# Composable and Adaptive Services Environment (CASE) – A Naturalistic System Architecture That Enables Command Staff to Organize

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## Abstract

*What is a system solutions architecture for a Command Control and Information System (C2IS) that helps the Commander and Staff to Organize?* 'Organizing' is a key function for an individual as well as for a group of warfighters. In an operational environment, a Command team needs to organize its information, its ideas, its problems and their solutions, and also the warfighting units under its Command and Control. A C2IS is a system built to support the Command Team in these functions. In the network-centric age, the function of organizing is further complicated by command posts that are not fixed to a location but distributed. In such a distributed environment, the C2IS would need to further help the individual and team communicate, collaborate and coordinate in a virtual way so that they could sensemake and act synergistically.

The purpose of this paper is to articulate the model that the SAF Centre of Military Experimentation (SCME) has developed to define the solutions architecture of a C2IS to support the warfighting organization. This model is called C2KS and is based on models of cognitive science, psychology and management science. The idea is to base C2IS developments on well established understanding of human and team cognition. An elaboration of this model is the *Organize* System, which focuses on the individual and team aspects of *organizing*. The *Organize* System is one which helps individuals carry out individual-level organizing functions such as information, thought, ideas organization, and team-level organizing functions such as co-operation, negotiation, and brainstorming.

CASE (Composable and Adaptive Services Environment) and SEFAR (Service-Enabled Fusion Architecture Reusable) together forms a prototype system architecture of the *Organize System*. Construction of CASE-SEFAR is already under way at the SCME, and this paper will explain how the system provides the collaboration capabilities, defines a mechanism for the publication, subscription and composition of information, and fusion algorithms. The environment allows the Command Team the liberty and flexibility to configure the information he needs from the Information Services published, compose the fusion algorithms to help manage the information from these sources, and determine how the

information will eventually be visualized. The technical implementation of CASE-SEFAR will be briefly discussed.

## Introduction

The SAF Centre of Military Experimentation, Future Systems Directorate started looking at C2 systems with a new perspective a year ago and derived the Command and Control Knowledge Model (C2KS) (Cheah, Chew, Tan 04). The C2KS model suggests that C2 systems should be naturalistic. By which we mean that the system ought to deal with the fundamental human processes of cognitive tasks rather than domain level processes. According to C2KS, one of the key system components that will support the individual and his team is the *Organize* System. As its name suggests, this system aims to help the command team and the individual staff to organize.

"Organize" is an important issue in the Network Centric era. With lower cost of communications, new organization structures will emerge and the challenge is to find the right structures and processes that eventually result in greater synergy within the organization.

This paper will first explain briefly the C2KS model. It will then outline a framework model to help us determine the intricacies involved in the process of organizing. Next, based on the framework model, a conceptual architecture of the *Organize* system will be articulated. To sufficiently manage the scope and length of this paper, the authors will only focus on C2 Systems aspects of Organize. As an example, the CASE-SEFAR system prototype, which has a design informed by the *Organize* system architecture, and developed by Defence Science Technology Agency (DSTA) and DSO National Laboratories will be presented.

## C2KS - A Model to Develop Naturalistic C2 Systems

The C2KS model was developed as part of our efforts to rethink C2 Information Systems (C2IS) design. Working from first principles, we decided that C2IS must play an intermediary role between the cognitive space (people and their organization) and the information space (sensors, information systems, networks of other agents etc). In simple terms, its task is to help the human and his team to internalize information so that they may be well disposed to make good decisions. To achieve this, the model proposes that the structure of the information space should not to be fixed by domain processes but should be an open architecture that is amenable to exploration by the individual. This is necessary because the process of information search and assimilation is highly dependent on the instinct of the human at the point of time of search and under the given situation. The next important challenge is to determine the structure of the cognitive space and to understand how it functions. According to the CCKS model, the baseline architecture components were determined to be aligned to cognitive psychology concepts: "*organize*", "*see*", "*access information*", "*discuss*", "*draw*, *explain and persuade*", "*think*", and "*plan*". Each of these is still under research and development based on knowledge and ideas garnered from the fields of cognitive psychology, management science, sociology, anthropology, artificial intelligence etc. The work on C2KS and a description of the *MissionMate* CCIS system, being a prototype of C2KS is covered in the paper by Cheah, Chew and Tan, 2004. Since the MissionMate is well covered in that paper, there will not be very substantive description of the MissionMate system in this paper, but it will be mentioned as appropriate.

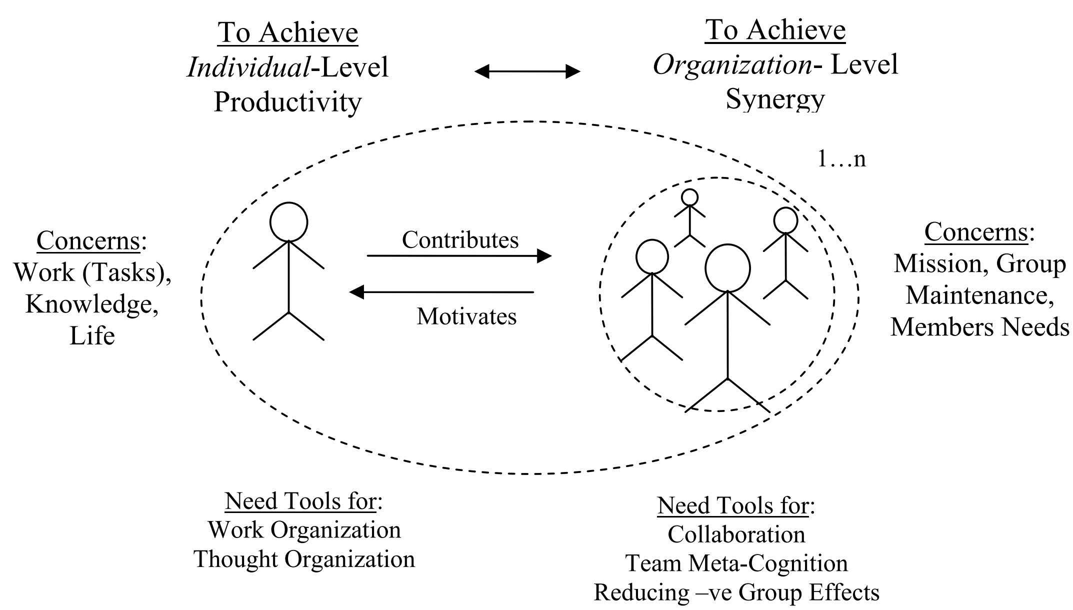
This paper discusses one component of the C2KS system – the *Organize* system. The aim of the C2KS model is ultimately to identify design principles and features to be used directly in C2 systems developments. This paper explains and demonstrates how this could be done.

