12TH ICCRTS
ADAPTING C2 TO THE 21ST CENTURY

Case-Studies of Decision Support Models for Collaboration in Tactical Mobile Environments

Track 7: Network-Centric Experimentation and Applications

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Abstract

The paper addresses experimental studies of decision support models for collaboration in tactical network-centric operations. This project, supported by partners from Lawrence Livermore National Laboratory (LLNL), US Special Operations Command (SOCOM), Swedish Armed Forces, Austria, and Singapore. Naval Postgraduate Schools (NPS) Tactical Network Topology (TNT) is the base for the testbed, comprised of long-haul OFDM networks combined with self-forming wireless mesh links to unmanned aerial vehicles (UAVs), radiation detection sensors, and geographically distributed experts. The case- study conducted by the NPS student team during the Summer of 2006 included Maritime Interdiction Operation (MIO), High-Value Target (HVT) tracking, and Emergency Response coordination scenarios, in which geographically distributed command centers and subject matter experts collaborate to facilitate situational understanding and course of action selection. During the study NPS students observed communication processes of geographically distributed teams and were able to position collaborative process in the decision making space of Simon’s problem solving model, Boyd’s OODA Loop, and Alberts and Hayes’ Collaboration Significant Influences model. The results show high fidelity of Alberts and Hayes’ Collaboration Significant Influences model and reveal the requirements to collaborative network topology as well as multi participant team structures.

1. Objective

The main objective for the described study is to explore the structure of decision making process and communication patterns observed in result of applying collaborative technology to the selected network-centric tactical scenarios:

- Collaboration on High-Value Target (HVT) tracking with Light-Reconnaissance Vehicle (LRV) as mobile command center,
- Collaboration with multiple Unmanned Aerial Vehicles (UAV) Ground Station crews in HVT and Intelligence, Surveillance, and Reconnaissance (ISR) missions
- Collaboration in Maritime Time Interdiction Operations (MIO),
- Collaboration in the Emergency Relief Operations.

The major question we were trying to address in this study is which of three main decision making cycle models: Simon's problem solving model (Simon, 1979) , Boyd's OODA Loop (see Hammond, 2001, Coram, 2002), and Albert's and Hayes' Collaboration Significant Influences model (Albert and Hayes, 2006), fits best into the tactical collaboration scenarios.

In addition to the decision making cycle mappings the observations include characterization of observed collaborative network topology in terms of: degrees of separation and clustering, as well as multi participant Decision Support topology (group, team, and committee).

The other answers we've been looking at include:

- Characterization of collaborative technology usage pattern in terms of frequency and timeline for using major Collaborative Technology (CT) building blocks: file sharing, white board, application sharing, chat, audio/video communications etc,

- Characterization of communication mode for collaboration (client-server, peer-to-peer, etc) and networking capabilities that were set up to execute Collaborative Technology applications,

- Characterization of decision support roles distribution in terms of *keepers, communicators, and coordinators*, and

- Recommendations for the tactically-oriented collaborative technology tools capabilities.

2. Plug-and-Play Testbed Environment

Figure 1 shows the Maritime Interdiction Operation (MIO) tactical network topology (TNT) used in San Francisco Bay for the MIO experiments (Bordetsky, et. al., 2006) Each of the nodes played a specific, unique role in the scenario. Figure 2 depicts the broadband wireless 100 mile stretch of the testbed to Camp Roberts, CA. This wireless tactical network provides real-time access to unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), unmanned surface vehicles (USV) and mobile Special Operations Command (SOCOM)/Marine Corps units for exploring collaboration for high-value target tracking operations. This part of the testbed will also be used for remote integration of UAVs/USVs in MIO or other scenarios, such as non-combatant evacuation experiments, where flying UAVs or operating UGVs is not feasible.

