DFIG Level 5 (User Refinement) issues supporting Situational Assessment Reasoning

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Abstract –*Subsequent revisions to the JDL model modified definitions for model usefulness that stressed differentiation between fusion (estimation) and sensor management (control). Two diverging groups include one pressing for fusion automation (JDL revisions) and one advocating the role of the user (User-Fusion model). The center of debate is real-world delivery of fusion systems which requires presenting information fusion results for knowledge representation (fusion estimation) and knowledge reasoning (control management). The purpose of the paper is to highlight the need of Users, with individual differences, facilitated by knowledge representations to reason about user situational awareness (SA). This position paper highlights:*

(1) Addressing the user in system management / control
(2) Assessing information quality (metrics) to support SA
(3) Evaluating Fusion systems to deliver user info needs,
(4) Planning knowledge delivery for dynamic updating
(5) Designing SA interfaces to support user reasoning

Keywords: *Fusion, Situational Assessment, Interface Design, Knowledge Representation, User Refinement*

1   Introduction

Applications for multisensor information fusion (IF) require insightful analysis of how these systems will be deployed and utilized. Increasingly complex, dynamically changing scenarios arise, requiring more intelligent and efficient reasoning strategies. Integral to information reasoning is decision making (DM) which requires pragmatic knowledge representation for user interaction. [1] Many IF strategies are embedded within systems; however the user-IF system must be rigorously evaluated by a standardized method over various locations, changing targets, differing sensor modalities, and IF algorithms. [2]

The current fusion model supporting the evaluation and deployment of sensor fusion systems is the User-Fusion model as shown in **Figure 1**. The key for Situational Awareness (SA) the user's *mental model*. [3] The mental model is the representation of the world as aggregated through the data gathering, IF design, and the user's perception of the social, political, and military situations.
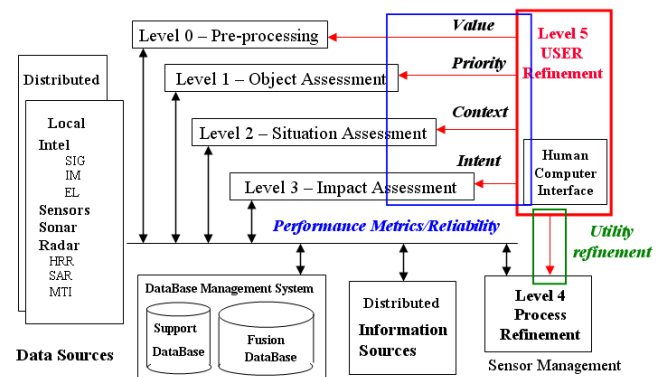

Figure 1. User Fusion model.

A useful model is one which represents a real world system instantiation. The IF community has railed behind the JDL process model with its revisions and developments. [4-6] The current team [1] (now called the Data Fusion Information Group) assessed the current model, shown in **Figure 2**. Note, SA is a user task (versus an algorithm) that utilizes results from the machine.
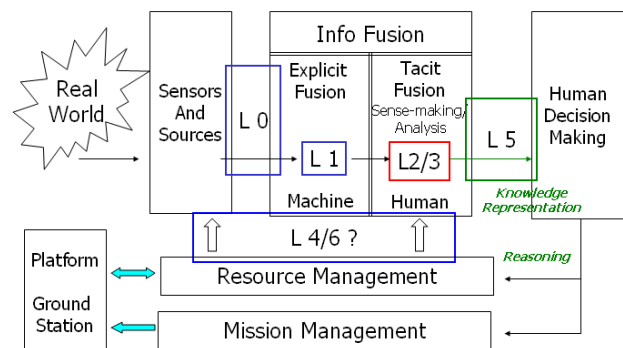

Figure 2. DFIG 2004 model.

In this model[2], the goal was to separate the information fusion and management functions [6]. Management functions are divided into sensor control, platform placement, and user selection to meet mission objectives.

Level 2 (SA) includes tacit functions which are inferred from level 1 explicit representations of object assessment. Since the unobserved aspects of the SA problem can not be processed by a computer, user knowledge and reasoning is necessary. The current definitions, based on the revised JDL fusion model [**5**], include:

Level 0 – Data Assessment: estimation and prediction of signal/object observable states on the basis of pixel/signal level data association (e.g. information systems collections);

Level 1 – Object Assessment: estimation and prediction of entity states on the basis of data association, continuous state estimation and discrete state estimation (e.g. data processing);

Level 2 – Situation Assessment: estimation and prediction of relations among entities, to include force structure and force relations, communications, etc. (e.g. information processing);

Level 3 – Impact Assessment: estimation and prediction of effects on situations of planned or estimated actions by the participants; to include interactions between action plans of multiple players (e.g. assessing threat actions to planned actions and mission requirements, performance evaluation);

Level 4 – Process Refinement (an element of Resource Management): adaptive data acquisition and processing to support sensing objectives (e.g. sensor management and information systems dissemination, command/control).