### ***Organize*** **System – The Framework**

Purpose and Structure

The aim of the *Organize* System is to achieve the well-known dictum "the whole is greater than the sum of its parts". The framework model addresses 2 questions: how people relate to their larger organization; and how people relate to their work and data? Whilst these 2 questions were asked in a one-dimensional manner drawing answers only from the individual perspective, the real relationship is actually bilateral, i.e. the individual has responsibility towards his organization just as his organization and team has obligations towards the individual. In order to devise a framework of study and development a model needs to describe how the individual staff organizes his work, knowledge and tasks and describe how he interacts with the larger organization. At the same time, it needs to describe how organization structures and processes enable a group of individuals to become synergistic and productive as well as how it motivates the individual to perform. A successful model would be one that could find the right balance to achieve all the above. Hence, in order to derive a comprehensive solution, the framework is divided into two key parts – *Organize*-level synergy which deals with the organization-level issues and how it relates to individuals, and *Individual*-level productivity which deals individual level of work and contributions to the organization.

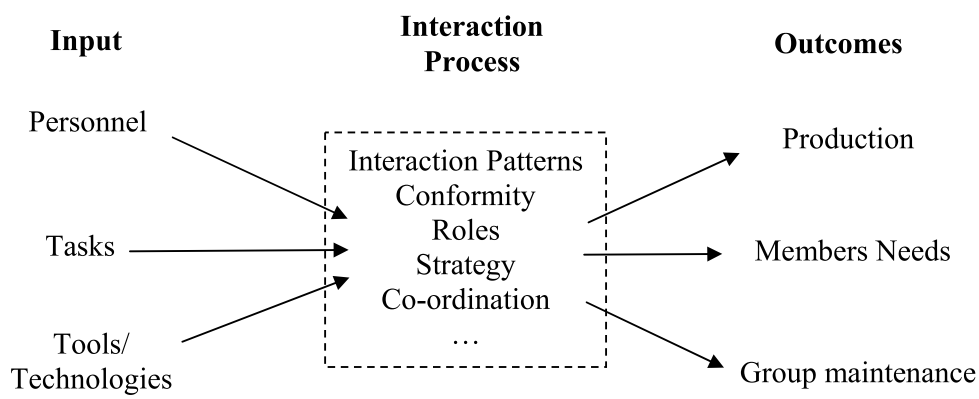
Figure 1: A Framework of study to develop the *Organize* System




Organization-Level Synergy

The whole may surpass individuals through two basic mechanisms – *aggregation* and *synergy* (Kraut, 2003). Aggregation of skills and knowledge occurs when different people of different competencies are brought together and each contributes their area of expertise to solve the problem. Synergy, on the other hand, comes about through joint action or co-operation. It is manifested when the group, with its aggregated set of expertise, surprises themselves to develop new ideas and solutions that surpass their own expectations or people's expectations of them. Synergy is not inevitable when people come together (so simply networking people together is not sufficient to make the organization better). In fact, there are many reasons that negative energy will occur. Consider the effects of cognitive overload in the networked organization. For example, a well known phenomenon with the advent of email is the generation of more work because efficient communication results in greater idea exchange leading to more tasks. Unintended negative consequences can occur. A study by Paddington in 1996 in a study commissioned by Reuters showed that people lose job satisfaction, has increased health problems (43% from the higher management) and incurred some strain in their personal relationships (63%), due to such cognitive and information overload problems (over-work). Other well-known contributions to negative synergy are well known effects such as *groupthink*, and *social loafing.* All these lead to poorer individual productivity ultimately affecting organization performance.

Figure 2: Input-Process-Output Model [Steiner (72), Hackman (87), McGrath (84)]

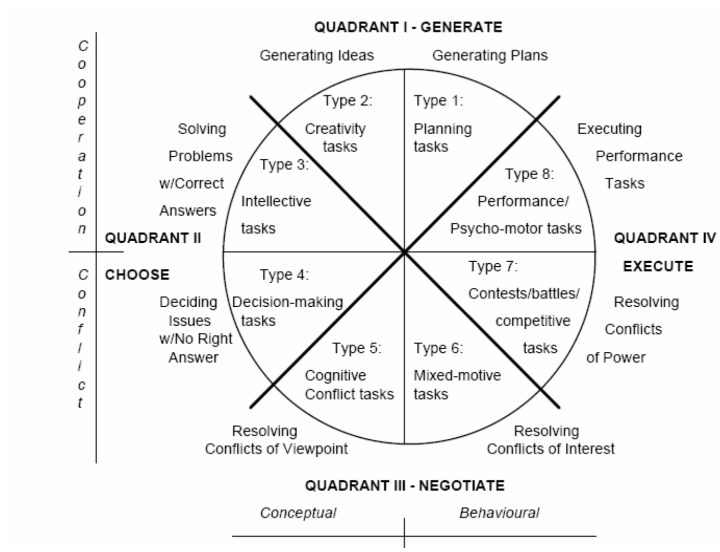



To achieve organization-level synergy, the C2 System design strategy must deal with organizing people in a way that promotes collaboration and co-ordination, and downplay negative group effects. Steiner et al's Input-Process-Output Model (Steiner et al, 72) is a process model that clearly articulates the interacting interdependent elements in group processes. It will serve as a basis to help us understand the model of organization-level synergy. This model holds that the success of the group depends on the multi-level interaction of *outcomes* of the group; *inputs* - the resources it has, the people involved; and the *processes* occurring within the group – the communication, competition therein. For example, we have often measured the success by the single dimension of effectiveness and efficiency of production. However, the case may be that whilst the production output may be very good but as the organization has driven the personnel too hard, they have developed very low morale, which then leads to poorer longer term group maintenance. Synergy therefore depends on the successful manipulation of inputs and interaction processes such that the three areas of production, group maintenance and members needs are well met. The authors surmise as a starting hypothesis that synergy can be achieved by improving collaboration, by improving team meta-cognition, and by reducing negative group effects.

*Collaboration*

Improving collaboration has the effect of improving joint action, a pre-requisite for synergistic outcomes. Experiments done by Olson (Olson and Olson, 96) showed that ideas generation improved in collaborative shared electronic workspace. The recent experiments conducted by the authors have also shown that collaboration tools and techniques have improved the output of a team. Collaboration is a focused activity by team members to achieve specific goals and our aim is to find a scheme that helps us manage and improve collaboration between people. It is important to note that collaboration takes time and sometimes it is not compelling for the individual to want to collaborate with others. Therefore, a good understanding of why, and what people are collaborating is important. McGrath's circumplex defining a taxonomy of interaction processes provides an excellent starting point to look at the common interaction patterns between people under different circumstances. It shows a primitive set of tasks that is generic enough to be applied in different domains and problems. Developing and applying the right set of protocols for different tasks type is important and it will help ensure better success in these tasks (organization level expectations) because they pre-determine the roles and behaviours for the individuals. Individuals knowing these protocols will immediately know his role in the interaction and how to behave and will therefore find stability even in highly chaotic and dynamic situations. These protocols help manage individual expectations and motivations because they spell out the "rules of the game" and provide assurance to the individuals that the outcomes are best for the organization as a whole.

