Assessing the C4ISR Architecture Framework for the Military Enterprise

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Abstract

The C4ISR Architecture Framework [C4ISRAF, 1997] is becoming increasingly prominent in Western defence circles. While the C4ISRAF has many positive attributes, it is sometimes used beyond its intended purpose. This paper briefly describes seven other organizational analysis approaches and compares them against C4ISRAF in order to uncover the relative strengths of each. The comparison identifies that the C4ISRAF is a descriptive framework that does not consider acquisition, human issues, system evolution or changing external environments. We conclude that the C4ISRAF is only one of a set of models providing different perspectives, each of which has a place in the analyst's "palette".

1. Introduction

The Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance [C4ISR] Architecture Framework Architecture Framework [C4ISRAF, 1997] is becoming increasingly prominent in Western defence circles. While the C4ISRAF has many positive attributes, the authors feel it is frequently misunderstood and is sometimes used beyond its intended purpose.

This paper examines a number of analysis approaches for gaining insight into information-rich enterprises. We find it useful to do this in a systems context where we consider a C4ISR system to be system at a level complexity greater than that of an information system but less than that of the whole military enterprise.

It is a long-held belief of systems thinkers that any system that serves another cannot be modeled until a definition and model of the system served is available, [Checkland, 1993, p 18; Hitchins, 1992, p272][1]. Furthermore, this analysis approach is particularly important for information systems because the effectiveness of these systems cannot be measured directly [Sproles, 2000][2] outside the enterprise context for which they were created.

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[1] Checkland [1993] explicitly states that this point is often ignored by much real-world work on information systems.

[2] Sproles [2000] distinguishes between measures of effectiveness and measures of performance on this criterion.

Thus we believe that the first step in the analysis is to identify the enterprise that is the containing system, ie the one in which the C4ISR system of interest is to operate. This identification is not entirely straightforward as the military enterprise is unlike a conventional business organisation. In the first instance, a business, as an enterprise, pursues a single homogenous set of goals in the normal conduct of its day-to-day activities; the success of which can be measured using well-established indicators. In contrast, Allison and Cook [1998] recognized that the military enterprise pursues at least two very different, and sometimes conflicting, sets of goals:

- Creation and evolution of the Force.
- Utilization of the Force-in-Being.

They also note that the pursuit that occupies the majority of the time and energy in the military enterprise, namely building the force, is not the one for which the military enterprise principally exists. This complicates the application of contemporary organizational improvement strategies [Senge, 1991] to the military organization and indicates the need for other strategies, most of which require some form of organizational modeling [Allison, 2000].

Sociotechnical systems such as military enterprises exhibit immense complexity. In order to try and quantify their complexity Kline [1995] proposed a complexity index (C_f) for systems based on the number of variables needed to describe the:

- State of a system.
- Number of parameters needed to distinguish it from other systems in the same class.
- Number of feedback loops.

Kline asserts that the complexity index of a system will lie somewhere between the sum and the product of these three terms depending on the degree of connectivity between the variables. Using this construct he estimated the complexity of sociotechnical systems as being $C_f > 10^{13}$. This estimate supports one of the tenets of systems theory and management science that states that in very complex systems, such as sociotechnical systems, there is no all-encompassing theory for the entire system and that organizations are too complex to model with any accuracy.

The accepted approach to overcome this lack of an all-encompassing theory when analyzing organizations as systems is to examine and amass data from the systems of interest from several different viewpoints. Flood and Jackson [1991] have formalized this paradigm in a meta-methodology called Total Systems Intervention (TSI): a systemic cycle of enquiry that encompasses the use of a range of established systems improvement methodologies to suit the systems of interest. TSI, and less codified approaches, require that the system analysts can select a range of methodologies that cover the salient behaviors of the system of interest.

In this paper we investigate the possibility of a parallel concept, that of describing or analyzing a system using a range of models or description formats. To this end, the paper summarizes eight models that can be used to provide perspectives from which to gain insight into the military enterprise. The paper concludes by comparing the coverage of the models and frameworks and indicates there is a need to use an appropriate combination of them when analyzing the military enterprise and most other complex systems.

2. The Models and Frameworks

This section contains a brief overview of the following system models and frameworks:

- Management In The 1990s (MIT90) framework.
- Tom Peters' passion and excellence paradigm (Peters).
- The People Process Product Time (PPPT) enterprise framework.
- The Allison Defence Enterprise Model (Allison).
- Checkland's (Human Activity) System Models (CSM).
- Process for Organizational Meaning (POM) model.
- Australian Army Fighting Power (AFP).
- C4ISR Architectural Framework (C4ISRAF).

