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Sustainment and Upgrades of Legacy Systems

How to Address Scope and Cost Risk for Obsolescence Upgrades

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How to Address Scope and Cost Risk for Obsolescence Upgrades

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- “It’s just a simple upgrade” Or is it? — The perils of repurposing
- Bottom line — Cost growth avoidance
- Why is this so difficult?
- Solutions and success strategies

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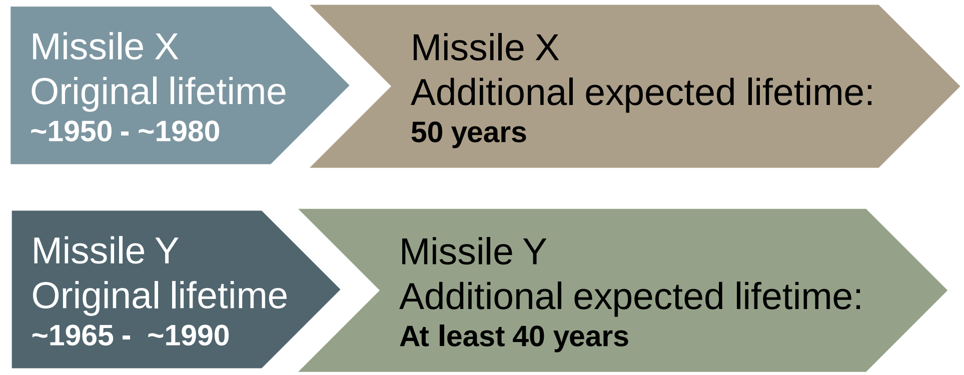
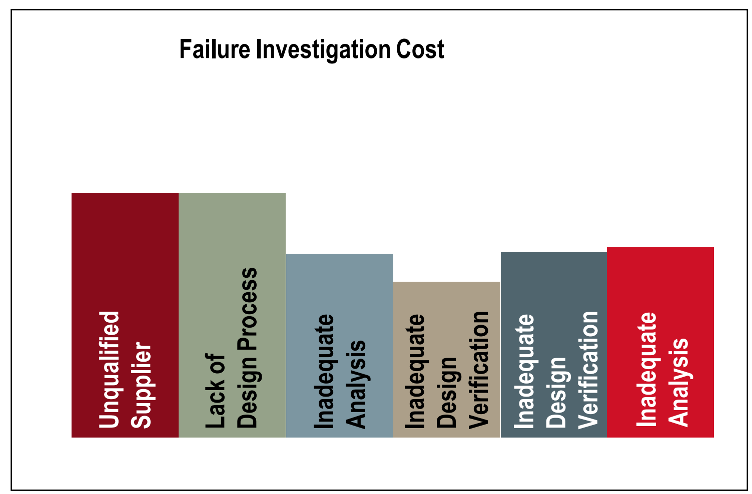
"It's Just a Simple Upgrade…"

- Service life extensions present the need for obsolescence and other upgrades
- Upgrades are fraught with challenges
- Cost and schedule risks are common





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Don't be trapped by "it is just a simple upgrade" — upgrades require real engineering discipline

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The Perils of Repurposing

- Too many assumptions about reuse can result in unintended consequences

Existing missile → Repurpose for new application → "Drop in" use of guidance section

Assumed sufficient requirements analysis and updates available

↓

Value Engineering upgrade of subassembly

Relied on production tests and delta qualification — no delta Design Verification or testing against all requirements

← Missile integration, build and fielding

Legacy testing not comprehensive to new conditions

← Missile dud results in flight failure, and the ensuing investigation and modifications cost 7 times the price of the missile

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Repurposing without proper planning, system thinking and engineering discipline creates failure

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Do the Real Engineering

- Capability upgrades and obsolescence respins require true system engineering at the subsystem level
- Inclusive engineering needed to readdress associated design artifacts and avoid unpredictable execution
- Proper scoping of engineering effort can avoid many issues