Figure 3: Task Circumplex ( McGrath, 1984)




The authors propose that there are different interaction protocols for different types of tasks. Some protocols become best practices for similar types of tasks. This is a growing trend in the Internet towards standard processes so as to enable Internet-based firms to immediately interoperate with other similar firms using standard transaction protocols, such as those listed in the Rosetta Net. For protocols to be quickly adopted and used, they could be supported by C2 systems that would guide members on what to do. For example, at the early stage of planning, the staff may engage in a period of brainstorming for ideas generation. The C2 system should enable each individual to develop his own idea and enable anonymity to encourage openness. For de-confliction of resources, competing parties could enter into a stage of contract bidding. The C2 system would help in the posting and management of bids for the competing agencies. Such interaction protocols would be generic and adapted for specific use according to the domain which needs it. In the area of co-ordination (mainly for the behavioral quadrants in the circumsplex), the work of Thomas Malone in the area of *Co-ordination Science* could be applied. Coordination Science defines coordination as "the act of managing interdependencies between activities performed to achieve a goal" (Malone, Crowston 1990). Co-ordination science spelt out several strategies for managing different types of interdependencies. For example, *hierarchy* interdependency is based on one party exercising the authority over the common object, and the *equal partnership* interdependency is such that contenders have equal claim, and therefore the protocol would necessarily be one of negotiation. An important idea under coordination science is that of *common objects,* which are the sources of 'contention' and hence the reasons for dependencies between activities. It could be a shared resource, an area of operations, or a plan. Making the common objects between parties explicit and providing tools to monitor and manage them in the C2 system will assist the staff in managing his interaction with his partners. Table 1 shows a summary of the various forms of interactions in the domain of C2 using McGrath's taxonomy and a brief description of the interaction protocols. It helps us relate to the various protocols to the activities common in C2.

Table 1. C2 activities by teams according to McGrath's taxonomy and some suggested generic protocols of interactions.

| **Types** | **Generate** | **Choose** | **Negotiate** | **Execute** |
|---|---|---|---|---|
| Cooperation | The cooperative set of protocols is meant to smoothen the interaction between team members. It helps to quickly enable an individual know his role in the interaction and help him assume the right behaviours quickly. | | | |
| | Creative. *C2*: Initial divergence phase of planning; Discussions to achieve shared understanding.<br><br>*Protocol*: Based on openness and strategies of brainstorming & ideation. | Intellective. *C2*: Support planning. Scheduling. Resource allocation based on plan. Development of plan.<br><br>*Protocol*: Blackboard protocols; Simple aggregation of plan components. | Cognitive Conflict. *C2:* Discussions to achieve shared understanding; plan evaluation.<br><br>*Protocol*: Red-Teaming (debate). | Performance/ Psychomotor. *C2*: Peacekeeping operations.<br><br>*Protocol:* Blackboard protocols. Coordination Strategies (Malone). E.g. Ensure timings and sequences are correct. |
| | Conceptual | Conceptual | Conceptual | Behavioural |
| | Planning. *C2*: Plan development; Co-ordination in joint operations.<br>*Protocol*: Coordination Strategies. Blackboard pattern. | | | |
| | Behavioural | | | |
| Conflict | The competitive set of protocols provide standard patterns for bargaining between groups such that organization goals could be best optimized and individual level satisfaction and morale is best managed. The standard protocol set provides "rules of the game". Knowing the rules of the game help mitigate ill feelings caused by conflict. | | | |
| | | Decision Making *C2*: Wargaming phase; Finalization of plan stage involving the choice of one option from many.<br><br>*Protocol:* Utility-based selection. | Mixed Motive<br>C2: Application for resource support (e.g. Air Taskings).<br><br>*Protocols*: E.g. Market mechanism (contract-net). Coordination Strategies | Competitive Tasks<br>*C2*: Warfighting. Battles.<br><br>*Protocol:* Co-ordination strategies. E.g. Ensure timings and sequences are correct. |
| | | Conceptual | Behavioural | Behavioural |

*Team Metacognition*

The process of synchronization between multiple parties involves an over-arching activity called meta-cognition, which is a top-down awareness of the team performance - common goals, awareness of team member's progress, member's strengths and weakness, member's workload. Strong team meta-cognition has strong correlation with successful performance as discovered by experiments done by experts in these areas (E.g. Kraut, 02). When a team has good meta-cognition, team members work more effectively together. For example, when sharing ideas, members of a new (novice) team tend to throw their ideas out without considering whether the ideas are contributing to the task or not. There is a tendency for the teams to diverge in uncontrolled directions. On the other hand, a mature team has members who are more circumspect and cautious in adding ideas to the pool and has a view towards resolving issues and solving the task (Klein, 99). The work of Kraut also showed that having shared cognition of team distribution of expertise improves coordination amongst the team members because having an awareness of other members expertise area enables individual members to anticipate the actions of the others better and allow them to make adjustments on their own (Kraut, 02). Kraut also found in the same work that with better awareness of expertise, the communication between members is reduced. Such behaviors are the inklings of team synergy because it shows signs of members contributing to the whole self-synchronously. Whilst self synchronization does not guarantee better team outcomes, it gives the team a better chance of better outcomes because the frictions of collaboration has been reduced giving them more space to contribute their area of expertise to the task.

Good team metacognition is likely to be more a function of training and experience than of systems and processes. Nonetheless with the advent of networked computer systems, it will be easier to create greater awareness between team members in the work they are doing, their goals, and their products. For example, it is now easier for team members to make their mental models more explicit by drawing and describing their ideas and sharing it with other team members. In SCME, the concept of Team Sight was developed in the MissionMate system and it allows different team members to peek at the work (plans and overlays) of his partner in a networked system. Experiments using the Team Sight showed positive results and comments towards collaboration. In addition, other forms of metacognition like workload sharing could be designed into the system such that members could view each other's progress, and take their own initiative to offer assistance to staff who are behind schedule in their work, thereby lifting overall team productivity.

*Dealing with Negative Group Effects*

People do not necessarily work better in groups. Natural but negative behaviors occur that will cause the group as a whole to degenerate in performance and sometimes fail in their tasks. *Judgmental biases* due to groups are well known phenomenon (Kam, 04). A well known bias is *groupthink*, which has on many occasions led to bad team decisions. For example, the Israeli command was totally surprised by the Egyptian and Syrian attacks during Yom Kippur war because they were locked in to a mindset that the Egyptians would start war before developing an Air Strike capability (Kam, 04). Irving Janis's (1972) definition of groupthink presupposes a policy-making "in-group", and suggests that the higher the espirit-de-corps of this in-group, the greater the danger that independent critical thinking will be replaced by groupthink due to a desire to achieve unanimity.

It is natural for an effective group to develop groupthink. After groups have "stormed and normed" and developed some level of engagement with each other, it is natural for members to desire to avoid conflict, and compromise in order to find consensus in certain decisions for the sake of longer term group maintenance. As a result, sharp and critical individual opinions, ideas, or solutions, which are important ingredients towards group outcomes, become watered down.

Besides groupthink, there are many other undesired group side-effects. Steiner (1976) coined the term "*Process Loss"* to describe the phenomena of degradation due to the processes of group interaction. In this regard, losses may come in two forms: *coordination problems* and *reduction in motivation*. Firstly, coordination problems relate to how coordination processes themselves could take a toll on the output. For example, we know that coordination takes effort and if it is done without the objective of reaping greater group gains, it will simply take away precious time that could be directed towards achieve individual production gains (this is called *coordination effect)*. Another common problem is the *synchronization problem*, which is a result of one group providing an output that does not meet the requirements for the input to a group activity resulting in time and cognitive energy wasted to resolve the inconsistencies.

