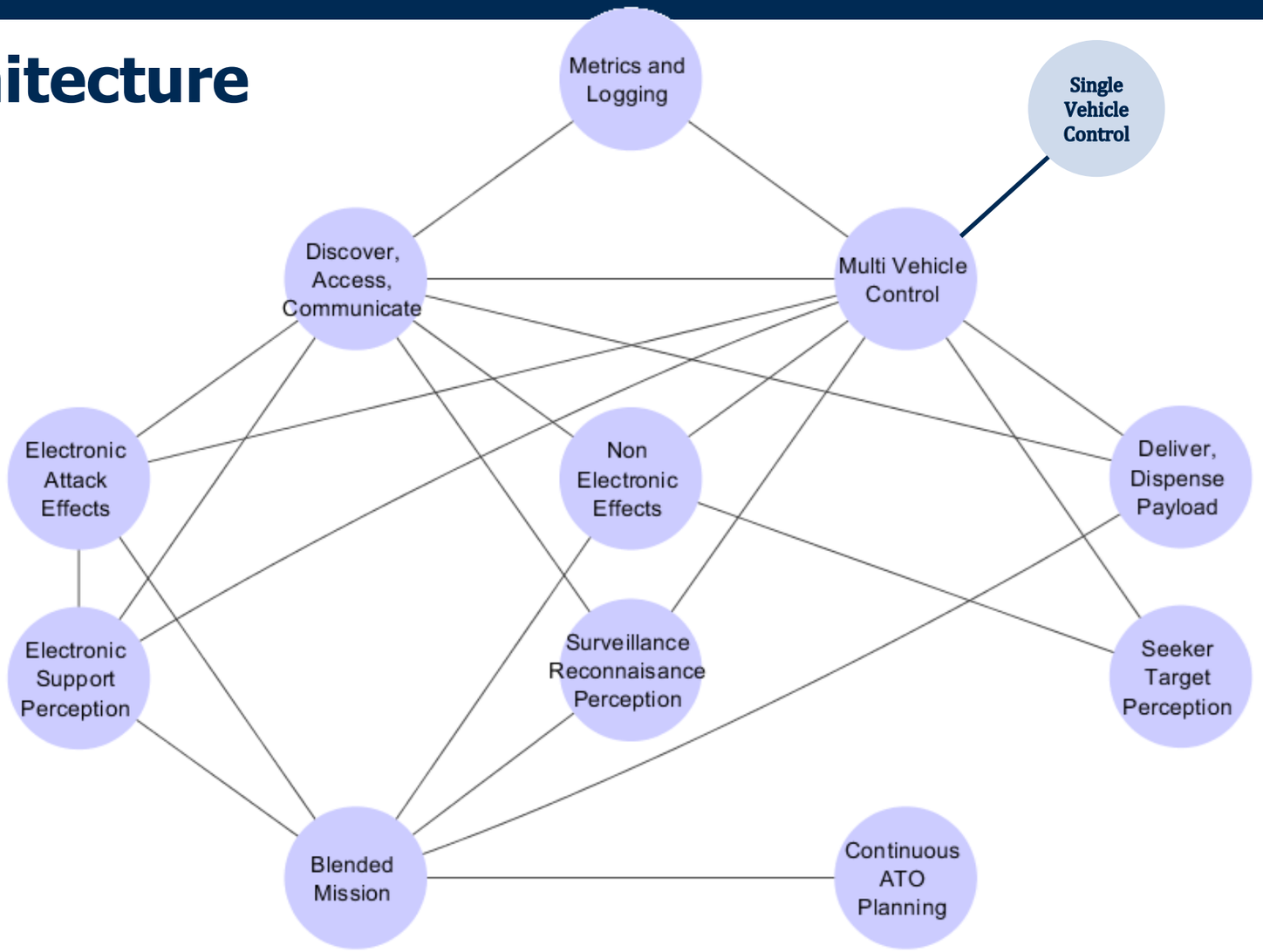
Microservices API Architecture

What are Microservices?

*"An approach to structuring systems as a collection of loosely-coupled services. Goes hand-in-hand with small, autonomous teams that develop, deploy, and scale their services independently."**

Decomposes an application into single-function modules with well-defined application programming interfaces (APIs).

*https://www.atlassian.com/software-development/practices/microservices



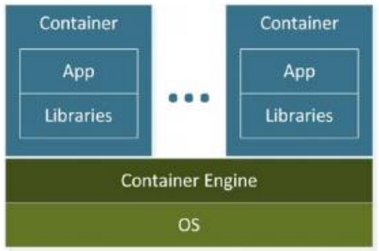
Well designed microservices and APIs are key to enabling low latency applications and fast, efficient testing.

