Software Is Never Done:
Refactoring the Acquisition Code for Competitive Advantage

Defense Innovation Board, 21 March 2019

J. Michael McQuade and Richard M. Murray (co-chairs)
Gilman Louie, Milo Medin, Jennifer Pahlka, Trae Stephens

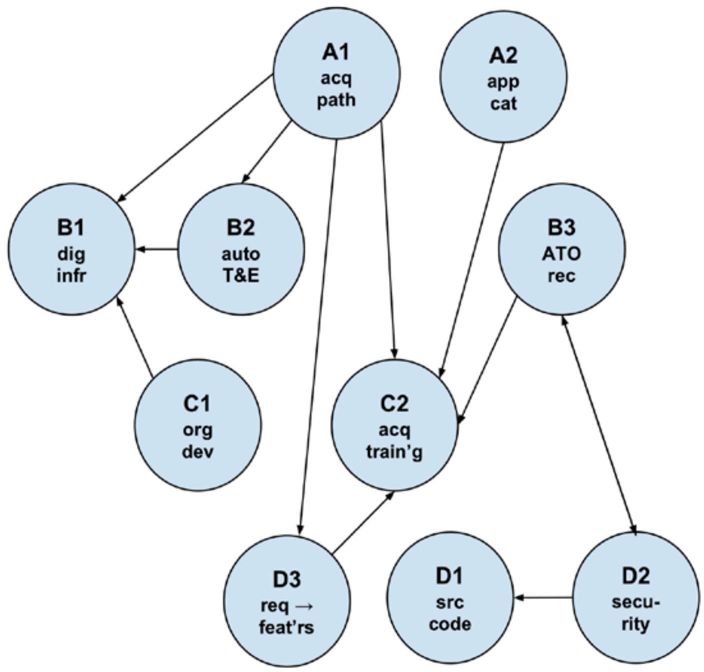
Supporting Information

This document contains the supporting information for the Defense Innovation Board (DIB) Software Acquisition and Practices (SWAP) study.

Contents

Appendix A: Draft Implementation Plan

The following pages contain summaries for each recommendation that give more detail on the rationale, supporting information, similar recommendations, specific action items, and notes on implementation. The beginning of each recommendation summary includes the recommendation statement, proposed owner, background information, description of the desired state, proposed role for Congress, and a short "action plan" describing how the recommendations might be implemented. The remainder of the summary contains a list of recommendations from the DIB Guides (contained in Appendix E of the supporting information), a list of recommendations from the working group reports (Appendix F of the supporting information), and some related recommendations from previous reports.



The recommendations listed here are relatively decoupled, but there are some dependencies between them, as shown to the right. In this figure, an arrow leading from one recommendation toward a second recommendation means that the first implementation depends at least somewhat on the implementation of the second. Hence by choosing one recommendation and following the arrows, the list of all recommendations that should also be implemented can be obtained.

The recommendations of the report are broken up into four primary lines of effort:

A. Refactor statutes, regulations, and processes for software

B. Create and maintain cross-program/cross-service digital infrastructure

C. Create new paths for digital talent (especially internal talent)

D. Change the practice of how software is procured and developed

For each of the lines of effort, we give a set of 2-3 primary recommendations (bold) and 2-4 additional recommendations (see Chapter 5 for insights).

Primary Recommendation A1
New Acquisition Pathway

Line of Effort	Refactor statutes, regulations, and processes for software
Recommendation	**Establish new acquisition pathway(s) for software that prioritizes continuous integration and delivery of working software in a secure manner, with continuous oversight from automated analytics**
Stakeholders	A&S, HASC/SASC, USD(C), CAPE, DOT&E, R&E/DT, SAE, Service FM & PA&E, Joint Staff
Background	Current law, regulation, and policy, and internal DoD processes make DevSecOps software development extremely difficult, requiring substantial and consistent senior leadership involvement. Consequently, DoD is challenged in its ability to scale DevSecOps software development practices to meet mission needs.
Desired State	Tailored software-specific pathways that provide guidance to acquisition professionals to navigate the acquisition and requirements lifecycle to rapidly deliver capabilities. Each pathway streamlines the processes, reviews, and documents based on the type of IT/SW capability. Programs choosing these pathways have the ability to rapidly field and iterate new functionality in a secure manner, with continuous oversight based on automated reporting and analytics, and utilizing IA-accredited commercial development tools. Rapid acquisition authority available for software already in use and accredited - especially when purchased as a capability delivery (as a service). Over time, this becomes the default choice for software and software-intensive programs/program elements.
Role of Congress	This should become the primary pathway that DoD chooses to use for software and software-intensive programs and should provide Congress with the insight required to oversee software projects that move at a much faster pace than traditional HW programs, with traditional metrics and milestones replaced by more software-compatible measures of progress.

Draft Implementation Plan		Lead Stakeholder	Target Date
A1.1	(optional) Submit legislative proposal using Sec 805 to propose new acquisition pathways for two or more classes of software (e.g, application, embedded), optimized for DevSecOps	USD(A&S), in coordination with USD(C) and CAPE	Q3 FY19
A1.2	Create new acquisition pathway(s) for two or more classes of software, optimized for DevSecOps (based on A2c.1 or Appendix B.1)	HASC, SASC	FY20 NDAA
A1.3	Develop and issue a Directive Type Memorandum (DTM) for the new software acquisition pathway	USD(A&S)	Q1 FY20
A1.4	Issue Service level guidance for new acquisition pathway	SAE	Q2 FY20
A1.5	Select 5 initial programs using modern software development (DevSecOps) to convert to or use new software acquisition pathway	USD(A&S), with SAEs	Q2 FY20
A1.6	Develop and implement training at Defense Acquisition	USD(A&S)	Q3 FY20

	University on new software acquisition pathway for all acquisition communities (FM, Costing, PM, IT, SE, etc.)		
A1.7	Convert DTM to DoD Instruction (5000.SW?), incorporating lessons learned during initial program implementation	USD(A&S)	Q4 FY20

SWAP working group inputs related to this recommendation

Acq	Define software as a critical national security capability under Section 805 of FY16 NDAA “Use of Alternative Acquisition Paths to Acquire Critical National Security Capabilities”.
Acq	Create an acquisition policy framework that recognizes that software is ubiquitous and will be part of all acquisition policy models.
Acq	Create a clear, efficient acquisition path for acquiring non-embedded software capability. Deconflict supplemental policies.
Acq	Develop an Enterprise-level Strategic Technology Plan that reinforces the concept of software as a national security capability and recognizes how disruptive technologies will be introduced into the environment on an ongoing basis
Acq	Additionally, take all actions associated with Rec A2a to refactor and simplify those parts of Title 10, DoD 5000 and other regulations and processes that are still in force for software-intensive programs.

Related recommendations from previous studies

DSB87	Rec 13: The Undersecretary of Defense (Acquisition) should adopt a four-category classification as the basis of acquisition policy [standard (COTS), extended (extensions of current systems, both DoD and commercial), embedded, and advanced (advanced and exploratory systems)]
DSB87	Rec 14: USD(A) should develop acquisition policy, procedures, and guidance for each category.
DSB’09	The USD (AT&L) should lead an effort, in conjunction with the Vice Chairman, Joint Chiefs of Staff, to develop new, streamlined, and agile capabilities (requirements) development and acquisition processes and associated policies for information technology programs

Primary Recommendation A2
New Appropriation Category

Line of Effort	Refactor statutes, regulations, and processes for software
Recommendation	**Create a new appropriations category that allows (relevant types of) software to be funded as a single budget item, with no separation between RDT&E, production, and sustainment**
Stakeholders	A&S, HAC-D/SAC-D, HASC/SASC, USD(C), CAPE, SAE, Service FM & PA&E, FASAB, OMB
Background	Current law, regulation, and policy treat software acquisition as a series of discrete sequential steps; accounting guidance treats software as a depreciating asset. These processes are at odds with software being continuously updated to add new functionality and create significant delays in fielding user-needed capability.
Desired State	Programs are better able to prioritize how effort is spent on new capabilities versus fixing bugs / vulnerabilities, improving existing capabilities, etc. Such prioritization can be made based on warfighter / user needs, changing mission profiles, and other external drivers, not constrained by available sources of funding.
Role of Congress	This should become the primary pathway that Congress uses to fund software and software-intensive programs and should provide Congress with the insight required to oversee software projects that move at a much faster pace than traditional HW programs, with traditional metrics and milestones replaced by more software-compatible measures of progress.

Draft Implementation Plan		Lead Stakeholder	Target Date
A2.1	(optional) Submit legislative proposal using Sec 805 to create a new appropriations category for software and software-intensive programs	USD(A&S), with USD(C) and CAPE	Q3 FY19 for FY20 NDAA
A2.2	Create new appropriation category for software-intensive programs, with appropriate reporting and oversight for software (based on Action A2.1 or Appendix B.1)	HAC-D, SAC-D, with OSD, HASC, SASC	FY20 NDAA, FY20 budget
A2.3	Select initial programs using DevSecOps to convert to or use new SW Appropriation in FY20	USD(A&S), with Service Acquisition Executives	Q4 FY19
A2.4	Define budget exhibits for new SW appropriation (replacement for P- and R-forms; see App C)	USD(A&S), with USD(C), CAPE, HAC-D, SAC-D	Q4 FY19
A2.5	Change audit treatment of software with these goals: (1) separate category for software instead of being characterized as property, plant, and equipment; (2) default setting that software is an expense, not an investment; and (3) there is no “sustainment” phase for software.	FASAB, with USD(A&S) and USD(C)	End FY20
A2.6	Make necessary modifications in supporting PPB&E	USD(C) and CAPE	Q1 FY21

	systems to allow use and tracking of new software appropriation		
A2.7	Ensure programs using new software appropriation submit budget exhibits in the approved format.	SAE with USD(C), CAPE	FY 22 POM

SWAP concept paper recommendations related to this recommendation

10C	Budgets should be constructed to support the full, iterative life-cycle of the software being procured with amount proportional to the criticality and utility of the software.
Visits	Construct budget to support the full, iterative life-cycle of the software

SWAP working group inputs related to this recommendation

Acq	Revise 10 USC 2214 to allow funding approved by Congress for acquisition of a specific software solution to be used for research and development, production, or sustainment of that software solution, under appropriate conditions.
App	A new multi-year appropriation for Digital Technology needs to be established for each Military Defense Department and the Fourth Estate.
App	Components will program, budget, and execute for information and technology capabilities from one appropriation throughout lifecycle rather than using RDT&E, procurement, or O&M appropriations -- often applied inconsistently and inaccurately -- allowing for continuous engineering
Con	Congress establishes new authority for contracting for SW development and IT modernization
M&S	Revise 10 USC 2460 to replace the “software maintenance” with “software sustainment” and use a definition that is consistent with a continuous engineering approach across the lifecycle
M&S	A DoD Working Group should be established to leverage on-going individual Service efforts and create a DoD contracting and acquisition guide for software and software sustainment patterned after the approach that led to creation of the DoD Open Systems Architecture Contracting Guide
M&S	Acquisition Strategy, RFP/Evaluation Criteria, and Systems Engineering Plan should address software sustainability and transition to sustainment as an acquisition priority.
Con	Manage programs at budget levels, allow programs to allocate funds at project investment level
Con	Work with appropriators to establish working capital funds so that there is not pressure to spend funds quicker then you're ready (iterative contracts may produce more value with less money

Related recommendations from previous studies

GAO15	3. Assigning resources to all activities. The schedule should reflect the resources (labor, materials, travel, facilities, equipment, and the like) needed to do the work, whether they will be available when needed, and any constraints on funding or time.
GAO17	Hold suppliers accountable for delivering high-quality parts for their products through activities including regular supplier audits and performance evaluations of quality and delivery.
GAO'17	Prioritize investments so that projects can be fully funded and it is clear where projects stand in relation to the overall portfolio.
CSIS18	Performance Based Logistics (PBL) contracts should have a duration that allow for tuning and re-baselining with triggered options and rolling extensions.
809	Rec. 41: Establish a sustainment program baseline, implement key enablers of sustainment, elevate sustainment to equal standing with development and procurement, and improve the defense materiel enterprise focus on weapon system readiness.
809	Rec. 42: Reduce budgetary uncertainty, increase funding flexibility, and enhance the ability to effectively execute sustainment plans and address emergent sustainment requirements.

Additional Recommendation A3
Metrics for Cost Assessment and Performance Estimates

Line of Effort	Refactor statutes and regulations for software
Recommendation	Require cost assessment and performance estimates for software programs (and software components of larger programs) of appropriate type be based on metrics that track speed and cycle time, security, code quality, and functionality
Stakeholders	CAPE, CMO, USD(A&S), Service CMOs and SAEs
Background	Current software cost estimation and reporting processes and procedures in DoD have proven to be highly inaccurate and time consuming. New metrics are required that match the DevSecOps approach of continuous capability delivery and maintenance and provide continuous insight into program progress.
Desired State	Program oversight will re-focus on the value provided by the software as it is deployed to the warfighter/user, and will rely more heavily on metrics that can be collect in a (semi-)automated fashion from instrumentation on the DevSecOps pipeline and other parts of the infrastructure. Specific metrics will depend on the type of software rather than a one-size-fits-all approach.
Role of Congress	Congress needs to emphasize the need for new software acquisition reporting that focuses on value provided for the investment in software, and frequency of deployments to the warfighter/user. Congress needs to work with CAPE and USD(A&S) to provide feedback on meaningful content and level of detail in reporting.

Draft Implementation Plan		Lead Stakeholders	Target date
A3.1	Identify (or hire) a small team (3-4) programmers to implement software for automated collection and analysis of metrics and provide them with a modern development environment	CAPE, DDS	Q4 FY19
A3.2	Identify low-level metrics that are already part of standard commercial development environments (see Appendix C for reporting approach and Appendix E.2 (DIB Metrics for Software) for initial lists)	CAPE, SAO	MVP Q4 FY19, then quarterly
A3.2a	Speed and cycle time: launch → initial use, cycle time	Dev team, users	
A3.2b	Code quality: unit test coverage, bug burn-rate, bugs-in-test:bugs-in-field	Dev team, users	
A3.2c	Security: patch → field, OS upgrade → field, HW/OS age	Dev team, users	
A3.2d	Functionality: user satisfaction, number/type of features/cycle	Dev team, users	
A3.2e	Cost: head count, software license cost, compute costs	Dev team, users	
A3.3	Identify 3-5 ongoing programs that are collecting relevant metrics and that partner with CAPE to collect and use data	CAPE, A&S, CMO, SAEs	In parallel with A6.2
A3.4	Create a mechanism to transfer and process low-level metrics from development team to PMO on a continuous basis with selectable levels of resolution across the program	CAPE, SAEs, PMO	MVP Q4 FY19, then quarterly

A3.5	Begin reporting metrics to Congress as part of annual reporting; iterate on content, level, format	CAPE, Comp, A&S	FY2020
A3.6	Use initial results to establish expectations for new proposed software or software-intensive projects and integrate use of new cost and performance estimates into contract selection	A&S, SAEs, CAPE	FY2020
A3.7	Establish ongoing capability within CAPE to update metrics on continuous basis, with input from users (of the data)	CAPE	FY2021
A3.8	Identify and eliminate remaining uses of ESLOC as metric for cost and schedule estimation of software/software-intensive programs	CAPE, SAEs	FY2022

SWAP working group inputs related to this recommendation

Con	Revise estimation models - source lines of code are irrelevant to future development efforts, estimations should be based on the team size and investment focused (Cultural)

Related recommendations from previous studies

SEI'01	Effort Estimation: • Utilize most likely effort estimates in proposals and status reports'; • Find ways to promote the use of accurate effort estimation and productivity evaluation; • Lowest cost is not equivalent to best value. Question outliers.
OSD'06	Adjust program estimates to reflect “high confidence”—defined as a program with an 80 percent chance of completing development at or below estimated cost—when programs are baselined in the Stable Program Funding Account.
SEI'10	Don’t require PMO to adopt contractors’ estimate for the program—or else use the difference as PM “reserve”
SEI'10	Change from traditional 50% estimation confidence level to 80% level
SEI'10	DoD should consider use of Vickrey “second price” auction mechanism for acquisition proposal bidding
SEI'15	Use the government’s cost estimates (using say an 80% confidence level) rather than contractors’ estimates as the basis for program budgets and place the difference (if the government’s estimate is larger) in a reserve fund available to program managers with sufficient justification. Contractors’ estimates should be acquired using mechanisms that promote accurate estimates, e.g., using Vickrey auctions, the Truth-Revealing Incentive Mechanism (TRIM), or more standard methods of review and acceptance by independent third parties.
DSB18	Rec 3b: The MDA with the Cost Assessment and Program Evaluation office (CAPE), the USD(R&E), the Service Cost Estimators, and others should modernize cost and schedule estimates and measurements.
DSB18	Rec 3b.1: [DoD] should evolve from a pure SLOC approach to historical comparables as a measurement, and should adopt the National Reconnaissance Office (NRO) approach (demonstrated in Box 5) of contracting with the defense industrial base for work breakdown schedule data to include, among others, staff, cost, and productivity.
DSB18	Rec 3c: The MDA should immediately require the PM to build a program-appropriate framework for status estimation.

Additional Recommendation A4
Simplify Laws and Policies

Line of Effort	Refactor statutes and regulations for software
Recommendation	Refactor and simplify Title 10, DFARS, and DoDI 5000.02/5000.75 to remove statutory, regulatory, and procedural requirements that generate delays for acquisition, development, and fielding of software while adding requirements for continuous (automated) reporting of cost, performance (against updated metrics), and schedule
Stakeholders	USD(C), CAPE, SAE, Service FM & PA&E, Joint Staff
Background	Current law, regulation, and policy, and internal DoD processes make modern software development extremely difficult, requiring substantial and consistent senior leadership involvement. Consequently, DoD is challenged in its ability to scale modern software development practices to meet mission needs. Recommendation A1 (new acquisition pathway) provides a pathway that is optimized for software, but it is also possible to modify existing statutes, regulations, and processes to remove barriers for software.
Desired State	Programs have the ability to rapidly field and iterate new functionality in a secure manner, with continuous oversight based on automated reporting and analytics, and utilizing IA-accredited commercial development tools. Congress has better insight into the status of software programs through improved reporting of relevant metrics (see also Recommendations A3 and D4 on metrics).
Role of Congress	Work with DoD to review current statutes and evaluate their effectiveness for different types of software, removing barriers that add time and interfere with the continuous nature of modern software development. See Appendix F for a list of issues to consider.

Draft Implementation Plan		Lead Stakeholders	Target Date
A4.1	Submit legislative proposal(s) to simplify Title 10 for software (see also: Sec 809 Panel report)	USD(A&S)	Q3 FY19
A4.2	Convene working group with stakeholders and develop and issue a Directive Type Memorandum (DTM) for the new simplified software acquisition process	USD(A&S)	Q1 FY20
A4.3	Issue Service level guidance for new simplified software acquisition process	SAE	Q1 FY20
A4.4	Identify initial set of programs using modern software development methods to convert to or utilize new simplified software acquisition process	USD(A&S), with SAEs	Q1 FY20
A4.5	Convert DTM to DoD Instruction, incorporating lessons learned during initial program implementation.	USD(A&S)	Q1 FY20
A4.6	Develop and implement training at Defense Acquisition University on new simplified software acquisition process for	USD(A&S)	Q1 FY20

	all acquisition communities (FM, Costing, PM, IT, SE, etc.)		

SWAP working group inputs related to this recommendation

Acq	Ensure appropriate integration of a data strategy and the Department's Cloud Strategy. Examine a Steering Committee approach for management.
Acq	Examine the organizational structure with the intent of achieving a more responsive and flat organizational model that de-conflicts roles and responsibilities between the DoD CIO, the USD(A&S) and the CMO regarding software.
Acq	Re-focus the software acquisition workforce on teaming and collaboration, agility, improved role definition, career path advancement methods, continuing education and training opportunities, incentivization, and empowerment.
Acq	Increase flexibility and agility for software programs by eliminating mandated content for acquisition strategies and authorities in Section 821 of the FY16 NDAA except for MDAPs.
Acq	Eliminate hardware-centric cost, fielding and performance goals in 10 USC 2488 (established by Sec 807 of the FY17 NDAA) for software-intensive programs.
Acq	Eliminate Nunn-McCurdy breaches (10 USC 2433) for software-intensive programs and replace with continuous evaluation of software performance metrics.
Acq	Remove statutory definition of "major system" for software-intensive programs in 10 USC 2302 and 2302d to remove confusion since most software in weapons systems inherently functions together to fulfill a mission need.
Acq	Develop language for 10 USC 2366a that allows exemption for software-intensive programs, where DOT&E must justify adding the program for oversight with the MDA and must streamline the process.
Acq	Only require DOT&E oversight for software-intensive programs when requested by the SAE, USD(A&S) or Congress, or if the program is an MDAP.
Acq	For the 4th estate, combine all three authorities for DBS under the DoD CMO. After one year conduct assessment and make a determination if this should be applied to the Services as well.
Acq	Eliminate the separate annual funding certification process for defense business system from 10 USC 2222 or require that funding certification be merged in to the PPBE process
Acq	Replace annual configuration steering board (CSBs) for software-intensive programs with board (or equivalent entities) established by the CAE, PEO, or PM [FY09 NDAA Sec 814; DoDI 5000.02]
Acq	Expand the FAR 39 (Acquisition of IT) to allow for one area to drive technology purchases. Unless otherwise stated, no other FAR rules would apply
Acq	Rewrite FMR Volume 2A, Chapter 1, Section 010212(B) to [1] acknowledge that, for the purpose or modifying or enhancing software, there is no technically meaningful distinction between RDT&E, Procurement, and O&M; [2] eliminate the $250,000 barrier between expenses and investments (i.e., stop explicitly tying to a dollar threshold the determination of whether software is an expense or an investment.
Acq	Revise or eliminate DoDI 8330.01 to eliminate the following elements for software-intensive programs: [1] NR KPP required; [2] DoD specific architecture products in the DoDAF format that are labor intensive and of questionable value; [e] Interoperability Support Plans (ISPs) required, where DoD CIO can declare any ISP of "special interest"; [2] requirement of DT authority to

	provide assessments at MS C; [5] mandates JITC to do interoperability assessments for IT with “joint, multinational, and interagency interoperability requirements”
Acq	Revise PfM policy (DoDD 7045.20) to consider the role of data and metrics, as well as additional portfolios (like NC3), and determine authority for the policy.
Con	Separate Contract requirements (scope, PoP, and price) from technical requirements (backlog, roadmap, and stories)
Con	Use SOO vs SOW to allow the vendor to solve the objectives how they are best suited
Con	Establish clear and intuitive guidelines on how and when to apply existing clauses
Con	Have standard clause applications for each of the above that must be excepted vs accepted
D&M	Congress could establish, via an NDAA provision, new data-driven methods for governance of software development, maintenance, and performance. The new approach should require on demand access to standard [and real-time?] data with reviews occurring on a standard calendar, rather than the current approach of manually developed, periodic reports.
M&S	Title 10 USC 2460 should be revised to replace the term software maintenance with the term software sustainment and definition that is consistent with a continuous engineering approach across the lifecycle [dup]
Req	The Joint Staff should consider revising JCIDS guidance to focus on user needs, bypassing the JCIDS process as needed to facilitate rapid software development. Guidance should specifically account for user communities (e.g. Tactical Action Officer (TAO), Maritime Operations Center (MOC) director) that do not have one specific PoR assigned to them, but use multiple systems and data from those systems to be effective
Req	The Joint Staff should consider revising JCIDS guidance to separate functionality that needs high variability from the functionality that deemed “more stable” (e.g. types of signals to analyze vs. allowable space for the antenna). Then implement a “software box” approach for each, one in which the contours of the box are shaped by the functionality variability
Req	The Joint Staff should consider revising JCIDS guidance to document stable concepts, not speculative ideas. The Joint Staff should consider revising JCIDS guidance to document stable concepts, not speculative ideas. Acknowledge that software requirement documents will iterate, iterate, iterate. JCIDS must change from a “one-pass” mentality to a “first of many” model that is inherently agile delegating approval to the lowest possible level

Related recommendations from previous studies

DSB87	Rec 21: DoD should examine and revise regulations to approach modern commercial practice insofar as practicable and appropriate.
NPS'16a	Program offices spend far too much time generating paperwork and navigating the bureaucracy rather than thinking creatively about program risks, opportunities, and key elements of their strategies
NDU'17	Develop and maintain core competencies in diverse acquisition approaches and increase the use of venture capital type acquisitions such as Small Business Innovative Research (SBIR), Advanced Concept Technology Development (ACTD), and Other Transaction Authority (OTA) as mechanisms to draw in non-traditional companies
NDU'17	Encourage employees to study statutes and regulations and explore innovative and

	alternative approaches that meet the statutory and regulatory inten
Sec 809	Rec. 62: Update the FAR and DFARS to reduce burdens on DoD’s commercial supply chain to decrease cost, prevent delays, remove barriers, and encourage innovation available to the Military Services.
Sec 809	Rec. 74: Eliminate redundant documentation requirements or superfluous approvals when appropriate consideration is given and documented as part of acquisition planning.
Sec 809	Rec. 75: Revise regulations, instructions, or directives to eliminate non-value added documentation or approvals.
Sec 809	Rec. 90: Reorganize Title 10 of the U.S. Code to place all of the acquisition provisions in a single part, and update and move acquisition-related note sections into the reorganized acquisition part of Title 10.

Additional Recommendation A5
Streamlined Processes for Business Systems

Line of Effort	Refactor statutes and regulations for software
Recommendation	Create streamlined authorization and appropriation processes for defense business systems (DBS) that use commercially-available products with minimal (source code) modification
Stakeholders	CMO, USD(A&S), Service CMOs, SAEs, DoD CIO
Background	Current DoD business processes are minimally standardized due to a high number of legacy systems that inhibit business process reengineering. In addition, solicitation for new business systems often insist on customization because DoD is "different", resulting in hard-to-maintain systems that become obsolete (and possibly insecure) quickly.
Desired State	DoD uses standard commercial packages for enterprise and business services, changing its processes to match those of large industries, allowing its systems to be updated and modified on a much faster cadence. The only specialized defense business systems should be those for which there is no commercial equivalent (to include cases in which minor modifications would be required) and there is a funded internal capability to maintain and update the software at a near-commercial cadence.
Role of Congress	Congressional approval for new software development programs should be based on a clear assessment of the current state of commercial software and the need for DoD-specific customization. In many cases it should be possible to make use of commercial systems and modify the DoD process to be consistent with commercial practice rather than attempting to build and maintain specialized business systems. Support legislative change of 10 USC §2222, as needed.

Draft Implementation Plan		Lead Stakeholders	Target Date
A5.1	Use a Net Promoter Score (NPS) assessment to identify 10 programs whose customers (soldiers, civilians, or others) believe the functionality could be better executed with commercial software	CMO, with USD(A&S), Service counterparts	Q4 FY19
A5.2	Using the results of A5.2, select 4 projects for a more detailed assessment of possible savings and/or efficiency improvements	CMO, with Service CMOs and business process owners	Q1 FY20
A5.3	Implement COTS opportunities, with contracts in place	Services, with CMO oversight	Q1 FY21
A5.4	Submit legislative change proposal to modify Title 10 §2222 to reflect the lessons learned through process re-engineering to utilize commercially-available system over DoD-specific solutions	CMO, with USD(A&S) and Service counterparts	FY21

SWAP concept paper recommendations related to this recommendation

10C	Use commercial process and software to adopt and implement standard business practices within the services
D&D	For common functions, purchase existing software and change DoD processes to use existing apps

Related recommendations from previous studies

DSB87	Rec 15: The USD(A) and the ASD(Comptroller) should direct Program Managers to assume that system software requirements can be met with off-the-shelf subsystem and components until it is proved that they are unique.
Sec 809	Rec 16: Combine authority for requirements, resources, and acquisition in a single, empowered entity to govern DBS portfolios separate from the existing acquisition chain of command
Sec 809	Rec 18: Fund DBSs [defense business systems] in a way that allows for commonly accepted software development approaches

Additional Recommendation A6
Enduring Capability

Line of Effort	Refactor statutes, regulations, and processes for software
Recommendation	Plan, budget, fund, and manage software development as an enduring capability that crosses program elements and funding categories, removing cost and schedule triggers associated with hardware-focused regulations and processes
Stakeholders	USD(A&S), USD(C), SAE, Service FM, HASC, SASC
Background	The current approach to acquiring software is based on projects that have a beginning and end. However, many missions are "enduring capabilities" and need software program and portfolio management that continually and perpetually deliver across the spectrum of new capability, incremental enhancements and life-cycle sustainment. The Department should pilot and then scale methods for appropriating software budgets for these enduring capability programs as an ongoing, regularly evaluated expense, with continuous oversight, rather than large , multi-year development contracts
Desired State	The Department can manage software acquisition as an activity requiring continuous development, deployment and sustainment, recognizing that software systems are long-lived and have a continuous need for a level of activity to evolve capabilities and address vulnerabilities. Assessment of progress will be maintained throughout the software lifespan by means of continual user engagement with working software, rather than at large-scale milestone gates that do not map well to the underlying technical activities.
Role of Congress	N/A

Draft Implementation Plan		Lead Stakeholder	Target Date
A6.1	Modify FMR to implement this continuous funding approach	USD(C)	Q4 FY19
A6.2	Select and launch five programs to be managed as enduring capability two year pilot projects	USD (A&S) with SAE	Q4 FY19
A6.3	Work with FASAB to create an audit treatment of enduring capability software that has a category distinct from Property, Plant, and Equipment; defaults to treating software as an expense, not an investment; and does not distinguish between development and sustainment	USD(A&S) with USD(C)	Q4 FY20

SWAP concept paper recommendations related to this recommendation

10C	Budgets should be constructed to support the full, iterative life-cycle of the software being procured with amount proportional to the criticality and utility of the software.
D&D	Treat software development as a continuous activity, adding functionality continuously

Additional Recommendation A7
Portfolio Management

Line of Effort	Refactor statutes, regulations, and processes for software
Recommendation	Replace JCIDS, PPB&E, and DFARS with a portfolio management approach to software programs, assigned to "PEO Digital" or equivalent office in each Service that uses and direct identification of warfighter needs to decide on allocation priorities for software capabilities
Stakeholders	USD(A&S), CAPE, JCS, USD(C), SAE, Service FM & PAE
Background	The current requirements process often drives the development of exquisite requirements that tend to be overly rigid and specific, and attempt to describe the properties of systems in dynamic environments years in advance. The speed of requirements development and analysis is out of sync with the pace of technology and mission changes. Most importantly, requirement documents that are developed are often disconnected with the end user requirements.
Desired State	Software programs are managed using a portfolio approach, in which resources are available for reallocation across programs and funding categories based on the importance and opportunities of given elements of the portfolio. Relevant portfolios are defined based on the linkages between programs of similar function, as defined by OSD and/or Services.
Role of Congress	Congress should approve and monitor metrics of success defined within different portfolios and measure the progress against those metrics in determining allocations of funding to different portfolios (with the decisions within a portfolio made by the portfolio office and held accountable for those decisions).

Draft Implementation Plan		Lead Stakeholders	Target Date
A7.2	Select initial capability areas in each service to place under portfolio management by PEO Digital (or equivalent)	SAEs	Q3 FY19
A7.1	Issue guidance for management of software portfolios with a “PEO Digital” or similar office with OSD and/or the Services.	USD(A&S) SAE	Q4 FY19
A7.3	Stand up PEO Digital or equivalent office with necessary resources allocated and aligned	SAE	Q1 FY20
A7.4	Implement new portfolio management methods for initial program capability areas	PEO Digital	Q3 FY20
A7.5	Determine intermediate successes of. or required modifications to. portfolio management approach	PEO Digital	Q1 FY21
A7.6	Establish portfolio management approach as standard work for software	PEO Digital, SAE	FY22

App	Within each Component-unique Budget Activity (BA), Budget Line Items (BLINs) align by functional or operational portfolios. The BLINs may be further broken into specific projects to provide an even greater level of fidelity. These projects would represent key systems and supporting activities, such as mission engineering.

App	By taking a portfolio approach for obtaining software intensive capabilities, the Components can better manage the range of requirements, balance priorities, and develop portfolio approaches to enable the transition of data to information in their own portfolios and data integration across portfolios to achieve mission effects, optimize the value of cloud technology, and leverage and transition to the concept of acquisition of whole data services vice individual systems.
App	This fund will be apportioned to each of the Military Departments and OSD for Fourth Estate execution.
App	Governance: management execution, performance assessment, and reporting would be aligned to the portfolio framework—BA, BLI, project.
Req	OSD and the Joint Staff should consider creating “umbrella” software programs around “roles” (e.g. USAF Kessel Run)

Related recommendations from previous studies

OSD'06	Transform the Planning, Programming, and Budgeting and Execution process and stabilize funding for major weapons systems development programs.
DSB’09	The USD (AT&L) aggressively delegate milestone decision authority commensurate with program risk
DSB’09	The USD (AT&L) consider a more effective management and oversight mechanism to ensure joint program stability and improved program outcomes
DSB’09	Consolidate all acquisition oversight of information technology under the USD (AT&L) by moving into that organization those elements of the OASD (NII)/DOD CIO and Business Transformation Agency responsible for IT acquisition oversight. The remainder of OASD (NII)/DOD CIO is retained as it exists today, but should be strengthened as indicated in the previous recommendation.
Sec 809	Rec 36: Transition from a program-centric execution model to a portfolio execution model
Sec 809	Rec 37: Implement a defensewide capability portfolio framework that provides an enterprise view of existing and planned capability, to ensure delivery of integrated and innovative
Sec 809	Rec. 38: Implement best practices for portfolio management.
Sec 809	Rec. 39: Leverage a portfolio structure for requirements.

Primary Recommendation B1
Digital Infrastructure

Line of Effort	Create and maintain cross-program/cross-service digital infrastructure
Recommendation	**Establish and maintain digital infrastructure within each Service or Agency that enables rapid deployment of secure software to the field and incentivize its use by contractors**
Stakeholders	A&S, CIO, SAE, USD(C)
Background	Currently, DoD programs each develop their own development and test environments, which requires redundant definition and provisioning, replicated assurance (including cyber), and extended lead times to deploy capability. Small companies have difficulties providing software solutions to DoD because those environments are not available outside the incumbent contractor or they have to build (and certify) unique infrastructure from scratch.
Desired State	Programs will have access to, and be stakeholders in, a cross-program, modern digital infrastructure that can benefit from centralized support and provisioning to lower overall costs and the burden for each program. Development infrastructure supporting CI/CD and DevSecOps is available as best of breed and GOTS provided so that contractors want to use it, though DoD programs or organizations that want or need to go outside of that existing infrastructure can still do so.
Role of Congress	Congress should track the availability, scale, use, and cost effectiveness of digital infrastructure, with the expectation that overall capacity will expand while unit costs decrease over time. Sufficient funding should be provided on an ongoing basis to maintain and upgrade digital infrastructure to maintain best of breed capability that accelerates software development.

	Draft Implementation Plan	Lead Stakeholder	Target Date
B1.1	Designate organization(s) responsible for creating and maintaining the digital infrastructure for each Service's digital infrastructure. Explore the use of tiered approaches with infrastructure at Service or Program level, as appropriate.	DoD CIO, USD(C) and Services (SAE and Service CIO)	Q3 FY19
B1.2	Designate organization(s) responsible for creating and maintaining digital infrastructure(s) for DoD agencies and organizations, including joint digital infrastructure available to the Services.	USD(A&S), with CIO, CMO	Q3 FY19
B1.3	Provide resources for digital infrastructure, including cloud solutions, pre-approved "drop-ship" local compute capability, approved development environments (see DIB Compute Environment concept paper, Appendix I [Glossary])	USD(A&S), SAE with CAPE, USD(C)	FY20 budget
B1.4	Define baseline digital infrastructure systems and implement procurement and deployment processes and capability	Responsible organizations from B1.1, B1.2	Q2 FY20

B1.5	Implement digital infrastructure and provide access to ongoing and new programs.	Responsible organizations from B1.1, B1.2	Q3 FY20
B1.6	Identify acquisition programs to transition to digital infrastructure	SAE	Q2 FY20
B1.7	Transition programs to digital infrastructure	SAE, CIO, PEO, PM	Q4 FY20

SWAP concept paper recommendations related to this recommendation

10C	Make computing, storage, and bandwidth and programmers abundant to DoD developers and users.
D&D	Use validated software development platforms that permit continuous integration & delivery evaluation (DevSecOps platform)
Visits	Separate development of mission level software from development of IA-accredited platforms

SWAP working group inputs related to this recommendation

T&E	Build the enterprise-level digital infrastructure needed to streamline software development and testing across the full DoD software portfolio.

Related recommendations from previous studies

DSB87	Rec 16: All methodological efforts, especially STARS, should look to see how commercially available software tools can be selected and standardized for DoD needs.
SEI'01	Infrastructure: In distributed development activities, get high quality, secure, broadband communications between sites. It is an enabler, not a cost.

Primary Recommendation B2
Automated Testing and Evaluation

Line of Effort	Create and maintain cross-program/cross-service digital infrastructure
Recommendation	**Create, implement, support, and use fully automatable approaches to testing and evaluation (T&E), including security, that allow high confidence distribution of software to the field on an iterative basis**
Stakeholders	DOT&E, USD(A&S), DDR&E(AC), SAE, Service Test Agencies
Background	To deliver SW at speed, rigorous, automated testing processes and workflows are essential. Current DoD practices and procedures often see OT&E as a tailgate process, sequentially after development has completed, slowing down delivery of useful software to the field and leaving existing (potentially poorly performing and/or vulnerable) software in place.
Desired State	Development systems, infrastructure and practices are focused on continuous, automated testing by developers (with users), with frequency dependent on type of software, but targets cycle times measured in weeks. To the maximum extent possible, system operational testing is integrated (and automated) as part of the development cycle using data, information, and test protocols delivered as part of the development environment. Embedded software in safety critical systems is tested with high confidence in representative (physical and simulated) environments. Testing and evaluation/certification of COTS components is done once (if justified) and then ATO reciprocity (Rec B3) is applied to enable use in other programs, as appropriate. System-level testing using modeling and simulation ("digital twin") is routinely used.
Role of Congress	DOT&E should provide annual reports to Congress that describe the availability, scale, use, and effectiveness of automated T&E, with the expectation that level/depth of testing will increase at the same time as speed and cycle time are being improved.

	Draft Implementation Plan	Lead Stakeholders	Target Date
B2.1	Establish procedures for fully automated testing on digital infrastructure (Rec B1), updating DoDI 5129.47 and Service equivalents as needed	USD(A&S), DOT&E, with Service Testers	Q1 FY20
B2.2	Establish processes for automated and red team-based security testing, including zero-trust assumptions, penetration testing, and vulnerability scanning	USD(A&S), DOT&E, with Service Testers	Q1 FY20
B2.3	Identify initial programs to use tools and workflows	SAE	Q1 FY20
B2.4	Implement minimum viable product (MVP) tools and workflows on digital infrastructure (Rec B1)	SAE, DOT&E, with PMOs	Q2 FY20
B2.5	Migrate initial programs to digital infrastructure using automated T&E	PEO, with Responsible Organizations	Q3 FY20
B2.6	Use tools and workflows, identify lessons learned and improvements (using DevSecOps iterative approach)	Service Testers, with PEO/PM	Q4 FY20
B2.7	Modify tools and workflows, document procedures	Responsible	Q4 FY20

		Organizations, Service Testers	

SWAP concept paper recommendations related to this recommendation

10C	Automate testing of software to enable critical updates to be deployed in days to weeks, not months or years.
D&D	Create automated test environments to enable continuous (and secure) integration and deployment to shift testing and security left
Visits	Automate testing of software to enable critical updates to be deployed in days to weeks, not months or years (also requires changes in testing organization)
Visits	Add testing as a service

SWAP working group inputs related to this recommendation

Acq	DOT&E should use test data collected through existing test methodologies present in a software-intensive programs and not recommend or prescribe additional independent one-time test events.
Acq	One time IOT&Es or cybersecurity test events should not be recommended for software-intensive systems except in specific circumstances if warranted
T&E	Build the enterprise-level digital infrastructure needed to streamline software development and testing across the full DoD software portfolio. [dup]
T&E	DoD should expand DOT&E's current capability to obtain state-of-the-art cyber capabilities on a fee- for-service basis

Related recommendations from previous studies

DSB87	Rec 27: Each Service should provide its software Using Commands with facilities to do comprehensive operational testing and life-cycle evaluation of extensions and changes.
SEI'12	Merge Agile and security best practices (e.g., integrate vulnerability scans into continuous integration process, leverage automated test cases for accreditation validation, adhere to secure coding standards)
SEI'16	Employ concurrent testing and continuous integration.
USDS	When issuing a solicitation, it should explain the Agile software development process. The solicitation should also describe the required testing of functional requirements and make it clear that testing should be integrated into each sprint cycle
IDA'18a	Analysis of planned operational test lengths indicates that the test scope is generally not long enough demonstrate operational reliability with statistical confidence

Primary Recommendation B3
ATO Reciprocity

Line of Effort	Create and maintain cross-program/cross-service digital infrastructure
Recommendation	**Create a mechanism for Authority to Operate (ATO) reciprocity within and between programs, Services, and other DoD agencies to enable sharing of software platforms, components and infrastructure and rapid integration of capabilities across (hardware) platforms, (weapons) systems, and Services**
Stakeholders	DoD CIO, A&S, Service CIOs, DISA
Background	Current software acquisition practice emphasizes the differences among programs: perceptions around different missions, different threats, and different levels of risk tolerance mean that components, tools, and infrastructure that have been given permission to be used in one context are rarely accepted for use in another. The lack of ATO reciprocity drives each program to create their own infrastructure, repeating time- and effort-intensive activities needed to certify elements as secure for their own specific context.
Desired State	Modern software components, tools, and infrastructure, once accredited as secure within the DoD, can be used appropriately and cost-effectively by multiple programs. Programs can spend a greater percentage of their budgets on developing software that adds value to the mission rather than spending time and effort on basic software infrastructure. Accreditation of COTS components is done once and then made available for use in other programs, as appropriate.
Role of Congress	N/A

Draft Implementation Plan		Lead Stakeholder	Target Date
B3.1	Issue guidance making reciprocity the default practice in DoD with limited exceptions and update DoDI 8510.01 to reflect updated risk management framework. Exceptions should require signoff by the DoD CIO to discourage their use	DoD CIO, with Service CIOs	Q3 FY19
B3.2	Establish DoD-wide repository for ATO artifacts with tools and access rules that enable Services to identify existing ATOs and utilize them when possible	DoD CIO, with Service CIOs, DISA	Q4 FY19
B3.3	Implement procedures and access controls so that Authorizing Officials have visibility over other programs that are using compatible ATOs	DoD CIO, with Service CIOs, DISA	Q2 FY20
B3.4	Implement mechanisms to allow FedRAMP and other non-DoD security certifications to be used for DoD ATO when appropriate based on intended use and environment	DoD CIO, with FedRAMP	Q4 FY20

SWAP working group inputs related to this recommendation

Sec	As security is “baked in” to software during the development process, people must be educated about what that means as different tools look at different security aspects.
Sec	People must learn to appreciate that speed helps increase security. Security is improved when changes and updates can be made quickly to an application. Using automation, software can be reviewed quickly.
Sec	The AO must also be able to review documentation and make a risk decision quickly and make that decision on the process and not the product.

Related recommendations from previous studies

SEI'12	Define criteria for reaccreditation early in the project.
SEI'12	Leverage long accreditation approval wait time with frequent community previews.
SEI'12	Don’t apply all the information assurance controls blindly.

Additional Recommendation B4
Prioritize Modern Software Development Methods

Line of Effort	Create and maintain cross-program/cross-service digital infrastructure
Recommendation	Prioritize secure, iterative, collaborative development for selection and execution of new software development programs (and software components of hardware programs), especially those using commodity hardware and operating systems
Stakeholders	USD(A&S), USD(C) DOT&E, SAE, Service Test Agencies
Background	Despite 37+ years of recommendations to stop using waterfall development for software programs, DoD continues to make use of hardware-centric approaches to development for software and software-intensive programs. While portions of the DoD 5000.02 Instructions apply to "Defense Unique Software Intensive" programs and "Incrementally Deployed Software Intensive" programs, these are still waterfall processes with years between the cycles of deployments (instead of weeks). These processes may be appropriate for some (though not all) embedded systems, but are not the right approach for DoD-specific software running on commercial hardware and operating systems.
Desired State	DoD makes use of commercial software (without customization) whenever possible. When DoD-specific software development is required, contractors with demonstrated ability in the implementation of modern software development processes (eg, agile, DevOps, DevSecOps) are prioritized in the selection process and a contract structure is used that enables those methods to be successfully applied. For those applications for which hardware and software development are closely coupled, modern methods are still used as appropriate, especially in terms of information assurance testing.
Role of Congress	Congress should review metrics for performance on software (and software-intensive) programs with the expectation that modern methods of software able to deliver software to the field quickly, provide rapid and continuous updates of capability, perform extensive automated testing, and track metrics for speed and cycle time, security, code quality, and useful capability.

Draft Implementation Plan		Lead Stakeholders	Target Date
B4.1	Establish metrics for evaluation of software development environments, following DSB 2018 recommendations on software factors and DIB "Development Environment" and "Agile BS Detector" Concept Papers	USD(A&S)	Q3 FY19
B4.2	Issue Directive-Type Memorandum (DTM) to specify DoD's default software development approach is secure, iterative, modular, and collaborative	USD(A&S)	Q3 FY19
B4.3	Create new DoD Instruction (DoDI) 5000.SW (or update DoDI 5000.02 and 5000.75) to specify DoD's default software development approach is secure, iterative,	USD(A&S)	Q1 FY20

	modular, and collaborative		
B4.4	Update courseware at Defense Acquisition University to specify DoD's default software development approach is secure, iterative, modular, and collaborative	USD(A&S)	Q2 FY20

SWAP concept paper recommendations related to this recommendation

10C	Adopt a DevOps culture for software systems.
D&D	Require developers to meet with end users, then start small and iterate to quickly deliver useful code
Visits	Adopt a DevOps culture: design, implement, test, deploy, evaluate, repeat

SWAP working group inputs related to this recommendation

Con	Use collaborative tools and libraries so that all content is available to all parties at all times
Con	Use an agile process to manage structure and technical requirements
Sec	As security is "baked in" to software during the development process, people must be educated about what that means as different tools look at different security aspects.
Wkf	Incentivize defense contractors to demonstrate their ability to leverage modern software methodologies
Wkf	Contractor Reform. Adjust future NDAA's to add incentives for defense contractors to use modern development practices. (See FY18NDAA / §§873 & 874)

Related recommendations from previous studies

DSB87	Rec 12: Use evolutionary acquisition, including simulation and prototyping, as discussed elsewhere in this report, to reduce risk.
DSB87	Rec 17: DoD should devise increased productivity incentives for custom-built software contracts, and much such incentivized contracts the standard practice.
DSB87	Rec 18: DoD should devise increased provide incentives on software quality.
DSB87	Rec 23: The USD(A) should update DoD Directive 5000.29, "Management of Computer Resources in Major Defense Systems", so that it mandates the iterative setting of specifications, the rapid prototyping of specified systems, and increment development.
DSB87	Rec 24: DoD STD 2167 should be further revised to remove any remaining dependency on the assumptions of the "waterfall" model and to institutionalize rapid prototyping and incremental development
DSB87	Rec 29: The USD(A) should develop economic incentives, to be incorporated into standard contracts, to allow contractors to profit from offering modules for reuse, even though built with DoD funds.
DSB87	Rec 30: The USD(A) should develop economic incentives, to be incorporated into all cost-plus standard contracts, to encourage contractors to buy modules and use them rather than building new ones.
DSB87	Rec 31: The USD(A) and ASD(Comptroller) should direct Program Managers to identify in their programs those systems, components, and perhaps even modules, that may be expected to be acquired rather than built; and to reward such acquisition in the RFP's.
SEI'12	Make sure Agile project teams understand the intent behind security requirements and organize the backlog accordingly
SEI'12	Ensure Agile development processes produce and maintain "just enough" design

	documentation.
SEI'12	Make sure there is at least one person with strong security analysis expertise on the Agile project team
SEI'12	Foster Agile project team and accrediting authority collaboration.
SEI'12	Leverage unclassified environments for Agile development and community previews.
SEI'12	Agile and the information assurance community must join forces to continue improving information assurance processes.
GAO'16a	Establish a department policy and process for the certification of majorIT investments' adequate use of incremental development, in accordance with OMB's guidance on the implementation of FITARA.
NPS'16a	Systems leveraging open architectures and incremental designs can focus on delivering initial capability quickly, and then iterate improvements over time. The DoD can tailor acquisition processes for each major type of system to streamline each program's path through focused guidance
SEI'16	Ensure that the RFP contains language that allows the use of Agile. One promising approach that is consistent with Agile is to make sure the original contract is written with Agile in mind and contains sufficient flexibility to permit a wide scope of activity that could be modified as the situation develops. Agile program managers (PMs) could establish contract vehicles that allow for collaborative discussions to resolve and address dynamic developments over the life of the effort.
DSB18	Requests for proposals (RFPs) for acquisition programs entering risk reduction and full development should specify the basic elements of the software framework supporting the software factory, including code and document repositories, test infrastructure, software tools, check-in notes, code provenance, and reference and working documents informing development, test, and deployment
DSB18	Rec 1: A key evaluation criterion in the source selection process should be the efficacy of the offeror's software factory.
DSB18	Rec 1a: Establish a common list of source selection criteria for evaluating software factories for use throughout the Department
DSB18	Rec 1b: Competing contractors should have to demonstrate at least a pass-fail ability to construct a software factory
DSB18	Rec 1c: Criteria for evaluating software factories should be reviewed and updated every five years.
DSB18	Rec 5e: Defense prime contractors must build internal competencies in modern software methodologies.
DSB18	Rec 2: The DoD and its defense industrial base partners should adopt continuous iterative development best practices for software, including through sustainment.
DSB18	Rec 2c: [DoD should] engage Congress to change statutes to transition Configuration Steering Boards (CSB) to support rapid iterative approaches (Fiscal Year (FY) 2009 National Defense Authorization Act (NDAA), Section 814).
DSB18	Rec 2d: [DoD] should require all programs entering Milestone B to implement these iterative processes for Acquisition Category (ACAT) I, II, and III programs.
DSB18	Rec 4a: For ongoing development programs, the USD(A&S) should immediately task the PMs with the PEOs for current programs to plan transition to a software factory and continuous iterative development.
DSB18	Rec 4c: Defense prime contractors should incorporate continuous iterative development into a long-term sustainment plan

DSB18	Establish a common list of source selection criteria for evaluating software factories for use throughout the Department.
FCW'18	Contractors would allow government to develop past performance reports with less documentation and less contractor opportunity to appeal their ratings
USDS	Agile software development is the preferred methodology for software development contracts that contribute to the creation and maintenance of digital services, whether they are websites, mobile applications, or other digital channels
USDS	Although Part 39 does not directly speak to Agile software development practices, it endorses modular contracting principles where information technology systems are acquired in successive, interoperable increments to reduce overall risk and support rapid delivery of incremental new functionality
USDS	With Agile software development, requirements and priorities are captured in a high level Product Vision, which establishes a high level definition of the scope of the project, specifies expected outcomes, and produces high level budgetary estimates.
USDS	Under Agile software development, the Government retains the responsibility for making decisions and managing the process; it plays a critical role in the IPT as the Product Owner by approving the specific plans for each iteration, establishing the priorities, approving the overall plan revisions reflecting the experience from completed iterations, and approving deliverables.
USDS	OMB’s 2012 Contracting Guidance to Support Modular Development states that IDIQ contracts may be especially suitable for Agile software development because they provide a high level of acquisition responsiveness, provide flexibility, and accommodate the full spectrum of the system lifecycle that provide both development and operational products and services. BPAs may work with Agile software development using modular contracting methods. Additionally, stand-alone contracts or single award contracts may be used.
USDS	The Agile process works only if there are appropriate dedicated resources, as the process can be labor intensive. Agencies need to ensure adequate resources are applied to manage their contracts irrespective of the strategy used. Strong contract management ensures projects stay on course and helps prevent the agency from becoming overly reliant on contractors.