Secondly, *reduction in motivation* is about how the process itself could discourage individuals from delivering the best performance. Social loafing is an instance of this and it occurs when the individual voluntarily decreases his productivity because he assumes that someone else will be doing the work. Other examples are social pressure; conformity pressure; evaluation apprehension (fear that other's may think badly of him); and production blocking (ideas blocked because individuals may not be given air-time).

C2 systems could help remove groupthink, and improve coordination and motivation of the staff and team. Much of the coordination-related problems can be resolved by the coordination strategies already mentioned in the previous paragraphs. The judgmental bias and motivational problems will require arrays of process and system strategies that change fundamental human behaviors in groups. For example, groupthink could be reduced by encouraging a managed process of divergent thinking and red-teaming.

Individual-Level Productivity

At the individual level, the member needs to organize his tasks, his knowledge, and his life (including his private life). In a highly networked environment, the danger is that the individual would be over-taxed by too many tasks and too much information resulting in cognitive overload. According to projections, with the increasing number of people communicating by email increasing by the day, an average person would have to spend his entire working day reading emails in the next few years. In time to come, the networked C2 environment could also arrive at such volumes. How then do we design a C2 system such as to help the individual staff to manage his tasks, manage his interaction with other fellow team members to achieve synergy, and increase his capacity to contribute to the organization?

*Organizing Work*

Most C2 systems provide structure of work according to processes, or information. The *process-approach* is the most common for C2. In this approach, the tasks to be fulfilled by the individual are determined by the stage of that process. This approach provides a great deal of stability to the individual. However, it becomes problematic when the individual has to multi-task, which is increasingly common. In the military domain, the staff may be least taxed in war because he is likely to concentrate on a single role, but the period before war is likely to be the most disconcerting to him because he would have to assume multiple roles - deal with day to day problems while at the same time assuming his "wartime tasks" to plan for an impending war. These problems are compounded if the process is linked to a C2 system that is solely dedicated to the process, which is common in the legacy C2 systems. What it means is that when he multitasks, he had to switch between computers and networks to get his work done.

A second approach to managing work is the *information*, a.k.a. the *"portal" approach*. The activity is centered on a shared portal which consolidates the information that the group is collectively building. The staff contributes by posting his documents onto the portal and works on information he downloads from the portal. Cognitive overload will arise if there is too much information, when the staff has to multi-task, and when it has limited capabilities to co-ordinate with his partners. Document workflow systems augmenting such portals sometimes solve the document versioning issues but do not solve the collaboration issues.

Another approach is the *email-centric* approach. This approach is about using the email as the mainstay for working. In such an environment, the staff manages almost everything by the email: sharing information, co-ordinate actions, receive information about his tasks and also administrative matters. Cognitive overload occurs when he receives many emails and do not have the capability to systematically run through them and manage the multiple tasks demanded from other people through the email. Bellotti et al (2003) found in an experiment that overload is related to the number of threads, and also the length of interval between those threads from the email that a person receives. This is not surprising because having to deal with multiple threads means that the individual had to deal with multiple tasks over a short period of time (time used to read and respond to the emails). The length of interval between emails of the same thread is also disconcerting because as the interval increases, the staff will progressively loose sight of the issues and would have to reinvest time to recall the issues again. Bellotti has also uncovered 7 problems relating to task management in email, all useful in helping us re-evaluate how to structure our individual workspace: (1) Keeping track of concurrent actions: One's own to-dos and to-dos one expect from others; (2) Marking things as important or outstanding amongst the less important items; (3) Managing activity extending over time or keeping track of threads of activity and discussions; (4) Managing datelines and reminds, which may be associated with particular messages or other content; (5) Collating related items (e.g. an extended thread or response to a survey) and associated files and links; (6) Application switching and windows management; (7) *Most important, getting a task oriented overview, at a glance, rather than scrolling around inspecting folders*.

The fact is that the above three approaches are necessary for any strategy of organizing work to work. The key problem today is a lack of an integration of these tools. In the organization, structure must be imposed when structure is due. For example, work associated with C2 processes that are time sensitive and requiring tight coupling of co-ordination needs to be tightly linked to the processes. In this regard, the staff needs to know precisely what he needs to deliver and when. Structure provides him with the stability he needs. Beyond these processes, the staff would need freedom and flexibility to communicate and work with others sometimes even in an ad hoc and temporary manner. Email being ubiquitous will enable all kinds of work, but as a tool it will soon become inadequate because of information overloading leading eventually to cognitive overload. A new structure to working based on tasks is necessary.

A task-centric approach uses tasks to the structure the flow of work. The idea is to have everything associated to a task such as task goals, team members, key information, task-related emails, and calendar events such as meetings related to the task all accessible at the corresponding task workspace. Each workspace would have its own flavor and will be designed specially for the task. Placing tasks at the centre is important for a few reasons. Firstly, it is intuitive for us to relate tasks to its environment because the 'place' (whether it is a physical or cyber) often plays an important part to remind us of the last discussion conducted, the state of development etc. The mere view of the site will immediately generate recall of these associated events (one-glance effect). Secondly, the staff's role will change from one task to another. Enabling him to systematically deal with one task at a time will also allow him to switch roles smoothly. Thirdly, it allows the individual to clearly prioritize which task need to be dealt with first. His cognitive load will be significantly reduced because he will be moving systematically from one space to another, and when in each workspace, he could concentrate on resolving the issues in that workspace before moving on to the next.

*Organizing Thoughts*

Data will remain uninteresting unless a staff internalizes and applies that data or information as useful knowledge. While the last section dealt with work, this section takes a more detailed look at a very common task in any process - organizing thought. This section will deal with how an individual relates to data and information and how they may organize them effectively for use.

Traditional C2 system design limits the usable data space of the staff and organization. This is so because most C2 systems are constructed based on a process-centric approach, i.e., the system is built around a process defined by the users. The data exploitation space hence is limited by the process which defines categorically the data to be used and presented at each stage of the process. In such a model, the staff would have no access to other information through the system. The problem is, when a staff is assigned to help define the process for the system, he does not have a complete picture of information needs of the eventual users (he may even be reassigned to a new post when the system is complete), i.e. he does not know what he needs to know. The fact is, human's search of information is a situation dependent, dynamic, and thought driven process.

The authors found the term *organizing knowledge* (knowledge management) inadequate to describe the cognitive activity of the human in demanding for data and information and assimilating them. The view of knowledge management often connotes a "librarian" or "file" management perspective of organizing knowledge. It tends to describe merely a means towards an end and does not address at all the propensities of the human towards data and information. *Organizing thought* is a more adequate term because data and information must ultimately support the thought process of the human. In this sense, it is not hard to imagine why the traditional process-centric design is inadequate because it is tied to a process defined and not to thinking strategies. Bates model is a good model to adopt because it describes and explains the process of information search by a human as "berry picking" (Bates, 89). In other words, the process is not predictable, and is driven totally by the human's instincts at different situations. The thought process, linked to his work in general, is dynamically and non-sequentially driving the data requirements.

Relating these ideas to C2 system design, we conclude that information access tools, comprising of search and organization functions, must be made available at every work area because this would enable them to relate data to the thoughts placed into each workspace. The choice of data and information to use and present must also be left to the discretion of the user as well. It is with this in mind that the CASE-SEFAR architecture is being developed.

