Adaptive Development of a Common Operating Environment for Crisis Response and Management

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ABSTRACT

Complex information and communication systems present a special challenge to system designers because these are generally deployed as large, distributed systems with diverse user groups. Crisis response and management organizations in particular expect systems to be interoperable, resilient, flexible and provide lasting benefit. Currently, systems such as Virtual USA (Department of Homeland Security) and WatchKeeper (United States Coast Guard) seek to create common situational awareness for all participating agencies in security and incident response operations. We propose *adaptive development* as a system development model to build upon the ideas of systems such as Virtual USA and WatchKeeper in order to create sustainable and adaptable systems. Adaptive development supports ongoing improvement through user-driven design and modification in the target environment. An internet-based dashboard demonstrated during a United States Coast Guard Sector Seattle incident response exercise serves as an emergent case study for the adaptive model.

Keywords

Common Operating Environment, Situational Awareness, Collaborative Decision Making, Service-Oriented Architecture, Precision Information Environments, System Development.

INTRODUCTION

Information and communication systems have become indispensable to government and non-government crisis response and management (CRM) organizations. Unambiguous and timely sharing of information have become key areas for improvement for CRM (Harrald & Jefferson, 2007). In particular, CRM organizations hope to create a common operating environment (COE) to aid multiple agencies and units in situational awareness and collaborative decision making. Currently, systems such as WatchKeeper (United States Coast Guard) and Virtual USA (United States Department of Homeland Security) are creating a common operating picture primarily through geographic information systems (GIS) comprised of maps with overlays, which allow multiple agencies to achieve common situational awareness and improve coordination during crises.

While relatively new, the development and maintenance of COEs remains problematic. Even in cases where due diligence in user requirements gathering and usability evaluations is applied, systems are created by software development companies in relative isolation from the client's organizational environment. Also, active development of the system largely concludes when the system is deployed to the client community. This is particularly problematic for highly dynamic and often unpredictable environments like those surrounding major crises and emergencies. While some programs create change control boards (CCBs) to review and judge system change proposals, the opportunity for parallel, contextually-customized development is stifled by a central development process.

These aspects of traditional software development models create information systems which are not sustainably integrated within the client's complex organizational environment, nor are they easily adapted to changing user needs. As a result, many organizations are forced to replace or overhaul their information and communication systems every 2 to 3 years to take advantage of advancements in technology and to address the organization's changing information environment.

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This paper proposes *adaptive development* (AD) as a unique and superior system development paradigm for COEs in the context of mission-driven organizations. AD does not address software development methods directly, but instead presents a holistic system design and development model based on *ongoing* and *contextual* development of the system. AD maintains a two-level development process that is driven by the community of practice: *macro-level system definition* and *micro-level system development*. AD is based on two principles of practice. First, the bulk of system development occurs "live" within the client organization after a base architecture and capability has been introduced to the target environment. Second, system analysts facilitate user-driven development of the COE application layer according to the client's overall information strategy and constraints.

This paper begins by presenting related research in the areas of models of ongoing information system development, and information sharing for crisis management. We list the motivations to create a new system development model, introduce the concept of AD, and set the context for this development model. Following this, we discuss a case study based on currently in-progress, experimental application of the AD process to initial development of a Puget Sound Interagency Common Operating Environment (PSICOE), an incident command decision-support system for the Puget Sound Area Maritime Security Committee, led by the United States Coast Guard Sector Seattle. We conclude with a discussion of the challenges and opportunities of using AD to develop COEs.

RELATED RESEARCH

This section presents research related to 1) information system development in the areas of ongoing system development and the needs of distributed organizations, and 2) communication and coordination of crisis response and management organizations. This is not meant to be an exhaustive research review, but an overview to set the context for AD as a proposed system development model.

