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Knowledge Engineering Experimentation Management System for Collaboration

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Abstract - This paper presents a methodology and system for the analysis of complex experiments currently utilized by the Department of Defense. Assessed are effectiveness and efficiency of systems interactions and affected intra- and inter-organizational processes. Methodology is derived from an operational experimentation analytics and management system designed to assess next-generation military e-services and infrastructure. A focus is the expansion of systems methodology beyond traditional transaction-oriented exchanges to include management layers for complex inter-organizational processes and mechanisms to accommodate sensitive company operations.

I. INTRODUCTION

A broad range of new technologies are being introduced to the military from the private sector and these are tested through large-scale and limited objective experiments. An enterprise information system (EIS) to manage the innovation process from introduction through experimentation to assessment was developed and is presented. Included are models for the analysis and experimentation management processes and illustrated examples of the implemented procedures as realized through the EIS. Objectives, management structures, experimentation and analysis processes, and final technology diffusion are presented as management forms and reports in the EIS.

The system is highly collaborative with security designed to support cooperative work. Management leads are responsible for information input, editing, and output such that day to day operations of the content, from innovation introduction to recommendations and diffusion, are distributed globally. Only a small team manages the database, information structure, and overall operations.

The system stresses not only engineering assessment of the base technology but also interfaces among the technologies in the "systems of systems" architecture common to the DoD. Of equal importance are the organizational structure(s) of the submitting organization and the management interface of personnel from very different specializations into a globally distributed team. This is managed through the EIS and its cooperative processes for distributed work.

Methodology establishes variables for analysis that include technical assessment of innovation capabilities along with frameworks to position the technologies within the strategic operational objectives that underlie the experiments.

II. MANAGEMENT ARCHITECTURE

Military systems and dynamics occur in an extremely complex environment and it is essential to accurately assess the state of operational capabilities, e.g. the associated operational activities, the ability of the process to deliver the performance expected with the people assigned, other systems needed for essential support activities, and the guidance that directs activities and interactions between all elements. Some perspective from previous studies can aid in the basic issues of content categorization for knowledge management.

A. Content Management

Categorization processes can be formalized through ontology specific to the experimental context. At the highest level ontology implies theory about objects, properties of objects, and relations between objects within a specified domain of knowledge, including metadata for describing that domain [1], [2], [3]. Content can then be embedded with meaning specific to the experimental technologies. Hopefully, the architectural models can describe this meaning, and relationships between meanings can be mapped with the result presented as domain knowledge to aid analysis [4], [5], [6], [7], [8].

In application, XML can provide syntax and structure, ontology a means to define terms and relationships, and RDF (Resource Definition Framework) a method to encode ontology-defined meaning [2]. There is a basis for such practices in the DoD. Ontology has been advanced by DARPA with their DAML (DARPA Agent Markup Language), and NATO with their LC2IEDM (Land C2 Information Exchange Data Model) and JC3IEDM (Joint

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Consultation, Command and Control Information Exchange Data Model) [9], [10]. NATO and U.S. Joint Forces Command have expressed interest in experimentation around common ontology and knowledge structures [11]. Additionally the Naval Postgraduate School (NPS) has a history of testing experimental systems that use ontology and metadata to categorize knowledge specific to new technologies in the DoD [12], [13], [14], [15], [16].

B. Knowledge Management

The NPS philosophy is to develop the best understanding possible of leading edge systems in a complex environment while keeping costs reasonable. A proven, rigorous process has been developed over the past 10 years to perform the assessment and this methodology is realized through an EIS. The methodology includes a proven taxonomy to direct and focus planning objectives, developments and resource requirements to ensure a comprehensive and accurate assessment of all elements under review in minimum time. The critical elements evaluated include the following:

- Processes – all aspects of the complex series of interactions that channel performance of systems to achieve certain goals.
- Systems – hardware, software, electronic, mechanical, electrical, or mechanical, all require rigorous evaluation.
- Human integration with systems and process to understand how to optimize performance with available manpower.
- Directives – complex guidance that demands, prohibits, or directs various actions associated with any process.
- Environment or context – typically highly complex in military matters, but the context must be quantified and considered when trying to assess the performance of systems.

Most important is a need to maintain a well-organized record of all aspects of the evaluation process and the eventual assessments. The archives need to be logically structured and integrated so that all evaluations can be incorporated, searched, and critical data and documents easily retrieved. Ideally, each user should have in independent view of the data.

The FORCEnet Innovative Research Enterprise (FIRE) was developed for Naval Networks Warfare Command and has evolved over the last nine years. It does not duplicate information available in other systems, but rather leverages them to track the complex dynamic between processes, systems, humans, and directives. FIRE contains taxonomy for evaluations and the data that populates that framework.