## Conceptual Architecture

The studies on synergy result in design features in C2 systems. This section articulates how an *Organize* system is designed based on our studies. These designs are meant as primers for developments and experimentation in C2. The conceptual architecture of the *Organize* System aims to help the individual to manage his individual productivity and his interaction with other team members for organization wide synergy. As identified by the framework, the following are some of the key components (an illustration is provided in Figure 4):

*Tasks, Roles and Workspaces*

The flow-path of the user starts from his tasks assignments. His task deadlines, information needs, his fellow collaborators, and communication means (e.g. Email) to reach them will all be organized around his task workspaces. Different workspaces would have different designs depending on the cognitive preferences of the team. The roles of the individual will be managed around these tasks. Workspace design should give individual users a sense of where and who he is (role) immediately thereby enabling him to multi-task; individuals could communicate and co-ordinate simultaneously with several team members using several task windows with color schemes and window look and feel that help him distinguish one domain from another.

*Sensemaker*

The sensemaker is a general name for a suite of "thinking" aides. Different tasks are best augmented with the appropriate types of platforms. For military operational and tactical level planning, the primary workspace would be the GIS (Geographical Information System) based interfaces, allowing the staff to lay down his thoughts pictorially with strong references to geography. Scheduling activities are best expressed by time-based activity charts, and analysis in the form of statistical charts and text documents. For all these to work, the sensemaker must allow the user to "touch the data" and even choose the data to view, analyze, and present. Data and information is meaningless unless the author is able to rationalize them according to his thoughts. Hence, systems like CASE-SEFAR, which will be explained in the next section, form a key foundation for the *Organize* System.

*Thought-Driven Information Retrieval*

Information search being thought driven must be accessible by the user at all points of the sensemaker (where thoughts are laid down). The user must be able to launch any query, and delve into periods of sensemaking: information search, analysis, rationalization, concept linking before he returns to his workspace platform. He must also be given the means to organize and include his new findings from his research into his current train of thoughts or to form new ones in his sensemaker.

*Collaboration Tools, Co-ordination Touch-points and Protocols*

The *Organize* System must help the user to improve on his co-ordination with other team members. For example, the MissionMate system, which is what the CASE system is based on, has a full suite of collaboration tools such as Team-Sight (GIS-based whiteboarding), chat, instant messaging, video conferencing and email to facilitate different demands of collaboration. Next, the idea of co-ordination touch-points is to make explicit the co-ordination interfaces – common objects - between different parties and allow the user to track it. Intelligent Software Agents could even be configured to help monitor automatically for coordination boundaries that may be breached. Besides co-ordination touch-points, different co-ordination strategies as discussed in the earlier sections will warrant different co-ordination protocols and these protocols will dictate the rules of the interaction that the collaborating parties would need to follow.

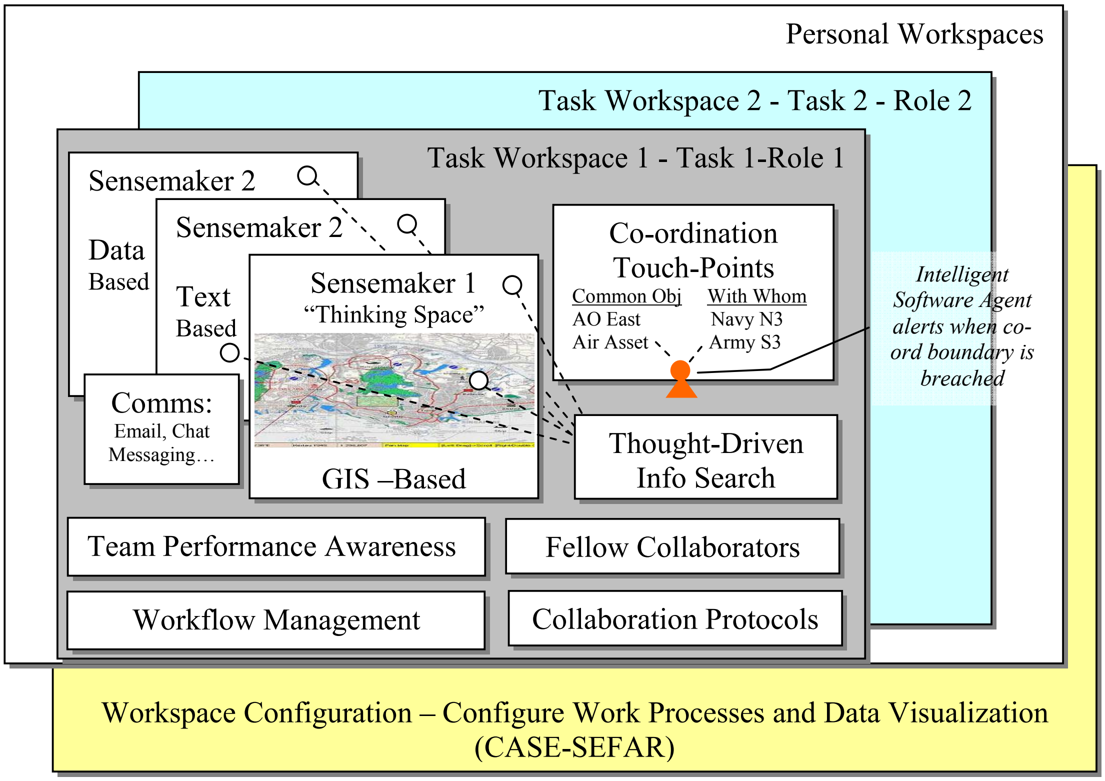
*Ad-Hoc Organizing with Structure (Workflow Management)*

Ad hoc organizations and temporary groups can be disruptive for individuals if they are not organized. Although such groupings may form for a short period, there may be a need to establish a simple workflow. Workflow management systems, configurable by the members of the group, provide them with the structure they need. After some time, temporary groups may become permanent groups when they become successful. When this occurs, the process that may have been initially a draft but have been run, evaluated and refined over time could eventually be registered as a permanent process (a best practice).

*Team Performance Awareness*

This component deals with team meta-cognition and team peer-motivations. A system that helps teams organize must have a component that oversees the team's performance and thereby enable team members to self-synchronize, or take their own initiative to help out other team members. Team performance awareness components enable members to oversee the outputs of team members, and eyeball their progress with reference to datelines.

Figure 4 : Conceptual Front-End Architecture of *Organize* System (Key Functional Elements)




**Some Developments of the *Organize* System**

The SCME, DSTA and DSO National Laboratories are cooperating to develop components for the Organize system and experimenting with them under different operational and work settings. The NEXT II project studies how tasks workspace could improve work productivity and reduce cognitive overload. The Large Integrated Search and Analysis (LISA) system was developed to give individuals the capability to deal with unstructured information, which is fundamental capability allowing a person to "touch the data". The LISA system will be integrated with the NEXT II system to experiment with the new task-centric paradigm for knowledge management. The SEFAR system is another foundation capability for the Organize system. SEFAR, which stands for Service-Enabled Fusion Architecture Reusable, exploits the Service-Oriented Architecture to provide a platform for the sharing of all data and (currently) only fusion services to the enterprise. The concept could be extended to other application services besides fusion in due course. Lastly, CASE, which stands for Composable and Adaptive Services Environment, is the front-end to SEFAR providing the front-end organization management component such as collaboration, sensemaking, and eventually team awareness components, identified to be key components of the Organize system, to the user.