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Lack of sufficient subsystem engineering causes cost growth in obsolescence respins and upgrades

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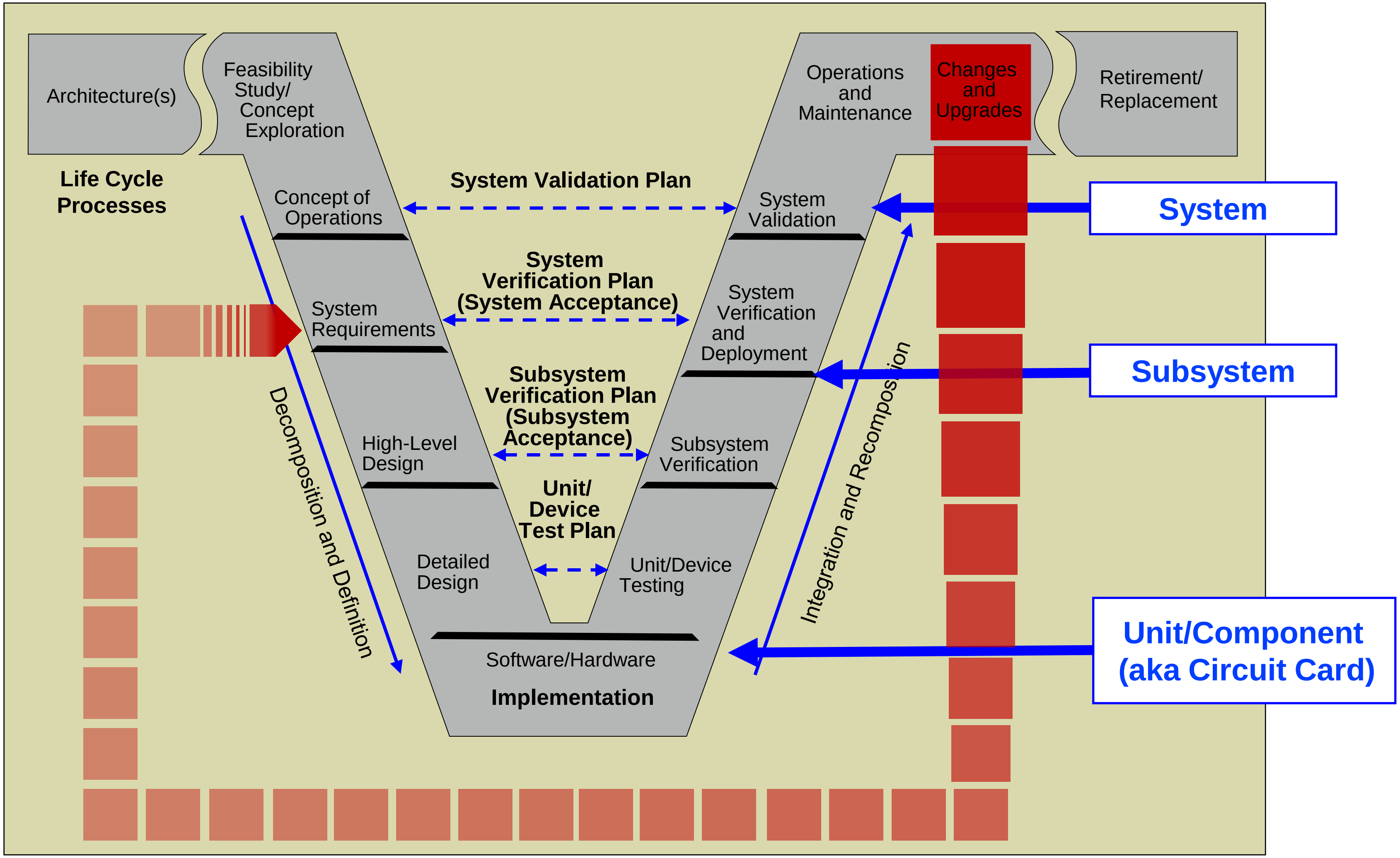
System Life Cycle — "The V"



