



National Defense Industrial Association

# Industry Recommendations for Implementing Continuous Iterative Software Development in the Defense Industry

**NDIA Systems Engineering Division  
in partnership with INCOSE and PSM**

**24-Oct-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 offered 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).

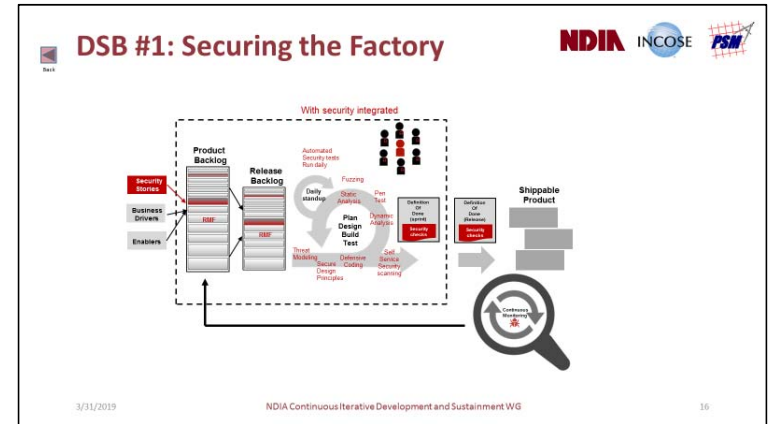
*Cross-cutting assumptions. Refer to the separate detailed report with assumptions specific to each DSB recommendation area.*

# DSB #1: Software Factory

## NDIA WG Recommendations



Picture of Success (end state)		
<b>People</b>	<ul style="list-style-type: none"> <li>Qualified factory workforce</li> <li>Continuous learning (relentless improvement, pipeline feedback)</li> </ul>	<ul style="list-style-type: none"> <li>Continuous learning (relentless improvement, pipeline feedback)</li> </ul>
<b>Process</b>	<ul style="list-style-type: none"> <li>Integrated PMB</li> <li>Metrics</li> <li>Predictability</li> </ul>	<ul style="list-style-type: none"> <li>Digital Blueprint / Play Book</li> <li>Ontology, Nomenclature</li> <li>Secure Supply Chain</li> <li>Relentless Improvement</li> </ul>
<b>Tools</b>	<ul style="list-style-type: none"> <li>Platform agnostic tool chain</li> <li>Adaptable to change</li> <li>Test automation at all levels</li> </ul>	<ul style="list-style-type: none"> <li>Model-based SW validation vs. architecture</li> <li>Red team / Blue team factory</li> </ul>



Security integrated into factory workflows (DevSecOps)

### Recommendations for Path Forward:

DSB #1: Software Factory (1 of 3)	
Initiative	Action Plan
<b>Contract for software factory delivery</b>	<ul style="list-style-type: none"> <li>Create a blueprint of contracts and language to enable software factory delivery</li> <li>Define approaches for different types of software (e.g., embedded, firmware, web); (life-critical, business-critical, low risk)</li> </ul>
<b>Fund value streams instead of projects</b>	<ul style="list-style-type: none"> <li>Pilot funding a value stream for a single vendor award program</li> <li>Pilot funding value streams on multi-vendor award program</li> </ul>
<b>Incentivize Suppliers to build interoperable software factories that are continuously exercised</b>	<ul style="list-style-type: none"> <li>Hold workshop with Industry to identify incentives</li> <li>Pilot options on some small short term modular contracts</li> </ul>
<b>Standardize software factory interfaces to facilitate data sharing</b>	<ul style="list-style-type: none"> <li>Common data architecture</li> <li>Define standards at the data layer for software factory to enable flexibility</li> <li>Define common nomenclature standards across vendors; use an existing framework such as the Scaled Agile Framework (SAFe)</li> </ul>

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DSB #1: Software Factory (2 of 3)	
Initiative	Action Plan
<b>Publish blueprints and playbooks</b>	<ul style="list-style-type: none"> <li>Collaborate with Industry to obtain software factory blueprints and playbooks and publish for use across programs to increase success</li> </ul>
<b>Transparent integrated PMB</b>	<ul style="list-style-type: none"> <li>Publish blueprint of integrated PMB (may differ across domains)</li> <li>Educate Government PMs on how to review PMB</li> </ul>
<b>Securing software factory</b>	<ul style="list-style-type: none"> <li>Define a defense-in-depth approach to secure factory</li> <li>Identify a required cadence of Red Team / Blue team to ensure factory safe.</li> </ul>
<b>Standards-based supply chain</b>	<ul style="list-style-type: none"> <li>Define supply chain standards</li> <li>Define interoperability for supply chain with multiple factories</li> </ul>
<b>Define value stream for delivery and push varied vendor baselines through factory</b>	<ul style="list-style-type: none"> <li>Define value stream for delivery and enable multiple vendor baselines to deliver into the factory.</li> <li>Ensure interoperability</li> </ul>

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DSB #1: Software Factory (3 of 3)	
Initiative	Action Plan
<b>Measure practices and process for results</b>	<ul style="list-style-type: none"> <li>Document program practices and processes being used</li> <li>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)</li> </ul>
<b>DoD-run retrospectives for a sampling of programs</b>	<ul style="list-style-type: none"> <li>Select a sampling of programs once a quarter and run a retrospective jointly between Industry and Government to identify root causes and improvements</li> <li>Publish best practices identified in retrospectives for all vendors</li> </ul>
<b>Open source</b>	<ul style="list-style-type: none"> <li>Research approach to instantiate Government-based open-sourced ways of working to leverage common modules across vendors and programs</li> </ul>
<b>Teams as a service (CID Cells)</b>	<ul style="list-style-type: none"> <li>Research approach to leverage cross-functional teams as a service in work areas where there is higher availability of workforce.</li> </ul>
<b>IATO for infrastructure</b>	<ul style="list-style-type: none"> <li>Research opportunity to obtain IATO on infrastructure of software Factory.</li> <li>bare metal / cloud / database (DB) are the longest lead-time items to approve                             <ul style="list-style-type: none"> <li>If we could secure a common architecture, the application layer would be cheaper and faster to approve, reducing cycle time for capabilities</li> </ul> </li> </ul>

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PMB: Performance Measurement Baseline

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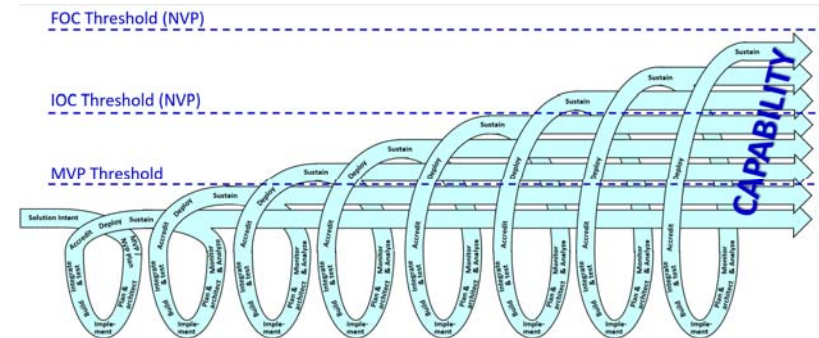
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# DSB #2: Continuous Iterative Development (MVP)