## CASE and SEFAR

CASE articulates a system architecture foundation that is highly adaptive to dynamic organizations. It is a derivative of the *Organize* System conceptual architecture. In order to adapt to organizations, the system architecture needs to adapt to not just the 'physical' information flow, but also the thinking processes of a group.

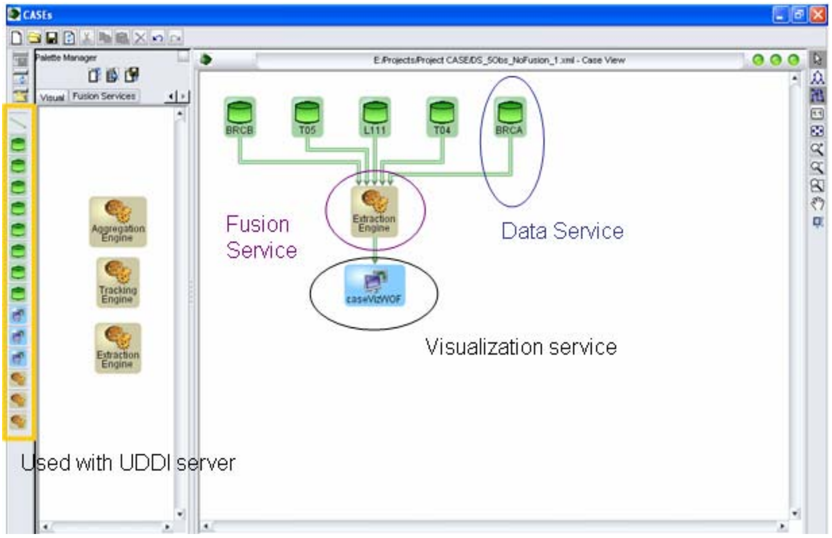
<u>The CASE-SEFAR Capability</u>

CASE aims to deal with how people and systems *Organize* to achieve synergy. It also aims to develop a systems architecture foundation that is highly adaptive so as to support dynamic organizations. The first level of organize occurs at the individual level, hence individual cognition. The next level of organize occurs at the team level where knowledge sharing and collaboration occurs. Both levels will determine how information will be organized for the human knowledge network (system). A good framework for dynamic knowledge interaction and synergistic co-evolution will enhance common understanding, sharing, innovation and creation of knowledge.

The design of CASE-SEFAR is based on man's fundamental preference on how data and information is treated. As discussed, man's method of searching for information can be described as "berry picking" - "moving through many actions towards a general goal of satisfactory completion of research related to an information need" (Bates 89). Interesting information is scattered like berries amongst bushes. The query will continually be shifting as the users may choose to move through a variety of sources, and with every new piece of information discovered, new ideas would emerge giving new directions. I.e. the query is not satisfied by a single, final retrieved set, but rather by a series of selections and bits of information found along the way. This illustration emphasizes the need for systems to provide users with the fundamental capability of managing his data and sensemaking space. The purpose of CASE-SEFAR is to give the user the ability to visualize the data available to him and enable him to decide how he wants his data to be presented. In addition to presenting data, CASE-SEFAR has also extended value-added services for the user to choose fusion algorithms to fuse data provided by different sensors. The data, fusion algorithms and presentation front-end choices are also offered to users in an intuitive and engaging user interface. This interface is a workspace where they can drag and drop services they want, and compose the services to create the desired presentation for his sensemaker "on-the-fly". Staffs can choose to save the different cases for future use and collaboration. These cases act as drawer plans for use.

Figure 5 shows the CASE workspace where staff can drag and drop the data, fusion and visualization services to achieve his desired presentation from different sensors contributing data. The left-most-column shows icons representing active services from data, fusion and visualization services being discovered real time and updated on the staff's screen. The staff selects the desired services and linking them up to form his choice of presentation on the composition workspace. He can also save his built cases for subsequent quick set-ups. When the staff is informed and updated of new services, he could add the new services into his system flow by dragging into the composition workspace to present an updated picture. In this illustration, the staff has built a case with five sensor services passing data through a simple data extractor (no fusion element) and finally to a visualization service.

Figure 5: Service Oriented Architecture – Allowing Service Composition.
CASE 1 – without Fusion.




The result of this “case” is shown in Figure 6 on a GIS-based map. What the staff will see is the situation picture unfolding over time with more and more tracks appearing, some of them may be duplicated tracks from different sensors and they are not be aggregated. This may become too complex for him. What he could do next is he could select a fusion algorithm from a suite of fusion engines to help unify some of the tracks. Whilst the capability of fusion is necessary to improve the visualization of the staff, the flexibility for him to remove the fusion services is also an important consideration because there would be occasions where the wrong targets may be fused, thereby resulting faulty interpretations. Allowing him to assess the raw data is important for the staff to use his instincts to rationalize his picture.

Figure 6: Visualization of data on GIS of CASE 1

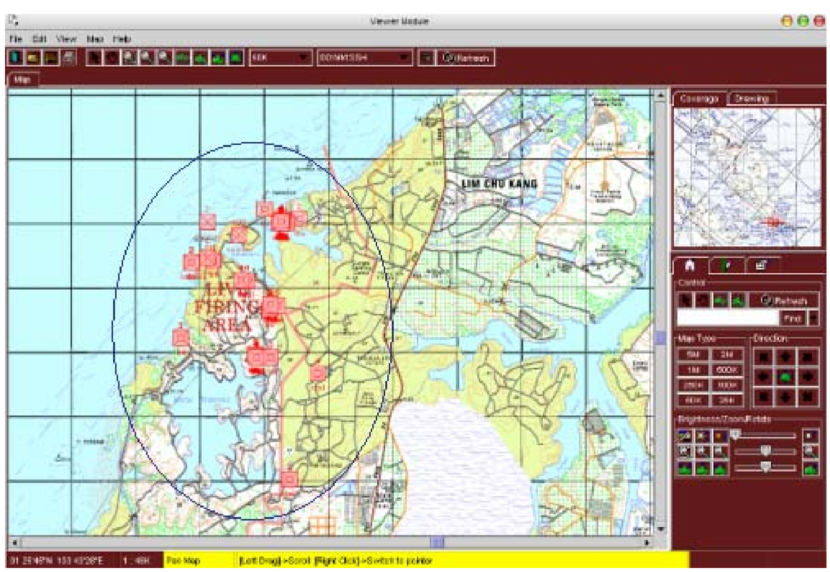


Figure 7 and figure 8 shows the effect of introducing the full suite of fusion services, namely the extraction, the tracking and the aggregation engine that help the staff present a fused picture, which is cleaner and clearer for him (Case 2). Maintaining multiple sensor tracks of targets enable a more accurate real-time rendition of the data.

Figure 7: CASE 2. Service composition with fusion services.

