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The Interoperability Score

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Abstract

As the U.S. military seeks to advance its ability to perform network-centric operations, clearly an important factor is improving interoperability of systems of all types. Since only a rare system operates alone, improving the interoperability of networks of systems becomes our research goal. Many non-homogeneous networks of technological, human, and organizational systems are employed in all types of military operations. Within DoD, these systems and their operational uses are often described by Department of Defense Architecture Framework (DoDAF) architectures and include system, technical and operational views. With architecture as a foundation, a methodology for measuring interoperability, called an "Interoperability Score," is introduced. The methodology first defines a baseline measurement of interoperability for a non-homogeneous network of systems as they are used within an operational scenario or "thread." The methodology then defines the theoretical optimum interoperability score and proposes some heuristics which can be used to improve overall network interoperability.

Introduction

The past decade has seen a focus on interoperability research driven by a government and commercial need for improved interoperability of systems. Our research shows nearly three dozen definitions of interoperability in use over the past thirty years. Within the past decade, it has been commonly defined as "The ability of systems, units, or forces to provide services to, and accept services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together." (Amanowicz and Gajewski 1996), (Curts and Campbell 1999), (Shelton 2000), (Clark and Moon 2001), (Fewell and Clark 2003), (Kasunic and Anderson 2004). Additionally, research shows that many over the past decade have proposed interoperability measures, notable of which have been: 1) the DoD Levels of Information Systems Interoperability (LISI) model (C4ISR 1998) which was recently deleted from CJCSI 6212.01D as a required model for acquisition programs, 2) the Australian Defence Science and Technology Organization's LISI-extending Operational Interoperability Model (OIM) (Clark & Jones 1999) and Organisational Interoperability Agility Models (OIAM) (Kingston, Fewell, and Richer 2005), 3) the Levels of Conceptual Interoperability Model (Tolk & Muguira 2003) designed to support modelling and simulation efforts, 4) the Carnegie Mellon System of Systems Interoperability (SoSI) Model (Morris, et al. 2004) which addresses the programmatic impact on interoperability, and 5) the Model for Assessing the Performance of Interoperable, Complex Systems (Huynh and Osmundson 2006) designed to augment a quantitative vulnerability assessment model

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14. ABSTRACT
As the U.S. military seeks to advance its ability to perform network-centric operations clearly an important factor is improving interoperability of systems of all types. Since only a rare system operates alone, improving the interoperability of networks of systems becomes our research goal. Many nonhomogeneous networks of technological human, and organizational systems are employed in all types of military operations. Within DoD, these systems and their operational uses are often described by Department of Defense Architecture Framework (DoDAF) architectures and include system, technical and operational views. With architecture as a foundation, a methodology for measuring interoperability called an ?Interoperability Score,? is introduced. The methodology first defines a baseline measurement of interoperability for a non-homogeneous network of systems as they are used within an operational scenario or ?thread.? The methodology then defines the theoretical optimum interoperability score and proposes some heuristics which can be used to improve overall network interoperability.

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(Gheorghe and Vamanu 2004). With the exception of the Huynh and Osmundson model which simply defines an interoperability measure as “the mean number of elements interoperable with [another] element in the system,” all of these models are more qualitative than quantitative and were designed as a means of attaching a label or level to a specific type of interoperability so that systems, networks, operations, and interactions could be reported and compared.

Mark Kasunic and William Anderson, noted researchers on interoperability at the Carnegie Mellon Software Engineering Institute, aptly recognize that “interoperability is a broad and complex subject” and that “developing and applying precise measurements…is difficult” (Kasunic & Anderson, 2004). They, however, recognize that “measuring, assessing, and reporting interoperability in a visible way is essential to setting the right priorities.” (Ibid). To this end, our research proposes the *i-Score* as a generalized measure of the interoperability of systems of all types, supporting an operational thread. While the *i-Score* methodology can be abused by making improper comparisons, the *i-Score* methodology has several strengths including 1) it is easily computed, 2) it is based upon an operational thread, 3) it makes use of existing architecture data, 4) it can be used for scenarios where one or more type of interoperability is represented (i.e., information and organiztional interoperability), 5) it defines the optimum interoperability for a given operational thread allowing a decision maker to understand what the limits of his/her interoperability improvements are and what can realistically be done to improve interoperability for an operation of interest, and 6) it provides a means of drilling down into a process to discover where interoperability problems lie.

i-Score Methodology

Many networks of non-homogenous systems exist and are described by architecture and architecture frameworks (e.g., DoDAF, Zachman, TOGAF, FEAF, MoDAF, etc.) which include various views including technical, system and operational views which describe how the systems are used. The *i-Score* methodology uses this existing architecture data (specifically, DoDAF OV-5, OV-2, and SV-3) and applies graph, optimization, and interoperability theory to provide a generalized measurement of interoperability.