Development for Distributed Organizations and Ongoing Development Models

The idea of creating loosely-coupled, easily extendable information systems for distributed organizations has been known for several decades. Burns and Rathwell (1987) proposed a *distributed decision making system*, based on modular information system components which could be integrated horizontally across an organization, rather than hierarchically. They posited that one benefit of this system architecture is that groups within the client organization may develop components in parallel, leading to development efficiencies. Burns and Rathwell espoused a development method which would give flexibility to each working group to develop and adapt their system components.

Costabile et al. (2006), make the case for recognizing the *co-evolution of users and systems*, based on research emphasizing that users adapt to new information systems, as well as adapting those systems to their needs. They pointed out that "the user social and organizational context is evolving during time, requiring new tasks and/or different ways of performing tasks," emphasizing that, over time, customizable and adaptable systems provide greater utility to users than rigidly developed systems. However, Costabile et al. stop a step short of proposing ongoing development.

In contrast, Bossen and Dalsgaard (2005) proposed truly ongoing technical alterations to a system as *strong appropriation* of a system by an organization. While strong appropriation of a system may indicate that the system is supporting work well, unregulated system development can lead to inappropriate system configurations. Creating a system which is meant to facilitate user appropriation and continuous development relieves some of the need for system developers to learn the explicit and implicit knowledge of workers and to account for all aspects of the work context, as users can adapt the system for those factors.

Information Sharing for Crisis Response Management

Mendonca and Wallace (2007, p. 553) described human planning behavior as "incremental, opportunistic, and multidirectional." ERM organizers and workers must be able to cope with incidents that cannot be predicted or modeled by utilizing resources in whatever way the emergency incident requires. Building upon Mendonca and Wallace, we believe that the electronic resources of emergency response managers should be geared toward adaptability and improvisation to align with the reality of emergency situations.

Wu and Zhang (2009) described the difficulty of achieving collaborative sensemaking in emergency management stemming from the fact that conveying information does not guarantee mutual understanding. Tools such as e-mail, telephones and shared databases do not directly support collaborative sensemaking, and hence the authors proposed map-based visualization tools in order to provide a shared picture of the incident situation. This approach has been enthusiastically adopted by government CRM information systems such as Virtual USA. In the current paper, we posit that in addition to a common tool set, such as map-based visualizations and analytic tools, CRM organizations would benefit from a common operating environment to house those components.

Mattioli et al. (2007) pointed out that "information needed by each civilian and military emergency response units differs according to its mission, the situation on the ground" and other contextual factors. They proposed various information sharing strategies, including information coding standards and geo-referencing data, to cope with these disparate stakeholder groups' needs. In this vein, we propose that a common operating environment employing an ongoing development model and information sharing capabilities at various levels of granularity will assist in providing the necessary and correct information to each ERM stakeholder group.

ADAPTIVE DEVELOPMENT FOR CRISIS RESPONSE MANAGEMENT

Context and Motivation

Adaptive development is related to the naturalistic decision making concept developed by Gary Klein (Klein, 1993; Zsambok & Klein, 1997). Naturalistic decision making is a theory of decision making which holds that emergency responders, such as firefighters, do not manage by objectives, but instead make decisions based on constantly reassessing an emergency situation and act on the current best option. In his latest work, Klein calls decision making under ambiguous and unpredictable conditions "adaptive decision making" (Klein, 2009). Our adaptive development model is based upon addressing these same conditions when developing information systems.

This paper is concerned with developing COEs for mission-driven groups such as CRM organizations. These organizations exhibit at least three characteristics which create a need for adaptive, in-context system development. First, CRM organizations generally have myriad internal and external stakeholder groups. This creates the need for a common operating environment which can still be adapted for the preferences and needs of individual users and user groups. To create a sustainable COE, the system development process must referee the tensions between user groups, while creating a system in which each group can effectively and efficiently achieve its objective (Maiers, Reynolds, & Haselkorn, 2005).

