National Defense Industrial Association

Implementing Continuous Iterative Development and Acquisition

Executive Summary

NDIA Systems Engineering Division

in partnership with INCOSE and PSM

22-Apr-2019

Background

Defense Science Board (DSB) released a report in Feb-2018 containing seven recommendations regarding software design and acquisition. Section 868 of NDAA 2019 mandates implementation of these recommendations within 18 months.

The Defense Innovation Board (DIB) Software Acquisition and Practices (SWAP) study group has also provided many insightful and largely compatible recommendations.

NDIA, INCOSE and PSM support the DSB and DIB concepts and the opportunities they offer to DoD and the defense industry.

- NDIA offers the recommendations herein to ASD(A&S) and ASD(R&E) representing an “industry perspective” on path forward.
- NDIA appreciates the opportunity to partner with DoD on implementation.

DSB SW Task Force Recommendations

1. **Software Factory** – A key evaluation criteria in the source selection process should be efficacy of the offeror's software factory.
2. **Continuous Iterative Development** – DoD and defense industrial base partners should adopt continuous iterative development best practices for software, including through sustainment.
3. **Risk Reduction and Metrics for New Programs** – For all new programs, starting immediately, implement best practices in formal program acquisition strategies (multiple vendors and down-selects, modernized cost and schedule measures, status estimation framework)
4. **Current and Legacy Programs in Development, Production, and Sustainment** – for ongoing development programs, PMs/PEOs should plan transition to a software factory and continuous iterative development.
5. **Workforce** – The U.S. Government does not have modern software development expertise in its program offices or the broader functional acquisition workforce. This requires Congressional engagement and significant investment immediately.
6. **Software is Immortal: Software Sustainment** – RFPs should specify the basic elements of the software framework supporting the software factory… reflected in source selection criteria
7. **IV&V for Machine Learning** – Machine learning is an increasingly important component of a broad range of defense systems, including autonomous systems, and will further complicate the challenges of software acquisition.

The NDIA working group developed consensus recommendations responding to each of the 7 DSB findings:

- **Assumptions**
- **Picture of Success (End State)**
- **Current State**
- **Description**
- **Obstacles**
- **Path Forward**

This briefing is an executive summary of those recommendations. Detailed report provided separately.

Framing Assumptions

Continuous iterative development (CID) methods have cross-functional implications. The scope includes not just SOFTWARE but also SYSTEMS ENGINEERING and supporting disciplines.

Software Factories include people, processes, and tools – not just a tool chain.

Funding and contracts must be aligned to support implementation and/or migration to SW factories with life cycle sustainment.

A collaborative approach to Intellectual Property (IP) across the entire acquisition life cycle will be developed that meets both Government and Supplier needs.

A business case can be made for the effective deployment and maintenance of integrated tool chains to build capability throughout the life of the system.

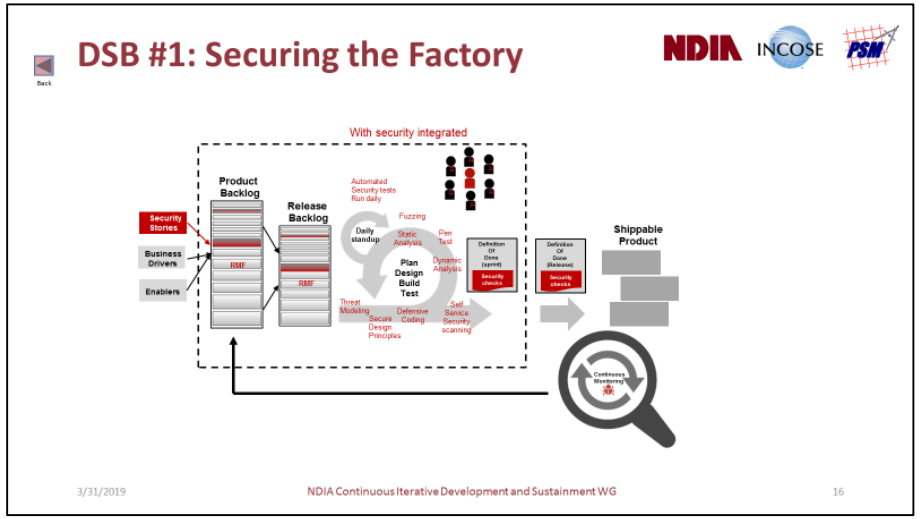
Traditional waterfall-based processes, tools, and measures are generally not well suited to CID.

A skilled SW-informed workforce cadre is available or can be developed across functions (e.g., software, acquisition, PMs, sustainment).

Cross-cutting assumptions. Refer to the separate detailed report with assumptions specific to each DSB recommendation area.