Level 5 – User Refinement (an element of Knowledge Management): adaptive determination of who queries information and who has access to information (e.g. information operations) and adaptive data retrieved and displayed to support cognitive decision making and actions (e.g. human computer interface).

Level 6 – Mission Management (an element of Platform Management): adaptive determination of spatial-temporal control of assets (e.g. airspace operations) and route planning and goal determination to support team decision making and actions (e.g. theater operations) over social, economic, and political constraints.

The IF community has had a numerous papers associated with a data-level, bottom-up, level 1 (object refinement) including target tracking and ID. Some efforts explored level 1 aggregation for SA.[**7-8**] If the fusion approach was attacked top-down, then the community would start IF designs by asking the customer what they need. The customer is the IF system (IFS) user, whether it be the business person, analyst, or commander. If we ask the customers what they want, they would most likely ask for something that affords reasoning and DM, given their perceptual limitations [**9**]. Different situations will drive different needs, however, the situation is never known *a priori*. The are general constructs of the initial guess of the situation, however, in the real world, not all the situational operating conditions will be known. To combat the difficulty with embedding known / unknown *a priori* situational information, the user has *a priori* notions that supersede the current situation which can augment the un-modeled situation. In the end, IF system designs are based on user, not a machine or the situation.

Management includes business, social, and economic affects on the fusion design. Business includes managing people, processes, and products. Likewise IF is managing people, sensors, and data. The ability to develop SA of the physical, social, economic, military, and political environment would entail user reasoning about the data to infer information. The current control needs are user, sensor, and mission management. For example, if sensors are on platforms, then the highest ranking official determines who gets control of the assets (which is not under automatic control). Once treaties, air space, insurance policies, and other documentation is in place, the automatic controller (e.g. sensor), can be turned on.

1.1 Active Reasoning

A user (or IF designer) is forced to address situational constraints. Once an IF design is in place, the user can act in a variety ways: *monitoring* a situation in an active or passive role or *planning* by either reacting to new data or proactive control over the fusion system. Thus, the user has to decide in which way to convey information: such as monitor (active versus passive) or planner (reactive vs. proactive). When a user interacts with an IF system, it is important to support knowledge reasoning. The user has the abilities to quickly reduce the search space of the fusion system and hence, guide the fusion system process. Such an example is when the user cues a fusion system to look for an object in a certain area of the earth. The user can interact with a fusion system, such as predict target motions, react to new information, and proactively cue the IF to search for things that are assumed to exist. If user does not take an active role in monitoring an IF system, then the IFS is prone to ignorance. The user roles are:

Passive – waiting - non-thought (not necessarily active)
Reactive – immediate, using available observations
Predictive – projective - analytical assessment
Proactive – anticipatory – practical, active reasoning

1.2 User Refinement in IF Designs

The user's roles are based actions provided to the user. The actions are a result of the fusion system interface and should be designed into future fusion systems so as to accomplish the ontological goals. We define user refinement (UR) operations as a function of responsibilities. One construct to determine how the user interacts with the fusion system is what management mode the user performs. Table 1 shows the different use management modes which varies from a passive to an active role. [**10**]

SA has many meanings that could be conveyed form the definition. One of the key issues of SA (defined in the next section), is that the IF must map to the **User's perceptual needs** as per spatial awareness [**11**], neurophysiological [**12**], perceptual [**13**], and psychological [**14**] and those that combine perceptual and cognitive [**15-17**]. If the display/delivery of information is not consistent with the user expectations, all is lost. The

machine can not reason, as Brooks stated in "Elephant's don't play chess." [18] While the fusion community still has yet to realize that no matter what the application, the machine can not deal with unexpected situations. [19] For this reason, there are numerous implications for incorporating the user in the design process, gathering user needs, and providing user actions in the IF process.