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Changes and upgrades happen outside the normal development process

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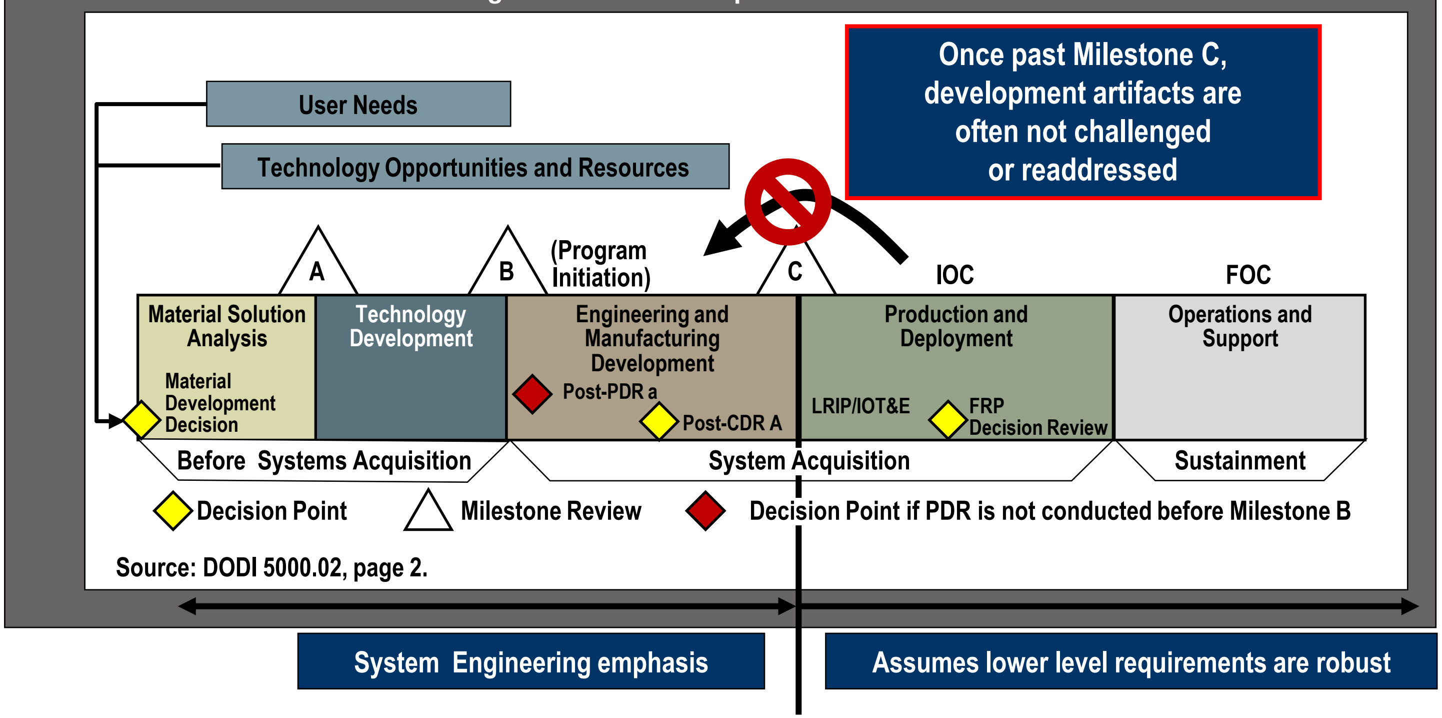
Acquisition Policy Impact

- Post-acquisition reform DoD acquisition practices (capability-based acquisition) initially drove minimalistic subsystem engineering
- Current defense acquisition policy expects engineering rigor before Milestone C

Figure 5. Defense Acquisition Milestones



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DoD acquisition scheme expects system and subsystem engineering completion before Milestone C — not budgeted for later in the life cycle

