Using Architecture Tools to Reduce the Risk in Systems-of-Systems Integration

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Chris Piaszczyk
Systems Analysis & Design Lead
Northrop Grumman Corporation

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Abstract

DoD acquisition is evolving from the traditional approach focused on individual systems to Systems-of-Systems (SoS) integration. In DoD terminology, SoS is a collection of systems integrated together to obtain a higher level system that offers more than the sum of its parts, though the individual systems are acquired independently. System interactions within the SoS typically produce emergent capabilities that may or may not be desired. Any undesired behavior represents an integration risk and must be recognized, analyzed, and understood. Architectural tools are evolving to provide this understanding. These tools can be used for analyses of SoS designs to predict unexpected couplings and to avoid the potential for missed, underutilized or duplicated functionalities. Architectural artifacts developed with these tools expose potential issues to the design community. In addition, these artifacts provide a foundation for integration test planning by identifying and documenting the interfaces between hardware, software and humans that constitute the SoS. This presentation describes the related concepts and processes.

Keywords:

Systems-of-Systems, Integration, Risk Reduction, Architectures

Research Issue:

Increasing complexity of today's DoD Systems-of-Systems presents increasing integration risk to the DoD acquisition. This work is proposing use of architectural tools and artifacts to reduce this risk factor.

Research Results:

Consistent use of architectural tools and artifacts is an efficient and effective method for SoS integration risk reduction.

Outline

- Systems-of-Systems and Systems
  - Systems-of-Systems consist of independent systems
  - Systems-of-Systems are Systems
- Elements of risk in Systems-of-Systems Integration
  - Missed/underutilized functionalities and/or interfaces
  - Emergent behavior, sneak interactions and unintended consequences
- Architectural Tools and Products
  - ZAF, DODAF, TOGAF, MODAF, NAF, UML, SysML, IDEF, SADT
  - Operational Views and System Views
  - Structural Hierarchy and Behavioral Modeling
- Using architectural tools and products to reduce the risks in Systems-of-Systems integration
  - Documenting systems functionalities, internal and external interfaces for components, assemblies, systems of systems
  - Creating open architectures with layers of abstractions
- Summary and Conclusions

From People in the Know ...

“Systems engineering is a mysterious field as no one seems to know what it is, what it does, what it does not do, and what it should be called. In fact very few universities even bother to teach the subject.”

(Norm Augustine, INCOSE Insight October 2009, p. 15)

Systems-of-Systems Definition
Multiple Criteria of Varying Weight

1) SoS components must be able to usefully operate independently

2) SoS components are independently acquired and maintain independent existence

   - Virtual, Collaborative, “Acknowledged”, Directed

3) SoS continues to evolve

4) SoS exhibits emergent properties

5) SoS components interact only by information exchanges

Systems-of-Systems definition by Mark Maier (1998)

Elements of Risk in Systems-of-Systems Integration Selective Sample

1) Missed/underutilized functionalities and/or interfaces
2) Undesirable emergent behavior, sneak interactions and unintended consequences
3) Independent components evolution drifting to non-compliance with original standards
4) Evolving SoS doesn’t follow stakeholder needs

Mitigation of Risk in Systems-of-Systems Integration For the Sample of Risks Identified Above

1) Use architectural tools to identify component functionalities and interfaces
2) Use modeling and simulation to predict undesirable emergent behavior, sneak interactions and unintended consequences
3) Use open standards to permit use of suitable replacements for components that will not be available as time progresses (avoid proprietary interfaces)
4) Manage evolving SoS requirements

