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Process Instrumentation Systems for Training and Operational Test Needs With Case Study of Use at JEFX 09

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Process instrumentation provides trainers and testers with deeper insight into the activities, both human and technology, that affect system and warfighter performance and mission effectiveness. To this end, the authors have designed and developed several process instrumentation systems, working with both U.S. Air Force warfighter trainers and testers. Both trainers and testers need to, in operationally relevant environments, reconstruct events to meet teaching needs or testing requirements. These similar reconstruction activities drive the need for a method to capture human, as well as technology, activities. This article describes process instrumentation systems and their benefits for trainers and testers and then describes, with examples and a case study, two process instrumentation systems.

Key words: Chat systems; communication; human activity; instrumentation; JEFX-09 experiment; reconstruction; trainee decisions; training; work process.

In training and test environments, the instrumentation of user–operator work processes and communications, in addition to the instrumentation of technology (e.g., computer systems and networks), can provide new and needed insights into mission effectiveness. In training environments, trainers can use the information collected and displayed by process instrumentation to reconstruct training events and augment after-action reviews, highlighting key trainee decisions. Similar information and reconstructions can assist operational testers in determining a system-under-test's impact on total performance and mission effectiveness.

During both training and test events, trainers and testers develop scenarios using Master Scenario Event List (MSEL) inputs. Both use these MSELs to stimulate desired outcomes for focused observation, analysis, and debrief and reporting. Training after-action reviews rely on reconstruction technology and human activities to determine student performance and reinforce teaching points. Test analysis of MSEL test inputs involves the reconstruction of technology and human activities to determine the efficacy of the system or network under test.

Over the past 5 years, the Johns Hopkins University Applied Physics Laboratory (JHU/APL) has developed several work process and personnel communication instrumentation systems. These systems have been used by the Time Sensitive Targeting/Dynamic Targeting trainers at the U.S. Air Force's Combined Air and Space Operation Center—Nellis (CAOC-N) and researchers at the Air Force Research Laboratory—711th Human Performance Wing for several training research exercises focused on dynamic effects, as well as assessors of the Warplan-to-Warfighter Forwarder (WWF) Spiral II initiative during the Air

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Force's Joint Expeditionary Force Exercise (JEFX) 09-3. In addition, the U.S. Joint Forces Command has incorporated several JHU/APL instrumentation capabilities into their Joint After-Action Review Resource Library.

This article provides an overview of the benefits of work process and personnel communication instrumentation in both training and test environments, a description of the instrumentation systems developed by JHU/APL with examples of their use by CAOC-N trainers, and a case study of WWF assessors during JEFX 09.

Benefits of work process instrumentation

Process instrumentation systems automatically collect, organize, and archive large amounts of work process and personnel communications data, as well as pertinent technology data. During events, instead of trainers and testers manually searching and recording the information they will later use for reconstructions and analyses, process instrumentation systems automatically, and with minimal intrusiveness, collect work process, communications, and system data. Collected data are organized and archived in databases, making it easily accessible to performance analysis and assessment systems, as well as searchable with user-specified criteria. Such instrumentation significantly improves the ability of trainers and testers to evaluate overall mission effectiveness, assess human-centric issues, such as effectiveness of Command and Control (C2), and contribute to Tactics, Techniques, and Procedures (TTP) development.

In addition to relieving trainers and testers of the burden of manually collecting data in real time during an event and the danger of missing key information because of trainer or tester task overload or data inundation, the persistent archive of data by process instrumentation systems creates a historical record of events and activities. Nowadays, all too often, the work process, communications, and system data during training and test events is lost after the event ends or is captured in nondigital, not easily accessible Information Technology (IT) system formats, like Microsoft Office documents or proprietary, stove-piped data sources. Without historical data to establish process and mission effectiveness baselines, the benefits of training programs and new systems under test become difficult to determine and are often subjectively assessed.

The ability to archive data and refer to it later also enables trend analysis. This can be particularly useful in the training environment to gauge students' progress in the training process. Trend analysis can also provide insights into effectiveness of training procedures as well as improvements over time of a technology being tested—given analysis is conducted to isolate contributions to effectiveness of specific material systems, processes, or learning.

Process instrumentation systems also provide the capability to reconstruct both technology and human activities, using empirically based "truth" data, that is, data from IT systems used by humans to complete an activity or process, as opposed to notes or memories of the participants, trainers, and testers. A reconstruction can take many forms but is most useful if it contains both technology actions and human actions that have been correlated and can be examined through specific events (e.g., MSEL items) in a larger mission context, often called a thread. With the activities correlated and focused on a single event thread, testers and trainers can better understand the timing and process actions to evaluate the performance impact of the MSEL input on the overall mission. Additional context from other threads provide insights into how C2 (e.g., leadership, team coordination, and decision making) and TTP positively (or negatively) influenced performance outcomes. With the technology and human activities correlated, attention is focused on total performance and mission effectiveness, as opposed to just warfighters' opinions.

Based on extensive JHU/APL observations, event reconstruction is often performed manually, consuming much time and labor, and limiting the amount and depth of analysis. Automating the collection and analysis of user–operator process data and communications results in a reduction in time and labor as well as improved quality in reconstruction and analysis. Existing instrumentation systems, such as the Air Combat Maneuvering Instrumentation and the Nellis Air Combat Training System used for tactical aircrew training, support this position.

A distinction needs to be made between IT system instrumentation, which focuses on data and system operation validation, and process instrumentation. Process instrumentation brings the human aspects of a system, such as workflows, decision making, and collaboration and communication, into focus for the training and testing communities and allows a full accounting of total system performance and mission effectiveness.