The *i-Score* methodology is firmly based upon the concepts of an operational thread and an interoperability spin. An operational thread is defined as a sequence of activities where each activity is supported by exactly one system (mechanism). An interoperability spin is defined as an intrinsic property of a system pair which indicates the quality of the pair’s interoperation. Borrowing from physics, spin is a quantized intrinsic property. In this research paper, we use the word spin and its connotation, to describe the intrinsic interoperability between two systems, i, j and quantize it as $s_{ij} \in \{-1, 0, +1\}$.

Our goal is to maximize interoperability for an operational thread or set of threads. We want to penalize our interoperability function when system pairs need translation in order to interoperate, and reward our interoperability function when their interoperation requires no translation.

To this end, the best spin (+1) is assigned when two systems can communicate without any translation (human or machine). An example of a system pair with $s_{ij} = +1$ is a cell phone and a cell phone tower. The next best spin (0) is assigned to a system pair which requires an intervening system (non-human) to do a machine translation to allow them to interoperate. An example of a system pair with $s_{ij} = 0$ is two cell phones (they require the cell phone tower to interoperate). The worst spin (-1) is assigned when the only way for two systems to interoperate is if a human system intervenes and translates. An $s_{ij} = -1$ spin is often assigned between two human systems when they require a third human to perform language translation services in order for them to communicate, conduct business, or otherwise interoperate.

The six steps in the *i-Score* methodology are presented next.

Step 1. Diagram the operational thread and define the set of supporting systems. Since the foundation of the *i-Score* methodology is an operational thread, it is reasonable to begin with an activity model. IDEF0 or UML activity diagrams are ideal because they require no modification in order to implement the *i-Score* methodology. The DoDAF OV-5, the functional flow block diagram, the N2 diagram, or IDEF3 diagrams can also be used with slight modification in order to capture the system supporting each activity in the operational thread. An example IDEF0 activity model (DoDAF 2004) is shown in Figure 1.

Each activity in the operational thread should be supported by at most one system (mechanism). Systems (both general and specific) can be technological (e.g., PDAs, cell phones, trucks, or wrenches), biological (e.g., human, bacteria, or virus), organizational (e.g., branch office, company, or working group), or environmental (e.g., weather, sun spot activity, or gravitational effects). After modelling the operational thread, let T be the ordered set of all systems supporting the thread. The ordered set of supporting systems for the thread in Figure 1 is $T = \{1,2,2,3,4,2\}$ where Strategic ISR is system #1, Tactical ISR is system #2, Command Authority is system #3, and Shooter is system #4.

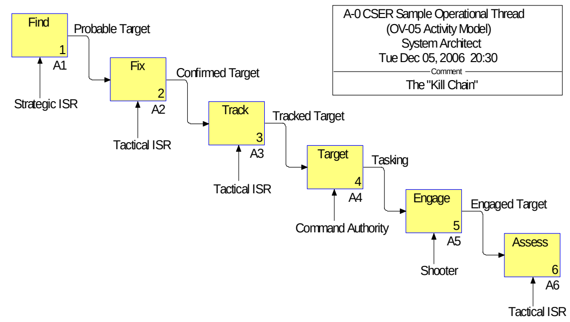

Figure 1. Sample Operational Thread (IDEF0)

