

“SQUEEZING THE LEMON”

MAXIMIZING THE USE OF DATA FROM PLATFORM SENSORS, OTHER ON-BOARD DIGITAL DEVICES AND C2 INFORMATION TO HELP PROVIDE SITUATIONAL UNDERSTANDING

Mr Richard Sparshatt
Agile Communications, Inc

dick.sparshatt@agilecommunications.com

Col Nick Justice US Army
Program Manager
Force XXI Battle Command Brigade and Below
justice@us.army.mil

10 February 2003

The paper/article represents the views and opinions of the authors which are not necessarily the official views of, or are endorsed by, the U.S. Government, Department of Defense or Department of the Army

FOREWORD

The Future Battle Command and Control System enables Battle Command on the Move and Battle Control in Near Real Time by Unobtrusive Monitoring of Situational Awareness (SA) Telemetry Data, that is then combined with Command and Control (C2) information and processed by the Tactical Knowledge Management Engine (TKME) to infer and publish the right information to all users in the system, dependent on their role within the Task Force and scenario.¹

1. This statement is taken from an already published article entitled “Future Battle Command and Control System”. It is the aim of such a system, and the article went on to define 6 principles for a future battle command and control system as follows:

Future Battle C2 System (FBC2S) – Principles

Framework

Principle 1. The FBC2S is an integrated system of systems that meets the needs of commanders and staff at every level, for all Battlefield Functional Areas (BFAs), and across the Services.

What are we trying to achieve?

Principle 2. The FBC2S must provide commanders at all levels and across all BFAs functionality to simultaneously plan, fight and reconstitute the Task Force to achieve Battle Command on the Move to meet the higher commander’s intent.

Principle 3. The FBC2S must provide commanders and staff at all levels and across all BFAs functionality to achieve Battle Control in Near Real Time to maximize freedoms and minimize constraints in support of commanders’ plans.

How are we going to achieve it?

Principle 4. The FBC2S must provide commanders and staff at all levels and across all BFAs Situational Awareness (SA) Telemetry by Unobtrusive Monitoring from which information is inferred, which when combined with C2 information provides true Situational Understanding and enables Battle Command on the Move and Battle Control in Near Real Time.

Principle 5. The FBC2S must provide functionality that requires zero or minimal interaction with the user for the input and output of SA Telemetry and C2 information, and that is attuned to his equipment and scenario.

Principle 6. The FBC2S must act as a Tactical Knowledge Management Engine (TKME) that infers generic information from SA Telemetry for other system users, and uses all available information to infer specific information for the local user who subscribes dependent on his role, level of command and scenario.

2. It should be possible for readers with prior knowledge and experience in this field to understand the concepts contained in the principles, and in this paper. Others may wish to read the previously published article first. It is available at www.agilecommunications.com.

3. This paper expands on Principles 4 and 6. It does not provide a complete technical design of how such principles should be implemented, but rather describes the concepts further, discusses design issues and explores potential implementation approaches.

¹ Mr Richard Sparshatt and Colonel Nick Justice, *Future Battle Command and Control System*, Battlespace C4ISTAR Technologies, Vol 5 – Issues No. 3 October 2002

PART 1 - CONCEPTS

INTRODUCTION

4. Situational Awareness (SA) is gained from the interpretation of all available information. Situational Understanding (SU) is only achieved when this SA is considered with the role, mission and task of the platform/unit or formation, and the commander's intent. It is SU that enables command and control decisions to be made – Battle Command on the Move and Battle Control in Near Real Time. This description of both SA and SU applies for any level of command, from the platform to the formation.

5. This paper describes concepts to expand current understanding of SA from being mostly seen as blue, red and green icons on a digital map, to include information about platform systems and sub-systems that will be available from sensors on modern fighting vehicles (SA Telemetry). It also describes other information that contributes to SA available from Plans and Orders, from ISTAR systems, and potentially from Reference Services available to the network which could give information about weather, terrain, media reports etc. Given this wealth of information available from the local platform and from across the network, the paper shows how the FBC2S computer decides what is relevant for its user, and discusses the issue of how to obtain it. Finally, the paper describes concepts that move forward from the current "Information Age" where the user is mostly presented with information to correlate manually. FBC2S is part of the "Knowledge Age" where the computer uses the relevant information to infer and present knowledge, specific to the needs of that FBC2S user, and so help his Situational Understanding.

6. This paper is more than an intellectual thought piece explaining some concepts. It discusses some of the design issues, and even describes potential implementations. The intent is to show that these concepts could be realized in the very near future, given today's sensor, computer hardware and software, and communications and networking technologies.

AIM

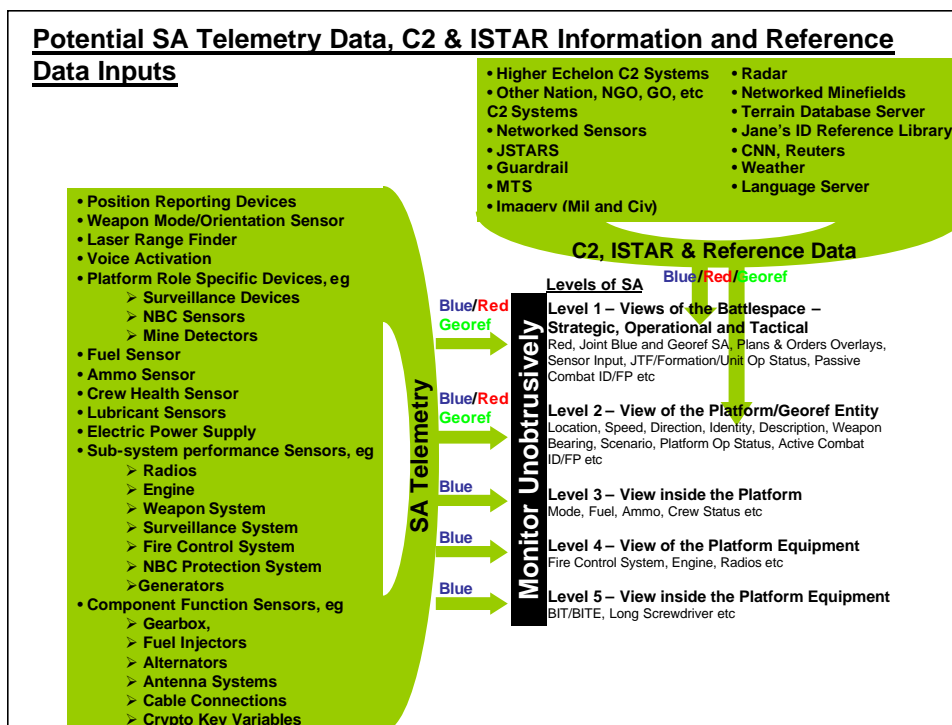
7. To describe how a FBC2S could use basic SA Telemetry and other known C2 information to help provide SU, by determining what information is relevant and then inferring knowledge specific to the needs of its users, which vary depending on their individual role, level of command and scenario.

SITUATIONAL AWARENESS

The FBC2S must provide commanders and staff at all levels and across all BFAs Situational Awareness (SA) Telemetry by Unobtrusive Monitoring from which information is inferred, which when combined with C2 information provides true Situational Understanding and enables Battle Command on the Move and Battle Control in Near Real Time.²

8. All too often SA is regarded as only blue, red and green icons on a digital map, depicting friendly (blue) and enemy (red) positions, and geographic entities like bridges, obstacles, hazard areas and neutrals (green). SA should be much more than that. Modern fighting platforms are equipped with a host of sensors and other digital devices. These measure and collect data about levels of expendables such as fuel and ammo, and about the status of platform systems such as the engine and radios, and from the actual mission systems such as the GPS device and Laser Range Finder. Remote measurement and collection of such data is known as telemetry, and all of it should be used by the FBC2S to contribute to SA. Additionally, FBC2S knows information from Plans and Orders, from ISTAR systems, and potentially from Reference Services available to the network which could give information about weather, terrain, media reports etc.

9. The diagram below describes the 5 different levels of SA and gives examples of the sources of SA Telemetry from platform sensors and other digital devices, and other information that contributes towards SA.



² ibid

10. Blue SA is Friendly Force information. Red SA is Enemy Force information. Green or Georef SA is other battlespace geo-referenced information like obstacles, bridges, supply points, etc. Levels of SA are best thought of as views.

