SYSTEMS ENGINEERING RESEARCH CENTER

CISA Center for Integrated Systems in Aerospace

Investigating Approaches to Achieve Modularity Benefits in the Acquisition Ecosystem

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Dr. Daniel DeLaurentis
Dr. Navindran Davendralingam
Dr. Cesare Guariniello
Dr. Mitchell Kerman
Dr. Lu Xiao

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Motivation

- Current DoD acquisition challenges
  - to affordably address emerging threats
  - component obsolescence
  - loss of critical suppliers, and planned technology upgrade for tightly coupled, highly integrated systems
- DoD acquisitions strategy : Better Buying Power 3.0 (BBP 3.0)
  - Implement best practices to improve productivity, affordability, capabilities, reduce unproductive states across DoD acquisitions
  - Includes encouraged use of modularization strategies to achieve desired end benefits…via a Modular Open Systems Approach (MOSA)
  - CHALLENGE: program managers need strategies and tools to be successful in a MOSA ecosystem

MOSA Initiative

- ODASD/SE Modular OPEN Systems Approach (MOSA)
  - Open System Architecture (OSA)
    - Business side of acquisition process
      - data rights, IP, legal matters
    - Most MOSA work currently under auspices of OSA efforts
      - need to extend to technical as well
    - *Requirement under law to include MOSA in acquisition language → current guidance on law and policy vs technical implications*
  - Modularity (in DoD)
    - Viewed as technical approach in defense acquisitions
    - Complex system decomposition: physical and functional architecture
    - Largely separated from OSA tenets that are more business oriented
    - Modular open systems leverages business driven benefits of adopting Open Architecture standards for development

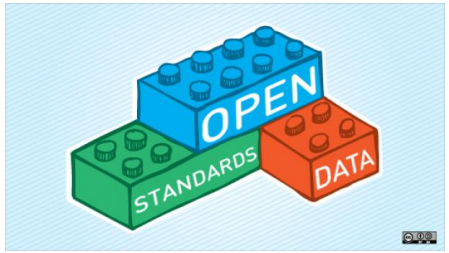
MOSA Goals

- **Cost savings/cost avoidance**
  - Savings via reduced burden on acquisition processes
- **Allow technology refresh**
  - Rapid updates of modules individually easier than addressing total monolithic complex system
- **Interoperability of systems/components**
  - Open standards use ensures compliance in interoperability
- **Increase competition between suppliers**
  - Leverage open standards and modularity to engage more business units for development (e.g. SBIRs etc)
- **Incorporate innovation**
  - Innovation can be more readily focused at localized modular level

Need to <u>connect desired program outcome</u> to a MOSA goal

MOSA Guidelines

- **Establish an enabling environment**
  - PM to generate business practices, technology development, test and evaluate, etc. needed for development of open systems
- **Employ modular design**
  - Four main characteristics: cohesive, encapsulated, self-contained, highly binned
- **Designate Key Interfaces**
  - Module interfaces defined to enable designers and system configuration managers
- **Use Open Standards**
  - Utilization of community accepted standards that are well defined/matured
- **Certify Conformance**
  - Use rigorous assessment mechanisms, interface control management and proactive conformance testing.



How to bring business and technical elements together in an ecosystem?