## NDIA WG Recommendations



Picture of Success (end state)	
Government / Contractor Interface	
Contracting	<ul style="list-style-type: none"> <li>New programs defined by solution intent (CV-1)</li> <li>Contracts defined by evolutionary viability products (MVP/NVP)</li> </ul>
Funding	<ul style="list-style-type: none"> <li>Contract funding structure supports seamless capability evolution</li> </ul>
Stakeholders	<ul style="list-style-type: none"> <li>Active engagement in CID lifecycle</li> </ul>
Design	<ul style="list-style-type: none"> <li>Guided by MOSA</li> </ul>
IP	<ul style="list-style-type: none"> <li>Government access to source code with negotiated IP protections</li> </ul>
Program Execution	
People	<ul style="list-style-type: none"> <li>Multi-discipline agile execution includes aligned milestones</li> <li>Direct user/developer interaction informs design (product owner)</li> </ul>
Process	<ul style="list-style-type: none"> <li>Early SE ➤ SW sequencing, refactoring, tools, environments</li> </ul>
Tools	<ul style="list-style-type: none"> <li>Test automation accelerates delivery (rapid release, deployment)</li> </ul>



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

### Recommendations for Path Forward:

DSB #2: Continuous Iterative Development NDIA WG Recommendations	
<b>Initiative</b>	<b>Action Plan</b>
<b>Establish CID pilot baseline</b>	<ul style="list-style-type: none"> <li>Establish &amp; communicate an initial high level CID approach</li> <li>Establish an initial approach to defining programs for CID implementation</li> <li>Train key Government and Supplier personnel</li> </ul>
<b>Pilot, learn and refine</b>	<ul style="list-style-type: none"> <li>Define a design set for CID</li> <li>Conduct pilot programs for CID, employing a set based design approach to explore options and refine approach</li> <li>Iterate until a small set of effective approaches and techniques emerge and standardize on it</li> </ul>
<b>Implement and evolve</b>	<ul style="list-style-type: none"> <li>Develop an approach to integrate feedback into the standard process for continuous improvement</li> <li>Define CID requirement phasing and Inspect and Adapt workshop timing</li> <li>Roll out CID as standard approach</li> <li>Manage feedback and evolution</li> </ul>

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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)	
<b>Competition</b>	<ul style="list-style-type: none"> <li>• Business case: win-win partnership, common goals, acquisition/support strategy</li> <li>• Objective downselect evaluation criteria (RFP L&amp;M) and feedback</li> <li>• Open architecture on critical components</li> </ul>
<b>Contracts</b>	<ul style="list-style-type: none"> <li>• IP agreement negotiated, sustained across the life cycle</li> <li>• Funding and contracts aligned to support factory migration</li> </ul>
<b>Metrics</b>	<ul style="list-style-type: none"> <li>• Continuous improvement, SMART measures against objectives</li> <li>• Risk-based decision making</li> </ul>
<b>Resources</b>	<ul style="list-style-type: none"> <li>• Funding, staffing, tools, environments to support multiple teams</li> </ul>

**DSB Recommendation #3 – Risk Reduction**  
Competitive Prototyping Survey, 2008 (USC CSSE)

Study indicates that CP can help in many situations, but has a number of pitfalls. CP does not solve all acquisition problems.

3/13/2009 NDIA Continuous Iterative Development and Sustainment WG

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

### Recommendations for Path Forward:

DSB #3a: Competitive Prototyping (1 of 2)	
Initiative	Action Plan
<b>Acquisition strategy</b>	Acquisition strategies that provide a fair opportunity to compete, retain competition throughout the lifecycle for critical components to enable rapid evolution of the product.
<b>Competitive prototyping</b>	<ul style="list-style-type: none"> <li>• Review analyses/reports from prior DoD competitive prototyping initiatives, and integrate lessons learned into action plan for DSB recommendations.</li> <li>• Competitive prototyping risk reduction strategy should account for both functional and non-functional requirements.</li> </ul>
<b>Cultural shift</b>	Migrate from subjective qualitative assessment to objective quantitative assessment of risk that support business decisions
<b>Resources</b>	DoD investment to acquire, deploy, integrate, and maintain evaluation tools and test beds
<b>Workforce development</b>	Recommend DoD initiate a development plan to provide workforce with skills and knowledge needed to plan, perform and execute the risk reduction strategies during competitive prototyping.

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DSB #3a: Competitive Prototyping (2 of 2)	
Initiative	Action Plan
<b>Program measurements</b>	<ul style="list-style-type: none"> <li>• Define a minimum core set of metrics and ownership for measures needed to do the job at the Program, Functional, and Integrated Product Team (IPT) levels</li> <li>• Develop and track metrics to control factory processes, measure against goals and objectives, assess/measure risk, and make decisions</li> <li>• Enable real-time insight into measures and program status</li> <li>• Ensure measures provide a comprehensive view of risk reduction strategy, including: functional and non-functional requirements; reliability, security, ...</li> <li>• Develop consensus Government/Industry measurement framework and common measures applied across defense software acquisition programs.</li> </ul>
<b>IP strategy</b>	<ul style="list-style-type: none"> <li>• Develop contracting approaches that protect Supplier IP while providing the Government access to source code for analysis, deployment, support, and evolution.</li> <li>• Sustain IP required for maintenance of the following: <ul style="list-style-type: none"> <li>• Renewable capital – patents, license, IR, ...</li> <li>• Human capital – People, skills, experience, surge/slack...</li> <li>• Structural capital – data bases, tools, processes, test scripts, ...</li> <li>• Relationship capital – customers, supplier agreements, business relationships, personal relationships, ...</li> </ul> </li> </ul>

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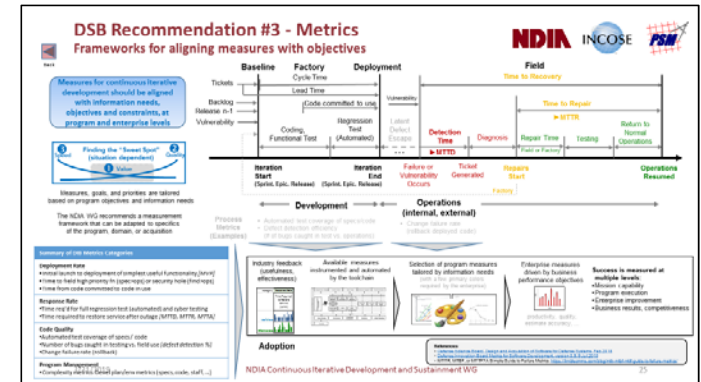
IP: Intellectual Property  
RFP: Request for Proposal  
SMART: Specific, Measurable, Achievable, Relevant, Time bound