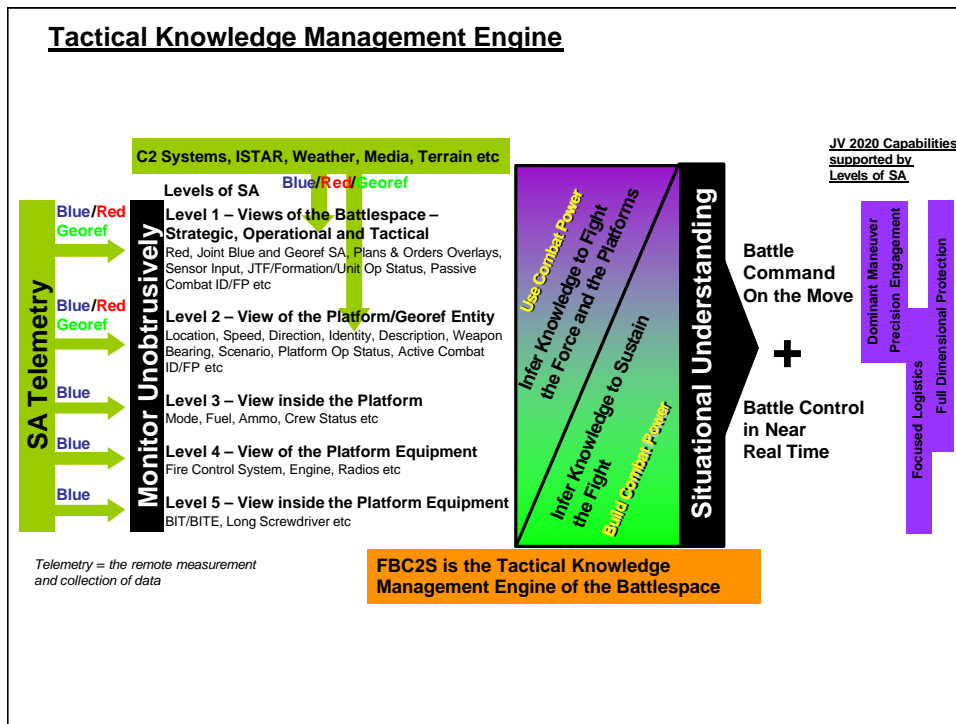
- Level 1 SA is the View of the Battlespace. It shows the plan in the form of overlays and linked orders information, operational status and progress of units, information about the enemy and the battlespace.
- Level 2 SA is the View of the Platform/Georef Entity and this gives specific information about each icon such as identity, location, speed, and operational status.
- Level 3 SA is the View inside the platform of things like fuel and ammunition holdings, crew status and whether it is in a mission mode or not.
- Level 4 SA is the View of individual platform equipments. It shows the status of the radios, the weapon/mission systems, the engine etc.
- Level 5 SA is the View of sub-systems inside each of these platform equipments, such as the antenna system, power supply, system computer, gearbox and brakes.

11. The information for each of these Views comes from 2 sources:

- Firstly, there is SA Telemetry Data from the platform itself. This is provided by various digital devices like position location devices (GPS etc), platform mission/role equipments like Laser Range Finders (LRF) and NBC detection systems, fuel gauges, ammunition magazine sensors, system performance sensors and BIT/BITE devices. SA Telemetry Data is monitored unobtrusively and is free – that is, if the digital devices are in place they can easily and automatically provide such data, and do so with no effort or interaction required by the platform commander or crew. Even red and georef SA Telemetry Data is obtained unobtrusively as it results from the platform commander and crew performing their mission. So for example, a Level 2 SA View of an Enemy Platform is gained from the crew locating the enemy vehicle using its LRF.
- Secondly, there is information from external sources like other FBC2S and other C2 systems, ISTAR sensor information, and Reference Services providing information about weather, media, terrain, and friendly and enemy platform characteristics such as identification features, on board systems, expected performance etc.

TACTICAL KNOWLEDGE MANAGEMENT ENGINE

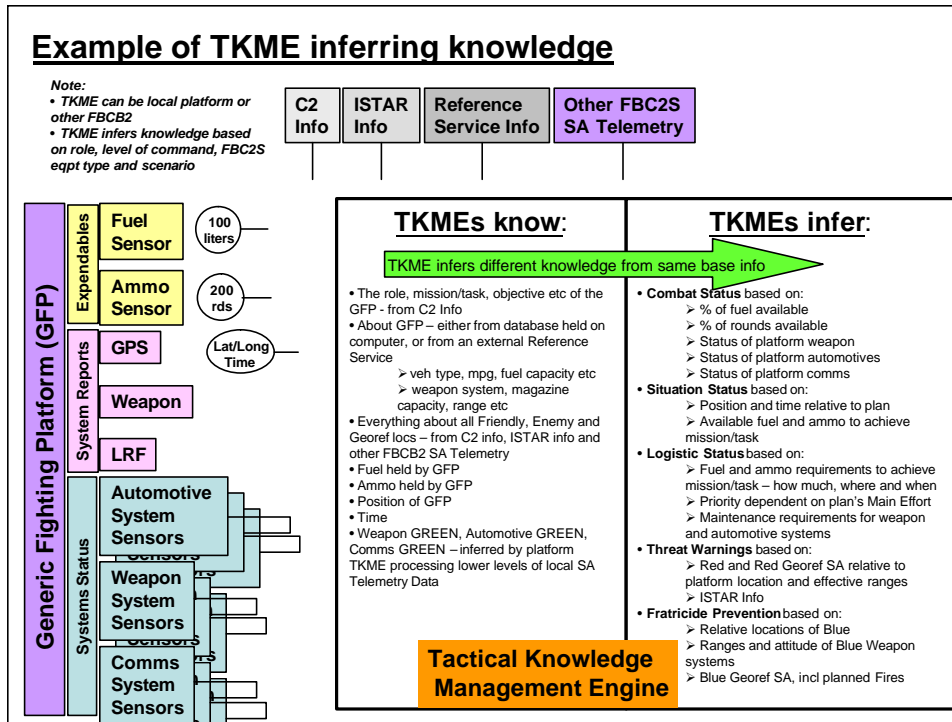
The FBC2S computer can be thought of as having a Tactical Knowledge Management Engine; an 'engine' in that it infers information, and 'knowledge management' in that it gets the right information to the right people at the right time, thereby increasing their range of information or understanding, which is knowledge.³



12. The diagram above shows that both types of information (SA Telemetry Data, and C2, ISTAR and Reference Information) will be available to the FBC2S. When combined/integrated and looked at collectively, more information can be inferred which is specific to the user's needs. Information from lower level views contributes towards knowledge about building combat power, and information from the upper level views supports the use of combat power. By getting the right information to the user at the right time we have expanded his knowledge, and thereby support his true Situational Understanding. This is the job of the Tactical Knowledge Management Engine (TKME), which is a part of the FBC2S.

13. To better understand the concept, let us create a simple Generic Fighting Platform (GFP) which is a motorized vehicle, equipped with a gun, LRF, a position location device and communications devices, as shown on the left in the diagram below:

³ Ibid



14. The GFP is fully digitized⁴ and there are 3 categories of SA Telemetry that it generates and passes to the TKME:

- Telemetry about Expendables. Digital sensors provide SA Telemetry regarding the amount of held fuel and ammunition.
- Telemetry from the GFP's Mission/Role Systems. The GPS provides information regarding the location of the platform, and used in conjunction with the Laser Range Finder enables other the locations to be determined.
- Telemetry about the Status of Systems that comprise the GFP. Digital sensors and BIT/BITE provide SA Telemetry about the GFP's automotive, weapon and communications systems. Either BITE passes overall system status to the TKME, or the TKME itself can infer overall status by processing Level 5 SA Telemetry.

