How much MOSA does your system need?

Hitting the Sweet Spot Between MOSA Ambition and Lifecycle Costs

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Hello.

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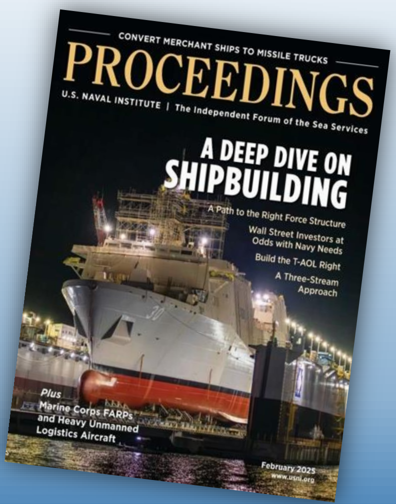
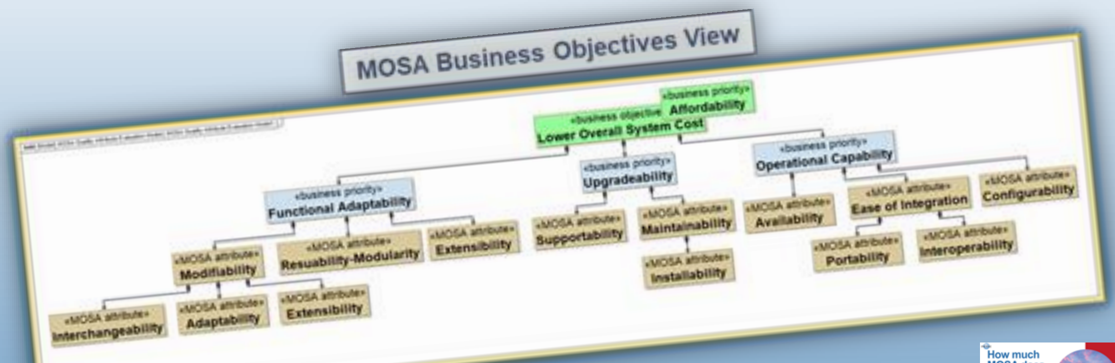
Is MOSA really the answer to performance at the speed of relevance?

Reform** [DoD] for performance at the speed of relevance **via Industrial Innovation Base

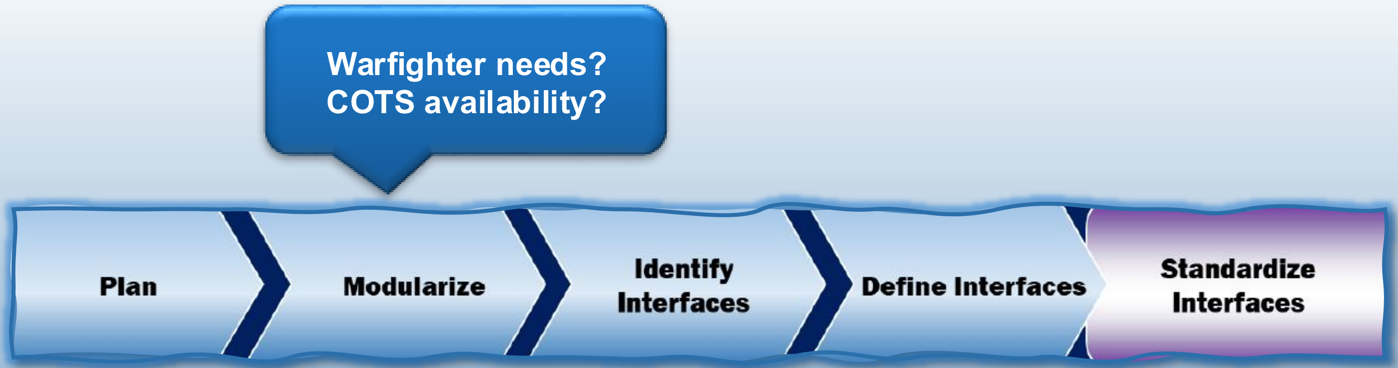
- *Continuously deliver performance with affordability and speed (MOSA? ... Always?)*
- *Establish twenty-first century National Security Innovation Base (MOSA? ... Always?)*





We discovered wholesale MOSA has not always been cheaper and faster.

Regarding achieving military dominance through innovation. . . MOSA may crumble as an institutionalized pillar.



Implementing a MOSA in DoD Programs, Figure 3-1. MOSA Planning Framework, OUSD(R&E), Office of SE&A, February 2025.

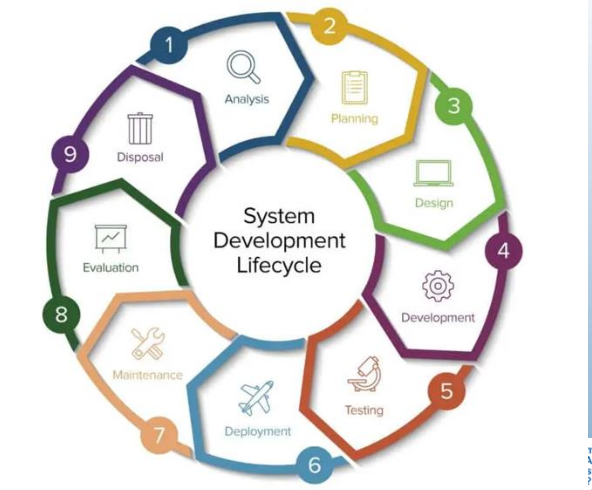
Can MOSA ambition and lifecycle cost encounters become more predictable?

As a standard, does a "sweet spot" for MOSA implementations exist?
How can it be characterized or accurately determined prior to initiation of system development?

DoD Ambition
Streamline rapid, iterative approaches from development to fielding

"Platform electronics and software must be designed for routine replacement instead of static configurations that last more than a decade. This approach,..will allow the Department to more quickly respond to changes in the security environment and make it harder for competitors to offset our systems."