# DSB #3b: Measures for CID

## NDIA WG Recommendations



Picture of Success (end state)	
Consensus frameworks	<ul style="list-style-type: none"> <li>Objectives first - measures aligned and tailored from information needs, goals and constraints, at program and enterprise levels</li> </ul>
Modernized measures	<ul style="list-style-type: none"> <li>Migration toward consensus alternatives to traditional waterfall and phase-based SW measures (LOC, EVM, milestones, ...)</li> <li>Derived from SW factory processes, automated by toolchain</li> <li>Basis for measuring cost and schedule vs. plan</li> </ul>
History-based estimates	<ul style="list-style-type: none"> <li>Repositories collect performance-based measures (e.g., WBS, staff, cost, productivity) supporting future comparisons, basis of estimates, proposals, and program monitoring</li> </ul>



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

### Recommendations for Path Forward:

Initiative	Action Plan
Software measurement framework for CID	<ul style="list-style-type: none"> <li>Validate measurement framework (objectives, categories, measures) with Government and industry stakeholders (e.g., NDIA, INCOSE, PSM, SERC)</li> <li>Finalize initial consensus measures for software CID</li> <li>Pilot and validate measures/analysis on selected CID /DevSecOps programs.</li> <li>Develop contracting language requiring measurement set for future programs.</li> </ul>
WBS-based estimating of historical comparables for staff, cost, productivity	<ul style="list-style-type: none"> <li>Recommend DoD expand WBS-based approach and historical DB measures to additional programs but at program level and <b>not specific to continuous software initiatives</b> (doubtful consistent data yet exists).</li> <li>Engage Government stakeholders on historical data estimating initiatives</li> <li>Partner with independent cost estimate (ICE) groups to migrate away from SLOC-based methods (CAPE, PARCA, ICE, ...); establish partnerships with industry for new methods (DSB #3)</li> </ul>
Reach consensus on cost and schedule measures vs. plan for software CID	<ul style="list-style-type: none"> <li>Consider alternatives to EVM for managing performance vs. plan.</li> <li>Review EVM agile studies, publications, and guidance. Hold workshops with Industry and Government to define framework and measures.</li> <li>Recommend consensus approach for DoD software acquisition</li> </ul>

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

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# DSB #4: Transition for Current and Legacy Programs

## NDIA WG Recommendations



Picture of Success (end state)	
<b>People</b>	<ul style="list-style-type: none"> <li>• Skill assessment for gap analysis</li> <li>• Skilled capable workforce for transition on legacy programs</li> </ul>
<b>Process</b>	<ul style="list-style-type: none"> <li>• Business case for transition</li> <li>• Playbooks and Blue Prints for legacy code transition</li> <li>• Assessment of supply chain and SW pedigree (FOSS, COTS, GOTS)</li> <li>• Risk adjusted product backlog</li> <li>• Strategies for incrementally building up test automation</li> </ul>
<b>Tools</b>	<ul style="list-style-type: none"> <li>• Tools to generate legacy 'as-built' documentation and models for legacy code base</li> </ul>

**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.	<ul style="list-style-type: none"> <li>• Collaborate with industry building program categorization table for varied types of software and products being built</li> <li>• Define common list of program readiness attributes</li> <li>• Define metrics for how to measure transition success</li> <li>• Develop common risk categories to evaluate</li> <li>• Prototype process for iteratively and incrementally transitioning programs</li> </ul>
Supply chain pedigree evaluation tool	<ul style="list-style-type: none"> <li>• Investigate methods for evaluating software pedigree</li> <li>• Prototype process and tools to evaluate supply chain pedigree</li> <li>• Validate pedigree on FOSS/COTS/GOTS/Supplier components</li> </ul>
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	<ul style="list-style-type: none"> <li>• Investigate standardized set of tools to auto-generate models and "As-Built" of the varied legacy systems</li> <li>• Define a prioritization strategy for migrating program components to the software factory</li> </ul>

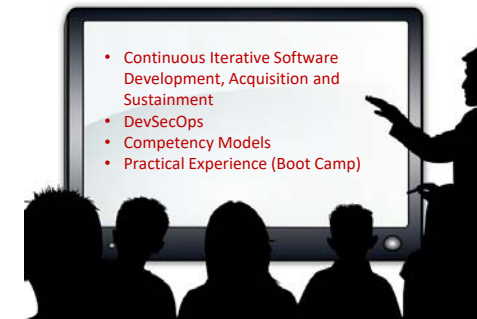
COTS: Commercial Off the Shelf  
FOSS: Free Open Source Software  
GOTS: Government Off the Shelf

# DSB #5: Workforce

## NDIA WG Recommendations



Picture of Success (end state)		
<b>Education and Training</b>	<ul style="list-style-type: none"> <li>• DAU curriculum for DevSecOps and modern SW-centric systems</li> <li>• Community of practice platforms</li> </ul>	<ul style="list-style-type: none"> <li>• Training across career fields (PM, sustainment, acquisition)</li> <li>• Aligned with current/future development and recruiting needs</li> </ul>
<b>Stakeholder Engagement</b>	<ul style="list-style-type: none"> <li>• Collaborative government / industry partnerships</li> <li>• Trained experienced industry partners and supply chain</li> </ul>	<ul style="list-style-type: none"> <li>• Consensus measurement framework</li> <li>• Multi-discipline CID support teams (CDRLs, events, milestones)</li> </ul>
<b>Staffing</b>	<ul style="list-style-type: none"> <li>• Increased hiring, retention, training for acquisition experts</li> <li>• Recruiting pipeline for SW experts</li> </ul>	<ul style="list-style-type: none"> <li>• Dedicated workforce funding and coaches across services</li> <li>• PMO IPTs for modern SW practices</li> </ul>



### Recommendations for Path Forward:

DSB #5: Workforce (1 of 2)	
NDIA WG Recommendations	
Initiative	Action Plan
Modern software-intensive-systems engineering competency model development	<ul style="list-style-type: none"> <li>• 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</li> <li>• Create ability to ID/code software-intensive-systems engineering in current/future software-centric systems skillsets</li> </ul>
Informed PMs and software SMEs Training	<ul style="list-style-type: none"> <li>• Development and deploy training at Defense Acquisition University on iterative software development for all acquisition communities (PM, Systems Engineering, Software, Financial Management, Cost Estimating, ...)</li> <li>• Develop a consensus government/industry measurement framework and common measures applied across defense software acquisition programs</li> <li>• Supply chain integration - Deploy supply chain pedigree evaluation tools and techniques</li> <li>• Develop blueprints and playbooks for low risk transition</li> <li>• Develop RFP guide for acquiring and transitioning to software factories</li> </ul>

DSB #5: Workforce (2 of 2)	
NDIA WG Recommendations	
Initiative	Action Plan
Workforce management	<ul style="list-style-type: none"> <li>• Baseline current software intensive capabilities and needs                             <ul style="list-style-type: none"> <li>• Identify workforce gaps; quantity/quality</li> <li>• Update workforce needs to shape workforce recruitment and training</li> </ul> </li> <li>• Create a new software-centric-systems Engineering O800 Occupational Series to enable tracking, management and growth of software-centric-systems engineers, managers, and functional personnel                             <ul style="list-style-type: none"> <li>• Fund software intensive develop training</li> <li>• Support continuous learning</li> </ul> </li> </ul>

