Presentation Date: 2 November 2004, IEEE MILCOM, Monterey, CA

Session: U074 - Evolving and Future Architectures, Networks, Systems and Technologies

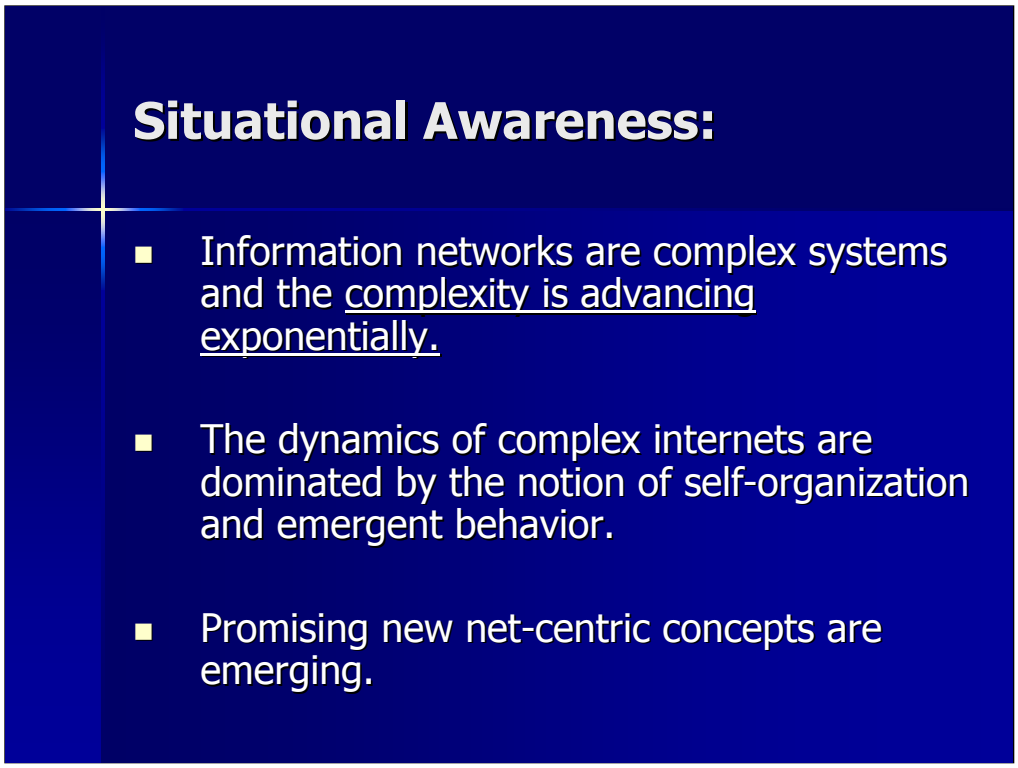
Leading Illustration:

How do birds flock together and fly in such a dynamic, ever changing and re-organizing patterns?

The notion of using biological metaphors to help us understand the complexity of our networks has gained considerable visibility in recent years and is rapidly becoming the leading candidate to help us understand emergent properties of complex inter-networks.

In this 20 minute presentation, we discuss evolving concepts in net-centric architectures, and in particular, these concepts in context with the IEEE MILCOM 2004 paper "*Service-Oriented Horizontal Fusion in Distributed Coordination-Based Systems.*"

Presented by: Tim Bass, President, Silk Road (www.silkroad.com)



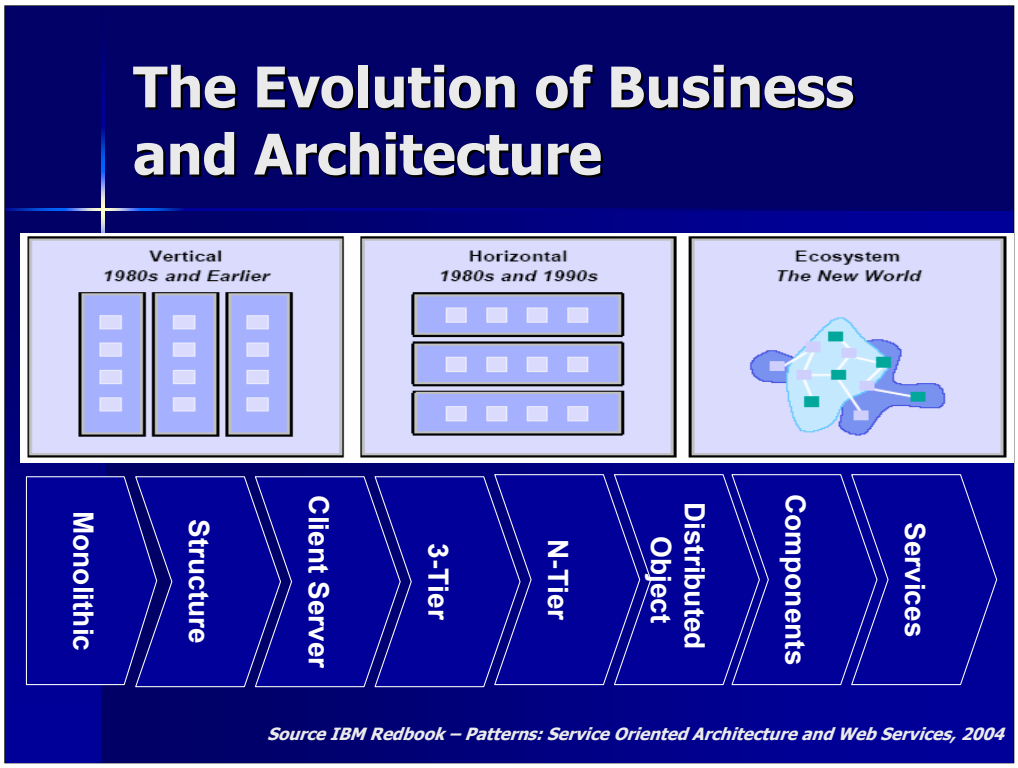
Complexity in our inter-networks is advancing exponentially (Kurzweil 2004) and at the very least, increasing. The way we do business changes with the changing dynamics of emergent network behavior.

