

Land Warfare Studies Centre

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**A TACTICAL COMMUNICATIONS SYSTEM
FOR FUTURE LAND WARFARE**

by

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and

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ABBREVIATIONS AND ACRONYMS

ADF	Australian Defence Force
ADFA	Australian Defence Force Academy
BCSS	Battlefield Command Support System
C2 Cycle	Command and Control Cycle
C4ISR	Command, Control, Communications, Computing, Intelligence, Surveillance and Reconnaissance
CNR	Combat Net Radio
CT2	Cordless Telephone No. 2
DECT	Digital European Cordless Telecommunications
EDC	error detection and correction
EPLRS	Enhanced Position-Locating and Reporting System
FM	frequency modulation
GEO	geostationary earth orbit
GPS	Global Positioning System
GSM	Global System for Mobiles
HF	high frequency
IR	infra-red
JCSS	Joint Command Support System
JTIDS	Joint Tactical Information Distribution System
kbps	kilobits per second
LEO	low earth orbit
locstat	location statement
LPI	low probability of interception
LWSC	Land Warfare Studies Centre
Mbps	megabits per second
MHz	megahertz
MPEG	Moving Picture Expert Group
PSTN	Public Switched Telephone Network
RF	radio frequency
SOP	Standard Operating Procedures
SSB	single sideband
TDMA	time-division multiple-access
WLANS	wireless local-area networks
UAV	uninhabited aerial vehicle
UHF	ultra-high frequency
UK	United Kingdom
VHF	very high frequency

ABSTRACT

Success on the battlefield depends to a large extent on the timely receipt of accurate information presented in a format that can be digested readily by the commander and staff to allow them to prepare appropriate plans. The receipt of sensor data, information processing and communication of orders all require the provision of suitable tactical communications systems providing high-speed data networks and voice communications. Without communications on the modern battlefield the commander is deaf, dumb and blind.

The Australian Army is entering a period of sustained and substantial change in structure, doctrine and use of technology, particularly with the current and planned introduction of a wide range of new communications and information systems. In the face of such change, the Australian Army must reassess its communications requirements through the development of a comprehensive, robust, flexible architectural framework for its Tactical Communications System. Such an architecture is essential to provide support to commanders as well as to provide the network to support sensor-to-shooter links.

This paper develops an architectural framework to define the Tactical Communications System. It begins by outlining key design drivers that shape the architecture of a tactical communications system. These design drivers include the traditional principles of military communications as well as a number of important issues governing the way in which the Tactical Communications System is to be employed. The Tactical Communications System must be organic to the supported force and must support communications between any two points in the battlespace, and between any point in the battlespace and the Strategic Communications System. Communications support must be provided to a range of battlefield, joint and combined systems. Access must also be gained to a range of additional Overlaid Communications Systems to increase the capacity of the minimum organic network when circumstances allow.

Options for a mobile Tactical Communications System are then examined and it is concluded that, while it is essential that the Tactical Communications System provides a single logical network, it is not possible to provide a single physical network. The range of candidate technologies available to provide access to mobile users constrains the physical architecture to the provision of five major subsystems. The underlying infrastructure of the organic network is provided by the Tactical Trunk Subsystem and the Combat Radio Subsystem. To extend the range of these two subsystems in dispersed operations, a Tactical Airborne Subsystem is required. Additionally, there is not sufficient capacity in the Combat Radio Subsystem (in particular) to cope with the high volume of data transfer required to support real-time situational awareness for commanders of combat forces; this need is met by the Tactical Data Distribution Subsystem. A Local Subsystem is proposed to simplify the user interface to the other communications subsystems.

A TACTICAL COMMUNICATIONS SYSTEM FOR FUTURE LAND WARFARE

INTRODUCTION

1. Success on the battlefield depends to a large extent on the timely receipt of accurate information presented in a format that can be digested readily by the commander and staff to allow them to prepare appropriate plans. The receipt of sensor data, information processing and communication of orders all require the provision of suitable tactical communications systems providing high-speed data networks and voice communications. Without communications on the modern battlefield the commander is deaf, dumb and blind.

2. The Australian Army is entering a period of sustained and substantial change in structure, doctrine and use of technology, particularly with the current and planned introduction of a wide range of new communications and information systems. In the face of such change, the Australian Army must reassess its communications requirements through the development of a comprehensive, robust, flexible architectural framework for its Tactical Communications System. Such an architecture is essential to provide support to commanders as well as to provide the network to support sensor-to-shooter links.

3. Plans are already in place to replace or enhance the current capabilities of *Raven* combat net radio and *Parakeet* trunk-communications system. In addition, new projects such as *Milsatcom* offer novel capabilities to support battlespace land operations. To varying degrees, each of these projects is addressing the changes required for modern land operations, although they are tending to do so based on the traditional delineation between trunk, combat-radio and satellite communications. It is therefore unlikely that an optimum solution will be achieved since neither the Australian Army nor the Australian Defence Force (ADF) has an overarching communications architecture that can provide a framework within which communication projects can progress. An

appreciation therefore needs to be conducted into the communications support required for land operations, with the aim of developing an architecture that provides the foundation for the seamless flow of information among all tactical entities operating in the battlespace.

4. This paper develops an architectural framework to define the Tactical Communications System. It begins by outlining key design drivers that shape the architecture of a tactical communications system. Options for a mobile Tactical Communications System are then examined and a suitable framework is developed for the subsequent consideration of architectural issues.

DESIGN DRIVERS

5. The following issues represent key design drivers for the provision of an architecture for the Tactical Communications System.

Principles of Communications

6. The principles for the provision of tactical communications are contained in MLW 2.1.1—*Land Force Tactical Communications*, which is now slightly dated as it was published in 1981. The following sections provide an updated set of principles, which are based on those given in MLW 2.1.1, but amended to reflect the requirements of the modern battlefield.

7. **Communications support the chain of command.** Tactical communications systems are extensions of the powers of speech and hearing of commanders and staffs; they are, therefore, very much functions of command. The communications system must facilitate the chain of command and not constrain the ability of commanders and staffs to implement the C2 Cycle. A commander's tactical plans must not be constrained by communications.

8. **Integration.** A tactical communications system cannot be operated efficiently in a series of discrete compartments. Communications must therefore be controlled at the highest level of deployed force, through an integrated network management structure that supports the chain of command. Complementary tactical and technical control must be exercised throughout the whole communications system.

9. **Reliability.** Tactical communications systems must be reliable because failure of communications in battle is always dangerous and often disastrous. A reliable system that provides minimum facilities is usually preferable to a less-reliable system providing superior facilities. Sound planning, good equipment and high standards of training reduce the risk of breakdown of communications systems. Providing redundancy through the use of both standby equipment and alternative systems can also increase availability of service.

10. **Simplicity.** Simple communications plans are more likely to withstand the stresses of all types of operation. A simple plan will be more readily understood, more easily implemented and more flexible; it will also have fewer areas of potential failure. While a degree of complexity will be inevitable to meet tactical requirements, planners must resist the temptation to increase the complexity of networks and organisations in order to provide marginal improvements. Communications equipment should be easy to operate and simple to repair.

11. **Capacity.** A communications system is of little use unless information is current when it reaches its destination. The system must therefore be able to cope with traffic peaks and transmit all communications within the desired time frame and according to priorities. However, communications capacity will always be a scarce resource on the modern battlefield, and measures must be devised to regulate the use of communications systems. Without such measures, systems are more likely to fail from overloading and abuse than from any other cause. There are three aspects in

providing a tactical communications network with sufficient capacity:

- a. sufficient capacity of individual bearers,
- b. adequate coverage, and
- c. adequate access.

12. **Quality.** There are considerable differences in the requirements for quality (including accuracy) between the military and the civilian user. At one extreme, the military user will accept intelligible voice whereas most commercial telephone systems provide a high quality of reproduction with a very good level of speaker recognition. At the other extreme, while the requirements for errorless data transmission from terminal to terminal are the same in both environments, the civilian expectation of high-quality transmission media (error rates of certainly less than one in 100 000) may be unacceptably high in the military. This disparity leads to difficulties when adopting civilian standards. Modern communications standards have generally been developed for transmission media such as fibre-optic cables; communications systems designers therefore expect that few or no errors are introduced during transmission. Adoption of civilian data communications protocols within military networks therefore tend to require that additional error detection and correction be incorporated into the standard or specially provided for by tactical communications protocols.

13. **Flexibility.** The supported force must be able to use the same communications equipment for as many military tasks as possible. Equipment must therefore be flexible in the way it is deployed to meet the wide variety of tactical circumstances. It must also be able to carry different sorts of traffic such as voice, data, telegraph and video. Flexibility relates to the ability of the tactical communications network to react to changing situations and unexpected developments and, in the provision of communications, to match the tactical mobility of combat forces. The main factors in the provision of flexible networks are:

- a. forethought in planning;
- b. alternative routing;
- c. reserve equipment and personnel;
- d. reserve capacity on circuits; and
- e. standing operating procedures (SOP), drills and a high standard of training to reduce planning and deployment times.

14. No single communications equipment can provide all the needs of all users in all tactical situations. A communications *system* is flexible if it provides a mix of equipment, combining the strengths of each.

