Examining the Necessity and Benefits of Systems Engineering in the Trenches

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Abstract. This paper examines the necessity and benefits of systems engineering in the trenches[1]. Planner, orchestrator, negotiator, relationship builder, and communicator are key roles for a systems engineer to take in the trenches. The systems engineering approaches used and roles taken to provide technical and business process engineering solutions required to implement collaboration[2] that operators used successfully to coordinate and approve fixed targets during the Operation Allied Force air campaign are documented. System objectives were: modify the existing process, leveraging collaboration to improve the effectiveness of information processes; improve product quality; and benefit federated efforts by geographically separated partners. This systems engineering effort took place at the United States European Command (USEUCOM) from February 1998 to June 1999 and continues as of this publication. USEUCOM targets community representatives estimate that using collaboration decreased target approval time from 2-4 days to 2-3 hours. Participants indicated collaboration improved process efficiencies, product quality, and synchronization. The success increased interest in and expansion of collaboration within the intelligence and operations communities, including expansion to the North Atlantic Treaty Organization (NATO). Clearly, the results and impact on mission effectiveness indicate systems engineering in the trenches is both necessary and beneficial.

INTRODUCTION

"The command, control, communications, and computer (C4) support to Operation Allied Force was highly successful. Several important communications capabilities saw their first significant combat application: use of Web-based technologies for coordination and information sharing; video teleconferencing for command, control, and coordination; and e-mail for coordination and tasking."[3] This paper describes the system engineering approaches used and roles taken to provide collaboration at the United States European Command (USEUCOM) to support portions of the targeting process during Operation Allied Force. The main points presented are:

1. System need, objectives, and requirements
2. System components
3. Challenges and issues encountered
4. Approach to providing collaborative capabilities: the infrastructure and tools components
5. Approach to applying collaboration to the mission: the people, process, and information components
6. USEUCOM collaborative sessions
7. Results and impact on mission effectiveness
8. Transfer considerations
9. Summary

SYSTEM NEED, OBJECTIVES AND REQUIREMENTS

The system need stemmed from an extended mission that required a continuous and increased production process. The extended air campaign against Serbia lasted 78 days and required an efficient targets development and production process. The USEUCOM Chief of Targets requested that the fixed targets development and nomination process be modified, leveraging collaboration to improve the coordination and approval process. The objective was to improve process efficiencies to increase target availability in support of mission objectives and strike operations.

According to Operation Allied Force participants, it is important to understand the process used prior to applying collaboration in order to fully appreciate the benefits gained after modifying the process to use collaboration. Nine geographically separated organizations coordinated products sequentially. One organization forwarded its initial work as email attachments, message traffic, fax, and/or phone calls to other organizations with different responsibilities.

[1] "In the trenches" refers to a systems engineering assignment at an operations or production site with customers and end users.

[2] "Collaboration" is more than just the technological capabilities (e.g. web-based applications, whiteboard, text chat, and audio). For this paper, collaboration includes:

- Technological capabilities
- Collaborative session techniques
- Concept of operations (e.g., process owners, roles and responsibilities, and procedures)
- Standardized product templates

[3] Kosovo/Operation Allied Force After-Action Report to Congress, 31 January, 2000, p.26

Another organization made product changes and sent the updates to participating organizations. The process continued until the final product was sent to decision-makers for review and approval. Decision-makers either accepted the product information or returned it for further development.

