



**Carnegie Mellon  
Software Engineering Institute**

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# Software-Intensive Systems Producibility

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# Producibility

*The ability to deliver needed capability in a timely, cost-effective, and predictable manner*



# Dimensions of Producibility

## Developer productivity (efficiency and effectiveness)

- Domain knowledge and expertise, effective methods
- Engineering discipline, process capability
- Technology base (applicability, effort reduction)
- Leveragable resources (legacy, COTS, open source)
- Addressing uncertainty, diversity, and change in needs

## Product utility and quality

- Functionality responsive to mission needs
- Quality attributes as determinants of system properties
- Compatibility with system and operational environment

## Acquirer acuity

- Producibility-enabling acquisition policies and practices
- Effective system-software engineering synergy
- Mechanisms for capability-cost-schedule predictability
- Infrastructure for product transition-into-use and evolution



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## Viewpoints on Problems/Solutions

*High Confidence Software and Systems Research Needs,*  
ITRD HCSS Coordinating Group, 2001  
<<http://www.nitrd.gov/subcommittee/hcss.html>>

*New Visions for Software Design & Productivity: Research  
& Applications (Vanderbilt Workshop), ITRD SDP*  
Coordinating Group, 2001  
<<http://www.nitrd.gov/subcommittee/sdp.html>>

*Report on the 2005 Software Producibility Workshops*  
(Draft 12/12/05), DUSD(S&T), 2005



# An OSD Strategy for Producibility

- Formulate a framework that gives a rationale basis for prioritizing research in producibility
- Coordinate and jointly sponsor basic and applied research to address specific producibility challenges
- Actively transition research successes into DoD use:
  - Establish centers for coordinating and assisting the maturation, validation, and packaging of research results into deliverable technology
  - Promote Federal/DoD acquisition practices that facilitate program-level adoption of producibility advances
  - Charter DoD technology transition agents for advocating and supporting program-level adoption of technology



# A Reference Vision for Producibility

## *CAD/CAM for software-intensive systems*

**Model-centric** – All problem/solution information is represented in a comprehensive multi-faceted product model

**Virtualized** – A system is defined by building, pre-deploying, and validating it in software for a hybrid hardware/software virtual environment

**Predictable** – Software and dependent system properties of interest are able to be accurately predicted and mutually optimized

**Decision-focused** – Multiple alternative solutions can be modeled, produced, and empirically evaluated based on identified customer/engineering choices

**Evolvable** – The problem/solution model can be continuously evolved to produce product variants that meet anticipated changing needs



## **Long-term Producibility Goals**

**Obtain a development environment in which multiple delivery-ready versions of a product can each be built and verified within 3 months**

**Create a capability to isolate unprecedented needs and formulate and explore alternative solutions within fixed time and resource constraints**

**Specify the cost and capabilities of proposed software in domain-specific models that enable a customer to negotiate a best fit to perceived needs**

**Be able to deliver software with zero defects operating in the customer's environment, consistent with associated domain-specific models**

**Be able to deliver software with precisely specified quality attributes relative to different operating conditions and verified in realistic operational use**

**Have the means to define how provided software will be changeable and the associated degree of effort required**



## **Near-term Producibility Opportunities**

**Define a standardized framework for precisely identifying and measuring critical software-system properties**

**Create a DoD-wide repository exhibiting large-scale use of effective software methods for requirements specification, architectural and component design, and verification**

**Reformulate relevant systems and software methods to foster collaborative software-based systems engineering**

**Identify Federal/DoD acquisition practices that motivate programs to adopt practices that address common lifecycle software problems early**

**Establish a DoD capability for facilitating the packaging and transition of effective R&D technology into use on acquisition programs**

**Initiate efforts on programs building multi-version solutions to create a model-driven development capability based on product line principles**



# Current Producibility Activities

## Broad Area Announcements

- **Systems and Software Test Track**

## SBIR Topics

- **Design Visualization**
- **Malicious Code Diffuser**
- **Robust Complex Systems**
- **Software Test Engineering**
- **Software Hub for High Assurance Model-Driven Development and Analysis**
- **Software Verification**

## STTR Topics

- **Error Handling Paths and Policy Analysis**
- **Security Escorts for Not-Yet-Trusted Software**
- **Software System Reliability Analysis**
- **Assessing Interoperability Through Cross-Domain Protocol Compatibility Analysis**