15. **Anticipation of requirements.** The requirement for flexibility can be mitigated in some regard by anticipating the requirements of the deployed force. Commanders must therefore ensure that communications staff are kept informed throughout the C2 Cycle, so that communications infrastructure can be deployed in anticipation of future plans.

16. **Mobility.** At all levels, the mobility of communications equipment must meet that of the user. In the case of combat troops, radio sets must be portable or able to be fitted into fighting vehicles and aircraft. For headquarters, a communications network should be able to cope with a considerable degree of movement by combat elements without needing to redeploy. The communications system must also allow commanders to command and control on the move. (Previously, commanders have been required to step up headquarters to achieve continuity of command.) However, when required to move, the components of a communications system must have the ability to change location as rapidly as the combat elements that they serve. The mobility of the combat elements must not be restricted simply because the communications system cannot keep up with the supported force.

17. **Security.** Due to its crucial role in support of the C2 Cycle, the tactical communications network will be a prime target of enemy intelligence-gathering. Protection of the information carried by the tactical communications system is therefore of prime importance. There are three aspects of a secure network:

- a. physical security,
- b. personnel security, and
- c. electronic security.

Security is a major factor in the provision of an adequate tactical communications system, and a comprehensive security architecture must be developed to provide guidance to the development of a communications architecture.

18. **Economy.** The complexity of modern warfare puts a great strain on most battlefield resources. Due to the scarcity of communications resources, the personnel and materials needed to establish, operate and maintain communications systems must be used economically. While all users will see their own requirements as paramount, facilities will invariably have to be shared and demands for communications should be kept to the minimum. The provision of sufficient bandwidth is not generally a problem in the commercial and fixed environments; however, bandwidth will always be a scarce resource on the modern battlefield.¹ Sole-user facilities will need to be restricted, usually to commanders and possibly to some key staff positions. In the past, the provision of sole-user facilities consumed resources, particularly bandwidth, even if no information was being transferred. The network provided such facilities to ensure immediate and guaranteed service to the sole user. Conceptually, sole-user facilities can be provided via permanent virtual circuits, which can release bandwidth resources

¹ This paucity of bandwidth on the land battlefield is mainly caused by the limitations of the physics associated with the methods of propagation available to tactical communications systems.

to lower-priority users when not required for the sole user. To maintain the principle of economy, users must ensure that:

- a. the appropriate means of communications are utilised,
- b. demands for communications are kept to a minimum,
- c. sole-user facilities are demanded only when absolutely necessary,
- d. plans are based on a realisable scale of communications, and
- e. contingency plans are available to accommodate operations if communications are disrupted for any period of time.

19. **Survivability.** The modern battlefield represents a harsh electromagnetic environment within which the tactical communications system must survive. A communication system is *survivable* if it has:

- a. sufficient capacity to handle traffic levels,
- b. an ability to manage existing capability through techniques such as dynamic bandwidth management,
- c. the necessary levels of security,
- d. low probability of intercept,
- e. resistance to jamming and interference,
- f. mobility,
- g. alternative routing,
- h. alternative means,
- i. redundancy, and
- j. sufficient reserves.

20. **Interoperability.** The systems and networks within the Tactical Communications System must be interoperable with other tactical networks, strategic networks, unclassified commercial networks, as well as networks and systems of other services and allies. This interoperability is essential if information is to be able to flow seamlessly between any two points in the battlespace or

between any point in the battlespace and the Strategic Communications System.

Size of Supported Force

21. In the communications appreciation that follows, attention is focused at the level of the brigade-sized group, that is, on brigade and below. While the architecture of the Tactical Communications System is developed with cognisance of larger formations, the most difficult problem is the provision of sufficient digital capacity to tactical combat forces at brigade level and below.

Communications Support for the Spectrum of Operations

22. The communications architecture must be able to support a force in the wide range of operational deployments that the ADF is expected to undertake. The spectrum of potential operations varies from conventional, high-density motorised or mechanised operations to low-density operations in defence against attacks on Australia, or in peacekeeping or peace-enforcing operations. The Tactical Communications System must therefore provide similar interfaces regardless of the type of operation. This concept produces two main design drivers:

- a. User equipment must be similar in all types of operations. The user should not be expected to have to adjust to a different communications interface in different operational circumstances. Therefore command posts, vehicles and weapons platforms must be configured with a flexible internal communications network that can interface to the range of available communications systems.
- b. Specialist communications equipment must also be similar in all types of operations. All brigade signal squadrons should therefore be similarly equipped. While the vehicles may differ between squadrons that support motorised and mechanised forces, the basic equipment configurations should remain similar. In a small army, this will greatly ease

procurement, logistic support, training, deployability and sustainability.

Command and Control on the Move

23. On the future battlefield it is essential that commanders be able to command and control on the move. This requirement includes continuity of command and control while deploying from bases as well as while moving around the battlespace. A commander should be able to control force elements regardless of location. This requirement provides one of the most significant design drivers because it impacts on the power available for transmitters, the antenna size that can be supported and so on. These issues are discussed in more detail in the following sections.

Communications Support Situational Awareness at all Levels

24. Communications must support *situational awareness* to commanders at all levels (in real time or near-real time) to provide accurate knowledge of enemy, friendly, neutral, and noncombatant entities. Situational awareness² is the knowledge of the operational environment required to gain the level of understanding necessary to achieve decision superiority over an adversary. The recently endorsed Command, Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance (C4ISR) concept³ calls for near-real time situational awareness at brigade headquarters. As is discussed later, this requirement provides a significant design driver for the Tactical Communications System.

² *Land Warfare Doctrine One (LWD1): The Fundamentals of Land Warfare*, Australian Army Doctrine Wing, CATDC, Puckapunyal, Vic., December 1998.

³ *The Australian Army C4ISR Concept for Land and Special Forces*, Australian Army, Canberra, 1999.

Seamless Connectivity

25. If concepts such as network-centric warfare are to be implemented on the future battlefield, the communications architecture must support seamless connectivity between:

- a. any two points in the battlespace, and
- b. any point in the battlespace and any point in the Strategic Communications System.

26. While it will not always be desirable to be able to support such extremes of connectivity, the possibility of such connections must be supported in the architecture if forces are to realise the full power of network-centric warfare.

Organic, Minimum-essential Communications

27. The brigade must have an organic, field-deployable Tactical Communications System that meets minimum-essential requirements for communications to support command and control. The minimum-essential system must provide guaranteed, robust, flexible communications that support the force whether deployed on foot, motorised, mechanised, airborne or seaborne. This Tactical Communications System is an organic brigade asset that is part of the brigade's combat power. As the brigade commander owns the minimum-capacity network, the essential communications requirements of the brigade can be guaranteed in any deployment. The network must also be modular so that units and sub-units are self-supporting when deployed separately from the main force and still retain communications functionality.

Expandable Communications

28. As its organic communications will invariably be limited, the brigade must be able to make use of other battlefield and strategic communications systems when available. While organic communications cater for essential brigade requirements, network managers can provide additional capacity, redundancy and reliability by using overlaid communications systems such as the

commercial public switched telephone network (PSTN), satellite communications, and theatre broadcast. These systems must be seamlessly integrated with the Tactical Communications System.

Scalable Communications

29. Within all available assets the brigade must have the ability to provide scalable communications, that is, a small advance party must be able to deploy taking with it sufficient communications for its task. As the force builds, so must the communications system be able to grow to accommodate the size and nature of the force.

Range

30. The Tactical Communications System must be able to support the force when it is deployed in any one of its roles. In the extreme, the communications system must be able to provide communications in conventional high-density deployments where the brigade is deployed with a 25-km frontage, as well as support widely dispersed deployments where the brigade may be spread over an area with a 500-km radius.

31. The Tactical Communications System must also be able to support high-capacity communications from the area of operations back into the Australian Strategic Environment. This support may require round-the-world communications.

Support for Real-time and Non-real time Services

32. The requirement to support both voice and data communications on the battlefield is often characterised as a voice-versus-data debate, which tends to belie the fact that both have relative advantages, as summarised in the following subparagraphs.

- a. **Voice messaging.** Voice has long been the preferred means of communications on the battlefield because it:
 - (1) conveys the imperative of the situation,
 - (2) carries the personality of the speaker,

- (3) is user friendly in that it is a familiar interface to the user and it allows for conversational interchange,
- (4) does not require off-line preparation,
- (5) is interactive, and
- (6) is immediate.

b. **Data messaging.** On the other hand, data messaging has a number of considerable advantages as well:

- (1) terminals do not need to be staffed permanently;
- (2) messages can be acknowledged automatically;
- (3) messages can be pre-formatted and can be prepared off-line;
- (4) error detection and correction (EDC) techniques ensure that messages have more chance of being received correctly under poor telecommunications conditions; and
- (5) encoding in digital form allows the efficient transfer of information through networking, particularly the integration of networks to allow the seamless transfer of information between any two points in the battlespace.

33. **Support for both voice and data.** As long as warfare remains a human endeavour, commanders will want to communicate using voice. However, concepts such as network-centric warfare cannot be force multipliers unless the communications architecture can support the rapid transfer of data across the battlefield. Since the Tactical Communications System must serve both types of user, both voice and data communications must be supported.

