Continuous Iterative Development and Deployment Practices

Eileen Wrubel, Initiative Lead

Hasan Yasar, Technical Manager

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

This material is based upon work funded and supported by the Department of Defense under Contract No. FA8702-15-D-0002 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

The view, opinions, and/or findings contained in this material are those of the author(s) and should not be construed as an official Government position, policy, or decision, unless designated by other documentation.

NO WARRANTY. THIS CARNEGIE MELLON UNIVERSITY AND SOFTWARE ENGINEERING INSTITUTE MATERIAL IS FURNISHED ON AN "AS-IS" BASIS. CARNEGIE MELLON UNIVERSITY MAKES NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, AS TO ANY MATTER INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR PURPOSE OR MERCHANTABILITY, EXCLUSIVITY, OR RESULTS OBTAINED FROM USE OF THE MATERIAL. CARNEGIE MELLON UNIVERSITY DOES NOT MAKE ANY WARRANTY OF ANY KIND WITH RESPECT TO FREEDOM FROM PATENT, TRADEMARK, OR COPYRIGHT INFRINGEMENT.

DM18-1199

Enduring Software Challenges

Agile/DevOps Automation

Affordable
Be Affordable such that the cost of acquisition and operations, despite increased capability, is reduced and predictable

Trustworthy
Be Trustworthy in construction, correct in implementation, and resilient in the face of operational uncertainties

Secure DevOps

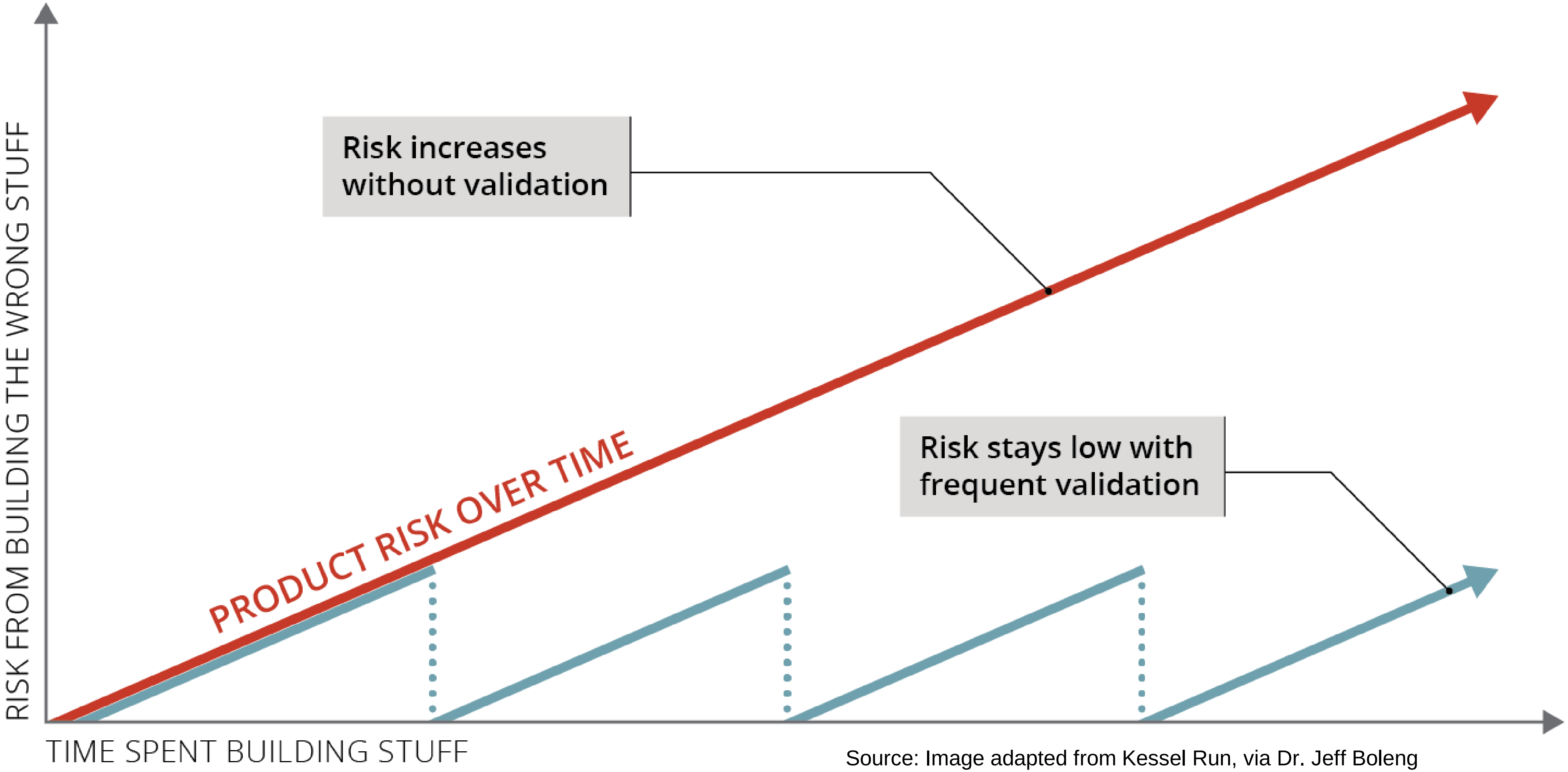
Agile

Capable
Bring Capabilities that make new missions possible or improve the likelihood of success of existing ones

Timely
Be Timely so that the cadence of fielding is responsive to and anticipatory of the operational tempo of the warfighter

DevOps

Decrease Risk to Programs with Continuous Iterative Development and Deployment Practices

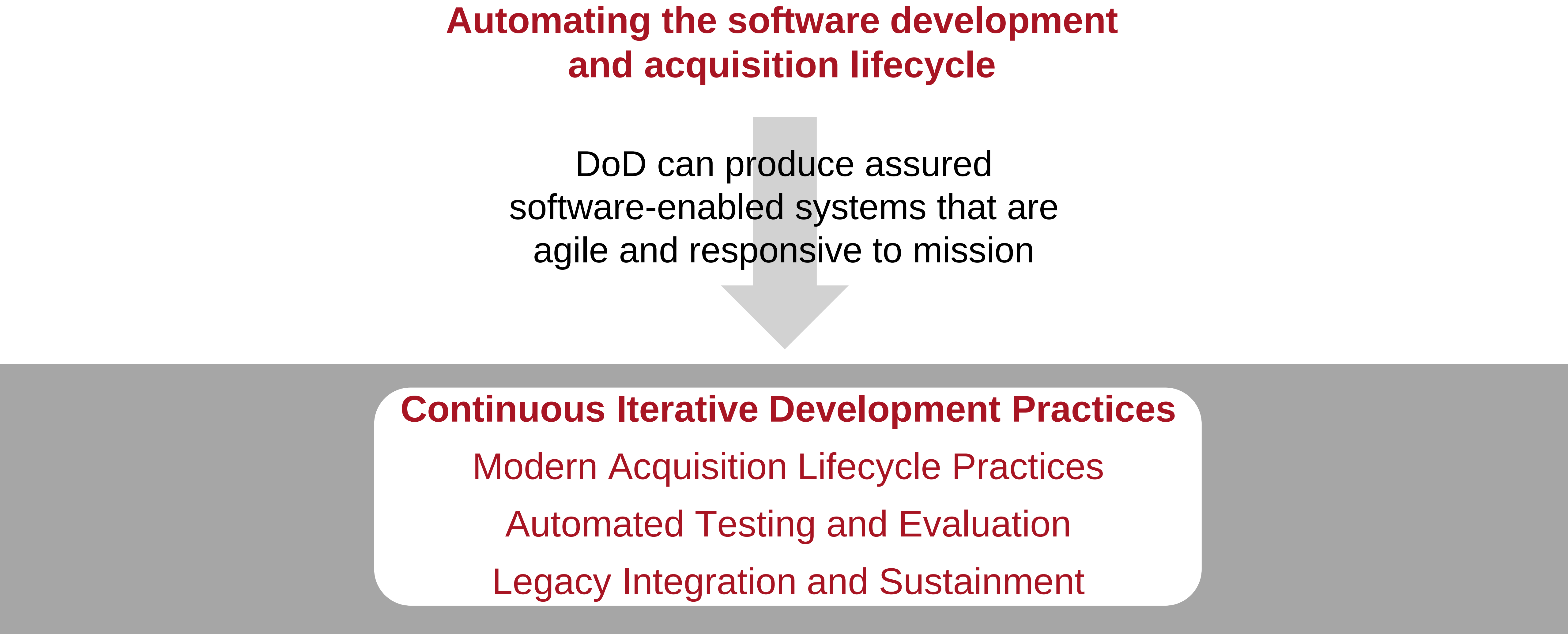


Risk increases without validation

Risk stays low with frequent validation

Source: Image adapted from Kessel Run, via Dr. Jeff Boleng

CMU SEI Objectives: DoD Outcomes



Automating the software development and acquisition lifecycle

DoD can produce assured software-enabled systems that are agile and responsive to mission