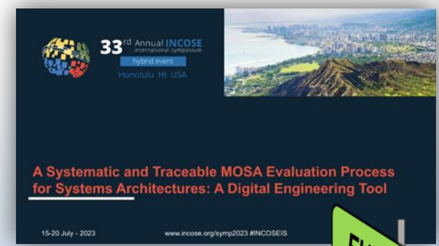
Jim Mattis, U.S. Secretary of Defense in Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive. Edge, January 19, 2018

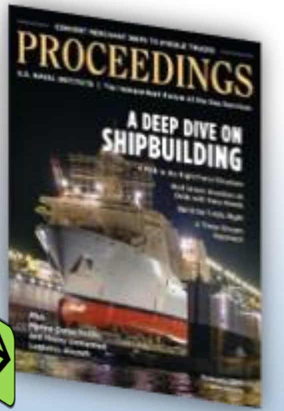


https://www.smartsheet.com/system-development-life-cycle-guide

We will present features and findings of our examination so far.

- *The previous MOSA assessment process*
- *MOSA lifecycle cost deliberations*
- *Representing a module (acquisition)*
- *Findings*
- *Conclusion (recommendations)*





Review of Previous Process

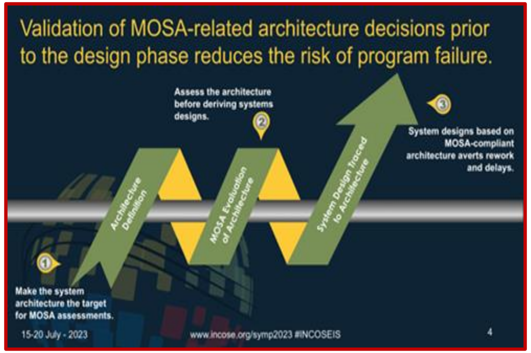
Revisiting the original MOSA compliance evaluation process

Original approach validated specified MOSA goals prior to system design

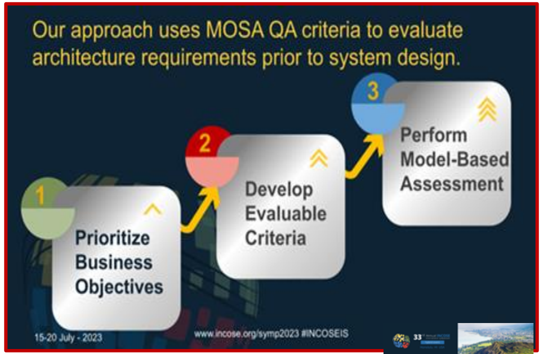
Intended to validate MOSA-related architecture decisions prior to system design. (US DoD MOSA Pillar V)

What?

Why?



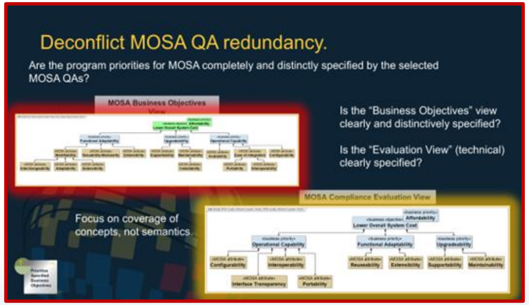
How?



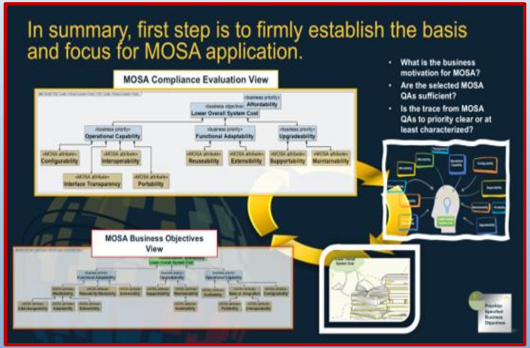
The process evolved and became a tangible, traceable, MOSA-justifying approach and digital tool.

But, . . .

How?

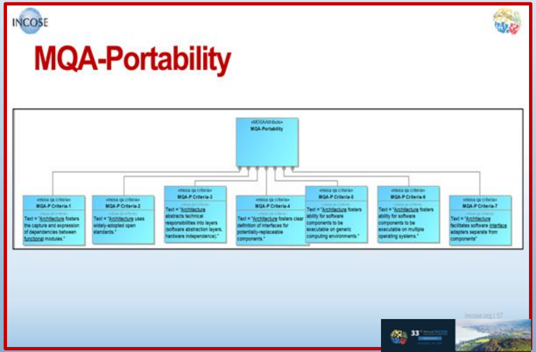


What?



How?

How?



Did not work well during a follow-on family-of-systems system development effort.

Application of systems engineering was nominal and ostensible.

Why?

Visibility of (and traceability to) highest-level goals and objectives was lost.

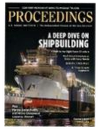
The importance and skill of functional decomposition (and its role in defining modularity and openness systematically) was not well understood.

The enabling environment was unestablished and nonexistent in practice.

MOSA Lifecycle Cost Deliberations

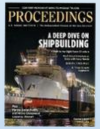
Challenges of Modular Design

Taking a closer, deeper look



The Economics of Modularity

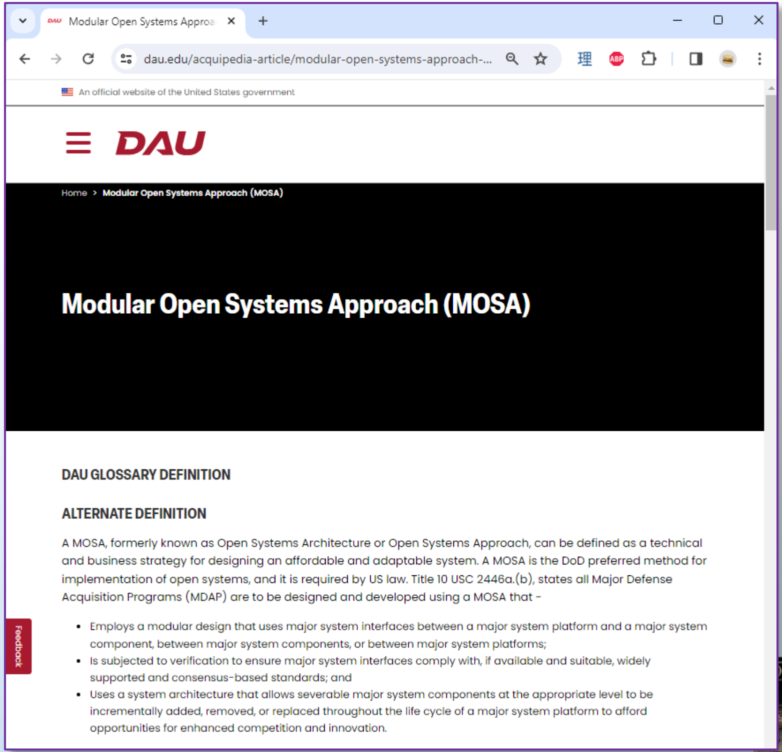
(Some material originally presented at Japan Symposium 2024 in Tokyo, February 2024.)