Process instrumentation systems: CPAS 1.2 and 1.3

To research and exploit the benefits of process instrumentation, JHU/APL developed two systems, the CAOC Performance Assessment System (CPAS) v1.2 and CPAS v1.3 (or eCPAS for Enhanced CPAS).

JHU/APL built CPAS v1.2 for the CAOC-N trainers. This version of CPAS collects work process

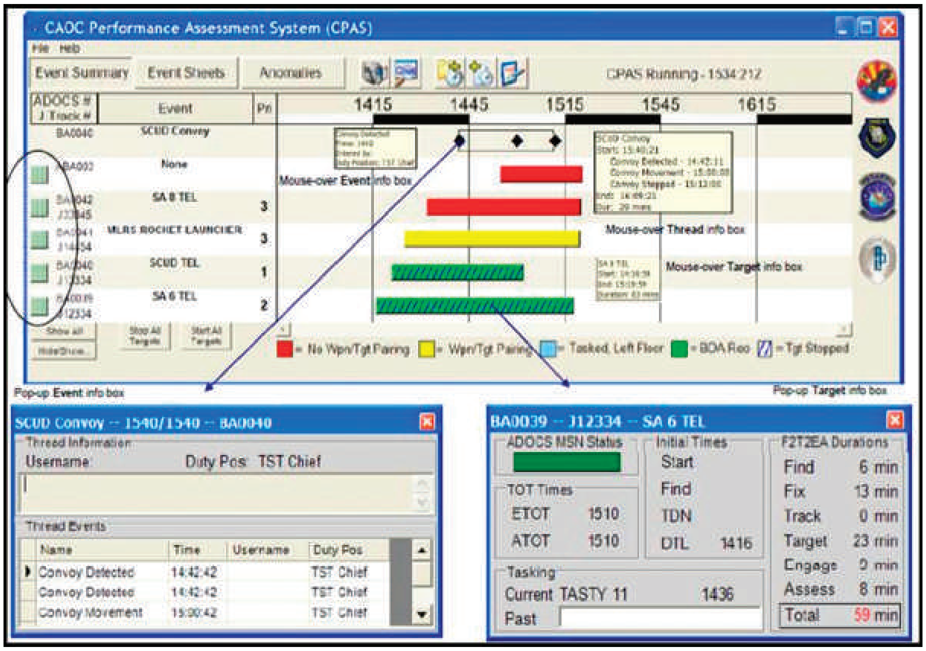

Figure 1. CPAS composite and drill-down views.

data from the Joint Automated Deep Operations Coordination System (JADOCS) mission collaboration technology and communications data from several text chat collaboration systems. CPAS stores the collected data in a relational database and displays it visually using timelines. Other capabilities include filtering and searching the collected communication messages, correlating key process events with communication messages, and detecting process anomalies using user-configured parameters.

A later version of CPAS, Enhanced CPAS (eCPAS), was customized to meet testing requirements from the Air Force's 605th Test and Evaluation Squadron. eCPAS added the capabilities to collect Link-16 messages, computer screen displays, and voice communications, as well as transcribe voice communications into text for improved search and correlation. Multiple data sources, including voice, Link-16, chat, and JADOCS remarks, may be searched simultaneously and displayed in user-customizable timelines.

CPAS version 1.2

CPAS was delivered to the Air Force in 2006. The primary purpose of the CPAS instrumentation system was to support individual and team training of the Air Force's Air Operations Center's dynamic targeting (DT) processes. Operational trainers use CPAS to monitor in near–real time individual and collective trainee performance. They compare observed performance against expectations, especially in relation to the lesson objectives, MSEL events, and other stimuli. By monitoring these activities in near–real time, trainers can flag critical learning opportunities for later analysis and debriefing, collaborate with others, and frame their initial understanding of individual and collective trainee performance. Using CPAS performance feedback, the trainers and event managers can also monitor and manipulate the event timeline to assess progress toward achieving lesson or exercise objectives. This includes monitoring the CPAS-generated JADOCS timeline (e.g., workflow manager playbacks) and warfighter chat systems for correlated activity. Finally, trainers use CPAS to support training debriefs after the training events and reconstruct student events and activities.

CPAS uses a combination of composite activity views (see top of *Figure 1*) and drill-down focus views (see bottom of *Figure 1*). The timescale is located along the top of the view, with each major event thread indicated by the track number, event name, and priority. In Figure 1, the trainer is exploring the DT Chief's SCUD convoy chat activity alongside the SA-6 TEL targeting process. Note the amount of detail CPAS displays (see *Figure 2*), mapping actual events onto the U.S. military's joint kill chain process steps: Find-Fix-Track-Target-Engage-Assess (F2T2EA).

Through interactions with Air Force personnel, JHU/APL realized that different training groups and warfighting regions apply region- or mission-specific approaches to their process steps. As a result, CPAS allows users to tailor each of the major process views. *Figure 2* shows the basic F2T2EA process with discrete color-coded steps, starting and ending times

