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Decision Support Tools to Enable Affordability for Responsive Space

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ABSTRACT
The acquisition of new space systems must address criteria beyond faster processing, better reliability, improved technology, greater payload capacity, etc. The benefits of performance improvements must be balanced against cost to arrive at a "best value," affordable technology solution. Affordability previously was not often prioritized for programs because technology was emphasized, with focus primarily on performance. This is relevant to next-generation space architectures because innovative cost analysis tools are needed to assess fiscal affordability of proposed investments, in addition to the technical viability. This paper outlines Frontier Technology effort to develop the decision support tools to measure and report affordability and return-on-investment for Responsive Space programs within a collaborative environment. Since cost savings cannot always be demonstrated for new technologies that provide previously unattainable capability, innovative methods of measuring both investment and return, is needed. This ongoing research develops an automated methodology, processes and tools to evaluate the affordability and financial returns on space investments. This capability is truly innovative because it uses the newest information technology capabilities to aggregate the best community-accepted cost data to assist the decision-making process. FTI can then apply affordability models with community-accepted data to projected space systems and architecture design changes to assess: systems and vehicles, operations costs and long-term life cycle affordability, cost implications of proposed manufacturing and testing techniques, plus advanced control concepts projected to reduce operational costs. This capability is also innovative because the estimating methodology enables program managers to conduct quick turn, high-level cost estimates to assess the affordability of proposed investments. This cost screening capability permits quicker focus on projects that have **both** technical and cost merit, rather than conducting longer analysis efforts on technical proposals that ultimately are not affordable.

As the space community focuses on injecting cost into the program manager work environment, FTI can assist in obtaining reliable, community-accepted cost estimating at the desktop. Achieving responsive space capabilities requires tools

to deal with the increasing emphasis on affordability, in addition to desired performance increases. Fortunately, innovative information technology capabilities and cost analysis tools exist that space capability customers may leverage to their benefit.

The desired end state of this research is to provide an automated analysis environment with assessment tools and processes to evaluate the utility, affordability and financial returns on Responsive Space investments under consideration. The resulting decision support tools and collaborative environment have great potential for effective use in any industry or commercial environment.

SIGNIFICANCE OF THE RESEARCH

Collaborative computing combined with integrated decision support tools is a capability increasingly required by Responsive Space Design teams to ensure not just design functionality, but ever more important, affordability. Decisions are made daily to invest in technologies that appear to have large performance potentials but do not deliver the desired return on investment (ROI) costing millions in lost opportunities. The reality that decisions in the early design phases ultimately determine the largest percent of the total cost of the system over its entire life cycle has become critical to new designs, especially in the current environment of decreasing budgets. In an effort to develop and produce Responsive Space systems better, cheaper and faster, many large industries, such as aerospace and automotive, are moving to virtual digital design environments. Classic examples are Boeing's 777 and Chrysler's Dodge Intrepid and Plymouth Neon.

Integrating cost and affordability into the Responsive Space design process creates a significant paradigm shift in which the fundamental technology and systems design process is changed. Cost and affordability now become basic design parameters and are used to trade and compare performance characteristics to ensure the technology or system is affordable and represents the best value.

In the past, candidate Responsive Space technology concepts with high life cycle cost projections have typically been assumed to have higher performance potential. These concepts, many of which are truly fiscally unrealistic were then often carried along in the planning process as an unnecessary drain on resources and possibly a detriment to the consideration of other, more cost-effective solutions that still provided satisfactory performance. There is, thus, a particularly strong case for (1) the use of a methodology that can trade-off system's performance and life cycle costs (LCC) from the beginning of the conceptualization process and (2) for tools both to increase the productivity of the technology / system planner and to facilitate the traceability of candidate system/technology concept assessments. The methods and tools described in this technical paper focus on the parametric and analogy approach to cost estimation and will integrate those cost estimates with an assessment of performance, evaluated against a set of metrics for the technologies and system operations that are relevant to information systems.