Step 2. Create an interoperability matrix. Let $D = (V, E)$ be a complete directed multigraph where the vertex set $V = \{v_1, v_2, \ldots v_n\}$ is the set of n systems supporting the operational thread and the edge set $E = \{e_1, e_2, \ldots, e_{n \times n}\}$ is the set of directed connections between systems (including loops). Note that $n \neq |T|$ if a system supports more than one activity. Define the spin matrix $S = \left[s_{ij} \right]_{n \times n}$, $s_{ij} \in \{-1, 0, +1\}$, $i, j = 1 \ldots n$ as a modified adjacency matrix (similar to a DoDAF SV-3) representing the intrinsic spins for all permutations of system pairs in the operational thread. Define the multiplicity matrix $C = \left[c_{ij} \right]_{n \times n}$, $c_{ij} \in \square^{\geq 0}$, $i, j = 1 \ldots n$ as a matrix of spin multiplicities where c_{ij} is the number of times a system pair is repeated when the elements of T are taken two at a time in a forward direction. Take as an example the operational thread in Figure 1. The set of systems taken two at a time is
$A = \{(1,2),(1,2),(1,3),(1,4),(1,2),(2,2),(2,3),(2,4),$
$(2,2),(2,3),(2,4),(2,2),(3,4),(3,2),(4,2)\}$
where $|A| = \binom{|T|}{2}$. Since the system pair $(1,2)$ appears three times in A, then $c_{12} = 3$. At this point, it is appropriate to explain why the multiplicity matrix is necessary. A system used early in a process interacts directly with the next successive system in the thread, but it

interacts indirectly with every successive system in the thread because information it creates or transforms is eventually passed to successive systems. The interoperability matrix is defined as $M = \left[c_{ij} s_{ij} \right]_{n \times n}$. Example spin, multiplicity, and interoperability matrices for the operational thread in Figure 1 can be seen in Figure 2.

$$C = \begin{bmatrix} 0 & 3 & 1 & 1 \\ 0 & 3 & 2 & 2 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{bmatrix}, \ S = \begin{bmatrix} 1 & -1 & -1 & -1 \\ -1 & 1 & 0 & -1 \\ -1 & -1 & 1 & 0 \\ -1 & -1 & 0 & 1 \end{bmatrix}$$

$$\Rightarrow \ M = \begin{bmatrix} 0 & -3 & -1 & -1 \\ 0 & 3 & 0 & -2 \\ 0 & -1 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{bmatrix}$$

Figure 2. Example Multiplicity, Spin, and Interoperability Matrices

All of these matrices could possibly be extended to k-dimensional hypercubes with additional dimensions representing multiple links, applications, and protocols used by and between systems. A look at layers of interoperability might be the best way to analyze this type of k-dimensional interoperability matrix.

Step 3. Calculate the *i-Score*. The *i-Score* is an objective function (Equation 1), which we will later seek to maximize and represents a summation of spins between all system pairs along the operational thread.

$$I = \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij}$$

Equation 1. *i-Score*

Step 4. Determine the Optimum *i-Score*. In order to determine how much the interoperability of the operational thread can be improved, we need to know the optimum *i-Score* for the thread. The optimum *i-Score* is defined as the maximum possible *i-Score* in light of physical and operational constraints. We begin be recognizing that two systems (i, j) are perfectly interoperable when $s_{ij} = +1$. Then an upper bound on the *i-Score* occurs when $S = [1]_{n \times n} \Rightarrow M = \left[c_{ij} \cdot (+1) \right] = \left[c_{ij} \right]$. But this does not take into account the physical and operational constraints mentioned in our definition of optimality. We need to know which system pair spins physically or operationally cannot be upgraded. For example, we may determine that in light of our operational thread, we want system i and system j to always use human translation. Therefore, their spin is fixed at $s_{ij} = -1$. Let $S_{opt} = \left[s_{ij} \right]_{n \times n}$, $s_{ij} = \max\{s_{ij}\}$ where $\max\{s_{ij}\}$ is the greatest possible spin that system pair (i, j) can achieve due to physical and operational constraints. Then $M_{opt} = \left[c_{ij} s_{ij} \big|_{s_{ij} = \max\{s_{ij}\}} \right]$ is the maximally upgraded interoperability matrix and the optimal *i-Score* is given by Equation 2.

$$I_{opt} = \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij} \Big|_{M_{opt}}$$

Equation 2. Optimum *i-Score*

Step 5. Calculate the Interoperability Gap. The interoperability gap (Equation 3) is a measure of how much interoperability improvement can be made considering physical and operational constraints on the operational thread. If $I_{gap} \neq 0$, then various analysis methods can be used to determine how to shrink I_{gap}.

$$I_{gap} = I_{opt} - I$$

Equation 3. Interoperability Gap

Step 6. Perform interoperability analysis. Theoretically, all system pairs whose spin is not +1 indicate possible areas for interoperability improvement. A discussion on spin upgrades, use of common systems, thread comparisons, and thread concatenations is included below along with a network interoperability visualization method, called the interoperability terrain, and two techniques (Average Spin and Average *i-Score*) for analyzing an interoperability matrix irrespective of a specific thread.

