Within ARDA’s GI2Vis program, we developed a unique framework for the definition of decision support requirements for intelligence analysis tools. This framework, based on a first-of-a-kind integration of a model of inferential analysis and principles for designing effective human-computer teams from Cognitive Systems Engineering, has defined the essential support functions to be provided to the intelligence analyst(s). This model has proven to be extremely useful in assessing the support provided by a large set of visualization tools. This assessment has identified clusters of support functions that are addressed by many tools as well as key missing support functions. In this way, the Support Function Model has been used to identify gaps in the support function coverage of existing tools. This can serve as a valuable focusing mechanism for future design and development efforts. In addition, we would like to see its use as a mechanism to enhance cross-discussions among research teams involved in Cognitive Task Analysis efforts within the Intelligence Community. Having others transform their analytic results into this framework would provide the mechanism for expansion of this model to become a more robust tool and have an even greater impact on the Intelligence Community.

The Need
Intelligence analysts are faced with one of the most formidable data overload problems in our world today. These include counter-terror, counter-insurgency, counter-drug, strategic assessment, etc. As a result, they need every advantage they can get. However, simply providing the analysts with additional data is not sufficient to make the necessary breakthroughs in intelligence analysis. Most technological advantages, however, are on the "front end" – providing greater data gathering techniques to help assure that critical events are not missed.

The challenge is to design effective collaborative decision support tools for the intelligence analysis process. Considerable support needs to be provided for (a) the cognitive activities involved in abductive inferential analysis which is at the heart of intelligence analysis and (b) the collaboration activities involved in interacting with advanced automation in order to build effective joint cognitive systems (analyst(s) paired with automation tools to form an effective team).

Our Solution
Our proposed solution is a "Support Function Model" for Intelligence Analysis. This model is a cross-product of two inter-related applications of Cognitive Systems Engineering (CSE) to the challenge of designing decision support tools for the Intelligence Community (IC).

First, as indicated in Figure 1, it is a model of interacting functions that comprise inferential analysis. This intelligence analysis model is an iterative broadening / narrowing convergent process. This model is a ‘closed loop’ model of interacting functions (not a sequence of tasks) based on the primary functions of Down Collect, Conflict and Corroboration, and Hypothesis Exploration. These functions were identified as the cornerstones for effective intelligence analysis. Down Collect is focused on the extraction of an essential, representative, ‘on analysis’ sample from available data. Conflict and Collaboration is focused on the construction of accurate interpretations of the findings from the Down Collect process. Hypothesis Exploration is focused on the construction of coherent stories/hypotheses to explain the interpretations of the findings. All of these functions are 'narrowing' functions, in that they focus on a reduction of the problem toward 'the answer'.

In addition, there are 'broadening' functions that serve as cross-checks against the predominantly narrowing aspects of the primary functions. The natural tensions between broadening (to fully explore all options) and narrowing (to a finding) at each 'edge' (between the three primary functions) defines success or failure in reaching the analytical conclusion. Convergence, then, is a stable balance between broadening and narrowing while premature closure (a typical source of analytical error) is a lack of broadening.

Our hypothesis is that in order to be effective, support must be provided for explicit control of this convergent, broadening / narrowing process.

Second, as indicated in Figure 2, our Support Function Model is a transformation of CSE support requirements overlaid into the specific context of the interacting functions that comprise inferential analysis. This is a significant breakthrough in the application of lessons learned from many years of research on human interaction with complex systems. This is manifest in a system design goal decomposition model of support requirements for these functions. The primary functions jointly support the top-level goal of "cooperative, multi-
human-multi-machine coordinated intelligence analysis". Within each of the primary functions (Down Collect; Conflict and Corroboration; Hypothesis Exploration) is a specific set of support functions for accomplishing the primary function.

At the 'edges' between these functions is a set of requirements that support the interaction of a coupling / transition of the primary functions. These include:

- B1 – Down Collect/Conflict & Collaboration broadening is focused on revising the down-collect process based on interpretations from the Conflict and Collaboration process as well as generating new interpretations from revised Down Collect results.
- B2 – Conflict and Collaboration/Hypothesis Exploration broadening is focused on revising the interpretations based on alternative hypotheses under consideration as well as generating new hypotheses based on the interpretations.
- B3 – Hypothesis Exploration/Down Collect broadening is focused on revising the down collect process based on alternative hypotheses under consideration as well as on generating new alternative hypotheses based on revised Down Collect results.

One of the key differentiators for our effort is the incorporation of a unique set of generic CSE Support Requirements for achieving highly effective human plus decision support system teams that we design into our systems. In our extensive work on designing effective decision support systems in a variety of work domains, five basic requirements have emerged and were integrated into our support function model of intelligence analysis in our GI2Vis effort. They are:

**Observability** – the ability to form insights into a process (either a process in the work domain or in the automation), based on feedback received. Observability overcomes the 'keyhole' effect and allows the practitioner to see sequences and evolution over time, future activities and contingencies, and the patterns and relationships in a process.

**Directability** – the ability to direct/redirect resources, activities, and priorities as situations change and escalate. Directability allows the practitioner to effectively control the processes in response to (or in anticipation of) changes in the environment.

**Teamwork with agents** – the ability to coordinate and synchronize activity across agents. This defines the type of coordination (e.g., seeding, reminding, critiquing) between agents. Teamwork with agents allows the practitioner to effectively re-direct agent resources as situations change.

**Directed attention** – the ability to re-orient focus in a changing world. This includes issues like tracking others' focus of attention and their interruptability. Directed attention allows the human-system team to work in a coordinated manner, resulting in increased effectiveness.