Since the life cycle costs associated with future systems are often established by design decisions in an early phase, it's hard to impact 80% of the cost of building and fielding a system once the design is finalized. However, a lot can be accomplished to change the majority of a system's LCC while still evolving the design, during the early acquisition phases, as illustrated on the left of Figure 1's time scale. This is the period of greatest

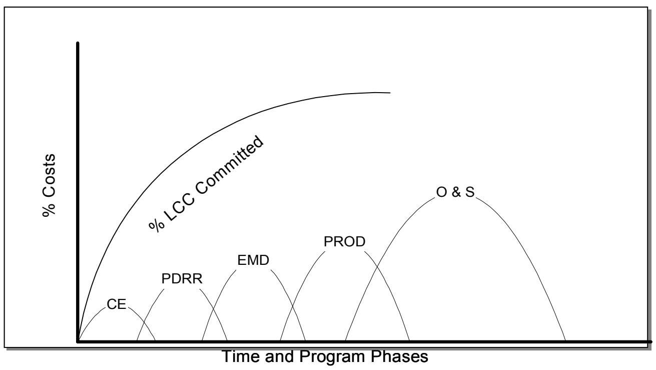

Figure 1: ***Most of LCC is set before EMD is complete***

opportunity for both improving performance and reducing cost. In the past, cost has not weighted as heavily in the design decision process and did not lead to filtering fiscally unrealistic concepts and technologies out of consideration. In addition, when companies optimized their production process, they did so to reduce cost. Now, companies are also seeking to optimize the design to reduce both production costs along with operation and support costs.

While the opportunity to reduce cost is greatest early in the life of a system, there is little accurate data available to make estimates and; therefore, a cost estimate will have a relatively high degree of uncertainty. Figure 2 illustrates the relative accuracy of cost estimates. However, the impact of the early design assessment can be the most dramatic because the program usually has more flexibility in design and configuration; and if a design change can be made to improve affordability, the program usually has the flexibility to make such a change. This is a strong reason for addressing affordability as soon as possible in the program's life. As the system matures, better detail and characteristics of the system become available and more actual cost data is obtainable. The uncertainty in the estimate is therefore reduced but so is design flexibility.

Good affordability assessments with strong return on investment (ROI) values make it easier to gain and sustain funding support for the program. Following a disciplined approach to affordability will provide program managers with strong justification when their program is compared with other programs that lack this level of justification. Programs that have strong justification based on high utility and good ROI values taken from well-defined affordability assessments have a great advantage as they progress through the planning and

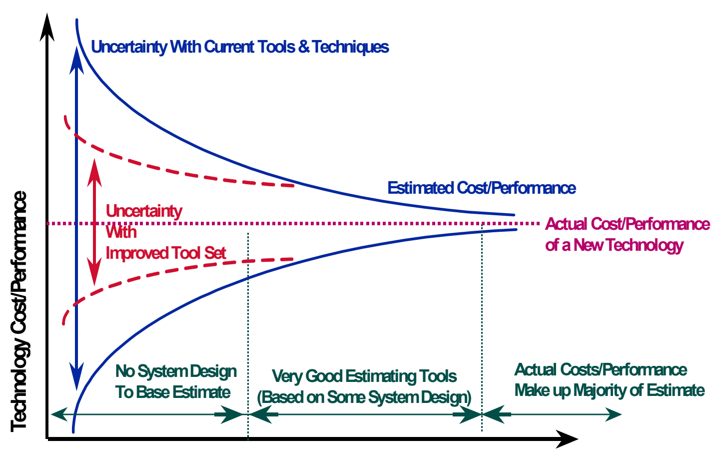

Figure 2: ***Relative Accuracy of Cost Estimates***

programming processes.

All of these factors combine to increase the importance of an effective collaborative computing environment with integrated decision support tools capable of providing accurate, top-level estimates for all Responsive Space acquisition phases.

RESEARCH OBJECTIVES

The primary objective of the research described is to provide a tool suite capable of use within a Distributed Collaborative Decision Support (DCDS) environment that will enable the users of the results of this research to evaluate the utility (value) of their technology investments, thereby enabling effective investments and design trades to ensure affordable Responsive Space systems. The methodology and tool suite have great potential for effective use in any industry considering using virtual, collaborative design tools (e.g., aircraft, transportation systems shipbuilding, architectural, and construction.). The computer tools and corresponding DCDS environment developed during this research will provide the space laboratory analyst, engineer or planner the capability to evaluate life-cycle costs of various technologies. This capability enables analysts to conduct performance trades for the various design parameters of innovative concepts, and determine the benefits of each in terms of life-cycle cost. This information can be critical to program justification documentation and the ability to develop affordable (and effective) technologies.

