Joker One:
A Tutorial in Cognitive Work Analysis

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Abstract

Cognitive work analysis is a multi-stage analytic framework for identifying the human-relevant work constraints in a socio-technical system. It offers a set of knowledge representation tools specifically tailored to analysis and design of large-scale information systems. Many cognitive engineers experience initial difficulty in understanding the diverse analytic stages that make up the framework of cognitive work analysis. They also experience initial difficulty in understanding how the stages inform each other and how the stages inform design. In this tutorial, I work through an example to illustrate each of the analytic stages and how the different analyses flow into each other. I also illustrate the implications of each stage for design of a cognitive support system. For source material, I draw primarily on a narrative of US Marine counter-insurgency operations provided by Donovan Campbell in his book, Joker One.

Author's Note

Over the 20 years or so that I have engaged with cognitive work analysis, I have struggled with two issues. One concerns the mechanics of how to do it and the other concerns terminology.

As many of you will already know, the framework of cognitive work analysis is based in the work of Jens Rasmussen, for example, Rasmussen (1986) and Rasmussen, Pejtersen and Goodstein (1994). These treatments are rich in conceptualisation but lack structure. Vicente (1999) performed a major service in providing that structure. In addition, he established a coherent and persuasive argument for why we would want to embark on such an extensive analytic endeavour. However, despite the structured approach offered by Vicente, the actual execution of the analysis remained a struggle.

My first book on this topic (Lintern, 2009) offered a theoretical perspective that had been neglected and also explained the mechanics of the analysis. Since the release of that book, I have taught this framework many times within extended workshops. The students within those workshops have primarily been professionals from the cognitive engineering and systems engineering communities. As I teach this material within those disciplines, I continue to be troubled by the terminology. Those of us who have experience in the use of cognitive work analysis have not been kind to others who seek to understand this framework for the first time. We do not always use words in a sense that corresponds to their natural language meaning and some of the words we use are just outright obscure.

In this book I describe the process of analysis in more detail than I have done before. Additionally, I continue to adjust the terminology. All of those adjustments are in the service of making this material more accessible. This is an ongoing effort. If you who have read my earlier book or have taken one of my workshops, you will notice that I even adjust my own terminology. I like to think that this book will be my final word but I fear that a month or a year from now I will find something I do not like and I will want to change the words I use. Nevertheless, I hope that any of my adjustments in terminology enhance accessibility sufficiently to overcome any confusion created by lack of consistency with my earlier treatments.

The Strategy for this Tutorial

The purpose of cognitive work analysis is to describe requirements for a future system. In a tutorial on a subject as extensive as cognitive work analysis, it is difficult to explain analytic techniques with reference to a work system that does not yet exist. The illustrations become obscure.

In this tutorial, I have chosen a different course. I take narratives from a work system in action and show how they can be represented within the framework of cognitive work analysis. I represent the system as it is, touching only occasionally on how it could be. Throughout this tutorial, you, the reader, should remain aware that this is not what cognitive work analysis is for. I become futuristic only in a later chapter on functional workspace design. I like to think that this later chapter will suffice to carry the important message that this is an analytic framework to be aimed at designing the future.

What I do here is most specifically aimed at familiarising you with the mechanics of the framework. To do that, I proceed systematically through the framework of cognitive work analysis to demonstrate how to develop each of the representational products and how to use them for design.

My tutorial illustrations draw on US Marine combat narratives offered by Donovan Campbell (2010) in his book, Joker One. The book provides an account of his experiences in Ramadi, Iraq in 2004, where his platoon battled insurgents for seven months. Figure 1 shows the area of operation and the location of the combat outpost and other key features within Ramadi. I list relevant pages of the book within the analytic products I develop. I also use several other sources to complete the analysis and design illustrations.

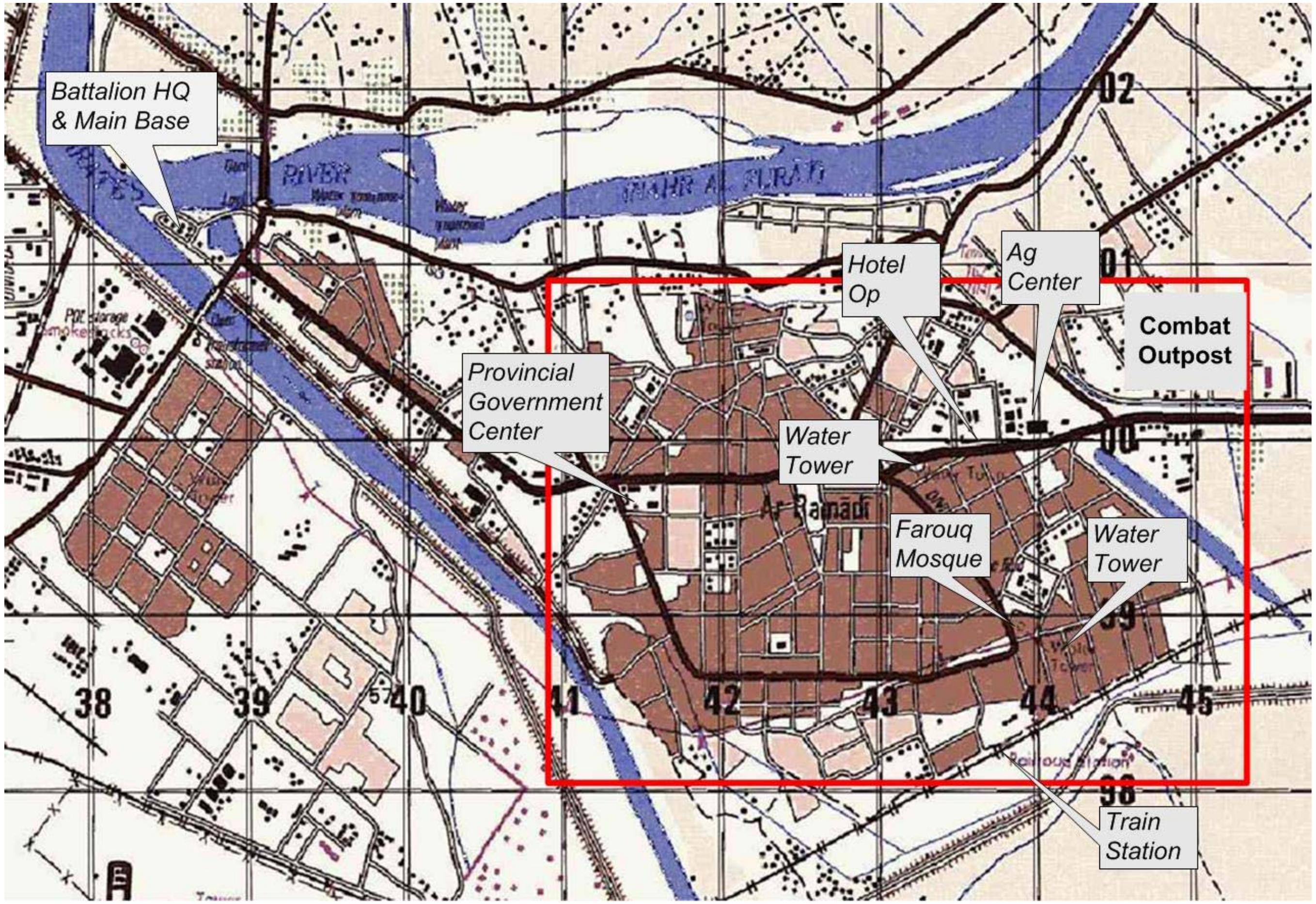

Figure 1: Ramadi, Iraq, showing Joker One's area of operation within the red perimeter and the location of their combat outpost and other significant features

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The Framework of Cognitive Work Analysis

Cognitive work analysis is employed to develop the basis for design of a new work system, one that is not constrained by existing work practices developed for use with obsolete technologies or for resolution of past problems. Cognitive work analysis identifies the constraints on work and is said to support a formative approach to design because it describes requirements that must be satisfied as it shows the space of possibilities. It supports design for the future. We ask, *given the socio-technical constraints that exist within the work domain together with the constraints on human action, what are the possibilities for satisfying the purpose for which the system is being designed*?

There is, however, an issue. We can only design what we can imagine, and our imagination is shaped by our experience. The struggle in design for the future is to imagine possibilities beyond the familiar. We need to be creative, allowing the past to seed our imagination without permitting it to lock us into old, unproductive ways. In formative design, there is an ongoing dance between the past and the future. We reflect on the past to discover immutable constraints on work but we do not want to be captured by habits or patterns of the past that no longer mesh with current demands or possibilities. Cognitive work analysis offers one strategy for engaging in that ongoing dance between the past and the future.

Cognitive work analysis is a multistage framework that offers a set of knowledge representation tools specifically tailored to analysis and design of large-scale information systems. In this tutorial, I identify six stages; work domain analysis, work organization analysis, social organization analysis, work task analysis, cognitive strategies analysis, and cognitive modes analysis. I depict these six stages in Figure 2.

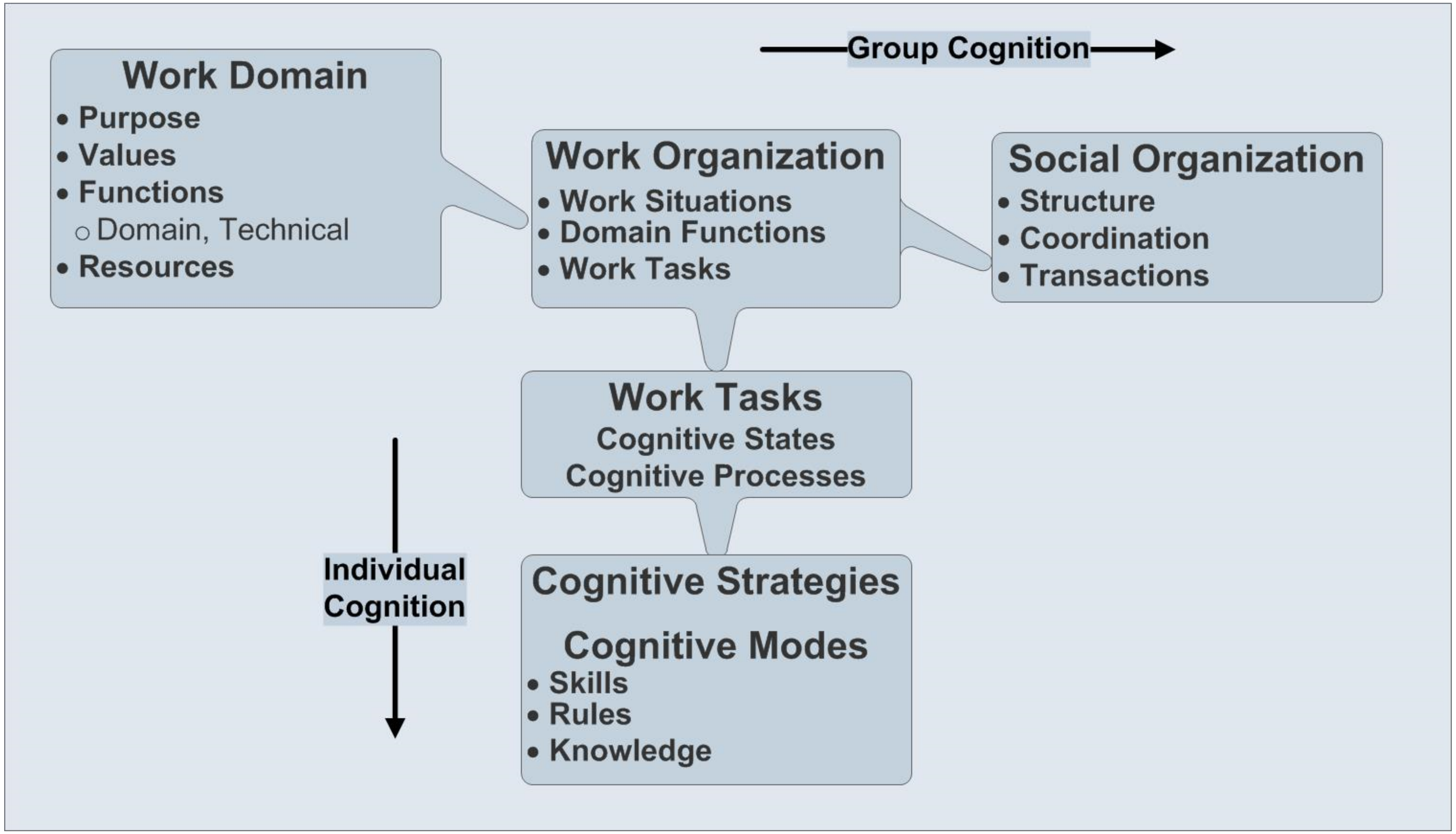

Figure 2: Cognitive work analysis is a multistage framework in which later stages draw on products from earlier stages

The Analytic Sequence

Figure 2 shows that the analysis is initiated with work domain analysis, the products of which inform work organization analysis. The analysis may then follow one of two branches, one dealing with group cognition by use of social organization analysis and one dealing with individual cognition by use of work task analysis, cognitive strategies analysis and cognitive modes analysis in that sequence. The analyst is free to choose which branch to follow first but, for a comprehensive cognitive work analysis, the analyst should then return to complete the other branch.

Different treatments of cognitive work analysis identify different numbers of stages and give them different names. Figure 3 compares the different stages as described by Vicente (1999) to those I describe here. However, there is no substantive difference in the analytic content between the different treatments. Rather, differentiation of analytic content by reference to stages is a pragmatic device that serves to aid organization of analytic workflow and description of the analytic work. Additionally, the names of the stages and the allocation of analytic content to various stages have evolved as analysts have sought better ways to organize their workflow and to describe what they are doing.

Name of Analysis (This Tutorial)	Representational Product (This Tutorial)	Vicente (1999) Chapter Titles
Work Domain Analysis	Abstraction-Decomposition Space	Work Domain Analysis
Work Organization Analysis	Work Task Scratch Pad Work Task Docket	
Work Task Analysis	Decision Ladder Cognitive States & Processes Table	Control Task Analysis
Cognitive Strategies Analysis	Annotations on a Decision Ladder Cognitive Strategies Table	Strategies Analysis
Cognitive Modes Analysis	Annotations on a Decision Ladder Cognitive Modes Table	Worker Competencies Analysis
Social Organization Analysis	Network Diagram Staffing & Transactions Dockets	Social Organization & Cooperation Analysis

Figure 3: Comparison of stage names from Vicente (1999) with those of this tutorial

Work Domain Analysis

A work domain is a *functional* space in which work can be accomplished. As a functional space, it has both intentional and physical properties where *intentional* refers to purpose-related properties and *physical* refers to objects and layouts. *Functional* refers to an activity-independent capability (potential) to accomplish something specific. Work domain analysis identifies the activity-independent properties that support and shape work. It does so at different levels of functional abstraction and to different degrees of decomposition.

The product of this stage of analysis is an abstraction-decomposition space, which is an activity-independent representation of both the intentional and the physical constraints embedded in the work domain.

Functional Work Structure

A *function* as used in cognitive work analysis is a capability. A sensor, for example, provides a capability to monitor the status of an area or event. In ecological terms, a function is an affordance, a property of the work environment that supports and guides (constrains) purposeful action.

In general use, the term *function* has diverse meanings. Vicente (1999, p 6) defines it as a goal-relevant structural property of a work domain that supports realization of the purpose for which the work domain was designed. By this definition, a function is a structural property of a work domain and is activity independent. Following Vicente, I use the term *function* to signify what can be accomplished with something if it is used in an appropriate manner. This usage corresponds to one of several definitions offered by Wiktionary.

Abstraction-Decomposition Space

An abstraction-decomposition space is a two-dimensional matrix (Figure 4). The vertical dimension is an abstraction hierarchy extending over the five levels of system purpose, domain values, domain functions, technical functions, and physical objects. The horizontal dimension is a decomposition hierarchy extending over the number of levels identified during analysis as relevant to an understanding of the functional structure of the work. A work domain has a functional, activity-independent structure, which is identified and mapped into an abstraction-decomposition space via work domain analysis.

An abstraction-decomposition space is not typically represented in the manner shown in Figure 4. While in principle, every cell in the matrix can be populated, in practice, the approximate diagonal from upper left to lower right contains the nodes that are informative for design and so these are the ones that analysts typically populate. Because of that, the two-dimensional format leaves considerable unused space in the diagram. As you will shortly see, even a simple abstraction-decomposition space becomes crowded with nodes at the different levels, which works against the viability of organizing different levels of decomposition in different columns.

As suggested by Figure 4, the analysis leads naturally to more decomposed descriptions at lower levels of abstraction. These different degrees of decomposition can be coded in different ways, as for example in Figure 5 where, at the technical functions level, capability **C** is shown as decomposed into three sub functions by the use of dashed arrows and capability **D** is shown as decomposed into two sub functions by the use of two nodes inside the capability **D** node. At other times, these decompositions may be left implicit.

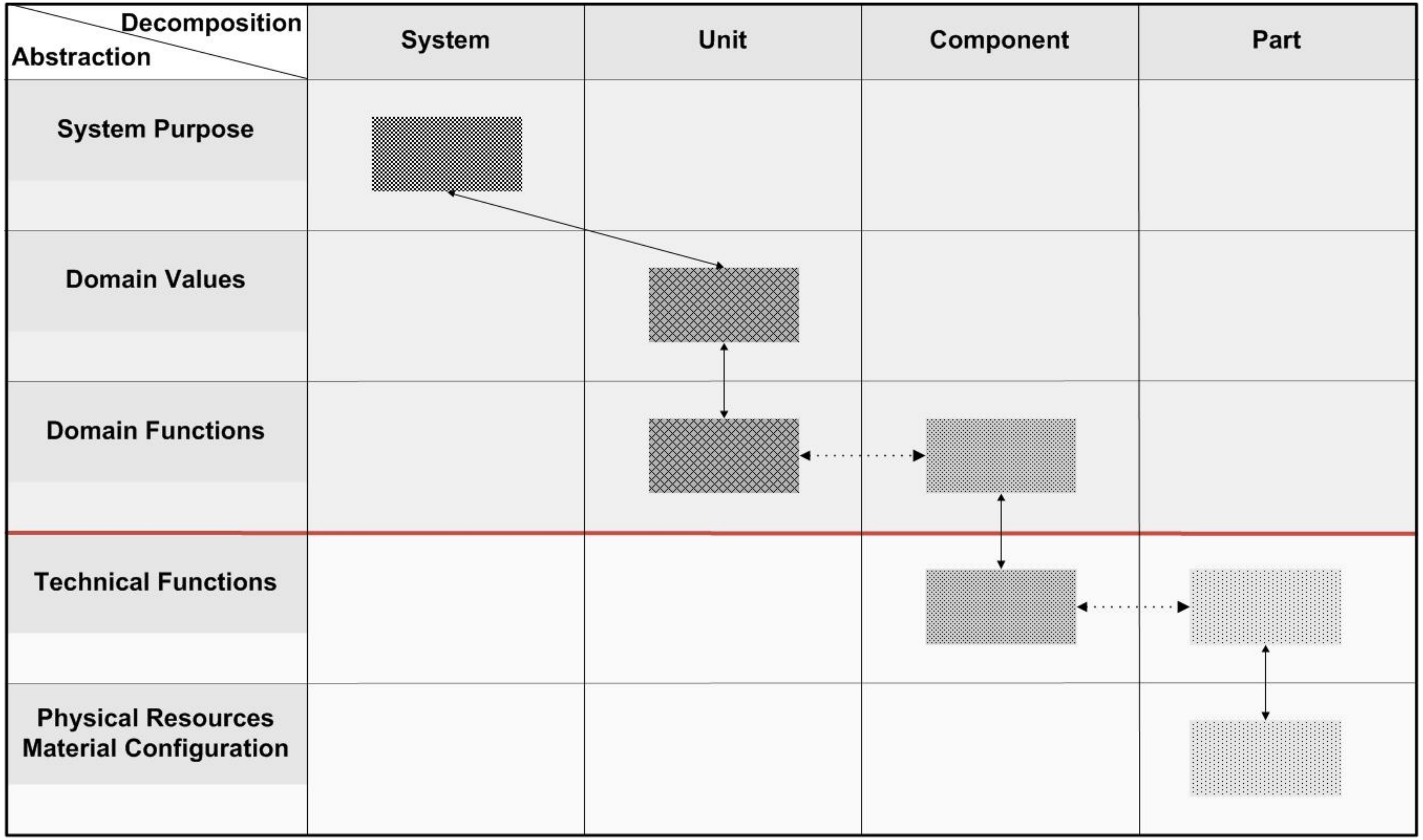

Figure 4: An abstraction-decomposition space is two-dimensional matrix with five levels of abstraction and several degrees of decomposition

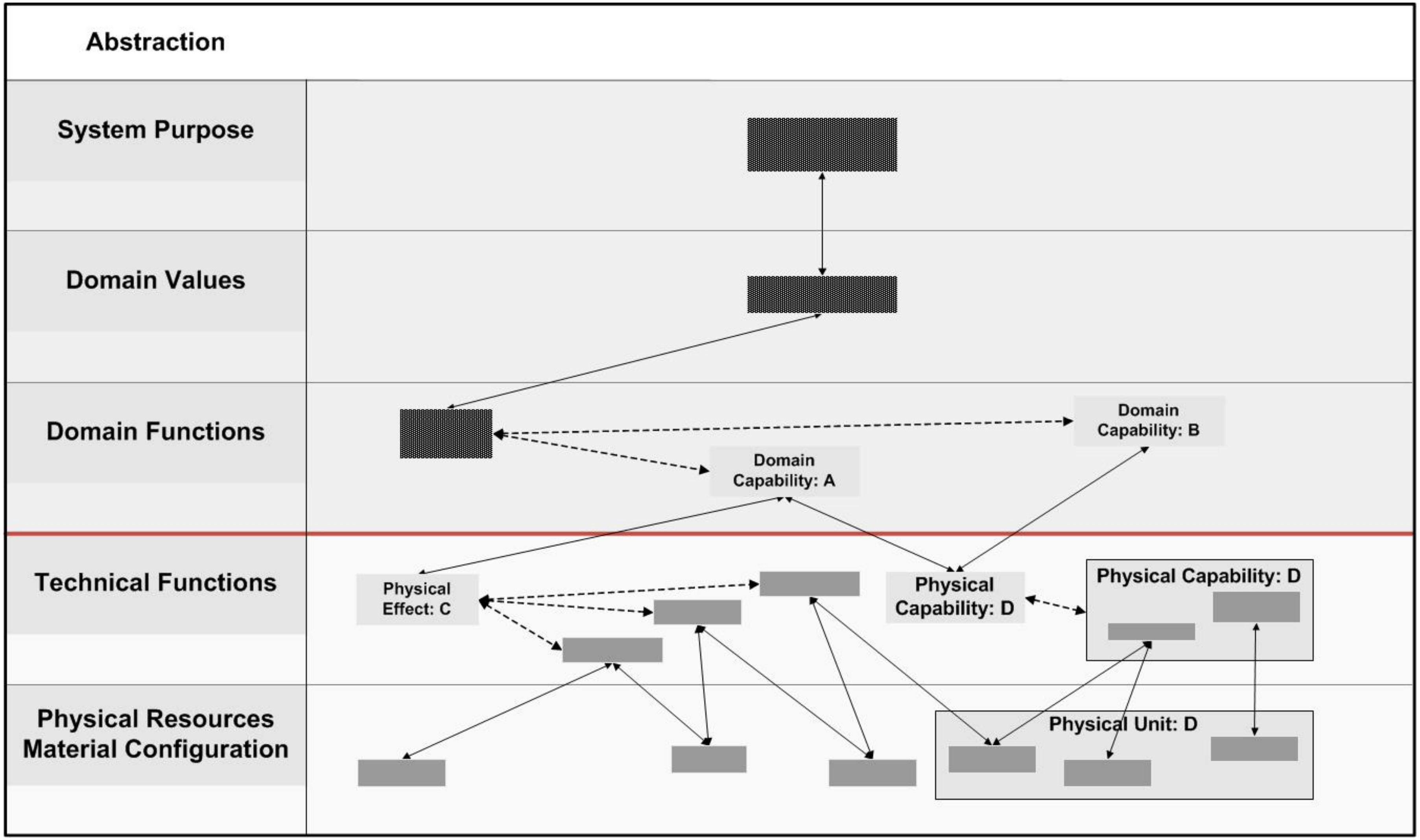

Figure 5: An abstraction-decomposition space is more efficiently presented as a single column with decompositions coded or implied

The upper three levels of abstraction reference human purposeful properties of the system while the lower two levels reference technical properties. Throughout this tutorial, I use a red line and a difference in background shading, as shown in Figure 4 and Figure 5, to emphasize this distinction.

An abstraction hierarchy, as developed via work domain analysis, is a stratified hierarchy defined by means-ends relations between adjacent levels. A series of means-ends relations link resources across levels of abstraction in a functional chain, as shown in both Figure 4 and Figure 5 by the two headed arrows that link nodes from adjacent levels of abstraction. A means-ends relation identifies the resources (the means) that are available for a worker to achieve work products (the ends).

The left panel of Figure 6 shows a minimal means-ends abstraction hierarchy. In this illustration, the compressor is the physical resource that enables the technical function of heat exchange and the heat exchange function is the resource that enables realization of the domain function of cooling.

The right panel of Figure 6 shows a similar relationship for a component of an ambush set up by US Marines (Campbell, 2010). In this scenario, the different squads engaged in the operation had to communicate with each other. This communication (a domain function) was enabled by voice transmission (a technical function), which in turn, was enabled by a portable communication device known as the Personal Role Radio (a physical resource).

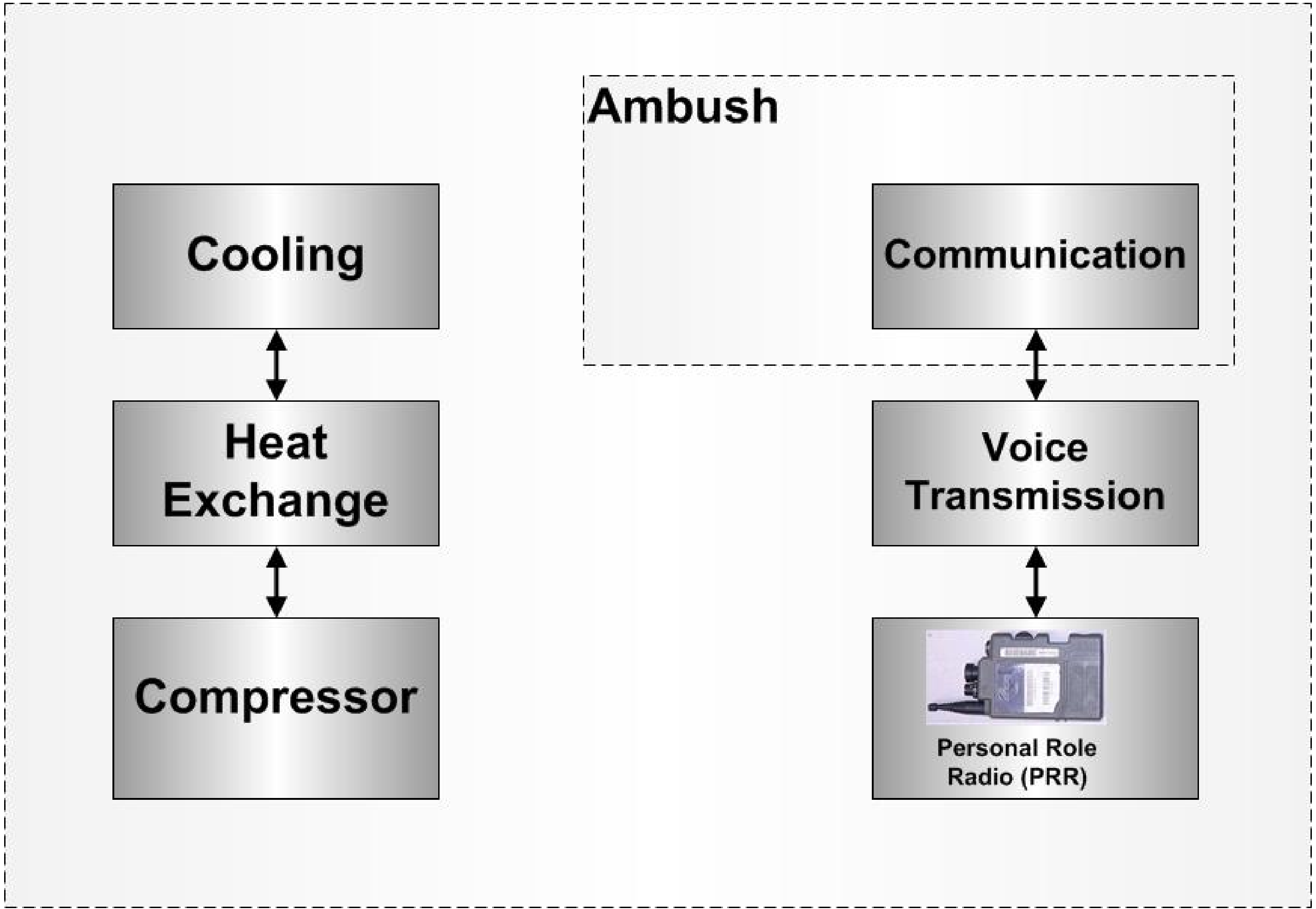

Figure 6: A minimal means-ends abstraction hierarchy for home cooling (left panel) and for the communication component of an ambush operation (right panel)

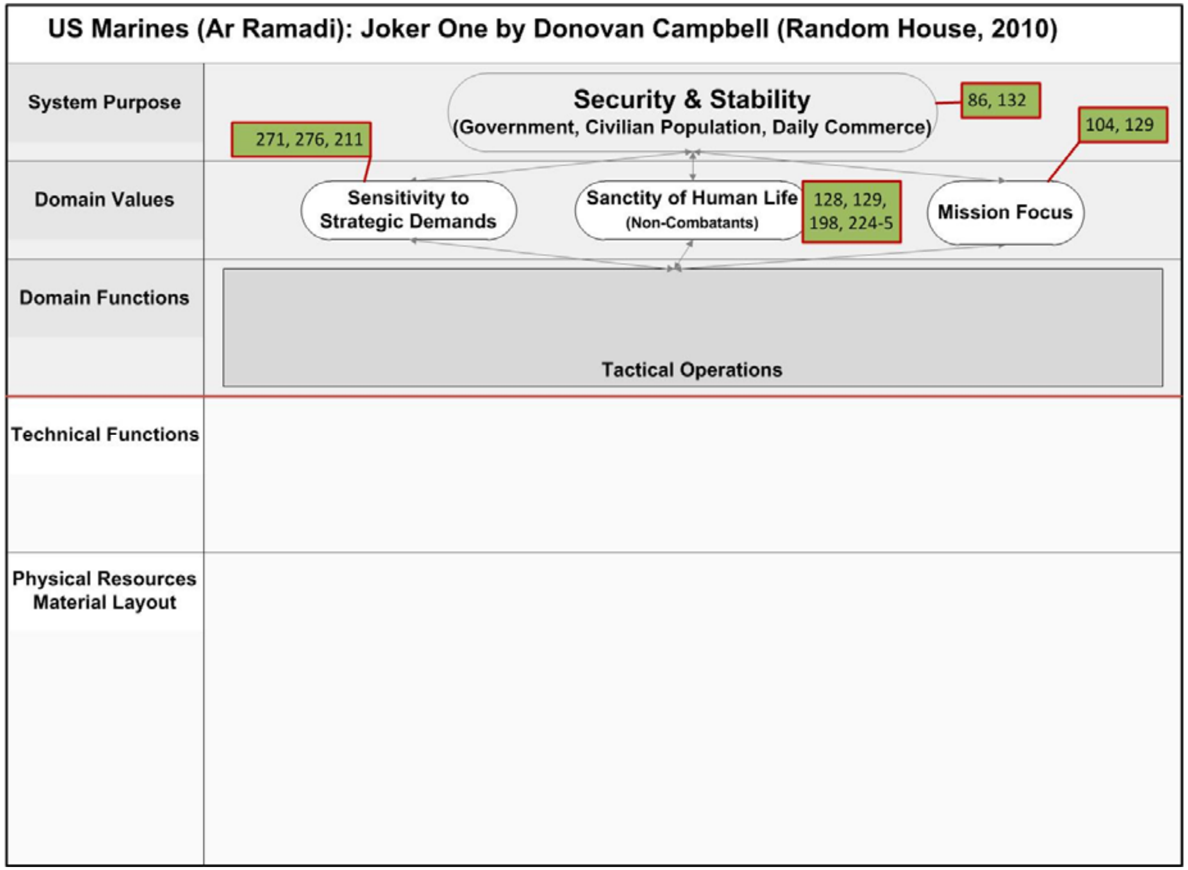

Figure 7: Abstraction-decomposition space for US Marine counterinsurgency operations with entries at the top two levels

Joker One: Work Domain Analysis

The US Marine platoon, Joker One, led by Lt Campbell, was deployed to Ramadi, Iraq in March, 2004 to engage in counter-insurgency operations. The purpose of the mission was to establish the security and stability of government functions, the civilian population and daily commerce. This is entered in Figure 7 at the top level of the abstraction-decomposition space.

Throughout the deployment, Joker One's operations were guided by values related to non-combatant safety and mission success. Additionally, Joker One responded to strategic demands as expressed by the military command and the Civilian Provisional Authority even though Lt Campbell had occasional misgivings about the wisdom of the directions. Figure 7 shows these domain values at the second level of the abstraction-decomposition space.

The means-ends relations connecting the domain values to the system purpose specify that realization of these values will support the system purpose. For example, sensitivity to strategic demands and pursuit of mission success will both contribute to the purpose of establishing security and stability. Within the abstraction-decomposition space, these are assumed relationships rather than factual ones. The abstraction-decomposition space makes such assumed relationships explicit so that they can be assessed. The analyst might conclude that there is a mismatch between purpose and values, thereby giving impetus to a redesign effort.

Additionally, satisfaction of all domain values should completely satisfy the system purpose. However, in this tutorial I will not develop a complete abstraction-decomposition space. Thus, I note above that satisfaction of these values will support rather than satisfy the system purpose.

An abstraction-decomposition space can be populated by consulting many different types of resources. Training manuals, operational manuals and interviews with operational experts are just three of the possibilities. In this tutorial, I rely largely on the mission descriptions provided by Donovan Campbell. However, a mission is an activity and the abstraction-decomposition space is not populated with activities but rather with resources, functions and values that support, guide and constrain those activities. Thus, in populating the abstraction-decomposition space, I use mission descriptions to infer the required nodal entries and the essential means-ends relations. Nevertheless, throughout this chapter, I offer page references within the abstraction decomposition space to the activities I rely on for the analysis as a means of reminding readers of the origin of the source material.

I should note at this point that this strategy of relying on specific events will produce a comprehensive abstraction-decomposition space only if the referenced activities cover all possibilities. In this particular case, we can safely assume that the activities described by Campbell constitute only a subset of the possibilities and that I would need to refer to other sources to complete the work domain analysis.

Joker One was engaged in tactical operations as entered in Figure 7 as a domain function at the third level of abstraction.

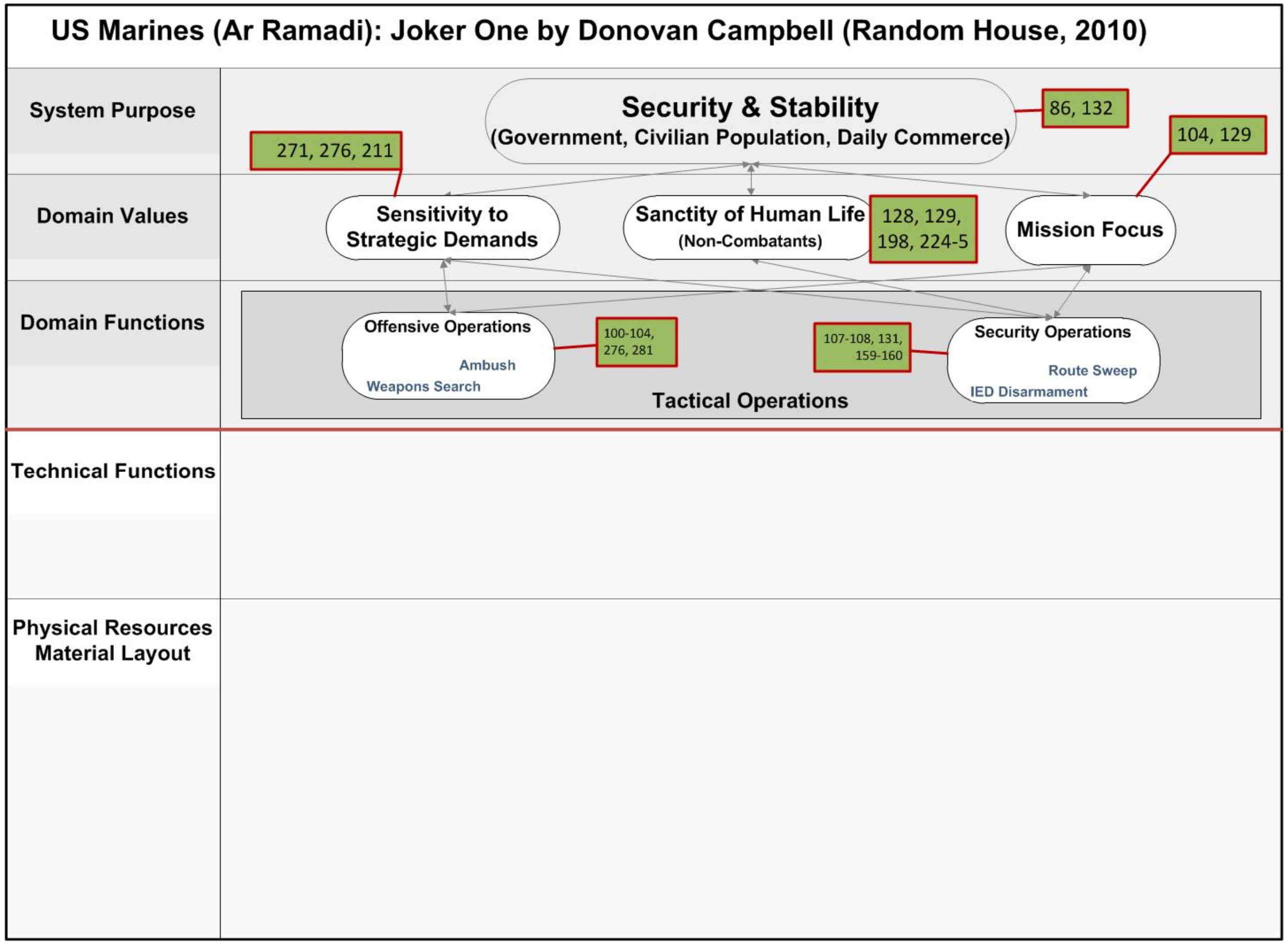

Figure 8: Abstraction-decomposition space for US Marine counterinsurgency operations with entries at the top three levels and showing decomposition of the tactical operations domain function

During their deployment, Joker One set up ambushes, they searched for weapons caches, and they searched for and disarmed improvised explosive devices along roadways. These activities imply the domain functions of offensive operations and security operations as shown in Figure 8. For example, the ambush described by Campbell (2010, pages 100-104) was mounted largely in the interest of completing an initial offensive mission against insurgents.

