NECSI: Complex Physical, Biological and Social Systems Project

The Characteristics and Emerging Behaviors of System of Systems

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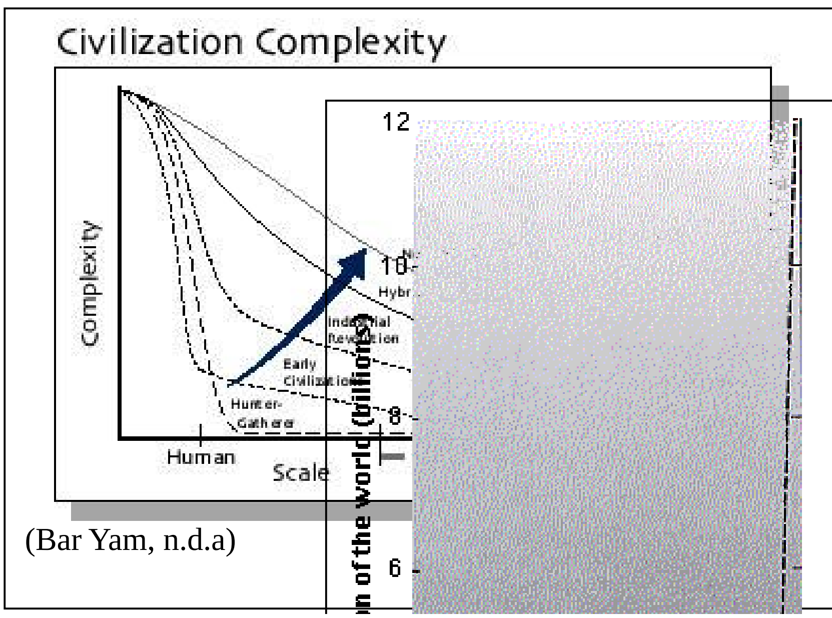
In recent years the concept of system of systems (SoS) has emerged as a new approach to solving complex problems. The expectation is that SoS will improve effectiveness and enhance one's ability to successfully address complex issues. The body of knowledge on SoS is in its infancy. While there have been many discussions, there is not a commonly accepted definition of SoS. Various fields and professions have produced their own definitions, and as such SoS are defined in the context of those fields and professions. The purpose of this paper is to provide an overview of SoS via current definitions and examples from the fields of biology, sociology, and military; offer additional characteristics of SoS that should be included in a more comprehensive and generalized definition; highlight some issues; and conclude with some preliminary insights on the emerging behaviors.

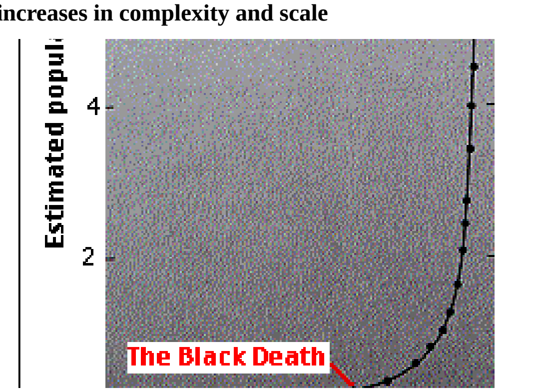
Introduction

With the continuing evolution of human civilization (Figure 1; [additional background can be found in Bar-Yam, n.d.a, 2004; Laszlo, 1996; Mainzer, 1998]) and the enormous increase in human population such that it now dominates the globe (Figure 2; [additional background can be found at Kimball, 2005]), governments, the military, businesses, and other organizations are now regularly confronted with problems that are likely to be either both more complex or larger in scale than earlier in human history—or both.



(Bar Yam, n.d.a)

Figure 1: Human civilization increases in complexity and scale



In recent years the concept of system of systems (SoS) has emerged as one new approach which may be developed to assist organizations in responding to the challenges arising in this environment. As thus far developed, these social-problem solving SoS are to be consciously developed and implemented. Consciously developed SoS differ from biological SoS and some social SoS which arose in an undirected evolutionary process. Among the goals of consciously-directed SoS are an increase in the complexity of response without an increase in hierarchy.