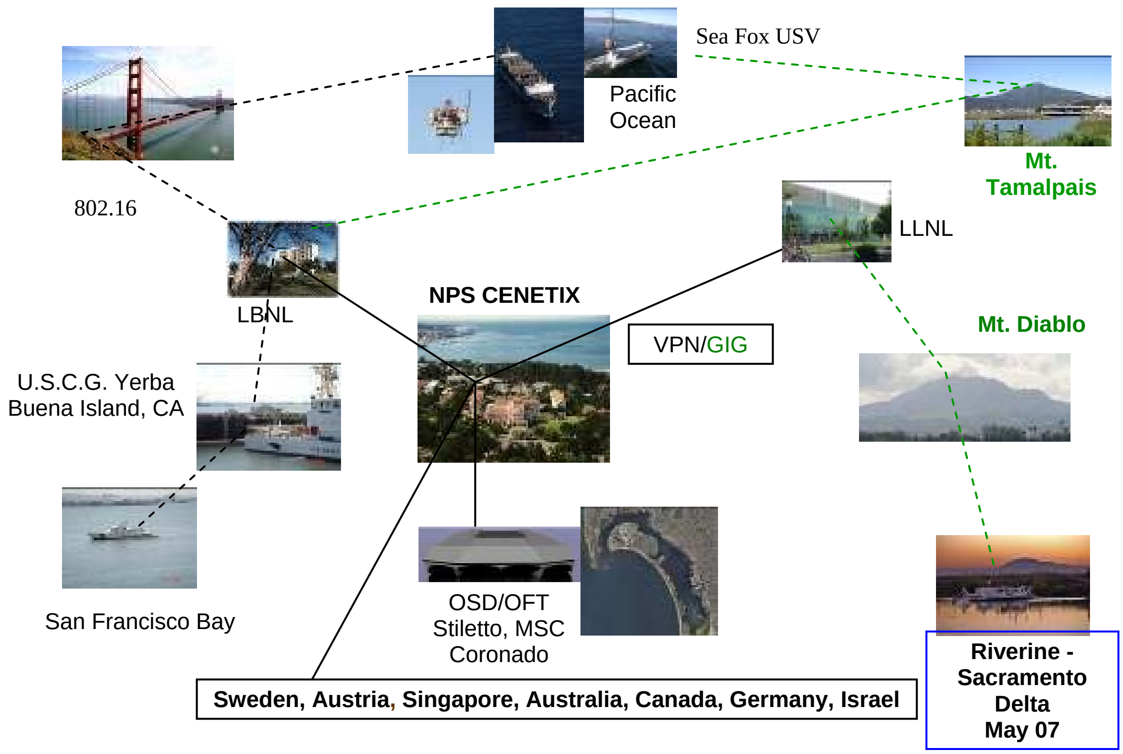

Figure 1. NPS Testbed Network with Unmanned Vehicles and Sensors in San Francisco Bay Area.

Figure 2. Area included in the testbed broadband wireless link to unmanned systems and sensors in Camp Roberts. (Illustration from Google Earth)

Virtual Private Network (VPN) is used to provide access between the testbed and individual participants who are connected via software clients from Lawrence Livermore National Labs (LLNL) among other places. The VPN architecture is essentially a hub-and-spoke model with NPS in the center, and the San Francisco Bay Area, San Diego, Army Biometrics Fusion Center, in West Virginia, the Stiletto in San Diego, and researchers in Austria, Sweden, and Singapore as spokes.

3. Collaborative Network: Maritime Interdiction Operation Example

The application Groove Virtual Office provides the majority of the collaborative tools for these experiments. Workspaces were created to perform the tasks described below.

A Tactical Operations Center (TOC) and networking workspace was established to resolve network malfunctions and other associated issues necessary to optimize network performance and to coordinate logistics and issues which are not part of the scenario.

A Boarding Party (BP) workspace was established to provide a venue for scenario participants (including remote experts) to perform the following tasks: analyze and compare spectrum files, track radiation materials, share atmospheric modeling and predictions, consider emergency medical actions; post biometrics matches from the National Biometric Fusion Center (BFC), radiation files/photos (boarding party), responses and expert evaluations (LLNL), and recommendations regarding additional actions to be taken by the BP when additional search information is required (LLNL-BFC).

The Regional Coast Guard Command Center (District 11) workspace provides the command and control assets; directs agencies and assets not directly under the commander's authority; and provides command and control to ensure the BP takes appropriate actions.

Each of the collaborative network nodes can use any subset of the collaborative tools. These tools provide the ability to remotely monitor both the status of operational assets (such as boats/vessels) and the progress of scenario events.

Groove application was used to perform the following functions: *Discussion Board and Chat* are used for text communication between nodes. The discussion board is better than chat because it enforces hierarchy relationships for the different posts, thus it facilitates tracking information flow in this asynchronous, distributed decision-making environment. *File transfer* is primarily used for distributing data files to and from the reach back facilities. *Task Manger* is used by experiment control in the TOC and networking workspace to provide participants a way to monitor the progress of the scenario.

Situation Awareness (SA) Agent provides geographic positions of the assets and status of the network links for the mobile nodes.

EWall system developed at MIT and adapted to MIO operational picture by NPS, was used to monitor information alerts. However, the sparse number of alerts posted in EWall limited the effectiveness of the tool during the experiments.

Voice Over IP (VOIP) phone was used for voice communications. Video streams were monitored from various nodes, but this functionality was not critical to the D11 decision making process.

Boarding Vessel. The primary collaboration tools used on the boarding vessel were Groove and VOIP phone. The boarding vessel served as a coordination entity that provided a link between the TOC, District 11 and the BP. The boarding vessel also provided the physical network link between the target vessel and Yerba Buena Island 802.16 node. The boarding vessel also provided a video feed, with the camera placed on the bridge.
Groove proved to be a valuable tool for the boarding vessel team. On the first day of the experiment network latency was unacceptable and cell phones provided the primary means of communication. On the second day these problems were rectified and both Groove and the VOIP phone proved exceptionally valuable. The VOIP phone is an outstanding tool and should be used even more widely in future experiments.

Stiletto Ship. Groove provided the majority of the collaborative tools and was used for Chat, discussion, file sharing, pictures, and task management. Video and voice communications were provided by VStream. Additional voice communications were conducted using cell phones.

NPS Network Operations Center. The NPS CENETIX NOC used all of the available collaborative tools for the experiment: Groove, E-Wall, SA agent, video conferencing, and audio conferencing. Groove was used for file sharing, messaging, chat, discussion board, pictures, and web links. This constituted approximately 80% of the collaborative tool utilization. EWall was used about 10% and teleconference another 10% mainly for coordination during the initial experiment setup.

The teams from Sweden, Austria, and Singapore used Groove, SA agent, a live video link, and occasional cell phone communication. In addition, the Swedish team provided feedback to EWall. Figure 3 depicts the different groups who participated in the MIO experiment collaborative network.