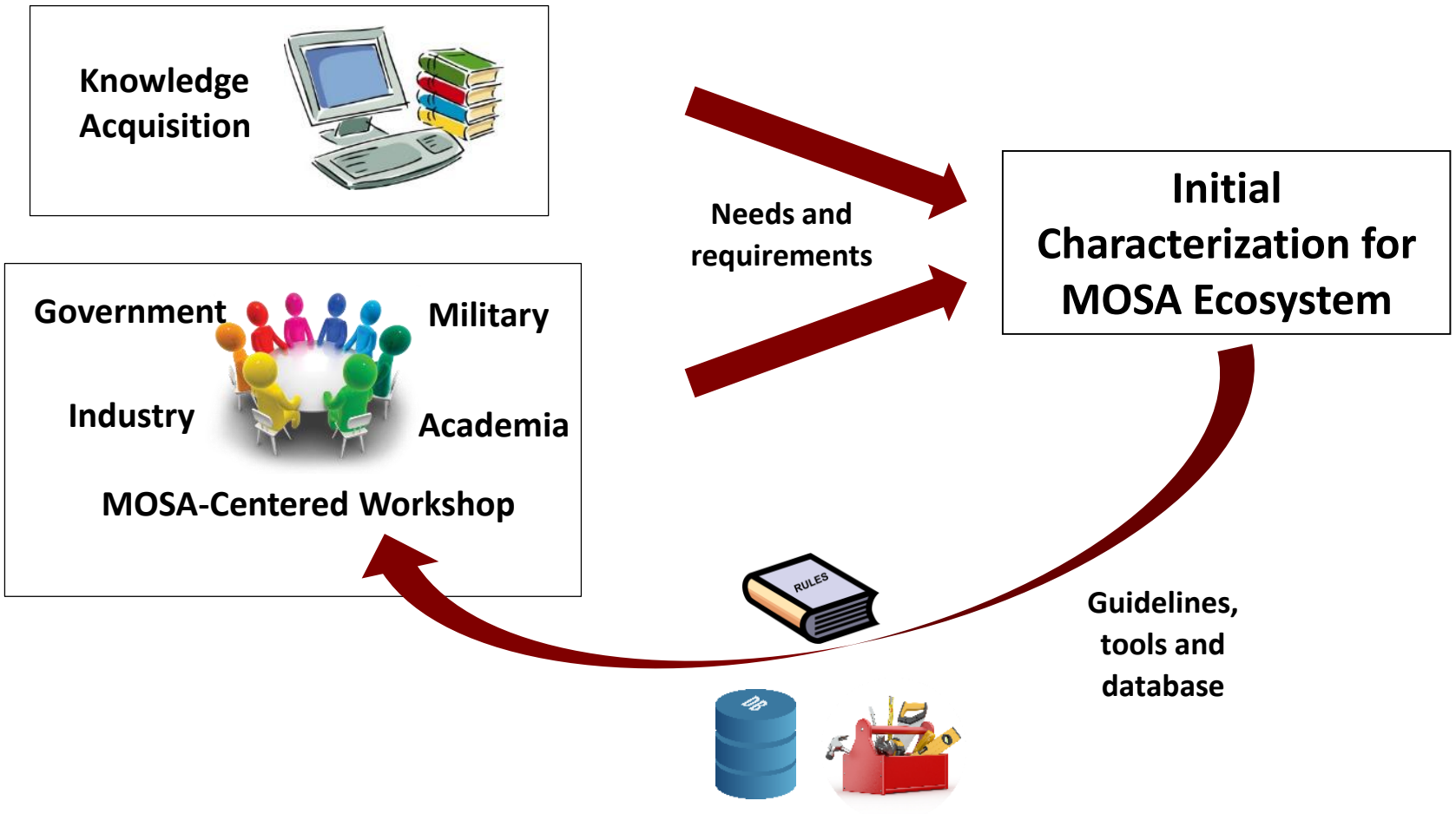
http://www.acqnotes.com/acqnote/careerfields/modular-open-systems-approach

Research Needed

MOSA Research Tasks with SERC have commenced: FY17 RT-163, FY 18 RT-185

- Investigate development of systems to **exploit modularity** to enhance defense acquisitions and military capabilities.
- Explore **concept of an ecosystem** that facilitates adoption of modular solutions to achieve benefits (business + technical ends)
- Investigate how to **encourage modularity** to gain its benefits – conducive modular patterns, decompositions, methods, factors, catalysts etc.
- Provide **guidance and insights** to:
  - aid program managers in decision-making on modularization and achieving the intended benefits
  - Connect desired program outcomes to a MOSA goal

RT-163 Research Approach



Modularity – An Intuitive Perspective

- **Definition:** *A general set of principles that help with managing complexity through breaking up a complex system into discrete pieces, which can then communicate with one another through standardized interfaces* [Langlois, 2002]

- **Types** of modularity [Baldwin 2006]
  - —*Modularity in Design*
    - Product divided into modules independently with minimal interactions
  - —*Modularity in Production*
    - Mass production driven that promotes flexibility and parallelism
    - Efficient innovations in production phases (e.g. vehicle production)
  - —*Modularity in Operations*
    - Shared components for increased operational flexibility
    - Interchangeable components for different missions

Benefits and Drawbacks

- **Benefits of Modularity**
  - Managing complex systems by breaking down into smaller pieces
  - Facilitates rapid evolution through changes at module level
  - Enables parallelisms (e.g. operations, development)
  - Accommodate future uncertainties

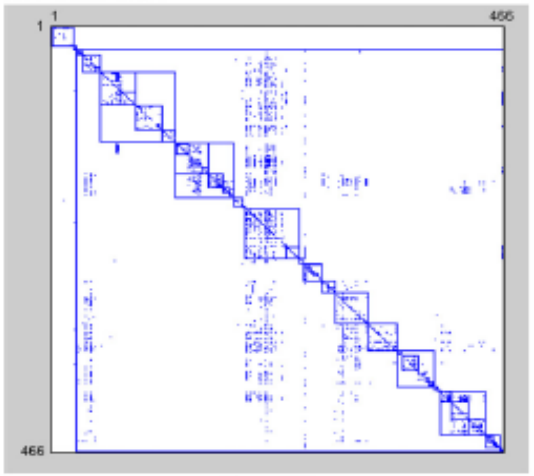
SECURITY ?