Continuous Iterative Development Practices

Modern Acquisition Lifecycle Practices

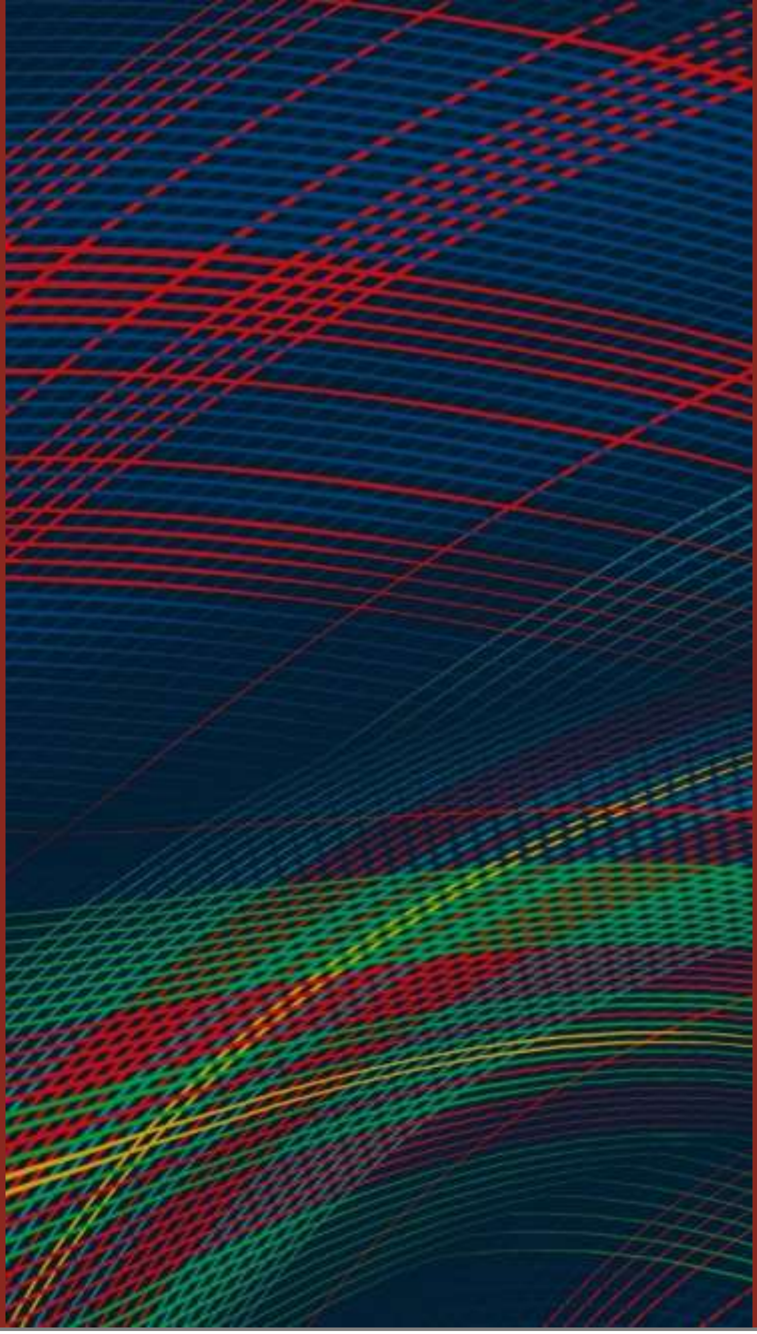
Automated Testing and Evaluation

Legacy Integration and Sustainment

Research Review 2018

Continuous Iterative Development and Deployment Practices

Why Is the DoD Software Landscape Different?



DoD Depends on Software but Does Not Control Development

Software and system complexity is increasing software cost and vulnerability, jeopardizing military capability

- DoD does not produce most of the software it uses, but it must maintain that software
- More and more capability results from software, and it will evolve for the lifetime of a system
- Latent cyber vulnerabilities, those exposed during operations, and those due to underlying dependencies are putting the DoD at risk
- Finding and fixing problems late causes rework and drives up costs
- Software cost overruns are overwhelming program delivery and sustainment

Modern software development and automated tools are critical

Defense Industrial Base and Commercial Companies Are the Main Developers of DoD Software

Challenges for DoD in adopting modern practices

- ✓ Risk acceptance
- ✓ Acquisition policy
- ✓ Testing
- ✓ Absence of DoD software ecosystems
- ✓ Slow adoption and enforcement of open standards
- ✓ Training
- ✓ Long delivery cycles
- ✓ Various software types on a single system

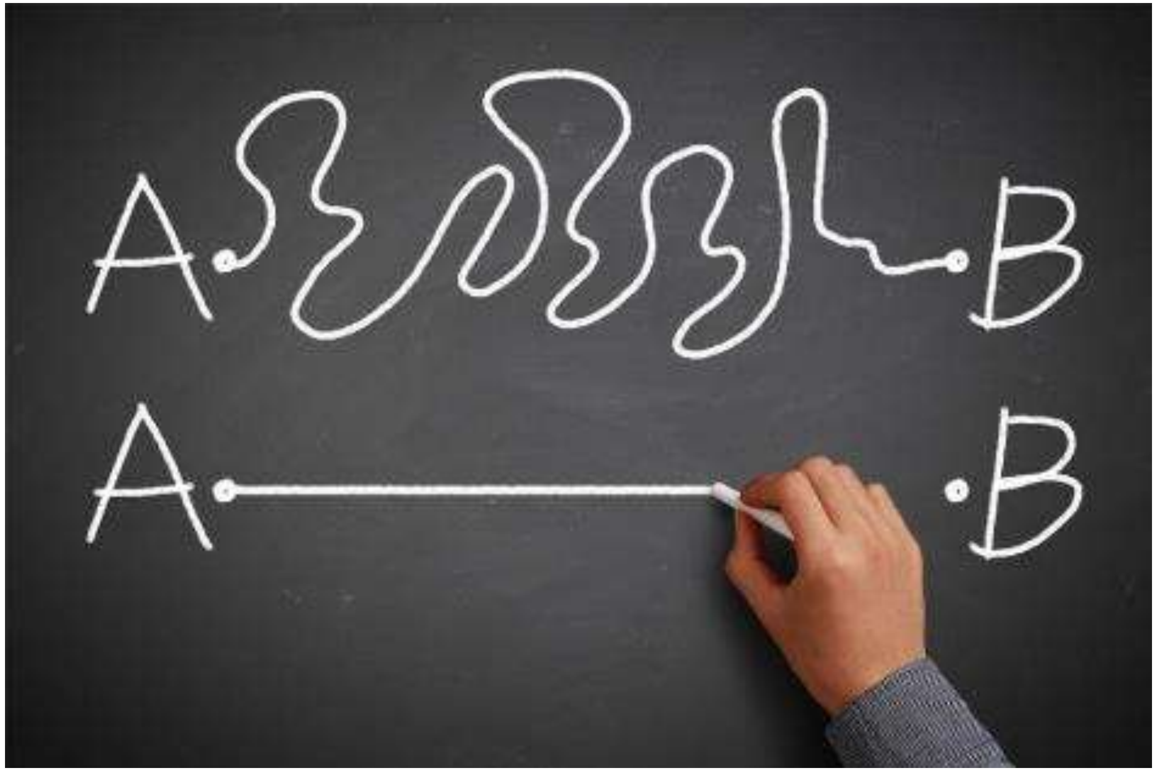
Commercial companies are widely adopting modern practices

- Use Agile, DevOps, cloud, automated test, continuous integration, and continuous release
- Goal: Ruthlessly automate all aspects of the development cycle

Defense industrial base is not incentivized to adopt modern practices

- Need new contracting and acquisition approaches

Modern Development Practices: Smaller Bites, Manageable Risk, Earlier in the Process



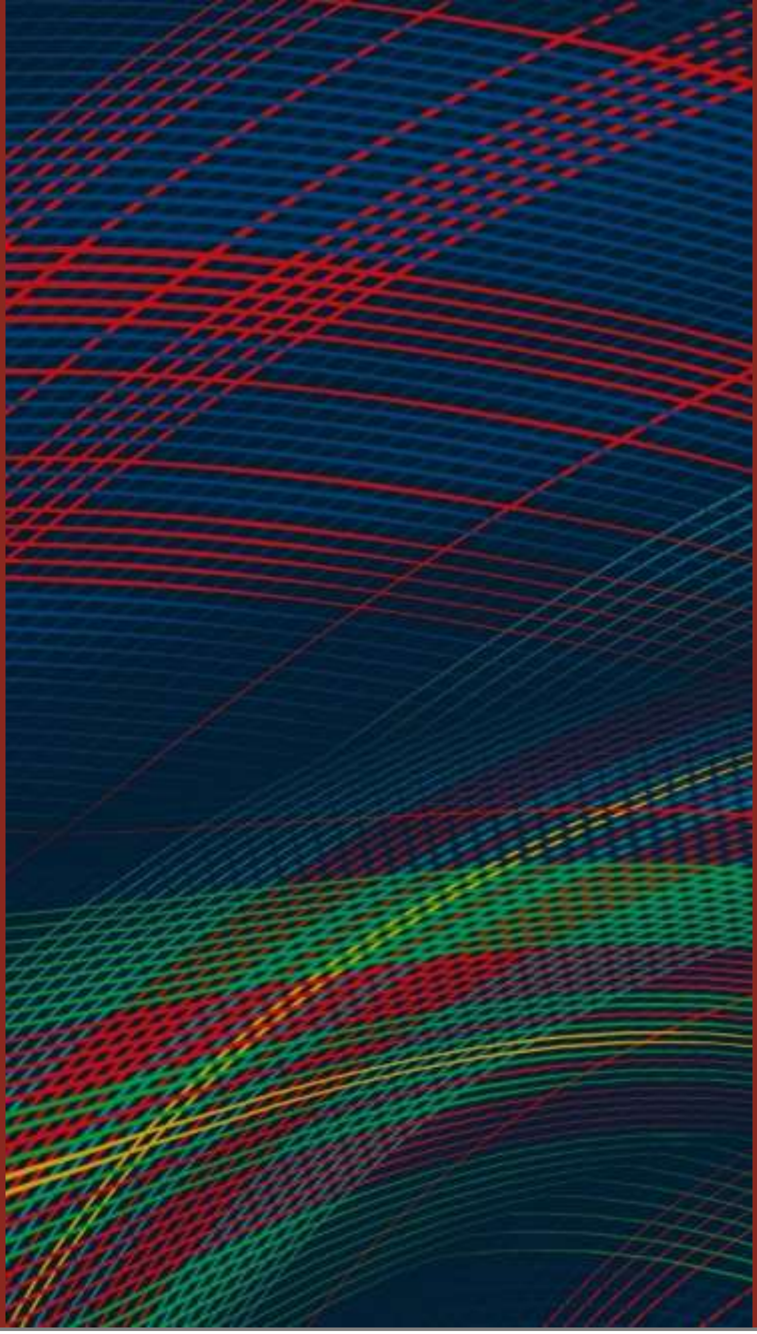
- Take advantage of tailoring allowed in acquisition policy
- Manage schedule in short, set increments
- Build capability in each sprint
- Automate test, integration, and assurance so they become ongoing engineering activities
- Build engaged, cross-functional teams that shift testing “to the left”
- Adopt approaches that fill technology gaps in the lifecycle
- Remember the importance of architecture

Agile, in its various forms, is an approach to software development in a DevOps environment, enabled by modern software factory tooling