Deploying Autonomy Microservices to Hardware

Autonomy code is built in microservice pipelines

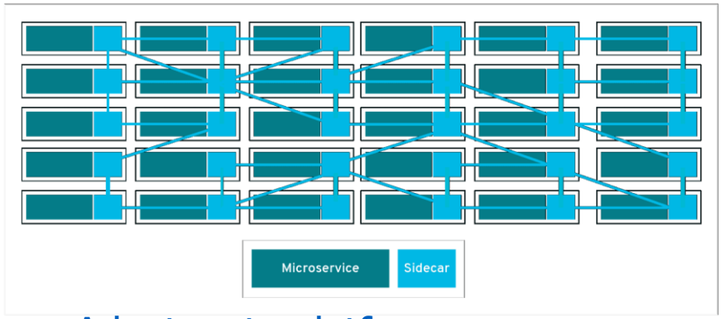
- Multi Vehicle Control (MVC)
- Electronic Attack Effects (EAE)
- Non-Electronic Effects (NEE)
- Electronic Support Perception (ESP)
- Surveillance & Reconnaissance Perception (SRP)
- Seeker-Target Perception (STP)
- Discover, Access, Communicate (DAC)
- Continuous ATO Planning (CAP)
- Blended Mission (BM)
- Metrics and Logging (ML)
- Deliver Dispense Payload (DDP)

Each microservice runs in it's own container

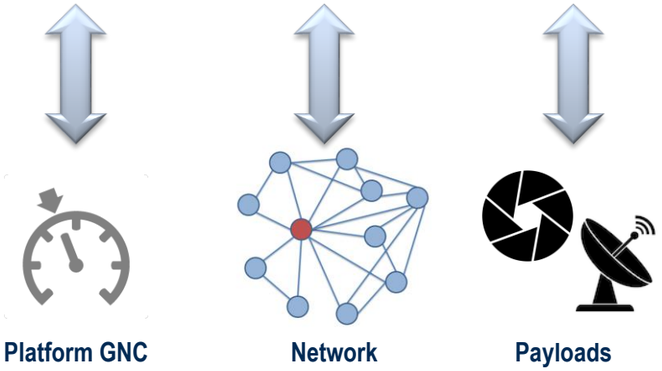


Multiple containers can run on the same OS

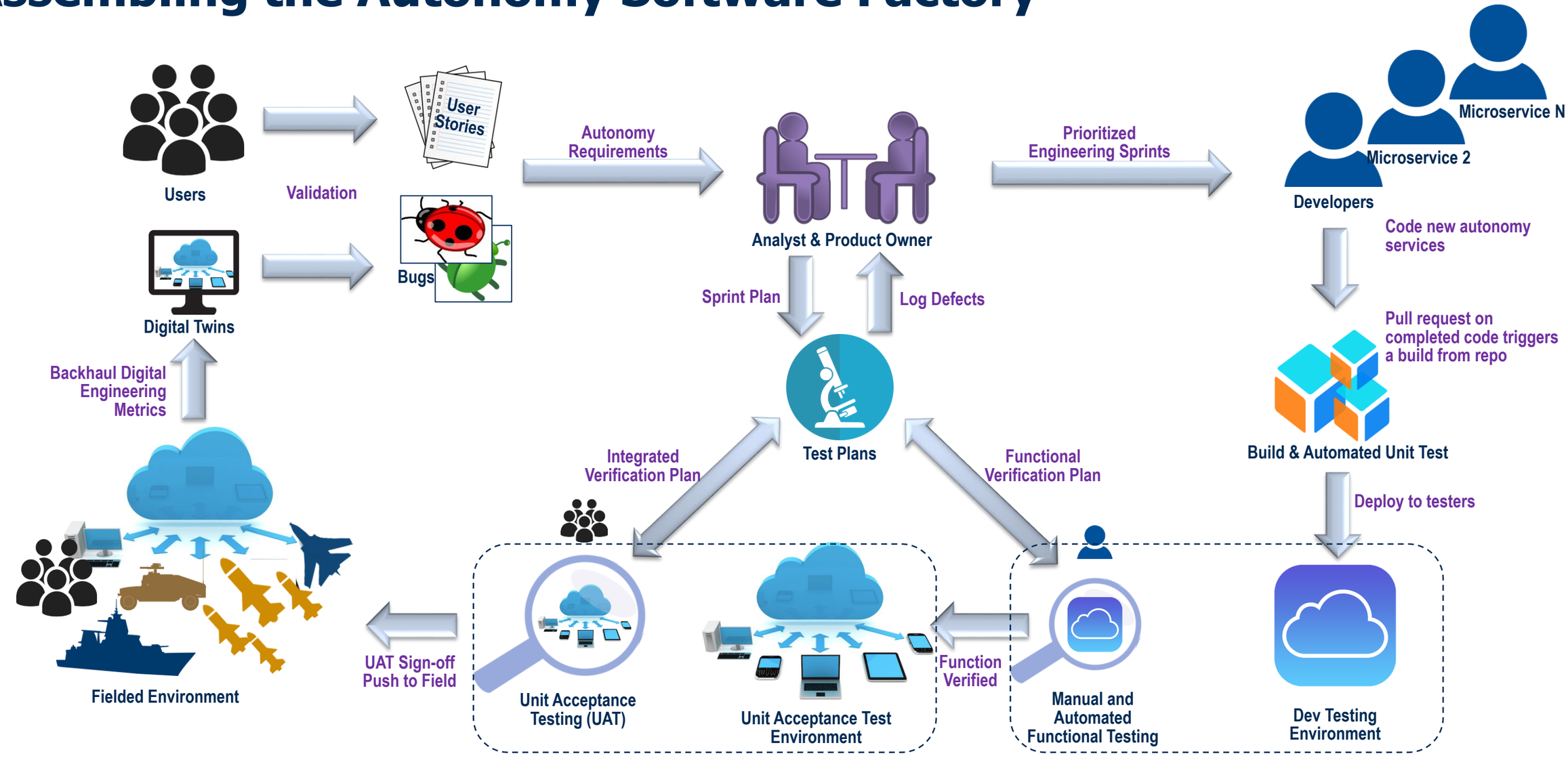
Containers are mesh deployed and coupled & secured with sidecars or a service mesh