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

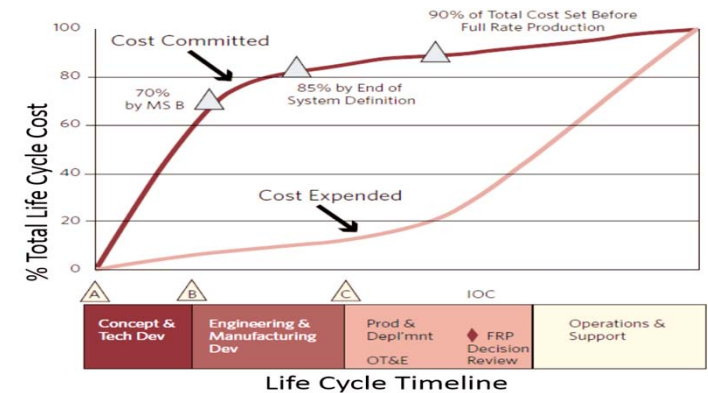
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# DSB #6: Sustainment (Software Is Immortal)

## NDIA WG Recommendations



Picture of Success (end state)	
Resources	<ul style="list-style-type: none"> <li>• Availability and support of a trained proficient workforce</li> <li>• Organic DoD software infrastructure, incentives, funding</li> <li>• Collaborative IP strategy throughout the life cycle, using a “work shared sustainment” approach</li> </ul>
Contracting Language	<ul style="list-style-type: none"> <li>• Contracts specify elements of framework supporting SW factory</li> <li>• Policies and guidance validated by workshops, pilots</li> </ul>
Sustainment Ecosystems	<ul style="list-style-type: none"> <li>• Understanding of current and future organizational ecosystems to ensure effective transfer of SW factories</li> </ul>



### Recommendations for Path Forward:

DSB #6: Software Sustainment NDIA WG Recommendations		NDIA INCOSE PSM
Initiative	Action Plan	
Develop contracting language that contains the basic elements of the software framework supporting the software factory	<ul style="list-style-type: none"> <li>• NDIA workshop with government and Supplier personnel</li> <li>• Generation and socialization of proposed contracting language</li> <li>• Conduct a set of pilot programs</li> <li>• Develop policies and guidance</li> </ul>	
Develop an understanding of the current and future sustainment organizational ecosystems to ensure the effective transfer of the software factories.	<ul style="list-style-type: none"> <li>• NDIA workshop with government and contractor personnel</li> <li>• Generation and socialization of effective transfer mechanism</li> <li>• Conduct a set of pilot programs</li> <li>• Develop policies and guidance</li> </ul>	

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# DSB #7: IV&V for Machine Learning

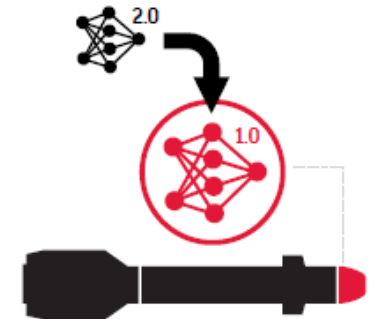
## NDIA WG Recommendations



Picture of Success (end state)	
<b>Consensus ML IV&amp;V Framework</b>	<ul style="list-style-type: none"> <li>Model-based inference engine considering full system context</li> <li>Risk-based methodology supporting T&amp;E needs, linked to ML model failures early in system development process</li> <li>Mitigation throughout system design, development, sustainment</li> </ul>
<b>Open Data Sets</b>	<ul style="list-style-type: none"> <li>High data quality, quantity, availability, and traceability</li> <li>Data repository accessible to government and industry</li> <li>Governance model for availability, level playing field, innovation</li> <li>New repository data continuously collected and published</li> </ul>
<b>Perpetual Updates</b>	<ul style="list-style-type: none"> <li>Continuous ML model updates – evolution at speed of relevance</li> <li>Continuous V&amp;V methods sensing changes from models, environment</li> <li>Performance/accuracy aligned with changing environment, threats</li> </ul>



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



*Perpetual Upgrades*

### Recommendations for Path Forward:

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

DSB #7: IV&V for Machine Learning (1 of 2) NDIA WG Recommendations	
<b>Adopt a risk-based framework</b>	Deploy a risk-based framework for managing ML risk in the same way that cyber risk is managed <ul style="list-style-type: none"> <li>For the IV&amp;V needs associated with ML in the system, use the mitigation of associated risks as a core part of the test and evaluation process</li> </ul>
<b>Research and experimentation programs should place a primary focus on approaches to mitigate risks</b>	Pilot R&D programs focused on approaches such as: <ul style="list-style-type: none"> <li>Data quality techniques to assess if training data sufficiently represent real-world distributions</li> <li>Run Time Assurance (RTA) approaches</li> <li>Formal methods and other approaches to prove correctness of ML models</li> <li>Enhancing trust in ML systems (see DARPA Explainable AI (XAI))</li> </ul>
<b>Address ML risks/concerns within CONOPS and architecture</b>	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 <ul style="list-style-type: none"> <li>The risks associated with ML in a system depends on how that ML model impacts overall system behavior</li> <li>We can manage risk levels through CONOPS and system architecture decisions</li> </ul>

DSB #7: IV&V for Machine Learning (2 of 2) NDIA WG Recommendations	
<b>Ensure data availability and traceability across industry</b>	Establish a data exchange that is not just a simple repository/dumping ground for data... Instead espousing a governance model and necessary security controls <ul style="list-style-type: none"> <li>DIB: "All data generated by DoD systems - in development and deployment - should be stored, mined, and made available for machine learning (ML)"</li> <li>To allow for greater innovation, make all this data available to industry via a secure data repository/exchange</li> <li>Include requirements for maintaining history, provenance and pedigree of data sets and ML models, and maintain data/model traceability</li> <li>Continuous V&amp;V methods tied to sensing of changes from models &amp; environment</li> </ul>
<b>Software factory considerations for ML systems</b>	Ensure that evaluation criteria for a "Software Factory" considers the special needs of ML systems: <ul style="list-style-type: none"> <li>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.</li> </ul>