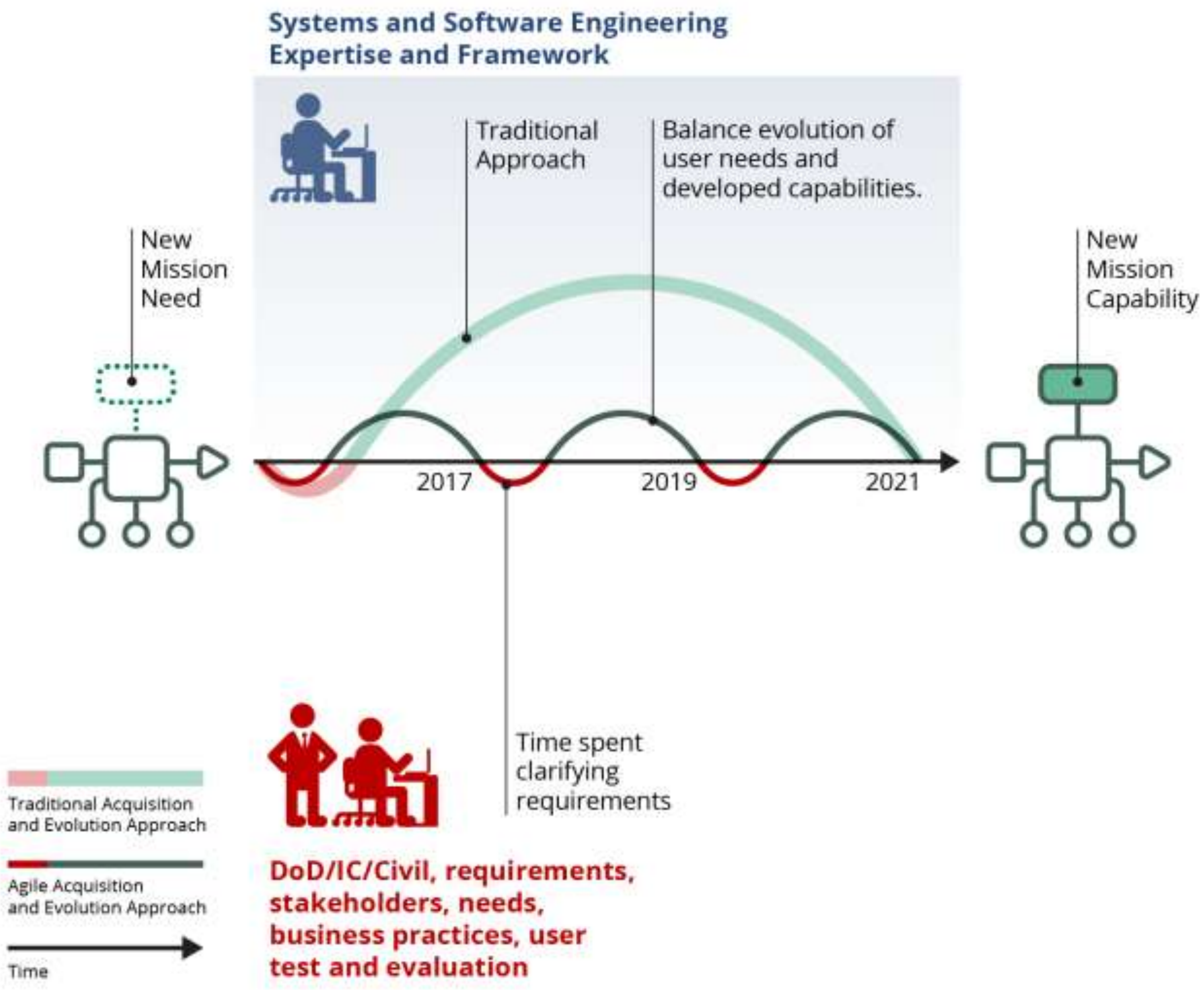
Research Review 2018

Continuous Iterative Development and Deployment Practices

Agile and DevOps Approaches Support the DoD’s Drive to Provide Capability While Controlling Quality, Cost, and Schedule



Motivation for Agile Approaches


Systems and Software Engineering Expertise and Framework
Traditional Approach
Balance evolution of user needs and developed capabilities.
New Mission Need
New Mission Capability
2017
2019
2021
Time spent clarifying requirements
Traditional Acquisition and Evolution Approach
Agile Acquisition and Evolution Approach
Time
DoD/IC/Civil, requirements, stakeholders, needs, business practices, user test and evaluation

- Deliver performance at the speed of relevance
- Streamline rapid, iterative approaches from development to fielding

Source: National Defense Strategy Summary, Jan. 2018

"…advance the capabilities required to restore our overmatch, speed the rate in which we field these advanced capabilities, and improve the overall affordability of our fighting forces weapons systems…."

Hon. Ellen Lord

Under Secretary of Defense for Acquisition and Sustainment

DevOps Principles

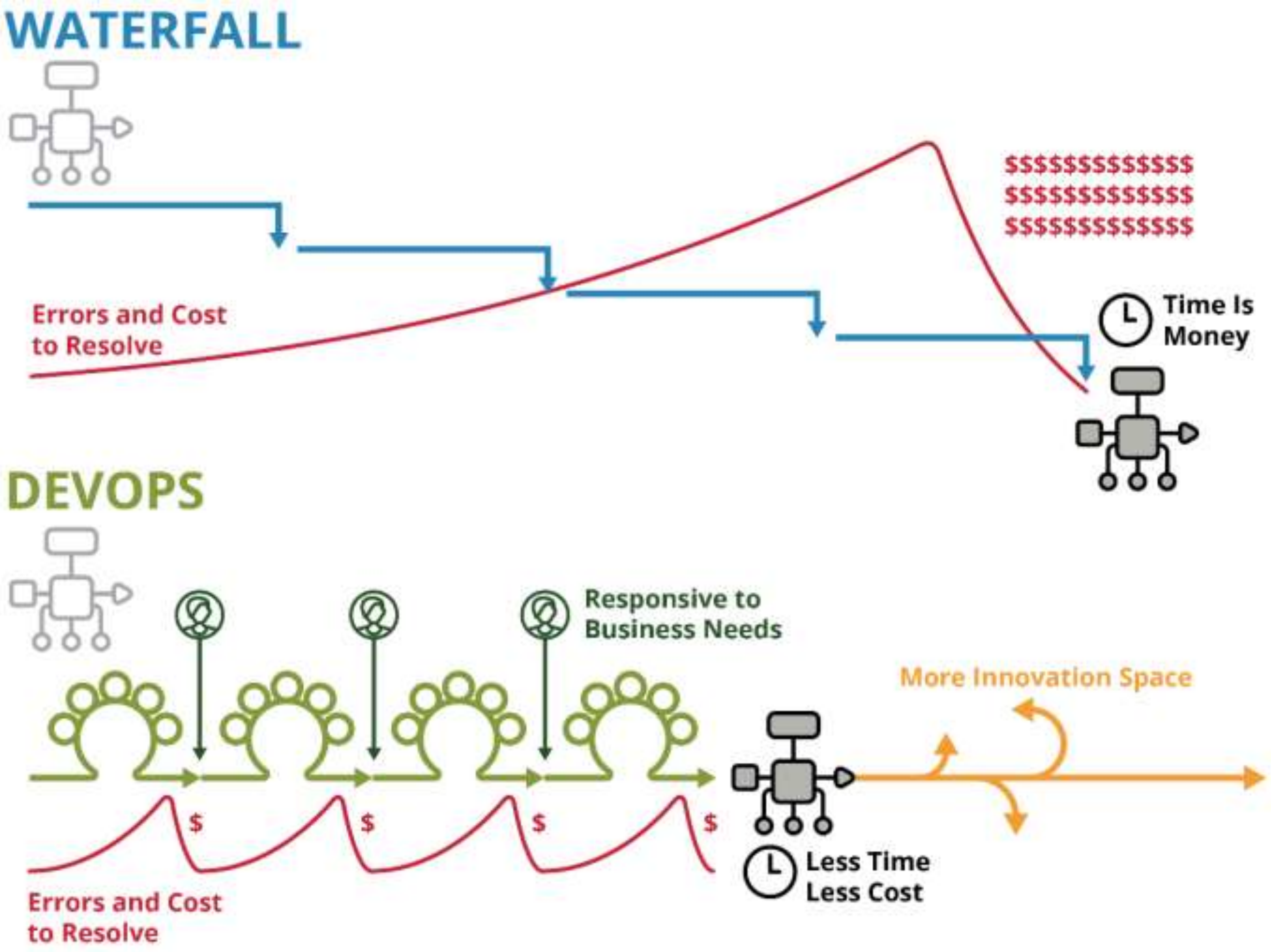
DevOps is a set of principles and practices emphasizing collaboration and communication between software development teams and IT operations staff along with acquirers, suppliers, and other stakeholders in the lifecycle of a software system[1]

Four Fundamental Principles

- *Collaboration* between all stakeholders
- *Infrastructure as code (IaC):* assets are versioned, scripted, and shared
- *Automation*: deployment, testing, provisioning, any manual or human-error-prone process
- *Monitoring*: any metric in development or operation that can inform priorities, direction, and policy

[1] IEEE P2675 DevOps Standard for Building Reliable and Secure Systems Including Application Build, Package, and Deployment