15. The TKME is part of the Future Battle Command and Control System, which is itself a system of the integrated system of systems. These external information sources contribute to the Level 1 and 2 SA Views of the Battlespace and the Platform respectively. The TKME thus knows about all the other Blue platforms in the Battlespace, their locations, mission/tasks, situations etc. It knows about Red platforms also, and Georef SA. From the C2 orders for the GFP the TKME knows its specific mission/task, objective etc. The TKME also knows all about the GFP itself - that it is a vehicle which can travel at 80km/hr, that it does 10 kmpg and has a fuel tank of 300

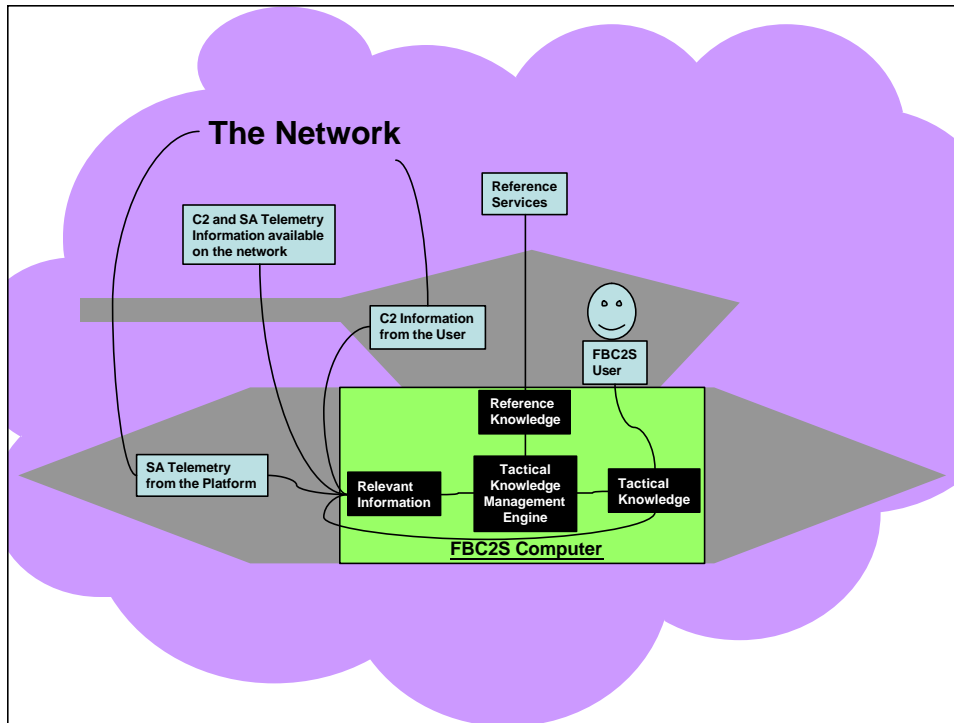
⁴ Stryker is a fully digitized vehicle. It has on board sensors which measure data from various platform systems components. Servers provide this data to computers for processing (either on the platform or at some other location).

liters, that it has a magazine for 600 rounds for a weapon with a range of 2km, lethal to armor less than 2cm thick, that it has armor protection of 1cm, that it has GPS, that it has certain radios, that it is crewed by 2 people, etc. It should be evident by now that it is possible for the TKME to know an immense amount of information about the GFP, it could even be about this specific GFP to account for equipment/system modifications or battle damage etc. All this information can be held in a database on each platform TKME and/or gathered from an external Reference Service.

16. At this stage it is important to realize that the TKME we have described could be either the one on our GFP or all the others in the wider system of systems. In fact it is both, and the next stage describes the real “free multiplier” effect when all the TKMEs use the same base information that they hold or get to infer knowledge specific to their user’s individual needs. Every FBC2S user requires knowledge that is specific to their role/Battlefield Functional Area (BFA), their platform and its weapon systems, their task/mission within the overall plan, their Unit Task Organization and level of command, the combat situation and their location in the battlespace relative to the plan, other blue, red and georef entities, the weather, the terrain, other resources at their disposal etc. So in the example depicted in the diagram, different TKMEs take the same base information and can infer knowledge specific to their user’s needs about such things as combat status, situation status, logistic status, threat warnings, fratricide prevention, etc. Taking the example of combat status, at our GFP this will be presented to the platform commander as status of his particular platform. The TKME of the next higher level commander will have the same base information for all the platforms under his command, and so from this will infer knowledge about the combat status of each of his subordinate platforms and the sub-unit overall, and so on up the levels of command.

17. In the case depicted in the diagram, we described earlier how the TKMEs in the network inferred things like combat status, situation status, logistic status, threat warnings, fratricide prevention, etc. It is important to note that this information has not been sent around the network to FBC2S users, like we send a SITREP or LOGSITREP, or Threat Warning message today. Each TKME has taken the same base data and from it inferred specific knowledge for its user, according to his needs at that time. We need to get away from the messaging environment. It is precisely because of messaging that we have never fully exploited the volume of information already held on our command and control systems. We have always constrained information within the context of the message and never considered its wider application for a different context. But in the case of the FBC2S we are sending SA Telemetry, that the platform has 55 liters of fuel, for example, and then TKMEs look at this and other information in various contexts to help infer combat status, logistic status and situation status (as to whether it could reach its objective) – many pieces of knowledge from one piece of relevant information viewed in many contexts.

18. To summarize, Part 1 of the paper has explored further the main concepts of how to achieve Situational Understanding to support Battle Command on the Move and Battle Control in Near Real Time. The diagram below shows what we want to achieve.



19. The FBC2S computer accepts as input SA Telemetry from the platform, C2 information from the user, C2 and SA Telemetry information available from the network, and knowledge that it has already inferred that may be relevant for the generation of other knowledge. The TKME then infers tactical knowledge from all the relevant information, if necessary referring also to Reference Knowledge. An example of Reference Knowledge is information about a platform's characteristics, such as the capacity of its fuel tank and its average fuel consumption. SA Telemetry will tell the TKME how much fuel a platform has, but the TKME can not infer whether that platform has sufficient fuel to reach its objective unless it has this Reference Knowledge about the platform's average fuel consumption, and the combat service support unit cannot know how much fuel to deliver to the platform unless it also knows the fuel capacity. This Reference Knowledge could either be held within the database of the FBC2S computer, or fetched from Reference Services accessible across the Network. Finally, remember that we are working based on the premise that inferred knowledge is not being distributed across the network, only the base SA Telemetry and C2 information (as shown), from which other FBC2S computers will infer the specific knowledge required by their user.

PART 2 - DESIGN ISSUES AND POTENTIAL IMPLEMENTATION APPROACHES

20. To this point the paper has described conceptually what we want to achieve. The following sections explore some of the design issues that need to be addressed to implement these concepts, and describe potential implementation approaches. Four major design issues arise:

- What is base SA Telemetry and how much needs to be sent across the network?
- Of all the base SA Telemetry and other information that could be available across the network, how does each FBC2S computer decide what information is relevant to meet their user's needs?
- How is the base SA Telemetry and other information sent across the network to FBC2S and other system users?
- How does the FBC2S use this relevant information to infer knowledge using its TKME?

What is base SA Telemetry and how much needs to be sent across the network?

21. In the examples described in the previous section, only base SA Telemetry has been distributed and received by FBC2S, locally and from across the network. Each TKME then uses relevant information to infer knowledge required by its user. There is a design decision to be made regarding what is the base level of SA Telemetry that is distributed freely to other FBC2S. Some SA Telemetry Data at Level 5 View for example could be used by that platform TKME to infer knowledge that the overall automotive system is "green", and this knowledge (green status) is then distributed to other TKMEs. On the other hand, the SA Telemetry about the performance of the automotive sub-systems is probably required by those responsible for the maintenance of the platform to infer knowledge about when the next service is due, or which component needs replacing. Or again, should this lower level of knowledge be inferred on that platform and then distributed? Whichever method is used, ultimately the FBC2S computer is passing information across the communications network, which only cares about how many data bytes have to be passed, to who and with what quality of service. In the lean tactical bandwidth environment the least data sent the better. Inferring knowledge on the local FBC2S, and then distributing this means that it has a specific context. But some of the base SA Telemetry used to infer this knowledge could probably have been used to infer different knowledge by another FBC2S user, for a different context. Instead, another message therefore has to be sent. Alternatively, the same base SA could be sent once only to all FBC2S, and each TKME use it to infer the knowledge that their user requires. In this latter case, we are not distributing information in the context of a message and so can maximize the use of this base SA Telemetry and achieve this "free multiplier" effect. In line with the notions of evolutionary spiral development that this FBC2S will follow, it makes sense to initially take the approach that offers maximum flexibility in the longer term. This would be to send all base SA Telemetry Data to other FBC2S and let each TKME infer the knowledge required by its user.