Spin Upgrade. One of the simplest ways to analyze an operational thread for interoperability improvement is by examining individual spins. Let $A=\{(i,j):i,j\in T\}$ be the combinatorial set of all system pairs supporting the operational thread. Let $F\subset A$ be the set of system pairs whose spins are fixed and cannot be upgraded. Then $\bar{F}=\{(i,j):s_{ij}\text{ upgradeable}\}$ is the set of system pairs whose spins can be improved through methods such as software upgrades, hardware changes, new company policies, or improvements in training. Unfortunately, sometimes no means of spin improvement is readily visible (i.e. $\bar{F}=\varnothing$). In these cases, it is often helpful to decompose the original operational thread down to a lower level and then re-compute the *i-Score*. This decomposition will often manifest lower-level interoperability problems that were not easily discovered at the higher level.

Once $\bar{F}$ has been determined, the analyst might wonder which system pairs to upgrade first. Cost and other factors aside, it is better to upgrade the systems earlier in the operational thread because their improvements benefit more of the thread's activities. To visualize this, take a five system thread $T=\{1,2,3,4,5\}$ in which the spin matrix is the identity matrix (i.e., all spins are zero except for the diagonal). If we upgrade interoperability with the first system in the thread ($s_{1j}=+1,\ j=1\ldots5$), we get $I=4$, if the middle system is upgraded ($s_{3j}=+1,\ j=1\ldots5$), we get $I=2$, and if the last system is upgraded ($s_{5j}=+1,\ j=1\ldots5$), we get $I=0$.

Using Common Systems. Intuitively, if the same system can be used to support multiple activities, interoperability should increase. In fact it doesn't matter whether the use of common systems occurs at the beginning, middle, or end of the thread—the resulting *i-Score* improvement is the same.

Operational Thread Comparisons. At this point, the analyst should be cautioned regarding *i-Score* comparisons. Just because one operational thread has a higher *i-Score* than another doesn't mean it is "better." Two operational threads which accomplish the same mission can be <u>roughly</u> compared by using a normalized *i-Score* (Equation 4) which compensates for the number of systems supporting the thread. But this type of comparison is not always appropriate. The analyst must decide whether it is better to upgrade systems, replace systems with common systems, or keep current systems but change operational uses. The *i-Score* is meant to provide a generalized starting point for discussion regarding interoperability improvement.

$$I_{norm}=\frac{1}{|T|}\sum_{i=1}^{n}\sum_{j=1}^{n}m_{ij}$$

Equation 4. Normalized *i-Score*

Operational Thread Concatenations. If more than one operational thread is concatenated together, one might hope that their overall *i-Score* is the sum of their individual *i-Scores*, but this is not the case. The *i-Score* of the new combined operational thread must be calculated anew following the steps described previously.

Average Spin. The average spin $\mu_S = \sum_S s_{ij}$ is a rough indicator of the interoperability of the network of systems irrespective of any specific thread.

The Interoperability Terrain. An interoperability terrain graph can be used to visualize the spins in a network and can help the analyst visualize the effort required for the thread's systems to interoperate. It is analogous to a hiking route overlaid upon a topological map. The xy plane in the interoperability terrain graph is a system-to-system plane and the z direction indicates the spin of the system pair. An example of an interoperability terrain graph can be seen in Figure 3 with the operational thread from Figure 1 overlaid.

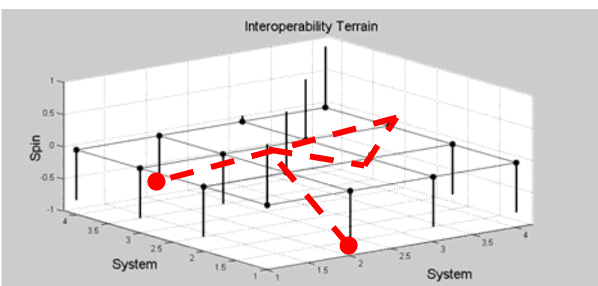

Figure 3. Interoperability Terrain (Example)

Average *i-Score*. An average *i-Score* I_N for the network can be calculated when multiple inter-connecting threads are of interest. If a set of shortest paths between all possible system pairs is calculated, recognizing that not all of the paths are necessarily operationally feasible, the average of the normalized *i-Scores* associated with the threads defined by those paths gives a general measure of whole network interoperability.

An Example

At this point, an example analysis is given to illustrate the *i-Score* methodology.