Users are not Gaussian processors, yet they do hypothesis confirmation. In hypothesis reasoning, we can never prove the null, but we can disprove the alternative

capabilities. A user fuses data and information over time and space and acts through their world reference (mental) model – whether it be in the head or with graphical displays, tools, and techniques. [22] The IFS is just an extension of the user's sensing capabilities. Thus, effective and efficient interactions between the fusion system and the user, the sum (as defined in the metrics) should be greater than the separate parts.

The reason why user will do better than a machine is that they are able to reason about the situation, assess what

Table 1 – Continuum of system control and management for operators

Management Mode	Automation Functions	User Functions	Level of Automation	Level of Involvement
Autonomous Operation*	Complete autonomous operation System may / may not be bypassed	User has no active role, not usually informed Monitors fault detection	Very High	Very Low
Management by Exception*	Automatic Decision Selection System informs user and monitors responses	User is informed of system intent; May intervene by reverting to lower level.	High	Low
Management by Consent*	Decisions are made by automation. User must assent to decisions before implemented	User consent to decisions User may select alternatives / decision option	Medium	Some
Management by Delegation*	Automation takes action only as directed by user Level of assistance is selectable	User specifies strategy and may specify level of computer authority	Some	Medium
Management by Interaction	Automation cues operator to key attributes and fusion incoming data	Directs, controls, plans, and coordinates fusion of information for action	High	High
Assisted Control*	Control automation is not available Database information is available	Direct authority over all decisions Voice control and coordination	Low	High
Unassisted Control *	Complete computer failure No assistance is available	Procedural control, Unaided decision-making,	Very Low	Very High

* Adapted from C. Billings, *Aviation Automation, The search for the Human-Centered Approach*, 1997, Lawrence Erlbaum.

hypothesis. Level 5 is intended to address the cognitive SA which includes knowledge representation and reasoning methods. The user defines a fusion system, for without a user, there is no need to provide fusion of multi-sensory data. The user has a defined role with objectives and missions. The IF community has typically overlooked the role of the user by designing them out of the system. However, through years of continuing debate, I postulate these impacts of the user on the fusion system design:

Level	Role
0	Determines what and how much data *value* to collect
1	Determines the target *priority* and where to look
2	Understands scenario *context* and user role
3	Defines what is a threat and adversarial *intent*
4	Determines which sensors to deploy and activate Assesses the *utility* of information
5	Designs user interface controls (shown in Figure 1).

Likewise – there are issues of determining which systems to buy, what sensors to deploy, what political, military, social, and economic arenas IF systems are to be researched, developed, implemented, and deployed.

Kokar [20] and others stress ontological and linguistic [21] questions concerning the user interaction with a fusion system such as semantics, efficacy, and spatio-temporal queries. Developing a framework for user refinement (UR) requires **semantics** or **interface actions** that allow the system to coordinate with the user. Such an example is a query system in which the user seeks questions and the system translates these requests into actionable items. An operational system must satisfy the user's functional needs and extend their sensory

are the likely routes of a target, bring in contextual information to reason over the uncertainty. [23] As the number of targets and speed increases, a user will get overloaded, and thus, some of the routine calculations and data processing can be offloaded to a computer. Hence, the session title "Knowledge Representation and Reasoning methods in SA" is at the critical crossroads of determining whether IF will succeed as a system, or die in the literature algorithmic applications.

The rest of this paper is organized around 5 key issues associated with supporting knowledge representation and reasoning for Situation Assessment. Section 2 lists SA models, and Section 3 advocates IF quality of service metrics-critical requirements for effective decision making. Section 4 discusses dynamic decision making: reactive, proactive, and preventive and Section 5 details knowledge representation of interface standards. Section 6 draws conclusions.

2   Situational Assessment

Situation assessment is an important concept of how people become aware of things happening in their environment. Situational Awareness (SA) can be defined as "keeping track or prioritized significant events and the condition's in one's environment". Level 2 SA is the estimation and prediction of relations among entities, to include force structure and relations, communications, etc. which requires adequate user inputs to define entities. Designing complex and often-distributed decision support systems—which process data into information, information into decisions, decisions into plans, and plans into actions—requires an understanding of both the fusion

processes and the DM processes. Important aspects of fusion include timeliness, mitigation of uncertainty, and output quality. DM contexts, requirements, and constraints add to the overall system constraints. Standardized metrics for evaluating the success of deployed and proposed systems must map to these constraints and other essential requirements to scores.