The second characteristic is that the information environment of CRMs is extremely data intensive and changes rapidly. New data sources and tools emerge quickly. Government policies and regulations are updated. The organization may restructure. Units are deployed to a yet unvisited region. Crisis incidents range in type and magnitude. Organization strategies are realigned. AD seeks to create sustainable COE by developing the system with stakeholder groups "in the wild" of the target environment as such changes and new needs arise.

Third, participants in crisis response and management must, in Klein's terms, deal with situational sensemaking and adaptive decision making. AD supports this kind of emergency response behavior by allowing users to mold the system to the unique characteristics of their group's context and mission.

Adaptive development specifies that the development organization provides an ongoing service to the client organization, rather than simply delivering a product. Both product and service-based business models would produce a COE; however, AD practitioners facilitate the client's ongoing development of the COE, whereas traditional development processes deliver a product which is essentially static. AD regards an efficient and effective system evolution, rather than simply "maintenance," as the key to creating sustainable COEs.

AD is development in the wild

Preliminary development

AD begins with the client organization's desire to adopt a common operating environment type of information and communication system, and to continuously develop this product to meet their information strategy. The next, important step is to establish a long-term, trusting relationship between designers and developers and the operational community of practice. Designers work with the client organizations to develop or evaluate their overall information strategy to accommodate the new system. This strategy acts as a guide for both the client and development organizations within which to create the COE. The client community's range of missions, values, and goals is used to clarify an overall information ecology for the diverse community of practice, and the development organization can apply AD within the parameters of this ecology.

The development organization creates or reuses a service-oriented software architecture (SOA) which will support the client community's information needs. The SOA becomes a framework within which various information and communication resources can be integrated. The platform should be extensible to several different media, such as mobile devices and very large screens. The platform should build in redundancy and robustness measures as appropriate to the client needs.

Application software resides on top of the software platform. Any visual analytic, communication, or information dissemination tool can be developed and dropped into the application layer as a module. The goal of the initial application development is to deliver a base capability to the client organization. This initial development phase may follow any appropriate software development model (even a waterfall model) and should be very short. For the system in the case study below, the initial development period was six weeks.

Requirements gathering for this initial deployment should focus on breadth, rather than on details. Usability testing and further requirements gathering/validation cycles are deferred until the COE is in use. The platform software, however, should be thoroughly tested before deployment in order to ensure a robust system. The idea is to deploy a base system which works to specifications, but with the expectation that user-driven specifications based on actual use will change the environment over time.

At deployment, the system should support independent user actions such as swapping which components are active or visible, and also adjusting the configuration of the screen. This already provides users the ability to tailor the interface to their needs and preferences, and sets the foundation for promoting further system development.