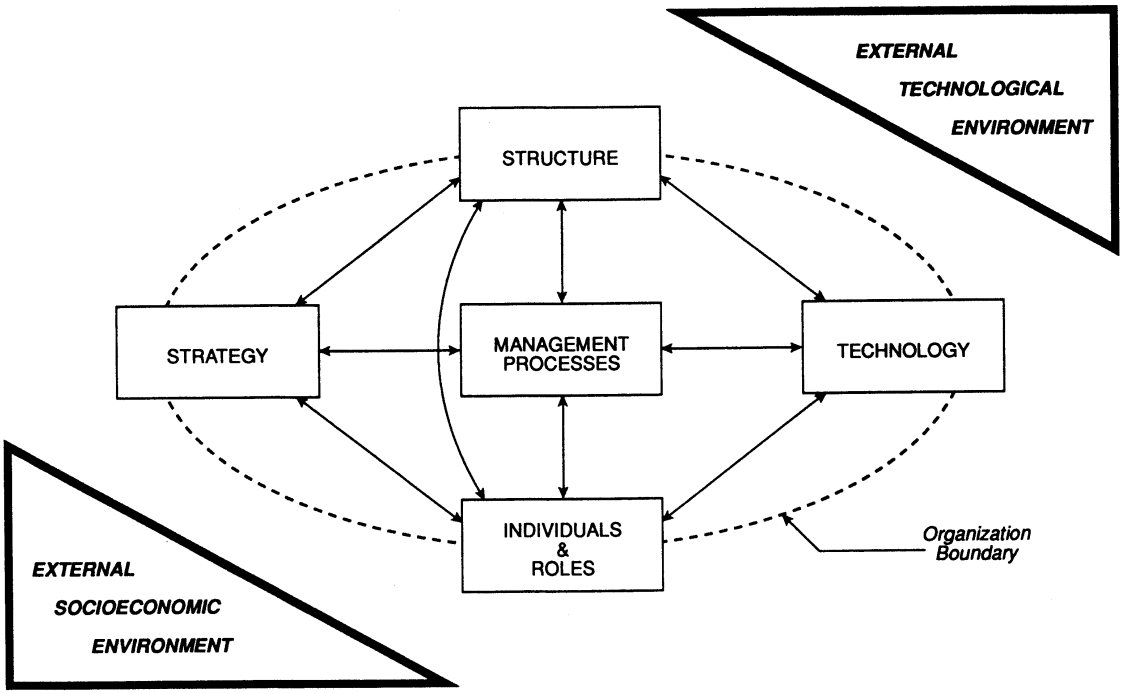

Figure 1. MIT90s framework [Scott Morton, 1991].

2.1 MIT90s Framework

The Management In The 1990s (MIT90) Research Program was created in 1984 to examine the impact of information technology on organizations of all kinds [Scott Morton, 1991]. The research program led to the MIT90 framework, see Figure 1, that has been found useful in considering the impact of information technology on organizations.

The MIT90 framework comprises five "forces" that interact within an information-technology-(IT) enabled organization in response to the external environment. These forces are:

- **Technology:** the IT that can be applied to facilitate business processes. Scott Morton points out that improvements in IT will lead to increasing shrinkage of time and distance effects,

greater interconnectedness, better organizational memory and greater capture of organizational rules.

- **Individuals and roles:** concerned with people within the organization, tasks they undertake, and the education and training they require to perform their functions. This force recognizes that there will be a blurring of job categories and tasks.
- **Structure:** the way that the organization is partitioned and the way the partitions interrelate. The organizational structure will be changed and new organizational structures will reflect the adoption of new IT and IT-enabled processes and practices.
- **Management processes:** the standardized sequences of activities that organizations adopt in order to undertake the tasks they perform regularly. Their character reflects the power and control distribution within an organization, the structure, the people and their assigned roles, and the enabling technology.
- **Strategy:** general modes of doing business in pursuit of organizational goals**.** Given that competing organizations will also exploit IT, strategy innovation is needed to generate competitive advantage.