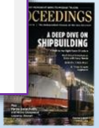


Modular Open Systems Approach (MOSA)

The Economics of Modularity

- Required by U.S. Law for Defense Contracts
- Modular Design
- Well-Defined Interfaces
- Consensus-Based Standards
- Compliance Verification
- Incremental Add, Remove, Replace

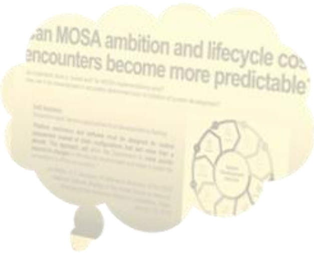




https://www.dau.edu/acquipedia-article/modular-open-systems-approach-mosa

It's Obvious

The Economics of Modularity

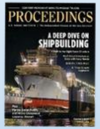


(MCIA) - Monolithic, Closed, Inflexible Approach (MCIA)

No One Would Want "MCIA"!

Modular Products are So Convenient

Example: USB Products



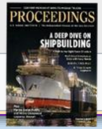
The Cost to Develop USB was Enormous.

The Economics of Modularity

- International Standards Activity
- Circuit Design and Simulation
- Connector Design and Testing
- Semiconductor Design
- Device Driver Design
- Software Application Design
- Thousands of Man-Years!

Available connectors by USB standard

Standard		USB 1.0 1996	USB 1.1 1998	USB 2.0 2001	USB 2.0 Revised	USB 3.0 2008	USB 3.1 2013	USB 3.2 2017	USB4 2019	USB4 v2.0 2022
Max Speed	***Marketing name*** **(operation mode)**	*Low-Speed* & *Full-Speed*		*High-Speed*		*SuperSpeed USB 5Gbps*, original: *SuperSpeed* (Gen 1)	*SuperSpeed USB 10Gbps*, original: *SuperSpeed+* (Gen 2)	*SuperSpeed USB 20Gbps* (USB 3.2 Gen 2×2)	*USB4 40Gbps* (USB4 Gen 3×2)	*USB4 80Gbps* (USB4 Gen 4)
	Signaling rate	1.5 Mbit/s & 12 Mbit/s		480 Mbit/s		5 Gbit/s	10 Gbit/s	20 Gbit/s	40 Gbit/s	80 Gbit/s
Connector	**Standard-A**	Type-A 1.0 - 1.1		Type-A 2.0		Type-A SuperSpeed		Type-A SuperSpeed [rem 1]	—	
	Standard-B	Type-B				Type-B SuperSpeed		Type-B SuperSpeed [rem 1]	—	
	Mini-A	[rem 2]	Mini-A			—				
	Mini-AB[rem 3][rem 4]		Mini-AB			—				
	Mini-B		Mini-B			—				
	Micro-A[rem 5]	[rem 2] [rem 6]			Micro-A	Micro-A SuperSpeed		Micro-A SuperSpeed [rem 1]	—	
	Micro-AB[rem 3][rem 7]				Micro-AB	Micro-AB SuperSpeed		Micro-AB SuperSpeed [rem 1]	—	
	Micro-B				Micro-B	Micro-B SuperSpeed		Micro-B SuperSpeed [rem 1]		
	Type-C (USB-C)	[rem 6]			(Enlarged to show detail)					