The serial workflow extended the process timeline and provided opportunities to introduce ambiguities and errors. Participants indicated that communicating point-to-point without consensus created confusion, reduced accuracy of product information, and caused duplication of efforts. The organizations involved did not always have a thorough understanding of other organizations' tasks and goals. Therefore, some organizations only understood the purpose, interdependencies, and value of their contributions from a parochial perspective. Process deficiencies made execution and approval too time consuming and difficult due to the following:

- Redundant information flowing to decision-makers
- Sequential coordination and approval by multiple organizations
- Maintaining currency of information and products existing in multiple versions and media types
- Understanding the rationale behind changes to avoid repetitious errors
- Tracking the status of products held for refinement or outstanding action
- Inconsistent quality control and standardization

The systems engineer selected collaboration to address the process deficiencies and inability to meet increased product demand and schedule requirements. The operational objectives and requirements were to:

- Provide collaborative capabilities at multiple geographic sites. The process owner's[4] initial requirement in mid-April 1999 was five geographically dispersed organizations:
  - Headquarters United States European Command (HQ USEUCOM) Stuttgart, Germany
    - Targets
    - Crisis Action Plans
  - Joint Task Force (JTF) NOBLE ANVIL Naples, Italy: Joint Target cell and Judge Advocate (JA)
  - United States Air Force Europe (USAFE) Ramstein AB, Germany: 32nd Air Intelligence Squadron (AIS) Targets
  - Joint Analysis Center (JAC) Royal Air Force (RAF) Molesworth, United Kingdom: JAC Targets

At the end of Operation Allied Force, four additional organizations participated:

- Headquarters United States European Command (HQ USEUCOM) Stuttgart, Germany: Judge Advocate/Operations Law
- COMSIXTHFLT Gaeta, Italy: Tomahawk Land Attack Missile (TLAM) Strike Cell, Plans and Targets
- Defense Intelligence Agency (DIA)/Joint Staff (JS) J2T Washington DC: Targets
- Combined Air Operations Center (CAOC) Vicenza, Italy: CAOC Targets U.S. representatives

Figure 1 Operation Allied Force Participants depicts the geographic locations of the organizations that participated.

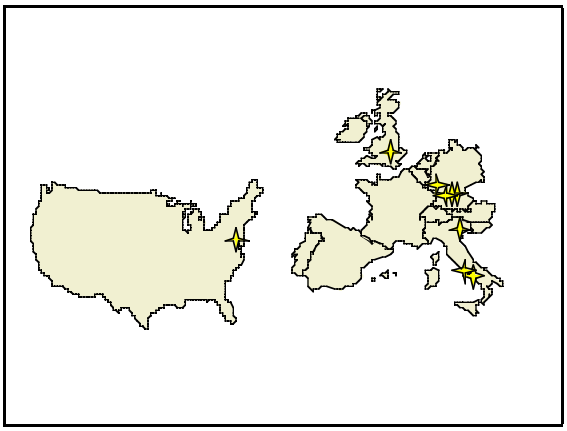

Figure 1 Operation Allied Force Participants

- Engineer a system with acceptable reliability, performance, simplicity, and flexible expansion
- Develop an approach to conduct collaborative sessions to support portions of the overall targeting process
- Modify the business process and apply collaboration to reduce or remove process deficiencies and decrease process timelines

SYSTEM COMPONENTS

The system had the following components:

- People: process owner and participants, the USEUCOM Chief of Targets and U.S. targets community representatives from multiple disciplines (e.g., intelligence, operations, legal, and execution)
- Process: current and modified, a portion of the U.S. contribution to the NATO target development and approval process
- Tools: collaborative capabilities (e.g., multi-point text chat, voice audio, and application sharing), briefing slide and web-page software
- Infrastructure: enterprise neT.120 conferencing server and software, Wide Area Network (WAN), site Local Area Networks (LANs), site baseline client workstations and software
- Information: current and accurate targeting

[4] The process owner is responsible for mission and session focus, participant roles and responsibilities, and results.

information

The systems engineer integrated the system components shown in Figure 2. Planning, orchestration, negotiation, relationship building, and communication skills were necessary to perform this integration.