These domain functions are entered into Figure 8 as decompositions of the tactical operations function and connected by means-ends links to the values they support.

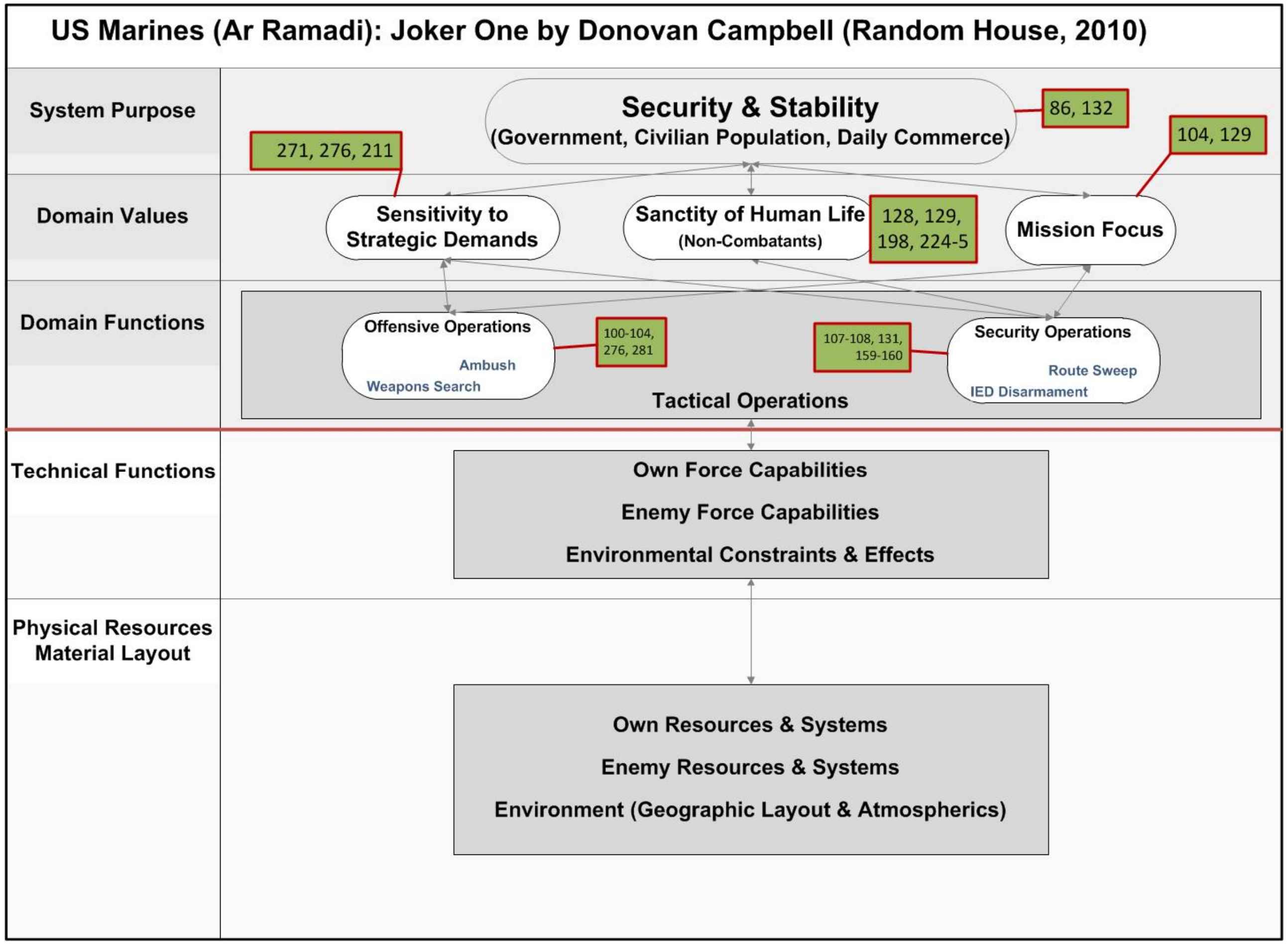

Figure 9: Abstraction-decomposition space for US Marine counterinsurgency operations with summaries of entries to be anticipated at the technical function and physical resource levels

In building an abstraction-decomposition space, it is often useful to summarize the sorts of things that might be entered at the technical function and physical resource levels as shown in Figure 9. Reference back to the activities from which I inferred the domain functions can help to identify at least some of the technical functions and physical resources.

Within a tactical operation, combatants will be concerned with their own capabilities, the capabilities of the enemy and the constraints imposed by the environment. These technical functions will be supported at the physical resources level by own resources and systems, by enemy resources and systems and by geographic layout and atmospherics of the environment.

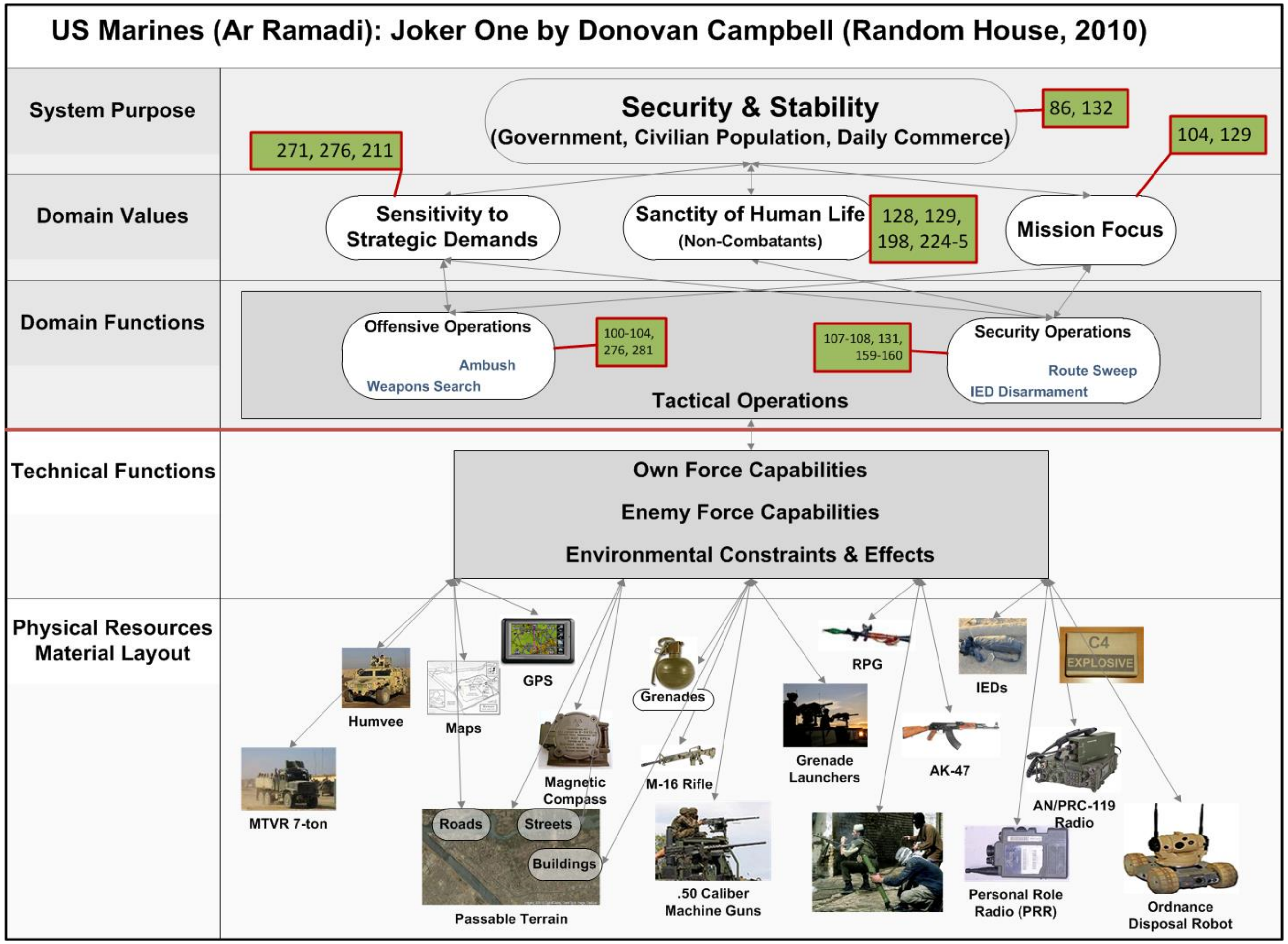

Figure 10: Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources that support the domain functions of offensive operations and security operations

As shown in Figure 10, it will then be useful to be more specific regarding the physical resources.

There is much more could be placed here but for tutorial purposes I have chosen to be selective by focusing on elements that are mentioned by Campbell (2009). The map and the M-16 rifle are examples of resources available to the marines. The AK-47 rifle and the rocket propelled grenade launcher are examples of resources available to the enemy. The roads, streets and buildings are physical resources in the environment that constrain or support action.

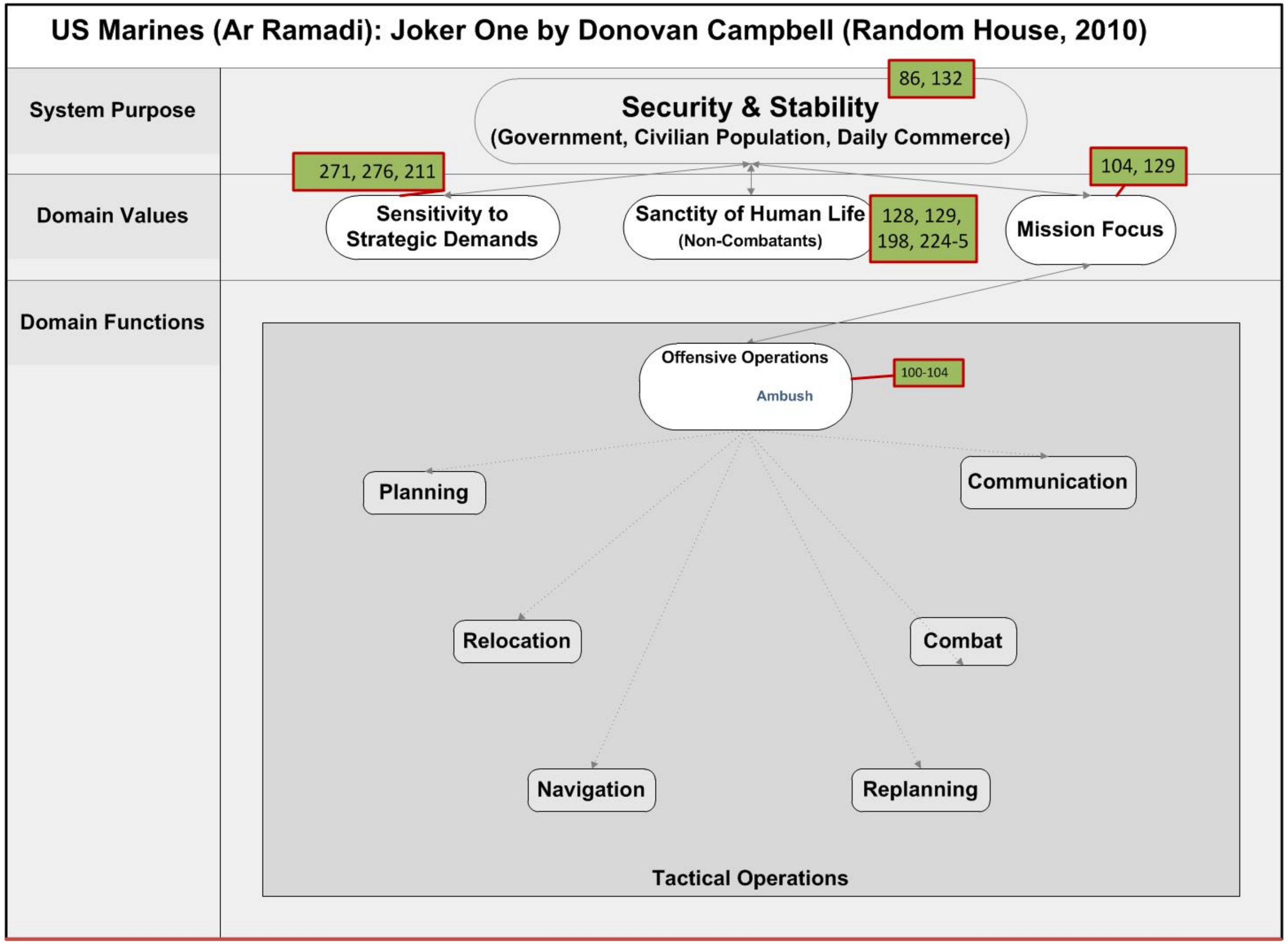

Figure 11: Abstraction-decomposition space for US Marine counterinsurgency operations showing components of the offensive operations domain function

I now illustrate the value of a further decomposition of offensive operations (Figure 11) with specific reference to the ambush mission.

Campbell planned this mission some time prior to departure from the combat outpost. To execute the mission, the marines of Joker One traveled by foot, navigating from the combat outpost to the ambush site, and maintaining inter-squad communication as they moved. Some replanning was required enroute to the ambush site. Although this mission did not result in combat, Joker One had to be ready for that.

Thus, Figure 11 shows the offensive operations domain function as decomposed into relocation, planning, navigation, replanning, combat and communication.

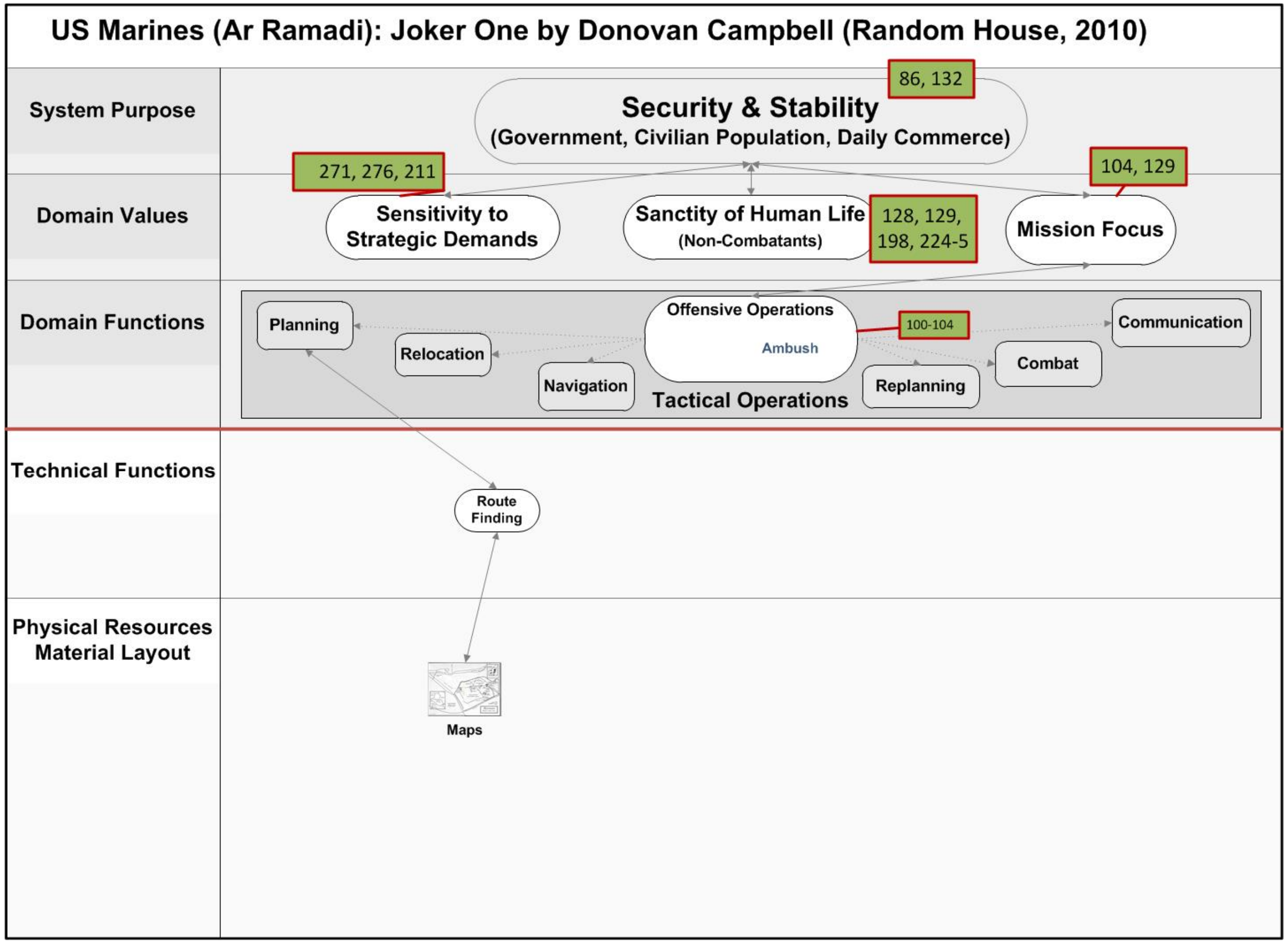

Figure 12: Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources and technical functions (and means-ends links) for the planning component of the offensive operations domain function

Figure 12 to Figure 17 show the technical resources and technical functions that support each of these components of offensive operations.

Figure 12 shows the physical resources (maps) used for route finding at the technical function level in support of the domain component of planning.

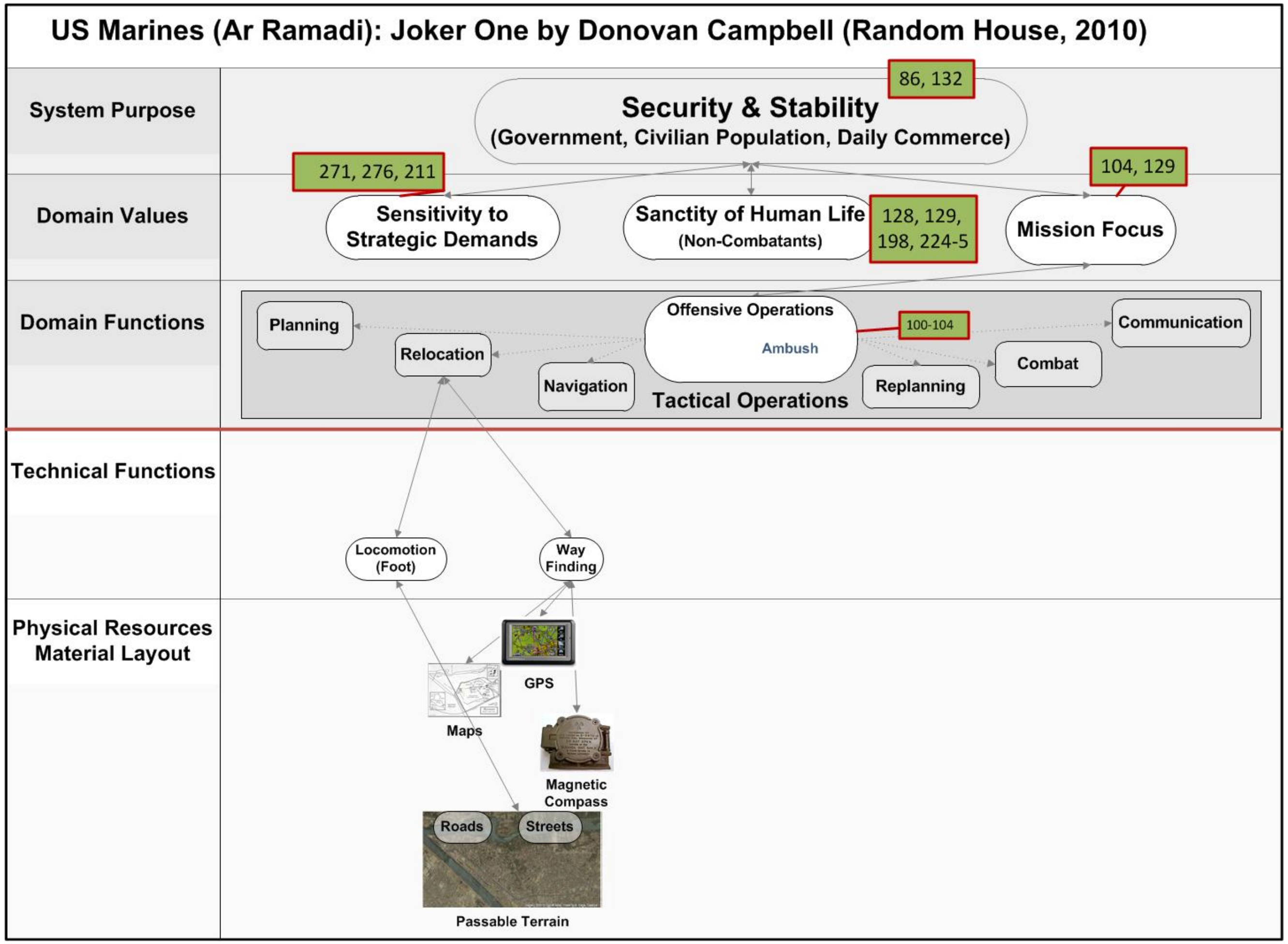

Figure 13: Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources and technical functions (and means-ends links) for the relocation component of the offensive operations domain function

Figure 13 shows the physical resources (roads, streets, passable terrain, maps, magnetic compass, GPS receiver) used for foot locomotion and way finding at the technical function level in support of the domain component of relocation.

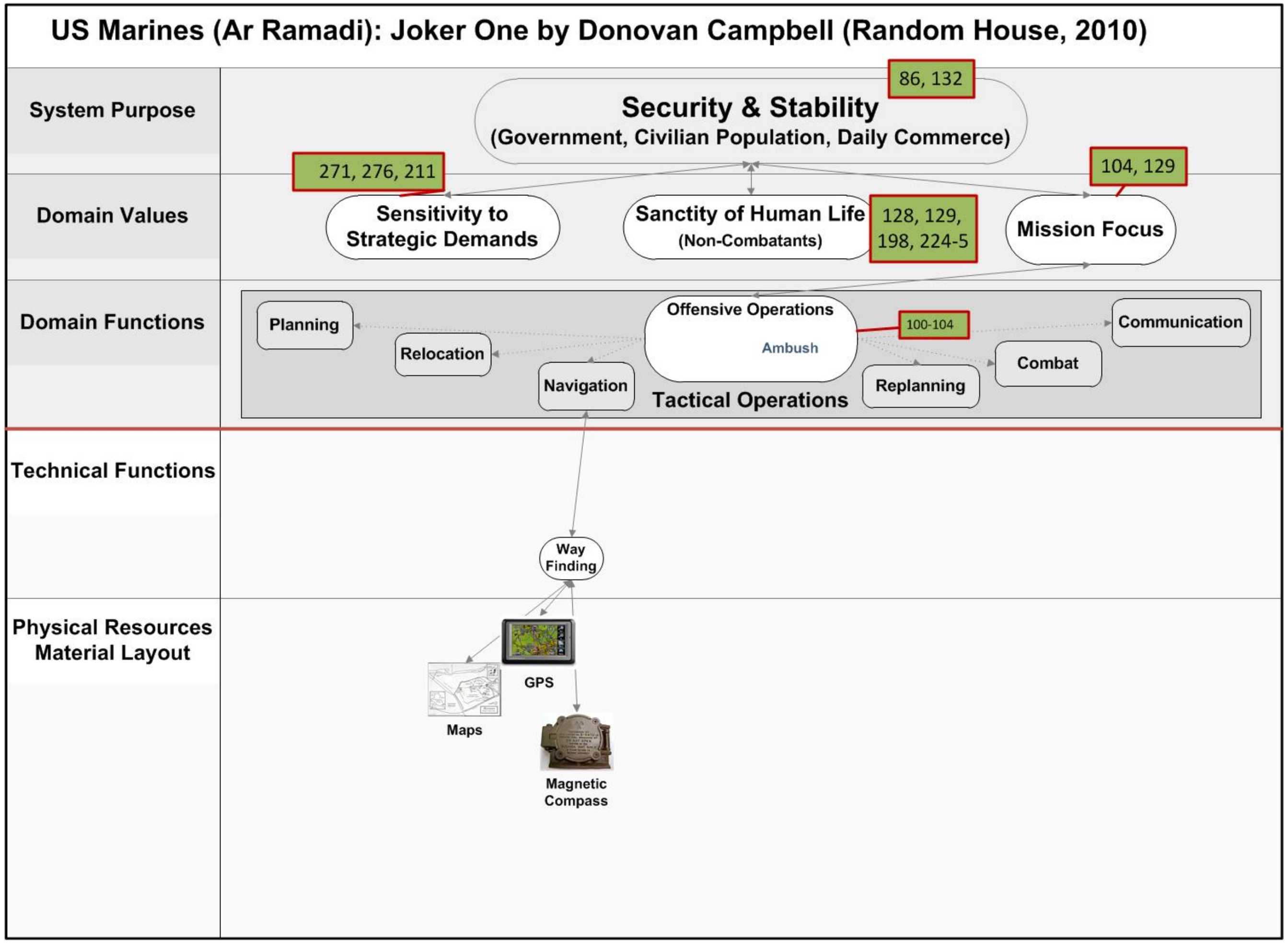

Figure 14: Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources and technical functions (and means-ends links) for the navigation component of the offensive operations domain function

Figure 14 shows the physical resources (maps, magnetic compass and GPS receiver) used for way finding at the technical function level in support of the domain component of navigation.

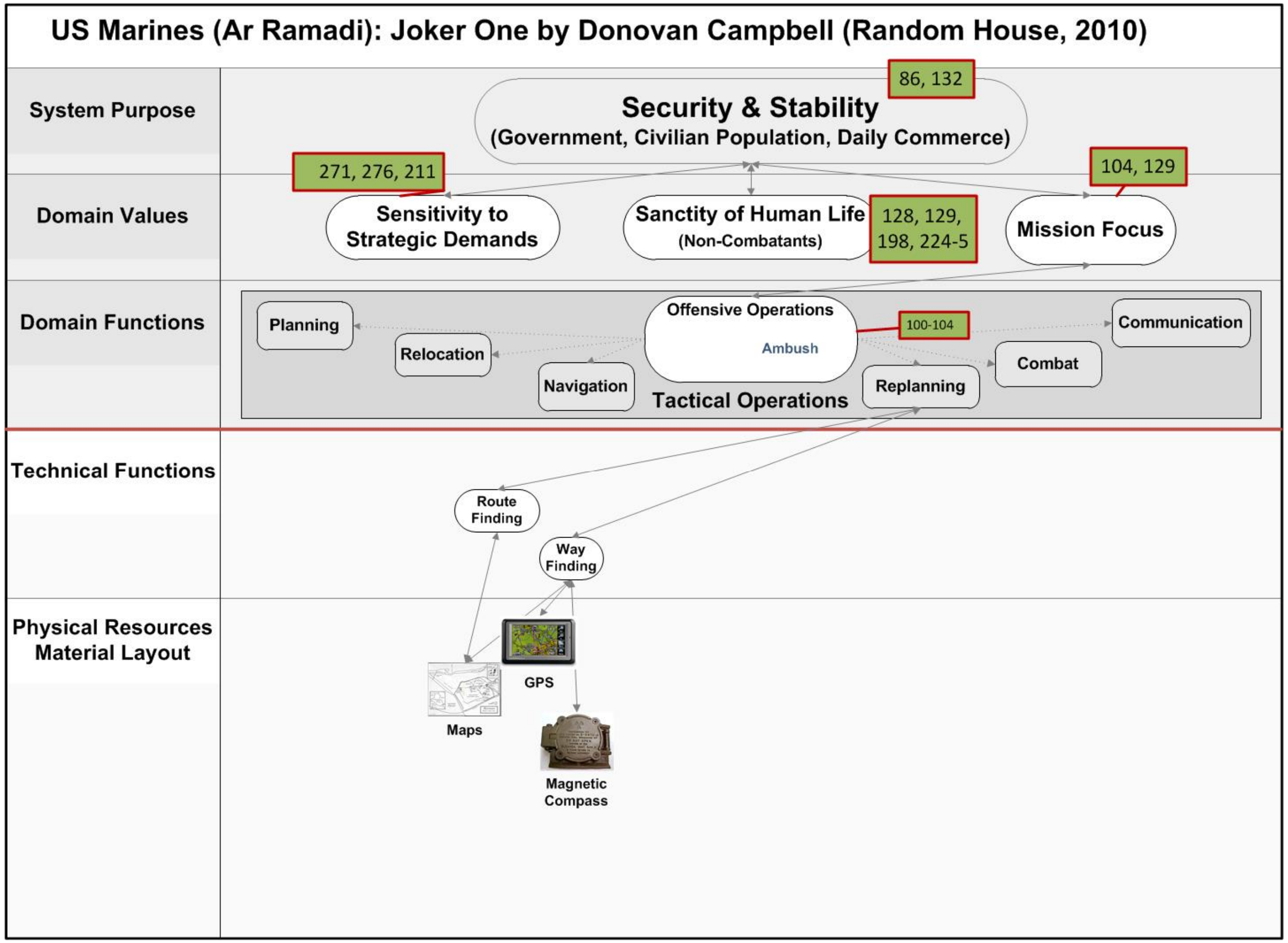

Figure 15: Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources and technical functions (and means-ends links) for the replanning component of the offensive operations domain function

Figure 15 shows the physical resources (map, magnetic compass and GPS receiver) used for route finding and way finding at the technical function level in support of the domain component of replanning.

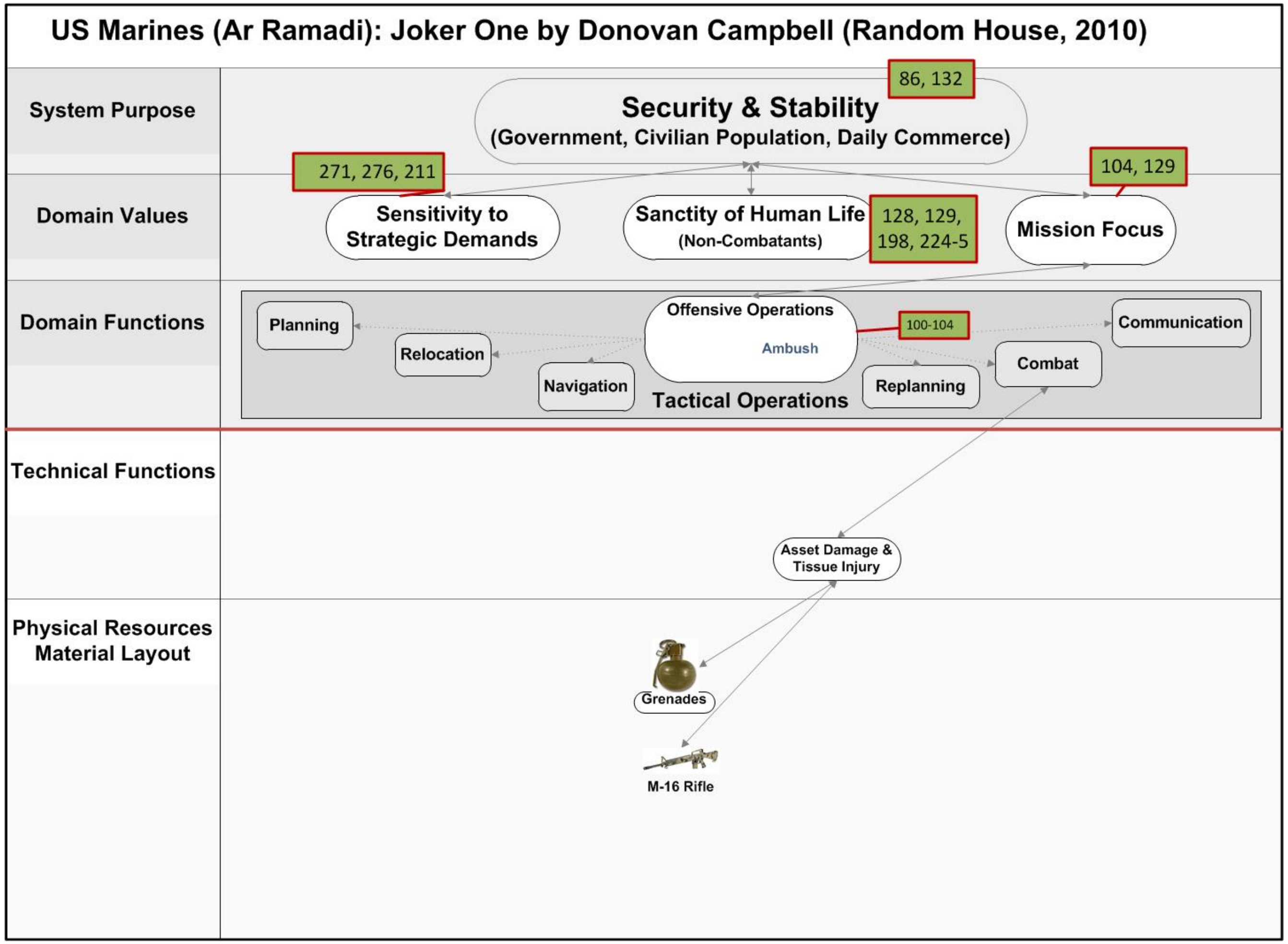

Figure 16: Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources and technical functions (and means-ends links) for the combat component of the offensive operations domain function

Figure 16 shows the physical resources (grenades, M-16 rifle) used for asset damage and tissue injury at the technical function level in support of the domain component of combat.

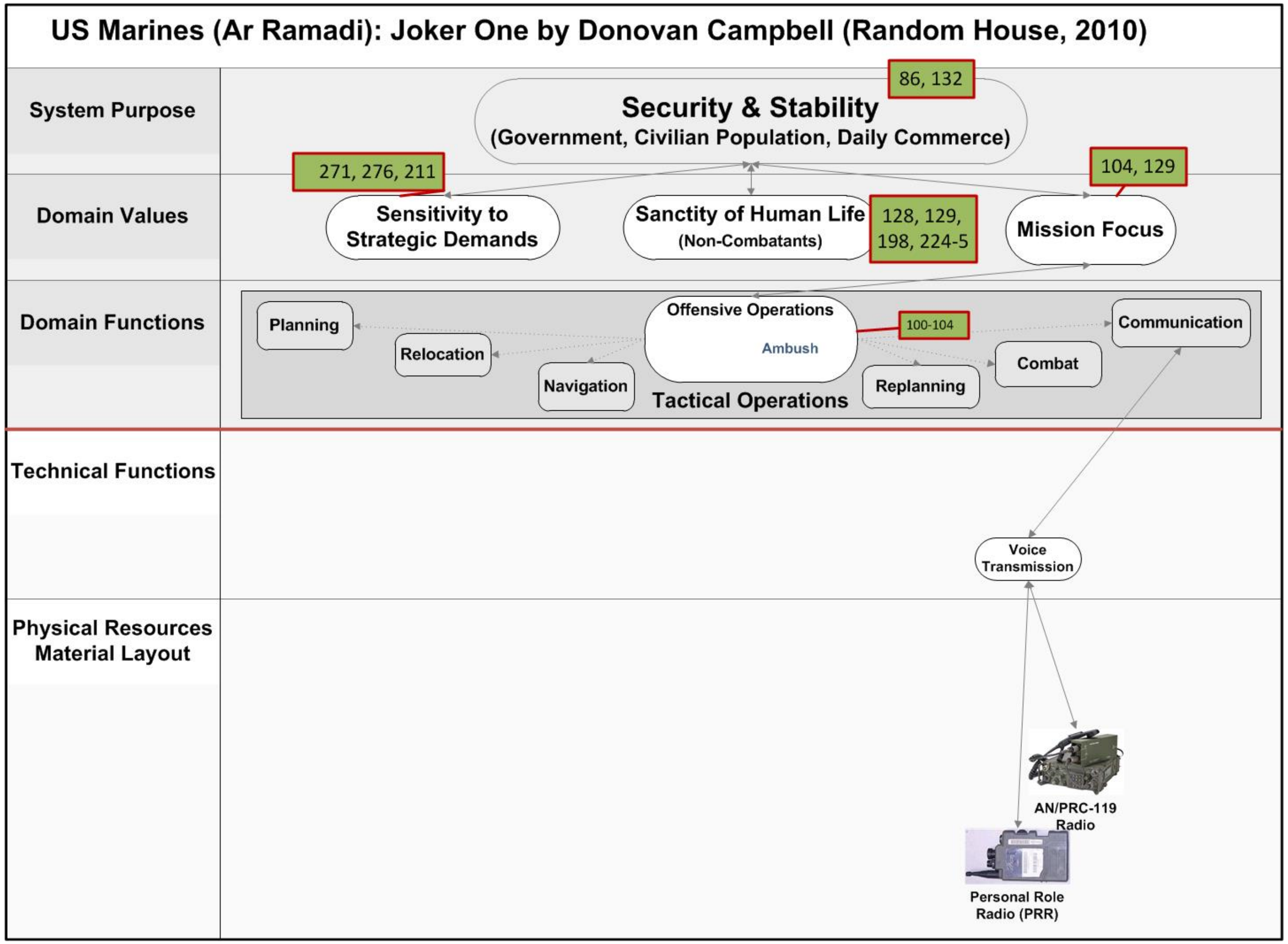

Figure 17 : Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources and technical functions (and means-ends links) for the relocation communication of the offensive operations domain function

Figure 17 shows the physical resources (the personal role radio, the longer range ANP RC-119 radio) used for voice transmission at the technical function level in support of the domain component of communication.