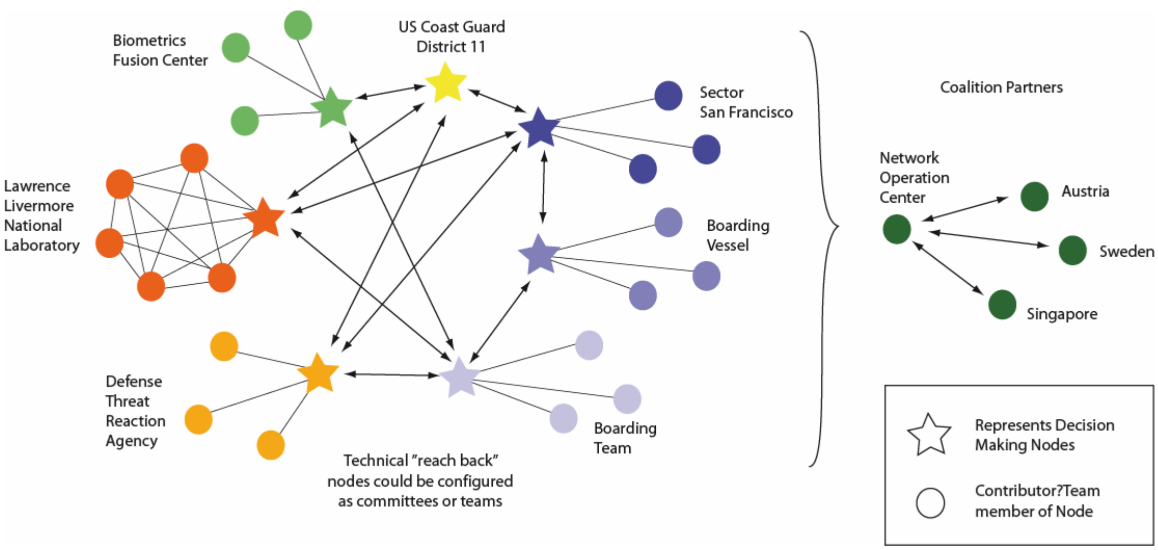

Figure 3. Exploring different teamwork models within the MIO collaborative network

4. Collaborative Technology in HVT scenario

Naval Postgraduate Schools Tactical Network Topology (TNT) experiment TNT 06-02 and TNT 06-03 were conducted in February 2006 and June 2006 respectively at Monterey, Camp Roberts and San Francisco Bay, California. The field experiment was part of the USSOCOM – NPS Cooperative Field Experimental Program. The experiments focused on various complex tasks aimed to establish a collaborative network amongst various players, to achieve situational awareness in the battlefield arena as well as between geographically dispersed participants. This case study pertains to the experiments conducted at Camp Roberts wherein the major technical areas under focus were:

- Airspace Management.

- Advanced network backbones.
- Persistent Air-Based Surveillance.
- Mobile Tactical Operations Center (TOC) / Light Reconnaissance Vehicle (LRV).
- HVT Identification including investigation of Rapid Identification and Tracking System (RMITS).
- Network Controlled UAV.
- UAV Detection of Identity, Friend or Foe (IFF) and Vehicle Mounted IFF.
- Activation of Individual IFF Patch on Moving Vehicles.
- Vehicle Mounted IFF.
- Evaluation of UAV Payloads.
- Air Force Research Laboratory's (AFRL), Airborne Information Management Services.
- UAV- Enhanced Battlefield Medical Situational Awareness and Tactical Networking.
- UAV for Precision Medical Supply Delivery and/or Combat Rescue.
- UAS, UGV, Perimeter Surveillance, and Biometrics Effectiveness in Day/Night Operations.
- Global Tracking, Detection and Interdiction of Maritime Sources of Weapons of Mass Destruction (WMD) and HVT.

Collaborative Process in Detection of HVTs using Raven UAVs

The process of detection and identification of HVTs using Raven UAVs process involved clear and precise collaborative elements. The entire process may be broken down into major sub-parts / sub-processes for undertaking detailed after action analysis thereby enabling it to be modeled into applicable decision support models.

- Establishment of backbone communication infrastructure.
- Airspace management and deployment of UAV in target area.
- Establishment of linkages – airborne UAVs and Ground Stations.
- Collection and initial assessment of UAV feed data at Camp Roberts.
- Transmission of UAV data to NPS for detailed analysis.
- Re-transmission of processed UAV data from NPS to Camp Roberts.
- Final analysis and decision at Camp Roberts.

The Camp Roberts scenario during TNT 06-03 that is analyzed as part of this case study is the *Force-on-Force Scenario – UAS, UGV, Perimeter Surveillance and Biometrics Effectiveness is Day / Night Operation* and is depicted in a diagrammatic form below. The case study hence covers the entire ISR collaborative scenario with specific reference to detection of HVTs.