The expectation is that SoS will improve effectiveness and enhance an organization's ability to successfully address complex issues. In this interdisciplinary paper, we seek to learn from the biological and undirected social evolution of SoS in order to inform our approach to consciously-developed SoS in the military and engineering.

While there have been many discussions, the body of knowledge is in its infancy and there is not a commonly accepted definition of SoS. Various fields and professions have produced their own definitions, and as such SoS are defined in the context of those fields and professions. A sample is shown below (Jamshidi, 2005).

> <u>Definition 1</u>*: Sage and Cuppan [2]*
> *Systems of systems exist when there is a presence of a majority of the following five characteristics: operational and managerial independence, geographic distribution, emergent behavior, and evolutionary development. Primary focus: Evolutionary acquisition of complex adaptive systems. Application: Military.*

Figure 2: Increases in Human Population 1

> <u>Definition 2</u>*: Kotov [5]*
> *Systems of systems are large scale concurrent and distributed systems that are comprised of complex systems. Primary focus: Information systems. Application: Private Enterprise.*
> <u>Definition 3</u>*: Carlock and Fenton [6]*
> *Enterprise Systems of Systems Engineering is focused on coupling traditional systems engineering activities with enterprise activities of strategic planning and investment analysis. Primary focus: Information intensive systems. Application: Private Enterprise.*
> <u>Definition 4</u>*: Pei [7]*
> *System of Systems Integration is a method to pursue development, integration, interoperability, and optimization of systems to enhance performance in future battlefield scenarios. Primary focus: Information intensive systems integration. Application: Military.*
> <u>Definition 5</u>*: Lukasik [8]*
> *SoSE involves the integration of systems into systems of systems that ultimately contribute to evolution of the social infrastructure. Primary focus: Education of engineers to appreciate systems and interaction of systems. Application: Education.*
> <u>Definition 6</u>*: Manthorpe [9]*
> *In relation to joint warfighting, system of systems is concerned with interoperability and synergism of Command, Control, Computers, Communications, and Information (C4I) and Intelligence, Surveillance, and Reconnaissance (ISR) Systems. Primary focus: Information superiority. Application: Military.*

From the viewpoint of our group, which consisted of those with backgrounds in the one of the fields of sociology, biology, engineering, and military, Sage and Cuppan provided a more concise definition of SoS than the others. However, we felt that definition did not address all the characteristics of SoS and the development of a more comprehensive and generalized definition is needed.

The following are examples of SoS in the fields of biology, sociology, and military.

Biological:

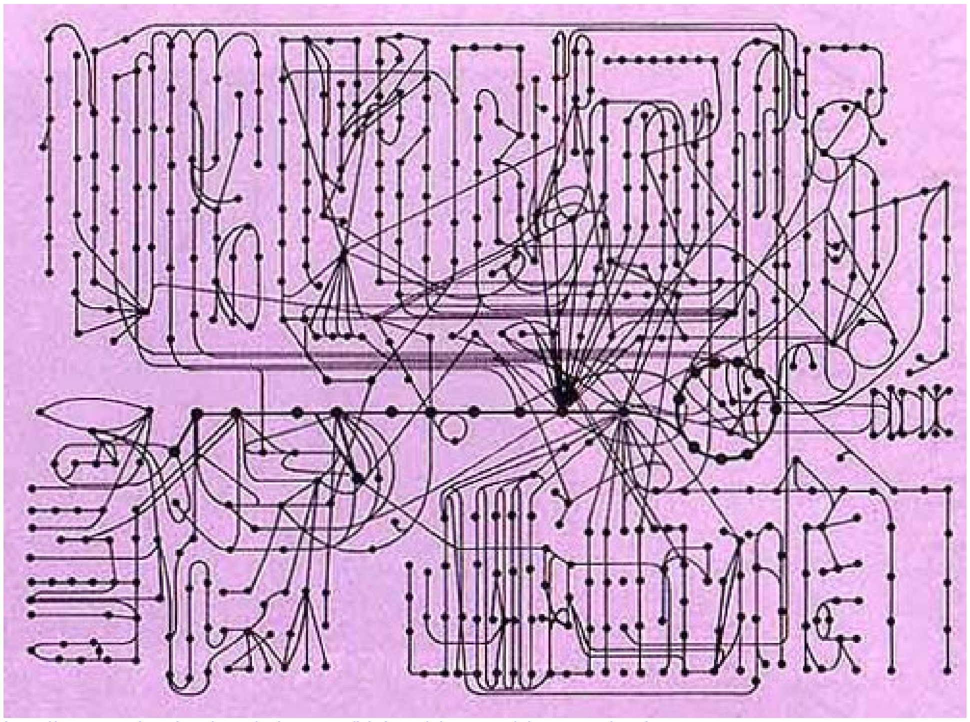
In biology, the inherent purpose of simple living organisms, such as a cell, is to reproduce and survive in order to pass along their DNA information. Each cell has its capability to live given the right conditions of their environment. For example, there are many different types of bacteria (single cell) that can live in different environments. Under these circumstances, each cell is a system by itself, and their goal is to reproduce and survive. Therefore, in advanced living organism, such as a dog, we can say that there is a collection of cells, which is a collection of systems. The collective goal is still the same, to reproduce and survive in order to pass along their DNA information. Due to evolution, and the environmental needs, the cells can differentiate into different "systems" that are in charge of keeping the whole organism alive. Here we observe, that each cell had its operational and managerial independence, but under needed evolutionary development, there has been an emergent behavior as well as a location distribution (of the cells along the body) allowing higher effectiveness of survival of this living organism.