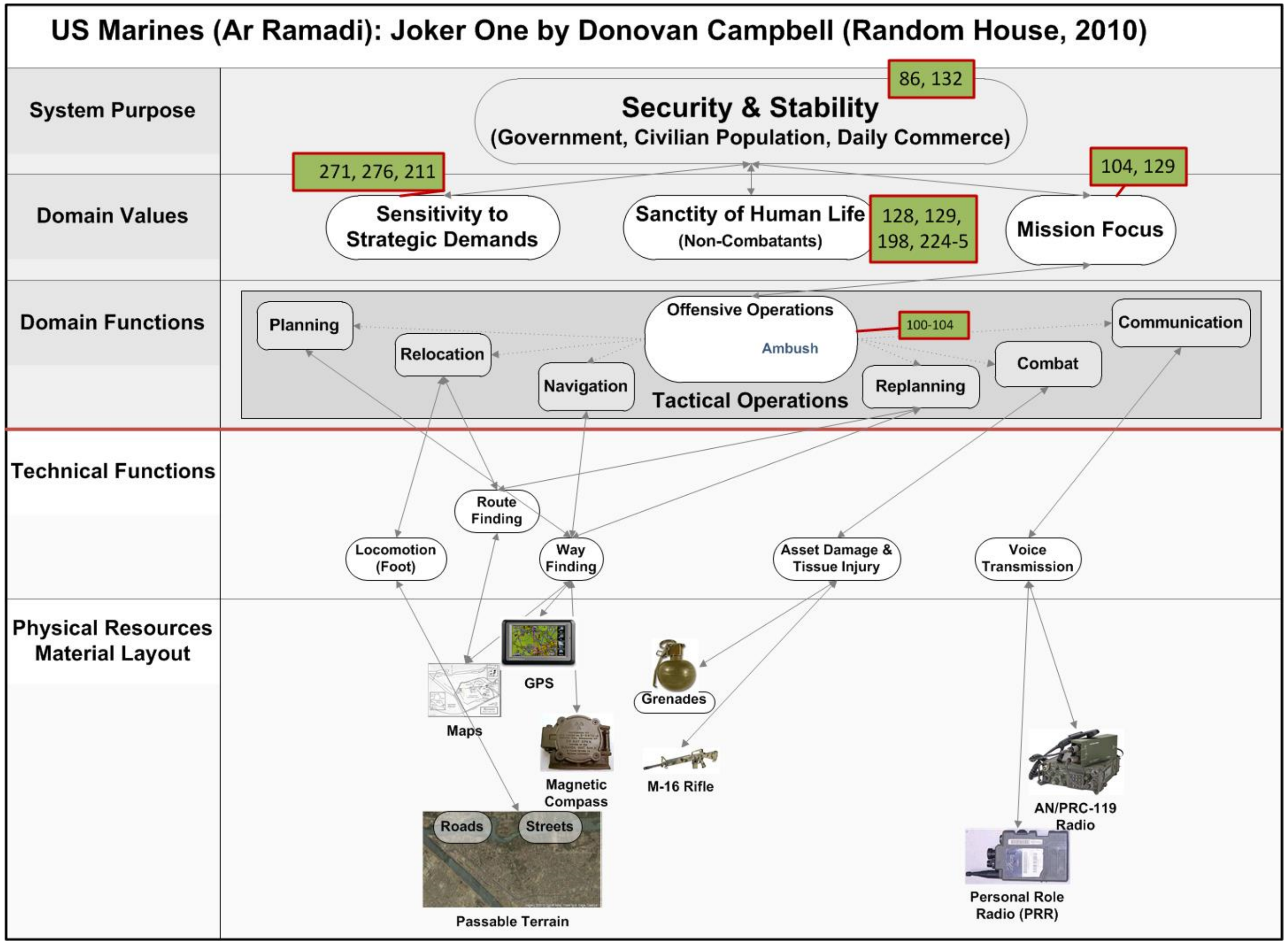

Figure 18: Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources and technical functions (and means-ends links) for all components of the offensive operations domain function

Figure 18 shows all previously noted physical resources that support the offensive operations domain function via their respective technical functions.

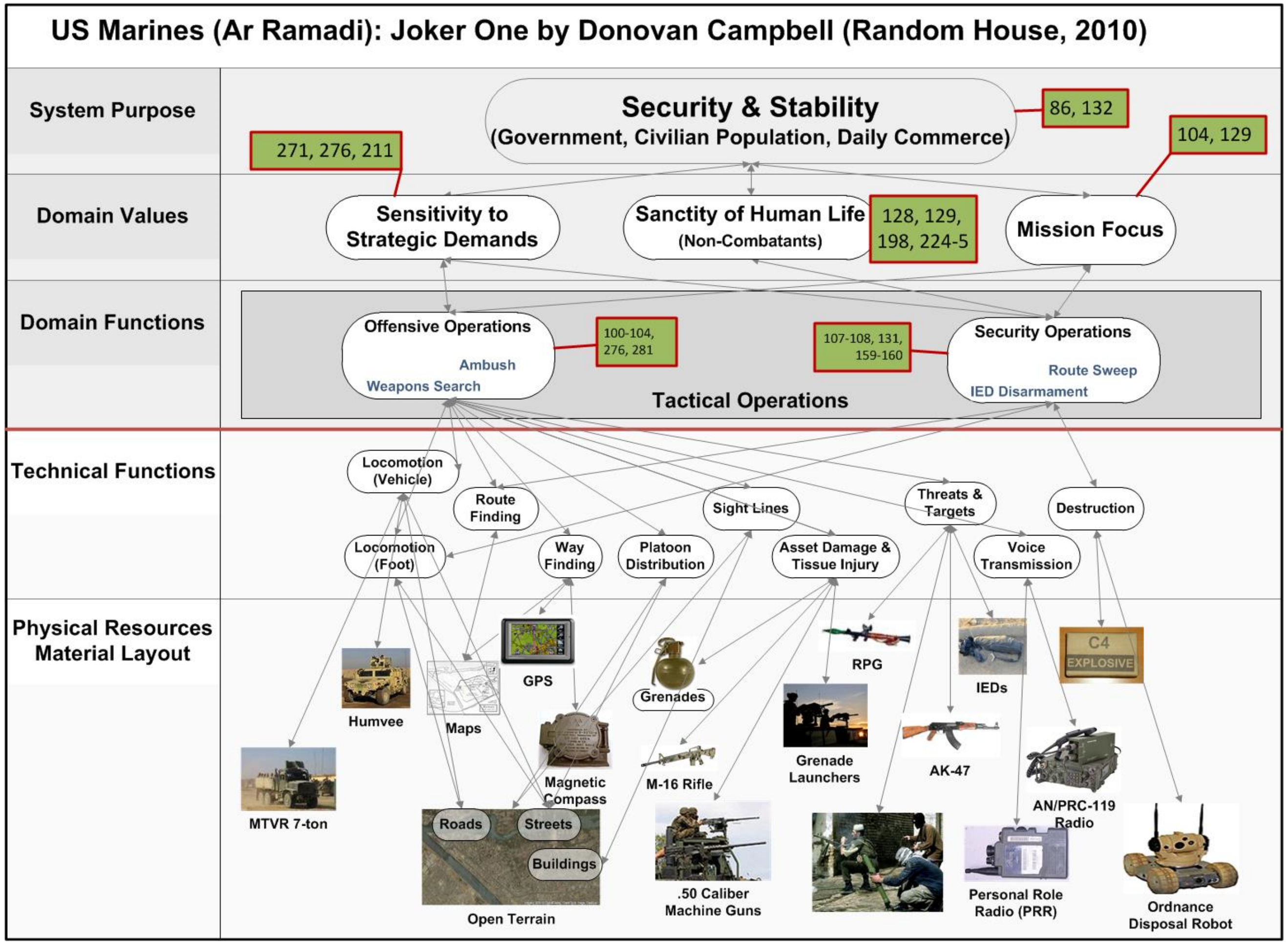

Figure 19: Abstraction-decomposition space for US Marine counterinsurgency operations showing physical resources and technical functions (and means-ends links) for the offensive operations and security operation domain functions

Figure 19 extends Figure 18 by showing the physical resources and technical functions that support an additional activity for offensive operations and two more activities for another domain function, that being security operations.

Notably, support of these additional activities can be accomplished in large part by the physical resources and technical functions already entered as supports for the ambush activity. The only additional physical resources are two types of high calibre weapon for the Marines, vehicles for vehicular locomotion, and the ordnance disposal robot and the C4 explosives.

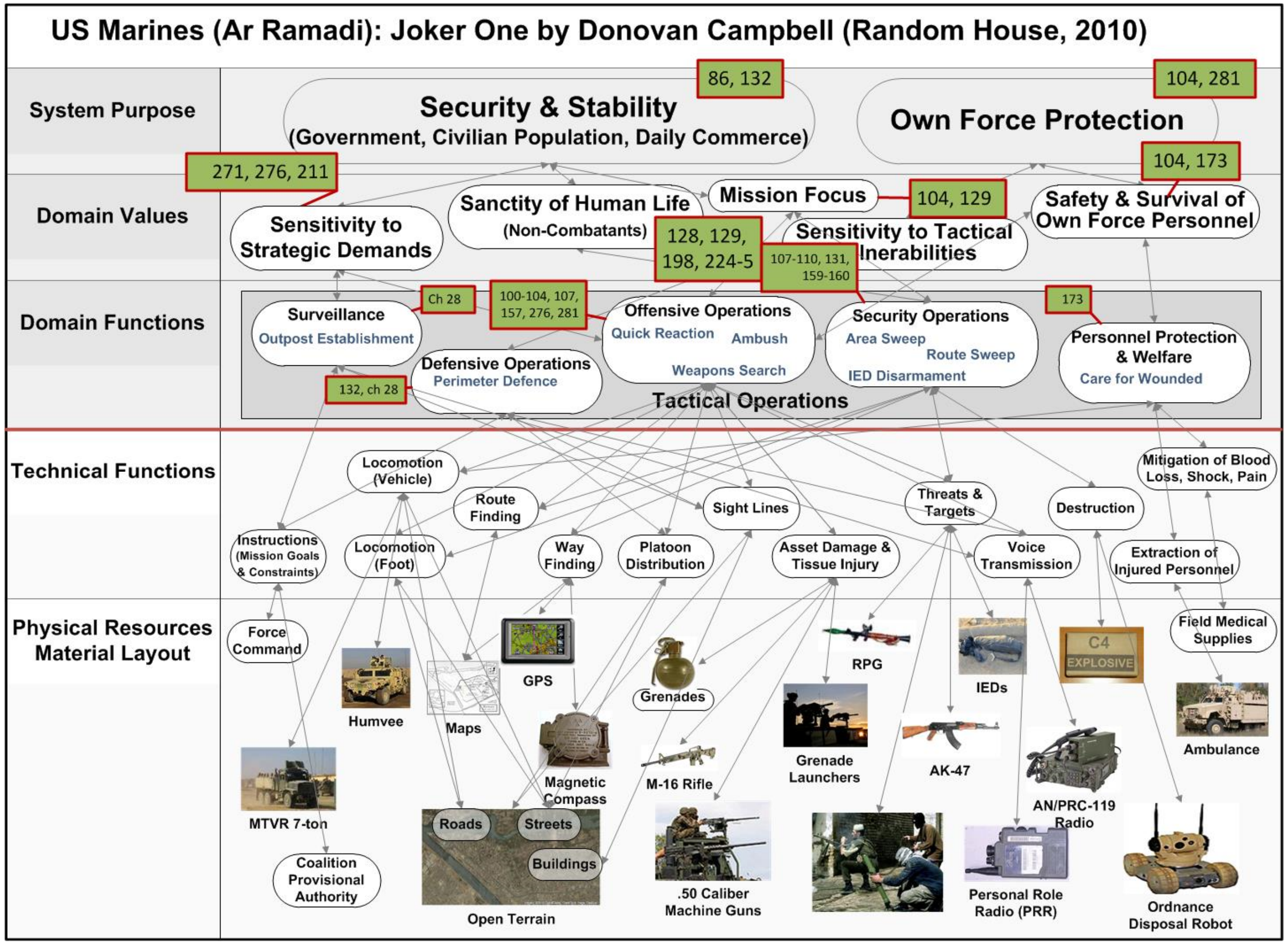

Figure 20: Abstraction-decomposition space for US Marine counterinsurgency operations as narrated by Campbell (2010)

Figure 20 captures most of the functional information from Campbell (2010) that is appropriate for an abstraction-decomposition space. It extends the abstraction-decomposition space of Figure 19 with the addition of entries at all five levels. Notable additions at the domain-function level are surveillance, defensive operations and personnel protection and welfare.

Figure 20 offers a reasonably complete representation of the view of one subject matter expert from a single geographic location and a single level of command. As such, it provides a good start to a work domain analysis, but a comprehensive analysis of counterinsurgency operations during the violent years in Iraq would require consultations with many more subject matter experts from different levels of command who operated in different areas of Iraq and at different times.

Insurgency: Work Domain Analysis

> *If you know your enemies and know yourself, you will not be imperilled in a hundred battles (Sun Tzu, The Art of War).*

An abstraction-decomposition space as shown in Figure 20 offers us a way to know ourselves. It includes insurgents and their resources as constraints on or challenges to our counterinsurgency operations. This does not, however, clarify insurgency purposes, values or domain functions. Additionally, it identifies only those resources available to the insurgents in their direct encounters with our counterinsurgency forces. For counterinsurgency planning, it can be more useful to develop an abstraction-decomposition space from the perspective of the insurgents, thereby completing Sun Tzu's dictum that we should also know our enemies.

Figure 21 shows an abstraction-decomposition space of insurgent resources and capabilities. I have drawn the entries in Figure 21 from a few accounts of insurgency action (Campbell, 2010; Fumento, 2006; Junger, 2011, West, 2005) plus an analysis I have undertaken (Lintern, 2006).

In my previous analysis (Lintern, 2006), I cite the role of automobile repair shops in assembly of improvised explosive devices (they mask construction noise) and the United Parcel Service in the acquisition by insurgents of items they could use in the construction of improvised explosive devices. West (2005) cites the use of garage door openers (as well as cell phones) to detonate improvised explosive devices. Junger (2011) notes the use by insurgents of cell phones to coordinate attacks on US forces (Box 1).

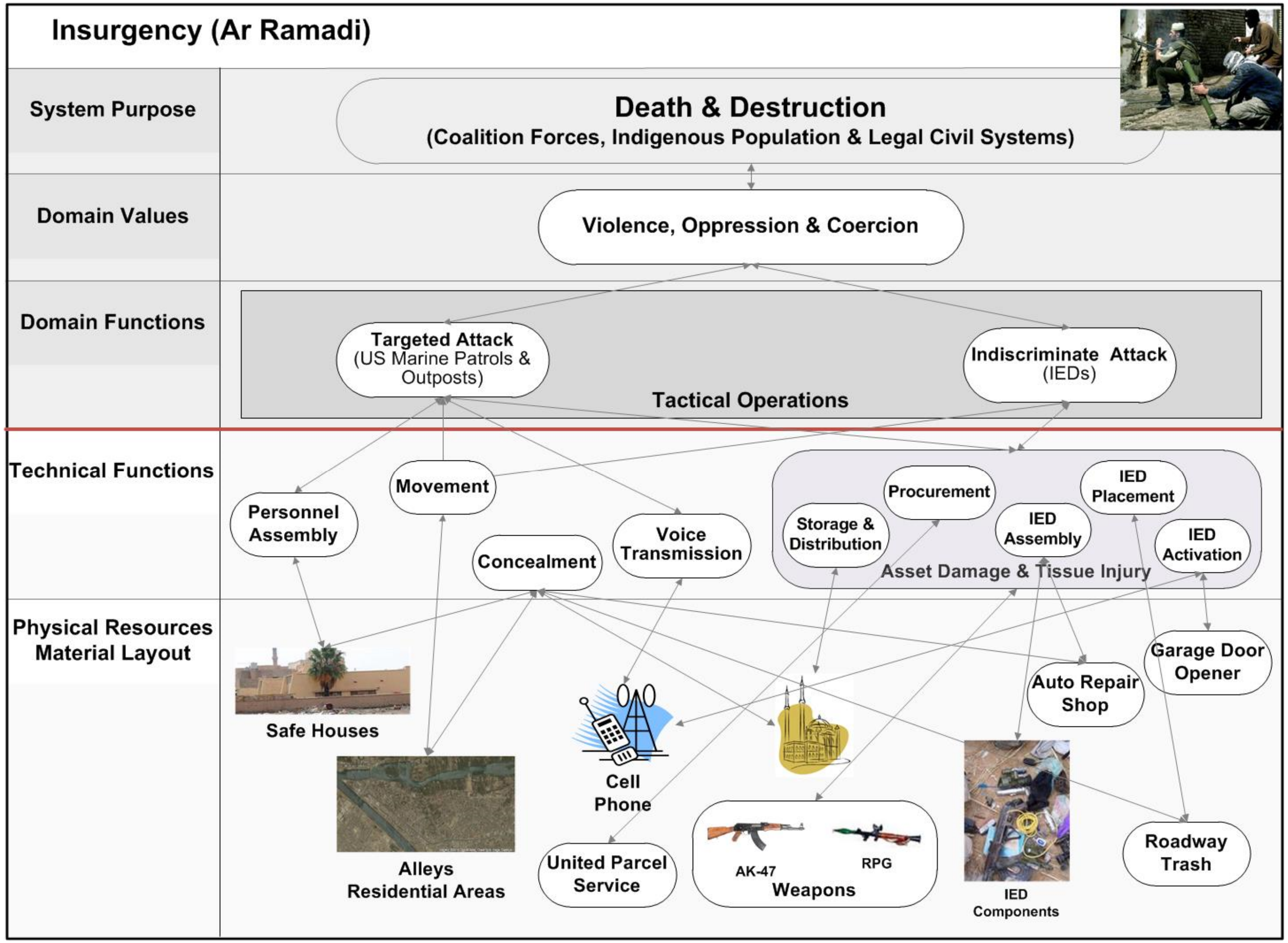

Figure 21: Abstraction-decomposition space for insurgency operations developed with reference to several sources

Box 1: Prepare for Attack

Junger (2011), in his book, War, narrates how the 173rd Airborne Brigade (US Army), while fighting in the Afghanistan's Korengal Valley, monitored cell phone conversations of insurgents as they planned attacks. In one particular incident, the insurgents engaged in the unusual activity of whispering as they passed messages to each other, a behavioral pattern that mystified the US Army personnel who were listening until it became apparent that the insurgents were so close to the US forces they were planning to attack that they could not speak at a normal volume without revealing their presence.

Summary: Work Domain Analysis

A work domain is a *functional* space in which work can be accomplished. As a functional space, it has both intentional and physical properties where *intentional* refers to purpose-related properties and *physical* refers to objects and layouts. *Functional* refers to an activity-independent capability (potential) to accomplish something specific. Work domain analysis identifies the activity-independent properties that support and shape work. It does so at different levels of functional abstraction and to different degrees of decomposition.

The representational product

The product of this stage of analysis is an abstraction-decomposition space, which is an activity-independent representation of both the intentional and the physical constraints embedded in the work domain. An abstraction-decomposition space is a two-dimensional matrix. The vertical dimension is an abstraction hierarchy extending over the five levels of system purpose, domain values, domain functions, technical functions, and physical resources. The horizontal dimension is a decomposition hierarchy extending over a number of levels identified during analysis as relevant to an understanding of the functional structure of the work. A series of means-ends relations link available resources (the means) to the desired work products (the ends) in a functional chain up through the levels of abstraction.

How to do it

An abstraction-decomposition space is populated with structural system properties: system purpose, values that shape how the purpose is to be achieved, functional system properties that can be used to realize the purpose within the constraints imposed by the values, and the physical resources that can be used to realize those functional system properties. This knowledge can be acquired from design, maintenance and operational personnel as well as from documents.

In development of an abstraction-decomposition space, it is not essential to proceed as I have done above. You may start anywhere you find convenient and then move to different levels as ideas come to you. However you proceed, you will eventually find yourself moving up and down the abstraction dimension somewhat opportunistically, inserting additional nodes, inserting additional means-ends links, renaming nodes, and moving specific nodes up or down a level.

Once an abstraction-decomposition space is complete, it can be assessed for internal consistency. The node labels need to be appropriate to the level of description and there needs to be a continuous path via means-ends links from the lowest to the highest level of abstraction. Except for nodes at the highest level, all nodes must support at least one node at the level above. Except for nodes at the lowest level, all nodes must be supported by at least one node at the level below.

You should also assess your abstraction-decomposition space in terms of external validity. At each level, consider whether you have all essential nodes. The purpose, the values, the domain functions, the technical functions and the physical resources can be assessed independently in relation to their appropriateness for the work domain and then, except for the physical resources level, all nodes should be examined to ensure they are appropriately supported.

For a tutorial illustration of the sorts of problems that might be uncovered during an assessment of internal consistency and external validity, see Lintern (2013a).

It would not be unusual for you to discover during your assessment of external validity that your abstraction-decomposition space is not an accurate or complete description of the system, in which case, you will need further analysis to gather knowledge that will allow you to correct the discrepancy.

However, at some stage, you will be satisfied that you have captured the system as it exists. Further review of the abstraction-decomposition space may then reveal system deficiencies that point to a need for redesign. The deficiency could be in relation to a problem at any level but problems found at upper levels will typically require redesign down through the levels beneath. Most obviously, every function at an upper level must be supported and every function at a lower level must support something. If the former is not true, the system is incomplete. If the latter is not true, the system has spurious functionality.

Note that while this may sound like a repetition of a point I made earlier, I am now directing your attention to a different problem. My earlier statement reflected on the fact that your analysis may have been incomplete. Here I am reflecting on the fact that the system may have a problem. There may be no means of realising important values or the means for realising important domain functions may be inadequate. In addition, there may be resources, technical functions, domain functions or values that do not support the system purpose. This, in particular, is often found in systems that have evolved over time as new functionality has been added but legacy (and now, redundant) functionality has not been removed.

Once you are satisfied with your abstraction-decomposition space, you can move to the next stage of cognitive work analysis. However, you will most likely revisit and continue to adjust the abstraction-decomposition space as you proceed through the remaining stages.

Relationship to other stages of cognitive work analysis

A well-structured and comprehensive abstraction-decomposition space establishes the foundation for the remaining stages of cognitive work analysis. The domain functions are entered directly into the next stage, work organisation analysis, and the rest of the stages examine activity that will be related in some way to the properties identified in the abstraction-decomposition space.

Implications for design

An abstraction-decomposition space is a model or, in other terms, a representation of an existing physical system or an envisaged physical system. As such, it is less than the physical system (because it is an abstraction), but it should contain markers for all important system resources, functions, values and purposes. Conversely, all entries within the abstraction-decomposition space should be implemented in the system that is being designed.

For example, if the new artefact is to be an interface, all properties represented in the abstraction-decomposition space must be available to those who operate that interface. However, that does not necessarily mean that they must be explicitly available through the interface. Some properties, most notably values, may have been established within the worker population through prior briefings or training. Nevertheless, when we develop a system on the basis of an abstraction-decomposition space, we need to ensure that those who operate the new interface have access to all functionality either explicitly within the interface or implicitly via other means.

The representation of means-ends links within the abstraction-decomposition space is a major (and as far as I can tell, a unique) contribution of work domain analysis. The explicit representation of these links in the abstraction-decomposition space should allow you, as the designer, to confirm that the configuration of the physical system is such that properties at a particular level of abstraction do support the intended properties at the next highest level. Additionally, it should allow you to check for unintended consequences across levels of abstraction; consequences such as a function at one level having an unintended effect on a function at the next level up.

Work Organization Analysis

Work can be described in terms of work situations (the situational contexts for work), domain functions (device-independent functional descriptions of properties essential to satisfying the system purpose, as identified in work domain analysis) and work tasks (what is to be accomplished). Work organization analysis results in a description of the partitioning and organization of work in these terms.

The product of this stage of analysis is a matrix referred to as a work task docket. An additional product, a work task scratch pad[1] is often useful as a preliminary to the development of the work task docket.

[1] A work task scratch pad is more useful in the analysis for a future system than for an existing system. I do not illustrate its use in this tutorial. Refer to Lintern (2013b) for an illustration of how it can be used within the analysis of a future system.

Work Organization

Work is conceived as organized by work situations and work tasks.

Work situations are different phases of work or different situational contexts that influence the choice of a pattern of work. For example, Naikar, Moylan and Pearce (2006) have identified a sequence of work situations for an airborne surveillance team *as on ground not in aircraft* (pre-mission*), on ground in aircraft*, *en route to station*, *on station*, *en route to base*, *on ground in aircraft*, and *on ground not in aircraft* (post-mission).

Although the work situations identified by Naikar, et al (2006) unfold in sequence, work situations do not have to be sequential. For example, although the primary work situations for process control of *start-up*, *normal operations* and *shut down* unfold in sequence, the other important work situations of *maintenance* and *emergency response* can occur at any time. Different work situations will typically share the same space and much of the same technology but will generate a different set of work tasks and function within different contextual constraints.

A work task is directed at accomplishing something useful. It has a purpose, it has associated values, and it has criteria. Do not think of a work task as a sequence of discrete activities that constitute the ideal or the best way to achieve an outcome or perform a job. Think of a work task as a generic activity such as planning or problem solving. Work tasks are identified within work organization analysis by a generic descriptor but are not examined in detail until later stages of cognitive work analysis.

Work can be either physical of cognitive. Physical work involves force transactions and cognitive work involves information transactions. While no work is entirely physical or entirely cognitive, in this tutorial I emphasize the type of work in which the cognitive challenges dominate; challenges that involve information analysis and transformation or some type of cognitive construction.

Typically, there will be many possible ways of performing a work task and the goal of work task analysis, which is a later stage of cognitive work analysis, is to identify the cognitive processes employed within those different ways.

Work Task Docket

As shown in Figure 22 a work task docket is structured around work situations, domain functions and work tasks. Work situations are typically identified through discussions with subject matter experts or analysis of documents while domain functions are drawn from the abstraction-decomposition space. Work tasks are identified by discovering what workers are seeking to achieve as they act on the domain functions.

To set up the work task docket, identify work situations and list them along the top row as shown in Figure 22. Then list the domain functions and also global descriptions of work tasks in the left column.

The second column is used to list work task components. There is a possible source of confusion in the identification of work task components as associated with domain functions. A work task component is an activity that should be referenced by use of a verb (e.g., *communicate*). A work task will often be associated with a component of a domain function with a similar name. However, a component of a domain function is a capability that should be referenced by use of a noun (e.g., *communication*). As is evident in this example, the words that reference a function and task can be similar.

When the function and task names do not correspond in this way, you will usually find that you have not decomposed to the same degree within your work domain analysis as within your work organization analysis. For example, Figure 11 lists combat as a component of the offensive operations domain function. The work tasks components associated with that domain function may be activities such as *engage enemy* and *establish defensive perimeter*.

I do not always find it useful to decompose to the same levels in these two analyses and so, in this tutorial, I illustrate the possibilities by mixing these two approaches. Note also that if you do decompose to the same level in both analyses, you will have one work task component for each domain function component. Otherwise you will have multiple work tasks for each of the domain function components.

Populate the work task docket by inserting checkmarks against work task components in each work situation column in which that work task component is executed. You may insert an expected time taken to complete the work task in place of a checkmark if the work task component is discrete and has an expected duration.

Insert a question mark where it is unclear whether a particular work task component is undertaken in that work situation. Use the universal no symbol to indicate that a particular task component is prohibited within a particular work situation. The prohibition must be such that execution of that work task component in that situation would cause harm or is otherwise undesirable.

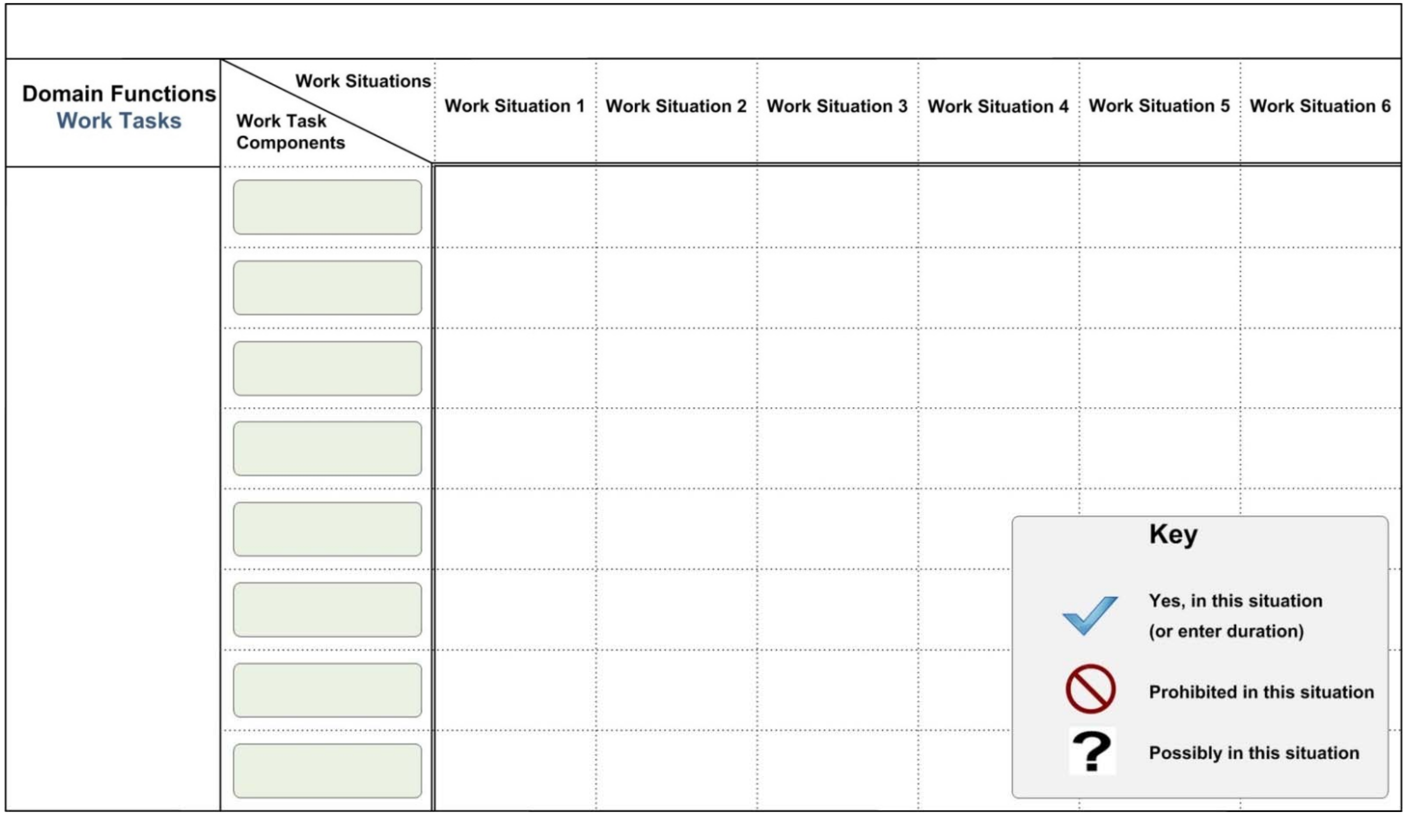

Figure 22: A work task docket template for work situations and work tasks associated with specific domain functions

Joker One: Work Organization Analysis

With respect to the counter-insurgency operations as narrated by Campbell (2010), we can inquire about the work situations. These are identified in Figure 23 as preparation (for the mission), en-route (to the mission location), operation (execution of the mission), return to base, debrief, and rest. Then, for each of the domain functions identified in work domain analysis, we can inquire about the work tasks that will be needed for them to be realized. In the following illustration, I will consider the offensive operations domain function and will infer from Campbell's narrative that one work task undertaken by US Marines in their counter insurgency role was to execute offensive missions. I will draw on two instances, the ambush and weapons search missions, for data for the work task docket.

Ambush Mission

Campbell (2010) had been made aware that insurgents met occasionally in early morning hours in the location of the Ramadi train station (Figure 1). The goal for the ambush mission was to surprise the insurgents during that meeting and to capture or kill as many as possible. Campbell developed a plan for the ambush based on his review of aerial photographs and a day-time visit to the location. The plan involved traveling south on foot from the combat outpost across open fields to the southern edge of the built-up area of Ramadi and then traveling west to set up in a cemetery just north of the train station (Figure 1).

Campbell chose to move over open fields rather than along the roadway near a canal at the eastern edge of the city. He did this to avoid being seen by residents who, typically at that time of year, slept on roof-tops to gain some respite from the stifling heat. Because the aerial photographs showed these fields as flat and reasonably clear of obstacles, Campbell anticipated trouble-free travel to the ambush location.

On leaving the combat outpost, Campbell's radioman advised the duty officer of their departure. The platoon travelled in three squads, separated by a distance that required communication to be supported by radio.

Work Task Docket; US Marines (Ar Ramadi): Joker One by Donovan Campbell (Random House, 2010)

Domain Functions / Work Tasks	Work Situations / Work Task Components	Preparation	En-route	Operation	Return to Base	Debrief	Rest
Offensive Operations	Plan	✓			P 126	126-129	Ch 23
	Relocate		✓		✓		
Execute Offensive Mission	Communicate	?	✓	✓	✓	✓	?
Data from ambush mission	Re-Plan		✓	✓			
(Ch 12, esp P100-104)	Navigate		✓		✓		
	Engage Enemy	?	?	✓	?	?	?

Figure 23: A work task docket of work situations associated with the counter-insurgency operations narrated by Campbell (2010) and the work tasks components associated with the Ambush mission

Very early in the move south, it became apparent that the aerial photographs had not told the whole story. A series of deep ditches ran across the direction of travel. Campbell's Marines had to descend into each ditch and then climb up the other side, a challenging task for anyone, let alone Marines wearing and carrying 50 pounds or more of equipment.

At that point, Campbell understood the need to adjust his plan. He redirected his squad to move towards the canal and travel along its adjacent roadway. He recognized the risk of being observed by Ramadi residents but reasoned that the risk would be minimized if the platoon moved quickly. He had his radioman contact the other squads to advise them of the adjustment in the plan. He learned at this time that the portable radios that had worked so well before deployment to Iraq did not have the necessary range in this operational environment. His radioman was able to contact the closest squad and had to rely on the radioman in that squad to pass the message on. That relay of the message was successful.

The platoon was able to set up the ambush in the cemetery before dawn as planned but on this occasion, there were no insurgents. After concluding that there was to be no meeting of insurgents, Campbell's platoon returned to base and debriefed.

As described in this narrative, the ambush mission involved the planning, relocation, navigation, replanning and communication components of the offensive operations domain function (see Figure 11). The Marines did not engage in combat on this particular mission but were ready for it. For this mission at least, Joker One needed to plan, to relocate, to navigate, to replan and to communicate and they also needed to be ready to engage the enemy. These are shown as the entries in the work task components column of Figure 23.

I have populated the work task docket for counterinsurgency operations (Figure 23) by inserting checkmarks and question marks in appropriate columns. I have not inserted expected completion times because the narrative provided by Campbell did not specify work task durations. In this particular narrative, there was no instance in which the use of the universal no symbol was required

Ambush, Preparation

I have inserted a check mark against *plan* in the *preparation* work situation column. I have inserted a question mark against *communicate* because it was unclear from the narrative whether, in fact, Campbell developed the ambush plan on his own or whether he communicated with others while he was developing it. I have also inserted a question mark against *engage enemy* because such an engagement remains possible in this and all other situations within the combat zone even when such engagement is undesirable.

Ambush, En-Route

I have inserted check marks against *relocate*, *communicate*, *re-plan* and *navigate*.

Ambush, Operation

I have inserted check marks against *communicate*, *re-plan*, and *engage enemy*. Although there was no combat on the particular occasion that this narrative describes, I have inserted a check mark here because engagement with the enemy was always possible.

Ambush, Return to Base

I have inserted check marks against *relocate*, *communicate* and *navigate*.

Ambush, Debrief

I have inserted a check mark against *communicate*.

Rest

The questions marks against *engage enemy* and *communicate* reflect the fact that rest can give way to emerging events.

Weapons Search Mission

Joker One was patrolling an area in the south of the city around noon when they received the order to search the Farouq Mosque several blocks north of their present location. The Farouq Mosque was the most anti-American mosque in Ramadi and was in the most anti-American part of the city. Furthermore, the middle of the day was a dangerous time to set up a position anywhere in the city because insurgents would soon hear that the Marines had stopped and would gravitate to the area to mount an attack.

While Campbell and other members of his platoon understood the risks, they nevertheless responded to the order without question. They moved by Humvee to the mosque. On the way, Campbell developed a plan that included establishment of a defensive cordon and observation posts. On arrival at the mosque, Joker One moved into the defensive cordon and set up observation posts on nearby buildings. Three members of the Iraqi Special Forces had accompanied Joker One on their earlier mission and it was intended that they search the mosque. However, they refused, arguing that it was disrespectful to search a mosque.

The delay induced Campbell to reset the defensive cordon but nevertheless, insurgents mounted an attack. A fire-fight ensued and US Army reinforcements arrived. At about the time hostilities ceased another Marine platoon arrived, which conducted the weapons search. They found two substantial caches that included antipersonnel mines and suicide vests. Following the search, all Marine and Army personnel returned to their combat base.

The weapons search mission relied on most of the work task components used in the ambush mission. No additional entries were required for the weapons search mission in any situations for these work task components.

The additional work task components are *establish defensive perimeter and defensive observation* and *search*. I added these to the work task components column of Figure 24. I have inserted a checkmark in the operation column against *establish defensive perimeter and observation* and question marks in the en-route and return to base columns. I have inserted a checkmark in the operation column against *search*.