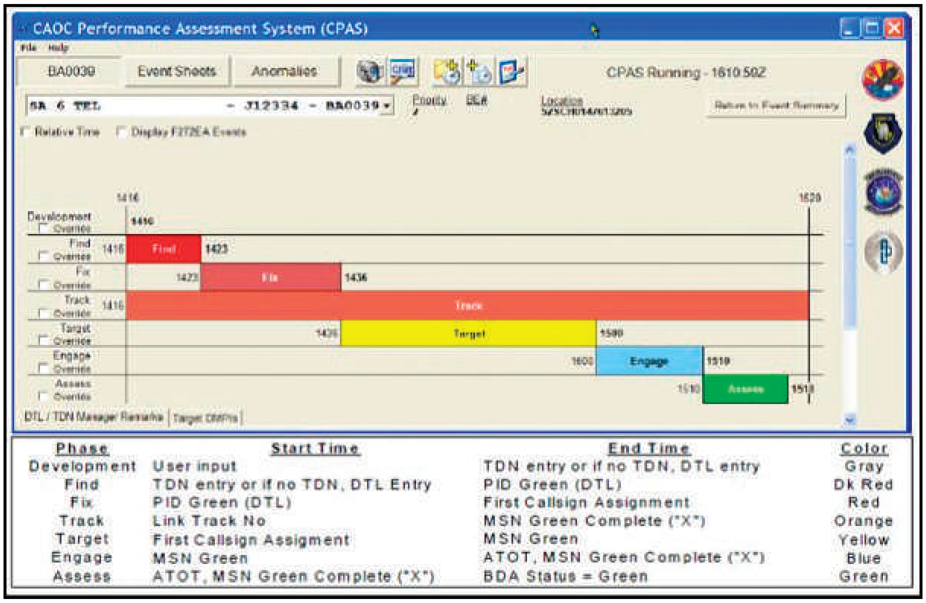

Figure 2. CPAS F2T2EA depiction of single mission.

defined as part of the CPAS configuration file for this unique training event.

CPAS was designed for realistic, dynamic scenarios and active instructor involvement in the training process. The system allows instructors to add their own notes, based on observations, trainee performance issues, or other potential learning opportunities, to the CPAS database.

Based on CAOC-N trainer requirements, CPAS exports relevant data fields into a Microsoft Excel spreadsheet for further analysis and development of debrief handouts.

The major analysis function in CPAS is a work-process anomaly detector (see *Figure 3*). Based on "school solution" process activities and timelines, trainers can compare individual and team trainee performance against the norm. In *Figure 3*, an intuitive display enables the trainer to recognize deviations from the expected work processes, providing instruction points for trainers to use during feedback sessions to the training audience.

CPAS augments trainer analysis and trainee performance feedback with a comprehensive JADOCS workflow manager playback feature (see bottom of

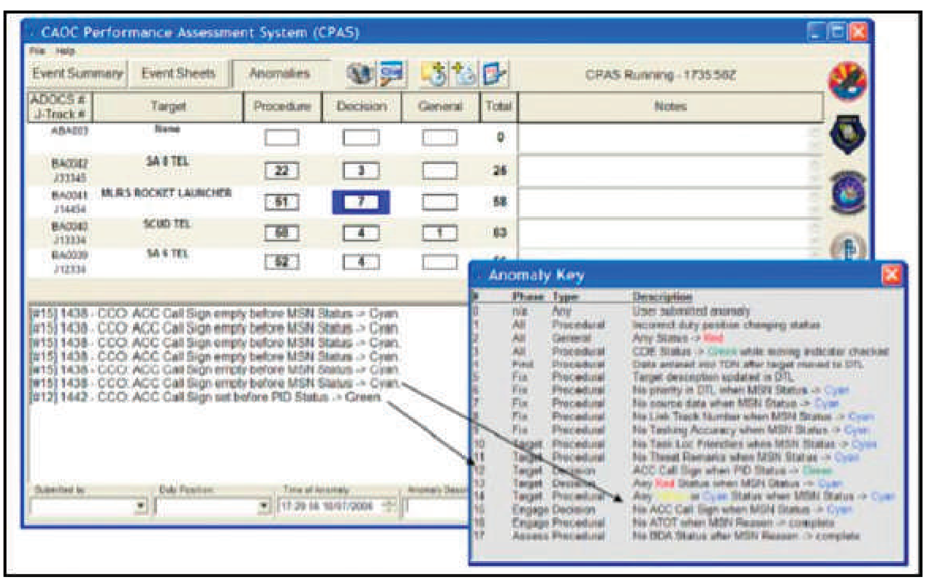

Figure 3. CPAS process anomaly display.

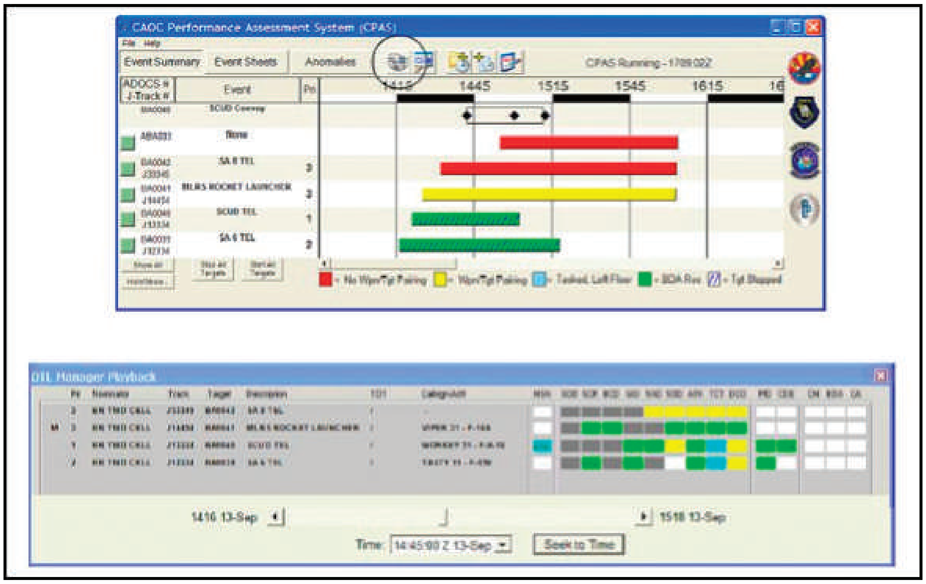

Figure 4. CPAS JADOCS manager playback display.