Additional Recommendation B5
Cloud Computing

Line of Effort	Create and maintain cross-program/cross-service digital infrastructure
Recommendation	Remove obstacles to DoD usage of cloud computing on commercial platforms, including DISA CAP limits, lack of ATO reciprocity, and access to modern software development tools
Stakeholders	DoD CIO, Service CIOs, USD(A&S)
Background	Lack of ATO reciprocity and current DoD procedures for cloud are obstacles to leveraging modern infrastructure and tools.
Desired State	DoD developers and contractors are able to use modern cloud computing environments and commercial development tools quickly, with a single certification that is transferable to other groups using the same environment, tools
Role of Congress	N/A

Draft Implementation Plan		Lead Stakeholders	Target Date
B5.1	Rescind Cloud Access Point (CAP) policy and replace with policy that ensures security at scale (including end-to-end encryption)	DoD CIO	Q3 FY19
B5.2	In conjunction with Rec B4, allow transfer of ATOs for commercial platforms between programs and services	DoD CIO	Q3 FY19
B5.3	Create specifications and certification process for approval of standard development tools (w/ ATO reciprocity)	DoD CIO	Q4 FY19
B5.4	In conjunction with Rec B1, establish a common, enterprise ability to develop software solutions in the "easy-to- acquire-and-provision" cloud that is fully accredited by design of the process, tools, and pipeline	USD(A&S)	Q1 FY20

SWAP working group inputs related to this recommendation

Acq	Include an approach for enterprise-level DevSecOps and other centralized infrastructure development and management, approach for shared services, and applications management.
Inf	Establish a DoD enterprise ability to procure, provision, pay for, and use cloud that is no different from the commercial entry points for cloud computing.
Inf	DoD should establish a common, enterprise ability to develop software solutions in the "easy-to-acquire-and-provision" cloud that is fully accredited by design of the process, tools, and pipeline.

Related recommendations from previous studies

Sec 809	Rec. 43: Revise acquisition regulations to enable more flexible and effective procurement of consumption-based solutions.

Additional Recommendation B6
Certify Code/Toolchain

Line of Effort	Create and maintain cross-program/cross-service digital infrastructure
Recommendation	Shift from certification of executables for low and medium risk deployments to certification of code/architectures and certification of the development, integration, and deployment toolchain
Stakeholders	USD(A&S), SAE, DoD CIO, Service CIO
Background	Today, the typical focus of security accreditation on programs is to certify each version of the code that is intended for release. This works against the goal of frequent updates since the more versions of software that are created, the more often the time and expense of the certification have to be borne by the program.
Desired State	The Department will accredit software infrastructures that are capable of producing quality code when used appropriately, enabling each version of the code produced on that infrastructure to be treated as certifiably secure (within appropriate limits, e.g. for versions that do not entail major architectural changes). This this change in certification, DoD will enable rapid fielding of mission-critical code at high levels of information assurance.
Role of Congress	N/A

Draft Implementation Plan		Lead Stakeholders	Target Date
B6.1	Identify and use commercial certification procedures for security assessments and deployment mechanisms that can be used for DoD software programs	CIO	Q4 FY19
B6.2	Identify 3 lead programs for initial implementation of certification procedures	A&S, SAE	Q1 FY20
B6.3	Expand certification procedures to 10 additional sites, spanning all Services and multiple OSD offices; update procedures with each new certification to streamline process.	A&S, SAE with CIO	Q3 FY20
B6.4	Update DoDI 8501.01, Risk Management Framework for DoD Information Technology, to reflect revised certification procedures.	CIO with SAE, A&S	Q4 FY20

SWAP working group inputs related to this recommendation

Acq	Exempt the DoD from the Clinger Cohen Act, 40 U.S.C. 1401(3)
Inf	DoD should establish a common, enterprise ability to develop software solutions in the “easy-to-acquire-and-provision” cloud that is fully accredited by design of the process, tools, and pipeline.

Related recommendations from previous studies

SEI'12	Use common operating environment (COE), software development toolkits (SDKs) and enterprise services to speed up accreditation time.
SEI'12	Apply a risk-based, incremental approach to security architecture.
SEI'12	Leverage design tactics such as layering and encapsulation to limit impact of change.
SEI'13	For an SoS or for the more likely case of a system or component that participates in an existing SoS, an effective risk management approach should • scale to size and complexity of systems of systems • incorporate dynamics • integrate across full life cycle: requirements to sustainment • focus on success as well as failure

Additional Recommendation B7
Hardware as a Consumable

Line of Effort	Create and maintain cross-program/cross-service digital infrastructure
Recommendation	Plan and fund computing hardware (of all appropriate types) as consumable resources, with continuous refresh and upgrades to current, secure operating systems and platform components
Stakeholders	USD(A&S), SAE, DoD CIO, Service CIO, USD(C), CAPE
Background	Current information technology (IT) refreshes take 8-10 years from planning to implementation, which means that most of the time our systems are running on obsolete hardware that limits our ability to implement the algorithms required to provide the level of performance required to stay ahead of our adversaries. Maintaining legacy code for different variants that have hardware capabilities ranging from 2 to 12 years old is an almost impossibly large spread of capability in computing, storage, and communications. From a contracting perspective, this change would require DoD to provide a stable annual budget that paid for new hardware and software capability (see Commandment #3), but this would very likely save money over the longer term.
Desired State	Whenever possible, applications are run in the cloud, so that algorithms can be run on the latest hardware and operating systems. For weapons systems, a continuous hardware refresh mentality is in place that enables software upgrades, crypto updates, and connectivity upgrades to be rapidly deployed across a fleet on an ongoing basis. The adoption rate of the latest hardware and operating system versions is tracked and targets are set for maintaining hardware and operating system “readiness”. The paradigm for computing hardware from current Property, Plant, and Equipment categorization (as investments with depreciation schedules) is modified to treat hardware as an expense.
Role of Congress	Provide funding for ongoing replacement of computing hardware as a consumable with a 2-4 year lifetime. Track “readiness” of currently deployed software capability in part by measuring age of the hardware and operating systems on which software is being run.

Draft Implementation Plan		Lead Stakeholders	Target Date
B7.1	Establish funds for initial existing weapons platforms involving computing hardware to replace hardware every 2-4 years (like oil)	CIO with USD(C), SAE	Q1 FY20
B7.2	Establish draft guidance for determining when to update hardware and operating systems to balance cost with risk/capability.	CIO	Q2 FY20
B7.3	Work with FASAB to change audit treatment of software/IT with these goals: (1) Separate category for software instead of being characterized as Property, Plant, and Equipment; (2) Default setting that software is an expense, not	USD(A&S), in coordination with USD(C)	Q4 FY20

	an investment; and (3) there is no “sustainment” phase for software.		
B7.4	Modify DoD Financial Management Regulation (FMR) to capture changes in how hardware is purchased and retired from service.	USD(C)	Q1 FY21

SWAP concept paper recommendations related to this recommendation

10C	Move to a model of continuous hardware refresh in which computers are treated as a consumable with a 2-3 year lifetime
Visits	Make use of platforms (hardware and software) that continuously evolve at the timescales of the commercial sector (3-5 years between HW/OS updates)

Related recommendations from previous studies

Sec 809	Rec. 44: Exempt DoD from Clinger–Cohen Act Provisions in Title 40:
Sec 809	Rec. 56: Use authority in Section 1077 of the FY 2018 NDAA to establish a revolving fund for information technology modernization projects and explore the feasibility of using revolving funds for other money-saving investments.

Primary Recommendation C1
Organic Development Groups

Line of Effort	Create new paths for digital talent (especially internal talent)
Recommendation	**Create software development units in each Service consisting of military and civilian personnel who develop and deploy software to the field using DevSecOps practices**
Stakeholders	USD(A&S), USD(P&R), SAE, Service HR
Background	The DoD’s capacity to apply modern technology and software practices to meet its mission is required in order to remain relevant in increasingly technical fighting domains, especially against peer adversaries. While DoD has both military and civilian software engineers (often associated with maintenance activities), the IT career field suffers from a lack of visibility and support. The Department has not prioritized a viable recruiting strategy for technical positions, and there is no comprehensive training or development program that prepares the technical and acquisition workforce to adequately deploy modern software development tools and methodologies.
Desired State	DoD recruits, trains, and retains internal capability for software development, including by service members, and maintains this as a separate career track (like DoD doctors, lawyers, and musicians). Each Service has organic development units that are able to create software for specific needs and that serve as an entry point for software development capability in military and civilian roles (complementing work done by contractors). The Department’s workforce embraces commercial best practices for the rapid recruitment of talented professionals, including the ability to onboard quickly and provide modern tools and training in state-of-the-art training environments. Individuals in software development career paths are able to maintain their technical skills and take on DoD leadership roles.
Role of Congress	Congress should receive regular “readiness” reports that include organic software development capability and provide budget required to maintain desired capability level and resources for modern software development.

Draft Implementation Plan		Lead Stakeholders	Target Date
C1.1	Exercise existing acquisition and cybersecurity hiring authorities to increase the number of software developers in DoD programs with vacant positions.	SAE, PEO, with CIO (cyber excepted service ability)	Immediately
C1.2	Create new military occupational specialty (MOS) and core occupational series plus corresponding career tracks for each Service; use to grow digital talent for modern software development (e.g., agile, DevSecOps)	J1 and comparable X1 for each Service with USD(P&R)	Q1 FY20
C1.3	Create regulations to allow standard identification, recruitment, and onboarding of experienced civilian software talent, especially on rotation from private sector roles	USD(P&R)	Q1 FY20
C1.4	Create mechanism for tracking software development expertise and use as preferred experience for promotion	A&S, CIO	Q2 FY20

	into software engineer and acquisition roles		
C1.5	Obtain additional manpower authorizations for military and civilian SW developers.	USD(A&S), with USD(P&R), SAE	FY20, FY21
C1.6	Stand up one or more software factories within each Service, tied to field needs that can be satisfied through organic software development groups.	SAEs, with PEOs Digital	FY20 (create), FY21 (scale)

SWAP concept paper recommendations related to this recommendation

10C	Establish Computer Science as a DoD core competency
D&D	Hire competent people with appropriate expertise in software to implement the desired state and give them the freedom to do so ("competence trumps process")

SWAP working group inputs related to this recommendation

M&S	The definition of "core capabilities" in 10 USC 2464 should be revisited in light of warfighter dependence on software intensive systems to determine the scope of DoD's core organic software engineering capability, and we should engage with Congress on the proposed revision to clarify the intent and extent of key terminology used in the current statute.
M&S	Revise industrial base policy to include software and DoD's organic software engineering capabilities and infrastructure. Start enterprise planning and investment to establish and modernize organic System Integration Labs (SILs), software engineering environments, and technical infrastructure; invest in R&D to advance organic software engineering infrastructure capabilities.
Wkf	Develop a core occupational series based on current core competencies and skills for software acquisition and engineering.
Wkf	Overhaul the recruiting and hiring process to use simple position descriptions, fully leverage hiring authorities, engage subject matter experts as reviewers, and streamline the onboarding process to take weeks instead of months
Wkf	Embrace private-sector hiring methods to attract and onboard top talent from non-traditional backgrounds that may require special authorities to join the Department
Wkf	Develop a strategic recruitment program that targets civilians, similar to the recruitment strategy for military members, [including] prioritizing experience and skills over cookie-cutter commercial certifications or educational attainment
Wkf	Establish an alliance across the services that incentivizes and provides software practitioners a modern engagement platform (e.g. a chatOps platform) to connect across services, share their skills, communicate through knowledge channels, gather pain points, and develop solutions leveraging the full enterprise.
Wkf	Allow for greater private-public sector fluidity across the workforce while empowering the existing workforce to create a place where they want to work
Wkf	Modify Title 10, §1596a to create a new Computer-language proficiency pay statute.
Wkf	Pilot a cyber hiring team with the necessary authorities to execute report recommendations and that can serve as a Department-wide alternative to organization's traditional HR offices and will provide expedited hiring and a better candidate experience for top tier cyber positions.

Related recommendations from previous studies

DSB87	Rec 26: Each Service should provide its software Product Development Division with the ability to do rapid prototyping in conjunction with users.

DSB87	Rec 36: Establish mechanisms for tracking personnel skills and projecting personnel needs.
DSB87	Rec 37: Structure some office careers to build a cadre of technical managers with deep technical mastery and broad operational overview.
SEI'10	Improve compensation and advancement opportunities to increase tenure.

Primary Recommendation C2
Acquisition Workforce Training

Line of Effort	Create new paths for digital talent (especially internal talent)
Recommendation	**Expand the use of (specialized) training programs for CIOs, SAEs, PEOs, and PMs that provide (hands-on) insight into modern software development (e.g., agile, DevOps, DevSecOps) and the authorities available to enable rapid acquisition of software**
Stakeholders	USD(A&S), DoD CIO, SAE, Service CIO
Background	Acquisition professional have been trained and had success in the current model, which has produced the world's best military but this model is not serving well for software. New methodologies and approaches introduce unknown risks, and acquisition professionals are often not incentivized to make use of the authorities available to implement modern software methods. At the same time, senior leaders in DoD need to be more knowledgeable about modern software development practices so they can recognize, encourage, and champion efforts to implement modern approaches to software program management.
Desired State	Senior leaders, middle management, and organic and contractor-based software developers are aligned in their view of how modern software is procured and developed. Acquisition professionals are aware of all of the authorities available for software programs and use them to provide flexibility and rapid delivery of capability to the field. Program leaders are able to assess the status of software (and software-intensive) programs and spot problems early in the development process, as well as provide continuous insight to senior leadership and Congress. Highly specialized requirements are scrutinized to avoid developing custom software when commercial offerings are available that are less expensive and more capable.
Role of Congress	Prioritize experience with modern software development environments in approval of senior acquisition leaders.

Draft Implementation Plan		Lead Stakeholders	Target Date
C2.1	Leverage existing training venues to add content about modern software development practices	USD(A&S), SAEs with DAU	Q4 FY19
C2.2	Create and provide training opportunities via boot camps and rotations for acquisition professionals to obtain hands-on experience in DevSecOps programs	A&S with SAEs, USD(P&R)	FY20 (MVP) FY21 (scale)
C2.3	Develop additional training opportunities for key leaders about modern software development practices	USD(A&S), SAE	Q2 FY20
C2.4	Create software continuing education programs and requirements for CIOs, SAEs, PEOs and PMs modeled after MCLE (Minimum Continuing Legal Education) for lawyers	A&S, DAU	Q3 FY20

SWAP working group inputs related to this recommendation

Con	Provide training to KOs, PMs, and leadership to understand the value and methods associated with agile and modular implementation
Wkf	Create a software acquisition workforce fund (similar to the existing Defense Acquisition Workforce Development Fund (DAWDF)) ... to hire and train a cadre of modern software acquisition experts.
Wkf	Pilot development programs that provide comprehensive training for all software acquisition professionals, developers, and associated functions.
Con	Provide training to KOs, PMs, and leadership to understand the value and methods associated with agile and modular implementation
Con	Educate PMs and KOs on Open Source, proprietary, and Government funded code

Related recommendations from previous studies

DSB'09	All CIOs should approve IT acquisition program manager training and certification and advise the personnel selection process.
DSB'09	The USD (AT&L) shall direct the Defense Acquisition University, in coordination with the Information Resources Management College, to integrate the new acquisition model into their curriculum.
DSB18	USD(A&S) should task the PMs of programs that have transitioned successfully to modern software development practices to brief best practices and lessons learned across the Services.
DSB18	Rec 5d: The USD(A&S) and the USD(R&E) should direct the Defense Acquisition University (DAU) to establish curricula addressing modern software practices leveraging expertise from the DDS, the FFRDCs, and the University Affiliated Research Centers (UARCs).
DSB18	Rec 5g: DoD career functional Integrated Product Team (IPT) leads should immediately establish a special software acquisition workforce fund modeled after the Defense Acquisition Workforce Development Fund (DAWDF), the purpose of which is to hire and train a cadre of modern software acquisition experts across the Services.
DSB18	Rec 5h: PMs should create an iterative development IPT with associated training. The Service Chiefs should delegate the role of Product Manager to these IPTs.
DSB18	Rec 5b: The Service Acquisition Career Managers should develop a training curriculum to create and train [a] cadre [of] software-informed PMs, sustainers and software acquisition specialists.
Sec 809	Rec 27: Improve resourcing, allocation, and management of the Defense Acquisition Workforce Development Fund (DAWDF)
Sec 809	Rec. 59: Revise the Defense Acquisition Workforce Improvement Act to focus more on building professional qualifications.

Additional Recommendation C3
Increase PMO Experience

Line of Effort	Create new paths for digital talent (especially internal talent)
Recommendation	Increase the knowledge, expertise, and flexibility in program offices related to modern software development practices to improve the ability of program offices to take advantage of software-centric approaches to acquisition
Stakeholders	USD(A&S), SAE, USD(P&R)
Background	Acquisition professionals do not always have experience and insights into modern software development environments, especially in the opportunities (and limitations) for continuous integration/continuous deployment (CI/CD), automated testing (including security testing), and modern cloud-computing architectures. New methodologies and approaches introduce unknown risks, while the old acquisition and development approaches built the world's best military. Program offices not incentivized to adopt new approaches to acquisition and implemention of software, and inertia represents a barrier to change.
Desired State	Program management offices have staff available with experience in modern software development environments and who are able to make creative (but legal) use of available authorities for acquisition of software to fit the needs of modern software development solutions. Management of most types of software relies on (continuous) measurement of capability delivered to the field rather than being tied to satisfaction of objectives. Time and cost are used as constraints with schedule of delivery of features replanned at each iteration cycle based on warfighter/user feedback.
Role of Congress	N/A

Draft Implementation Plan		Lead Stakeholders	Target Date
C3.1	Establish list of skills and experience needed by program office staff to be considered "fully staffed" for a software program	A&S with SAEs, USD(P&R)	Q4 FY19
C3.2	Modify Position Descriptions for those in leadership positions in software acquisition programs to prioritize and reward prior experience in software development	USD(A&S), SAE, Service HR	Q1 FY20
C3.3	Create and provide training opportunities via boot camps and rotations for acquisition professionals to obtain hands-on experience in DevSecOps programs	A&S with SAEs, USD(P&R)	Q2 FY20 (MVP) FY21 (scale)
C3.4	Modify PM training requirements to obtain DAU Level IIII certification to include hands-on experience with modern software development	USD(A&S)	Q3 FY20
C3.5	Evaluate readiness level of software (and software-intensive) program offices by comparing experience/skill sets available with the list of needed skills from C3.1 (hint: consider tracking those skills sets; see Action C1.2)	A&S with SAEs, USD(P&R)	Q4 FY20 (MVP) FY21 (scale)

SWAP concept paper recommendations related to this recommendation

D&D	Hire competent people with appropriate expertise in software to implement the desired state and give them the freedom to do so ("competence trumps process") [dup]

SWAP working group inputs related to this recommendation

Acq	Lead tester from either DOT&E or JITC (preferably both, if JITC is being used as test org) must be a subject matter expert in the subject being tested, similar to how qualified test pilots run test flights (health records, financial systems, etc.)
Wkf	Empower a small cadre of Highly Qualified Experts and innovative Department employees to execute changes
Wkf	Create a software acquisition workforce fund (similar to the existing Defense Acquisition Workforce Development Fund (DAWDF)) ... to hire and train a cadre of modern software acquisition experts. [dup]
Wkf	Provide Agile, Tech and DevSecOps coaches in Program Offices to support transformations, adoption of modern software practice and sharing lessons across the enterprise
Wkf	Develop a core occupational series based on current core competencies and skills for software acquisition and engineering. [dup]
Wkf	Modernize Position Description and Hiring Practices. Modifying Existing Language - Title 5, Part III, Subpart D, Chapter 53, the addition of this pilot program needs to be added.
Wkf	Develop a Modern Academy. Modification Language - Title 10 §1746: This section should be added under the Defense Acquisition University, however, the HQE Cadre from Proposal #1 will lead the development of this pilot training program. Note: Tied with FY18 NDAA §891
Wkf	Private-Public Sector Fluidity. Modification Language - Title 5, §§3371-3375: Expand the Inter-Government Personnel Act and allow more civil service employees to work with non-Federal Agencies and Educational Institutions. Modification Language - Title 10, §1599g: Expand the Public-Private Talent Exchange Program and modify the language to reduce the "repayment" period from 1:2 to 1:1 ratio.
Wkf	Establish Workforce Fund. New Legislation - Similar to DAWDF, but the primary use will be for hiring and training a cadre of modern software acquisition experts.

Related recommendations from previous studies

DSB18	Rec 5a: The service acquisition commands (e.g., the LCMC, the NAVAIR, the U.S. Naval Sea Systems Command (NAVSEA), and the AMC) need to develop workforce competency and a deep familiarity of current software development techniques.
DSB18	Rec 5a.2: Services acquisition commands should use this cadre early in the acquisition process to formulate acquisition strategy, develop source selection criteria, and evaluate progress.
DSB18	Over the next two years, the service acquisition commands need to develop workforce competency and a deep familiarity of current software development techniques.
Sec 809	Rec. 40: Professionalize the requirements management workforce.
Sec 809	Rec. 46: Empower the acquisition community by delegating below threshold reprogramming decision authority to portfolio acquisition executives.
NPS'16a	The growth of rapid acquisition organizations gives acquisition executives new

	avenues to meet their top priority and rapid capability demands. However, these organizations may also have negative effects on traditional acquisition organizations. TheDoD's top talent will flock to the rapid acquisition organizations so that they can work onhigh-priority programs with minimal restrictions and likely achieve greater success.
NPS'16a	Contracting Officers (COs) must function as strategic partners tightly integrated into the program office, rather than operate as a separate organization that simply processes the contract paperwork
NPS'16b	Culturally, the acquisition community needs to embrace the available tools as opportunities, while being selective with procurement methods and adaptive to the market environment
CSIS'15	Rapid acquisition succeeds when senior leaders are involved in ensuring that programs are able to overcome the inevitable hurdles that arise during acquisition, and empower those responsible with achieving the right outcome with the authority to get the job done while minimizing the layers in between
CSIS'15	Rapid acquisition is fundamentally an ongoing dialogue between the acquisition and operational communities about what the real needs of the warfighter are and what the art of the possible is in addressing them.
GAO'17	Empower program managers to make decisions on the direction of the program and to resolve problems and implement solutions.
GAO'17	Hold program managers accountable for their choices.
GAO'17	Require program managers to stay with a project to its end.
GAO'17	Encourage program managers to share bad news, and encourage collaboration and communication.
SEI'15	5. Government Personnel Experience. Government personnel with extensive experience in developing and managing acquisition strategy and technical architecture should be dedicated and available to a program throughout its duration. <possible extension of C7>
SEI'10	Improve qualifications of acquisition staff emphasizing software expertise.
SEI'10	Assign PMs, DPMs, and other key positions for the program"s duration and into deployment. Use civilians if military rotations are not amenable.
OSD'06	Fully implement the intent of the Packard Commission. Create a streamlined acquisition organization with accountability assigned and enforced at each level.
OSD'06	Realign responsibility, authority and accountability at the lowest practical level of authority by reintegrating the Services into the acquisition management structure.
OSD'06	Seek legislation to retain high-performance military personnel in the acquisition workforce to include allowing military personnel to remain in uniform past the limitations imposed by the Defense Officer Personnel Management Act and augment their pay to offset the "declining marginal return" associated with retired pay entitlement.
OSD'06	Request that the White House Liaison Office create a pool of acquisition-qualified, White House pre-cleared, non-career senior executives and political appointees to fill executive positions, to provide leadership stability in the Acquisition System.
OSD'06	Immediately increase the number of federal employees focused on critical skill areas, such as program management, system engineering and contracting. The cost of this increase

	should be offset by reductions in funding for contractor support.
OSD'06	Establish a consistent definition of the acquisition workforce with the Under Secretary of Defense for Acquisition Technology and Logistics, working with the Service Secretaries to include in that definition all acquisition-related budget and requirements personnel.

Additional Recommendation C4
Recruiting (Transient) Digital Talent

Line of Effort	Create new paths for digital talent (especially internal talent)
Recommendation	Restructure the approach to recruiting digital talent to assume that the average tenure of a talented engineer will be 2-4 years, and make better use of HQEs, IPAs, special hiring authorities, reservists, and enlisted personnel to provide organic software development capability, while at the same time incentivizing and rewarding internal talent
Stakeholders	USD(A&S), USD(P&R), SAE, A-1/G-1/N-1
Background	Current DoD personnel systems assuming that military and government employees will "grow through the ranks" and that individuals will stay in government service for long periods of time. The attractions of the private sector creates challenges in retaining personnel that are not likely to be overcome, so a different approach is needed.
Desired State	DoD takes advantage of all individuals who are willing to serve, whether for a long period or a short period and amplifies the ability of individuals to make a contribution during their time in government. Internal talent is recognized and retained through merit-based systems of promotion and job assignment.
Role of Congress	Support and encourage the use of existing authorities to hire digital talent in creative ways that match the intent of Congress and solve the need for more flexible arrangements in which talented individual move in and out of government service (without creating unnecessary barriers).

Draft Implementation Plan		Lead Stakeholders	Target Date
C4.1	Exercise existing hiring authorities to increase the number of highly skilled software people in DoD program, such as the Cyber Excepted Workforce.	SAE, PEO	Starting now
C4.2	In conjunction with Recs C1, create a database of individuals in enlisted, officer, reserve, and civilian positions with software development skills and experience for internal recruiting use to software squadrons & PAOs	USD(P&R) and Service equivalents	Q3 FY19
C4.3	Within organic software programs, create processes for maintaining release cadence under the assumption of up to 25% turnover per year	PMOs	Q4 FY19
C4.4	Require software-intensive project proposals to include a plan for maintaining cadence-related metrics in face of up to 25% turnover of staff	SAEs	Q4 FY19
C4.5	Identify bottlenecks in providing security clearances for software developers and target granting of interim clearances within 1 month of start date	???	Q1 FY20
C4.6	Revise GS and military promotion guidelines for software developers to allow rapid promotion of highly qualified individuals with appropriate skills, independent of "time in grade"	USD(P&R)	FY20 for FY21 NDAA
C4.7	Obtain additional funding for military, civilian SW developers,	USD(A&S),	FY21

	including existing personnel, HQEs, IPAs, reservists, and direct commissioning	USD(P&R), SAE	

SWAP concept paper recommendations related to this recommendation

10C	Establish Computer Science as a DoD core competency

SWAP working group inputs related to this recommendation

Wkf	Develop a core occupational series based on current core competencies and skills for software acquisition and engineering.
Wkf	Overhaul the recruiting and hiring process to use simple position descriptions, fully leverage hiring authorities, engage subject matter experts as reviewers, and streamline the onboarding process to take weeks instead of months
Wkf	Embrace private-sector hiring methods to attract and onboard top talent from non-traditional backgrounds that may require special authorities to join the Department
Wkf	Develop a strategic recruitment program that targets civilians, similar to the recruitment strategy for military members, [including] prioritizing experience and skills over cookie-cutter commercial certifications or educational attainment

Related recommendations from previous studies

DSB87	Rec 34: Do not believe that DoD can solve its skilled personnel shortage; plan how best to live with it, and how to ameliorate it.
SEI'10	Divide large acquisition development efforts into multiple smaller, shorter duration programs.
Sec 809	Rec. 45: Create a pilot program for contracting directly with information technology consultants through an online talent marketplace.

Primary Recommendation D1
Source Code Access

Line of Effort	Change the practice of how software is procured and developed
Recommendation	**Require access to source code, software frameworks, and development toolchains – with appropriate IP rights – for DoD-specific code, enabling full security testing and rebuilding of binaries from source**
Stakeholders	USD(A&S), CIO, SAE
Background	For many DoD systems, source code is not available to DoD for inspection and testing, and DoD relies on suppliers to writer code for new compute environments. As code ages, suppliers are not required to maintain codebases without an active development contract and "legacy" code is not continuously migrated to the latest hardware and operating systems.
Desired State	DoD has access to source code for DoD-specific software systems that it operates and uses to perform detailed (and automated) evaluation of software correctness, security, and performance, enabling more rapid deployment of both initial software releases and (most importantly) upgrades (patches and enhancements). DoD is able to rebuild executables from scratch for all of its systems, and has the rights and ability to modify (DoD-specific) code when new conditions and features arise. Code is routinely migrated to the latest computing hardware and operating systems, and routinely scanned against currently-known vulnerabilities. Modern IP language is used to ensure that the government can use, scan, rebuild, and extend purpose-built code, but contractors are able to use licensing agreements that protect any IP that they have developed with their own resources. Industry trusts DoD with its code and has appropriate IP rights for internally developed code.
Role of Congress	N/A

Draft Implementation Plan		Lead Stakeholders	Target Date
D1.1	Work with industry to modernize policies for software code ownership, licensing, and purchase. See 2018 Army IP directive as an example.	USD(A&S)	Q3 FY19
D1.2	Modify FAR/DFARS guidance to require software source code deliverables for GOTS and for government-funded software development. Obtain rights for access to source code for COTS wherever possible (and useful)..	USD(A&S)	Q3 FY20
D1.3	Modify DoDI 5000.02 and DoDI 5000.75 to make access to code and development environments the default.	USD(A&S)	Q3 FY20
D1.4	Develop a comprehensive source code management plan for DoD including the safe and secure storage, access control, testing and field of use rights.	USD(A&S), with CIO	Q4 FY20

SWAP concept paper recommendations related to this recommendation

10C	Every purpose-built DoD software system should include source code as a deliverable.

D&D	Require source code as a deliverable on all purpose-built DoD software contracts. Continuous development and integration, rather than sustainment, should be a part of all contracts. DoD personnel should be trained to extend the software through source code or API access

Related recommendations from previous studies

DSB87	Rec 22: DoD should follow the concepts of the proposed FAR 27.4 for data rights for military software, rather than those of the proposed DoD 27.4, or it should adopt a new “Rights in Software” Clause as Recommended by Samuelson, Deasy and Martin in Appendix A6.
DSB18	Rec 6b: Availability, cost, compatibility, and licensing restrictions of [the proposed software factory] framework elements to the U.S. Government and its contractors should be part of the selection criteria for contract award.
DSB18	Rec 6c: all documentation, test files, coding, application programming interfaces (APIs), design documents, results of fault, performance tests conducted using the framework, and tools developed during the development, as well as the software factory framework, should be delivered to the U.S. Government at each production milestone; OR escrowed and delivered at such times specified by the U.S. Government (i.e., end of production, contract reward).
DSB18	Rec 6d: Selection preference should be granted based on the ability of the United States to reconstitute the software framework and rebuild binaries, re-run tests, procedures, and tools against delivered software, and documentation.

Primary Recommendation D2
Security Considerations

Line of Effort	Change the practice of how software is procured and developed		
Recommendation	**Make security a first-order consideration for all software-intensive systems, recognizing that security-at-the-perimeter is not enough**		
Stakeholders	USD(A&S), CIO, DDS, SAE, DDR&E(AC), DOT&E		
Background	Current DoD systems often rely on "security at the perimeter" as a means of protecting code for unauthorized access. If this perimeter is breached, then a large array of systems can be compromised. Multiple GAO, DoDIG, and other reports have identified cybersecurity as a major issue in acquisition programs.		
Desired State	DoD systems use a zero-trust security model in which it is not assumed that anyone who can gain access to a given network or system should have access to anything within that system. Regular and automated penetration testing is used to track down vulnerabilities and red teams are engaged to attempt to breach our systems before our adversaries do.		
Role of Congress	Review (classified) reporting of vulnerabilities identified in DoD systems and provide the resources required to ensure that hardware and operating systems are at current levels (see Recommendation B7, Hardware as a Consumable).		
Draft Implementation Plan		Lead Stakeholders	Target Date
D2.1	Adopt standards for secure software development and testing that use a zero-trust security model	CIO, with DDS	Q3 FY19
D2.2	Develop, deploy, and require the use of IA-accredited (commercial) development tools for DoD software development	CIO, PEO Digital	Q4 FY19
D2.3	Establish automated and red-team based penetration testing as part of OT&E evaluation (integrated with program development)	DOT&E	Q1 FY20
D2.4	Establish a red team responsible for ongoing vulnerability testing against any defense software system	CIO with DDS	Q2 FY20
D2.5	Establish security as part of the selection criteria for software programs	A&S with CIO, SAEs	Q3 FY20

SWAP concept paper recommendations related to this recommendation

10C	Only run operating systems that are receiving (and utilizing) regular security updates for newly discovered security vulnerabilities.
10C	Data should always be encrypted unless it is part of an active computation.
D&D	Create automated test environments to enable continuous (and secure) integration and deployment to shift testing and security left

SWAP working group inputs related to this recommendation

Sec	People must learn to appreciate that speed helps increase security. Security is improved when

	changes and updates can be made quickly to an application. Using automation, software can be reviewed quickly.
Sec	The AO must also be able to review documentation and make a risk decision quickly and make that decision on the process and not the product.
T&E	Establish a statutory "Live Fire" requirement on software-intensive systems as there is on "Covered Systems" for protecting our warfighters from kinetic threats. “Shoot at it” before design is complete and certainly before it is put into the operational environment.
T&E	Establish a federation of state-of-the-art cyber testing capabilities from non-profit institutions to support trusted, survivable and resilient defense systems and ensure the security of software and hardware developed, acquired, maintained, and used by the DoD.
T&E	Establish cyber security as the “4th leg” in measurement of Acquisition system/program performance: Cost, Schedule, Performance, Cyber Security.
T&E	Develop mechanisms to enforce existing software and cyber security policies (from cradle-to-grave) that are not (now) being adequately enforced.
T&E	Ensure each DoD Component is responsible for representing its own forces and capabilities in a digital modeling environment (e.g., M&S, digital twin, etc.), making them available to all other DoD users, subject to a pre-defined architecture and supporting standards. DIA will represent threat forces and capabilities in a digital form consistent with this architecture/standards. Programs are required to use DIA-supplied threat models, unless sufficient justification is provided to use other.

Related recommendations from previous studies

DSB’09	In the Services and agencies, the CIOs should also have strong authorities and responsibilities for system certification, compliance, applications development, and innovation.
DSB’09	The DOD CIO, supported by CIOs in the Services and agencies, should be responsible for certifying that systems and capabilities added to the enterprise do not introduce avoidable vulnerabilities that can be exploited by adversaries.
Sec 809	Rec. 77: Require role-based planning to prevent unnecessary application of security clearance and investigation requirements to contracts.

Primary Recommendation D3
Software Features

Line of Effort	Change the practice of how software is procured and developed
Recommendation	**Shift from the use of rigid lists of requirements for software programs to a list of desired features and required interfaces/characteristics, to avoid requirements creep, overly ambitious requirements, and program delays**
Stakeholders	USD(A&S), Joint Staff, SAEs
Background	Current DoD requirements processes significantly impede its ability to implement modern SW development practices by spending years establishing program requirements and insisting on satisfaction of requirements before a project is considered "done". This impedes rapid implementation of features that are of the most use to the user.
Desired state	Rather than a list of requirements for every feature, programs should establish a minimum set of requirements required for initial operation, security, and interoperability, and place all other desired features on a list that will be implemented in priority order, with the ability for DoD to redefine priorities on a regular basis.
Role of Congress	Modify relevant statutes to allow the use of evolving features over rigid requirements and develop alternative methods for obtaining information on program status (See Rec A2, Action A2.4)

Draft Implementation Plan		Lead Stakeholders	Target Date
D3.1	Modify requirements guidance by memo to shift from a list of requirements for software to a list of desired features and required interfaces/characteristics.	USD(A&S), with CMO	Q4 FY19
D3.2	Update CJCSI 3170.01H (JCIDS requirements process) to reflect contents of guidance memos	Joint Staff	Q1 FY20
D3.3	Modify DoDI 5000.02 and DoDI 5000.75 (or integrate into new DoDI 5000.SW)	USD(A&S)	Q2 FY20
D3.4	Define and use new budget exhibits for software programs using evolving lists of features in place of requirements (see also Rec A2).	USD(A&S), with USD(C), CAPE, HAC-D, SAC-D	Q3 FY20

SWAP concept paper recommendations related to this recommendation

10C	Adopt a DevOps culture for software systems.
10C	All software procurement programs should start small, be iterative, and build on success – or be terminated quickly.
D&D	Accept 70% solutions in a short time (months) and add functionality in rapid iterations (weeks)

Related recommendations from previous studies

SEI'01	Ensure that all critical functional and interoperability requirements are well specified in the contract (statement of work, Statement of Objectives).
SEI'01	Handle requirements that have architectural consequences as systems engineering

	issues—up front.
SEI'12	Ensure requirements prioritization of backlog considers business value and risk.
GAO'17	Match requirements to resources—that is time, money, technology, and people—before undertaking new development efforts.

Additional Recommendation D4
Continuous Metrics

Line of Effort	Change the practice of how software is procured and developed
Recommendation	Create and use automatically generated, continuously available metrics that emphasize speed, cycle time, security, user value and code quality to assess, manage, and terminate software programs (and software components of hardware programs)
Stakeholders	USD(A&S), CAPE, USD(C), SAE, Service Cost Orgs
Background	Current program reporting requirements are largely manual, time consuming, and provide limited insight into the SW health of a program. New metrics are required that match the DevSecOps approach of continuous capability delivery and maintenance and provide continuous insight into program progress.
Desired State	Program oversight will re-focus on the value provided by the software as it is deployed to the warfighter/user, and will rely more heavily on metrics that can be collect in an automated fashion from instrumentation on the DevSecOps pipeline and other parts of the infrastructure. Specific metrics will depend on the type of software rather than a one-size-fits-all approach.
Role of Congress	N/A (but see Rec A3)

Draft Implementation Plan		Lead Stakeholder	Target Date
D4.1	Modify acquisition policy guidance to specify use of automatically generated, continuously available metrics that emphasize speed, cycle time, security, and useful functionality	USD(A&S)	Q3 FY19
D4.2	Modify cost estimation policy guidance to specify use of automatically generated, continuously available metrics that emphasize speed, cycle time, security, and code.	CAPE	Q3 FY19
D4.3	Develop specific measure of software quality, value, and velocity and the tools to implement the automatic generation and reporting	DDS, with CAPE, CIO, USD(C)	Q4 FY19
D4.4	Modify DoDI 5000.02, DoDI 5000.75, and DoDI 5105.84 to reflect use of updated methods, remove earned value management (EVM) for software programs	A&S	Q1 FY20

SWAP working group inputs related to this recommendation

Acq	Revise DFARS Subpart 234.201, DoDI 5000.02 Table 8, and OMB Circular A-11 to remove EVM requirement
Con	Allow for documentation and reporting substitutions to improve agility (agile reporting vs EVM) (Cultural and EVM Policy)
Con	Establish a clear definition of done targets for software metrics for defense systems of different types (code coverage, defect rate, user acceptance) (Cultural)

D&M	Congress could establish, via an NDAA provision, new data-driven methods for governance of software development, maintenance, and performance. The new approach should require on demand access to standard [and real-time?] data with reviews occurring on a standard calendar, rather than the current approach of manually developed, periodic reports. [dup]
D&M	DoD must establish the data sources, methods, and metrics required for better analysis, insight, and subsequent management of software development activities. This action does not require Congressional action but will likely stall without external intervention and may require explicit and specific Congressional requirements to strategically collect, access, and share data for analysis and decision making.
T&E	Establish requirements for government-owned software to be instrumented such that critical monitoring functions (e.g., performance, security, etc.) can be automated as much as possible, persistently available, and such that authoritative data can be captured, stored, and reused in subsequent testing or other analytic efforts.

Related recommendations from previous studies

DSB87	Rec 19: DoD should develop metrics and measuring techniques for software quality and completeness, and incorporate these routinely in contracts.
DSB87	Rec 20: DoD should develop metrics to measure implementation progress.
Sec 809	Rec 19: Eliminate the Earned Value Management (EVM) mandate for software programs using Agile methods
MITRE'18	Elevate Security as a Primary Metric in DoD Acquisition and Sustainment

Additional Recommendation D5
Iterative Development

Line of Effort	Change the practice of how software is procured and developed
Recommendation	Shift the approach for acquisition and development of software (and software-intensive components of larger programs) to an iterative approach: start small, be iterative, and build on success or be terminated quickly
Stakeholders	USD(A&S), CAPE, USD(C), USD(P&R), SAE, Service HR
Background	Current language DoD acquisition guidance is largely based around a hardware-centric paradigm, with a well-defined start and end and sequential lifecycle activities..
Desired State	Software acquisition in the DoD follows an iterative approach, with frequent deployment of working software, supported by a DevSecOps infrastructure that enables speed through continuous integration / continuous deployment. Software projects are continuously evaluated by the quality of their deployed capability and are terminated early if they are found to be non-performant. Software is never "complete". Programs are viewed as an ongoing service rather than a discrete project.
Role of Congress	Authorize and track software programs that utilize iterative methods of development rather than milestone-based progress. Recognizing that the distinction between RTD&E, procurement, and sustainment is not appropriate for many types of software, identify new ways of providing oversight while enabling much more flexibility for programs.

Draft Implementation Plan		Lead Stakeholders	Target Date
D4.1	Issue guidance immediately changing default for acquisition programs use iterative software development methodologies (e.g., DevSecOps, agile development)	USD(A&S)	Q3 FY19
D4.2	Issue guidance changing default for acquisition programs to be iterative software development methodologies	SAE	Q3 FY19
D4.6	Select three software programs widely perceived to be in dire straights and go through a program termination exercise to identify new potential solutions and the blockers to more effectively terminating non-performing programs.	USD A&S	Q1 FY20
D4.3	Modify DoDI 5000.02 and 5000.75 (or DoDI 5000.SW) to reflect more iterative approaches for software development	USD(A&S)	Q2 FY20
D4.4	Modify Service acquisition policy to reflect more iterative approaches for software development	SAE	Q2 FY20
D4.5	Build a Congressional Reporting Dashboard that would be available to the four Defense Committees to show the progress of DoD and Services DevSecOps programs, including speed and cycle time, code quality, security, and user satisfaction..	USD (A&S)	Q4 FY20

SWAP concept paper recommendations related to this recommendation

10C	Adopt a DevOps culture for software systems.
10C	All software procurement programs should start small, be iterative, and build on success – or be terminated quickly.
D&D	Accept 70% solutions in a short time (months) and add functionality in rapid iterations (weeks)
D&D	Take advantage of the fact that software is essentially free to duplicate, distribute, and modify
D&D	Treat software development as a continuous activity, adding functionality continuously across its life cycle
Visits	Spend time upfront getting the architecture right: modular, automated, secure

SWAP working group inputs related to this recommendation

Con	Treat procurements as investments "what would you pay for a possible initial capability"
Con	Leverage incentives to make smaller purchases to take advantage of simplified acquisition procedures
Con	Use modular contracting to allow for regular investment decisions based on perceived value
Con	Streamline acquisition processes to allow for replacing poor performing contractors
T&E	Develop the enterprise knowledge management and data analytics capability for rapid analysis/ presentation of technical RDT&E data to support deployment decisions at each iterative cycle.

Related recommendations from previous studies

DSB18	Rec 2b: [DoD programs should] establish MVP and the equivalent of a product manager for each program in its formal acquisition strategy, and arrange for the warfighter to adopt the initial operational capability (IOC) as an MVP for evaluation and feedback
DSB18	Rec 2a: [DoD programs should] develop a series of viable products (starting with MVP) followed by successive next viable products (NVPs);
DSB18	Rec 3a: The MDA (with the DAE, the SAE, the PEO, and the PM) should allow multiple vendors to begin work. A down-select should happen after at least one vendor has proven they can do the work, and should retain several vendors through development to reduce risk, as feasible.
NDU'17	Prioritize technical performance and project schedules over cost. Maintain aggressive focus on risk identification and management across all elements of the open system and resolve technical problems as rapidly as possible.
GAO'17	Follow an evolutionary path toward meeting mission needs rather than attempting to satisfy all needs in a single step.
GAO'17	Ensure that critical technologies are proven to work as intended before programs begin. Assign more ambitious technology development efforts to research departments until they are ready to be added to future generations (or increments) of a product.
OSD'06	Change DoD's preferred acquisition strategy for developmental programs from delivering 100 percent performance to delivering useful military capability within a constrained period of time, no more than 6 years from Milestone A. This makes time a Key Performance Parameter.
OSD'06	Direct changes to the DoD 5000 series to establish Time Certain Development as the preferred acquisition strategy for major weapons systems development programs.

Additional Recommendation D6
Software Research Portfolio

Line of Effort	Change the practice of how software is procured and developed
Recommendation	Maintain an active research portfolio into next-generation software methodologies and tools, including the integration of machine learning and AI into software development, cost estimation, security vulnerabilities, and related areas
Stakeholders	USD(R&E), USD(A&S)
Background	Software is essential to national security and DoD needs to stay ahead of adversaries on emerging SW development practices.
Desired State	DoD benefits from a feedback loop between research and practice, in areas important to retaining the ability to be able to field innovations in software-enabled technologies. Mission needs and a practical understanding of the acquisition ecosystem inform research programs in emerging technologies. Results emerging from research impact the department's warfighting and other systems thanks to high-quality and modular software systems, a DevSecOps infrastructure capable of moving fast, and other enablers. Model-based engineering of software (including "digital twin" approaches) is routinely used to speed development and increase security.
Role of Congress	N/A

Draft Implementation Plan		Lead Stakeholders	Target Date
D6.1	Designate a responsible person or organization to coordinate software research activities	USD(R&E)	Q4 FY19
D6.2	Stand up a Chief Engineer for Software to direct the implementation of next generation software methodologies and tools	SAEs	Q4 FY19
D6.4	Direct the Principal Civilian Deputy to the SAE to implement the acquisition infrastructure for DevSecOps, allowing quick incorporation of new technologies into DoD systems, implemented by someone with software development experience	SAEs	Q4 FY19
D6.6	Create a documented DoD Software strategy, perhaps patterned on the DoD cyber strategy,[1] with ties to other existing national and DoD research strategies, and with involvement of A&S and the Services.	USD(R&E)	Q4 FY19
D6.5	Make acquisition data collected continuously from DevSecOps infrastructure and tools available to researchers with appropriate clearances, as a testbed for AI, ML, or other technologies. (See Recs A3, D4)	USD(A&S)	Q4 FY20

Related recommendations from previous studies

DSB18	Rec 7a: Under the leadership and immediate direction of the USD(R&E), the Defense Advanced Research Projects Agency (DARPA), the SEI FFRDC, and the DoD laboratories should establish research and experimentation programs around the practical use of machine learning in defense

[1] https://media.defense.gov/2018/Sep/18/2002041658/-1/-1/1/CYBER_STRATEGY_SUMMARY_FINAL.PDF

	systems with efficient testing, independent verification and validation (IVV), and cybersecurity resiliency and hardening as the primary focus points.

Additional Recommendation D7
Transition Emerging Tools and Methods

Line of Effort	Change the practice of how software is procured and developed
Recommendation	Invest in transition of emerging tools and methods from academia and industry to creating, analysis, verification, and testing of software into DoD practice (via pilots, field tests, and other mechanisms)
Stakeholders	USD(A&S), USD(R&E), Service Digital PEOs
Background	Software is essential to national security and DoD needs to stay ahead of adversaries in implementing emerging SW development practices. Research work at universities and in the private sector, along with best practice implementation from the private sector can provide value tools and methods to be deployed across the DoD.
Desired State	Development and test technology, tools and methods that are being created and used in the private sector and academia are known and visible to the PEOs Digital who enable transition into service programs. DoD labs are investing internally and externally maturing software development and analysis tools.
Role of Congress	N/A

Draft Implementation Plan		Lead Stakeholders	Target Date
D7.1	Create community of practice, code repositories and other mechanism to keep all practitioners knowledgeable about latest trends and capabilities in software development, testing and deployment.	USD(A&S)	Q4 FY19
D7.2	Invest in and engage with academic and private sector efforts to transition tools to do software engineering: creating, analyzing, verifying, testing and maintaining software.	Service DIgital PEOs	FY20
D7.3	Invest in and engage with academic and private sector efforts to transition tools to do software engineering: creating, analyzing, verifying, testing and maintaining software.	USD(R&E)	FY20

SWAP working group inputs related to this recommendation

Req	OSD should consider identifying automated software generation areas which can apply to specific domains

Related recommendations from previous studies

OSD'06	Direct the Deputy Director for Research and Engineering to coordinate service science and technology transition plans with the appropriate military service.
OSD'06	Direct the Deputy Director for Research and Engineering to actively participate in the Joint Capabilities Acquisition and Divestment process to reemphasize technology push initiatives.