2.2 Tom Peters' "Passion and Excellence" Paradigm

According to Peters and Austin [1985] "… the two most important basics of managerial success are pride in one's organization and enthusiasm for its works. A quick check of the twenty-five leading textbooks on management finds neither in any index." The focus of Peter's work is on leadership. The concept of leadership is so crucial that Peters and Austin believe that the words "managing" and "management" should be discarded. The Passion and Excellence paradigm focuses on people, care and trust. As an example, Peters and Austin [1985, p 369] provide the general principles for operation simplification at the UK firm of Marks & Spencer. They are:

- **Sensible approximation:** the price of perfection is prohibitive.
- **Reporting by exception:** only when absolutely necessary.
- **Manuals**: no attempt is made to legislate for every contingency and eventuality. Before simplification by Marcus Sieff at the beginning of his tenure as managing director, there were thirteen instruction manuals. Two small booklets replaced these manuals: *Guide to Staff Management* and *Store Regulations*.
- **De-categorization:** people have been moved from watertight compartments and placed in general categories.
- **Trust:** people can be trusted, so checks can be eliminated. This in turn saves time, staff and money, and leads to increased self-confidence and a sense of responsibility among staff. The principles of statistical control can be applied to exercise selective and occasional spot checks, which are usually more satisfactory and productive and are less expensive than a whole series of permanent control systems and continuous routine checks.

2.3 The People Process Product Time (PPPT) enterprise framework

The PPPT approach [Kasser 1995] is a control and information system paradigm rather than a production paradigm. It views the enterprise from the perspective of Information Systems, the

application of Knowledge Management, and modern Quality theory. It has explicit emphasis on Configuration Management and building Quality into the process.

PPPT combines prevention with testing and is based on the recognition that prevention is planned anticipation [Crosby 1981]. It is used within an Organizational Engineering or *integrated product-process and management* paradigm [Kasser 1999]. The most significant factor in the PPPT approach is the *recognition that cost reductions [improvements] in the product and process do not occur in a vacuum* [Kasser 1995]. The product under construction is a system and the process producing the product is a system. Thus, *the process, product and organization represent three tightly coupled dimensions of quality* and must not be considered independently [Kasser 1995]. In addition, every one of the systems changes over time.

Frosch [1969], when he was Assistant Secretary to the United States of America Navy, wrote: "Systems, even very large systems, are not developed by the tools of Systems Engineering, but only by the engineers using the tools." Engineers are people. PPPT emphasizes effective people [Covey, 1989] since people working within the context of an enterprise framework (system) build a product over a period of time**.**

From the PPPT perspective, the creation and evolution of the Force is a time-ordered sequence of activities in a multi-threaded environment managed by the Configuration Control Board (CCB). PPPT combines prevention with in-process testing in a synergistic manner to eliminate defects and so reduces project cost and schedule overruns. The PPPT task management methodology[3]:

- Emphasizes teamwork and customer involvement.
- Is loosely based on a methodology used for eight years in a task-ordered environment by a large contractor to the National Aeronautical and Space Administration [NASA].
- Improves on the basic methodology by adding the elements of Quality. The improvement:
    - Ensures work is performed in a cost-effective manner.
    - Maps very well into managing tasks performed in geographically distributed locations by different elements of a distributed organization.
    - Intrinsically incorporates task management into program management.
    - Builds the Quality into the task.
    - Reduces the cost of doing work.
- Allows the needed staffing levels and skill-mix to undergo the gradual change required to perform the planned work in an optimal manner as tasks progress through their life cycle.
- Monitors task and contract performance relative to the baseline plan.
- Develops measures of effectiveness of the work.
- Incorporates control functions that effectively deal with deviations from the baseline plan in a timely manner.

Deming [1986, 139] wrote: "Improvement of quality and productivity, to be successful in any company, must be a learning process, year by year, top management leading the whole company". Drucker [1995] discussed learning organizations as organizations in continuous change.

[3] A manuscript in process elaborates this concept [Kasser, in process].

PPPT includes:

- **Continuously monitoring and improving the task:** Training before doing, and applying lessons learned on one project to the next (the feedback loop). Prevention and continuous improvement are important elements of the Malcolm Baldrige National Quality Award.
- **Making the Technical Performance Measurements:** Supplying the standards and controls for the current task to provide:
  - Visibility of actual vs. planned performance.
  - Early detection or prediction of problems which require management attention.
- **Managing changes:** Supporting the assessment of the program impact of proposed change alternatives.
- **Acting as the advocate for the customer:** During the design and test phases of the task and whenever the customer is not present.
- **Performing Risk Management:** Identifying and mitigating risks to future tasks.
- **Tracking implementation:** Allowing the Program Manager to ensure that tasks are completed on schedule.