Figure 4). Using the slider bar at the bottom of the figure, the user can "playback" and observe activity and state changes in the respective JADOCS managers over time.

Based on JHU/APL's analysis of warfighter DT processes and TTP documentation, CPAS 1.2 focused on the chat environment as the primary context variable. This gave the instructor an increased understanding of "what's going on" among DT team members during a mission. *Figure 5* shows the wide variety of search and filter functions available for the trainer to analyze chat communications.

By collecting JADOCS and chat transactions, CPAS provided trainers with the ability to easily correlate these two disparate data sources for their trainee performance analysis and debriefing. *Figure 6* illustrates CPAS's correlation capability.

The capabilities CPAS provides to Air and Space Operations Center (AOC) DT trainers is enabling a transformation in the way AOC DT training is accomplished. CPAS reduces the subjective assessments of trainers and students, and creates more reliable, objectively recorded and measured facts. Already, CPAS functions as a training-force multiplier.

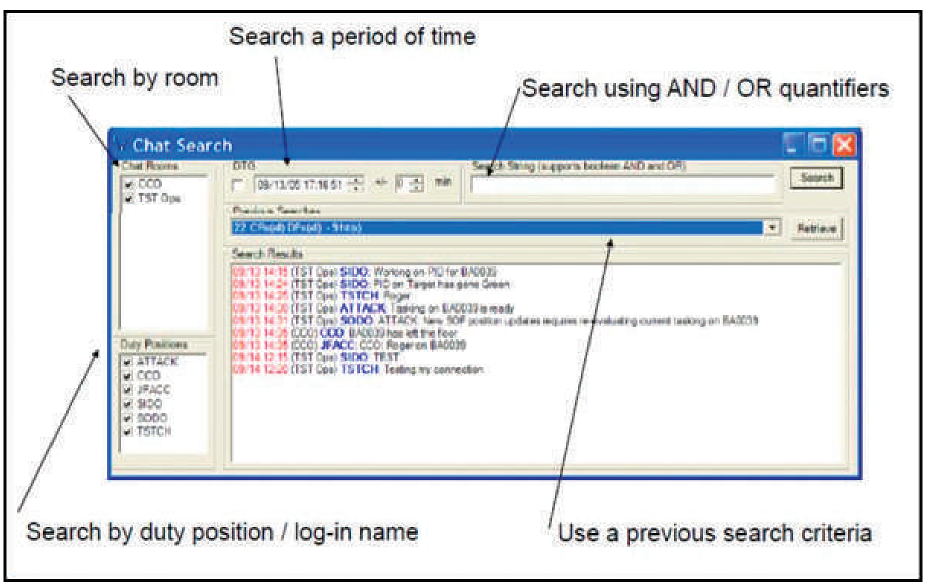

Figure 5. CPAS chat search interface.

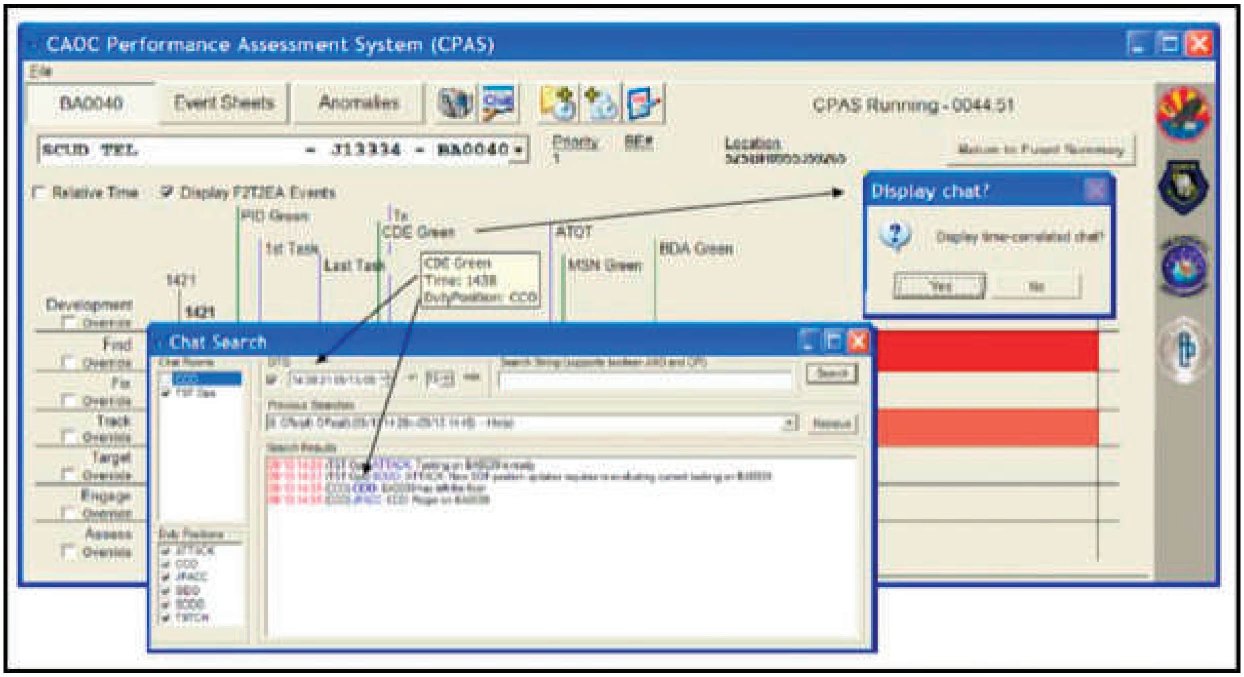

Figure 6. CPAS timeline-chat correlation displays.

