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A Perspective on DoD Satcom Architecture

R.E. Eaves
T.H. Shake
D.R. McElroy

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Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

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Administrative Contracting Officer
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

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R.E. EAVES
T.H. SHAKE
Group 64

D.R. McELROY
Division 6

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LEXINGTON MASSACHUSETTS

ABSTRACT

This report examines the diverse and evolving requirements of military satellite communication (Milsatcom) systems with a view toward the future. The characteristics of a Milsatcom system architecture that will be necessary to meet these requirements are described, including an outline of potential transition pathways from today's Milsatcom systems to those of the future.

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1. INTRODUCTION

Today's military satellite communication (Milsatcom) systems support a diverse set of communication services for many different classes of users. But with all of the capabilities they offer, they are becoming increasingly inadequate in the face of evolving requirements for information distribution and processing. Within 10 to 15 years, a new generation of Milsatcom systems will need to supply a wider variety of communication services at higher speeds and in a more highly networked information environment than today's systems can support. A new Milsatcom architecture is needed that will encompass the diversity of services and connections that these systems must support. This paper describes what the overall shape of such an architecture might look like.

2. THE CHANGING INFORMATION ENVIRONMENT

The fast pace of technological advancement in the fields of computing and telecommunications continues to create opportunities to support many new types of data and communication services. The changing nature of these services, along with the military requirements to supply communication services of the highest quality to the warfighter, places great pressures on the architecture and design of the coming generations of military communications systems, and on Milsatcom systems in particular.[1] These pressures range from growing demands for information distribution of all types on both geographically local and global scales, to increasing needs for portability and ease of use in user equipment, to continuing needs for survivability and protection against denial, interception, and corruption of critical information services in the face of evolving threats.

At the same time that both technology and the demand for information distribution and processing are pressing ahead, the DoD finds itself under budgetary pressures to contain or even reduce its expenditures on these types of systems. These pressures, along with the need to make smooth transitions from existing information distribution systems to new ones offering new and/or more efficient services, exert a restraining influence on the development and procurement of new military information systems. Such pressures have also been a strong factor in motivating investigation of new acquisition strategies, such as the increased use of already developed commercial information technologies to meet many military requirements.

All of these pressures combine to produce a central challenge to the architects and designers of the next generation of DoD Satcom systems. This challenge is to find a cost-effective mix of commercial services, revised acquisition approaches, and unique DoD developments to meet the evolving communication requirements of the United States Armed Services. This challenge must be met in a way that allows Satcom systems to integrate seamlessly with other elements of the DoD communications infrastructure to form a worldwide defense information network.

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[1] Satcom systems are just one part of a larger DoD communication infrastructure, but they represent a unique and important part of this infrastructure and must support the same types of information services that are emerging everywhere in the information world today, be it in the spheres of personal, commercial, or military communications. DoD Satcom services are particularly important because of their ability to support the rapid and flexible deployment of communication services anywhere in the world, and because of their ability to link widely dispersed users in remote locations.

3. TODAY'S SYSTEMS, TOMORROW'S NEEDS

A good way to begin to define a Milsatcom system architecture that will meet tomorrow's needs is to look at the user requirements that such a system must satisfy. DoD information systems, and especially Milsatcom systems, must accommodate a very diverse set of requirements. Figure 1 illustrates this diversity by showing several different categories of requirements and listing examples of services and scenarios that have differing requirements in each category. For example, single voice channel communications typically require relatively low data rates (e.g., 2.4 kbps), whereas global broadcast and video systems require data rates that may typically be 10,000 times higher (e.g., GBS services at ~24 Mbps). There are many types of users, missions, and situations, and each will have its own particular requirements for data rate, protection, connectivity, mobility, and terminal platform constraints.

Given such diverse requirements, it is very difficult to envision a single Milsatcom system that can efficiently encompass them all. A future architecture will almost certainly consist of several different systems designed to work together in complementary ways. In the far term, connections among these different systems will become more complete and less visible to the users, with the whole collection of systems resembling one large network of communication assets.