2.4 The Allison Defence Enterprise Model

Allison [2000] defines the Defence Enterprise as belonging to a class of enterprises that comprise

- A set of aims.
- A corresponding set of strategies.
- A set of tasks and objectives - the **'what'** of Defence - derived from the aims and strategies of the enterprise.
- A management structure with defined lines of responsibility and accountability.
- A set of processes (derived from policies, concepts, doctrine, procedures, etc.) that define the way in which the tasks are to be executed - the **'how'** of the Defence enterprise.
- A set of resources (limited by budget, and including people, organizations, systems, equipment, knowledge, etc.) that provides the means by which the tasks are executed - the **'what with'** of the Defence enterprise.

Allison goes on to define an **Enterprise Model** to be a federation of representations or descriptions of some or all of: -

- The enterprise's tasks, including temporal and structural relationships between tasks.
- The ways (processes) and means (resources) by which the enterprise's tasks are executed, including management processes.
- The influences of the external environment on these ways and means during the execution of the task.
- Linkages, interfaces, and other relevant relationships between enterprise components, enterprise data, including component inputs and outputs.
- Descriptions of interactions (including interfaces) that define relationships between enterprise elements.
- Descriptions of interactions that define relationships between enterprise elements and the external environment.

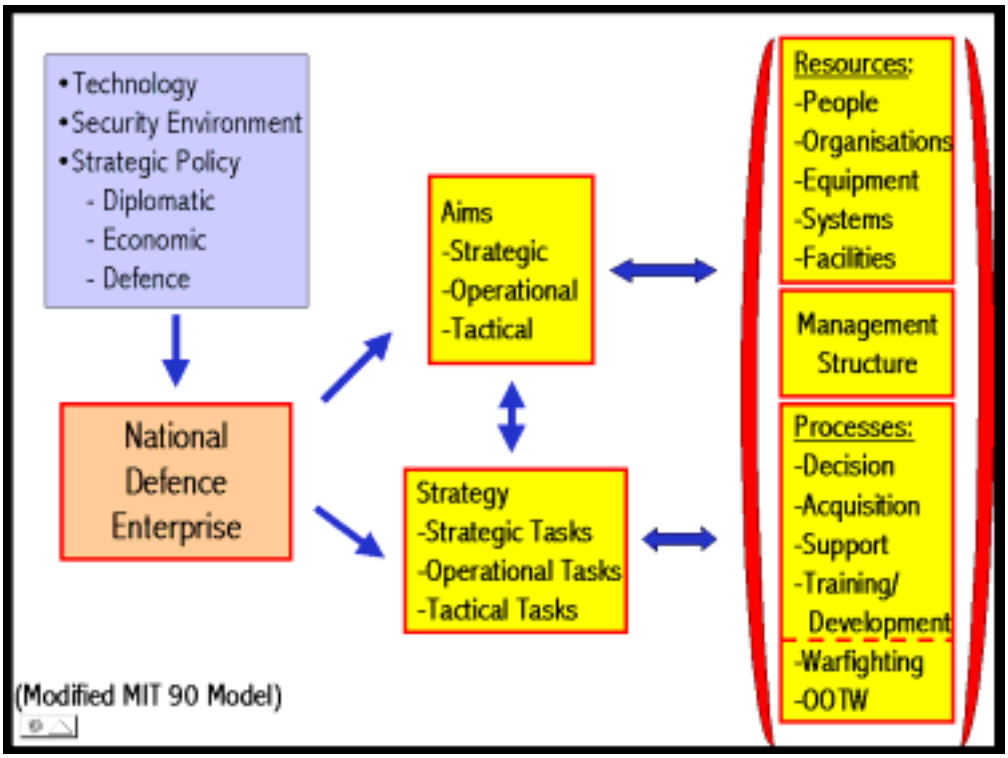

Figure 2 Allison's Structure of the Defence Enterprise Model [Allison, 2000]

Allison further states that "The enterprise model structure as defined above has the useful property that it is generic and scaleable, and can, therefore, be applied at all levels of undertaking within the entire defence enterprise. The model is thus a scaleable, generic architecture for this particular class of enterprises. In principle, it can be used to support the decomposition and integration of enterprises that fit within the defence family. As well, it allows organizations, concepts, and technology to be addressed within a common framework."

Figure 2 shows how the model can be drawn in a form that is analogous to the MIT90 framework.