Many well-respected researchers and business experts have come to the conclusion that traditional approaches to viewing IT systems and enterprise architectures fall short in grasping the overall situational awareness and an understanding of powerful and dynamic market forces.

Much of the research has gravitated toward the application of complex systems theory and the (unpredictable) emergent properties of these systems, including information networks.

When viewed from this perspective, service-oriented architectures offer promising new capabilities for advancing the state-of-practice for information and data fusion.

These promising SOA concepts are congruent with the concepts of concurrent blackboard architectures and event-driven architectures.

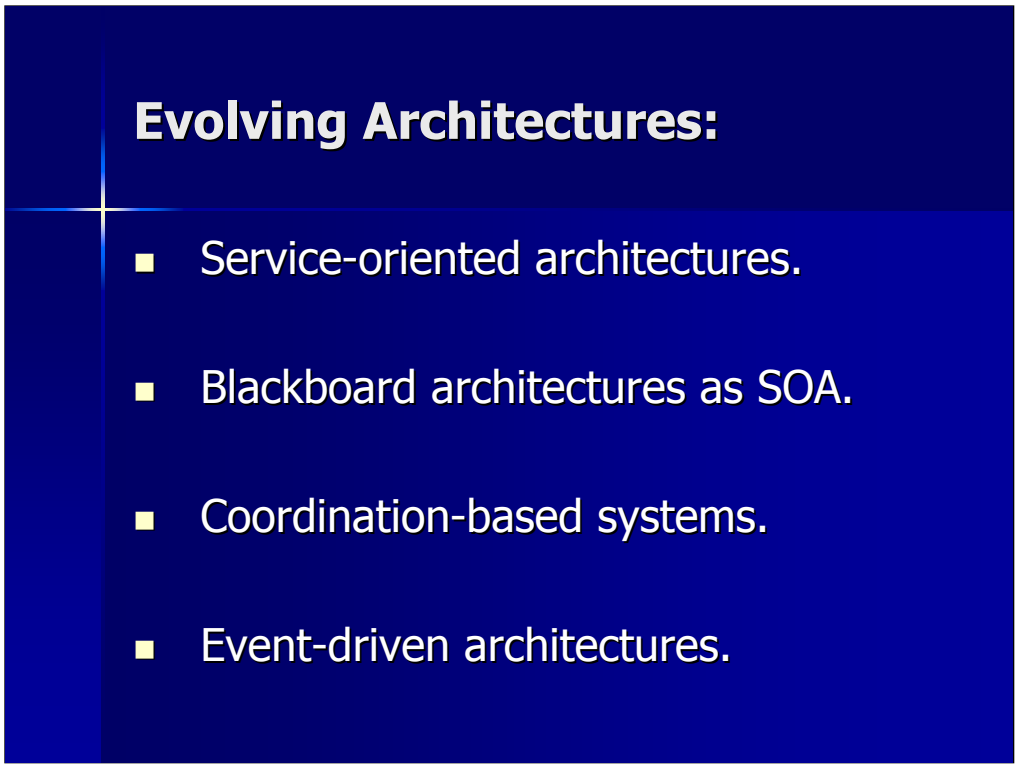


The current thinking in IT architecture (including enterprise architecture) is that there are many important lessons to be learned from the biological metaphors of complex systems theory.

This slide, courtesy of IBM, illustrates the evolution of both business and architecture prior to 1980 to the present.

Note the shift from monolithic information systems to client-server, then to three and N-tier architectures, then component models to the state-of-the-art in service-oriented architectures.

Viewed in context with three broad architectural perspectives (i) vertical systems, (ii) horizontal (layered) systems and then (iii) ecosystems, it becomes increasing clear that a basic understand of complex systems theory is useful for today's IT architects.