Due to global dynamics and topology of previous cells, it would determine the cell's fate (differentiation) conforming the dog (see Table 1 for a summary of selected features of a dog as a system of systems).

BIOLOGICAL SYSTEM OF SYSTEMS	**SELECTED SPECIALIZED COMPONENT SYSTEMS**	**INTERACTION/ INTEROPERABILITY OF COMPONENT SYSTEMS**	**SoS FORMATION**	**SoS ACTIVITY**
- Dog	- Digestive System - Nervous System - Respiratory system	- Interaction: yes - Interoperability: only as specifically evolved	- Evolutionary self organization (unconscious)	- Living - Reproducing - Competing - Cooperating

Table 1: Selected features of a biological SoS (table structure adapted from Bar-Yam, 1997, p. 8)

This is a highly evolved system of systems. It is interesting to note that there is a tradeoff between independencies and interdependency. It seems that the more evolved the system of systems is, the more dependent each system become. Each cell will perform different tasks or complete the complex metabolic pathways required for the proper functioning of the body. The pathway is shown in Figure 3. Each dot represents a chemical reaction or a step catalyzed by enzymes.



http://sun.menloschool.org/~dspence/biology/chapter4/chapt4_1.html

Figure 3. Human metabolic pathway.

Social:

Although there is a significant body of work addressing hierarchical systems in human social groups (Parsons, 1964, 1970, 1971; Stacy, 1960), systems (for example, Laszlo 1972, 1996), and complex systems (Bar Yam 1997, n.d.a, n.d.b, Mainzer 1996), there is no literature on SoS—as developed in engineering and the military and the starting point for this paper—in sociology. Unlike military and engineering applications which are developed in support of specific development projects and more like biology, the purpose of studying systems of systems in the social arena is to increase knowledge (i.e., “pure” research). The knowledge may then be applied in many ways.

Social systems—including SoS—may be directed (i.e., consciously planned and organized), “naturally emergent,” or a combination. It is our hypothesis that social SoS are either developed to meet a goal that the individual systems are not capable of handling or are triggered by a change in the environment. In either case, the emergence of new social SoS indicate an increase in the complexity of the environment and foreshadow a major evolutionary change in social form. If the current individual social systems could handle the goals and/or environment, there would be no need for the new SoS.

An example of a planned SoS which was created in response to increasing environmental complexity during the twentieth century (gesellschaft) is the United Nations. The UN is an SoS of nation-states founded to handle some of the problems that nation-states could not handle individually. The social form in both cases is bureaucratic. Although the UN has been able to address some environmental issues, it has ultimately not succeeded in achieving the bulk of its goals and its very existence and failure presages the emergence of new social forms which (we hope) are better adapted to the environment.

In this newly-emerging social period (gecyberschaft), we suggest social systems of systems which emerge in this societal period will have two types of purposes: 1) the addressing of environmental problems which cannot be effectively addressed by single groups of purpose and/or remediated social forms such as remediated bureaucracies and 2) the pursuit of the initial conditions which will facilitate social evolution which moves in the direction of permitting group self actualization in a wide variety of categories (increasingly unconstrained choice).