34. **Other forms of data.** In addition to data messaging, battlefield entities need to transfer other forms of data including video and database transfers. With the proliferation of battlefield information systems, these types of data have the potential to dominate over the more traditional data messaging. In fact, as most modern battlefield

communications systems are increasingly digital, all forms of traffic are invariably digitised before transmission. As there are many different types of data on the modern battlefield it does not make sense to distinguish them by their source necessarily. Rather it is more useful to characterise them by the requirements that each type of data has for services across the network. In that regard there are two main types of traffic: those that require real-time services (predominantly video and voice) and those that require non-real time services (such as computer-to-computer transfer).

Low Probability of Interception

35. Tactical communications systems have a critical requirement for low probability of interception (LPI). Survival on the modern battlefield requires protection of communications systems as the first step in protecting the command systems that they support. LPI techniques include short-duration transmission; spread spectrum (direct sequence spread spectrum as well as frequency hopping); directional antennas; low power settings; terrain screening; and use of airborne relays so that ground terminals can direct their power upwards, away from a land-based enemy.

Jamming Resistance

36. The provision of communications links also critically depends on jamming resistance. Operation in a harsh electromagnetic environment requires the ability to implement measures to provide resistance to jamming. Techniques listed above for LPI are also relevant to increase jamming resistance. Other techniques that may conflict with LPI requirements include increased power; strong error-coding; jamming-resistant modulation; and adaptive antennas with steerable nulls.

Supported Systems

37. The Tactical Communications System architecture must support the following battlefield, joint and combined systems:

- a. **Command elements.** Arguably, the principal purpose of the communications system architecture is to support the C2 Cycle and the transfer of information between command elements.
- b. **Sensors.** Any point in the battlespace must be able to access information provided by any sensor. However, this does not imply that all sensor data are transferred across the Tactical Communications System, which simply cannot be provided with enough capacity to cope with large volume sensors connecting into the network at any point. What is required is a transfer of information, not data. Each sensor system must be examined in the context of the architecture of the Tactical Communications System, with a view to determining the most effective way of interfacing that sensor to the network.
- c. **Weapons platforms.** Weapons platforms must be able to connect in to any point in the Tactical Communications System and subsequently be able to access any sensor, the supported command element as well as their own command post.
- d. **Information systems.** Information is provided to commanders by many different information systems, whether they are tactical, operational or strategic systems. These systems extend from the Battlefield Command Support System (BCSS) at the tactical level to the Joint Command Support System (JCSS) at the higher tactical, operational or strategic level. Additionally, on deployment, access is required to a wide range of administrative systems.
- e. **Information services.** The Tactical Communications System must support the provision of vital information services throughout the battlespace. These services include security, messaging, video teleconferencing, data replication

and warehousing, distributed computing, and search engines.

- f. **Network management.** Network management is essential if the Tactical Communications System is to be deployed as a single logical network. A single, integrated, network-management system must be deployed to manage the entire Tactical Communications System.

OPTIONS FOR A MOBILE TACTICAL COMMUNICATIONS SYSTEM

38. As illustrated in Figure 1, the present Tactical Communications System has evolved to comprise two major components:

- a. **Trunk-communications Subsystem.** The Trunk-communications System provides high-capacity links (terrestrial radio-relay, satellite, fibre-optic, or line) that interconnect headquarters at brigade level and above. The network is provided by a number of trunk nodes interconnected by trunk links to form a meshed area network. Access is normally gained through access nodes that interconnect to one or more trunk nodes. Voice, telegraph, data, facsimile and video facilities are provided to staff officers and commanders. Within the Australian Army, trunk communications are provided by equipment procured under Project *Parakeet*.
- b. **Single-channel Radio Subsystem.** The Single-channel Radio Subsystem—also commonly called the Combat Net Radio (CNR) Subsystem—is a ruggedised, portable radio network carried as an organic communications system for combat troops (brigade level and below). Radios are invariably interconnected to form single-frequency, half-duplex, all-informed, hierarchical nets, providing commanders with effective support to command and control. Within the Australian Army, the CNR Subsystem is provided by

equipments procured under Projects *Raven*, *Wagtail* and *Pintail*.

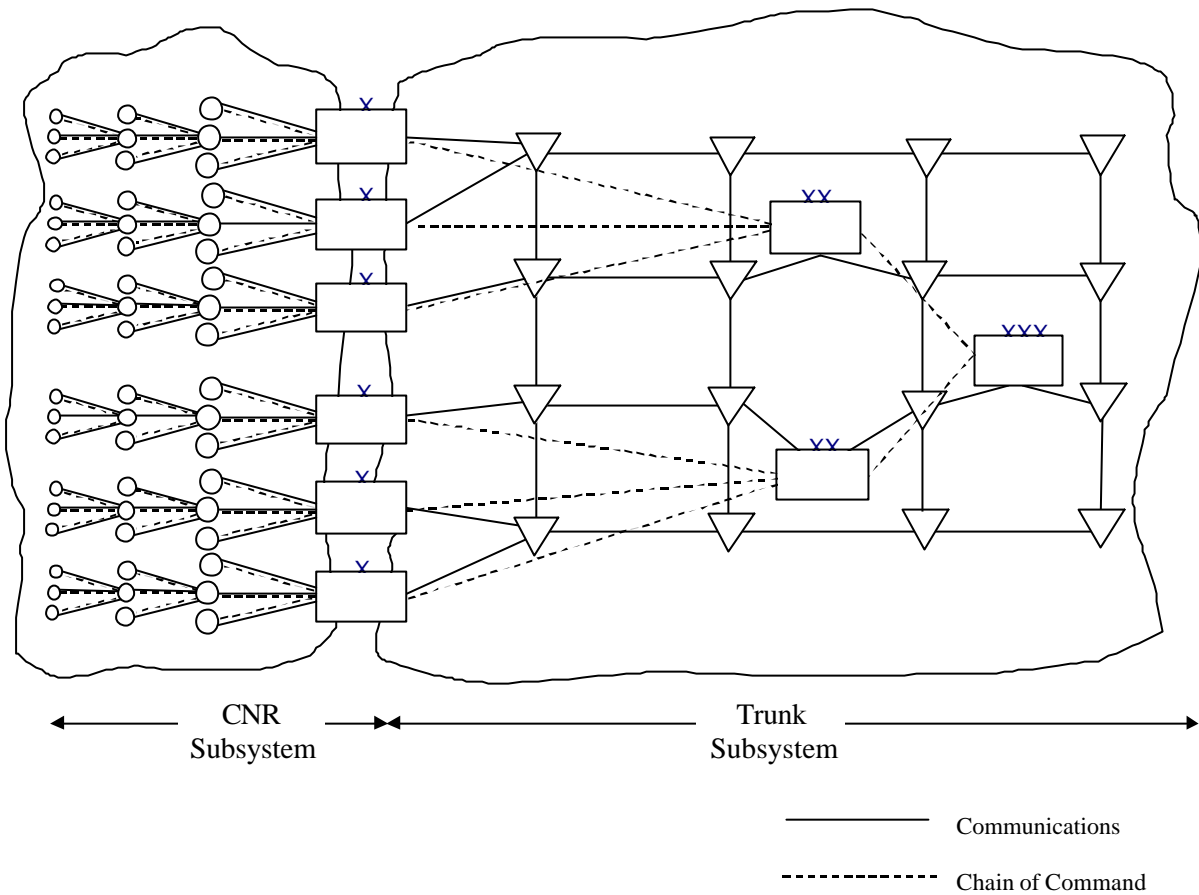


Figure 1: The Current Tactical Communications System

39. There are a number of major problems with the current Tactical Communications System if it is to support command and control in future land warfare. Some of these problems are outlined below.

- a. Due to its hierarchical, analogue voice net structure, the Combat Net Radio Subsystem is poorly placed to provide a network to transfer data between combat units.
- b. The networks are not seamlessly integrated to allow the transfer of information between any two points in the battlespace.
- c. The Tactical Communications System is not seamlessly integrated with the Strategic Communications System to allow the transfer of information between any point in the

battlespace and any point in the Strategic Communications System.

- d. There is not sufficient capacity below brigade to cope with future levels of data traffic required to provide commanders with near–real time situational awareness.
- e. Neither the current CNR Subsystem nor the Trunk-communications Subsystem provides enough range to allow dispersal of brigade elements when required to meet the tactical situation.

40. Philosophically, support for command and control in future land warfare requires the Tactical Communications System to be a single logical network (as shown in Figure 2) in order to provide connectivity between any two points on the battlefield. The Tactical Communications System is an organic asset that provides the minimum essential voice and data communications requirements to support situational awareness within the brigade and to allow for the transfer of command and control information. The Tactical Communications System interfaces with the Strategic Communications System to provide seamless connectivity between any two points in the battlespace and between any point in the battlespace and any point in the Strategic Communications System.