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Faulty Planning and Flawed Expectations

- Drivers of cost over-runs
  - Flawed assumptions about readily available data or documentation
  - Requirements of original design not fully understood or applicable
  - Scope of replacement may grow after uncovering additional needs
- Engineering discipline required after Milestone C
  - Upgrading a legacy capability based system may require going through some of the proper development process for the first time at the subsystem level

We can't afford to understate, sit on or cover up problems in any program — at any time — at any level. They must be brought forward. This includes not just "show stoppers" but also "show slowers." I can't stress this strongly enough [19:26].

(Former Under-Secretary of Defense for Acquisition, Donald J. Yockey)[2]

[including scope definition,]

Without more realistic estimates, ^ senior management may be lulled into a false sense of security about their programs and fail to take appropriate action to correct problems

~ *An Analysis of Cost Overruns on Defense Acquisition Contracts*[2]

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"Faulty initial engineering plans and concepts are not the root of all cost growth, but are involved in much of it."[3]

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Why Is This So Difficult?

- **Legacy solutions may be incompatible with modern practices and component selections**

Legacy/Modern Incompatibilities
▪Older systems were not designed with Modular Open System Architecture (MOSA) approach
▪Partitioning and interfaces may not easily accommodate modern interfaces
▪Accommodating legacy interfaces may in fact add complexity
▪Modern components with sufficient environmental requirements may not exist
▪Power system requirements — small changes may affect the whole power system
▪Modern devices with fast timing may require changes to grounding techniques or other interfacing components

- **Lack of documented requirements and implementation at the subsystem level**

Lack of Subsystem Engineering Artifacts
▪Difficult to respin a single Circuit Card Assembly (CCA) for obsolescence without its set of detailed requirements
▪May spend a significant amount of time creating/documenting requirements
▪Missing implementation details hinders insight into original design choices

- **'Price to win' contract strategies force tradeoffs in the resources allocated to the Systems Engineering process during proposal and execution[4]**
- **Cost and schedule constraints drive avoidance of robust re-qualification**

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Replacements have many constraints and drivers — "faster is not always better" — hence the need for real engineering discipline

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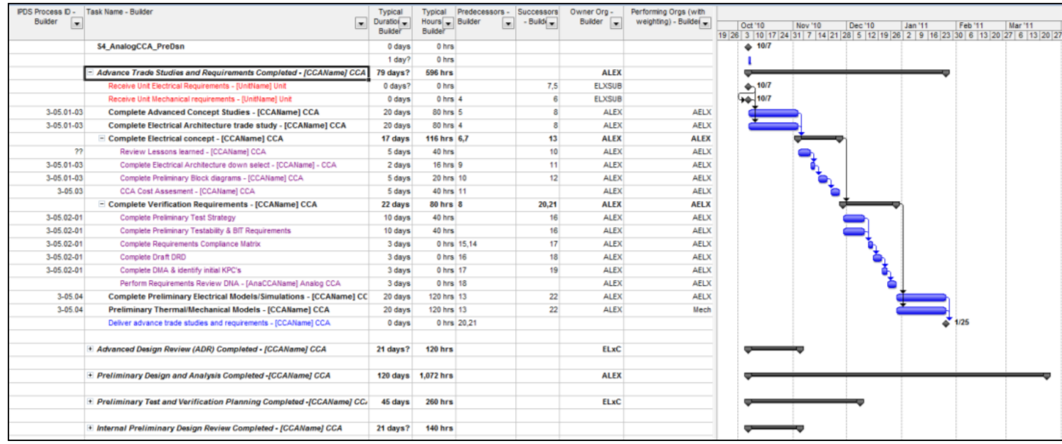
Engineering Solutions

- Two fundamental approaches to addressing unexpected issues during legacy system upgrades:
  - **Planning:** Complete and comprehensive initial bid