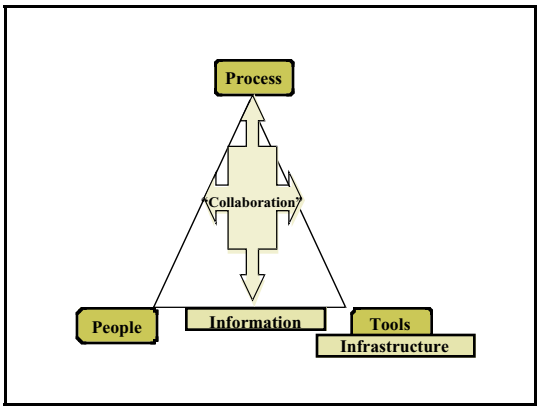

Figure 2 System Components

CHALLENGES AND ISSUES ENCOUNTERED

The systems engineer faced several challenges to meet the system objectives and requirements. Each site had an independent and unique:

- Local Area Network (LAN), hardware and software baseline
- Security accreditation criteria and authority
- Operational user culture and business process

The systems engineer analyzed the Wide Area Network (WAN) and orchestrated the implementation of the enterprise server. The systems engineer did not have authority over personnel. Gaining cooperation required informal influence. Building working relationships between key personnel (e.g., enterprise and site operational, systems/networks, and security) played a key role in asserting informal influence and gaining cooperation.

Environment. USEUCOM has a dynamic Area of Responsibility (AOR). A dynamic AOR requires flexible systems that responsively support expansion to new locations or changing requirements as much as possible. Planning, orchestrating, and communicating with personnel at operational customer sites are subject to spontaneous limited "windows of opportunity". Being prepared for these opportunistic meetings to delegate action, provide or obtain information, and execute actions germane to the systems engineering objective is imperative. Listening to site personnel benefited cooperation. Choosing local solutions improved responsiveness and is a recommended approach as long as the overall system objectives are met.

Systems/Networks. Sites controlled the configuration of their LAN, and software and hardware baseline. Site baselines were unique. The systems engineer looked for system component common denominators across baselines that met the system requirements. The systems engineer orchestrated, negotiated, and coordinated baseline modifications to ensure the availability of necessary capabilities, infrastructure, and interfaces at each site. Relationship building, negotiation, and realistic planning were critical to modifying independently controlled baselines. What may take a few hours to install in a laboratory may take days or months to obtain approval and installation at independent sites within an operational command.

Security Accreditation and Approval to Operate. Each site has an independent security and approval to operate authority. Each authority's criteria varied. As a result, the amount of systems engineering involvement and security requirements varied greatly from site to site. The systems engineer took on the roles of orchestrator and negotiator to ensure security accreditation issues were addressed.

Obtaining accreditation and "approval to operate" for collaboration requires dedicated effort. Cooperatively working with each site's security authority is the recommended approach. Site operational users and systems/network personnel assisted the systems engineer or independently accomplished this task. Security accreditation personnel must be included in the team from the beginning to implement procedural and technical solutions that satisfy *both* collaboration and accreditation requirements.

Operational User Culture and Business Process. Operational personnel had the shortest and fewest "windows of opportunity". The systems engineer gave priority to these "windows of opportunity". Actions taken to build relationships with the operational community included:

- Attending community conferences to meet and get to know users and leadership from multiple organizations
- Learning what tasks users perform by spending time with them during operations in their environment to obtain a feel for the mission objectives, environment, and constraints (e.g., timelines)

This investment yielded significant returns in developing mutual respect and building rapport with the operational community. Nurturing efforts to integrate the process with the appropriate mix of collaboration proved valuable. Moreover, important operational requirements and areas to impact mission effectiveness were highlighted. The intent of system requirements documented in specifications or verbally provided by users may be difficult to understand. Placing systems engineers with users in the operational environment provides a realistic understanding of the

intent of individual and aggregate requirements (e.g., how the capability will be used and for what purpose). In addition, the myriad of constraints (e.g., time, footprint, regulations, organizational politics, and funding) with which the system interacts, are more likely to be experienced.