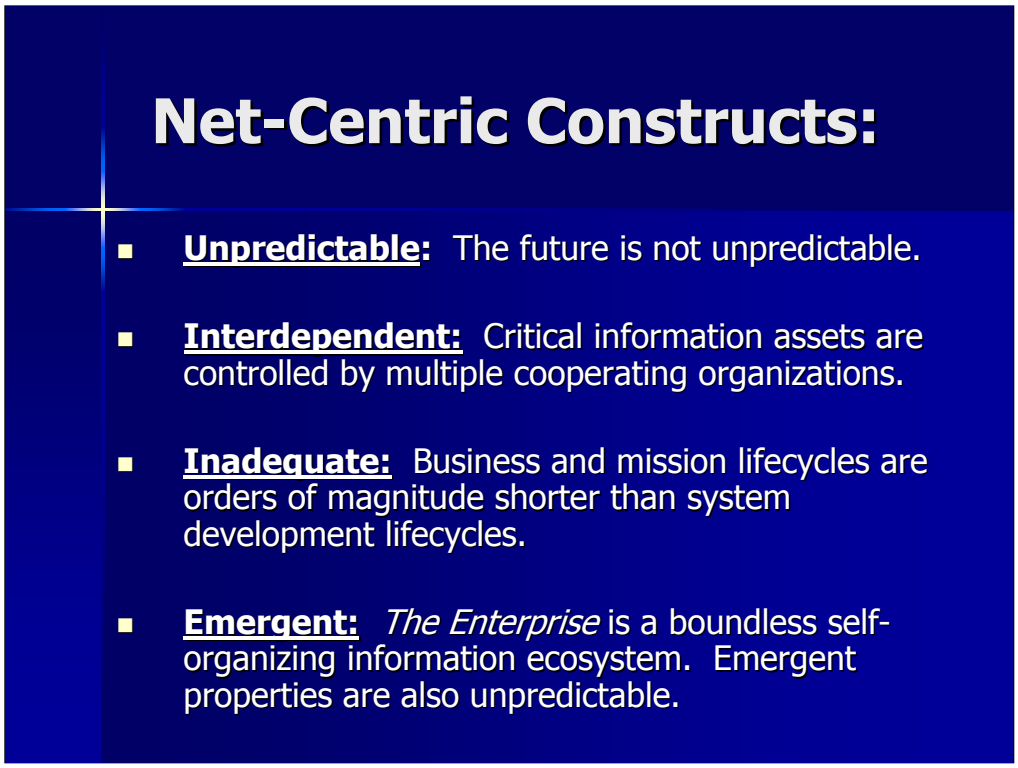


Service-oriented architectures are based on the concept of distributed services in a loosely-coupled software communications model.

Distributed blackboard architectures can be designed based on the concept of distributed services in a loosely-coupled software communications model.

Coordination and event-driven architectures support both SOA and BB architectures.

We will highlight these similarities in the remainder of the presentation.



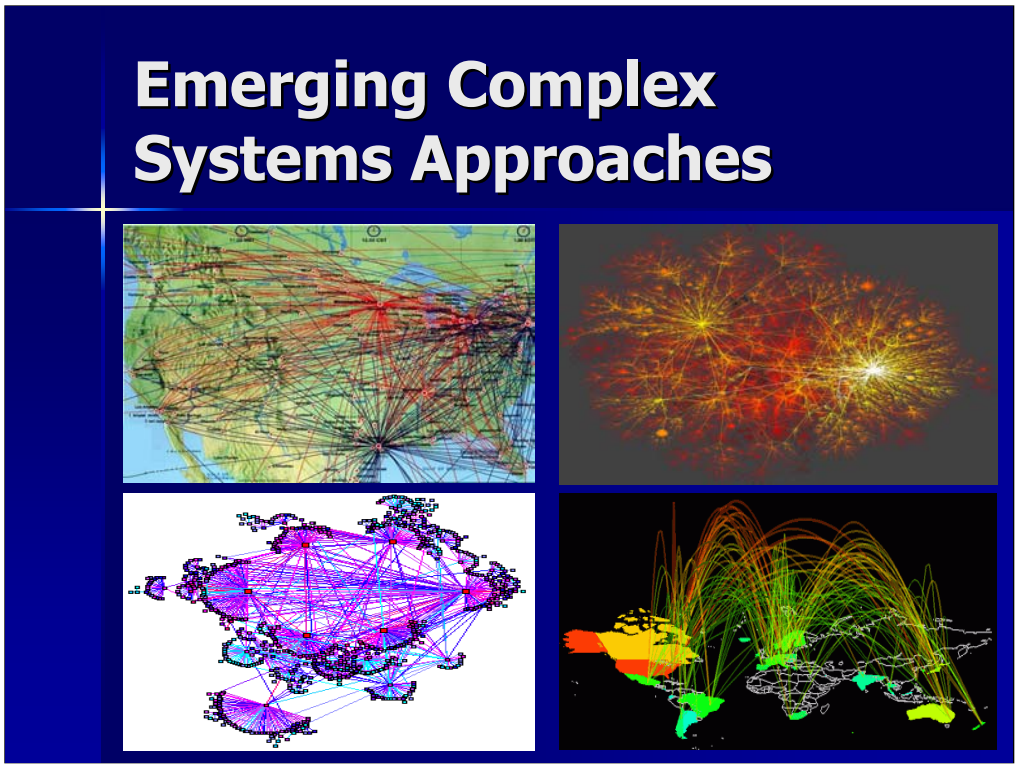
The dynamics of information networking is complex and unpredictable. In most, if not all cases, the return-on-investment (ROI) for most large net-centric capital expenditures cannot be predicted.

One of the reasons for the inherent unpredictable nature of these IT investments is that the net-centric environment transforms the very nature of business and human relationships. The health of one business is dependent of the health of other businesses. This interdependency supports the notion of 'business ecosystems' and/or 'information ecosystems'.

By definition, is not possible to predict the emergent behavior of complex systems.

This fact is further complicated by the fact that the lifecycle for many business and mission processes are much shorter than enterprise architecture and system development lifecycles.

How do we begin to 'get our arms around' this increasing complexity?



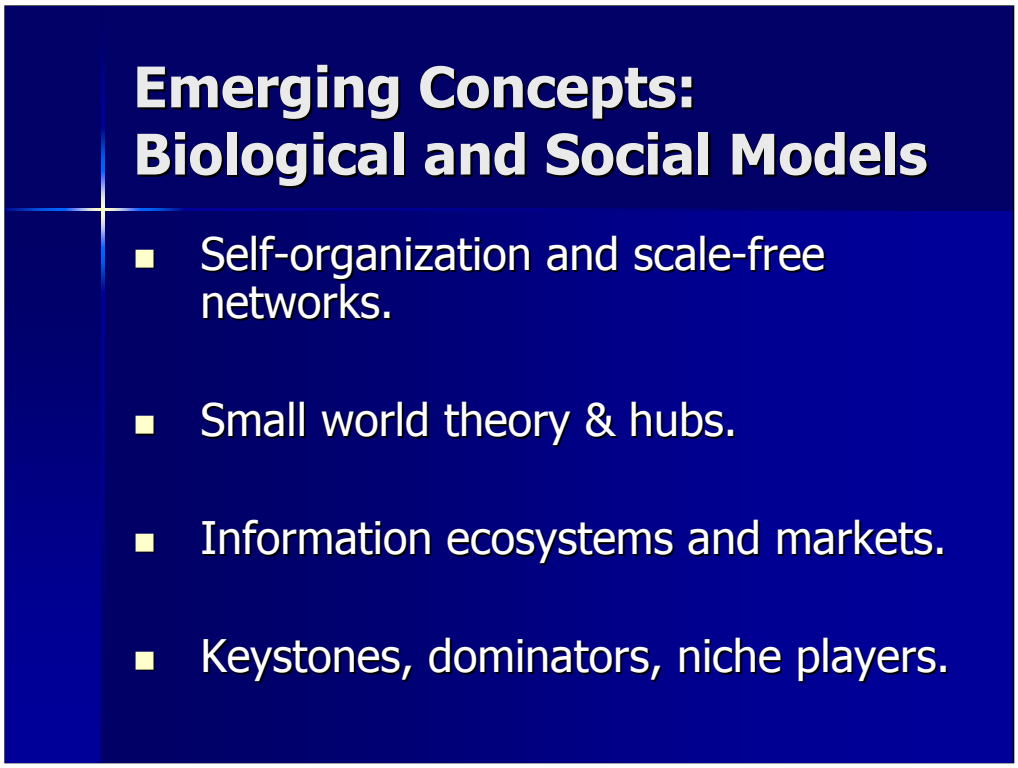
There is an emerging school-of-thought that begins to look at self-organizing characteristics of complex biological systems.