During planning, analysis, and reporting phases FIRE is a collaboration tool accessible via internet by any authorized user with no special software or hardware required. Once the military utility assessment is concluded, FIRE becomes the repository for the work just concluded, as it is for all previous work. FIRE is password protected and each user is limited to specific authorized areas.

III. System Implementation

A depiction of the overall assessment process is shown in Fig. 1. The process begins at the top with a capabilities assessment where some form of shortfall, e.g. "gap" is identified. The program sponsor identifies potential ways to achieve the desired performance goals. These objectives are used to populate the FIRE taxonomy, an "expert process," which sets off an iterative process of defining the best way to assess the performance of the system in question, considering and measuring all the aspects listed above (processes, systems, human integration, directives, and context). Static elements are defined then operational scenarios developed to provide a match to real-world context.

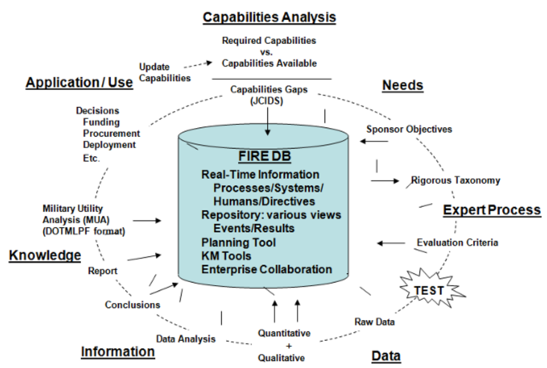

Fig. 1. Analysis flow and management processes.

Tests are run within operational scenarios and all attributes and measures defined in the taxonomy are observed and collected. The data collected are both quantitative and qualitative and both types are used in the ensuing analysis. Comprehensive reports of the conclusions and findings of the analyses are developed and the information is used to develop an assessment of military utility. This assessment looks at doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) and reports the findings and implications in each of those categories. The flow is also represented in Fig. 2 which lists the 13 step process which guided development of the FIRE management applications, forms and reports.

Phase	1	2	3	4	5	6
Due Dates	Pre-CDC	CDC	Pre - IPC	Pre - IPC	Pre - MPC	Pre - MPC
Step	Establish Team	Concept Development	Technology / TTP Harvest	Asset Identification	Develop Experiment Objectives	IDEF / OSD / Process Action Maps
Required Product	Defined Names and R /R	Defines Experiment Scope and Focus Areas. Insure aligns with Naval Vision	Defines and Researches selected Tech and TTPs	Platforms ID'ed and Install Scheduled	Defines the So What and how to measure	Turns the Words into Design Diagrams

Phase	7	8	9	10	11	12	13
Due Dates	Pre - MPC	Pre-FPC	Pre - FPC	TBD	TBD	TBD	TBD
Step	Experiment Design	Event Definition	Data Collection Plan	Execution	Final Report	Assessment OAA	MUA
Required Product	Lays out the Flow and Applicable Scenarios to Meet Objectives	Defines the Detailed execution Plan	Maps the Data to be Collected to the means	Insure Plan is Flexable to changing enviornment	Must be Quick and Good	Necks down Analysis to Assessment	Necks Down Assessment to DOTMLPF Recommenda tions

Fig. 2. 13-step flow for experimentation management.

The Navy can use this knowledge to make substantive decisions with respect to funding, acquisition, deployment of technology, appropriate manning, etc. Following an update to the capability database, the process repeats.

A. Collaborative Portals

There are two primary portals for the FIRE services. The first was launched as TACFIRE (Tactical Applications for Collaboration in FIRE) and provides the primary user interfaces and collaborative capabilities (Fig. 3). Portals are personalized for each user with that user's email, personal and group calendar, task manager, web conferences, enterprise content manager, mailing lists, personal and group workspaces, and instant messenger.

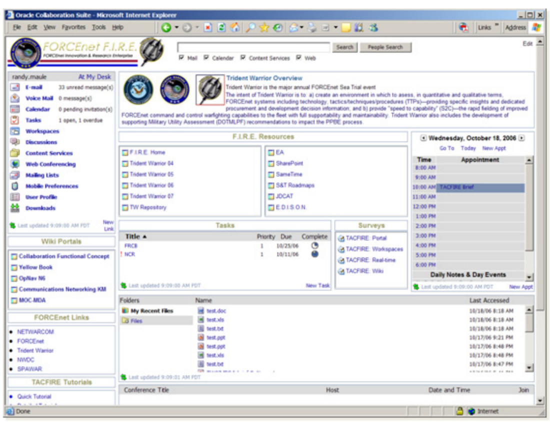

Fig. 3. TACFIRE collaborative portal.