2.1 Situational Awareness Model

The Human in the Loop (HIL) of a semi-automated system must be given adequate SA. According to Endsley, "SA is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." [**24-26**]. This now-classic model, shown in **Figure 3**, translates into 3 levels:

- Level 1 SA - *Perception* of environment elements.
- Level 2 SA - *Comprehension* of the current situation
- Level 3 SA - *Projection* of future states

Figure 3. Endsley's Situation Awareness Model

Dynamic systems operators use their SA in determining their actions. To optimize DM, the SA provided by a IFS should be as precise as possible as to the objects in the environment (Level 1 SA). A SA approach should present a fused representation of the data (Level 2 SA) and provide support for the operator's projection needs (Level 3 SA) in order to facilitate operator's goals. From the SA model presented in Figure 3, *workload* [**27**] is a key component of the model that affects not only SA, but also the user decision and reaction time.

2.2 Recognition Primed Decision Making Model

To understand how the human uses the situation context to refine the SA, we use the recognition primed decision making (RPD) model [**28**], shown in **Figure 4**. The RPD model develops the user decision making capability based on the current situation and past experience. The RPD model shows the goals of the user and the cues that are important. From the IFS, both the user and the IFS algorithm can cue each other to determine data needs. The user can cue the IFS by either selecting the data of interest or choosing the sensor collection information. For the case of the user, the IFS algorithm can focus the attention

of the target type based on the targets of interest. The RPD model allows us to capture the *reduction in reaction time* and *increase in accuracy* for the cases in which the user cues the data FS (DFS) and when the IFS cues the human. Additionally, the RPD model can afford confidence metrics. To address the reaction time, we need to model the user's course of actions.

Figure 4. RPD model for SA.

As another example, the Fusion SA Model components [**29-30**], shown in **Figure 5**, developed by Kettani and Roy, show the various *information needs* to provide the user with an appropriate SA. To develop the SA model further, we note that the user must be primed for situations to be able to operate faster, more effectively and have metrics for SA assessment.

Figure 5. Fusion Situation Awareness Model

3 SA Metrics

Standardized performance and quality of service (QoS) metrics are *sine qua non* for evaluating every stage of data processing and subsystem hand-off of data and state information. Without metrics, proper scientific evaluation method cannot proceed across myriad and disparate proposed systems having high complexity and criticality. A chief evaluation aim regarding any system is

the ongoing facilitation of adequate situation awareness (SA). SA is not automatically guaranteed for the operator relying on new fused hybrid sensor systems. Even though these seem to promise much desired increases in capacity, data acuity (sharpened resolution, presumably resolving more information from noise), and timeliness among the QoS metrics, the human cognitive process capacity is a bottleneck in overall process operation. The detriment thus posed to SA maintenance occurs at the *perception* level of SA, Level 1 in the most frequent characterization. Detriments at this level account for 77% of SA related errors [27], as well as indirectly affecting DM acuity at levels 2 and 3, called *comprehension* and *projection*.

Furthermore, IF depends not only upon individuals making decisions, or single subsystems generating analyses. Rather, team communication and team-based decision making have always been integral to complex operations, whether civilian or military, tactical or strategic, municipal, federal, or inter-governmental. Team communication takes many forms across operational environments and changes dynamically with new situations. Communication and DM can be joint, allocated, shared, etc., and this requires the maintenance of *team SA*.

3.1 Information Timeliness is Paramount for SA

Because every stage of IF DM has inherent delays—in receiving sensor information, in presenting a fused information to the user, and in the information user's processing capacity—the entire system operation must be evaluated, in addition to the unit testing of fusion components or DM subsystems. The bottom-level component in the human-system operation is comprised of data from the sensors. "Data fusion" is a term used to refer to the bottom-level, data-driven fusion, whereas "information fusion" refers to processing of already-fused data, such as from primary sensors or sources, into meaningful and preferably relevant information to another part of the system, human or not.

Cognitive processes, human or machine equivalent 'smart' algorithms, require non-trivial amounts of time to reach a decision, at both the individual and team levels. This applies, analogously, to both the individual component and inter-component/subsystem levels of the machine-side DM. DM duration will either *run shorter* than the inter-arrival time interval of data generated by sensors, leading to starvation of the DM process, or else DM duration will *run longer* than the interval between new data arrivals. Both cases create situations prone to errors, whether the DM operator is human or machine. The former case has consequences of starving the human's cognitive flow, including vigilance waning as attention wanders, and the dissipation or overwriting of information chunks, held in short term memory, which could have been relevant to later-arriving data. In the latter case, data arrives while the information processing, or DM process, operator is occupied, so this data often "balks" out of the system without being used by that operator. This occurs

when systems are not adequately designed to hold in reserve the excess inputs to an overburdened process. These excess inputs balk out of the system if there is no buffer in which to queue these, or if the buffer is so small as to overwrite data. The operator and team must be able to access quality information in various ways over a timely manner. Therefore, beyond the already-complex science of data fusion, information processing and analysis systems must not only queue and index that fused data, but built upon models of the actual work and DM that occurs at each stage in real operational scenarios.