22. The second element to this issue is how much of this base SA Telemetry needs to be sent across the network. Platform sensors and other digital devices can be constantly measuring and collecting data, but this does not necessarily mean that it all has to be sent immediately to the FBC2S, and so use valuable communications bandwidth. Instead different reporting mechanisms could be implemented, as follows:

- Run Time Base Data Measurements. This is simply a report of the measurement carried out by the sensor. If this mechanism is used then the periodicity of the report is the factor that affects how much network bandwidth is used. So examples for each category of SA Telemetry (as described earlier in the paper) where this reporting mechanism might apply are:
 - Telemetry about Expendables. Fuel level, ammunition holding, etc
 - Telemetry from the GFP's Mission/Role Systems. Lat/Long, time, gun orientation, chemical hazard levels. Some sensor reports/measurements are one time only, such as enemy emitter frequency, direction and range.
 - Telemetry about the Status of Systems that comprise the GFP. Engine revolutions per minute, vibration frequency and amplitude, hydraulic pressure, electric current and voltage, available battery power, crew body temperature, crew pulse rates etc
- Threshold Triggers. This SA Telemetry is sent when a certain upper and/or lower threshold is reached. This mechanism applies to each category of SA, and could be in regard to any of the ongoing measurements described above. So for example the SA Telemetry is sent when there is a certain amount of fuel or ammunition, or when a certain chemical hazard level is reached, or when a certain hydraulic pressure is reached.
- Boolean Triggers. This is similar to the above mechanism, but the report is based on whether something is held, or has happened. Again this mechanism applies to each category of SA, and examples are:
 - Telemetry about Expendables. Whether the platform has the next crypto key, whether it has the current orders, whether the platform has a re-supply scheduled, etc
 - Telemetry from the GFP's Mission/Role Systems. Whether the laser sensor detects that the platform is being targeted, whether a mine is detected, etc
 - Telemetry about the Status of Systems that comprise the GFP. Whether the gun is in a engage mode, whether the radar is active, whether the radios are being jammed, etc

23. Such reporting mechanisms could reduce the amount of network bandwidth used. But of course SA Telemetry can be sent to the local host platform TKME more often that it is sent to others, thereby ensuring that the platform TKME has the best information available, and the FBC2S user has the best knowledge possible, in line with his needs at that time. It is important to realize that the needs of the FBC2S user are dynamic, dependent on his situation at the time. In other words, just because the TKME has inferred the knowledge does not mean that it has to be presented to the

platform commander. He probably does not want to know, for example, about service status of the gearbox when he is in combat, but will want to know later.

Of all the base SA Telemetry and other information that could be available across the network, how does each FBC2S computer decide what information is relevant to meet their user's needs?

24. In the Information Age we had to deal with an ongoing concern (founded in reality) that the human user would be swamped with information and would not be able to quickly and easily sort the wheat from the chaff to discern what is relevant. True, today's computer based information systems can provide the user with almost limitless amounts of information, either automatically or if the user wants to go and get it. There are 2 challenges here, one for the computer and one for the user. How does the computer know what information is relevant that it must automatically present to the user, and how does the user know what information is available to go and get? The computer can send the user too much information, too little information and irrelevant information. The user could go and get the right information, the wrong information or more likely only partial information or the right information hidden in masses of irrelevant information. In any of these cases the problem is ensuring that the user has the best possible information that is relevant to his needs. In the future we want to move beyond the Information Age to the Knowledge Age. We want the computer to do the work; to identify, get and present relevant information to the user, and when possible, infer from it knowledge specific to the user's needs.

25. But what information is relevant? Of course "relevance of information" will depend on the command and control doctrine and processes practiced at that time. It is widely recognized that to fully realize the potential capabilities of the Network Centric Warfare environment envisioned in US DoD's Joint Vision 2020 there must be a radical change to our doctrine for the employment, command and control of resources. In turn, the way we do business will change. Today's capabilities/resources are mostly commanded, controlled, supported and sustained according to a defined chain of command. In some respects, the technical limitations of previous communications and information systems constrained the way of command and control. Today's, and moreover tomorrow's technologies mean that communications and information systems are no longer a limiting factor. Any way the Army, and indeed the Joint Community, wants to do business can be supported, they just have to decide.

26. Even without the knowledge of future warfighting doctrine and ways of business, it is still possible to be more abstract and conceptualize what will be relevant information for the FBC2S to process and infer specific knowledge for its user. It is actually the TKME that requires relevant information in order to be able to infer knowledge, specific to the user. The TKME can be thought of as a set of Knowledge Tools, some of which are invoked dependent on the roles and responsibilities of the FBC2S user, and to ensure the successful running of his platform, and its survival. It follows therefore that the FBC2S has to know and tell its TKME about the user it is serving, his roles and responsibilities, and his platform. User and Platform Information can be gained at login,

or the platform information could be gained from a smart interface when the computer is turned on. The user's role is to a certain extent based on his appointment, and this is all that is required for more generic Knowledge Tools. To be able to invoke more specific Knowledge Tools the TKME might need to know the user's mission and tasks in the context of the bigger plan and the commander's intent. Such information can only be gained from Orders, and subsequent C2 information. Thus we have established 3 Information Profiles (IP) – the User IP, the Platform IP and the Mission/Task IP – and these are used firstly by the TKME to decide what Knowledge Tools to invoke. Then each Knowledge Tool will require input information to which rules are applied to infer more information or knowledge for the user. The TKME therefore informs the FBC2S what information it requires from both the local platform sensors and digital devices, and from across the network – the relevant information. As an example, a generic tool that would be invoked for every platform is Platform Survival Knowledge Tool. The TKME knows all about its local platform, its levels of protection, its weapon systems, its mobility etc from the Platform IP. When provided relevant information about an enemy platform, an NBC event, or the terrain, the TKME will provide survivability knowledge to the platform commander. To infer such knowledge the TKME will probably require other information, some of which is held in the local IPs and some of which is required from Reference Services. It has been told of the location of an enemy weapon for example, but in order to discover the potential effects of that weapon on its host platform it will need to get information about the range and caliber from Reference Services, and then if a threat, weigh this against the local platform's levels of protection from the Platform IP. Reference Service information could be held on the local computer or accessed from the network, or both.

27. So the IPs are more than just parameters which enable the TKME to decide which tools to invoke. They also contain information that the Knowledge Tools use in order to infer knowledge. Let us look at the IPs in more detail to show the amount of information that could easily be accrued given simple login information and C2 orders. Then it should be possible to imagine the worth of such information for the Knowledge Tools. The tables below show the Source Information required and the possible IP that could then be generated.

Source Info	Possible User Information Profile - <i>Example/Comments</i>
Role/ Appointment	Role - <i>PLT Comd (Armr)</i>
	URN - <i>1001264</i>
	Command Level - <i>PLT</i>
	Subordinate unit URNs - <i>The URNs of the other 3 platforms that comprise the PLT.</i>
Security Level	Permitted classification of information - <i>SECRET</i>

28. Because this User Information Profile is relatively stable, it could be either Reference Knowledge held on each computer, or gained from Reference Services

across the network. By knowing which appointment it is supporting, the FBC2S is also able to now establish Platform Information Profiles for its own platform and those that its user's commands/controls/supports/sustains.

Source Info	Possible Platform Information Profile – Examples/Comments
Platform VRN	Platform type - <i>M1A2</i>
	Platform systems - <i>Engine, armor, collective NBC system, crew number</i>
	Platform system capabilities - <i>Range, speed, protection</i>
	Platform system sensors - <i>Fuel sensor, drive sprocket vibration sensor</i>
	Mission systems - <i>Main Gun, machine gun, LRF</i>
	Mission system capabilities - <i>Ranges, magazine size</i>
	Mission system sensors - <i>Main gun barrel temp sensor, magazine holding sensor</i>
Platform Crew IDs	Personnel records - <i>Ranks, names, individual skills – such as language skills</i>
	Medical records - <i>Blood groups, vaccinations, allergies</i>