**Resilience** – the ability to anticipate and adapt to surprise and error. This includes issues such as failure-sensitive strategies, exploring outside the current boundaries or priorities,
overcoming the brittleness of automation, and maintaining peripheral awareness to maintain flexibility.

These generic support requirements apply to cognitive work by any cognitive agent or any set of cognitive agents, including teams of people and machine agents. There is a significant amount of design advantage gained by integrating these CSE Support Requirements into the Intelligence Analysis Support Function Model (Billings and Woods, 1994; Dekker and Woods, 1999; Christoffersen and Woods, 2002).

The critical aspects of our Support Function Model include the following:

- The overall structure of the Support Function Model is based on the model of inferential analysis. That is, the nature of the specific nodes in the model follows the convergent broadening / narrowing model.
- The relationships within the model are based on a system goal – sub-goal decomposition approach. That is, goal nodes at the top level are decomposed into the sub-goals required to achieve the parent goal.
- The specific nodes are an instantiation of the CSE Support Requirements in the context of the model of inferential analysis. That is, the support functions specify the interaction between the CSE Support Requirements and the particular broadening / narrowing function.

**Walkthrough of a Specific Example**

As indicated in the following figure (a sample decomposition of a portion of the "Down Collect" function), specific sub-goals are a result of applying Cognitive Systems Engineering Support Requirements (citation to other paper) within the context of the model of inferential analysis. For example, the "determination of relevance" is one of the sub-goals for the primary goal within Down Collect, "extraction of essential, representative, "on analysis" sample from available data". Within this node, one of the sub-goals is "observability of the relevance determination process". This is an instantiation of the "observability" requirement. In addition, "determination of relevance with automation as an amplifier of human interpretation" is an instantiation of the "teamwork with agents" requirements.

This is a critical and powerful aspect of this Support Function Model. Requirements arise from two fundamentally different but complementary dimensions. First, there is the decomposition of system goals into sub-goals based on the framework defined by the convergent broadening / narrowing model of intelligence analysis. Second, that system goal decomposition model is augmented with requirements specific to a joint cognitive system perspective. This integration results in a totally unique set of system requirements that define the decision support requirements for inferential analysis as well as support for effective human-automation interaction.

**Benefits**

The benefits of our solution include the following:

First, our Support Function Model provides a common framework for communication about requirements for intelligence decision support tools. Since it is a transformation and synthesis of results from a number of cognitive task analysis efforts, it is designed to provide the necessary common ground for constructive dialog about the support needs for the intelligence analysis domain.

Second, our Support Function Model can (and already has) serve as a mechanism to evaluate the decision support capabilities of intelligence analysis tools. Given our premise that, in order to be effective, tools must support the variety of analytic activities as well as support joint cognition, this model defines the objectives for analytic tools to strive to achieve. In this manner, it has been used as the primary means for assessing a set of analytic tools with respect to the degree of decision support provided. While any individual tool would not be expected to satisfy the entire set of requirements, it should satisfy a coherent subset of requirements and, taken together, a suite of analytic tools should provide broad coordinated coverage.
Our Support Function Model provides a unique, first-of-a-kind integration of Cognitive Systems Engineering support requirements into a model of decision-making in intelligence analysis. In this manner, it has specified unique decision support requirements to be satisfied in order to truly provide effective joint cognitive systems. The principles at the core of these requirements are, in general, lacking in most tool suites. They define requirements that are outside of the traditional focus area of tool developers because they focus on decision needs, not the technological emphasis of most tools. However, providing explicit features for these requirements has been shown to provide significant increases in the overall effectiveness of the joint cognitive team.

In addition, the Support Function Model has been used to identify gaps in the support function coverage of existing tools. This was accomplished by referencing a large sample of visualization tools onto the Support Function Model. This can provide a valuable focusing mechanism for future design and development efforts. As an example, we identified the lack of support for managing the evolution of multiple hypotheses as a critical need for the intelligence community.

Next Steps
We are working on extending and refining the Support Function Model to increase its usefulness in the areas described above. To accomplish this, we are validating the initial model against sample scenarios from the operational intelligence community. We are using one tactical and one strategic scenario in this capacity. As an integral part of the development of our Support Function Model, we employed a Subject Matter Expert from the intelligence community to provide operational insights into our concept. While this validated the concept as operationally sound and technically focused in the right direction, the next step in validating the concept is to collect a set of scenarios and define relationships between events in the scenarios and concepts in the Support Function Model. These relationships will provide insights into the validity of the concepts in the model as well as concepts that need to be added to the model. In addition, this will define dynamic, temporal relationships between concepts in the model that may identify necessary modifications.

Conclusions and Call to Action
In this effort, we have developed a unique framework for the definition of decision support requirements for intelligence tools. This framework, based on a first-of-a-kind integration of a model of inferential analysis and principles for designing effective computer team members, has defined the essential support functions to be provided to the intelligence analyst(s). This model has proven to be extremely useful in assessing the support provided by a large set of visualization tools. This assessment has identified clusters of support functions that are addressed by many tools as well as key missing support functions in need of tool development.

In addition, we would like to see its use as a mechanism to enhance cross-discussions among research teams involved in Cognitive Analysis efforts within the Intelligence Community. Having others transform their analytic results into this framework would provide the mechanism for expansion of this model to become a more robust tool and have an even
greater impact on the Intelligence Community. Our support function model has undergone initial vetting by Subject Matter Experts, but we intend to continue this validation and refinement of the model in order to extend its robustness and completeness in defining the support function space to be addressed by intelligence analysis tools. The intent is not to create one 'right' model, but a useful framework that others can modify and extend to suit the particular aspects of their focus area.

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