https://en.wikipedia.org/wiki/USB

Modularity For a Single Unit

The Economics of Modularity

Function Cost

Platform Cost

One Unit: Custom Design

Economic Nonsense

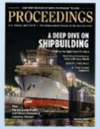
Function Cost

Modularity Cost

Modularity Cost

Platform Cost

One Unit: Modular Design



Commercially Available Function Module

The Economics of Modularity

Function Cost

Platform Cost

One Unit: Custom Design

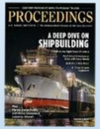
Commercially Available Function Module

Modularity Cost

Platform Cost

One Unit: Modular Design

This Might Work



Commercially Available Platform

The Economics of Modularity

Function Cost

Platform Cost

One Unit: Custom Design

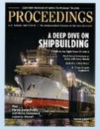
Function Cost

Modularity Cost

Commercially Available Platform

One Unit: Modular Design

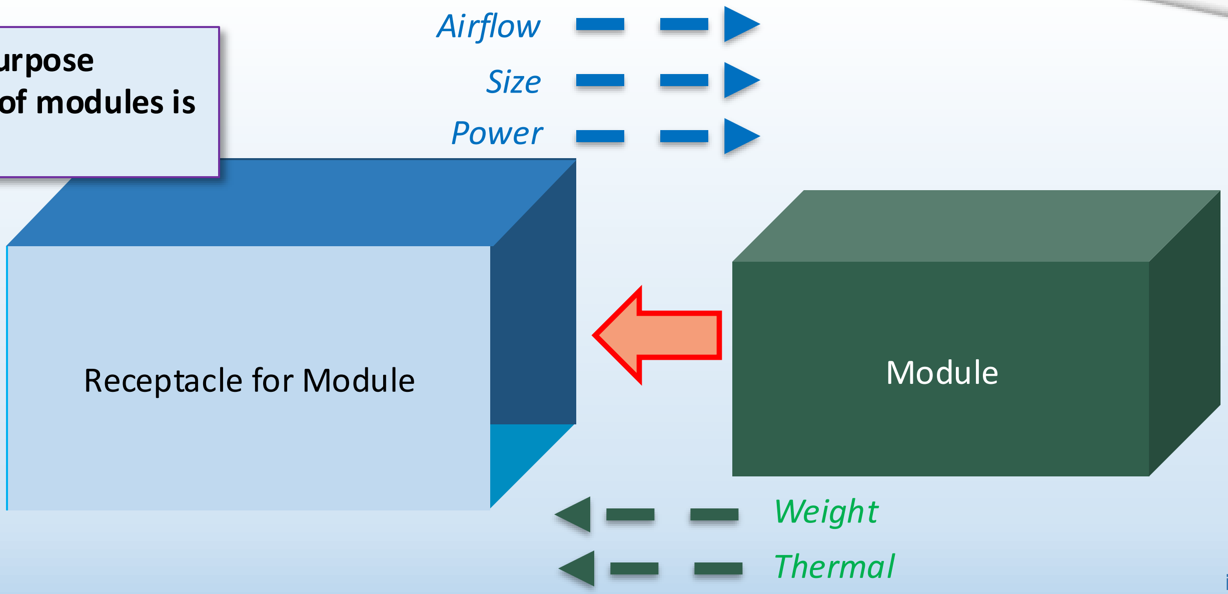
This Might Work

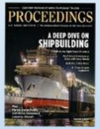


Size, Power, Airflow, Weight, Thermal

The Economics of Modularity

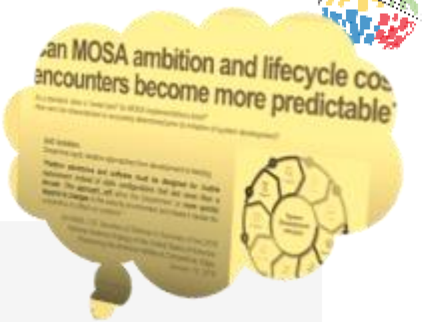
Designing a general-purpose platform for a variety of modules is very difficult.