SE Process Risk Reduction
Using Architectural Tools and Artifacts

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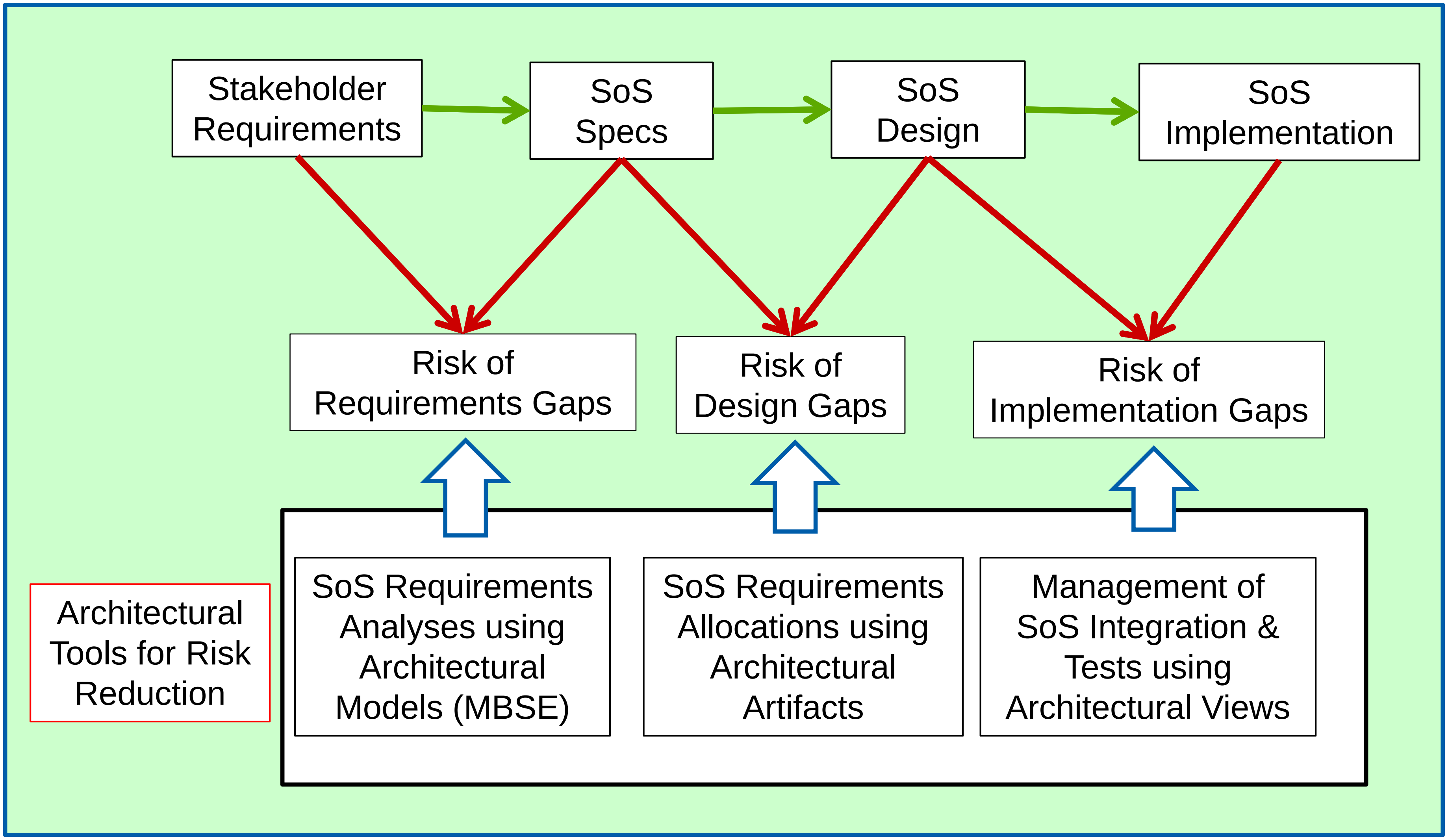
Stakeholder Requirements
SoS Specs
SoS Design
SoS Implementation
Risk of Requirements Gaps
Risk of Design Gaps
Risk of Implementation Gaps
Architectural Tools for Risk Reduction
SoS Requirements Analyses using Architectural Models (MBSE)
SoS Requirements Allocations using Architectural Artifacts
Management of SoS Integration & Tests using Architectural Views

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Architectural Tools and Products

ZAF, DoDAF, TOGAF, MoDAF, NAF, UML, SysML, IDEF, SADT

Zachman Architectural Framework (ZAF)
DoD Architectural Framework (DoDAF)
The Open Group Architectural Framework (TOGAF)
MoD Architectural Framework (MoDAF)
NATO Architectural Framework (NAF)

... define how to organize the structure and views associated with an architecture.