IPDS Process ID - Builder	Task Name - Builder	Typical Duration - Builder	Typical Hours - Builder	Predecessors - Builder	Successors - Builder	Owner Org - Builder	Performing Orgs (with weighting) - Builder
	S4_AnalogCCA_PreDsn	0 days	0 hrs				
		1 day?	0 hrs				
	Advance Trade Studies and Requirements Completed - [CCAName] CCA	79 days?	596 hrs			ALEX	
	Receive Unit Electrical Requirements - [UnitName] Unit	0 days?	0 hrs		7,5	ELXSUB	
	Receive Unit Mechanical requirements - [UnitName] Unit	0 days	0 hrs	4	6	ELXSUB	
3-05.01-03	Complete Advanced Concept Studies - [CCAName] CCA	20 days	80 hrs	5	8	ALEX	AELX
3-05.01-03	Complete Electrical Architecture trade study - [CCAName] CCA	20 days	80 hrs	4	8	ALEX	AELX
	Complete Electrical concept - [CCAName] CCA	17 days	116 hrs	6,7	13	ALEX	ALEX
??	Review Lessons learned - [CCAName] CCA	5 days	40 hrs		10	ALEX	AELX
3-05.01-03	Complete Electrical Architecture down select - [CCAName] - CCA	2 days	16 hrs	9	11	ALEX	AELX
3-05.01-03	Complete Preliminary Block diagrams - [CCAName] CCA	5 days	20 hrs	10	12	ALEX	AELX
3-05.03	CCA Cost Assesment - [CCAName] CCA	5 days	40 hrs	11		ALEX	AELX
	Complete Verification Requirements - [CCAName] CCA	22 days	80 hrs	8	20,21	ALEX	AELX
3-05.02-01	Complete Preliminary Test Strategy	10 days	40 hrs		16	ALEX	AELX
3-05.02-01	Complete Preliminary Testability & BIT Requirements	10 days	40 hrs		16	ALEX	AELX
3-05.02-01	Complete Requirements Compliance Matrix	3 days	0 hrs	15,14	17	ALEX	AELX
3-05.02-01	Complete Draft DRD	3 days	0 hrs	16	18	ALEX	AELX
3-05.02-01	Complete DMA & identify initial KPC's	3 days	0 hrs	17	19	ALEX	AELX
	Perform Requirements Review DNA - [AnaCCAName] Analog CCA	3 days	0 hrs	18		ALEX	AELX
3-05.04	Complete Preliminary Electrical Models/Simulations - [CCAName] CC	20 days	120 hrs	13	22	ALEX	AELX
3-05.04	Preliminary Thermal/Mechanical Models - [CCAName] CCA	20 days	120 hrs	13	22	ALEX	Mech
	Deliver advance trade studies and requirements - [CCAName] CCA	0 days	0 hrs	20,21			
	Advanced Design Review (ADR) Completed - [CCAName] CCA	21 days?	120 hrs			ELxC	
	Preliminary Design and Analysis Completed -[CCAName] CCA	120 days	1,072 hrs			ALEX	
	Preliminary Test and Verification Planning Completed -[CCAName] CC.	45 days	260 hrs			ELxC	
	Internal Preliminary Design Review Completed - [CCAName] CCA	21 days?	140 hrs				

  - **Execution:** Engineering at the subsystem level

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Good systems engineering must extend down to subsystem level

Planning Solutions — Complete a Comprehensive Initial Bid

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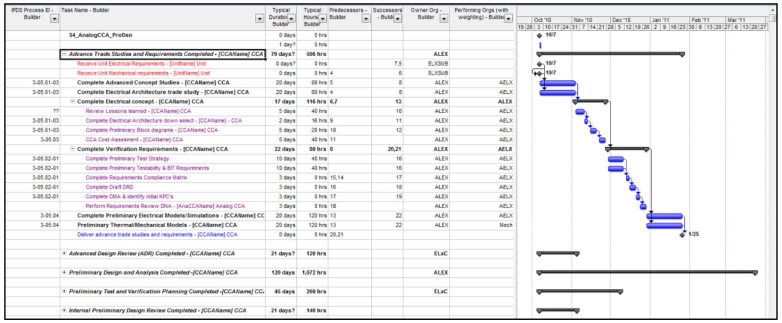
- **Better tailoring and execution**