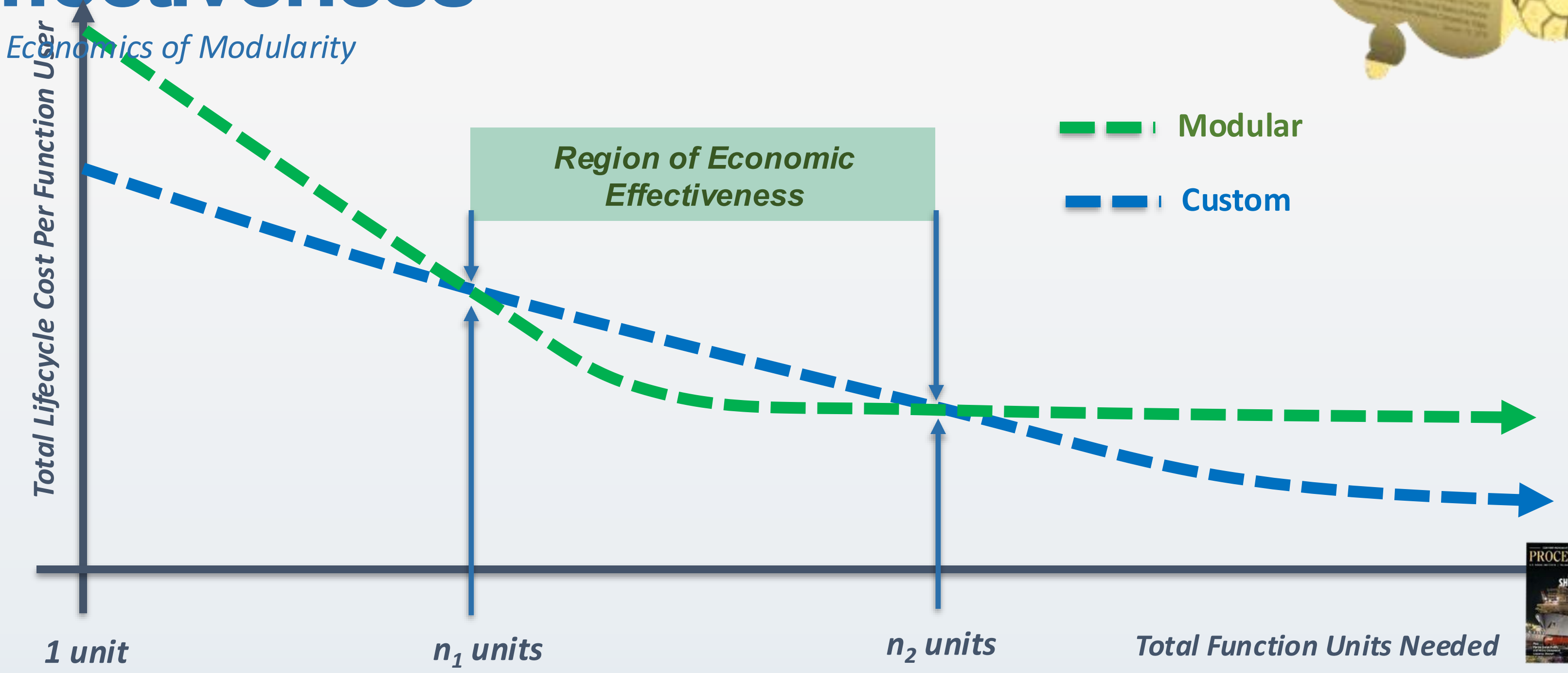


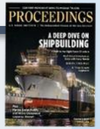


Region of Economic Effectiveness

The Economics of Modularity







Example: Blade Servers

The Economics of Modularity

It Sounded Promising…

Standard 42U Rack Contained 42 "Pizza Box" Servers

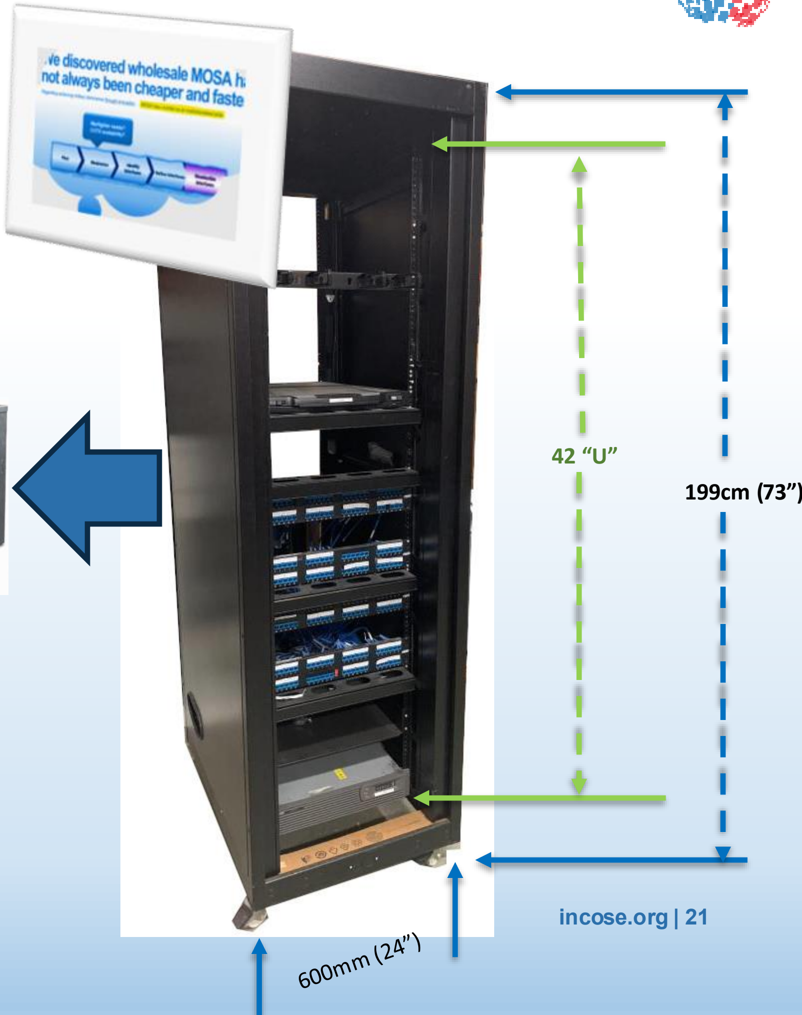
42 Fans and 42 Power Supplies

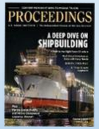
Very Wasteful

IBM, Dell, and HP All Prepared Modular Servers

14 Servers in 7U

Density Doubled!





Example: Blade Servers

The Economics of Modularity

Google, Microsoft, Facebook, eBay hired their own engineers

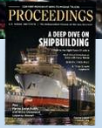
Bare minimum custom design

No faceplates, no logos, no extra connectors

Small businesses and small departments did not need 14 servers

Only mid-sized customers purchased blade servers

https://im.ziffdavisinternational.com/pcmag_gr/photo/default/google-servers_paxb.jpg



Example: Littoral Combat Ship

The Economics of Modularity

2000 – CNO: “I want a truck!”

< 9 months later: Congress allocates billions $

Vision of modularity….

Two different ships, one aluminum, one steel

Different form factor…

Navy managed to change a module one time.

Forward basing of modules: Not feasible

Module/Ship crew sync: Not feasible

2013 decided to install modules permanently…

https://www.navytimes.com/newsletters/2025/07/15/final-independence-class-combat-ship-delivered-to-navy/

v.navalnews.com/naval-news/2023/04/us-navys-final-freedom-variant-lcs-launched-b…ntieri/

(Worst of all worlds.)

Acquisition

Unit of Modularity (UoM) Standardization Considerations

Representing a module

Representing a Module: Problem Statement

Common ideas, but varied modular representation solutions

- **How to start a fight in MBSE:**
  - Which abstraction levels?
  - Well-defined interface?
  - Tracing through decomposition?
- **It depends**
  - “Good enough”?
  - Business high level or implementation low level?
  - External or internal interface standards?
  - Quantity?
- **Commonality in representation?**

Lot of incompatible ways of defining modules.
“One perfect” representation for all programs does not exist.

Proposal for Representing a Module

The Unit of Modularity (UoM) and the UoM Solution

- **Unit of Modularity (UoM) is self-contained decomposable block.**
  - Contains everything needed to define a module, sufficient for acquisition.
  - Includes what is common about all modules, excludes what is not.
- **What does a UoM *Solution* look like?**
  - ***Modularity Basics***
    - Well-defined interfaces
    - Well-defined black box behavior
    - Low coupling between modules
    - High cohesion within a module
  - ***Pattern for representing each level of decomposition***
    - System of Systems UoM -> System UoM -> Subsystem UoM -> Component UoM -> . . .

UoM Solution includes all the peripheral "stuff" needed for describing any particular module.

UoM Solution supports flexibility and traceability of "How much MOSA?"

Representing a Module: UoM

Summary of Use Cases for a Unit of Modularity Solution

- **Identify compliance** of UoM for Rules of Construction (RoC), validation and verification, sufficient for acquisition.
- **Create** UoM.
- Within a system context, **replace existing UoM** with new UoM demonstrating compatibility.
- Curate, version control, and share **common libraries** (UoM, DSDM, interface, signal, datatype).
- **Self Test** UoM Solution shared example.
- **Extend** from base UoM Solution for **program-specific acquisition.**
- **Estimate metrics** for cohesiveness and coupling.

Basic Goals: *Compliance, Usability, Curation, Customization*

Parts of Unit of Modularity Solution

UoM Solution should include

- **Extendable** general **Rules of Construction** (RoC) to constrain how the models are created.
  - Common Libraries
  - UoM Traceability
  - UoM Behavior and Test Case Definition
  - Standard modeling practices
- **Test model** showing positive and negative test cases **for RoC.**

Implemented via robust and extendable rules of construction.