2.5 Checkland's (Human Activity) System Models (CSM)

The crux of Checkland's Soft System Methodology [Checkland, 1993] is the formation of root definitions of the system (organization) of interest. Root definitions are simple descriptions of systems identified within the system of interest that can be expected to be of interest when wishing to improve the overall organization. To ensure that the root definitions encompass all the crucial characteristics of the system, Checkland proffers the use of six elements, encompassed by the mnemonic CATWOE, that are derived from his earlier work on formal human activity systems models. The CATWOE elements are:

- **C**ustomers: the beneficiary or victim of the system's activity.
- **A**ctors: persons who carry out one or more of the activities in the system.
- **T**ransformation: the means by which defined inputs are converted into defined outputs.

- **W**eltanschauung: the (unquestioned) image or model of the world that makes this particular human activity system a meaningful system to consider.
- **O**wners: some agency having a prime concern for the system and the ultimate power to cause the system to cease to exist.
- **E**nvironment: impositions that the system takes as given.

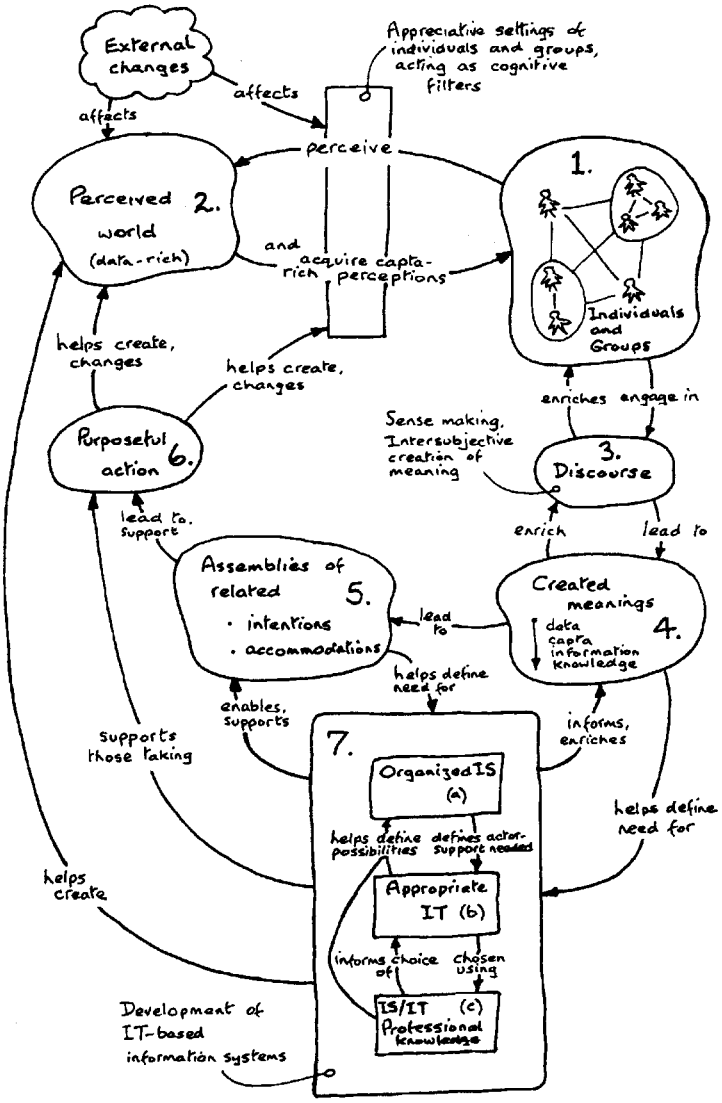

Figure 3 POM Model [Checkland and Holwell, 1998]

2.6 Process for Organizational Meaning (POM)

Checkland and Holwell [1998] describe a process for organizational meaning (POM) model that is an organizational model of the social process that underpins organizations. This model is shown in Figure 3.

The POM model is a loop that relates to the processes in which organizational meaning is created.

- Element 1 consists of people as individuals and as group members.
- Element 2 is the data rich world they perceive selectively through their various taken-as-given assumptions or "cognitive filters".
- Element 3 the organizational discourse, is the arena in which meaning is created.
- Element 4 is the information and knowledge created by Element 3.
- Element 5 is the assembling of intentions and accommodations (see below)
- Element 6 is the purposeful action that arises from the process

As Checkland and Holwell put it: "[Element 5] … is a very complex social process in which persuasion and/or coercion is attempted, battles are fought and scores settled - the whole process embodying politics as well as, perhaps, rational instrumental decision taking! Organizations have to be able to encourage but at the same time contain such a process to survive. They have to enable assemblies of related meanings, intentions and accommodations between conflicting interests to emerge (Element5) so that purposeful action (Element 6) … can be taken".