The figure in the upper left corner represents a scale-free network in the form of an air transportation services map. The figure in the bottom left hand corner represents the information connectivity of over 800 million web documents (by S. Lawrence, 1999) collected by a net-crawling software robot.

The figure in the upper right hand corner represents a view of the Internet in 1999 (Albert, Jung, and Barabasi, Nature, 401 130 (1999)). The figure in the lower right hand corner represent a view of Internet traffic flows between fifty countries, as measured by the NSFNET backbone in 1993 (from Cox, Eick, and Taosong, 3D geographic network displays, ACM Sigmod Record, 25(4), 50-54, December 1996).

These colorful figures represent a small handful of a very large body of knowledge that attempts to understand the emergent properties of complex inter-networks.

Where is all of this research leading us?



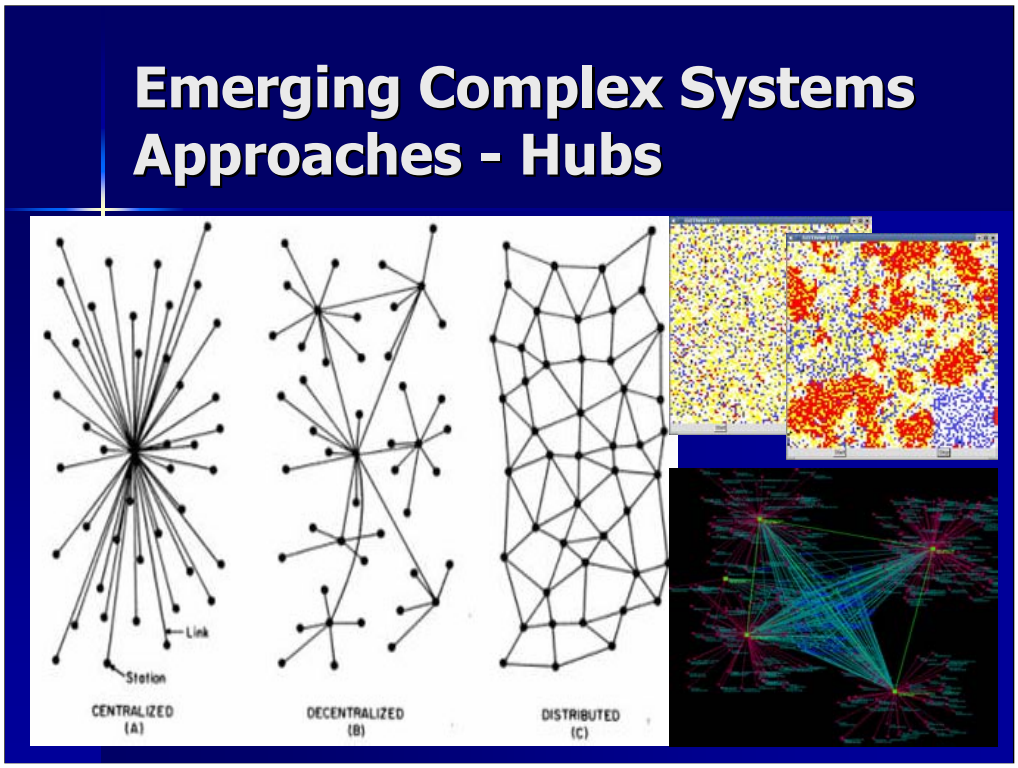
The leading emerging concepts for net-centric architectures are based on complex systems theory. They tend to look toward complex, self-organizing biological models (ants colonies, flocks of birds, genetics, insect swarming, etc.) to help us understand the underlying dynamics of complex networks.

Scale-free networks, small world theory, hubs in nature, business ecosystems, all of these schools-of-thought are thought to hold keys to our understanding of net-centric architectures. Subjects we can only briefly introduce in a 20 minute presentation!

The concepts may seem a bit abstract and futuristic. On the other hand… the future is now! This helps explain why there is so much interest and research into the domain of complex systems theory and IT business models.

In a nutshell, and because of a lack of time today, these slides only scratch the surface in the state-of-the-art for concepts that are beginning to influence enterprise architecture thinking in the net-centric environment.

Source: Bass, T., *Emerging Concepts in Net-Centric Architectures,* E-Government 2004 Conference on Enterprise Architecture, 21 September 2004.



Baran's networks, the three textbook figures on the left, provide a basis to view the more complex self-organization that occurs in complex networks.

The figure on the upper right represents a model of criminal activity. These types of models are also used to help us understand emergent criminal behavior such as terrorism.