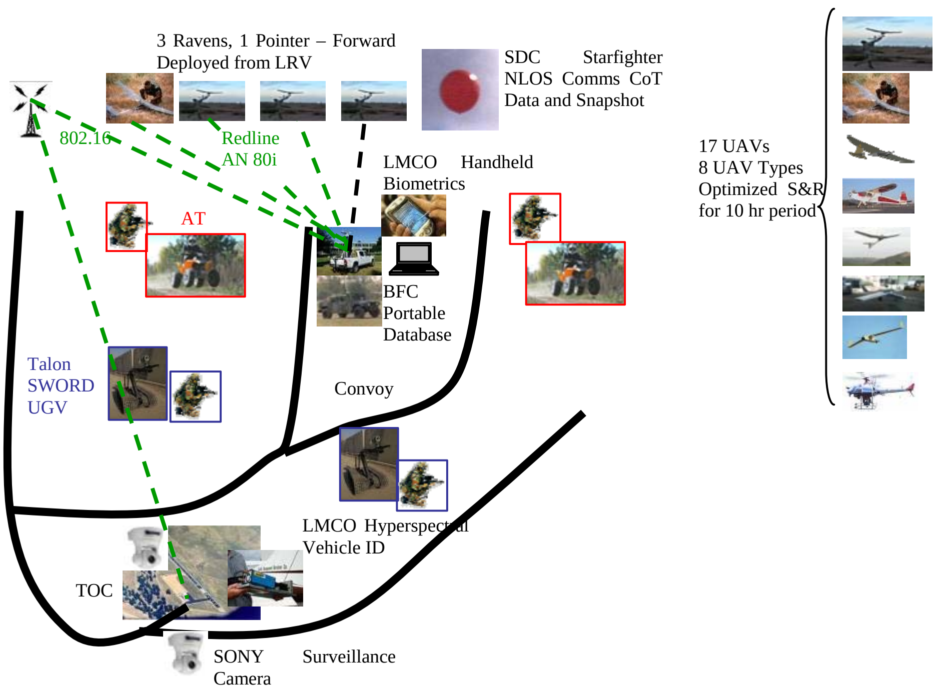

Figure 4. HVT Scenario

5. Mapping Collaborative Tasks to Major Decision Support Models

Using a systematic approach, team of NPS students (Creigh, Dash, and Rideout, 2006; Pena and Withee, 2006) researched the TNT archives of previous CT usage in support of MIO and HVT experiments between multiple agencies and organized pertinent data for qualitative and quantitative analysis. Files reviewed included: Groove chat/discussion groups, event logs, exercise reports including Executive Summaries, Plans, Team Reports and After-Action Reviews (AAR), as well as interviews with resident experts. Members of the teams consolidated MIO Events, Measures of Performance (MOP), and AAR trends to assist in forming a template from which we would position the described collaborative process in the space of three major military decision support models including Simon's problem solving model, Boyd's OODA Loop, and Albert's and Hayes' Collaboration Significant Influences model.

5.1 Maritime Interdiction Operation (MIO)

The MIO experiment in support of TNT 06-3 contained 25 main events. Our team assessed each event individually across the three models and attempted to match them to the best component or sub-component of each model. For example, Event 1 states, “While on routine patrol in San Francisco Bay, a San Francisco Police Department (SFPD) Maritime Division boat receives an alarm from an installed radiation sensor as it cruises past a fishing boat (Alameda Sheriff’s Department boat).” This event most aptly applies to Boyd’s “Observe” portion of the OODA Loop, the “Intelligence” block of Simon’s model, and arguably, the “Information” component of Albert’s and Hayes’ model. This process was repeated for all 25 events using a “group consensus” approach.

In order to obtain qualitative and quantitative statistics on the relevancy of these models as they pertain to CT in support of this particular TNT MIO, a Lickert Scale was developed with common “score” descriptions ranging from 1-10. In addition to facilitating statistical analysis, this scale also mitigated the subjectivity of the individual team members. Each member than applied this 1-10 scale across the pre-selected components from the three models for all 25 MIO events. A spreadsheet was developed to capture and average the results in order to graphically depict the results. The intent was to statistically display which model applied the most to this specific scenario and these particular events. If the frequency of components combined with team scores was any indication of which portions of particular models best served the MIO CT environment, we planned to propose a hybrid model based on this data.

The study team used the following mapping technique:

1. Look at the event (example 1 – for Boyd, we say it applied to the Observe section, Simon’s: Intelligence and Al/Hayes: Information)
2. Open the Excel doc and read the 1-10 scale (best way to think of this is 10 = 100%, 5 = 50%, etc).
3. Assign a value under your particular name (1-10) for each event –and for each model (example 1 –I give Boyd a 7/10 for Event 1 matching the Observe portion of the model, a 8/10 for Event 1 matching Simon’s model and a 9/10 for Event 1 matching the Information portion of the Albert-Hayes model).
4. The averages will automatically calculate and populate the graphs.