Selected features of these two examples are shown below in Table 2.

BIOLOGICAL SYSTEM OF SYSTEMS	SELECTED COMPONENT SYSTEMS	INTERACTION/ INTEROPERABILITY OF COMPONENT SYSTEMS	SoS FORMATION	SoS ACTIVITY
Example from the twentieth century (gesellschaft)				
- United Nations (system of nation-state social systems)	- nation-states - communications and information technologies	- mediated communication - bureaucratic governance - participation in joint projects	- consciously designed within bureaucratic framework	- information focal point - voluntary governance - intervention in selected conflicts - humanitarian programs
Example from the twenty-first century (gecyberschaft; [Allison, 2005])				
- system of social systems, yet to emerge	- groups of purpose (approx 7 specialized groups) - communications and information technologies	- mediated communication - maintenance of shared purpose	- combination of conscious seeding and undirected social evolution	- addressing second order complex problems - building connective infrastructure and seeding social evolution - generating influence fields

Table 2: Selected features of social SoS

Military:

Since the cold war break-up of the two super powers, the global bipolar balance broke yielding first a magnetic single polar world, and then naturally transitioning gradually to a multi-polar world, with the US military remaining the dominant military power. Because of this two things are true: (1) no clear peer competitor exists against which to design and build military force structural capabilities and, (2) adversaries have chosen asymmetric approaches to challenging the US conventional strength avoiding direct conflicts (using terrorist or guerilla tactics). This is quite different from WWII and the cold war when both sides of the conflict were primarily using large-scale conventional military force structures. The result is a mismatch of forces with different complexities at different scales; this ensuing imbalance allows turmoil which adversaries are capitalizing upon.

In order to build a modern force while maintaining a highly competent current force structure, the US has begun to change its way of measuring future competitive action from massive force-on-force to precision engagements directed towards achieving specific effects and employing an appreciation of complex systems. The system approach incorporates a new concept called Effects Based Operations & Planning. When fully implemented it should help to define orders of effects and consequences of actions taken in handling asymmetric warfare. Instead of measuring conventional force-on-force conflict, the U.S. military has decided to develop the capabilities to consciously affect a multitude of levels of effects. Rather than using a wholesale approach to transformation, it has started planning, experimenting, and developing within the Congressional mandated policies and Constitutional constraints currently in place

Since the military's budgets are divided at the Service levels (according to Title 10 US code), each Service has responsibility to develop, train and equip as a separate system, with its own core purposes mostly based on the environments in which it operates. In the past this has resulted in the development of highly sophisticated and specialized warfare capabilities in these separate environments (land, sea, air (air emerging as a distinct environment after WWII). Today, space is being added and the lead for that has been assigned to the US Air Force as popular perception associates space with air missions *

Effects based operations and planning is being chosen to counter asymmetric competition because the DoD has realized if a force doesn't have a specific competitor driving its development, it still needs a multitude of capabilities to handle niche competitors. Since the US military is finding that competitors are using more complexity in networks to approach and degrade our social systems (financial, information, political, willingness to endure, individual freedoms, etc.), the US military had to find a way to get into this game. The plan is to capitalize on innovative advantages while maintaining some current structure (not collapsing and starting over, as what some would say is the historical way of changing military organizations). To induce this evolution without a complete catastrophic change which would expose our vulnerabilities the US military has begun to develop a more holistic approach to counter asymmetric competition in developing interoperable systems that can be used interdependently.

Since each Service has been built on responses to their specific environments, each has systems within systems of specialization. This complexity within itself is driving each to look at its own SoS while the Joint Force community realizes that from a broader and even more complex role and new technologies, the overlap of capabilities from the various services are growing. In this regard, we will look at two area of military SoS, one at the Joint level (all the Services working under a Unified Commander) and one at the Service level (the US Army).