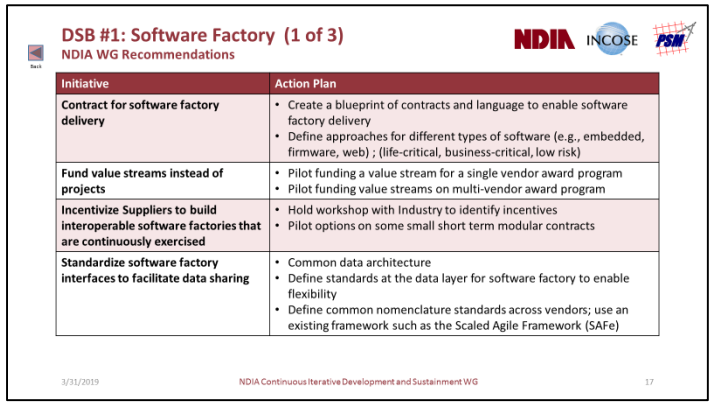
DSB #1: Software Factory
NDIA WG Recommendations

Picture of Success (end state)		
People	• Qualified factory workforce	• Continuous learning (relentless improvement, pipeline feedback)
Process	• Integrated PMB • Metrics • Predictability	• Digital Blueprint / Play Book • Ontology, Nomenclature • Secure Supply Chain • Relentless Improvement
Tools	• Platform agnostic tool chain • Adaptable to change • Test automation at all levels	• Model-based SW validation vs. architecture • Red team / Blue team factory

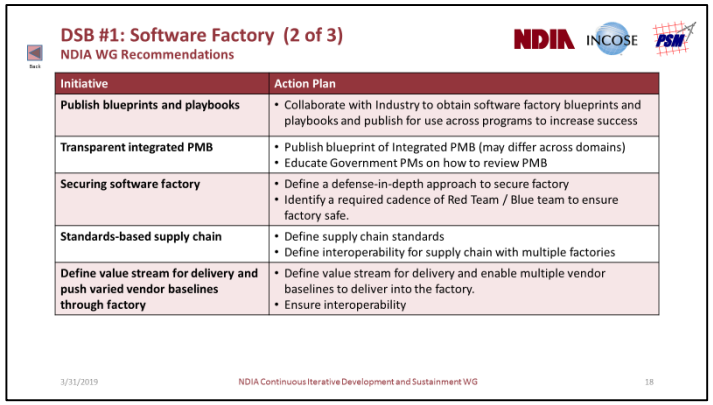


Security integrated into factory workflows (DevSecOps)

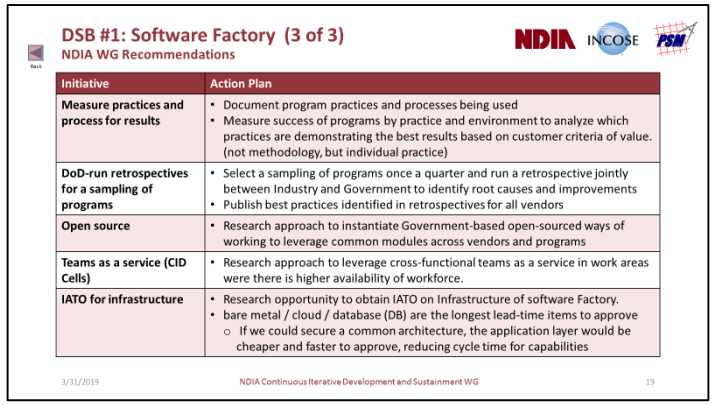
Recommendations for Path Forward:



Initiative	Action Plan
Contract for software factory delivery	• Create a blueprint of contracts and language to enable software factory delivery • Define approaches for different types of software (e.g., embedded, firmware, web) ; (life-critical, business-critical, low risk)
Fund value streams instead of projects	• Pilot funding a value stream for a single vendor award program • Pilot funding value streams on multi-vendor award program
Incentivize Suppliers to build interoperable software factories that are continuously exercised	• Hold workshop with Industry to identify incentives • Pilot options on some small short term modular contracts
Standardize software factory interfaces to facilitate data sharing	• Common data architecture • Define standards at the data layer for software factory to enable flexibility • Define common nomenclature standards across vendors; use an existing framework such as the Scaled Agile Framework (SAFe)



Initiative	Action Plan
Publish blueprints and playbooks	• Collaborate with Industry to obtain software factory blueprints and playbooks and publish for use across programs to increase success
Transparent integrated PMB	• Publish blueprint of Integrated PMB (may differ across domains) • Educate Government PMs on how to review PMB
Securing software factory	• Define a defense-in-depth approach to secure factory • Identify a required cadence of Red Team / Blue team to ensure factory safe.
Standards-based supply chain	• Define supply chain standards • Define interoperability for supply chain with multiple factories
Define value stream for delivery and push varied vendor baselines through factory	• Define value stream for delivery and enable multiple vendor baselines to deliver into the factory. • Ensure interoperability



Initiative	Action Plan
Measure practices and process for results	• Document program practices and processes being used • Measure success of programs by practice and environment to analyze which practices are demonstrating the best results based on customer criteria of value. (not methodology, but individual practice)
DoD-run retrospectives for a sampling of programs	• Select a sampling of programs once a quarter and run a retrospective jointly between Industry and Government to identify root causes and improvements • Publish best practices identified in retrospectives for all vendors
Open source	• Research approach to instantiate Government-based open-sourced ways of working to leverage common modules across vendors and programs
Teams as a service (CID Cells)	• Research approach to leverage cross-functional teams as a service in work areas were there is higher availability of workforce.
IATO for infrastructure	• Research opportunity to obtain IATO on Infrastructure of software Factory. • bare metal / cloud / database (DB) are the longest lead-time items to approve ○ If we could secure a common architecture, the application layer would be cheaper and faster to approve, reducing cycle time for capabilities