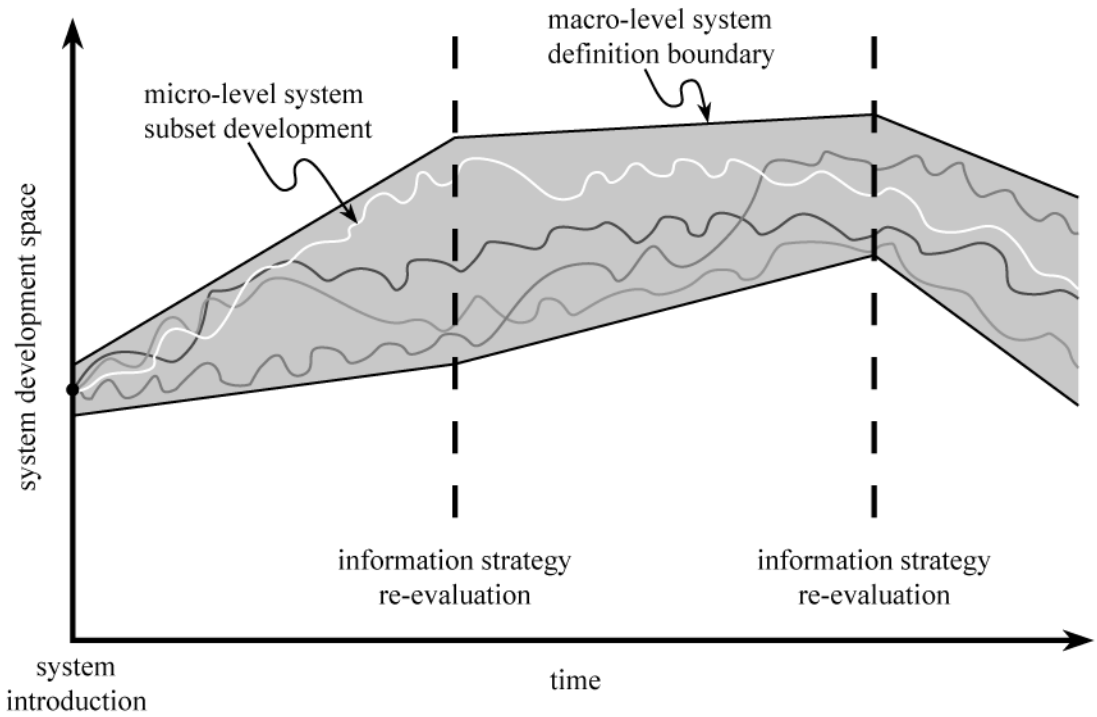

Figure 1 Adaptive development process model.

Overview of the adaptive development process

The adaptive development process is diagrammed in Figure 1. The y-axis of the graph depicts the possible "space" the system can be defined within. Elements which comprise the y-dimension include features, user profiles, possible system components/tools, interface configurations, information sharing options, security procedures/features, and any other system configuration elements.

The *system definition boundary,* depicted in Figure 1 by the solid lines bounding the filled area, is determined through the macro-level system development, which is described below. These lines bound the system based on the system development guidelines and procedures imposed centrally by the client organization. All micro-level development must occur within those guidelines and boundaries in order to be legitimate.

Each of the squiggly lines inside the shaded region depicts a subset of the system which is developed independently. In most cases such a subset will correspond to a particular user group. Importantly, these subsets are developed in parallel and independently within the rules and guidelines of the system definition boundary.

The x-axis of the diagram depicts time. The change of the system through time is the expansion and reconfiguration depicted by the movements of the subset lines, as well as the change in direction of the system boundary definition lines. The latter phenomena is initiated at scheduled or spontaneous re-evaluations of the client organization's information strategy (depicted by vertical dashed lines in Figure 1).

The micro-development level

At this juncture, AD departs more radically from typical software development models. The COE, which by this point consists of the software platform and the initial applications suite, is immediately deployed to the client organization. At deployment, the development organization positions user-centered system design experts within the client organization. These analysts facilitate user-driven design of the system within the context of the organization's information strategy. The goal is to foster client ownership of the system. This is a key method by which AD aims to create sustainable COEs. The analysts may use human-centered design methods, such as ethno-methodological observations, semi-structured interviews, personas and paper prototyping to gather further feature and usability requirements. However, emphasis should always remain on participatory and user-driven system development.

Analysts should strive to encourage users to not only suggest, but push for changes in the system according to their needs. Participatory design sessions should be established to vet ideas, particularly as to whether they are aligned with the overall organizational information strategy. System developers participate in these sessions by acting as facilitators and maintaining the high-level view of the system and applying the organization's system development guidelines. Regional exercises are a wonderful opportunity to push this agenda, with after-action reviews including analysis of future development directions.

Analysts continuously report requirements to the software developers, who immediately develop, test and deploy new features or changes. This rapid development model is of course currently being employed by internet service companies, such as Google and Facebook. We argue that this same paradigm will be beneficial to CRM organizations in light of their rapidly changing information environment. Developing a regional, interagency COE presents a perfect opportunity to study how micro-development with intra- and interagency units creates a sustainable and useful COE. This is the case with the PSICOE case study described below.