From the personalized portals users can navigate into the FIRE application portals specific to an ongoing or previous experiment (Fig. 4). From these portals are links to specific forms and reports that initiative leads, experiment, and analysis managers use to manage their technologies and objectives, and to coordinate data input and refinement with their distributed teams. Initiative leads serve as managers for technologies within a focus area (capability) and parse input security to technology subject matter experts (SMEs).

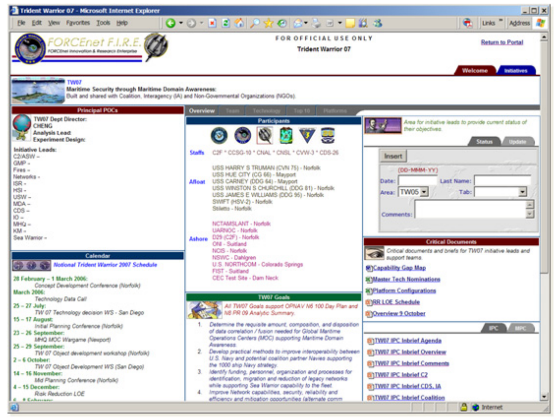

Fig. 4. FIRE experimentation portal.

IV. Systems Integration

An important facet of DoD information systems are the processes through which systems interface. These interfaces will be aided through Service-Oriented Architecture (SOA) and there is a major push in the DoD into SOA for the ability to publish/subscribe experiment results such that program office can better use result data in their purchasing decisions.

Fig. 5 provides an example of a large-scale systems integration effort in which FIRE serves as a host for several components of an end-to-end innovation diffusion process. Working from the left side of the diagram is the needs assessment and requirements analysis. Then the EDISON process, hosted in FIRE, through which industry submits technologies into the experimentation process. Various databases are then integrated through the experimentation process until final recommendations and dissemination. To date many of the integration efforts are minimal. Evolution into SOA and service-based interfaces will enable full integration and are a work in process.

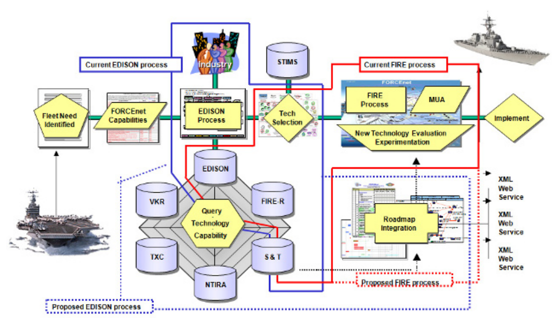

Fig. 5. High-level systems integration flow.

Application Interfaces

As highlighted in Fig. 1 and 5 the management flow begins with establishing system requirements; in the Navy requirements analysis is framed as desired “capabilities”. These capabilities are then published in a Commercial Area Announcement to which industry can reply. Various means are used to collect proposals, ranging from simple white papers describing a technology to automated processes.

One of the automated processes developed as part of the FIRE configuration was named “EDISON” and addressed the “technology harvest” and “asset identification” phases of the 13-step process (Fig. 2). The EDISON process consisted of a workflow through which industry technology sponsors entered their technology information into a form in FIRE in the EDISON application in which desired capabilities (requirements) were identified. In the workflow sponsors would first fill out the specifics of their technology via a form (Fig. 6).

Submissions were automatically aggregated by capability into reports for the review committee. Another form enabled reviewers to rate each technology for its match to the requirements specification and a report was automatically generated that provided cumulative scores and reviewer comments. Finally came the approval or rejection stage and a means to provide feedback to the sponsors. A progress tab in the application provided sponsors and reviewers with current status in the review process.

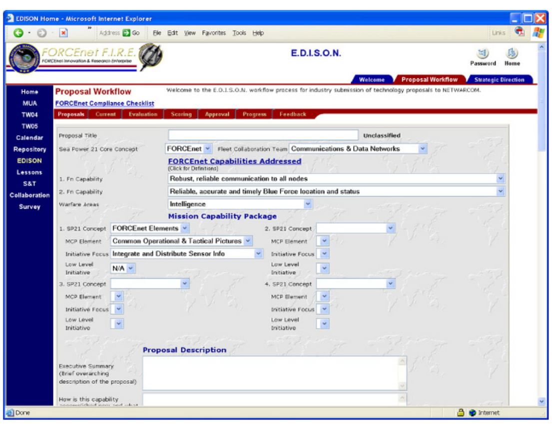

Fig. 6. EDISON technology submission process.