Additional Recommendation D8
Collect Data

Line of Effort	Change the practice of how software is procured and developed
Recommendation	Automatically collect all data from DoD national security systems, networks, and sensor systems and make available for machine learning (via federated, secured enclaves, not a centralized repository)
Stakeholders	USD(A&S), USD(P&R), SAE, CMO, CAPE, DOT&E, DDR&E(AC)
Background	DoD discards or does not have access to significant amounts of data for its systems and has not established an infrastructure for storing data, mining data, or making data available for machine learning. Current analytical efforts are siloed and under-resourced in many cases.
Desired State	DoD has a modern architecture to collect, share, and analyze data that can be mined for patterns that humans cannot perceive. Data is being used to enable better decision-making in all facets of the Department, providing significant advantages that adversaries cannot anticipate. Data collection and analysis is done without compromising security and DoD, with minimum exceptions, should have complete data rights for all systems (developed with industry).
Role of Congress	N/A

Draft Implementation Plan		Lead stakeholders	Target Date
D8.1	Develop comprehensive data strategy for the DoD taking into account future AI/ML requirements	CDO with USD(A&S), SAE	Q1 FY20
D8.2	Implement a minimum viable product (MVP) that collects and analyzes the most critical data element for 1 or more programs	CDO with USD(A&S), SAE	Q3 FY20
D8.3	Create digital data infrastructure to support collection, storage, and processing	CDO with USD(A&S), SAE	Q1 FY21
D8.4	Require that all new major systems should specify a data collection and delivery plan.	A&S	Q2 FY21
D8.5	Implement data collection requirements for new sensor and weapon system acquisition	A&S	FY21

SWAP concept paper recommendations related to this recommendation

10C	All data generated by DoD systems - in development and deployment - should be stored, mined, and made available for machine learning.

Related recommendations from previous studies

DSB18	Rec 7b: [USD(R&E)] should establish a machine learning and autonomy data repository and exchange along the lines of the U.S. Computer Emergency Readiness Team (US-CERT) to collect and share necessary data from and for the deployment of machine learning and autonomy.
DSB18	Rec 7c: [USD(R&E)] should create and promulgate a methodology and best practices for the construction, validation, and deployment of machine learning systems, including architectures and test harnesses.

Appendix B: Legislative Opportunities in Response to 2016 NDAA Section 805

(Template Language for Recommendations A1 and A2)

This appendix provides a template for the type of legislative language that could represent a new category/pathway to procure, develop, deploy and continuously improve software for DoD applications, aligned with Recommendations A1 and A2 in Chapter 5. This template is designed to serve as an example of how the types of changes we envision might be implemented and has not been reviewed or endorsed by the Department. It is written to be consistent with 2016 NDAA Section 805 (Use of alternative acquisition paths to acquire critical national security capabilities).

SEC. [???]. SPECIAL PATHWAYS FOR RAPID ACQUISITION OF SOFTWARE APPLICATIONS AND UPGRADES.

(a) GUIDANCE REQUIRED.—Not later than [90, <u>180</u>, 270] days after the date of the enactment of this Act, the Secretary of Defense shall establish guidance authorizing the use of special pathways for the rapid acquisition of software applications and upgrades that are intended to be fielded within one year.

(b) SOFTWARE ACQUISITION PATHWAYS.—

(1) The guidance required by subsection (a) shall provide for the use of proven technologies and solutions to continuously engineer and deliver capabilities in software. The objective of an acquisition under this authority shall be to begin the engineering of new capabilities quickly, to demonstrate viability and effectiveness of those capabilities in operation, and continue updating and delivering new capabilities iteratively afterwards. An acquisition under this authority shall not be treated as an acquisition program for the purpose of section 2430 of title 10, United States Code or Department of Defense Directive 5000.01.

(2) Such guidance shall provide for two rapid acquisition pathways:

(A) APPLICATIONS.—The applications software acquisition pathway shall provide for the use of rapid development and implementation of applications and other software and software improvements running on commercial commodity hardware (including modified or ruggedized hardware) operated by the Department; and

(B) EMBEDDED SYSTEMS.—The embedded systems software acquisition pathway shall provide for the rapid development and insertion of upgrades and improvements for software embedded in weapon systems and other military-unique hardware systems.

(c) EXPEDITED PROCESS.--

(1) IN GENERAL.—The guidance required by subsection (a) shall provide for a streamlined and coordinated requirements, budget, and acquisition process that results in the rapid fielding of software applications and software upgrades to embedded systems in a period of

not more than [one year] from the time that the process is initiated. It shall also require the collection of data on the version fielded and continuous engagement with the users of that software, so as to enable engineering and delivery of additional versions in periods of not more than one year each.

(2) EXPEDITED SOFTWARE REQUIREMENTS PROCESS. –

(A) Software acquisitions conducted under the authority of this provision shall not be subject to the Joint Capabilities Integration and Development System Manual and Department of Defense Directive 5000.01, except to the extent specifically provided in the guidance required by subsection (a).

(B) The guidance required by subsection (a) shall provide that –

(1) Requirements for covered acquisitions are developed on an iterative basis through engagement with the user community, and utilization of user feedback in order to regularly define and prioritize the software requirements, as well as to evaluate the software capabilities acquired;

(2) The requirements process begins with the identification of 1) the warfighter or user need, 2) the rationale for how these software capabilities will support increased lethality and/or efficiency, and 3) the identification of a relevant user community;

(3) Initial contract requirements are stated in the form of a summary-level list of problems and shortcomings in existing software systems and desired features or capabilities of new or upgraded software systems;

(4) Contract requirements are continuously refined and prioritized in an evolutionary process through discussions with users that may continue throughout the development and implementation period;

(5) Issues related to lifecycle costs and systems interoperability are considered; and

(6) Issues of logistics support in cases where the software developer may stop supporting the software system are addressed.

(3) RAPID CONTRACTING MECHANISM.— The guidance required by subsection (a) shall authorize the use of a rapid contracting mechanism, pursuant to which --

(A) a contract may be awarded within a [90-day] period after proposals are solicited on the basis of statements of qualifications and past performance data submitted by contractors, supplemented by discussions with two or more contractors determined to be the most highly-qualified, without regard to price;

(B) a contract may be entered for a period of not more than one-year and a ceiling price of not more than [$50 million] and shall be treated as a contract for the acquisition of commercial services covered by the preference in section 2377 of title 10, United States Code;

(C) a contract shall identify the contractor team to be engaged for the work, and substitutions shall not be made during the base contract period without the advance written consent of the contracting officer;

(D) the contractor may be paid during the base contract period on a time and materials basis up to the ceiling price of the contract to review existing software in consultation with the user community and utilize user feedback to define and prioritize software requirements, and to design and implement new software and software upgrades, as appropriate;

(E) a contract may provide for a single one-year option to complete the implementation of one or more specified software upgrades or improvements identified during the period of the initial contract, with a price of not more than [$100 million] to be negotiated at the time that the option is awarded; and

(F) an option under the authority of this section may be entered on a time and materials basis and treated as an acquisition of commercial services or entered on a fixed price basis and treated as an acquisition of commercial products, as appropriate.

(4) EXECUTION OF RAPID ACQUISITIONS. The Secretary shall ensure that —

(A) software acquisitions conducted under the authority of this provision are supported by an entity capable of regular automated testing of the code, which is authorized to buy storage, bandwidth, and computing capability as a service or utility if required for implementation;

(B) processes are in place to provide for collection of testing data automatically from [entity specified in (A)] and using those data to drive acquisition decisions and oversight reporting;

(C) the Director of Operational Test and Evaluation and the director of developmental test and evaluation participate with the acquisition team to design acceptance test cases that can be automated using the entity specified in (A) and regularly used to test the acceptability of the software as it is incrementally being engineered;

(D) acquisition progress is monitored through close and regular interaction between government and contractor personnel, sufficient to allow the government to understand progress and quality of the software with greater fidelity than provided by formal but infrequent milestone reviews;

(E) an independent, non-advocate cost estimate is developed in parallel with engineering of the software, and is based on an investment-focused alternative to current estimation models, which is not based on source lines of code;

(F) the performance of fielded versions of the software capabilities are demonstrated and evaluated in an operational environment; and

(G) software performance metrics addressing issues such as deployment rate and speed of delivery, response rate such as the speed of recovery from outages and cybersecurity vulnerabilities, and assessment and estimation of the size and complexity of software development effort are established that can be automatically generated on a [monthly, weekly, continuous] basis and made available throughout the Department of Defense and the congressional defense committees.

(5) ADMINISTRATION OF ACQUISITION PATHWAY.—The guidance for the acquisitions conducted under the authority of this section may provide for the use of any of the following streamlined procedures in appropriate circumstances:

(A) The service acquisition executive of the military department concerned shall appoint a project manager for such acquisition from among candidates from among civilian employees or members of the Armed Forces who have significant and relevant experience in modern software methods.

(B) The project manager for each large software acquisition as designated by the service acquisition executive shall report with respect to such acquisition directly, and without intervening review or approval, to the service acquisition executive of the military department concerned.

(C) The service acquisition executive of the military department concerned shall evaluate the job performance of such manager on an annual basis. In conducting an evaluation under this paragraph, a service acquisition executive shall consider the extent to which the manager has achieved the objectives of the acquisition for which the manager is responsible, including quality, timeliness, and cost objectives.

(D) The project manager shall be authorized staff positions for a technical staff, including experts in software engineering to enable the manager to manage the acquisition without the technical assistance of another organizational unit of an agency to the maximum extent practicable.

(E) The project manager shall be authorized, in coordination with the users of the equipment and capability to be acquired and the test community, to make trade-offs among life-cycle costs, requirements, and schedules to meet the goals of the acquisition.

(F) The service acquisition executive or the defense acquisition executive in cases of defense wide efforts, shall serve as the decision authority for the acquisition.

(G) The project manager of a defense streamlined acquisition shall be provided a process to expeditiously seek a waiver from Congress from any statutory or regulatory requirement that the project manager determines adds little or no value to the management of the acquisition.

(6) OTHER FLEXIBLE ACQUISITION METHODS. – The flexibilities provided for software acquisition pathways under this section do not preclude the use of acquisition flexibilities otherwise available for the acquisition of software. The Department may use other transactions authority, broad agency announcements, general solicitation competitive procedures authority under section 879 of the National Defense Authorization Act for Fiscal Year 2017, the challenge program authorized by section 2359b of title 10, United States Code, and other authorized procedures for the acquisition of software, as appropriate. Such authorities may be used either in lieu of or in conjunction with the authorities provided in this section.

(d) FUNDING MECHANISMS. --

(1) SOFTWARE FUND.—

(A) IN GENERAL.—The Secretary of Defense shall establish a fund to be known as the [‘‘Department of Defense Rapid Development of Effective Software Fund’’] to provide funds, in addition to other funds that may be available for acquisition under the rapid software development pathways established pursuant to this section. The Fund shall be managed by a senior official of the Department of Defense designated by the [Under Secretary of Defense for Acquisition and Sustainment]. The Fund shall consist of amounts appropriated to the Fund and amounts credited to the Fund pursuant to section [???] of this Act.

(B) TRANSFER AUTHORITY.—Amounts available in the Fund may be transferred to a military department for the purpose of starting an acquisition under the software acquisition pathway established pursuant to this section. These funds will be used to fund the first year of the software acquisition and provide the Department an opportunity to field software capabilities that address newly discovered needs. A decision to continue the acquisition on other funds will be made based upon the progress demonstrated after the first year. Any amount so transferred shall be credited to the account to which it is transferred. The transfer authority provided in this subsection is in addition to any other transfer authority available to the Department of Defense.

(C) CONGRESSIONAL NOTICE.—The senior official designated to manage the Fund shall notify the congressional defense committees of all transfers under paragraph (2). Each notification shall specify the amount transferred, the purpose of the transfer, and the total projected cost and funding based on the effort required each year to sustain the capability to which the funds were transferred. The senior official will also notify the congressional defense committees at the end of the one-year timeframe and report on the fielded capabilities that were achieved. A notice under this paragraph shall be sufficient to fulfill any requirement to provide notification to Congress for a new start.

(2) PILOT PROGRAM. The Secretary may conduct a pilot program under which funding is appropriated in a single two-year appropriation for lifecycle management of software-intensive and infrastructure technology capabilities conducted under the authority of this section. The objective of the appropriation software pilot program would be to provide 1) greater focus on managed services versus disaggregated development efforts, 2) additional accountability and transparency for information centric and enabling technology capabilities, and 3) flexibility to pursue the most effective solution available at the time of acquisition; 4) much greater insight into the nature of software expenditures across the DOD enterprise; 5) an improved ability to measure costs and program performance;

Appendix C: An Alternative to P-Docs and R-Docs: How to Track Software Programs

Background. The DoD's Planning, Programming, and Budgeting System (PPBS) establishes the basis for the budget submission to Congress. Multiple statues, instructions and directives must be addressed in order to change the way the budget is put together, adjudicated, enacted and managed. Exhibits are prepared by OSD and the DoD Components to support requests for appropriations from Congress and help justify the President's budget. These include a number of forms that are aligned with the existing appropriations process:

- P-Form: Procurement
- R-Form: Research, Development, Test, and Evaluation (RDT&E)
- O-Form: Operations and Maintenance
- M-Form: Military Personnel
- C-Form: Military Construction

As described by the Section 809 panel, the competing objectives of the acquisition system make it very difficult for Congress and the Department to effectively budget and manage defense projects, as illustrated in the following diagram (from the Section 809 panel, Volume 3):

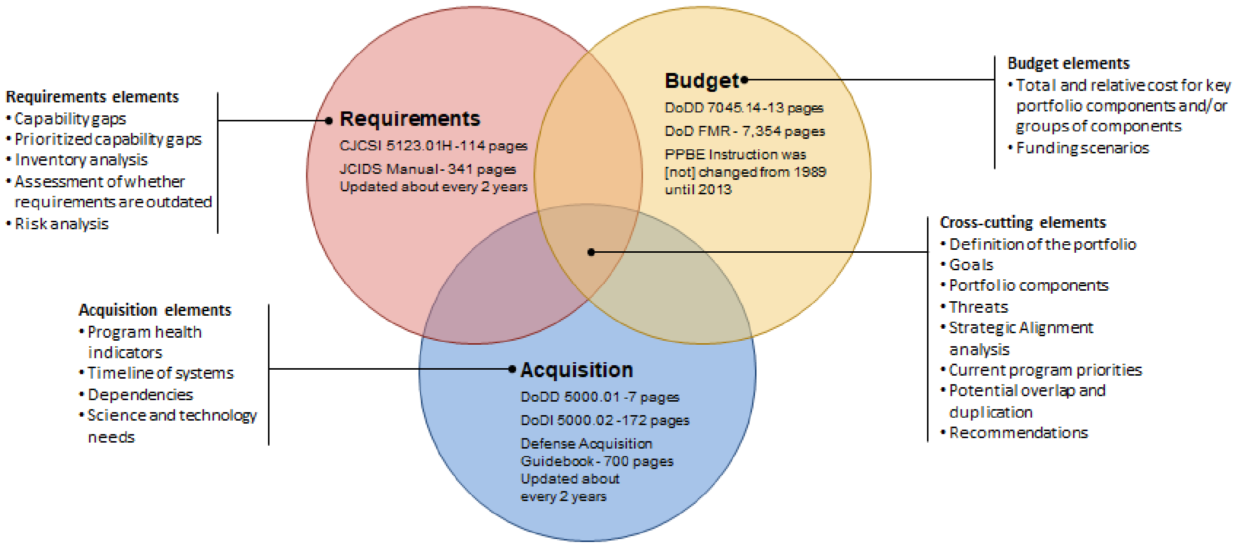


Figure C.1. Multi-Layered DoD Budget Environment

In this appendix, we describe a different type of mechanism for budget management for software programs, one that is tuned to the nature of software development. We envision this design to reflect and be interweaved with our primary recommendations—in particular A1 (new acquisition pathway for software) and A2 (new appropriations category for software). It could be also be used for software programs that are making use of other pathways (e.g., traditional DoD 5000.02, mid-tier [Sec 804] acquisition, other transaction authority [OTA] based pathways, or operations and maintenance [O&M]).

Key Characteristics. It is useful to list some of the properties that the new process should satisfy before presenting a specific approach for new methods of managing the budget for software programs. The characteristics that we believe are most important are that the process be:

- *Iterative*: In proposing a new approach for approval and oversight of software programs, we envision a process very similar to the way that software itself is developed: Congress and DoD should articulate what their needs are for oversight and approval of software programs, then try out different ways to gain transparency in proposing and monitoring of software programs. Oversight processes can evolve iteratively, ultimately achieving better oversight

- *Efficient:* The current budget process requires the separate creation of standalone forms and documents that are not a part of the regular information that is maintained and tracked as part of the planning and execution of the software program. Instead, we emphasize the use of automated and machine-readable budget information that is interoperable with financial management tools (with translation to human-readable form when useful).

- *Insightful.* The process should provide insights to both DoD and Congress about the planned and current capabilities of the program and opportunities for portfolio optimization. This includes making use of metrics that are appropriate for software (cycle time, rollback time, automated test coverage, etc.), extracting those metrics in an automated fashion wherever possible, and treating software as an enduring capability.

- *Electronic.* Consistent with the nature of software and software development, the budget artifacts used by Congress and DoD should be largely electronic in nature. By “electronic” we do not mean electronic forms that are “printable” (e.g., PDF and word files), but rather information that is available in electronic form and requires no further processing to be ingested into analysis systems.

Budget Information for Ongoing Software Programs. Since software is never done, the most important budget artifacts will be those for ongoing programs. The information that is required depends on the type of software, so we briefly describe here our advice for what information should be most relevant in evaluating and renewing the budget of an ongoing program.

- *Type A (commercial off-the-shelf apps):* By its nature, ongoing expenses for COTS apps will be based on the commercial price of the software or service. Existing mechanisms for budgeting materials, supplies, and consumables for DoD functions should be used: usage, spend rate, attainment of (volume) price discounts, etc. It is also important to track resources (money and people) needed to perform upgrades made mandatory by vendor version updates and obsolescence.

- *Type B (customized software)* and *Type C (COTS hardware/operating system):* These classes of software represents custom software that is developed, assured, deployed, and maintained by either organic developers or a contractor/vendor for DoD-specific purposes. Type B software will require primarily configuration management and customization, whereas Type C software will involve customized coding. These types of software are perhaps the least well-suited to the traditional spiral development/hardware-focused acquisition and budgeting process, since they often represent an enduring capability in which new features are continuously added.

The diagram below shows the expected cost profile of a software program of this type, in which the annual cost starts small (and may terminate, if not successful), rises as the software is scaled to its full extent, and then falls as it is optimized and continuously improved.

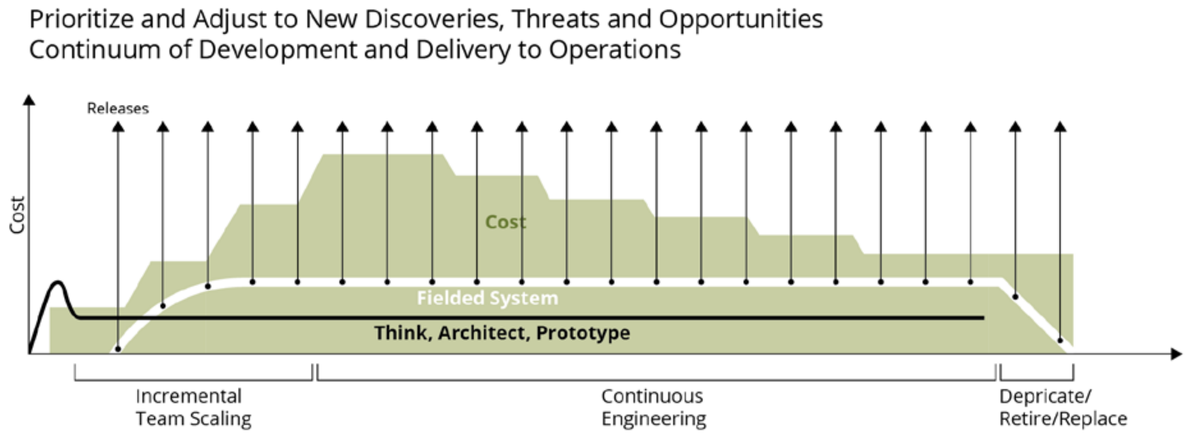


Figure C.2: DevSecOps Life Cycle Cost Profile

The information available as part of the budget process should reflect the following data on the current and desired state of the program:

- List of features implemented and those planned for future releases
- Number of active users and level of satisfaction of the user base
- Time required to field high priority functions (specifications → operations) or fix newly found security holes (discovery → operations)
- Time from code committed to code in use
- Time required for full regression test and cybersecurity audit/penetration testing (and the percentage of such testing that is automated)
- Time required to restore service after outage
- Percentage test coverage of specs / code, including percentage of tests that are automated
- Number of bugs caught in testing versus in field use
- Change failure rate (rollback deployed code)
- Percentage code available to DoD for inspection/rebuild

The cost data associated with the program should include the following information:

- The size and annual cost of the development team, along with the percentage of programmers, designers, user interface engineers, system architects and other key development categories.
- The size and annual cost of the program management team, including both government and contractor program management (if applicable).

- Software licensing fees
- Computing costs (including cloud services)
- Other costs associated with the program

These metrics should be tracked over time, with reports of the past three years of data as well as targets for the coming two years. Annual budget submissions should compare the projected metrics and costs of the program from the past fiscal year with the actual metrics and costs for that period, as well as rolling updating the time horizons to drop the oldest year of tracking data and add the newest year of projected data.

- *Type D (custom hardware and software, including embedded systems):* Embedded systems associated with custom hardware that is still in the development phase is most likely to be reported as part of the hardware development program (using traditional budget items). However, once the software/hardware platform and form factor has been designed then the continued development of the software should be reported in a manner similar to Type C (COTS hardware/operating systems).

Budget Information for New Software Programs. Creating new software programs involves estimation of the cost of the software over at least the initial procurement and deployment phases. Such programs should start small, be iterative, and build on success—or be terminated quickly. Whenever possible, new software programs should have small budgets, require early demonstration of results, and then be turned into ongoing programs (with budget justification as described above). We remark briefly on specific considerations based on the type of software.

- *Type A (commercial off-the-shelf apps)* and *Type B (customized software).* For commercial software of these two types, the most relevant information is the features to be provided by the software, the number of instances of the software expected over time, and the cost of that software (either as purchase cost or licensing costs). For Type B software, additional information should be provided regarding the staffing needs for software configuration, in a manner that is similar to customized software (Type C), though with less intensive development costs.

- *Type C (COTS hardware/operating system).* For custom software running on commodity hardware and operating systems, there are two primary questions that must be addressed: (a) is the software functionality available in commercial products that meets the (primary) needs of the Department and, if not, (b) how large should the initial development effort be in order to create a minimum viable product (MVP) and then begin to scale the initial deployment if successful.

  For comparing customized software to commercially available software, the following information should be provided:

  - A list of features that are desired and an indication of which of those features are available in commercial packages versus those that are DoD-specific.
  - A list of commercial software packages providing similar functionality and the cost of purchasing or licensing that software for initial and full-scale deployment.

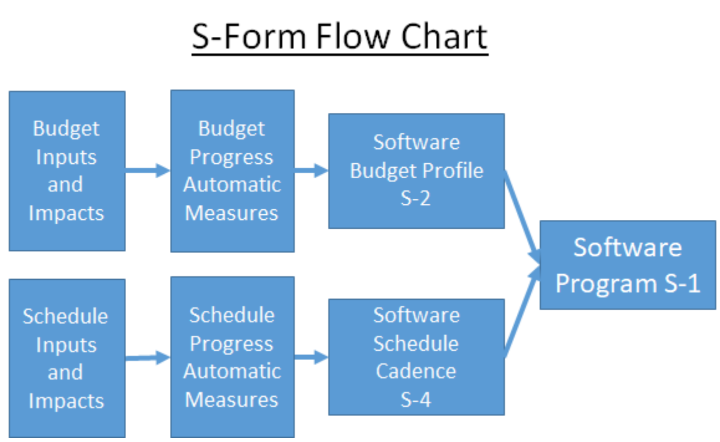
   ○ A justification for why DoD processes cannot be adopted to the development and operations practices of standard commercial approaches and/or why a smaller software development program focused on interfacing DoD specific cases to commercial packages cannot be accomplished.

  The goal of providing this information is to ensure that commercial processes/software can be adopted and implemented as standard business practices within DoD. If a DoD-customized software is needed, this information also serves as a good comparison point on the rough costs that are available for related commercial software (when it exists).

- *Type D (custom hardware and software, including embedded systems):* The initial phases of development for custom hardware and software are likely to track hardware development, although in some cases it may be possible to begin software development using emulation and simulation. Care should be taken that embedded software truly requires custom solutions: the trend in commercial software is to establish a layer between hardware and software that allows software to be hardware agnostic (converting Type D into to Type C). This approach is quite prevalent in consumer electronics (smart phones) and transportation systems (automobiles, aircraft).

Software Program Budget Exhibits. Since software programs will be integrated into larger programs and elements of larger programs will have software component, it will be necessary to provide budget exhibits that are compatible with other budget processes used by Congress and DoD. As described above, we believe that the primary information used for tracking ongoing programs should be electronic in nature, and that it should be pulled from existing databases and systems rather than compiled specifically for the budget process.

Following the format used by R-docs, we believe that software programs budget exhibit can broken down into 5 levels, as shown in the diagram to the right. Each of the exhibits should reflect the information described above (depending on the type of software program) and should exist primarily as electronic databases whose information can be presented in a form consistent with the information that Congress desires.



The individual exhibits are as follows:

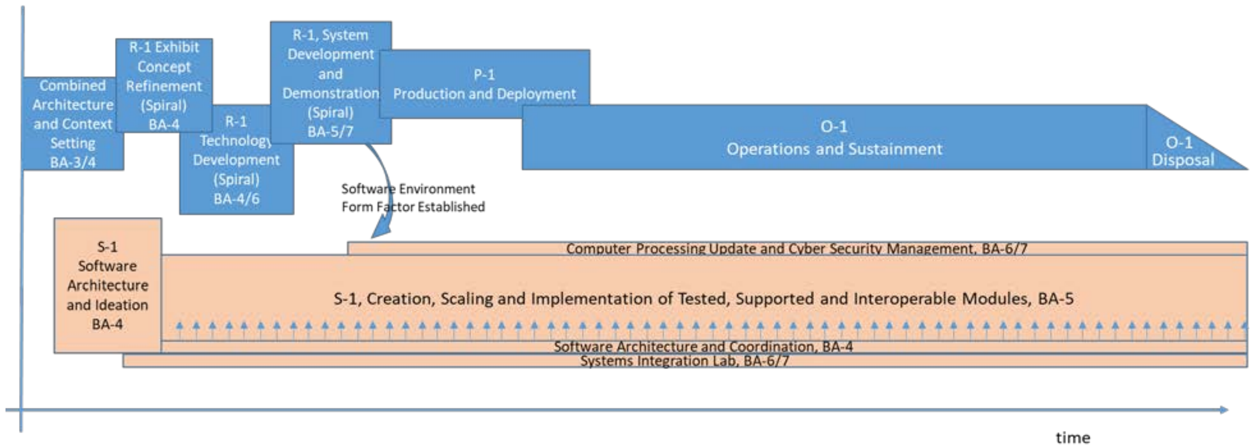
- S-1 Exhibits: the basic document for presenting DoD's software program information. The S-1 is prepared at the OSD-level, with one exhibit for each separate software appropriation account/portfolio. Because the S-1 is a summary document, all other software exhibits submitted for a program element must reconcile to the numbers shown on the S-1. The S-1 form should be automatically generated from information maintained by the Component headquarters based on information provided (electronically) be individual software program elements.

- S-2 Exhibits: feeds into the S-1 and are automatically populated to provide summary funding information, program description, metrics, and budget justification for each software program element.

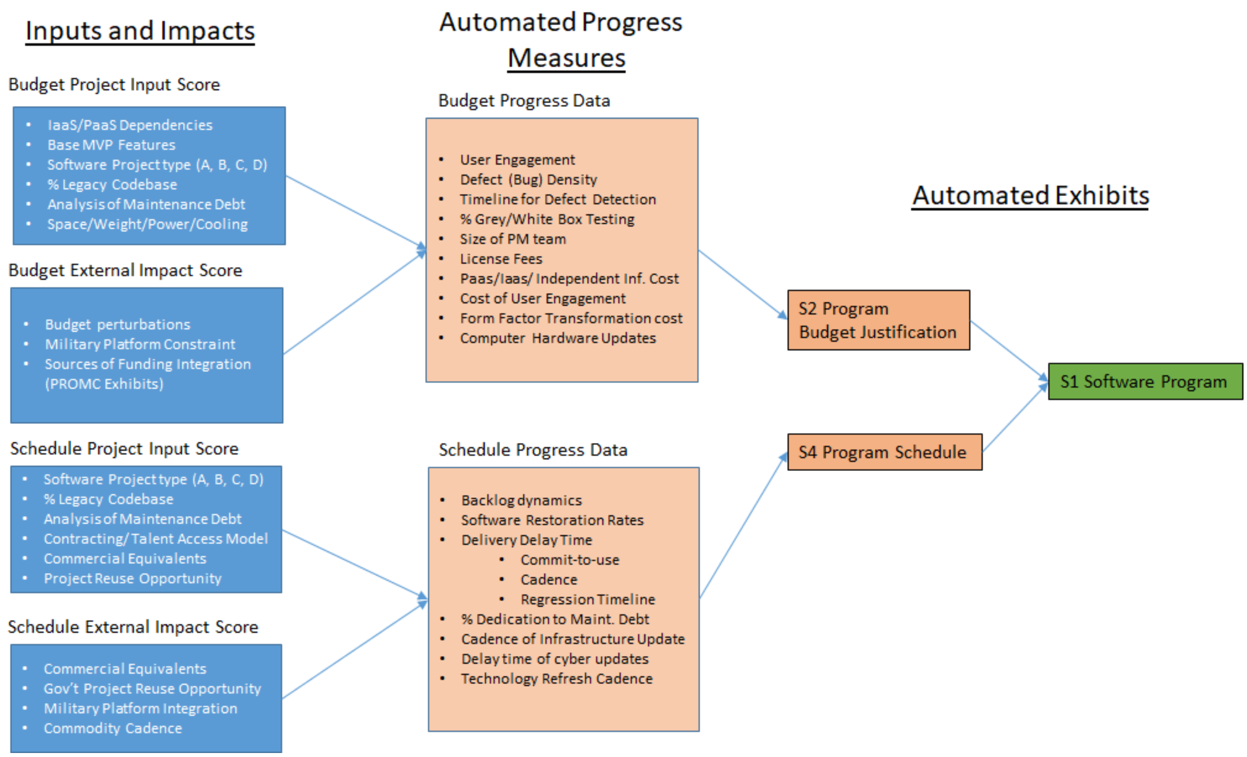
- S-4 Exhibits: generate a display of major program releases. This exhibit is required for each project. If a program element consists of only one project, then the S-4 is prepared for the entire program element.

Multi-Element Program Budgets. For the purpose of establishing a new funding authority that will address the continuous improvement nature of software, a coordinated set of budget exhibits must be put in place. Capability elements that are solely software are relatively rare. The hardware platform that the software must run on will either be provided by a different program under a platform-as-a-service (PaaS), or involve computing hardware that is necessarily coincident to a military vehicle (carried in a ship, aircraft, ground or space). When physical space, power, weight and cooling needs for the computer services have to be managed at the vehicle level, a coordination of the design and implementation of the hardware/software environment must be established and managed over a long period – several epochs of lifespans for computer equipment on which the continuously changing software must run. This is a fundamentally different environment than hardware and must be accommodated in a new software budget exhibit, at the right time of development, while managing within the appropriate form-factor.

Fortunately, the PPBS environment has a mechanism for managing this – the multi-Program Element Project. The coordination of research (R-Doc), Procurement (P-Doc) and Operations (O-Doc) with software program information (electronically generated S-Doc) can be accommodated in a single project or set of projects in the PPBS. The most limiting case is the one that requires the greatest level of coordination in software-intensive and embedded products. The figure below shows a parallel timeline for the ideation, creation, scaling and implementation phases of software with the spiral nature of hardware for research, engineering/manufacturing development, procurement, operations, sustainment and disposal.



Sample Budget Exhibits. To illustrate the type of information that could be presented to Congress as part of the budgeting process, we provide below a sample of some "S-docs" that might be used to describe a hypothetical software program. For the purposes of illustration, we focus here on a Type C (custom software on commercial hardware/operating system). Other types of software could make use of similar exhibits. We again emphasize that the desired state is that these documents are automatically populated based on electronic databases used within program offices and maintained as part of ongoing development activities.



Appendix D: Frequently Asked Questions (FAQ)

This document captures some of the common questions and comments that we have received as we discussed the report with various groups.

1. **Haven't all of these ideas already been recommended in previous studies? Why is this study/report any different?**

   Yes, the vision for how to do software right has existed for decades and most of the best practices that we and others have recommended are common practice in industry today. Chapter 3 (Been There, ~~Done~~ Said That) summarizes previous work and provides our assessment of why things haven't changed. Here are the parts we think are new and different:

   - The recommendations in this report serve primarily as documentation of a sequence of iterative conversations and the real work of the report is the engagements before and after the report is released.

   - Our engagements in the process, and the iterative ways we have worked on this study (just like good software!) have created a willing group of advocates (inside the Department) ready to move forward. If we permit them, we believe change will occur.

   - We focus on speed and cycle time as the key drivers for what needs to change and recommend optimizing statutes, regulations, and processes to allow management and oversight of speed at scale. This won't fix everything, but if you optimize for speed then many other things will improve as well (including oversight).

   - This report is shorter and pithier than previous reports, so we hope people will read it.

2. **Shouldn't Congress just get out of the way and let DoD run things the way they want?**

   This is not the way that the Constitution works. The Legislative branch is an equal branch of government and has a responsibility to see that the Executive branch performs its duties well and properly uses taxpayer resources. This makes implementation of many of the ideas in this report a challenge, but we believe that oversight of software is actually *easier* than oversight of hardware, and Congress can and should take advantage of the insights provided by optimizing speed and cycle time to perform oversight of defense software.

3. **Military software is different than commercial software since lives and national security are at stake, so we can't just do things like they do in industry.**

   Not all (defense) software is the same. Some software requires different consideration in DoD compared with industry, but some software is very much equivalent. Foreign governments perform espionage against U.S. companies and those companies should be protecting themselves in the same way as the U.S. government should (and in many cases, companies are doing better at protecting their code than the government, in our experience).

And even for those types of software that are very different from what we would find in the commercial world, the broad themes of modern software development are the same: software is never done, speed and cycle time are critical measures, software is by people and for people, and software is different from hardware. In all cases we believe that the acquisition of software must recognize these broad themes to take advantage of the opportunities provided by modern software development practices.

While certainly agreeing that the role of military is different, there are many areas of the private sector in which health, economic well-being, and life safety are critically dependent on software - aircraft, hospitals, traffic management, etc.

4. **Embedded software (in weapons systems) is different than commercial software since it is closely tied to hardware, so we can't just do things like they do in industry.**

   Not all software is the same, and embedded systems have different requirements for testing and verification that may not be present in other types of systems. The broad themes of modern software development also hold for embedded systems: software is never done, speed and cycle time are critical measures, software is by people and for people, and software is different from hardware. The issue of cycle time is the one that usually raises the most concern, but we note that embedded software can also have bugs and vulnerabilities and figuring out how to deploy patches and updates quickly is a valuable feature (think about hardware-coupled features in a smartphone or a Tesla as examples of where this is already being done in industry).

5. **For military systems, training is an essential element and we can't change the software quickly because we can't retrain people to use the new version.**

   Not all software is the same and many types of software have functions that are not directly evident to the user. Indeed, there are some types of software where you might want to update things more slowly to avoid creating confusion for a human operating under stress and having to rely on their training to avoid doing something wrong. For those systems, it will be important to figure out how to couple software updates with training so that warfighters have access to the latest version of the software that provides the functionality and security required to carry out their mission. It is also important to continuously evolve our training regimes to take advantage of what may be increased flexibility and adaptability of "digital natives."

6. **Providing source code to the government is a non-starter for industry. How will they make money if they have to give the government their code?**

   It is critical that DoD have access to source code for purpose-build software: it is required in order to do security scans to identify and fix vulnerabilities, and only with access to the source code and build environment can the government maintain code over time. However, providing source code is different than handing over the rights to do anything they want with that code. Modern intellectual property (IP) language should be used to ensure that the government can use, scan, rebuild, and extend purpose-built code, but contractors should be able to use licensing agreements that protect any IP that they have developed with their own resources.

8. **Won't Congress simply reject modern continuous, incremental software programs believing that "software is never done" is just an open invitation to make programs last forever?**

   "Software is never done" specifically highlights that certain capabilities will be enduring, e.g., the DoD will always need the capability to ingest data from overhead assets, process that data, and disseminate it and the information it contains. In this situation sensors will change, new analyses will be developed and new products will be required by decision makers. In the traditional DoD software world, a highly defined requirement would be defined, a program would be launched and years later a (likely) out-of-date capability would be delivered, followed immediately by a new, large scale, highly definable requirement, blah, blah, blah. In a world where this need will endure, a continuously funded, incrementally managed software program works better. We must be comfortable that we will spend a certain amount of money each year, we let the program use modern tools for delivering value to real end users incrementally, and we measure success by real-time metrics delivered by the development infrastructure and through direct feedback from the user community. This is the best way to provide Congress with the oversight it deserves.

9. **Have you read a P-form and an R-form?**

   We have! To us, these do not seem to be able to provide the type of insight into a software (or software-intensive) program that would be required to make a sound judgement about whether a program is in trouble. In addition, they appear to require substantial manual effort to generate and that effort has relatively little added value, they are missing key metrics that are important to understand whether a software program is on track (speed, cycle time, bugs found in test versus in the field, etc), and the information they contain is updated to infrequently.

   In Appendix C of our report we describe a different type of mechanism for budget submissions for software programs, one that is tuned to the nature of software development. We believe that it is possible to implement a mechanism for managing software program that makes use of digitally generated information that is part of the ongoing data that are used in the software development process and that provides improved insight into how well that program is delivering value to the end user.

10. **Government will never hire software developers that are as good as industry.**

    While it is certainly true that the vast majority of the highest capability software developers are in the private sector, it is also true that we found extremely capable and dedicated people in the Department – just not nearly enough of them. Actions as consistently detailed in our study can help to address this gap. First, the government should continue to partner with industry and to make use of contractors as a mechanism for obtaining the talent that it needs to develop software that meets its needs. For those cases where it makes sense to use organic (government) software development, the government should make use of existing or new hiring authorities to offer salaries that are as competitive as possible. It is highly unlikely that these will match commercial salaries, but it will show that DoD values software development expertise and that it recognizes that this expertise is in high demand and short supply. On top of this, DoD should anticipate that they will not be able to attract software developers for their entire career. Instead, DoD should have a plan and a set of mechanisms that allow it to hire people for shorter periods of time (e.g., 2-4 years), a period which we believe individuals who are interested in serving their country will be willing to devote. Recommendation C4 (Recruiting (Transient) Digital Talent) provides some ideas for how this might be implemented.

11. What is the purpose of the use of commercial services guidance In the new acquisition pathway that you propose (Recommendation A1 and Appendix B)?

Commercial item procurement was established in 1994 by Congress as a way of encouraging new entrants into the industrial base. While the law was directed at Silicon Valley it also included the vast majority of other types of commercial products at the time — eventually to expand into a greater number of services. Procedures were established (under FAR Part 12) to exempt these types of fixed price contracts from a significant portion of defense-unique acquisition requirements. A preference was also established for the government to buy commercial products and solutions where they existed over defense unique solutions.

The rapid contracting mechanism in Appendix B would essentially treat all purchases through this mechanism as a commercial item covered under FAR Part 12 to limit DoD from applying unique accounting and oversight procedures applicable to traditional defense contracts. Defining these purchases as commercial item purchases triggers two things: (1) a purchasing preference and (2) relief from regulatory burdens, including government-unique contract clauses and data requirements. The purpose of this language is to ensure this favorable treatment for the alternative acquisition pathway without requiring the contractor to make any proof that is a "commercial" vendor.

12. Would the use of the proposed acquisition pathway (Recommendation A1) and/or proposed appropriation category (Recommendation A2) be required for all software programs?

No. We envision this as becoming the *preferred* pathway for software because it is optimized for software. However, traditional acquisition pathways would still be available.

Appendix E: DIB Guides for Software

As a mechanism for obtaining feedback as it carried out its work, the SWAP study wrote a sequence of short "concept papers" that provided a view on what software acquisition and practice should look like. These documents were released on the DIB web site (http://innovation.defense.gov/software) and discussed in DIB public meetings. Feedback from the DIB and other stakeholders was used to iterate on the concept papers. The current snapshot of these papers is provided in this appendix.

List of concept papers:

1. Ten Commandments of Software
2. Metrics for Software Development
3. Do's and Don'ts for Software
4. Detecting Agile BS
5. Is Your Development Environment Holding You Back?
6. Is Your Compute Environment Holding You Back?
7. Site Visit Observations and Recommendations
8. How To Justify Your Agile Budget

The copies of the concept papers in this appendix reflect versions in place as of the approval of this report. We anticipate updating and augmenting these reports as the study continues into the implementation phase. The most up-to-date versions of the concept papers can be found at http://innovation.defense.gove/software.

Defense Innovation Board
Ten Commandments of Software

Authors: Michael McQuade, Richard Murray, Milo Medin
Contributors: Bess Dopkeen, Jennifer Pahlka, Eric Schmidt, Raj Shah
Version 2.0, last modified 18 Mar 2019

Executive Summary

The Department of Defense (DoD) must be able to develop and deploy software as fast or faster than its adversaries are able to change tactics, building on commercially available tools and technologies. Recognizing that “software” can range from off-the-shelf, non-customized software to highly-specialized, embedded software running on custom hardware, it is critical that the right tools and methods be applied for each type. In this context we offer the following ten “commandments” of software acquisition for the DoD:

1. Make computing, storage, and bandwidth abundant to DoD developers and users.
2. All software procurement programs should start small, be iterative, and build on success – or be terminated quickly.
3. The acquisition process for software must support the full, iterative life-cycle of software.
4. Adopt a DevSecOps culture for software systems.
5. Automate testing of software to enable critical updates to be deployed in days to weeks, not months or years.
6. Every purpose-built DoD software system should include source code as a deliverable.
7. Every DoD system that includes software should have a local team of DoD software experts who are capable of modifying or extending the software through source code or API access.
8. Only run operating systems that are receiving (and utilizing) regular security updates for newly discovered security vulnerabilities.
9. Security should be a first-order consideration in design and deployment of software, and data should always be encrypted unless it is part of an active computation.
10. All data generated by DoD systems - in development and deployment - should be stored, mined, and made available for machine learning.

Motivation and Scope

The latest industry best practices for developing, fielding, and sustaining software applications and information technology (IT) systems are substantially outpacing the US government's industrial-era planning, programming, budgeting, and execution system (PPBES) methods. In the commercial software industry, there is no clear delineation between development, procurement, and sustainment; rather it is a continuous cycle that changes rapidly. New functionality is made available and deployed to users in months to weeks (and even days, for truly critical updates). Existing government appropriation structures make it difficult to implement this approach in the DoD.

Currently available commercial technology for rapidly deploying new advances in software, electronics, networking, and other areas means that our adversaries can rapidly develop new tactics that will be used against us. The only defense is to get inside our adversaries' observe, orient, decide and act (OODA) loop, which requires the ability to rapidly develop and deploy software into operational environments. For software that is used as part of operations, whether it is run in the Pentagon or in the field, this will require new methods for (automated) testing and rapid deployment of updates, patches, and new functionality.

In this document, we provide ten "commandments" (principles) for DoD software that provide an approach to development that builds on the lessons learned in the software industry and enables rapid deployment of software into military operations. These principles are not universal and may not apply in all situations, but they provide a framework for improving the use of software in DoD operations going forward that we believe will provide substantial improvements compared to the current state of practice.

Software Types

Not all software is alike and different types of software require different approaches for procurement and sustainment. It is important to avoid a "one size fits all" approach to weapons systems. Acquisition practices for hardware are almost never right for software: they are too slow, too expensive, and too focused on enterprise-wide uniformity instead of local customization. Similarly, the process for obtaining software to manage travel is different than what is required to manage the software on an F-35. We suggest a taxonomy with four types of software requiring four different approaches:

- A: commercial ("off-the-shelf") software with no DoD-specific customization required;
- B: commercial software with DoD-specific customization needed;
- C: custom software running on commodity hardware (in data centers or in the field);
- D: custom software running on custom hardware (e.g., embedded software).

While many of the principles below apply to all DoD software, some are relevant only for specific types, as we indicate at the end of each description.

To amplify at the extremes of this continuum of software types, we note especially the tendency of large organizations to believe their needs are unique when it comes to software of Type A. Business processes, financial, human resources, accounting and other “enterprise” applications in DoD are generally not more complicated nor significantly larger in scale than those in the private sector. Commercial software, unmodified, can be deployed in nearly all circumstances. At the opposite end of the spectrum we recognize the highly coupled nature of real-time, mission critical, embedded software with its customized hardware, denoted in Type D. Examples here include primary avionics or engine control, or target tracking in shipboard radar systems, where requirements such as safety, target discrimination and fundamental timing considerations demand that extensive formal analysis, test, validation and verification activities be carried out.

The DIB’s Ten Commandments of Software

Commandment #1. Make computing, storage, and bandwidth abundant to DoD developers and users, especially in operational systems. Effective use of software requires that sufficient resources are available for computing, storage, and communications. The DoD should adopt a strategy for rapidly transitioning DoD IT to current industry standards such as cloud computing, distributed databases, ubiquitous access to modernized wireless systems (leveraging commercial standards), abundant computing power and bandwidth that is made available as a platform, integration of mobile technologies, and the development of a DoD platform for downloading applications. Unit cost of IT infrastructure and services should be used as a metric in track improvements. An important metric of abundance must be the ability to actually deliver code, and DoD must be able to count the number of programmers within an organization and make sure that the balance of coders to managers is correct [All types]

Commandment #2. All software procurement programs should start small, be iterative, and build on success – or be terminated quickly. Good software development provides value to the customer quickly, based on working with users starting on day one and defining success based on customer value, not creation of code. Large software programs are doomed to fail because of the rigidity, process, competition protests, and bureaucracy that accompany them (typically starting with the Joint Capabilities Integration Development System (JCIDS) process). The separation of software development into research, development, test and evaluation (RDT&E), procurement, and operations & maintenance (O&M) appropriations (colors of money) – and the use of cost-based triggers within each acquisition category (ACAT) – causes delays and places artificial limitations on the program management office’s (PMO’s) ability to quickly meet the changing needs, resulting in increased lifetime cost of software and slower deployment. Modern (“agile”) approaches used in commercial software development will result in faster deployment *and* significant cost savings. [All types, especially B and C]

Commandment #3. The acquisition process for software must support the full, iterative life-cycle of software. Software does not age well. It must be constantly maintained and updated, ideally in an automated fashion. The PPBES process is nominally a two (2) year timeline to request and receive funding, with initial planning occurring five (5) years prior to actual receipt, and funding must be requested by intent of use (RDT&E, procurement, and

O&M). But this fiscal separation does not match the process of software development, where all creation of code is "development", whether it falls within the fiscal law definition or not. As an alternative, the DoD should make use of "level of effort" (or capacity) constructs to allow continuous development and testing. Assume that low criticality software that is routinely used will require 10% of the development cost to maintain (per year) and more critical software will likely require more resources. This funding must be planned for at the time of initial development, not as an annual allocation that could be interrupted. Enhanced software capability should never be considered "ahead of need". [All types]

Commandment #4. Adopt a DevSecOps culture for software systems. "DevOps" represents the integration of software development and software operations, along with the tools and culture that support rapid prototyping and deployment, early engagement with the end user, automation and monitoring of software, and psychological safety (e.g., blameless reviews). "DevSecOps" adds the integration of security at all stages of development and deployment, which is essential for DoD applications. These techniques should be adopted by the DoD, with appropriate tuning of approaches used by the agile/DevSecOps community for mission-critical, national security applications. Open source software should be used when possible to speed development and deployment, and leverage the work of others. Waterfall development approaches (e.g. DOD-STD-2167A) should be banned and replaced with true, commercial agile processes. Thinking of software "procurement" and "sustainment" separately is also a problem: software is never "finished" but must be constantly updated to maintain capability, address ongoing security issues and potentially add or increase performance (see Commandment #3). [Type C; Type D when tied to iterative hardware development and deployment methodologies]

Commandment #5. Automate configuration, testing, and deployment of software to enable critical updates to be deployed in days to weeks, not months or years. While operational test and evaluation (OT&E) is useful, it must not be the pacing item for deployment of software, especially upgrades to existing software. Automated configuration management, unit testing, software/hardware-in-the-loop (SIL/HIL) testing, continuous integration, A/B testing, usage and issues tracking, and other modern tools of software development should be used to provide high confidence in software correctness and enable rapid, push deployment of patches, upgrades, and apps. Make use of modern software development tool sets that support these processes (and other types of development stack automation and software instrumentation) to enable code optimization and refactoring. [All types]

Commandment #6. Every purpose-built DoD software system should include source code as a deliverable. DoD should have the rights to and be able to modify (DoD-specific) code when new conditions and features arise. Providing source code will also allow the DoD to perform detailed (and automated) evaluation of software correctness, security, and performance, enabling more rapid deployment of both initial software releases and (most importantly) upgrades (patches and enhancements). [Types C, D]

Commandment #7. Every DoD system that includes software should have a local team of DoD software experts who are able to modify or extend the software through source

code or API access. Modern weapons systems are software-driven and utilization of those systems in a rapidly changing environment will require that the system (software) be customizable by the user. In order to do this, all fielded DoD systems that include software must also have a local team (responsible to the operational unit) that has the skills and permission to modify and extend the software through either source code (Commandment #6) or application programming interface (API) access. Local experts should have "reachback" capabilities to larger team and the ability to pull new features into their code (and generate pull requests for features that they add which should go back into the main codebase [repository]). [Types B, C, sometimes D]

Commandment #8. Only run modern operating systems that are receiving (and utilizing) regular security updates for newly discovered security vulnerabilities. Outdated operating systems are a major vulnerability and the DoD should assume that any computer running such a system will eventually be compromised. Standard practice in industry is that security patches should be applied within 48 hours of release, though this is probably too big a window for defense systems. Treat software vulnerabilities like perimeter defense vulnerabilities: if there is a hole in your perimeter and people are getting in, you need to patch the hole quickly and effectively. [Types A, B, C]

Commandment #9. Security should be a first-order consideration in design and deployment of software, and data should always be encrypted unless it is part of an active computation. All data should be encrypted, whether in motion (across a network) or at rest (memory, disk, cloud, etc). A possible exception is real-time data that is part of an embedded control system and is being sent across an internal bus/network that is not accessible from outside that network. [Types A, B, C and D when possible]

Commandment #10. All data generated by DoD systems – in development and operations – should be stored, mined, and made available for machine learning. Create a new architecture to collect, share, and analyze data that can be mined for patterns that humans cannot perceive. Utilize data to enable better decision-making in all facets of the Department, providing significant advantages that adversaries cannot anticipate. Forge culture of data collection/analysis to meet the demands of a software-centric combat environment. Such data collection and analysis can be done without compromising security: in fact, a comprehensive understanding of the data the DoD collects can improve security. [All types]

Supporting Thoughts and Recommendations

In addition to the ten principles given above, we offer the following thoughts and recommendations for how the DoD can best take advantage of software as a force multiplier. While not directly related to software, they are enablers for adopting the principles required for rapid development and deployment of software.