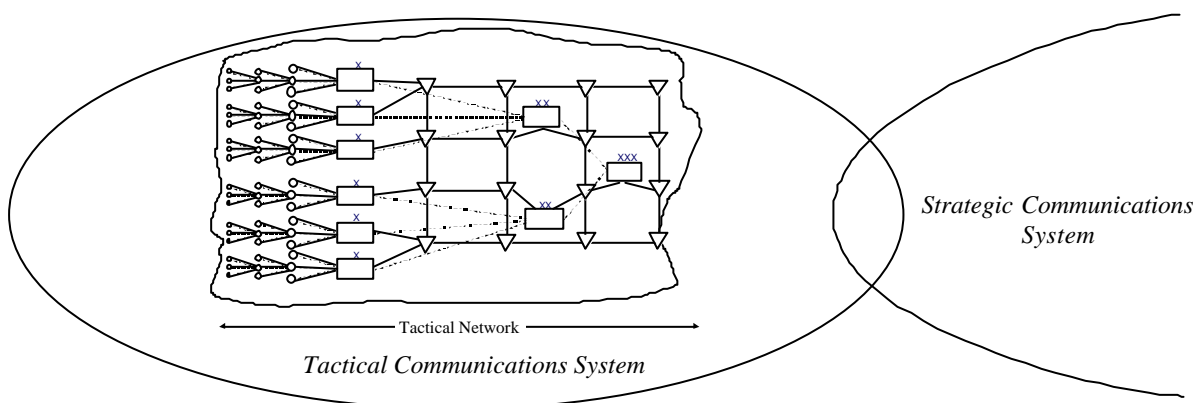


Figure 2: Tactical Communications System and Strategic Communications System

41. The development of a suitable architecture for the Tactical Communications System can draw on the considerable body of knowledge available in existing commercial and military networks that provide mobile communications. However, in some respects, *mobile communications* is a misnomer when used in the commercial environment because only the user is mobile in such systems; the communications system (the communications network) is very much fixed, with mobile access to this fixed infrastructure being provided by a wireless connection. In the military environment, the provision of a mobile communications system normally implies that both the user and the network infrastructure are mobile. Mobility therefore has markedly different meanings in the commercial and military environments. Consequently, while many commercial communications technologies are useful in the military environment, the mobility of the network infrastructure for military communications systems tends to require unique solutions.

42. However, even within military mobile-networks, a distinction must be made between networks provided with mobile infrastructure and transportable infrastructure. It is therefore useful to consider potential mobile-network architectures under the following three categories:

- a. mobile users, fixed-network infrastructure;
- b. mobile users, semimobile-network infrastructure; and
- c. mobile users, mobile-network infrastructure.

43. The following sections briefly examine the commercial and military mobile-communications systems available within each of the categories.

Fixed-network Infrastructure

44. As briefly described earlier, commercial mobile-communications systems are based on a fixed-network infrastructure, with mobility provided by a wireless interface between the user and the network.

Major systems include terrestrial mobile telephony and wireless networking.

Terrestrial Mobile Telephony

45. Mobile-telephone systems provide wireless access to users that can have varying degrees of mobility:

- a. **Cellular Telephones.** In cellular phone systems, mobile-telephone users are connected by wireless telephone handsets to one of a number of base stations, each of which serves a number of mobile users within an area called a cell. Base stations are then interconnected using high-speed trunk-lines provided by fixed infrastructure, normally that of the PSTN. A group of base stations is controlled by a mobile-switching centre, which supports the handover of a mobile user as that user moves from one cell (base station) to another. Users are therefore able to make calls as they roam throughout the network. Cellular-telephone networks are designed predominantly for voice, but can also pass data at rates of up to 9.6 kbps (although the introduction of third-generation systems should considerably increase data rates).
- b. **Cordless Telephones.** A number of applications do not require the complexity of cellular-telephone system, particularly the arduous (and expensive) requirement to hand over users between base stations to maintain continuity of communications for mobile subscribers. These simpler mobile-telephone techniques (such as CT2 and DECT) allow a mobile user to be supported by a single base-station for the period of a call. Handover is generally not supported, although an exception to this is DECT, which does support a limited form of handover. Range is therefore very limited to line-of-sight between the user and the base station. Cordless-phone systems are generally designed for voice calls only.

Wireless Networking

46. Wireless local-area networks (WLANS) provide some flexibility for computer users who want to be able to detach and attach quickly, or for networks (such as those provided in classrooms) where users move in and out of the network on a regular basis. WLANS can be based on infra-red (IR) or radio frequency (RF) bearers. IR WLANS have very limited range, since they are constrained by line-of-sight and high atmospheric attenuation. RF WLANS have relatively longer ranges but are still too short for wide-area coverage. While wireless networking has great utility within command posts and other locations where computers are deployed on the battlefield, ranges are too limited to be of any use as an organic part of the Tactical Communications System.

Military Utility

47. Although they may have the potential to provide the highest capacity and quality of service to deployed forces, fixed-infrastructure (commercial) mobile communications systems have limited utility as the basis for the Tactical Communications System:

- a. **Provision of infrastructure.** In commercial mobile communications systems, only the user is mobile, while the considerable network infrastructure is fixed. Terrestrial mobile communications systems require the provision of a significant amount of infrastructure in the form of base stations every 20 or 30 km. In addition, base stations are connected by the fixed infrastructure of the public-telephone network. Since the provision of this infrastructure cannot be guaranteed within any potential area of operations, the Tactical Communications System would need to provide the necessary equipment and personnel. Significant infrastructure would be required to support the force over a widely dispersed area.
- b. **Range.** Calls in terrestrial mobile-communications systems cannot be placed outside the range of the network because

not only are communications ranges to base stations limited by terrain but, in systems such as GSM, range is limited to 35 km for power balancing at the base station.

- c. **Flexibility.** As they are connection-oriented, mobile cellular-communications systems lack flexibility. A user can only make a call to another user. While some systems may support, or may be able to be adapted to support, broadcast or conference calls, these are established as a series of point-to-point connections. All-informed communications are therefore not easily obtained. In addition, while the service provider can provide connection to a data network, it is very difficult to provide the type of network required to support the seamless transfer of data between any two points in the battlespace, as any such network would be essentially circuit-switched. A circuit-switched network is adequate if the mobile user is the initiator and the connection is simply to a server. Problems ensue if contact with the mobile user is sought from a server on the fixed network (or another mobile user through the fixed network).
- d. **Capacity.** Cellular-telephony systems have limited capacity—currently about 9.6 kbps. While there is promise that these rates will increase somewhat in the near to medium term,⁴ they will still only serve single military users because only a single connection is provided. It should also be noted that higher-capacity cellular systems come with a limitation on the number of simultaneous active connections.
- e. **Cost-effectiveness.** Significant quantities of infrastructure are required to provide base stations that cover a population of users. In regions that have high populations, a large number of base stations is required to accommodate possible calls. A significant number of base stations is still required in

⁴ Third-generation systems promise up to 2 Mbps in the smallest cells (pico cells).

regions of low population, as communication is terrain-limited to tens of kilometres. The provision of this infrastructure on the battlefield is not cost-effective to provide complete coverage.

- f. **Security.** Both terrestrial mobile-telephony and wireless networking are very limited in their ability to provide security services to applications.

48. These limitations mean that fixed-infrastructure systems have little utility for inclusion in the Tactical Communications Systems because they cannot provide the minimum, organic, flexible communications required to support voice requirements. Additionally, such systems do not easily support the provision of a data network. However, these systems provide a very useful adjunct to the Tactical Communications Systems and must be able to be used when available.

Semimobile Network Infrastructure

49. In these networks, mobile users connect to semimobile infrastructure, which can deploy and redeploy to meet changes in the operational requirement. This mobility is essential to support military operations.

Trunk-communications Networks

50. Most modern armies employ trunk-communications systems that provide semimobile infrastructure to support communications between headquarters. Mobility of these trunk networks is constrained by their size and deployment times. However, they are sufficiently mobile to allow combat forces, and particularly command elements, to be fully mobile within the area of operations. In particular, trunk-communications networks provide high-capacity point-to-point links between transportable switching nodes. The network deploys to cover an area of operations and command elements connect into a convenient node. More detail on trunk-communications systems is provided by Ryan's article in the

November/December 1997 issue of the *Australian Defence Force Journal*.⁵

Cellular-communications Systems

51. As outlined above, mobile-communications systems tend to rely on too much fixed infrastructure to be of any great use in a Tactical Communications System. However, with reduced functionality, a mobile base-station could be deployed to support isolated communities of users, such as in command posts, logistics installations and airfields. If the tactical situation allows, mobile base-stations could be interconnected by high-capacity radio links. Such an interconnection becomes particularly feasible when base stations are collocated with, or integrated into, trunk-network nodes.

Military Utility

52. Although modern trunk-communications systems may one day become fully mobile, they are currently constrained in their mobility by their size, power requirements and the need to orient the high-gain antennas required to support high data-rates over useful distances. Some research is currently being conducted in this area, but planned high-capacity radios (45–155 Mbps) have very limited ranges (only tens of kilometres). Current trunk-communications systems architectures are therefore likely to remain for the next ten to fifteen years.

53. Additional systems, such as semimobile cellular-communications systems, will continue to find applications as adjuncts to trunk-communications systems. However, they are unlikely to develop the functionality to replace them.

⁵ M. J. Ryan, 'The Development of the Tactical Communications System', *Australian Defence Force Journal*, no. 127, November/December 1997, pp. 43–50.

54. Therefore, there will still be a requirement for the high-capacity backbone of the Tactical Communications System to be provided by a system similar in design to the current trunk-communications system provided by Project *Parakeet*. However, a number of changes are required. In particular, trunk communications must be extended to below brigade headquarters, and the trunk network must be seamlessly integrated with other battlefield networks.