In this model, information systems support the process but are somewhat peripheral to it. The model recognizes that the POM process existed before the augmentation IT promises came into being and will continue, albeit impaired, without it.

2.7 Australian Army Fighting Power (AFP)

The Australian Army's Land Warfare Doctrine as described in [LWD1, 1998] provides a useful enterprise model for military operations in its chapter on Fighting Power. Figure 4, extracted from that document, shows that the Australian Army considers fighting power to comprise the following three first tier components: intellectual, moral and physical. The 11 items that comprise the second tier components elaborate these further. The Physical Component contains social, cultural and epistemological considerations. From reading the document we interpret the Physical Component to mean that the Army chooses to emphasize that it is people that are the Army's scarcest and most valuable resource and only through them can it achieve its mission. There is no evidence of the machine metaphor [Flood and Jackson, 1991] so often attributed to military organizations.

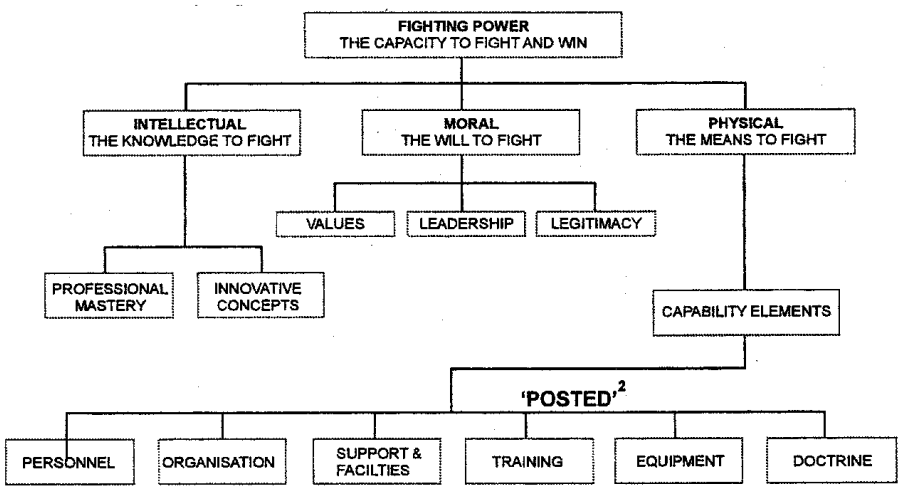

Figure 4 Australian Army Fighting Power [LWD1, 1998]

The terms used in Figure 4 are self-explanatory and will not be described further.

2.8 C4ISR Architectural Framework

The C4ISR Architecture Framework, (C4ISRAF) [C4ISRAWG, 1997], is an Architecture Description Framework[4] developed by the US DOD to produce Information Architectures, ie architecture descriptions[5] of systems from an information perspective. Indeed, [Levis 1997], refers to the C4ISRAF as an Information Architecture Framework.

The C4ISRAF has three Architecture Views[6] named the Operational Architecture View, the Systems Architecture View and Technical Architecture View, see Figure 5.
The views are defined, [C4ISRAWG, 1997], as follows[7].

- The **Operational Architecture View** is a description of the tasks and activities, operational elements, and information flows required to accomplish or support a military operation.
- The **Systems Architecture View** is a description, including graphics, of systems and interconnections providing for, or supporting, warfighting functions.
- The **Technical Architecture View** is the minimal set of rules governing the arrangement, interaction, and interdependence of system parts or elements, whose purpose is to ensure that a conformant system satisfies a specified set of rules.

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[4] Burke, [Burke 2000], defines an Architecture Description Framework as "a set of guidelines, rules and representational conventions for developing and presenting architecture descriptions". He distinguishes Architecture Description Frameworks from both Architecture Implementation Frameworks and Architecture Concept Frameworks.
[5] Burke, [Burke 2000], defines an Architecture Description as an "a representation of aspects of knowledge about a system".
[6] Burke, [Burke 2000], defines Architecture Views as "classes of architecture descriptions that allow knowledge about systems to be represented from particular perspectives".
[7] Levis, [Levis 1997] indicates that these definitions have been modified since the publication of Version 2.0 of the C4ISR AF document in December 1997, [AWG 1997].

Architecture Views selectively emphasize different types of characteristics of knowledge about systems. However, redundancy can exist between different architecture views if their perspectives overlap.