This systems engineering experience clearly demonstrated that *the best technical systems solution may not be the best "systems" solution* because of the numerous constraints and interactions found in an operational environment. According to Operation Allied Force participants, the performance, reliability, and simplicity of the collaborative capabilities were the primary factors that affected acceptance and use. If the important operational requirements are met and mission effectiveness benefits, the system has a higher probability of being sold and used. The key requirements obtained using this systems engineering approach included:

- Capabilities must reside on a baseline workstation. The environment does not allow separate workstations for unique capabilities. Users need access to existing baseline applications, services, and information.
- The capabilities must be *reliable*, tested, and proven in the operational environment (vice a laboratory environment). Operational processes do not allow for reboots or system lockups during sessions. Users defined reliability in terms of system down time to be less than one 15-minute segment per month during crisis operations.
- Capabilities need to be *simple* to allow operators with basic computer skills to participate. Users defined simple collaborative capabilities as someone who has not seen the capability being able to use it after 15-30 minutes of training, supplemented by a two page instruction sheet. Moreover, users can train colleagues after using the capability for 2-3 sessions. A trade off between complex capabilities and keeping the system simple should be made with users. Use of capabilities will probably evolve as the process matures and increased benefits are realized.
- Capabilities must have acceptable *performance* to meet operational timelines
- Capabilities selected should remain in place long enough to resolve technical issues and determine best fit in conjunction with the current/modified processes. *More capabilities are not necessarily better and changing capabilities frequently in search of more productivity will often result in less.*

APPROACH TO PROVIDING COLLABORATIVE CAPABILITIES: THE INFRASTRUCTURE AND TOOLS COMPONENTS

The systems engineer took the role of communicator to obtain capability alternatives from research and development engineers. The system engineer analyzed and determined the best overall systems solution to meet operational, systems/networks, and security requirements within the operational environment and associated constraints at the enterprise and local site levels.

The systems engineer orchestrated and built a systems foundation with systems/networks personnel at the initial organizations requested by the process owner. Obtaining systems/networks and security personnel approval to establish the initial capability at the initial organizations took ten months. Users received insight into the system's potential by using the capability to support a few operational sessions. Users recognized that the system benefited their processes and levied a multi-point audio requirement on 20 January 1999 during a TLAM mission planning session.

The formal multi-point audio requirement proved imperative to meet the operational community's requirement for immediate and daily use during Operation Allied Force. The systems engineer analyzed network topology, performance (e.g., latency, bandwidth) and concept of operations (e.g., roles, responsibilities) to determine the best location for the enterprise conference server. The multi-point requirement and analyses provided operational and systems justification to request systems/networks personnel at HQ USEUCOM install a multi-point server. The systems engineer took on the role of negotiator to obtain cooperation. Negotiations resulted in a planned evaluation between two different conferencing software alternatives that could meet the multi-point audio, standards compliance, and other system requirements. HQ USEUCOM's systems/network staff constraints and competing tasks did not allow this plan to be executed. Three months later, in April 1999, the Chief of Targets requested the capability for immediate use to support Operation Allied Force. However, only one of the conferencing software alternatives was installed and the evaluation had not yet started.

Communication with systems colleagues at other commands uncovered an alternative. Colleagues confirmed the availability of a multi-point conference server approved for use in Hawaii at another command. Operational demands outweighed network latency and reliability concerns from Europe. The system engineer orchestrated and conducted operational tests and demonstrated the viability of this alternative.

The systems engineer used past investments and efforts

in conjunction with working relationships developed with enterprise and each site's systems/networks, security, and operational personnel to establish a 3-6 May 1999 initial operational capability. Operational users experienced some audio corruption due to latency during the first hour of each collaborative session. USEUCOM's dependence on a server not under its control also increased mission risk. For this reason, the systems engineer continued to address the need for a local multi-point conference server with HQ USEUCOM's systems/networks personnel.