Unified Modeling Language (UML)
System Modeling Language (SysML)
Integration Definition (IDEF)
Structured Analysis Design Technique (SADT)

... are diagrammatic notations designed specifically to help people describe and understand systems and systems-of-systems

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DoD Architecture Framework (DoDAF) Available Architectural Artifacts

- DoDAF Operational Views are an Extension of the Use Case Concept
  - Can be used to elucidate user roles, activities and requirements
  - DODAF V1.0 & V1.5 focused in C4ISR
    - OV-5 collects activities and information exchanges
    - OV-2 bundles activities into nodes and information exchanges into needlines
    - OV-6c represents event traces
  - DoDAF V2.0 extends the notion of information exchanges to resource flows that can represent funding, materiel, and people in addition to information
- DoDAF Systems Views are an extension of the Block Diagram Concept
  - SV-1 depicts SoS entities and interfaces (including human performers in V2.0)
  - SV-4 depicts SoS system functions and inter-systems data flows
  - SV-2 is a rendition of the physical implementation of the SoS
  - SV-5 maps operational activities to system functions (a) and systems (b)
  - SV-10b shows systems states and transitions

A Bad Case of SoS Integration Testing: **10 August 1628** …

- **It was a beautiful summer day and hundreds of Stockholmers had come to the quay at Lodgården just below the Royal Castle to wish bon voyage to the Vasa on her maiden voyage. She was a "royal ship," the biggest, most powerful, expensive and richly ornamented vessel ever built for the Swedish navy, and likely any other navy, at the time. With 64 guns this massive warship was designed to engender pride in the soul of the Swedish people and to strike fear in the hearts of her enemies. And she was decorated for power and glory. According to the prevailing belief of the time, "Nothing can be more impressive, nor more likely to exalt the majesty of the King, than that his ships should have more magnificent ornamentation than has ever before been seen at sea" (Jean-Baptiste Colbert, Louis XIV's pro-navy Minister of Finance).**

- **After vespers services on Sunday August 10, 1628 the Vasa was pulled out of harbor. For the first 200 yards or so she was tugged along shore by her anchors, still in the shelter of a small tier of cliffs to the south. A light wind was blowing from the southwest. As the big ship was pulled seaward, beyond the protection of the last cliff, Captain Söfring Hansson issued his order: "Set the foresail, foretop, maintop and mizzen." Obediently, the sailors scurried up the great ship's rig and hoisted four of her ten sails. Just as they did, a slight squall arose from the south southwest, instantly catching the canvases, popping them open, and thrusting the ship ahead.**

- **Watching from the quay the well-wishers witnessed a spectacle that lives in history. According to the Council of the Realm's letter to the king, the Vasa "... immediately began to heel over hard to the lee side; she righted herself slightly again until she approached Bechholmen, where she heeled right over and water gushed in through the gun ports until she slowly went to the bottom under sail, pennants and all." In all, she had sailed only some 1400 yards. Now this glorious ship lay 110 feet below the surface of the water. Of the 125 crew, wives and children aboard for this festive occasion, at least fifty perished in the sinking.**

http://www.albany.edu/faculty/miesing/teaching/cases/vasahome.html

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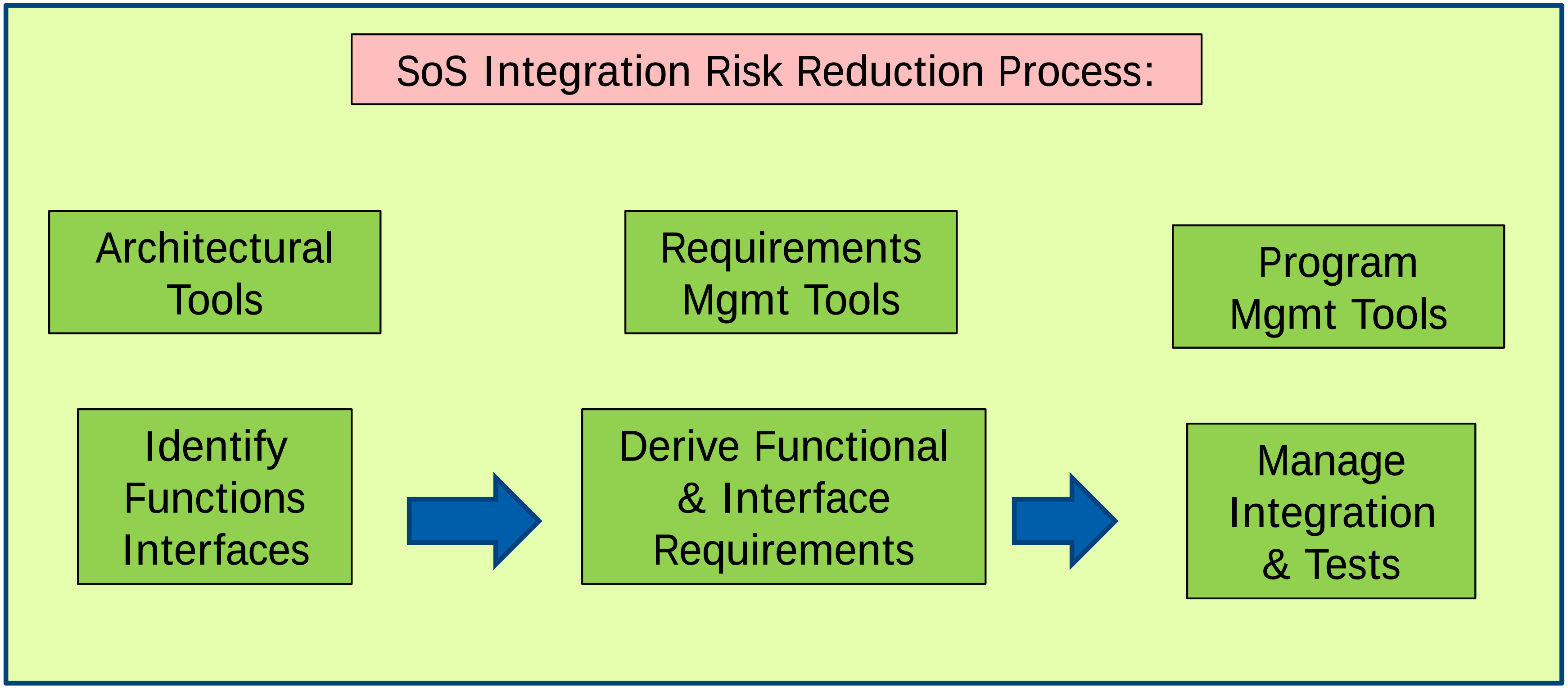
Using Architectural Tools and Products to Reduce the Risk in Systems-of-Systems Integration