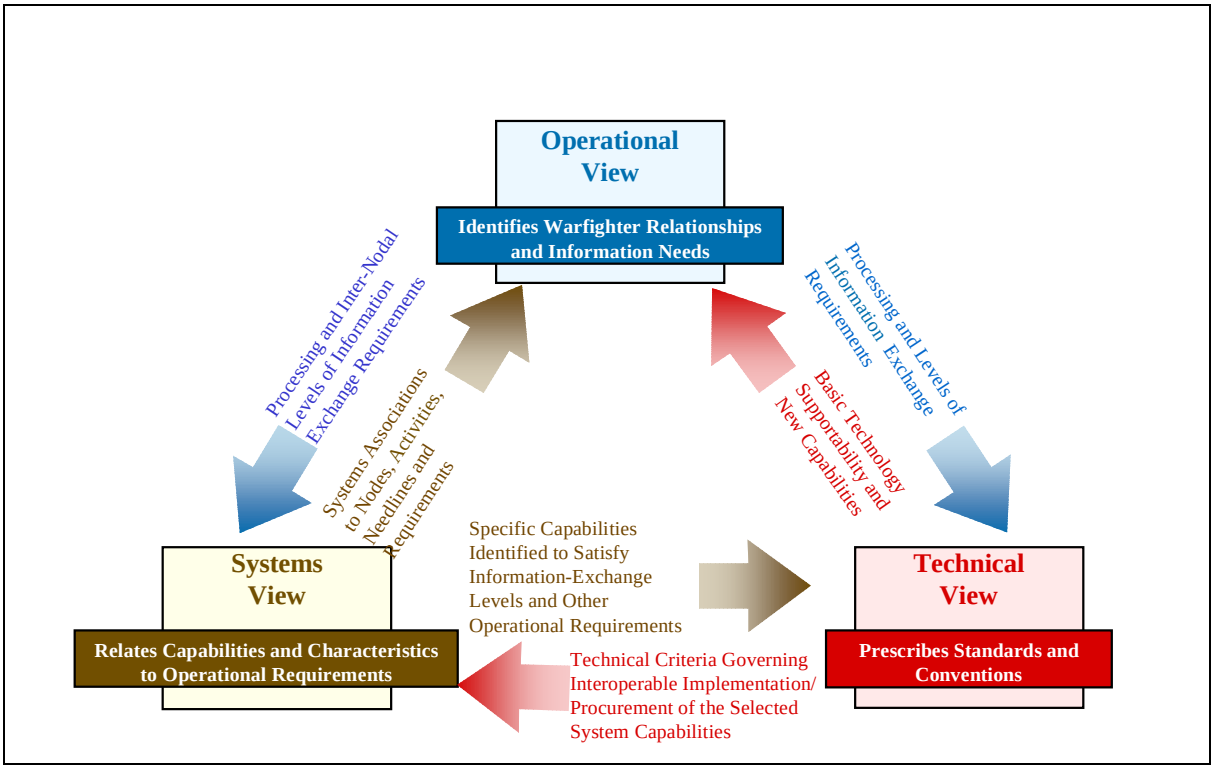

Figure 5 Fundamental linkages among the views [C4ISRAF, 1997].

Architecture Views are said to be orthogonal[8] if their perspectives do not overlap in which case there is no redundancy in the knowledge about systems that they represent.

Note that the C4ISRAF's set of Architecture Views are not orthogonal since redundancy can exist in the knowledge about systems that they represent.

Architecture Views are said to be mutually consistent[9] if their perspectives do not conflict in which case there is no contradiction in the knowledge about systems that they represent. Note that the C4ISRAF's set of Architecture Views are not necessarily mutually consistent since their perspectives may conflict.

3. A Comparison of the Models

The approach used to compare the richness of the models and frameworks summarized in the previous section was to use a single table that indicates the extent to which each model or organizational framework maps into a high-level generic list of attributes derived from the Social

[8] Burke, [Burke 2000], defines Orthogonal Architecture Views as "architecture views whose perspectives are such that there is no redundancy in the knowledge about systems that they represent".

[9] Burke, [Burke 2000], defines Mutually Consistent Architecture Views as "architecture views whose perspectives are such that there is no contradiction in the knowledge about systems that they represent".