Not Parts of Unit of Modularity Solution

Specifically missing to allow for flexibility in defining the modularity needs of the program/project

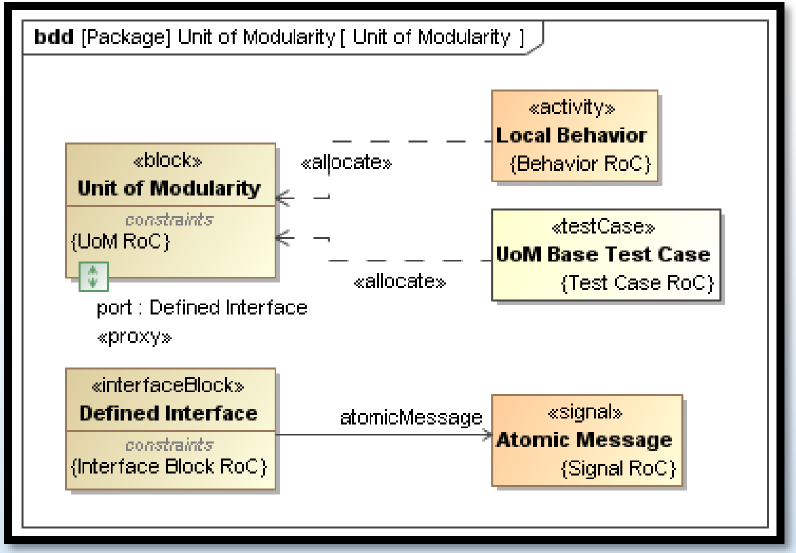
- Predefined abstraction levels
- Fully defined RoC for all programs/projects
- Expecting perfect traceability
- Expecting perfectly passing Rules of Construction checks.

Not constrained by someone else's idea of how to describe your system.

Example Unit of Modularity

Incomplete example showing basic additions to the standard idea of a module

- Basic SysML structure
- Extendable constraints for each type
- White-box behavior for shared understanding
- Black-box test case for validation/verification
- Programs can extend RoC and definitions



Example of basic structure following common SysML practices

Findings

Pertaining to the economics of modularity

Findings

David Hetherington, “Truly Modular and Open System Design is Difficult.”

Where program expectations were not met, a few themes stood out:

Stakeholder Needs

Analysis of the stakeholders was insufficient. *First, some crucial stakeholders were overlooked. In aggregate, too much focus was placed on the intricate mechanical packaging problem. Not enough thought was put into whether the solution was going to work well for the stakeholders and how those stakeholders might react if the solution was not perceived to match their needs very well.*

Cost Analysis

Economic cost analysis was weak. *Overall full lifecycle costs were not well modeled. Alternatives that might have looked attractive to stakeholders were not modeled in sufficient depth to determine whether the proposed modular solution was in fact a winner from a cost point of view.*

Program Risks

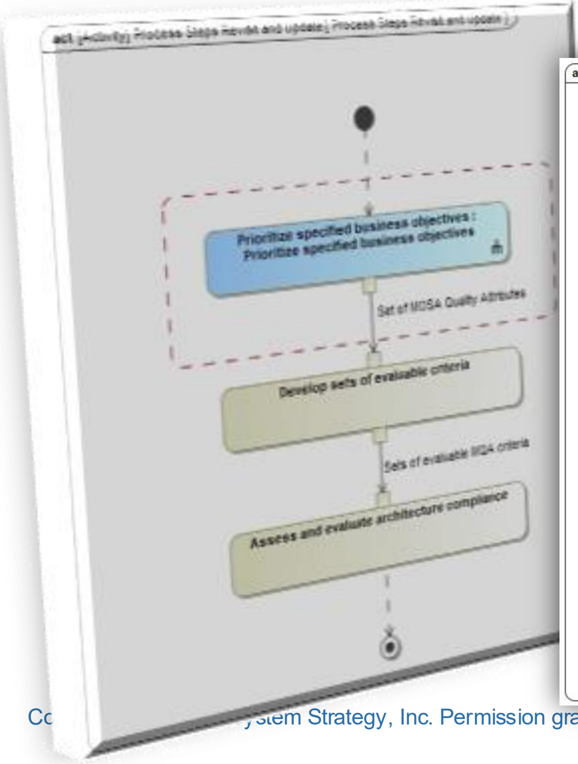
Program risk analysis may have been insufficient. *What could go wrong? Were there economic options that might have traded up front costs for improved information in advance of major financial commitments?*

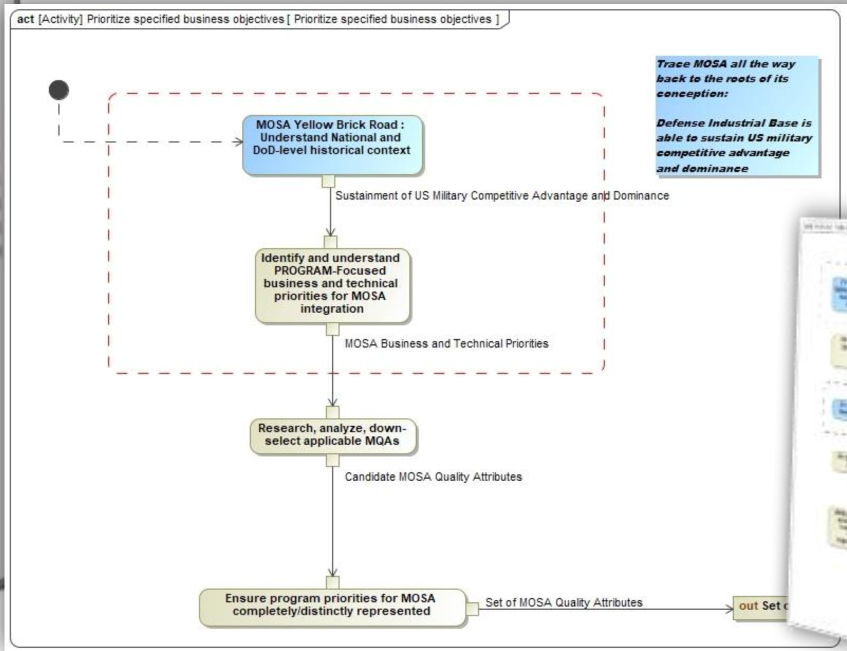
Findings

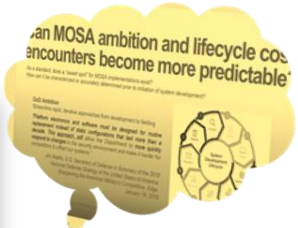
Pertaining to the National goal of military competitive advantage