In the joint level of SoS, all Services meet the requirements of a SoS: they have operational and managerial independence, geographic distribution, emergent behavior, and evolutionary development within the battlespace. To optimize "effects" in a timely manner, the interoperability of each Service should already exist and be used in training for specific missions. This interoperability will generate interdependence. In scientific research, this feature of interdependence has, in some cases been shown to prompt the evolution of multiple interdependent systems into a completely new overall system. This new system might then be expected to draw on the same budgets and management structure. In the joint military world, there is considerable interest in exploring the possibilities of going to a "block Four" organization, where interdependence is the rule not the exception. If this interdependence is not produced in adhoc fashion, some leaders are suggesting a directed evolution. This change might become the "Goldwater-Nichols after next" (a public law that changed the military structure to what is it today since the 1980's) where alignment of the joint community refocuses.

Despite these changes, there continue to be many obstacles in the way of such a transition. Based on our changes in the past 30 years—during and since the Vietnam war—we see that when we were met with an asymmetric adversary, military strategists learned that the best counter was to get into their game and out of our game (the US game being large scale forces). This reduction in scale and increase in complexity was seen with the use of Special Forces Units. In the early 1980s, this, in turn, produced a new command—the US Special

Forces Command—in which a combination of Services were put together to work as coherent units to counter guerilla type warfare. Currently these select groups of Joint Fighters are being assessed as more effective in fighting terrorism/asymmetric warfare but their expansion is limited due to existing US laws. It is very difficult to transform a force to be jointly focused when the respective Services are still the chain for promotion and livelihood of each of the Special Forces personnel. One of the solutions currently under review is the proposal to set up separate joint funds to equip and train forces. We recommended that future research be done in this area.

This approach to being effects-based measurement—when fully implemented—will broaden the complexity and reduce scale (as referred to Figure 1 on page 3) of combining all aspects of national power. It ranges from the national strategic to operational down to the tactical levels. An example of a Service specific effort in this area taken from the US Army, a critical element in our national security, is discussed below.

The United States Military is undergoing a transformation to enable its ability to dominate and maintain superiority over future adversaries. Of particular focus are the emerging challenges from adaptive, asymmetric threats. The Army is changing from sequential and linear operations to distributed and simultaneous operations. The Future Force—characterized by networks of people enabled with systems that provide actionable information and decision superiority—will operate in a system of system environment to successfully execute its missions.

The Future Force is the name of the Army's future full-spectrum force; it will be organized, manned, equipped and trained to be more strategically responsive, deployable, agile, versatile, lethal, survivable and sustainable than it is today. It is designed to operate across the full spectrum of military operations as an integral member of a cohesive joint team.

Equipped with new systems designed to meet the needs of the Army's future fighting formations, the Future Force will be a networked system of systems. This system of systems includes Soldiers equipped with the Land Warrior system; a family of 18 integrated, synchronized, manned and unmanned Future Combat Systems (FCS); and critical complementary systems such as a Future Attack Helicopter and the Future Tactical Truck System. The Future Force will also consist of current systems (Abrams Tank, Bradley Fighting Vehicles, etc.). It utilizes advanced communications and technologies to link soldiers with both manned and unmanned ground and air platforms and sensors and in turn provide operating pictures relevant to the needs of the various systems.

The Future Force will operate as part of a joint, combined, and/or interagency team. It will be capable of conducting rapid and decisive offensive, defensive, stability and support operations and will be able to transition among any of these missions without a loss of momentum. It is envisioned that the Future Force capabilities will be seamlessly integrated with the capabilities of joint forces, Special Operations Forces, other federal agencies, and multinational forces. Please see Table 3 for an illustration of consciously developed SoS.

* The space environment is an interesting further example. Because of current policy in the US bureaucratic structure and there is no willing champion to enter this new environment as a joint venture (all aspects of warfare combined), it recently was decided to assign it to one service for “care and feeding.” This will constrain the effort as it will be based on a single service’s views of the space environment.

MILITARY SYSTEM OF SYSTEMS	SELECTED COMPONENT SYSTEMS	INTERACTIONS	SoS FORMATION	SoS ACTIVITY
- Future Force	- Soldiers with Land Warrior systems - Future Combat Systems - More……	- Consciously-designed and organized - Linked by advanced communications and technologies	- Consciously constructed	- Defending - Nation/society building

Table 3: Selected features of military SoS

SoS Characteristics

Common elements of definition: From our review of literature and analysis we concluded that these following characteristics were common across the three fields of biology, sociology and military: Evolutionary development, emergent behavior, self-organization, adaptation, complex systems, individual specialization, and synergy. The remaining characteristics in Table 4 below were not seen across the board. Note that the military, due to modern pressure for evolution, has all the characteristics of a SoS and is struggling with how this will lead to a transformational force as noted in issues below. Those characteristics with an (*) were developed by this group.