No longer are trainers required to spend valuable training time manually collecting data for reconstruction. Instead, trainers have more time to observe, interact, and assess. Although not formally evaluated, the trainers have estimated that the use of CPAS has provided a 75% reduction in the amount of time required to prepare a debrief. Furthermore, CPAS has enabled the training debrief process to evolve from filling in key event times in a Microsoft Excel spreadsheet to spending more time analyzing the training threads and understanding what happened, when, and why.

CPAS version 1.3

CPAS 1.3, or eCPAS, was delivered to the Air Force in 2009. The primary purpose of the eCPAS instrumentation system was to support operational testing, as well as continue support for individual and team training of several of the AOC's combat operations division processes. eCPAS enables operational testers to monitor mission thread activities under test in near–real time. They can compare observed activities and events against expectations outlined in the test plan. By monitoring these activities in near real-time, they can flag critical observations for later analysis, collaborate with others, and frame their initial understanding of tested system performance in the context of the mission conditions, processes, and systems used.

Building on the successes of CPAS, eCPAS added several valuable capabilities. eCPAS retained the JADOCS timelines and workflow manager playbacks, as well as the warfighter chat systems for correlated activity. Based on operational tester requirements, eCPAS added the collection of additional chat systems, voice on C2 audio channels, and selected Link-16 messages. Testers can also identify significant observations via eCPAS by inserting flags directly onto the user interface. Flags can include both comments and screen captures to provide primary source data for anomaly analysis. The test team can take an instantaneous screen capture or set up periodic capture for the duration of the test event.

eCPAS has a "unified search" to support its correlation and analysis capability. *Figure 7* shows the increased fidelity of data capture that distinguishes eCPAS from CPAS. Testers can selectively search chat systems, rooms, and users; data link sources; and voice data sources. Testers can also query JADOCS data to view specific transactions from JADOCS' mission history files. In addition, testers can filter by keywords and times across all the selected communications simultaneously. Once the user-defined search data are returned, three different keywords can be highlighted throughout the data to show relevant trends and pick out threads. Finally, user-defined search data can be sent to a new timeline for display and analysis.

eCPAS improves on the CPAS framework for the JADOCS mission manager playbacks (see *Figure 8*) by making it easier for testers to configure and update the manager displays in real time.

Testers can inject events into the eCPAS database by generating process "flags" at any time during test event planning or execution (see *Figure 9*). Flags allow the testers to integrate their notes and observations with the

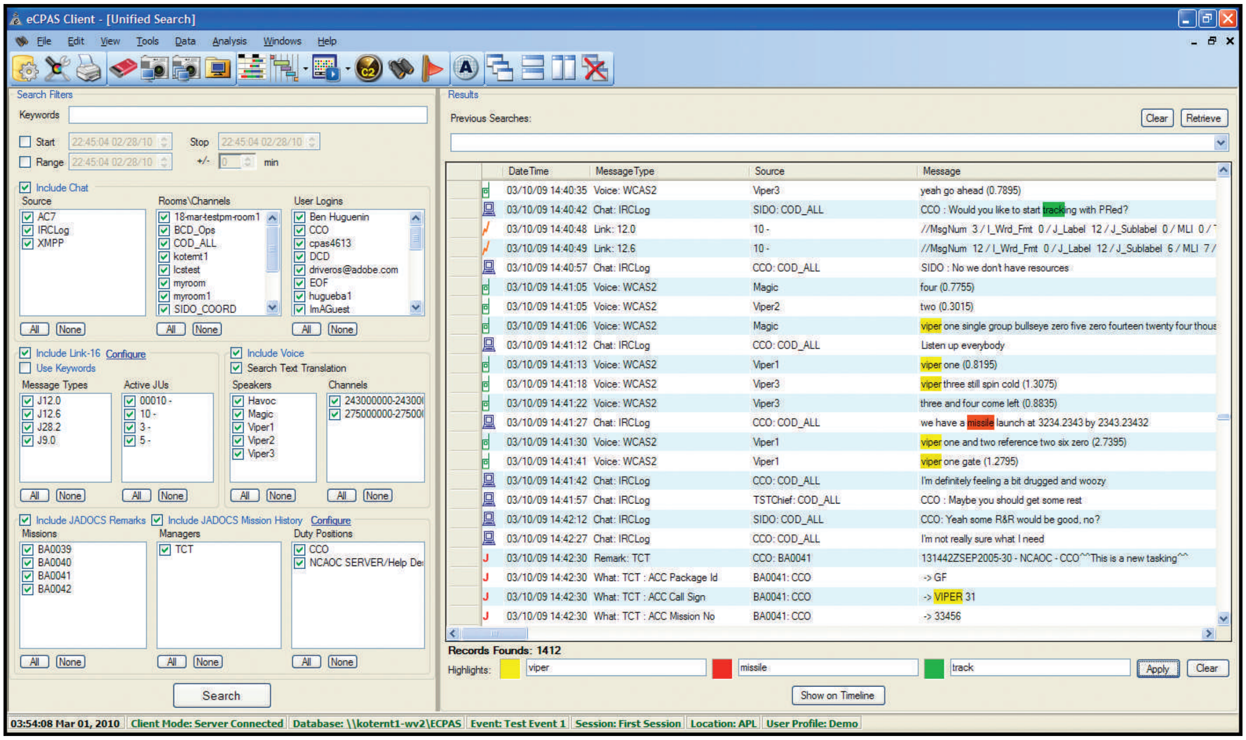

Figure 7. eCPAS unified search control display.