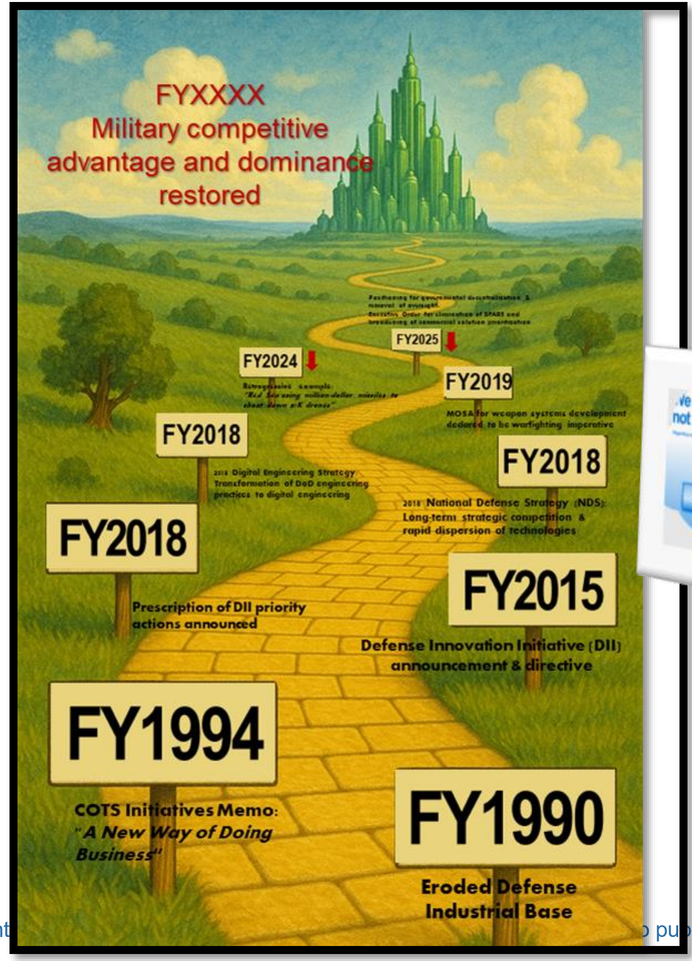
Visibility of highest-level goals and objectives was lost.

Endeavored to go back in time and history to understand national and DoD-level historical context for MOSA . . .



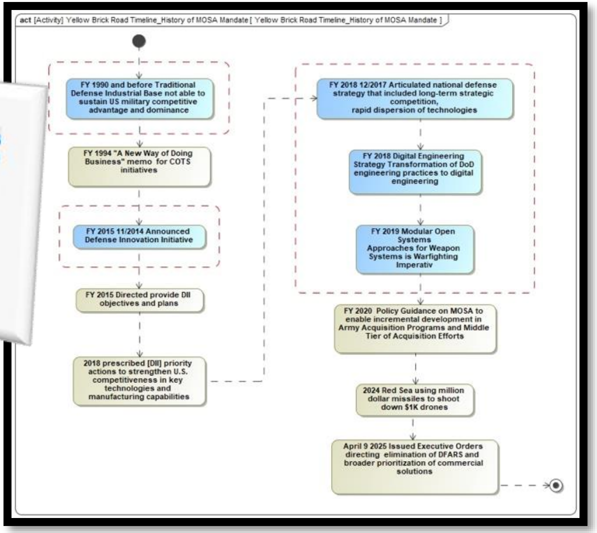






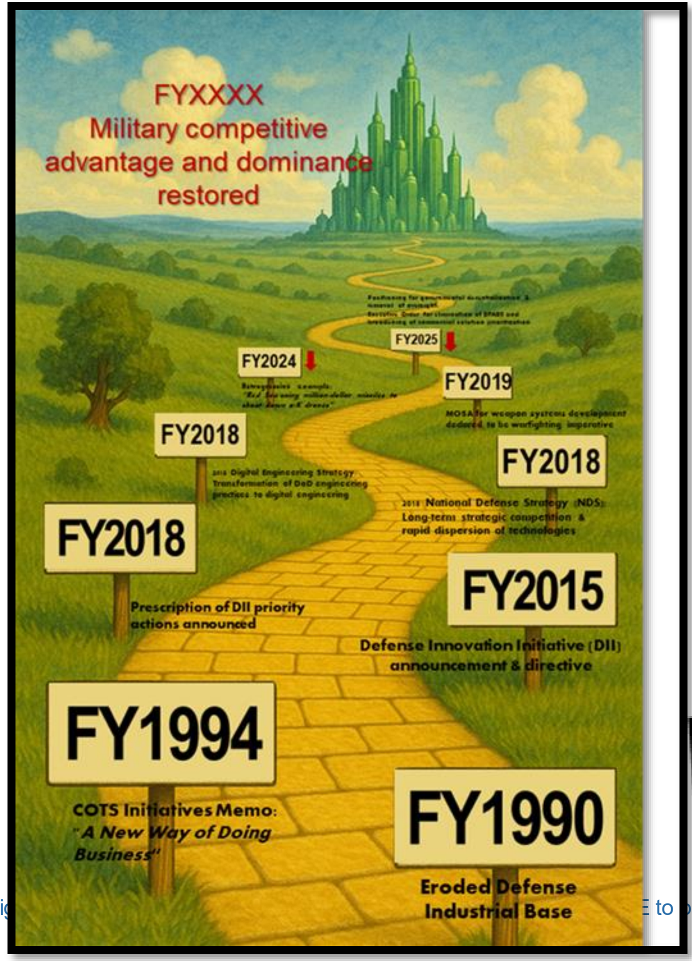
Visibility of highest-level goals and objectives was lost.

Follow the Yellow Brick Road: Searching for Emerald City "home", point in time when Military competitive advantage and dominance restored . . .

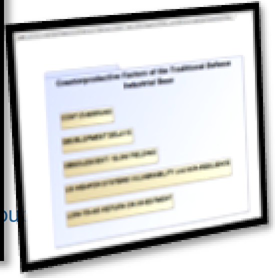


Visibility of highest-level goals and objectives was lost.