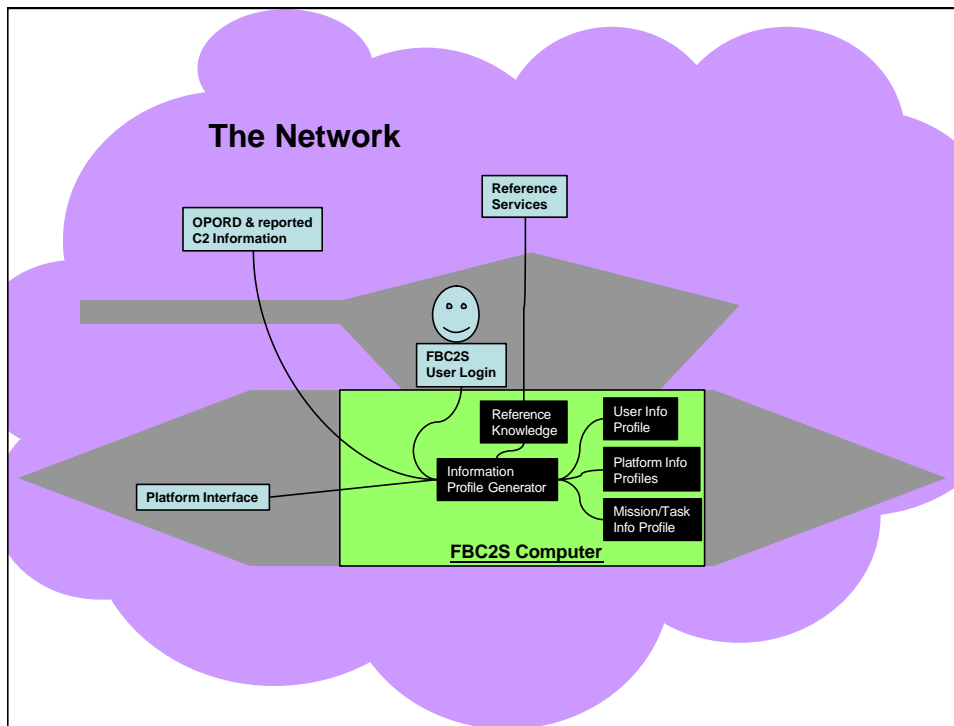
29. The table shows items that could be contained in the Platform IP given some minimal source information. For example, given only the Platform Registration/ID it is possible to look up Reference Knowledge about that specific platform and the systems it comprises, and so know their performance capabilities, their modification state, etc. Knowledge of the available system sensors could be a factor in determining whether a Knowledge Tool could be invoked. Again, Platform IPs are relatively stable and could be either Reference Knowledge held on each computer, or gained from Reference Services across the network. As discussed earlier, not only do these IPs enable the TKME to ascertain what tools to invoke, they also provide information that the TKME needs to enable it to infer Knowledge given other minimal information. For example, the PLT Comd's TKME has invoked the Combat Status Knowledge Tool which infers knowledge about all his subordinate platforms. SA Telemetry information about a subordinate Wingman's platform is therefore relevant. However, SA Telemetry only gives the amount of fuel held by the Wingman, and the Platform Information Profile therefore can help the TKME establish the range of the platform.

30. Now that the FBC2S knows which appointment and platforms it is supporting, it needs to know what they are all supposed to be doing – to give the TKME the context of the information – it needs to know the plan. This is provided in the Mission/Task IP. Much of this profile is related to the ground and time, and attempts to tie these parameters to enemy units, friendly units and effects. Unlike the previous IPs, the Mission/Task IP is dynamic. It is dependent on orders received for that particular mission/task, and subsequent C2 orders and reported information. Very little, if any of the IP can be defined a priori as Reference Knowledge, and the profile will change during the operation. The table below shows the possible information that could be contained in this profile, derived initially from C2 orders. Again, it is not exhaustive, but shows potentially the amount of information that could be accrued.

Source Info	Possible Mission/Task Information Profile - <i>Example/Comments</i>
UTO	FBC2S User's place in the chain of command – <i>ties FBC2S user to higher command, subordinates, supporting and supported units. Many SOPs, and implied tasks fall out of the UTO.</i> UTO could also specify what other capabilities and areas of coverage/reach are available to the formation, like fires, ISTAR, joint assets etc - <i>using Reference Knowledge the TKME can know the capabilities and potential effects of friendly units in its tasking chain. Later parts of the orders may tie these capabilities to certain units/areas of ground/priorities.</i>
Ground	Identify features and their names – <i>rivers, hills, phase lines, boundaries, objective names, obstacles etc - tie feature names to map grids so that the features can be referred to later and have geographic meaning on the digital map. Some of the detailed info will be available from Coord Instr.</i>
SITUATION	Enemy units and dispositions – <i>this information could come from Annex B</i>
Enemy Forces	
Friendly Forces (2 up and 1 up)	Friendly Force (FF) units, dispositions (if undigitized, otherwise will be known) and planned dispositions/effects in time/phases - <i>tie FF units to AORs, tie planned effects to areas on ground, tie planned effects to enemy units</i>
Higher Commander's Mission	
Higher Commander's Intent	Identify ME FF units.
Higher Commander's Concept of Ops	
MISSION	Tie unit/formation to AOR, effect on the enemy/ground and time – <i>could also identify the inter relationships of units, and their actions</i>
EXECUTION	
Intent	
Concept of Ops (incl) Main Effort	<i>Information could also be gained/supplemented from Annexes</i>
Tasks	
Coordinating Instructions	Effective time of orders CCIRs Reporting requirements, unless SOP Phase Line descriptions
SERVICE SUPPORT	Priority of support
COMMAND & SIGNAL	Locations Succession of command – <i>if user is in succession then FBC2S and TKME could maintain a separate Information Profile in case the user has to take command.</i> Key Variable
Annexes	Annexes would enable Mission/Task Information Profiles for engineer, air defense, etc.

31. It can be seen that this information is obtained directly from C2 orders and reported C2 information. It is therefore necessary to have a mechanism by which discrete elements of C2 orders/information can be identified, including the inter relationships of these elements to tie units/ground/time and effects together.

32. The diagram below summarizes the generation of Information Profiles. There are three sources of information for the Information Profile Generator – the User Login, Orders and reported C2 Information, and the Platform interface. The FBC2S computer also uses Reference Knowledge, either held already by itself or available from the network, to generate the Information Profiles for the Platform, the User and the Mission/Task.



How is the base SA Telemetry and other information sent across the network to FBC2S and other system users?

33. Now that the FBC2S has established what information is relevant for its TKME to infer knowledge for its user, we need to consider how this relevant information is obtained. Remember that the FBC2S is serving the user's command and control responsibilities for his platform, and for his appointment. There are two general sources of information – internal information sourced by the platform itself, and external information sourced by others on the network. Obviously the internally sourced information can easily be gained by the platform FBC2S/TKME, but how do we get the externally sourced relevant information to the FBC2S/TKME?