The macro-development level

As system developers facilitate and harmonize the individual changes to the COE, they must also assist the client organizations with regularly evaluating the system state with respect to the community's overall information strategy. Should the system, or components of the system, deviate from the goals and guidelines, the system must be tweaked to comply with the information strategy. For U.S. multi-agency coordination, the overall strategy is the National Incident Management System's Incident Command System (NIMS ICS). NIMS ICS provides a context where different groups with different roles, jurisdictions, information needs and decision making responsibilities work together on a given complex evolving situation. In this case, the COE must be aligned with the overall ICS strategy.

The other side of this same coin is that the client organizations must periodically reevaluate and adjust their information strategy to address environmental changes. Indeed, sometimes an environmental change, such as a significant budget cut or organizational restructuring, will cause a spontaneous adjustment to the information strategy. In this case the system must again be evaluated against the new direction of the organization and tweaked to accommodate the changes.

Adjusting the information strategy then sets a new direction for the system boundary line, based on the goals and constraints of the client organization. In Figure 1, the shaded area between system definition boundary lines is the *possible* system configuration space each system subset may occupy, based on the central rules and guidelines of the entire organization.

A CASE STUDY: PSICOE

The Puget Sound Common Operating Environment (PSICOE) is an internet-based dashboard COE which was deployed during an exercise of the United States Coast Guard (USCG) Sector Seattle. One facet of the exercise was to study the potential of using AD to develop COEs for CRM organizations. The PSICOE and its study are a collaborative effort between regional maritime security agencies and three DHS university centers of excellence: the Visual Analytics for Command, Control and Interoperability Environments Center (VACCINE), the National Center for Foreign Animal and Zoonotics Disease Defense (FAZD), and the National Center for Border Security and Immigration (NCBSI).

The primary client organization is the Puget Sound Area Maritime Security Committee (AMSC), which is led by the USCG Sector Seattle and includes first responder agencies; the regional Ports; other Federal agencies such as Customs and Border Protection (CBP); State, city and county emergency managers and centers; maritime unions, and others. This is an extremely complex community and the PSICOE must support both intra-agency and interagency information exchange and decision making.

Development of the PSICOE

The PSICOE was adapted from the Dynamic Preparedness System (DPS—developed by FAZD at the Texas Center for Applied Technology), which is an internet-based, adaptive software architecture. The application layer of the technology is a component-based framework. A component can be developed independently of the other components in the application layer and dropped into the system. The COE is independent of the application components running within its framework and development of those components is highly modular.

The independence of component applications and simplicity of integration may be traded off for integration with the environment and other components. For example, the PSICOE contained a component to provide weather information. This component simply opened a web site which presented the local weather information. This component is highly modular and the introduction of that component into the environment is extremely simple, but the information is also visually separated from the remaining COE. For a more integrated information visualization, the component could, for example, be integrated with the GIS map component to overlay weather information on the area map. This example illustrates the tradeoff between component integration and modularity. Such tradeoffs should be the subject of the macro-development level of system definition within a client organization.

The application layer also supports unique views, called profiles. A profile is a pre-set configuration of components and interface settings. The four profiles created for the AMSC exercise were: 1) field, 2) command center, 3) Unified Command (UC) and 4) media/public information. Importantly, every user of the dashboard may manipulate the components and interface under their own account, without changing the view of other users. The users may then choose to broadcast information to selected units within the organization.

As part of creating the PSICOE, the application layer was populated with relevant regional information and augmented with components relevant to the target exercise. In particular, a plume model (developed by VACCINE) that presented a visualization of estimated impacts of a radioactive event given various conditions was integrated into the COE. The COE was further tailored to regional conditions through an analysis of the key decision making communities and the decisions to be supported during the target exercise.