PMB: Performance Measurement Baseline

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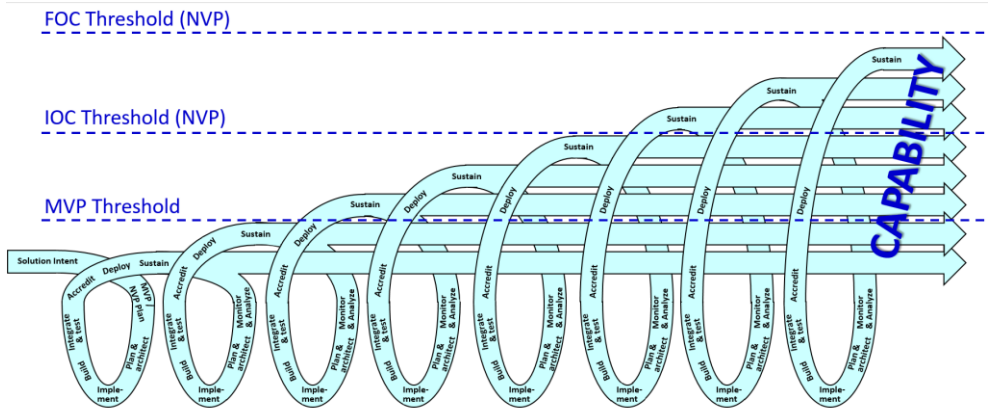
DSB #2: Continuous Iterative Development (MVP)

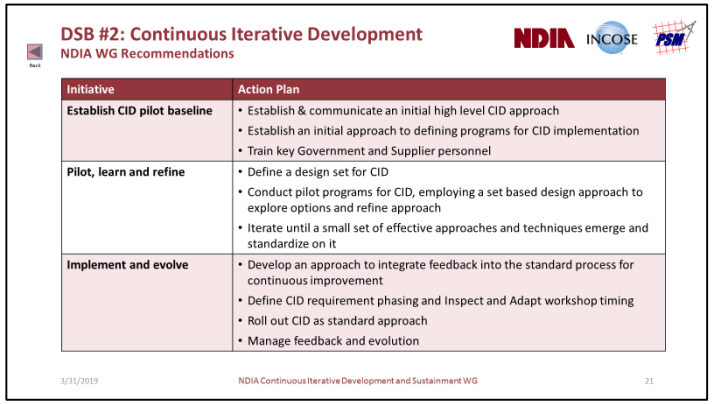
NDIA WG Recommendations

Picture of Success (end state)	
Government / Contractor Interface	
Contracting	• New programs defined by solution intent (CV-1) • Contracts defined by evolutionary viability products (MVP/NVP)
Funding	• Contract funding structure supports seamless capability evolution
Stakeholders	• Active engagement in CID lifecycle
Design	• Guided by MOSA
IP	• Government access to source code with negotiated IP protections
Program Execution	
People	• Multi-discipline agile execution includes aligned milestones • Direct user/developer interaction informs design (product owner)
Process	• Early SE ➢ SW sequencing, refactoring, tools, environments
Tools	• Test automation accelerates delivery (rapid release, deployment)



Procurements based on iterative development of releases according to product capability thresholds

Recommendations for Path Forward:



DSB #2: Continuous Iterative Development
NDIA WG Recommendations

Initiative	Action Plan
Establish CID pilot baseline	• Establish & communicate an initial high level CID approach • Establish an initial approach to defining programs for CID implementation • Train key Government and Supplier personnel
Pilot, learn and refine	• Define a design set for CID • Conduct pilot programs for CID, employing a set based design approach to explore options and refine approach • Iterate until a small set of effective approaches and techniques emerge and standardize on it
Implement and evolve	• Develop an approach to integrate feedback into the standard process for continuous improvement • Define CID requirement phasing and Inspect and Adapt workshop timing • Roll out CID as standard approach • Manage feedback and evolution

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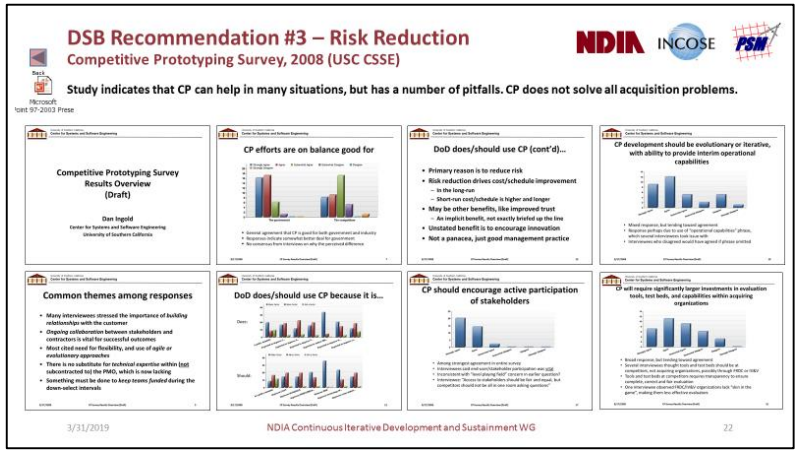
CID: Continuous Iterative Development
FOC: Final Operating Capability
IOC: Initial Operating Capability
IP: Intellectual Property
MOSA: Modular Open Systems Architecture
MVP: Minimally Viable Product
NVP: Next Viable Product