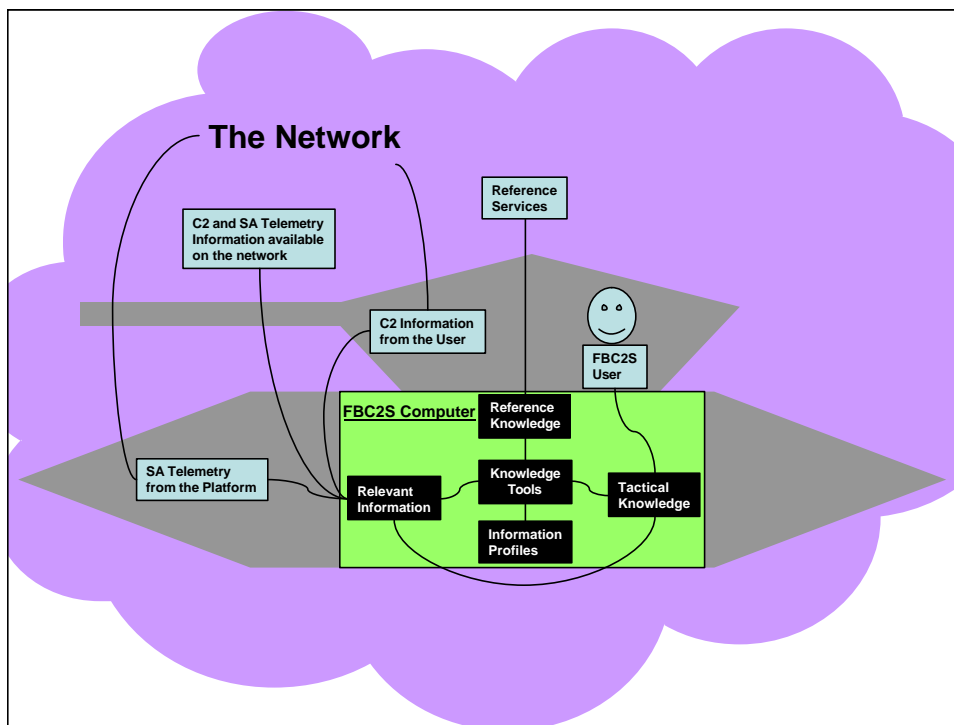
34. Units are commanded, controlled and supported within a defined hierarchical task organization. FBC2S consists of many hundred computers (per BDE) serving users mostly at brigade and below. Base SA Telemetry and other C2, ISTAR and Reference Service information is required by many FBC2S users, each of whom use their TKME to infer specific knowledge from much of this same information. Communications networks at this level are mainly based on tactical radio where bandwidth is at a premium. So we need to find both an effective and bandwidth efficient means of getting relevant information to FBC2S computers. Conceptually, there are 2 mechanisms to get relevant information to FBC2S computers, and a third that is a hybrid of the two. Either the senders push relevant information across the network to other FBC2S users, or FBC2S receivers pull (extract) relevant information from the network, or information is pushed to notice boards and users go and get that which is relevant to them. The driving issue though is how the information is categorized/labeled to relate its relevance, so that users know who to send it to or what to get and get. At one extreme there could be many small categories/groups of information, but this would probably mean that information would be repeated across categories so effectively it is being sent many times. Also, there would be many messages requesting or registering for these groups of information. On the other hand there could be a few large categories and so fewer registration messages, but then extraneous information would probably be sent. Consideration of the communications environment suggests that fewer large categories is the better approach. Tactical radio communications are inherently a one to many/all broadcast media, and so information will be seen at the radio level, regardless of whether the FBC2S requires it. It makes sense therefore to use a one to many/all push mechanism, with few large groupings of information, and have the FBC2S computer accept and filter out the relevant information that it requires from all the information in this group. Although the onus is now on the receiving FBC2S to find relevant information it is probably fair to say that extra processing on the computer is more affordable and attainable than bandwidth. The issue now is identifying what the few large groups of information should be. Firstly they must be well known and stable, so that FBC2S knows what groups are available, otherwise there is the burden of advertising and managing groups of information. Secondly, identifying which group information belongs to must be obvious. It is like the school corridor where notices are posted to inform students of a particular issue. There is a relationship or understanding between the person posting the notice and the person reading the notice. If the message is about art then it is put on the art notice board, and those interested in art will go to the art notice board. Finding such well known and obvious groupings on the battlefield is actually simple. Much of the information is in regard to the command and control process. The current way of business is very much based on hierarchy of command. Units command/control/support/sustain other units, and in turn are commanded/controlled/supported and sustained themselves by others. Because of these inter relationships it means that relevant information for units can be broadly grouped based on command hierarchy, and recipients can then filter down the information to get that which is relevant to their needs as per their command and control responsibilities. The other factor that can be used (in parallel) to group and identify relevant information is its geographic significance. The Mission/Task Information Profile enables the FBC2S to determine Areas of Interest/Responsibility. The FBC2S needs to

know everything that is going on, or planned within these areas. This includes information about friendly, enemy and neutral entities, their dispositions, reach, effects, coverage, actions, and information about the battlespace itself, and so includes features, obstacles, weather etc. So when sending information it could be labeled/grouped by the geographic area to which it pertains. FBC2S computers could subscribe for information related to their geographic Areas of Interest/Responsibility.

35. In summary, groupings based on task organizations and sections of ground are well known, relatively stable and most battlefield information can be easily categorized. Senders push information to these groups, receivers register/subscribe for the main groups of information they require and then their FBC2S computer extracts whatever is relevant and needed by the TKME to infer knowledge specific to that user's needs.

How does the TKME infer knowledge from the relevant information?

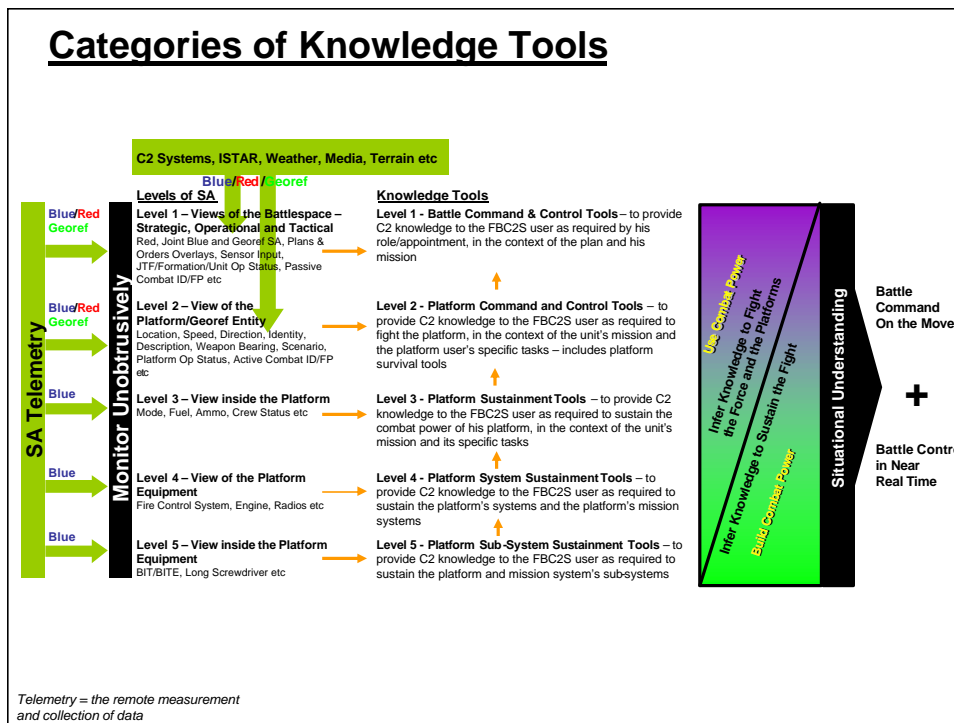
36. To remind ourselves, the TKME could be thought of as a set of Knowledge Tools. Dependent on the responsibilities of the FBC2S user, and to ensure the successful running of his platform, and its survival, some of these Knowledge Tools are invoked to provide specific knowledge. Knowledge Tools inform the FBC2S what types of information are relevant, ie, information that it needs to be able to infer knowledge. Knowledge Tools take this relevant information and possibly combine it with information from Information Profiles (IPs) and Reference Information to infer knowledge, as shown in the diagram below:



37. For example, a battalion commander's FBC2S knows from the User Information Profile that it must provide Combat Power knowledge, and so the Combat Power Tool