Benefits of DevOps

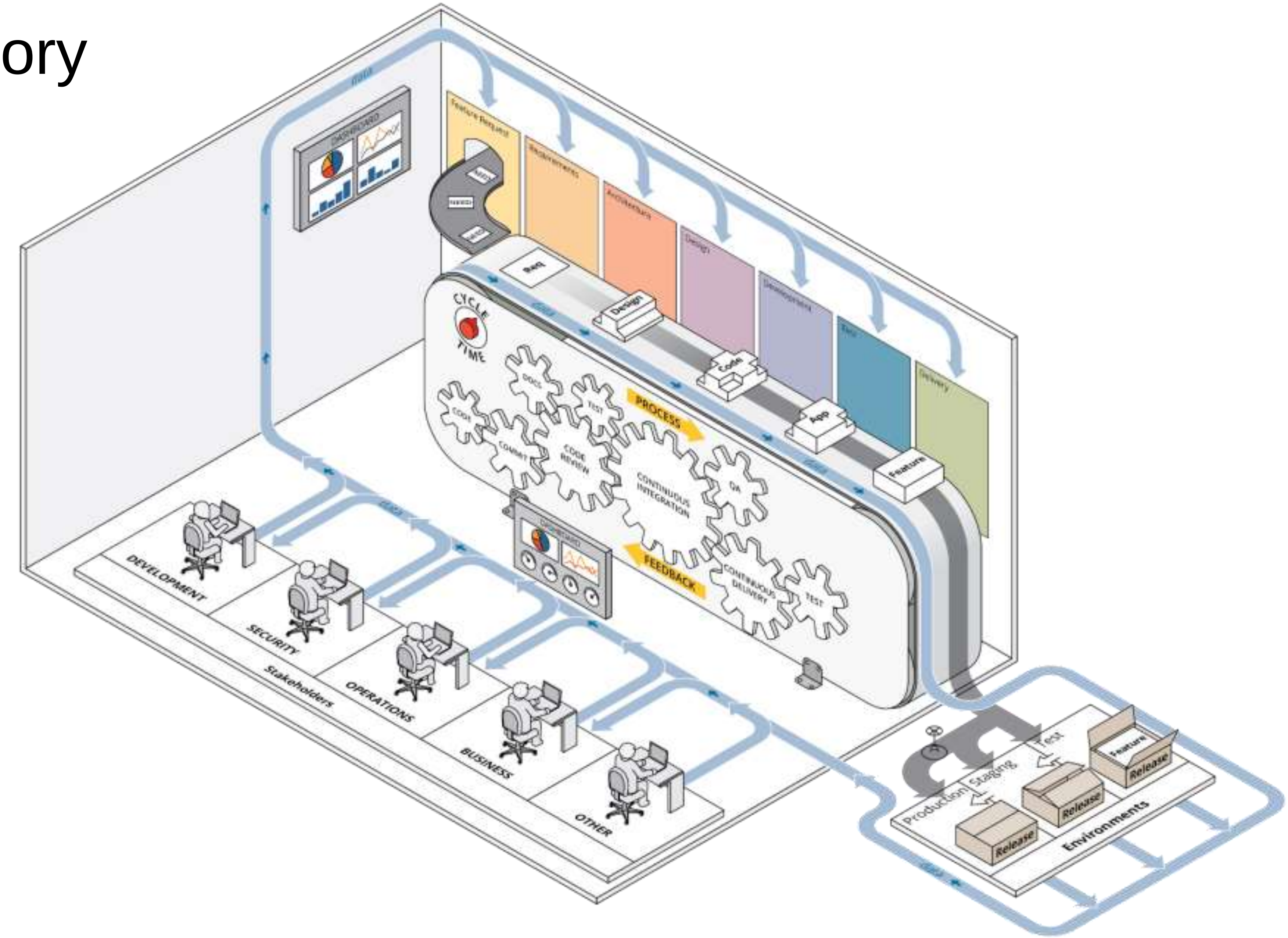


Benefits of DevOps

- Reduced errors during deployment
- Reduced time to deploy and resolve discovered errors
- Repeatable steps
- Continuous availability of pipeline and application
- Increased innovation time
- Responsiveness to business needs
- Traceability throughout the application lifecycle
- Increased stability and quality
- Continuous feedback

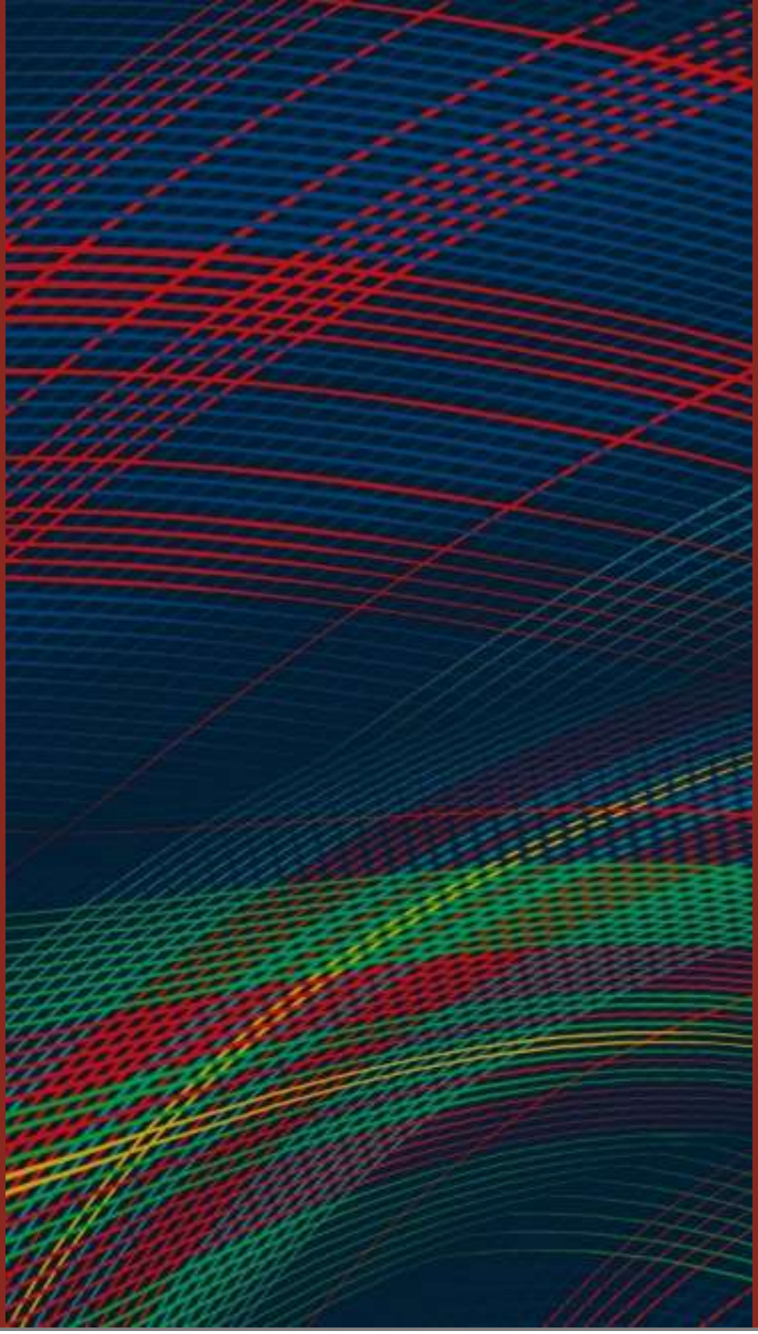
The DevOps Factory

- Feature to deployment
- Iterative and incremental development
- Automation in every phase of the SDLC
- Continuous feedback
- Metrics and measurement
- Complete engagement with all stakeholders
- Transparency and traceability across the lifecycle



Continuous Iterative Development and Deployment Practices

Real-World Results Using Agile and DevOps Approaches in Government Environments



Orion Independent Verification and Validation: The Challenge

Orion Multi-Purpose Crew Vehicle is NASA's next human-rated spacecraft

IV&V supports rapid software composition by assessing untrusted components:

- Adds evidence-based assurance that minimizes the overall risk that Orion software will prevent the EM-1 flight from occurring safely and successfully
- Adds assurance that all safety-critical mission events happen as expected or with satisfactory responses to adverse conditions and appropriate protection against undesirable conditions

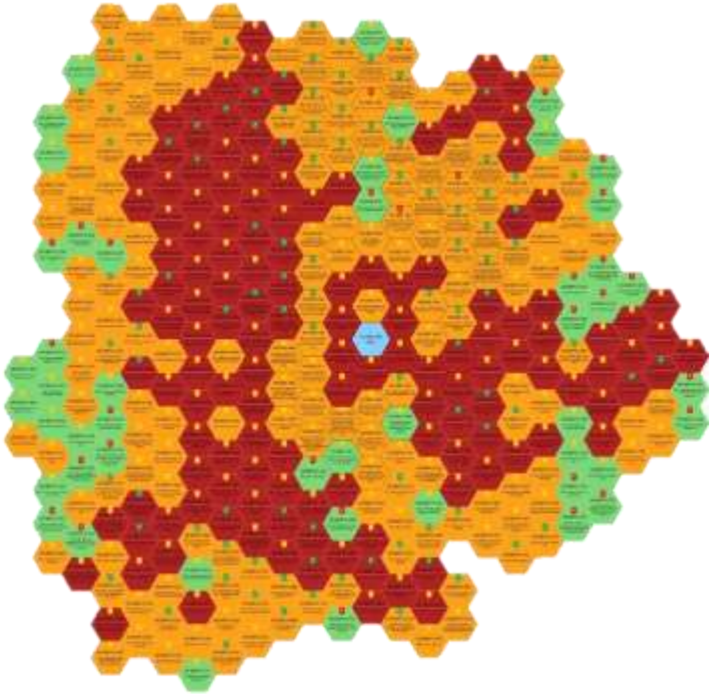
Orion IV&V previously analyzed entities in their entirety, with some entities not considered risky enough to analyze at all

Orion IV&V updated its flight software risk assessment and plan for what assurance would be added twice a year

- GNC: high
- Electrical: medium
- Video: low

Source: Briefing to SEI Agile Colloquium and TRISMAC by our collaborators, NASA Orion IV&V and Engility

Orion IV&V: Goals and Results



Switch to Capabilities/Follow the Risk

- Orion IV&V was uncomfortable with the residual risk that would have resulted from the previous approach
- IV&V decided to analyze the *mission capabilities* with highest risk regardless of their association to the entities
- Evaluating risk more dynamically and more frequently matches the changing risk landscape of the Orion Program

Following the risk focuses the Orion IV&V team's effort on areas of highest concern

Orion IV&V changed delivery cadence from *months* to *weeks*

Stakeholders were happy with the changes:

> "IV&V's capability-based approach and 'follow the risk' strategy allows them to have relevant opinions on the most difficult issues the program is facing."

The Agile Program Office: The Challenge

Vision: Demonstrate that Agile methodologies can be successfully implemented in a program-management environment

Get real-life experience with Agile

Government needs experience with

- Agile processes
- Agile tools

Why?