DSB #3a: Risk Reduction (Competitive Prototyping)

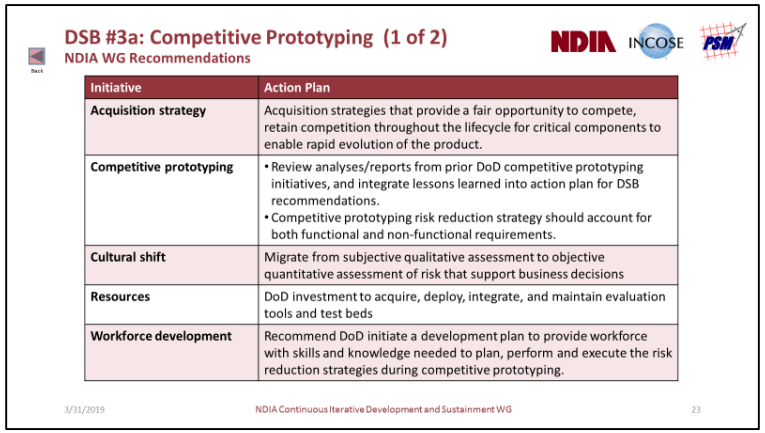
NDIA WG Recommendations

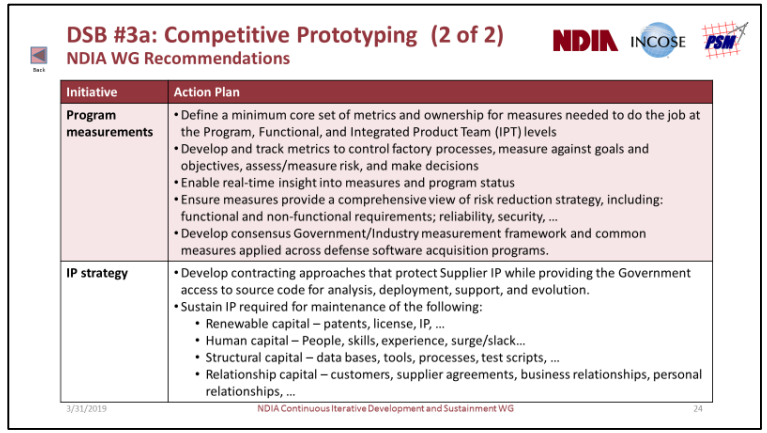
Picture of Success (end state)	
Competition	• Business case: win-win partnership, common goals, acquisition/support strategy • Objective downselect evaluation criteria (RFP L&M) and feedback • Open architecture on critical components
Contracts	• IP agreement negotiated, sustained across the life cycle • Funding and contracts aligned to support factory migration
Metrics	• Continuous improvement, SMART measures against objectives • Risk-based decision making
Resources	• Funding, staffing, tools, environments to support multiple teams



Competitive prototyping can help in many situations, but does not solve all acquisition problems.

Recommendations for Path Forward:





IP: Intellectual Property
RFP: Request for Proposal
SMART: Specific, Measurable, Achievable, Relevant, Time bound

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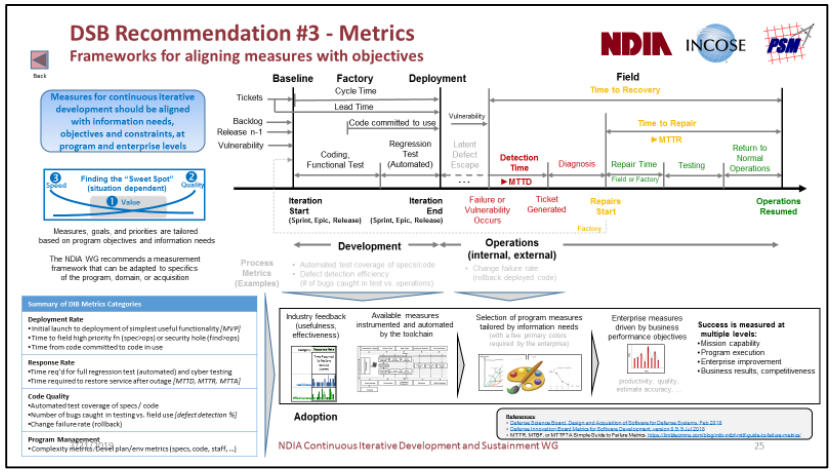
DSB #3b: Measures for CID