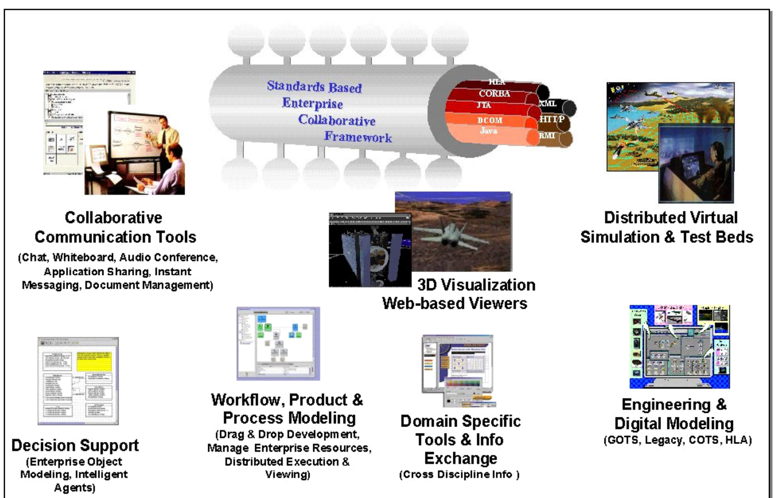

Figure 3: ***Components of a distributed collaborative environment***

RESEARCH DESCRIPTION

Distributed Collaborative Decision Support Environment

A Distributed Collaborative Decision Support environment (depicted in Figure 3) is the application of advanced distributed modeling and simulation, information science, and engineering tools in an integrated framework to support technology development, system design, performance, cost, and producibility trade-off analyses throughout the entire product and system engineering life cycle.

A DCDS consists of a domain-independent framework that enables the exchange of information across engineering disciplines and a set of domain and mission-dependent tools. The framework ties together the physical assets, engineering processes, and personnel needed to accomplish an engineering design. Previously, members of Responsive Space engineering, testing, management, and procurement teams worked fairly independently on their specific part of the problem. Integration of results from these different efforts was difficult, expensive, and error prone. The DCDS environment is an enabling technology which will allow the entire research or design team to solve problems simultaneously using a common set of models, simulations, databases, and tools. A description of the technical objectives and primary tool suite components for the DCDS follows.

Technical Objectives

The objective of FTI's ongoing research is to integrate PC-based cost evaluation and decision support tools into a distributed collaborative decision support environment with which analysts in various industries can evaluate the affordability and return on investment of the Responsive Space system(s) under consideration.

Specific sub-objectives for our research are to:

- Develop and test a methodology to evaluate return on investment and resultant affordability of customer's Responsive Space investments.
- Identify software and databases required to implement the overall methodology. This will be used to customizing the tool prototype, and provides the baseline for future development efforts.
- Identify required modifications / enhancements to FTI's I-CAIV™ and ICE™ tools or other partners' tools.
- Demonstrate methodology using Responsive Space customers' real-world problems.
- Obtain customers' consensus on the ROI (utility) and affordability measures.
- Formulate the performance-based affordability tool requirements.
- Prototype key features of the methodology to provide a vehicle for demonstrations and a means of risk reduction for subsequent research phases. These features will become the baseline for the next generation Responsive Space development effort.

Components of DCDS

Leveraging Existing Capabilities

Very powerful integrated desktop solutions are needed to implement the "vision" discussed above for the system acquisition community. Commercial-off-the-shelf software development environments offer open, widely compatible architectures. These greatly expedite the desktop automation of the DCDS complex models, and data-intensive projects, all with user-friendly graphical user interfaces (GUI's). The challenge, then, is aptly applying these already ample and still evolving information technologies for the benefit of the customer. When properly integrated, this innovative information technology will support a DCDS environment based on community accepted modeling and simulation.

For this research FTI is using the DCDS environment developed under Air Force Research Laboratory (AFRL) sponsorship as the "motherboard" for enabling affordability assessments for customers' Responsive Space initiatives in a DCDS environment.