Mobile-network Infrastructure

55. Mobile networks provide the greatest flexibility and mobility to support military operations, as all users are mobile—like the network itself. These types of networks, apart from satellite communications systems, tend to be unique to the military environment.

Combat Net Radio

56. The traditional means of providing communications on the move is CNR. Radios are mounted in aircraft or vehicles, or are carried in soldiers' packs. Radios provide both user terminals and network nodes. Most radios provide voice communications, although data communications are increasingly available in modern radios. The major disadvantage of CNR is that it is generally terrain-limited rather than power-limited. This causes additional difficulties in establishing and maintaining communications.

Packet Radio

57. Packet-radio systems were developed as an extension of combat net radio systems. Their main design driver was to be able to handle the requirement to send data over tactical mobile links. Radios are digital; they exchange information by breaking messages up into packets and then routing them around the network. Packets are stored at each radio and then forwarded when the next link is available. Packets may take a number of hops to reach their destination. While packet-radio systems can have fixed infrastructure, they are most useful for military use when mobile. Packet-radio networks offer one of the few architectures available

for providing a data network on the battlefield that could support mobile users with mobile network infrastructure. Like CNR, however, packet-radio networks are terrain-limited, which causes difficulty in maintaining network connectivity between mobile forces that naturally keep low in the terrain.

Satellite Communications

58. Mobile communications can also be provided by satellite communications systems. While the network infrastructure is not mobile in the sense that we have considered other infrastructure, it is ubiquitous over all possible areas of operations. Since the infrastructure itself does not place any constraints on the mobility of the users, satellite communications have been included in this mobile-infrastructure category.

- a. **Geostationary earth orbit (GEO) communications systems.** GEO satellites orbit the Earth at approximately 36 000 km. Because of this long range, mobile users need to have reasonably large antennas, and the phones are considerably larger than cellular phones (normally small briefcase-sized terminals). Users connect to a terrestrial gateway that is connected to the PSTN. If one mobile satellite user wants to talk to another, connection is made through the terrestrial gateway, requiring two uplinks and two downlinks. However, the user is provided much greater mobility than in terrestrial cellular networks, as the coverage of the system is far greater. It should be noted that UHF satellite-based CNR systems can simplify communications using bent-pipe architectures.
- b. **Low earth orbit (LEO) communications systems.** LEO communications satellites have a much lower orbit than GEO: approximately 800 km above the Earth's surface. LEO mobile communications systems therefore require much smaller terminals (at least twice the size of a modern cellular phone) than GEO systems. In systems such as Iridium, users communicated directly with each other

without using terrestrial infrastructure (after gaining approval from a terrestrial gateway), supported by inter-satellite links. Other systems, such as Globalstar, provide communications between terminals by switching through a base station on the ground. A LEO-based mobile communications system potentially covers the entire surface of the Earth, providing users with complete mobility and the ability to make a call anywhere at any time.

59. In the near future, satellite mobile communications systems are likely to be seamlessly integrated with terrestrial cellular systems through the work being conducted in the development of third-generation systems.

Fully Meshed and Repeater-based Networks

60. Fully meshed architectures such as the US Joint Tactical Information Distribution System (JTIDS) have been developed for air-to-air and air-to-ground communication, providing up to 30 nets, each of which is shared on a time-division multiple-access (TDMA) basis. Communications are broadcast to the net providing considerable survivability, as there are no critical nodes. Communications are line-of-sight, although JTIDS has a relay capability to support communications beyond line-of-sight. However, setting up a relay requires manual configuration by an operator, and the use of relays also significantly degrades overall system performance.

61. As a fully meshed network, JTIDS is inherently inefficient because range (timing) and Doppler corrections cannot be made at the transmitter and because there is no frequency re-use. In a repeater-based architecture, all transmitters can adjust timing and frequency to correct for their range from the repeater and their relative velocity. In a fully meshed network, all of the other nodes are potential receivers, but correction for range and Doppler can only be done for one of them. If more than one base station is used in a repeater-based network, frequencies can be re-used allowing for significant increases in capacity over fully meshed and single-

repeater networks. Some terrestrial networks, such as the Enhanced Position-Locating and Reporting System (EPLRS), provide a compromise solution with limited meshed networks controlled by a base station. EPLRS stations are also capable of automatic repeating between stations.

Airborne Repeater

62. With repeater networks, guard times can be much smaller than in a fully meshed network. Transmitters can adjust their transmit times to correct for range differences, and guard times need be no longer than the uncertainty in propagation time to the repeater plus timing errors. With accurate position and time information available at each node through GPS, it should be possible to virtually eliminate guard-time overhead. Using multiple-access protocols to an airborne repeater would allow high (UHF or X-band) frequencies to be used, providing up to 500 MHz of spectrum. The net effect of these factors might be a 100-fold increase in system capacity relative to a system such as JTIDS. With multiple relays and frequency or code re-use, even larger capacities might be realised.⁶

63. Additional advantages would accrue if the airborne platform was to be used for other communications functions, such as an airborne cellular base station; HF, VHF, UHF rebroadcast; UHF theatre broadcast; or even as a surrogate satellite. In other words, the platform could be used with existing terrestrial terminals to extend their limited ranges.

64. An airborne repeater therefore has the advantages of providing range extension to terrain-limited nets and opening up new opportunities in multiple-access communications that can provide coverage of the entire area of operations.

⁶ P. M. Feldman, *Emerging Commercial Wireless Technology and Standards: Suitable for the Army?*, RAND Corporation Report MR-960-A, Rand, Santa Monica, CA, 1998.

Military Utility

65. While all of the above communications systems have the potential to provide tactical mobile communications architecture, the following comments apply.

- a. **Architecture.** Available satellite communications systems are point-to-point and are therefore not well suited to all-informed voice nets or data networks providing seamless connectivity.
- b. **Range.** CNR and packet-radio solutions are difficult to provide and maintain because the radios are terrain-limited in range, rather than power-limited. This is a function of low antennas mounted on low-profile vehicles or on soldiers' backs. Range limitations are even worse for fully meshed systems such as JTIDS, where it is unlikely that one terminal can see any more than two or three others at any one time. Due to their significantly greater heights, satellite and airborne systems are able to cover the area of operations and be visible to all ground terminals. UHF CNR can have long-range extensions offered by satellite-based systems.
- c. **Capacity.** CNR and packet-radio solutions have capacities limited by the transmission techniques and modulation schemes as well as the possible multiple-access techniques. GEO systems are limited in capacity by the size of antenna that can be mounted on the mobile platform. Only semimobile terminals can sustain significant rates. Mobile terminals can be used with LEO systems, but data rates are constrained to 9.6 kbps in the near term. UHF satellite communications also have limited capacity, particularly for reasonable numbers.
- d. **Cost-effectiveness.** CNR and packet-radio systems provide cost-effective solutions to the voice communications requirements of combat troops as they provide relatively cheap, flexible communications to support the full range of

deployments. However, data rates are generally very low and only able to support limited transfer of situational awareness data. Unfortunately, the cost of satellite PCS systems tends to preclude their widespread use, although they are highly effective forms of communication for limited use by small units such as reconnaissance teams. Airborne systems provide high-capacity, long-range, flexible communications at some significant cost, although aerostat solutions are an order of magnitude less than uninhabited aerial vehicles (UAVs)⁷.

- e. **Flexibility.** CNR (and its packet-radio variant) has evolved to provide very flexible communications to combat forces in a wide variety of deployments and operational environments. All-informed communications can be provided across the deployed force enhancing the coordination of complex tasks. The additional range extension provided by an airborne rebroadcast platform increases the usefulness of such systems. Satellite-based systems are constrained by their connection-oriented nature, as the only thing a user can do with a satellite phone is make a phone call. This constraint limits the usefulness of such systems in support of military operations as it is difficult and expensive to form an all-informed voice-net or a robust data-network using a connectionless protocol.
- f. **Security.** All forms of mobile communications can be secured by the use of cryptographic equipment. Additional security is provided within the CNR nets by the fact that the users carry and own the equipment and that ranges are limited, reducing the opportunity for interception. Satellite-based systems are very vulnerable to interception and jamming, and rely on infrastructure that is not owned by the user (or even the ADF in most cases). This makes its availability very doubtful in time of crisis.

⁷ T. Edwards, 'More Than Just Hot Air', *Communications International*, September 1999, pp. 42–5.

High Capacity / Long Range

66. One of the most significant architectural issues is the provision of a communications system that provides high capacity as well as long range. Unfortunately, these two requirements are more often in conflict than in synergy. This section examines the trade-offs required in tactical communications systems by examining the effects of frequency of operation, addressing capacity and range issues, and then drawing some conclusions about potential solutions.