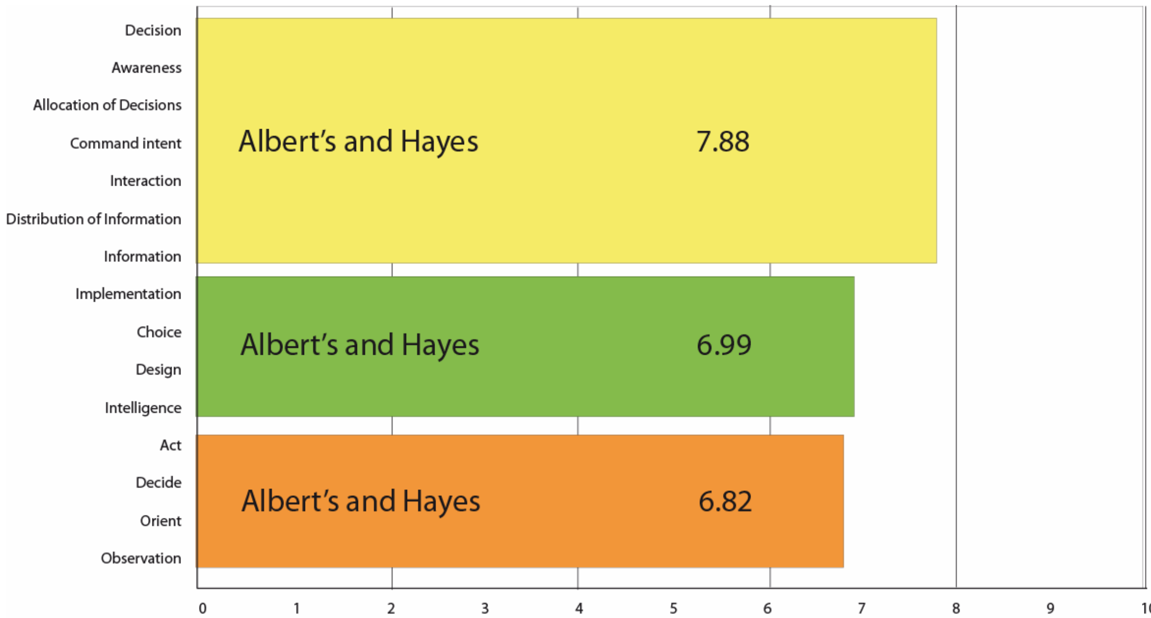

Figure 5. Overall "Fit" of Models to Scenario Tasks

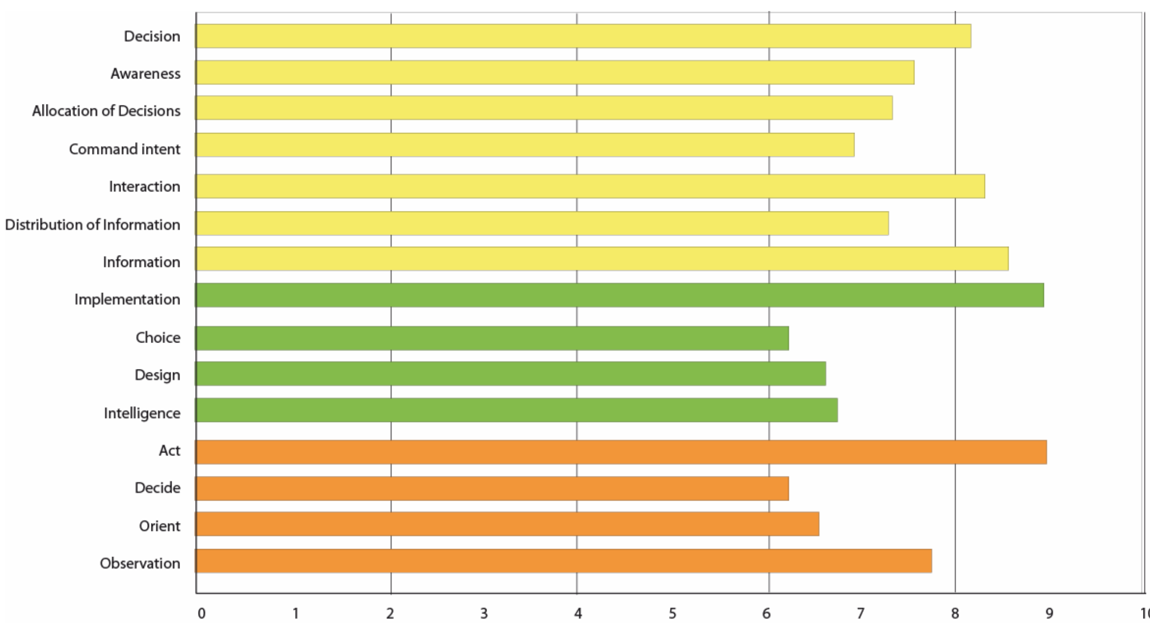

Figure 6. "Fit" of Model Dimensions to Related Scenario Tasks
(green - Albert-Hayes / blue - Simon / orange - Boyd)

5.2 High Value Target Tracking Operation

The three decision support models under consideration in this case study are the – Simon's model, Boyd's (OODA loop) model and the Albert's and Hayes model. The collaborative tools utilized during the experiments were – Groove, Situational Analysis (SA) Agent, Video Conference (VC), Pelco Viewer, Video Stream (VStream), Falcon View, Cursor on Target (CoT) and EWall. The experiments TNT 06-02 and TNT 06-03 were conducted not with an intent to evaluate collaborative tools nor with an intention to evaluate the decision support models; the experiments actually took for granted the existence of a backbone network as well as the availability of specific collaborative tools to the various participants. Also, the decision support structure was neither required to be evaluated nor was it expected. The experiment was conducted with an over-view of performing tactical operations within an existing collaborative super-structure.

The detailed analysis on the usage of collaborative tools and applicability of different phases of the three decision support models during the TNT 06-03 experiment as available through the TNT 06-03 Planning and Schedule document.