- More practical knowledge of the art of the possible when collaborating with Agile contractors
- Greater understanding for contractors when they have problems

Take advantage of Lean principles

Leverage small batches:

- Increase flow
- Improve productivity
- Deliver quality

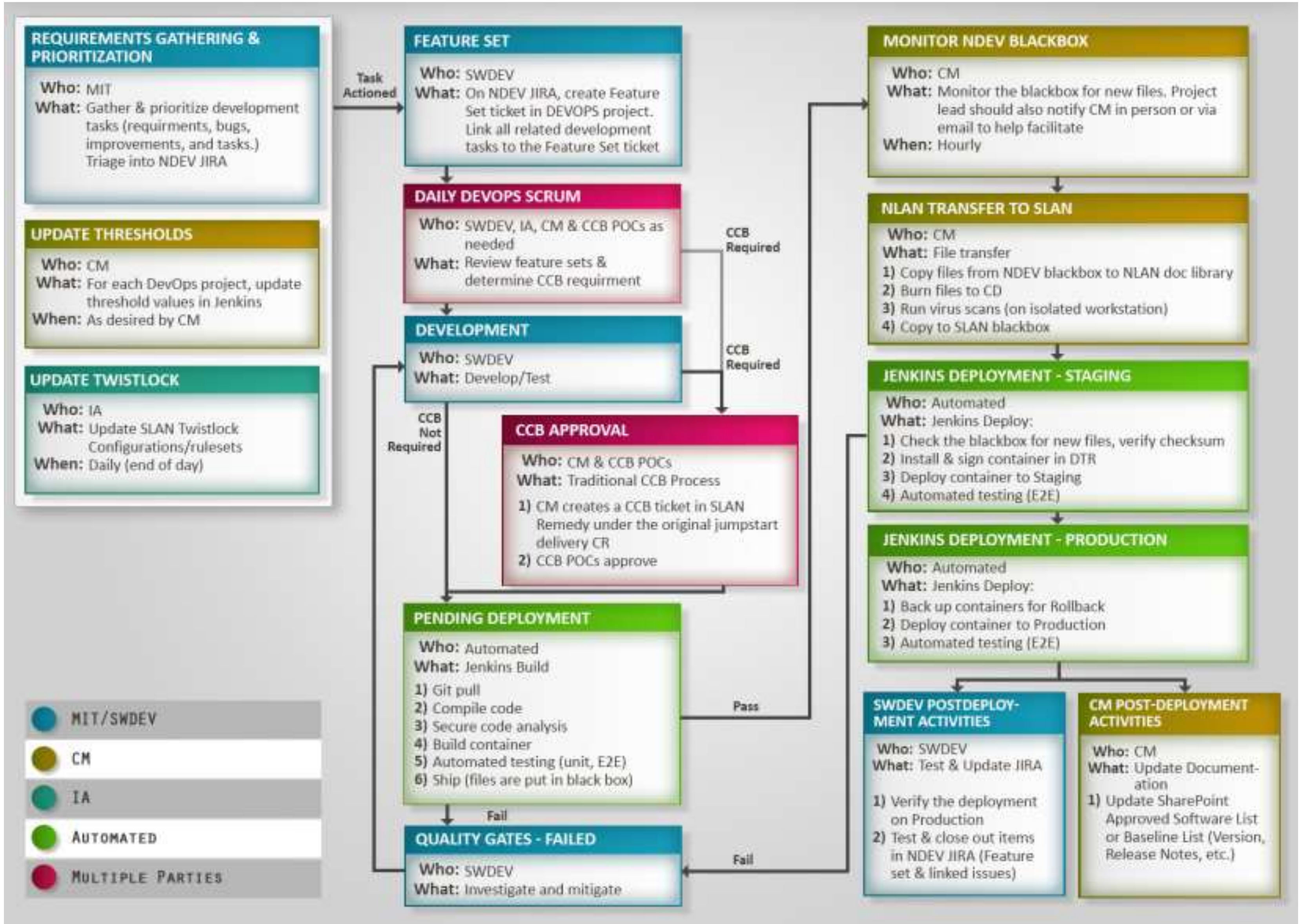
Visualize and manage work in progress (WIP):

- WIP limits
- WIP policies
- See the work being done

The Agile Program Office: Goals and Results

Program Goals	Results
Make timely and high-quality decisions Reliably repeat success and learn from failure	“We recently completed a $600K+ tech eval in only 17 days. This would normally take 90 days or more.” “We reconfigured the vehicle with added complexity in only 3 months. This would normally take a year to 18 months.” “We also demonstrated agility when we moved up the delivery date by 14 days to better accommodate another mission.”
Improve visibility of workflow; centralize data and info using cloud-based platform (Jira/Confluence) Understand the work better (flow, bottlenecks, anomalies)	“Our cloud-based tracking tool helps us to corral our work into manageable tasks. The filters help us manage the flow of work, which, in turn, accelerate the velocity…”
Improve stakeholder management (transparency)	“With the customization in the tool, we’ve created a sort of bespoke platform that feeds us data how we want it, when we want it.”

JIDO SecDevOps: Pipeline→ ATO in a Day!



REQUIREMENTS GATHERING & PRIORITIZATION
Who: MIT
What: Gather & prioritize development tasks (requirments, bugs, improvements, and tasks.) Triage into NDEV JIRA

UPDATE THRESHOLDS
Who: CM
What: For each DevOps project, update threshold values in Jenkins
When: As desired by CM

UPDATE TWISTLOCK
Who: IA
What: Update SLAN Twistlock Configurations/rulesets
When: Daily (end of day)

FEATURE SET
Who: SWDEV
What: On NDEV JIRA, create Feature Set ticket in DEVOPS project. Link all related development tasks to the Feature Set ticket

DAILY DEVOPS SCRUM
Who: SWDEV, IA, CM & CCB POCs as needed
What: Review feature sets & determine CCB requirment

DEVELOPMENT
Who: SWDEV
What: Develop/Test

CCB APPROVAL
Who: CM & CCB POCs
What: Traditional CCB Process
1) CM creates a CCB ticket in SLAN Remedy under the original jumpstart delivery CR
2) CCB POCs approve

PENDING DEPLOYMENT
Who: Automated
What: Jenkins Build
1) Git pull
2) Compile code
3) Secure code analysis
4) Build container
5) Automated testing (unit, E2E)
6) Ship (files are put in black box)

QUALITY GATES - FAILED
Who: SWDEV
What: Investigate and mitigate

MONITOR NDEV BLACKBOX
Who: CM
What: Monitor the blackbox for new files. Project lead should also notify CM in person or via email to help facilitate
When: Hourly

NLAN TRANSFER TO SLAN
Who: CM
What: File transfer
1) Copy files from NDEV blackbox to NLAN doc library
2) Burn files to CD
3) Run virus scans (on isolated workstation)
4) Copy to SLAN blackbox

JENKINS DEPLOYMENT - STAGING
Who: Automated
What: Jenkins Deploy:
1) Check the blackbox for new files, verify checksum
2) Install & sign container in DTR
3) Deploy container to Staging
4) Automated testing (E2E)

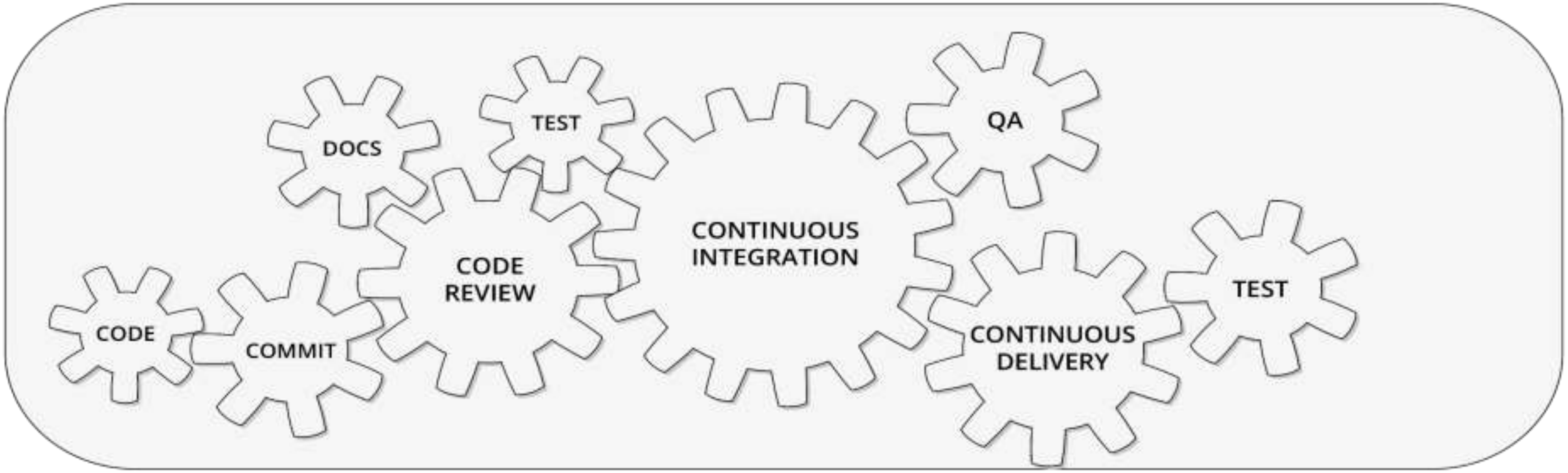
JENKINS DEPLOYMENT - PRODUCTION
Who: Automated
What: Jenkins Deploy:
1) Back up containers for Rollback
2) Deploy container to Production
3) Automated testing (E2E)

SWDEV POSTDEPLOYMENT ACTIVITIES
Who: SWDEV
What: Test & Update JIRA
1) Verify the deployment on Production
2) Test & close out items in NDEV JIRA (Feature set & linked issues)

CM POST-DEPLOYMENT ACTIVITIES
Who: CM
What: Update Documentation
1) Update SharePoint Approved Software List or Baseline List (Version, Release Notes, etc.)