Adapters to platform resources

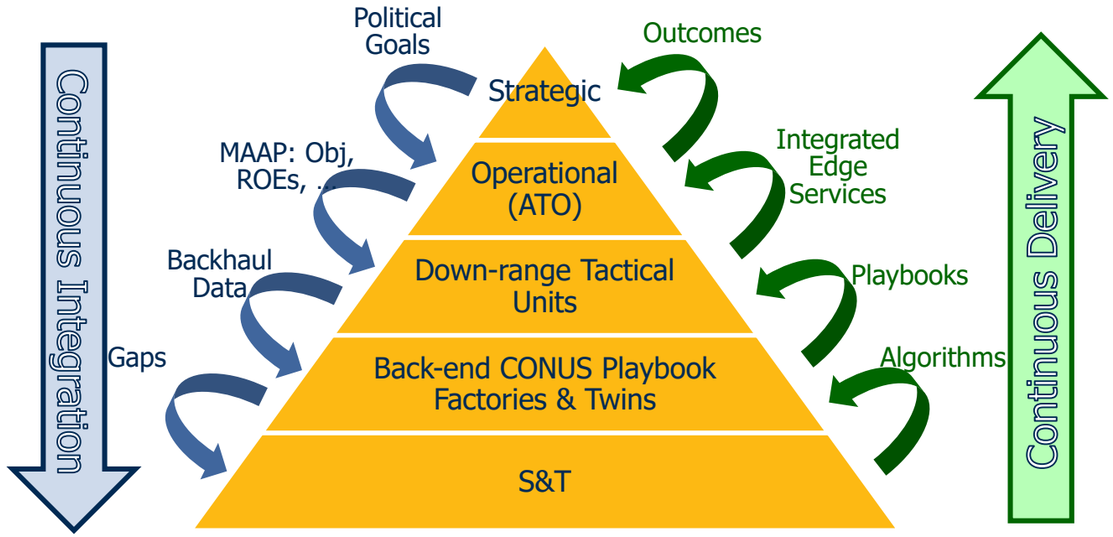


Assembling the Autonomy Software Factory



Integrate "Digital ATO Enterprise" into autonomy services factory

- Data collection for machine learning of new autonomy microservices
  - Ml requires massive data sets – cannot rely exclusively on simulated data
  - How do we "backhaul" operational data?
    - Must be sparse – challenged comms
    - Inverse reinforcement learning, transfer learning
    - Digital twin, "IoT on a weapon" linked to edge service
- Enhanced delivery pipelines to support continuous ATO
  - How do we push new microservices to the field at anytime and anywhere?
    - Algorithms to Playbook Production – CI/CD Dev Pipelines
    - Mission data, playbooks – CI/CD Ops Cloud & Edge



What is Continuous Verification Testing?

Testing Throughout Development. Learning throughout Operations.

- **Unit Build Testing**. Prioritized by risk. Mostly automated.
- **Functional Validation**. Ensure the functionality expressed in user stories works as expected.
- **Integration Testing**. Microservice integration is through APIs. So API testing becomes critical.
- **End-to-End Regression Testing**. Last step prior to fielding (Unit Acceptance Test).