SoS Integration Risk Reduction Process:

Architectural Tools

Requirements Mgmt Tools

Program Mgmt Tools

Identify Functions Interfaces → Derive Functional & Interface Requirements → Manage Integration & Tests

A Car that Won’t Start without the Stereo ...

- “I have a 2006 G6 with stock stereo (not Monsoon) and no On-star. I'm trying to install an aftermarket stereo using the Metra 99-3303 kit. I seem to have it hooked up properly (stereo works fine), but the car won't start. Lights, remote door locks, wipers, etc work fine, but the engine doesn't seem to even turn.

  If I pop out the aftermarket kit and put the factory back in, it works fine. As soon as I unhook the factory stereo, I can't make the car turn on again, even without the Metra kit hooked up. I was under the impression that the G6 should work even without the DIC hooked up.

  Crutchfield tech support was stumped too. Their best guess is that either there is some sort of security lockout (I don't have an alarm system, though) or that the Metra was bad, although, like I said, I thought the car should work with no stereo or DIC at all. Does anyone have any ideas?

  Thank you much. “

http://www.g6ownersclub.com/forum/showthread.php?t=7945

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Using Architectural Tools and Products to Reduce the Risk of Undesired Behavior

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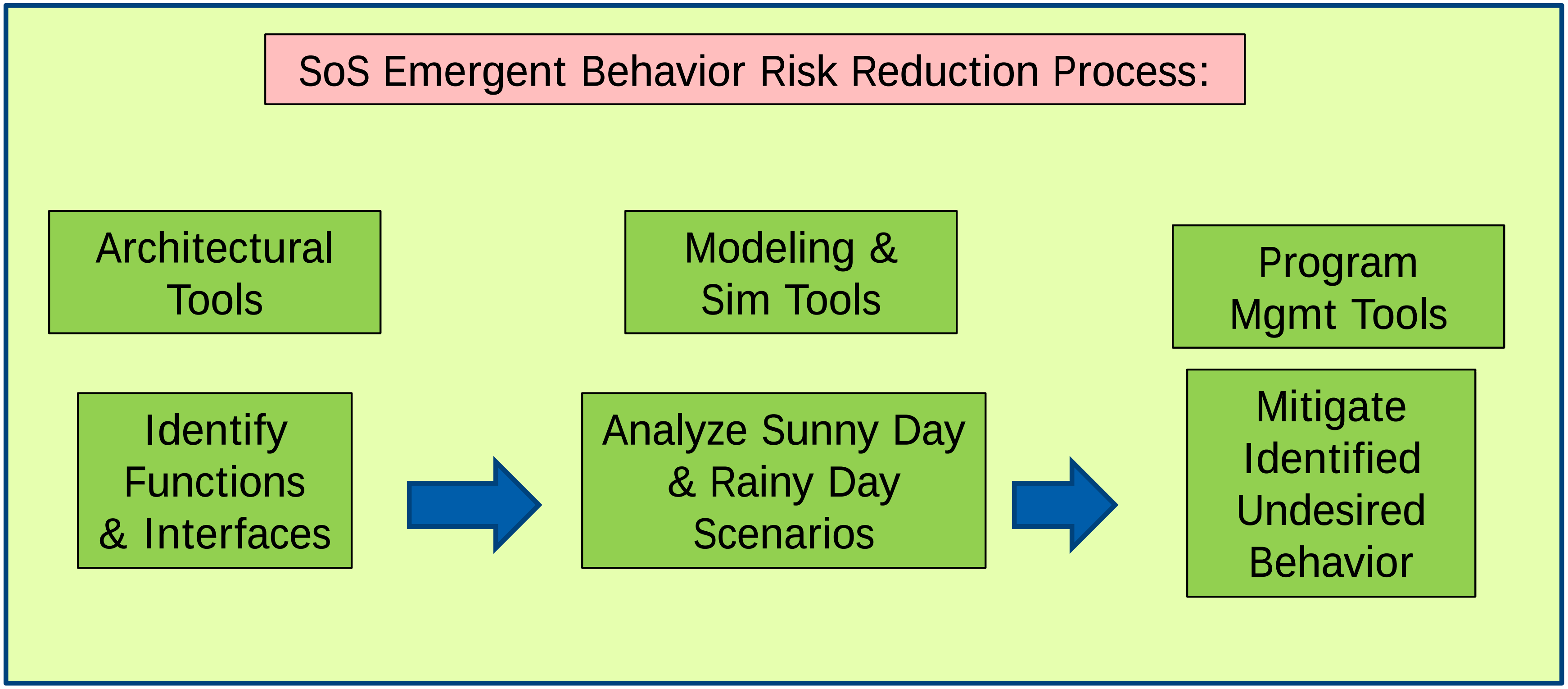
SoS Emergent Behavior Risk Reduction Process:
Architectural Tools
Modeling & Sim Tools
Program Mgmt Tools
Identify Functions & Interfaces
Analyze Sunny Day & Rainy Day Scenarios
Mitigate Identified Undesired Behavior

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An Obsolescence Program Offer …

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- We strive to extend the life of the Corporation's products you use to control your process. Now, with the Corporation's Obsolescence program, we offer you the ability to plan for and manage the migration from retiring to current Corporation's products.