Click thumbnails to zoom

# 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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Thank  
You

# Backup

## Supporting Content (Hidden Slides)

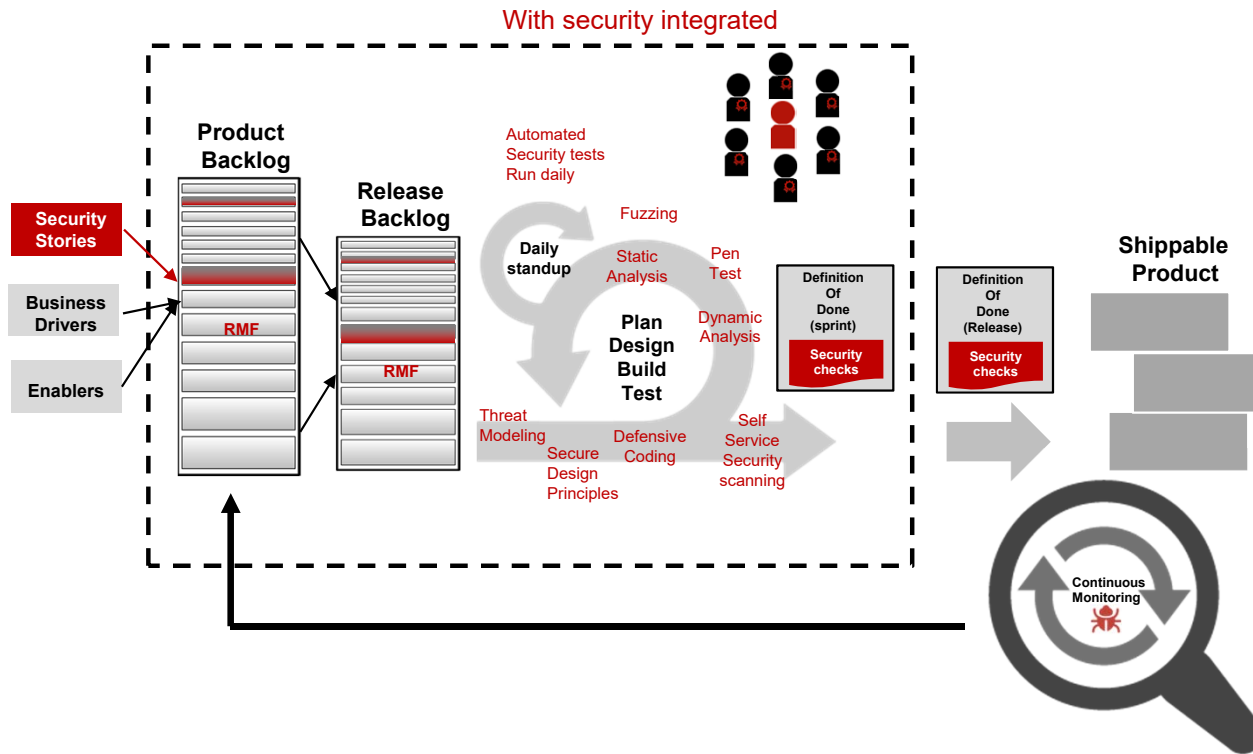
### Excerpts of NDIA Recommendations by DSB Finding

(see separate briefing package for full details)





# DSB #1: Securing the Factory





# DSB #1: Software Factory (1 of 3)

## NDIA WG Recommendations



Initiative	Action Plan
<b>Contract for software factory delivery</b>	<ul style="list-style-type: none"> <li>• Create a blueprint of contracts and language to enable software factory delivery</li> <li>• Define approaches for different types of software (e.g., embedded, firmware, web) ; (life-critical, business-critical, low risk)</li> </ul>
<b>Fund value streams instead of projects</b>	<ul style="list-style-type: none"> <li>• Pilot funding a value stream for a single vendor award program</li> <li>• Pilot funding value streams on multi-vendor award program</li> </ul>
<b>Incentivize Suppliers to build interoperable software factories that are continuously exercised</b>	<ul style="list-style-type: none"> <li>• Hold workshop with Industry to identify incentives</li> <li>• Pilot options on some small short term modular contracts</li> </ul>
<b>Standardize software factory interfaces to facilitate data sharing</b>	<ul style="list-style-type: none"> <li>• Common data architecture</li> <li>• Define standards at the data layer for software factory to enable flexibility</li> <li>• Define common nomenclature standards across vendors; use an existing framework such as the Scaled Agile Framework (SAFe)</li> </ul>



# DSB #1: Software Factory (2 of 3)

## NDIA WG Recommendations



Initiative	Action Plan
<b>Publish blueprints and playbooks</b>	<ul style="list-style-type: none"> <li>Collaborate with Industry to obtain software factory blueprints and playbooks and publish for use across programs to increase success</li> </ul>
<b>Transparent integrated PMB</b>	<ul style="list-style-type: none"> <li>Publish blueprint of Integrated PMB (may differ across domains)</li> <li>Educate Government PMs on how to review PMB</li> </ul>
<b>Securing software factory</b>	<ul style="list-style-type: none"> <li>Define a defense-in-depth approach to secure factory</li> <li>Identify a required cadence of Red Team / Blue team to ensure factory safe.</li> </ul>
<b>Standards-based supply chain</b>	<ul style="list-style-type: none"> <li>Define supply chain standards</li> <li>Define interoperability for supply chain with multiple factories</li> </ul>
<b>Define value stream for delivery and push varied vendor baselines through factory</b>	<ul style="list-style-type: none"> <li>Define value stream for delivery and enable multiple vendor baselines to deliver into the factory.</li> <li>Ensure interoperability</li> </ul>



# DSB #1: Software Factory (3 of 3)

## NDIA WG Recommendations



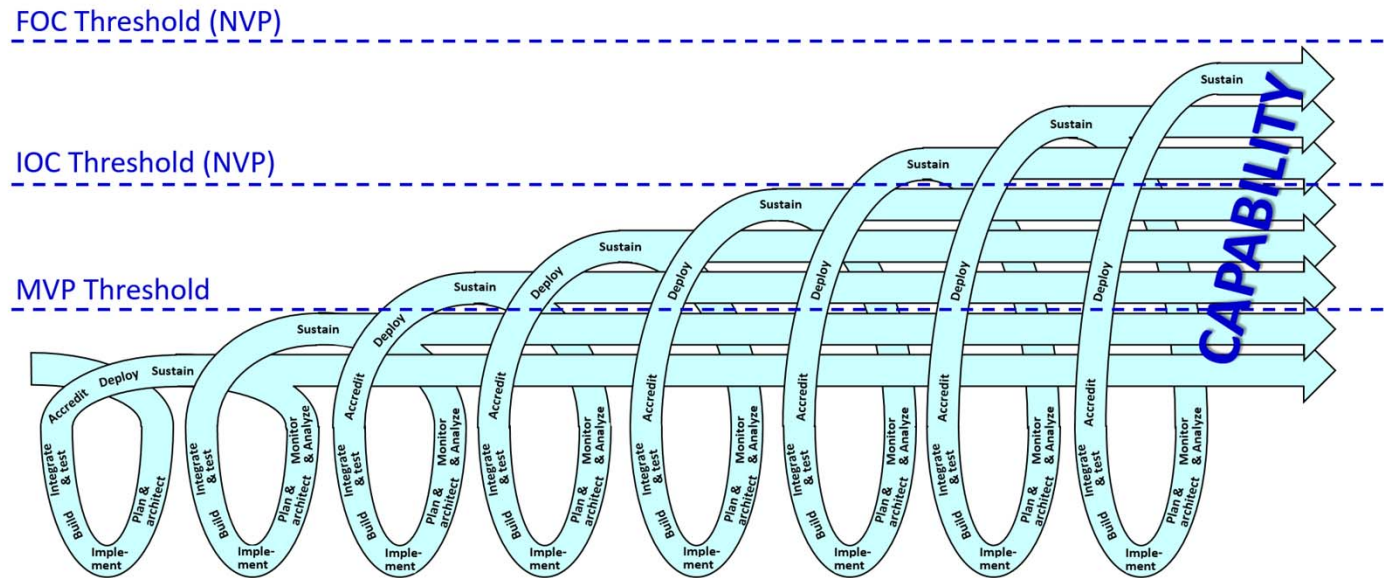
Initiative	Action Plan
<b>Measure practices and process for results</b>	<ul style="list-style-type: none"> <li>• Document program practices and processes being used</li> <li>• Measure success of programs by practice and environment to analyze which practices are demonstrating the best results based on customer criteria of value. (not methodology, but individual practice)</li> </ul>
<b>DoD-run retrospectives for a sampling of programs</b>	<ul style="list-style-type: none"> <li>• Select a sampling of programs once a quarter and run a retrospective jointly between Industry and Government to identify root causes and improvements</li> <li>• Publish best practices identified in retrospectives for all vendors</li> </ul>
<b>Open source</b>	<ul style="list-style-type: none"> <li>• Research approach to instantiate Government-based open-sourced ways of working to leverage common modules across vendors and programs</li> </ul>
<b>Teams as a service (CID Cells)</b>	<ul style="list-style-type: none"> <li>• Research approach to leverage cross-functional teams as a service in work areas where there is higher availability of workforce.</li> </ul>
<b>IATO for infrastructure</b>	<ul style="list-style-type: none"> <li>• Research opportunity to obtain IATO on Infrastructure of software Factory.</li> <li>• bare metal / cloud / database (DB) are the longest lead-time items to approve               <ul style="list-style-type: none"> <li>○ If we could secure a common architecture, the application layer would be cheaper and faster to approve, reducing cycle time for capabilities</li> </ul> </li> </ul>