Simon's Model

Simons model was presented in 1979, but his original work did not include implementation, which has been added later on (Fig. 7) by. The classic Simon's problem solving model is comprised of three well known phases: the Intelligence Phase, wherein the decision maker looks for indications that a problem exits, the Design Phase, wherein the alternatives are formulated and analyzed, and finally the Choice Phase, wherein one of the alternatives is selected and implemented. In the study we used the version of the original Simon's model augmented by the Implementation Phase (Sprague and Carlsson, 1982). Although the entire process of detection and identification of HVT can be easily mapped with this model but the actual use of collaborative process required in the entire decision making cycle is only implicit and needs to be visualized.

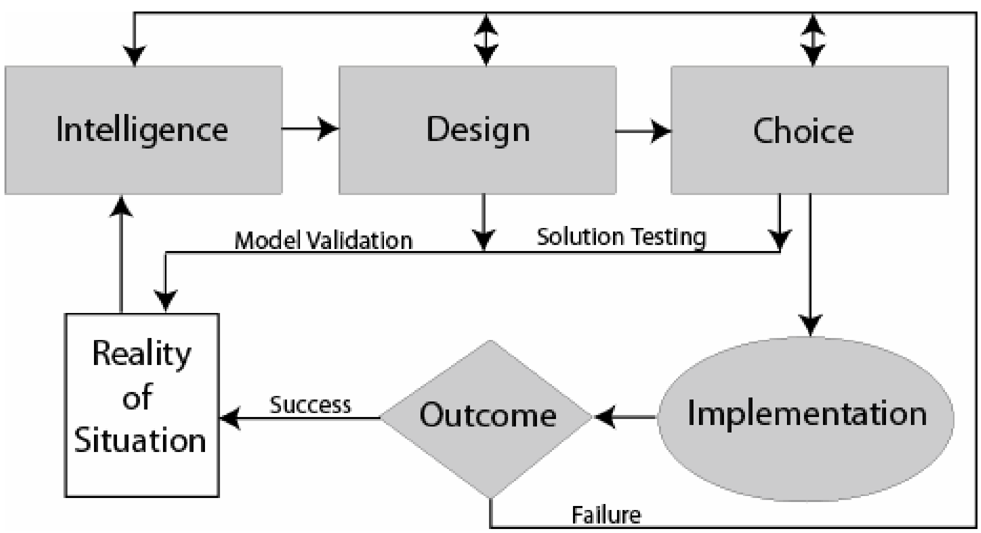

Figure 7. Simon's problem solving model

Boyd's Model

The Boyd's model is comprised of four phases – Observe, Orient, Decide and Act. The model is not exactly cyclical and cannot be treated as such. The impact of the model is evident when strong feedback is realized between all the four phases. Generally, most of the times, a decisions are based on only two parts of the model – Observe and Act.