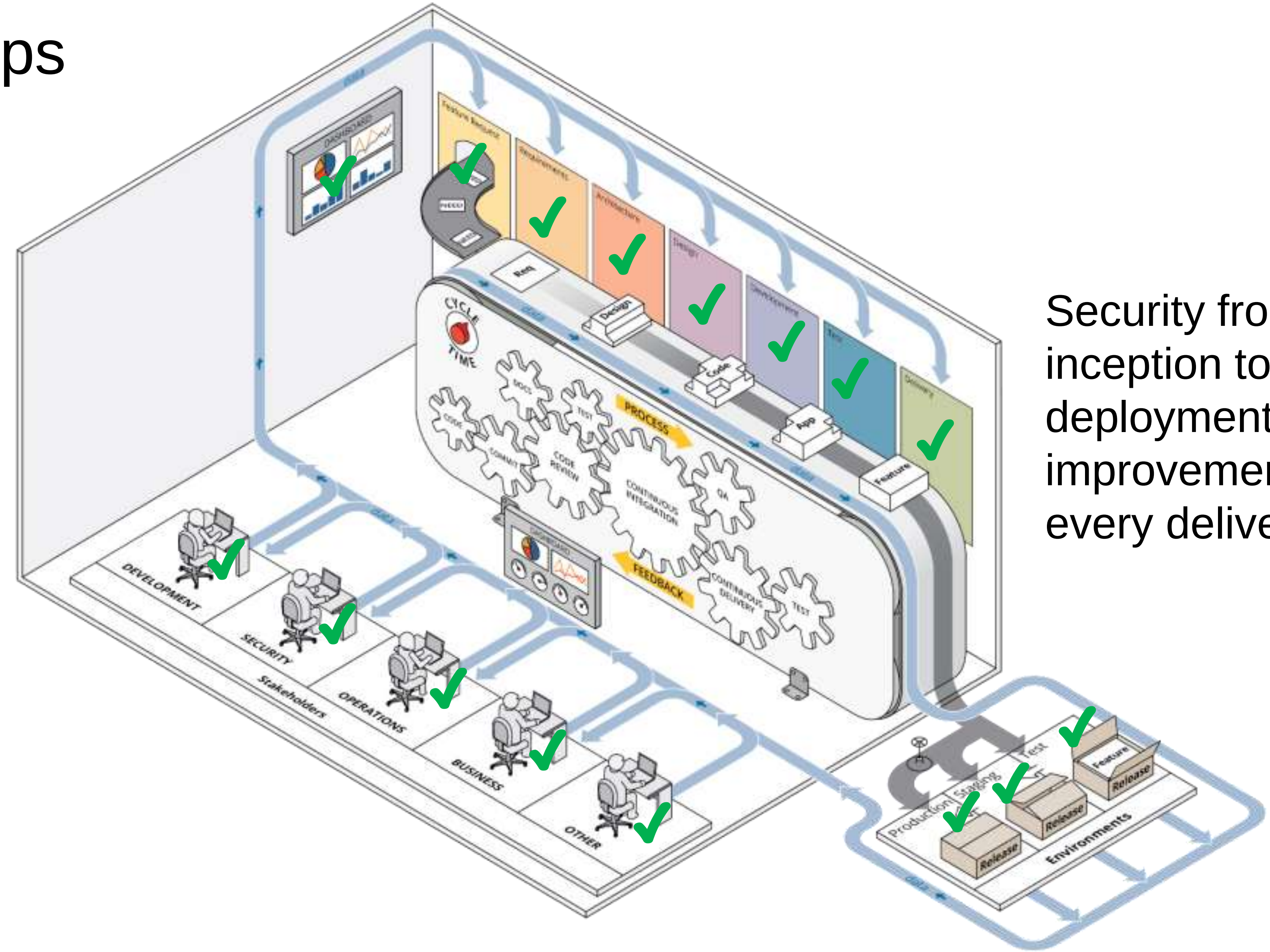
● MIT/SWDEV
● CM
● IA
● AUTOMATED
● MULTIPLE PARTIES

Security Requires Automation with IaC, CI, and CD



- Security requirements and traceability
  - Risk Management Framework: (1) categorize, (2) select controls, (3) implement, (4) assess, (5) authorize, (6) monitor
- Code review and static analysis
- Automated security testing and verification
- Automated dependency vulnerability analysis
- Immutable system, infrastructure (re-)provisioning

SecDevOps

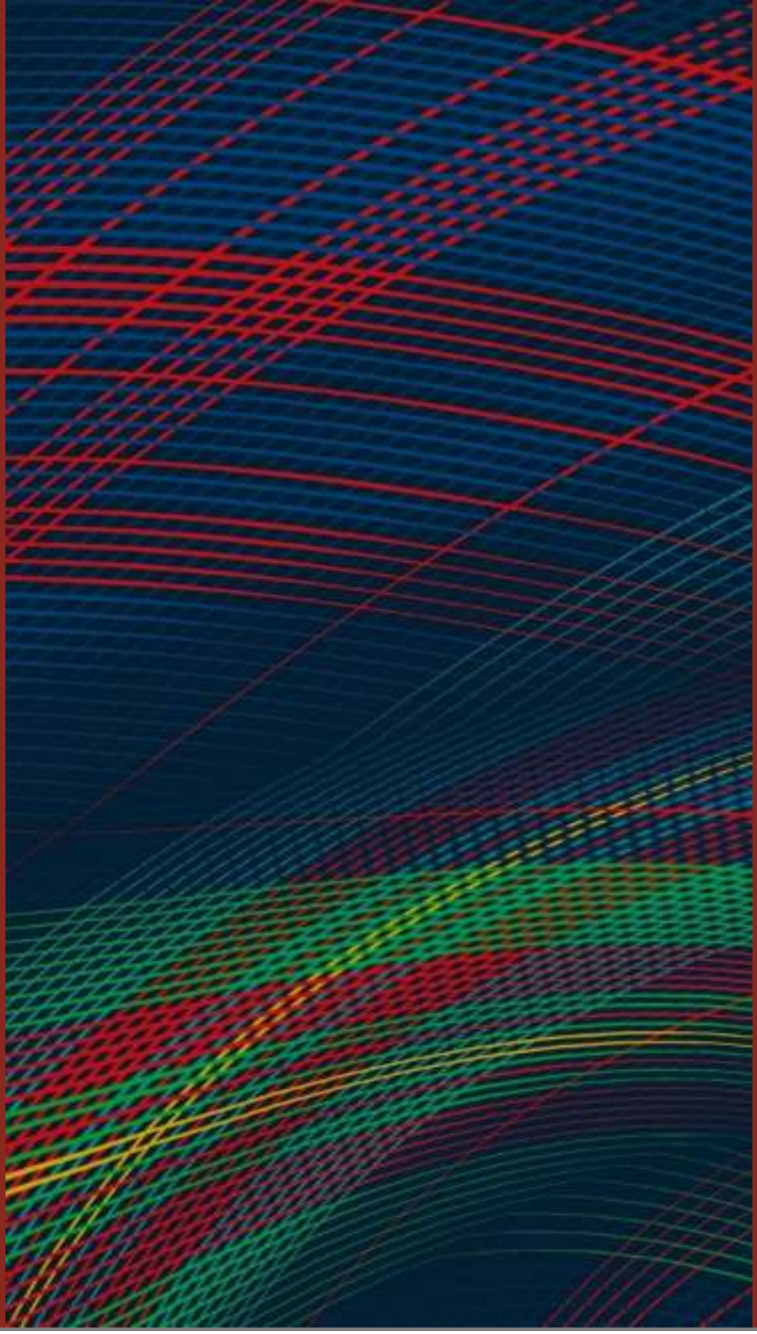


Security from inception to deployment and improvement with every delivery

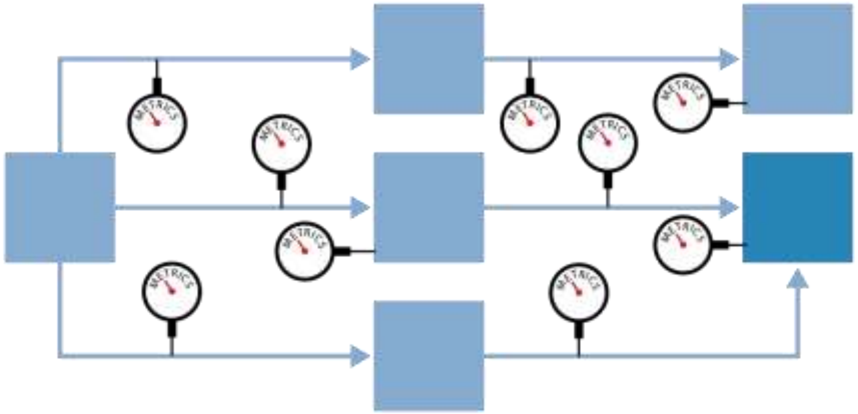
Research Review 2018

Continuous Iterative Development and Deployment Practices

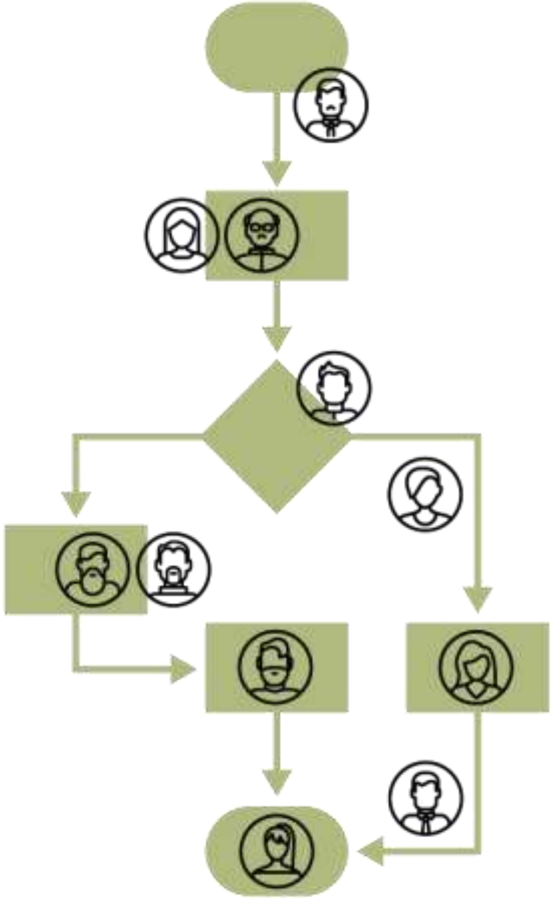
Ongoing Work: Applying Agile and DevOps Principles to Modernize Legacy Systems and Deliver Trusted Software Faster