Work Task Docket; US Marines (Ar Ramadi): Joker One by Donovan Campbell (Random House, 2010)							
Domain Functions Work Tasks	Work Situations / Work Task Components	Preparation	En-route	Operation	Return to Base	Debrief	Rest
Offensive Operations Execute Offensive Mission Data from ambush mission (Ch 12, esp P100-104) Additional data from weapons search mission (p 276)	Plan	✓			P 126	126-129	Ch 23
	Relocate		✓		✓		
	Communicate	?	✓	✓	✓	✓	?
	Re-Plan		✓	✓			
	Navigate		✓		✓		
	Establish Defensive Perimeter & Observation		?	✓	?		
	Engage Enemy	?	?	✓	?	?	?
	Search			✓			

Figure 24: A work task docket of work situations associated with the counter-insurgency operations narrated by Campbell (2010) and the work tasks components associated with the Ambush and Weapons Search missions

Summary: Work Organization Analysis

Work can be described in terms of work situations (the situational contexts for work), domain functions (device-independent functional descriptions of properties essential to satisfying the system purpose) and work tasks (what is to be accomplished). Work organization analysis results in a description of the partitioning and organization of work in these terms.

The representational product

The product of this stage of analysis is a two-dimensional matrix referred to as a work task docket, which is structured around work situations, domain functions and work tasks. Work situations are different phases of work or different situational contexts that influence the choice of a pattern of work. A work task is a generic activity directed at accomplishing something useful, an activity such such as planning, problem solving, navigating or communicating.

How to do it

Domain functions are drawn from the abstraction-decomposition space while work situations and work tasks are typically identified through discussions with subject matter experts. Sometimes analysis of the same documents used to identify properties for the abstraction-decomposition space will also help populate the work task docket, although it is unlikely that documents will provide all the information you need. The availability of documents with rich and detailed narratives, such as found in Joker One, offers one possible exception to this caveat. However, even the Joker One narratives are not as complete as is desirable, and it would be useful to engage in discussions with others who participated in the reported activities.

Whatever your source of subject matter expertise, you will need to identify what workers are seeking to achieve as they act on the domain functions to realize the system purpose. You will also need to identify the situations in which they act on those domain functions. That is, you will need to identify work tasks and work situations.

Relationship to other stages of cognitive work analysis

Primarily, work organization analysis guides the remaining stages of cognitive work analysis. It identifies the work tasks that are to be subjected to more in-depth analysis of cognitive processes, cognitive states, cognitive strategies and cognitive modes. It also provides a base for analysis of coordinative work processes where the work task docket is further developed into a social transactions docket by assigning agents to work tasks and by identifying and characterizing the coordination links between agents.

Implications for design

Work organization analysis does, however, have some specific design implications. Cognitive support tools that assist with execution of particular work tasks must be available within the applicable work situation. In the Joker One illustrations, for example, communication tools were required in both the ambush and the weapons search missions during the en-route and operation work situations. Not only should those tools be available within those situations but they should have the required functional capability. For the ambush mission at least, the primary inter-squad communication tool (the Personal Role Radio) did not fully support communication over the required range.

Social Organization Analysis

A complex, socio-technical system is distributed and heterogeneous, comprising diverse human and technological functions. Social organization analysis identifies the structures and processes that maintain such a system as a coherent, purposeful and coordinated entity in contrast to a dismembered conglomeration of parts. Social organization analysis examines management and team structures, the organization and allocation of work tasks, and the supporting coordination processes in the form of vertical communication between the hierarchical levels within an organization and lateral communication between peers within a team or work group at any level of the organization.

Two products are developed in this stage of analysis; a matrix referred to as a staffing docket and a matrix referred to as a transactions docket. The development of these matrices can be supported by the use of network scratch pads that lay out the organizational structure and the communication links as a prelude to filling in the staffing and transactions dockets.

Social Organization

Management and team structures

Management and team structures will necessarily be based on needs for authority, oversight, strategic guidance and reporting, and on the size of the organization. For large enterprises, structures will be designed at several levels of scale, for example at the scale of the whole organization, at the scale of individual business units within the organization, and at the scale of work teams. It is unlikely that a particular organizational structure will work for all business units or all teams.

Organization and allocation of work tasks

The nature of the work will suggest how the work might be distributed among workers and may suggest an appropriate teaming structure. The ensemble of work tasks as identified in work organization analysis constitutes the work that is to be undertaken. Social organization analysis assesses how those tasks might be organized into effective and efficient work units that allow work processes to sequence as needed and to support each other where that is needed.

Coordination processes

The work that is undertaken must be coordinated through interactions between workers; the lateral connectivity that supports essential collaboration (and sometimes, competition) between peers. There will be requirements for information access and product transfers within the work unit and across its boundaries. Additionally, vertical connectivity will support the essential manager-worker coordination.

The supporting coordination processes, both lateral and vertical, are primarily communication events of various types. Social organization analysis identifies the generic properties of those communication events as a means of stimulating ideas for design.

Social Organization Analysis in Outline

The strategy of social organization analysis has generally not been well described. In Lintern (2013c), I provide a tutorial in which I describe the strategy I use. Figure 25 offers a graphical summary of that strategy.

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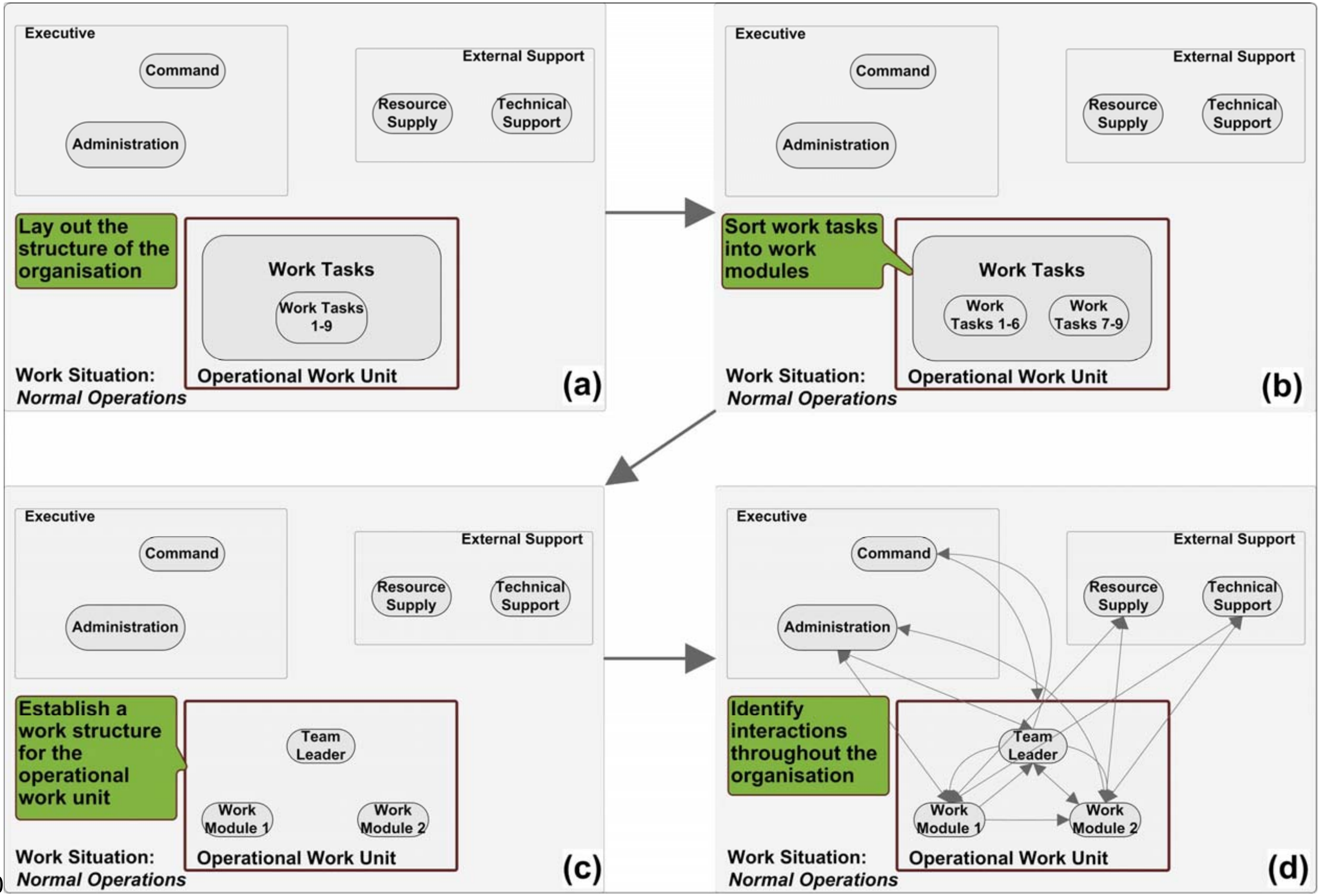

Figure 25: An overview of the essential elements of social organization analysis

Panel **(a)** in Figure 25 shows that we are concerned with the design of an operational work unit within a work situation of normal operations. This operational work unit will interact with an executive and a support unit as shown panel **(a)**. Our statement of work specifies that we are to redesign the operational work unit and also its interfaces with the executive and support units. We do not have authority to redesign either of those external units.

Our work organization analysis will have identified the essential work tasks (work tasks 1- 9 in panel **(a)** of Figure 25). The first step in social organization analysis is to review these work tasks to assess how they fit into a reasonable workflow (based on such characteristics as sequential dependencies and cognitive workload) and the basic skill sets required for their execution.

In this schematic illustration, those considerations have led to the conclusion that work tasks 1 to 4 can be integrated into a single work module because the basic skill sets for their execution are similar and because their products flow rather naturally from one to the other. As shown in panel **(b)** of Figure 25, work tasks 5 to 9 can similarly be established as a work module.

There is a further requirement for oversight and guidance from a senior, experienced member of the workforce and so a team leadership position is established as shown in panel **(c)**.

Panel **(d)** illustrates the final step of social organization analysis; the identification of interactions between individuals and between constellations of individuals within the operational work group and between the operational work group and the external units.

In summary, the first goal is to determine staffing requirements, role allocations and team structures. The second is to identify and characterise the interaction patterns within the work force.

Staffing, Role Allocation and Team Structure

The nature and demands of the work (essential expertise, workflow and workload) will determine staffing level and role allocations. It may be preferable to give different workers responsibility for different components of work tasks or it may be preferable to have the different workers take care of complete tasks.

Team structures must be established for work groups. Requirements for authority and oversight will suggest team structure and leadership roles.

Staffing Docket

These ideas can be laid out in a staffing docket as shown in Figure 26. This docket is used to record the sub groups within an operational work group and the proposed staffing assignments for each sub group. Separate columns are used to list the selection criteria for staffing assignments. The selection criteria shown in Figure 26 are illustrative rather than definitive. The particular selection criteria and the manner in which they will be applied should be identified early in the social organization analysis.

Staffing Docket (Operational Work Group)

Operational Sub- Group	Selection Criteria / Staff Roles	Education, Training, Qualifications	Seniority	Experience, Competency
Group Leaderership	Team Leader			
Work Group 1	Specialist Senior Member 1 Junior Member 1			
Work Group 2	Senior Member 1 Junior Member 1 Junior Member 2			

Figure 26: A generic staffing docket used to record proposed staffing assignments tabled against selection criteria

Social Transactions

A social transaction is an exchange or transfer, either in a face-to-face interaction or as mediated by technology. Information exchange or transfer is central whether it is face-to-face or geographically distributed and whether it is concurrent or temporally distributed.

A face-to-face transaction can be a conversation between two persons, a meeting between many or a presentation by one to many. Similarly, a temporally and geographically distributed transaction can be a conversation between two persons, a meeting between many or a presentation by one to many, but some type of communication technology must be employed. Some transactions will involve instructions and procedures from specialist teams to workers, advisories or guidance from management to workers, or reports and advisories from workers to management.

Social transactions may be characterized in terms of their demands (the intensity, complexity and reciprocity as is characteristic of engagement patterns such as dialog, instruction, discussion, explanation and command) and their dimensions (in terms of whether they co-located or geographically separated and in terms of whether they are synchronous or asynchronous). Additionally, for design purposes, it is useful to characterize transaction demands in terms of supporting technologies (what is used, what might be used).

Social transactions instantiate collaborative work processes that support execution of the work tasks identified in the Work Task Docket. Although work processes in support of collaboration can be both physical and cognitive, the emphasis within cognitive work analysis is on the cognitive with reference to physical processes only when they support or are supported by cognitive processes.

Social transactions can be mapped onto a network scratch pad as illustrated in Figure 27.

Social Transactions Docket

The annotations on the network scratch pad of Figure 27 can be transferred to a transactions docket as shown in Figure 28. This docket tables the reach of the transactions (their organisational distance) and the human agents involved in those transactions. Separate columns are used to characterize the transactions in terms of demand and dimension. Following the strategy of Crandall, Klein & Hoffman (2006, p 175) for decision requirements tables, the final column offers design ideas that might be used to support the transactions.

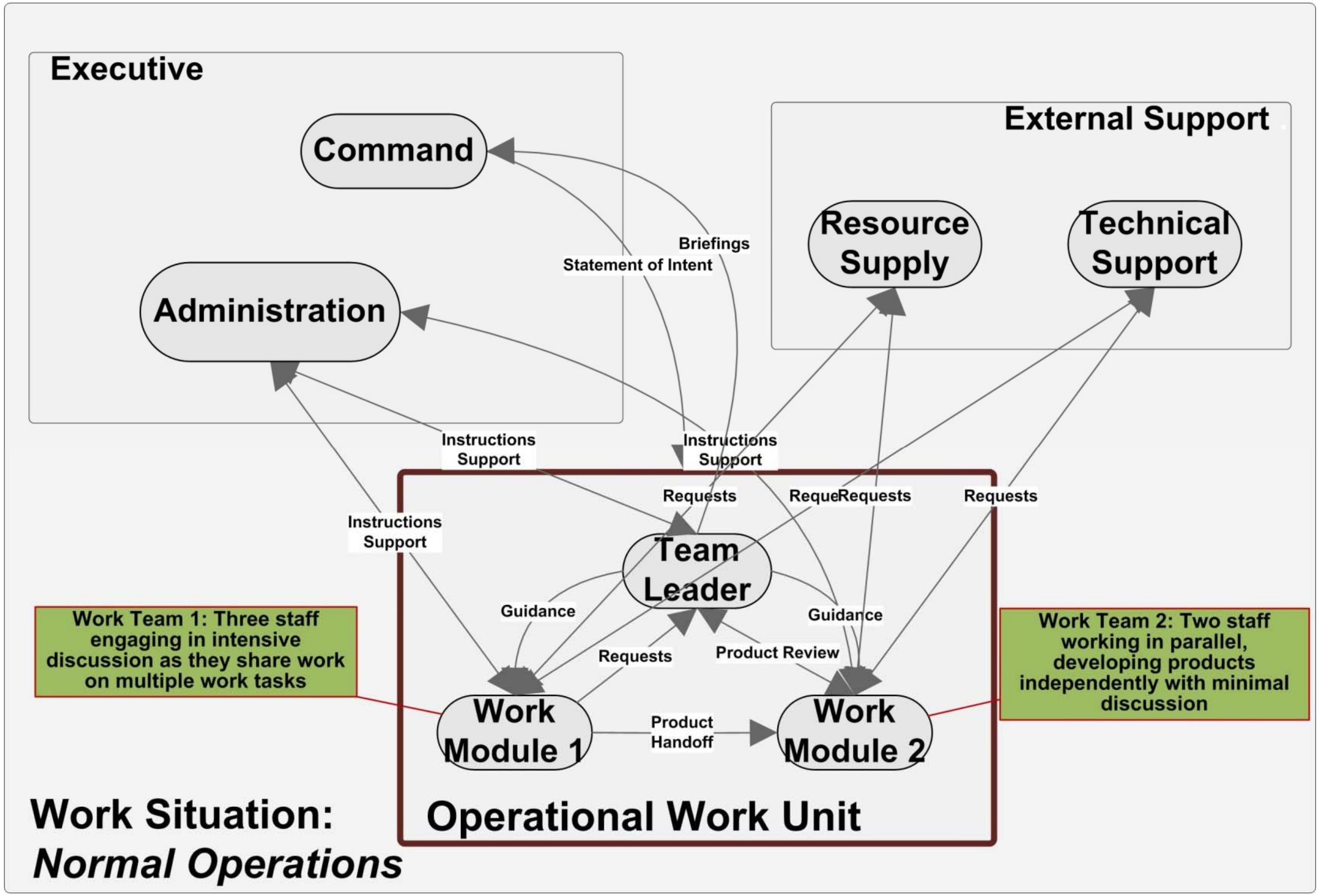

Figure 27: A generic depiction of a modular work organization and transaction patterns within an operational work unit and within a particular work situation also illustrating transaction patterns between the operational work unit and other units within the larger organization

Transactions Docket (Operational Work Unit)

Transaction Reach	Transaction Properties / Interacting Agents	Transaction Demands	Transaction Dimensions	Design Ideas
Internal	Team Ldr<->Staff	Guidance, Review, Update	Co-located, Synchronous	Shared Status Board, Work Boards & Notice Boards
	Team 1 <-> Team 2	Product Transfer	Co-located, Synchronous	Document Link
	Work-Team 1 (Internal)	Discussion, Problem Solving	Co-located, Synchronous	Shared Work Boards and Electronic Table
	Work-Team 2 (Internal)	Information Sharing	Co-located, Synchronous	Shared Work Boards
External	Team Ldr->External	Discussion, Problem Solving, Coordination, Briefing	Separated, Synchronous Separated, Asynchronous	Communications Systems (Text & Voice) Shared Desk Top
	Staff->External	Discussion, Information Seeking, Negotiation	Separated, Synchronous Separated, Asynchronous	Communications Systems (Text & Voice) Shared Desk Top

Figure 28: A generic social transactions docket

The entries in the transactions docket of Figure 28 derive from an illustrative narrative for the generic operational work unit with a team leader and two work teams as shown in Figure 27 (and Figure 25). The team leader and the two work teams interact with each other and with others outside their own work unit. Much of the work undertaken within this operational work unit involves searching for and organising information and preparing and transmitting plans and reports via a computer interface. The team leader interacts extensively with a command or headquarters entity while the staff members within the work unit interact occasionally with support and administrative entities. I have entered representative properties into Figure 27 to illustrate the character of the type of entries that are useful.

The categories under transaction reach should differentiate distinctive patterns of communication that are likely to require different types of technological support. In this generic illustration, the communications internal to the work unit are distinctively different to those between staff members within the work unit and staff members external to it.

The interacting-agents column lists the interaction pairings for the transaction-reach categories. Transaction demands, transaction dimensions and proposed resources are identified for these pairings as shown in Figure 28. The terms used to characterise the transaction demands should signify the cognitive intensity of the transaction and the degree to which it is one-way versus two-way. The spatial and temporal classifications under transaction dimensions should suggest useful differences in the way work tasks are executed.

Joker One: Social Organization Analysis

Joker One conformed to the usual organizational structure of a US Marine platoon, which has a complement of 43 personnel (Figure 29). Campbell was the platoon commander with rank of lieutenant. He was supported by a platoon sergeant with rank of staff sergeant, a platoon guide with rank of sergeant, and a messenger with rank of private. The remainder of the platoon was divided into three squads, each with 13 members. Each squad has a leader with rank of sergeant and three fire teams, each with four Marines. The fire teams had a leader with rank of corporal, an automatic rifleman with rank of lance corporal (who handled the team’s light machine gun), an assistant automatic rifleman with rank of lance corporal (who carried extra ammunition for the light machine gun), and a rifle man with rank of private.

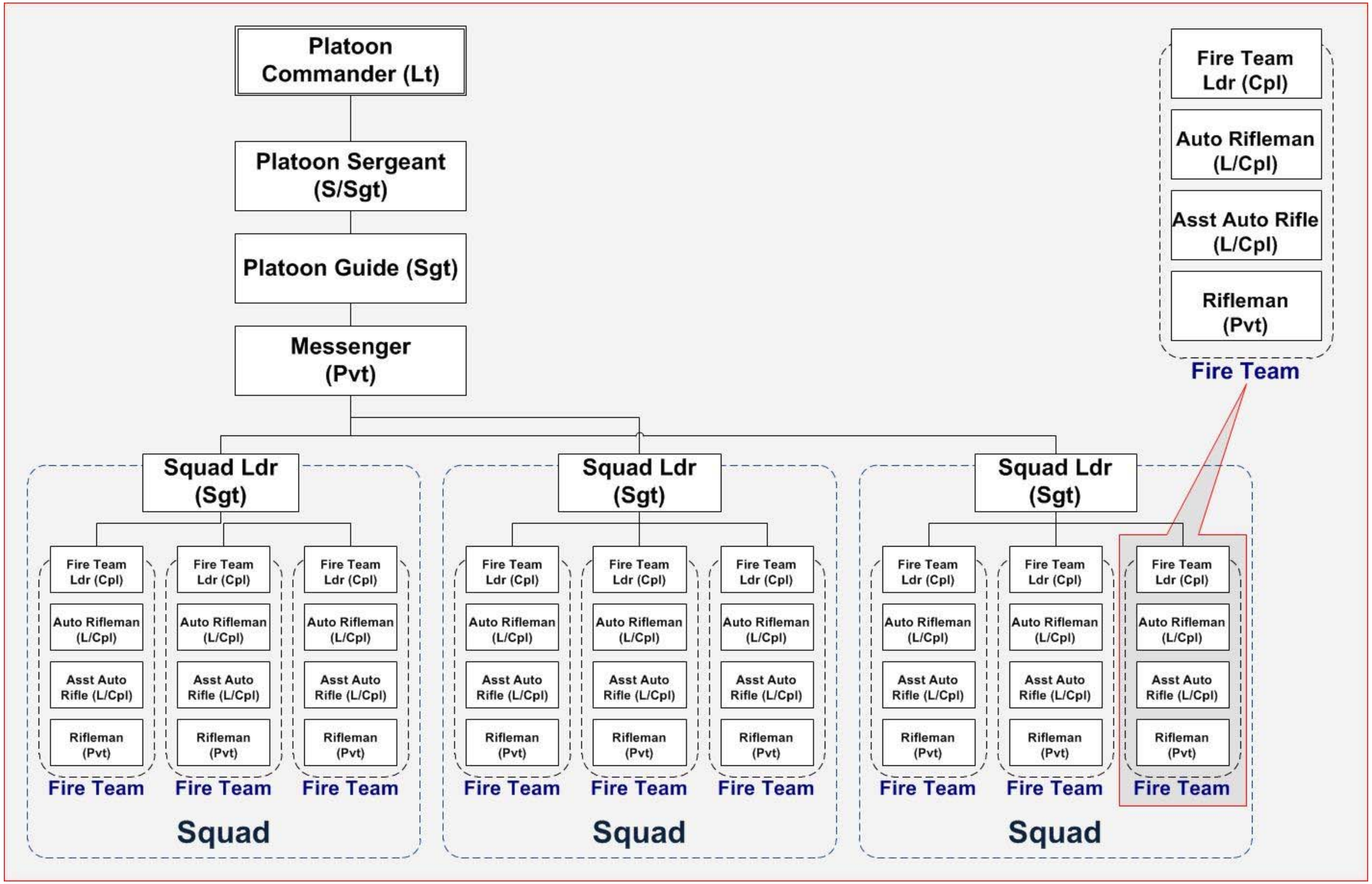

Figure 29: The organizational structure of a US Marine platoon

In that the structure, staffing requirements and work assignments of a US Marine platoon are well established, there is no need to develop requirements for staffing, role allocation and team structure. While it would be possible to develop a partial staffing docket on the basis of the information in Figure 29, there is insufficient information within Campbell's book to fill out the selection criteria. With so little information available, that seemed like a pointless exercise.

A platoon is a component of a company and a company is a component of a battalion. The narratives within Campbell's book reveal that Joker One took direction from Company Headquarters (sometimes directly from the Company Commander and sometimes indirectly through an officer on duty) and from Battalion Headquarters. Joker One also interacted with other platoons in their company and with other military units. All of these agents external to the platoon, as well as all members of Joker One, could potentially be involved in the execution of a work task.

Ambush & Weapons Search Missions

I will continue my examination of the Ambush and Weapons Search missions to illustrate the development of a social transactions docket.

Network Diagram

As a preliminary to filling out a social transactions docket, I have developed a network diagram that shows how the work unit under consideration (in this case, Joker One) interacts internally and externally with other entities.

Review of the ambush and weapons search missions reveals that Campbell interacts internally with his platoon as a whole, with his squad leaders and with individual members of his platoon. As shown in the network diagram of Figure 30, these interactions involve discussions, instructions, briefings, mission reviews, performance reviews and commands. Additionally, squad leaders interact with their squad members through discussions and instructions.

Externally, Campbell interacts directly with Company Headquarters and 2nd Platoon and indirectly with Battalion Headquarters. The interactions with Company Headquarters involve mission directives and requests (from Campbell to Company Headquarters) for guidance and assistance. The interactions with 2nd Platoon involve discussions and briefings.

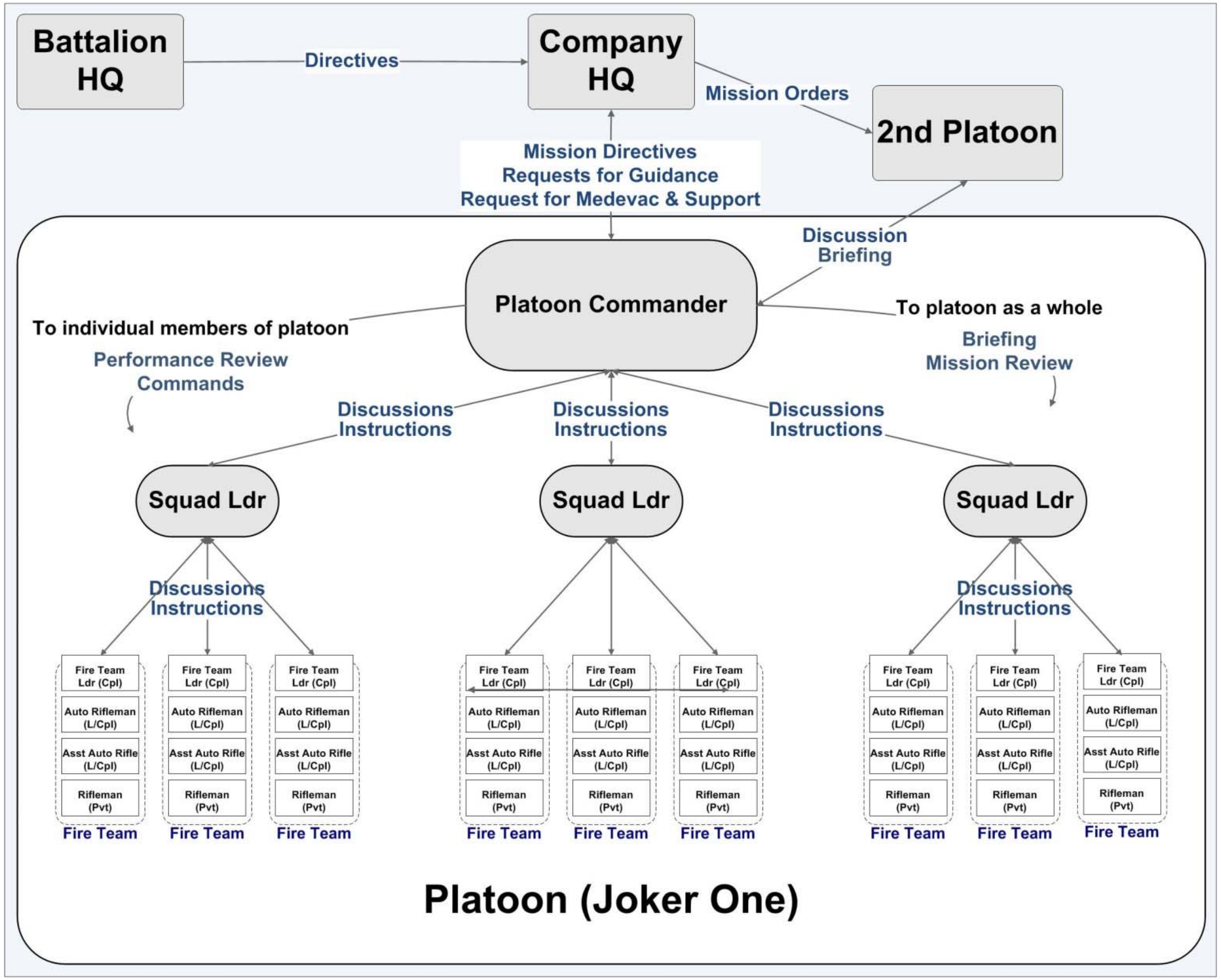

Figure 30: A Network diagram showing how Joker One fits within the larger organization

Transactions Docket

The transactions docket (Figure 31) is set up by filling in the categories of transaction reach (Internal, External). The interacting agent pairs will be identified from the narratives and will already be recorded on the network diagram. Transaction demands can be transcribed from the network diagram. Transaction dimensions can be filled in by reflection on the nature of the transactions described in the narratives and the resources can similarly be identified.

Figure 31 shows the completed transactions docket.

Social Transactions Docket, US Marines (Ar Ramadi): Joker One by Donovan Campbell

Transaction Reach	Transaction Properties / Interacting Agents	Transaction Demands	Transaction Dimensions	Resources
Internal	Campbell<->Squad Ldrs	Discussion, Instructions	Co-located, Synchronous Separated, Synchronous	Face to Face, Squad Radio, Hand Signals
	Campbell<->Platoon (Group)	Briefing, Mission Review	Co-located, Synchronous	Face to Face
	Campbell<->Platoon (Individual)	Performance Review, Commands	Co-located, Synchronous	Face to Face
	Squad Ldrs<->Squad Members	Discussion, Instructions	Co-located, Synchronous Separated, Synchronous	Face to Face, Hand Signals
External	Campbell<->Company HQ	Mission Directives, Requests	Separated, Synchronous	AN/PRC-119 Radio
	Campbell, <->2nd Platoon	Discussion, Briefing	Co-located, Synchronous	Face to Face

Figure 31: A social transactions docket for the Ambush and Weapons Search domain functions

Summary: Social Organization Analysis

Social organization analysis examines management and team structures, the organization and allocation of work tasks, and the supporting coordination processes in the form of vertical communication between the hierarchical levels within an organization and lateral communication between peers within a team or work group at any organisational level. The nature of the work will suggest how the work might be distributed among workers and may suggest an appropriate teaming structure. The ensemble of work tasks, as identified in work organization analysis, constitutes the work to be undertaken. Social organization analysis assesses how those tasks might be organized into effective and efficient work units that allow work processes to sequence as needed and support each other where that is needed.

Work systems remain coordinated in part through collaboration between peers and collaboration between management and workers; the lateral connectivity that supports essential work collaboration (and sometimes, competition) between peers and the vertical connectivity that supports essential manager-worker coordination. The supporting coordination processes are primarily communication events of various types. Social organization analysis identifies the generic properties of characteristic communication events that maintain social organization within a work domain.

The representational products

Two products are developed in this stage of analysis; a two-dimensional matrix referred to as a staffing docket and another two-dimensional matrix referred to as a transactions docket. Development of these products can be aided by scratch pads in the form of network diagrams that can be used to summarize the essential properties that will populate the staffing and transaction dockets.

The staffing docket lists essential work packages and indicates how they might be staffed. The staffing docket also shows the selection criteria for staff members as derived from a consideration of types and levels of expertise demanded by the work.

The transactions docket is structured around transaction properties, transaction reach (their organisational distance) and the human agents involved in those transactions. Transaction properties are characterized in terms of transaction demand, separation in time and space, and supporting resources. The agents are those human actors who contribute information processing capabilities to execution of work tasks.

How to do it

For development of a staffing docket, the work tasks identified in the work task docket are assembled into work packages. The work domain considered in this tutorial does not lend itself to the development of a staffing docket. However, to summarise the basic ideas as I describe them elsewhere (Lintern, 2013c), the ensemble of work tasks as identified in work organization analysis are assembled into modular constellations by reference to work situations and cognitive content. The nature of the work will suggest how the work might be distributed among workers and may suggest an appropriate teaming structure. The aim is to group work tasks that require similar types of cognitive expertise and that contribute to an identifiable work product so that the organizational structure is populated by loosely-coupled work modules made up of tightly-coupled work tasks.

The general approach for construction of a transactions docket is to review work narratives to identify instances in which individuals search for information, assess it, exchange it or promulgate it. The agent pairings involved in these transactions (at least one in each pair will be internal) are identified and categorised in terms of transaction reach. A pair of agents (as entered into the Interacting Agents column of the transactions docket) can engage in different types of transactions. All transactions are collated for each pair of agents and characterised in terms of their generic demand properties (a generic characterisation of the type of information transaction; e.g., observation, information processing, problem solving, discussion) and dimensions (spatial and temporal properties). The particular physical resources employed for those transactions are also identified.

A transaction network as shown in Figure 30 offers a useful organizing tool. The transaction links can be annotated in terms of demand (their interactivity and complexity) and dimensions (their geographic distance and separation in time). Transaction demand can be further characterized in terms of whether it is a transfer of information (push, pull, broadcast, command), an exchange (discuss, advise, inquire), an assessment (identify, review, interpret), or a construction (decide, plan, schedule). Transaction dimensions can be further characterized in terms of whether the agents are co-located or separated and whether the transaction is synchronous or asynchronous.

Relationship to other stages of cognitive work analysis

The work tasks provide the links to other stages of cognitive work analysis. Firstly, the work tasks to be examined in the social organisation analysis are derived from the work organisation analysis. All work tasks identified in the work organisation analysis are subsequently examined not only in social organisation analysis but also in the other remaining stages of cognitive work analysis, those being work task analysis, cognitive strategies analysis, and cognitive modes analysis. As will become evident during discussion of the remaining stages of analysis, the transactions identified in social organisation analysis will be subject to further investigation in these other stages.

Implications for design

The analysis should indicate whether the resources identified in the final column of the social transactions docket are adequate. If not, the characterizations of the transactions in terms of demand and dimension should suggest possibilities for redesigning the transaction or for developing more effective supports.

Work Task Analysis

A work task is something to be accomplished (e.g., resolution of a problem, development of a plan, a decision). A cognitive work task is accomplished by use of cognitive processes that transform cognitive states en route to that accomplishment. Work task analysis (also known as control task analysis) identifies the cognitive states and cognitive processes involved in a work task. Work task analysis results in a description of work tasks in terms of transformations between cognitive states as induced by cognitive processes.

The representational product of this stage of analysis is a decision ladder.

Cognitive States and Processes

Work task analysis is based on the assumption that tasks are accomplished, problems resolved and decisions made via transformations between cognitive states as induced by cognitive processes. A cognitive state is a condition of being (e.g., the state of being alert, the state of being aware, the state of being certain or uncertain, the state of knowing) while a cognitive process is an activity (e.g., the process of seeking information, the process of planning).

In a physical system, a state is a condition described in terms of phase, form, composition, or structure (e.g., ice is the solid state of the chemical compound, H2O, and water is its liquid state). A physical process acts on a state to change it (e.g., the process of cooling transforms water into ice). Cognitive states and processes can be viewed similarly. There can be no state transition in a physical system without an intervening process. In the realm of cognition, processes are often not accessible to conscious awareness, in which case they are said to be implicit.

The Decision Ladder

The product of this stage of analysis is a decision ladder as shown in Figure 32. It provides a template for mapping the generic cognitive states and cognitive processes involved in a work task as identified by a work narrative provided by an operational expert.

There is some discussion regarding whether the decision ladder is a model or a template. Pragmatically, within the analysis of a work task, it is used as a template. It is not a model in the sense that it describes a sequence or unfolding of cognitive activity but it does make a strong theoretical statement. The elements in the decision ladder (the nodes and the arrows) represent all possible cognitive states and cognitive processes. There are no others.

Because a decision ladder is not a model in the sense I describe above, a narrative as mapped onto one should not be interpreted as implying a fixed sequence of cognitive states and processes for all, or even for any tasks. Nevertheless, it should be possible to first map a work narrative onto a decision ladder and then to read that decision ladder.

A work narrative that follows the perimeter of the updated decision ladder, starting at the lower-left node and finishing at the lower-right node might be read as follows:

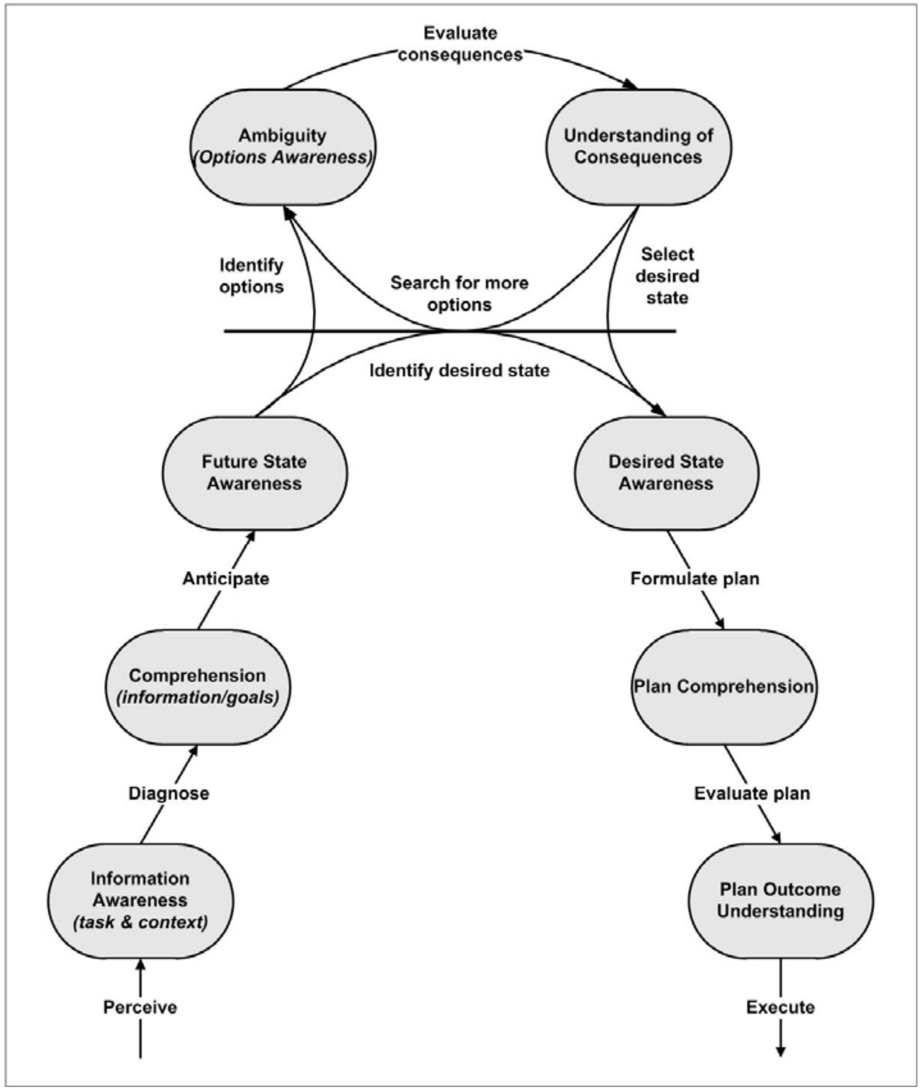

Figure 32: The decision ladder with cognitive states depicted as ovals and cognitive processes as arrows

A worker who is immersed in a work situation will be aware of the types of events that demand intervention. On becoming alerted to or aware of such an event, s/he may diagnose the situation to discover what is going on. S/he will first seek information about the task and about the surrounding conditions and with that information in hand, s/he will seek to identify the current system state and to anticipate the future system state given no intervention while remaining cognizant of situational exigencies that may demand reassessment. S/he will then identify a desirable and reachable system state.