  - **Higher fidelity plans:** Avoid “quick and dirty” Rough Order of Magnitude (ROMs) that lack fidelity and consideration for all life-cycle aspects, but can set false expectations
  - **Thoughtful assumptions:** Avoid “misuse of reuse” by determining availability of documented requirements and implementation, fabrication and test capability, and minimizing assumptions
  - Prevent under-planning and ease execution by gaining a solid **understanding of the leverage** gained from reuse and industry standards (or lack thereof)
  - A realistic and comprehensive plan will result in **flawless execution**

Plans must not sacrifice proper subsystem engineering

Execution Solutions — Engineering at the Subsystem Level

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- **Engineering integrity required to avoid later unintended consequences**

  – Engineering rigor will **reduce multiple iterations**, lowering cost
  – To minimize iterations during respin or upgrade, **ensure design integrity and compatibility** with remaining system from the beginning
  – Extra effort up front can **eliminate one or more unexpected qualification or test failures** late in the program
  – **Early investment** in generation or modification of requirements, analysis, modeling and simulation, and verification activities can prevent escapes during later stages of the life cycle
  – Documentation of requirements, analysis and results at all levels helps with **knowledge transfer** later in product life cycle

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Subsystem engineering supports design integrity

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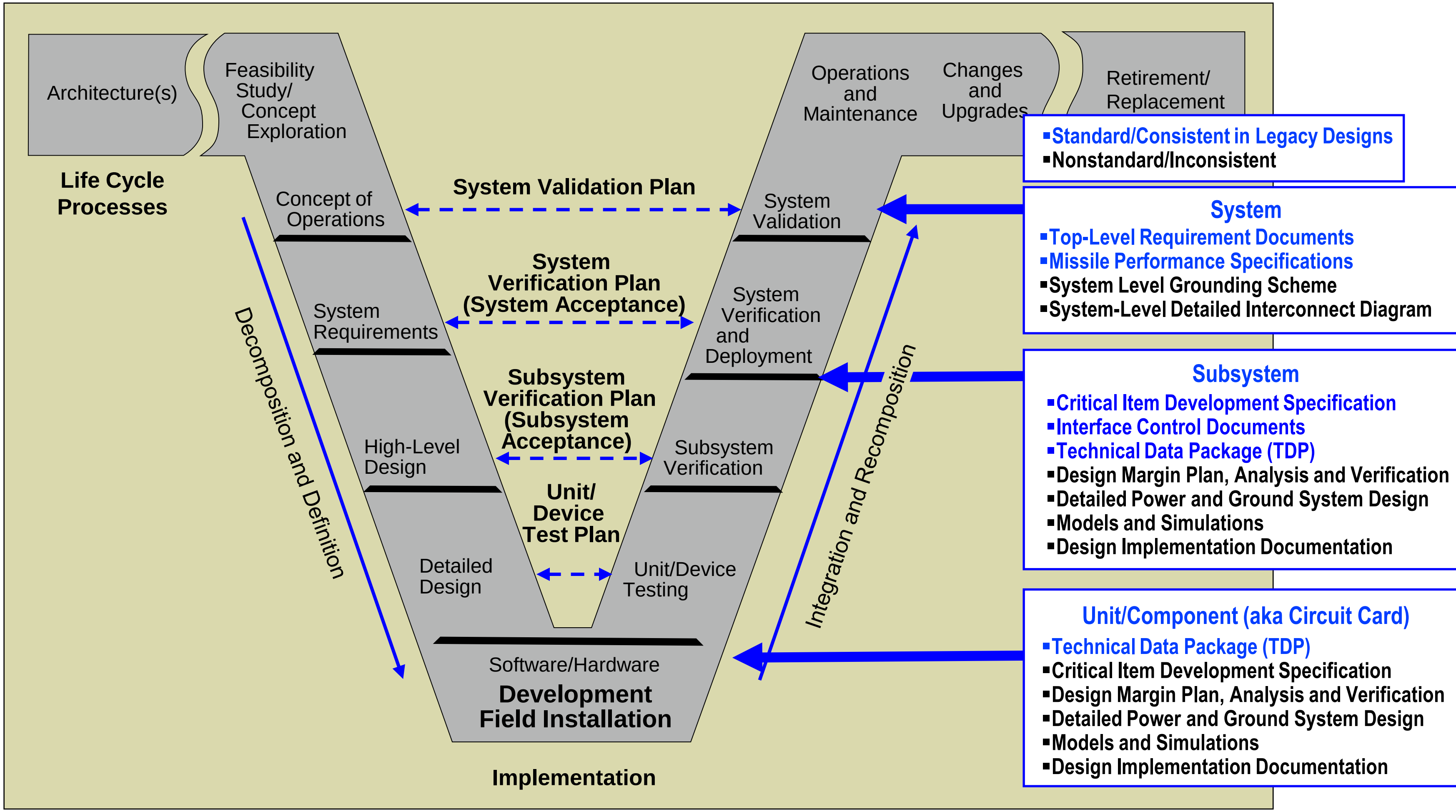
Subsystem Engineering Specifics