Successful operational demonstrations of the conference server located in Hawaii allowed the systems engineer to negotiate with HQ USEUCOM's systems/networks personnel and supercede the planned evaluation. The HQ USEUCOM's systems/networks supervisor approved the use of the local multi-point conference server. The May 7 transition to the European based server decreased mission risk as shown by the following results:

- Improved performance
- Resolved latency issues
- Removed dependence on another command's server
- Increased confidence in reliability

The process owner requested the participation of four additional organizations prior to the end of Operation Allied Force. The effort taken to provide a systems solution that supported flexible expansion to new locations allowed the process owner's requests to be satisfied quickly. Figure 3 shows the system infrastructure.

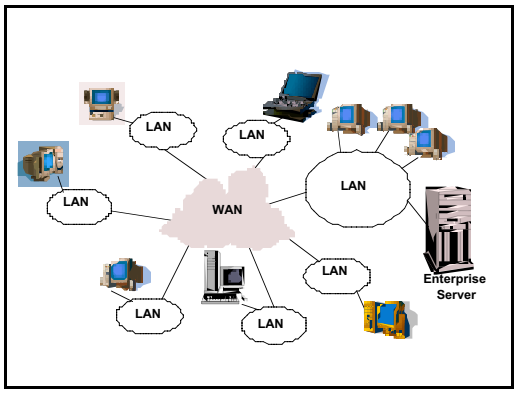

Figure 3 System Infrastructure

Finally, the systems engineer planned for the migration to the intelligence community standard. By communicating with the USEUCOM enterprise architecture planners and operational community directors, the capabilities used during Operation Allied Force are part of the intelligence community standard. This planning and communication eased the potentially turbulent transition and introduction of the new system to the user community.

APPROACH TO APPLYING COLLABORATION TO THE MISSION: THE PEOPLE, PROCESS, AND INFORMATION COMPONENTS

Often in system's development, two of the most critical system components are overlooked and may not even be considered part of "the system". These components are the users and process. Dedicating a significant amount of system engineering resources to understand and integrate the user and process components into the overall system's solution is necessary based on this project's experiences.

The systems engineer requested the command appoint a process owner with existing or delegated authority and responsibility recognized by participating organizations. The command appointed the Chief of Targets as the process owner.

The process owner assigned a veteran user, who had broad operational expertise and professional contacts at participating organizations, to work with the systems engineer. The systems engineer and operational user identified required participant organizations and selected part of the overall targeting process for modification, focusing on coordination and approval by applying collaboration. The user selected a standardized product template with targeting information and imagery as the collaborative session's focus. The systems engineer provided recommendations on how to apply collaboration. The systems engineer and operational user developed a concept of operations and standard operating procedures taking into account process preparation requirements, roles, responsibilities, and system performance. The standard operation procedure used the Keep It Simple Strategy (KISS) since multiple organizations were staffed by three rotating shifts and new temporary users. Collaborative capabilities and techniques selected for application with the modified business process took into account reliability, number of participants, simplicity, performance, business rhythm, timeline constraints, and environment. The three primary capabilities used were text chat, voice audio, and application sharing.

Prior to the first session, the process owner issued a directive to participants. The user representative distributed the concept of operations and standard operating procedure to each participating organization. With the operational user's assistance, the systems engineer orchestrated system testing, a training walk-through of procedures, and a discussion of roles and responsibilities with each organization. The results of the first operational session, compared with the previous process, gave the Chief of Targets confidence to conduct daily sessions.

Defining roles and responsibilities in a Concept of Operations (CONOPs) and preparing for the collaborative sessions is important to achieve success.

Session roles (e.g., leader, information coordinator, product developer) and responsibilities assigned took into account the process timeline, experience, control desired, command structure, and number of participating organizations. The interdependent roles and responsibilities required definition for the "before", "during", and "after" phases of the collaborative session. These roles and responsibilities were critical to establish and execute successful sessions. All organizations, except those with the lead role, participated for coordination purposes. Examples of three key roles[5] are described below.

Leader: The leader works with the information coordinator to ensure preparation and execution of collaborative sessions.