Cost Estimation

For the last few years, FTI has actively supported the implementation of the Department of Defense (DoD) initiative to move affordability to the forefront for all DoD program development and modification decisions. Under contract to AFRL, FTI is enhancing its' ICE tool with several cost modules that assist AFRL personnel in meeting their policy directive that all future Science and Technology investment decisions are based on affordability, as well as the usual performance issues. FTI's lessons-learned evaluating AFRL affordability initiatives are directly transferable to evaluating affordability for customers' Responsive Space initiatives. The ICE tool forms the foundation of the affordability capabilities that are described in this paper.

The ICE tool is capable of providing accurate, credible cost estimates, based on recent historical, parametric data for each phase of the acquisition process, for a life cycle cost estimate that is complete, except for some minor factors related to government operation of the program, developing-contractor profits, system disposal, and some operational testing. These factors can be added by the user.

The ICE tool uses several integrated cost models that are accepted by the DoD for estimating costs in each phase of a system's life cycle, including the important operations and support. The models and data sources are integrated into the tool and are used through a graphical user interface that "guides" the user through the cost-estimating process. Figure 4 illustrates the concept of the integrated cost models integrated in the ICE tool.

The cost estimates developed using the ICE tool or its derivatives have accuracy appropriate for determining funding levels and for making the relative cost comparisons between two or more technical alternatives.

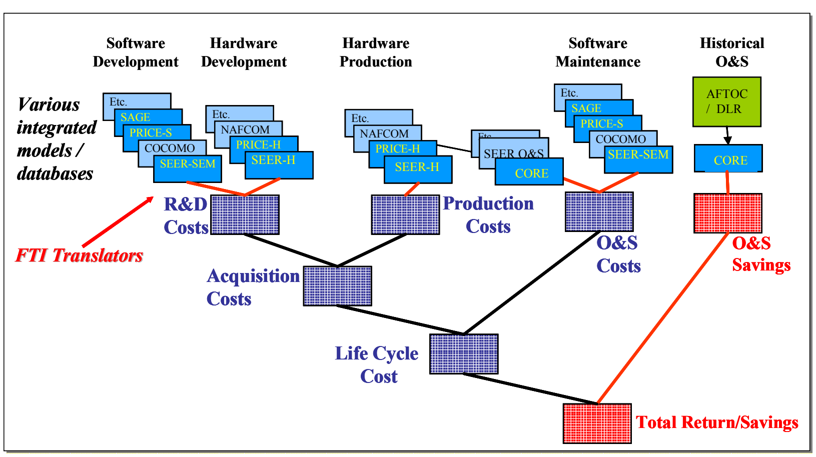

Figure 4: ***ICE provides an integrated suite of community accepted cost models***

This makes ICE a suitable tool for affordability evaluations in the early Responsive Space program phases (i.e., concept exploration). FTI will use ICE as the basis for DCDS cost estimates in customers' evaluation of cost and return-on-investments for its technology initiatives after it has been enhanced to include additional data that focuses on customer specific technologies.

Decision Analysis

Cost as An Independent Variable (CAIV) is the primary acquisition process strategy for meeting customer requirements while reducing Total Ownership Costs (TOC). CAIV, as defined by DoD Instruction 5000 is "The process of using better business practices, allowing "Trade Space" for industry to meet user requirements, and considering operations and maintenance costs early in requirements definition to procure systems smarter and more efficiently." It is required for all DoD acquisition programs and is linked to several Defense System Affordability Council goals.

The proper use of CAIV will ensure that cost is a factor in all design decisions throughout the Responsive Space development processes. The CAIV methodology facilitates identification of the "best value" solution or group of alternatives and also the cost vs performance trade-off ramifications of including certain performance parameters. Early application of the CAIV considerations may allow certain unaffordable alternatives or too expensive performance requirements to be eliminated early in the process so the Responsive Space team can focus on fewer, more viable and affordable solutions. Critical to the effective use of CAIV is the availability of cost models, such as ICE, and decision tools that have a high degree of community acceptance, and are generally easy to use by the designers, engineers, and planners involved in the key design decisions.

FTI's I-CAIV tool provides a comprehensive architecture assessment process in a PC-Based environment that highly leverages Contractor-off-the-shelf (COTS) software applications. The I-CAIV analysis process provides a complete forwards and backwards "Chain-of-Assessment" that remains traceable to the overall analysis requirements. The "Chain-of-Assessments" is based on a framework of linked matrices that reflect assessment and prioritization of requirements, measures of effectiveness (MOEs), system performance parameters, and raw analysis data. The framework also supports the integration of this data with risk and cost assessments. These assessments are dynamically rolled-up to the overarching analysis level where a variety of flexible post-processing features are provided, such automated CAIV profile development, key variable sensitivity analysis, and analysis results visualization.