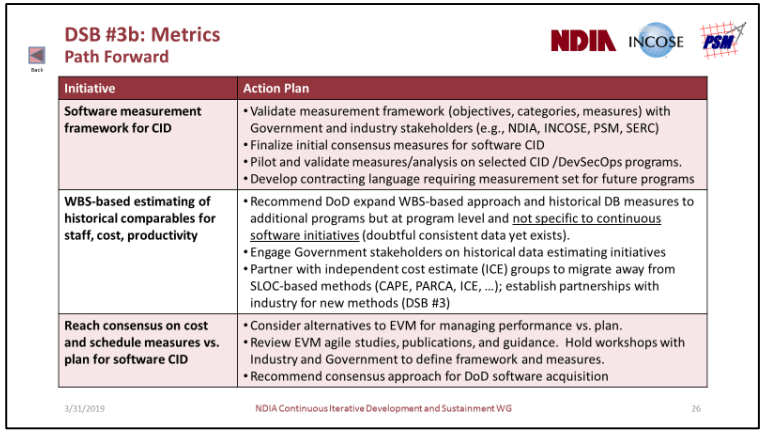
NDIA WG Recommendations

Picture of Success (end state)	
Consensus frameworks	• Objectives first - measures aligned and tailored from information needs, goals and constraints, at program and enterprise levels
Modernized measures	• Migration toward consensus alternatives to traditional waterfall and phase-based SW measures (LOC, EVM, milestones, …) • Derived from SW factory processes, automated by toolchain • Basis for measuring cost and schedule vs. plan
History-based estimates	• Repositories collect performance-based measures (e.g., WBS, staff, cost, productivity) supporting future comparisons, basis of estimates, proposals, and program monitoring



Measures for CID should be aligned with information needs and constraints, at program and enterprise levels

Recommendations for Path Forward:



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CID: Continuous Iterative Development
EVMS: Earned Value Management System
LOC: Lines of Code
WBS: Work Breakdown Structure

DSB #4: Transition for Current and Legacy Programs

NDIA WG Recommendations

Picture of Success (end state)		
People	• Skill assessment for gap analysis	• Skilled capable workforce for transition on legacy programs
Process	• Business case for transition • Playbooks and Blue Prints for legacy code transition • Assessment of supply chain and SW pedigree (FOSS, COTS, GOTS)	• Risk adjusted product backlog • Strategies for incrementally building up test automation
Tools	• Tools to generate legacy 'as-built' documentation and models for legacy code base	

COTS: Commercial Off the Shelf
FOSS: Free Open Source Software
GOTS: Government Off the Shelf

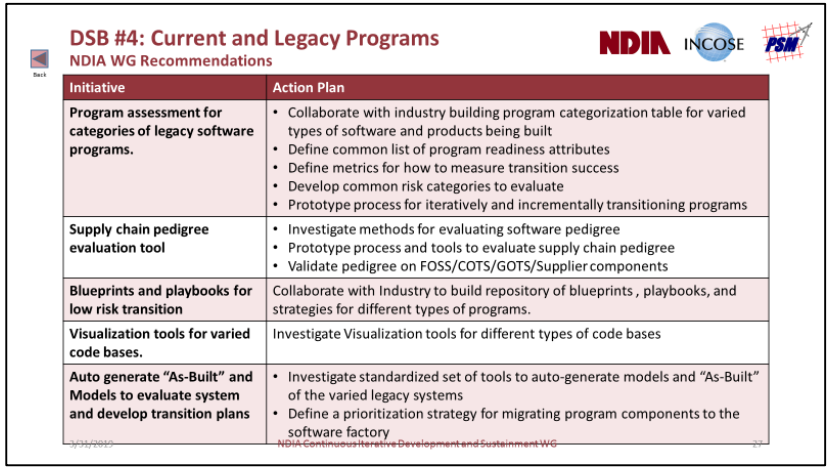
6 Box 6: Example of Legacy Program Moving to Iterative Development: Tomahawk

Tomahawk is currently executing a streamlined, hybrid-Agile approach, with good results. The development approach for Tomahawk add-on, however, is still Waterfall. The program is conducting two-week long sprints over a defined period of time (i.e., the Waterfall spiral time) with the goal of discovering defects earlier, not necessarily shortening the time to completion. The benefit of this process is that shorter sprints allow for periodic deliveries for early integration and testing, as well as cyber scans. This approach will be implemented in full in the next baseline *(Tactical Tomahawk Weapons Control System v5.6.1).*

Defense Science Board, Design and Acquisition of Software for Defense Systems, Feb 2018

See also: Defense Innovation Board SWAP Study Report: Supplementary Documents, Appendix B.6 Sustainment / Modernization Subgroup Report

Recommendations for Path Forward:



DSB #4: Current and Legacy Programs
NDIA WG Recommendations

Initiative	Action Plan
Program assessment for categories of legacy software programs.	• Collaborate with industry building program categorization table for varied types of software and products being built • Define common list of program readiness attributes • Define metrics for how to measure transition success • Develop common risk categories to evaluate • Prototype process for iteratively and incrementally transitioning programs
Supply chain pedigree evaluation tool	• Investigate methods for evaluating software pedigree • Prototype process and tools to evaluate supply chain pedigree • Validate pedigree on FOSS/COTS/GOTS/Supplier components
Blueprints and playbooks for low risk transition	Collaborate with Industry to build repository of blueprints , playbooks, and strategies for different types of programs.
Visualization tools for varied code bases.	Investigate Visualization tools for different types of code bases
Auto generate "As-Built" and Models to evaluate system and develop transition plans	• Investigate standardized set of tools to auto-generate models and "As-Built" of the varied legacy systems • Define a prioritization strategy for migrating program components to the software factory