# DSB #2: Continuous Iterative Development Picture of Success (End State)



## Government/Contractor Interface:

- New Programs Defined by Solution Intent
- Contracts Defined by Minimal Viable Product (MVP)
- Funding Supports Capability Evolution
- Stakeholders Actively Engaged in Continuous Iterative Development Lifecycle
- Design Guided by MOSA
- Government Access to Source Code with IP Protections



## Program Execution:

- Multi-discipline agile execution includes milestones
- Direct user interaction informs design
- Test automation accelerates delivery



# DSB #2: Continuous Iterative Development

## NDIA WG Recommendations



Initiative	Action Plan
<b>Establish CID pilot baseline</b>	<ul style="list-style-type: none"> <li>• Establish &amp; communicate an initial high level CID approach</li> <li>• Establish an initial approach to defining programs for CID implementation</li> <li>• Train key Government and Supplier personnel</li> </ul>
<b>Pilot, learn and refine</b>	<ul style="list-style-type: none"> <li>• Define a design set for CID</li> <li>• Conduct pilot programs for CID, employing a set based design approach to explore options and refine approach</li> <li>• Iterate until a small set of effective approaches and techniques emerge and standardize on it</li> </ul>
<b>Implement and evolve</b>	<ul style="list-style-type: none"> <li>• Develop an approach to integrate feedback into the standard process for continuous improvement</li> <li>• Define CID requirement phasing and Inspect and Adapt workshop timing</li> <li>• Roll out CID as standard approach</li> <li>• Manage feedback and evolution</li> </ul>

# DSB Recommendation #3 – Risk Reduction

## Competitive Prototyping Survey, 2008 (USC CSSE)



Back



Microsoft

Point 97-2003 Present

Study indicates that CP can help in many situations, but has a number of pitfalls. CP does not solve all acquisition problems.

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### Competitive Prototyping Survey Results Overview (Draft)

Dan Ingold  
Center for Systems and Software Engineering  
University of Southern California

University of Southern California  
Center for Systems and Software Engineering

### CP efforts are on balance good for

- General agreement that CP is good for both government and industry
- Responses indicate somewhat better deal for government
- No consensus from interviews on why the perceived difference

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### DoD does/should use CP (cont'd)...

- Primary reason is to reduce risk
- Risk reduction drives cost/schedule improvement
  - In the long-run
  - Short-run cost/schedule is higher and longer
- May be other benefits, like improved trust
  - An implicit benefit, not exactly briefed up the line
- Unstated benefit is to encourage innovation
- Not a panacea, just good management practice

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### CP development should be evolutionary or iterative, with ability to provide interim operational capabilities

- Mixed response, but tending toward agreement
- Response perhaps due to use of "operational capabilities" phrase, which several interviewees took issue with
- Interviewees who disagreed would have agreed if phrase omitted

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### Common themes among responses

- Many interviewees stressed the importance of *building relationships* with the customer
- Ongoing collaboration* between stakeholders and contractors is vital for successful outcomes
- Most cited need for flexibility, and use of *agile or evolutionary approaches*
- There is no substitute for *technical expertise* within (not subcontracted to) the PMO, which is now lacking
- Something must be done to *keep teams funded* during the down-select intervals

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### DoD does/should use CP because it is...

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### CP should encourage active participation of stakeholders

- Among strongest agreement in entire survey
- Interviewees said end-user/stakeholder participation was vital
- Inconsistent with "level playing field" concern in earlier question?
- Interviewee: "Access to stakeholders should be fair and equal, but competitors should not be all in one room asking questions"

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### CP will require significantly larger investments in evaluation tools, test beds, and capabilities within acquiring organizations

- Broad response, but tending toward agreement
- Several interviewees thought tools and test beds should be at competitors, not acquiring organizations, possibly through FRDC or IV&V
- Tools and test beds at competitors requires transparency to ensure complete, correct and fair evaluation
- One interviewee observed FRDC/IV&V organizations lack "skin in the game", making them less effective evaluators



# DSB #3a: Competitive Prototyping (1 of 2)

## NDIA WG Recommendations



Initiative	Action Plan
<b>Acquisition strategy</b>	Acquisition strategies that provide a fair opportunity to compete, retain competition throughout the lifecycle for critical components to enable rapid evolution of the product.
<b>Competitive prototyping</b>	<ul style="list-style-type: none"> <li>• Review analyses/reports from prior DoD competitive prototyping initiatives, and integrate lessons learned into action plan for DSB recommendations.</li> <li>• Competitive prototyping risk reduction strategy should account for both functional and non-functional requirements.</li> </ul>
<b>Cultural shift</b>	Migrate from subjective qualitative assessment to objective quantitative assessment of risk that support business decisions
<b>Resources</b>	DoD investment to acquire, deploy, integrate, and maintain evaluation tools and test beds
<b>Workforce development</b>	Recommend DoD initiate a development plan to provide workforce with skills and knowledge needed to plan, perform and execute the risk reduction strategies during competitive prototyping.