Must of the body of literature on the subject points to the importance of hubs, including naturally occurring hubs. In this brief 20 minute talk, we can only introduce the emerging concepts. We should understand, …….

Complex systems theory and biological models help us understand the significance of naturally occurring hubs and how they effect business ecosystems.

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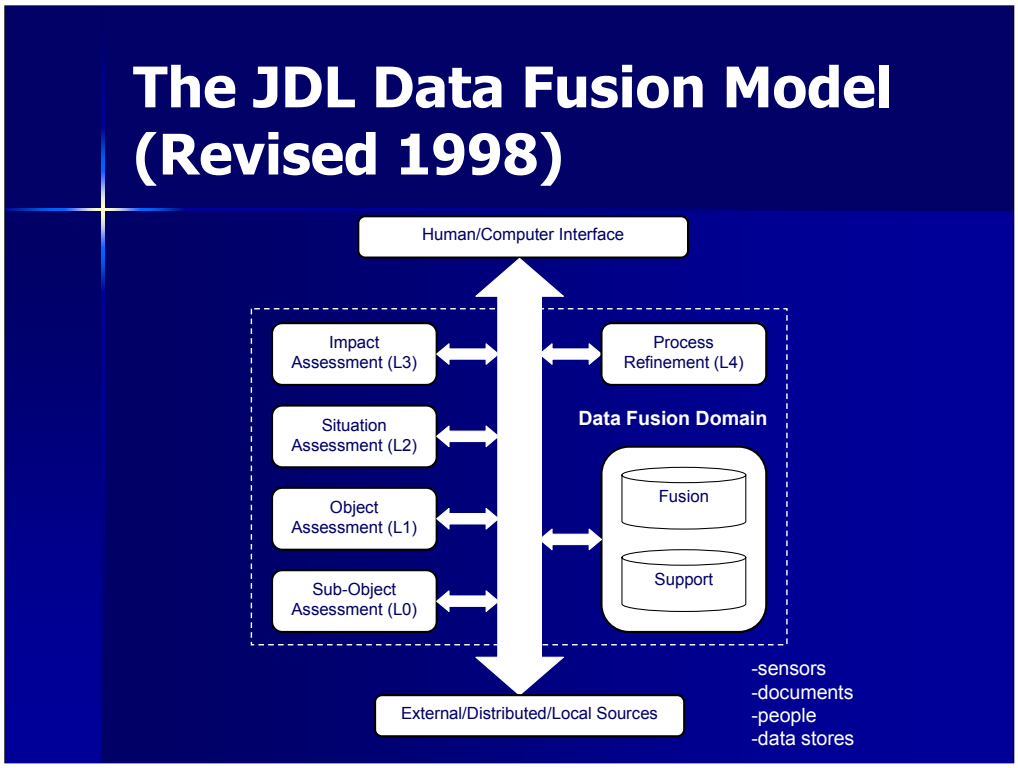
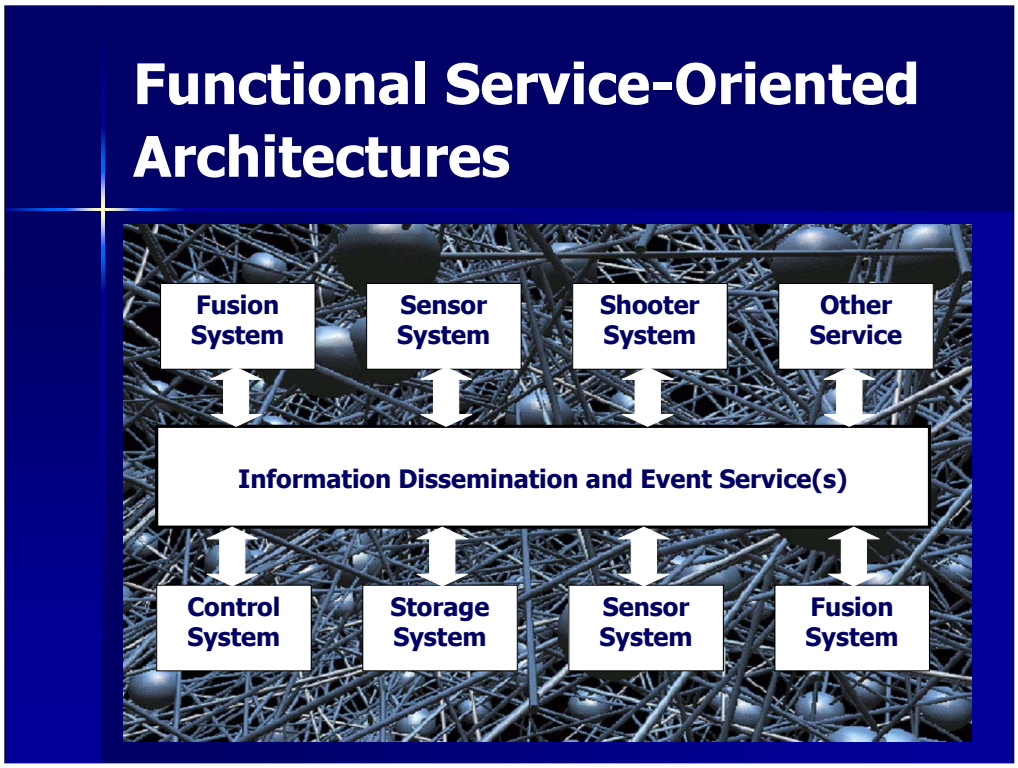


The Joint Directors of Laboratories (JDL) data fusion model is an important functional fusion model and has been the basis for numerous multisensor data fusion architectures.

It is logical to assert that the JDL data fusion model is a key foundation for horizontal fusion (and other data and information fusion) architectures.

Key point: The JDL data fusion model can be implemented using distributed blackboard architectures as an SOA.