Frequency of Operation

67. Frequency (wavelength) has a number of fundamental implications for military communications systems. In summary:

- a. **Capacity.** Higher capacity (that is, either more channels or wider channels) requires more bandwidth. The number of channels available in each band increases as the frequency increases. It is also possible to transmit a wider bandwidth at higher frequencies, with less distortion of the signal. Thus higher frequencies provide greater information-handling capacity.
- b. **Quality.** Better quality requires a more faithful reproduction of the baseband frequencies. This in turn requires a greater spread of modulated frequencies, and therefore a greater bandwidth to be transmitted.
- c. **Range.** The range of any communications system depends on the frequency of operation. Lower frequencies have longer wavelengths so that natural features become less significant as obstacles. Therefore, when communicating along the surface of the earth (using surface wave propagation), lower frequencies mean longer ranges. In space wave communications, lower frequencies also mean longer ranges (or, conversely, higher frequencies mean shorter ranges) since free-space loss is inversely proportional to the square of frequency. However, in space wave communications, the curvature of the earth will ultimately limit range.

d. **Antenna size.** Antenna length is directly related to wavelength (an efficient antenna is either one or one-half a wavelength); therefore the higher is the frequency, the smaller is the antenna. Thus higher frequencies allow the use of more manageable and more tactically deployable antennas. This must be balanced, however, with the greater pointing accuracy required for the higher frequencies.

68. The relative military usefulness of each band is illustrated in Figure 3, showing the relative quality and capacity, and ground-wave range, as functions of frequency. However, the reader should bear in mind that, while the x-axis represents frequency, the effect is more related to the modulation technique employed in each frequency range.

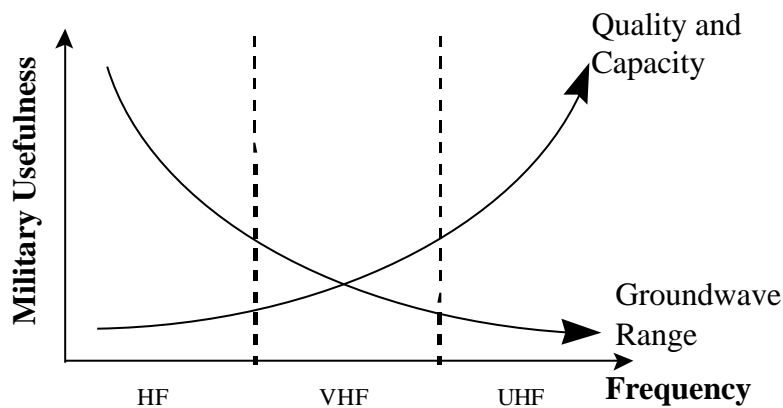


Figure 3: The relative military usefulness of each RF band

69. It is obvious from the above figure that the decision to use one frequency rather than the other depends on the value judgment of whether range is more important than quality and capacity. Traditionally, combat troops have had to make use of three different radios. VHF is chosen as the most useful band for CNR as it represents the best trade-off between range and capacity. However, for longer ranges HF is essential, and UHF is required to communicate on air-ground nets. While the need to carry three different types of radio has been alleviated somewhat by the development of multi-band, multi-mode radios, it will be some time before a signaller carries a light radio that allows communication in all three bands.

70. HF ranges are considerable; however, the quality and capacity is correspondingly poor. Despite this, there are many military circumstances when long ranges are required. HF man-pack and vehicle-mounted combat-radio is therefore used for the following nets:

- a. company/battalion/brigade nets;
- b. rear links;
- c. armoured/reconnaissance/engineer/administrative nets; and
- d. special forces patrols.

71. For closer communications between sub-units, combat troops prefer to use VHF frequencies, which provide the best compromise between range and quality/capacity. At these frequencies there is sufficient range (20 to 40 km, depending on terrain) and sufficient bandwidth available to use frequency modulation and thereby dramatically improve quality. Man-pack and vehicle-mounted VHF combat radio is used for the following nets:

- a. platoon/company/battalion/brigade nets; and
- b. armoured/reconnaissance/engineer/artillery/administrative nets.

72. While large capacity (and therefore high quality) is available at UHF, the range is limited to line-of-sight. UHF combat radio is therefore used for the following nets:

- a. platoon/section nets;
- b. artillery communications between guns;
- c. within administrative areas;
- d. personal locating-beacons;
- e. forward observers for close air support; and
- f. special forces patrols.

High Capacity

73. The data transfer required to support near-real time situational awareness requires a significant capacity in the Tactical Communications System. This capacity is not currently available within VHF and HF CNR nets for two reasons: the networks are hierarchical, and the laws of physics constrain the available bandwidth.

Hierarchical Architecture

74. To illustrate this point, consider a notional mechanised brigade, the basis of which is a mechanised troop that has four vehicles. Real-time situational awareness would require that the locations of all vehicles be known at any instant. As will be seen shortly, this is an unrealistic expectation. Near-real time situational awareness requires that the location of each vehicle be reported to within at least 10-m accuracy (for battlefield identification and to prevent significant errors on sensor-to-shooter target sharing). A locstat requires at least 100 bytes (800 bits) of data, which with the added overhead of EDC would be at least 200 bytes.

75. Assuming that the troop is advancing at a high cross-country speed of 40 km/hr (11 m/s), each vehicle must transmit a locstat at least every second so that its location is known within 10 m. The troop net would therefore have to have sufficient capacity to cope with $4 \times 200 \times 8 = 6.4$ kbps, the squadron net would require capacity for 25.6 kbps, the regimental net for 102.4 kbps, and the brigade net for approximately 500 kbps.

76. However, the current tactical communications systems are poorly placed to provide the capacity required. Figure 4 illustrates the problem. At the troop level, vehicles will generally be in sight of each other and are able to use UHF communications, which can provide ample capacity for the needs at this level. However, VHF radio is required between troop and squadron. VHF radio is also required between squadron and regiment, with HF being necessary for longer ranges. Between regiment and brigade, however, VHF radio normally has insufficient range and HF radio is used instead.

Currently, most analogue CNR is restricted to approximately 8 kbps at VHF and 300 bps at HF.

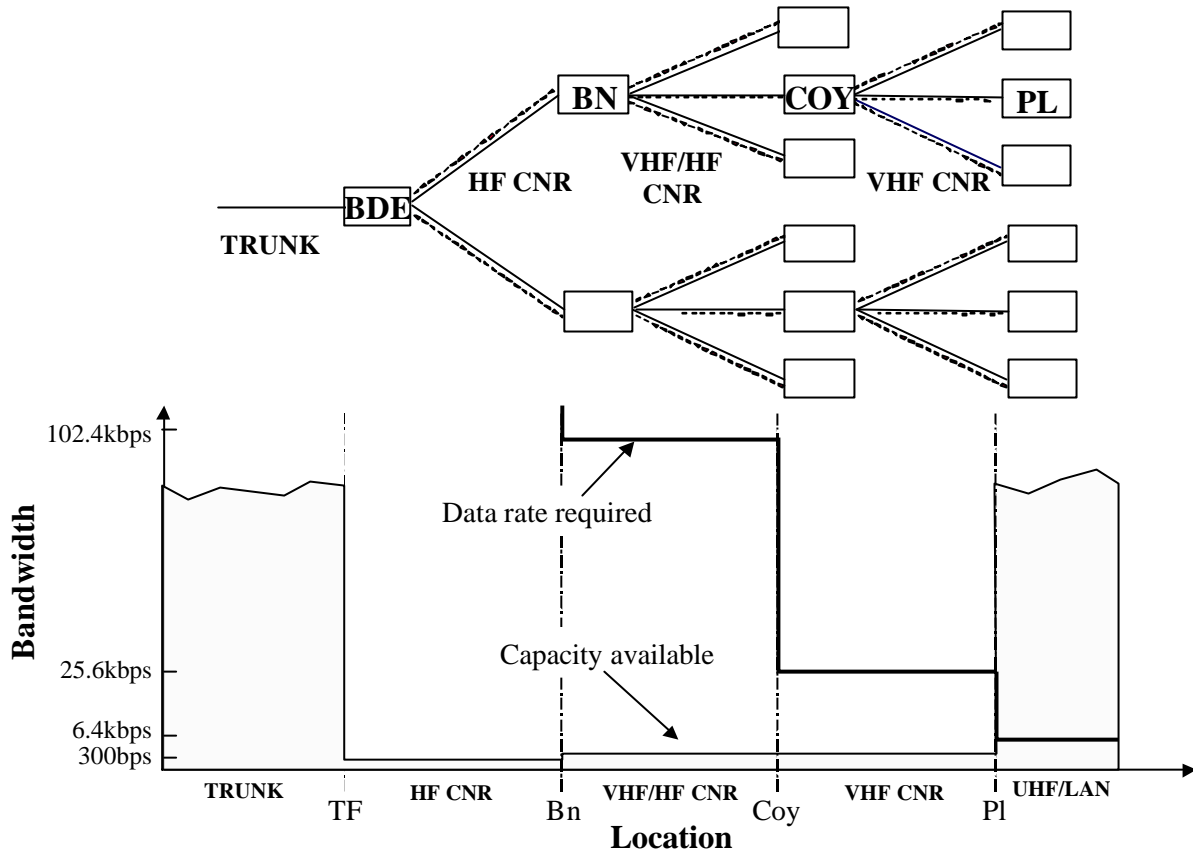


Figure 4: Data rate required versus capacity available

77. As illustrated in Figure 4, the data rate required increases as the situational awareness data is passed back to brigade headquarters. Unfortunately, in most dispersed deployments, the available capacity significantly decreases as data moves between higher headquarters.

78. To avoid the aggregation of data as it is passed up the chain, CNR nets must change in architecture from hierarchical to a networked structure. Even so, the constraints of physics mean that there will not be sufficient capacity available for more than low-capacity data rates. While future technological advances may allow some increase in data rates across CNR, it is unlikely that such nets will ever carry the volume of traffic required to support situational awareness. This is particularly true when it is recognised that these CNR nets will also be required to carry voice data, significantly

reducing the bandwidth available for data. It is also noted that information will need to be passed from higher to lower levels, making the situation even worse.