## HPEC-SI

- **Signal Processing Library**



## 5 Themes for Funding Research

- Disciplined engineering methods  
Increase engineering discipline in the interdependent development of software and systems
- Model-based development  
Bridge the conceptual gap between domain experts and product developers
- System virtualization  
Reduce the effort to pre-verify real world behavior of software and systems
- Predictable software attributes  
Build software and systems whose properties are predictable and adjustable
- Infrastructure and emerging technology  
Adapt producibility advances to exploit or accommodate changes in infrastructure and enabling technologies



## **Disciplined Engineering Methods**

- **Management:** How is iterative, concurrent, multi-version development planned, monitored, and controlled to ensure meeting schedule/budget/quality goals?
- **Requirements:** How do developers accurately and concisely represent the capabilities and limitations of a system/software being produced?
- **Architectural design:** What forms are sufficient to define the structure and composition of software in a system, as a basis for achieving tradeoffs?
- **Component design:** What information does an implementor need to be provided in order to build, use, or safely modify a software component?
- **Implementation:** How can implementation practices be improved to eliminate defects and reduce rework due to requirements or design changes?
- **Verification:** How can inconsistencies be precluded among multiple changing software representations (code, models/specifications, documents, tests)?
- **Product families:** How can an envisioned set of similar/evolving products be represented to eliminate redundant development efforts?



# Model-based Development

**Model:** A representation of a product that enables approximate answers to a designated set of questions about the product

- **Representation:** what problem-solution information is needed to define a system, what purposes should it serve, and how should it be represented?
- **Problem analysis and specification:** can the problem-solution space be abstracted into domain-specific representations to reduce the development process to an iteratively converging decision process?
- **Solution analysis and validation:** what capabilities are needed to permit rapid visualization and empirical resolution of solution alternatives for a specified problem?
- **Product generation:** What mechanisms will enable rapid correct generation of customized software, documentation, and support materials from a model?
- **Model-product verification:** what capabilities are needed to ensure that a derived solution product correctly implements a model?



# System Virtualization

- **Platform independence:** What form should implementations take to permit alternative physical realizations while avoiding unnecessary dependence on any specific realization?
- **Hardware abstraction:** How is hardware represented to enable simulated use for verifying software and supporting hardware/software codesign?
- **Environment simulation:** How can capabilities and constraints of the operational environment (systems, devices) be represented to enable simulated use for software validation?
- **Usage simulation:** How are potential uses of a system adequately represented to enable realistic automated testing?
- **System validation:** What techniques enable validation of a solution under realistic (normal and degraded) conditions?



# Predictable Software Attributes

Design => Analysis of Alternatives and Risk Mitigation

- Identification: What are critical software-affected attributes and how do they interact? (Performance, reliability, availability, security, safety, usability, ...?)
- Measurement: What behavior does the system exhibit in terms of critical attributes and how is this determined by implemented software?
- Prediction: Given a proposed software design and implementation, how will critical attributes be affected?
- Optimization: What design/implementation decisions lead to the best combination of critical attribute values?



## Infrastructure & Emerging Technology

How is producibility enhanced or changed due to capabilities of computing infrastructure and emerging technologies such as these?

- **Computational technology: Multi-core processors; distributed processing, services, and data; autonomous agents; grid computing**
- **Componentization: Packaged pluggable components and frameworks (COTS, legacy, open-source; defined interfaces outward & underneath)**
- **Customization: Total-product variant and configuration management; product family and generator techniques**
- **Commoditization: Standardized cross-domain frameworks for common system capabilities**
- **Cross-speciality collaborative engineering: Tools and techniques for communication and coordination**



# Considerations for Investment

**Payoff:** Directly addresses some aspect of the producibility problem as experienced by DoD programs

**Timeframe:** Offers specific near-term benefit to current DoD programs

**Pragmatics:** Compatible with current DoD practices and emerging technology trends and not dependent on other advances that are not timely

**Research opportunity:** Not otherwise adequately funded relative to DoD needs

**Transitionability:** Credible plan for packaging into a discretely adoptable form for near-term transition

**Transition opportunity:** Identified DoD acquisition programs anticipate near-term benefit and agree to evaluate utility



## A Notional Producibility Task Timeline

- Propose a viable task for near-term progress on a producibility issue [ 1 month ]
- Develop and demonstrate proof-of-concept [ 6 months ]
- Propose a follow-on task to develop, package, and deliver/support technology [ 2 months ]
  - Define a business case and identify a DoD/industry transition agent and DoD programs targeted for adoption
  - Refine the approach and plan for development and transition-to-practice
- Develop and package transferrable technology [ 12 months ]
- Support adoption and use of packaged technology by targeted DoD programs/industry, and improve [ 12 months ]