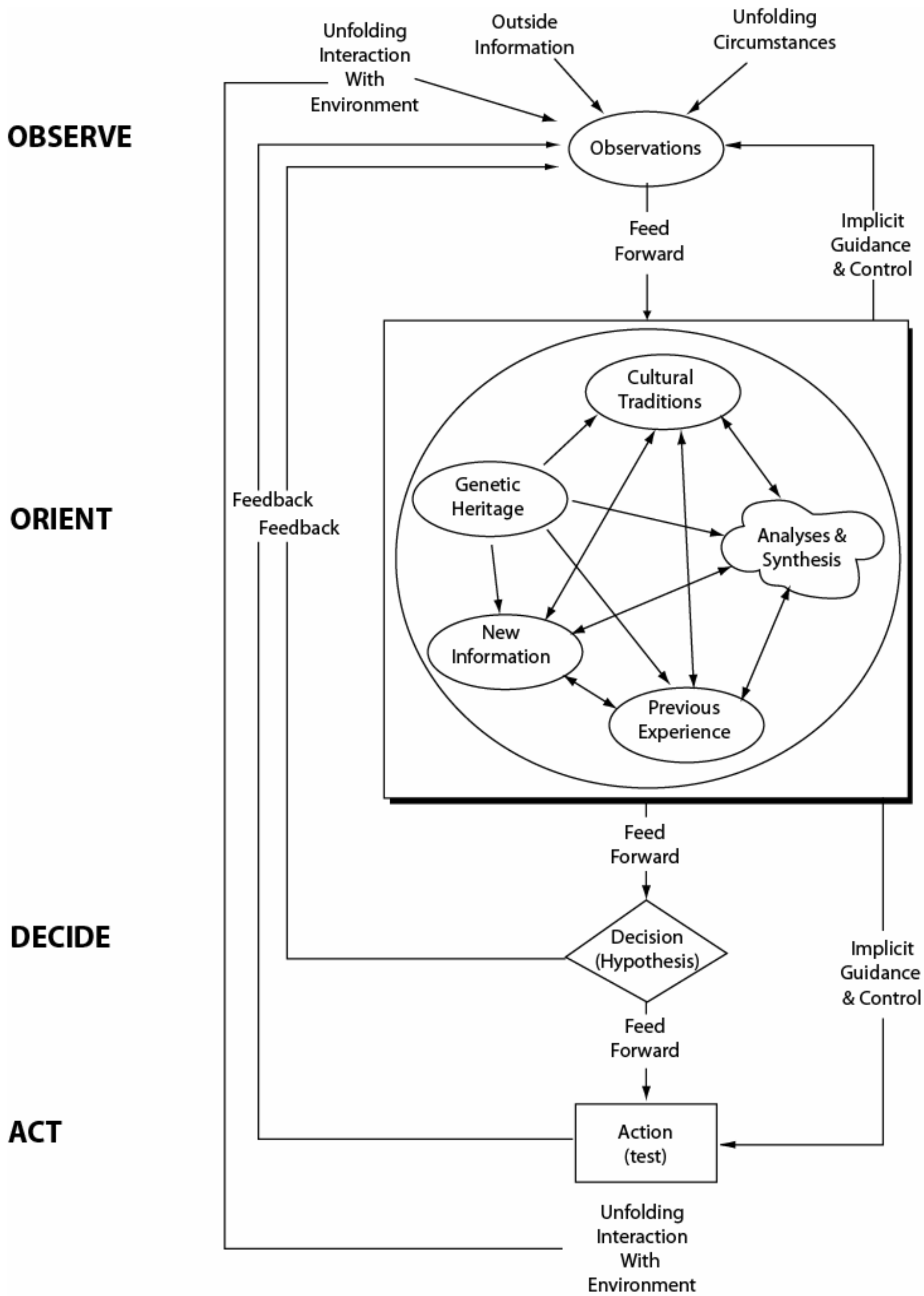

Figure 8. the OODA loop (Boyd sketched the original and then Chuck Spinney, Conram, 2002, p. 344)

This misses out the Orientation Phase that is extremely important towards the final Act Phase. The Action Phase not only defines the final decision but also gives direction to the entire organization towards speeding up the loop in the next iteration.

The experimental setup of the TNT in particular the HVT process does follow the order of the model and there are linkages established between all the processes to allow feedback. But again, the collaborative process is only implicit and is not emphasized in the model.

Albert's and Hayes Model

This model more explicitly defines the entire process of decision making and lays emphasis on information as a resource, the value of information towards decision making and defines collaboration as an important aspect towards sound decision making. This model breaks the cyclical or hierarchical aspects of the previous two models and highlights the strength of the organization as a whole working towards a common decision wherein each individual involved in the process has some sort of decision making ability.