3.2 Sensor fusion evaluation

As computers increase in processing, there are ways to correctly design IF systems and incorrect ways. The incorrect way is to fully automate a system in which the user has no role. The **correct** way is to design in the role of the operator at the inception of the IF design. Fusionists are aware of many techniques, such as Level 1 target identification and tracking methods, however, these techniques only support the user, they do not replace the user. In the case of target identification, a user typically does better for a low number of images. However, as the number of collected images increases, and/or throughput, a user does not have the time to process all the images. True, you could hire more people and meet demand; however, team dynamics plays a role.

Dynamic DM requires: (1) SA, (2) dynamic responsiveness to changing conditions, and (3) continual evaluation to meet throughput and latency requirements. These three factors are instantiated by a IF system, an interactive display to allow the user to make decisions, and metrics for replanning and sensor management.[31] To afford interactions between future IF designs and users *information needs*, metrics are required. The metrics chosen include timeliness, accuracy, throughput, confidence, and cost. These metrics are similar to the standard QoS metrics in communication theory and human factors literature, as shown in Table 1. [1]

Table 2: Metrics for various Disciplines.

COMM	Human Factors	Info Fusion	ATR/ID	TRACK
Delay	Reaction Time	**Timeliness**	Acquisition /Run Time	Update Rate
Probability of Error	Confidence	**Confidence**	Prob. (Hit), Prob. (FA)	Prob. of Detection
Delay Variation	Attention	**Accuracy**	Positional Accuracy	Covariance
Throughput	Workload	**Throughput**	No. Images	No. Targets
Cost	Cost	**Cost**	Collection platforms	No. Assets

In addition to the metrics that establish the core quality (reliability/integrity) of information, there are issues surrounding information security and parsimony.

Evidence of performance measure precision may be reflected by *content validity* (whether the measure

adequately measures the various facets of the target construct), *construct validity* (how well the measured construct relates to other well-established measures of the same underlying construct) or *criterion-related validity* (whether measures correlate with performance on some criterion task). The validity of IF metrics need to be verified in an operational setting.

4   Dynamic Decision Making

In previous papers we addressed issues of **trust**, **workload**, and **attention** in SA. [**32**] The key is to understand how the user reasons for action based on IF results. Without user inputs, the fusion system refinement is based only on the data received. The roles and behaviors that the user can play in the "User refinement" (UR) of *rely, consult, neglect* and *interact* to support UR functions of *planning, organizing, coordinating, decision* and *action*. [**33**]

4.1   The Skills-Rules-knowledge Hierarchy

There are many ways to address the user's roles in IF design. The user fuses many sets of modalities to gain an understanding of SA. Likewise, it is also important to develop metrics for the interactions to enhance the users abilities in a defined role or task. One way to understand how a user operates is to address the actions performed by the user. The basic actions are *automatic* (e.g. muscle movement). Additionally, the user *associates* past experiences to current expectations, such as identify targets from an image which includes eye-arm movements. Intelligent actions includes the *cognitive* functions of reasoning and understanding. Rasmussen developed these ideas by mapping behaviors into decision actions including skills, rules, and knowledge through a means-end decomposition. An abstraction/decomposition delineates the operator processes and rules.

In Rasmussen's model [**14**], user goals are determined from the decision desired. To achieve the correct goal, planning of actions and situation identification is performed at the *knowledge* level. Once a situation or task is learned, *rules* can be instantiated as to the recognition of features to be associated from one situation to the next. Such a case is when a user is proactive to receive data inputs for pre-established rules of behavior. One the rules are in place, the user can utilize *automatic* actions to signal and data inputs to allow for faster response time performance. The depiction of the Rasmussen's [**14**] levels are shown in Table 3.

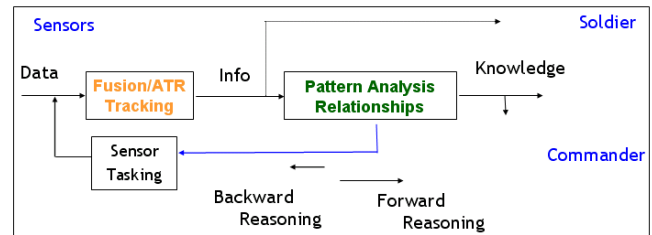**Table 3**: User Behaviors mapped to actions.