Before Session

- Determine what items to review and distribute
- Assign preparation responsibilities
- Identify products to review and revisit during session
- Inform organizations of key personnel and functional skill mix required during session
- Develop agenda and set schedule

During Session

- Run the session and obtain results in a reasonable time frame
- Task development work and issue priorities
- Assign action items and suspenses
- Chair session in close coordination with information coordinator
- Approve or hold information and product release
- Act as final authority on questions and decisions

After Session

- Write and provide summary of session and actions to participants

Information Coordinator: The information coordinator works with the leader to ensure preparation and execution of collaborative sessions. The information coordinator is responsible for information and product management.

Before Session

- Schedule session time and setup conference on server
- Coordinate agenda with session lead organization
- Test participant organizations' systems (e.g., audio checks)
- Gather product information for sessions

During Session

- Manipulate data and share product information with participant organizations
- Make and save final product changes
- Record text log of significant audio discussions, decisions with rationale, actions, due dates, and product hold or approval status

After Session

- Save text chat log and provide to participants
- Post products in proper format for participants, consumers, and next phase of process

Product Developer: The product developer provides product information to the information coordinator before or during sessions.

Before Session

- Perform detailed development, research, and analysis
- Address data and information shortfalls
- Develop product for session review

During Session

- Obtain priorities from lead organization
- Provide rationale or explain product information

After Session

- Work action items assigned from lead organization and prepare for next session

The systems engineer also planned and orchestrated the necessary product and information management efforts with the information coordinator and user representative. Tasks included:

- Selecting mission application software to use and developing standard product templates to organize information that focused the collaborative session
- Determining information used in session, information structure, and information repository location for products
- Determining product format
- Developing an information flow and structure to transfer and hold product information between various stages in the process
- Developing information change procedures to ensure the currency, accuracy, and integrity of the information. Information change procedures for shared information is critical to provide version control.

[5] An organization may have multiple roles or role may be shared by multiple organizations.

The importance of information management to conduct productive collaborative sessions cannot be over emphasized.

USEUCOM COLLABORATIVE SESSIONS

Daily, USEUCOM and US national-targeting agencies held regularly scheduled, collaborative sessions. The standardized template contained specific target information required for approval and aided the communication and coordination process. The template standardized terminology and ensured accurate documentation of required targeting information prior to delivery to executive decision-makers. The collaborative sessions focused on targeting information. Participants used the concept of operations with roles and responsibilities and standard operating procedures to properly prepare for and control sessions.

The Joint Task Force (JTF) targets cell led the sessions. Headquarters USEUCOM targets branch controlled the target information during sessions and monitored quality control. Intelligence product development or other functional personnel (e.g., legal and operations) contributed to or reviewed the product information. Collaboration enabled participants to view imagery products and collate existing intelligence information into a single product. Collaboration allowed the target information to be reviewed, discussed, and modified. Concurrence of JTF decisions and action items was documented. The JTF targets cell approved or held target information for release to operations. Operations forwarded the target information to executive decision-makers for final approval or provided additional requirements during the session. Figure 4 depicts USEUCOM's collaborative sessions during Operation Allied Force.

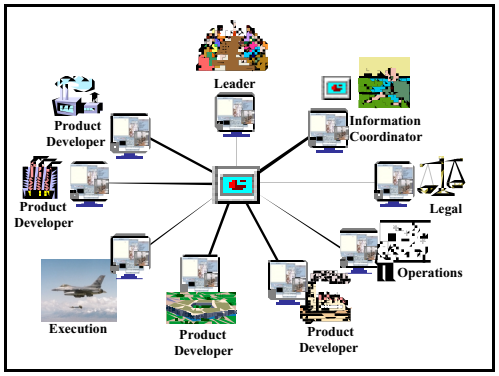

Figure 4 USEUCOM Collaborative Sessions

RESULTS AND IMPACT ON MISSION EFFECTIVENESS

Government systems acquisition and development efforts typically measure success by how well they meet system specification and contractual requirements. This systems engineering experience provided an operational perspective on measuring success. Operation Allied Force participants' responses to and an assessment of the following questions provide an operational perspective on meeting the systems requirements and measuring the success of this effort.