- **Potential Drawbacks**
  - Duplicated subsystems at local levels
  - Limited innovation due to compartmentalization
  - Many choices of measure for modularity
  - Unseen impacts on complex system due to changes at module level

Case: Modularity and Organizational Structure

Open Source

Gnucash 1.8.4



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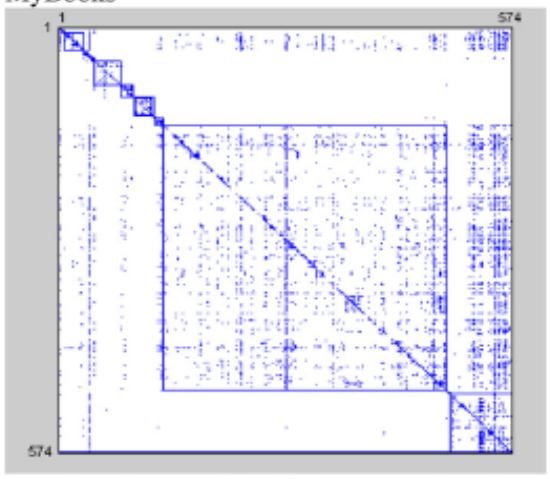
Dependency Density = 1.3672%
Propagation Cost = 7.7428%

Commercial

MyBooks



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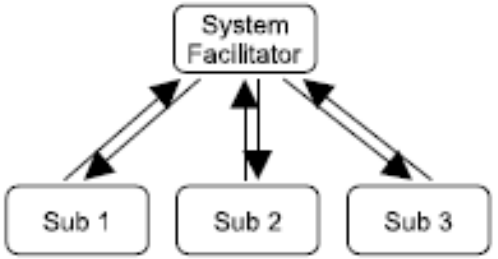
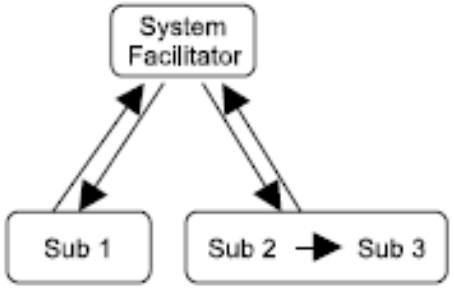
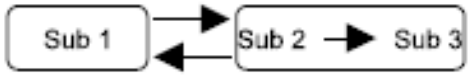
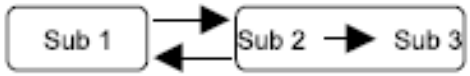
Propagation Cost = 47.1394%









- Prior work by McCormack et al on mirroring effect/Conway's Law (propagation costs, IP modularity)
- Honda work on information passing → impacts end design

*From McCormak et al., "Exploring the Duality between Product and Organizational Architectures: a Test of the Mirroring Hypothesis", 2012

Case: Modularity and Supply Chain

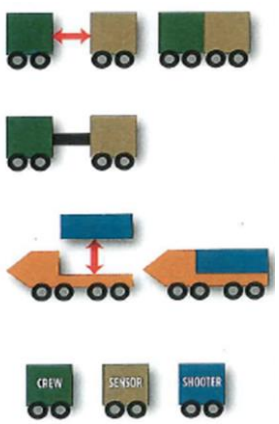
- Daimler designs closely knit and carefully designed integrated component

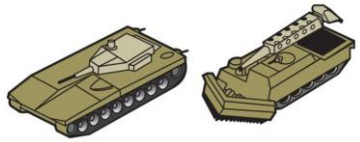
- Chrysler design focus on modular designs
  - Autonomous suppliers design, supply and innovate based on standards