Source: Bass, T., *Service-Oriented Horizontal Fusion in Distributed Coordination-Based Systems,* IEEE MILCOM 2004, Monterey, CA, 2 November 2004.



These concepts suggest a high level service-oriented architecture for service-oriented data fusion, information fusion and critical infrastructure protection.

Distributed data fusion can provide a degree of scalability and robustness that cannot be achieved with centralized architectures. Decentralization can also permit a network of nodes to exchange information and coordinate activities in a flexible and scaleable architecture that would be impractical or impossible to achieve with a single, monolithic systems platform

Sources:

Diagram: Bass, T., *Service-Oriented Horizontal Fusion in Distributed Coordination-Based Systems,* IEEE MILCOM 2004, Monterey, CA, 2 November 2004.

Background Graphic: Barabási A-L, et al. , *"The Architecture of Complexity: From the Diameter of the WWW to the Structure of the Cell,"* Slide Presentation (San Diego)

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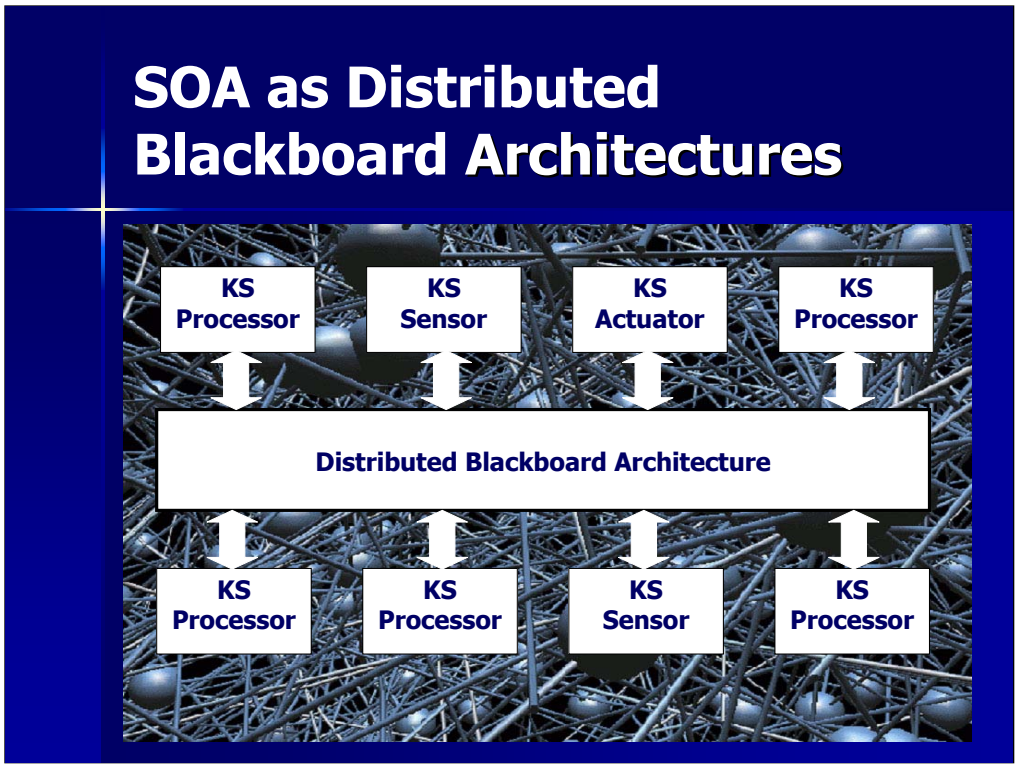
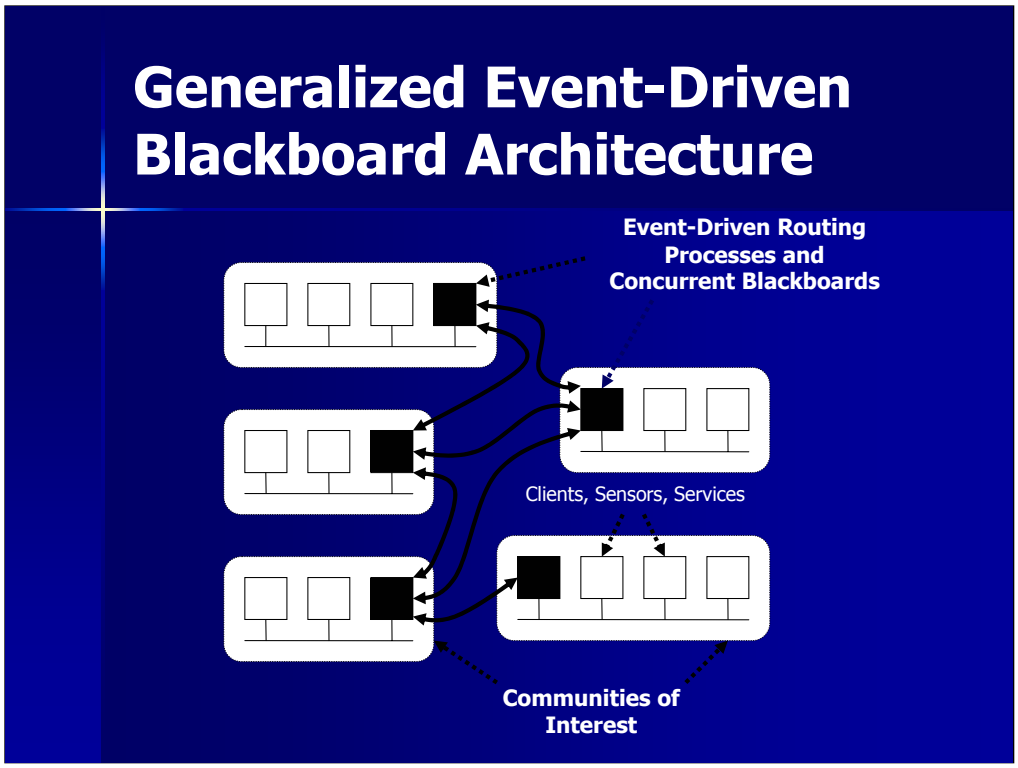


Notice the similarity between the model on the previous slide and the distributed blackboard architectural model.