I-CAIV provides a disciplined, structured yet flexible methodology, based on system engineering principles, needed to assess the disparate parts of the architectures and integrate qualitative and quantitative analyses results in the decision trade space. The type of trade space is illustrated on the right side of Figure 5. The display can be either three-dimensional or two-dimensional for each combination of parameters. In a recent application for AFRL, the results were highlighted as a best practice. Typically, the cost, utility (performance) and risk are displayed for several system / technology alternatives, enabling decision-makers to select the most "cost-effective" option. The environment provides direct traceability to requirements and system performance parameters from anywhere in the assessment process. This traceability provides insights into how the combined influences of key system architectural drivers affect the overall performance.

Risk Reduction

The FTI decision support tool suite within the DCDS environment will identify, assess, track, and develop mitigation steps to insure minimum technical, schedule, and cost impacts. One mitigation step is to obtain early and frequent customer feedback on the methodology and utility measures of effectiveness (MOEs).

FTI employs an "oversight" Technical Review Board (TRB) of technical and operational experts to periodically review the focus, direction and results of the research. Subject Matter Experts are included from the operations, training, and model simulation areas for their critical perspectives. FTI uses the experience of the TRB to assist in identifying early the "traps" that would cause false starts or dead ends in

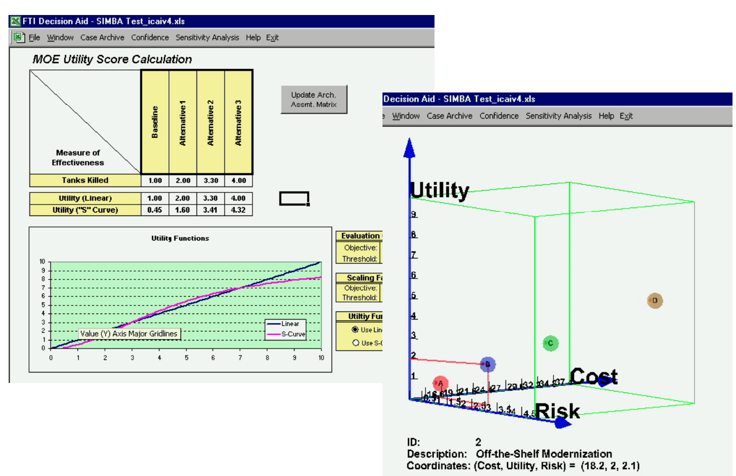

Figure 5: ***FTI's I-CAIV tool determines best value based on cost, risk, and utility derived from results of performance models***

the Responsive Space development effort. The TRB helps ensure the research results in an effective methodology/tool for evaluating financial returns on science and technology investments, which will benefit customers. Additionally, if necessary, FTI will, mitigate any possible external interface risks for modeling tools developed by establishing teaming agreements with other model developers.

Evaluating Affordability

The affordability evaluation process is intended to provide feedback to a continuing design process that will improve the performance of a design, through collaboration while ensuring it remains affordable.

As depicted in Figure 6, affordability is a combination of cost and performance. It can be viewed synonymously with best value. It does not necessarily imply the least costly solution to a technical problem. Instead, affordability emphasizes the technical solutions that provide the best overall value. This concept implies a balance among the traditional program variables of cost, schedule, and performance. What is new about current affordability initiative is the emphasis on life-cycle (or total ownership) costs.

An effective cost-estimating capability and affordability methodology flow (Figure 7) will help the Responsive Space designer/developer to quantify the investment, help refine the design trades with feedback on the cost of improved performance, and facilitate solutions to these typical acquisition / affordability problems:

- How does system cost vary as a function of key design parameters, risk, schedule, and supportability concepts?