79. If the data rates called for by the C4ISR Concept are to be provided, a higher-capacity network must be provided that is dedicated to the transfer of situational-awareness data.

The Laws of Physics

80. Within each of the bands, fundamental laws of physics constrain the capacity available.

- a. **HF.** In the HF band, battlefield communications propagate by either surface wave or sky wave. In both cases, the bandwidth available is limited to 3 kHz channels because additional bandwidth would introduce too much noise. The quality of HF links is therefore generally poor due to the limited bandwidth that dictates the use of single-sideband (SSB) modulation for voice. The small bandwidth available also means a maximum data signalling rate of 2.4 kbps which, when overhead (for error detection and multiple access) is included, means a data throughput of the order of a few hundred bits per second.
- b. **VHF.** At VHF, more channels are available, and there is sufficient room within a 25 kHz channel to provide good-quality voice through the use of frequency modulation (FM). A data rate of 16 kbps can be sustained within this channel although, after overhead is incorporated, this generally means information rates of the order of 2.4 kbps. Higher bandwidths are not normally available due to the large pressure on bandwidth caused by the continued introduction of a large number of systems using radio frequencies. Additionally, VHF CNR links require the use of small, omni-directional antennas that tend to limit the available signal-to-noise ratio and therefore limit the possible signalling rate.

- c. **UHF.** Very large bandwidths are potentially available within this band. However, as is discussed in the next section, range is very limited.

Long Range

81. Range is the other major communications consideration on the battlefield.

- a. **HF.** In the HF band, surface-wave communications provide reasonable ranges, although they are limited on dry soils to about 30 km. Long ranges are possible using HF skywave, giving approximately 1500-km ranges for single hops. Round-the-world communications are possible if the transmission power is increased to allow multiple hops.
- b. **VHF.** Communications at VHF and above utilise direct wave and are therefore limited more by terrain than power. VHF propagation is refracted slightly towards the Earth and the radio horizon is slightly longer than the visual horizon. Still, the communications range between two *Raven* radios placed on flat ground is limited to approximately 8 km. Small, omni-directional antennas further exacerbate range problems.
- c. **UHF.** At UHF frequencies, propagation is via line-of-sight and is therefore constrained by terrain even further than VHF. Small, omni-directional antennas further exacerbate range problems.

82. Long-range communications are therefore provided by low frequencies but, as was seen earlier, low frequencies can only provide very low bandwidths. The battlefield trade-off between range and capacity is discussed in the following section.

Range/Capacity Trade-off

83. In the commercial world bandwidth is rarely a problem: a company with a communications need would simply determine the scope of the need, dimension the links and networks required,

and then buy or lease bandwidth from a carrier. The amount of bandwidth required and the distance between communications nodes will provide some technical constraints on the solution but, in general, any amount of high-quality bandwidth is available (for example, the upper bound on the bandwidth available from a single optical fibre is not yet understood). Additionally, once implemented, the communications network will remain fixed and will only be modified to incorporate the need for growth.

84. The only real bandwidth and range limitations in the commercial world are for mobile users who are limited to a wireless (normally radio frequency) interface. For example, even though third-generation mobile users may have up to 2 Mbps available at short ranges, only 9.6 kbps will be available at more than a few kilometres. These situations tend to contrast sharply with military environments where almost all battlefield entities are mobile—even headquarters need to communicate on the move. As discussed earlier, moderate capacities are only available at short ranges because, for mobility, users are constrained to a small terminal and a low omnidirectional antenna. This is acceptable at the lowest tactical levels such as section and platoon, which can get fairly high capacities using UHF because the desired ranges are short. At the other end of the tactical deployment, good capacities are available between headquarters using one or more of the trunk-communications system, satellite bearers or civilian infrastructure. However, for the bulk of mobile combat forces in between, the combination of long range and high capacities presents an almost intractable problem.

85. The solution to high capacity is to use a high frequency; however, terrestrial ranges are low at those frequencies. The major restriction on the provision of long-range, high-capacity communications is the height of the antennas. Most battlefield radios are terrain-limited rather than power-limited. Potential solutions must therefore raise the antenna height:

- a. **Antenna masts.** Trunk-communications systems have traditionally used guyed, telescopic masts to increase ranges to 30–40 km. Such systems use high VHF or UHF frequencies, providing large capacities up to 2 Mbps between trunk nodes. Even so, longer ranges are not normally possible due to the practical height of a tactically deployable antenna being limited to 10 m. For practical deployment and wind loading, antennas are also limited in their design.
- b. **Satellite communications.** Most modern trunk-systems provide range extension through the use of satellite links, providing high-capacity, long-range communications. However, the most significant limitation for the Tactical Communications System is that the infrastructure is not at all within the control of the commander and therefore should not form part of the organic communications system. However, satellite communications do provide a great range advantage, and battlefield systems should be able to utilise satellite systems if available.
- c. **Tactical airborne communications.** Rather than utilising satellite communications, it is possible to extend communications ranges by communicating through an airborne platform such as an aircraft, a UAV or a tethered or untethered aerostat (or a dirigible, or balloon). The major advantage of such a solution is that users do not have to change terminals for extended range, but can use CNR and trunk systems repeated through the airborne platform. The platform can also be owned by the tactical commander and is therefore able to be included in the minimum organic communications system.

AN ARCHITECTURAL FRAMEWORK

System Components

86. The ideal Tactical Communications System architecture would provide a mobile infrastructure to support mobile users. It would therefore be a single homogeneous network supporting all communicating entities in the battlespace. However, as identified in the preceding discussion, there are a number of difficulties in providing such an architecture:

- a. A mobile infrastructure (CNR) provides ideal flexibility for voice and limited data communications between combat troops. However, this flexibility is gained at the cost of capacity and range. Therefore, CNR cannot provide the capacity required for useful data communications or for voice and data communications between command posts. In addition, ranges beyond those required for conventional deployments cannot be supported by CNR systems.
- b. The trunk-communications system provides significant capacity to support the transfer of data between command posts. However, trunk-communications systems are not sufficiently mobile to provide directly the intimate support required by combat troops.
- c. Neither the current CNR nor the trunk-communications systems provide enough range to allow dispersal of brigade elements.
- d. Current CNR nets and trunk-communications systems do not provide an architecture that supports a large number of mobile voice and data users; the transfer of real-time situational awareness data is therefore correspondingly limited.

87. These points lead to the following conclusions:

- a. While the Tactical Communications System can be provided as one logical network, it cannot be provided as one single physical network.
 - (1) At the lower level, combat troops carry a device that must be a network node as well as the access terminal. Battery power and the need for small omni-directional antennas mean that ranges and capacities are therefore limited.
 - (2) At the higher level, the large capacities required of trunk-communications systems mean that they will remain semimobile for the foreseeable future. Large power requirements need the use of generators, and high-gain antennas must be deployed on guyed masts to provide reasonable ranges.
- b. The data-handling capacity of the trunk-communications system will be sufficient (with some modification to the architecture) to cope with the volumes of data required to be transmitted between major headquarters. However, the CNR system's ability is severely limited, especially as it is still required to transmit voice information. Therefore, an additional, purpose-designed, data distribution system is required to provide sufficient capacity to transfer situational-awareness data across the lower levels of the battlefield. However, CNR must still be voice- and data-capable in order to allow organic communications of both types within sub-units, should they be deployed individually or beyond the range of the data distribution subsystem. The additional (albeit limited) data capacity in the combat radio subsystem would also provide an overflow capability should the data distribution subsystem be unable to meet all the data needs.

- c. Neither the CNR nor the trunk-communications system is able to cover the large ranges required for dispersed operations. The only solution to providing high-capacity, long-range communications is to elevate the antennas. In the extreme, the provision of a satellite-based or an airborne repeater or switch will greatly increase the ranges between network nodes. A satellite-based solution is not considered desirable due to its inability to meet the requirements of a minimum organic communications system. An airborne subsystem is therefore required to support long-range operations. In addition, an airborne system would increase the capacity of lower-level tactical communications by removing the range restriction on high frequencies that can provide additional capacity from small omnidirectional antennas.
- d. A minimum organic Tactical Communications System would be able to provide a basic level of service and must be able to be augmented where possible by overlaid communications systems such as the public telephone network, satellite-based communication systems and personal communication systems. These overlaid systems cannot be guaranteed to be available and cannot therefore be included in the minimum organic system. However, if they are available, great advantage is to be gained from their use.
- e. In order to simplify the user interface to these subsystems, a local communications subsystem (most probably containing a level of switching) is required. This local subsystem could take a number of forms from a vehicle harness to a local-area network around brigade headquarters.

88. The Tactical Communications System will therefore require five subsystems:

- a. *Combat Radio Subsystem*, providing the mobile infrastructure required for voice and data communications to support the command and control of combat troops;

- b. *Tactical Data Distribution Subsystem*, providing high-capacity data communications to support the situational awareness required for the command and control of combat troops;
- c. *Tactical Trunk Subsystem*, providing the transportable infrastructure to support communications between command elements and other large-volume users; and
- d. *Tactical Airborne Subsystem*, providing range extension and additional capacity, when the tactical situation allows.
- e. *Local Subsystem*, simplifying the user interface to the other communications subsystems and to overlaid communications systems.