What benefit does the system provide?

- Collaborative sessions successfully facilitated synchronized and consolidated coordination and approval of fixed targets
- Collaboration removed or reduced previous process deficiencies
- Posting synchronized information to web-sites replaced multiple email attachments
- Collaboration drove parallel, not sequential planning and real time, not prearranged, decision-making
- Targets community representatives estimate that the timeline decreased from 2-4 days to 2-3 hours
- Coordination and synchronization benefited, improving process efficiencies and product quality
- Collaboration provided an alternative to video teleconferences that senior leadership dominated
- Estimated daily productivity increased 200%-300%
- Staff effort significantly reduced

Is the system reliable and does the system fit into the operational environment?

- No systems problems reported, other than infrequent workstation-specific issues
- System used daily for more than a month during Operation Allied Force
- System support to operations and contingency planning since Operation Allied Force has reported no problems

Are operators using the system on different missions/task?

- System used approximately 2 hours/day during Operation Allied Force
- System use expanding as necessary to support on-going and new operations and contingency planning. Collaborative sessions are now applied from beginning-to-end for target development, nomination, and production processes. USEUCOM's dynamic Area of Responsibility (AOR) required expansion of participants since Operation Allied Force. As a result, ten new organizations now participate in collaborative sessions.

What is the system impact to the enterprise?

- Due to the positive impact of collaboration on the process, USEUCOM senior leadership is advocating the expansion of collaboration within the intelligence community, including expansion to NATO allies. Senior executives from USEUCOM and other commands have requested and received demonstrations. *Prior to this success,*

collaboration was regulated to a non-interference basis with operations.

This effort met the systems requirements and was successful from an operational perspective. According to Operation Allied Force operators, proper application of collaboration improves the effectiveness of information processes, improves product quality, and benefits federated efforts by geographically separated partners. Collaboration allows USEUCOM's geographically separated organizations to work as a team and manage increased battle management complexity by mitigating the effects of information overload, improving team decision-making, and synchronizing situational awareness.

TRANSFER CONSIDERATIONS

Are the systems engineering experiences and lessons learned from this project transferable or applicable to industry? Considering the successful results from this project, this question is worth exploring. Four different transfers or applications come to mind. First, training and placing systems engineers in the trenches will provide opportunities to build key relationships and assist in understanding the intent of systems requirements and objectives. Second, collaboration could be judiciously applied to system engineering processes internally and between partners to improve process efficiencies and quality. Third, global companies with geographically separated partners could substantially benefit product quality, time to market, team decision-making, synchronization, and customer support objectives. Fourth, in the services sector, slow sequential processes may be streamlined with collaboration driving parallel processes and real-time decisions. Collaboration does not replace the need for the right functional combination of well-trained, prepared personnel who have access to current and accurate information.

SUMMARY

Based on the successful results at USEUCOM, it is possible to apply customized systems engineering approaches and take on multiple systems engineering roles successfully in the trenches. Are systems engineering approaches and roles necessary and beneficial in the trenches? One must only examine the results of the systems engineering approaches and roles taken through and operational perspective in meeting system requirements to answer this question. Clearly, the answer is yes to both based on this experience.

REFERENCES

Kosovo/Operation Allied Force After-Action Report to Congress 31 January 2000

BIOGRAPHY

Gregory G. Chapin has been a systems engineer for 13 years. Currently, he is a senior systems engineer for the MITRE Corporation. He is assigned to the European Operations site located at the Headquarters United States European Command in Stuttgart, Germany. His focus the past two years has been the application of collaboration to mission processes. He has a Master of Arts degree in International Relations from St. Mary's University in San Antonio, Texas. He also holds two Bachelor of Science degrees, majoring in Electrical Engineering; and Mathematics and Computer Science from Valparaiso University in Valparaiso, Indiana.