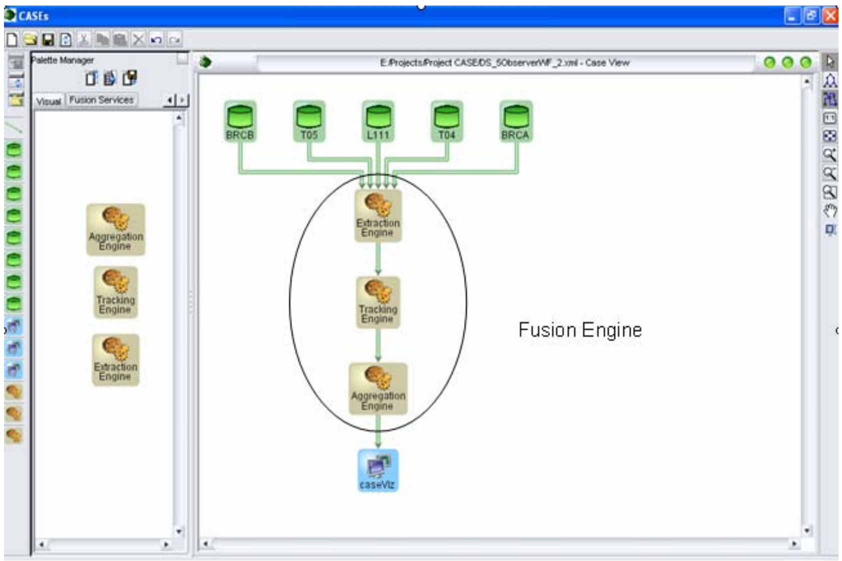



Figure 8: The fused situation picture displayed on the visualization.

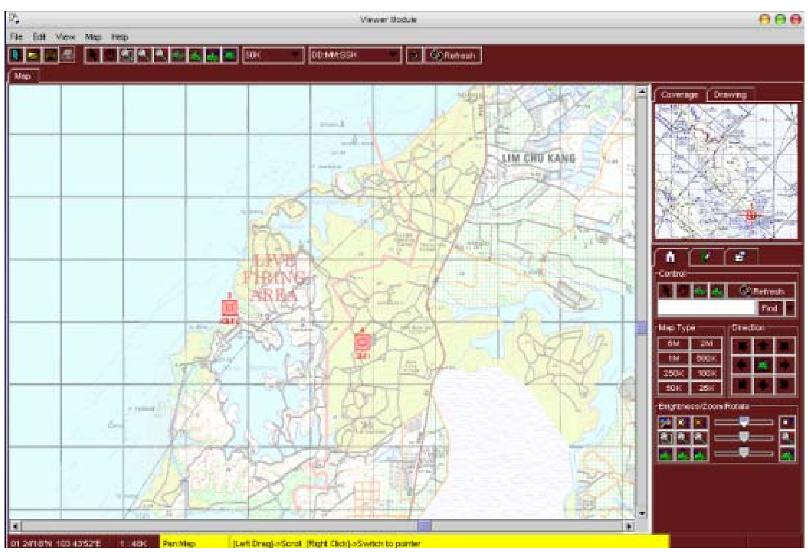



Figure 9 and figure 10 shows CASE 3 whereby additional data sources become available (T03, T06 and T12) and the staff could now include them to his picture to increase his situation awareness. The aggregation algorithm is able to fuse the sources of data and deduce that the set of data indicates an armor column forming as part of a battalion heading south.

Figure 9 : CASE 3. Service composition including additional data services for increased situation awareness

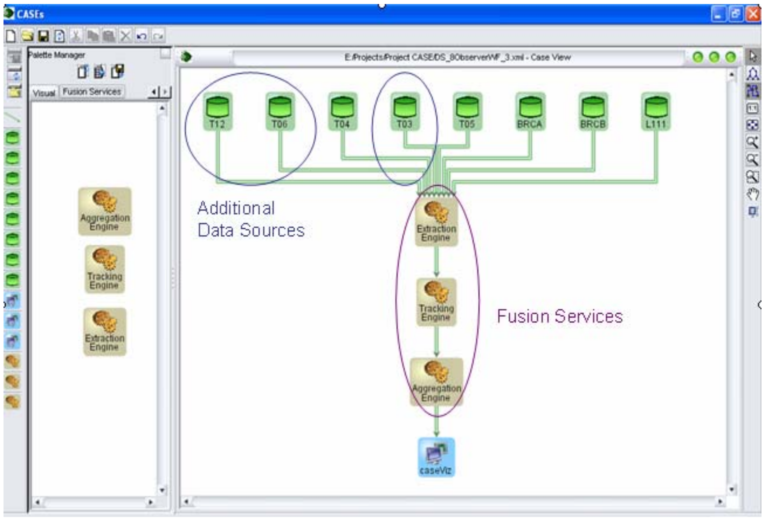
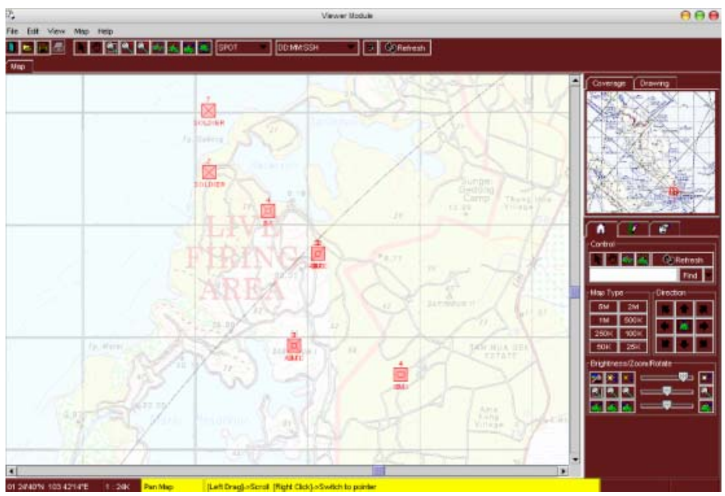



Figure 10: Visualization of CASE 3 with increased situation awareness.




## The CASE-SEFAR Architecture

CASE[1] forms the front-end architecture and SEFAR forms the backbone architecture. The idea of SEFAR is to provide a standard platform to host all future fusion systems, to allow sharing of data, algorithms and visualisation across multiple organisation, and to provide an environment where users can dynamically select fusion services on-the-fly (i.e. services orchestration) that best meet their operational needs. Extending the idea even further, the applications that can be shared and composed need not necessarily be restricted to fusion services. Other services developed according to the SEFAR architecture, which is based on

[1] The CASE is built on the MissionMate system architecture developed by SCME/DSTA. The underlying architecture is based on a service bus concept using J2EE as a application server foundation. The CASE front-end is developed also based on J2SE, such that the applications can be launched anywhere in the network.

standard open source definitions of Web Services, can be integrated using the same interfaces. There are five essential software components in SEFAR architecture. The architecture diagram is shown in Figure 11.

*Workflow MMI Display (also known as the Orchestration Workflow Editor)*

The workflow MMI allows a user to compose (i.e. aggregate or federate) Web Services dynamically on-the-fly. The output of this module is in a XML format (a standard message exchange format between computer systems) and we called it the workflow XML. The workflow XML describes the relationship between data, fusion and visualisation services orchestrated. Most importantly, the workflow depicts the data and information flow between the federated services. This workflow XML is then passed to the orchestration layer for further processing.