In blackboard architectures, knowledge sources (KS) can be classified in three broad categories:

- KS as a sensor;
- KS as an actuator; and,
- KS as a knowledge processor.

More information on distributed blackboard architecture may be found in the references provided at the end of this 20 minute presentation.



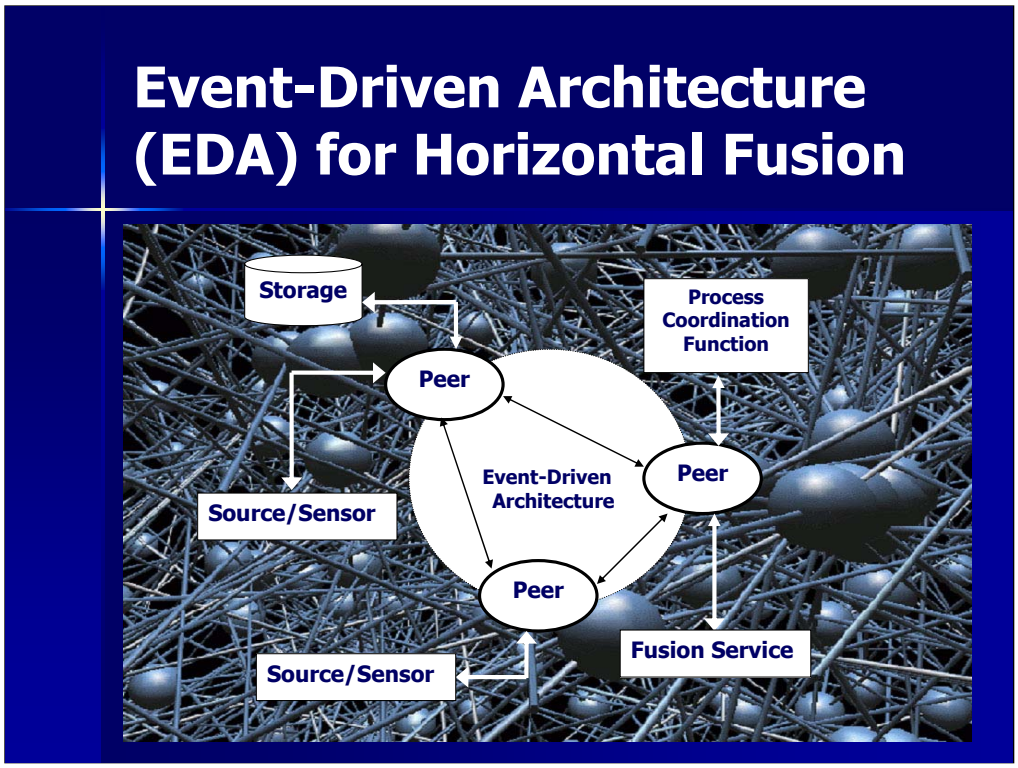
I suggested in my MILCOM paper that an important architecture in support of horizontal fusion is based on a generalized distributed peer-to-peer coordination-based system

Tanenbaum and van Steen discussed coordination-based systems as a collection of autonomous distributed computational processes. The process coordination functionality manages interprocess communications and cooperation.

The central design principles are that the core communications system is highly application independent; the interprocess messages are self describing; and the processes are not required to be directly referenced. These requirements allow fusion information to flow in a fault-tolerant service-oriented architecture that compensates for network and process outages.

This architecture also permits the dynamic introduction of fusion services, sensors and clients as required.

Source: Bass, T., *Service-Oriented Horizontal Fusion in Distributed Coordination-Based Systems,* IEEE MILCOM 2004, Monterey, CA, 2 November 2004.



Here is another illustration of the relationships between sensors, fusion services and the underlying communications infrastructure.

The key concepts are twofold: (a) the processing abstraction is a distributed system architecture of semi-autonomous nodes and (b) information moves between systems based on an event-driven communications architecture.

Process coordination for service-oriented horizontal fusion is a workflow service that manages and coordinates distributed communications between distributed network-centric processes.

Diagram: Bass, T., *Service-Oriented Horizontal Fusion in Distributed Coordination-Based Systems,* IEEE MILCOM 2004, Monterey, CA, 2 November 2004.