# DSB #3a: Competitive Prototyping (2 of 2)

## NDIA WG Recommendations



Initiative	Action Plan
<b>Program measurements</b>	<ul style="list-style-type: none"> <li>• Define a minimum core set of metrics and ownership for measures needed to do the job at the Program, Functional, and Integrated Product Team (IPT) levels</li> <li>• Develop and track metrics to control factory processes, measure against goals and objectives, assess/measure risk, and make decisions</li> <li>• Enable real-time insight into measures and program status</li> <li>• Ensure measures provide a comprehensive view of risk reduction strategy, including: functional and non-functional requirements; reliability, security, ...</li> <li>• Develop consensus Government/Industry measurement framework and common measures applied across defense software acquisition programs.</li> </ul>
<b>IP strategy</b>	<ul style="list-style-type: none"> <li>• Develop contracting approaches that protect Supplier IP while providing the Government access to source code for analysis, deployment, support, and evolution.</li> <li>• Sustain IP required for maintenance of the following:               <ul style="list-style-type: none"> <li>• Renewable capital – patents, license, IP, ...</li> <li>• Human capital – People, skills, experience, surge/slack...</li> <li>• Structural capital – data bases, tools, processes, test scripts, ...</li> <li>• Relationship capital – customers, supplier agreements, business relationships, personal relationships, ...</li> </ul> </li> </ul>

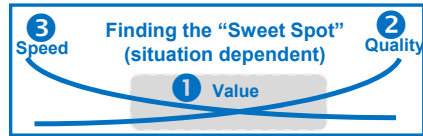
# DSB Recommendation #3 - Metrics

## Frameworks for aligning measures with objectives



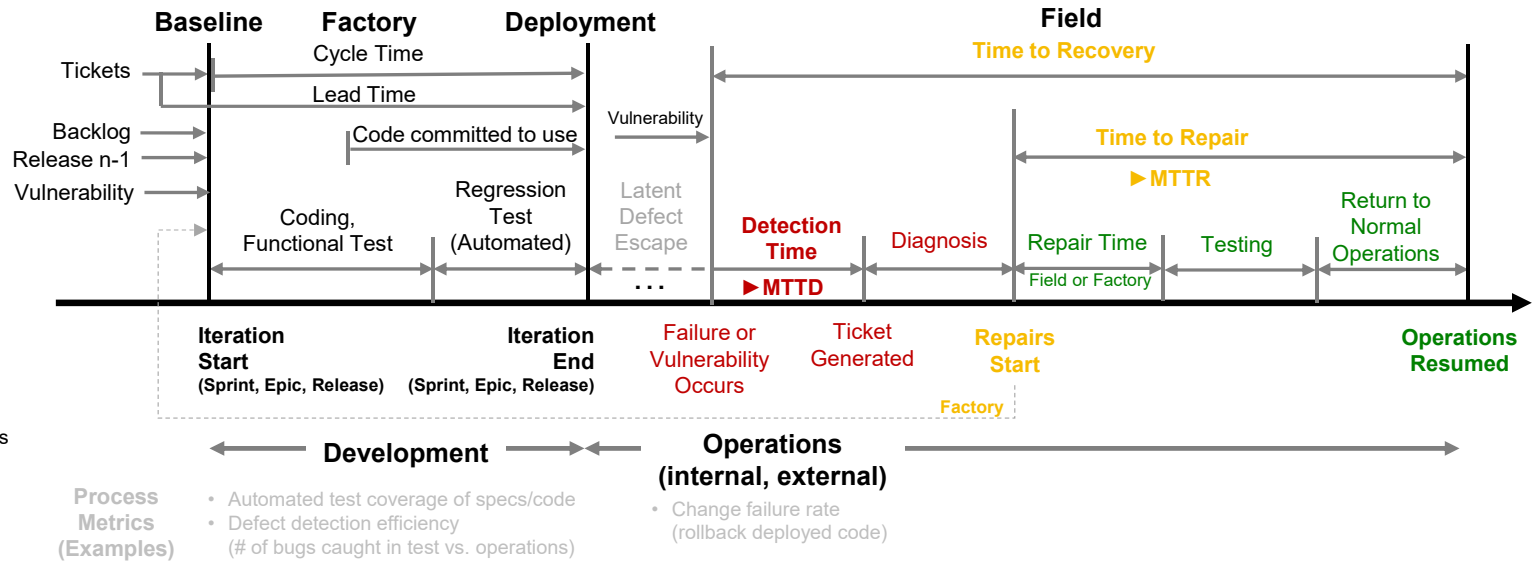
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Measures for continuous iterative development should be aligned with information needs, objectives and constraints, at program and enterprise levels



Measures, goals, and priorities are tailored based on program objectives and information needs

The NDIA WG recommends a measurement framework that can be adapted to specifics of the program, domain, or acquisition

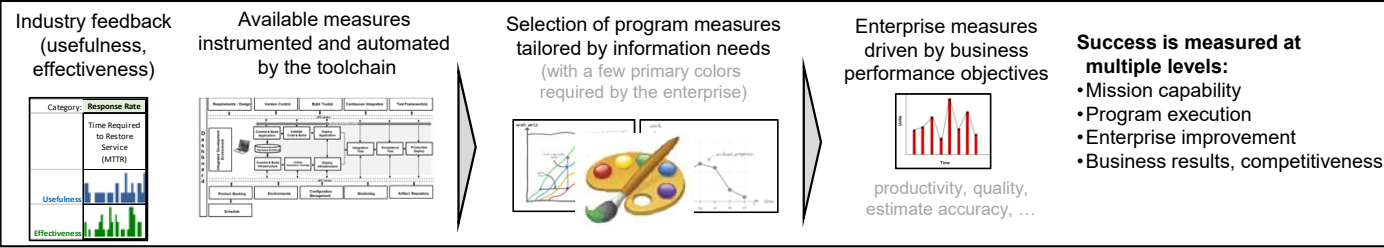


Process Metrics (Examples)

- Automated test coverage of specs/code
- Defect detection efficiency (# of bugs caught in test vs. operations)
- Change failure rate (rollback deployed code)

### Summary of DIB Metrics Categories

- Deployment Rate**
  - Initial launch to deployment of simplest useful functionality [MVP]
  - Time to field high priority fn (spec>ops) or security hole (find>ops)
  - Time from code committed to code in use
- Response Rate**
  - Time req'd for full regression test (automated) and cyber testing
  - Time required to restore service after outage [MTTD, MTTR, MTTA]
- Code Quality**
  - Automated test coverage of specs / code
  - Number of bugs caught in testing vs. field use [defect detection %]
  - Change failure rate (rollback)
- Program Management**
  - Complexity metrics. Devel plan/env metrics (specs, code, staff, ...)