Alternatively, it may be difficult to identify a desired system state directly, in which case the worker will divert through the options-analysis loop to identify and then evaluate the consequences of various options as a prelude to settling on one that will result in a desirable system state.

Once a suitable system state or option is identified there will be a need to develop a plan or select a course of action. When that is done, the worker will confirm that the plan achieves the goal. If satisfied, the worker will execute the plan.

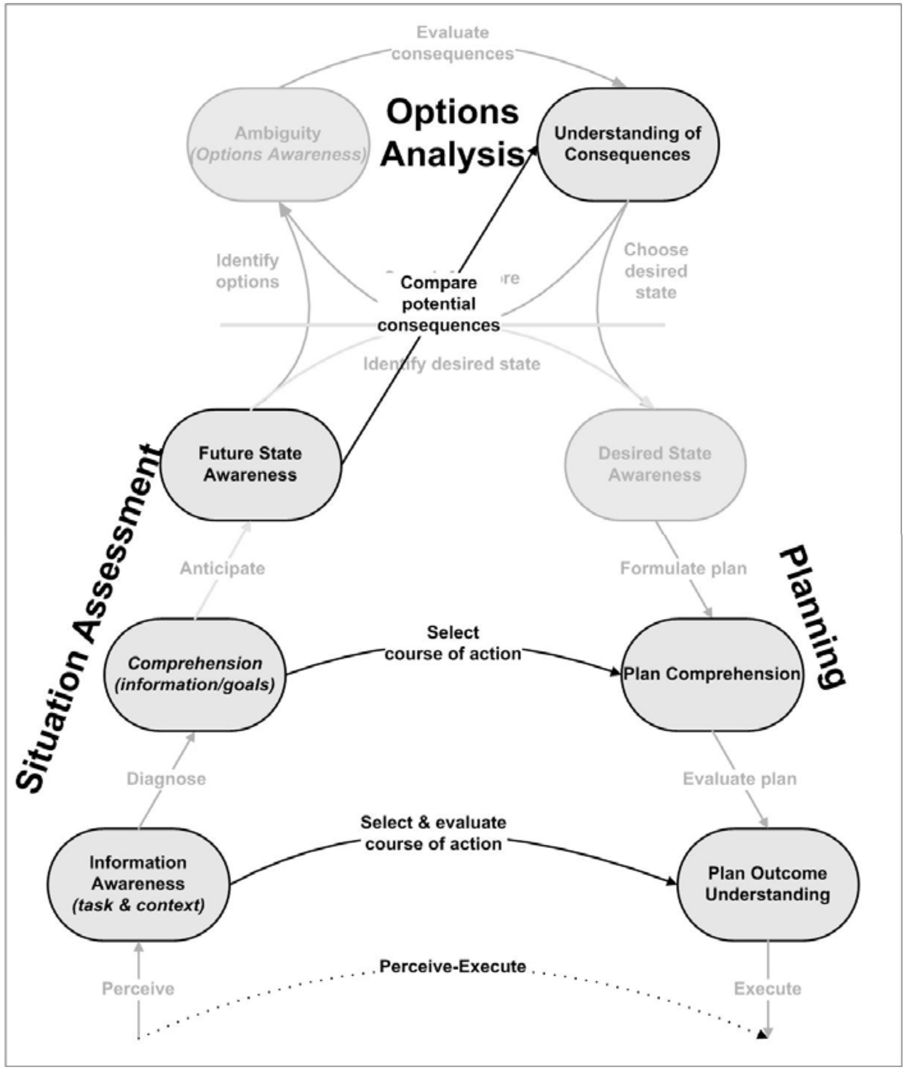

Figure 33: The decision ladder with a sample of alternate routes

A work event will not normally follow the perimeter of the decision ladder from the lower-left node to the lower-right node. It could start and finish anywhere in the ladder and could use alternate routes to bypass states or to transition across the ladder. Four alternate routes are shown in Figure 33. An implicit process, whether following the perimeter or not, can be represented by dotted line (e.g., the Perceive-Execute process at the bottom of Figure 33).

Figure 33 also shows how it is possible to think of the decision ladder in three main stages, situation assessment, options analysis and planning.

Joker One: Work Task Analysis

I will reference the preparation and en-route situations for the ambush mission described above to illustrate the use of work task analysis in mapping a work task trajectory onto a decision ladder.

Preparation (Plan)

As noted above, Campbell (2010) developed his plan after he reviewed aerial photographs and visited the ambush site. He wanted to arrive at the cemetery in time to catch the insurgents in their meeting but also wanted to ensure that his platoon was not seen by Ramadi residents who might warn the insurgents.

He planned to have his platoon patrol to the cemetery on foot, heading directly south from the Combat Outpost, across Michigan and through a thick cluster of buildings that lined the southern edge of the highway. The platoon would then cross a large open plain to the east of an irrigation canal, keeping away from the populated areas until the last minute. Because the natural ambient light was predicted to be low and the illumination from the electric lighting of the southern portion of Ramadi was generally low, Campbell imagined that the darkness would cover their movement.

The cognitive states associated with this plan are mapped onto the decision ladder shown in Figure 34.

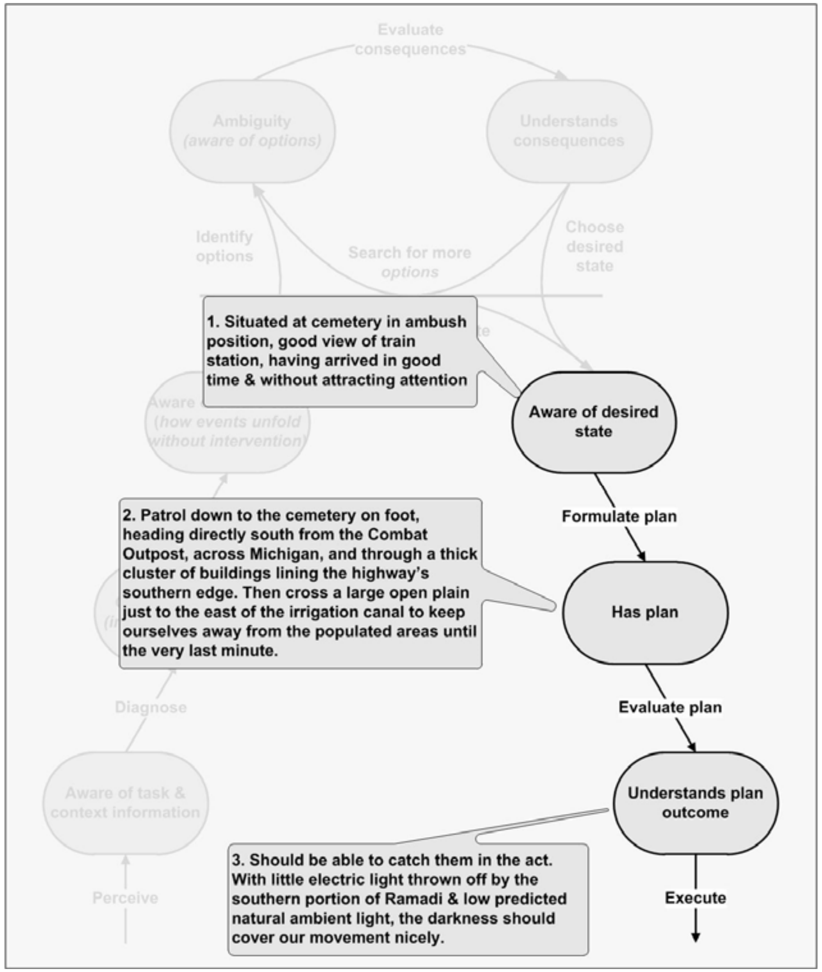

Figure 34: The cognitive states associated with Campbell's plan for the ambush mission

En-Route (Relocate)

While crossing the open plain, Campbell's platoon encountered a series of deep ditches that ran across the direction of travel. His Marines had to descend into each ditch and then climb up the other side, a challenging task for anyone, let alone marines wearing and carrying 50 pounds or more of equipment. Campbell realised that progress would be difficult but he decided to continue as planned (Figure 35).

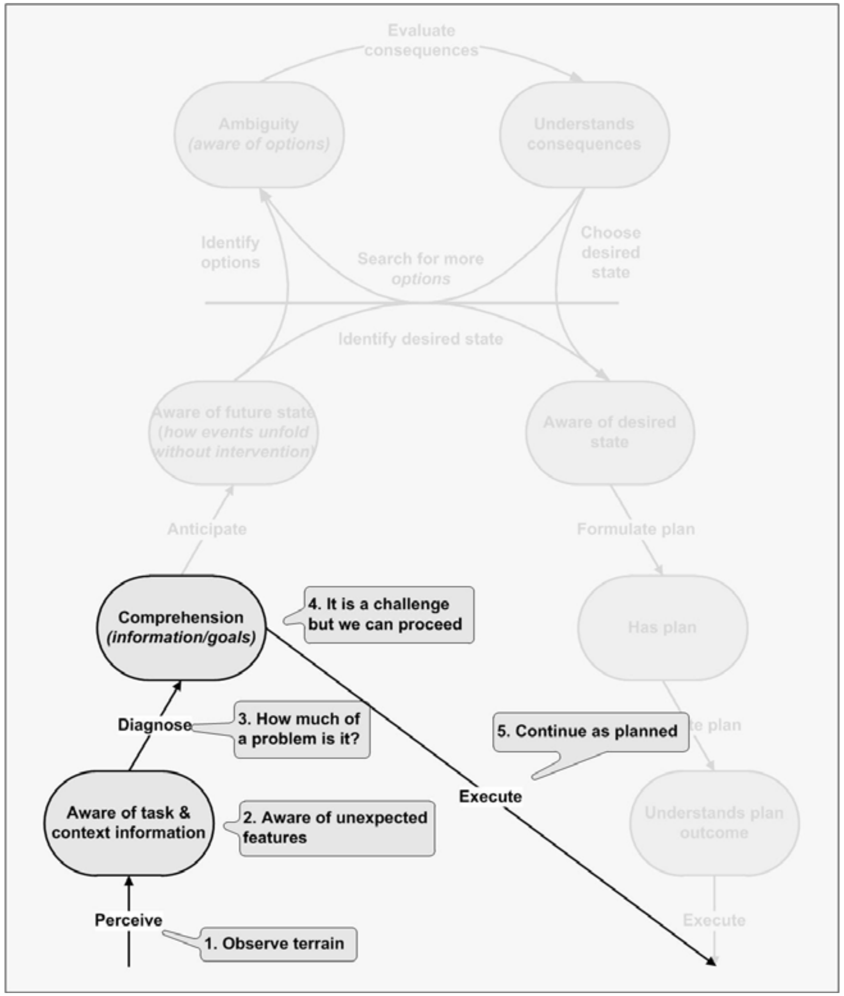

Figure 35: The cognitive states and processes associated with Campbell noticing obstacles to his platoon's progress and his decision to continue as planned

En-Route (Replan)

Campbell soon realised that progress was slower and more difficult than he had anticipated and that he needed to adjust his plan. He realised that he would have to find a way around the ditches (Figure 36).

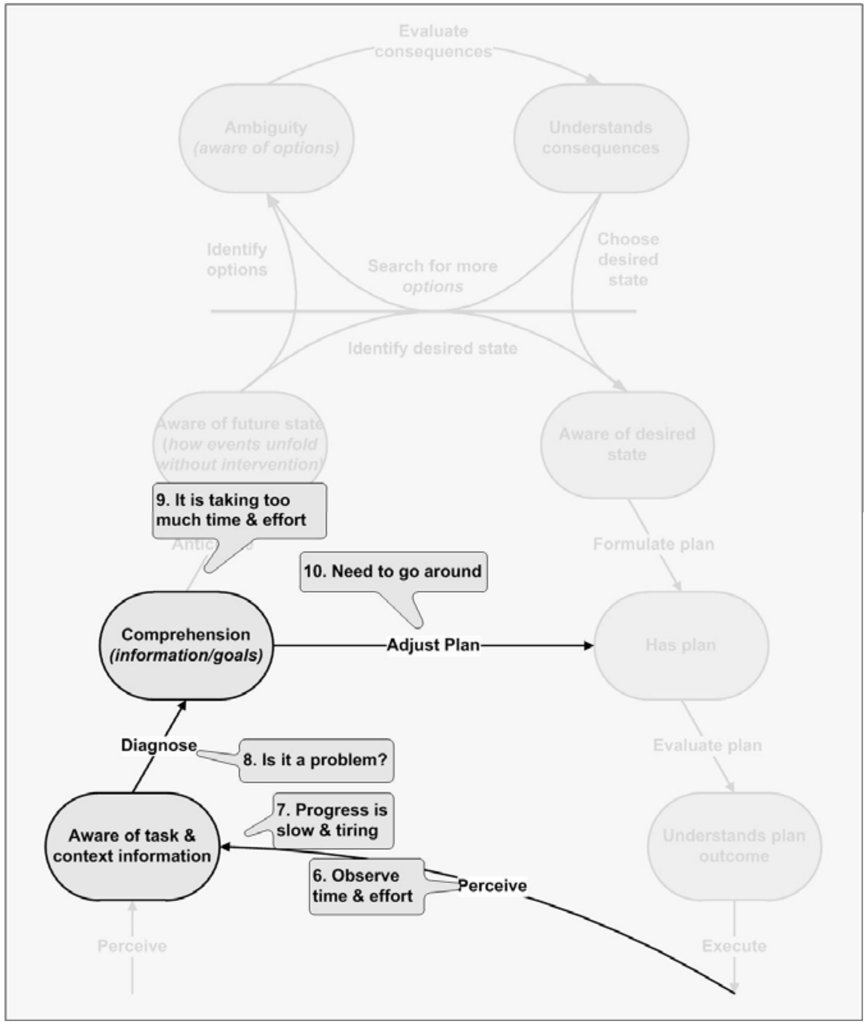

Figure 36: The cognitive states and processes associated with Campbell realising that he would have to adjust his plan

Campbell realised that he could avoid the ditches if he directed his marines to move 200 m to the west so that they could travel along the side of an irrigation canal. This would, however, move the platoon closer to be lighted Farouq area of Ramadi and would increase the risk of being spotted by Iraqi citizens sleeping on their rooftops (Figure 37).

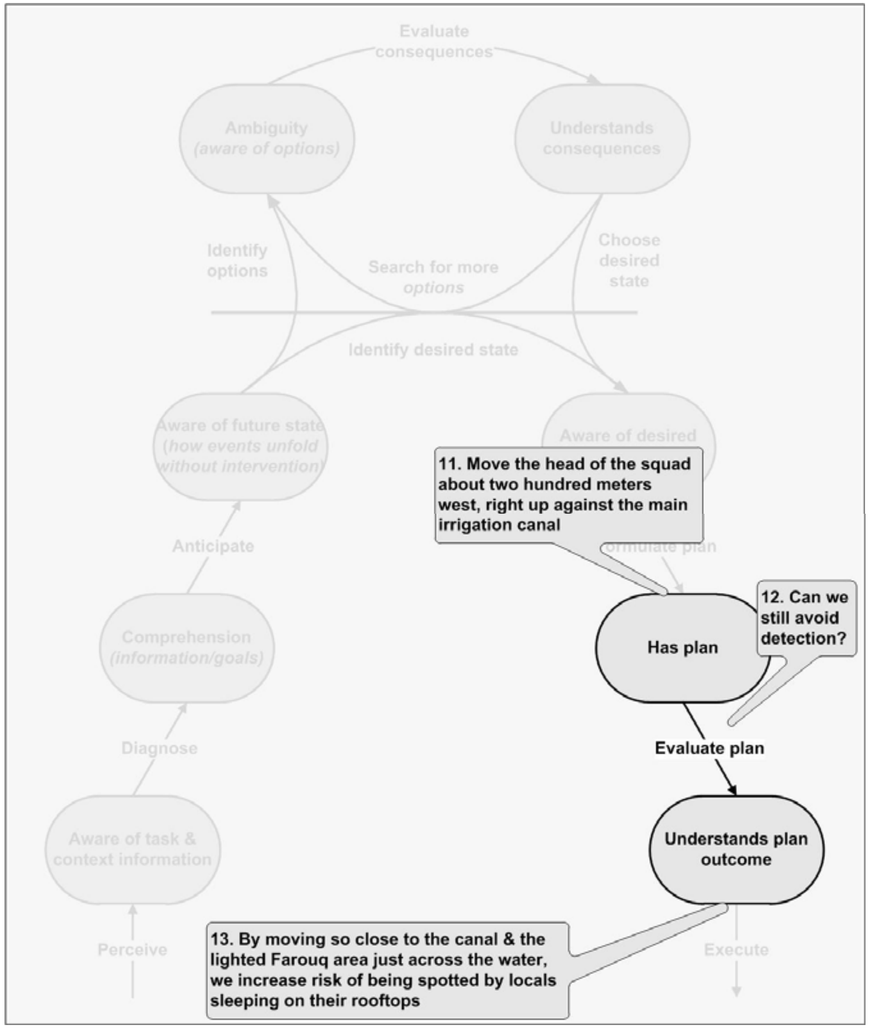

Figure 37: The cognitive states and processes associated with Campbell formulating and evaluating his new plan

He imagined they might avoid detection if they moved quickly. Thus, he stayed with his plan to travel along the side of the canal but decided to have his marines move rapidly through the danger area. He recognized the risk of being observed by Ramadi residents but reasoned that the risk would be minimized if the platoon moved quickly (Figure 38).

He redirected his squad to move towards the canal and travel along its adjacent roadway and had his radioman contact the other squads to advise them of the adjustment in the plan.

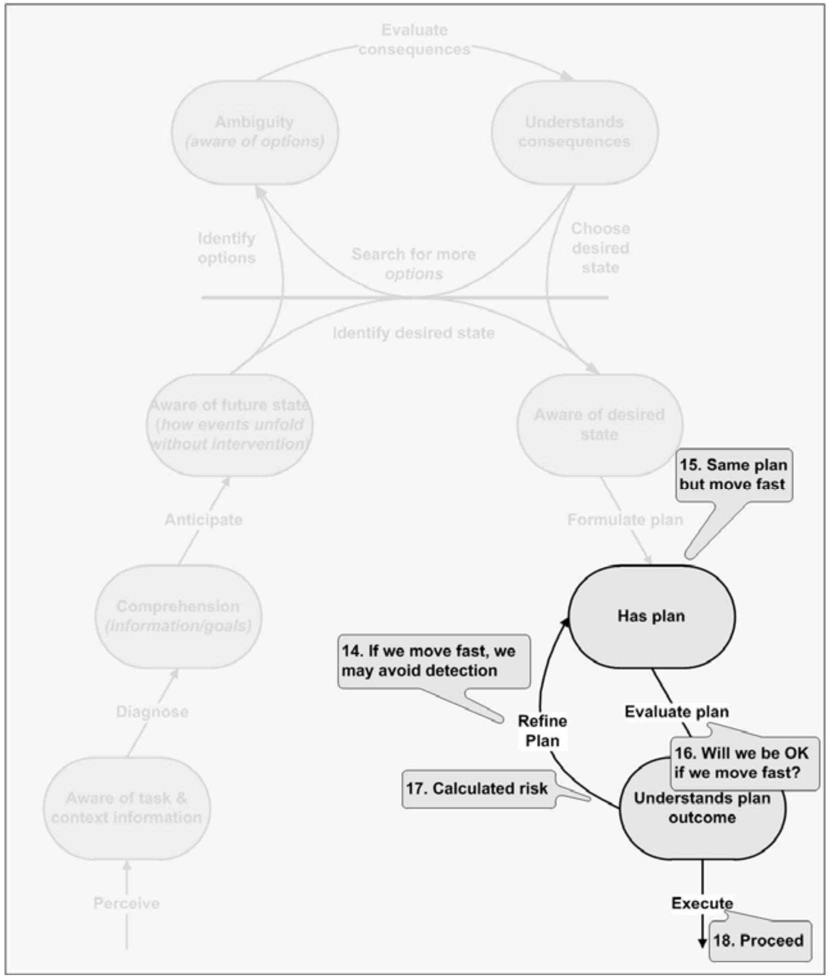

Figure 38: The cognitive states and processes associated with Campbell considering whether rapid movement through the danger area would be an acceptable risk and then executing that plan

En-Route (Relocate and Replan)

The complete narrative is shown in Figure 39.

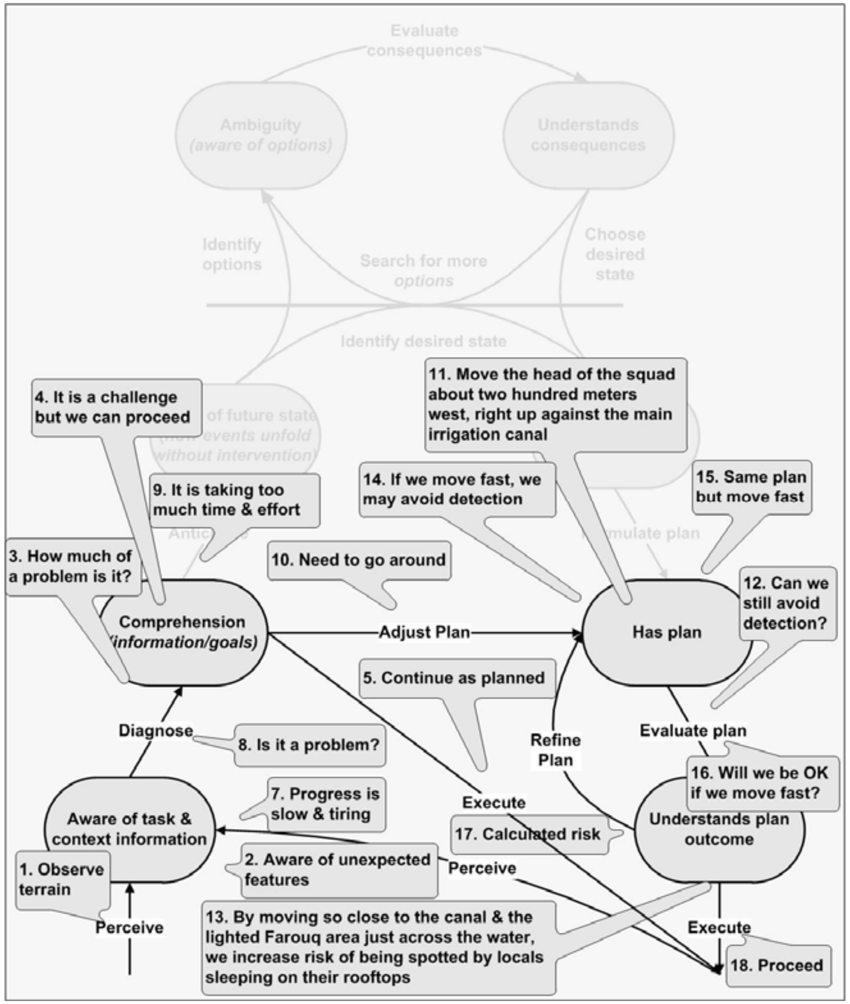

Figure 39: All cognitive states and processes identified in Figure 35 to Figure 38.

An Alternative to the Decision Ladder

Especially in a large project, the process of mapping narratives onto a decision ladders becomes cumbersome. Once I become familiar with the way work tasks unfold within a domain, I develop a form as shown in Figure 40. The domain function and work situation are identified in the heading and the work tasks are identified in the first column. The cognitive processes and states are assigned in columns. The labels at the head of each column identify processes in black font and states in red font. The cognitive processes and states are grouped into the three main stages of situation assessment, options analysis and planning.

Figure 40 duplicates the information shown in Figure 35 to Figure 38. The cells associated with the coordinate and navigate work tasks have not been filled out because I have not yet mapped those work tasks onto decision ladders.

It is immediately apparent that there is no sequential information represented in Figure 40. That is not, however, a concern. The purpose of the decision ladder is to show which cognitive states and cognitive processes are active within a work task and not the process-state sequence in which the work task unfolds.

In filling out a form such as this, processes that follow alternate routes are accommodated by assuming that a particular cognitive state is typically evoked by a similar cognitive process whether it be one from the perimeter of the decision ladder or otherwise. This becomes problematic only when an alternate route combines two types of processes as defined in the decision ladder (e.g., the Perceive-Execute process represented in Figure 33). The notes column can be used to reference any complication of this sort.

Ambush: En-Route (Cognitive States & Processes)

Work Task	Situation Assessment							Options Analysis						Planning						Notes
	Perceive	Information Awareness	Diagnose	Comprehension	Anticipate	Future State Awareness	Identify Desired State	Identify Options	Options Awareness	Evaluate Consequences	Understanding of Consequences	Select Desired State	Search for More Options	Desired State Awareness	Formulate Plan	Plan Comprehension	Evaluate Plan	Plan Ourcome Awareness	Execute Plan	
Relocate	X	X	X	X															X	
Coordinate																				
Replan	X	X	X	X											X	X	X	X	X	
Navigate																				

Figure 40: A table format can be used to record the cognitive states and processes that are active within a work task

Summary: Work Task Analysis

A work task is something to be accomplished (e.g., resolution of a problem, development of a plan, a decision). A cognitive work task is accomplished by use of cognitive processes that transform cognitive states en route to that accomplishment. Work task analysis (also known as control task analysis) identifies the cognitive states and cognitive processes involved in a work task.

The representational product

This stage of analysis results in a description of work tasks in terms of transformations between cognitive states as induced by cognitive processes. The product is a decision ladder, which depicts the generic cognitive states and cognitive processes involved in execution of a work task. A cognitive state is a condition of being (e.g., the state of being alert, the state of being aware, the state of being certain or uncertain, the state of knowing) while a cognitive process is an activity (e.g., the process of seeking information, the process of planning).

How to do it

Initiate a work task analysis by selecting work tasks of interest from the work task docket of work organisation analysis and then collect work narratives specific to the work tasks from operational experts. Essentially, you should ask your operational experts how they do each of their work tasks. You should encourage them to be explicit about the details. You want to identify the cognitive states and processes although you should not typically use that sort of language with your subject matter experts. You should encourage them to speak in terms that allow you to infer what cognitive states and processes they are talking about.

Use a blank decision ladder as a template to lay out the sequence of the work task as described by the subject matter expert. The trajectory of the work task will not normally follow the perimeter of the decision ladder from the lower-left node to the lower-right node. It could start and finish anywhere in the ladder and could use alternate routes to bypass states or to transition across the ladder. Especially within large projects with many work tasks, you may prefer a form of the type shown in Figure 40 to the decision ladder template.

During the discussion with your subject matter experts, you will also gather information that is relevant to the two remaining stages of cognitive work analysis, cognitive strategies analysis and cognitive modes analysis. I will explain how you do that in the subsequent summaries of those two stages.

Relationship to other stages of cognitive work analysis

The work tasks to be examined in the work task analysis are derived from the work organisation analysis and are those that are examined in social organisation analysis. Many of the cognitive processes involved in execution of a work task involve information transactions that are also relevant to the social organisation analysis. Your work task analysis will identify the initial and final cognitive states that bracket an information transaction and will thereby provide detail about how that information transaction should work. That will inform your selection of support technology.

Additionally, the result of the work task analysis guides the two later stages, cognitive strategies analysis and cognitive modes analysis, as I describe in the next two chapters. You should try to avoid treating the knowledge elicitation for these three stages of cognitive work analysis as separate or independent exercises. With some experience, you should be able to collect information relevant to cognitive strategies analysis and cognitive modes analysis as you collect information for your work task analysis.

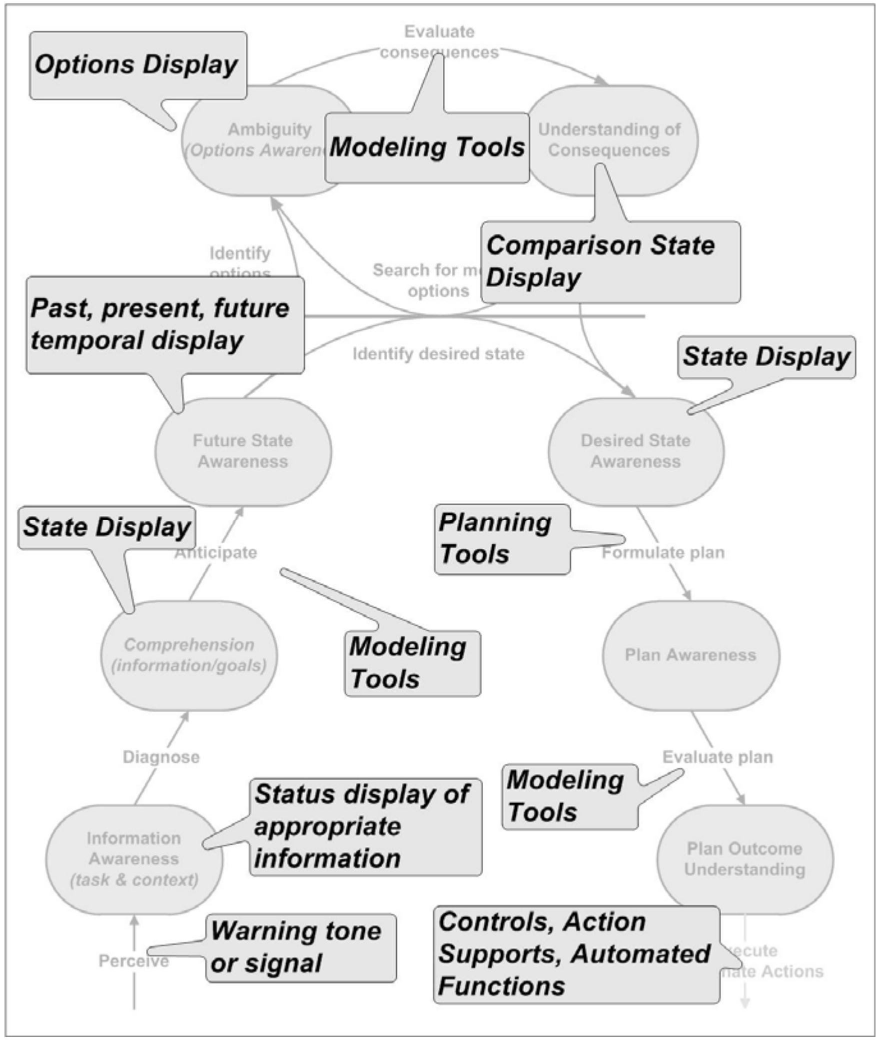

Figure 41: A sample of potential design interventions

Implications for design

Enhanced cognitive support might come through one of or some combination of technological redesign, work process redesign, or training focused on the specific cognitive states or processes that offer a challenge in execution of a work task. Figure 41 offers a sample of potential design interventions that could support work tasks. Whether any form of support is desirable for any specific cognitive state or process will depend largely on whether that state or process offers a particular cognitive challenge that could be eased by the form of support being proposed.

Commentary

Vicente (1999) refers to this stage as control task analysis. To many, the term *control* will imply moment-to-moment adjustments in a closed-loop feedback activity such as maintaining an automobile in the center of a lane. I doubt that Vicente (1999) intended that implication and I suggest that the best way to avoid it is to substitute a more appropriate term. That is why I refer to this stage as work task analysis.

I also avoid the common strategy of associating work tasks with goals and of labelling decision ladders with goal designators. As I note above, a work task is something to be accomplished. For example, planning is a work task. In identifying a work task in this way, the goal is implied and any further elaboration is redundant.

Cognitive Strategies Analysis

A cognitive strategy is a generic pattern or, alternatively, a behavioural prototype for a work task or a component of a work task. It is a way of transforming one cognitive state into another and is therefore a class of cognitive process. It offers a more detailed description of the way in which one cognitive state can be transformed into another than is offered within work task analysis. It may be a generic method of executing a single process (e.g., the process of diagnosis may be accomplished by use of a pattern matching strategy) or a generic method of executing multiple processes. Cognitive strategies analysis identifies the actual and potential strategies that are or could be used in execution of a work task and the reasons that a particular strategy might be selected in preference to other possible strategies. It results in a description of the cognitive strategies that might be used to execute cognitive processes identified in work task analysis.

Cognitive Strategies within Work Tasks

Within work task analysis, we seek to identify the cognitive processes involved in execution of a work task whereas within cognitive strategies analysis, we seek to describe the manner in which cognitive processes are executed. Typically, diverse strategies will be available to effect a transition between two specific cognitive states or to transition through multiple cognitive states. Furthermore, a worker may shift unpredictably and opportunistically between available strategies during execution of a cognitive process aimed at inducing a cognitive state transition.

The Cognitive Strategies Table

The product of this stage of analysis is a description of potential strategies that can be used to execute the cognitive processes identified in the work task analysis and a description of the factors that will prompt selection of one strategy over another. A table offers the best representation for this information (Figure 42).

Joker One: Cognitive Strategies Analysis

The development of a cognitive strategies table proceeds through two stages.

Some parts of a narrative as mapped onto a decision ladder within the work task analysis may suggest different possibilities for courses-of-action that would complete the work task. Information about these different courses-of-action is used to fill out the first column of a courses-of-action table similar to Figure 42. The reasons for selecting one course-of-action over another are entered into the second column.

However, a course-of-action is not a generic pattern or behavioural prototype but rather a context-dependent sequence of actions. The analyst must transform the courses-of-action table into a strategies table by inferring the generic or prototypical nature of the activity that has been employed and also the generic or prototypical nature of the reasons for preferring one strategy versus another.

I will illustrate this process by reference to one scheduled activity and two incidents from Joker One. The scheduled activity was a daily requirement to check the main east-west road through Ramadi for Improvised Explosive Devices (IEDs). One of the incidents related to the disposal of two enemy grenades that were thrown into the middle of a joker one squad and the other related to the disposal of an IED discovered during a routine patrol.

Cognitive Strategies		
Strategy	**Reasons for Selection**	**Design Ideas**

Figure 42: Template for summarising cognitive strategies and the reasons for selecting a particular strategy

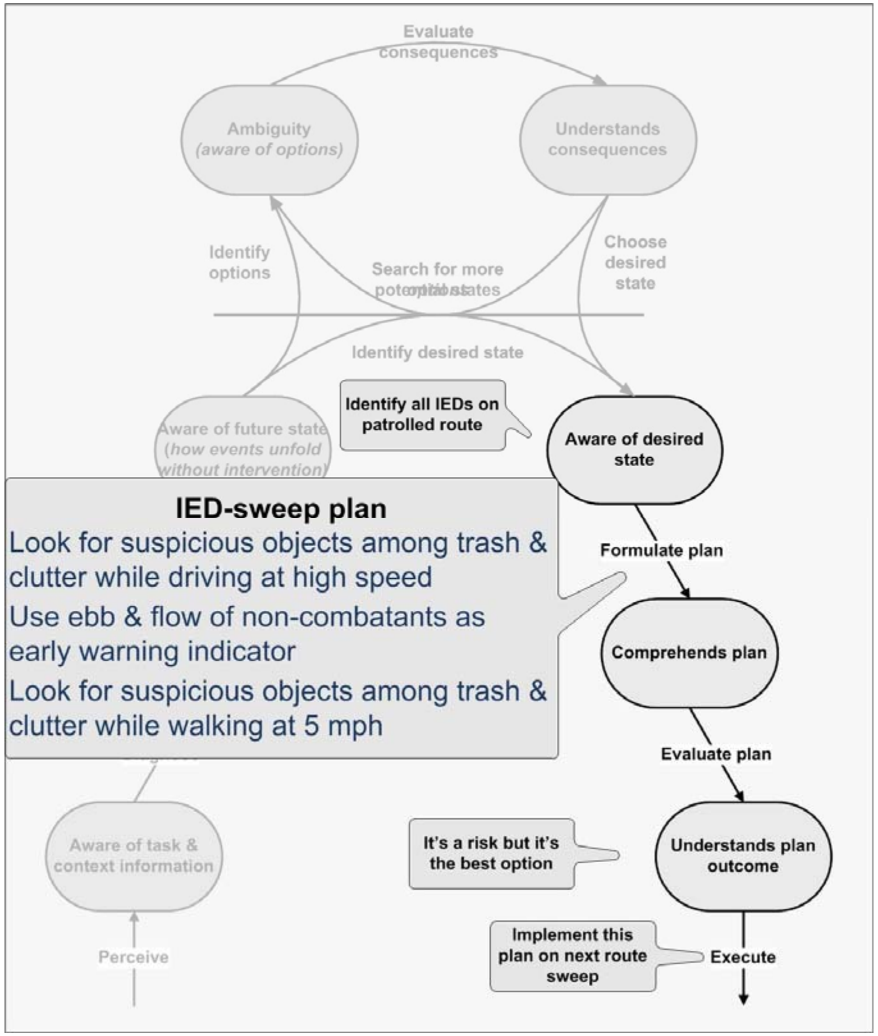

Figure 43: Route sweep strategies

IED Indicators

There was a daily requirement to check the main east-west road through Ramadi for Improvised Explosive Devices (IEDs). Prior to the arrival of the marines, army personnel drove along the road at high speed looking for suspicious objects among the trash and clutter. The marines executed this task on foot. One of Campbell's colleagues preferred a mid-morning schedule when the streets would normally be crowded with Ramadi residents. He reasoned that residents would be aware of the presence of IEDs. He used any deviation from normal patterns as an indicator that something was amiss. In contrast, Campbell reasoned that the insurgents had shown little regard for residents and would be unlikely to warn them. He preferred an early morning schedule before residents emerged for their daily business. With the streets clear of residents, the insurgents would have more difficulty concealing their activity.