Behavior	Representation of Problem Space
Knowledge-Based	Mental model; explicit representation of relational structures; part-whole, means-end, causal, generic, episodic, etc. relation
Rule-Based	Implicit in terms of cue-action mapping; black-box action-response models
Skill-Based	Internal, dynamic model representing the environment and the body in real time

4.2 DM Modes: Reactive, Proactive, Preventive

When tasked with an SA analysis, a user can respond by one of three manners, broadly: reactive, proactive or preventive, as shown in **Figure 6**. In a ***Reactive mode***, the user makes a rapid detection and minimizes damage or repeat offense. An IFS would gather information from a sensor grid detection of in-situ threats and is ready to act. In this model, the system interprets and alerts users to *immediate threats*. The individual user selects the immediate appropriate response (in seconds) with aid of sensor warnings of non-lethal or lethal threats.

In the ***Proactive mode***, the user utilizes sensor data to anticipate, detect, and capture needed information prior to an event. In this case, a sensor grid provides surveillance based on prior intelligence and predicted target movements. A Multi-INT sensor system could detect and interpret anomalous behavior and alert an operator to *anticipated threats* in minutes. Additionally, the directed sensor mesh tracks individuals back to dwellings and meeting places, where troops respond quickly and capture the insurgents, weapons, or useful intelligence.

Figure 6. Reasoning in proactive strategies

The mode that captures the entire force over a period of time (i.e. an hour) is the ***Preventive Mode***. To prevent *potential threats* or actions, we would (a) increase insurgent risk (i.e. arrested after being detected), (b) increase effort (i.e. make it difficult to act), and (c) lower payoff of action (i.e. reduce the explosive damage). The proactive mode includes an Intel database to track events before they reach deployment.

The integration of decision modes to perceptual views is shown in **Figure 7**. The differing displays for the foot soldier or command center would correlate with the decision making mode of interest. For the reactive mode, the user would want an actual location of the *immediate threats* on a physical map. For the *anticipated threats*, the user would want the predicted locations of the adversary and the range of possible actions. Finally, for the *potential threats*, the user could utilize behavior analysis displays that piece together aggregated information of group affiliations, equipment stores, and previous events to predict actions over time. These domain representations

were postulated by Waltz [**17**] as cognitive, symbolic and physical views that capture differing perceptual needs.
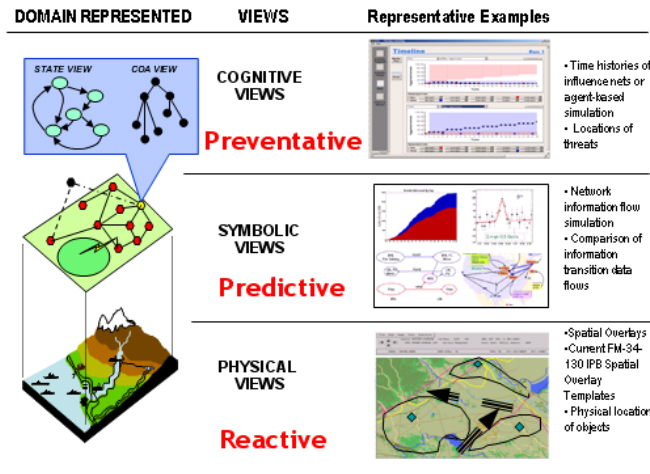

Figure 7. Categories of Analytic Views

4.3 Decision Making Cycle

Intelligent decision making employs many knowledge-based information fusion (KBIF) strategies such as neural networks, fuzzy logic, Bayesian networks, evolutionary computing, and expert systems. [**34**] Each KBIF strategy has different processing durations. Furthermore, each strategy utility differs in the extent to which it is constrained by the facility with which the user-fusion system may employ it. Observe-orient-decide-act (OODA) loops helps to model a DM user's planned, estimated, or predicted actions. Assessing susceptibilities and vulnerabilities to detected/estimated/predicted threat actions, in the context of planned actions, requires a concurrent timeliness assessment. Such assessment is required for adequate DM, yet is not easily attained.