Step 1. Define the Operational Thread. Use the process model with corresponding operational thread in Figure 1.

Step 2. Create an interoperability matrix. Based upon the operational thread and explanatory information (see Appendix, Table 2), the multiplicity, spin, and interoperability matrices are given in Figure 4.

$$C = \begin{bmatrix} 0 & 3 & 1 & 1 \\ 0 & 3 & 2 & 2 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{bmatrix}, \quad S = \begin{bmatrix} 1 & -1 & -1 & -1 \\ -1 & 1 & 0 & -1 \\ -1 & -1 & 1 & 0 \\ -1 & -1 & 0 & 1 \end{bmatrix}$$

$$\Rightarrow M = \begin{bmatrix} 0 & -3 & -1 & -1 \\ 0 & 3 & 0 & -2 \\ 0 & -1 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{bmatrix}$$

Figure 4. Multiplicity, Spin, and Interoperability Matrices for Example Operational Thread

Step 3. Calculate the *i-Score*. Using Equation 1, $I = -6$.

Step 4. Determine the Optimum i-Score. Setting non-fixed spins at their operational and physical max (see Appendix, Table 2), the optimum spin and interoperability matrices are given in Figure 5. Using Equation 2, $I_{opt} = 4$.

$$S_{opt} = \begin{bmatrix} 1 & 0 & -1 & 0 \\ -1 & 1 & 0 & 1 \\ -1 & -1 & 1 & 0 \\ -1 & 1 & 0 & 1 \end{bmatrix}$$

$$M_{opt} = \begin{bmatrix} 0 & 0 & -1 & 0 \\ 0 & 3 & 0 & 2 \\ 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}$$

Figure 5. Optimal Spin and Interoperability Matrices

Step 5. Calculate the Interoperability Gap. For this example, $I_{gap} = I_{opt} - I = 4-(-6) = 10$, indicating substantial room for improvement in interoperability.

Step 6. Perform Interoperability Analysis. First analysis of the operational thread is undertaken. For our example thread, $A = \{(1,2),(1,3),(1,4),(2,2),(2,3),(2,4),(3,2),(3,4),(4,2)\}$ is the set of all combinatorial system pairs supporting the operational thread. For illustrative purposes, $F = \{(1,3),(2,2),(2,3),(3,2),(3,4)\}$ is the set of system pairs whose spins are fixed, and $\bar{F} = \{(1,2),(1,4),(2,4),(4,2)\}$ is the set of system pairs whose spins are not fixed. Then four spins $\{s_{12}, s_{14}, s_{24}, s_{42}\}$ can be improved (see Appendix, Table 2). Operationally, one improvement that might be useful is to provide a live Tactical ISR video or radar track feed to the Shooter. This could raise the spin between the Tactical ISR and Shooter systems (s_{24}) from -1 to +1. Since this spin has multiplicity $c_{24} = 2$, this spin upgrade has bang-for-the-buck from an interoperability viewpoint. This one spin upgrade increases $I = -6$ to $I = -2$, a big step towards closing the interoperability gap ($I_{gap} = 10$ before the upgrade vs. $I_{gap} = 6$ after). Use of common systems yields even better improvement. For example, if the Tactical ISR system is an unmanned aerial vehicle, it may be possible to use that UAV for tactical ISR and as a shooter. This use of a common system for multiple functions further increases our *i-Score*. Analysis of the entire network yields an average spin for the network of $\mu_S = -0.3125$. The mean and variance of the interoperability matrix can also be calculated. Results of the interoperability analysis are tabulated below.

Table 1: Analysis of Operational Thread

Measure	M	$M_{upgraded}$	M_{opt}
I	-6	-2	4
I_{norm}	-0.4	-0.133	0.267
μ_M	-0.375	-0.125	0.25
σ_M^2	1.583	1.716	1

According to the data in Table 1, our starting *i-Score* for our operational thread was poor, but the interoperability gap could be decreased by 40% by upgrading interoperability between the Tactical ISR and Shooter systems. Better improvement in interoperability comes from adding Shooter capability to the Tactical ISR system.

Areas for Further Research

While immediately useful, there are several areas related to the *i-Score* methodology that can benefit from further research. We have identified some of these areas as: 1) How can we account for decision logic in the operational thread when computing the *i-Score*? 2) How can we factor in simultaneous activity in operational thread when computing the *i-Score*? 3) Can we compute an *i-Score* when multiple systems support one activity (i.e., multiple mechanisms on the IDEF0 diagram) without decomposing the activity? 4) What is the best way to use the *i-Score* in the requirements definition or early system design phases? 5) Can the *i-Score* be described so that interoperability at various layers (e.g., protocol, application, system, organization) can be analyzed? 6) Are there better ways to compare *i-Scores*?