- **What the Obsolescence Program Offers**
- When it is clear that we cannot continue to build a specific product, we designate that product as Obsolete. Obsolete is a designation we give to existing products BEFORE we can no longer offer them for sale. These are products — controllers, I/O modules, operator interface devices, and others – that you may currently have installed in your plant. This designation means that the product will continue to be manufactured, but for only a limited time, until the product's Obsolescence Date. **The Obsolescence Date is the last date the Corporation will accept orders for new product shipments, terminating its Obsolete status.** The product is no longer offered for general sale. This gives you:
  - time to buy spares
  - time to consult with us about a transition plan
  - time to schedule and budget for updates
  - time to migrate to newer products
- Before a product becomes inactive, the Obsolete designation offers you:
- **Time to Plan** — By knowing that a product will soon be unavailable as a replacement, you can choose when to migrate to newer technology, include an upgrade in your planning cycle, and manage your spare parts inventory.
- **Direction for the Future** — We also offer direction for both replacement and reuse of products with the intent of allowing you to retain much of the equipment you may have installed and working. The migration is planned.
- When a product is no longer available for sale, we announce that the product has become "inactive". For our customers, this means we are still keeping an inventory of components to allow us to repair and support their installations. We strive to postpone the transition to inactive status as long as possible, but when it happens, our goal is to help our customers reuse as much of their existing architecture as possible. "

http://www.allsimilaritytoanyrealcorporationswebsiteiscoincidentalandnotintendedandcontrarytothepointbeingmade.com

Accessed & modified to protect the innocent 5/05/2011

Using Architectural Tools and Products to Reduce the Risk Components Obsolescence