Establish Computer Science as a DoD core competency. Do not rely solely on contractors as the only source of coding capability for DoD systems. Instead, the DoD should recruit, train, and retain internal capability for software development, including by service members, and maintain this as a separate career track (like DoD doctors, lawyers, and musicians). This should complement work done by civilians and contractors. Create new and expand existing programs to attract promising civilian and military science, technology, engineering and math (STEM) talent. Reach into new demographic pools of people who are interested in the work DoD does but otherwise would not be aware of DoD opportunities. Be able to count the number of programmers within an organization and make sure that the balance of developers to managers is correct

Use commercial process and software to adopt and implement standard business practices within the services. Modern enterprise-scale software has been optimized to allow business to operate efficiently. The DoD should take advantage of these systems by adopting its internal (non-warfighter specific) business processes to match industry standards, which are implemented in cost-efficient, user-friendly software and software as a service [SaaS] tools. Rather than adopt a single approach across the entire DoD, the individual services should be allowed to implement complementary approaches (with appropriate interoperability).

Move to a model of continuous hardware refresh in which computers are treated as a consumable with a 2-3 year lifetime. The current approach — in which technology refreshes take 8-10 years from planning to implementation — means that most of the time our systems are running on obsolete hardware that limits our ability to implement the algorithms required to provide the level of performance required to stay ahead of our adversaries. Moving to the cloud provides a solution to this issue for enterprise and other software systems that do not operate on local or specialized hardware. However for weapons systems, a continuous hardware refresh mentality would enable software upgrades, crypto updates, and connectivity upgrades to be rapidly deployed across a fleet, rather than maintaining legacy code for different variants that have hardware capabilities ranging from 2 to 12 years old (an almost impossibly large spread of capability in computing, storage, and communications). From a contracting perspective, this change would require DoD to provide a stable annual budget that paid for new hardware and software capability (see Commandment #3), but this would very likely save money over the longer term.

Defense Innovation Board
Metrics for Software Development

Version 1.1, last modified 18 Mar 2019

Software is increasingly critical to the mission of the Department of Defense (DoD), but DoD software is plagued by poor quality and slow delivery. The current state of practice within DoD is that software complexity is often estimated based on number of source lines of code (SLOC), and rate of progress is measured in terms of programmer productivity. While both of these quantities are easily measured, they are not necessarily predictive of cost, schedule, or performance. They are especially suspect as measurements of program success, defined broadly as delivering needed functionality and value to users. Measuring the health of software development activities within DoD programs using these obsolete metrics is irrelevant at best and, at worst, could be misleading. As an alternative, we believe the following measures are useful for DoD to track performance for software programs and drive improvement in cost, schedule, and performance.

#	Metric	Target value (by software type)[2]				Typical DoD values for SW
		COTS apps	Custom-ized SW	COTS HW/OS	Real-time HW/SW	
1	Time from program launch to deployment of simplest useful functionality	<1 mo	<3 mo	<6 mo	<1 yr	3-5 yrs
2	Time to field high priority fcn (spec → ops) or fix newly found security hole (find → ops)	N/A <1 wk	<1 mo <1 wk	<3 mo <1 wk	<3 mo <1 wk	1-5 yrs 1-18 m
3	Time from code committed to code in use	<1 wk	<1 hr	<1 da	<1 mo	1-18 m
4	Time req'd for full regression test (automat'd) and cybersecurity audit/penetration testing	N/A <1 mo	<1 da <1 mo	<1 da <1 mo	<1 wk <3 mo	2 yrs 2 yrs
5	Time required to restore service after outage	<1 hr	<6 hr	<1 day	N/A	?
6	Automated test coverage of specs / code	N/A	>90%	>90%	100%	?
7	Number of bugs caught in testing vs field use	N/A	>75%	>75%	>90%	?
8	Change failure rate (rollback deployed code)	<1%	<5%	<10%	<1%	?
9	% code avail to DoD for inspection/rebuild	N/A	100%	100%	100%	?
10	Number/percentage of functions implemented	80%	90%	70%	95%	100%

[2] Target values are notional; different types of software (SW) as defined in DIB Ten Commandments.

Acronyms defined: Commercial-Off-the-Shelf (COTS), apps is short for applications, specs is short for specifications, Hardware / Operating System (HW/OS), Hardware / Software (HW/SW)

<table>
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Supporting Information

The information below provides additional details and rationale for the proposed metrics. The different types of software considered in the document are described here in greater depth, followed by comments on the proposed metrics, grouped into four categories: (a) deployment rate metrics, (b) response rate metrics, (c) code quality metrics, and (d) program management, assessment and estimation metrics.

Software Types (from DIB Ten Commandments)

Not all software is alike, and different types of software require different approaches for development, deployment, and life-cycle management. It is important to avoid a “one size fits all” approach to weapons systems. Acquisition practices for hardware are almost never right for software: they are too slow, too expensive, and too focused on enterprise-wide uniformity instead of local customization. Similarly, the process for obtaining software to manage travel is different than what is required to manage the software on an F-35. We suggest a taxonomy with four types of software requiring four different approaches:

- A: commercial (“off-the-shelf”) software with no DoD-specific customization required;
- B: commercial software with DoD-specific customization needed;
- C: custom software running on commodity hardware (in data centers or in the field);
- D: custom software running on custom hardware (e.g. embedded software).

Type A (COTS apps): The first class of software consists of applications that are available from commercial suppliers. Business processes, financial management, human resources, accounting and other “enterprise” applications in DoD are generally not more complicated nor significantly larger in scale than those in the private sector. Unmodified commercial software should be deployed in nearly all circumstances. Where DoD processes are not amenable to this approach, those processes should be modified, not the software.

Type B (Customized SW): The second class of software constitutes those applications that consist of commercially available software that is customized for DoD-specific usage. Customizations can include the use of configuration files, parameter values, or scripted functions that are tailored for DoD missions. These applications will generally require configuration by DoD personnel, contractors, or vendors.

Type C (COTS HW/OS): The third class of software applications is those that are highly specialized for DoD operations but can run on commercial hardware and standard operating systems (e.g. Linux or Windows). These applications will generally be able to take advantage of commercial processes for software development and deployment, including the use of open source code and tools. This class of software includes applications that are written by DoD personnel as well as those that are developed by contractors.

Type D (Custom SW/HW): This class of software focuses on applications involving real-time, mission-critical, embedded software whose design is highly coupled to its customized hardware. Examples include primary avionics or engine control, or target tracking in shipboard radar systems. Requirements such as safety, target discrimination, and fundamental timing considerations demand that extensive formal analysis, test, validation, and verification activities be carried out in virtual and "iron bird" environments before deployment to active systems. These considerations also warrant care in the way application programming interfaces (APIs) are potentially presented to third parties.

Types of Software Metrics

Deployment Rate Metrics

Overview: Consistent with previous Defense Innovation Board (DIB) commentary, and software industry best practices, an organizational mentality that prioritizes speed is the ultimate determinant of success in delivering value to end users. An approach to software development that privileges speed over other factors drives efficient decision-making processes; forces the use of increased automation of development and deployment processes; encourages the use of code that is machine-generated as well as code that is correct-by-construction; relies heavily on automated unit and system level testing; and enables the iterative, deliver-value-now mentality of a modern software environment. Thus we list these metrics first.

#	Metric	Target value (by software type)				Typical DoD values for SW
		COTS apps	Custom ized SW	COTS HW/OS	Real-time HW/SW	
1	Time from program launch to deployment of simplest useful functionality	<1 mo	<3 mo	<6 mo	<1 yr	3-5 yrs
2	Time to field high priority fcn (spec → ops) or fix newly found security hole (find → ops)	N/A <1 wk	<1 mo <1 wk	<3 mo <1 wk	<3 mo <1 wk	1-5 yrs 1-18 m
3	Time from code committed to code in use	<1 wk	<1 hr	<1 da	<1 mo	1-18 m

Background: These measures capture the rate at which new functions and changes to a software application can be put into operation (in the field):

1. The time from program launch to deployment of the "simplest useful functionality" is an important metric because it determines the first point at which the code can start doing useful work and also at which feedback can be gathered that supports refinement of the features. There is a tendency in DoD to deliver code only once it has met all of the specifications, but this can lead to significant delays in providing useful code to the user. We instead advocate getting code in the hands of the user quickly, even if it only solves a subset of the full functionality. Something is better than nothing, and user feedback often reveals omissions in the specifications and can refine the initial requirements. As code becomes more customized, this interval of time might extend due to the need to run more complex tests to ensure that all configurations operate as expected, and that complex timing and other safety/mission-critical specifications are satisfied. It is important to note that this metric is not just about coding time. It also measures the time required to process and adjudicate the changes (including release approval), often the most time-consuming part of providing new or upgraded functionality.

2. Once the code is deployed, it is possible to measure the amount of time that it takes to make incremental changes that either implement new functions or fix issues that have been identified. The importance of the functionality or severity of the error will determine how quickly these changes should be made, but it should be possible to deploy high priority code updates much more quickly and in much smaller increments than typical DoD "block" upgrades. A similar measure to the time it takes to deploy code to the field is deployment frequency. Deployment frequency can be on-demand (multiple per day), once per hour, once per day, once per week, etc. Faster deployment frequency often correlates with smaller batch sizes.

3. The time from which code is committed to a repository until it is available for use in the field is referred to as "lead time," and good performance on this metric is a necessary condition for rapid evolution of delivered software functionality. Shorter product delivery times demand faster feedback, which enables tighter coupling to user needs. For commercially available applications, the lead time will be based on vendor deployment processes and may be slower than what is needed for customized code, be it for commercial hardware/operating systems or custom hardware. However, we believe that in the selection of commercial software, emphasis should be given to the vendor's iteration cycles and lead time performance. Embedded code will often require much more extensive testing before it is deployed, and therefore its lead time may be longer.

Response Rate Metrics

Overview: Our philosophy is that delivering a partial solution to the user quickly is almost always better than delivering a complete or perfect solution at the end of a contract, on the first attempt. Consistent with that, mistakes will occur. No software is bug-free, and so it is unrealistic and unnecessary to insist on that, except where certain safety matters are concerned.[3] Code that does most things right will still be useful while a patch is being identified

[3] The Department and its suppliers (due to the requirements of the contracts to which they are bound) often resort to blanket pronouncements about safety and security, which often lead to applying the most extreme measures even when not needed; this risk-averse approach to treating everything as a grave

and fielded. How gracefully software fails, how many errors are caught and resolved in testing, and how rapidly developers patch bugs are excellent measures of software development prowess.

#	Metric	Target value (by software type)				Typical DoD values for SW
		COTS apps	Customized SW	COTS HW/OS	Real-time HW/SW	
4	Time required for full regression test (automated) and cybersecurity audit/penetration testing[4]	N/A <1 mo	<1 da <1 mo	<1 da <1 mo	<1 wk <3 mo	2 yrs 2 yrs
5	Time required to restore service after outage	<1 hr	<6 hr	<1 day	N/A[5]	?

Background: These two metrics are intended for "generic" software programs with moderate complexity and criticality. Their purpose is to:

4. Measure the ability to conduct more complete functional tests of the full software suite (e.g. regression tests) in a timely fashion, to identify problems in deployed software that can be quickly corrected, and to restore service after an incident such as an unplanned outage or service impairment, occurs (also called "mean time to repair," (MTR)).

5. Track the time required to resolve an interruption to service, including a bad deployment.

Code Quality Metrics

Overview: These metrics are intended to be used as a measure of the quality of the code and to focus on identifying errors in the code, either at the time of development (e.g. via unit tests) or in the field.

#	Metric	Target value (by software type)				Typical DoD values for SW
		COTS apps	Customized SW	COTS HW/OS	Real-time HW/SW	
6	Automated test coverage of specs / code	N/A	>90%	>90%	100%	?

risk to cyber security or safety has been labeled by the DIB as a "self-denial of service attack". While cybersecurity is clearly critical for software systems, the Department needs to rely on product managers who use judgment to make subtle, nuanced, and risk-based judgments about trade-offs during the software development process.

[4] The two different response rate metrics for different types of software reflect the level of complexity of the software, the likely resources available to identify and fix problems, and the level of integration of the hardware and software.

[5] We note that for embedded systems, which must be running at all times and which are updated much less frequently, the notion of "restoring" service is not directly applicable.

7	Number of bugs caught in testing vs field use	N/A	>75%	>75%	>90%	?
8	Change failure rate (rollback deployed code)	<1%	<5%	<10%	<1%	?
9	% code avail to DoD for inspection/rebuild	N/A	100%	100%	100%	0%

Background:

6. Automated developmental tests provide a means of ensuring that updates to the code do not break previous functionality and that new functionality works as expected. Ideally, for each function that is implemented, a set of automated tests will be constructed that cover both the specification for what the performance should achieve as well as the code that is used to implement that function.

7. The percentage of specifications tested by the automated test suite provides rapid confidence that a software change has not caused some specification to fail, as well as confidence that the software does what it is supposed to do. Test coverage of the code is a common metric for software test quality and one that most software development environments can compute automatically (e.g. in a continuous integration (CI) workflow, each commit and/or pull request to a repository would run all the automated developmental tests and compute the percentage covered). For customized software and applications that run on commercial hardware and operating systems, 90% unit test coverage is a good target. Embedded code should strive for 100% coverage (i.e., no “dark” code) since it is often safety- or mission-critical.[6] The focus of these metrics is on developmental tests, as operational testing is important, but expensive, so it is far less expensive to find and fix defects through developmental testing.

8. Developmental tests do not cover every conceivable situation in which an application might be used, so errors will be discovered in the field. The percent of bugs caught in testing (via unit tests or regression tests) versus those caught in the field provide a measure of the both the quality of the code and the thoroughness of the testing environment. Bugs discovered late in the development cycle or after deployment can “cost” an order of magnitude more than early bugs (in terms of time to fix and impact to a program), and a software system that is mature finds many more bugs during testing and few in the field. Late bugs are particularly expensive when fixing those bugs can require hardware changes, and so code running on custom hardware should be tested more strenuously. Bugs should be prioritized by severity and the trends over time for serious bugs should be monitored and used to drive changes in the test environment and software development process.

9. When bugs do occur, it may be necessary to roll back the deployed code and return to an earlier version. Change fail percentage is the percentage of changes to production that fail, including software releases and infrastructure changes. This should include changes that result in degraded service or subsequently require remediation, such as those that lead to service impairment or outage, or require a hotfix, rollback, fix-forward, or patch. For COTS applications, this should occur rarely because the amount of testing done by the vendor, including test deployments to beta users, will typically be very high. There may be a higher

[6] Safety- or mission-critical software often strives for more rigorous test coverage metrics, such as high branch coverage or in some cases high modified condition/decision coverage (MC/DC).

change failure rate as the application becomes more customized – because it can be difficult to test for issues where there is a variety of hardware configurations operating in the field, for example – but for embedded code, the change failure rate should be small, due to the more safety-critical nature of that code leading to more emphasis on up-front testing.

Functionality metrics

Overview: These metrics are intended to capture how useful the software program is in terms of delivering value to the field. We envision that a software program will have a number of desired features that define its functionality. Software should be instrumented so that the use of those features is measured and, when appropriate, users of the software should be monitored or surveyed to determine their use of/satisfaction with the software.

#	Metric	Target value (by software type)				Typical DoD values for SW
		COTS apps	Custom -ized SW	COTS HW/OS	Real-time HW/SW	
10	Number/percentage of functions implemented	80%	90%	70%	95%	100%
11	Usage and user satisfaction	TBD	TBD	TBD	TBD	?

Background:

10. An ongoing software program will have some number of functions that it performs and a list of additional functions that are to be added over time. These new functions could be feature requires from users or desired features generated by the program office that are on the list for consideration to be implemented next. Keeping track of these features and the rate at which they are implemented provides a measure of the delivery of functionality to the user. This specific way in which functionality is measured will be dependent on the type of software being developed.

11. For software that is used by a person, the ultimate metric is whether the software is helping that person get useful work done. Keeping track of the usage of the software (and different parts of the software) can be done by instrumenting the code and keeping track of the data it generates. To determine whether or not the software is providing good value to the person who is using it, surveying the user may be the most direct mechanism (similar to rating software that you use on a computer or smart phone).

Program Management, Assessment, and Estimation Metrics

Overview: The final set of metrics are intended for management of software programs, including cost assessment and performance estimation. These metrics describe a list of "features" (performance metrics, contract terms, project plans, activity descriptions) that should be required as part of future software projects to provide better tools for monitoring and predicting time, cost, and quality. In its public deliberations regarding software acquisition and practices, the DIB has described how metrics of this type might be used to estimate the cost, schedule, and performance of software programs.

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Background:

12. Structure of specifications, code, and development and execution platforms**.**

To measure the complexity of a software program, and therefore assess the cost, schedule and performance of that program, a number of features must be measured that capture the underlying “structure” of the application. The use of the term “structure” is intentionally flexible, but generally includes properties such as size, type, and layering. Examples of features that can be captured that related to underlying complexity include:

- *Structure of specifications:* Modern specification environments (e.g. application lifecycle management [ALM] tools) provide structured ways of representing specifications, from program level requirements to derived specifications for sub-systems, or individual teams. The structure represented in these tools can be used as a measure of the difficulty of the application that is being designed.

- *Level and type of user engagement during application development:* How much time do developers spend with users, especially early in the program? How many developers are “on site” (in the same organization and/or geographic location as the end user)?

- *Structure of the code base (software architecture):* Modern software development environments allow structured partitioning of the code into functions, libraries/frameworks, and services. The structure of this partitioning (number of modules, number of layers, and amount of coupling between modules and layers) can provide a measure of the complexity of the underlying code.

- *The amount of reuse of existing code, including open source code:* In many situations there are well-maintained code bases that can be used to quickly create and scale applications without rewriting software from scratch. These libraries and code frameworks are particularly useful when using commodity hardware and operating systems, since the packages will often be maintained and expanded by others, leveraging external effort.

- *Structure of the development platform/environment:* This includes the software development environments that are being used, the types of programming methodologies (e.g., XP, agile, waterfall, spiral) that are employed, and the level of maturity of the programming organization (ISO, CMMI, SPICE).

- *Structure of the execution platform/environment:* The execution environment can have an impact on the ability to emulate the execution environment within the development environment, as well as the portability of applications between different execution environments. Possible platforms include various cloud computing environments as well as platform-as-a-service (PaaS) environments that support multiple cloud computing vendors.

13. Structure and type of development and operational environment.

    To predict and monitor the level of effort required to implement and run a software application, measurement of the development and operation environments is critical. These measurements include the structure of those environments (e.g., waterfall versus spiral versus agile, use of continuous integration tools, integrated tools for issue tracking/resolution, code review mechanisms), the tempo of development and delivery, and use of the functionality provided by the application. Example of features that can be captured that relate to the structure and type of development and operation use:

    - Number and skill level of programmers on the development team
    - Number of development platforms used across the project
    - Number of subcontractors or outside vendors used for application components
    - Number and type of user operating environments (execution platforms) supported
    - Rate at which major functions (included in specifications) are delivered and updated
    - Rate at which the operational environment must be updated (e.g. hardware refresh rate)
    - Rate at which the mission environment changes (driving changes to the code)
    - Number (seats or sites) and skill level of the users of the software

14. Tracking software program progress

    To properly manage the continuous development and deployment of software, DoD should be able to track the metrics above with minimal additional effort from the programmers because this information should be gathered and transmitted automatically through the development, deployment, and execution environments, using automated tools. Some examples of the types of metrics that are readily available include commit activity data (number and rate of commits), team size, number of commenters (on pull requests), number of pull request mergers, average and standard deviation of the months in which there was development activity, average and standard deviation of the number of commits per month.

    Thresholds should be established to determine when management attention is required, but also when a program is so far off its initial plan that it should be re-evaluated. Today's "Nunn-McCurdys" or "Critical Changes" refer to breaches in cost or schedule thresholds. The current 25% unit cost growth and 50% total program cost growth thresholds often will not make sense for continuously developed software programs.

An alternative to cost-based thresholds is to establish thresholds based on the metrics listed above, with different thresholds for different types of software. A notion of a “Nunn-McCurdy type breach” for software programs based on some of the above performance metrics recorded at lower levels of effort or on specific applications could serve as better means of identifying major issues earlier in a program. Commercially available software, with or without customization, should be the easiest type for which to establish accurate metrics, since it already exists and should be straightforward to purchase and deploy. Metrics for customized software running on either commercial or DoD-specific hardware is likely to be more difficult to predict, so a higher threshold can be used in those circumstances.

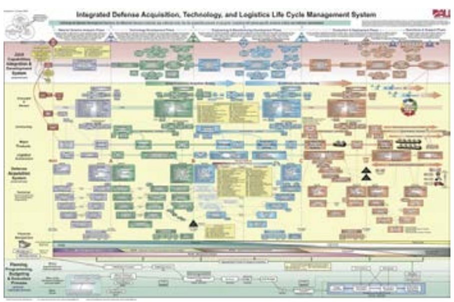
Defense Innovation Board Do's and Don'ts for Software

Authors: Michael McQuade, Milo Medin, Richard Murray

Version 0.7, last modified 1 Nov 2018

This document provides a summary of the Defense Innovation Board's (DIB's) observations on software practices in the DoD and a set of recommendations for a more modern set of acquisition and development principles. These recommendations build on the DIB Ten Commandments of Software. In addition, we indicate some of the specific statutory, regulatory, and policy obstacles to implementing modern software practices that need to be changed.

Executive Summary

Observed practice (Don'ts)	**Desired state (Do's)**	**Obstacles**
 Defense Acquisition University, June 2010	 https://commons.wikimedia.org/wiki/File:Devops-toolchain.svg (modifications licensed CC-BY-SA)	10 U.S.C. §2334 10 U.S.C. §2399 10 U.S.C. §2430 10 U.S.C §2433a 10 U.S.C. §2460 10 U.S.C. §2464 DODI 5000.02, par 5.c.(2) and 5.c.(3)(c)-(d)
Spend 2 years on excessively detailed requirements development	Require developers to meet with end users, then start small and iterate to quickly deliver useful code	DODI 5000.02, par 5.c.(2) CJCSI 3170.01I App A.1.b
Define success as 100% compliance with requirements	Accept 70% solutions[7] in a short time (months) and add functionality in rapid iterations (weeks)	10 U.S.C. §2399 OMB Cir A-11 pp 42-43
Require OT&E to certify compliance after development and before approval to deploy	Create automated test environments to enable continuous (and secure) integration and deployment to shift testing left	10 U.S.C. §139b/d 10 U.S.C. §2399 Cultural
Apply hardware life-cycle management processes to software	Take advantage of the fact that software is essentially free to duplicate, distribute, and modify	10 U.S.C. §2334 10 U.S.C. §2399 10 U.S.C. §2430 48 CFR 207.106 DODI 5000.02
Require customized software	For common functions, purchase existing	Culture

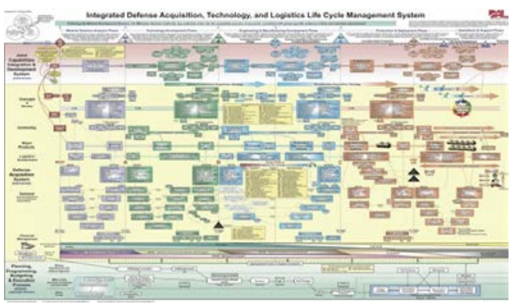
[7] 70% is notional. The point is to deliver the simplest, most useful functionality to the warfighter quickly.

solutions to match DoD practices	software and change DoD processes to use existing apps	
Use legacy languages and operating systems that are hard to support and insecure	Use modern software languages and operating systems (with all patches up-to-date)	10 U.S.C. §2334 DoDI 5000.02, Enclosure 11 Culture
Evaluate cyber security after the systems have been completed, separately from OT&E	Use validated software development platforms that permit continuous integration & evaluation (DevSecOps)	DOT&E Memos Culture
Consider development and sustainment of software as entirely separate phases of acquisition	Treat software development as a continuous activity, adding functionality across its life cycle	10 U.S.C. §2399 10 U.S.C. §2430 10 U.S.C. §2460 10 U.S.C. §2464 DODI 5000.02, par 5.c.(2) and 5.c.(3)(c)-(d)
Depend almost entirely on outside vendors for all product development and sustainment	Require source code as a deliverable on all purpose-built DoD software contracts. Continuous development and integration, rather than sustainment, should be a part of all contracts. DoD personnel should be trained to extend the software through source code or API access[8]	Culture (no apparent statutory obstacle) FAR/DFARS technical data rights
Turn documents like this into a process and enforce compliance	Hire competent people with appropriate expertise in software to implement the desired state and give them the freedom to do so ("competence trumps process")	Culture

[8] As noted in the DIB's 10 Commandments of Software

Supporting Information

The information below, broken out by entry in the executive summary table, provides additional information and a rationale for each desired state.

Don’t	Do
 Defense Acquisition University, June 2010	 https://commons.wikimedia.org/wiki/File:Devops-toolchain.svg

The DoD 5000 process, depicted on the left, provides a detailed DoD process for setting requirements for complex systems and ensuring that delivered systems are compliant with those requirements. The DoD’s “one size fits all” approach to acquisition has attempted to apply this model to software systems, where it is wholly inappropriate. Software is different than hardware. Modern software methods make use of a much more iterative process, often referred to as “DevOps,” in which development and deployment (operations) are a continuous process, as depicted on the right. A key aspect of DevOps is continuous delivery of improved functionality through interaction with the end user.

Why this is hard to do, but also worth doing:[9]

- DoD 5000 is designed to give OSD, the Services, and Congress some level of visibility and oversight into the development, acquisition, and sustainment of large weapons systems. While this directive may be useful for weapons systems with multi-billion dollar unit costs, it does not make sense for most software systems.
- While having one consistent procurement process is desirable in many cases, the cost of using that same process on software is that software is delivered late to need, costs substantially more than the proposed estimates, and cannot easily be continuously updated and optimized.
- Moving to a software development approach will enable the DoD to move from a *specify, develop, acquire, sustain* mentality to a more modern (and more useful) *create, scale, optimize* (DevOps/DevSecOps) mentality. Enabling rapid iteration will create a system in which the US can update software at least as fast as our adversaries can change tactics, allowing us to get inside their OODA loop.

[9] These comments and the similar ones that follow for other area were obtained by soliciting feedback on this document from people familiar with government acquisition processes and modern software development environments.

Acronyms defined: Office of the Secretary of Defense (OSD), OODA is short for the the decision cycle of Observe, Orient, Decide, and Act.

Don’t	Do
Spend 2 years on excessively detailed requirements development	Require developers to meet with end users, then start small and iterate to quickly deliver useful code
Define success as 100% compliance to requirements	Accept 70% solutions in a short time (months) and add functionality in rapid iterations (weeks)

Developing major weapons systems is costly and time consuming, so it is important that the delivered system meets the needs of the user. The DoD attempts to meet these needs with a lengthy process in which a series of requirements are established, and a successful program is one that meets those requirements (ideally close to the program’s cost and schedule estimates). Software, however, is different. When done right, it is easy to quickly deploy new software that improves functionality and, when necessary, rapidly rollback deployed code. It is more useful to get something simple working quickly (time-constrained execution) and then exploit the ability to iterate rapidly in order to get the remaining desired functionality (which will often change in any case, either in response to user needs or adversarial tactics).

Why this is hard to do, but also why it is worth doing:

- Global deployment of software on systems which are not always network-connected (e.g., an aircraft carrier or submarine underway) introduces very real problems around version management, training, and wisely managing changes to mission critical systems.
- In the world of non-military, consumer Internet applications, it is easy to glibly talk about continuous deployment and delivery. In these environments, it is easy to execute and the consequences for messing up (such as making something incredibly confusing or hard to find) are minor. The same is not always true for DoD systems -- and DoD software projects rarely offer scalable and applicable solutions to address the need for continuous development.
- Creating an approach (and the supporting platforms) that enables the DoD to achieve continuous deployment is a non-trivial task and will have different challenges than the process for a consumer Internet application. The DoD must lay out strategies for mitigating these challenges. Fortunately, there are tools that can be build upon: many solutions have already been developed in consumer industries that require failsafe applications with security complexities.
- Continuous deployment depends on the entire ecosystem, not just the front-end software development.
- Make sure to focus on product design and *product* management, which prioritizes delivery of capability to meet the changing needs of users, rather than program/project management, which focus on execution against a pre-approved plan. This shift is key to user engagement, research, and design.

Don’t	Do
Require OT&E to certify compliance after development and before approval to deploy	Create automated test environments to enable continuous (and secure) integration and deployment to shift testing left

Evaluate cyber security after the system has been completed, separately from OT&E	Use validated software development platforms that permit continuous integration and evaluation

Why this is hard to do, but also worth doing:

- The DoD typically performs a cyber evaluation on software only after delivery of the initial product. Modern software approaches have not always explicitly addressed cyber security (though this is changing with "DevSecOps"). This omission has given DoD decision-makers an easy "out" for dismissing recommendations (or setting up roadblocks) for DevOps strategies like continuous deployment. Cyber security concerns must be addressed head on, and in a manner that demonstrates better security in realistic circumstances. Until then, change is unlikely.

- More dynamic approaches to address the cyber security concerns must be developed and implemented through some amount of logic and a fair bit of data. Case studies of red teaming also help: *Hack the Pentagon* should be able to provide some true examples that generate concern. It may be necessary to obtain access to some additional good data that goes beyond what corporations are willing to share publicly.

- To succeed, it will be important not to assume that it will be clear how these recommendations solve for all cyber security concerns. Recommendations should make explicit statements about what can be accomplished, taking away the reasons to say "no."

Don't	**Do**
Apply hardware life cycle management processes to software	Take advantage of the fact that software is essentially free to duplicate, distribute, and modify
Consider development and sustainment of software as entirely separate phases of acquisition	Treat software development as a continuous activity, adding functionality across its life cycle

Why this is hard to do, but also worth doing:

- Program of record funding is specifically broken out into development and sustainment. These distinct categories of appropriations lead program managers and acquisition professionals to the conclusion that new functionality can only be added within development contracts and that money allocated for sustainment cannot be used to add new features. Vendor evaluation for development and sustainment contracts are different; vendors on sustainment contracts often do not have the same development competencies and frequently are not the people who built the original system. To create an environment that will support a DevOps/DevSecOps approach, DoD Commands and Services should jointly own the development and maintenance of software with contractors who provide more specialized capabilities. Contracts for software should focus on developing and deploying software (to operations) over the long term, rather than the typical, sequential approach - "acquiring" software followed by "sustaining" that software.

Don’t	Do
Require customized software solutions to match DoD practices	For common functions, purchase existing software and change DoD processes to use existing apps

Business processes, financial, human resources, accounting and other “enterprise” applications in the DoD are generally not more complicated nor significantly larger in scale than those in the private sector. Commercial software, unmodified, should be deployed in nearly all circumstances. Where DoD processes are not amenable to this approach, those processes should be modified, not the software. Doing so allows the DoD to take advantage of the much larger commercial base for common functions (e.g., Concur has 25M active users for its travel software).

Don’t	Do
Use legacy languages and operating systems that are hard to support and insecure	Use modern software languages and operating systems (with all patches up-to-date)

Modern programming languages and software development environments have been optimized to help eliminate bugs and security vulnerabilities that were often left to programmers to avoid (an almost impossible endeavor). Additionally, outdated operating systems are a major security vulnerability and the DoD should assume that any computer running such a system will eventually be compromised.[10] Standard practice in industry is to apply security patches within 48 hours of release, though even this is probably too big a window for defense systems. Treat software vulnerabilities like perimeter defense vulnerabilities: if there is a hole in your perimeter and people are getting in, you need to patch the hole quickly and effectively.

Why this is hard to do, but also worth doing:

- DoD looks at the cost of upgrading hardware as a major cost that is tied to “modernization.” But hardware should be thought of as a consumable like any other, such as fuel and parts,that must be continually replaced for a weapon system to maintain operational capability. This change would require DoD to provide a stable annual budget that paid for new hardware and software capability.
- The advantage of using modern hardware and operating systems on DoD systems are manifold: better security, better functionality, reduced (unit) costs, and lower overall maintenance costs.

Don’t	Do
Turn documents like this into a process and	Hire competent people with appropriate expertise in

[10] See the DIB 10 Commandments of Software supporting thoughts and recommendations. “*Move to a model of continuous hardware refresh in which computers are treated as a consumable with a 2-3 year lifetime.”*

enforce compliance	software to implement the desire state and give them the freedom to do so ("competence trumps process")

Why this is hard to do, but also why it is worth considering doing it:

- Good engineers want to build things, not just write and evaluate contracts. If their jobs are mainly contracting or monitoring, their software skills will quickly become outdated. This can be solved in the short term by a rotational program: do not allow programmers to stay in contracting for more than 4 years, so their technical capabilities are current.
- The government must team with commercial companies to ensure that it has access to the collection of talent required to develop modern software systems, as well as develop internal talent. The DoD should increase its use of contractors whose aim is not just to provide software, but to increase the software development capabilities and competency of the department. By making use of enlisted personnel, reservists, contractors, and other resources, it is possible to create and maintain highly effective teams who contribute to national security through software development.

Additional Obstacles

In addition to the specific obstacles listed above, we capture here a collection of statutes, regulations, processes and cultural norms that are impediments to implementing a modern set of software acquisition and development principles.

Statutes

The statutes below provide examples of impediments to the implementation of modern software development practices in DoD systems.

Acquisition strategy (10 U.S.C §2431a): 2431a(d) establishes the review process for major defense acquisition programs and is written around the framework of waterfall development for long timescale, hardware-centric programs. In particular, this statute establishes decision-gates at Milestone A (entry into technology maturation and risk reduction), Milestone B (entry into system development and demonstration), and entry into full-rate production. For many software programs this set of terms and approach does not make sense and is incompatible with the ability to deliver capability to the field in a rapid fashion.

Critical cost growth in major defense acquisition programs (10 U.S.C. §2433a [Nunn-McCurdy]): 2433 establishes the conditions under which Congress reviews a major program that has undergone critical cost growth and determines with it should continue. By the time a software program hits a Nunn-McCurdy breach it has already gone well past the point where the program should have been terminated and restarted using a different approach. All software procurement programs should start small, be iterative, and build on success – or be terminated quickly.

Independent cost estimation and cost analysis (10 U.S.C. §2334)

Working capital funds (10 U.S.C. §2208(r)):

- 2+ year lead times from plan to budget does not allow for continuous engineering
- Differentiating software development workload as Research, Development, Test and Engineering (RDT&E), Procurement, or Operations and Maintenance (O&M) is meaningless as there should be no final fielding or sustainment element to continuous engineering
- System--defined program elements hinder the ability to deliver holistic capabilities and enable real-time resource, requirements, performance and schedule trades across systems without significant work.

Operational Test and Evaluation (10 U.S.C. §139b/d, 10 U.S.C. §2399): 139 establishes the position of the Director of Operational Test and Evaluation (DOT&E) and requires that person to carry out field tests, under realistic combat conditions, of weapon systems for the purpose of determining the effectiveness and suitability of those systems in combat by typical military users. 2399(a) states that a major defense acquisition program "may not proceed beyond low-rate initial production until initial operational test and evaluation of the program, subprogram, or element is completed". 2399(b)(4) further states that the program many not proceed "until the Director [of Operational Test and Evaluation] has submitted to the Secretary of Defense the report with respect to that program under paragraph (2) and the congressional defense committees have received that report". These are obstacles for DevSecOps implementation of software, where changes should be deployed to the field quickly as part of the (continuous) development process. They are an example of a "tailgate" process for OT&E that impedes our ability to deploy software quickly and drives a set of processes in which OT&E impedes rather than enhances the software development process. Instead of this process, Congress should allow independent OT&E of software to occur in parallel with deployment and also require that OT&E cycles for software match development cycles through the use of automated workflows and test harnesses wherever possible.

Additional issues:

- Testing and evaluation (T&E) must be integrated into the development lifecycle to facilitate DevSecOps, and reduce operations and sustainment (O&S) costs. T&E should be present from requirements setting to O&S
- Programs need persistent and realistic environments that permit continuous, agile testing of all systems (embedded, networked, etc) in a representative SoS environment
- Software environments should be part of the contract deliverables and accessible to T&E, including source code, build tools, test scripts, data

Definition of a major acquisition program (10 U.S.C. §2430): The designation of a program as a major acquisition program triggers a set of procedures that are designed for acquisition of hardware. This includes triggering of the DoD Instruction 5000.02, which is currently tuned for hardware systems. An alternative instruction, DoD Instruction 5000.75, is better tuned for software, but can only used for defense *business* systems; it is not valid for "weapons systems".

Depot level maintenance and repair; core logistics (10 U.S.C. §2460, 10 U.S.C. §2464): The definitions of maintenance, repair, and logistics are based on an acquisition model that is appropriate for hardware but not well aligned with the operation of modern software. For example, §2464 says that services will “maintain and repair the weapon systems”. But software is not maintained, it is *optimized* (with better performance and new functionality) on a *continuous* basis. §2460(b)(1) further states that depot level maintenance and repair “does not include the procurement of major modifications or upgrades of weapon systems that are designed to improve program performance”.

Additional issues:

- DoD’s challenge in shifting from applying a Hardware (HW) maintenance mindset to Software (SW) hinders DoD’s ability to better leverage DoD’s organic SW engineering infrastructure to deliver greater capability to the warfighter.
- DoD’s acquisition process is not emphasizing an upfront focus on design for software sustainment and a seamless transition to organic software engineering sustainment to reduce the life cycle cost of software and to speed delivery of capability over the life cycle. Such upfront emphasis is critical given the scope, complexity, and mix of the growing software sustainment demand, in the face of persistent affordability concerns.
- DoD’s organic software engineering capabilities and infrastructure are critical to national security, but there is limited enterprise visibility of this infrastructure, its capabilities, workload, and resources to leverage it at the enterprise level to deliver greater capability more affordably to the warfighter.

Regulations

The regulations are the mechanism by which the DoD implements the statutes that govern its operations. They provide additional examples of impediments to the implementation of modern software development practices in DoD systems.

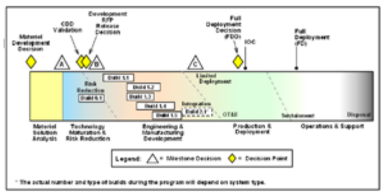
Cost estimating system requirements (48 CFR 252.215-7002) : These regulations set out the expectations for estimation of costs of a program against a set of system requirements. While perhaps appropriate for a hardware-oriented system, they do not take into account the type of continuous development cycle that is required to implement modern software.

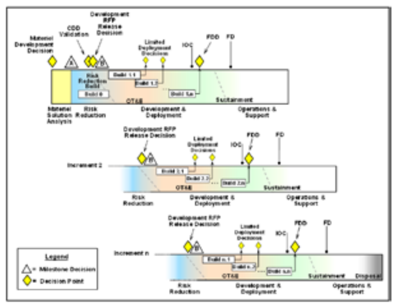
Additional requirements for major systems (48 CFR 207.106): These regulations set out procedures for competition of contracts and are written in a manner that separates out the initial deployment of a system with the operation and sustainment of that system. This doesn’t make sense for software.

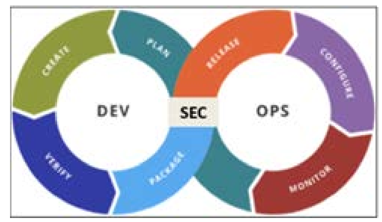
Processes (Instructions)

The detailed processes used to implement the regulations are laid out in Department of Defense Instructions. We illustrate here some of the specific instructions that are obstacles to implementation of modern software development practices.

Major acquisition program development process (DODI 5000.02, par 5.c.(2) and 5.c.(3)(c)-(d)): These portions of the DoD Instructions apply to “Defense Unique Software Intensive” programs and “Incrementally Deployed Software Intensive” programs. While well-intentioned, they are still waterfall processes with years between the cycles of deployments (instead of weeks). These processes may be appropriate for some embedded systems, but are not the right approach for DoD-specific software running on commercial hardware and operating systems, as the diagrams below illustrate:

<table>
<tr><td>Definitely not this:</td><td>Better, but still not right:</td><td>What we need:</td></tr>
<tr><td>Specify, design, deploy, sustain


DODI 5000.02, Figure 4. Model 2: Defense Unique Software Intensive Program</td>
<td>

DODI 5000.02, Figure 5. Model 3: Incrementally Deployed Software Intensive Program</td>
<td>Implement, scale, optimize


https://commons.wikimedia.org/wiki/File:Devops-toolchain.svg (modifications licensed CC-BY-SA)</td></tr>
<tr><td>Waterfall development</td><td>Waterfall development with overlapping builds</td><td>Continuous integration and deployment (DevSecOps)</td></tr>
</table>

Requirements for programs containing information technology (DoDI 5000.02, Enclosure 11): This enclosure attempts to define the requirements for ensuring information security. It is written under the assumption that the standard waterfall process is being used.

Preparation, Submission, and Execution of the Budget - Acceptance (OMB Cir A-11, II.10): This document is the primary document that instructs agencies how to prepare and submit budget requests for OMB review and approval. Section II.10 describes the conditions for acceptance of an acquired item by the government, and requires that the asset meets the requirements of the contract. The impact of this procedure is that it establishes a “100% compliance” mentality in order for the government to accept a software “asset”.

Culture

In this final section we catalog a list of culture items that do not necessarily require changes in statutes, regulations, or instructions, but rather a change in the way that DoD personnel interpret implement their processes. Changing the culture of DoD is a complex process, depending in large part on incentivizing the behaviors that will lead to the desired state.

Data and metrics

- Multiple, competing, and sometimes conflicting types of data and metrics used, or not used, for assessing software in DOD
- Inability to collect meaningful data about software development and performance in a low cost manner, at scale
- Inability to turn data into meaningful analysis and inability to implement decisions or changes to software activities (L/R/C)

Contracts

- Individual contracts are subject to review processes designed for large programs (of which they are likely enabling). This limits the agility of individual contract actions, even when modular contracting approaches are applied. In addition, the acquisition process is rigid and revolves around templates, boards, and checklists thus limiting the ability for innovation and streamlining execution.
- Contracts focus on technical requirements instead of contractual process requirements. The contract should address overall scope, PoP, and price. The technical execution requirements should be separate and managed by the product owner or other technical lead.
- Intellectual Property (IP) rights are often generically incorporated without considering the layers of technology often applied to a solution. A single solution might include open source, proprietary SW, and government custom code. The IP clauses should reflect all of the technology that is used.

Security Accreditation

- Although developing and operating software securely is a primary concern, the means to achieve and demonstrate security is overly complex and hampered by inconsistent and outdated/misapplied policy and implementation practices (e.g. overlaying historical DoD Information Assurance Certification and Accreditation Process (DIACAP) over risk management framework (RMF) controls for individual pieces of software versus system accreditation). The sense is that the certification and accreditation process is primarily a "check- the-box" documentary process, adds little value to the overall security of the system, and is likely to overlook flaws in the design, implementation, and the environment in which the software operates.
- The DoD needs to be able to calculate the true and component costs for implementing the RMF and certification and accreditation (C&A) in order to identify inefficiencies, duplicative / capabilities, and redundant or overlapping security products and services that are being acquired or developed. Absent a set of metrics it is difficult to prioritize risk areas, investments, and evaluating risk reduction and return on -investment.
- The DoD needs to ensure that each Joint Capability Area (JCA) flow-down its strategy, best practices, and implementation requirements / guidance for security and accreditation to allow the Component responsible for implementing the software to appropriately tailor RMF and plan the development, accreditation, and operation of the software.
- The DoD needs to provide automated tools and services needed to integrate continuous monitoring with the development lifecycle, enable continuous assessment and accreditation, and delegate decision making at the lowest level possible. The DoD should embrace DevSecOps (not just DevOps) and provide policy supported processes, certified libraries, tools, and a toolchain reference implementation to produce "born secure" software

Testing and Evaluation

- The DoD lacks the realistic test environments needed to support test at the pace of modern software methods.
- The DoD lacks the modern software intellectual property (IP) regime needed to support test and evaluation at the pace of modern software methods
- The DoD lack the enterprise knowledge management/data analytics capability needed to support evaluation of test data at the pace of modern software methods

Workforce

- No defined requirements for software developers
- Antiquated policies (talent management, software development)
- Culture and knowledge (DoD, societal, defense contractors)

Appropriations/Funding

- 2+ year lead times from plan to budget does not allow for continuous engineering
- Differentiating software development workload as Research, Development, Test and Engineering (RDT&E), Procurement, or Operations and Maintenance (O&M) is meaningless as there should be no final fielding or sustainment element to continuous engineering.
- System defined program elements hinder the ability to deliver holistic capabilities and enable real-time resource, requirements, performance and schedule trades across systems without significant work.

Infrastructure

- Creating software: The DoD lacks availability of vetted, secure, reusable components, either as source code, or other digital artifacts (think hardened Docker containers or virtual machines (VMs) here). A repository of discoverable, well indexed, vetted, secure, and reusable components could go a long way. This also emphasizes the point that an awful lot of software now-a-days is software by construction with minimal "glue" code applied.
- Building/managing/testing software: There is a general lack of available tools to build software, especially automated tools (testing/scanning/fuzzing etc.) integrated into a secure pipeline supporting rapid agile development. There is also a significant need to have a common, government owned and managed code repository that all programs could/should/must use (e.g. and government-furnished GitHub).
- Running/hosting software: The DoD needs to continually push the level of abstraction up as much as possible for programs. Traditionally programs, even cloud-based solutions, tend to start at Infrastructure as a Service (IaaS) and build their own rest of the stack. We need secure and available Platform as a Service (PaaS) and Function as a Service (FaaS) so that programs only need to focus on core business logic and not on securing a database or message bus over and over again.
- Operating/updating securely: Once developed and instantiated on a secure and available platform, we need to continually monitor, red team (automated?), and evolve the software. This requires proper instrumentation, logging, and monitoring of the platform, supporting libraries / components, and the core program code. A standard/common way to provide instrumentation and monitoring of the running services built into the infrastructure would be very helpful.

Requirements

- A byproduct of top-level requirement flow down is rigidity and over specificity at the derived requirements level that greatly hinders agile s/w design.
- Too often exquisite requirements are levied on a system that in turn drive extensive complex software requirements and design, affecting development, integration, and system test.
- Data sets are siloed within programs: a common “law of requirements” is that programs of record try to avoid dependencies with other programs of record. This is problematic for software-based capabilities because data is often siloed within single programs of record. We have network programs to "pass" data, but the promise of artificial intelligence (AI), including machine learning (ML), is that software algorithms can leverage pools of data from disparate sources (data lakes).
- By tying software to a program of record, it becomes harder to transfer that code across systems and data environments. As a result, DoD limits code reuse within and across Services.

Modernization and sustainment

- DoD’s challenge in shifting from applying a hardware maintenance mindset to software hinders DoD’s ability to better leverage DoD’s organic software engineering infrastructure to deliver greater capability to the warfighter.
- DoD’s acquisition process is not emphasizing an upfront focus on design for software sustainment and a seamless transition to organic software engineering sustainment to reduce the life cycle cost of software and to speed delivery of capability over the life cycle. Such upfront emphasis is critical given the scope, complexity, and mix of the growing software sustainment demand, in the face of persistent affordability concerns.
- DoD’s organic software engineering capabilities and infrastructure are critical to national security, but there is limited enterprise visibility of this infrastructure, its capabilities, workload, and resources to leverage it at the enterprise level to deliver greater capability more affordably to the warfighter.

Acquisition Strategy

- Acquisition policy framework: Create a cohesive acquisition policy architecture within which effective, efficient software acquisition policy has a home.
- Acquisition management and governance: Flip the concept of an oversight model on its head.

DIB Guide: Detecting Agile BS

Michael McQuade, Milo Medin, Richard Murray, Jennifer Pahlka
Version 0.4, last modified 3 Oct 2018

Agile is a buzzword of software development, and so all DoD software development projects are, almost by default, now declared to be "agile." The purpose of this document is to provide guidance to DoD program executives and acquisition professionals on how to detect software projects that are really using agile development versus those that are simply waterfall or spiral development in agile clothing ("agile-scrum-fall").

Principles, Values, and Tools

Experts and devotees profess certain key "values" to characterize the culture and approach of agile development. In its work, the DIB has developed its own guiding maxims that roughly map to these true agile values:

Agile value	**DIB maxim**
Individuals and interactions over processes and tools	"Competence trumps process"
Working software over comprehensive documentation	"Minimize time from program launch to deployment of simplest useful functionality"
Customer collaboration over contract negotiation	"Adopt a DevSecOps culture for software systems"
Responding to change over following a plan	"Software programs should start small, be iterative, and build on success – or be terminated quickly"

Key flags that a project is not really agile:

- Nobody on the software development team is talking with and observing the users of the software in action; we mean the *actual* users of the *actual* code.[11] (The PEO does not count as an actual user, nor does the commanding officer, unless she uses the code.)
- Continuous feedback from *users* to the development team (bug reports, users assessments) is not available. Talking once at the beginning of a program to verify requirements doesn't count!
- Meeting requirements is treated as more important than getting something useful into the field as quickly as possible.
- Stakeholders (dev, test, ops, security, contracting, contractors, end-users, etc.)[12] are acting more-or-less autonomously (e.g. 'it's not my job.')