### Adoption

#### References:

- Defense Science Board, Design and Acquisition of Software for Defense Systems, Feb 2018
- Defense Innovation Board Metrics for Software Development, version 0.9, 9 Jul 2018
- MTTR, MTBF, or MTTTF? A Simple Guide to Failure Metrics. <https://limblecmms.com/blog/mttr-mtbf-mttf-guide-to-failure-metrics/>

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## DSB #3b: Metrics Path Forward



Initiative	Action Plan
<b>Software measurement framework for CID</b>	<ul style="list-style-type: none"> <li>• Validate measurement framework (objectives, categories, measures) with Government and industry stakeholders (e.g., NDIA, INCOSE, PSM, SERC)</li> <li>• Finalize initial consensus measures for software CID</li> <li>• Pilot and validate measures/analysis on selected CID /DevSecOps programs.</li> <li>• Develop contracting language requiring measurement set for future programs</li> </ul>
<b>WBS-based estimating of historical comparables for staff, cost, productivity</b>	<ul style="list-style-type: none"> <li>• Recommend DoD expand WBS-based approach and historical DB measures to additional programs but at program level and <u>not specific to continuous software initiatives</u> (doubtful consistent data yet exists).</li> <li>• Engage Government stakeholders on historical data estimating initiatives</li> <li>• Partner with independent cost estimate (ICE) groups to migrate away from SLOC-based methods (CAPE, PARCA, ICE, ...); establish partnerships with industry for new methods (DSB #3)</li> </ul>
<b>Reach consensus on cost and schedule measures vs. plan for software CID</b>	<ul style="list-style-type: none"> <li>• Consider alternatives to EVM for managing performance vs. plan.</li> <li>• Review EVM agile studies, publications, and guidance. Hold workshops with Industry and Government to define framework and measures.</li> <li>• Recommend consensus approach for DoD software acquisition</li> </ul>



# DSB #4: Current and Legacy Programs

## NDIA WG Recommendations



Initiative	Action Plan
<b>Program assessment for categories of legacy software programs.</b>	<ul style="list-style-type: none"> <li>• Collaborate with industry building program categorization table for varied types of software and products being built</li> <li>• Define common list of program readiness attributes</li> <li>• Define metrics for how to measure transition success</li> <li>• Develop common risk categories to evaluate</li> <li>• Prototype process for iteratively and incrementally transitioning programs</li> </ul>
<b>Supply chain pedigree evaluation tool</b>	<ul style="list-style-type: none"> <li>• Investigate methods for evaluating software pedigree</li> <li>• Prototype process and tools to evaluate supply chain pedigree</li> <li>• Validate pedigree on FOSS/COTS/GOTS/Supplier components</li> </ul>
<b>Blueprints and playbooks for low risk transition</b>	Collaborate with Industry to build repository of blueprints , playbooks, and strategies for different types of programs.
<b>Visualization tools for varied code bases.</b>	Investigate Visualization tools for different types of code bases
<b>Auto generate “As-Built” and Models to evaluate system and develop transition plans</b>	<ul style="list-style-type: none"> <li>• Investigate standardized set of tools to auto-generate models and “As-Built” of the varied legacy systems</li> <li>• Define a prioritization strategy for migrating program components to the software factory</li> </ul>



# DSB #5: Workforce (1 of 2)

## NDIA WG Recommendations



Initiative	Action Plan
<b>Modern software-intensive-systems engineering competency model development</b>	<ul style="list-style-type: none"> <li>• 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</li> <li>• Create ability to ID/code software-intensive-systems engineering in current/future software-centric systems skillsets</li> </ul>
<b>Informed PMs and software SMEs Training</b>	<ul style="list-style-type: none"> <li>• Development and deploy training at Defense Acquisition University on iterative software development for all acquisition communities (PM, Systems Engineering, Software, Financial Management, Cost Estimating, ...)</li> <li>• Develop a consensus government/industry measurement framework and common measures applied across defense software acquisition programs</li> <li>• Supply chain integration - Deploy supply chain pedigree evaluation tools and techniques</li> <li>• Develop blueprints and playbooks for low risk transition</li> <li>• Develop RFP guide for acquiring and transitioning to software factories</li> </ul>



# DSB #5: Workforce (2 of 2)

## NDIA WG Recommendations



Initiative	Action Plan
<b>Workforce management</b>	<ul style="list-style-type: none"> <li>• Baseline current software intensive capabilities and needs               <ul style="list-style-type: none"> <li>• Identify workforce gaps; quantity/quality</li> <li>• Update workforce needs to shape workforce recruitment and training</li> </ul> </li> <li>• 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               <ul style="list-style-type: none"> <li>• Fund software intensive develop training</li> <li>• Support continuous learning</li> </ul> </li> </ul>



## DSB #6: Software Sustainment NDIA WG Recommendations



Initiative	Action Plan
<p><b>Develop contracting language that contains the basic elements of the software framework supporting the software factory</b></p>	<ul style="list-style-type: none"> <li>• NDIA workshop with government and Supplier personnel</li> <li>• Generation and socialization of proposed contracting language</li> <li>• Conduct a set of pilot programs</li> <li>• Develop policies and guidance</li> </ul>
<p><b>Develop an understanding of the current and future sustainment organizational ecosystems to ensure the effective transfer of the software factories.</b></p>	<ul style="list-style-type: none"> <li>• NDIA workshop with government and contractor personnel</li> <li>• Generation and socialization of effective transfer mechanism</li> <li>• Conduct a set of pilot programs</li> <li>• Develop polices and guidance</li> </ul>



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

## NDIA WG Recommendations



Initiative	Action Plan
<b>Adopt a risk-based framework</b>	Deploy a risk-based framework for managing ML risk in the same way that cyber risk is managed <ul style="list-style-type: none"> <li>For the IV&amp;V needs associated with ML in the system, use the mitigation of associated risks as a core part of the test and evaluation process</li> </ul>
<b>Research and experimentation programs should place a primary focus on approaches to mitigate risks</b>	Pilot R&D programs focused on approaches such as: <ul style="list-style-type: none"> <li>Data quality techniques to assess if training data sufficiently represent real-world distributions</li> <li>Run Time Assurance (RTA) approaches</li> <li>Formal methods and other approaches to prove correctness of ML models</li> <li>Enhancing trust in ML systems (see DARPA Explainable AI (XAI))</li> </ul>
<b>Address ML risks/concerns within CONOPS and architecture</b>	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 <ul style="list-style-type: none"> <li>The risks associated with ML in a system depends on how that ML model impacts overall system behavior</li> <li>We can manage risk levels through CONOPS and system architecture decisions</li> </ul>





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

## NDIA WG Recommendations



Initiative	Action Plan
<p><b>Ensure data availability and traceability across industry</b></p>	<p>Establish a data exchange that is not just a simple repository/dumping ground for data... Instead espousing a governance model and necessary security controls</p> <ul style="list-style-type: none"> <li>• DIB: <i>“All data generated by DoD systems - in development and deployment - should be stored, mined, and made available for machine learning (ML)”</i></li> <li>• To allow for greater innovation, make all this data available to industry via a secure data repository/exchange</li> <li>• Include requirements for maintaining history, provenance and pedigree of data sets and ML models, and maintain data/model traceability</li> <li>• Continuous V&amp;V methods tied to sensing of changes from models &amp; environment</li> </ul>
<p><b>Software factory considerations for ML systems</b></p>	<p>Ensure that evaluation criteria for a “Software Factory” considers the special needs of ML systems:</p> <ul style="list-style-type: none"> <li>• 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.</li> </ul>