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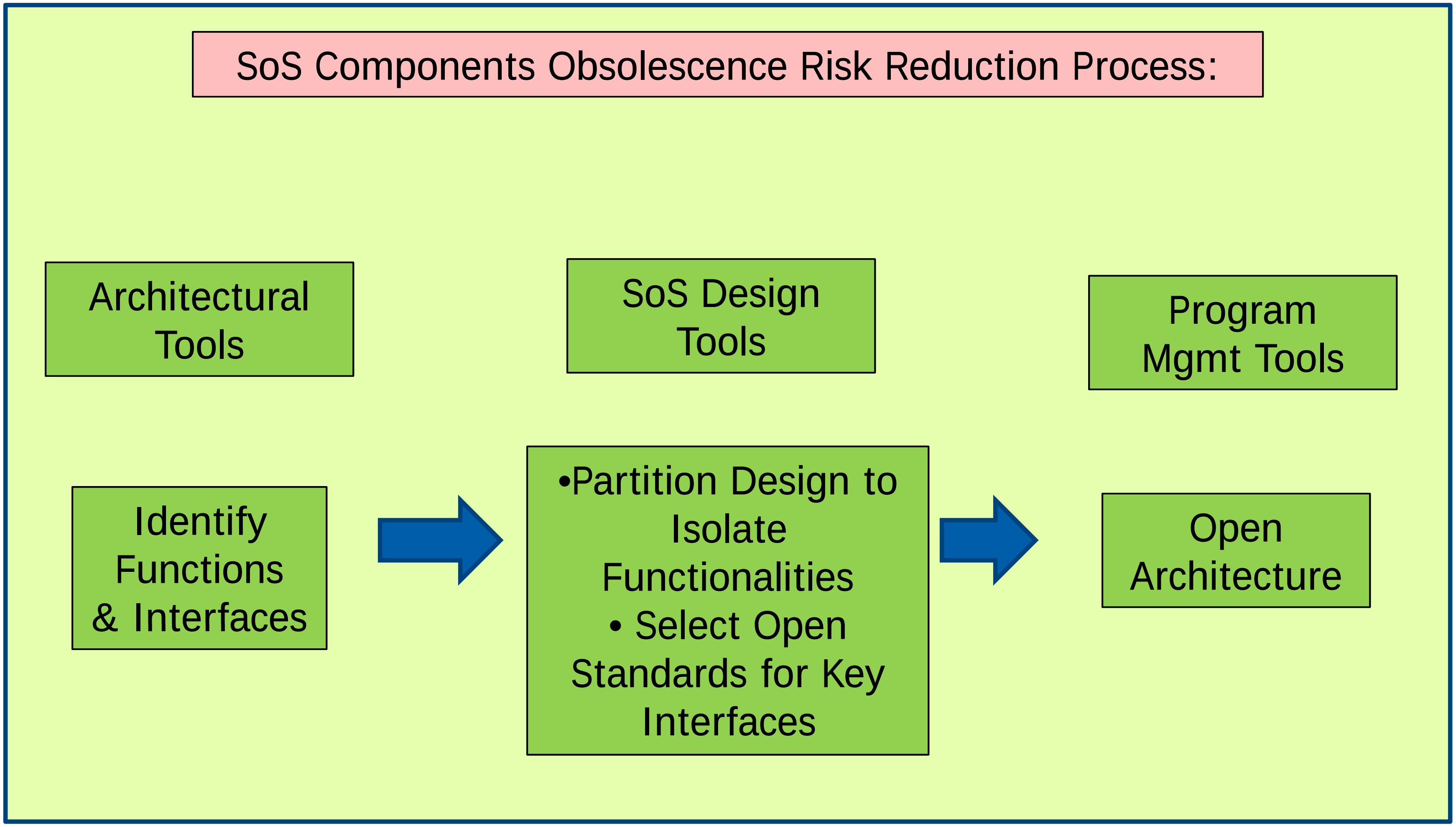

SoS Components Obsolescence Risk Reduction Process:

Architectural Tools

SoS Design Tools

Program Mgmt Tools

Identify Functions & Interfaces

•Partition Design to Isolate Functionalities
• Select Open Standards for Key Interfaces

Open Architecture

Summary and Conclusions
Recommendation to Use Architectural Models

- Using architectural tools and products does reduce the risks in Systems-of-Systems integration
  - Having documented functionalities and interfaces for SoS components enables generation of requirements for better planning of system integration and test (and these reduce risk of program failure)
  - Having documented functionalities and interfaces for SoS components enables higher fidelity modeling and simulation providing more insight into emergent behavior (and this reduces risk of possible surprises)
  - Having documented functionalities and interfaces for SoS components facilitates creation of open architectures with layers of abstractions that will enable future integration of component replacements (and this reduces the risk of component obsolescence)