This is similarly posed in the Endsley model of SA: the "*projection*" level 3 of SA maps to this assessment processing activity [**27**]. DM is most successful in the presence of high levels of projection SA, or high accuracy of vulnerability or adversarial action assessments. DM is enhanced by correctly anticipating effects and state changes that will result from potential actions. The nested nature of effects upon effects creates difficulty in making estimations within an OODA cycle. For instance, effects of own-force intended courses of action (COAs) are affected by the decision-making cycle time of the threat instigator and the ability to detect and recognize them. Three course of action (COA) processes to reduce the IFS search space: (1) Manage similar COA, (2) Plan related COA, (3) Select novel COA, shown in **Figure 8**.
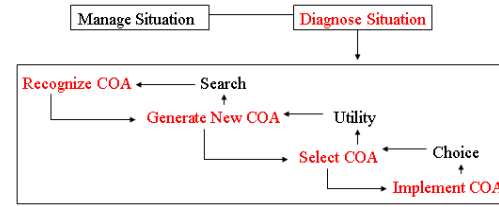

Figure 8. Course of Action model.

Given that proactive and preventive actions have a similar foundational set of requirements for communications, employment of new sensor technologies, and managing interactions in complex dynamic and surprising environments, evaluation starts with a construct of generally applicable metrics. Adding to the general framework, we must create an evaluation analysis that measures responsiveness to unanticipated states, since these are often the first signals of relevant SA threats. A comparative performance analysis, for future applications require intelligent reasoning, adequate IF knowledge representation, and process control in realistic environments. In this case, we are interested in the detection of events and state changes, and pragmatic ways to display the information.

5 Knowledge Representation

The key to the support user reasoning is designing a display that supports the users task and work roles.

5.1 SA to Support Task and Work Flow

A Task Analysis (TA) is the modeling of user actions in the context of achieving goals. In general, actions are analyzed to move from a current state to a goal state. Different approaches, based on actions include [**35**]:

- **Sequential Task Analysis** - includes organizing activities and describing them in terms of the perceptual, cognitive, and manual user behavior to show the man-machine activities.
- **Timeline Task Analysis** – is an approach that assesses temporal demands of the tasks or sequences of actions and compared time availability for task execution.
- **Hierarchical Task Analysis** - represents the relationships between what tasks and subtasks need to be done to meet operating goals.
- **Cognitive Task Analysis** - describes the cognitive skills and abilities needed to perform a task proficiently, rather than the specific physical activities carried out in performing the task CTA is used to analyze and understand task performance in complex real-world situations, especially those involving change, uncertainty, and time pressure.

5.2 Cognitive Work Analysis (CWA)

Level 2/3-5 issues require and understanding of the workload, time, and information availability. Workload and time can be addressed through a task analysis, however, user performance is a function of the task within the mission. A **Cognitive Work Analysis** [CWA] includes (1) what is the task the user is doing, (2) what is the order of operations, (2) does the interface support SA,

(3) what is the decomposition of required task and (4) what the human actually perceives. [**36**] The CWA looks at the tasks the human is performing and the understanding of how the tasks correlate with the information needs for intelligent actions. The five Stages of a CWA are (a) work domain, (b) control task, (c) strategy, (d) social-organizational, and (e) worker competency analysis. Vicente [**36**] shows that a CWA requires an understanding of the environment and the user capabilities. An evaluation CWA requires starting from the work domain and progressing through the fusion interface to the cognitive domain. Starting from the work domain, the user defines control tasks and strategies (i.e. utilizing the fusion information) to conduct the action. The user strategies, in the context of the situation require an understanding of the social and cognitive capabilities of the user. Social issues would include no-fly zones for target identification and tracking tasks and cognitive abilities includes the reaction time of the user to a new situation. User performance is a function of time and subjective mental workload requires answers to who, what, where, when, why, and how much time questions. Elements of the CWA process include, reading the fusion display, errors, sensory information and mental workload.

5.3 Display / Interface Design

The display interface is key to allowing the user to have control over the data collection and fusion processing. [**37, 38**] Without designing a display that matches the cognitive perception of the information, it is difficult for the user to reason over the fused result. While many papers and books address the interface issues (i.e. multimodal interfaces), it is of concern for the fusion community to address the cognitive user issues to ensure that the fusion system designed is to emulate the functional roles required of the fusion system, such as ontological relations and associations [**39**, **40**].