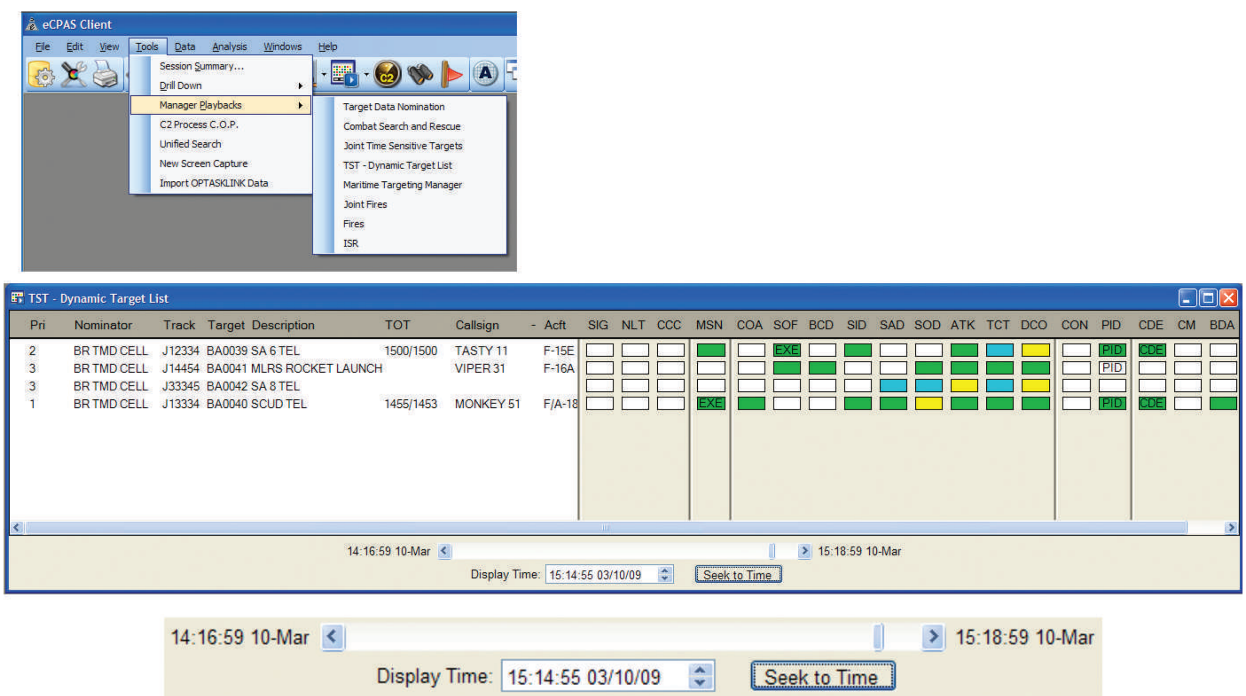

Figure 8. eCPAS JADOCS manager playback display.