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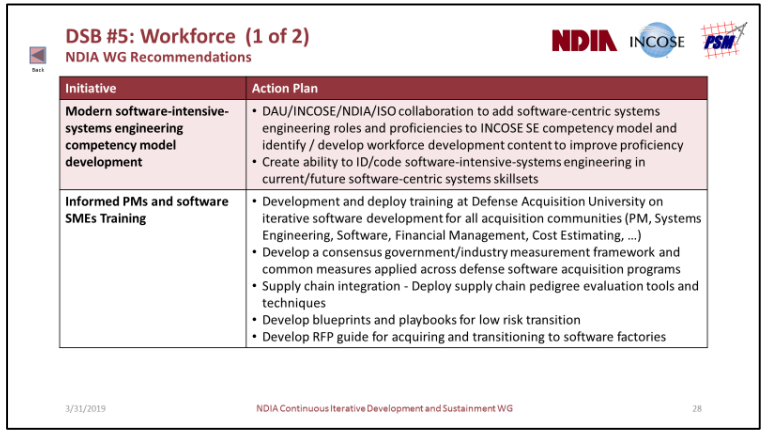
DSB #5: Workforce
NDIA WG Recommendations

Picture of Success (end state)		
Education and Training	• DAU curriculum for DevSecOps and modern SW-centric systems • Community of practice platforms	• Training across career fields (PM, sustainment, acquisition) • Aligned with current/future development and recruiting needs
Stakeholder Engagement	• Collaborative government / industry partnerships • Trained experienced industry partners and supply chain	• Consensus measurement framework • Multi-discipline CID support teams (CDRLs, events, milestones)
Staffing	• Increased hiring, retention, training for acquisition experts • Recruiting pipeline for SW experts	• Dedicated workforce funding and coaches across services • PMO IPTs for modern SW practices

CDRL: Contract Data Requirements List
CID: Continuous Iterative Development
DAU: Defense Acquisition University
IPT: Integrated Product Team
PM: Program Manager
PMO: Program Management Office

Recommendations for Path Forward:


DSB #5: Workforce (1 of 2)
NDIA WG Recommendations

Initiative	Action Plan
Modern software-intensive-systems engineering competency model development	• DAU/INCOSE/NDIA/ISO collaboration to add software-centric systems engineering roles and proficiencies to INCOSE SE competency model and identify / develop workforce development content to improve proficiency • Create ability to ID/code software-intensive-systems engineering in current/future software-centric systems skillsets
Informed PMs and software SMEs Training	• Development and deploy training at Defense Acquisition University on iterative software development for all acquisition communities (PM, Systems Engineering, Software, Financial Management, Cost Estimating, …) • Develop a consensus government/industry measurement framework and common measures applied across defense software acquisition programs • Supply chain integration - Deploy supply chain pedigree evaluation tools and techniques • Develop blueprints and playbooks for low risk transition • Develop RFP guide for acquiring and transitioning to software factories

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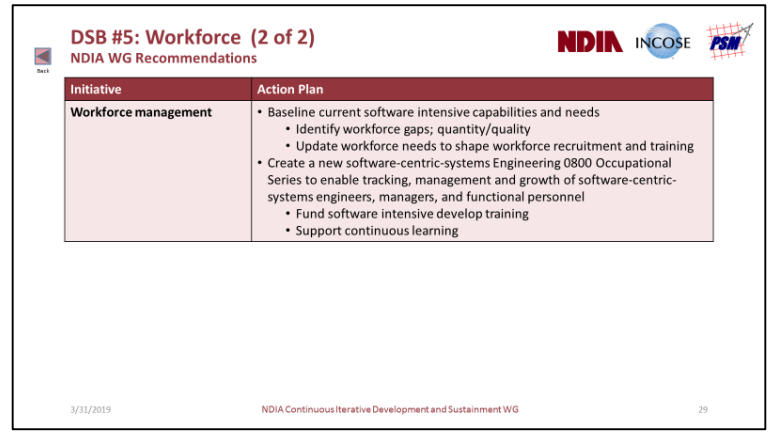
DSB #5: Workforce (2 of 2)
NDIA WG Recommendations

Initiative	Action Plan

Workforce management	• Baseline current software intensive capabilities and needs
	  • Identify workforce gaps; quantity/quality
	  • Update workforce needs to shape workforce recruitment and training
	• Create a new software-centric-systems Engineering 0800 Occupational Series to enable tracking, management and growth of software-centric-systems engineers, managers, and functional personnel
	  • Fund software intensive develop training
	  • Support continuous learning