The exercise

As a trial of the AD process, the transformation of DPS to PSICOE was accomplished in six weeks, and demonstrated a set of basic capabilities for an AMSC on-water exercise involving small vessels with potential radioactive threats. An analysis of the information environment and needs was conducted with the AMSC and five key decision making questions were identified to drive the development of components of the PSICOE. These five questions/decisions were: 1) Where are the threatening vessels and what is their status? 2) What is the nature of the threat? Is there a dispersal device? 3) What should we do with the identified threat? Is there a place and/or condition (e.g. scuttled) that would lower the threat risk? 4) How are we managing the commercial and pleasure vessel traffic? 5) What are we telling the public? Pre-configured user profiles were developed to support the stakeholder roles in answering these questions.

The focus of the AMSC water exercise was to support the Coast Guard's implementation of NIMS ICS in the detection of small vessels transporting radioactive material, possibly with a detonation device, in the Puget Sound maritime arena and to take action to minimize this threat. Three choke points were established at inlets to the Sound and each was monitored by a branch of field operations units. Blue force units were tracked using a transponder data stream which was displayed on the PSICOE. Participating Coast Guard vessels designated as "Red force" units were also fitted with transponders which were tracked. Commercial shipping traffic was monitored through a separate open-source tracking system. These and many other data components from a wide range of disparate sources were accommodated within the COE framework.

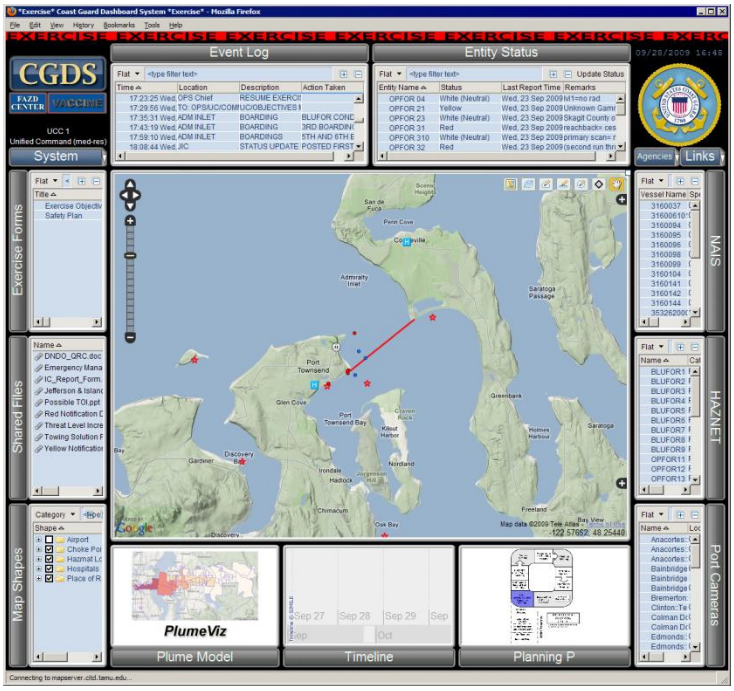

Figure 2 A screen capture of the PSICOE Unified Command profile during the AMSC exercise

The PSICOE was an adjunct experiment to the field exercise and not intended to be a primary communication system, nor was it incorporated into the interagency action plan. It was included in the exercise rather as a demonstration and presentation of the COE, rather than as a fully functional information and communication system.

For this reason, participants received minimal training in using the PSICOE prior to the exercise. The university teams trained the Coast Guard participants in how to use the PSICOE for approximately 2 hours, 2 days prior to the exercise. Participants were taught only those features that were anticipated to be of use for the various command roles. For example, training of on-water field participants focused on how to place a shape representing a potentially threatening vessel on the map component, mark that entity as unknown/cleared/threatening, and share that component and information with other selected units. Other training covered selecting a profile, entering event log entries, using the plume model component, broadcasting data to other units, sharing files with other units, and using the resource/entity status component. The entity status component was intended to track vessels and report the current status of that entity. (For a video of the exercise common operating environment, see http://citdweb.tamu.edu/dreams/CGDS_Overview.wmv)

During the exercise, a university team member was stationed with each of the participating units in the command center. The units in the field were able to request assistance in using the PSICOE through cell phone contact with the university teams. For several of the participating units, such as Unified Command, the university team representative became a dedicated PSICOE operator throughout the exercise. In other units, such as the public media joint information center (JIC), participants operated the PSICOE themselves.