These three different search strategies are shown in Figure 43.

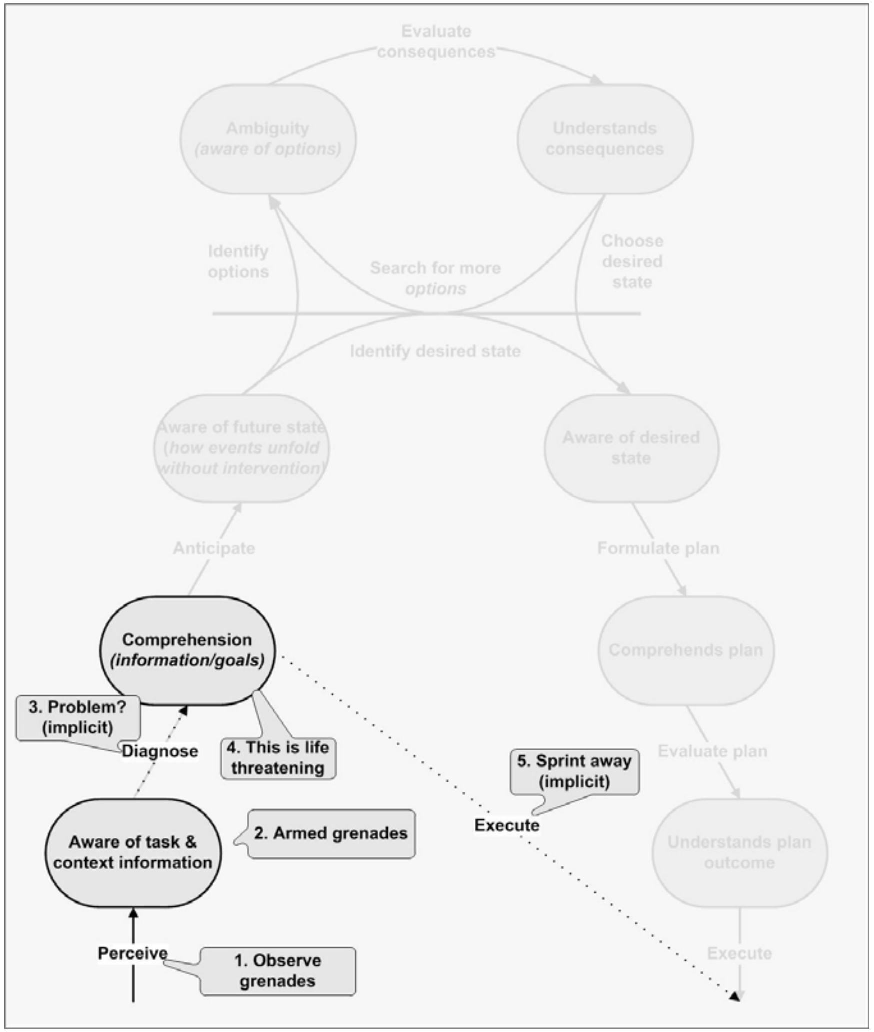

Figure 44: Marines respond to a grenade thrown in their midst

Grenade Disposal

During a major battle, Joker One marines were moving through Ramadi when two enemy grenades came over the wall of a nearby fence to land within in their midst. Several marines ran in one direction and the remainder ran in the opposite direction (Figure 44).

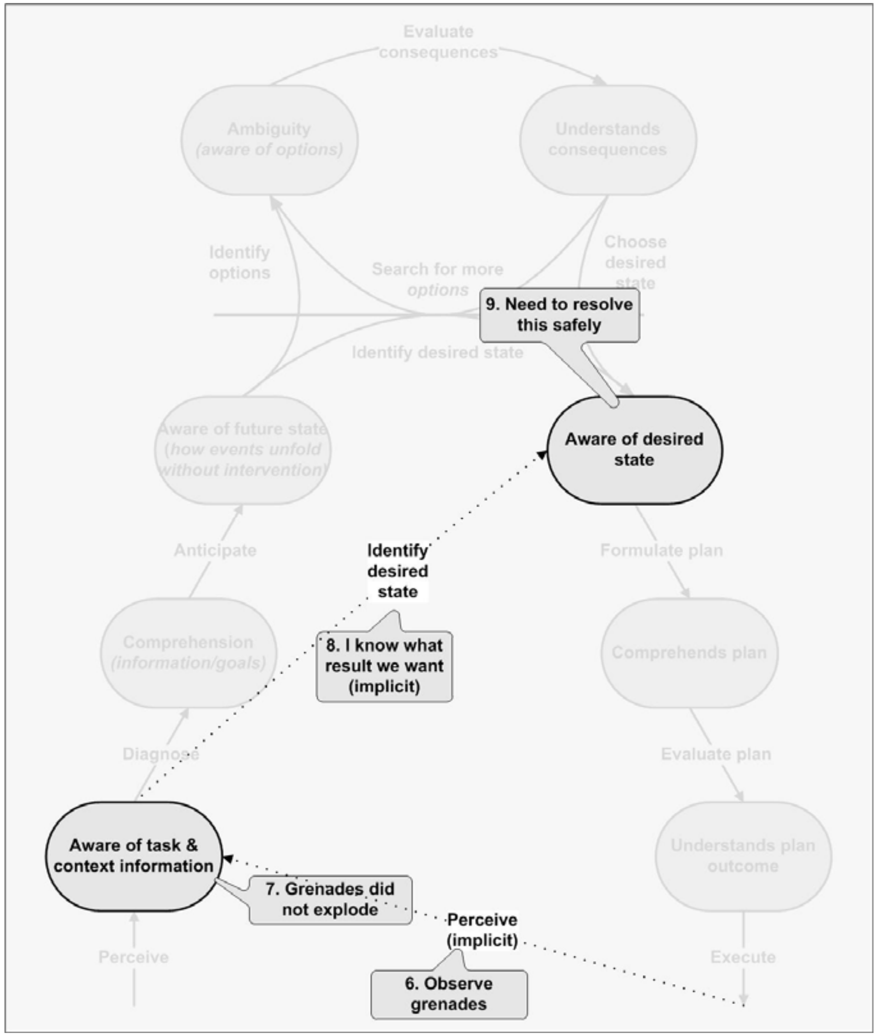

Figure 45: Marines of Joker One are separated by enemy grenades that did not detonate

The two enemy grenades did not, however, detonate.

Two sections of the platoon were now separated by the unexploded grenades, raising the problem of how they could rejoin without risking harm if the grenades should detonate (Figure 45).

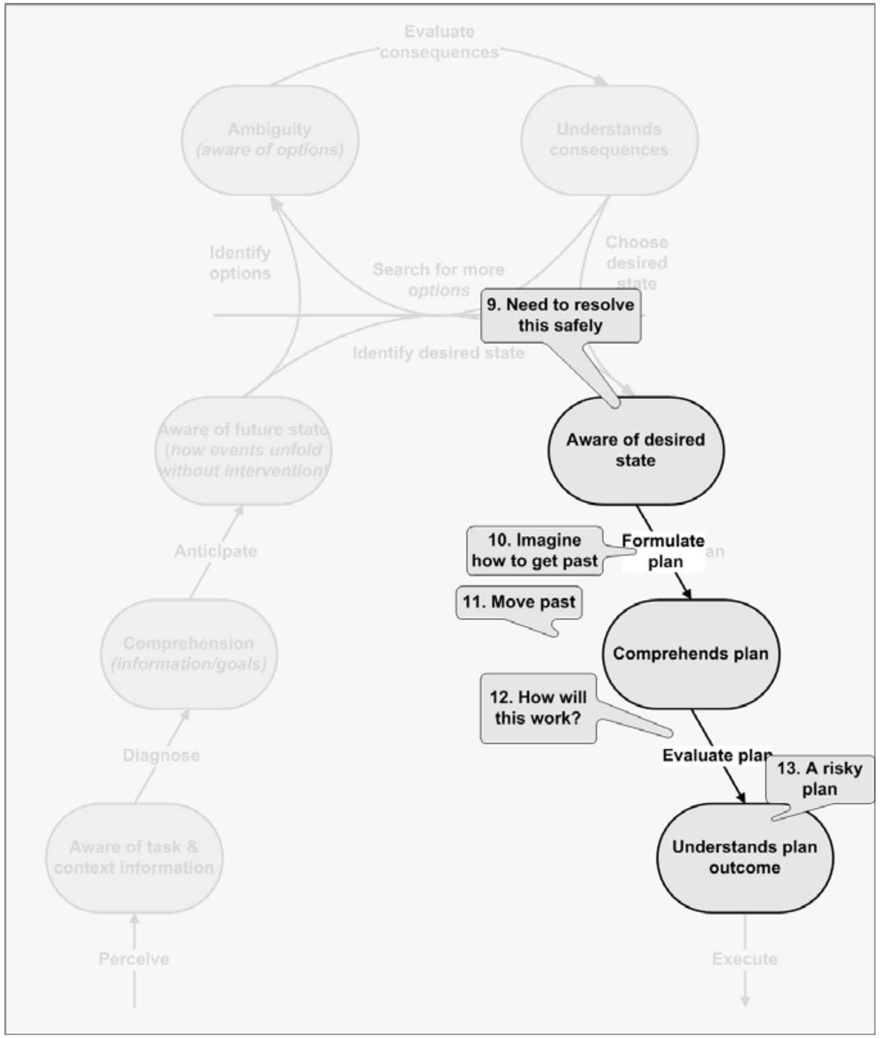

Figure 46: A plan to move past the grenades is judged as risky

Campbell considered instructing the marines to move past the grenades but concluded that was too dangerous (Figure 46).

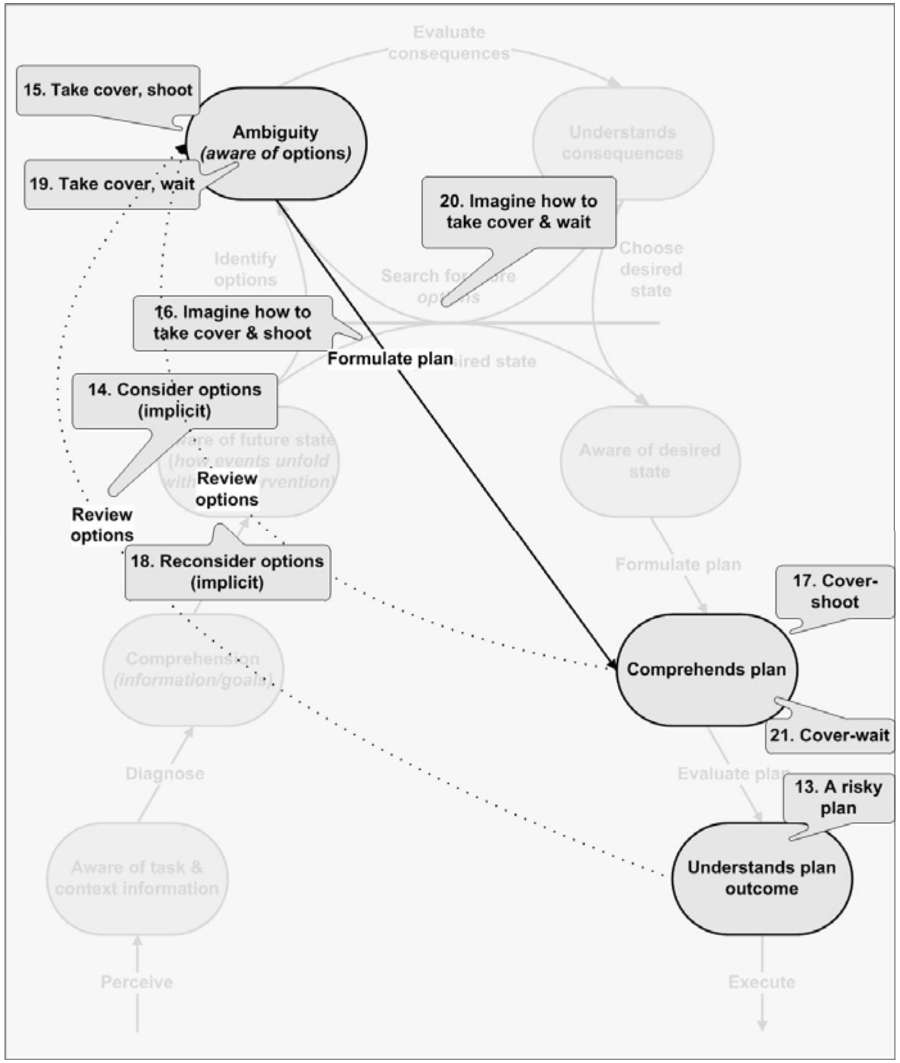

Figure 47: Two strategies (shoot the grenades, take cover & wait) are considered

He then considered shooting the grenades to detonate them and also thought of taking cover to wait for something to happen (Figure 47).

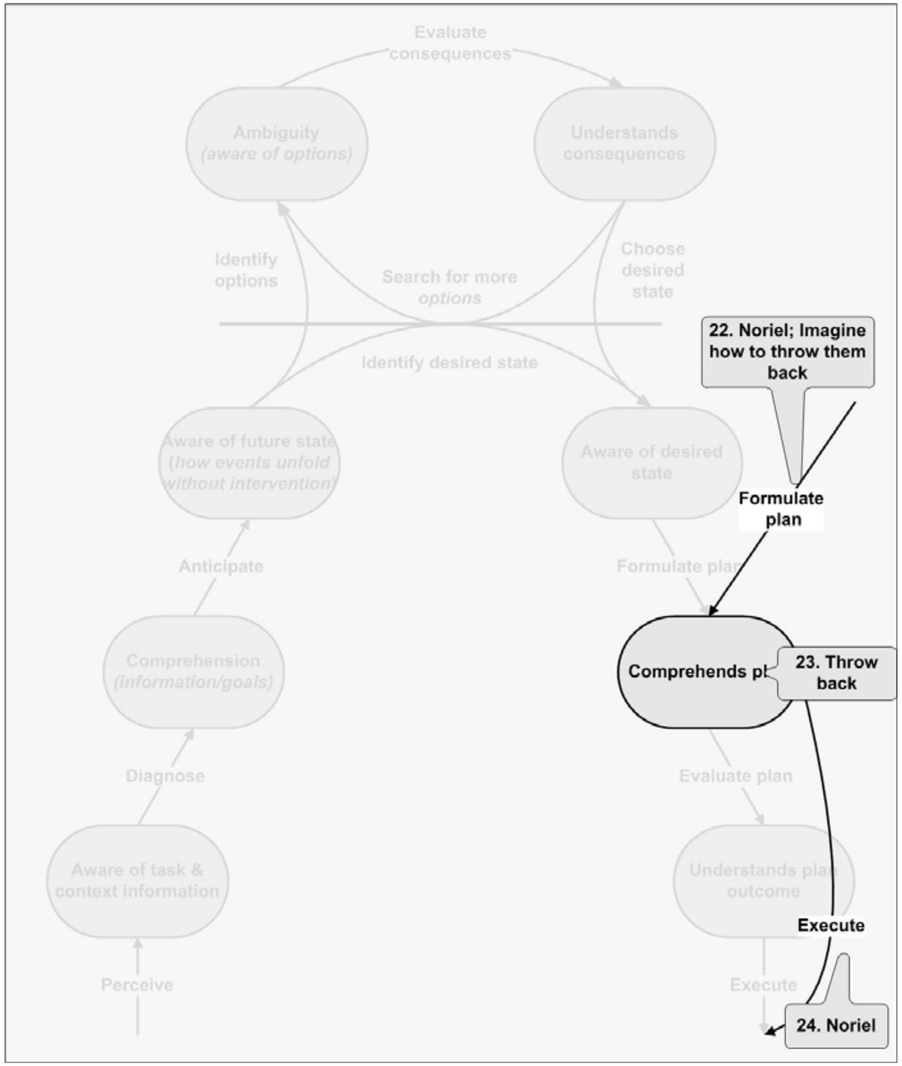

Figure 48: The strategy of seizing the grenades and throwing them back over the wall is planned & executed without further evaluation

While Campbell was considering his options over a period of about five seconds, one of his marines (Noriel) solved the problem by running up to the grenades, seizing each of them in turn and throwing them over a nearby fence (Figure 48).

Courses of Action for Grenade Disposal	
Course of Action	**Reasons for Selection**
Run past & leave	Acceptable only if sure that the grenades will not detonate
Detonate by shooting from a safe distance	Will delay progress & might not work
Wait for detonation	Will delay progress & grenades might not detonate
Pick up and throw over wall	Extremely risky but resolves the problem immediately

Figure 49: Courses-of-action table for grenade disposal showing reasons for preferring the different courses-of-action

The narrative, as mapped onto the decision ladders of Figure 44 to Figure 48, considers four possible courses-of-action. These are summarised in first column of Figure 49. The reasons for preferring one over the others are listed in the second column. These potential courses of action are not strategies because they are specific to the situation described. I will review a second narrative before illustrating how courses-of-action can be used to characterise strategies.

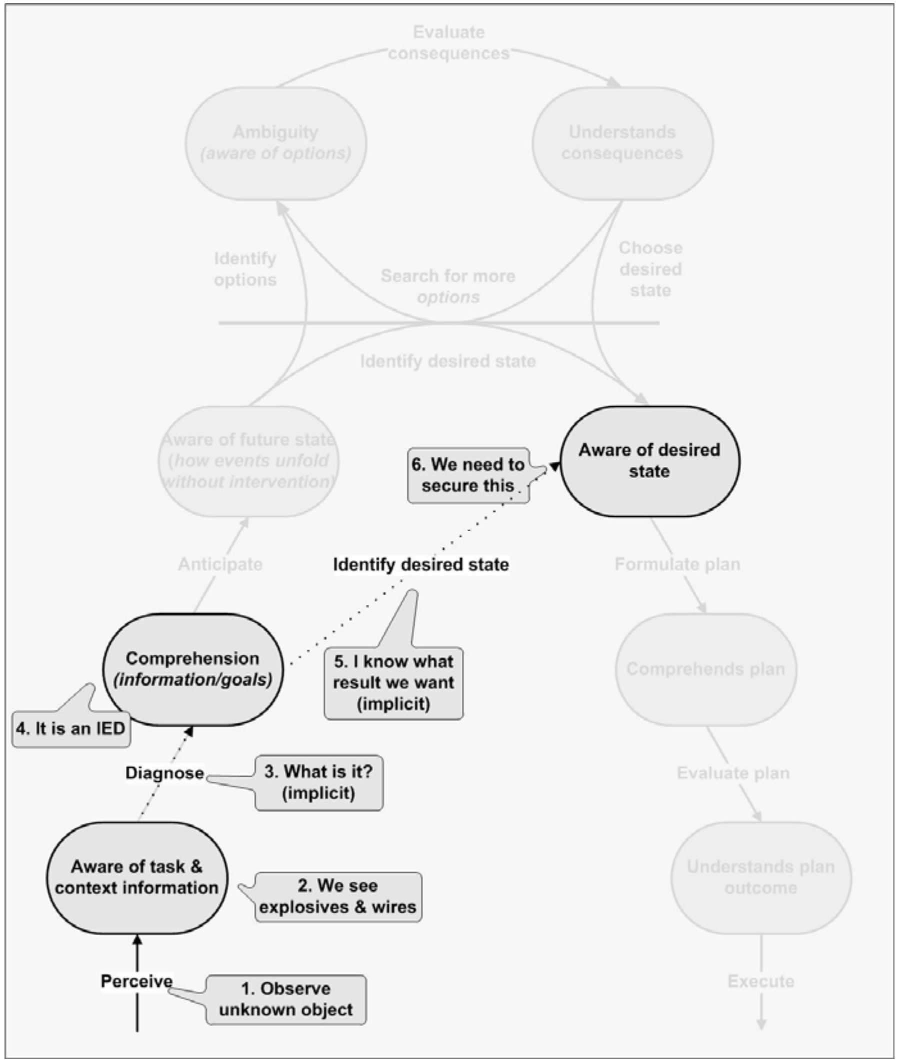

Figure 50: Marines of Joker One identify an Improvised Explosive Device

IED Disposal

A member of Joker One became aware of a suspicious object during a route sweep (Figure 50). After closer inspection, Campbell determined it was and IED and realized that he had to neutralize it.

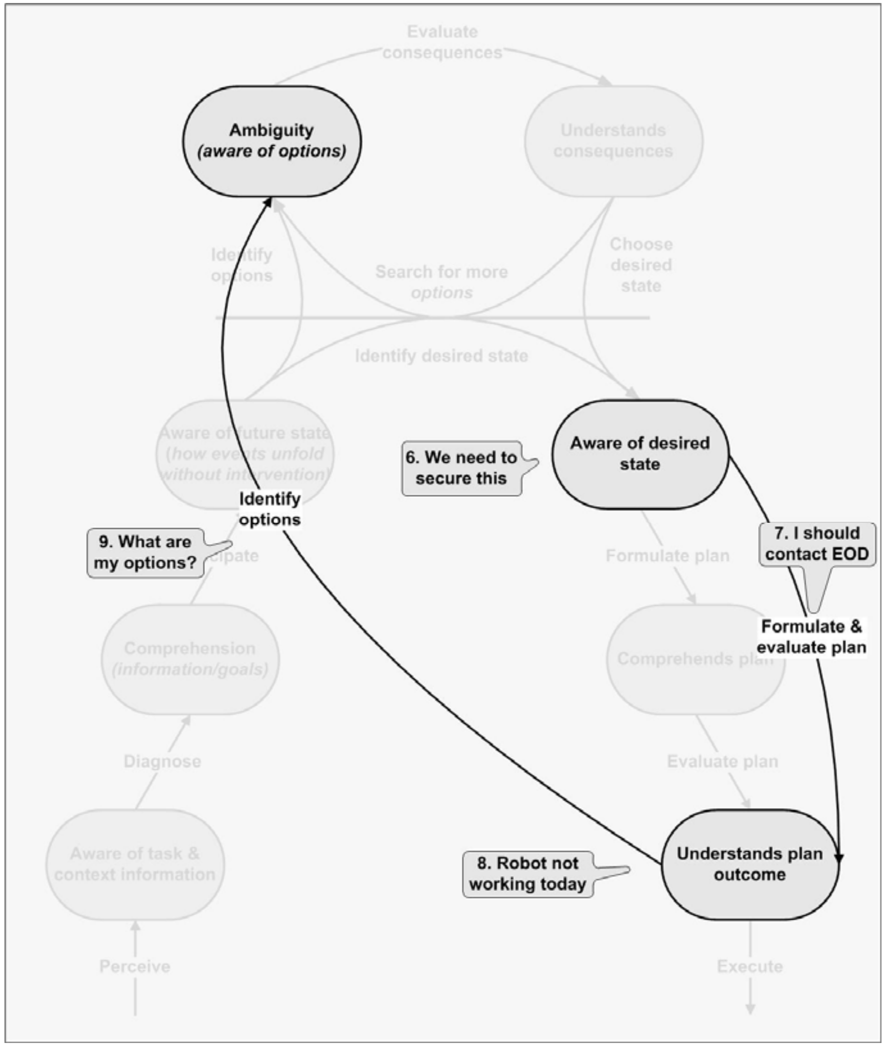

Figure 51: With the robot unavailable the normal strategy of contacting the explosive ordnance disposal unit is not workable

The normal procedure was to contact the explosive ordnance disposal unit (EOD) which would then send and ordnance disposal team with a robot that would be used to detonate the IED (Figure 51). Campbell was, however, aware that the ordnance disposal robot was not operational at that time and he did not know when it would again become available.

On realising there was no point in contacting EOD, Campbell reviewed his options.

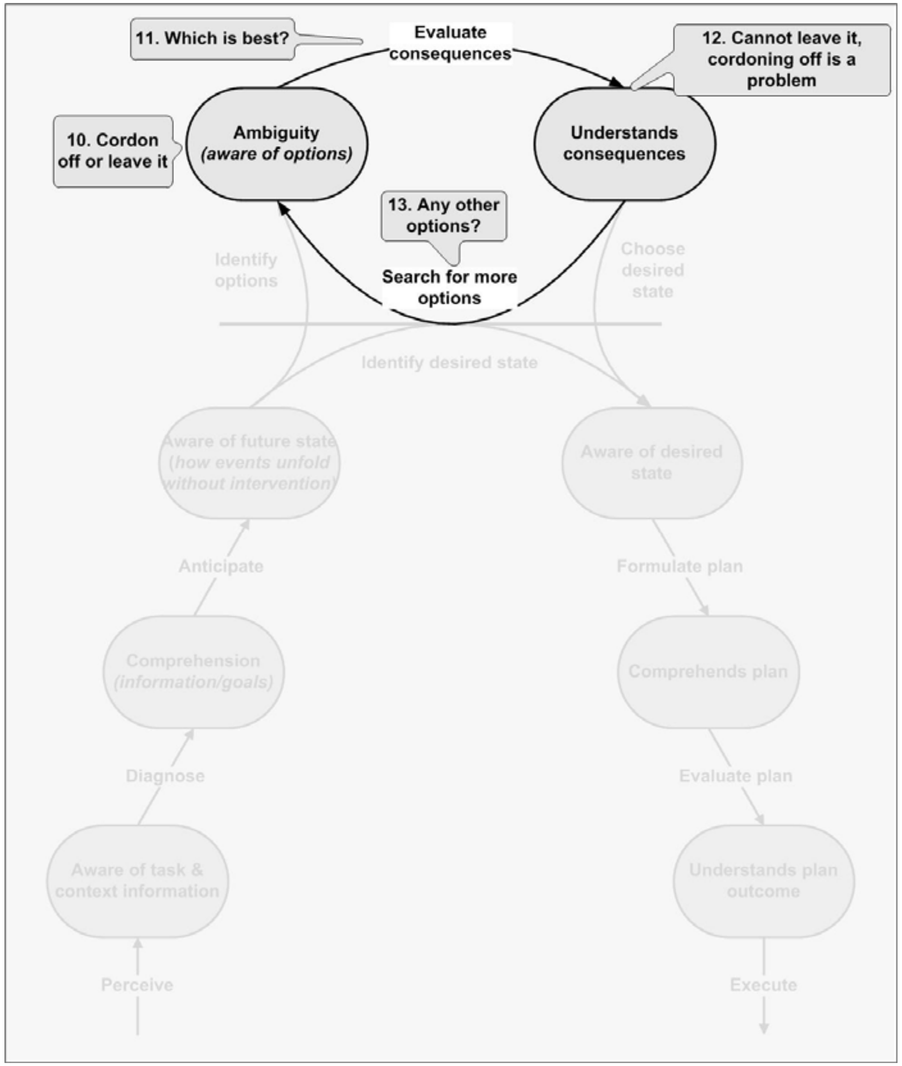

Figure 52: Campbell considers two options (cordon off or leave)

He first considered whether he should set up a cordon around the IED and wait or whether he should leave it and move on (Figure 52). He concluded that neither option was acceptable. He then thought about whether there was anything else he could do.

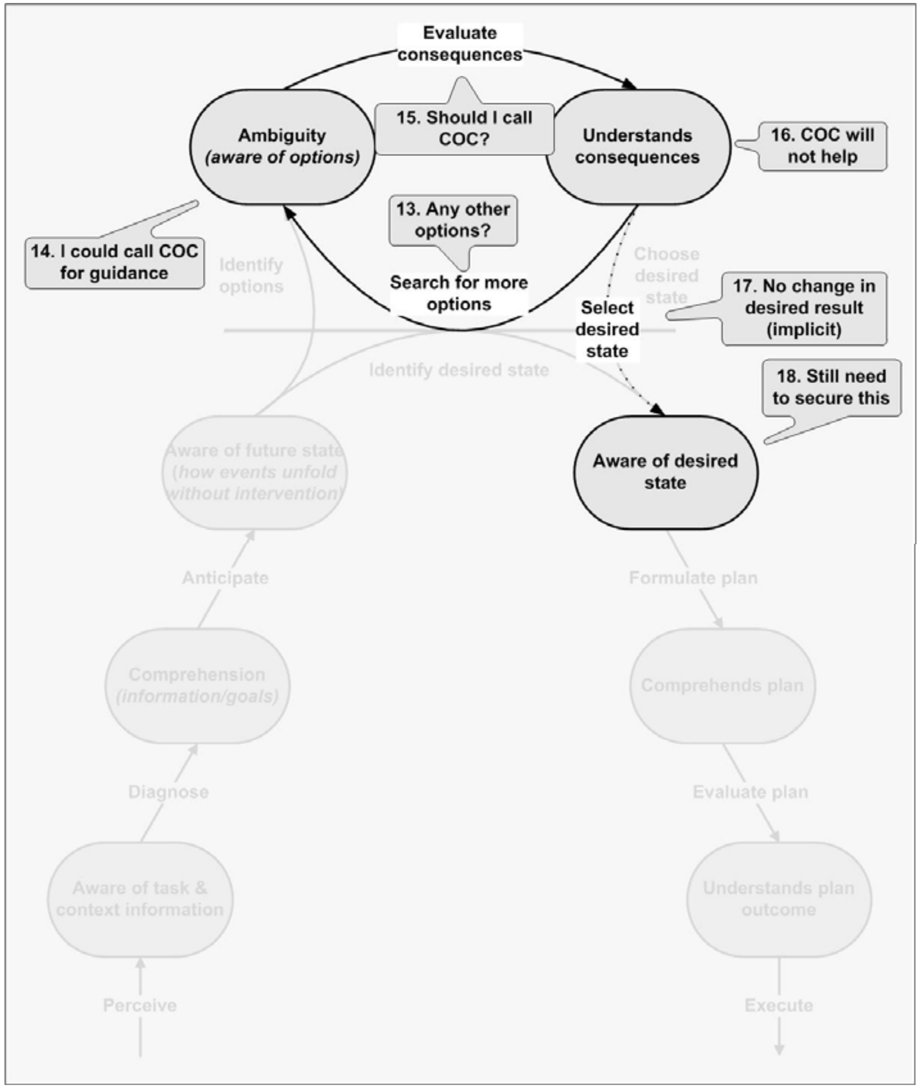

Figure 53: Campbell reviews his options and considers but then rejects the strategy of calling the company's duty officer

He thought of calling his company's duty officer but his earlier experiences with that individual suggested to him that he would not get any useful advice (Figure 53). Thus, he had not identified a workable course of action and was still in the situation that he needed to neutralise the IED.

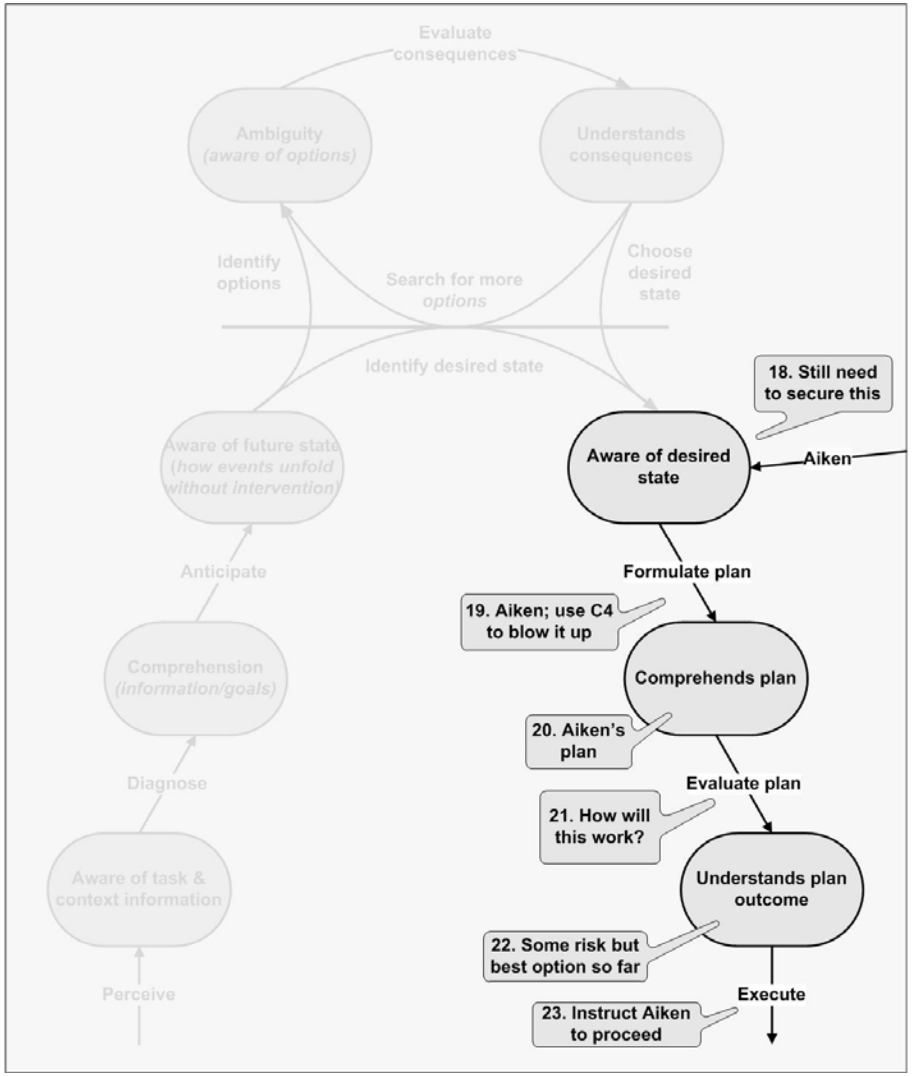

Figure 54: One of Campbell's Marines suggests they blow the improvised explosive device up with C4

While Campbell was contemplating the problem, one of his men (Aiken) suggested that he (Aiken) could use some C4 explosive he was carrying to blow it up (Figure 54). That plan carried some risk because the IED might explode or might be detonated by insurgents as Aiken was setting the charge.

Although fully aware of the danger, this seemed to be the best option available at the time and so Campbell instructed Aiken to proceed.

Courses of Action for IED Disposal	
Course of Action	**Reasons for Selection**
Cordon Off & Call in EOD	The recommended strategy; use this whenever possible
Seek Guidance from Combat Operations Center	Possibly the recommended strategy whenever there is a problem but may create significant issues
Defer Resolution	Not an acceptable solution
Blow Up in Place	Some risk, but at an acceptable level & resolves the situation promptly

Figure 55: Course-of-action table for IED disposal showing reasons for preferring the different courses-of-action

The narrative, as mapped onto the decision ladders of Figure 50 to Figure 54, considers four possible courses-of-action. These are summarised in first column of Figure 55 and the reasons for selecting one or another are listed in the second column. As with the courses-of-action summarised in Figure 49, these potential courses-of-action are not strategies.

The two illustrations offered in this section, grenade disposal and IED disposal, suggest a generic problem, that of disposing of explosives found during patrols or combat engagements. This might be characterised generically as ordnance disposal in the field. A strategies table for this work task is shown in Figure 56. The courses-of-action identified in Figure 49 and Figure 55 are characterised in generic terms and summarised in the first column of the strategies table. For example, *run past and leave* and *wait for the problem to resolve itself* both for grenade disposal and *defer resolution* for IED disposal can be characterised as the same defer resolution strategy. The reasons for selection can similarly be summarised in common terms. In that no course of action for either incident was entirely satisfactory, this problem is ripe for new design ideas, some of which I show in the final column.

Cognitive Strategies for Ordnance Disposal in the Field		
Strategy	**Reasons for Selection**	**Design Ideas**
Cordon off & call In the experts	The recommended strategy; use this whenever possible	Experts need to have redundant systems
Seek Guidance	Do this only if it is likely that someone else will have a viable solution	Identify individuals with a good record of solving problems from a distance and provide direct links to them
Defer resolution	Acceptable only if it does not generate a residual danger	Provide some sort of backup if the platoon has to move on
Resolve immediately with available resources	Generally risky but may be acceptable if the risks associated with delay or failure to resolve are also high	Develop portable system that allows the operator to detonate explosive at a safe distance

Figure 56: Strategies table for ordnance disposal showing reasons for preferring the different strategies

Summary: Cognitive Strategies Analysis

A cognitive strategy is a generic pattern or, alternatively, a behavioural prototype for a work task or a component of a work task. A strategy is a way of transforming one cognitive state into another and is therefore a class of cognitive process. Cognitive strategies analysis identifies the actual and potential strategies that can be or could be used in execution of a work task and the reasons that a particular strategy might be selected in preference to other possible strategies.

The representational product

It is possible to map the alternate strategies onto a decision ladder but a two- or three-column table offers a more convenient representational format. Use the first column to list the potential strategies and add sufficient detail to each to make it clear how the strategy is executed. Use the second column to specify the circumstances under which a specific strategy may be preferred. A third column may be used to list design ideas.

How to do it

The most effective way of identifying strategies is through methods of knowledge acquisition that access the expertise of experienced workers. Focus on the work tasks for which you have already constructed decision ladders. Your earlier discussions with subject matter experts, especially in eliciting knowledge for your work task analysis, should have already uncovered one or more cognitive strategies for many cognitive transformations.

Be aware that strategies are often implicit, that is, the subject matter expert is not always aware of their particulars. You may need a special technique to uncover this information. The critical decision method from cognitive task analysis (Crandall, Klein and Hoffman, 2006) is a good procedure for this. In the execution of this method, an interviewer elicits information from an operational expert about cognitive processes within a specific challenging incident. The operational expert is asked to describe decisions s/he made during an incident and also to describe the information and rules of thumb s/he used during the decision process. S/he is further asked to identify situational features that might have made decisions difficult and situational elements that characterized the incident as familiar. The interviewing team (usually two, an interviewer and a recorder) works through four sequential sweeps; incident identification, time-line verification, deepening and exploration of alternative actions. A number of specific probes are recommended for the final to sweeps but you should feel free to tune these probes to your specific purpose, in this case to identify alternate strategies.

The development of a cognitive strategies table builds on narratives as mapped onto a decision ladder within the work task analysis. Within strategies analysis, any process within a work task narrative that offers different possibilities for its execution are mapped onto the decision ladder as alternate courses-of-action[2]. Information about these different courses-of-action is used to fill out the first column of a courses-of-action table similar to Figure 55. The reasons for selecting one course-of-action over another are entered into the second column. However, a course-of-action is not a generic pattern or behavioral prototype but rather a context-dependent sequence of actions. The analyst must transform the courses-of-action table into a strategies table by inferring the generic or prototypical nature of the activity that has been employed and also the generic or prototypical nature of the reasons for preferring one strategy versus another.