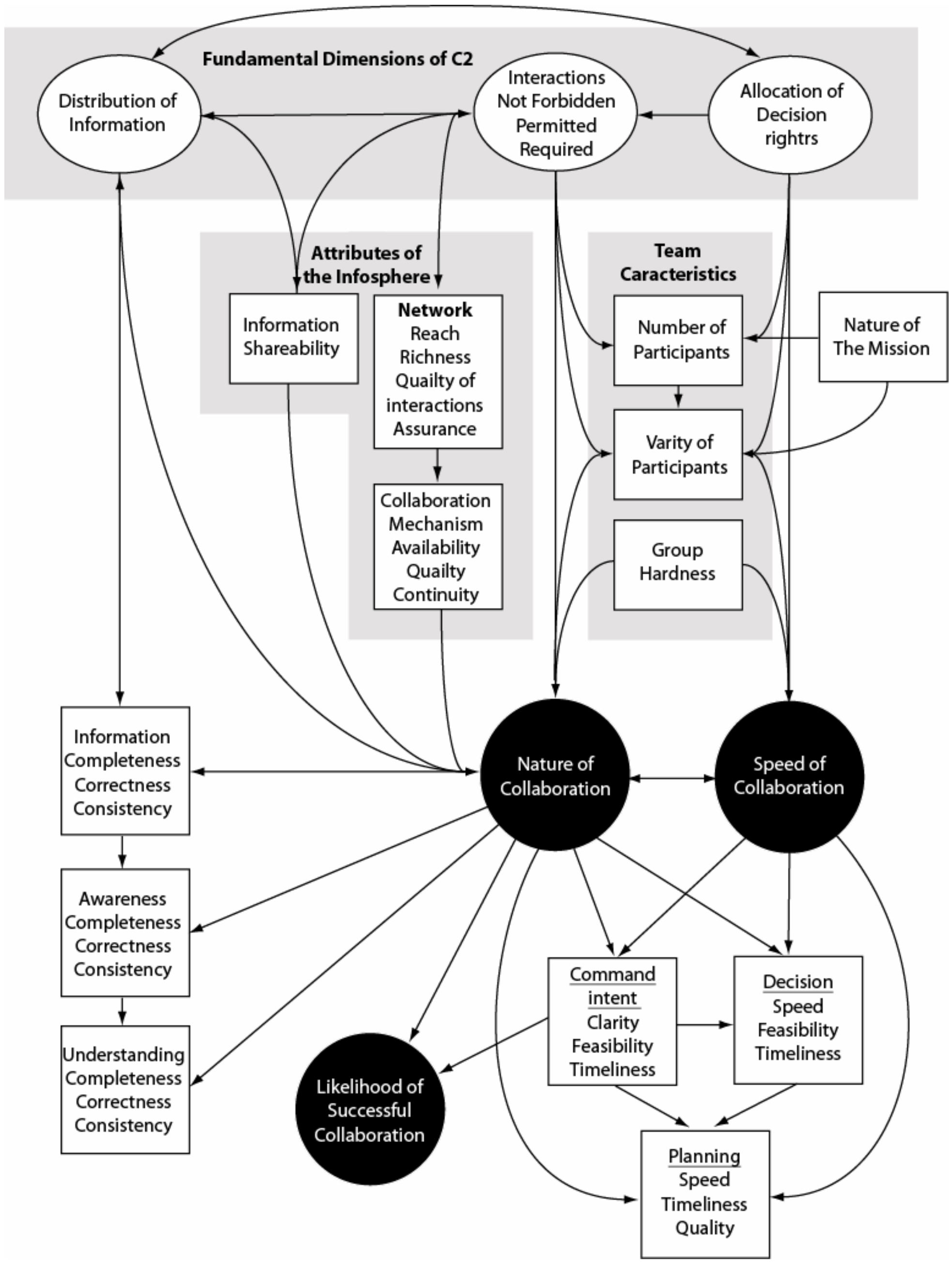

Figure 9. Albert's and Hayes' Collaboration Significant Influences model (Albert and Hayes, 2006, p. 181)

The model maps on the experimental setup quite naturally and emphasizes the Team characteristics leaning towards a 'committee' structure towards decision making. This highlights the collaborative phenomenon that exits in the experiment and is more of an organization evolution model rather than an explicit decision support model.

6. Conclusions and Recommendations

After analyzing the information from the experiment and comparing it to the three given decision making models, the MIO team concluded that none of the models accurately represent the collaborative decision making environment that exists for MIO. They proposed a new model below, although not a perfect fit, which combines the elements of the three decision support models team analyzed. This model takes into consideration the collaborations piece, but still allows for an individual to make a decision without collaboration.

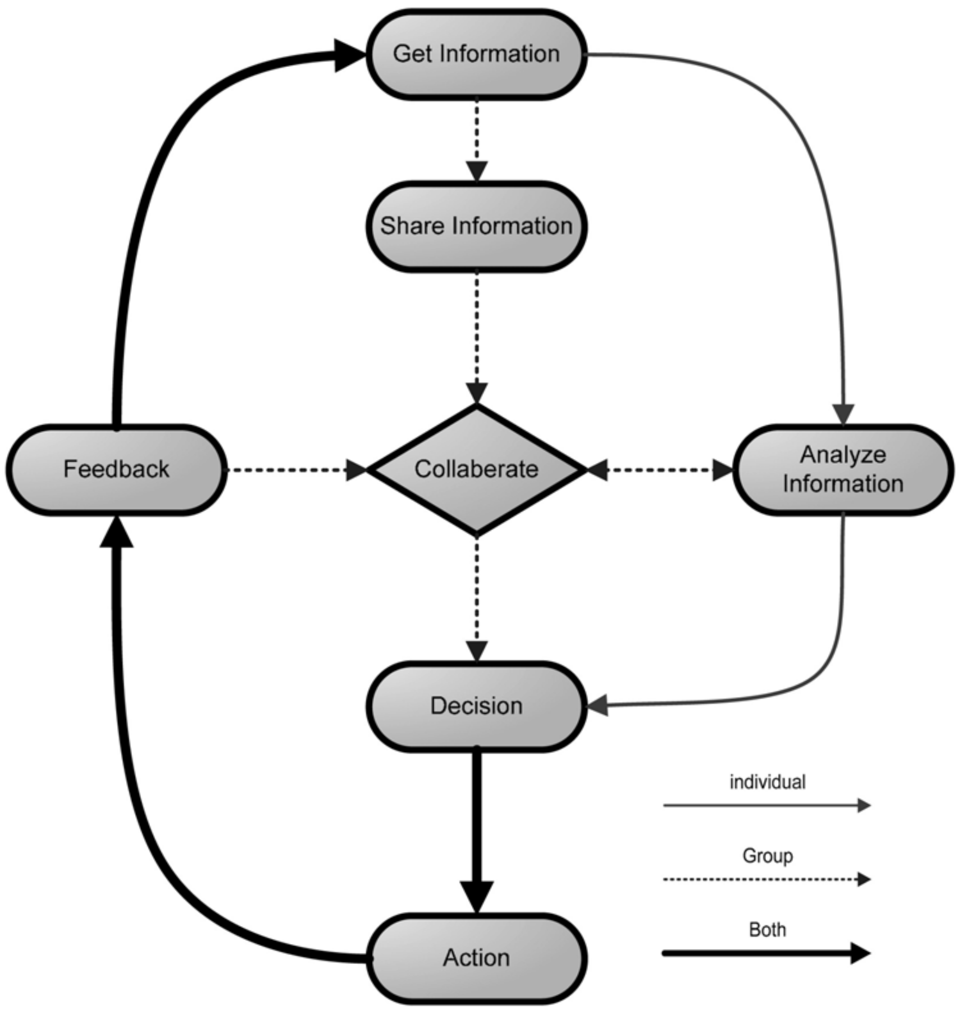

Figure 10. Model proposed by the MIO study team

Surprisingly the HVT operation study team came up with similar conclusion. The have identified that none of the three decision support models themselves are adequate to deal with the HVT scenario. Boyd's and Simon's models do not lend themselves well to the initial set up of the network and the Albert-Hayes model lacks an execution phase as well as full exploitation of the synergy developed through the collaborative process. If forced to choose, Simon's model would be the preferred model because it is more robust than

Boyd’s and is not as complex as the Albert-Hayes model. However, the best answer is to borrow the best features from all the models and design a decision support model that better incorporates collaboration and includes an execution portion once a decision has been made.

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