_ Different Elements	Biological	Social	Military
Operational independence	**Maybe**	**Yes**	**Yes**
Managerial independence	**Maybe**	**Doesn't apply in some cases; maybe**	**Yes**
Geographic distribution	**Yes**	**Changing**	**Yes**
Interdependence*	**Yes**	**Sometimes**	**Qualified Goal**
Multiple Taxonomies*	**Yes**	**Maybe**	**Yes**
Goal / Need Seeking*	**Maybe**	**Need; goal seeking may evolve**	**Goal**

Table 4: SoS Characteristics Not Common Across Fields of Biology, Sociology, Military

Issues

Evolution has played a key role in the formation of complex systems or Systems of Systems (SoS), in areas such as society, biology and the military. One of the interesting aspects in comparing these systems is in the trade off between interdependence and the ability for systems within the larger system to act independently.

Cellular Biology: The Krebs Cycle, a complex system, refers to a portion of the metabolic pathway of amino acids in the conversion of carbohydrates and lipids (sugars and fats) into ATP, which is responsible for the energy production for cells in all plants and animals. The Krebs, or Citric Acid, Cycle resides in the mitochondria, which is one of the common set of organelles that make up all plant and animal cells.

Plants and animals are extremely adaptable, living in the majority of environments presented on Earth. The level of adaptability achieved by plants and animals has come at the cost of independence, at least in the case of the Mitochondria, which was once a bacterium. The evolution of cellular biology has led to the high levels of interdependency, at the loss of component independence.

Society**:** Human are mammals, the majority of which are social. Some of our ascendancy in the animal world comes from improvements to the individual, e.g. larger brains and opposable thumbs, but perhaps a larger portion came from our collaboration and cooperation in groups, and the evolution of these group skills, e.g. hunter-gatherers. The individual was at greater risk of starvation or predation. More effective groups ate and bred better.

The availability of rich sources of nutrition, meat and grain, added energy to the human system and allowed the development of more complex behaviors. The cycle of human interaction and cooperation has led to increased efficiency in the fulfillment of basic human needs, as well as the production and usage of more energy, hence greater complexity, ad infinitum, at least to date.

With respect to the question of tradeoffs between interdependence and independence, humans can operate at the independent level, and some choose to do so. However, independence usually comes at the cost of efficiency of filing basic human needs, e.g. the hermit.

Maier (1998) suggests three categories of social SoS development and evaluates them from an engineering perspective with a focus on control as follows:

1) Directed: Directed systems are those in which the integrated system-of-systems is built and managed to fulfill specific purposes. It is centrally managed during long term operation to continue to fulfill those purposes, and any new ones the system owners may wish to address. The component systems maintain an ability to operate independently, but their normal operational mode is subordinated to the central managed purpose.

2) Collaborative: Collaborative systems are distinct from directed systems in that the central management organization does not have coercive power to run the system. The component systems must, more or less, voluntarily collaborate to fulfill the agreed upon central purposes.

3) Virtual: Virtual systems lack a central management authority. Indeed, they lack a centrally agreed upon purpose for the system-of-systems. Large scale behavior emerges, and may be desirable, but the supersystem must rely upon relatively invisible mechanisms to maintain it.

This emphasis on control suggests that those methods for establishing trust are key to reaping the full potential of social SoS.

Military: Land warfare has almost certainly been around at least as long as the hunter/gatherer period of human development, and has had an equally long period to evolve. The Romans demonstrated extremely effective warfare with the interdependent use of infantry (with novel tactics, techniques and procedures), cavalry and large ballistic and/or pyrotechnic weapons.

Naval warfare became significant during the Greek era and has evolved within its domain. However, interactions with the Army were usually limited to troop transport. The Air Force appeared in the 20th century, initially as the Army Air Corps, with tasking such as transport, air-air combat, bombing, and surveillance. For the majority of their history, military forces have worked within their own domain, e.g. navy deals with naval targets. This has led to duplication of capabilities as technology and complexity have increased.