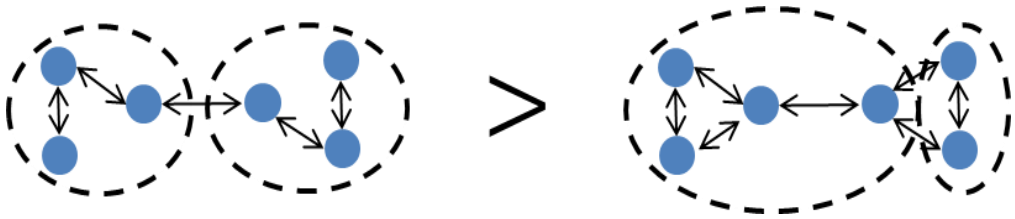
- Merger of Daimler-Chrysler was overall deemed detrimental
  - Mixing JIT supply chain with Daimler supply chain proved challenging and costly

Case: Modularity Measures

- Choice of measure (metric) for modularity? How is one system more modular/open than another?
- TARDEC choice of vertical vs. horizontal modularity metric observed to drive effectiveness of approach
- Openness – Navy Open Architecture Assessment Tool (OAAT) to measure level of openness
- Need to focus on metrics that inform attainment of MOSA benefits for program goals







*Dasch,J., Gorisch, D., "Survey of Modular Military Vehicles: Benefits and Burdens", Defense Acquisition Research Journal, January 2016, Vol 24 No1.:2-27

MOSA Workshop

- MOSA workshop held in Washington DC [Government, Academia, Industry attendees] 5th October 2016
  - 31 attendees [13 Gov, 6 Industry, 12 Academia]

- Purpose to focus on exploring key question/have in depth discussions on:
  - **Defining, quantifying** and **assessing** modularity
  - **Generating candidate strategies**, cognizant of current barriers
  - Synthesizing key list of **stakeholder needs**/concerns in MOSA ecosystem
  - **Mapping beneficial elements** of modularization strategies to appropriate acquisition processes
  - Generate **repository** of useful case studies/anecdotes

Some MOSA Workshop Outcomes

- Modularity should not be seen as an "output" but **as means to achieve end benefits**
- Need **"feedback measures"** to inform choices
- Care for multiple stakeholders and their needs
- To show "compliance", **evaluate** the degree to which programs show that their approaches are good **in terms of the of the estimated benefits**
- **"good modularity" is same as "good architecting"** – can be hard for complex systems development
- Encourage greater intentionality in adequate amount and style of modularity

RT-163 produced an Initial MOSA Guidance Document for PMs

- Guidance Categories
  - *What to Measure and Why*
  - *Useful Strategies Exist at Different Acquisition Lifecycle Phases*
  - *Caution! Emergent phenomenon in benefits and risks*
  - *Ouch! Technical and programmatic pain points*

- Preliminary 'living' document informed by prior research effort
  - Current refinement efforts:
    - Further exchanges with key collaborators and contributors from government, industry, academia
    - Directed knowledge acquisition and canvassing of case studies based on prior efforts

Ecosystem Needs & Future Work

- **Establish the long-term business strategy, drivers and objectives for each stakeholder,** and their time horizons for MOSA-generated benefits
  - Keep into account competing interests
- Provide **tools to categorize and assess consequences** of modularization choices, under uncertainty
  - Holistic level tools (e.g. **MBSE**) to capture main viewpoints
  - Measure t[illegible]ts

Focus of current SERC RT-185 Effort

- **Provide feedback mechanisms**, to help stakeholders understand the consequence of their actions and that of others (e.g. decision support framework)
- **Develop a database of case studies,** based on best practices, tacit knowledge, anecdotes, that is well mapped to the acquisition process
- **Map case studies to appropriate parts of the overall acquisition lifecycle, in**

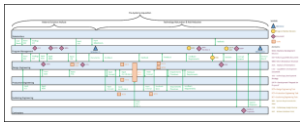
Concept Decision-Support Framework

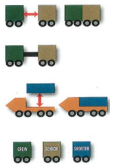
SME Knowledge Base

Literature/ Case Study Knowledge Base

Decision Support Framework

Impact on Acquisition Processes





Program Manager Queries

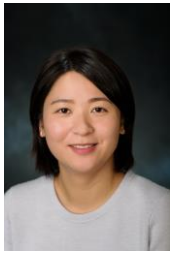
PM Decision Feedback

Acquisition Process relevant outputs

RT-185 Research Team

Dr. Gary Witus
Wayne State University

Dr. Daniel DeLaurentis
Purdue University



Dr. Lu Xiao
Stevens Institute of Technology

Dr. Jean (Charles) Domercant
Georgia Tech Research Institute

Dr. Cesare Guariniello
Purdue University

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Contact: Dr. Daniel DeLaurentis
Director
Center for Integrated Systems in Aerospace (CISA)
ddelaure@purdue.edu