Details of the Yellow Brick Road. . .



FISCAL YEAR	DIRECTION OF PROGRESS	MOSA HISTORICAL CONTEXT	
		EVENT	DESCRIPTION
FY2025	↓	Executive Order for elimination of DFARS and broadening of commercial solution prioritization	*Pre-positioning for elimination of governmental oversight & decentralization*
FY2024	↓	"Red Sea using million-dollar missiles to shoot down $1K drones"	*Retrogressive example*
FY2019	↑	MOSA for weapon systems development	*Declared to be warfighting imperative*
FY2018	↑	2018 Digital Engineering Strategy	*Transformation of DoD engineering practices to digital engineering*
FY2018	↑	2018 National Defense Strategy (NDS)	*Long-term strategic competition & rapid dispersion of technologies*
FY2018	↑	Defense Innovation Initiative (DII) Priority Actions	*Prescribed in order to strengthen competitiveness in key technologies and manufacturing capabilities*
FY2015	↑	Defense Innovation Initiative (DII) directive	
FY2015	↑	Defense Innovation Initiative (DII) announcement	
FY1994	↑	COTS initiatives memo from US Secretary of State	*"A New Way of Doing Business"*
FY1990	↓	Eroded and declining defense Industrial Base	*Attributed as cause of erosion of US military competitive advantage and dominance. Characterized by: Cost overruns as the rule; Delays on the order of years; Obsolescent and slow fielding of weapon systems; US weapon system vulnerability and non-resilience to much less sophisticated and cheaper weapons of adversaries; (See retrogressive example.) Rampant and persistent low-to-no return on investment (Example: program cancellations)*

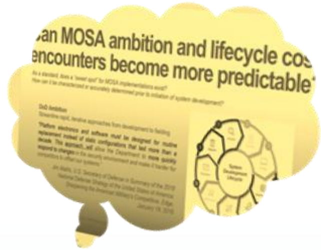


Conclusion

Recommending an updated MOSA assessment framework

Proposing an updated framework.

Each time, doing what really makes sense. . .



What?

*Incorporating MOSA lifecycle cost deliberations and UoM Solution considerations **to answer** the **question**, **"How much MOSA does your system really need?"***

Why?

Pursuing lower overall system cost. . . as the rule.

How?

Revisiting (and tracing to) [National and DoD weapon] system development goals and objectives.

Proposing an updated framework.

David Hetherington, “Truly Modular and Open System Design is Difficult.”

My recommendations track the conclusions outlined in the previous section.

Stakeholder Needs Analysis

A rigorous identification of stakeholders, their needs, their goals, and their expected reactions to the proposed system should be conducted in advance of any large commitment of funding.

Region of Economic Effectiveness

The modularity sweet spot shown in Figure 5 should be calculated early in the development of the system concept. Are you planning to build only one system? Don’t bother making it modular! Does one of your module applications need 100,000 units? Purpose-build something for that application; don’t bother with a modular platform approach.

Analysis of Required Level of Interoperability

A hard-eyed look should be trained on the question of exactly how much interoperability or modularity is actually really needed. Pareto economics will tend to prevail: 20% of the modularity will yield 80% of the benefits. Identify this 20% early in the program. Implement that, and only that.

Proposing an updated framework.

David Hetherington, "Truly Modular and Open System Design is Difficult."

My recommendations track the conclusions outlined in the previous section.

Total Cost of Ownership Analysis

Cradle-to-grave cost analysis is a must. Cost analysis must include not only the hardware, but the full life cycle deployment, maintenance, manning, logistics, and eventual retirement costs. This analysis should be conducted not only on the proposed modular system, but also the specialized purpose-built, simpler systems the stakeholders are likely to prefer.

Program Risk Assessment

What could go wrong? What if technical objectives are not met? Do we have multiple interlocking programs that are critically dependent on each other? What if key stakeholders withdraw their support at crucial points in the program? What is the "Plan B"?

Focus on Early Program Risk Mitigation

Ruthlessly squash program risks early and completely.

Proposing an updated framework.

Pertaining to the National goal of <u>military</u> (not industrial) competitive advantage and dominance. . .

Revisit DoD weapon system development goals, objectives, and approaches.

What?

***Answering** "Can MOSA ambition and lifecycle cost encounters become more predictable?"*

For greater probability of achieving the goal and achieving the goal comprehensively and sensibly, in accordance with Systems Engineering tenets.

Why?

For increasing ownership within the Defense Industrial Base, solid history and advancing continuum now exists of intentional cost overruns, development delays, obsolescent /slow fielding, weapon system vulnerability and non-resilience, and low-to-no return on investments.

How?

*Conduct tough discussions with stakeholders about **what level of MOSA is actually required for mission success** and **at what cost**.*
***Don't over invest in MOSA capability beyond the actual mission needs**.*
***Make sure** your V&V efforts throughout the life of the program confirm that **the advertised MOSA benefits are actually delivered and realized by the program**.*
*For example, if your program is advertising that the system will be able to accept COTS modules of some kind, the V&V effort should include a rigorous test program with real-world COTS modules to **prove that** the **advertised benefit was delivered**.*

Modularity is not “Yes” or “No”.

The Economics of Modularity

Microservices +Agile + DevSecOps approach reduces difficulty across the board.
However, there are still cost differences for different ambition levels.

Hardware Side

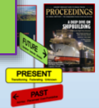
- Plug-and-play hot-swap with system in operation
- Cold swap with system reboot
- Replace at service depot
- Easy to field modify at service depot
- Easy to clone and reuse design
- Just partition for acquisition

COST!!

Software Side

- Plug-and-play hot-swap with system in operation
- Over-the Air Update (OTA)
- Cold software update with system reboot
- Software update at service depot
- Well structured so that it is easy to make modifications to code
- Easy to clone and reuse design
- Just partition for acquisition

Microservices Approach



Can MOSA ambition and lifecycle cost encounters become more predictable?
Yes; however, the economics of modularity is, “Modularity is not ‘yes’ or ‘no’ ”.

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