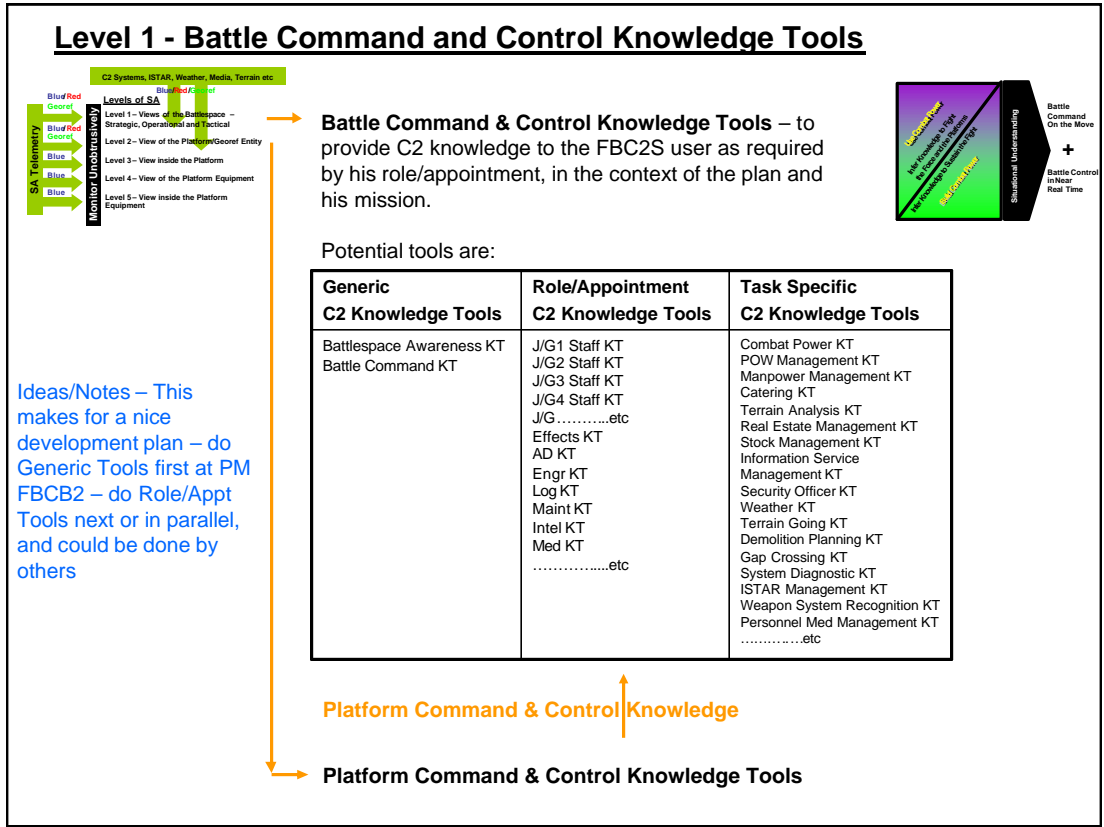
is invoked. The Mission/Task Information Profile holds the UTO information of its subordinate units/platforms, and so enables the FBC2S to gather the relevant information. The FBC2S gets relevant SA Telemetry, from the local platform sensors and from across the network. In order to infer Combat Power knowledge the tool needs to know platform characteristics, eg, fuel capacity and consumption rates. This information is held in the Platform Information Profiles. Other information required could be gained from held Reference Knowledge or from Reference Services across the network. The TKME infers Combat Power knowledge for the FBC2S user. Combat Power information is also relevant to other Knowledge Tools that have been invoked. The Battle Command Knowledge Tool infers knowledge to support the FBC2S user's role within the context of the plan and his specific mission/tasks. So this Combat Power information feeds into this tool which might infer, for example, that only 25% of the unit has sufficient fuel to reach their objective. This example has also shown that Knowledge Tools can infer knowledge for the local FBC2S user, and can also infer knowledge about other platforms from the SA Telemetry and C2 Information received across the network.

38. Knowledge Tools can be categorized as per the level of knowledge they provide, consistent with the levels of SA described earlier. This is shown in the diagram below:



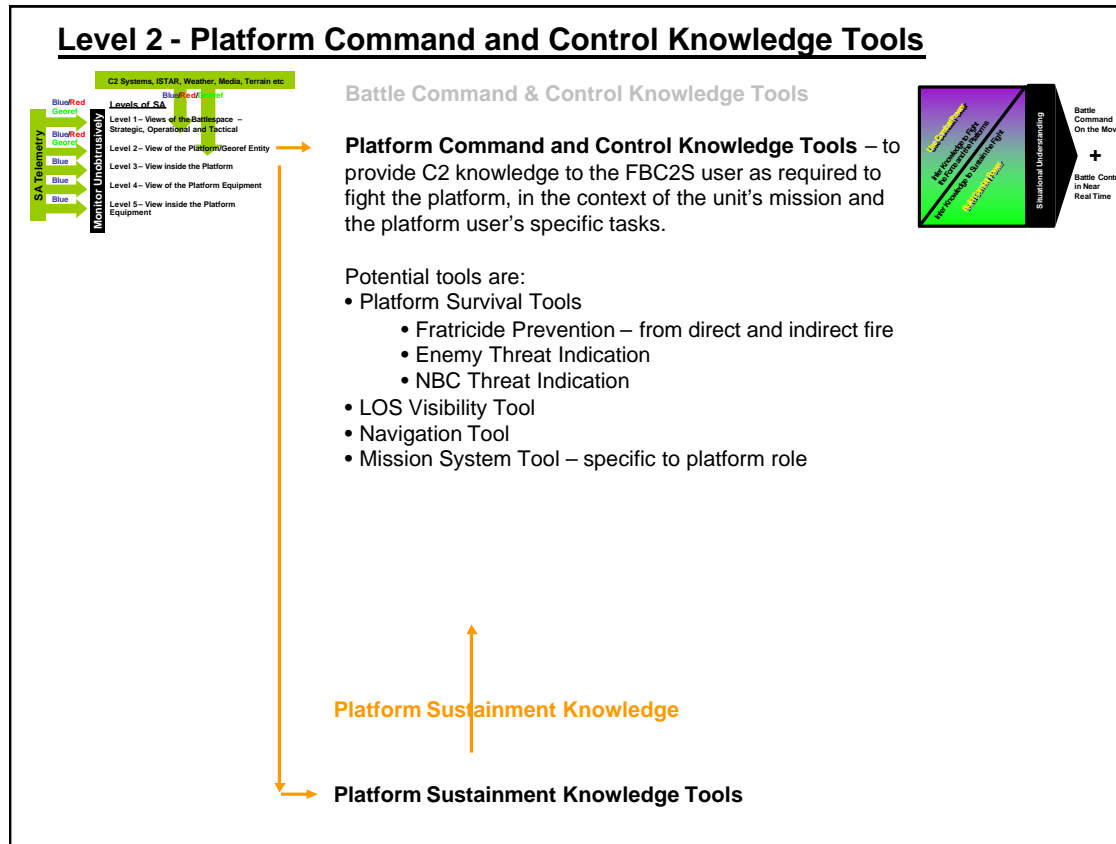
39. Each level of Knowledge Tools takes as input information the corresponding level of SA information, and the knowledge inferred by the next lower level Knowledge Tools. This shows that some Knowledge Tools might only be invoked because their output knowledge is required by a higher level tool. The lower level Knowledge Tools provide knowledge to help build combat power, and the upper level Tools relate to the use of

combat power. The following diagrams look in more detail at what might comprise the Toolset at each Knowledge Level.



40. There are 3 categories of potential Level 1 Knowledge Tools.
- Generic C2 Knowledge Tools. These provide Battlespace Awareness and Battle Command Knowledge. They provide the FBC2S user with knowledge inferred from SA Telemetry about the battlespace, and from C2 orders etc. These Generic Tools are very much akin to what is provided today by Force XXI Battle Command, Brigade and Below (FBCB2) – command and control functionality, and SA of the locations of blue, red and neutral forces, and anything that has a geographic reference, like obstacles, bridges, supply points, routes, weather, etc. FBCB2 also uses such information to infer threat warning information, when in range of an enemy tank, for example.
 - Role/Appointment C2 Knowledge Tools. As shown in the diagram, these tools provide C2 knowledge tailored for BFA roles and appointments. The Future Battle Command and Control System paper defined as its first principle that the system is, “an integrated system of systems that meets the needs of commanders and staff at every level, for all Battlefield Functional Areas (BFAs), and across the Services.” Thus this Knowledge Tool concept incorporates the specific tools required to provide knowledge for all Staff and BFAs, and could conceptually provide for the other Services also.
 - Task/Specific Knowledge Tools. These tools provide knowledge for tasks that are not specific to any particular role or appointment. The concept shows that it

should be possible to have modular Knowledge Tools which can be used as required by everyone, regardless of role/appointment.

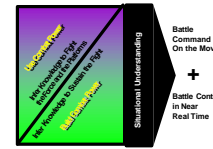


41. Level 2 Knowledge Tools provide C2 knowledge to support the local FBC2S user's role of fighting his platform. The potential tools combine SA Telemetry from the platform's mission systems – weapon, GPS, surveillance devices, NBC sensors, etc, with information from the Platform IP and Reference Knowledge to provide Platform Command and Control Knowledge. For example, the Platform Survival Knowledge Tool provides the FBC2S user with knowledge inferred from SA Telemetry to support the survival of the platform. From the Platform Information Profile, the tool will know the protection characteristics of the platform, and by referring to Reference Knowledge it will also know the threat characteristics of enemy (and other friendly) platforms or systems. Using this information the tool will use a set of rules to infer knowledge about the threat to the platform. So, if the FBC2S receives information relevant to its geographic area about an enemy Fire Mission, the tool can inform the FBC2S user if he is in range of the fires effect, and because it knows about the level of armor protection of its host platform it can infer any threat to its survival. Such an example applies equally to the threat posed by a planned friendly Fire Mission.

Level 3 - Platform Sustainment Knowledge Tools



Battle Command & Control Knowledge Tools Platform Command and Control Knowledge Tools



Platform Sustainment Knowledge Tools – to provide C2 knowledge to the FBC2S user as required to sustain the combat power of his platform, in the context of the unit's mission and its specific tasks.