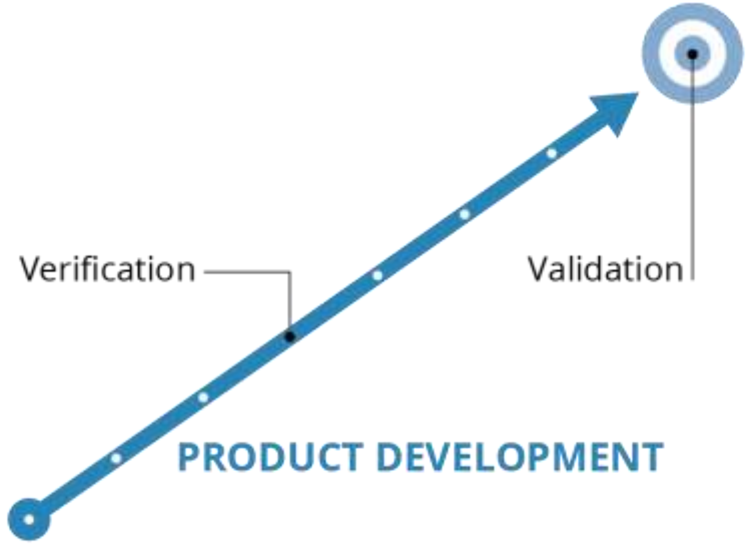


Addressing Challenges in Research and Client Program Engagement



More and more metrics in new contexts

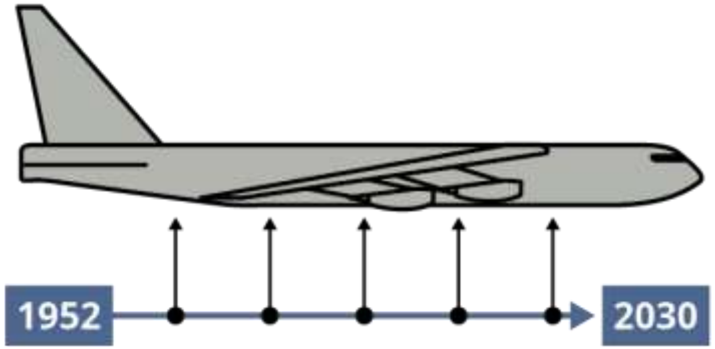




IV&V

SecDevOps in safety-critical and hardware systems

Organizational agility for programs



Migration of legacy systems

Research: Migration of Legacy Systems to Cloud Environment

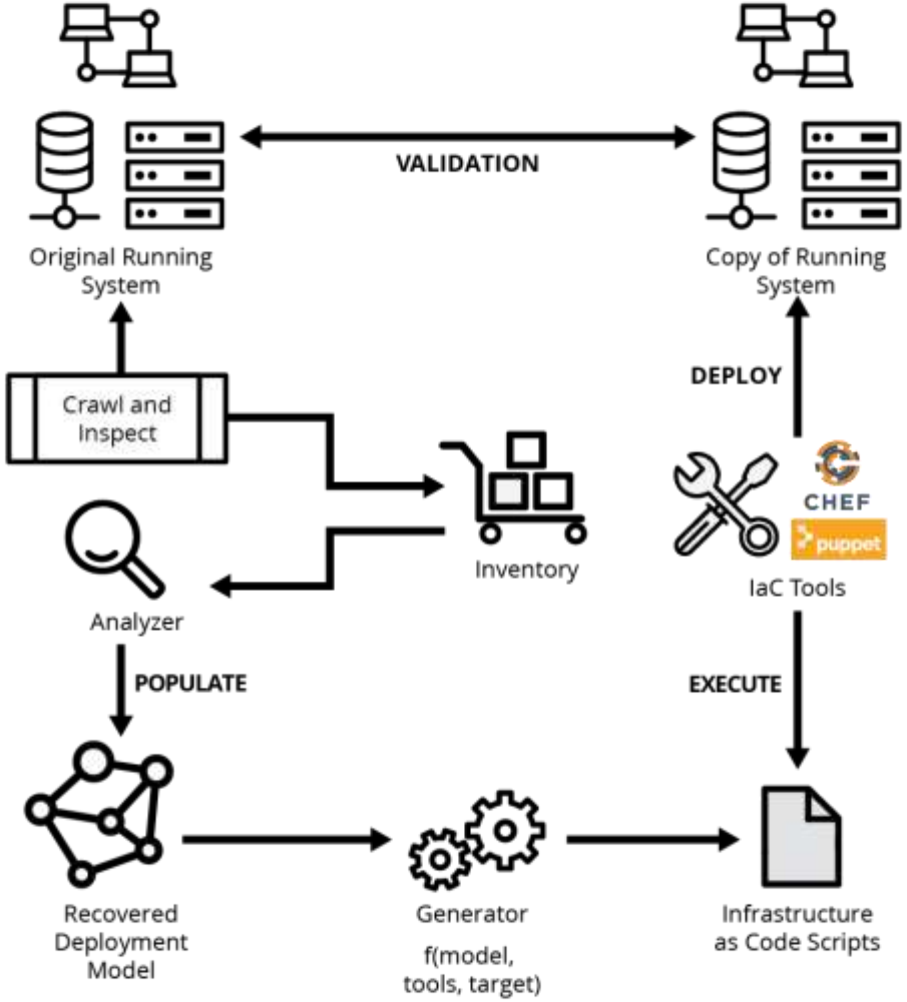
Software engineering centers, software maintenance groups, and other sustainment organizations want to realize the benefits of IaC

They must first recover the technical baseline for the deployment, but

- IaC doesn’t exist for legacy systems
- government has no data rights to ask for contractor deployment scripts
- often the only authoritative artifact is an instance of the running system

Can the deployment structure be automatically recovered from an instance of the running system?

Solution with IaC



Automatically recover a deployment model from a running system and generate IaC scripts from a model

Model-based deployment enables automation:

- Port scripts to new tools or IaaS
- Analyze the model against design rules
- Transform the model (moving target defense)

Research: How to Build Trusted Systems

Problem: Modern software development challenges developers to build **trusted systems** that include increasing numbers of **untrusted components**

Solution: Component **scorecards** based on **project health** and aggregated **quality attribute indicators** will enable rapid delivery of software capability with greater developer confidence and 10% reduction in downstream rework

Approach: Apply existing automated analyses (e.g., code and repository analyses) mapping to common indicators from DoD projects, develop several candidate health and quality attribute indicators, and validate with open-source corpus and relevant stakeholders

Score Card on Selected Components

Project Health Indicators

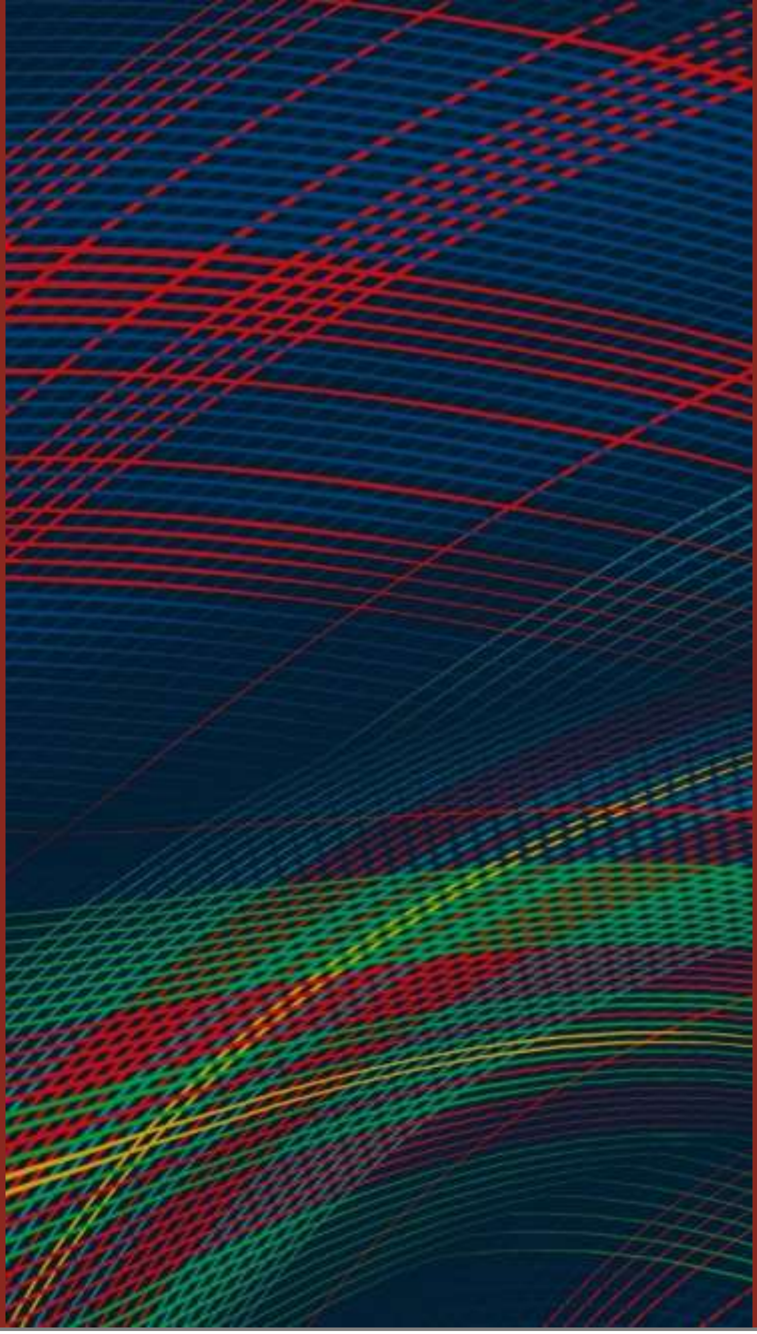
Properties	Indicator	Measurement approach or tool (example)	Ease of collection
Community health	**# developers**	code-maat	Simple, with project history
	Commit frequency	code-maat	Simple, with repo access
	Bug frequency	code-maat	Simple, with repo access
Codebase	**LOC**	cloc	Simple, needs source
	License	gh-license	Simple
Team	**Countries of origin**	LinkedIn/social metrics	Moderate
	Previous experience	Social metrics	Hard
(Others)	…		

Quality Attribute Indicators

Qualities	Indicator	Measurement approach or tool (example)	Ease of collection
Maintainability	**# imported libraries**	cvs_analy, sonatype	Simple
	Level of coupling	DV8	Simple
	Architecture flaws	DV8	Moderate
Performance	**CPU load, peak**	gprof	Moderate
	Disk access	gprof	Simple
	Memory use	valgrind	Moderate
Security	**# CVE violations**	fortify, coverity, SCALe	Moderate
(Others)	…		