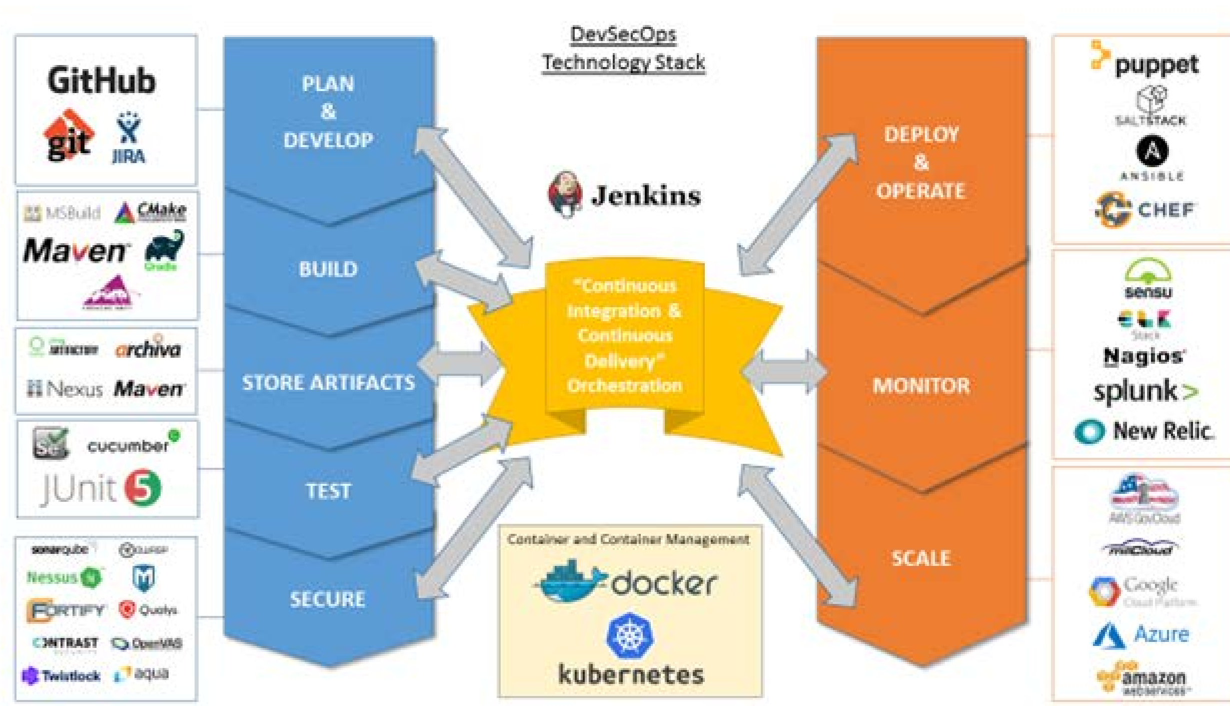
[11] Acceptable substitutes for talking to users: Observing users working, putting prototypes in front of them for feedback, and other aspects of user research that involve less talking.
[12] Dev is short for development, ops is short for operations

- End users of the software are missing-in-action throughout development; at a minimum they should be present during Release Planning and User Acceptance Testing.
- DevSecOps culture is lacking if manual processes are tolerated when such processes can and should be automated (e.g. automated testing, continuous integration, continuous delivery).

Some current, common tools in use by teams using agile development (these will change as better tools become available):[13]

- Git, ClearCase, or Subversion - version control system for tracking changes to source code. Git is the *de facto* open source standard for modern software development.
- BitBucket or GitHub - Repository hosting sites. Also provide issues tracking, continuous integration "apps" and other productivity tools. Widely used by the open source community.
- Jenkins, Circle CI or Travis CI - continuous integration service used to build and test BitBucket and GitHub software projects
- Chef, Ansible, or Puppet - software for writing system configuration "recipes" and streamlining the task of configuring and maintaining a collection of servers
- Docker - computer program that performs operating-system-level virtualization, also known as "containerization"
- Kubernetes or Docker Swarm for Container orchestration
- Jira or Pivotal Tracker - issues reporting, tracking, and management

Graphical version:



Questions to Ask Programming Teams

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13 Tools listed/shown here are for illustration only: no endorsement implied.

- How do you test your code? (Wrong answers: “we have a testing organization”, “OT&E is responsible for testing”)
    - Advanced version: what tool suite are you using for unit tests, regression testing, functional tests, security scans, and deployment certification?
- How automated are your development, testing, security, and deployment pipelines?
    - Advanced version: what tool suite are you using for continuous integration (CI), continuous deployment (CD), regression testing, program documentation; is your infrastructure defined by code?
- Who are your users and how are you interacting with them?
    - Advanced version: what mechanisms are you using to get direct feedback from your users? What tool suite are you using for issue reporting and tracking? How do you allocate issues to programming teams? How to you inform users that their issues are being addressed and/or have been resolved?
- What is your (current and future) cycle time for releases to your users?
    - Advanced version: what software platforms to you support? Are you using containers? What configuration management tools do you use?

Questions for Program Management

- How many programmers are part of the organizations that owns the budget and milestones for the program? (Wrong answers: “we don’t know,” “zero,” “it depends on how you define a programmer”)
- What are your management metrics for development and operations; how are they used to inform priorities, detect problems; how often are they accessed and used by leadership?
- What have you learned in your past three sprint cycles and what did you do about it? (Wrong answers: “what’s a sprint cycle?,” “we are waiting to get approval from management”)
- Who are the users that you deliver value to each sprint cycle? Can we talk to them? (Wrong answers: “we don’t directly deploy our code to users”)

Questions for Customers and Users

- How do you communicate with the developers? Did they observe your relevant teams working and ask questions that indicated a deep understanding of your needs? When is the last time they sat with you and talked about features you would like to see implemented?
- How do you send in suggestions for new features or report issues or bugs in the code? What type of feedback do you get to your requests/reports? Are you ever asked to try prototypes of new software features and observed using them?
- What is the time it takes for a requested feature to show up in the application?

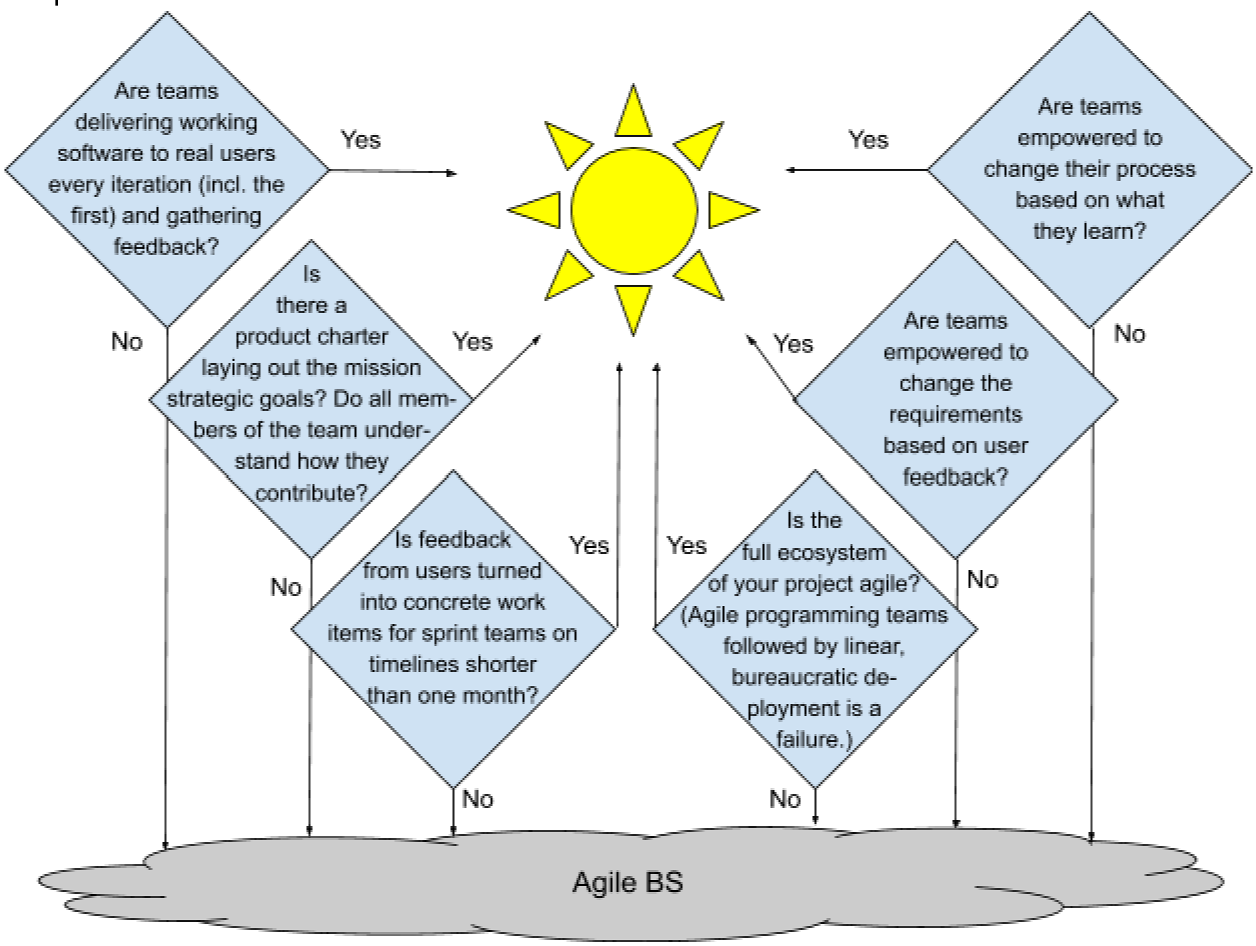
Questions for Program Leadership

- Are teams delivering working software to at least some subset of real users every iteration (including the first) and gathering feedback? (alt: every two weeks)

- Is there a product charter that lays out the mission and strategic goals? Do all members of the team understand both, and are they able to see how their work contributes to both?
- Is feedback from users turned into concrete work items for sprint teams on timelines shorter than one month?
- Are teams empowered to change the requirements based on user feedback?
- Are teams empowered to change their process based on what they learn?
- Is the full ecosystem of your project agile? (Agile programming teams followed by linear, bureaucratic deployment is a failure.)

For a team working on agile, the answer to all of these questions should be "yes".

Graphical version:



More information on some of the features of DoD software programs are included in Appendix A (DIB Ten Commandments on Software), Appendix B (DIB Ten Metrics for Software), and Appendix C (DIB Do's and Don'ts of Software).

Is Your Development Environment Holding You Back?
A DIB Guide for the Acquisition Community

Authors: Jen Pahlka, Michael McQuade, Richard Murray

Version 0.2, last modified 3 Oct 2018

A strong software development team is marked by some common attributes, including the use of practices, processes, and various tools.

An effective team starts with clear goals. The entire software team should have a clear sense of the project's goals and the value they seek to provide "the client." The goals should be translated into specific objectives, which may be measured in terms of agreed-upon key performance indicators (KPIs) or other frameworks. An effective development environment is one designed to deliver value towards those goals. (This KPI-driven paradigm should *not* be seen as an invitation to reprise an extended debate about requirements.)

Technical practices and processes that enable a development environment to deliver value towards those goals include:

- Organization of activities through discrete "user stories" that can be broken down into smaller components and continually prioritized by the product owner
- Relatively short "sprints" (often two weeks), each ending in a retrospective, that enable measurement and learning throughout the process
- Blameless post-mortems that allow for maximum learning and speedy recovery from failures
- Automated testing, security, and deployment
- Testing (including user testing) and security ~~testing~~ should be shifted to the left and be part of the day-to-day operations within the development teams
- Continuous integration, in which developers integrate code into a shared repository several times a day, and check-ins are then verified by an automated build for early problem detection
- Continuous delivery or continuous deployment, in which the software is seamlessly deployed into staging and production environments
- Trunk-based development, in which team members work in small batches and develop off of trunk or master, rather than long-lived feature branches
- Version control for all production artifacts including open source and third party libraries
- Infrastructure as code: version control for all configuration, networking requirements, container orchestration files, continuous integration/continuous delivery (CI/CD) pipeline files
- Ability to execute A/B testing and canary deployments
- Ability to get rapid and continuous user feedback and to test new features with users throughout the development process

Effective teams will practice continuous delivery, in which teams deploy software in short cycles, ensuring that the software can be reliably released at any time. Continuous deployment can be measured by a team's ability to achieve the following outcomes:

- Teams can deploy on-demand to production or to end users throughout the software delivery lifecycle.
- Fast feedback on the quality and deployability of the system is available to everyone on the team, and people make acting on this feedback their highest priority.

Specific measures that will help you gauge if your development environment is working as it should include development frequency; lead time for changes; time to restore service after outage; and change failure rate (rollback deployed code). These questions and data, borrowed from the [2017 State of DevOps Report] from DORA, can help assess where your teams stand:

	High performance	**Medium performance**	**Low performance**
Deployment frequency How often does your organization deploy code?	On demand (multiple deploys per day)	Between once per week and once per month	Between once per week and once per month
Lead time for changes What is your lead time for changes (i.e., how long does it take to go from code-commit to code successfully running in production)?	Less than one hour	Between one week and one month	Between one week and one month*
Mean time to recover (MTTR) How long does it generally take to restore service when a service incident occurs (e.g., unplanned outage, service impairment)?	Less than one hour	Less than one day	Between one week and one day
Change failure rate What percentage of changes results either in degraded service or subsequently requires remediation (e.g., leads to service impairment, service outage, requires a hotfix, rollback, fix forward, patch)?	0-15%	0-15%	31-45%

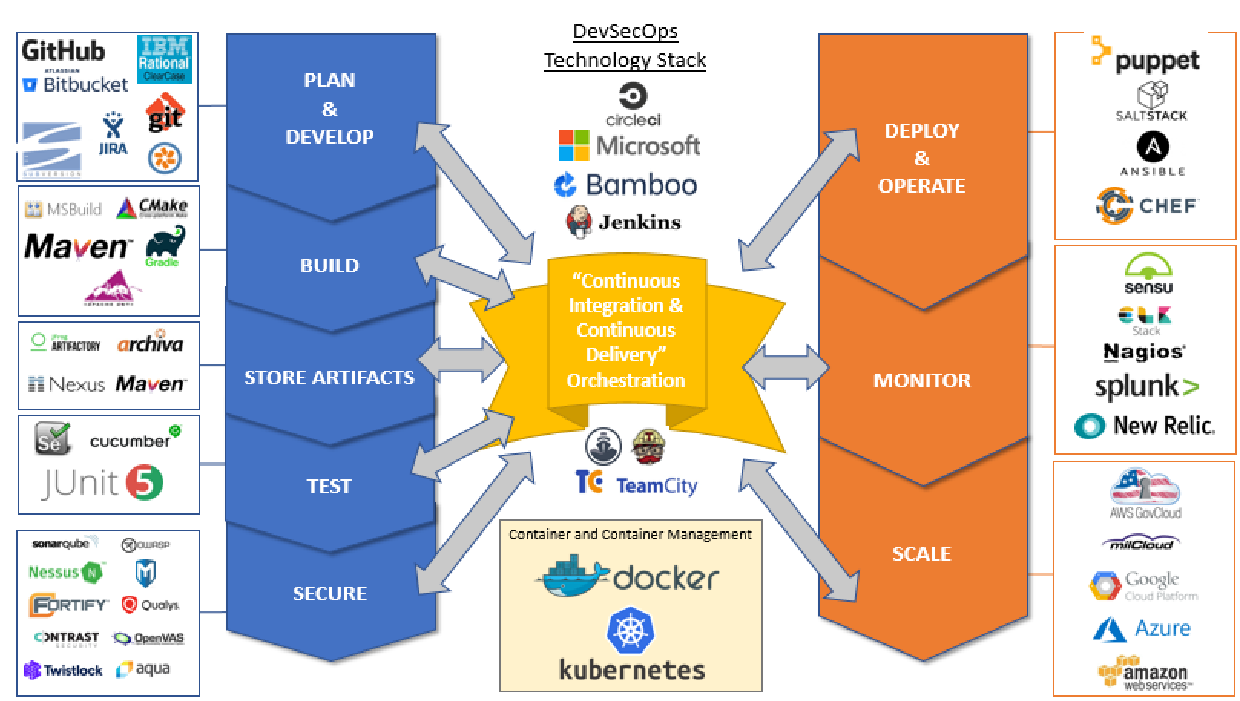
* Low performers were lower on average (at a statistically significant level), but had the same median as the medium performers (2017 DevOps Report)

There is ***no exact set of tools*** that indicate that your development environment is working as it should, but the use of some tools will often indicate that the practices and processes above are in place. You commonly see effective software teams using:

- An issue tracker, like Jira or Pivotal Tracker
- Continuous integration and/or continuous integration/continuous delivery (CI/CD) tools, like Jenkins, Circle CI, or Travis CI

- Automated build tools, like Maven, Grable, Cmake, and Apache Ant
- Automated testing tools, like Selenium, Cucumber, J-Unit
- A centralized artifacts repository, like Nexus, Artifactory, or Maven
- Automated security tools for static and dynamic code analysis and container security, like Sonarqube, OWASP ZAP, Fortify, Nessus, Twistlock, Aqua, and more.
- Automation tools, like Chef, Ansible, or Puppet
- Automated code review tools, like Code Climate
- Automated monitoring tools, like Nagios, Splunk, New Relic, and ELK
- Container and container orchestration tools like Docker, Docker Swarm, Kubernetes, and more

*



Warning signs that you may have screwed up your development environment include:

- If teams cannot effectively track progress towards defined goals and objectives roughly every two weeks
- If teams cannot rapidly deploy various environments that mirror production to test their code such as in development, QA, and staging
- If teams cannot have real-time feedback regarding their code building, passing tests, and passing security scans
- If it takes months for end users to be able to see changes and provide feedback
- If teams cannot rapidly roll-back to previous versions or perform rolling-update to new versions without downtime
- If recovering from incidents results in significant drama or the assignment of blame
- If having code ready to deploy is a big event (it should happen routinely and without drama)

- If changes to the software frequently result in breaking it

If developers are not empowered to change the code or build new functionality based on user feedback, or to change their process based on what they learn.

Is Your Compute Environment Holding You Back?
A DIB Guide for the Acquisition Community

Authors: Milo Medin, Michael McQuade, Richard Murray

Version 0.1, last modified 3 Oct 2018

To enable software to provide a competitive advantage to the warfighter, DoD must adopt a strategy for rapidly transitioning DoD IT to current industry standards. This modernization agenda should include providing distributed databases and abundant computing power; making bandwidth available as a platform; integrating mobile technologies; and developing DoD platforms for downloading applications. This document outlines compute and infrastructure capabilities that should be available to DoD programmers (and contractors) who are developing software for national defense. The capabilities include:

1. **Scalable compute.** Access to computing resources should never be a limiting factor when developing code. Modern cloud environments provide mechanisms to provide any developer with a powerful computing environment that can easily scale with the needs of an individual programmer, a product development team, or an entire enterprise.

2. **Containerization.** Container technology provides sandbox environments in which to test new software without exposing the larger system to the new code. It “packages up” an application with all of the operating system services required for executing the application and allowing that application to run in a virtualized environment. Containers allow isolation of components (that communicate with each other through well-defined channels) and provide a way to “freeze” a software configuration of an application without freezing the underlying physical hardware and operating system.

3. **Continuous integration/continuous delivery (CI/CD) pipeline (DevSecOps platform).** A platform that provides the CI/CD pipeline is used for automated testing, security, and deployment. This includes license access for security tools and a centralized artifacts repository with tools, databases, and a base operating system (OS) with an existing authorization to operate (ATO).

4. **Infrastructure as code: automated configuration, updating, distribution, and recovery management.** Manual configuration management of operating systems and middleware platforms leads to inconsistencies in fielded systems and drives up the operating costs due to the labor hours required for systems administration. Modern software processes avoid this by implementing “infrastructure as code,” which replaces manual processes for provisioning infrastructure with automated processes that use machine-readable definition files to manage and provision containers, virtual machines, networking, and other components. Adopting infrastructure as code and software distribution tools in a standardized way streamlines uniformity of deployment and testing of changes, which are both vital to realizing the benefits of agile development processes.

5. **Federated identity management and authentication backend with common log file management and analysis.** Common identity management across military,

government, and contractors greatly simplifies the assignment of permissions for accessing information across multiple systems and allows rapid and accurate auditing of code. The ability to audit access to information across multiple systems enables the detection of inappropriate access to information, and can be used to develop the patterns of life that are essential for proper threat analysis. Common identity management can ease the integration of multi-factor authentication across servers, desktops, and mobile devices. Along with public key infrastructure (PKI) integration, it allows verification of both the service being accessed by the user and the user accessing information from the service.

6. **Firewall configuration and network access control lists.** Having a common set of OS and application configurations allows network access control not just through network equipment, but at the server itself. Pruning unnecessary services and forcing information transfer only through intentional interfaces reduce the attack surface and make servers more resilient against penetration. Server-to-server communication can be encrypted to protect from network interception and authenticated so that software services can only communicate with authorized software elements.

7. **Client software.** Remote login through remote desktop access is common throughout DoD. This greatly increases the difficulty of integrating mobile platforms and of permitting embedded devices to access vital information, especially from the field. It also complicates uniform identity management and multi-factor verification, which is key to securing information. By moving to web client access mobile integration - and development - is greatly eased. It also becomes possible to leverage industry innovation, as this is where the commercial sector is heading for all interactions.

8. **Common information assurance (IA) profiles.** Information assurance (IA) for DoD systems is complex, difficult, and not yet well-architected. Test, certification, and IA are almost always linear “tailgate” processes instead of being integrated into a continuous delivery cycle. Common IA profiles integrated into the development environment and part of the development system architecture are less likely to have bugs than customized and add-on solutions.

Desired State with Examples

Effective use of software requires sufficient resources for computing, storage, and communications. Software development teams must be provided with abundant compute, storage, and bandwidth to enable rapid creation, scaling, and optimization of software products.

Modern cloud computing services provide such environments and are widely available for government use. In its visits to DoD programs, the DIB Software Acquisition and Practices (SWAP) team has observed many programs that are regenerating computing infrastructure on their own -- often in a highly non-optimal way -- and typically due to constraints (or perceived constraints) created by government statutes, regulations, and culture. This approach results in situations where compute capability does not scale with needs; operating systems cannot be upgraded without upgrading applications; applications cannot be upgraded without updating the operating systems; and any change requires a complete information assurance recertification. Compute platforms are thus “frozen” at a point established early in the program lifecycle, and development teams are unable to take advantage of new tools and new approaches as they become available. The DIB SWAP team has noted a general lack of good tools for profiling code, maintaining access and change logs, and providing uniform identity management, even though the DoD has system-wide credentials through Common Access Control (CAC) cards.

It would be highly beneficial to create common frameworks and/or a common set of platforms that provide developers with a streamlined or pre-approved Authority to Operate (ATO). Use of these pre-approved platforms should not be mandated, but they create cost and time incentives by enabling more consolidated platforms. DoD could make use of emerging government cloud computing platforms or achieve similar consolidation within a DoD-owned data center (hybrid cloud). DoD should move swiftly from a legacy data center approach to a cloud-based model, while taking into account the lessons learned and tools and services available from commercial industry, with assumed hardware and operating system updates every 3-5 years.

Warning signs

Some indicators that you may have screwed up your compute environment include:

- Your programmers are using tools that are less effective than what they used in school
- The headcount needed to support the system grows linearly with the number of servers or instances
- You need system managers deployed with hardware at field locations because it is impossible to configure new instances without high skill local support
- You have older than current versions of operating systems or vendor software because it is too hard to test or validate changes
- Unit costs for compute, network transport and storage are not declining, or are not measurablable to be determined
- Logging in via remote desktop is the normal way to access an information service
- You depend on network firewalls to secure your compute resource from unauthorized access
- You depend on hardware encryptors to keep your data safe from interception
- You have to purge data on a regular basis to avoid running out of storage
- Compute tasks are taking the same or longer time to run than they did when the system was first fielded
- Equipment or software is in use that has been “end of lifed” by the vendor and no longer has mainstream support
- It takes significant work to find out who accessed a given set of files or resources over a reasonable period of time
- No one knows what part of the system is consuming the most resources or what code should be refactored for optimization
- Multifactor authentication is not being used

- You cannot execute a disaster recovery exercise where a current backup up of a system cannot be brought online on different hardware in less than a day

Getting It Right

These capabilities should be available to all DoD programmers and contractors developing software for national defense:

Scalable compute
- Modern compute architectures
- Environments that make transitions across cloud and local services easy
- Graphics Processing Unit (GPU)- and ML-optimized compute nodes available for specialized tasks
- Standardized storage elements and ability to expand volumes and distribute them based on performance needs
- Standardized network switching options with centralized image control
- Property management tagging -- no equipment can be placed in a data center without being tagged for inventory and tracked for End of Life support from vendors
- Supply chain tracking for all compute elements

Containerization
- Software deployment against standard profile OS image
- Containers can be moved from physical to cloud-based infrastructure and vice versa
- Applications and services run in containers and expand or contract as needed
- OS updates separated from application container updates
- Centralized OS patch validation and testing
- Containers can be scaled massively horizontally
- Containers are stateless and can be restarted without impact
- Configuration management for deployment and audit

Continuous integration/continuous delivery (CI/CD) pipeline (DevSecOps platform)
- Select, certify, and package best of breed development tools and services
- Can be leveraged across DoD Services as a turnkey solution
- Develop standard suite of configurable and interoperable cybersecurity capabilities
- Provide onboarding and support for adoption of Agile and DevSecOps
- Develop best-practices, training, and support for pathfinding and related activities
- Build capability to deliver a Software Platform to the Defense Enterprise Cloud Environment
- Self-service portal to selectively configure and deliver software toolkit with pre-configured cybersecurity capabilities

Infrastructure as code: automated configuration, updating, distribution and recovery management
- Ability to test changes against dev environments

- Standardized profiling tools for performance measurement
- Centralized push of patches and updates with ability for rapid rollback
- Auditing and revision control framework to ensure proper code is deployed and running
- Ability to inject faults and test for failover in standardized ways
- Disaster recovery testing and failover evaluation
- Utilization tracking and performance management utilities to predict resource crunches
- Standardized OS patch and distribution repositories
- Validation tools to detect manual changes to OS or application containers with alerting and reporting

Federated identity management and authentication backend with common log file management and analysis

- Common identity management across all DoD and contractors
- Common multifactor backends for authentication of all users along with integration of LDAP/Radius/DNS or active directory services
- Integrated PKI services and tools for automated certificate installation and updating
- Common DRM modules that span domains between DoD/contractors and vendor facilities that can protect, audit and control documents, files, and key information. All encrypted at rest, even for plain text files.
- Useful for debugging and postmortem analysis
- Develop patterns of life to flag unusual activity by users or processes
- Automated escalation to defensive cyber teams

Firewall configuration and network access control lists

- Default configuration for containers is no access
- Profiles for minimal amounts of ports and services being open/run
- All network communications are encrypted and authenticated, even on the same server/container

Client software

- Web-based access the norm, from desktops/laptops as well as mobile devices
- Remote login used as a last resort - not as the default
- Security technical implementation guides (STIGs) for browsers and plugins, as well as common identity management at the browser interface (browsers authenticate to servers as well as servers authenticating to browsers)
- Minimal state kept on local hardware - purged at end of session

Common information assurance (IA) profiles

- Enforces data encrypted in flight and at rest
- Software versions across DoD with automated testing
- Application lockdowns at the system level so only authorized applications can run on configured systems
- “Makefile” to build configurations from scratch from base images in standardized approved configurations

- Use of audit tools to detect spillage and aid in remediation (assisted via DRM)

SWAP Program Visits: Questions and Observations

October 10, 2018

Programs Reviewed

Reviewed 6 programs to date:

- Next Generation fighter jet
- Next Generation ground system
- Kessel Run – AOC Pathfinder
- Space tracking system
- Naval radar system
- Cross-service business system

What we hope to understand:

- Why is the software the way it is?
- How have you gone about developing and deploying it?
- What constraints/obligations have you been under and what would be your recommendations to change those?

Standard Questions

- What is the coding environment and what languages/SW tools do you use?
- What do the software and system architectures look like?
- What is the computational environment (processing, comms, storage)?
- How is software deployed and how often are updates delivered to the field?
- What determines the cycle time for updates?
- How does software development incorporate user feedback? What is the developer-user interface? How quickly are user issues addressed and fixed?
- How long does it take to compile the code from scratch?
- How much access does the DoD have to the source code?
- How is testing done? What tool suites are used? How much is automated? How long does it take to do a full regression test?
- How is cybersecurity testing done? How are programs/updates certified?
- What does the workforce look like (headcounts, skill sets)? How many programmers? How much software expertise is there in the program office?
- What is the structure of the contract with the government? How are changes, new features, and new ideas integrated into the development process?

Preliminary Observations

- Software is being delivered to the field 2-10X slower than it could be due to outdated requirements, test requirements, and lack of trust in SW
- Many systems are using legacy hardware and outdated architectures that make it much harder to exploit advances in computing and communications
- Program requirements were often formulated 5+ years ago (when the threat environment + available technologies were very different => wasted effort)

- New capabilities and features are added in multi-year (multi-decade?) development “blocks” instead of continuously and iteratively
- Most program offices don’t have enough expertise in modern SW methods
- Most SW teams are attempting to implement DevOps and “agile” approaches, but in most cases the capabilities are still nascent (and hence fragile)
- Transition to DevOps is often hindered by a gov’t support structure focused on technical performance in a waterfall setting (“waterfall with sprints”)
- Information assurance (IA) is complex, difficult, and not yet well architected
- Test, certification and IA are almost always linear “tailgate” processes instead of being integrated into a continuous delivery cycle.

What should be done differently in future programs?

- Spend time upfront getting the architecture right: modular, automated, secure
- Make use of platforms (hardware and software) that continuously evolve at the timescales of the commercial sector (3-5 years between HW/OS updates)
- Start small, be iterative, and build on success – or terminate quickly
- Construct budget to support the full, iterative life-cycle of the software
- Adopt a DevOps culture: design, implement, test, deploy, evaluate, repeat
- Automate testing of software to enable critical updates to be deployed in days to weeks, not months or years (also requires changes in testing organization)
- Have a local team of DoD software experts who are capable of modifying or extending the software through source code or API access
- Separate development of mission level software from development of IA-accredited platforms

How to Justify Your Budget When Doing DevSecOps
A DIB SWAP Team Concept Paper
v0.5, 7 March 2019

As we transition software development from big spiral programs into DevSecOps, program managers will have to wrestle with using new practices of budget estimation and justification, while potentially being held to old standards that should no longer apply. In addition to all of the regular challenges of retaining a budget allocation (budget reviews, audits, potential reductions and realignment actions, all many times a year), defending a budget for a DevSecOps acquisition requires additional explanation and justification because those charged with oversight – whether inside the Department or in Congress – have come to expect specific information on a tempo that doesn't make sense for DevSecOps projects. Program managers leading DevSecOps projects therefore must not only do the hard work of leading agile teams towards successful outcomes, but also create the conditions that allow those teams to succeed by convincing cost assessors and performance evaluators to evaluate the work differently. Fortunately, commercial industry already has best practices for budget estimation and justification for DevSecOps and that the DoD should follow industry approaches rather than create new ones

This DIB Guide is intended to help with this challenge. It seeks to provide guidelines and approaches to help program managers of DevSecOps projects[14] interact with those cost assessors and performance evaluators through the many layers of review and approval authorities while carrying out their vital oversight role. This guide should help with projects where the development processes is optimized for software rather than hardware and where most key stakeholders are aligned around the goal of providing needed capability to the warfighter without undue delay.

Questions that we attempt to answer in this concept paper:

1. What does a well-managed software program look like and how much should it cost?
2. What are the types of metrics that should be provided for assessing the cost of a proposed software program and the performance of an ongoing software program?
3. How can a program defend its budget if the requirements aren't fixed or are changing?
4. How do we estimate costs for "sustainment" when we are adding new features?
5. Why is ESLOC (effective source lines of code) a bad metric to use for cost assessment (besides the obvious answer that it is not very accurate)?

What does a well-managed DevSecOps program look like and how much should it cost?

The primary focus for DevSecOps programs is about t regular and repeatable, sustainable delivery of innovative results on a time-box pattern, not on specifications and requirements without bounding time (Figure 1). The fixed-requirements spiral-development spending model has created program budgets that approach infinity. DevSecOps projects, on the other hand will

[14] Not all software is the same; we focus here only on software programs using or transitioning to DevSecOps.

be focused on different activities at different stages of maturity. In a DevSecOps project, management should be tracking services and measuring the results of working software as the product evolves, rather than inspecting end items when the effort is done, as would be expected in a legacy model. Software is never done and not all software is the same, but generally the work should look like a steady and sustainable continuum of useful capability delivery.

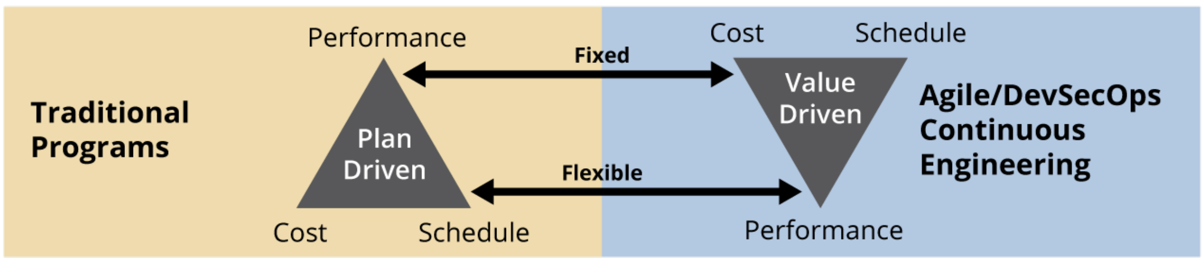


Figure 1. Value Driven Iron Triangle (Carnegie Mellon University, Software Engineering Institute).

- During the creation phase, program managers will most likely decide to adopt agile based on criteria that fits their design challenge (e.g. software dependant). They would also be motivated to build their products on top of widely used software platforms that are appropriate for the technical domain at hand (e.g. embedded vs. web applications). During this phase team also establishes base capability and what they consider a minimum viable product[15]. This is where all programs start and many should end. Starting small and incrementing is not only the right way to do software, but it is also a great way to limit financial exposure. A key tenet of agile development is learning early and being ready to shift focus to increase the likelihood for success.
- During the scaling phase, the entire team (industry and government) commit and learn how to transition to appropriate agile activities that are optimizing for implementing DevSecOps for the project. This should focus the team on transitioning to a larger user base with improved mechanisms for automated testing (including penetration testing), red team attacks, and continuous user feedback. A key management practice in agile development is to keep software projects to a manageable size. If the project requires more scope, divide the effort into modular, easily connected chunks that can be managed using agile methods and weave the pieces together in implementation.
- Once into implementation, a well-managed program should have a regular release cadence (e.g. for IT projects every 2-3 weeks, while safety-critical products could run a bit longer, 3-4 weeks). Each of these releases delivers small increments of software that are as intuitive to use as possible and directly deployable to actual users. DevSecOps programs move from small successes into larger impacts.

With allowances made for different sizes of project, DevSecOps should share certain characteristics, including:

[15] MVP should not be over specified and the importance of getting the MVP into the hands of users for feedback. (more)

- An observer should easily find an engaged program office, as well as development teams that are small (5-11 people), and well connected to one another through structured meetings and events (a.k.a. “ceremonies”).
- A set of agile teams work on cross-functional capabilities of the system and include a planning team and a system architecture team.
- The teams should have frequent interaction with subject matter experts and users from the field or empowered product owners. Active user engagement is a vital element of an Agile approach, but getting actual users (*not* just user representatives) to participate also needs to be a managed cost that the program needs to plan for.
- The project should have a development environment that supports transparency of the activities of the development teams to the customer. Maximal automation of reporting is the norm for commercial development and should be for DoD programs as well.
- The program should include engaged test and certification communities who are deeply involved in the early stages (i.e., who have “shifted left”) and throughout the development process. Not just checkers at the end of that process. They would help design and validate the use of automation and computer assisted testing/validation tools whenever possible as well.
- Capability should also be delivered in small pieces on a continuing basis – as frequently as every two weeks for many types of software (see the DIB’s Guide to Agile BS).

The cost of a program always depends on the scale of the solution being pursued, but in an agile DevSecOps project, the cost should track to units of 5-11 person cross-functional team (team leader, developers, testers, product owners, etc.) with approximately 6-11 teams making up a project. If the problem is bigger than that, the overall project could be divided up into related groups of teams. A reliance on direct interaction between people is another central element of Agile and DevSecOps; the communication overhead means that this approach loses effectiveness with too many people in a team (typically 5-11 cross-functional members). Also, groups of teams have difficulty scaling interactions when the number of teams gets too large (less than twelve). A team-of-teams approach will allow scaling to fit the overall scope. Organizing the teams is also a valuable strategy where higher-level development strategies and system architectures get worked out and the lower level teams are organized around cross-domain capabilities to be delivered. Cost incentives for utilizing enterprise software platform assets should be so attractive, and the quality of that environment so valuable, that no program manager would reasonably decide to have his/her contractor build their own.

Here are some general guidelines for project costs when pursuing a DevSecOps approach:

- Create: deliver initial useful capability *to the field* within 3-6 months (the use of commodity hardware and rapid delivery to deployment). If this cannot be achieved, it should be made clear that the project is at risk of not delivering and is subject to being canceled. Outcomes and indicators need to be examined for systematic issues and opportunities to correct problems. Initial investment should be limited in two ways: 1) in size to limit financial exposure and 2) in time to no more than 1 year.

- Scale: deliver increased functionality across an expanding user base at decreasing unit cost with increased speed. Investment should be based on the rate limiting factors of time and talent, not cost. Given a delivery cycle and the availability talent, the program should project only spending to the staffing level within a cycle.

- Good agile management is not about money, it is about regular and repeated deliver. That is to say, it is about time boxing everything. Releases, staffing, budget, etc. Nick, strongly recommend that you rework this to reflect time boxing as the most important aspect of "defending your agile budget.

- Optimize: deliver increased functionality fixed or decreasing unit cost (for a roughly constant user base). Investment limit should be less than 3 project team sets[16].

What are the types of metrics that should be provided for assessing the cost of a proposed software program and the performance of an ongoing software program?

Assessing the cost of a proposed software program has always been difficult, but can be accomplished by starting one or more set of project teams at a modest budget (1-6 sets of teams) and then adjusting the scaling of additional teams (and therefore the budget) based on the value those teams provide to the end user. It may be necessary to identify the size of the initial team required to deliver the desired functions at a reasonable pace and then price the program as the number of teams scales up. The DIB recommends that program managers start small, iterate quickly, and terminate early. The supervisors of program managers (e.g., PEOs) should also reward aggressive early action to shift away from efforts that are not panning out into new initiatives that are likely to deliver higher value. Justifying a small budget and getting something delivered quickly is the best way to provide value (and the easiest way to get and stay funded).

The primary metric for an *ongoing* program should be user satisfaction and operational impact. This can be different for every program and heavily depends on the context. The challenge, and therefore responsibility of the PM then is to define mission relevant metrics to determine achieved and delivered value. Examples could include, personnel hours saved, number of objects tracked or targeted, accuracy of the targeting solution, time to first viable targeting solution, number of sorties generated per time increment, number of ISR sensors integrated, etc. Other key metrics that are often advocated by agile programs (inside and outside of DoD) include:

- *deployment frequency* (Is the program getting increments of functionality out into operations?),
- *lead time* (how quickly can the program get code into operation?),
- *mean time to recover* (how quickly can the program roll back to a working version, if problems are found in operation?), and
- *change fail rate* (rate of failures in delivered code).

[16] Average of 8 people per team with an average of 8 teams per project.

These four break down into two process metrics (release cadence and time from code-commit to release candidate, and two are quality metrics (change fail rate and time to roll back). In addition, each project should also have 3-5 key value metrics that are topical to the solution space being addressed. Metrics must be available both to the teams and the customer so they can see how their progress compares to the projected completion rate for delivering useful functionality. A key reason for Government access to those metrics is for supporting the real-time tracking of progress and prediction of new activities in the future. The biggest difference between a DevSecOps program and the classic spiral approach is that the cadence of information transparency between the developers and the customer is, at slowest, weekly, but if properly automated, should be instantly and continuously available.. Quality metrics and discovery timelines (such as defects identified early in development versus bugs identified in the field) can also be used to evaluate the maturity of a program. This kind of oversight enables fast and effective feedback before the teams end up in extremis, or set up unrealistic expectations.

Software projects should be thought of as a fixed cadence of useful capability delivery where the “backlog” of activities are managed to fit the “velocity” of development teams as they respond to evolving user needs. Data collected on developers inside of the software development infrastructure can be provided continuously, instead of packaged into deliverables that cannot be directly analyzed for concerns and risks.

The DIB’s Metrics for Software Development provide a set of metrics for monitoring performance:

1. Time from program launch to deployment of simplest useful functionality.
2. Time to field high priority functions (spec → ops) or fix newly found security holes
3. Time from code committed to code in use
4. Time required for regression tests (automated) and cybersecurity audit/penetration tests
5. Time required to restore service after outage
6. Automated test coverage of specs/code
7. Number of bugs caught in testing vs field use
8. Change failure rate (rollback deployed code)
9. Percentage of code available to DOD for inspection/rebuild
10. Complexity metrics
11. Development plan/environment metrics

These data provide management flexibility since data about implementation of capability can be made *during* development – instead of at a major milestone review or after “final” delivery, when changing direction comes at much higher cost and schedule impact. So data collection and delivery must be continuous as well. Another note, these metrics are recommendations and not intended to be prescriptive. Use what fits your program. Not all of these may be required.

An additional pair of overarching key metrics are headcount and expert talent available. If the project headcount is growing, but delays are increasing,, aggressive management attention is called for. The lack of expert talent also increases risks of failure.

How can a program defend its budget if the requirements are not fixed years in advance, or are constantly changing?

It is relatively easy to defend changing capability by making changes to the software of existing systems, as compared to starting up a new acquisition. Software must evolve with the evolving needs of the customers. This is often the most cost effective and rapid way to respond to new requirements and a changing threat landscape. A new approach to funding the natural activities of continuous engineering and DevSecOps requires a system that can prioritize new features and manage these activities as dependent and tightly aligned in time (see Figure 1). A continuous deployment approach is needed for delivering on the evolving needs culled from user involvement combining R&D, O&M, Procurement, and Sustainment actions within weeks of each other, not years (see Figure 2). Great software development is an iterative process between developers and users that see the results of the interaction in new capability that is rapidly put in their hands for operational use.

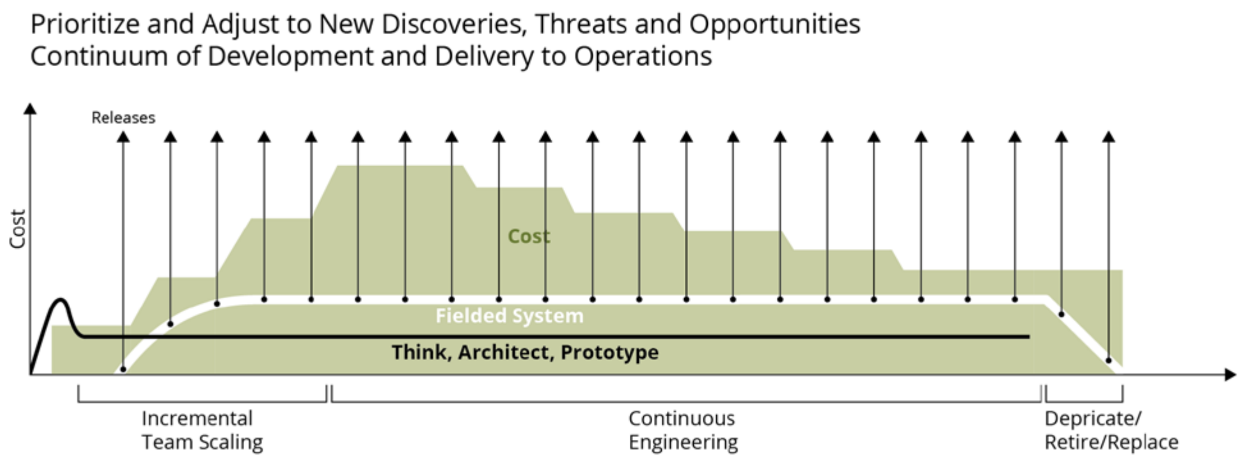


Figure 2. Continuous Deployment of Modular Changes to Working Software (Carnegie Mellon University, Software Engineering Institute).

Elements to address include in budget justification and management materials:

- DevSecOps programs have to be at least as valuable and urgent to fund as a classic DoD spiral program in the hyper-competitive budget environment. Over time, DoD will realize that the DevSecOps approach is inherently more valuable. However, time is of the essence. It must be acknowledged that the current waterfall approach is no longer serving us well in the area of software. The mainstream software industry has already made the move to agile ten years ago and the methods are rigorously practices and proven valuable.
- The classic approach of doing cost estimates of designs based on fixed requirements has always been wrong, even when accounting for intended capability growth because the smart adversaries get a continuous vote on the threat environment. Accurate prediction of a rapidly changing technology environment and solution methods only exacerbate the unknowns of product development outcomes.

- DevSecOps programs have requirements, but start out at a higher level and use a disciplined approach to continuously change and deliver greater value.
- DIB's "Ten Commandments of Software" calls for the use of shared infrastructure and continuous deployment, which will reduce the cost of infrastructure and overhead, thus freeing up capital to advance unique military capability.
- Data available above the program manager's level has been insufficient for cost and program evaluation communities to assess software projects. However, the reporting of metrics that are a natural consequence of using DevSecOps approaches should be automated to provide transparency and rapid feedback.

The benefits of this approach are manifold. It allows for thoughtful rigor up front and early and the rapid abandonment of marginal or failure-prone approaches early in the design cycle before large investments are sunk. Details are allowed to evolve. More stable chunks of capability are defined at the "epic" level and a stable cadence of engineering and design pervades the life cycle. Under this operational concept, testing is performed early, during the architecture definition stage and continuously as new small deployments of functionality are delivered to the user. The identification of budget is redistributed as value is provided and validated for warfighting impact. A closer alignment of flexible requirements and budget allocation/ appropriation will be necessary in order to ensure that the national defense needs and financial constraints are continuously managed.

Continuous access to design and delivery metrics will illuminate developer effectiveness, user delight, and the pace of delivery for working code to include analytical data for in-stride oversight and user/programmatic involvement This will replace the standard practice of document-based deliverables and time-late data packages that take months to develop and are not current when provided.

The way that DoD has classically managed these activities is to break them up into different "colors of money" associated with hardware-centric phases (see Figure 3). This places an artificial burden on excellence in software. Rapid and continuous delivery of working code requires addressing these different types of requirements within shorter time-horizons than is natural for the existing federal budgeting process.

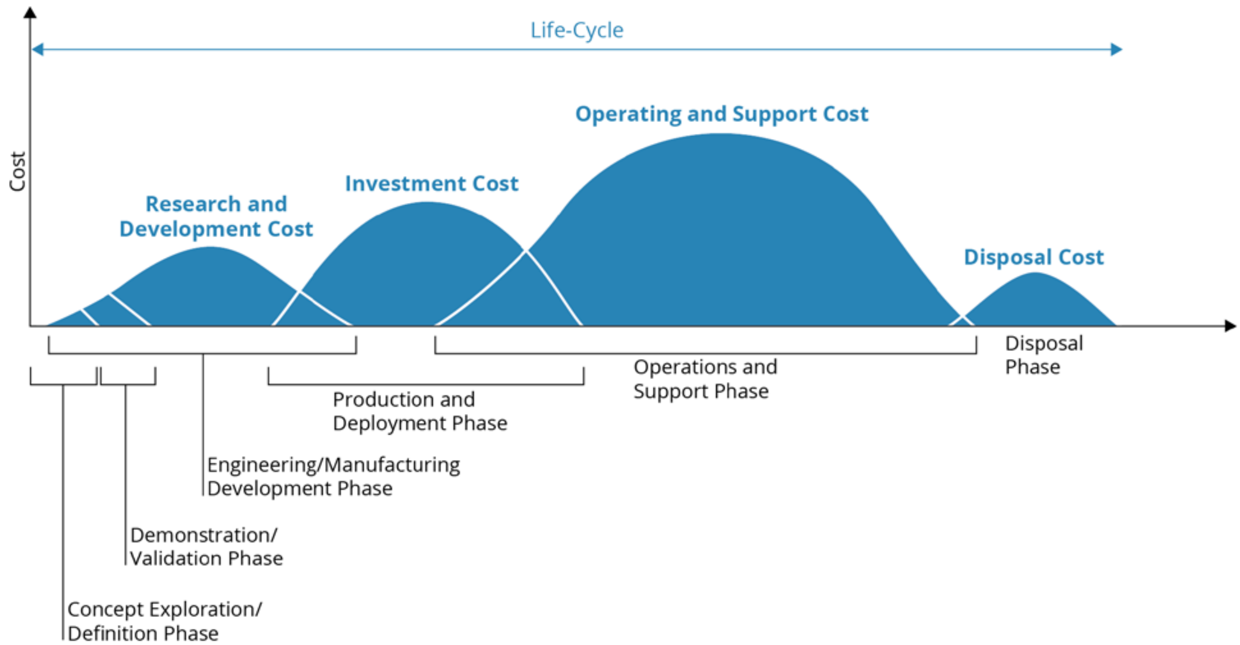


Figure 3. Notional DoD Weapon System Cost Profile (Defense Acquisition University).

In addition, the classic approach of developing detailed technical requirements far in advance of performing product design needs to be replaced. The new paradigm must begin with an architecture that will support the requirements and scale associated with needs for future compatibility (e.g. modularity security, or interoperability). Also, using an agile approach, a program can incorporate the best available technologies and methods throughout the entire life cycle and avoid a development cycle is longer than the useful life of the technology it is built on. Getting these things wrong is not recoverable. Establishing detailed requirements over a period of years before beginning, to be followed by long development efforts punctuated by major design reviews (i.e. Software Requirements Review, Preliminary Design Review, Critical Design Review, Test Readiness Review, Production Readiness Review) that require a span of years between events are inherently problematic for software projects for at least two reasons. First, these review events are designed around hardware development spirals that are time-late and provide little in the way of in-stride knowledge of software coding activities that can be used to aid in real-time decision making. Second, development teams are in frequent contact with users and adjusting requirements as they go, which up-ends the value of major design reviews that are out of cadence with the development teams. DevSecOps implementation methods such as feature demonstrations and cycle planning events provide much more frequent and valuable information on which program offices can engage to make sure the best value is being created.