A pivotal moment during the exercise occurred when the covered communications radio channel became unavailable to Coast Guard units on the water. The exercise was nearly cut short; however, the Unified Command decided to continue when field units began improvisationally using the PSICOE event log and entity status components as a communications workaround for the remainder of the exercise. The PSICOE abruptly became a focal point of the exercise, because units relied upon it for information and communication.

Because no procedure for using the PSICOE communication components had been established prior to the exercise, the field units began improvising on how to use the PSICOE as their primary communications channel. Two field units used the event log to report which vessels they had boarded and what the subsequent vessel status was. The other field unit reported this information using the entity status component. Interestingly, without specific training and using the flexible COE with different strategies, the units were able to successfully complete the exercise. This demonstrated a proof-of-concept for the COE's flexibility and ease of use.

Once the simulated nuclear material had been discovered during the exercise, the Unified Command used the PSICOE to brainstorm and visualize possible courses of action to mitigate the threat. The plume model became a primary visual analytics tool for this effort. The UC used the PSICOE as a decision-support tool while devising plans which would minimize projected deaths and illnesses if the nuclear device detonated. In this manner, the UC decided on a plan to move the vessel in question into open water, where a crane and barge could be used to raise the vessel for inspection and neutralize the simulated radioactive threat.

While creative and successful, this operation of the Unified Command was outside of regular ICS procedures. In their ad hoc communications solution, field units provided all available information to the UC, whereas under usual conditions the Situation Unit, Planning, and Operations teams gather and sift information before presenting to UC. Under normal ICS conditions, these groups periodically report the situation on the ground and suggest plans for the next operational period to the UC, which is responsible for vetting and eventually approving a suggested plan. As a spur-of-the-moment workaround, PSICOE upset this procedure during the exercise by allowing field units to provide all information to all units within the command center.

DISCUSSION

Lessons from the Exercise

Two events from the AMSC exercise are particularly relevant with respect to AD. First, after the primary communications channel failed, the different methods invented by the Field units to report information illustrated the importance of developing the COE in parallel with procedures for its use. AD must incorporate a holistic approach to system design which includes human, physical, technological and procedural components in order to achieve the goal of creating sustainable systems.

Hence, one lesson learned from the exercise is that an initial set of procedures should be developed jointly between the client and development organizations during the preliminary development period of the COE. Ideally, the COE should be introduced to the client organization in tandem with training on procedures to use the environment. In addition, a set of guidelines should be introduced at the same time for developing further applications and making interface changes. This is intended to preserve the common operating picture of the system while allowing flexibility for individual user groups to develop the COE to their needs.

Second, introducing the PSICOE without incorporation into the incident action plan upset the established information gathering, processing and sharing procedures of the ICS. The PSICOE shared all available information with all units and hence, the Unified Command circumvented the Situation Unit, Planning and Operations sections to evaluate information and formulate plans. Unintended consequences, such as this disturbance in the procedures of the client organization, should be anticipated and explored by the joint client/systems development team. Otherwise, the power of a shared information and communication environment can upset existing organizational strategies.

However, this issue of information sharing illustrates the complexity of the Sector Seattle information system as a whole. The ICS structure and procedures currently in place are meant to provide the Unified Command with regular information feeds which have been filtered for relevance and distilled by the other ICS units. However, given the access to all information (through an environment such as the PSICOE), the members of the UC, who are generally also the decision making bodies of the Sector and other participating agencies, are not likely to relinquish this complete view in favor of the distilled information picture prescribed by ICS procedures. System developers must work as facilitators for just this kind of tension to be resolved to adhere to the overall strategy of the organization.