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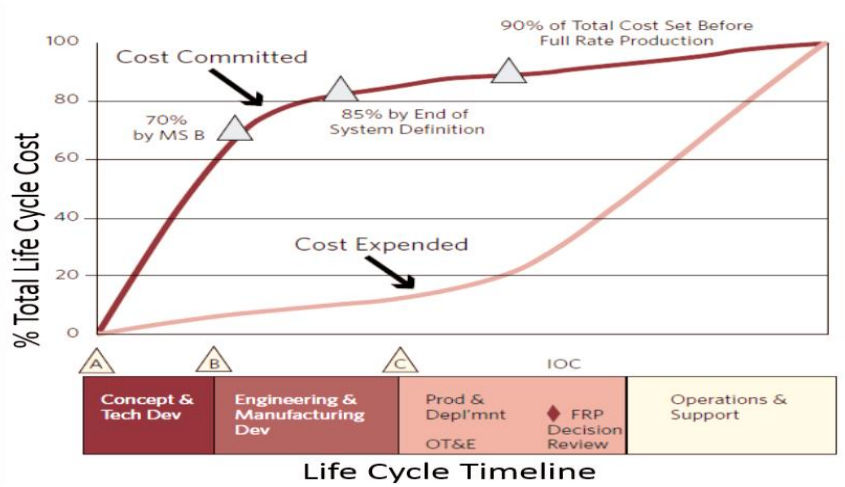
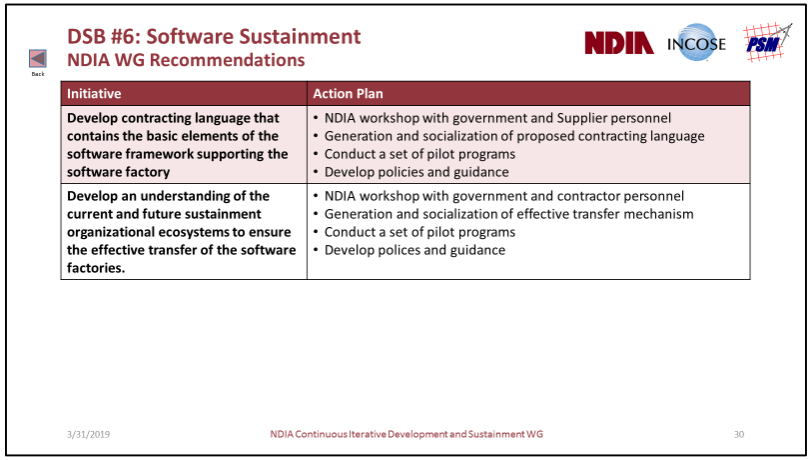
DSB #6: Sustainment (Software Is Immortal)

NDIA WG Recommendations

Picture of Success (end state)	
Resources	• **Availability and support of a trained proficient workforce** • **Organic DoD software infrastructure, incentives, funding** • **Collaborative IP strategy throughout the life cycle, using a "work shared sustainment" approach**
Contracting Language	• **Contracts specify elements of framework supporting SW factory** • **Policies and guidance validated by workshops, pilots**
Sustainment Ecosystems	• **Understanding of current and future organizational ecosystems to ensure effective transfer of SW factories**



Recommendations for Path Forward:



DSB #6: Software Sustainment
NDIA WG Recommendations

Initiative	Action Plan
Develop contracting language that contains the basic elements of the software framework supporting the software factory	• NDIA workshop with government and Supplier personnel • Generation and socialization of proposed contracting language • Conduct a set of pilot programs • Develop policies and guidance
Develop an understanding of the current and future sustainment organizational ecosystems to ensure the effective transfer of the software factories.	• NDIA workshop with government and contractor personnel • Generation and socialization of effective transfer mechanism • Conduct a set of pilot programs • Develop polices and guidance

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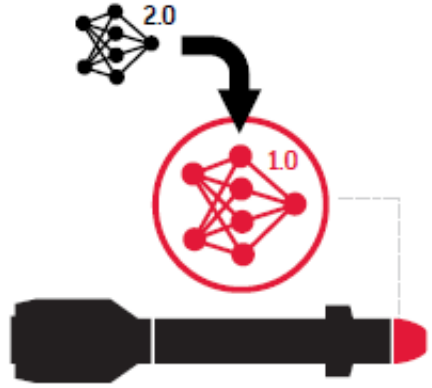
DSB #7: IV&V for Machine Learning

NDIA WG Recommendations

Picture of Success (end state)	
Consensus ML IV&V Framework	• Model-based inference engine considering full system context • Risk-based methodology supporting T&E needs, linked to ML model failures early in system development process • Mitigation throughout system design, development, sustainment
Open Data Sets	• High data quality, quantity, availability, and traceability • Data repository accessible to government and industry • Governance model for availability, level playing field, innovation • New repository data continuously collected and published
Perpetual Updates	• Continuous ML model updates – evolution at speed of relevance • Continuous V&V methods sensing changes from models, environment • Performance/accuracy aligned with changing environment, threats

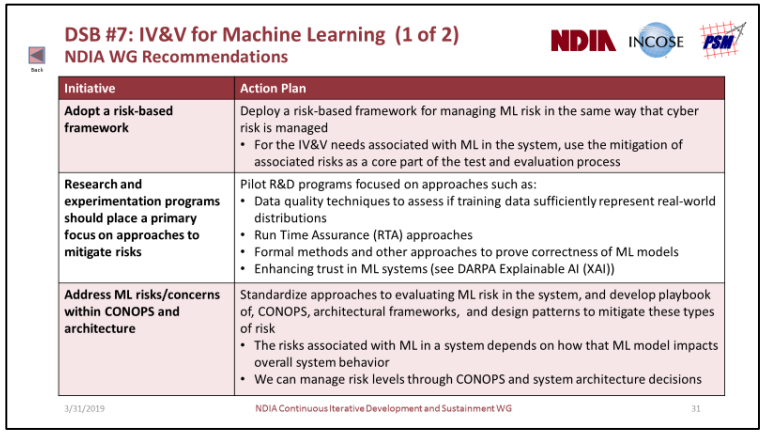
T&E is a full lifecycle activity focused on mitigating risk of failing to meet operational needs