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[2] As noted in the previous section, once an analyst has become familiar with the work activity and how it unfolds, it can be cumbersome to continue by explicitly mapping narratives onto the Decision Ladder.

Relationship to other stages of cognitive work analysis

Work task analysis identifies the cognitive processes involved in execution of a work task whereas cognitive strategies analysis examines the manner in which selected cognitive processes are executed. Thus, cognitive strategies analysis is essentially an extension of work task analysis.

Implications for design

The design goal is to assist workers in their use of effective strategies.

You should seek to develop support for the range of useful strategies rather than to promote one as the preferred strategy. In reviewing your figures or tables, you should consider how challenging the alternate strategies are to execute, how effective they are in accomplishing the work and how well-suited they are to the situational constraints within which they are used. You may already have gleaned some of that from your subject matter experts but you may also have to draw on your own knowledge about effectiveness of strategies from the literature on this topic. Remember that by tapping different cognitive states and processes, different strategies impose different cognitive demands. Assess each strategy as a distinct cognitive event.

If you succeed to this point, you should be able to assess rather easily whether any specific strategy needs some sort of technological or procedural support or possibly should be discouraged in favor of a different strategy. Some strategies are best left alone, but for those for which some intervention is desirable, the next step, to design that intervention, is more challenging. There may be a hint towards an appropriate intervention within the description of the strategy or in observations about why it may be difficult to execute or how it may fail. You might also find some guidance in the literature on design of support for various cognitive activities.

Cognitive Modes[3] Analysis

An action mode is a particular means of accomplishing something. A cognitive mode is, therefore, a particular style of cognitive processing used to execute a work task.

Cognitive modes analysis develops a description of the different modes of cognitive processing that are used to execute cognitive processes and strategies. This stage of analysis identifies and describes the modes associated with work task elements (i.e., cognitive processes and cognitive strategies of work task components).

[3] Following Vicente (1999), I have previously referred to this stage as cognitive competencies analysis (e.g., Lintern, 2009). However, a competency is a capability to perform a task to a certain level of effectiveness, which is not what is assessed in this stage.

Cognitive Modes

Within cognitive work analysis, we refer to cognitive modes of three types;

- Skill based; which has no conscious processing between perception and action and results in highly automated and integrated patterns performed in real time and coupled directly to the environment in a continuous perception-action loop,
- Rule based; which is guided by sets of procedural instructions or familiar perceptual properties that specify sequences of actions, and
- Knowledge based; which is grounded in conscious and explicit reasoning based on a symbolic mental representation of relevant capabilities and constraints.

This three-mode classification stands in contrast to the approach of Kahneman (2011) who refers to two modes, identified in his work as system 1 (corresponding to skill based) and system 2 (corresponding to knowledge based).

Cognitive modes analysis identifies the modes used with various cognitive processes or strategies in the execution of a work task. Cognitive processes and cognitive strategies do not typically involve only one cognitive mode but rather may rely on a combination of two modes or on all three.

The Cognitive Modes Table

The product of this stage of analysis is a detailed description of the activity elements involved in executing the cognitive processes identified in the work task analysis or the cognitive strategies identified in the cognitive strategies analysis. A table offers the best representation for this information.

As in cognitive strategies analysis, it is possible to annotate a decision ladder with the appropriate information but an adaptation of the table developed for cognitive strategies analysis offers a more convenient representational format (Figure 57). The first column identifies work task elements such as cognitive processes, clusters of cognitive processes or potential strategies. If the first column specifies strategies, it can be useful to repeat the *Reasons for Selection* from the strategies table in a center column as shown in Figure 57. The next column specifies the cognitive modes associated with particular strategies or work task elements and another column may be added to propose design ideas.

Work Task			
Work Task Component Strategy or Process(es)	**Reasons for Selection** (if relevant)	**Cognitive Mode(s)**	**Design Ideas**

Figure 57: A template for a cognitive modes table

In this section I will work through two illustrations. The first continues the ordnance disposal strategies analysis to identify the cognitive modes associated with each strategy. The second examines the cognitive modes associated with planning the ambush mission.

Joker One: Cognitive Modes Analysis

Ordnance Disposal

I identify the strategy of *cordoning off the ordnance and calling in the experts* (the explosive ordnance disposal unit) as rule-based because it appears to be a standard operating procedure.

I identify the strategy of *seeking guidance* as knowledge-based because it requires distinguishing who might be able to help from those who would waste time or add to the difficulty. I identify the strategy of *deferring resolution* as skill-based on the assumption that this choice would be guided by implicit recognition of the difficulty of doing anything about the unexploded ordnance.

I identify the strategy of *resolving the problem immediately with available resources* as partially skill-based on the assumption that this choice will be guided by implicit recognition of the opportunity and partially as a knowledge-based because of the need to reason through the method of adapting resource for a different purpose.

In that the narratives of Joker One are not sufficiently explicit to establish a definite interpretation of all cognitive modes to be used, I made inferences based on my own experience to complete column three of Figure 58. Within a project in which subject matter experts were available for further discussion, these inferences would need to be confirmed by further exploration.

Cognitive Modes for Ordnance Disposal Strategies		
Strategy	**Reasons for Selection**	**Cognitive Mode(s)**
Cordon off & call In the experts	The recommended strategy; use this whenever possible	Rule-Based: Follow guidance
Seek Guidance	Do this only if it is likely that someone else will have a viable solution	Knowledge-Based: Know who can be relied upon for resolving challenging problems
Defer resolution	Acceptable only if it does not generate a residual danger	Skill-Based: Recognize the extreme challenge
Resolve immediately with available resources	Generally risky but may be acceptable if the risks associated with delay or failure to resolve are also high	Skill-Based: Recognize situational opportunity Knowledge-Based: Reason through a solution

Figure 58: Strategies and modes for ordnance disposal

Ambush Mission

There was insufficient information in Donovan Campbell's book to complete a systematic modes analysis for the ambush mission. For the following illustrative analysis, I have gone beyond the details contained in the book to make some inferences about how Donovan Campbell might have gone about this work.

I have assumed four components for planning, those being;

- anticipation of where the insurgents will go and how they will behave,
- planning how Joker One would manoeuvre and position at the ambush site,
- planning of ingress and egress routes, and
- coordination with the combat operations center.

Based on an imagined discussion with Donovan Campbell, I conclude the following:

Campbell will anticipate where the insurgents will go and how they will behave by studying any intelligence he can acquire on the insurgents and by studying the local area map and then reflecting on his experience with insurgent behaviors. The first of these is knowledge-based and the second is skill-based.

In planning the platoon's manoeuvers and positioning at the ambush site, he will study the map for sightlines but also implicitly notice opportunities for advantageous positioning and maneuvering based on his own experience. As before, the first of these is knowledge-based and the second is skill-based.

In planning the platoon's ingress and egress routes, he will use a map to reason about how he could trade-off stealth against ease of movement. He will estimate his travel time and how to evade detection with implicit judgments informed by his own experience. As before, the first of these is knowledge-based and the second is skill-based.

In coordinating with the combat operations center, he will follow procedures. This is therefore rule-based.

I have entered these judgments into the second column of Figure 59.

Cognitive Modes for Mission Planning (Tactical)		
Work Task Component	**Cognitive Mode(s)**	**Design Ideas**
Adversary Location & Behavior	Knowledge-Based: Study map & visit site	More detailed map Distributed collaborative system to get assistance from platoon leaders previously assigned to the area
Own-Force Positioning & Maneuvering	Knowledge-Based: Visit site to identify sight lines & advantageous positioning Skill-Based: Recognize advantageous positioning based on training experience	Air surveillance system (micro, remote-control, video cam payload) to reconnoitre area Intensive recognition training
Ingress & Egress Routes	Knowledge-Based: Use map to trade off stealth & ease of movement Skill-Based: Use experience to estimate travel time & to evade detection	Hand-held planning tool to assist with replanning en-route Intensive recognition training
Coordination with Combat Operations Center	Rule-Based: Follow procedures	After-Action Review to include combat operations staff

Figure 59: Cognitive modes for mission planning

In the development of cognitive interventions, you must support the particular modes of cognitive processing where they are to be used in the execution of work tasks.

- Support the information aspects of skill-based processing with familiar perceptual patterns. Support its action aspects with forms of direct manipulation.
- Support the information aspects of rule-based processing with familiar perceptual patterns linked in procedural sequences that show a consistent one-to-one mapping between the work domain constraints and the information provided at the interface. Support the action aspects with manipulative capabilities that are linked directly to the perceptual forms that are intended to stimulate the action.
- Support the information aspects of knowledge-based processing with an information resource that encourages workers to assemble the necessary constellation of information for the current activity; activities such as of decision making, maintaining situation awareness, planning or anticipating the future. That constellation should contain all necessary information in a form that can be readily assimilated (its meaning in the current context should be readily evident). The information contributing to the constellation should be filtered to ensure it does not include distracting elements. The action aspect of knowledge-based processing may be supported with planning and modelling tools.

Do the design ideas offered in Figure 59 implement these principles? The design ideas for adversary location and behaviour suggest ways of gathering more information, thereby supporting the knowledge-based mode of cognition. The design ideas for coalition positioning and manoeuvring similarly suggest a means of gathering more information to support the knowledge-based mode of cognition but also suggest intensive recognition training as a means of supporting the skill-based requirement for recognition of advantageous positioning. The design ideas for ingress and egress routes offer similar support for knowledge-based and skill-based modes of cognition. The design idea of after-action reviews for coordination with combat operations center supports the rule-based mode by encouraging the two interacting groups to work out effective procedures.

Summary: Cognitive Modes Analysis

A mode is a particular means of accomplishing something. A cognitive mode is a particular style of cognitive processing used to execute a work task. Within cognitive work analysis, we refer to three modes of cognition; skill-based, rule-based and knowledge-based. The skill-based mode has no conscious processing between perception and action, the rule-based mode is guided by sets of procedural instructions that specify sequences of actions, and the knowledge-based mode is grounded in conscious and explicit reasoning. Cognitive modes analysis identifies the modes of cognition used with various cognitive processes or strategies in the execution of a work task.

Following Vicente (1999), this stage of cognitive work analysis is typically identified as cognitive competencies analysis where a competency is a qualitatively distinct ways a worker can interact with the environment. However, the word *competency* more commonly refers to a capability to perform a task to a certain level of effectiveness. By referring to skills, rules and knowledge, we are identifying characteristic patterns of behaving rather than levels of competency. Vicente occasionally uses the term *mode* as an alternative to *competency*. In this tutorial, I prefer the use of *mode* to characterize this stage because its normal meaning aligns with the intent of the analysis whereas the normal meaning of *competency* does not.

The representational product

The product of this stage of analysis is a description of the activity elements associated with the different modes of cognitive processing. As in cognitive strategies analysis, it is possible to annotate a decision ladder with the appropriate information but an adaptation of the table developed for cognitive strategies analysis offers a more convenient representational format. As before, the first column is used to list work task components or cognitive strategies. Another column is used to specify the cognitive modes associated with particular work task components or cognitive strategies. A third column will list design ideas for support of the work task elements or strategies.

How to do it

For cognitive modes analysis, you must identify the types of information used in various strategies, how that information is transformed and how it is put to use. For both knowledge- and skill-based processing, identify what information is used, how it is accessed, how it is transformed and how it is used. For rule-based processing, identify procedures or activity sequences used to accomplish specific strategies. The most effective way of proceeding systematically with this analysis is to extend the methods of knowledge acquisition you have used in the previous stage of strategies analysis. In general, you should integrate the knowledge acquisition efforts from these two stages.

I noted in the previous chapter that strategies are often implicit, that is, the subject matter expert is not always aware of their particulars. This is especially true for skill-based processing. For this mode, you are unlikely to find anything that is useful in documents and you are an unlikely to get much from subject matter experts unless you approach this carefully. This is where the critical decision method as described by Crandall, et al (2006) and as I described in the previous chapter, becomes most useful. It was developed to uncover information about implicit skills. In the use of this method, I adjust the approach described by Crandall, et al (2006) to devote the third sweep to probes that will identify strategies and the fourth sweep to probes that will explore the skill-based mode of cognitive processing. I also include probes related to the other processing modes to the extent I am dissatisfied with the coverage provided from document analysis or from less structured discussions with subject matter experts.

Relationship to other stages of cognitive work analysis

Cognitive modes analysis is essentially an extension of cognitive strategies analysis.

Implications for design

You must support the particular modes of cognitive processing where they are to be used for execution of work tasks.

Functional Workspace Design

A functional workspace is one in which fragmented and dispersed data from the operational world has been transformed first to information and then to meaning by application of work-focused analysis and design tools. The result is a workspace that represents function and meaning and that offers functionally direct action capabilities.

The foundational image is of a natural environment that offers diverse, heterogeneous information mapped directly to the affordances offered by the natural environment, with action opportunities that work directly on the affordances as a means of achieving human goals.

Ecological Interface Design

The purpose of cognitive work analysis is to organise and summarise the dimensions of work so that we can grasp its substantive properties in order to proceed with design. Cognitive work analysis is typically associated with a design method termed ecological interface design.

Most generally, ecology is the study of interactions between organisms and their environment. In reference to human cognition, it refers to the ways in which our surrounding environment influences the way we think and how we reshape our surrounding environment to assist or support our thinking.

It might seem that our natural environment is exquisitely tuned to our mode of cognition, but that is not the case. Rather, through the innate plasticity of our cognitive structures, our cognitive system becomes exquisitely tuned to the opportunities offered by our natural environment. Our innate creativity then encourages us to reshape our environment so that it becomes even more compatible with our cognitive structures.

This is the sense in which Gibson (1979) used the term in his development of the ecological approach to visual perception. Rasmussen et al (1994, P 125) argued that their approach to information system design was ecological in Gibson's sense because it leads to interfaces that allow the deep structure of the work domain to be accessible to direct perception. They called this the ecological approach to information system design, which Vicente (1999) shortened to ecological interface design.

However, the term ecological is open to misinterpretation because it has been adopted by a number of influential theorists within psychology who, *although sharing a broader viewpoint, otherwise hold somewhat different perspectives* (Heft, 2001, p xv). Even more troubling, this term is often used in our profession to stand in for other entirely unsatisfactory terms such as *natural* or *real world*. In that sense it is used to mean *outside the laboratory*.

Any implication that ecological means *natural* or *real world (i.e., outside the laboratory)* distorts the meaning of ecological. James Gibson, for one, and Eleanor Gibson for another, did much of their ecological research in laboratory settings. They thought of their research as ecological because they were interested not in how information impinged on human receptors (the prevailing concern of perceptual psychologists of their time) but in how human observers interacted with their environment, not only reacting to information presented by their environment but also reacting to information they found or generated through their own actions.

Functional Workspace Design

Given the frequent misinterpretation of the term *ecological*, I prefer to avoid it. The term *functional* is less puzzling and is generally better understood. Thus, I refer to functional rather than to ecological design.

Additionally, I like to think of the product that ensues not as an interface sitting between a human operator and a technical system but as a workspace where a worker can access information, work with it, and then do something based on any new understandings arising out of that cognitive activity. Thus, I prefer to think of this as workspace design rather than as an interface.

Thus, my preferred term, functional workspace design. In summary, the product is a functional workspace (or, possibly, an information-action workspace) that provides a portal to all information that is potentially useful in a work environment and that fully supports all essential activities.

Data to Meaning

As I note above, the foundational image is of a natural environment that offers diverse, heterogeneous information mapped directly to the affordances offered by the natural environment, with action opportunities that work directly on the affordances as a means of achieving human goals. An operational world is rarely configured in this manner. Most commonly, there are multiple and diverse sources of information that are poorly integrated and difficult to interpret in terms of desirable action.

Figure 60 depicts the challenge. The operational world contains decentralised data that reveal a fragmented picture. Some form of work-focused analysis and design is needed to transform that fragmented picture into a workspace in which the function of physical objects in the operational world and the action-relevant meaning of information can be readily assessed. While many different analysis methods and design methods might facilitate some progress on this problem, the combination of cognitive work analysis and functional workspace design offers an integrated framework that supports a comprehensive and systematic approach.

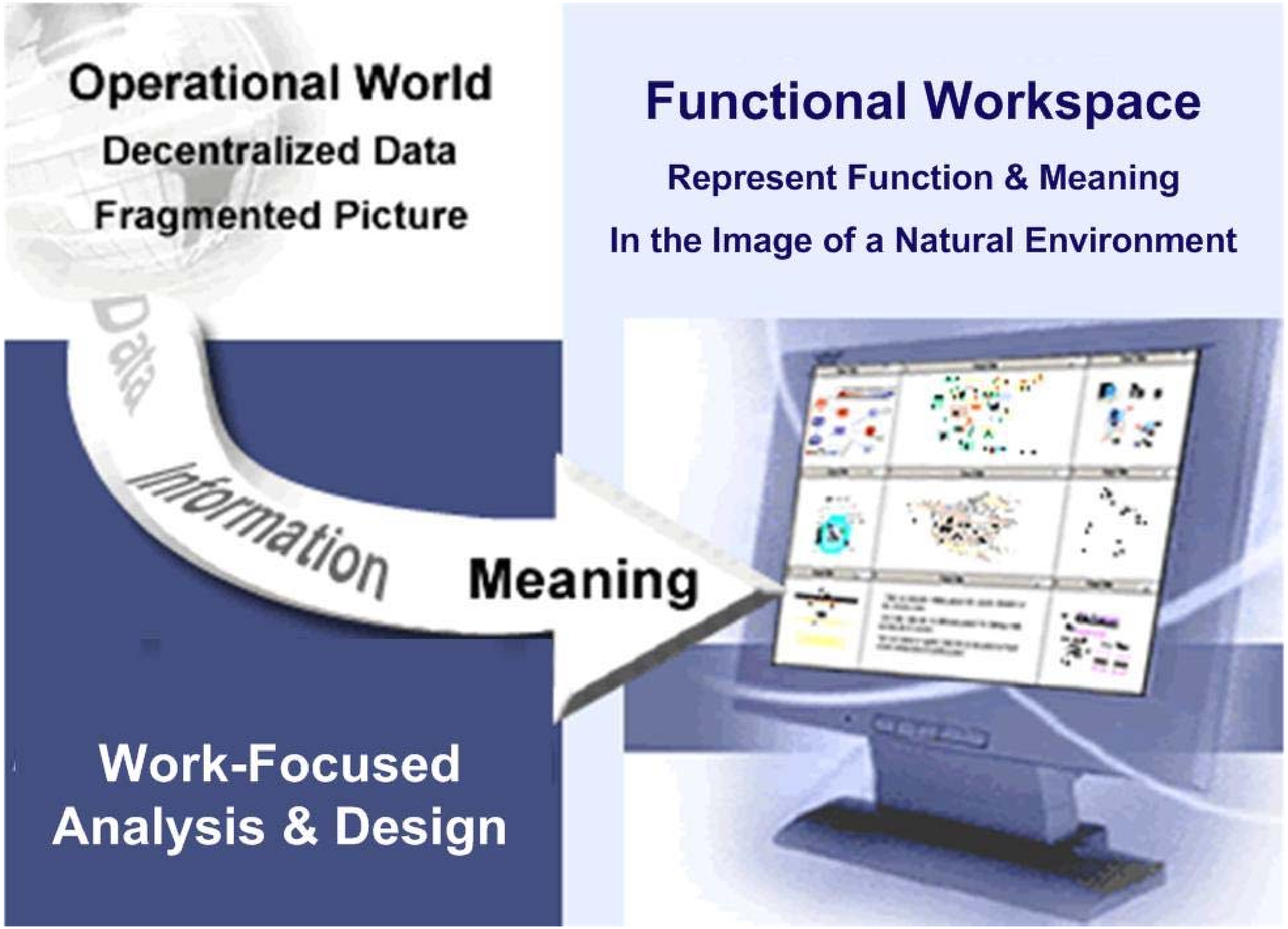

Figure 60: Work-focused analysis and design transforms the fragmented picture of the operational world into a functional workspace in which the function of physical objects the meaning of information can be readily assessed.

Functional Workspaces

A standard workspace offers a number of information sources that reveal individual parameters of system states. Such workspaces serve to guide workers through set courses of action but leave them with the task of integrating the many parameters into a meaningful interpretation of system function. This can be cognitively demanding and may be impossible under tight time constraints. In contrast, a functional workspace is one in which information is structured in a manner that reflects the structure of the cognitive work so that workers can assimilate the information readily and then act on it in naturally compatible ways.

It might initially seem that the flood of information available through a functional workspace would result in cognitive overload. However, think of libraries, many of which have thousands upon thousands of books. We do not suffer cognitive overload when we walk into a library because the library system is structured in a manner that allows us to be selective. Even if we do not know what we want, we can converge quite rapidly onto satisfactory resources.

Similarly, functional workspaces present more information than conventional interfaces without overloading us. They use integrated capabilities to permit more work with less cognitive effort. They do so by providing multiple integrated capabilities with complex nestings and overlaps at diverse levels of abstraction. They reveal the operation of underlying system processes, the interactions between system states, and the constraints on action and draw attention to critical sources of information by use of symmetric displays and frames of reference.

On the activity side, they emphasize seamless and robust navigation between resources so that workers can converge naturally on momentarily important constellations of information. They provide robust, accessible action modes and diverse action capabilities via multiple-dimension controllers and direct, compatible action modes.

The common techno-centric approach to displaying a mass of information is a multidimensional matrix in which different sources are tagged and possibly color-coded with cells provided for the state values. Nature does it differently. The multiple sources of information that assail us as we operate in the world come in endless sizes, shapes, intensities and forms. It is this diversity that helps us make sense of what is around us. We readily filter the relevant from the irrelevant and we readily discriminate the relevant items from each other and recognize the meaning of each of them for the work at hand. Within a short while, later today, or possibly tomorrow, the work will be different, and some of what is irrelevant now will become relevant then. Some of what is relevant now will become irrelevant then. For that new work, we will readily assemble a new constellation of information that will help us act within the new circumstances.

In summary, a functional workspace has much in common with a natural workspace, one in which there are diverse and functionally relevant sources of information that can be explored and acted upon in diverse ways. Such a workspace encourages workers to operate within a space of potential action, leaving them free to develop solutions to complex patterns of events that cannot be anticipated. It encourages a stronger appreciation of emerging issues and opportunities and promotes more robust and more accurate performance. Finally, it helps novices shape their behavior to that of experts as it places less reliance on selection and training.

The Role of Cognitive Work Analysis

The design of a functional workspace flows naturally from the products of cognitive work analysis. Each stage contributes critical information (Figure 61).

- Work domain analysis provides a catalogue of all functional properties that should be represented in the workspace.
- Work organisation analysis identifies situations in which the workspace will be used and the work tasks that will be relevant to each situation. A situation selector that foregrounds the relevant task related information can be provided in a workspace.
- Social organisation analysis identifies the communication and coordination tools that should be embedded in the workspace.
- Work task analysis identifies the cognitive states and cognitive processes that will need to be supported. Figure 41 offers illustrative suggestions for cognitive state and cognitive process supports.
- Cognitive strategies analysis identifies the types of strategies that need to be supported, thereby suggesting specific design options for support of cognitive processes.
- Cognitive modes analysis identifies whether cognitive process interventions should be tuned to skill-, rule- or knowledge-based behaviour in accordance with the formative design principles discussed on page 106 under the heading of Implications for design.

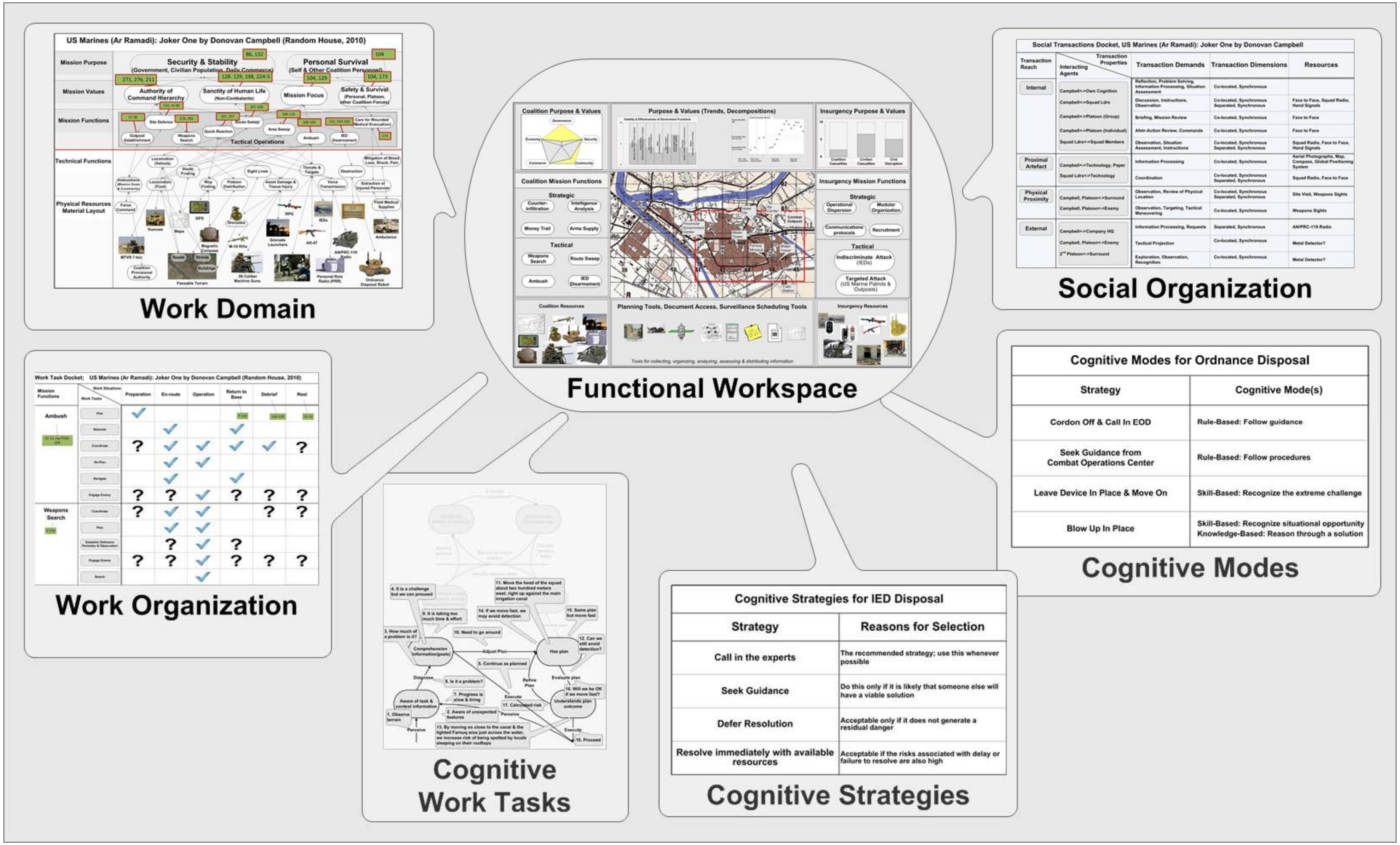

Figure 61: Each stage of cognitive work analysis contributes critical information to the design of a functional workspace

Layout, Form and Navigation

Beyond the implications of cognitive work analysis, decisions must be made about layout, form, navigation and action.

Layout

In my early applications of cognitive work analysis to workspace design, I used a layout that mimiced an abstraction-decomposition space. That did not work well. I eventually adapted a six-panel view-port layout from the Dinadis and Vicente (1999) into a nine-panel layout as shown in Figure 62. I have found this to be an effective layout for workspaces related to adversarial action over a geographic area of operation.

The center panel, which provides a situation map of the area of operation, is surrounded by the resources and constraints that support and influence the work. I typically depict coalition resources in the left-hand column and adversary resources in the right-hand column. The top row deals with values, with the top left and the top right corners containing representations of coalition and the adversary values respectively. The center top panel shows more detail of selections from either the top left or top right panels.

Domain functions are depicted in the center-left and center-right panels. With large organizations in general, and military organizations specifically, it is often useful to classify domain functions as either strategic or tactical. Further detail on selected domain functions can be displayed in the bottom left and bottom right panels.

The bottom center panel provides access to planning, scheduling and analysis tools.

Forms

I have developed a library of perceptual forms by co-opting ideas from the human factors and engineering literature and from books on visualisation and display design. I have also accumulated a number of potentially useful forms from websites and from innovative working systems. I allow my selection of a form for a specific element of information to be guided by the representational requirements. I find that representational requirements can typically be established by reference to the functional properties identified in the abstraction decomposition space. Figure 63 offers a list of the types of formats I employ in my designs, referenced against representation requirements and functional properties of the domain.

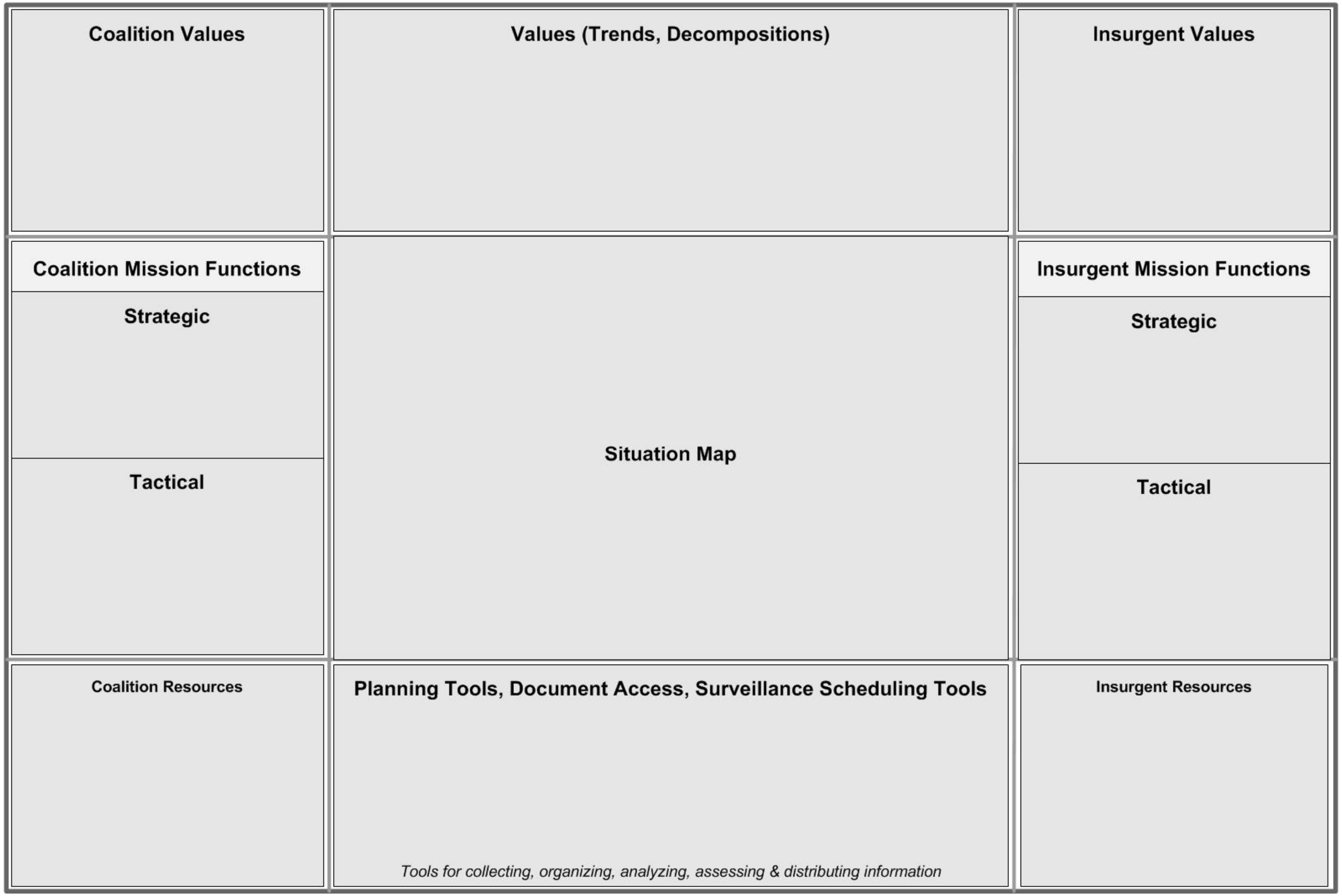

Figure 62: A nine-panel layout for workspaces related to adversarial action over a geographic area or of operation

Functional Properties	Representation Requirements	Formats
System Purpose	Overview	Configural Displays Limit-Constraint Diagrams
Values	Balances, Contrasts	Configural Displays Displays of Balances & Relationships between Functions & States Priority Indicators
Domain Functions	Relations Affordances Status of process variables with reference to target states & to the limits of acceptable operation	Predictor Elements & Envelopes Visual Perspective & Gradients Fields Of Action State-Space Diagrams
Technical Functions	States Trajectories Capabilities Magnitudes, Accumulations Dispersions Persistence Temporal Proximity Availability	Symbolic Diagrams Target Lists Visual Perspective Constraint Boundaries, Limit Envelopes Icons, Symbols, Signs Access & Routing Diagrams, Flow Maps Temporal Access & Availability Indicators Time to Contact Indicators
Physical Resources Material Layout	Topography, Layout Location Size Color Designation, Identifier Time	Object Representations Icons, Symbols, Signs Mimic Diagrams Pictures Routes, Paths, Connections Locations

Figure 63: A sample of display formats referenced against representation requirements and functional properties

Note that while I consider this list currently complete, I imagine I will keep adding to it over time.

Navigation and action

For navigation and action, I rely heavily on the standard select and drag-and-drop functionality of modern computer operating systems. For dynamic action, I rely on predictor and aiding algorithms as well as on automated subroutines.

A Functional Workspace for Counter Insurgency

General Structure

Figure 64 depicts a workspace for counterinsurgency in Iraq. Values, functions and resources represented in this workspace are taken from the various abstraction-decomposition spaces discussed earlier in this tutorial. The three-panel columns to the left and right display the values, domain functions and resources for both the coalition (left) and the insurgents (right).

Figure 64 shows one configuration based on analyses described above. The tactical domain functions for the coalition and the insurgent are drawn from Figure 20 and Figure 21. The strategic domain functions for the coalition and the insurgent are drawn from analyses not presented in this tutorial.

The upper-left and upper-right panels display parameter summaries for coalition and insurgent values. The use of two different display forms for these two panels is intended to show possible variations rather than to suggest that the coalition and insurgent values should be represented by different forms.

The upper-left panel uses a pentagram to display five values relevant to the counterinsurgency operation in Iraq. These are *governance*, *economic stability*, *commerce*, *security* and *community stability*. The global score for each is derived from a combination of factors. These global scores are normalised so that a symmetric figure, in support of skill-based cognition, will indicate that the counterinsurgency is satisfying the values. Any distortion in the pentagram will indicate a problem that the analyst or planner might investigate.

The upper-right panel uses a histogram to display three values relevant to insurgent values. These are *coalition casualties*, *civilian casualties* and *civil disruption*. Low values indicate that the insurgents are not satisfying their values.

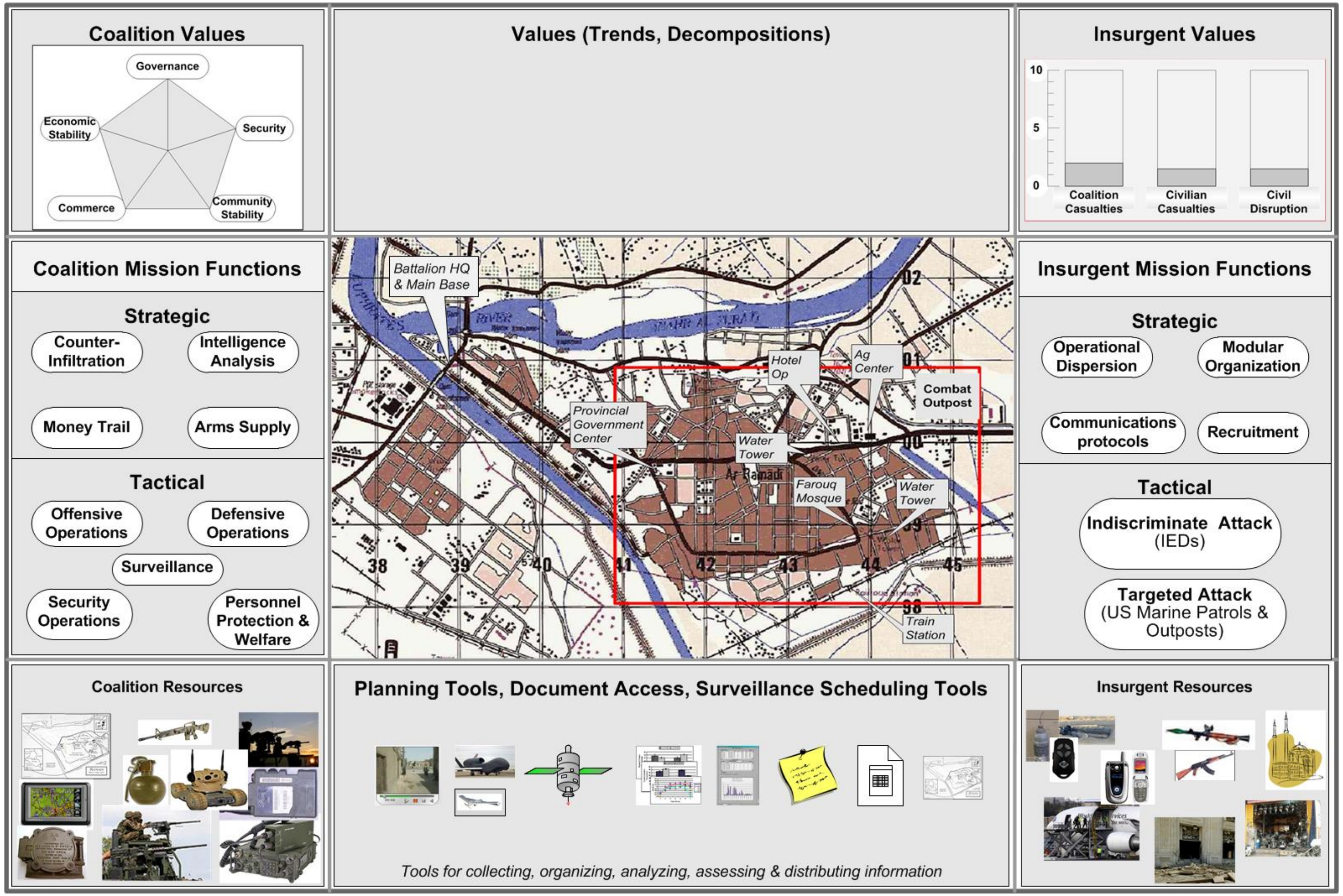

Figure 64: A counterinsurgency workspace

An analyst or planner will be able to get more detailed information about factors underlying a value by interrogating the appropriate label. An interrogation will insert that more detailed information into the upper-center panel as will interrogation of an insurgent value.