Political Epistemological Cultural Technological Relative Environmental (SPECTRE) attribute framework. In SPECTRE the terms mean the following:

- **Social:** the means and ways by which groups of people are **structured and organized** to pursue ends.
- **Political:** means and ways by which power is assigned in groups of people in the pursuit of ends.
- **Epistemological:** means and ways by which individual people develop understanding.
- **Cultural:** means and ways by which groups of people attempt to share understanding.
- **Technological:** means and ways by which artifacts are used to pursue ends.
- **Relative:** means and ways by which different states of an enterprise can be compared. This attribute captures the dynamics of an enterprise by describing changes over time.
- **Environmental:** factors external to the enterprise that interact with the enterprise through the enterprise boundary.

These are further subdivided as shown in Table 1. The authors completed Table 1 by allocating the level of coverage of each attribute by the respective model using the following five-point scale:

- Excellent (E)
- Good (G)
- Moderate (M)
- Poor (P)
- Omitted (O) or don't care

4. Discussion

The preliminary research summarized in Table 1 has shown that while the C4ISRAF is very well suited to product descriptions of Information Systems, it is less well suited to other issues which, when expressed in terms of the PPPT Framework include:

- **People issues:**
  - Leadership
  - Personal and organizational military knowledge (including doctrine)
  - Development
  - Training
  - Posting cycle
- **Process issues:**
  - Systems development (acquisition) process
- **Product issues:**
  - The assessment of capability and performance
- **Time issues:**
  - Generative learning and organisation structure evolution
  - Strategic policy evolution
  - Changes in force deployment policy

In addition, seven essential products and nineteen supporting products[10] are specified in [AWG 1997]; it states that these are not an exhaustive set of products that could be used. This suggests that C4ISRAF is likely to be cumbersome in practice. In particular, it may prove poorly suited to dealing with the rapid and often extensive changes that characterize the modern Information Systems domain. Consequently, it may be not be unrealistic to anticipate analogous difficulties in the practical application of the C4ISRAF to those experienced in using software documentation standards such as DOD-STD-2167A. Vernik [1996], Section 2.2.2, provides a full discussion of this experience.

Furthermore, the nature of the information orientation of the C4ISRAF suggests that it might be difficult to augment or extend it to accommodate the description of knowledge and culture aspects of Defence systems. This is an important issue given the knowledge- and culture-orientation of future Defence systems foreseen by Strategic Policy and Plans Division, ADHQ.

It is clear from Table 1 that different modeling approaches offer different degrees of coverage and are aimed at different levels of abstraction. For example, the Allison model is the most comprehensive but is aimed primarily at whole of capability, whereas the C4ISRAF is much stronger in technical areas at the task force level. We suggest that SPECTRE can be considered to be a “palette” of attributes that can be used to select the approach model of framework for the specific task in hand. This concept is to be pursued in subsequent research.

5. Conclusion

The C4ISRAF is excellent for gaining insight into, and describing the technical nature of military Information Systems. However, it is only one of a set of models providing different perspectives, each of which has a place in the analyst's palette. The comparison presented in this paper indicates that alternative models and frameworks can be better suited for gaining insight into, and describing the nature of other aspects the military enterprise. We propose that Models and frameworks should be used in conjunction with the C4ISRAF to gain a fuller insight into information-rich military enterprises and how to build them.

[10] The intention is that supporting products are used selectively to achieve the objectives of specific architecture descriptions.

		Organization Models and Frameworks							
General Attributes	Detailed Attributes	MIT90	Peters	PPPT	CSM	POM	AFP	Allison	C4ISRAF
		Model	Model	Framework	Model	Model	Model	Framework	Framework
Social	Customers	P	E	E	E	E	G	P	O
	Actors	E	E	E	E	E	E	E	E
	Owners	P	M	M	E	E	G	M	O
	Leaders	P	E	E	P	M	E	P	O
	Aims	P	E	E	E	E	G	E	G
	Strategy	E	E	E	P	P	E	E	M
	Structure	E	E	E	P	P	E	E	E
Political	Political	P	P	G	M	M	O	O	O
Epistemological	Knowledge	P	E	E	O	G	E	G	P
	Training	O	E	E	O	O	E	G	O
Cultural	Representation	O	P	M	O	O	G	M	O
	Doctrine	O	P	M	O	O	E	M	M
	Processes	E	G	E	G	M	M	E	E
	Identity	O	E	E	E	E	E	P	P
Technological	Technology	E	O	E	O	M	E	E	E
Relative	Change	M	M	E	M	M	G	M	O
	Temporal	P	M	E	M	M	G	E	O
Environmental	Environment	G	M	E	G	G	G	G	P

Table 1 Summary of coverage of the system models or framework descriptions against the SPECTRE framework.

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