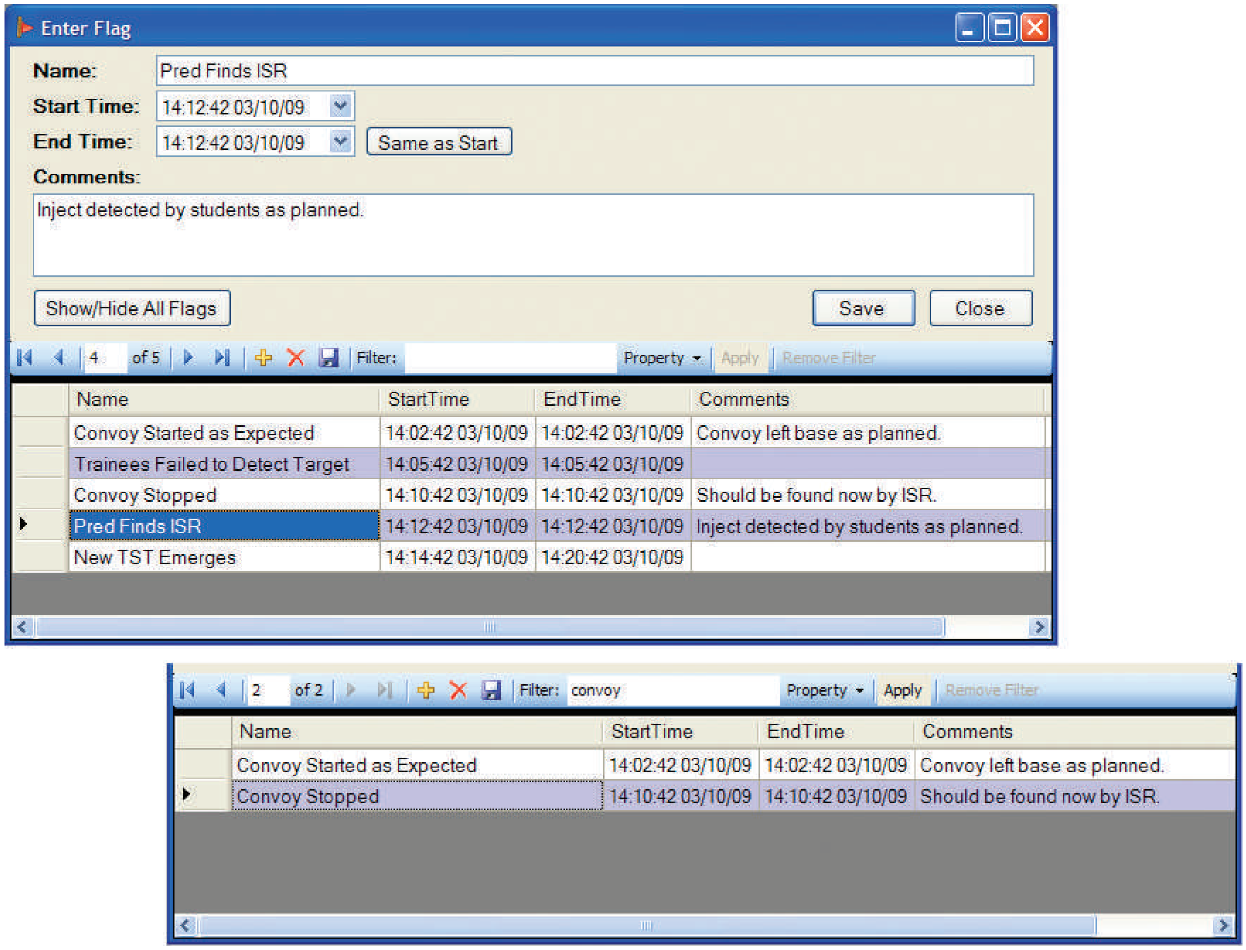

Figure 9. eCPAS "flag" entry.

rest of the data being collected by eCPAS. Multiple testers can create and edit these flags, which are viewable by the entire test team. Flags can be filtered (see bottom of *Figure 9*) for quick access and editing.

Another capability added in eCPAS allows testers to view timelines of data alongside one another. This new view, the Command and Control Process Common Operating Picture, or "C2 Process COP," is shown in *Figure 10*. The aggregate activity in JADOCS, chat, Link-16, and observer flags in area (1) shows the correlation of events in these different domains over time. This view would logically trigger the tester to conduct further analysis in this time slice and also provide the "at a glance" overview for the test team leadership. Conversely, the proliferation of observation flags (2) over a greater time slice might cause the tester to question why no activities have been recorded in the other (e.g., JADOCS, chat, Link-16) domains.

Table 1 provides an overview of the CPAS and eCPAS data sources, and the information they provide. In addition, it provides a one-sentence summary of each version's targeted use.

JEFX-09 case study

The goal of the Warplan-to-Warfighter Forwarder Spiral II (WWF II) system was to enable JADOCS, Target Package Generator, and Network Enabled Weapons Control Interface Manager to send machine-to-machine targeting data from the AOC directly to the airborne C2 aircraft, combat aircraft, or Network-Enabled Weapons (NEW) using Link-16 standards (MIL-STD-6016D) and allow automated status updates in a dynamic targeting environment. The task being performed by the team assessing WWF II in JEFX 09-3 was to analyze the timeliness, accuracy, and completeness of all the J-series messages that were transmitted on the network. Although not a formal operational test event, the JEFX 09-3 experiment was a suitable surrogate that included real operators and aircrew conducting operations in a live, virtual, and constructive environment. Live aircraft (F-15Es, F-16CMs, a B-2, and an E-3 AWACS) flew missions in the Nellis ranges; simulated aircraft, both virtual (E-8 JSTARS) and constructive (F-15E, F-16C), were located at Eglin Air Force Base (AFB), FL;

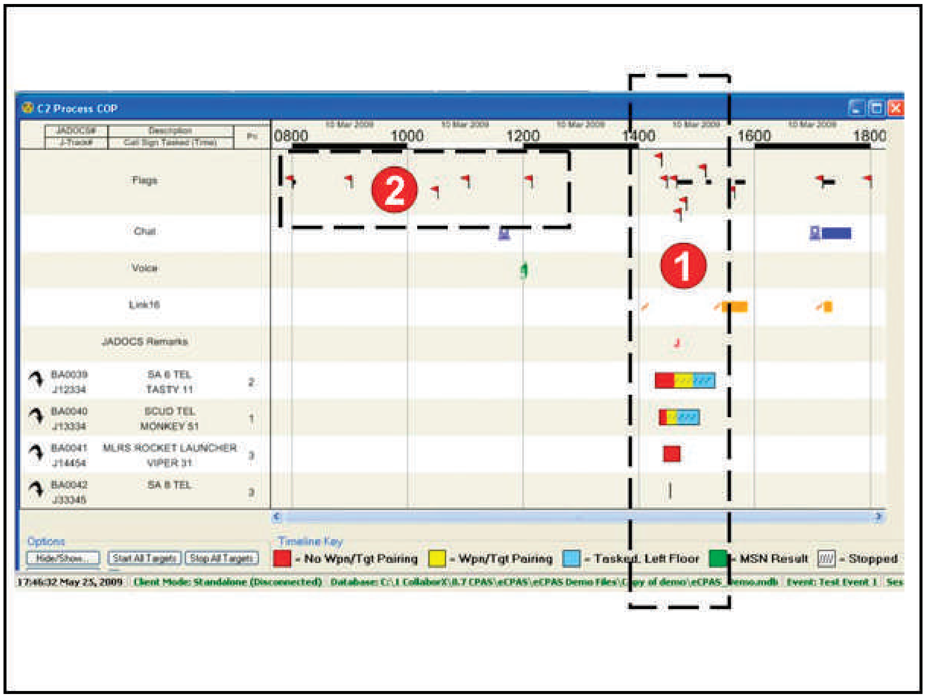

Figure 10. eCPAS C2 Process COP for visual correlation and event overview.

and a live AOC manned by real operators was in place at Nellis.

The primary technology used by one member of the assessment team to monitor, in near–real time, the WWF II system during JEFX 09-3 was JADOCS. The JADOCS workflow managers (Joint Time Sensitive Target Manager and the Intra-AOC Manager) together with the Coordination and Target Data tabs in each mission folder provided most of the data needed to maintain an understanding of the mission information flow. Other technologies used to build and maintain situational awareness during live-fly operations included the CPAS instrumentation displays, the XMPP chat client (transverse), the multilink translational and display system, the tactical view command and control, the joint windows warfare assessment model, and audible voice communications.