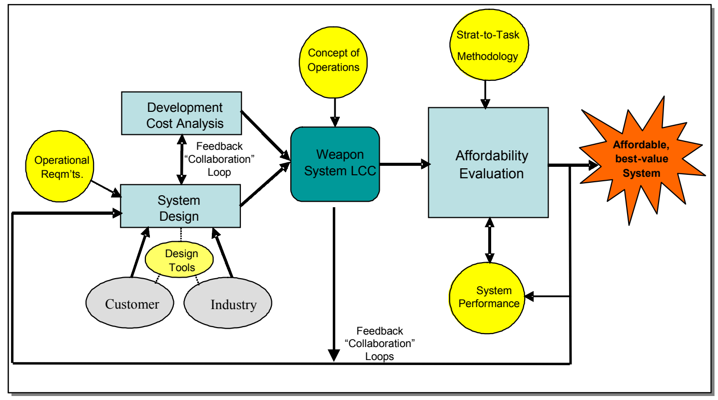

Figure 6: ***An effective best value system affordability estimation process.***

- What is the cost to operate the space system over its entire life?
- What is the ROI for the technology or system?
- How do different support concepts impact total system life-cycle costs and affordability?
- What are the cost, schedule, and risk impacts of transitioning new technologies into the design?

Evaluating ROI Utility

Return on investment (ROI) can be quantified. In the commercial sector, ROI is

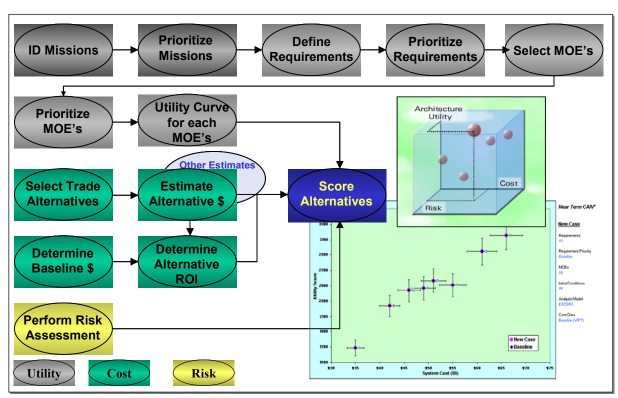

Figure 7: ***Affordability Methodology Flow***

usually a comparison of profit versus investment and is a measure of how long it takes to recoup the investment. In the defense arena, ROI must include performance capability. Although some projects, such as modifications or upgrades can be evaluated on cost (investment versus O&S savings), new projects, especially S&T ones that provide new or added capability need a ROI based on utility.

An example of using ROI utility to evaluate Responsive Space affordability was previously illustrated by Figure 5. The figure depicts the I-CAIV scoring process used during simulation-based acquisition experiment to evaluate several architectural alternatives in a given scenario. One of the major elements of the research methodology is the development of the ROI utility.

CONCLUSIONS

A Decision Support Tool Suite integrated with a Distributed Collaborative Decision Support environment will create a revolution in Responsive Space design capabilities, with design considerations and data available, in real-time from many relevant sources. The tools and DCDS methodology will enable technologists to calculate a credible life-cycle cost and savings estimate for new technologies. The analysts can also conduct sensitivity analyses on various technology parameters to identify key cost "drivers" for the space technologies. The effective use of the tools within each customer trade space environment will enable cost and system affordability to be a constant and key consideration during the decision process for new space program technologies. The resultant integrated, DCDS environment of the cost-analysis community's accepted tools will enable space managers, engineers and scientists to have an important and quick insight into cost and potential return-on-investment for their technologies. This research will have great potential for effective use in any industry and the commercial environment in addition to DoD applications.

RELATED RESEARCH

Aeronautical Systems Center. "Analysis of Jet Engine Modification Alternatives." Feb 02–Ongoing.

AFRL. "Integrated Cost Estimating" and "Collaborative Engineering Environment (Phase I, Phase II Effort)." Mar 98 – Apr 02.

AFRL-Ball Aerospace. "Collaborative Enterprise Environment/ Dual Use Applications Program." Sep 97 - Sep 00.

Air Force Studies and Analyses Agency. "Program Dynamics Model." May 00 – May 02.

DARPA-AFRL. "Dual Use Application Program's Collaborative Engineering and Virtual Prototyping." $4M research, and $5M in prior SBIR work.

Defense Advanced Research Projects Agency. "Simulation Based Design." $40M investment.

Lockheed Martin. "Integrated System Command and Control (ISC2)." Oct 00 – Ongoing.