Critical subsystem artifacts need to be available or created for legacy systems

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Detailed Strategies for Successful Upgrades

- **Requirements must be product (subsystem) based**

System-Based Requirements Considerations
▪Flow environmental and other requirements to the level of the replacement
▪Fully understand and document the contribution of the subsystem to overall system performance
▪Comprehend the reasons behind legacy implementation to ensure necessary functionality/operation not negatively affected by the upgrade
▪What requirements were waived or not met previously that should be met now?
▪What were initially implementation details became requirements when system was completed

- **Trades must account for further future upgrades**

Subsystem Trade Considerations
▪Was modular open architecture implemented in legacy system? If not, can it be added and in what portion(s) of the system?
▪Can partitioning within the subsystem ease later obsolescence replacements?
▪Can an older technology be retained and sustained or must it be upgraded to something more available?

The devil is in the details

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Detailed Strategies for Successful Upgrades

- **Analyses must extend beyond subsystem to ensure full compatibility**

Subsystem Analysis Considerations
▪Will implementation details of the replacement negatively affect surrounding subsystem (or vice-versa)?
▪Can newer technologies directly interface with existing or are translations necessary?
▪Will the modification adversely affect power, grounding, software or other system aspect?

- **Models and simulations should be as high fidelity as possible**

Modeling and Simulation Considerations
▪Do high-fidelity models and simulations exist or must they be created or upgraded?
▪Readdressing the models and simulations forces engineers to think through the details of the upgrade and ensure nothing is missed
▪Leveraging existing higher fidelity models and simulations can save significant effort

Models, simulations and analyses must be updated and validated

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Detailed Strategies for Successful Upgrade

- **Verification must be performed at all levels**

Verification Considerations
▪Design margin verification and delta design verification testing (DVT) must be completed
▪**Qualification:** What was done previously and how much "similarity" can be gained?
▪Model verification and validation: use test data to validate models
▪What failures occurred or deviations were requested during the original development effort?