*Orchestration Layer*

This module is further divided into two modules. They are the XML Mapper and the XML Actor. The XML Mapper is responsible for parsing the workflow XML into events. This chain of events is then passed to the XML Actor for services initialisation and invocation. The XML Actor is responsible for service synchronisation and mediation based on the list of events output from the XML Mapper. The orchestration layer is packaged together with the Workflow MMI component and runs at the client-side.

*Service Container*

A service container is a network node hosting Web Services. In the SEFAR concept, service containers can be located across multiple organisations. During orchestration mode, SEFAR will communicate with these service containers automatically and to perform services invocation.

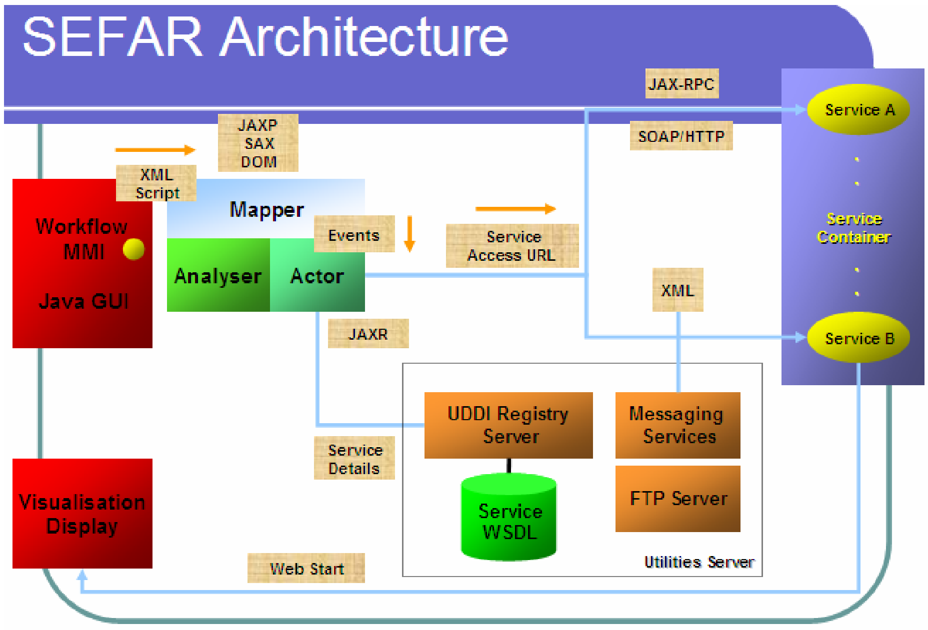
*Visualisation Display*

Visualisation display allows computed results to be displayed at the client-side, allowing users to view and perform analysis work on the data. In SEFAR, visualisation can be referred to as either maps display, bar charts or any form of visualisation that can be used to make sense of the data output. The idea is to keep the visualization means neutral so that different sensemakers may draw on the same data but use different sensemaking features to analyze the data. In our case, the CASE architecture is the visualization output used.

*Utilities Servers*

Utilities servers are made up of a number of UDDI Registry Servers, FTP Servers and Message-Queue Broker Servers. The UDDI Registry Server keeps track of all registered Web services and its services information (i.e. end-point address, functions and parameters), which essentially serves as an important technology component for service-discovery. Whereas, the Message-Queue Broker Server provides messages (i.e. text or XML) exchange channels between Web Services. The FTP Server serves as a repository to store Workflow constructed by users and to enable workflow to be published across organisation.

Figure 11: SEFAR Architecture




**Conclusion**

This paper aims to define a conceptual architecture of a C2 system component that helps military commanders and staff to *organize* – the *Organize* system. This system is a component of the C2KS. To derive this architecture, the authors need to develop a good understanding of how the individual human and the organization deal with the issue of organizing. An important understanding the authors gained from the work of Steiner et al is that the group dynamics must be seen in the light of multi-dimensional inter-relationships between production outcomes, group maintenance, and individual needs. A right set of tools supporting interaction processes must be found to ensure that these outputs are best met. The authors decided that the way to achieve this is by dealing with firstly the organizational level and applying solutions to achieve the effect of *synergy*. The authors explained how a combination of strategies of enabling collaboration, team meta-cognition and downplaying negative group effects will improve synergy. Secondly, a set of strategies dealing with individual level productivity needs to complement the organization-level strategies. The authors suggested C2 system tools used to enhance work and thought organization as the means to achieve this.

The conceptual architecture defined in this paper is a guide for eventual system development. The conceptual architecture will evolve over time as we conduct further research, build components, and experiment to evaluate their effectiveness. The CASE-SEFAR architecture was presented as a foundation of the *Organize* system. CASE-SEFAR has a flexible back-end architecture that enables the user to define how he might want to visualize the data. This capability is fundamental to organizing because humans will not be able to state his information requirement upfront but this requirement is based on the situation and his thoughts at the point of time of his sensemaking. The CASE-SEFAR is a prototype and it will form the foundation for SCME to grow the *Organize* system.

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# Biographies

**LTC Lock Pin, Chew** is a Naval Officer and is the Head of Command Post of the Future, SAF Centre of Military Experimentation, and concurrently the Division Manager of Knowledge-Based Solutions Division (KBSD) in Defence Science and Technology Agency. He has been involved in the conceptualisation and development of the IKC2 with the SAF.

His current work involves Command Post Experimentation with the Military Services. He is also involved in the IKC2 Enterprise Architecture Developments, Information Architecture Developments for C2IS systems, and the development of the prototype Mission Mate system in the SAF Centre for Military Experimentation. Lock Pin has a Masters of Technology Degree in Knowledge Engineering and a Bachelor of Science Degree in Physics.

**LTC Cheah, Mervyn** graduated in 1995 from Cranfield University/Royal Military College of Science with a Masters in Defence Technology. His thesis involved the research and development into an interoperable knowledge-based engineering software for application in the military defence. He also holds a first class honours in Computer Science. LTC Cheah is an Artillery officer by vocation and has commanded an Artillery Battalion. He also had staff tours in the Joint and Army Departments focusing on C4I developments. He is currently the Head of the SAF Centre for Military Experimentation (SCME).

**Mr Low, Linus** is a key engineer of the STAR (Systems, Technology and Architecture) team involved in developing the CASE system as well as other C2IS systems. He is also a development engineer with Knowledge-Based Solutions Division (KBSD) in Defence Science & Technology Agency. Additional areas of work include research in Bayesian Networks, decision analysis, etc. He was a recipient of DSTA scholarship award. He graduated from NUS (National University of Singapore) with a first class honours in Electrical and Computer engineering with a Minor in Management of Information Technology. LTA (NS) Low is an Infantry officer by vocation.

**Mr Kong, Jonathan** is a senior technical staff in DSO National Laboratories involved in developing SEFAR. Current responsibility includes project management and technical solutioning as well as software architecture. Current area of research involves service-oriented architecture, infrastructure and real-time operation systems. He graduated from NTU (Nanyang Technological University) with a Masters of Science (Computing). He was previously working in the commercial sector for 6 years as a technical consultant and an architect in various projects.