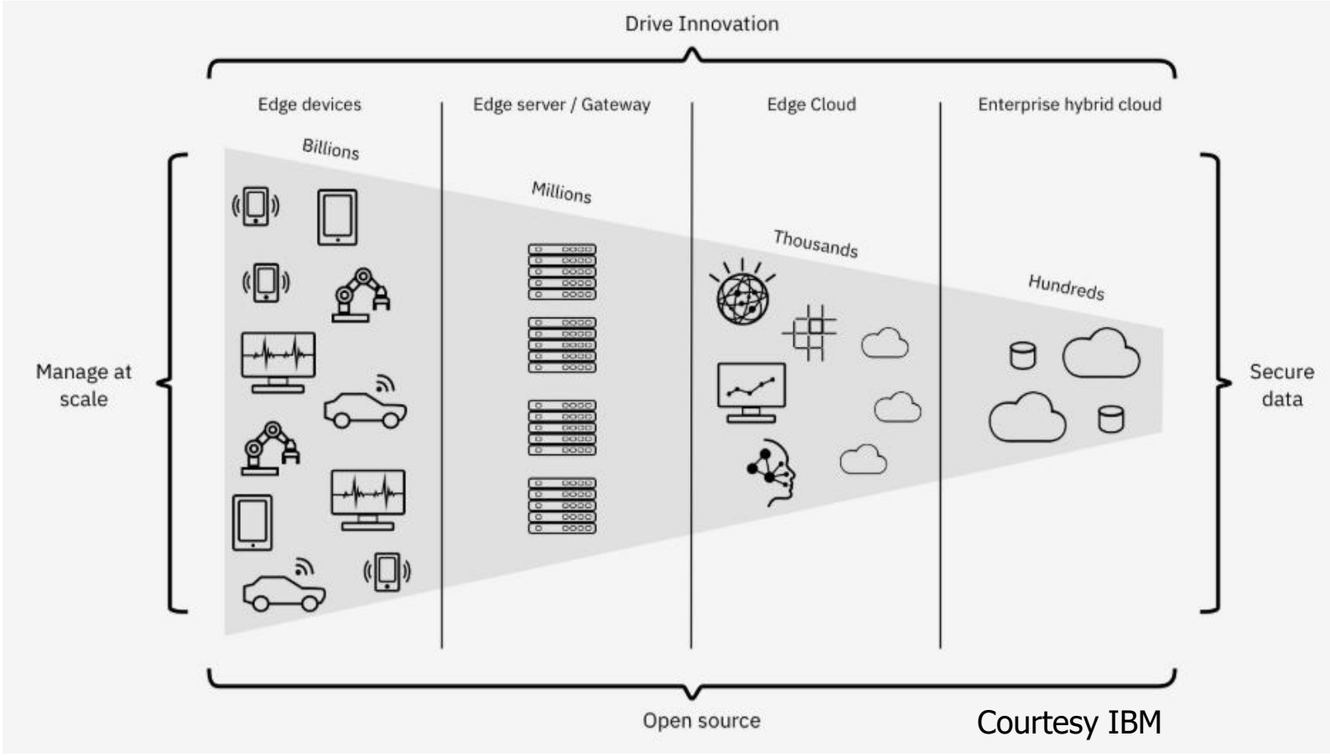
CT Practices	Why it Matters
"Chunk" change requests	Smaller units of code are easier and faster to build and verify
Shift left	Pulling production environments into early testing heads-off errors when cheaper to fix
Use "stubs" to accelerate testing	Simulated stand-ins for missing (hard) pieces help define the missing piece
Automate testing process	Automate pull requests to build, log defects, … speeds up time to fielding
Automate testing	Computer built scripts & test execution have fewer errors, more efficient use of test resources
"Canary" deployments	Deploying to small parts of the fielded system allow in situ eval without system-wide risk
Monitor fielded system	Automated digital engineering reliably captures user stories, bug reports, analytics, ML

A Note on Continuous Validation Testing (not yet solved)

- **Validation is strongly linked to the user**
  - Does it do what the user needs it to do (or not do)?
- **Validation is typically performed at the end of the testing cycle.**
- **DevSecOps methods: an <u>opportunity</u> to start validation much earlier.**
  - We could use “user stories” at functional level for incremental validation.
  - Short development iterations on small code changes with continual feedback from users: In the limit this is “continuous validation.”

Challenges Remain.
Multi Domain Autonomy as a Cyber Physical Deployment Problem.

- Devices (like IoT) exist on cloud edges.
- Edge devices create and consume data.
- Idea of Edge Computing is to compute at the edge. **This is autonomy.**
- However, we still want the benefit of the cloud
  - Analytics
  - Learning
  - Centralized development



Expect the demand for autonomy services to scale just as IoT and 5G will likewise need to scale. How will we test this?

Questions?

Thank you for your attention!

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