The left-center panel shows the strategic and tactical domain functions for coalition forces. Strategic and tactical domain functions for insurgents are shown in the right-center panel. Both sets of resources are represented in a functional workspace so that coalition analysts and planners can compare own resources to adversary's resources. This comparison should facilitate development of tactics and strategies in which own resources are deployed to good effect in countering adversary resources.

The bottom-left and bottom-right panels are reserved for coalition and insurgent resources. Interrogation of a domain function in the left-center or right-center panels will insert relevant resources into one of those bottom corner panels. Interrogation of a particular resource will activate a pop up window with a summary of the technical capabilities of that resource.

The center panel contains a situation display, essentially a map of the operational area. The geographic coverage of the situation display is flexible. Strategic operations are likely to require larger coverage than tactical operations. As with most other resources, the map can be enlarged, as shown in Figure 65.

The bottom-center panel provides access to a number of tools that can support analysis and planning.

Illustration: Values

Figure 66 repeats the workspace of Figure 64 but now shows a problem with *civilian casualties* inflicted by insurgents and with the coalition value of *governance*. By interrogating each of these (by mouse click), the analyst or planner can display more detailed representations in the upper-center panel. Figure 67 shows how either of these detailed representations might be expanded to examine the problem more closely. The pop-up for *civilian casualties* is modelled after a graphical module described by Tufte (1997, p110-111).

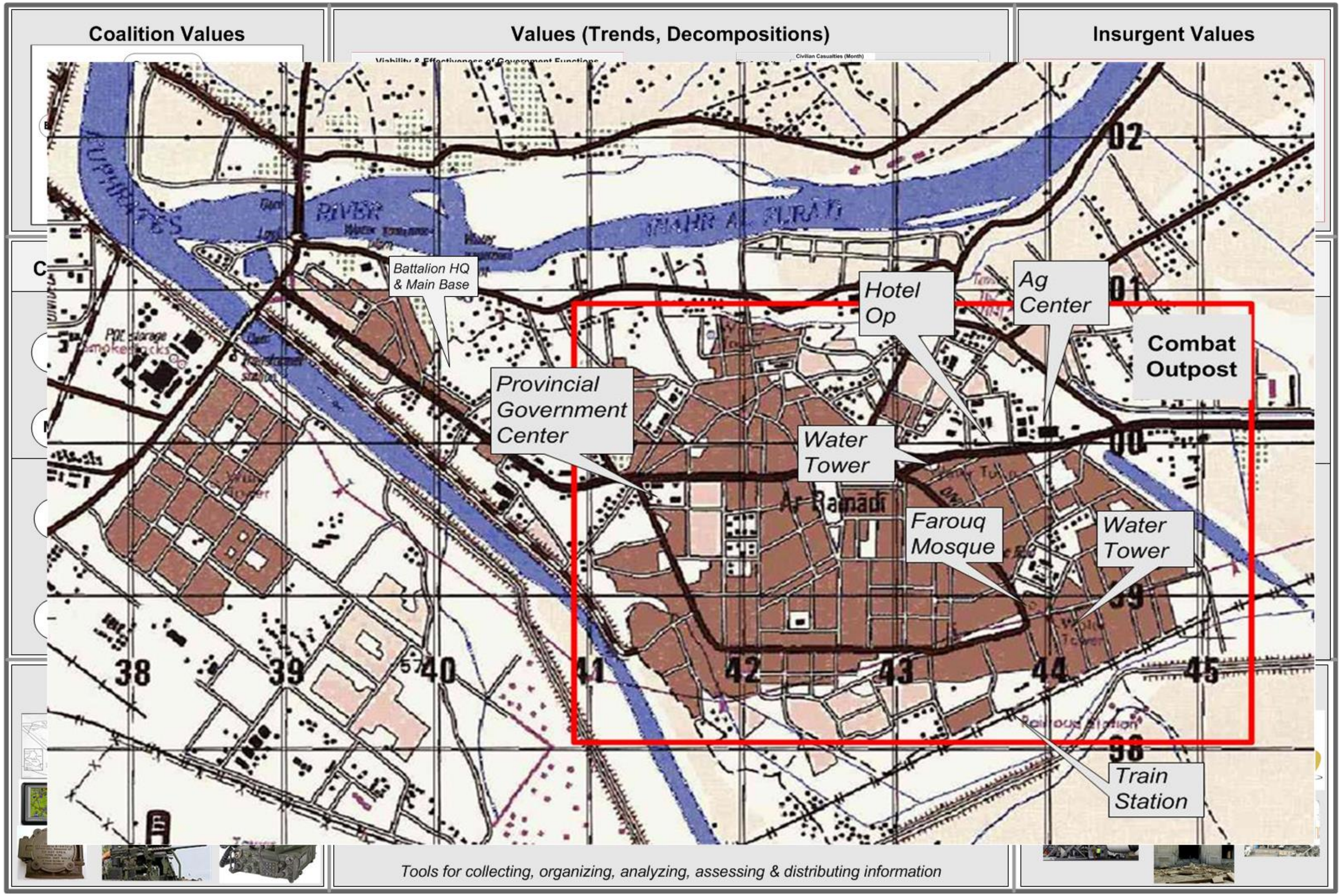

Figure 65: The counterinsurgency workspace of Figure 64 with an enlarged situation display

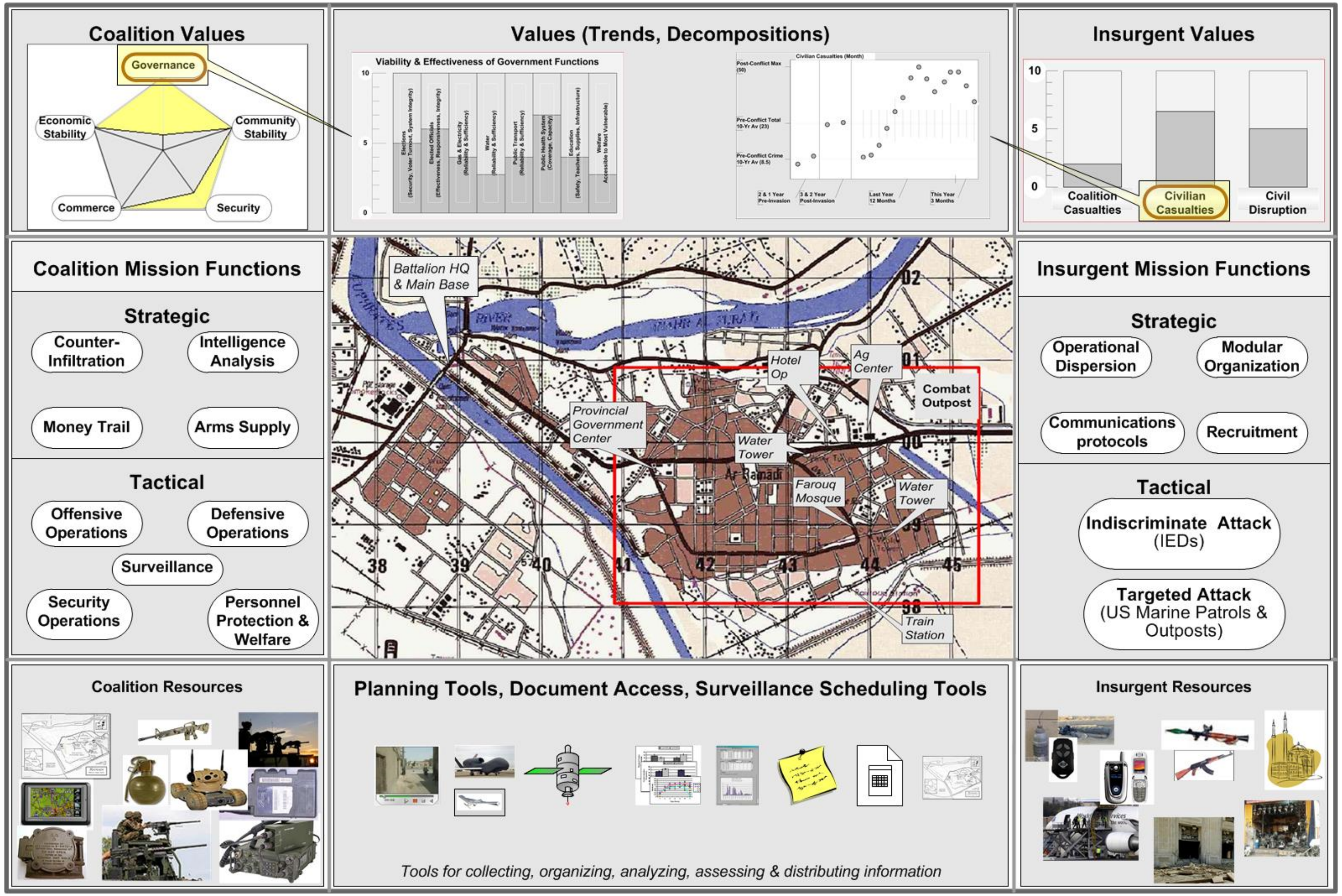

Figure 66: The counterinsurgency workspace of Figure 64 showing problems with the coalition value of governance and the insurgency value of civilian casualties

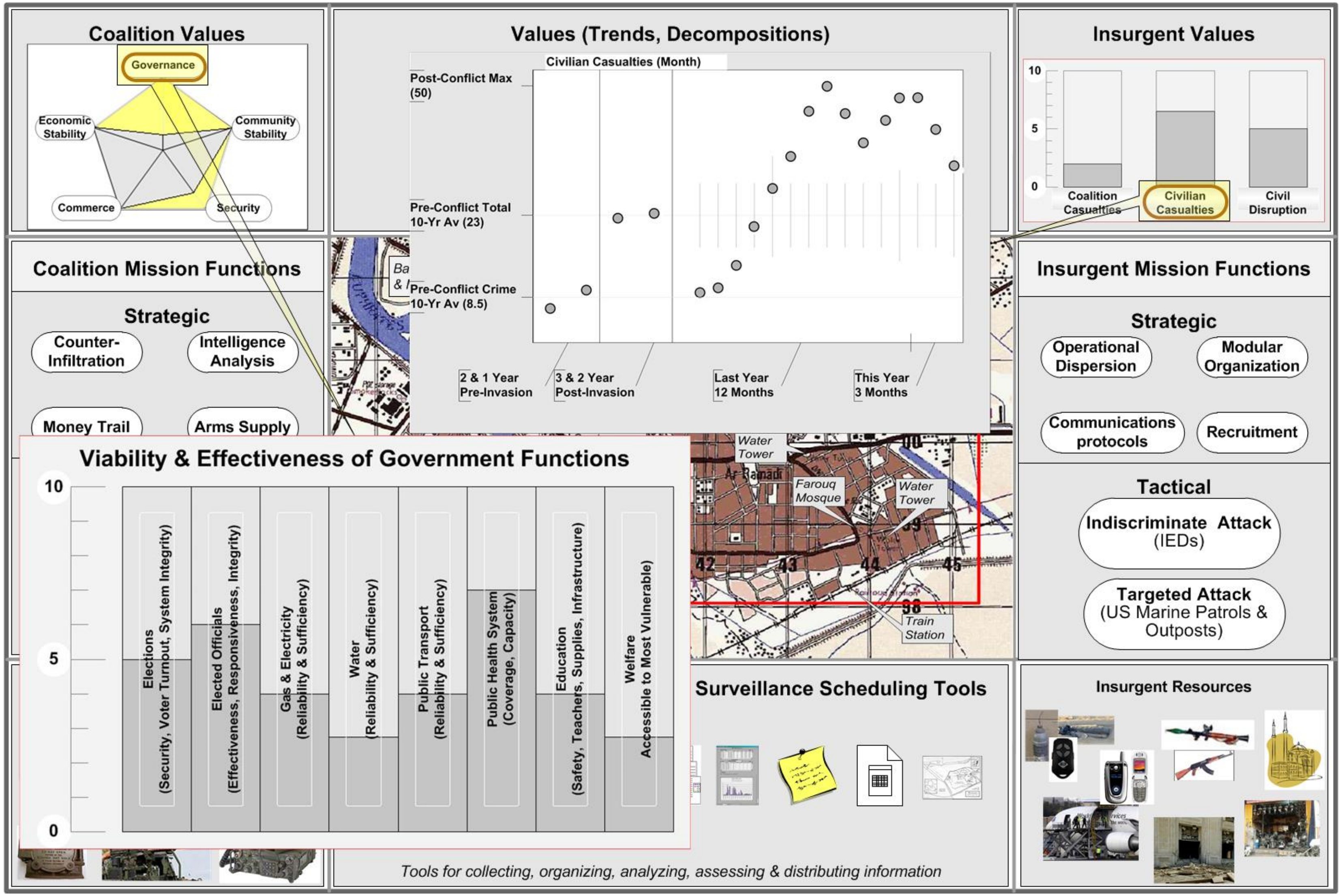

Figure 67: The counterinsurgency workspace of Figure 66 showing diagnostic detail for the problematic values of governance (coalition) and civilian casualties (insurgents)

Illustration: Ordnance Disposal

As discussed earlier, the recommended strategy for dealing with an IED is to request the services of the robot from the ordnance disposal experts. Someone who is unfamiliar with the capabilities of the robot might question whether this is a useful strategy. They might want to know specifically how the robot can be used to deactivate an explosive device. Does it set a charge to destroy an improvised explosive device and how does it do that? What sort of terrain can it manoeuvre over and can it operate in any sort of weather? Most would assume it is remotely controlled but it would be important to know the range of the remote control system. What about specific vulnerabilities of the device and if it is available, how long will it take for the ordnance disposal squad to get to the desired location?

As shown in Figure 70, interrogation of the IED disarmament domain function will insert a robot icon into the coalition resources panel. A summary description of the device's capabilities could be available in a pop up window that would be activated by hovering the mouse over the robot icon. Ideally, much of that information would be represented pictorially or graphically. Additionally, useful information about construction and vulnerabilities of IEDs might be obtained by interrogating the relevant tactical node for the insurgent mission functions.

Illustration: Alternate Ordnance Disposal Narrative

In this section I offer an alternative (fictional) narrative that describes an additional option. An Iraqi Police Bomb Squad is available to deal with bombs and other unexploded ordnance. They have a water disruptor, which is a device that shoots a ball of water at high speed and with sufficient force to blow any reasonably fragile object apart. It is reputed to work well with explosive devices that have exposed wiring and an exposed detonator, such as is common with an improvised explosive device, but not with a device encased in a shell such as a grenade or an artillery round. Nevertheless, you and I have never seen one of these in operation and we remain sceptical of its effectiveness.

Furthermore, given the indications of questionable loyalties and incompetence of Iraqi police and military evident throughout Campbell's narrative, we might question whether a call to the Iraqi Police Bomb Squad would be useful. Would they answer the call? Would they respond in a timely manner? Would they even respond at all? If they did respond, would they know how to handle the problem?

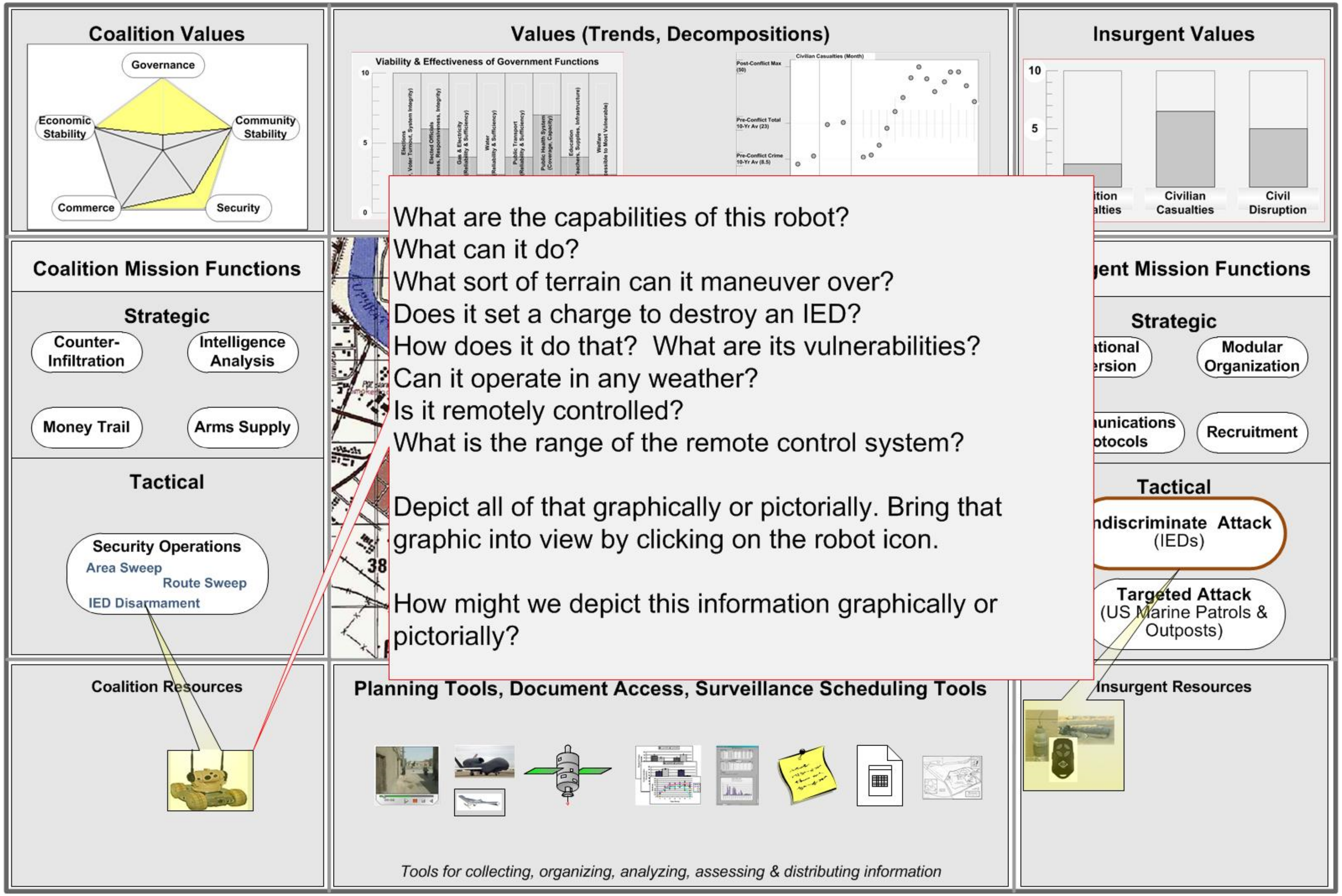

Figure 68: The counterinsurgency workspace showing resources for IED disarmament

The cognitive strategies table of Figure 69 summarises our dilemma.

Cognitive Strategies for IED Disposal	
Strategy	**Reasons for Selection**
Use our own experts (Call In EOD)	**The recommended strategy; use this whenever possible**
Try other experts (Iraqi Special Force Bomb Disposal)	**Possibly when out of alternatives but sceptical of their loyalty, their competence & their responsiveness & sceptical of the effectiveness of their technical systems**

Figure 69: Cognitive strategies for IED disposal

At this point in time we are puzzling over whether we should call for the robot or whether we should call the Iraqi Police Bomb Squad. We have reviewed the information on the robot and now we want to know whether the Iraqi squad is effective. How reliable are its members? Will we be able to contact them? How long will it take for them to get here?

Additionally, we are somewhat skeptical of this water disruptor idea. We doubt that hosing an IED down with water will do very much.

The workspace might help us explore the issues that trouble us by providing pop-up windows as shown in Figure 70. Interrogation of the IED disarmament domain function has not only inserted an icon representing the robot into the coalition resources panel but also an icon representing the Iraqi Police Bomb Squad. If we hover over the Iraqi Police Bomb Squad icon, we find an encouraging summary. Apparently, some analysts within our own coalition forces regard the members of this bomb squad to be reliable. Additionally, the pop-up window tells us that they are on call at all times and that they arrive quickly after a call. The pop-up window also indicates how they can be contacted.

The device they use, the water disruptor, is depicted along with a short description of what it does. You and I are, however, resolute in our skepticism and we still wonder whether it is useful to shoot water at an improvised explosive device. A short video clip of the device in action is available and so we click on that. (For full screen view, right click and select full screen option. If you cannot activate the video clip embedded in Figure 70 in your copy of this book, be assured that it is impressive. A loud bang and the test object is blown to pieces.)

Our skepticism dissipates and we call the Iraqi police bomb squad.

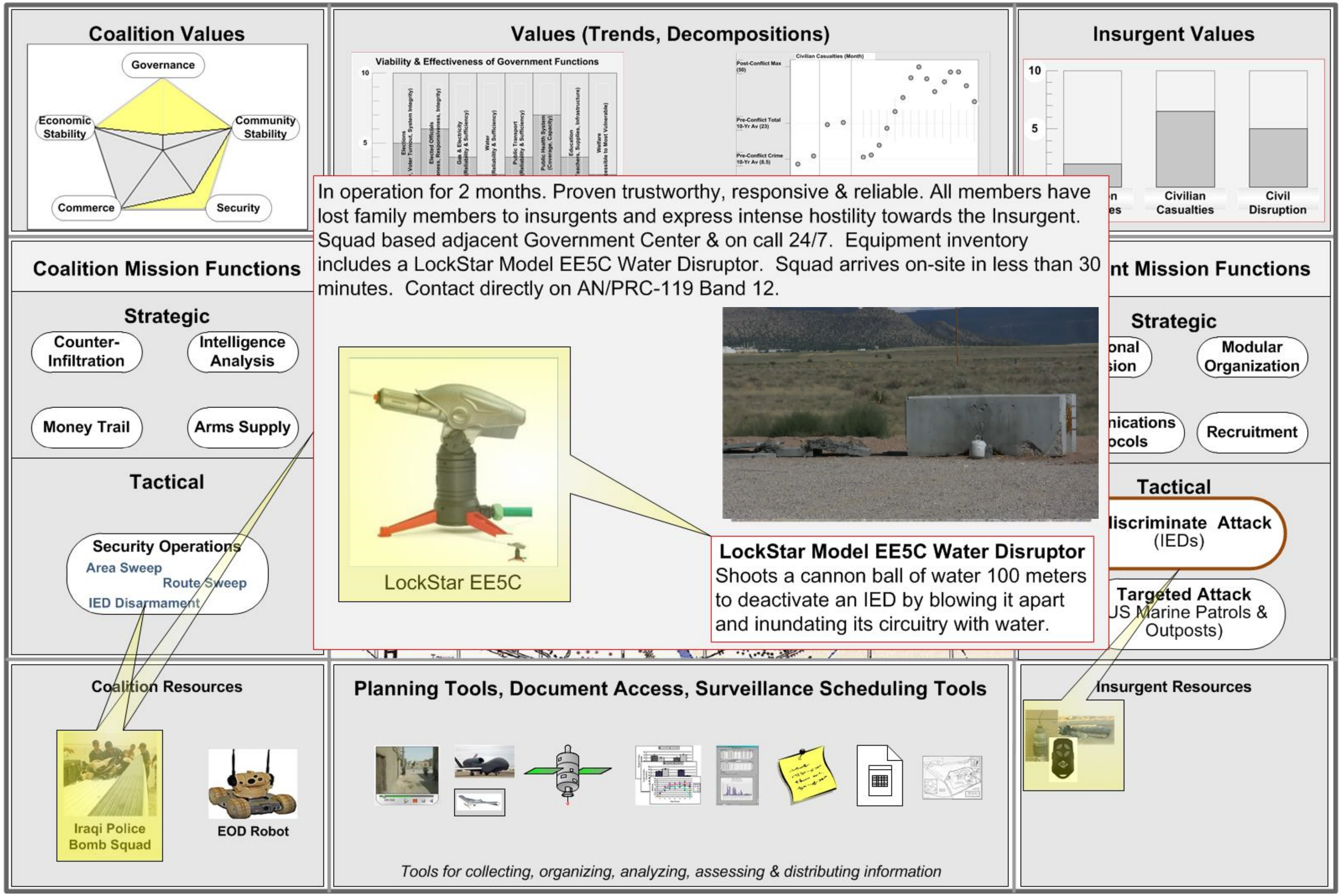

Figure 70: The counterinsurgency workspace showing further detail on effectiveness of the Iraqi Police Bomb Squad

Illustration: Video Surveillance

For the purpose of this illustration, you are the duty officer in the Combat Outpost at the time of the insurgent attack at the Farouq mosque (described on page 40). By monitoring communications traffic, you become aware that Joker One has been directed to the mosque and, when Joker One calls for reinforcements, become aware that a fire-fight has commenced. As you may recall, the Quick Reaction Force dispatched to reinforce Joker One arrived with little delay but its commander apparently had no appreciation of the intensity of the ongoing fire-fight or of the physical constraints in the area of the mosque.

You, as duty officer and with the functional workspace in front of you, will anticipate this possibility. You will see the availability of air surveillance resources in your tools panel and will use your mouse to select the micro remotely-controlled surveillance air vehicle. On selection, a callout will pop up with a summary description of the technical capabilities of this vehicle (Figure 71). You note that speed and endurance are satisfactory but most specifically note the desired payload (a high resolution video camera). You are concerned with time-to-station (time for preparation, take off and travel to the Farouq mosque) but that does not become available until you drag the vehicle icon to the desired surveillance station.

The technical specification callout shows that the surveillance vehicle is located at Battalion Headquarters, which is close by and so time-to-station should be minimal. When you do drop the surveillance vehicle icon on station, an algorithm automatically calculates that time (Figure 72). You note the time at seven minutes, which is longer than desirable but you probably cannot do better.

When you drop the surveillance vehicle icon on the desired station, you also trigger a high priority notification directly to the surveillance vehicle controller. It includes your contact details and your authorization code. The controller launches the surveillance vehicle immediately on notification and calls you on a voice link moments later. You brief the controller on the situation and you keep the voice link open for the remainder of the surveillance operation.

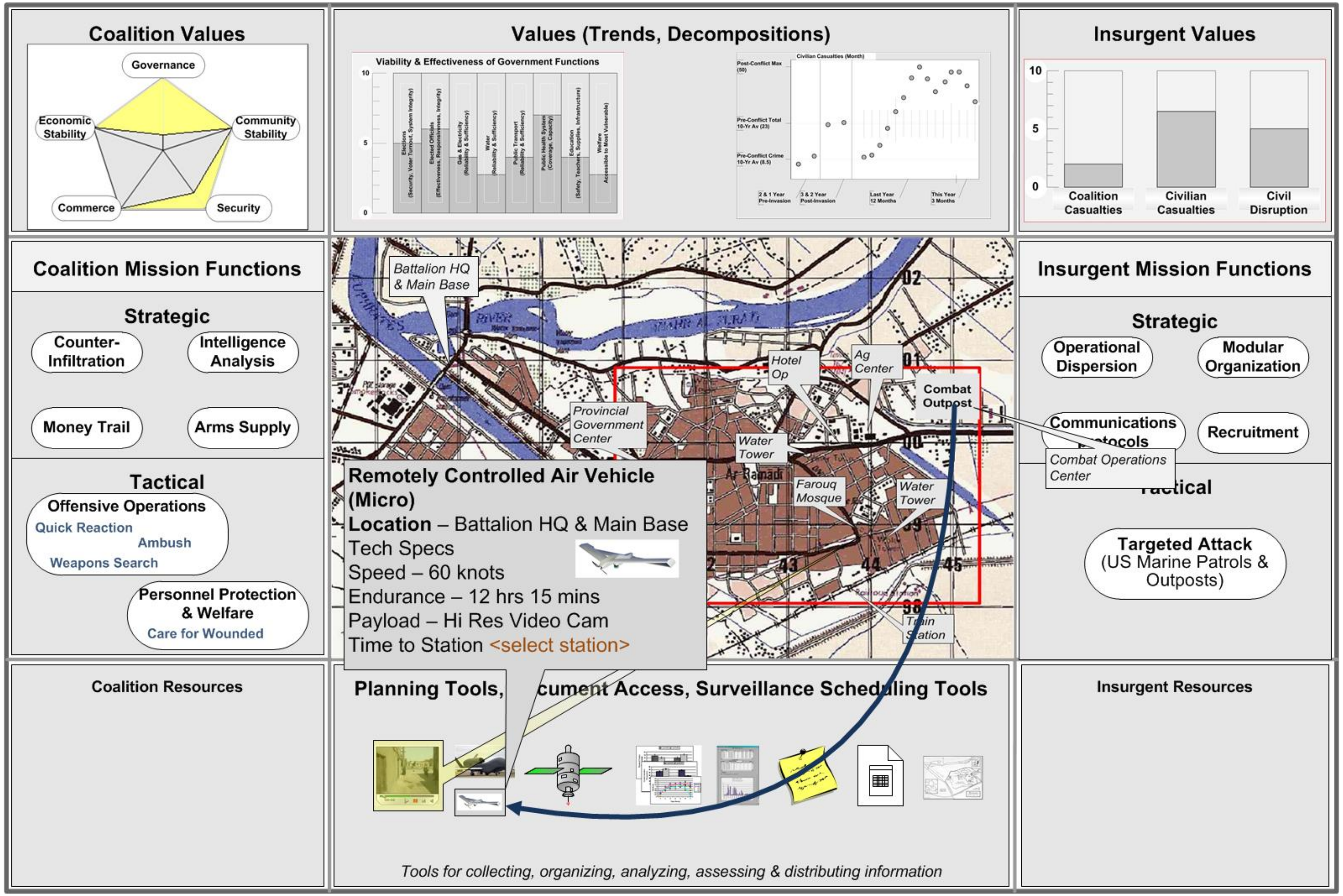

Figure 71: The counterinsurgency workspace showing selection of the surveillance air vehicle (blue arrow indicates activity link)

En-route to station, the controller activates the video camera. The video feed is routed directly to your workspace and you position and size your video tool as suits you. Within all of this activity, you have found time to select the relevant domain functions for both the Marines (*weapons search*, *care for wounded*) and the insurgents (*targeted attack*). The resources available to both groups appear in the bottom corner panels. In addition, you have established a communications link with the commander of the Quick Reaction Force now on his way to the Farouq mosque and have ascertained the makeup of the Quick Reaction Force (number and types of vehicles, number of troops) by rapid interrogation of the Battalion Headquarters information system.

Your surveillance air vehicle arrives on station while the Quick Reaction Force is enroute, approximately five minutes out from the Farouq mosque. The air vehicle controller is highly experienced and needs no instruction regarding scanning of the battle area. You ascertain from the video feed the disposition of Joker One and the insurgents and also the physical layout of the area. You identify ingress routes that will position the Quick Reaction Force advantageously in relation to the insurgents with due regard for Joker One's defensive perimeter.

You then annotate a schematic map of the area with all of this information (disposition of joker one, disposition of the insurgents, and preferable ingress routs) and also sketch out a plan for dispersing vehicles and troops on arrival. Your action and annotation tools allow you to complete this task within two minutes. You transmit your sketch, as a suggested plan, to the commander of the Quick Reaction Force. He views it on a handheld device that has some of the functionality of your functional workspace.

The commander of the Quick Reaction Force responds within approximately 30 seconds with a text message, *OK Tx*. You take this to mean that he has accepted your advice and you should now transmit your sketch to all members of the Quick Reaction Force with an advisory copy to the commander of Joker One.

The surveillance air vehicle remains on station throughout the firefight and you continue to update Battalion Headquarters and feed information to the on-ground commanders as the situation evolves.

Summary

This completes the tutorial illustration for this functional workspace. As will be evident, there is considerably more potential functionality that could be described but this description should help you appreciate the possibilities.

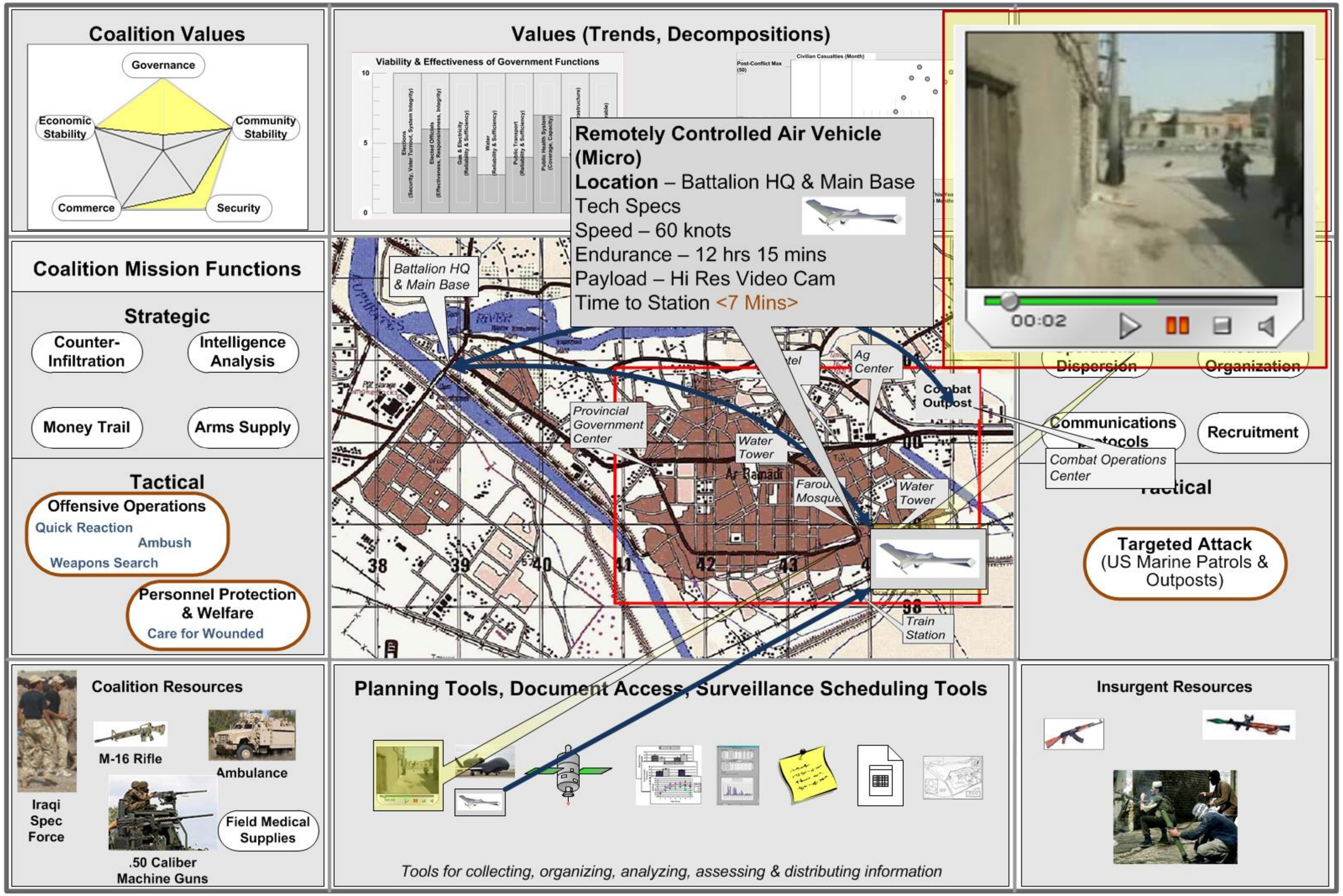

Figure 72: The counterinsurgency workspace showing the surveillance air vehicle dragged to its surveillance station (blue arrows indicate activity links)

Summary: Functional Workspace Design

A functional workspace provides a portal to all information that is potentially useful in a work environment and fully supports all essential activities. It is termed *functional* because the information it provides is mapped directly to the affordances offered by the work environment and the action opportunities it provides permit direct manipulation of those affordances as a means of achieving work goals. A functional workspace is one in which information is structured in a manner that reflects the structure of the cognitive work so that workers can assimilate the information readily and then act on it in naturally compatible ways.

It might initially seem that the flood of information available through a functional workspace would result in cognitive overload. However, functional workspaces avoid that problem by exploiting symmetric displays and frames of reference that set information in context and draw attention to global issues in a manner that prompts workers to focus selectively on currently relevant details. Functional workspaces support cognitive performance by revealing the operation of underlying system processes, the interactions between system states, and the constraints on action. On the activity side, they emphasize seamless and robust navigation between resources so that workers can converge naturally on momentarily important constellations of information. They provide robust, accessible action modes and diverse action capabilities via multiple-dimension controllers and direct, compatible action modes.

In summary, a functional workspace has much in common with a natural workspace, one in which there are diverse and functionally relevant sources of information that can be explored and acted upon in diverse ways. Such a workspace encourages workers to operate within a space of potential action, leaving them free to develop solutions to complex patterns of events that cannot be anticipated. It encourages a stronger appreciation of emerging issues and opportunities and promotes more robust and more accurate performance.

Reflection

This completes my tutorial on cognitive work analysis. As will be evident, cognitive work analysis is extensive and requires a substantial commitment of resources. I have not, in this tutorial, explained why you might want to embark on such an extensive undertaking. Rasmussen et al (1994) and then Vicente (1999) have done that very well. Since Vicente's book appeared, I have been concerned that neither the foundational theory nor the particulars of the various methods within the framework have been explained well enough. My earlier book, The Foundations and Pragmatics of Cognitive Work Analysis (Lintern, 2009), constitutes an attempt to correct both of these problems.

I remain satisfied with my 2009 treatment of the foundational theory but not with my treatment of method. I have undertaken many different analyses since then and my views about particulars of the method have changed during the course of each one. The particulars I describe in this tutorial constitute my current thinking although I doubt I have yet converged on a suite of methods that will continue to satisfy me as I deal with new analytic challenges. The lesson for you, the reader, is that you can take the descriptions I offer here as a foundation for your analytic work but you should feel free to adapt my approach as the specifics of your work would seem to demand.

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