Perpetual Upgrades

IV&V: Independent Verification & Validation
ML: Machine Learning
T&E: Test and Evaluation

Recommendations for Path Forward:



DSB #7: IV&V for Machine Learning (1 of 2)
NDIA WG Recommendations

Initiative	Action Plan
Adopt a risk-based framework	Deploy a risk-based framework for managing ML risk in the same way that cyber risk is managed • For the IV&V needs associated with ML in the system, use the mitigation of associated risks as a core part of the test and evaluation process
Research and experimentation programs should place a primary focus on approaches to mitigate risks	Pilot R&D programs focused on approaches such as: • Data quality techniques to assess if training data sufficiently represent real-world distributions • Run Time Assurance (RTA) approaches • Formal methods and other approaches to prove correctness of ML models • Enhancing trust in ML systems (see DARPA Explainable AI (XAI))
Address ML risks/concerns within CONOPS and architecture	Standardize approaches to evaluating ML risk in the system, and develop playbook of, CONOPS, architectural frameworks, and design patterns to mitigate these types of risk • The risks associated with ML in a system depends on how that ML model impacts overall system behavior • We can manage risk levels through CONOPS and system architecture decisions

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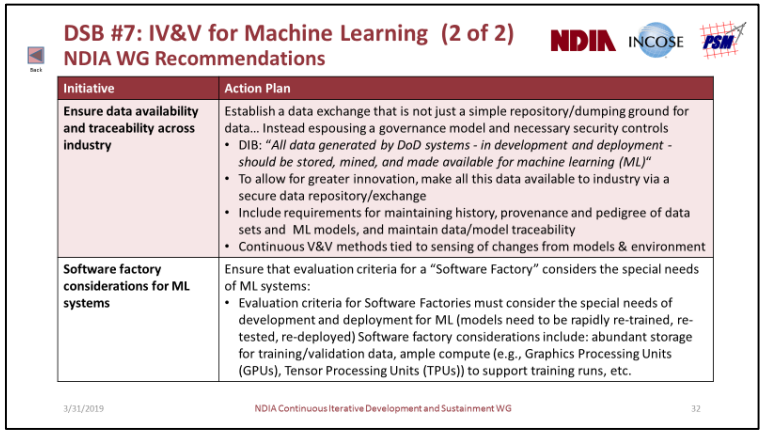

DSB #7: IV&V for Machine Learning (2 of 2)
NDIA WG Recommendations

Initiative	Action Plan
Ensure data availability and traceability across industry	Establish a data exchange that is not just a simple repository/dumping ground for data… Instead espousing a governance model and necessary security controls • DIB: *"All data generated by DoD systems - in development and deployment - should be stored, mined, and made available for machine learning (ML)"* • To allow for greater innovation, make all this data available to industry via a secure data repository/exchange • Include requirements for maintaining history, provenance and pedigree of data sets and ML models, and maintain data/model traceability • Continuous V&V methods tied to sensing of changes from models & environment
Software factory considerations for ML systems	Ensure that evaluation criteria for a "Software Factory" considers the special needs of ML systems: • Evaluation criteria for Software Factories must consider the special needs of development and deployment for ML (models need to be rapidly re-trained, re-tested, re-deployed) Software factory considerations include: abundant storage for training/validation data, ample compute (e.g., Graphics Processing Units (GPUs), Tensor Processing Units (TPUs)) to support training runs, etc.

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Summary

The NDIA WG provides an industry perspective on picture of success, current state, obstacles and path forward for each DSB recommendation

DSB Recommendation	NDIA "Path Forward" recommendations	
#1 – Software Factory	14	Contracting, funding, incentives, methods, security, supply chain, and measures
#2 – Continuous Iterative Development	3	Pilots and continuous improvement
#3 – Risk Reduction & Metrics	10	Acquisition strategy, competitive prototyping, culture, workforce, IP, and measures
#4 – Legacy Systems	5	Assessments, supply chain, methods, tools, and modeling
#5 – Workforce Development	3	Competency models, workforce assessment, workforce management, and training
#6 – Sustainment	2	Contracting and industry-government transfer of sustainment responsibilities
#7 – Machine Learning	5	Risk, research, CONOPs, ML data, and Software Factory interactions

Details of each topic and recommendation are provided in the separate report.

Acknowledgments

The NDIA Systems Engineering Division and its partners, INCOSE and PSM, appreciate the opportunity to provide an industry perspective for advancing the use of iterative methods in defense software acquisition.

The defense industrial base embraces the opportunities offered by the DSB and DIB recommendations and looks forward to supporting the Department of Defense with implementation.

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Backup

Supporting Content (Hidden Slides)

Excerpts of NDIA Recommendations by DSB Finding

(see separate briefing package for full details)