Potential tools provide knowledge about the status of the main platform systems – to indicate health status and needs of the platform. Much like the knowledge found on an instrument panel, but could account for future needs as required by the platform's specific tasks.

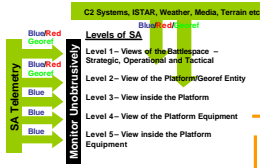
- Platform Expendables Status Tools
 - Fuel
 - Ammo
 - Water
 - Rations
- Mission System Status Tools
 - Crew Status
 - Primary Weapon/Mission System
 - Communications
- Vehicle/Platform System Status Tools
 - Electric Power System
 - Hydraulic System
 - Automotive System
- Battle C2 System Status Tools

Platform System Sustainment Knowledge

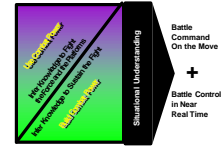
Platform System Sustainment Knowledge Tools

42. Level 3 Knowledge Tools provide much the same knowledge that would be gained by looking inside the platform and observing whether it has all systems working, whether the crew are present and healthy, and how well sustained the platform is with fuel, ammo, water, rations etc. The Tools could also account for future needs as required by the platform's specific tasks – does it have enough fuel to reach the objective, or do the crew have enough water for the next 24 hours, etc?

Level 4 - Platform System Sustainment Knowledge Tools



Battle Command & Control Knowledge Tools
 Platform Command and Control Knowledge Tools
 Platform Sustainment Knowledge Tools



Platform System Sustainment Knowledge Tools – to provide C2 knowledge to the FBC2S user as required to sustain the platform’s systems and the platform’s mission systems.

Potential tools provide knowledge about the status of individual systems – to indicate system health status, immediate and future needs of the each system.

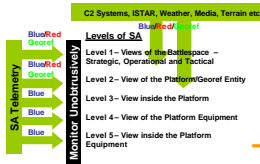
Examples are:

- Comms System Status Tools
 - Radio
 - Router
 - Crypto System
- Automotive System Status Tools
 - Fuel System
 - Suspension System
 - Braking System
 - Engine System

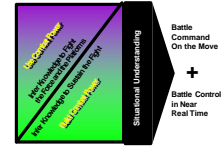
Platform Sub-System Sustainment Knowledge

Platform Sub-System Sustainment Knowledge Tools

Level 5 - Platform Sub-System Sustainment Knowledge Tools



Battle Command & Control Knowledge Tools
 Platform Command and Control Knowledge Tools
 Platform Sustainment Knowledge Tools
 Platform System Sustainment Knowledge Tools



Platform Sub-System Sustainment Knowledge Tools – to provide C2 knowledge to the FBC2S user as required to sustain the platform and mission system’s sub-systems.

Potential tools provide knowledge about the status of the sub-systems that comprise individual systems.

Examples are:

- Radio Sub-Systems Status Tools
 - Power Supply
 - Amplifier
 - RF Tuner
 - Mod/Demod
 - I/O
 - Antenna
- Fuel Sub-Systems Status Tools
 - Fuel Storage
 - Fuel Filter
 - Fuel Pump
 - Fuel Injection

43. Level 4 and 5 Knowledge Tools provide knowledge about the sustainment of the platform systems and sub-systems. It should be understood that this knowledge will feed the higher level Knowledge Tools to enable them to infer knowledge about the Combat Power for example, of a platform or sub-unit or unit. This knowledge is also likely to be inferred by other FBC2S users (from the SA Telemetry sent across the network) who have a responsibility to command, control, support or sustain that platform. For Levels 4 and 5 Knowledge Tools, the knowledge inferred could be generic to that system and sub-system, and so less refined, or specific to that individual system, and even specific to that sub-system, and so account for modifications or status history.

44. These concepts describing how Knowledge Tools require certain input information point towards the need for an Information Architecture. We should be able to define what information, in what format, is required to be sent to local platforms and across the network. Also, we should be able to define what information is required for IPs and to be provided by Reference Services. This would go a long way to achieving an integrated system of systems, and enable maximum use of this information. Today we cope by providing information in the context of preformatted messages. We suffer as a result by having a set of messages that are so complex and rigid that they are often not used, in favor of a free text message. Also, they are inefficient in that information is used only in the context of the message, and so is repeated in another message for a different context. In the future a tremendous amount of information could be obtained automatically from sensors and other digital devices, and be extracted from C2 orders, and be used to populate IPs and be provided by Reference Services. An Information Architecture will help ensure that it is used to its maximum extent to provide the best Situational Understanding for the FBC2S user, and so enable better and faster decisions and actions.

CONCLUSIONS

45. This paper has described conceptually how a FBC2S could use basic SA Telemetry and other known C2 information to help provide SU, by determining what information is relevant and then inferring knowledge specific to the needs of its users, which vary depending on their individual role, level of command and scenario. There are several important points to be noted:

- These concepts move away from the current approach of distributing information in messages, where the information is only used in the context of the message. The same base SA Telemetry and other C2 information is being sent across the network to many FBC2S. Each infers and presents knowledge to its user which has been tailored to his specific needs, dependent on his role, level of command, mission/tasks and scenario. For example, base SA Telemetry of 55 liters of fuel is used by one FBC2S to infer knowledge about whether the platform has sufficient fuel to reach its objective, and by another FBCB2 to infer how much fuel has to be supplied and when. This “free multiplier” effect from one piece of information is possible because the information about fuel was not sent in the

context of a message. Today's systems would have required a SITREP message and a LOGSITREP message to be sent.

- SA Telemetry especially, but also reported C2 information from digital devices is being sent and provided to all FBC2S unobtrusively and so does not interfere with the crew's task of fighting their platform.
- We are now presenting the FBC2S user with specific tailored knowledge, and not information that he has to sift through, decide what is relevant, and then correlate with other information. We are increasing the speed and fidelity of the user's Situational Understanding, and so enabling faster and better decisions, and subsequent action.
- The Tactical Knowledge Management Engine utilizes Knowledge Tools. There are 5 levels of Knowledge Tools, corresponding to the 5 levels of SA. At each level there are conceptually many different tools, and each one provides knowledge for a distinct function within a defined information architecture. This approach benefits the developer and the FBC2S user, as follows:
 - Developer.
 - Each tool can be considered a separate product that is developed and subsequently evolved to provide the types of knowledge required. The TKME could therefore start with only a basic set of tools, and in time more could be added, and existing tools evolved. Thus we have a system that is agile enough to be easily adapted to meet future requirements resulting from changes in the way the military does business as it learns how to conduct warfighting in the future, and brings into service new systems and technologies.
 - This building block approach supports the concept of a single integrated battle command and control system. Importantly, it enables reuse of products – the Knowledge Tools – to provide capabilities for each potential user, across all BFAs, levels of command, and potentially across all the Services of the Armed Forces.
 - User. The FBC2S invokes Knowledge Tools that will provide the required knowledge to its user, dependent on Information Profiles. Again, we now have a system agile enough to adapt to changing needs of the user resulting from changes in command and control doctrine and processes, or the differing requirements of types of operations. If a user's role changes to require him to fulfill other responsibilities, then his Information Profiles change and so FBC2S will invoke different Knowledge Tools.
- Knowledge Tools require relevant input information to which rules are then applied to infer knowledge. The FBC2S is responsible for obtaining this relevant information from its local platform and from across the network. Information must be categorized into well known and stable groups so that senders know where to publish information, and receivers know where to go and get it. Consideration of the nature and demands of the tactical radio environment, the command and control process, and the geographic relevance of information lead to the grouping of information based on Unit Task Organization and sections of the ground.

46. A conclusion of the parent paper and published article entitled “Future Battle Command and Control System”⁵ is that, “... *it must be recognized that the enabling software and hardware technologies are available today. The Future Combat System Programs now provide an opportunity to design and build a system that fully implements all of the principles described, towards realizing the quantum leap in operational capability and effectiveness sought in US DoD’s Joint Vision 2020 resulting from the evolution of digital communications, computers, digital sensor and surveillance technologies.* This paper has added weight to this conclusion by expanding some of the concepts described in the parent paper, discussing design issues and exploring potential implementation approaches.

⁵ Mr Richard Sparshatt and Colonel Nick Justice, *Future Battle Command and Control System*, Battlespace C4ISTAR Technologies, Vol 5 – Issues No. 3 October 2002