Defending a budget has to be done in terms of providing value. Different programs value different things – increasing performance, reducing cost, minimizing number of humans-in-the-loop – so there is no one size fits all measure. But in an agile environment, knowing what to measure to show value is possible because of the tight connection to the user/warfighter. Those users are able to see the value they need because they are able to evaluate and have an impact on the working software. This highlights the need to collect and share the measures that show improvement against a baseline in smaller increments.

How do we do cost for "sustainment" when we are adding new features?

The first step is to eliminate the concept of sustaining a fixed base of performance. Software can no longer be thought of as a fixed hardware product like a radar, a bomb, or a tank. That leads to orphaned deployments that need unique sustainment and a growth of spending that does not deliver new functionality (see Figure 4).

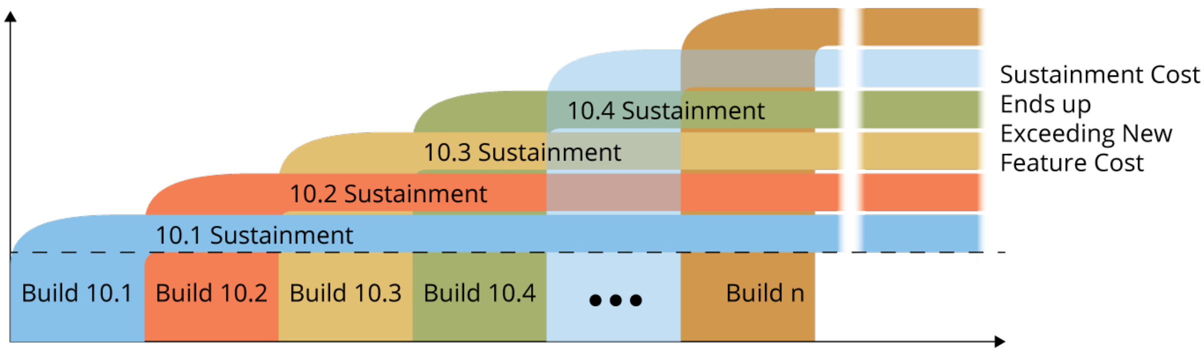


Figure 4. Layers of Sustainment to Manage Unique Deployments

Software can continue to evolve and be redeployed for comparatively little cost (see Figure 2). Users continue to need and demand greater performance and improved features, if for no other reason than to retain parity with warfighting threats. Also internal vulnerabilities and environmental updates must be continuously deployed to support ever improving cyber protections. The most secure software is the one that is most recently updated. Lastly, new capabilities for improved warfighting advantage are most often affordably delivered through changes to fielded products.

Software development is a very different way of delivering military capability. It should be considered more like a service of evolving performance. When new features are needed, they get put in the backlog, prioritized, and scheduled for a release cycle (see Figure 5). If the program is closer to providing satisfactory overall performance, then the program can dial down to the minimum level needed to satisfy the users and keep the environment and applications cyber-secure. It can be thought of as recursive decisions on how many (software) "squadrons" are required for our current mission set and then fund those teams at the needed staffing level to create, scale, or optimize the software (depending on the stage of continuous development). Because these patterns can be scaled up and down by need in a well-orchestrated way, new contracting models are available that might not have been used in the past. For example, fixed price contracts for a development program was strongly discouraged, but under this model, where schedule and team sizes are managed and capability is grown according to a rigorous plan (Figure 1), a wider array of business, contracting and remuneration models can be explored.

Figure 5. Release Cycle With New Opportunities, Discoveries and Response to Threats (Carnegie Mellon University, Software Engineering Institute).

Two financial protections built into acquisition laws and regulations need to be reexamined in the light of software being continuously engineered, vice sustained: Nunn-McCurdy and the Anti-Deficiency Act. The continuous engineering pipeline will continue to push out improved capability until the code base is retired. While Nunn-McCurdy is a valid constraint for large hardware acquisitions, it does not apply to software efforts. In a similar vein, software should also never trigger the Anti-Deficiency Act - just like keeping a ship full of fuel, or paying for air-traffic controllers; we know we are going to be doing these things for a long time. To build a ship that will need fuel for 40 years does not invoke the ADA. Therefore, starting a software project that will incrementally deliver new functionality for the foreseeable future should not do so either.

Why is ESLOC a bad metric to use for cost assessment?

The thing we really want to estimate and then measure is the effort required to develop, integrate, and test the warfighting capability that is delivered by software. SLOC might have been a used as a surrogate for estimating the effort required, but it has never been accurate. Not all software is the same, not all developers are the same, and not all development challenges use the same approaches to reduce problems into solutions. For example, in a project there may things like detailed algorithms that require deep expertise and detailed study to properly implement small amounts of code, running alongside large volumes of automatically generated code of relatively trivial complexity. Many different levels of effort are needed to create a line of code that will deliver military capability, and estimations of source code volume is an inherently problematic and error-filled approach to describing the capability thus produced. That's why DevSecOps efforts use measures of relative effort like story points to communicate across a particular set of teams how much effort it will take to turn a requirement into working software that meets an agreed upon definition of done within a set cadence of activity. Because these story points are particular to a specific team, they do not accurately transition to generally prescribable measures of cost.

Estimating by projecting the lines of code starts the effort from the end and works backwards. SLOC is an output metric (something to know when the job is done – akin to predicting what size clothing your child will wear as an adult). It does not capture the human scale of effort. Traditional models like COCOMO or SEER attempt to use a variety of parameters in their models to capture things like formality, volatility, team capabilities, maturity and others.

However, these surrogates for effort have well documented error sources and have failed time and again to accurately capture the cost of executing a software program. There are also inherent assumptions built into these models that are obviated by performing agile development of capability models running on a software platform.

In the beginning stages of the DoD's transformation to DevSecOps methods, the development and operations community will need to work closely with the cost community to derive new ways of predicting how fast capability can be achieved. For example, estimating how many teams worth of effort will be needed to invest in a given period of time to get the functionality needed. As they do this, it needs to be with the understanding that the methods are constantly changing and the estimation methods will have to evolve too. New parameters are needed, and more will be discovered and evolve over time.

Appendix F: SWAP Working Group Reports

v1.0, 19 Mar 2019

The information in this appendix was developed based on feedback and analysis performed by members of a working group that included subject matter experts (SMEs) within the Department who provided input for consideration to the SWAP study. The working group was asked to: (1) distill the feedback received from case studies, interviews, literature reviews, and feedback from the Board members into main issue points; (2) as SMEs identify the statutory, regulatory, and cultural obstacles to achieving the Board's vision for a desired end state; and (3) provide suggested language to remove the barriers.

Subgroup reports:

- Acquisition Strategy
- Appropriations
- Contracting
- Data and Metrics
- Infrastructure
- Requirements
- Security Accreditation/Certification
- Sustainment and Maintenance
- Test and Evaluation
- Workforce

Appendix F.1: Acquisition Strategy Subgroup Report

This appendix examines pain points, obstacles, change ideas, and future vision for the Defense Innovation Board (DIB) Software Acquisition and Practices (SWAP) Study in the area of Acquisition Strategy and Oversight (i.e., *Acquisition Environment*). In 2017 the Office of the DASD(C3CB) under the ASD(A) commissioned an IT acquisition study with Deloitte. The study recommended the following attributes of an effective and efficient IT acquisition structure:

- *Fast* to incorporate current technology and make efficient use of Agency resources
- *Flexible* and adaptable to support rapid changes in technology and input from stakeholders about capability needs
- *Collaborative* to seek stakeholder involvement and input to be incorporated throughout

In a previous study completed in September 2016, Deloitte also provided key findings on commercial IT practices. Findings were taken into consideration when forming the proposals following in this appendix. The team recognizes that DoD is falling short of the preferred attributes outlined above with the current IT acquisition structure, in addition to multiple statutory, regulatory, and cultural issues that currently hinder an effective and efficient DoD acquisition environment that would benefit from reform.

Pain points

Acquisition Policy Environment. The DoD lacks a cohesive acquisition policy architecture and robust policy for software acquisition. Existing policies, to include tangential or supplemental policies that are integral to the operation of the defense acquisition system, do not fit well together and result in discrepancies, conflicts, and gaps. The defense acquisition system is monolithic, compiled in pieces as needs arose instead of as an integrated and evolving environment. It has proven unable to keep up with or remain ahead of the pace of change and technological advancements that require speed and agility. While it has regularly been revised, the changes tend to be conservative and incremental, requiring the agreement of too many parties protecting narrow interests and who are reluctant to relinquish authority or evolve. The system remains focused on oversight and situational control rather than insight and trust. The policies, practices, and documents become quickly entrenched and manifest themselves in the form of the Department’s culture, leading to additional bureaucracy and decreased levels of organizational trust, that are difficult to rapidly reverse. Furthermore, the environment is risk averse, seeking out what is perceived to be the “safest” route to get things done, stifling the innovation and risk- taking that’s required to maintain an advantage over adversaries.

As an example, one DoD weapons system program, which is implementing a DevSecOps pipeline to enable agile capability releases, informed us it took 18 months to get approval of a Test and Evaluation Master Plan (TEMP). The process within the TEMP drove them into sequential developmental and operational test - which is antithetical to continuous delivery under the DevSecOps concept.

Governance and Management. The Department lacks a strategic approach that recognizes software's criticality as the backbone and nervous system of the Department's mission and operations, often leading to widespread duplication of capabilities that could be consolidated and scaled at an enterprise level (whether Service-enterprise or OSD-enterprise). This absence of any strategy, compounded by a long-standing lack of organizational trust in the Department, is exemplified by various situations in the software environment. For example, the lack of reciprocity on matters such as security standards, architecture, and compliance methods – my way is "better" (insert "less expensive," "more efficient," "more effective") than your way, or, "our requirements / processes are unique," regardless of validity. Further, the DoD issues separate policies on matters such as cloud, architecture, and risk management, with no unified approach at the strategic level. Management and governance of these matters takes the form of prolific numbers of senior working groups (or equivalent) that make few decisions but have frequent meetings. The DoD's lack of an overarching strategic plan for key technologies, with a robust decision making framework that pushes responsibility and authority down to the lowest executable level, creates inefficiency, duplication, and waste.

Organization and Culture. The DoD lacks an organizational structure with clear responsibility and authority for software acquisition and management; there are confusing roles and responsibilities between DoD CIO, USD(A&S), and the DoD CMO. This state of ambiguity leads to overlap, inefficiency, and unnecessary bureaucracy; and it is replicated at the Service level. The result is a slow, rigid, siloed organization unable to adapt in the present and plan for the future in order to maintain competitive advantage. The DoD is not a change-ready environment and the acquisition system was not designed for rapid change. DoD employees tend to receive change mandates rather than participating in them. A case in point is that when DoD issues a policy, the Services will implement their own supporting version or "supplemental guidance", which expands the policy and introduces multiple layers of bureaucracy, eliminating any semblance of flexibility that was intended by the original policy issued. For example, the Department issued DoD Instruction 5000.75 in February 2018, a tailored requirements and acquisition approach for business systems. Subsequently, the Army produced accompanying implementation guidance – 91 pages – which introduces additional forms, templates, processes, and time constraints.

Desired (end) state An acquisition system that enables rapid delivery of cost-efficient, relevant software capability through the application of creative compliance and fact-based critical thinking under a logical and minimal policy framework. The Department treats software as a national security capability and continuously retrains the workforce to be able to adapt to an ever-changing technology environment, embraces continuous collaboration between user and developers, embraces changing requirements, accepts and take risks, and deliver adversary- countering capabilities to the warfighter. Executing the approach requires an end state with an efficient contracting environment; a culture that rewards informed risk-taking and fast failures; the use of limits or guardrails instead of prescriptive requirements that limit creativity; outcome-based metrics that focus on value vs. execution against a plan; and a move away from traditional funding models and compliance-driven management.

Obstacles The Department operates with a general lack of urgency regarding its software – it is not recognized or treated as a national security capability. There is an aversion to informed risk-taking regarding new and innovative approaches to doing business and adopting emerging (or even simply relevant) technologies, even though it's risky, or riskier, to continue using outdated technologies that are not secure or facing obsolescence in the face of evolving threats. Dramatic changes in policy or process are viewed as risky yet our current ways of operation are not despite a known degradation in strategic advantage previously enjoyed over adversaries. The inability to evolve and support rapid changes in technology and input from stakeholders about capability needs is bred through organizational silos and stovepipes that stifle the collaboration necessary to develop and operationalize software. Further, stakeholder involvement is limited by following restrictive controls, timelines, and processes in a sequential manner that impedes progress and results in a lower state of readiness. The duplication of authorities and responsibilities among organizations both horizontally and vertically, within the defense acquisition system only exacerbates an already complex environment where a protectionist culture is ingrained and the workforce is not incentivized to change. In its endeavors to improve the status quo, “help” from Congress over the past decades translates into entrenched policies, processes, and procedures – “cultural norms” that are difficult to reverse.

Ideas for Change

*Acquisition Policy Environment***.** Define software as a critical national security capability under Section 805 of FY16 NDAA “Use of Alternative Acquisition Paths to Acquire Critical National Security Capabilities”. Create an acquisition policy framework that recognizes that software is ubiquitous and will be part of all acquisition policy models. Recommend the creation of a clear, efficient acquisition path for acquiring non-embedded software capability. Reconcile and resolve discrepancies among supplemental policies that lead to conflicts. Consider the following tenets in development of a reformed software acquisition policy:

- Emphasis on quickly delivering working software
- Encourage projects and pilot efforts that serve to reduce risk and complexity - fail fast
- Reimagine program structures and program offices – i.e., accommodate move to “as-a-service” capabilities, agile, microservices, and micro-applications
- Iterative, incremental development practices based on agile methods
- Rapid adoption of emerging technologies through piloting or prototyping
- Elimination of traditional A, B, C milestones; replaced by more sprint-centric decision points
- Elimination of arbitrary phases or merge phases to reflect rapid, agile development methods
- Tailor in requirements (statutory, regulatory – i.e., documentation) rather than tailor out; start with a minimum set
- No big-bang testing with sequential DT/OT; move to fully integrated test approaches driven by automated testing as well as regular, automated cybersecurity scanning
- Use a “guardrail-based” (upper / lower limit) approach for software requirements rather than defining every requirement up front
- Track value-driven outcome metrics which can be easily and continuously generated rather than measuring execution against a plan

*Governance and Management - Software as an Asset***.** Develop an enterprise-level Strategic Technology Plan that reinforces the concept of software as a national security capability. Include an approach for enterprise-level DevSecOps and other centralized infrastructure development and management, an approach for shared services, and applications management. The plan should recognize how disruptive technologies will be introduced into the environment on an ongoing basis. Ensure appropriate integration of a data strategy and the Department's Cloud Strategy. Examine a Steering Committee approach for management.

*Organization and Culture Reform***.** Examine roles and responsibilities with the intent to streamline reconcile, and resolve discrepancies for software acquisition and management among the DoD CIO, the USD(A&S) and the CMO. Re-focus the software acquisition workforce on teaming and collaboration, agility, improved role definition, career path advancement methods, continuing education and training opportunities, incentivization, and empowerment. Involve them in the change process.

Appendix F.2: Appropriations Subgroup Report

The Department's current Planning, Programming, Budgeting and Execution (PPBE) system framework and process using defined Program Elements (PEs), is categorized by lifecycle-phased appropriations, and requires two years or more in lead time from plan to start of execution. This approach was designed and structured for traditional waterfall acquisition used to deliver monolithic platforms such as aircraft, ships, and vehicles. The PPBE framework and process is challenging when leveraging agile and iterative acquisition methodologies to deliver software-intensive, information-enabling capabilities through a continuous delivery process. The current process limits the ability to quickly adapt systems against rapidly changing threats and increases the barriers for integrating advancements in digital technology in a timely and effective manner.

Pain points and Obstacles

Appropriation methods intended for hardware systems and platforms are not consistent with the speed and technology pace of modern software and how it is successfully acquired and deployed. DoD continues to acquire and fund information-centric systems using processes designed for hardware-centric platforms. Current funding decision processes and data structures do not effectively support leading software development practices. As a result, the DoD is not effective in leveraging and adapting at the pace of innovation seen in industry. Differentiating continuous iteration and continuous delivery of software workload into hardware-defined phases (Research, Development, Test & Evaluation (RDT&E), Procurement, or Operations and Maintenance (O&M)) is meaningless in a world view where software is never done - not because planned work isn't accomplished but because modern methods allow a project to continuously improve, adapt to evolving threats, and take advantage of rapid technology advances. There should be no final fielding or sustainment element in continuous engineering. System defined program elements hinder the ability to deliver holistic capabilities and services and do not enable real-time resource, requirements, performance, and schedule trades across systems without significant work.

Establishing a culture of experimentation, adaptation and risk-taking is difficult. The Department requires a process that supports early adoption of the most modern information-centric technologies and enables continuous process improvement. The Deputy Secretary of Defense directed aggressive steps "…to ensure we are employing emerging technologies to meet warfighter needs; and to increase speed and agility in technology development and procurement." The current cycle of planning, budgeting, and executing across appropriation categories slows acquisition, development, and execution to a pace that is not sustainable for mission success.

Example. An Information & Technology project using an agile approach to continuous development and integration may still require funding from more than one appropriation. The underlying purpose of each discrete task within the software system determines the correct appropriation for budgeting of that task. This drives significant complexities into the program management, budgeting, review, and oversight of every software-intensive system, and causes insufferable delays in funding awards and delivery of continuous improvements.

Desired state. The desired state for the Department would be one in which continuous capability deployment throughout a software program's lifecycle is possible, and the lengthy two-plus year lead times for programming and budgeting is removed. This would provide flexibility to execute desired features with the speed and agility necessary to meet the rapid changes in threats, information technologies, processes, and services. The single appropriation across the lifecycle of a capability will enable continuous development, security, and operations (DevSecOps); allow for minimum viable product delivery at a relevant speed; support the use of managed (or cross PoR/enterprise) services; provide for greater transparency for information-centric capabilities; and provide the flexibility to pursue the most effective solution available at the time of acquisition without current restrictions of appropriations.

Ideas for change. *A new multi-year appropriation for Digital Technology needs to be established for each Military Defense Department and the Fourth Estate.* This appropriation fund would provide a single two-year appropriation for the lifecycle management of software-intensive and infrastructure-technology capabilities. This could be a stand-alone appropriation, or fall under the umbrella of an already established appropriation, with the appropriate caveats that allow it to behave as the single source of funding across the lifecycle. The Department would seek to couple this new appropriation with the movement to a capability or service portfolio management construct. A project framework within each capability PE (i.e., logistics or intelligence) would represent the systems and key investments supporting the delivery of information-centric capabilities such as data conditioning and process reengineering. Capability portfolio management would better enable agile/iterative force development and management decisions to include realignment of resources from one system to another system or process reengineering effort within the portfolio to increase the velocity of minimum viable product output and overall capability delivery. PPBE decision making would be adjusted to allow for less detail in the programming process and greater specificity in the budgeting process – as close to execution as possible – to realize the benefits of agile/iterative development.

- The Components will program, budget, and execute for information and technology capabilities from one appropriation throughout the lifecycle rather than using RDT&E, procurement, or O&M appropriations, which are often applied inconsistently and inaccurately. This will allow for continuous engineering.
- Within each Component-unique Budget Activity (BA), Budget Line Items (BLINs) align by functional or operational portfolios. The BLINs may be further broken into specific projects to provide an even greater level of fidelity. These projects would represent key systems and supporting activities, such as mission engineering.
- By taking a portfolio approach for obtaining software intensive capabilities, the Components can better manage the range of requirements, balance priorities, and develop portfolio approaches to enable the transition of data to information in their own portfolios and data integration across portfolios to achieve mission effects, optimize the

value of cloud technology, and leverage and transition to the concept of acquisition of whole data services vice individual systems.

- This fund will be apportioned to each of the Military Departments and OSD for Fourth Estate execution.
- Governance: management execution, performance assessment, and reporting would be aligned to the portfolio framework—BA, BLI, project.

Appendix F.3: Contracting Subgroup Report

The contacting challenges faced by the DoD today are almost entirely cultural. This premise is asserted by instances of excellence throughout the Department where effective contracting methods have been executed (DDS, DIU, Kessel Run).

That said, rather than attempting to battle each cultural challenge as they arise, it is easier to create a new modern acquisition platform from which to execute contracts that starts from a point of “how should it be done” as a product of “what should we be buying”.

The historical acquisition system was created to prevent fraud. The new priority is to establish technical superiority over our adversaries. While the prevention of fraud continues to be, and always will be, important, as a singular priority it serves to undermine the current identified need of speed and efficiency, which results in technical excellence for the Department.

Pain Points

Individual contracts are subject to review processes designed for large programs (of which they are likely enabling). This limits the agility of individual contract actions, even when modular contracting approaches are applied. In addition, the acquisition process is rigid and revolves around templates, boards, and checklists thus limiting the ability for innovation and streamlining execution.

Contracts focus on technical requirements instead of contractual process requirements. The contract should address overall scope (required capability), Period of Performance and price. The technical execution requirements should be separate and managed by the product owner or other technical lead.

Intellectual Property (IP) rights are often genetically incorporated without considering the layers of technology often applied to a solution. A single solution might include open source, proprietary software, and government custom code. The IP clauses should reflect all of the technology used.

Desired state

The desired state is an acquisition model that is liberated from the decades of policy and regulations that singularly focus on fraud prevention and provides for efficiency allowing the DoD to keep pace with the private sector and adversaries. This can be accomplished through a new authority Congress establishes a separate *new* authority for contracting for software development and IT modernization.

Obstacles

- Requires act of Congress ⇒ work with Armed Service Committees Staffers
- There is no infrastructure to support this ⇒ establish policy for guidance

- There are no Contracting Officers with specific certifications ⇒ Leverage current certifications
- Could cause confusion on implementation (what applies, what doesn't) ⇒ A&S issues guidance

Ideas for change

Congress establishes a separate *new* authority for contracting for software development and IT modernization

To address "Individual contracts being subject to review processes designed for large programs":

- Treat procurements as investments "what would you pay for a possible initial capability" (cultural).
- Manage programs at budget levels, allow programs to allocate funds at a project investment level (policy).
- Work with appropriators to establish working capital funds so that there is not pressure to spend funds quicker then you're ready (iterative contracts may produce more value with less money) (statute).
- Leverage incentives to make smaller purchases to take advantage of simplified acquisition procedures (cultural).
- Revise estimation models - source lines of code are irrelevant to future development efforts, estimations should be based on the team size, capability delivered, and investment focused (cultural).
- Allow for documentation and reporting substitutions to improve agility (agile reporting vs EVM) (cultural and EVM policy).
- Provide training to contracting officers, program managers, and leadership to understand the value and methods associated with agile and modular implementation (cultural).

To address "*Contracts focus on technical requirements instead of contractual process requirements*":

- Separate contract requirements (scope, PoP, and price) from technical requirements (backlog, roadmap, and stories) (cultural).
- Use statement of objectives (SOO) vs statement of work (SOW) to allow the vendor to solve the objectives how they are best suited (cultural).

- Use collaborative tools and libraries so that all content is available to all parties at all times (cultural).
- Use an agile process to manage structure and technical requirements (cultural).
- Establish a clear definition of done for the end of a sprint (code coverage, defect rate, user acceptance) (cultural).
- Use modular contracting to allow for regular investment decisions based on realized value (cultural).
- Streamline acquisition processes to allow for replacing poor performing contractors (cultural).
- Provide training to contracting officers, program managers, and leadership to understand the value and methods associated with agile and modular implementation (cultural).

To address "*Intellectual Property (IP) rights which are often genetically incorporated without considering the layers of technology often applied to a solution*":

- Establish clear and intuitive guidelines on how and when to apply existing clauses (cultural).
- Educate program managers and contracting officers on open source, proprietary, and government funded code (cultural).
- Have standard clause applications for each of the above that must be excepted vs accepted (cultural).

Appendix F.4: Data and Metrics Subgroup Report

The Department of Defense (DoD) has long standing methods for capturing data, developing metrics, and reporting program progress, however these practices do more to obfuscate than provide insight when it comes to software and stand in the way of more effective methods. The DoD's approach to data and metrics is fundamentally intertwined with its governance and compliance culture, which centers around reporting on individual programs to inform specific decisions by senior leaders and the Congress. Attempts to change DoD's data and metrics methods must therefore also address this culture and, critically, link with other reform efforts including policy, tools for the software development environment, and overall approaches to governance and investment.

Note: in the context of this appendix, data refers to` information associated with the development, maintenance, enhancement, and performance of software systems, not the substantive data that they process or generate.

Pain points

Multiple, competing, and sometimes conflicting types of acquisition/management data and metrics are used for divergent purposes in the assessment of software in DoD. DoD has long standing practices to collect data on programs: primarily cost, schedule, and performance. These data are imperfect and do not necessarily reflect the health of software in any way but are important, particularly for satisfying existing reporting requirements. These data must be improved and linked with data and metrics focused on assessing the health of software activities. Doing so will potentially cause bureaucratic confusion and competition.

Challenges collecting meaningful data, in a low cost manner, at scale. To the extent that DoD currently collects data on its software activities, it does so through the manual entry of reporting data in separate and disparate reporting/management systems. This approach is prone to errors and incredibly time-consuming and burdensome to program offices. DoD components responsible for developing and maintaining the systems reporting information have few incentives to share such data, as they are often used against them, meaning that the data are hard to capture, include mistakes, and no constituency wants to invest in systems to automate data collection.

Inability to turn data into meaningful analysis and inability to implement decisions or changes to software activities. Even if DoD had clarity on its use of data and the ability to collect those data passively and at scale, it may not be able to meaningfully change the outcomes of its software activities and could become caught in a Cassandra predicament. The culture of decision making, acquisition policy, contracting, formality of requirements, appropriations rules and oversight mean that data driven insights do not naturally translate into improved decision making on DoD software activities.

Desired state

An operational system and culture that makes policy, investment, and program decisions based on insight and analysis developed in a transparent manner from standardized data collected automatically from software development tools.

Obstacles

The Department, in most but not all instances, does not possess the tools or analysts to achieve the desired state. Those are addressable challenges. The bigger obstacle is the culture of high level reporting, driven from Congress and OSD, on individual programs on a period basis, for example congressionally mandated annual Selected Acquisition Reports (SARs), and in turn, Defense Acquisition Executive Summary (DAES) reports that inform OSD quarterly of the same information. This approach means that data are not strategically collected at the level that allows for real insight and longitudinal analysis, instead they are developed at a summary level to minimally meet requirements and avoid further scrutiny. Most importantly, they do not provide the real-time tools to enable a software program manager to manage her program.

While there are few legislative barriers to implementing the desired state, Congressional action may be required to create the right incentives for the DoD to generate, capture, and use data in useful ways. Congress should also address its own oversight culture, which can sometimes drive much of the behavior the Congress dislikes.

Ideas for change

- Congress could establish, via an NDAA provision, new data-driven methods for governance of software development, maintenance, and performance.[17] The new approach should require on demand access to standard data with reviews occurring on a standard calendar, rather than the current approach of manually developed, periodic reports.
- DoD must establish the data sources, methods, and metrics required for better analysis, insight, and subsequent management of software development activities. This action does not require Congressional action but will likely stall without external intervention and may require explicit and specific Congressional requirements to strategically collect, access, and share data for analysis and decision making.
- Key steps for implementation:
    - Identification of existing definitive data sources (e.g. DAVE, FPDS[18]);
    - Establishment of robust data crosswalks to analyze data across systems and use cases;

[17] Congress could build on Secs 911-913 of FY2018 NDAA
[18] Defense Acquisition Visibility Environment (DAVE) https://dave.acq.osd.mil/; Federal Procurement Data System (FPDS) https://www.fpds.gov/

- Identification and mitigation of any significant gaps in existing data, with priority placed on building out functionality from existing applications where possible;
- Establishment of mechanisms to ensure data sharing and transparency (i.e. require all components to share their data);
- Disambiguation of roles and responsibilities, e.g. OSD = policy/governance ≠ program review. Components = execution;
- Linking data and metrics to governance and policy analysis and decision making.

Appendix F.5: Infrastructure Working Group Report

Despite several years of effort to “move DoD to the cloud,” significant friction still exists for the DoD to easily leverage the required compute, storage, and bandwidth infrastructure that the commercial world so readily enjoys. The major obstacle is not at all technical, but is broadly one of accessibility: the ability to specify, contract for, pay for, connect to, secure, and continuously monitor sufficient modern computing infrastructure. Modern computing infrastructure refers primarily to cloud-based computing technologies and stacks. “Cloud-based” does not necessarily presuppose commercial cloud, but could also be on premises or hybrid cloud solutions. Similarly, “computing technologies and stacks” can run the full spectrum from infrastructure, to platform, to function, to software as a Service (IaaS, PaaS, FaaS, SaaS).

Pain Points and Obstacles

How much cloud do I need? Countless developers and IT professionals have wrestled with this question, and often the answer is to “dive in,” move some apps, see what is needed, and then scale and tweak from there. The Department’s culture hampers our ability to even take a “leap of faith” like this. We must be able to precisely size and cost our cloud requirements before ever starting to experiment or prototype. It should become more clear why this analysis paralysis exists as the below pain points are outlined and considered.

How do I buy cloud? Oh, just head on over to FedRAMP, pick an approved provider, sign up and you’re on your way… FedRAMP? Is that a cloud? What about GovCloud, cloud.gov (not the same thing by the way), and MilCloud (is that version 1.0 or 2.0?)? What’s the difference between AWS GovCloud and Azure Government? Can I just sign up with a credit card like a normal private citizen and start hosting my compute and data in the cloud? Sadly, the answer is a definitive and resounding NO! Even if you know which “government-approved” cloud you’re moving to, it’s just not easy to contract for it or buy it.

There is not space here to answer all these rhetorical questions. For a good description of the difficulty of buying cloud, please refer to the DoD Cloud Acquisition Guidebook at https://www.dau.mil/tools/t/DoD-Cloud-Acquisition-Guidebook. Here the Defense Acquisition University (DAU) outlines the multiple activities that need to be accomplished to contract for cloud services. Starting with the dreaded IT Business Case Analysis (BCA), moving on to applying the DoD Cloud Security Requirements Guide (SRG - more on this soon), to getting an Authority to Operate (ATO), ensuring DISA approves of your Boundary Cloud Access Point (BCAP) and your Cyber Security Service Provider (CCSSP), and lastly to applying the DFARS supplementary rule to your cloud contact. No friction here right?

How do I know my cloud is secure? Easy. FedRAMP pre-evaluates and approves Cloud Service Providers (CSSPs) for Information Impact Levels (IILs) 2, 4, 5, and 6 (don’t ask about levels 1 and 3; apparently we over specified and they aren’t necessary any longer). Whew, now things are making sense… Not so fast, the FedRAMP IILs are for US Government cloud use, but not DoD![19] We need FedRAMP+ for DoD use, and DISA doesn’t evaluate Cloud Service

[19] Don’t ask… we know DoD is part of the US Government.

Providers (CSPs), only Cloud Service Offerings (CSOs). Huh? Be sure to go through the DoD Cloud Computing SRG, ensure those extra security controls are in place for FedRAMP+, and you're on your way. Again, not so fast Program Manager (or small business owner)! How are you and your customers going to access the fancy new cloud you just finally got on contract?

How do I access my cloud? The cloud, sort of by definition, implies ease of access, right? The National Institute of Standards and Technology (NIST) definition in SP 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." Well, if you're a DoD user, you need to ensure you've got a BCAP in place between your application/service and your users. It's OK and accurate to immediately envision bottleneck and single point of failure here.[20] Mis-configuring and under-provisioning BCAPs is the norm rather than the exception, so even with all that compute and storage in the cloud that you somehow ran the contracting gauntlet to get, you're going to severely lack adequate bandwidth and likely suffer from significant latency. Friction++.

How do I pay for cloud? The best part of cloud computing is that I can only pay for what I use. A true consumption-based cost model. Just like a utility. Not so for Government and DoD though. The Anti-Deficiency Act doesn't allow us to pay for cloud computing like a utility. A common way around this is to pay a third party contractor to buy the cloud service for us. This results in a situation where we estimate the highest charges we could ever incur in a year, add a bit of padding to that (say 20-30%), pay the third party, and we've paid for our cloud. What happens if we don't use it all up by the end of the year? Nothing (i.e. no refunds). Money spent. The third party contractor makes (quite?) a bit of extra profit for "taking the risk off the government." So much for consumption-based payments.

Desired State

The ability to provision, pay for, consume, access, and monitor cloud computing (compute, storage, and bandwidth) the same way any commercial organization does. It is understood that there are unique DoD security requirements, but that should only affect cloud pricing (say 1.5 to 2 times commercial, worst case), and not any of the other procedures to easily access cloud computing technologies and resources.

Obstacles

Significant obstacles remain to easily leverage commercially equivalent compute, storage, and bandwidth infrastructure. Contracting, security procedures (not necessarily requirements), network access (i.e. a modern technological approach to BCAP), and billing all loom large. The most important of these is the DoD's inability to contract and pay for cloud computing on a consumption basis.

[20] There are better ways to do this, like zero trust networks. The commercial world has some really good examples and architectures that don't require this man-in-the-middle attack called a BCAP which actually breaks end-to-end encryption by design…

Ideas for change

Establish a DoD enterprise ability to procure, provision, pay for, and use cloud that is no different from the commercial entry points for cloud computing. The Joint Enterprise Defense Infrastructure (JEDI) Cloud initiative is a bold attempt at this solution and should be awarded. Cloud.gov (which is ironically hosted in GovCloud) is another promising program that is already very straightforward to provision and buy, but is limited to IIL 2 data and applications. The objective cloud procurement and billing contract must include the ability to truly pay for consumption of cloud services and not be artificially limited by the Anti-Deficiency Act. Modern software demands the ability to consume and pay for cloud services just as we do any other utility.

In addition to this, the DoD should establish a common, enterprise ability to develop software solutions in the “easy-to-acquire-and-provision” cloud that is fully accredited by design of the process, tools, and pipeline. Said another way, the DoD should stop the security accreditation of individual applications, but *should instead invest in accrediting the ability to produce software*. The pipeline, automated tooling, procedures, and operational monitoring and auditing of software should be the focus and target of security accreditation, not each individual application and version of an operating system or application.

Another essential and necessary, though not sufficient, change that must occur is to adopt modern commercial approaches to software and system security in the cloud that does NOT involve BCAPs, Internet Access (choke) Points (IAPs), or CSSPs that cannot be performed entirely by trusted commercial entities. The DoD must adopt modern cloud security approaches such as zero trust networks[21], micro-segmentation, and eliminate the perimeter approach to network security and trust that is based on assigned IP address or network connection point. Perimeter-based security cannot scale to accommodate the bandwidth, traffic, and latency demands of modern cloud access, applications, and services. Furthermore, it is a failed architectural practice that has proven to be readily exploitable by adversaries and is especially vulnerable to insider threats.

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[21] https://www.oreilly.com/library/view/zero-trust-networks/9781491962183/ch01.html

Appendix F.6: Requirements Subgroup Report

The Department of Defense (DoD) in 2003 institutionalized the identification and validation of requirements via the Joint Capability Integration and Development System (JCIDS). Created to support the statutory responsibility of the Joint Requirements Oversight Council (JROC), it is one of three processes (Acquisition, Requirements, and Funding) that support the Defense Acquisition System (DAS). Considered revolutionary in its design, moving DoD from a threat-based to a capability-based model, it has begun to show its age in today's era of software-intensive systems intending to leverage agile software practices. These evolving agile practices upend traditional industrial-age process attempts to credibly and accurately predict a future 15-20 years away, necessitating unimaginable precision and foresight upfront in support to capability development. The requirement process, writ large, must adapt to support delivering capabilities at the speed of relevance; processes, cultures, and expectations of the Service and Joint Force requirement communities.

Pain points

A byproduct of top-level requirement flow down is rigidity and over specificity at the derived requirements level, that greatly hinders agile software design. Capability validated by the JROC does not proscribe requirement allocation to either hardware or software solutions. However, the resulting flowdown of derived requirements incorporated into the source selection/contract award and the subsequent allocation of these between hardware and software by the prime can ultimately discourage software design flexibility. The decisions, often made years before software coding even begins, locks the prime and the government into a proscribed path that often does not produce the desired warfighter capability within the needed time frame. Preserving software design flexibility must be a key component throughout the requirements validation process. "Requirers" will need to learn to settle for "less" not "more" at capability need inception.

Too often exquisite requirements, intended to be 100 percent correct, are levied on a system that in turn drives extensive complex software requirements and design, affecting development, integration, and system test. Today's requirements process more closely mimics the "big-bang" theory often vilified by industry, government, and Congress. As the warfighting community loses faith in the acquisition community's ability to meet their commitments through timely incremental improvements, the temptation to "gold-plate" a requirement becomes more prevalent. Likewise, as the acquisition community is forced to defend shifting warfighter priorities in budget deliberations and Congressional engagements, the temptation to "lock requirements down early" permeates acquisition strategies. With both of these choices in play, exquisite requirements must be described perfectly at capability inception in order to maintain a low-risk acquisition program - obviously an impossible outcome.

Data sets are siloed within programs - a common Law of Requirements is that programs of record (PoR) try to avoid dependencies with other PoRs. By tying SW to a PoR, it becomes nearly impossible to transfer that code across systems and data environments. Data "lakes," "pools," and "ponds" will be the foundation for future weapon system data repositories, and the requirements process must be flexible enough to accommodate this new archetype. Breaking from the past mold of tying software code to a program of record and a specific data environment frees the program manager from the arduous task of integrating seams across multiple PORs.

Example. The Navy operates forward at sea and on-shore at maritime operations centers (MOCs). Command and control between sea and shore is a key aspect of how they fight – they need shared battlespace awareness at aligned actions across distributed units at best. However, the systems afloat and ashore are not always the same because ships need systems that are hardened for combat at sea. If a new algorithm can help manage supply and logistics on the cloud ashore, it may not run the same at sea because different system exists afloat. Extrapolating across Services, the USAF writes an algorithm to optimize F-16 maintenance, however it is highly unlikely that the Navy can pick it up and apply it to F-18s. This depends on the vertical integration of the algorithm, data, and system (PoR).

Desired State. Go from Sailor (Airman, Rifleman, etc)-stated need to software delivery in their hands within days to support future conflicts. This necessitates a process for concept/requirements determination/setting that takes advantage of the agility in software development and software products to increase the agility and modifiability in our systems. Requirements flow down must also maintain a broad-based approach into the lowest levels of design. We also note that one of the overarching agile principles is that “increments are small.” Fast requirements, fast deployments and fast test cycles for usefulness are tough to accomplish with huge, monolithic software projects. Start small, stay small! Finally, recognizing that documenting and contracting for a moving target is not easy but must be done.

Obstacles. Breaking the tyranny of siloed PoRs will require a concerted effort across the Department, Combat Support Agencies, and will require Congressional engagement and support. Considerable cultural barriers must also be overcome as the algorithms themselves become capability, and the methods used to document, validate, and maintain currency enter the mainstream. Complexity and dependencies among multiple elements prevent widespread usage of Family-of-Systems (FoS) and System-of-Systems (SoS) requirement documents. Government requirements and acquisition communities take on extra oversight burden when they take a FoS or SoS approach because they have to manage all the pieces coming together effectively. Lastly, current statutory guidance does not promote, encourage, or reward the use of agile software development practices or environments.

Ideas for Change

- The Joint Staff should consider revising JCIDS guidance to separate functionality that needs high variability from the functionality that deemed “more stable” (e.g., types of signals to analyze vs. allowable space for the antenna). Then implement a “software box” approach for each, one in which the contours of the box are shaped by the functionality variability

- OSD should consider identifying automated software generation areas that can apply to specific domains
- The Joint Staff should consider revising JCIDS guidance to document stable concepts, not speculative ideas.
  - Specifying needed capabilities is important up front, however it must be acknowledged that initial software requirements need to be “just barely good enough” for the situation at hand or, in other words, “document late”
  - Acknowledge that software requirement documents will iterate, iterate, iterate. JCIDS must change from a “one-pass” mentality to a “first of many” model that is inherently agile delegating approval to the lowest possible level
- The DoD should consider instituting a distributed model-based approach to requirements development extended across the enterprise
  - The model should be used to develop result-based metrics for requirement evaluation
- The Joint Staff should consider revising JCIDS guidance to focus on user needs, bypassing the JCIDS process as needed to facilitate rapid software development. Guidance should specifically account for user communities (e.g. Tactical Action Officer (TAO), Maritime Operations Center (MOC) director) that do not have one specific PoR assigned to them, but use multiple systems and data from those systems to be effective
- OSD and the Joint Staff should consider creating “umbrella” software programs around “roles” (e.g. USAF Kessel Run)

Appendix F.7: Security Accreditation/Certification Subgroup Report

The Department's current Security Certification and Accreditation (C&A) process is a complicated and time-consuming process that is measured in months and years. The process is typically seen as a serial process that occurs after development with a checklist mentality. While this fits with a waterfall approach to development, the Department is changing to an agile, DevSecOps approach. The overall security paradigm must change from one where updates to software happen optimistically on a yearly basis to one where software is updated weekly or daily in response to emerging threats and this is recognized as more secure than the slow, static process. Additionally, we must strive to accredit the process, tools, and platforms to allow and enable continuous authority to operate (ATO) when software changes meet the required thresholds.

Pain points

Complex, time-consuming, and misapplied process. Although developing and operating software securely is a primary concern, the means to achieve and demonstrate security is overly complex and hampered by inconsistent and outdated/misapplied policy and implementation practices (e.g. overlaying historical DoD Information Assurance Certification and Accreditation Process (DIACAP) process over Risk Management Framework (RMF) controls for individual pieces of software versus system accreditation). The sense is that the Certification and Accreditation (C&A) process is primarily a "check-the-box" documentary process, adds little value to the overall security of the system, and is likely to overlook flaws in the design, implementation, and the environment in which the software operates.

No way to calculate total costs of C&A process. The Department needs to be able to calculate the true and component costs for implementing the RMF and C&A in order to identify inefficiencies, duplicative capabilities, and redundant or overlapping security products and services that are being acquired or developed. Absent a set of metrics it is difficult to prioritize risk areas, investments, and evaluating risk reduction and return on investment.

Lack of top-down security requirements. The Department has not decomposed security requirements from an enterprise level to a mission level to a functional implementation level. Programs waste resources implementing security controls that should be inherited.

Lack of automation. The C&A process is predominantly a manual process which makes it a very low process. Programs must plan in terms of months and years to get a product through the security accreditation process. This slow process does not provide the warfighter the timely, modern solutions that are needed.

Desired state

Accredit the process, not the product. Done correctly, security is applied from the beginning of software development using automated tools. Before transitioning into operations, an Authorizing Official (AO) reviews the process under which the software was developed and accepts the risk as determined from various scans and tests. The AO signs a Continuous Authority to Operate (ATO) so that as long as the process remains intact and is continuously operationally monitored, the subsequent software releases are accredited.

Obstacles

Two primary obstacles are culture change and workforce skills. The current security culture is that security is a checkbox activity at the end of the development process. As RMF is implemented, this is beginning to change the culture of security from compliance to continuous risk assessment. However, the process is still very manual. The culture change needs to include using automation to speed up risk assessment and continuous risk monitoring of operational software.

The other obstacle is the security and accreditation workforce skill set. While tools can provide reports and speed up security activities like scans and code analysis, it takes a particular skill set to understand those inputs and recommend or make a risk decisions. The current security workforce must be trained in these new skills.

Ideas for change

Embrace DevSecOps. The Department should embrace DevSecOps (not just DevOps) and provide the necessary resources to develop the common software components and automation to assemble, test, accredit, and operate software systems. DevSecOps also includes policy-supported processes, certified libraries, tools, and an operational platform (with appropriately instrumented run-time software), and a toolchain reference to implementation to produce “born secure” software.

Automate, Automate, Automate! The Department needs to provide automated tools and services needed to integrated continuous monitoring with the development lifecycle, enable continuous assessment and accreditation, and delegate decision making at the lowest level possible. Examples of automation are using static code analysis during the “build” stage, running automated unit tests, functional test, regression tests, integration tests, and resiliency/performance tests during the “test” stage, using dynamic code analysis, fuzzing scans, running container security scans, STIG compliance scans, and 508 compliance scans during the “secure” stage, and running continuous monitoring tools and ensuring logs are being pushed to the appropriate entity during the “monitoring” and “operational” stages.

Define top-down implementation requirements. The Department needs to ensure that each Joint Capability Area (JCA) flows-down its strategy, best practices, and implementation requirements/guidance for security and accreditation to allow the Component responsible for implementing the software to appropriately tailor RMF nd plan the development, accreditation, and operation of the software. Furthermore, each JCA should endeavor to clearly state its risk profile and tolerance so that the RMF can be applied effectively and appropriately mitigate identified risks.

Education is necessary at all levels. As security is “baked in” to software during the development process, people must be educated about what that means as different tools look at different security aspects. They must also be educated in what it means to bring different security reports together and make a risk decision, both during development, and continuously during operations.

Culturally, people must learn to appreciate that speed helps increase security. Security is improved when changes and updates can be made quickly to an application. Using automation, software can be reviewed and updated quickly. The AO must also be able to review documentation and make a risk decision quickly and make that decision on the process and not the product and document it in a “Continuous Authority to Operate.”

Appendix F.8: Sustainment and Modernization Subgroup Report

Improving the materiel readiness of our fielded weapon systems and equipment is an imperative across the Department in accordance with the new National Defense Strategy.[22] The time is now to shift from our traditional, hardware-centric focus and identify what core[23] means for software intensive weapon systems and associated software engineering capabilities. Software is a foundational building material for the engineering of systems, enabling almost 100 percent of the integrated functionality of cyber-physical systems, especially mission- and safety-critical software-reliant systems. More simply, these systems cannot function without software.

For fielded weapon systems and military equipment, software life-cycle activities follow somewhat predictable cycles of corrective, perfective, adaptive, and preventative modifications while major modifications drive new periods of development. Software development activities, even those following Agile methods, encounter a phase where the program transitions from adding new features to supporting and sustaining day-to-day use and operations. At that point, development changes and signals a move to "sustainers" within the organic industrial base. Therefore, sustainment may be defined as the sum of all actions and activities necessary to support a weapon system or military equipment after it has been fielded.

Prioritizing the transition to software sustainment during requirements and engineering development is critical to timely, effective, and affordable sustainment, regardless of how software engineering organizations are structured and resourced. Software sustainment organizations must be engaged and embedded at the earliest design stages to ensure we can keep pace with new capabilities as systems become operational. Lastly, access to software source code, emphasizing an early focus on designing for sustainment, and investment into establishing and modernizing system integration laboratories, are just a few of the challenges faced by the DoD software enterprise.

Pain points

Applying a hardware maintenance mindset to software hinders the DoD's ability to better leverage the organic software engineering infrastructure. DoD maintenance policies and maintenance-related Congressional statutes have traditionally been optimized for hardware and are difficult to change due to long standing policies, practices, inertia, and incentives. The goal of hardware maintenance is to repair and restore form, fit, and function. This mindset does not align well with the ever evolving nature of software. The scope of software engineering for sustainment mitigates defects and vulnerabilities, fact-of-life interface changes, and add new enhancements. Software is never done and any time it is "touched," it triggers the software engineering development life cycle which produces a new configuration. Therefore, any system that is dependent on software to remain operational, is always in a state of continuous engineering during sustainment (or O&S phase of the life cycle).

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[22] "Summary of the 2018 National Defense Strategy" (Washington, DC: Department of Defense, 2018), https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

[23] As defined in 10 USC 2464, *Core logistics capabilities.*

DoD's acquisition process is not emphasizing an upfront focus on design for software sustainment and a seamless transition to organic sustainment. It is critical that software be designed to be more affordably sustained with high assurance and the ability to integrate changes and enhancements more rapidly to provide a continual operational capability to the warfighter. Moreover, software must be decoupled from hardware to the greatest extent possible in order to enable leveraging rapid and continuous hardware improvements. We need to place increased emphasis in acquisition on designing in software sustainability with a consistent emphasis on how DoD contracts for software as well as the span of requirements, architecture, design, development, and test. Additionally, this includes making provisions for timely access to the necessary range of software technical data to enable timely and effective organic software engineering and rapid re-hosting. It is essential that the DoD and industry work collaboratively to meet the increasing software sustainment demand.

Public Private Partnerships (PPPs) provide one means to leverage DoD and industry capabilities as a team to deliver warfighter capability. However, PPPs and other options are not being considered up front and leveraged across DoD as an inherent element of the acquisition and engineering strategy of programs. This team strategy may facilitate mutual access to the technical data inherent in executing the software development life cycle.

Limited visibility of the DoD organic software engineering infrastructure, capabilities, workload, and resources. Title 10 USC 2464 establishes a key imperative for DoD to establish core Government Owned Government Operated (GOGO) capabilities as a ready and controlled source of technical competence and resources for national security. DoD's focus has traditionally been on hardware and therefore there has seen significant Service and DoD enterprise focus on hardware GOGO capabilities and infrastructure for core. However, there has been significantly less upfront acquisition focus and visibility on what core means for software intensive systems and the associated GOGO software engineering capability. For the traditional DoD hardware-centric model, core capability is based on individual weapon systems or platforms at the depot level. All systems operate interdependently in a net-centric environment, where force structure and execution of mission capabilities are products of a system-of-systems capability. In a software intensive environment "Go to War" analysis of what core means as it relates to software requires more strategic thinking about core than just focusing on individual weapon systems or platforms (aircraft, ship, tank, etc.) as hardware. The hardware-centric focus on weapon systems likely underestimates the scope and magnitude of what should be considered a core requirement in a software intensive systems operational environment.

Desired State. Require government integrated software sustainment participation from the very beginning of development activities.

Ideas for Change

- Title 10 USC 2460 should be revised to replace the term software maintenance with the term software sustainment and a definition that is consistent with a continuous engineering approach across the lifecycle.

- DoD should establish a capability for visibility into the size and composition of DoD's software sustainment portfolio, demographics, and infrastructure to better inform enterprise investment and program decisions.

- A DoD working group should be established to leverage on-going individual Service efforts and create a DoD contracting and acquisition guide for software and software sustainment patterned after the approach that led to creation of the DoD Open Systems Architecture Contracting Guide.