89. The architecture of Figure 5 illustrates the major architectural components of the Tactical Communications System and provides the start point for more detailed discussion. It is a convenient start point since it recognises that, while the Tactical Communications System is to be considered as one logical network, for practical deployment reasons, it will be provided as a number of physical networks (at least in the short term). It is also a convenient point to begin the development of an architecture as it broadly coincides with the current deployed architecture, requiring the addition of a Tactical Data Distribution Subsystem and a Tactical Airborne Subsystem to increase capacity and range.

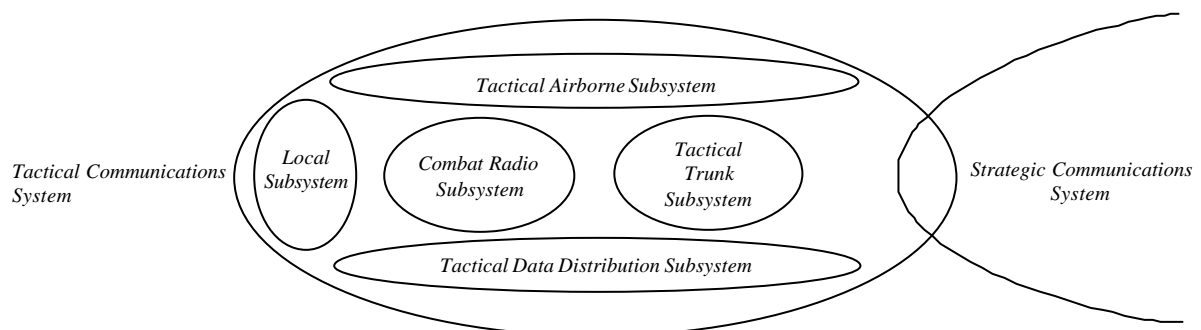


Figure 5: Components of the Tactical Communications System and Strategic Communications System

Supported Systems

90. The Tactical Communications System does not exist in isolation; it exists to support a number of battlefield, joint and combined systems. These supported systems interface with the Tactical Communications System as illustrated in Figure 6.

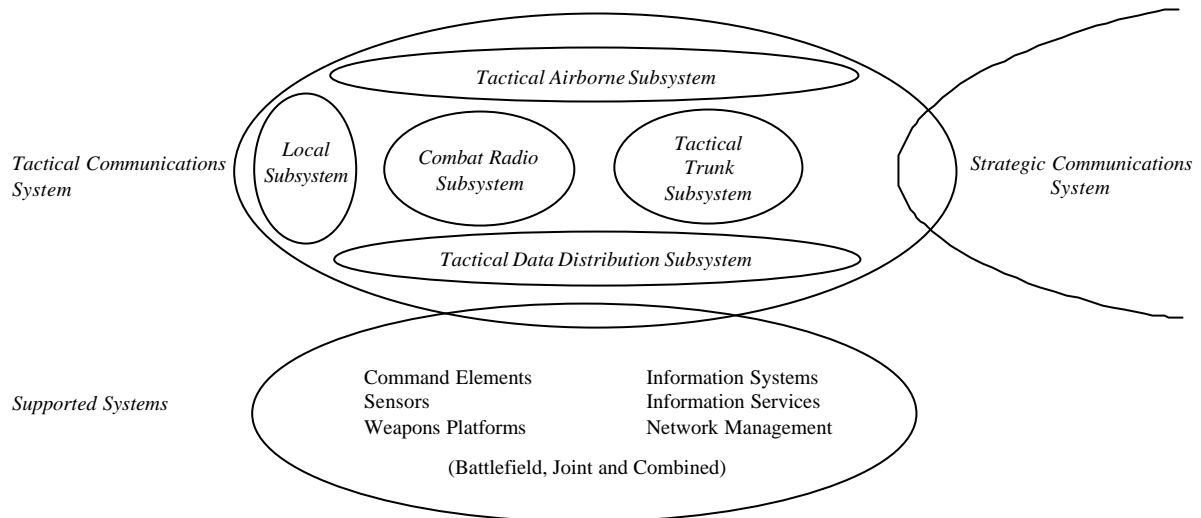


Figure 6: Interface of Supported Systems to the Tactical Communications System

Overlaid Communications Systems

91. The minimum-essential Tactical Communications System is augmented where possible by a range of Overlaid Communications Systems as shown in Figure 7.

Tactical Communications System Architecture

92. Figure 7 illustrates the proposed architecture for the Tactical Communications System and the interfaces with its environment. This framework provides a solid foundation on which to base further consideration of architectural and procurement issues.

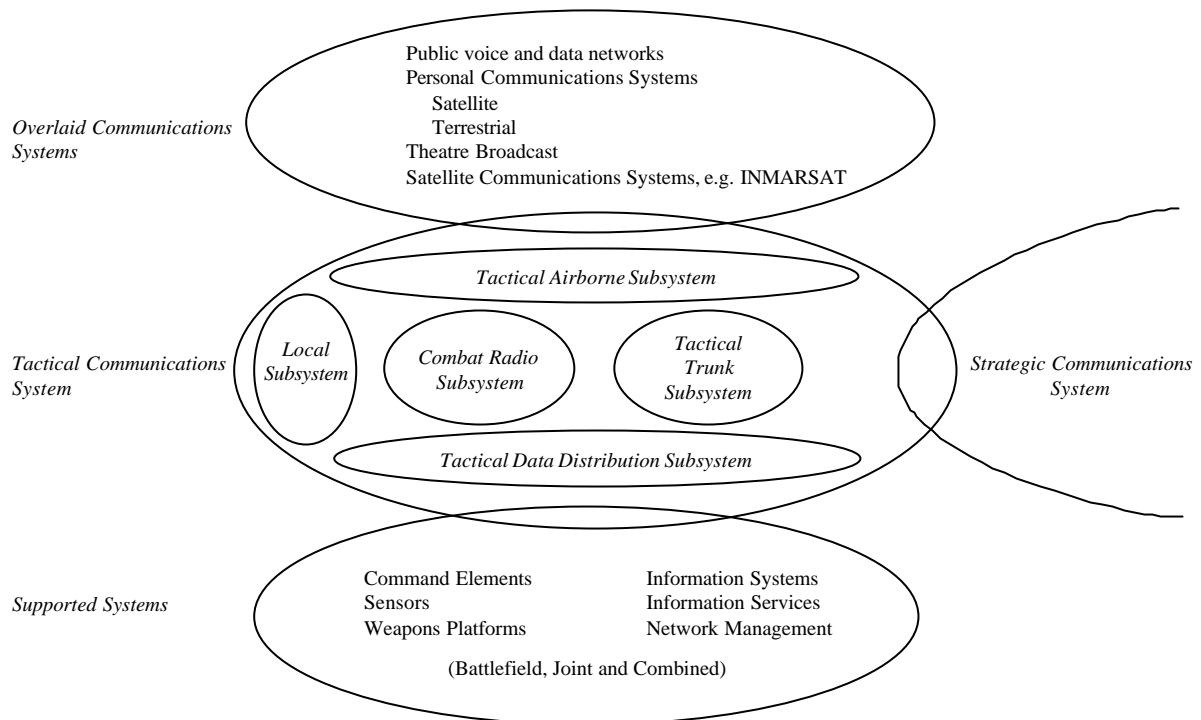


Figure 7: Interface of Overlaid Systems to the Tactical Communications System

93. The adoption of such an architecture would greatly simplify the capability development and acquisition process by providing guidance to project and development staff on the top-level functional requirements for a communications system to support land operations. The architecture details the design and interoperability philosophies that drive the requirement for common standards and specifications. The architecture also establishes the mechanisms to mandate and oversee the implementation and review of the selected standards and specifications. While there are advantages for the acquisition phase, the most tangible benefits are derived in service throughout the utilisation phase where, because interoperability and flexibility have been built in at the highest levels, commanders have more freedom to operate, unconstrained by the communications and information systems that support them.

CONCLUSION

94. This paper has discussed the key design drivers for the development of an architecture for the Tactical Communications System. These design drivers include the traditional principles of military communications as well as a number of important issues governing the way in which the Tactical Communications System is to be employed.

95. The Tactical Communications System must be organic to the supported force and must support communications between any two points in the battlespace, and between any point in the battlespace and the Strategic Communications System. Communications support must be provided to a range of battlefield, joint and combined systems. Access must also be gained to a range of additional Overlaid Communications Systems to increase the capacity of the minimum organic network.

96. While it is essential that the Tactical Communications System provide a single logical network, it is not possible to provide a single physical network. The range of candidate technologies available to provide access to mobile users constrains the physical architecture to the provision of two major subsystems: the Tactical Trunk Subsystem and the Combat Radio Subsystem. To extend the range of these two subsystems in dispersed operations, a Tactical Airborne Subsystem is required. Additionally, there is insufficient capacity in the Combat Radio Subsystem (in particular) to cope with the high volume of data transfer required to support real-time situational awareness for commanders of combat forces; this need is met by the Tactical Data Distribution Subsystem. The Local Subsystem simplifies the user interface to the other communications subsystems and the Overlaid Communications Systems.

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