Conclusion

This research investigated an architecture-based method of measuring interoperability of complex networks of non-homogeneous systems called the *i-Score*. It uses the operational thread as its foundation and provides a single number measure of how well the systems (technological, biological, organizational, and environmental) interoperate along the thread. The *i-Score* methodology is useful not just to those interesting in measuring, analyzing, reporting, and improving interoperability of technical systems, but is applicable to any situation for which an activity model can be described. As such, the *i-Score* methodology will be especially useful to policy-makers, those interested in business process improvement, system architects, engineers, as well as a variety of others interested in improving interoperability of their network of systems.

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Biography

Thomas Ford is a Systems Engineering Ph.D. student at the Air Force Institute of Technology. Prior to becoming a student, Major Ford helped formulate Air Force architecture policy and guidance at Headquarters Air Force. Before serving on the Air Staff, he was Deputy Chief of Joint STARS production and oversaw the production and delivery of two aircraft. This paper is the result of his initial dissertation literature search on combining interoperability measurement, network optimization and architectural design.

John Colombi is an Assistant Professor of Electrical Engineering at the Air Force Institute of Technology. He teaches graduate courses and leads sponsored research in support of the Systems Engineering program. Before joining the faculty, Dr. Colombi led various Air Force C4ISR systems integration activities including the C2 Constellation. He served as Chief of Systems Engineering for U.S. AWACS. He has served at NSA developing information security and ran communications networking research at the Air Force Research Laboratory.

Scott Graham is an Assistant Professor of Computer Engineering at the Air Force Institute of Technology. He teaches graduate courses in computer networking and leads sponsored research in the area of mobile military networks. Prior to joining the faculty, Dr. Graham conducted software evaluation at the Air Force Operational Test and Evaluation Center and led testing of the Combat Talon II Mission Rehearsal Device at the Aeronautical Systems Center's Training Systems Product Group.

David Jacques is an Assistant Professor of Aeronautical Engineering and joined the faculty of the Air Force Institute of Technology in the summer of 1999. Prior military assignments included tactical missile intelligence analysis, ballistic missile test and evaluation, and research and development for advanced munition concepts. In the winter of 2002-2003, LtCol Jacques led the activation of the new Air Force Center for Systems Engineering initiated by then Secretary of the Air Force Dr. James Roche. Dr. Jacques' research interests include multi-objective or constrained optimal design, and cooperative behavior and control of autonomous vehicles.

Appendix

Table 2: Explanation of Example Thread Spins

Spin	Upgradeable?/ (Max Spin)	Rationale for Spin
$s_{ii} = +1$	NO	All systems have perfect interoperability with themselves
$s_{12} = -1$	YES (0)	Strategic ISR can only communicate with Tactical ISR through a human (no automated cueing)
$s_{13} = -1$	NO	Strategic ISR can only interoperate with the Command Authority through a human (i.e., strategic ISR intelligence is first interpreted by a human and then passed to the command authority)
$s_{14} = -1$	YES (0)	Strategic ISR intelligence can only be passed to the Shooter through a human
$s_{21} = -1$	NO	Tactical ISR intelligence can only be used to re-cue the Strategic ISR system through human intervention
$s_{23} = 0$	NO	Tactical ISR intelligence can be seen directly by the Command Authority without human intervention (i.e., Predator video feed).
$s_{24} = -1$	YES (+1)	Tactical ISR intelligence can be communicated to the Shooter only through a human-to-human radio call.
$s_{31} = -1$	NO	Command Authority can re-cue the Strategic ISR system only through a human ground station operator.
$s_{32} = -1$	NO	Command Authority can re-cue the Tactical ISR system only through a human operator.
$s_{34} = 0$	NO	Command Authority can pass targeting information machine-to-machine to the Shooter.
$s_{41} = -1$	NO	Shooter can request re-cueing of the Strategic ISR system, but only through human controllers.
$s_{42} = -1$	YES (+1)	Shooter can request re-cueing of the Tactical ISR system, but only through human controllers.
$s_{43} = 0$	NO	Shooter can interoperate directly with the Command Authority by radio.