- Acquisition Strategy, RFP/Evaluation Criteria, and Systems Engineering Plan should address software sustainability, re-hosting, and transition to sustainment as an acquisition priority. The engineering strategy and plan should engage software sustainment engineers upfront and co-locates government software sustainment engineers on the contractor software development teams to enable effectively and timely transition to an organic sustainment capability.

- The definition of "core capabilities" in 10 USC 2464 should be revisited in light of warfighter dependence on software intensive systems to determine the scope of DoD's core organic software engineering capability, and we should engage with Congress on the proposed revision to clarify the intent and extent of key terminology used in the current statute.

- The DoD should revise industrial base policy to include software and DoD's organic software engineering capabilities and infrastructure. Start enterprise planning and investment to establish and modernize organic System Integration Labs (SILs), software engineering environments, and technical infrastructure; invest in R&D to advance organic software engineering infrastructure capabilities.

Appendix F.9: Test and Evaluation Subgroup Report

The fundamental purpose of DoD test and evaluation (T&E) is to provide knowledge that helps decision makers manage the risk involved in developing, producing, operating, and sustaining systems and capabilities. While colloquially referred to as a single construct, T&E is composed of two distinct functions: obtaining the data and assessing the data. This distinction is important because the T&E community will report "pain points" in both functions. There are also two major types of test: Developmental Test (DT) and Operational Test (OT). DT, by nature, is "experimental," performed on behalf of the Program Management Office (PMO), supporting a formative evaluation and identifying design elements that will drive mission critical capability to inform the evolution of component and system design. OT is "evaluative," performed by and on behalf of the warfighter, supporting a summative evaluation of system capabilities to support warfighting missions across the operational envelope.

Because T&E has historically occurred toward the end of, often, a long and costly acquisition process (e.g., requirements, design, development, etc.), it can be perceived as simply adding time and cost to an already late and over-budget effort; PMOs therefore can view this "last step" T&E as simply making the situation worse. And if T&E finds a system substantially defective, necessitating expensive re-engineering of the design late in developing, it adds to the perception that T&E simply adds cost and time to project execution. A continuous iterative T&E model is clearly called for, occurring alongside design and development, where T&E can both; catch defects early so they can be solved quickly and cheaply and inform/shape system requirements based on early feedback from the warfighter. Experience shows that active, early involvement by independent testers – combined with a PMO who responds to the independent testers' advice – makes a positive difference to program outcomes. We have seen this in modern iterative approaches, such as agile development, applied effectively in the DoD, especially in Major Automated Information Systems (MAIS).[24] Taken together, these observations point to the need to move away from what can be a linear waterfall process segregated by siloes, to a more iterative and collaborative model that fuses all development, test, processes, tools, and information to enable the continuous delivery of tested capability. T&E can then be viewed as saving time/cost in development, instead of adding time/cost.

Pain Points and Obstacles

The DoD lacks the enterprise digital infrastructure needed to test the broad spectrum of software types and across the span of T&E to support developmental efficiency (in DT) and operational effectiveness (in OT). Digital models of test articles (e.g., "Digital Twins") are not always available and not built to common standards. T&E environments, including threat surrogates or models, are often program-focused and funded, with short-term development goals and narrowly-scoped capabilities defined by the program. Building (and re-building) representative T&E environments is time and cost prohibitive for individual programs and results in duplicative infrastructure investments across DoD. Moreover, current T&E practices in the Services,

[24] FY16 DOT&E Annual Report.

including those focused on software-intensive systems, do not adequately test systems in Joint and Coalition environments, nor do they consistently use appropriate risk-based, mission-focused testing.

The DoD lacks the enterprise data management and analytics capability needed to support the evaluation of test data in accordance with the pace of modern iterative software methods. As data required to make informed acquisition decisions continues to grow due to higher resolution measurements, higher acquisition rates, and other additional requirements for software intensive systems (e.g., interdependency, need to operate in system-of-systems, family-of-systems, Joint, and Coalition environments, etc.), the need for a T&E infrastructure to collect, aggregate, and analyze this data must likewise evolve to keep pace. More timely data fusion will require improvements in data management techniques, access speeds, data access policies, data verification techniques, and the availability of more intelligent and agile tools. Without this infrastructure, and within the current paradigm, we are failing to adequately gather and analyze these highly diverse and complex datasets, which leads to invalid assessments of acquisition program progress and system performance, undercuts mission readiness, and places warfighters at risk. This gap becomes an even more prominent choke point in an iterative cycle. Thus, even if we mitigate the first pain point with modernized realistic test environments, and had the capability to collect the appropriate mix/quantity of data in testing, we would still not have the analytics horsepower to turn around an assessment to support the pace of an Agile/DevSecOps iterative cycle.

The DoD lacks the resources needed to adequately emulate advanced cyber adversaries, to support fielding of trusted, survivable, and resilient software-intensive defense systems. Various oversight entities (e.g., NDAAs, GAO Reports, etc.) have acknowledged this gap, and past DOT&E Annual Reports have documented a significant number of adverse cyber findings in OT that should not require an operational environment to discover. While the gap exists now (in the absence of modern software methods), it will become an even more prominent choke point in a rapid development and operational fielding paradigm. We do not have the advanced cyber test resources (manpower, methods, and environment) to support a true Agile/DevSecOps approach to developing, testing, and fielding the broad range of software-intensive systems needed by DoD now and in the future, in an environment increasingly populated by advanced cyber adversaries.

The DoD lacks a modern software intellectual property (IP) strategy to support T&E in a rapid software development and fielding environment. Overcoming this pain point is critical to overcoming all of the three previously described pain points. Specifically, none of the previously described pain points is fully achievable without sufficient access to necessary technical data associated with the software deliverables. Software acquisition processes are and will continue to be suboptimal (with respect to time and risk) without access to relevant technical data and this gap will become an even more prominent choke point in an Agile/DevSecOps-based paradigm without that access. A modern software IP strategy must include access to software environments (e.g., source code, build tools, test scripts, cybersecurity artifacts/risk assessments, etc.) so tests are repeatable, extendable, and reusable. This strategy will also have to strike a balance with the IP rights of the innovator (usually industry) to ensure continued engagement of DoD with leading-edge technology organizations.

A modern software IP strategy would support the three previously described pain points via:

- Enhance our ability to operationalize the concept of “digital twins,” with sufficient access to the source code of a given system (balancing DoD and innovator IP rights), so as to be able adequately represent that system.
- Support the instrumentation of software-intensive systems as needed during testing.
- Support cyber vulnerability assessments and the assignment of risks to residual vulnerabilities, via access to system data (e.g., code, technical data, etc).

Desired state

While the DoD does a fair amount of “integrated testing” now (across DT and OT), that is not the same as “integrating T&E with the Voice of the End User continuously and alongside software development.” T&E must strive for continuous software testing, automated and integrated into the development cycle to the fullest extent possible, across the entirety of the DoD’s software portfolio. The qualifier, “fullest extent possible” is important, as many experts have acknowledged that no single “one size fits all” approach will work best across the entire DoD software portfolio all of the time.[25,26] In this envisioned state, independent testers would work alongside developers and operators to help software development programs succeed and deliver capability at the speed of need. T&E would no longer be perceived as “slowing things down” or “costing money post-development” because it occurs toward the end of a highly linear and inefficient process, but would instead be associated with saving time and money during development. This vision, applied across the entire DoD software portfolio (i.e., beyond just IT or MAIS) requires the right kinds of tools, architectures and standards (see first three pain points), access to the right kind of data (see second and fourth pain points), and an ability to partner with and work alongside the developer, while yet maintaining independence and objectivity in our assessments.

Ideas for change

Build the enterprise-level digital infrastructure needed to streamline software development and testing across the full DoD software portfolio. Beyond the DevSecOps platform (or Digital Technology concept), the DoD requires a digital *engineering* infrastructure to streamline integration and testing. This suggests that the DevSecOps platform must be made available to all DoD software developers and:

- Integrated with (systems-level) model-based/digital engineering infrastructure, including digital twin(s),
- Integrated with existing T&E infrastructure (e.g., open-air ranges, labs, and other test facilities),

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[25] 2018 Defense Science Board Task Force on Design and Acquisition of Software for Defense Systems.

[26] Boehm and Turner, 2009. Balancing Agility and Discipline: A Guide for the Perplexed. Addison-Wesley. Boston, MA.

- Integrated with comprehensive tactical/mission-level infrastructure, and
- Available to others who could benefit (e.g., analysis, training, planning, etc.).

Even with this kind of complete testing infrastructure providing the capability to collect the appropriate mix/quantity of data in testing, we would still not have the analytics horsepower to turn around an assessment sufficiently rapidly to support the pace of an Agile/DevSecOps iterative cycle. We must develop the enterprise knowledge management and data analytics capability for rapid analysis/presentation of technical data to support deployment decisions at each iterative cycle.

Finally, to advance our cyber test resources such that we can achieve overmatch to our most capable adversaries while yet supporting the pace of the modern software development, the DoD should expand DOT&E's current capability to obtain state-of-the-art cyber capabilities on a fee- for-service basis. This provides a straightforward way to acquire skilled cyber personnel from leading institutions (e.g., academia, university affiliated or federally funded research and development centers, etc.), to help the DoD to keep pace with advanced cyber adversaries.

Appendix F.10: Workforce Subgroup Report

DoD's workforce (civilian, military, and supporting contractor personnel) is our most valuable resource. The workforce's capacity to apply modern technology and software practices to meet the mission is the only way we can remain relevant in increasingly technical fighting domains, especially against our sophisticated peers, Russia and China.

Improved management of the Department's software acquisition talent will also drive success across the other subgroups and sections of this report. Policies, processes, and bureaucratic practices are never a sufficient substitute for competence.

The Department's challenges are well documented and well known by the software acquisition and engineering professionals who suffer most from the accrued technology, cultural, and leadership debt. The Workforce Subgroup identified prevalent pain points, but focused on providing concrete and actionable solutions for improving the recruitment, retention, development, and engagement of the workforce.

Pain Points

The Department's reputation as an employer is a weakness rather than a strength. Candidates base their employment decision on a variety of factors, but the organization's reputation and day-to-day work are chief among their considerations. The demand, and competition with the private sector, for an experienced and qualified workforce, is increasing as threats to our data security become more sophisticated. DoD has a reputation as an antiquated employer that rewards time in grade rather than competence and most often outsources its technical execution. Technical employees often serve as oversight or move away from "hands-on-keyboard" as they advance in their careers; no longer contributing to creative or innovative execution.

The Department does not adequately understand which competencies and skill sets are possessed and needed within its software acquisition and engineering workforce. Without the ability to distinguish the workforce, the DoD cannot effectively drive human capital initiatives. Furthermore, there is no enterprise-wide talent management system to manage the workforce (e.g., geographically, skills, etc.), which leads to bureaucratic silos and the inability to leverage the Total Force.

The Department has not prioritized a comprehensive recruiting strategy or campaign targeting civilians (90 percent of the acquisition workforce) for technical positions. When candidates do apply, they face an "overly complex and lengthy hiring process (that) frequently results in the Government losing potential employees to private sector organizations with more streamlined hiring processes," according to the President's Management Agenda.[27]

[27] "President's Management Agenda: Modernizing Government for the 21st Century," (Washington, DC: Office of Management and Budget, April 2018), 20, https://www.whitehouse.gov/omb/management/pma/.

There is no comprehensive training or development program that prepares the software acquisition and technical workforce to adequately deploy modern development tools and methodologies within our dynamic environments. Hiring top technical talent into the Department will never be a silver bullet. The Department also needs to consider how to equip, reward, promote, and empower its existing workforce.

The Department is unable to leverage modern tools that are common in the private sector and our personal lives (e.g., cloud storage, collaborative software, etc.) due to bureaucratic barriers. Top talent expects access to these tools to meet mission demands, and their absence may discourage qualified candidates from applying or staying. Although the Department has pockets of innovation and entrepreneurship within rapid fielding offices across the services, this culture has not scaled to the larger acquisition programs and offices. Long-cycle times, bureaucratic silos, and information-hoarding prevail.

Desired State

The Department requires a workforce capable of acquiring, building, and delivering software and technology in real time, as threats and demands emerge. This workforce should resemble successful technology companies that must move quickly to meet market challenges. They do so by promoting an agile culture, celebrating innovation, learning from calculated failures, and valuing people over process.

The Department's workforce embraced commercial best practices for the rapid recruitment of talented professionals. Once onboarded quickly, they will use modern tools and continuously learn in state-of-the-art training environments, bringing in the best from industry and academia, while pursuing private-public exchange programs to broaden their skill sets.

Obstacles

The bureaucratic culture of the Department creates significant barriers compared to a commercial sector ecosystem that moves at the speed of relevance. These barriers are now ingrained within the institution, perpetuating a risk-averse environment that represents the most significant obstacle to reform. While there are minor legislative solutions to achieving the desired state, we believe that the Department has the necessary authorities and flexibilities, but has shown lack of impetus to move to the modern era of talent management.

While small pockets of expertise and progress exist, the Department as a whole lacks sufficient understanding of current software development practices and talent management models that support them. Studies on the workforce dating back 35 years that show "limited evidence these different efforts had any lasting impact or resulted in meaningful outcomes."[28]

Ideas for Change

Foundational. Taking into account history and the significant challenges with changing the culture in a bureaucracy, the Department should *empower a small cadre of Highly Qualified*

[28] McLendon, Michael H.; Shull, Forrest; Miller, Christopher, "DoD's Software Sustainment Ecosystem: Needed Skill Sets," (Naval Postgraduate School, Monterey, California, April 30, 2018).

Experts and innovative Department employees to execute changes from this report. This cadre is empowered with the authority to create, eliminate, and change policies within the Department for organizations beyond themselves. If needed, create a software acquisition workforce fund similar to the existing Defense Acquisition Workforce Development Fund (DAWDF). As called out by the Defense Science Board, the purpose of this fund will be to hire and train a cadre of modern software acquisition experts. This fund should also be used to provide Agile, Tech, and DevSecOps coaches in Program Offices to support transformations, adoption of modern software practice and sharing lessons across the enterprise.[29]

Workforce Foundations. The Department must develop a core occupational series based on current core competencies and skills for software acquisition and engineering. This occupational series should encompass all workforce roles required for modern software development and acquisition - engineers, designers, product managers, etc. Additionally, the Department should create a unique identifier or endorsement of qualified (experience & training) individuals who are capable of serving on an acquisition for software. This includes the development of a modern talent marketplace (and associated knowledge and skill tags/badges) to track these individuals. The competencies for this series should be flexible enough to evolve alongside technology, something that has constrained the 2110 IT Series.

Contractor Reforms. Defense contractors develop the majority of software in the Department. The Department should incentivize defense contractors that demonstrate modern software methodologies; this may take the form of software factory demonstrations and rapid software delivery challenges when evaluating proposals. Additional consideration should be given to contractors with demonstrated excellence creating commercially successful software.

Recruitment and Hiring. The Department must overhaul its recruiting and hiring process to use simple position titles and descriptions, educate hiring managers to leverage all hiring authorities, engage subject-matter experts as reviewers, and streamline the onboarding process to take weeks instead of months. The Department needs to embrace private-sector hiring methods to attract and onboard top talent from non-traditional backgrounds (e.g., hackers and entrepreneurs). Too often, these types of candidates are passed over or require special authorities to join the Department, due to lack of education or regular pay stubs. Furthermore, the Department must develop a strategic recruitment program that targets civilians, similar to its recruitment strategy for military members. This includes prioritizing experience and skills over cookie-cutter commercial certifications or educational credentials.

Development, Advancement, Engagement, and Retention. The Department must pilot development programs that provide comprehensive training for all software acquisition professionals, developers, and associated functions. Programs should be built in partnership with academia and industry, leveraging commercial training solutions rather than custom and expensive Federal solutions. This will include continuing education courses to help the workforce stay current and ensure technical literacy across the acquisition workforce. The Department must emphasize promoting and rewarding those that have proven both commitment

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[29] Design and Acquisition of Software for Defense Systems," Defense Science Board, Feb. 2018, https://www.acq.osd.mil/dsb/reports.htm

and technical competence. Continually looking outside the Department is demoralizing and insulting to existing professionals that demonstrate innovation, excellence, and the ability to deliver already. The Department should incentivize and provide software practitioners access to modern engagement and collaboration platforms to connect, share their skills and knowledge, and develop solutions leveraging the full enterprise.

Finally, the Department should encourage greater private-public sector fluidity within its workforce. Federal employees who come from the private sector bring with them best practices, modern methodologies, and exposure to new technologies. Federal employees who leave bring their understanding of our unique mission and constraints, helping the private sector develop offerings and services that meet our needs.

Appendix G: Analysis the Old Fashioned Way: A Look at Past DoD Software Projects

The Department has been building and buying software for decades. The study's initial idea was to take a cutting edge machine learning tool, hook it up to the Department's databases, and do an analysis across all of the plentiful software data collected over the years.

Unfortunately, initial attempts at analysis quickly led to the realization that the Department had never strategically collected data on its software. The data that have been collected cover only a subset of the systems the Department acquires and are typically collected by hand, with all the potential for erroneous or missing values that that implies. The granularity at which data are collected also does not typically support insight into specific questions of acquisition performance. Without massive data calls, enormous amounts of PDF scanning, and an impossible number of non-disclosure agreements, a comprehensive analysis would not be possible.

Instead, the SWAP members broke the analysis into two main efforts:

1. Analysis of the available data in order to test the board's hypotheses as they evolve. Subject Matter Experts who are familiar with the existing data and its constraints explored the available data in search of insights that would confirm or refute the board's hypotheses about DoD software acquisition performance. These results are described in this appendix.

2. Application of cutting edge machine learning and other modern analytical techniques to datasets from outside of the DoD, to support reasoning about the type of insights that could be gained and reported, if the Department had access to more comprehensive data about its software. These results are described in Appendix D.

G.1 Data Used in This Analysis

The focus of this study is on software-intensive programs – and the specific software scope within these programs – presenting top-level insights into software acquisition performance. We focused our analysis on a few major data sources collected by the Department, which can provide insight on these issues.

The data in our first source are known as Software Resources Data Reports (SRDRs). The SRDR data were selected for use because they are specifically focused on the software activities of DoD acquisition programs. The SRDR is a contract data deliverable that formalizes the reporting of software metrics data and is the primary source of data on software projects and their performance. The SRDR reports are provided at the project level or subsystem level, not at the DoD Acquisition Program level. The data points included in the analyses reported here are representative of software builds, increments, or releases. In many cases, there are multiple data points in the set that represent different subsystems or projects from the same program.

The SRDR applies to all major contracts and subcontracts, regardless of contract type, for contractors developing or producing software elements that meet specific criteria[30] and with a projected software effort greater than $20M.

SRDR reports are designed to record both the estimates and actual results of new software development efforts or upgrades, with the goal of supporting cost estimation. The reports collect many characteristics about software activities in both structured and unstructured formats. The primary data analyzed in our work were size, effort, and schedule. Notably absent from the SRDRs are any data about quality. Defect data have been optional until recently and hence were not reported.

Other data sources used to explore some of the assumptions and recommendations of the DIB are the IPMR (Integrated Program Management Report) and SAR (Selected Acquisition Report) datasets. Programs in these datasets fall into the category of Major Defense Acquisition Programs (MDAPs). These datasets include:

1. Software development effort measured in labor hours, software size, and development activity duration metrics delivered as mandated respective to contractual agreements.

2. Software development performance as identified within each contract report. However, each contract contained common elements supporting both software and non-software activity on contracts. These were treated in proportion to the weight of software activity cost on contract. These reports contain data for measuring contractor's cost compared to budget baselines on Department acquisition contracts as well as projections of cost at completion.

3. Planned and executed schedule milestone dates reported to the Department at the aggregate program level as required by acquisition policy. This information is included as a part of a comprehensive summary of total program cost, schedule, and unit cost breach information.

These software development effort metrics, contract performance, and program level schedule data represent the best source of product development, contract cost, and schedule performance information available on various projects throughout DoD. In addition, these datasets are also independently validated by agencies within the Department and subject to audits that require maximum fidelity to accounting standards.

It is worth noting that these datasets provide the best available information on DoD software acquisition, but are mainly limited to contract cost and budget performance (versus technical functionality performance) and were collected by hand. This scenario seems to address larger structural and cultural problems:

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[30] Specifically, "within acquisition category (ACAT) I and IA programs and pre-MDAP and pre-MAIS programs, subsequent to milestone A approval."

- The Department has no real acquisition data system that holds anything more than top-level data on our largest programs.
- There is no automated collection of acquisition data, despite the fact that software tools and infrastructures, from which data can be automatically extracted, are integral parts of the state of the practice in the software industry.
- For much of the limited software-specific data that we do have (for example, source lines of code, or SLOC), this study has argued that they do not provide meaningful technical insight. Metrics like SLOC are not what the private sector would use to assess and manage programs.
- Leadership often relies on experience and trusted advisors because timely, authoritative data are not available for real analysis.

G.2 Software Development Project Analysis

One area of analysis focused on the SRDR data to describe, at an enterprise- or portfolio-level, what the Department is able to say about its software based on the software-specific data. As described above, SRDR data are more project- or subcomponent-focused versus program- or contract-focused; indeed, it is not easy and perhaps not possible to create a program-level understanding of software activities from the SRDR data.

The results reported here address 3 three questions:

1. How well do software projects perform in terms of effort and schedule?
2. Is there a difference in project performance related to the size of the project and the use of agile development?
3. How long do software projects take to reach completion?

The source of the data was the May 2018 compilation file published by members of the Software Resources Data Report Working Group. This file contains 3993 submissions that yielded 475 initial reports of planning estimates, 598 reports of final actual values, and 295 pairs of initial and final reports. Upon further investigation, 131 pairs contained full lifecycle information and therefore serve as a better dataset for studying effort and schedule growth. Thus, while we base our conclusions in this section on the best available data for software, it is important to keep in mind the data represent only a small subset of the Department's software.

The results presented below were primarily based on common statistical methods. Although a variety of additional explorations were conducted, the results were not found to be stable or to have achieved high confidence. These included dynamic simulation modeling, causal learning, and analysis with repetitive partitioning and regression trees.

Software Project Effort and Schedule Performance

In the current DoD acquisition lifecycle, substantial effort goes into defining requirements upfront in extensive detail, and projecting the cost and schedule for achieving the capabilities so described. Despite that, it is often said that the Department has problems acquiring the software capabilities it needs within budget and schedule. This analysis explored whether there was support for this conventional wisdom.

DoD projects in the dataset generally do indeed experience substantial effort growth. As seen in the following figure, the median number of estimated hours is 22,250 while the median number of actual hours is 30,120. (Note that the vast majority of points lie above the green line, indicating that actual values were greater than estimated.) The median rate of growth is 25%. However, there are some projects that expend less than their estimated effort, sometimes by a substantial amount as reflected by the points within the red circle. Unfortunately, based on the data reported we cannot discern whether they delivered the full committed functionality or not.

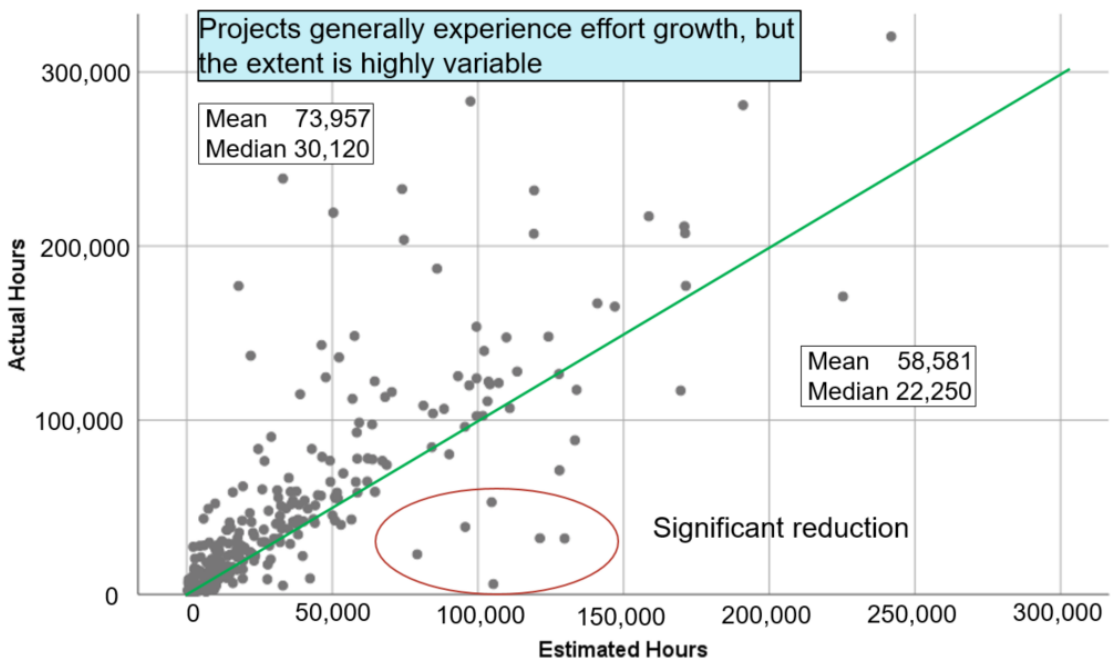


Figure 1. Estimated and actual project hours for project with less than 300,000 estimated hours.

The growth in project duration is generally not as large as the growth in effort. The median planned duration is 28 months and the actual duration is 34.9 months. The median growth in duration is 12%.

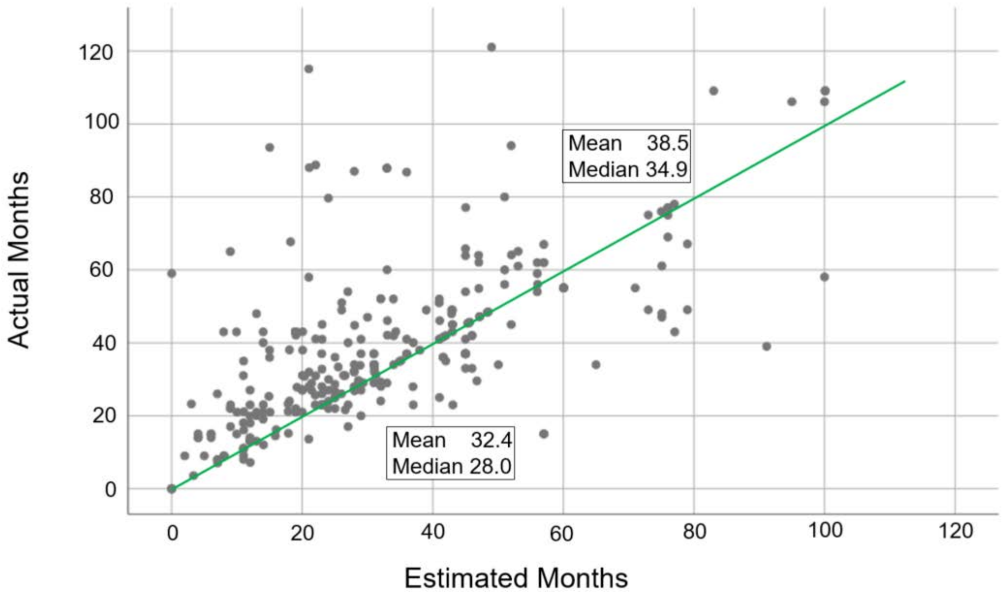


Figure 2. Estimated and actual project duration.

Interestingly, effort and duration growth are only weakly correlated and the highly skewed nature of their distributions means that averages create a more negative impression of performance than may be warranted. That is, the average exaggerates the degree of growth across the portfolio of projects. Nonetheless, in the data we have available, overruns of effort and duration are the norm.

Does Project Size Affect Performance?

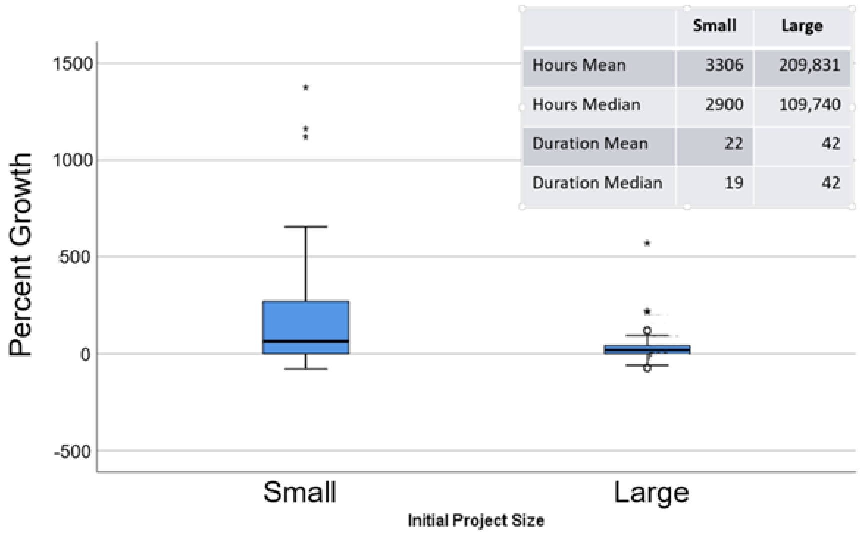
The DIB has recommended that software programs should start small. The next analysis examined the historical data available to test whether small programs performed better than large ones, at least in terms of delivering capabilities on time and within budget.

To perform this analysis, projects were categorized in terms of their estimated equivalent source lines of code (ESLOC)[31] and effort. ESLOC is not collected but computed from the detailed SLOC measures that are collected: ESLOC combines the different sources of lines of code, new, modified, reused, and autogenerated, into a single count. Projects that were in the lower and upper quartiles on both effort and ESLOC measures were labelled as small and large projects respectively. This yielded 53 small and 55 large projects. An analysis of variance was conducted for growth in effort and duration.

The results found that small projects do not outperform large projects. Large projects do have less effort growth on a percentage basis but more growth in terms of raw hours. Surprisingly,

[31] Elsewhere in this report, we reflect on the problems inherent with using SLOC as a measure. However, this is a key measure that has been collected historically by the department and so represents the best available data for this analysis.

schedule growth is very similar. Variation in performance overwhelms any apparent difference and the results do not achieve statistical significance.



	Small	Large
Hours Mean	3306	209,831
Hours Median	2900	109,740
Duration Mean	22	42
Duration Median	19	42

Figure 3. Effort growth by project size.

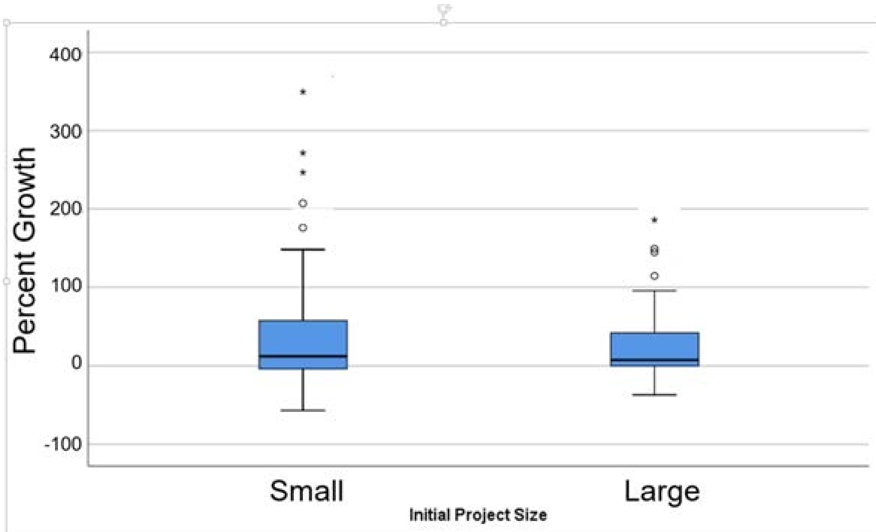


Figure 4. Duration growth by project size.

The fact that small projects still experience the same growth as large projects does not negate the advice that projects should start small, iterate often, and be terminated early if unsuccessful, since this can still result in significant savings in costs for projects that are not performing well.

Do Development Approaches Affect Performance?

There is much interest in the software development community and the DoD in the use of Agile methods. While the most recently updated SRDR form explicitly calls out measures for Agile projects, this has not been the case for the historical SRDR data upon which these analyses rely. Furthermore, the identification of the development approach is captured in an open text field. This necessitated interpretation and grouping of the entries in order to perform this analysis. A significant number of projects reported using "Waterfall," "Incremental," "Spiral," or "Iterative" approaches. The remainder suggest use of a customized or hybrid approach. For the analysis here, "Waterfall" is compared to "Incremental," "Spiral," and "Iterative" projects.

Again, using ANOVA, the results indicate that effort growth does not significantly vary by development approach. However, duration growth is significantly less for projects using incremental development approaches as compared to waterfall (28% v 70% on average).

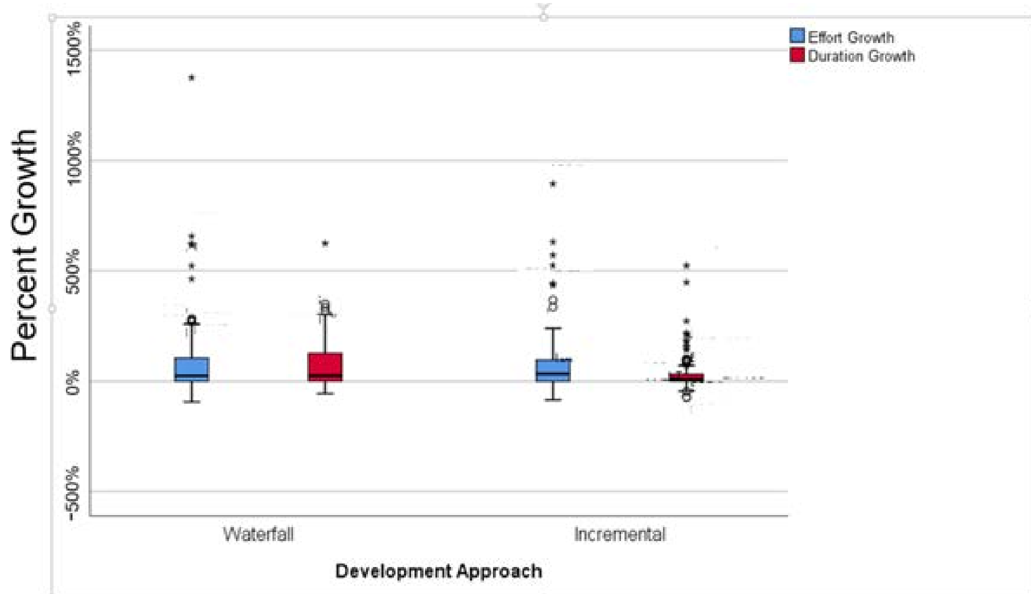


Figure 5. Effort and duration growth by development approach.

How Long Does It Currently Take to Complete a Project/Deliver Software?

As can be seen in the following figure, it is very rare for a project to complete in 12 months or less. Out of 371 projects used for this analysis, only 21 (6%) completed in this timeframe.

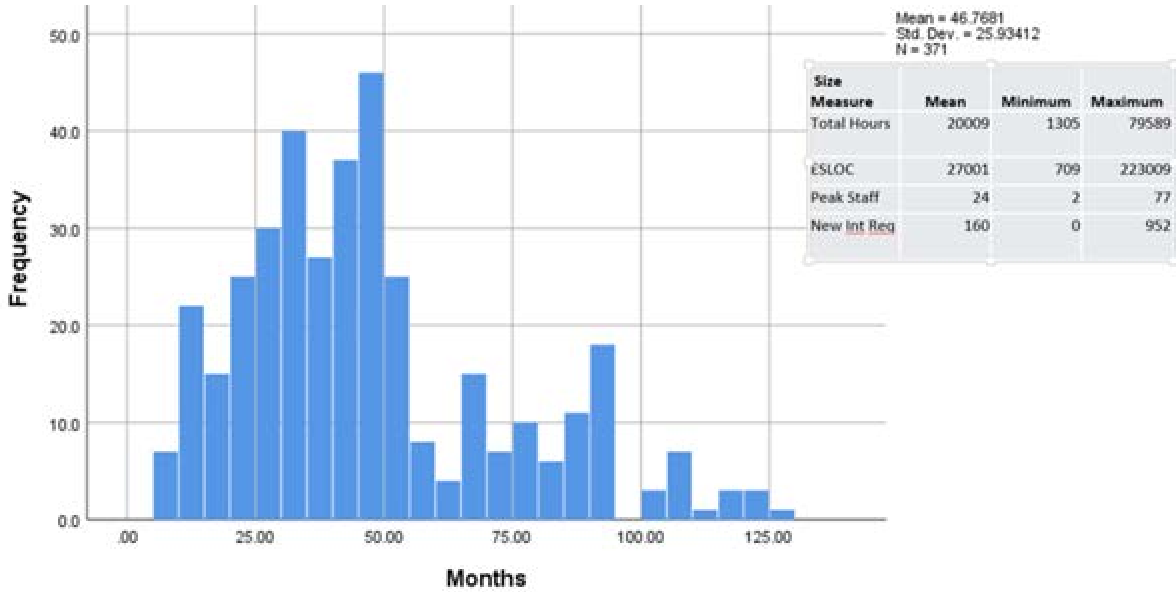


Figure 6. Actual duration for 371 AIS, Engineering, and Real-time projects.

Additional Insights from the SRDR Data

The preceding analyses were guided by the recommendations and proposed measures in DIB authored documents. In the course of performing those analyses, other questions and issues were posed and investigated. Briefly, these findings are:

1. Extreme variability in project performance confounds the identification of statistically significant results. This was noted above and is most likely actually due to performance and reporting inconsistencies.

2. Planned values can be useful for establishing expectations regarding reported actual effort and duration. That is, planned and actual values tend to be highly correlated with each other.

3. Planning for reuse is associated with significantly more schedule growth as compared to projects that do not plan for reuse.

The last one deserves more explanation as it is a somewhat counterintuitive result. Based on 275 projects that reported either no plan for code reuse or did plan for code reuse, the growth analysis showed no statistically significant differences in effort growth, but a significant difference in the amount of duration growth. Projects planning for code reuse had 52% duration growth as compared to only 20% for those that did not plan for code reuse. This phenomenon has been noted before and attributed to over-optimism about the amount and ease of code reuse. As the ability to reuse code falls short, unplanned effort and time go into producing new or modified code to compensate for the unrealized code reuse. Why effort growth is not significantly different is but likely at least partially related to the extreme variability in the performance measures.

Opportunities for Improving SRDR Data for Use

Issues regarding the data quality of SRDR data used here hampered the analyses. As is noted earlier, there is a substantial reduction from the number of submissions in the system to the number of usable records. At its most extreme there are 131 high quality pairs (262 records) out of the 3993 submissions included in the compilation dataset. That is, roughly 93% of the data is discarded.

The following opportunities are available for improving SRDR data for use in addition to supporting the needs of the DOD cost community. Briefly, they are:

1. Leverage data collection and reporting from automation within the software environments (software factory). Minimize the need for manual entry and transformation.

2. Capture information about the quality of the delivered system.

3. Make the data more broadly available and encourage analyses into DoD software challenges (DIB Recommendation A3).

4. Identify the information needs of the stakeholders and intended users of the data beyond the cost community.

G.3 Software Development Data Analyses

A second investigation focused on cost and schedule performance data reported on recently completed and ongoing software development efforts within DoD. As these data provided insights *within* programs (and allowed understanding how values changed over time), we expected that this analysis would allow for deeper dives that could better explain how software acquisition occurs in programs.

This information was extracted from IPMRs, which are deliverables required by most contracts. The team also reviewed SARs for the large ACAT I programs to gain perspective on programs as they evolve over time.

Poor Data Quality and Inconsistent Data Reporting

There are approximately 130 ACAT I programs reporting research and development (R&D) contract performance over the past 10 years. We discarded from our analysis:

- Contracts for which the first IPMR report showed 65% (or about two-thirds) completed in work scope, reasoning that too much of the work had occurred before data collection began;

- Contracts for which the latest IPMR reported work that was less than 70% complete, reasoning that we would not have the ability to evaluate a significant portion of work completed.

146 contracts (35%) did not meet these data quality criteria out of the total of the 413 ACAT I program development contracts for which we have data (Figure 7). The fact that more than one-third of contracts do not meet this criterion implies that DoD would benefit from improving the quality and consistency of software development performance reporting. DoD cannot comprehensively assess the performance and value of the billions of dollars in investment without insight into a third of the complete portfolio.

Additionally, there are many data that are of limited utility due inconsistencies related to reporting. These have to do with problems with filing the mandated regular reports, and a lack of contextual data (i.e., metadata) being collected in a readily analyzable form. The DIB Software Metrics Recommendations contain recommended best practices on data collection and metrics definitions to not only capture data, but to establish standards meant to enhance software development performance.

Cost and Schedule Data

The resulting list of contracts was prioritized based on the budget assigned to the software-specific development efforts, and the top 46 contracts with the largest budgets were included in this study. These 46 contracts covered roughly half of the total dollar scope for all development programs in our dataset, and thus provided a reasonable sample size for our analysis. In addition, 35 contracts for smaller ACAT II and ACAT III software intensive Command and Control (C2) and Automated Information System (AIS) programs were included in this analysis. This resulted in the study capturing 81 total contracts valued at $17.9B in software development cost over the past 10 years (2008-2018). This study did not attempt to qualify or quantify the reasons for cost and schedule growth, recognizing that growth is not always indicative of poor performance by the program and/or contractor.

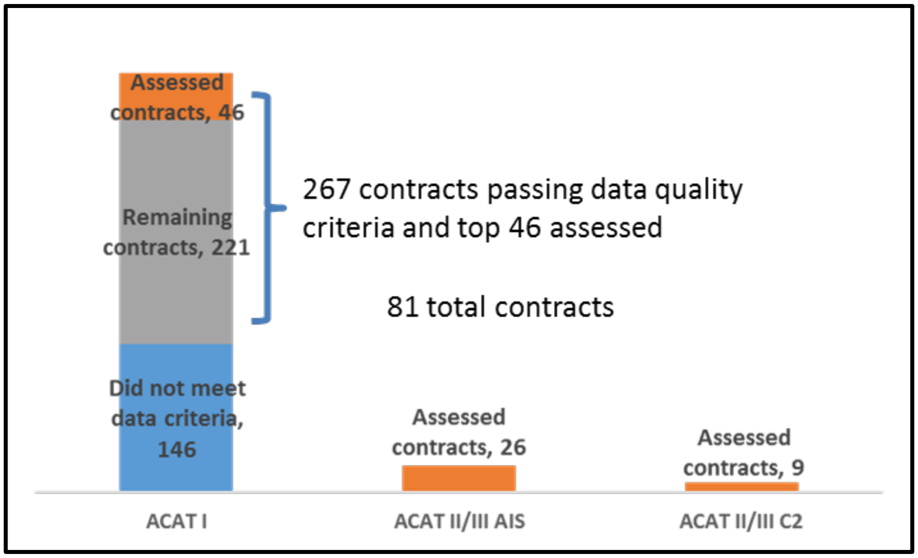


Figure 7. Results of Contract Selection Process

The 81 total contracts included in this analysis covered the portfolio of DoD programs, including software intensive C2 and AIS programs as well as aircraft, radars, land vehicles, and missile weapon systems, as shown in Figure 8.

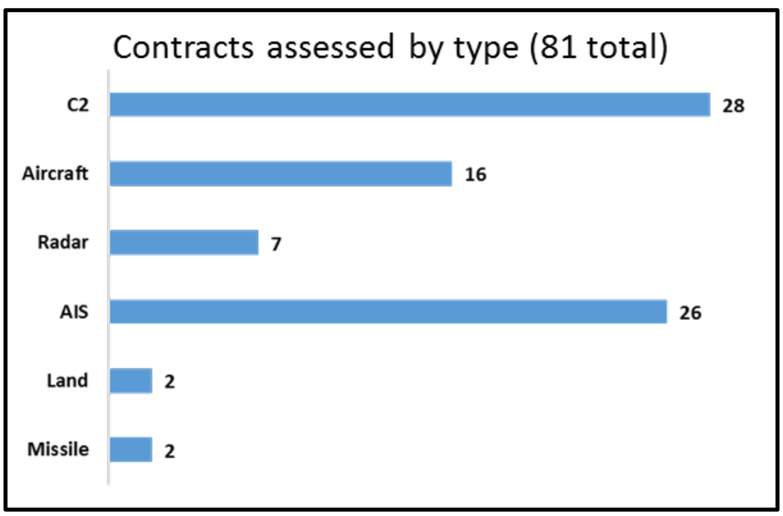


Figure 8. Contracts Analyzed by Weapon System Type

Large Software Cost Growth

The analysis of IPMR data found that on average, the contracts experienced 138% cost growth. The total combined value of the software development budgets within these contracts was $7.6B at the time of initial reporting. By the time these contracts reported the latest (or in some cases, final) performance baseline, the software development budget total grew by $10.4B. Based on the analysis completed, significant software development cost growth was experienced across all platform and program types, resulting in a second observation: In general, the DoD struggles to minimize software development cost growth across the complete portfolio of projects. Figure 9 provides a summary of the 81 contracts evaluated, organized by project and by platform type. Note that the cost growth of “C2 Program A05” was truncated in the figure as it was an outlier in the analysis.

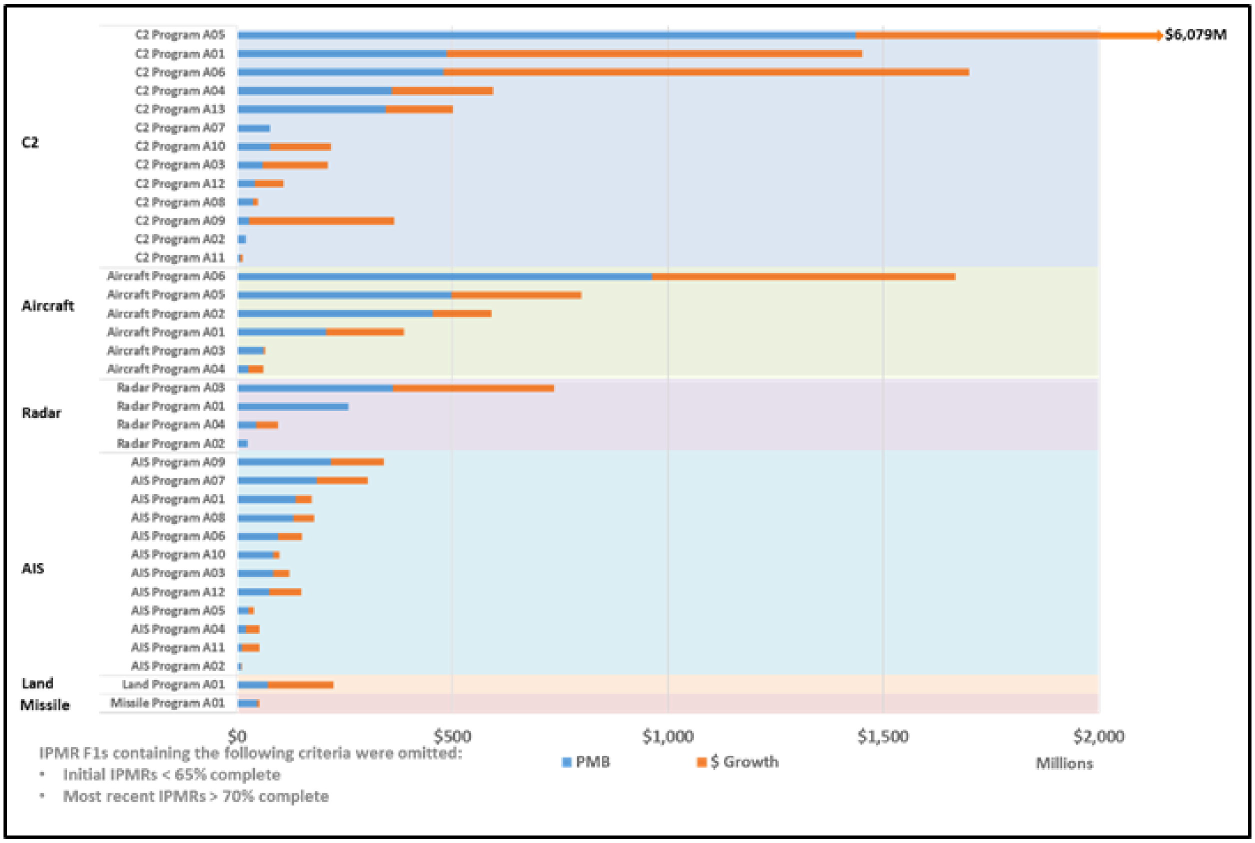


Figure 9. Contract Software Development Cost Growth by Program and by Platform

The study team used information provided by SARs and other relevant acquisition documentation to calculate project schedule growth. Figure 10 illustrates both dimensions of cost and schedule performance and identifies programs for which actual performance exceeds more than twice the baseline cost and schedule. Two programs, “AIS Program A01” and “C2 Program A02,” experienced cost or schedule growth so extreme that the bounds of the diagram axis plots were exceeded. This figure also supports the second observation that recent software development programs experience significant cost growth. The DIB SW Commandment 3 addresses cost growth by advocating that software budgets be planned upfront to support the full lifecycle versus the current funding lifecycle, defined around Planning, Programming, Budgeting, and Execution (PPB&E).