Continuous Iterative Development and Deployment Practices

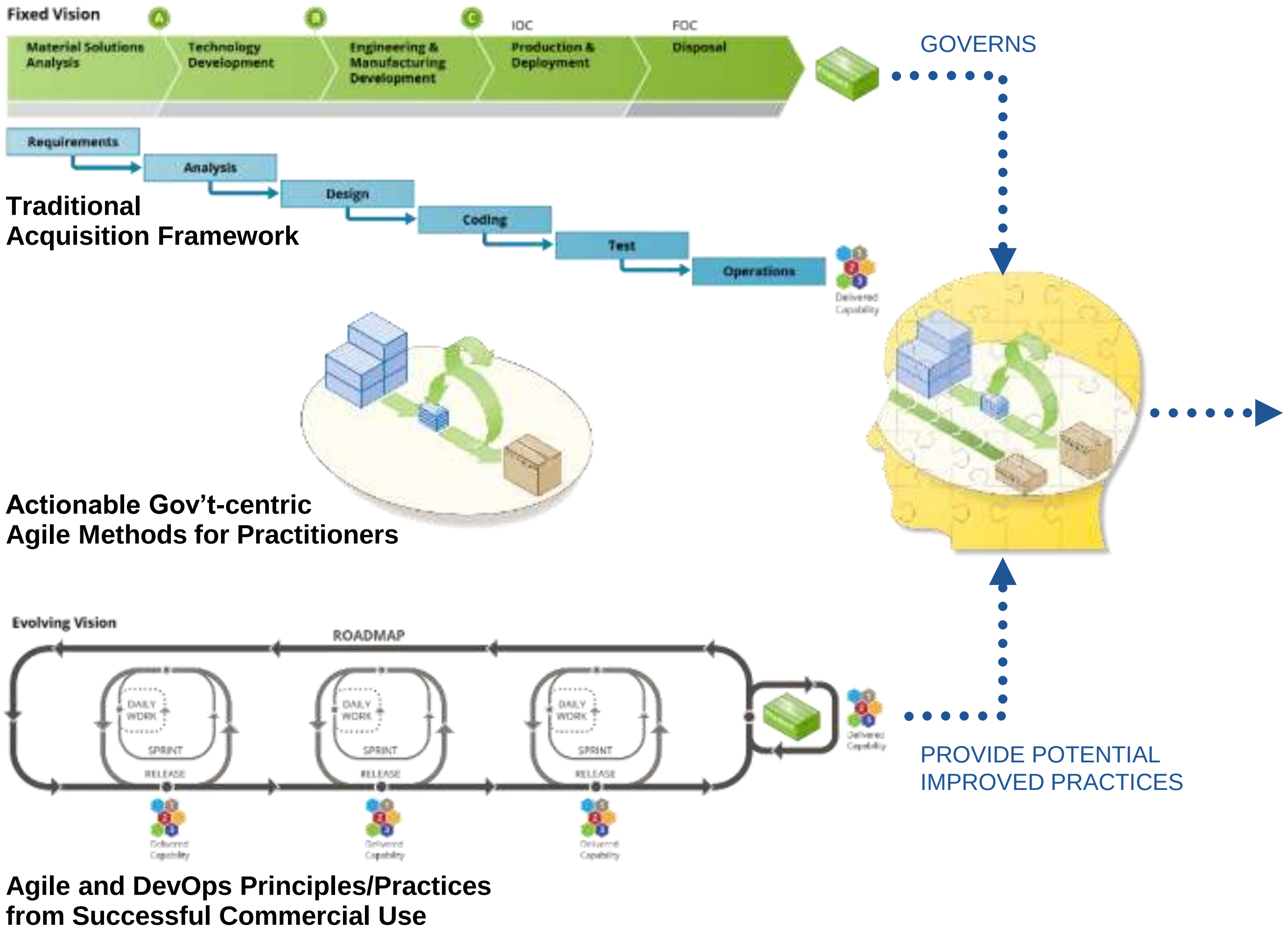
Transition: Now and in the Future



SEI Agile and SecDevOps Resources

- Learn more:
  - webinars, courses, podcasts
  - *Agile in Government* booklet series
  - conference presentations: RSA, AppSec, Velocity, AgileDev, ARES, IEEE, O’Reilly
  - research publications: IEEE, ACM, “DevOps in Government”
  - blogs at SEI Insights, dZone, and DevOps.com
- Join our community: 240+ member Agile Collaboration Group with 80+ organizations
- Attend our conferences and workshops:
  - Annual Agile Colloquium, Annual ADAPT Agile in Government Summit
  - AllDayDevOps, DevSecOpsDays
  - Secure DevOps, DevOps for Managers, DevOps in Practice
- Use our guidance:
  - partnered with DAU on Agile curriculum and course assets
  - GAO guidance for Agile programs uses SEI Agile Readiness & Fit Analysis
  - IEEE 2675 DevOps standard

SEI Client Program: Distributed Program Office Delivering (Non-Software) Services Now Tasked with New Function



GOVERNS

Traditional Acquisition Framework

Actionable Gov't-centric Agile Methods for Practitioners

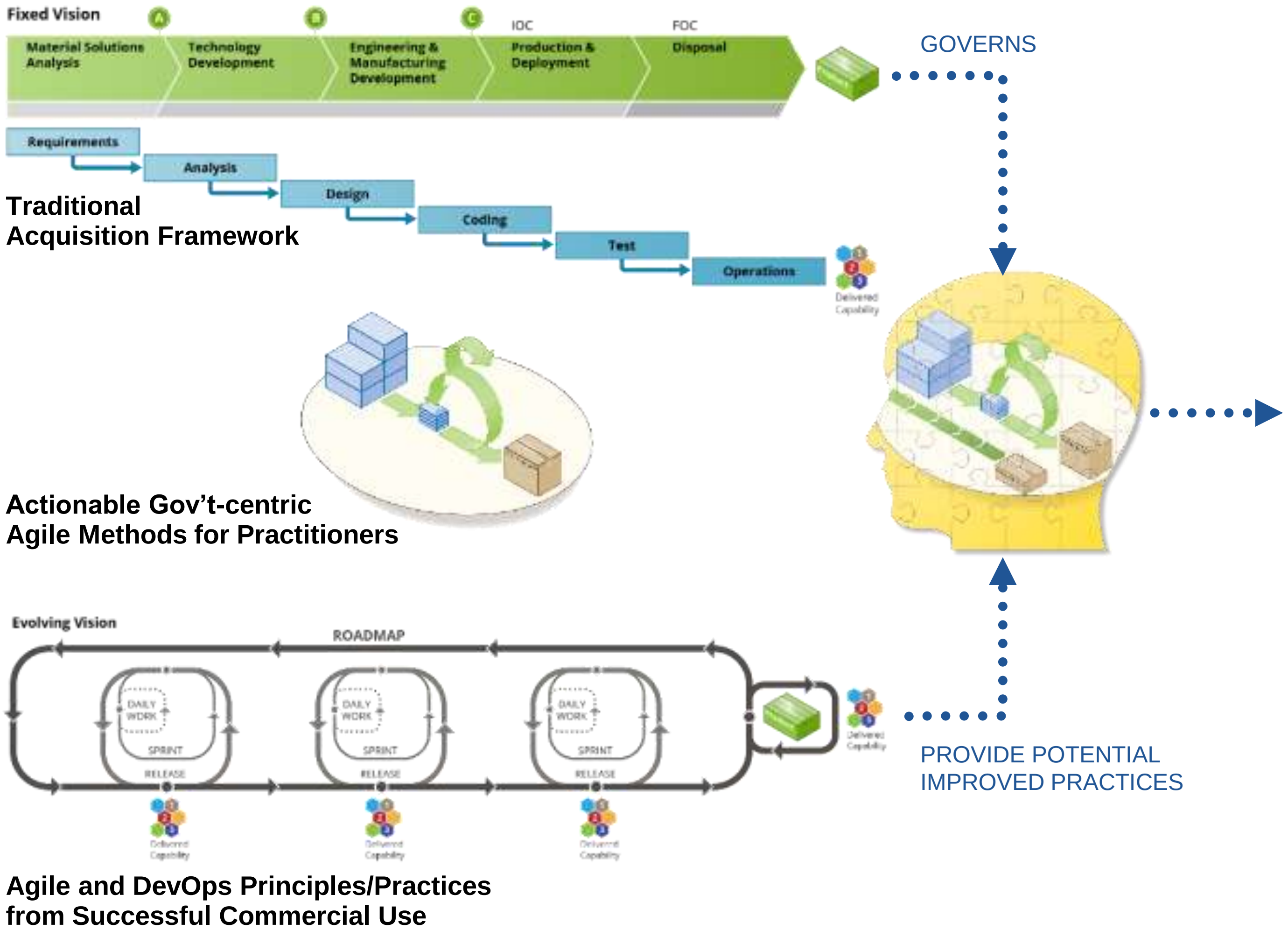
Agile and DevOps Principles/Practices from Successful Commercial Use

PROVIDE POTENTIAL IMPROVED PRACTICES

How the SEI Helps This Program	
Readiness & risk assessment: Considerations for Agile and DevOps adoption/transformation pilots	
Training needs assessment: Review knowledge-specific needs for diverse program stakeholders	
Expert coaching	• Basics through larger scale adoption (custom and COTS-based) • Agile methods for program teams, executive leaders • Role/function-specific • DevOps pipeline • Identify best practices • Process adoption support • Change management • Replication of success
Metrics development: Defining, implementing, and instrumenting for oversight	
Program start-up workshops: Strategic goal-setting workshops	
Devising workable hybrid options: Reconciling future approach with new and existing program policies and practices	
Expertise in DevOps practices, deployment pipeline	

Benefits
Access broad expertise in acquisition, Agile and traditional methods, and rich library of tools, methods, and courseware supporting Agile transformation in DoD
Apply lessons learned from other programs and research to avoid known barriers and pitfalls, take advantage of improved flow with DevOps/Agile
Apply unique and practical perspective, integrated and incremental development environment model
Enhance program-unique practices with practices that contribute to improved execution for other government agencies
Employ Trusted Broker

SEI Client Program: Large Program Adopting Agile to Better Manage Dynamic, Critical Changes to User Needs



Traditional Acquisition Framework

Actionable Gov't-centric Agile Methods for Practitioners

Agile and DevOps Principles/Practices from Successful Commercial Use

GOVERNS

PROVIDE POTENTIAL IMPROVED PRACTICES

How the SEI Helps This Program	
Readiness & risk assessment: Considerations for Agile and SAFe adoption/transformation	
Training needs assessment: Review knowledge-specific needs for diverse program stakeholders	
Expert coaching	• Basics through larger scale adoption (custom and COTS-based) • Agile methods for program teams, executive leaders • Role/function-specific • DevOps pipeline • Process adoption support • Change management • Replication of success
Metrics development: Defining, implementing, and instrumenting for oversight	
Custom training	• Basics through role-specific support • DevOps process and practices • Process adoption • Workshop program-specific opportunities and barriers • Hands-on DevOps in practice workshop
Identifying workable hybrid options: Reconciling future approach with new and existing frameworks, program processes, and procedures	
Expertise in DevOps practices, deployment pipeline	

Benefits
Access broad expertise in acquisition, Agile and traditional methods, and rich library of tools, methods, and courseware supporting Agile/DevOps transformation in DoD
Apply lessons learned from other programs and research to avoid known barriers and pitfalls
Apply unique and practical perspective, innovative solutions
Enhance program-unique practices with known successful Agile-related practices used by other government programs and agencies
Employ Trusted Broker

For More Information

Agile and DevOps: https://www.sei.cmu.edu/go/agile
https://www.sei.cmu.edu/go/devops

DevOps Blog: https://insights.sei.cmu.edu/devops

Webinars: https://www.sei.cmu.edu/publications/webinars/index.cfm

Podcasts: https://www.sei.cmu.edu/publications/podcasts/index.cfm

YouTube: https://www.youtube.com/user/TheSEICMU