During both live-fly and modeling and simulation operations in the experiment, the event summary timeline display of CPAS version 1.2.5.3 was used to maintain insight into the state of each of the 15 to 20 missions that had been tasked. Multiple missions were prosecuted simultaneously; therefore, the event summary timeline feature helped the assessor to keep track of the missions and key events as they occurred. When required, further details of a specific mission were available by drilling down to the detailed mission phase's display from the event summary window. These drill-down views allowed analysis of key events in the context of the phases defined by WWF II assessors.

Another useful CPAS feature was the JADOCS workflow manager's playback displays. Using the Intra-AOC Manager playback, an assessor could quickly find when the critical columns changed status by viewing changes in the color and/or three-letter status code of the manager's display lights, known as "chicklets." Many times during the exercise, the JADOCS Intra-AOC Manager chicklets (which are incredibly small on an extremely crowded computer monitor) changed very quickly and an assessor had to be observing the specific chicklet at the exact moment to verify the transitory status. With the playback manager in CPAS, however, the assessor could easily go back and step through the scenario to verify which actual transactions occurred at which time. The CPAS chat search also proved useful by allowing different chat rooms and roles to be selected and then searched around a specific timeframe or for specific keywords. Thus, CPAS helped in tracking the various human and machine actions and chat communications, helping assessors reconstruct and understand the exact interactions among the systems under test.

Although eCPAS version 1.3.0.14 wasn't fully functional during JEFX 09-3, it did demonstrate its potential value with certain features, such as screen capture technology that helped the assessor to record and replay an operator's screens during the experiment. Other useful features, such as capturing Link-16 messages and displaying JADOCS remarks and mission history information in a timetable with the unified search function, proved their worth during detailed data

Table 1. CPAS/eCPAS capability summary.

	Data sources	Information provided
CPAS 1.2*	JADOCS	Dynamic targeting mission histories (e.g., who, what, when, where, how)
	IWS	Dynamic chat content (e.g., who, when, what)
	Jabber (XMPP)	
	mIRC	
CPAS 1.3†	JADOCS	Dynamic targeting mission histories (e.g., who, what, when, where, how)
	IWS	Dynamic chat content (e.g., who, when, what)
	Jabber (XMPP)	
	mIRC	
	Adobe Connect	
	Link-16	Dynamic data link content (e.g., C2 system messages between AOC and tactical units)
	Voice	Recorded .wav files of tactical communications
	Voice text	Transcribed files of tactical voice communications
	Video capture	Single view and/or sequenced screen shots of selected user work station displays

IWS = Ezenia InfoWorkspace, XMPP = eXtensible messaging and presence protocol, mIRC = Madam-Bey Internet relay chat.

*CPAS 1.2 supports individual and team training. The system correlates AOC dynamic targeting activities with chat, exposing activities in context to exploit learning opportunities.

†CPAS 1.3 supports individual and team training and operational testing. The system correlates AOC dynamic targeting activities with multiple interactive chat systems, data link messages, and voice transmissions exposing activities in a rich context to exploit learning opportunities and generate empirical assessments of systems under test.

analysis (using eCPAS version 1.3.0.27) after JEFX 09-3. The scalable timetable feature also helped assessors zoom into critical timeframes, such as when messages are sent from the AOC to identify potential problems when mission scenarios do not proceed as planned.

In summary, the CPAS process instrumentation systems proved useful as both experiment monitoring tools and analysis augmentation tools for WWF II assessors. These CPAS instantiations still require additional functionality to serve as the primary analysis tools. Specifically, feedback from the WWF II assessors indicates the need to expand the Link-16 data collection to other J-messages, as well as to pursue the ability to collect and transcribe voice communications with better accuracy.

Conclusion

The authors believe process instrumentation, which focuses on collecting information about human activities, provides great benefits to the training and test communities. Future efforts to improve and enhance the current CPAS capabilities will more fully realize the goal of process instrumentation and analysis. JHU/APL currently has, or is, applying the concept to Air Force Air Support Operations Center operations, U.S. Navy Maritime Operations Center operations, and the Joint Forces Command Joint After-Action Review Resource Library. In addition, JHU/APL is working on the next iteration of the C2 process instrumentation concept, the Operational Command and Control Instrumentation System (OC2IS, pronounced Oh-sis). OC2IS is an FY10 Resource Enhancement Program project sponsored by the Office of the Secretary of Defense's Test Resource Management Center and managed by the Air Force 505th Command and Control Wing. Although requirements for OC2IS are not yet finalized, potential enhancements include distributed data collection, remote data collector control, Web-based user interfaces, a service-based architecture, more robust voice transcription, automated analyses capabilities, workflow tracking, improved user configurations, more powerful reconstruction tools, and collectors for new data sources. By capturing data on the human view and perspective during process execution and then correlating that data to other data to determine the overall impact of the human-in-the-loop, OC2IS will contribute to the assessment of how well systems under test are meeting mission effectiveness requirements.

Along with developing technology to collect new types of data, JHU/APL is also researching how to best portray these data to provide meaningful insight into the processes and the human component of total system performance. By providing a better understanding of human activities and their effects, JHU/APL wants to develop capabilities to evaluate the impacts to C2 and TTP of new technologies and training methodologies. This includes tracing threads of human and technology activities, as well as evaluating human aspects, such as workload, situation awareness, and decision making for individuals, and the collaboration and coordination of teams. ❑

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