During the 20th century, notable exceptions paved the way for today's desire for "Jointness" or interdependency between military forces, US and coalition. The first was Billy Mitchell's demonstrations illustrating the utility of air power through the historic bomber vs. battleship trials (1921) which led to the advent of Aircraft Carriers, and the second was the development of Close Air Support for American ground troops which was first worked out in the North African campaigns in World War ll.

However, the desire for Joint Operations is in conflict with the services' hesitancy to give up much, if any, capability for independence, to gain interdependence. This comes from a strong desire within the military to maintain "control" of their systems. This appears to be true for a majority of the history of the military. Desire for control has its roots in internal force bureaucracies, as well as external governance bureaucracies. As such, the military has evolved a hierarchical command structure, which will allowing centralized control, is diametrically opposed to what is desired to maximize the benefits of information technology, which enables interoperability. The military is moving towards the goal of interoperability as a means of increasing effectiveness. One interesting aspect of the goals of interoperability is that it does not require that a sacrifice be made. The system will be able to operate independently, with the capabilities on-hand, or interdependently, with additional capabilities if present.

With the move to develop interoperability a few questions are begged to be asked: Assuming increased effectiveness with a marginal level of interdependence, will systems be able to act independently, i.e. will we take a step backward? If a hierarchical command structure is the least efficient for the enabling technology for interoperability, what will it morph into? What is the effect of interdependence and different command structures on control?

Hierarchy

We concluded that the effectiveness of two systems, when put together with certain characteristics, should increase the overall effectiveness. We assume that the hierarchical levels do not change but after creating a SoS the overall structure has a tendency to flatten as the interdependence between the two systems should gain effectiveness while maintaining the same amount of management and resources as before. There is an unintended consequence that should be a goal that the hierarchy does not increase. This is a powerful tool for evolution while maintaining managerial independence for each system.