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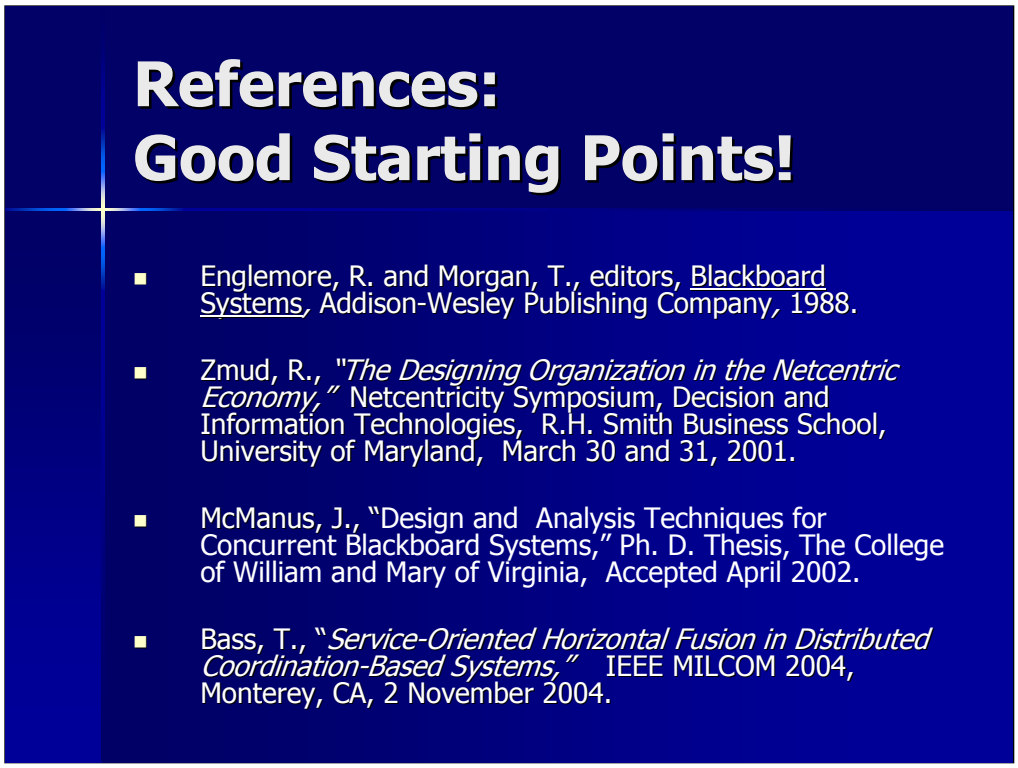


It is only possible to scratch the surface on how complex system theory, SOA and blackboard architectures may impact the future of net-centric architectures.

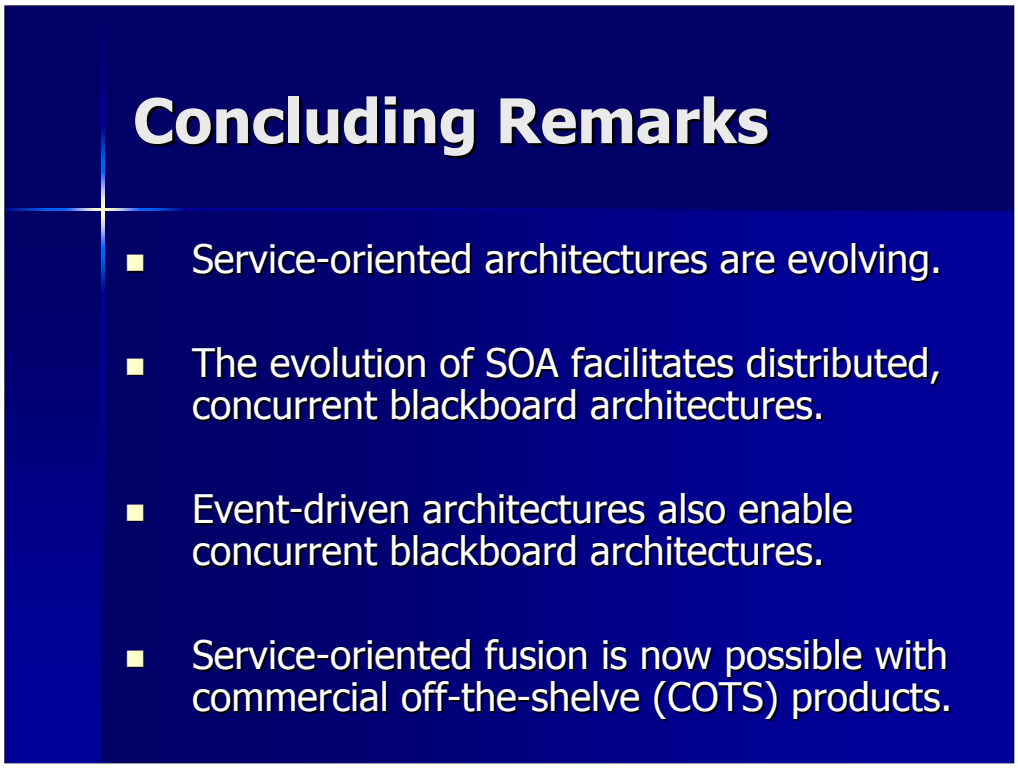
For the interested conference participant, here are three excellent references that are a great place to start.

•The first reference is highly recommended and may be found in the used book trade.

•Dr. Robert Zmud's paper does a great job discussing net-centric concepts.

•Dr. John McManus, NASA CTO and DCIO, is the author of a very good PhD thesis on concurrent blackboard architectures.

•The last reference is my 2004 IEEE MILCOM paper, the primary reference for this short 20 minute presentation.



Service-oriented architectures are evolving and can facilitate distributed, concurrent blackboard architectures and fusion processing.

Event-driven architectures also enable concurrent blackboard architectures and distributed fusion architectures.

The state-of-the-art in commercial off-the-shelf software (COTS) has advanced significantly.

Please feel free to contact me if you have any further questions or comments.

Thank you for your kind attention.

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A copy of this MILCOM presentation and paper may be found on-line:

http://www.silkroad.com/events/ & http://www.silkroad.com/papers/published.html

Thanks Again!

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Tim Bass (bass@silkroad.com) is a Senior Net-Centric Subject Matter Expert with Silk Road, specializing in operational concepts, systems design, architecture and security of distributed Internet applications. He provides senior subject matter expertise to the USAF, Office of the CIO, the Defense Information Systems Agency (DISA) and other large enterprises. He graduated B.S.E., Tulane University, School of Engineering, 1987 *Magna Cum Laude*, Electrical Engineering and has been providing Internet domain expertise as an independent trusted advisor to the US military and commercial industry for over 12 years. Mr. Bass' work on Internet security and countermeasures for the USAF has been featured in Popular Science Magazine and Federal Computer Week. His list of publications, detailed biography and company information is available at the Silk Road web site (www.silkroad.com).