- **Test strategies must be considered from the beginning**

Test Considerations
▪Planned test reduction for production programs may have eliminated equipment needed to verify a design spin
▪Updated interfaces at lower levels of assembly may require modifications to existing test setups
▪Reprogrammability and built-in test (BIT) should be designed in at every opportunity
▪Initial data for statistical process control in the factory must start being collected during verification phase
▪Clear understanding of production line capabilities and availability is essential

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Need detailed verification at lower levels to support higher-level operability and reliability

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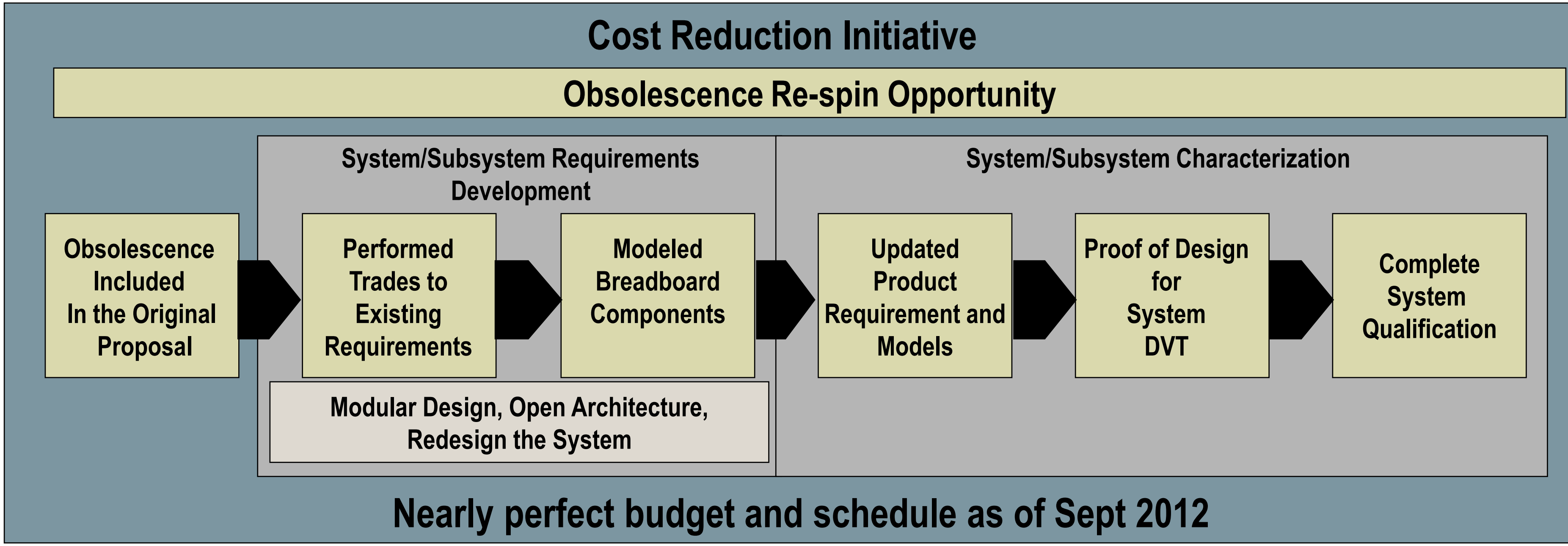
Success Story



- Assumptions about availability of engineering artifacts validated
- Model Development and design verification well thought out and properly planned and executed
- System level EMI testing included
- Teamwork between the customer and the contractor to define a clear statement of work
- All of the legacy design documentation was reviewed for completeness and updated as necessary
- Customer is ecstatic with the performance

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Proper planning strategy and engineering rigor help to keep cost under control even with a very aggressive schedule

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Summary

- **Don't be trapped** by "it is just a simple upgrade"
- The constraints and drivers of capability and obsolescence upgrades can result in **cost-driven decisions** that **reduce subsystem engineering** and ultimately add risk
- **Subsystem design information** required to efficiently and effectively replace portions of a system **should be assumed as not available** (validate those assumptions)
- Incorporating the **outlined strategies** will promote design integrity
- **Subsystem engineering discipline and proper scoping of the effort will keep cost and schedule in check**

Subsystem engineering discipline is a key to long term success

Questions?

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About the Authors

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