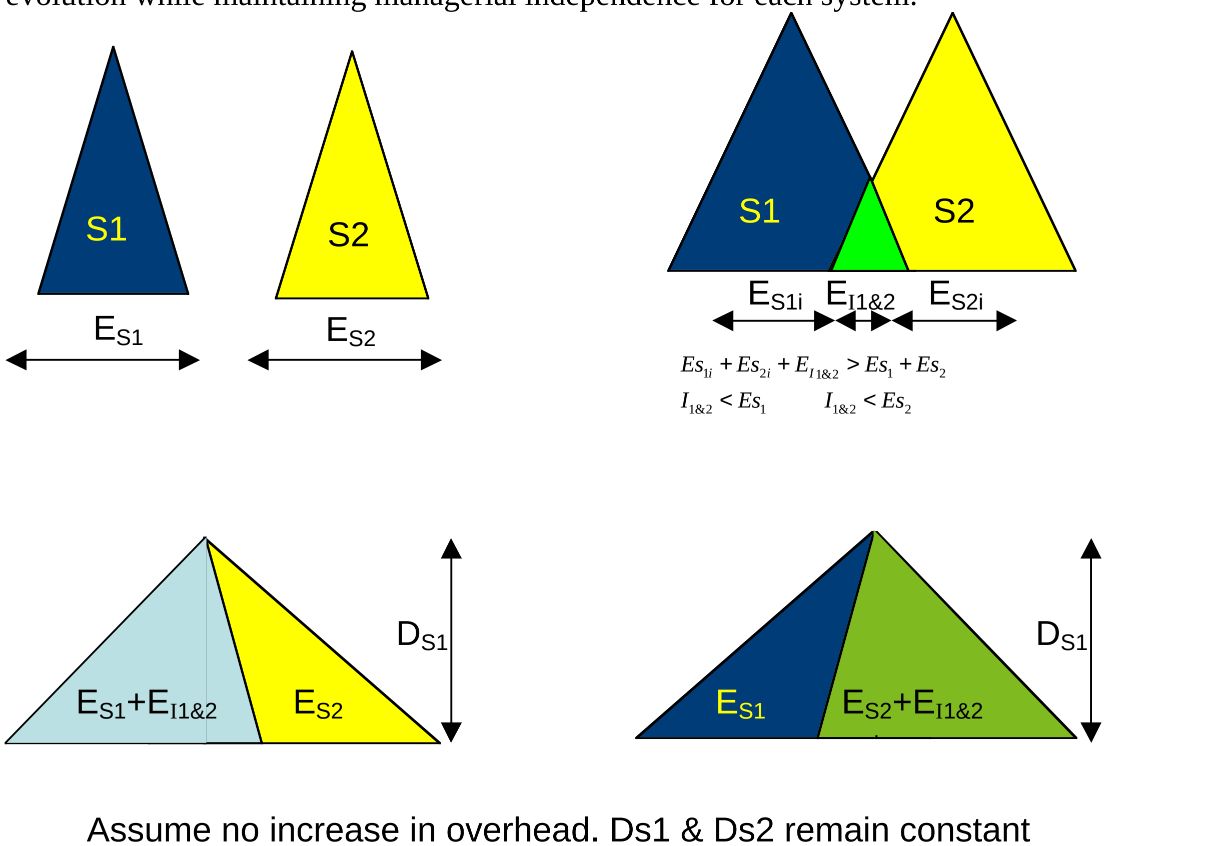


Figure 4: Hierarchy - The description above illustrates that with interdependence of two systems of a SoS, an increase in overall E (effectiveness) may be expected. This adaptation may be expected to be evolutionary, with a new hybrid system forming. The two pyramids at the bottom of the figure illustrate the goal of obtaining this effectiveness without an increase in overhead expense. If there is an increase in overhead, it reduces the advantages of SoS and is likely to prompt the formation of a separate stove-piped hierarchy.

The SoS trend is leading us towards networking in today's complex world in an evolutionary manner. It changes the traditional hierarchical structure required under predominantly large-scale organizations such as the military or large corporations. The finding that networks perform much more efficiently at Random or in highly complex or rapidly-changing environment than a managed hierarchy brings an innovative attribute for organization structures that have great potential for exploration. It would seem reasonable to energize the development of a middle ground (hybrid network) solution to link the present with the future.

As we continue to march towards an ever increasing complex world (the more we know and understand, the more we know "we don't know"), and as information flow opens avenues of possibilities, we will need to develop networked structures to survive. Since most large corporations, governments, and defense institutions have grown in hierarchy and currently use this management form, we are at a critical cross road in history. The flattening of organization— an adaptive and evolutionary trend in the late 20^{th} century—is in itself working towards a hybrid network solution. A significant challenge is to generate a shared understanding of potential structures which are designed for the good of the whole (survival as a group) as apposed to individual motives (survival of the individual… ego) to maintain hierarchical structure. The history of the evolution of teams (which might be considered networking) within social species including humans offers one rich source of information and should be explored.

Preliminary Findings on Emerging Behaviors

In this SoS paper, from the Biological point of view, there is a tradeoff between independencies and interdependency. It seems that the more evolved the system of systems is, the more interdependent each system become. Each cell will perform different tasks or complete the complex metabolic pathways required for the proper functioning of the body. The SoS, in this case, assures its survival and reproduction for the survival of the DNA information.

From a social systems perspective, it's our hypothesis that new SoS do not emerge unless something in the environment poses a problem which the current social system type cannot address. Thus, the emergence of a social SoS is useful as one potential indicator of increased environmental complexity and a punctuation point in the evolution of social forms.

From a military point of view, the effective capability can be realized through the integration of existing and future military systems of systems (SoS). The future of engineering systems will require their incorporation into increasingly integrated complex systems of systems. If we assume that the Traditional systems engineering (TSE) approach is effective for future complex systems problems than it is a questionable assumption. Therefore, systems of systems engineering (SoSE) have recommended an alternative to evolve TSE to deal with the emerging class of complex systems problems which is ahead of the TSE approach.

Suggestions for further research.

In the short time period of our effort, we only skimmed the surface. There is much to be learned and we believe that we have contributed, albeit small, to the body of knowledge on SoS. From an engineering perspective in planned SoS, how is evolution seeded and what are the selection mechanisms? How is adaptation seeded and nudged? What can be removed with the system of systems remaining functional?

An informal historical scan leads us to suggest that most social SoS have arisen in response to a need to handle increases in complexity rather than increases of scale. Further research in this area would be illuminating. In the case of social SoS, how might success be judged from the several points lower on the scale? What can we learn from teaming (inherent and contrived) that are attributes for networks that gets away from a hierarchical approach?

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