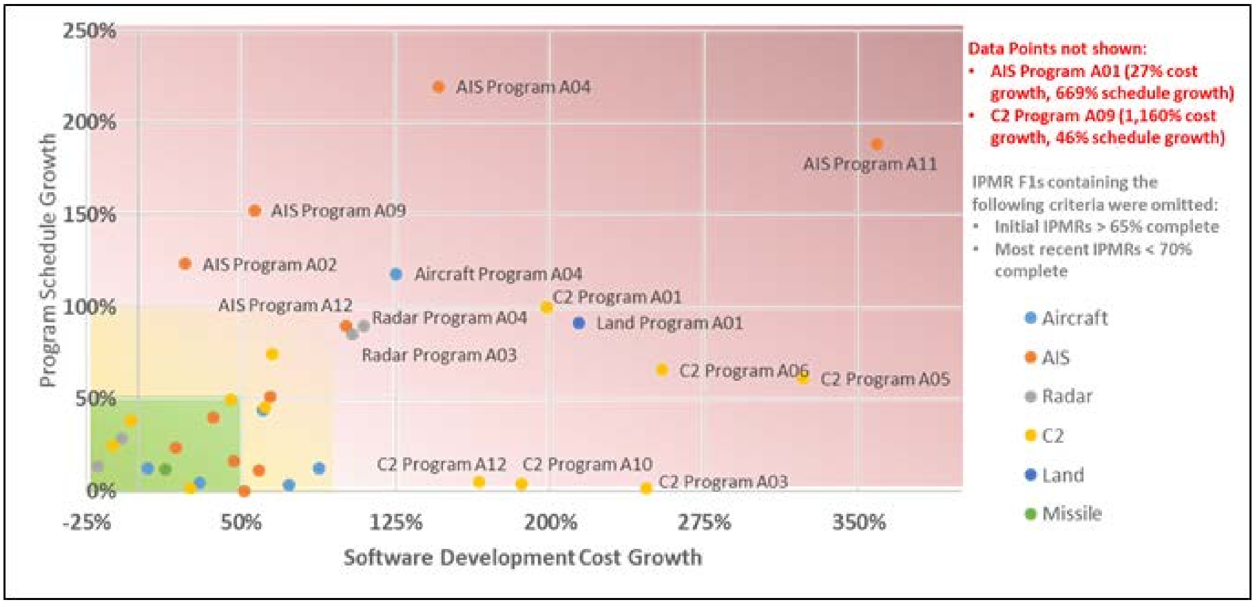


Figure 10. Software Development Cost Growth vs. Program Schedule Growth

Long Planned Durations and Frequent Re-baselining

The third study observation results from a deeper look into programs with high cost growth. This research found that in numerous instances, program baselines shifted (re-baselined) during the contract period of performance. The contracts with what appear to be significant "re-rebaselining" (i.e., multiple recurring increases to the expected cost) were analyzed in further detail.

SAR program milestones and available open source data were evaluated to provide a scale of time and functionality. It is observed that the software development effort crosses the same percent complete, as defined by the Earned Value Management (EVM) metric as the ratio of Budgeted Cost of Work Performed (BCWP) to Budget at Completion (BAC), multiple times. This represents an incremental method of adding cost, which is presumably associated with the addition of technical scope and requirements, which can result in a doubling or tripling of the total original budgeted value of the software development effort.

Figure 11 provides an example of this behavior, showing the "C2 Program A01" program effort that appears to re-baseline several times. The software development effort crosses the same percent complete point multiple times.

DIB Software Commandment 2 provides the recommendation that software development should begin small, be iterative and build on success; otherwise, be terminated quickly. DoD programs that take this approach are likely to see an improvement in performance once scope and requirements can be delimited through successful iteration. The behavior demonstrated in Figure 11 seems to indicate that to some extent, at least some programs are already behaving in an iterative way that better suits the technical work of software evolution. Unfortunately, our reporting mechanisms are not suited to reflect this reality, and in fact cannot differentiate a reasonable approach to incremental development from problematic cost or schedule growth. Looking just at the top-line numbers, these instances could be interpreted as excessive cost growth on the program, representing a problem from the Department's point of view since the predictability of performance against cost and schedule baselines are normally taken as indicators of success. What this scenario seems to point to is a need to improve our metrics collection to better reflect the underlying technical reality of software, where good performance often leads to a demand for new capabilities and new scope, as well as better educating our decision makers about how to interpret the results.

Thus this example provides more information about associated reporting issues tied to observation 5, that budgets should be contracted to support the full, iterative lifecycle of the software being procured with amounts definitized proportionally to the criticality and utility of the software.

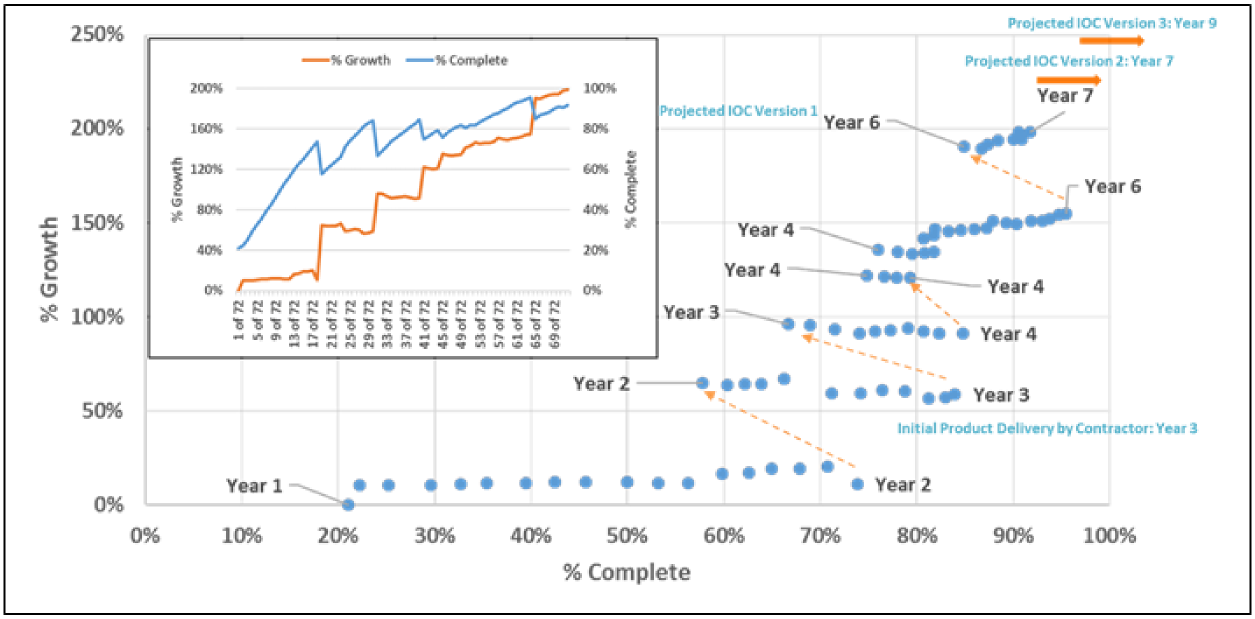


Figure 11. C2 Program A01 Performance Measurement Re-baselining

Agile Software Development Can Improve Program Performance

This study researched the performance of agile development methods that are implemented in existing programs. IPMRs do not explicitly state the type of development effort being used (incremental, agile, etc.). However, an article published in the journal Defense Acquisition provided an instance where agile development was applied and considered a success story. Although this article did not name the program, we were able to identify the most likely candidate, "Aircraft Program A05," by matching the timeline presented in the article against the timeline of contracts that we could see in the program data.

The IPMR data for this program are shown in Figure 12. The contract work completed using an agile approach are shown in blue and represent a 21% cost reduction when compared to the initial budgeted value. This is in contrast to the contracts that seem to adopt a waterfall development methodology, i.e., contracts with planned long durations, which are shown in shades of orange and represent a 129% cost growth compared to the initial budgeted cost.

This analysis supports the fourth study observation that agile development may reduce cost growth compared to more traditional waterfall approaches. The DIB SW Commandment 2 also advocates that agile approaches seen in commercial development result in faster deployment of functionality and cost savings which we observe in this instance.

Though a comparison of cost is one facet of performance, more research is required to increase the certainty that better overall performance and results were achieved with agile methods.

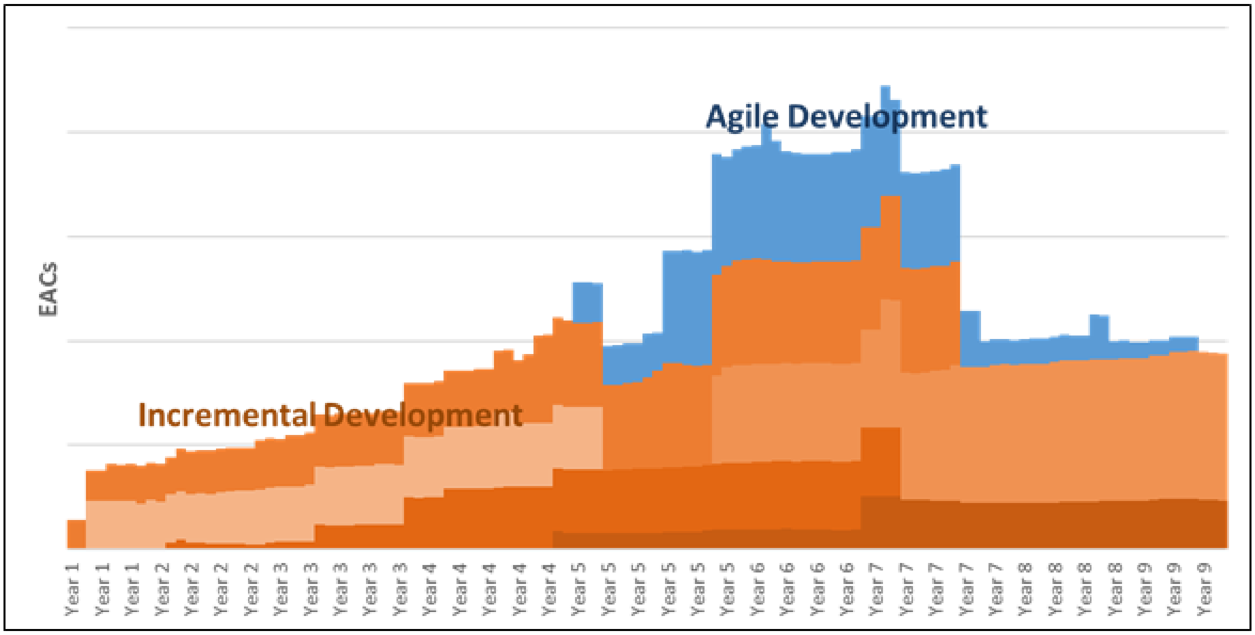


Figure 12. Aircraft Program A05: Incremental vs. Agile Development Efforts

Cost and Schedule Analysis Summary

In important ways, this analysis was typical of other efforts that aim to use Department data to examine the performance of acquisition. Due to the limited nature of the data available, our best analyses typically take months to create, with substantial time needed to find the data, to collect them, and to compile them into a structured format from multiple siloed and restricted systems.

The observations taken from data analysis of DoD program cost and schedule performance support the supposition that the current state of software acquisition is highly problematic and unsustainable relative to affordability and functionality. The DIB SW Commandments 2, 3, and 4 provide recommended measures to contain growth and increase the opportunity for cost savings by detaching software development from a hardware manufacturing industrial model and integrating software development and operations to quickly provide functionality to users and meet changing needs dictated by a dynamic global environment.

The preceding sections have described specific conclusions from the analyses our team conducted. Equally important, however, are the types of analyses we were *unable* to conduct given the data that were available.

A notable omission is that the Department is unable to address questions of *how much* software it has. Not in terms of software size but in terms of an index of how many important software systems have been acquired or are being sustained by the Department: There is no DoD or Service framework for describing the types of software intensive systems, or any inventory / catalogue of the software in use. As a result, it is challenging to comprehend the scope and magnitude of the DoD software enterprise, and to design appropriate solutions for issues such as infrastructure or workforce that can meet the magnitude of the problem. Although done at a smaller scale, NASA's software inventory is an example of such an inventory model that is used to make strategic decisions for a federal agency.[32]

There is a large and growing body of work on software analytics, the automated or tool-assisted analysis of data about software systems (usually collected automatically) in order to make decisions. Conferences such as Mining Software Repositories[33] and Automated Software Engineering[34] annually showcase the best of the new research in these areas, and these methods are having a practical impact in commercial and government environments as well. A summary of software analytic applications lists several important questions that can be explored in this way: to name just a few, "using process data to predict overall project effort, using software process models to learn effective project changes, … using execution traces to learn normal interface usage patterns, … using bug databases to learn defect predictors that guide inspections teams to where code is most likely to fail."[35] Without access to its own software data, the DoD is missing the opportunity to exploit another area of research that could provide practical benefit for improving acquisition.

In a later section of this report (Appendix H), we provide the results of a small study that was undertaken to demonstrate potential practical impacts that could be achieved if software data access could be possible in the future.

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[32] NASA Engineering Handbook (https://swehb.nasa.gov/display/7150/SWE-006+-+Agency+Software+Inventory#_tabs-6).

[33] https://2018.msrconf.org/

[34] http://ase-conferences.org/

[35] T. Menzies and T. Zimmermann, "Software Analytics: So What?," in *IEEE Software*, vol. 30, no. 4, pp. 31-37, July-Aug. 2013. DOI: 10.1109/MS.2013.86

Appendix H: ~~Replacing~~ Augmenting CAPE with AI/ML

Linda Harrell, John Piorkoski, Phil Koshute, Erhan Guven, Marc Johnson (JHU/APL)
Vladimir Filkov, Farhana Sarkar, Guowei Yang, Anze Wang (UC Davis)
Steven Lee (Rotunda Solutions)

H.1 Introduction

The Defense Innovation Board (DIB) Software Acquisition and Practices (SWAP) study chartered an exploratory study to explore the use of modern tools in data analytics and Machine Learning (ML) to provide insights into cost, time, and quality of Department of Defense (DoD) software projects. The data analytics and ML effort were performed by a team from academia (University of California Davis (UC-Davis)), a university affiliated research center (The Johns Hopkins University Applied Physics Laboratory (JHU/APL)) and industry (Rotunda Solutions). Since a suitable DoD data set was not available, the three teams leveraged existing data sets that were readily available to perform ML experiments and quickly get results.

ML models were created to predict the cost, time, and other aspects of software projects and gain a deeper understanding of the potential impact of project characteristics on overall project budget and effort. The models were trained with different data sets and were constructed to predict different performance metrics throughout the software development lifecycle.

The JHU/APL team developed ML models to predict software project duration and effort using the commercially available International Software Benchmarking Standards Group (ISBSG) Development and Enhancement (D&E) Repository of completed software projects. The UC-Davis team developed ML models to forecast software project duration, effort, and popularity using the publicly available GitHub repository of open-source projects. Finally, Rotunda Solutions created a defect density ML model to capture the code complexity and predict potential risk of code modules using a publicly available NASA dataset.

Additionally, the Rotunda Solutions team identified a number of opportunities for harnessing ML and Artificial Intelligence (AI) to improve the software acquisition process during different phases of the procurement cycle. This research effort is referred to as the Opportunities for Analytic Intervention. Rotunda Solutions also started development of a conceptual mock-up to explore some of these opportunities.

Overall, the three ML model development approaches demonstrated promising results aimed at improving predictions of software cost, time, and quality during different life-cycle phases.

- The JHU/APL team identified features (software metrics) that can support predictions of duration and effort at the project onset and shows that ML models have very good accuracy even with as few as 5 to 15 important features, most of which can be easily collected. It also shows how the prediction accuracy increases slightly by also including the effort expended in different life-cycle phases (e.g., planning, specification, design, build, test, and implementation). Since this analysis addresses the whole software lifecycle, the APL effort is referred to as the Software Life-Cycle Prediction Model.

- The UC-Davis team shows how monitoring of software development activities over time via automated tools that capture metrics (such as the number of lines of code, the number of commits, and team size) can support accurate forecasts of duration, software effort (SWE), and software popularity. Additionally, the UC-Davis analysis showed that the ML models could obtain very good forecasting accuracy only 6 months after code development has started. Hence the UC-Davis ML model can serve as an early warning indicator. Since this analysis leveraged data obtained during software development activities to forecast future outcomes, it is referred to as the Software Development Forecasting Model.

- The Rotunda Solutions defect density model automatically processed code files and output code complexity metrics to aid efficient resource allocations and risk mitigation.

Interestingly, despite the differences in the approaches taken by JHU/APL and UC-Davis, the teams shared similar conclusions. For instance, both teams identified the team size and the project timing as being important features for the predictions.

Section D.2 of this document describes the methodology applied to the APL Software Life-Cycle Prediction Model and the UC-Davis Software Development Forecasting Model. Section D.3 summarizes the major findings of all three analyses. Section 4 offers implications of these study results for DoD programs.

H.2 Methodology

The approaches taken for the APL Software Life-Cycle Prediction Model and the UC-Davis Software Development Forecasting Model were complementary. Table 2.1 summarizes key aspects of the two approaches. These aspects include:

ML Techniques. Both studies leveraged readily available commercial or open- source ML techniques. This enabled the teams to meet the task's quick reaction turn-around timeline and also ensures that DoD government personnel and contractors can apply a similar approach when they develop their own prediction models for software projects. Although the teams developed several types of ML models, this report focuses on those with the best results: the APL Random Forest (RF) and the UC-Davis Neural Network (NN) models.

Data Sets. The APL team leveraged the 2018 International Software Benchmarking Standards Group (ISBSG) Development and Enhancement (D&E) Repository of completed software projects. This diverse database contains thousands of software projects that are described by a rich set of features that span the whole software lifecycle, but most of these projects have less than one year in duration or less than two years of effort. The UC-Davis team mined the GitHub collaborative project development and repository site, which contains historical trace data captured from millions of open-source software projects. The resulting database includes hundreds of thousands projects of various sizes. Its feature set is not as rich as in the ISBSG database, but it automatically tracks development metrics including commits, discussions, and other activities.

Target Variables. The APL team focuses on predicting software project duration and effort, two of the three metrics of greatest interest to the DIB. On the other hand, the UC-Davis team aims to predict the project duration (via its proxy months committed), the number of software commits (which is an incomplete proxy for software effort), and the number of stars (which is an indicator of the popularity of a project in GitHub).

Project Tiers and Boundaries. Large differences between proposal estimates and actual outcomes for software development duration and effort cause the biggest challenges for the DoD; small deviations are much more manageable. To reflect this perspective, both studies gathered their target variables into discrete tiers with boundaries shown in Figure 2.1.

Performance Metrics. Both studies assessed the performance of their models with confusion matrices (which shows the distribution of predictions in terms of predicted and actual tiers) and overall accuracy.

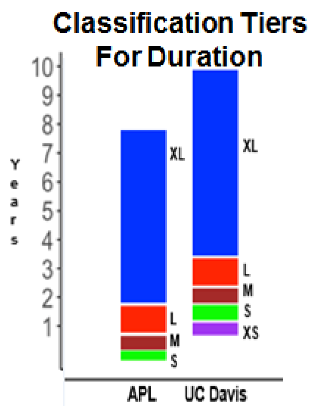
Table 2.1. Key Aspects of APL and UC-Davis Studies

Parameter		**APL Software Life-Cycle Prediction Model**	**UC-Davis Software Development Forecast Model**
Data Set		2018 ISBSG D&E Repository	2018 GitHub Repository
Number of Projects (after preprocessing)		2,818	Approx. 127,000
Number of Features (after reduction)		176	36
Target Variables for …	Duration	Project Duration	Months Committed
	Effort	Effort	Total Number of Commits
	Popularity	N/A	Number of Stars
ML Techniques		Off-the-shelf (NB, SVM, RF)	Off-the-shelf (MR, NB, RF, NN)
Results: Overall Accuracy; Confusion Matrices		Overall accuracy: Yes Confusion Matrix: 4 tier	Overall accuracy: Yes Confusion Matrix: 5 tier
Prediction Snapshots		Early concept development and procurement; Software development in process	After 6 months of software development ; Most recent software development
Feature Reduction		Yes	Yes

Definitions: NB = Naive Bayes, SVM = Support Vector Machines, MR = Multivariate Regression, NN = Neural Networks

APL Classification Tiers

Project Size	Software Effort
Small	2 months to 0.999 year
Medium	1 year to 1.999 years
Large	2 years to 7.999 years
Extra Large	>= 8 years



UC Davis Classification Tiers

Project Size	Number of Commits	Number of Stars
Extra Small	30 - 90	0 - 2
Small	91 - 140	3 - 7
Medium	141 - 217	8 - 22
Large	218 - 384	23 - 90
Extra Large	385 - 3469	91 - 31168

Figure 2.1. Classification Tier Boundaries

Prediction/Forecasting Snapshots. APL made predictions at two project phases (snapshots). The first snapshot is at onset, which includes features that are available or can be estimated during the concept, proposal, and procurement stage. The second is after software development has been underway; it can include additional features as they become available. UC-Davis made predictions at three snapshots, corresponding to the time elapsed for each project: 6 months from first commit, 12 months from first commit, and most recent snapshot (1/1/2018). The most recent snapshot is taken to be the actual outcome (even if the project is still under development). For simplicity, the results with the 12-month snapshot are not discussed herein.

Feature Importance Ranking and Reduction. The APL RF and UC-Davis NN models both determined feature importance by evaluating the importance of each feature to the overall accuracy prediction and developed corresponding models with only the top ranked features.

Pre-Processing and Feature Selection. The pre-processing actions taken by the APL and UC-Davis are discussed in separate reports.

Project Context (Cluster) Creation. To fine-tune their predictive models, UC-Davis used an Autoencoder NN to group projects into four similarity clusters (i.e., contexts). A separate model NN was trained for each cluster. This technique allows for greater accuracy when project context is known early on, by, for example, tracking project metrics from the start.

H.3 Key Results and Findings

APL Software Life-Cycle Prediction Model

Table 3.1 shows the performance of the APL models that predict software project duration and effort with all features included. Even with minimal data cleaning, model tweaking, or sensitivity studies, and using a very sparse and unevenly distributed data set, the ML models predict a project's size tier with an overall accuracy ranging from 57% to 74%. These are impressive results for a quick-turnaround exploratory analysis.

As expected, the prediction estimates once development is underway are better than the predictions at program onset. This is because additional features, such as the effort expended in various life-cycle phases, help to improve predictions. However, with the features included in this analysis, the improvement was slight.

Even when the ML model does not correctly predict the size of the software project, the prediction is most often in adjacent tiers rather than significantly further away. This is evident in the confusion matrix in Table 3.2 and the additional confusion matrices provided in separate reports. This is important because it indicates that incorrect predictions still tend to be fairly close (e.g., an extra large project predicted as large or vice versa).

Table 3.1. Performance Summary for APL Prediction Models (with all features)

Model	**Overall Accuracy**
Predicting Duration at Project Onset	57%
Predicting Duration after the Project is Underway	58%
Predicting Effort at Project Onset	68%
Predicting Effort after the Project is Underway	74%

Table 3.2. APL Confusion Matrix for Predicting Effort as Project is Underway (with all features)

Accuracy values are shown as a percent of all projects of a given class		**Predicted Class**			
		S	**M**	**L**	**XL**
Actual Class	**Small (S)**	80	18	2	0.1
	Medium (M)	23	59	18	0.6
	Large (L)	2	20	73	5
	Extra Large (XL)	0.1	0.8	14	85

Table 3.3 identifies the most important features that influence the predictions. Naturally, the ranking of importance for each feature varies slightly for the predictions of duration and effort and for the two different phases (at project onset versus while the software development is underway), but the discrepancies are generally slight. Encouragingly, the features in this table

are generally easy to obtain or estimate: function point standards, team size, software type, project implementation date, scope, programming language. The only feature category that is time consuming to gather is the functional size estimate. Each of the features in these tables is further described in the APL report.

Table 3.3 Most Important Features for ML Accuracy Predictions

Category of Feature	Most Important Features	Project Phase
Software Size	Functional Size, Relative Size, Adjusted Function Points	Project Onset
Standards for Function Point Estimates	Function Point Standards, Count Approach	Project Onset
Team	Maximum Team Size, Team Size	Project Onset
Type of Software	Industry Sector, Organization Type, Application Type, Business Area	Project Onset
Timing	Year of Project, Implementation Date	Project Onset
Scope	Project Activities, Development Type	Project Onset
Programming Language	Primary Programming Language, Language Type, Development Platform	Project Onset
Incremental Effort	Effort in the Planning Phase, Effort in Specify Phase, Effort in Design Phase, Effort in Build Phase, Effort for Implementation, Effort in Test Phase	When the Project is Underway
Cost	Total Project Cost	When the Project is Underway

Figure 3.1 depicts the accuracy prediction with small subsets of the most important features, and shows how the accuracy increases as additional features are added. This figure shows that although the database includes 176 features, very good predictions can be obtained using only as few as 5 to 15 features. These features are captured in Table 3.3.

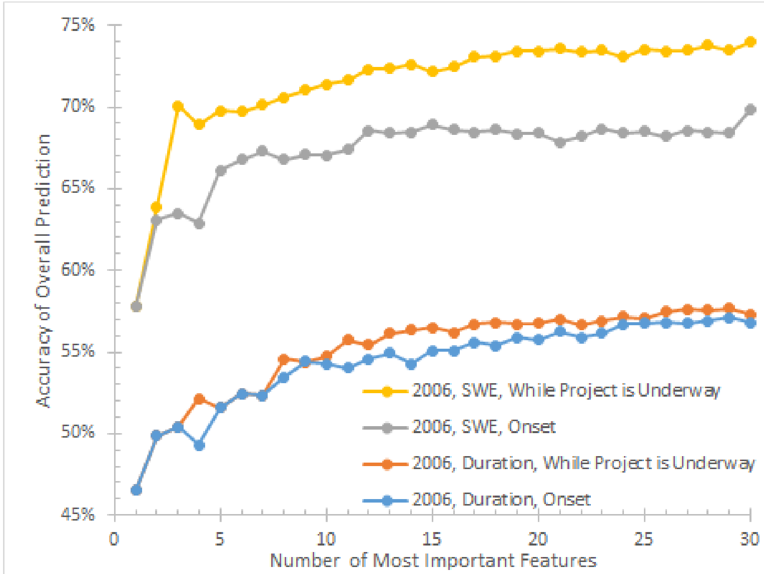


Figure 3.1. Accuracy of APL's Software Project Duration and Software Effort (with reduced, prioritized feature set)

The APL Software Life-Cycle Prediction model results clearly show that ML models can quickly be developed and trained using only a relatively small number of projects, a very small number of features, and a large amount of missing data. Furthermore, the resulting predictions for a software project's duration and total effort can be reasonably accurate at the project onset, and can then improve slightly over time by tracking the effort that is expended over the lifecycle. Only about 5 to 15 features are required to achieve reasonable predictions. The most important features for the predictions were identified; most of them are easy to obtain or estimate.

UC-Davis Software Development Forecasting Model

UC-Davis developed models that predict project duration, number of commits, and popularity using all available historical data of completed projects in the January 2018 snapshot, starting from the first commit of software. Table 3.4 shows the best-case overall prediction accuracies that can be obtained with these models and all of this data. The best-case overall accuracy of the prediction estimate for project duration is 84% and the best-case overall accuracy of the prediction estimate for the number of commits is 72%. Predictions for popularity were less accurate. These results indicate that the features in the GitHub database will be very useful for predicting software project duration and to a lesser extent the predictions for the number of commits. It appears that additional features will be necessary to improve the predictions for software popularity.

Additionally, Table 3.4 also shows that the best-case overall accuracy results for these models vary for different context clusters of similar projects. For instance, the accuracy values for each target variable increase within certain clusters; accuracy is greater in Cluster 1 by 16% for project duration and by 24% for number of commits and in Cluster 4 by 13% for popularity. These increases suggest that clustering projects based on similar context can increase the best-case prediction accuracy and that different models may be necessary to best predict different project contexts. The descriptions of these different clusters are not available at this time, but it would be valuable to investigate this further in order to understand the project characteristics that distinguish the clusters.

Table 3.5 shows the best-case overall accuracy of the UC-Davis models that use only the 9 most important features from the full project lifetime. These results are very close to those of the models that use all available features, indicating that the reduced feature set is sufficient for accurate predictions.

Table 3.4. Full Lifetime (Best-Case) Prediction Accuracy

Target Variable	All Projects	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Number of Projects	126,799	21,462	31,918	55,065	18,354
Project Duration (months committed)	84%	99.5%	83%	80%	78%
Number of Commits	72%	96%	70%	62%	69%
Popularity (number of stars)	49%	46%	48%	42%	62%

Table 3.5. Full Lifetime (Best-Case) Prediction Accuracy with Reduced Feature Set

Target Variable	**All Features** (All Clusters)	**9 Most Important Features** (All Clusters)
Project Duration (months committed)	84%	84%
Number of Commits	72%	74%
Popularity (number of stars)	49%	48%

Table 3.6 shows the accuracy results of the forecasting models, which predict the target variable in the final snapshot using features from a snapshot taken 6 months after project starts. These results are averaged over each of the 4 clusters (i.e., include 126,799 projects). These forecasting results show that data from only the first 6 months into a project can predict future outcomes, reaching accuracies of approximately 50% for both project duration and number of commits.

Table 3.7 identifies the most important features that influenced the UC-Davis predictions and forecasting. This table shows that features related to teams and commit activity are the most important for the UC-Davis models.

Table 3.6. Forecasting Accuracy (Averaged Over All Clusters)

Target Variable	Prediction of target variable at last snapshot given 6 month snapshot	Prediction of target variable at last snapshot given all data
Project Duration (months committed)	53%	84%
Number of Commits	50%	72%
Popularity (number of stars)	41%	49%

Table 3.7. Most Important Features for the UC-Davis Predictions and Forecasting

Feature Category	Most Important Features
Commit Activity Data	First Commit Date, Months Committed
Team Member Data	Team Size, Number of Commenters, Number of Pull Request Mergers, Average Months Active, Standard Deviation (SD) Months Active, Average Commits per Month, SD Commits per Month

In summary, the UC-Davis analysis shows excellent results for being able to forecast project duration and the number of commits only 6 months into a project. Only 9 features are required to achieve these forecasts. The most important features for the predictions were identified; all of them easily obtained with automation tools that track software development activities. Additionally, UC-Davis uncovered clusters of projects that if better understood could lead to improved models and accuracy predictions.

Rotunda Solutions Investigation of Opportunities for Analytic Intervention

The Rotunda Solutions effort focused on identifying strategic opportunities to leverage ML and AI at key points in the overall DoD procurement process. It extended academic research and state-of-the-art quality management principles to identify opportunities to improve the likelihood of successful software development outcomes. It also developed initial conceptual mock-ups to explore potential applications, including a defect prediction platform.

Rotunda Solutions adopted a basic stage-gate model to represent the general structure and stages of a DoD procurement and project development effort. Multiple opportunities are identified in each stage where analytics, ML, and other modern techniques can assist project managers. First, analytics can provide metrics and insights to support the project manager's yes/no/hold decision for whether the project should move to the next development stage. Second, analytics and ML can facilitate the search and interpretation of DoD procurement and development data sets so that decision makers have better access to historical data. Third, analytics can be run on this historical data to provide insights that can inform future projects. The application of modern techniques within a basic stage-gate model for a typical DoD procurement and development project can be envisioned as follows.

Stage 1: Idea Generation/Need Analysis. Analyze the internal unstructured documents from the program office and communications between suppliers and procurement officials. Then apply problem identification analytics to define the problem to be solved, considering the following 5 major groups/factors: need spotting, solution spotting, mental invention, market research, and trend. The literature shows a clear trend in savings of time and resources during the development process by maximizing the effectiveness of the idea generation stage.

Stages 2 and 3: Proposal Development and Response. Analyze internal unstructured documents from the program office and communications as they relate to proposal development and response. Use qualitative techniques such as focus groups, in-depth interviews, and surveys to determine factors associated with development success and failure. Additionally, use natural language processing (NLP) techniques to prepare the documents for further analysis. Both methods can identify key mechanisms and characteristics of software development success.

Stage 4: Contract and Award. Identify keywords through analysis of prior software contracts. Use NLP and topic extraction on legal documents surrounding the final selection of the supplier, contract vehicles, set-asides, and all stipulations to determine content. This can increase the ease of detecting associations between numerous demographic and supplier characteristics and software development performance. It also provides the ability to build a grading system and general profile of contractors and their performance on projects.

Stage 5: Software Development. Gather representative data regarding project management metrics, code base, and development metrics, and compile a list of metrics that can help identify the likelihood of success of a DoD software development project. This helps the DoD in two ways: first by identifying projects that are likely to succeed or fail in each stage; and second by informing cost and time estimates for future software acquisition projects. Alternatively, analyze code to inform the development of ML tools to assist project managers and developers understand the state of their code. Potential benefits of this analysis include tools that can rapidly identify errors and increase efficiency for automation, audits, process checkpoints, and standardization.

Stage 6: Implementation. Harness available information on users, development, delivery personnel, and performance metrics of the software system. Measure the efficacy of the deployed or implemented software systems through metrics such as dependability, system performance, extensibility, and cross-platform functionality. This provides a post-mortem analysis of the efficiency and effectiveness of the software and the development process, allowing DoD to learn from past experience and increase the likelihood of future development success.

Conceptual Mock-Ups

Rotunda Solutions aims to help the DoD in four ways: (1) understand the potential impact of variables, decisions, and project characteristics on project budget and effort, based on historical data of similar projects; (2) make data-informed project decisions pertaining to the adjustment of project structure, methods, and other details; (3) create and explore what-if scenarios to promote better planning; and (4) encourage transparency and traceability of factors and decision-points affecting project performance. To this end, a number of concepts offer potential for further development and exploration. For instance, the concept of an "intelligent" burn-down chart is especially intriguing. Given sufficient sprint data and historical trend data, effort estimation tools and ML algorithms can be leveraged to make real-time predictions and issue alerts when estimates of team effort needs a closer review. Also, a defect prediction algorithm may be able to support risk mitigation activities and improve resource allocations.

Focus Area: Defect Prediction Platform

Software defect prevention is an essential part of the quality improvement process; timely identification of defects is important for efficient resource allocation, increased productivity, and risk mitigation, yet complete testing of an entire system is generally not feasible due to budget and time constraints. Studies show that the majority of software bugs are often contained within a small number of modules. To more rapidly identify these modules, Rotunda Solutions developed a system to automatically process code files and output code complexity metrics. They built off extensive industry research and tested representative NASA software modules using NN, SVM, Gaussian mixtures, and ensembles of ML techniques. The NN model performed best and was selected for production.

The NN model consists of 8 hidden layers, each layer becoming smaller until converging on a single probability to represent the existence of defects in the file. This model learns to assign importance weights to each of the 17 features and to combine these features in non-linear ways to identify any potential defects. The NN can then be used to give a probability of defects for future files. This could help the management team in three ways: (1) to recognize the likeliest modules to have defects and allocate corrective resources effectively; (2) to provide an overview of the riskiest code modules to identify opportunities to re-architect the application; and (3) to understand the risk of deployment in production by an automated code complexity review.

Conclusions

The Rotunda Solutions exploration outlined the potential benefits of harnessing ML/AI throughout the DoD software acquisition lifecycle. These benefits include increased accuracy of budget predictions, comprehensive planning, mitigation of expensive defects, and transparency. Rotunda Solutions also identified many opportunities and applications that may improve DoD software development and estimation practices.

H.4 Implications of the Study Results for DoD

This ML study demonstrated promising results by creating models with publicly available software project data. It uncovered a promising approach (the APL Life-Cycle Prediction Model) that can be used to develop good predictions of software duration and effort in the early stages of software procurement and development. The study also uncovered another approach (the UC-Davis Forecasting Model) that can further improve project estimates once software development has been underway for 6 months or more. Finally, the Rotunda Solutions defect density model can highlight modules requiring additional resources and risk mitigation efforts.

The generalizability of these models to DoD software projects requires validation. For instance, a pilot study could be conducted with a small subset of DoD projects. Ultimately, strategies can be developed to enable DoD leadership to effectively leverage ML models.

One strategy could entail a strong centralized mandate for DoD software development teams to provide project data to DoD oversight personnel for evaluation with the APL and UC-Davis models.

A second, more streamlined and evolutionary strategy is to provide these models as tools for DoD software development teams to use as part of best practices to guide their development plans. This strategy would alleviate the exchange of data and would allow a more collaborative community effort to refine the models and resulting software development performance over time.

H.5 Caveats and Limitations

It is important to note that there are significant differences between the software repositories used in this work and important classes of software acquired by the DoD. For example, embedded software used in DoD weapons platforms is typically marked by high complexity, with low tolerance for reliability, availability, safety, and security issues. Although the testbeds on which the ML approaches were applied do contain some NASA software, only a small subset at best of the systems providing data are expected to have similar characteristics. As a result, it is important to view these results as showing a potential method that would be applicable to DoD programs and could learn characteristics of interest within that environment. While the method may be of interest, the specific results summarized may not directly carry over to some types of software present in the DoD environment.

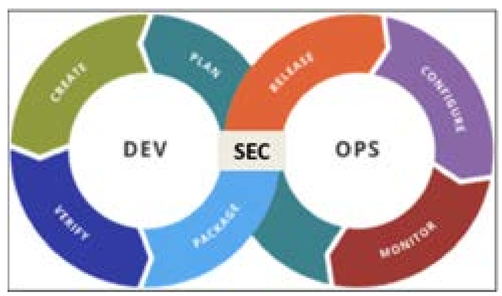
Appendix I: Acronyms and Glossary

Acronyms (not yet complete)

- CAPE - Cost Assessment and Performance Evaluation
- CFR - Code of Federal Regulations
- DFARS - Defense Federal Acquisition Regulation Supplement
- DODI - Department of Defense Instruction
- DOT&E - Director, Operational Test & Evaluation
- FAR - Federal Acquisition Regulation
- FFRDCs - Federally Funded Research and Development Centers
- JCIDS - Joint Capabilities Integration and Development System
- OODA - Observe, Orient, Decide and Act
- OT&E - Operation, Test & Evaluation
- PPB&E - Planning, Programing, Budgeting and Execution
- T&E - Testing & Evaluation
- USC - United States Code

Glossary (not yet complete)

In this subsection we provide a short glossary of some of the terms that we use throughout the report. For each term we provide a short definition of that term, including references if it is a term used elsewhere, and then provide some context and motivation for the use of the term in this report.



https://commons.wikimedia.org/wiki/File:Devops-toolchain.svg (modifications licensed CC-BY-SA)

DevSecOps. "DevOps" represents the integration of software development and software operations, along with the tools and culture that support rapid prototyping and deployment, early engagement with the end user, and automation and monitoring of software, and psychological safety (e.g., blameless reviews). "DevSecOps" is a more recent term that reflects the importance of integrating security into the DevOps cycle (and not bolting on security at the end). DevOps development is closely related to agile development and the two are often used interchangeably. The term DevSecOps places more focus on security as a critical element. More information: https://tech.gsa.gov/guides/understanding_differences_agile_devsecops/.

DevSecOps techniques should be adopted by the DoD, with appropriate tuning of approaches used by the agile/DevOps community for mission-critical, national security applications. Open source software should be used when possible to speed development and deployment, and leverage the work of others. Waterfall development approaches (e.g. DOD-STD-2167A) should be banned and replaced with true, commercial agile processes. Thinking of software "procurement" and "sustainment" separately is also a problem: software is never "finished" but must be constantly updated to maintain capability, address ongoing security issues and potentially add or increase performance.

Moving to a DevSecOps software development approach will enable the DoD to move from a specify, develop, acquire, sustain mentality to a more modern (and more useful) create, deploy, scale, optimize mentality. Enabling rapid iteration will create a system in which the US can update software at least as fast as our adversaries can change tactics, allowing us to get inside their OODA loop.

Digital Infrastructure. Enterprise-scale computing hardware and software platforms that enable rapid creation and fielding of software. Critical elements include:

- *Scalable compute*: elastic mechanisms to provide any developer with a powerful computing environment that can easily scale with the needs of an individual programmer, a product development team, or an entire organization enterprise.

- *Containerization*: sandbox environments that "package up" an application or microservices with all of the operating system services required for executing the application and allowing that application to run in a virtualized segmented environment.

- *Continuous integration/continuous delivery (CI/CD) pipeline*: platform for automated testing, security, and deployment of software, including licenses access for security tools and a centralized artifacts repository of containers with tools, databases, and operating system images.

- *Automated configuration, updating, distribution, and recovery management:* automated processes that use machine-readable definition files (stored in the same source code repository as your software source code) to manage and provision environments, containers, virtual machines, load balancing, networking, access rules, and other components.

- *Federated identity management and authentication*: common identity management for accessing information across multiple systems and allows rapid and accurate auditing of code.

- *Firewall configuration and network access control lists*: forces information transfer only through intentional interfaces to reduce the attack surface and make system servers more resilient against penetration.

- *Common information assurance (IA) profiles*: Common IA profiles integrated into the development environment and part of the development system architecture are less likely to have bugs than customized and add-on solutions.

- *Modeling and simulation (digital twin) capability:* [add]

Currently, DoD programs each develop their own development and test environments, which requires redundant definition and provisioning, replicated assurance, including cyber, and extended lead times to deploy capability. Digital infrastructure, common in commercial IT, is critical to enable rapid deployment at the speed (and scale) of relevance. The Services and defense contractors will need to build on a common set of tools (instead of inventing their own) *without* just requiring that everyone use one DoD-wide (or even service-wide) platform.

Digital twin. A digital twin is a digital synthetic representation of a system or capability. Digital twins are useful in concept development, designing, developing, testing, and validation of software. The use of high fidelity simulations and digital models, enables software developers to develop and validate software more quickly with greater reliability. In the future, as we leverage the use of Machine Learning (ML) and Artificial Intelligence (AI) in software design, development, and test, the ability to leverage simulation and modeling will be critical. For example, today, in the commercial world where self-driving cars are being pioneered, sensors are used to collect data on millions of miles of roads. Before software updates are pushed to the autonomous driving cars and before the first mile is every driven on real roads, the software "drives" those millions of miles through simulation. It is important that the Department and our defense industrial base develop and support similar capabilities to that of commercial industry.

Enduring capability. Refers to a class of mission software needs that will persist for the foreseeable future and should be budgeted and managed as an ongoing level of effort with a portfolio management approach to balance – in real time – maintenance, upgrades and major new functionality. An example is the acquisition, processing and distribution of data and information from overhead assets which, when separated from the sensor and satellite programs to which each iteration is traditionally attached, is an area of investment we will always be making.

Throughout this report we make reference to the modern view of software as a continuously, incrementally delivered capability and we use that definition to drive many of the recommendations we propose, especially around the use of DevSecOps. This view is characterized by rapid user feedback loops and continuous deployment to deal with that feedback and with such "maintenance" functions as cyber protection, operating system upgrades, etc. This is the overall vision we espouse for the acquisition and delivery of most types of software – think about the software to deliver spare parts management for a fighter fleet, the software to manage the movement of service personnel and their families, or the software to provide tanker scheduling for a combat air fleet in an AOR.

We believe it is also important to look at certain kinds of software that will need to be delivered against a *mission* need that will persist for long enough into the future that we should think about it as an *enduring capability* need. A good example of an enduring capability is the processing, exploitation, and distribution (PED) software that ingests data from multi-domain overhead assess, processes that data into a series of information products and makes those products available to a wide array of global users. Satellites will change, sensors will change, and the kinds of analyses will change, but the underlying software to process this chain will endure.

Historically PED has been mapped to new or upgraded satellite launches – new satellite, new ground station – and as such are mapped to long cycle times, large, non-incremental programs and oversized budgets broken into the traditional buckets of R&E, acquisition and maintenance.

A different model would be to recognize the enduring need for PED capability, fund as a stable ongoing effort, manage the capability through an integrated program team / PEO responsible in real time for the portfolio trades between fixes, upgrades and new capabilities. The core is to separate software from the hardware platforms that provide it data and from the downstream systems that consume the output of the software, recognize that this software need will persist for the foreseeable future, and fund and manage the program in this fashion.

Security-at-the-perimeter. An approach to security that relies on perimeter access control as the primary mechanism for protecting against intrusion.

Catch phrases

Self denial of service attack. Not letting your organization make use of tools or processes that are available to others.

Staple test. Any report that is going to be read should be thin enough to be stapled with a regular office stapler. A standard office stapler is able to staple 25 sheets of paper together => staple test limit is ~50 pages (but you can get a bit more if you bend over the staples manually).

Takeoff test. Reports should be short enough to read during takeoff, before the movies start and drinks are served (assuming you got upgraded). The average time from closing the door to hitting 10,000 ft (wifi on) at IAD is 25 minutes (15 taxi + 10 cruise). Average reading time for a page is 2 minutes => takeoff test limit is ~12 pages.

Waterfall with sprints. A too common approach to implementing agile development principles in a DoD environment. Development teams work on a rapid sprint cycle and deliver code into a test environment that takes months to complete (versus actual agile, where code would be released to users at the end of the spring).

Appendix J: Study Information

Defense Innovation Board
Software Acquisition and Practices (SWAP)
Study Membership

Chairs

Dr. Richard M. Murray
California Institute of Technology

Dr. J. Michael McQuade
Carnegie Mellon University

Members

Mr. Milo Medin
Google

Ms. Jennifer Pahlka
Code for America

Mr. Trae' Stephens
Founders Fund

Mr. Gilman Louie
Alsop Louie Partners

Study Sponsor

HON Ellen Lord

Government Advisors

Dr. Jeff Boleng
Special Advisor for Software (A&S)

Federally Funded Research and Development Center Support

Dr. Forrest Shull
Software Engineering Institute

Mr. Kevin Garrison

Mr. Craig Ulsh
MITRE

Mr. Nicolas Henri-Guertin
SEI

Study Support

Ms. Courtney Barno
Artlin Consulting

Ms. Devon Hardy
Artlin Consulting

Ms. Sandra O'Dea
E-3 Federal Solutions

SWAP Working Group Membership

Acquisition Strategy
Ms. Melissa Naroski Merker (lead)
Mr. Don Johnson
COL Harry Culclasure
Mr. Paul Hullinger
Mr. Gabe Nelson
Mr. Larry Asch
Mr. Nick Tsiopanas
Mr. Nick Kosmidis

Appropriations
Ms. Jane Rathbun (lead)
Ms. Shannon McKitrick

Contracts
Mr. Jonathan Mostowski (lead)

Data and Metrics
Mr. Ben Fitzgerald (lead)

Infrastructure
Dr. Jeff Boleng (lead)
Mr. John Bergin
Mr. Nicolas Chaillan

Requirements
Mr. Fred Gregory (lead)
Ms. Victoria Cuff
Ms. Jennifer Edgin
Ms. Margaret Palmieri
Mr. Owen Seely
Ms. Philomena Zimmerman

Security & Accreditation
Mr. Leo Garciga (lead)
Mr. Tom Morton
Ms. Ana Kreiensieck

Sustainment and Modernization
Mr. Kenneth Watson (lead)
Mr. Stephen Michaluk
Dr. Bernard Reger

Testing & Evaluation
Dr. Greg Zacharias (lead)
Dr. Amy Henninger

Workforce
Major Justin Ellsworth (lead)
Mr. Sean Brady
Mr. Kevin Carter

Programs and Companies Visited [incomplete list]

As part of its data gathering activities, the SWAP study visited the following companies:

Date	Companies	Locations
Mar 2018	Lockheed Martin	Ft Worth, TX
Apr 2018	Pivotal, Raytheon	Boston, MA
Aug 2018	Raytheon	Los Angeles; Aurora, CO
Aug 2018	SPAWAR, ARL	Colorado Springs, CO
Sep 2018	Lockheed Martin	Moorestown, NJ
Oct 2018	Leidos, Cerner	Rosslyn, VA
Nov 2018	Raytheon	Tucson, AZ

Thanks to: Ms. Samantha Betting, Mr. Richard Calabrese, Major Neal Catron, Ms. Victoria Cuff, RDML Tom Druggan, Lt Col Thomas Gabriele, Mr. Jack Gellen, Mr. Arturo Gonzalez, Ms. Jill Hardash, Mr. Brian Henson, Ms. Cori Hughes, Capt Bryon Kroger, Col Jennifer Krolikowski, Lt Col Jason Lee, Mr. Myron Liszniansky, Lt Col Steve Medeiros, Mr. David Norley, Mr. Scott Paulsen, Ms. Kelci Pozzi, Ms. Sandy Scharn-Stevens, Ms. Terry Schooley, Mr. Thomas Scruggs, Lt Col Kenneth Thill, Mr. Eric Todd

Department Meetings [not yet available]

Charge from Congress

2018 NATIONAL DEFENSE AUTHORIZATION ACT

SEC. 872. DEFENSE INNOVATION BOARD ANALYSIS OF SOFTWARE ACQUISITION REGULATIONS.

(a) STUDY.—

(1) IN GENERAL.—Not later than 30 days after the date of the enactment of this Act, the Secretary of Defense shall direct the Defense Innovation Board to undertake a study on streamlining software development and acquisition regulations.

(2) MEMBER PARTICIPATION.—The Chairman of the Defense Innovation Board shall select appropriate members from the membership of the Board to participate in the study, and may recommend additional temporary members or contracted support personnel to the Secretary of Defense for the purposes of the study. In considering additional appointments to the study, the Secretary of Defense shall ensure that members have significant technical, legislative, or regulatory expertise and reflect diverse experiences in the public and private sector.

(3) SCOPE.—The study conducted pursuant to paragraph (1) shall—

(A) review the acquisition regulations applicable to, and organizational structures within, the Department of Defense with a view toward streamlining and improving the efficiency and effectiveness of software acquisition in order to maintain defense technology advantage;

(B) review ongoing software development and acquisition programs, including a cross section of programs that offer a variety of application types, functional communities, and scale, in order to identify case studies of best and worst practices currently in use within the Department of Defense;

(C) produce specific and detailed recommendations for any legislation, including the amendment or repeal of regulations, as well as non-legislative approaches, that the members of the Board conducting the study determine necessary to—

(i) streamline development and procurement of software;

(ii) adopt or adapt best practices from the private sector applicable to Government use;

(iii) promote rapid adoption of new technology;

(iv) improve the talent management of the software acquisition workforce, including by providing incentives for the recruitment and retention of such workforce within the Department of Defense;

(v) ensure continuing financial and ethical integrity in procurement; and

(vi) protect the best interests of the Department of Defense;
and

(D) produce such additional recommendations for legislation as such members consider appropriate.

(4) ACCESS TO INFORMATION.—The Secretary of Defense shall provide the Defense Innovation Board with timely access to appropriate information, data, resources, and analysis so that the Board may conduct a thorough and independent analysis as required under this subsection.

(b) REPORTS.—

(1) INTERIM REPORTS.—Not later than 150 days after the date of the enactment of this Act, the Secretary of Defense shall submit a report to or brief the congressional defense committees on the interim findings of the study conducted pursuant to subsection (a). The Defense Innovation Board shall provide regular updates to the Secretary of Defense and the congressional defense committees for purposes of providing the interim report.

(2) FINAL REPORT.—Not later than one year after the Secretary of Defense directs the Defense Advisory Board to conduct the study, the Board shall transmit a final report of the study to the Secretary. Not later than 30 days after receiving the final report, the Secretary of Defense shall transmit the final report, together with such comments as the Secretary determines appropriate, to the congressional defense committees.