Those sponsors with successful submissions were then invited into the FIRE experimentation management and analysis system for the selected experiment as steps 5 and 6 of the 13-step process. This stage included a high-level screen to frame the experiment and processes (Fig. 7), followed by linked forms for objective input in a workflow from high-level to data collection specifics and analysis methodology. Various models were input to support the technology and systems integration, ranging from IDEF to Use-Case and data flow diagrams.

Fig. 7. Technology objectives management.

Progress through the objectives and related management processes is difficult and generally entails weekly teleconferences by the initiative lead with the technology sponsors assigned to that lead. Since the technologies may involve participants anywhere in the world a series of evaluation and progress mechanisms were devised to help manage the projects. Stoplight charts are common in the military as a means to provide the status of a system at a glance and these were adopted to monitor team progress toward completion of objectives, data sheets, models, analysis methodology, testing routines, and data collection procedures. Tests are conducted in large experiments involving several thousand DoD personnel, including several fleets, several countries, in live global operations. As such, it is important to have a clearly defined management process and analysis routine. An example of a tracking system to help ascertain status is presented in Fig. 8.

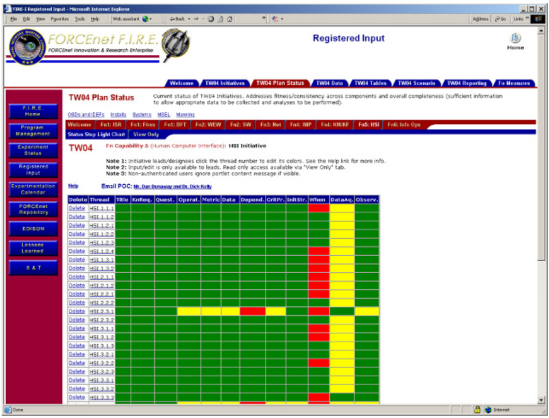

Fig. 8. Analysis management stoplights.

In process, an initiative lead would review the inputs of their technology providers and then indicate a status color. A green color would trigger an assigned member of the experiment analysis team to review all inputs. If agreed that all systems are "go" (green), indicating that all facets of the objective development process are completed, then the technology is ready for inclusion in the experiment. This includes steps 7 and 8 of the 13-step process and the manner in which the scenario tests the objective. Events must be clearly defined and a detailed execution plan presented.

A variety of instruments have been developed to help with data collection during experiment execution. These have ranged from spreadsheets to custom reports that include objectives, events, analysis methodology, and collected data.

The final step in the process is the reporting. This includes a QuickLook report that provides near immediate assessment of tested objectives and their technologies and is completed a few days after the experiment. An Operational Agent Assessment helps structure the analysis, to match the tested objectives to the requested capabilities.

A Military Utility Assessment (MUA) next provides high-level recommendations to senior decision makers. Fig. 9 provides an example of an information capability utilized within FIRE to support the MUA process. At the MUA a technology is either dismissed, recommended for adoption and integration into the funding cycle, or pushed back for further test and evaluation.

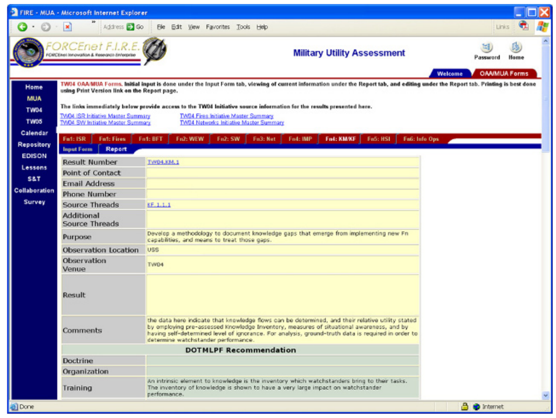

Fig. 9. Military Utility Assessment.

The Final Report is completed a few months after the end of the experiment and is generally a 1000+ page document. This includes the reports of each of the individual technologies, with experiment results from the operational scenarios, plus the integration and overall assessment from the analysis team.

IV. Conclusion

This paper presented an operational enterprise information system and its supporting methodology for the analysis of complex experiments. The system is currently utilized by the Department of Defense for Navy and Joint Forces experimentation. Assessed are effectiveness and efficiency of systems interactions and affected intra- and inter- organizational processes to assess next-generation military e-services and infrastructure. A focus is the expansion of systems methodology beyond traditional transaction-oriented exchanges to include management layers for complex inter-organizational processes and mechanisms to accommodate sensitive operations.

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