Once user IF requirements have been identified, good user interface design transforms these requirements to display elements and organizes them in a way that is compatible to how users perceive and utilize information based on the work context and use conditions. [**35**] The following items are some of the more familiar principles:

- *Consistency:* Interfaces should be consistent with experiences, conform to work conventions, and facilitate reasoning to minimize use errors in navigation, information retrieval, & action execution.
- *Visually pleasing composition:* Interface organization includes balance, symmetry, regularity, predictability, sequentially, economy, unity, proportion, simplicity, and groupings.
- *Grouping:* Gestalt principles provide six general ways to group screen elements spatially: principles of proximity, similarity, common region, connectedness, continuity, and closure.
- *Amount of information:* This should be calibrated to that required for the task. Too little information could result in important information that is hidden; too much information could result in confusion. Using Miller's principle that people

cannot retain more that 7±2 items in short-term memory, chunking data using this heuristic could provide the ability to add more relevant information on the screen as needed.
- *Meaningful ordering:* The ordering of elements and their organization should have meaning with respect to the task and information processing activities.
- *Distinctiveness:* Objects should be distinguishable from other objects and the background.
- *Focus and emphasis.* Salience of objects should reflect the relative importance of focus.

Usability Evaluation is a *user-centered, user-driven* method that defines the system as the connection between the application software and hardware. It focuses evaluations on whether the system delivers the right information in the appropriate way for users to complete their tasks. Typically there are nine usability areas considered when evaluating interface designs with users:

- *Terminology.* This refers to the labels, acronyms, and terms used in the application.
- *Workflow:* This refers to the natural sequence of tasks in using the application.
- *Navigation:* This refers to the methods used to navigate to various parts of the application.
- *Symbols:* This refers to symbols and icons used in the application to convey information and status.
- *Access:* This refers to the availability and ease of access of information and functions to the user.
- *Content:* This refers to the content of information available to the user.
- *Format:* This refers to the format in which the content is conveyed to the user.
- *Functionality* This refers to the specific functionality of the application and its usefulness to the user.
- *Organization:* This refers to the layout of the application screens.

The **usability criteria** typically used for evaluation are noted below for the areas above: [**35**]

- *Visual clarity:* This displayed information should be clear, well-organized, unambiguous, and easy to read to enable users to find required information, draw the user's attention to important information, and allow the user to see where information should be entered quickly and easily.
- *Consistency:* This dimension conveys that the way the system looks and works should be consistent at all times. Consistency reinforces user expectations by maintaining predictability across the interface.
- *Compatibility* This dimension corresponds to whether the interface conforms with existing user conventions and expectations. If the interface is familiar to users, it will be easier for them to navigate, understand, and interpret what they are looking at and what the system is doing.
- *Informative feedback.* Users should be given clear informative feedback on where they are, and what actions were taken, whether successful, and what should be taken.
- *Explicitness:* The way the system works and is structured should be clear to the user.
- *Appropriate functionality* The system should meet the user requirements and needs when carrying out tasks.

E. Blasch and S. Plano, "DFIG Level 5 (User Refinement) issues supporting Situational Assessment Reasoning", *Fusion 05*, July 2005.

- *Flexibility and control:* The interface should be sufficiently flexible in structure - the way information is presented and in terms of what the user can do, to suit the needs and requirements of all users, and to allow them to feel in control.
- *Error prevention and correction:* A system should be designed to minimize the possibility of user error, with built-in functions to detect when these errors. Users should be able to check their inputs and to correct potential error situations before inputs are processed.
- *User guidance and support:* Informative, easy-to-use, and relevant guidance should be provided to help the users understand and use the system.
- *System usability problems:* Problems associated with using the system should be minimized.

6   SUMMARY

The purpose of this paper was to provide some insight into user *information needs* for knowledge representation and cognitive reasoning. The DFIG requires user needs presentation to support effective and efficient proactive decision making. Ecological Interface Design (EID), with other methods – shown below, establishes effective interface designs. Integrating work environment elements (domain, activities, people and technology) with interface design elements (information requirements generation, interface design, and evaluation), can satisfy SA knowledge representation, analysis, and reasoning.

This paper discussed important IF issues, complementing Hall's [41], for SA reasoning and knowledge representation including (1) designing for users, (2) supporting dynamic decision making, and (3) interface guidelines to support user trust through IF quality of service metrics.

	WORK DOMAIN	ACTIVITIES
INFO Requirements	EID, Cognitive Work Analysis, SA Analysis, Contextual Inquiry	Task Analysis, Contextual Inquiry, Scenario-based Design, Participatory Design.
Interface DESIGN	EID User Interface Design Principles	Participatory Design, User Interface Design Principles
EVALUATION	Situation Awareness Analysis, Usability Evaluation	SA Analysis, Scenario-based Design, Participatory Design, Usability Evaluation

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