Challenges of Implementing AD

Several prerequisites exist for applying AD in a crisis response management organization. First, the organization's leadership must support the system development and foster ownership of the COE within the organization. The success of AD depends upon how much the user groups take ownership of the system and continue to cultivate the COE. The client organizations must lead in guiding the evolution of the system to meet their needs while using the expertise of the development organization to facilitate that progress.

Second, the system development organization and the client organization must establish a long-term, trusted relationship to successfully cultivate the COE. This service business model for technology development is already being adopted in other contexts, such as internet services, but has yet to be recognized as a superior method for creating sustainable COE in CRM organizations.

A third challenge to successfully implementing an AD paradigm is that usability experts, designers and system analysts must relinquish some of their roles as creators and owners of systems and take up the challenge of facilitating design and development of systems owned by users. Such professionals will likely be required to augment their skill sets to accommodate this change in roles.

Other challenges are likely to emerge as we continue to evaluate AD. This paper does not attempt to definitively capture the concept of AD, but to propose, and call for future research on, this model.

Opportunities

AD is meant to address the deficiency in current development processes for creating sustainable COE. The greatest opportunity AD presents is that it may allow us to create and manage systems which last 10, 15 or more years while becoming more useful over time. This presents clear incentives based on costs of creating new systems from scratch every few years, retraining, mistakes and inefficiencies due to technology turnover.

AD also presents the opportunity to create more useful and successful COE. Through a two-tiered development process, one level focusing on aligning the COE with the information strategy of the organization and the other level focusing on developing flavors of the system for individual user groups, AD provides a more holistic and comprehensive development process than preceding models.

Interagency collaboration is another area where AD is likely to provide greater benefits than other system development models. This is because AD classifies changes in trusted partners, selective information sharing, and rapid application development as routine systems development. The process's continuous development strategy is geared to accommodate rapid changes in relationship and information sharing within and between organizations.

CONCLUSION

We presented research related to ongoing software/system development practices, user-centered design, and crisis response and management communication to set the context for our proposed system development model. We introduced the concept of *adaptive development* as an ongoing, contextual system development model. We also described and discussed the status of an in-progress case study of applying AD toward demonstrating a common operating environment for a Puget Sound Area Maritime Security Council's on-the-water exercise in September, 2009. We also discussed the opportunities and challenges of applying adaptive development to creating common operating environments in crisis response and management organizations.

AD presents a promising system development method for complex COE in the context of mission-driven organizations. AD is geared toward creating sustainable, useful COE for organizations with myriad stakeholder groups working in rapidly changing environments. Community-of-practice driven, evolutionary development is AD's key strategy for achieving system sustainability. This is accomplished "in the wild" through continuous micro-level and macro-level system development.

We identified several challenges to implementing AD as a development model. The development organization must work closely in a trusted partnership with the client to facilitate the evolution of the COE. Also, usability experts and systems analysts must adapt their roles to those of system development facilitators, thinking on a more strategic level than previously required of them.

Further study is needed to develop the concept of AD for mission-driven organizations. The PSICOE project is an ongoing effort which can continue to reveal the challenges and successes of using a AD development approach within the United States Coast Guard and other DHS agencies.

Finally, it should be noted that the AD approach to COEs presented here represents a future direction that builds on the important current situational awareness/information sharing effort known as Virtual USA. Most importantly, we add the support of an inter-agency ICS management strategy and a framework for future Precision Information Environments (PIE). The PIE concept, introduced by the DHS Basic/Futures Research thrust area (under Dr. Joe Kielman), will combine an overwhelming number of diverse data sources and advanced visual analytic tools with information tailored to the users' roles, needs and cognitive capacities.

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