The DoD has existing allocations in several different frequency bands that can be used by Satcom systems for satisfying these requirements. Figure 2 shows where these allocations fit within the frequency spectrum. The principal bands available for DoD-controlled systems are UHF, X-band, Ka-band, and EHF. Each of these bands has its own characteristics that are defined by the physics of electromagnetic propagation, by available component and antenna technology, and by the amount of bandwidth available in each band's allocation. These varying frequency band characteristics make each particular band well suited for certain kinds of communications and poorly suited for others. For example, the EHF band has a relatively large amount of bandwidth available, which makes it particularly useful for antijam spread-spectrum communications. However, signals at EHF frequencies are attenuated rather highly by foliage and rain. On the other hand, there is relatively little bandwidth available in the UHF band, making antijam communications difficult, but signals in this band penetrate foliage and rain storms much better than EHF signals.

Milsatcom system designers have traditionally tried to take advantage of the unique features of each frequency band when designing systems that use these bands. Most existing Satcom systems, both military and commercial, have been designed for use in one (or sometimes two) of these frequency bands. This approach has led to the development of several distinct Satcom systems, each meeting the needs of users with certain types of requirements. Figure 3 shows an overview of today's Satcom systems and summarizes the types of services that each system supports. These systems provide a wide variety of services, and the multiband, multisegment architecture of these systems is a promising way of supporting diverse sets of user requirements.

However, all considered, today's Satcom systems are not adequate to meet the emerging requirements of the DoD. This is partially because cost-effective technology to support the high data rates that will required of future systems was not available when today's systems were implemented, and partially because of the development of some new types of services that were not envisioned when the current systems were designed (e.g., global broadcast). New Satcom system designs must be developed to support the DoD's evolving information requirements, and these new systems must be knit together more closely in an overall architecture than today's systems have been. Otherwise, the seamless connectivity throughout the Defense Information Infrastructure that is so often mentioned today will not be achieved.

4. TOWARD A FUTURE ARCHITECTURE

While today's Milsatcom systems cannot fully support the DoD's emerging Satcom requirements, they do employ many sound architectural features that can and should be applied to the next generation of Milsatcom systems. One of these features is the use of a few different Satcom systems operating in different frequency bands and filling complementary roles. In the far term these systems could all be linked together with crosslinks and could employ similar processing and switching features. In the nearer term interconnectivity will need to be accomplished via gateways and teleports.

Perhaps the most central role to be filled in a Milsatcom architecture is the provision of highly survivable and protected services. This is one of the most important features separating military systems from commercial ones. Provision of highly protected services is one of the primary reasons that some Milsatcom systems exist today as entities separate from commercial Satcom systems, and even with all of the recent developments in commercial information technology, commercial Satcom service providers have little incentive to develop or offer highly protected communication capabilities.

Users requiring different levels of protection can be grouped into three categories: those requiring robust protection, those requiring assured access, and those requiring noncritical services that do not need much protection or assurance of immediate access. Those users and services requiring highly jam-protected and survivable communications should be served by a "hard core" of communication assets, as shown in Figure 4. Users in the other categories would then be served by a "soft shell" of communication assets, which should include both military systems providing assured, immediate access to communication channels, and commercial services that can provide significant assets but are not guaranteed to be available all the time. The hard core/soft shell concept ensures that those users with the most critical needs have access to the most robust and reliable communication resources. Within both the hard core and the soft shell, systems should be flexible and capable of supporting different applications, and they should accommodate open system standards for maximum interoperability.

Figures 5 and 6 show another view of the various roles that need to be filled in a Milsatcom architecture of the future. Here, these roles are organized by frequency bands. The hard core military communication services would be primarily filled in the EHF band, with X-band and Ka-band systems being used primarily for assured wideband access and global broadcast systems. The UHF band would be used to provide assured access low data rate services supporting mobile networked and point-to-point communications, including handheld personal communication services. All of the services shown in Figure 5 would be provided by government-owned and -controlled systems. Such systems would assure access to DoD users and avoid the potential for competition for resources between DoD and nongovernment or international users.

The services shown in Figure 6 would be provided by commercially developed, market-driven systems. These systems would provide valuable communication capacity on an as-needed basis, subject to the availability of the service provider's resources. These resources would generally be used for noncritical communication needs and could include the whole spectrum of Satcom services (e.g., transponded fixed broadcast services, processed medium data rate services, mobile point-to-point services).

The systems that will be developed to fill the roles described above will need to make extensive use of advancing technologies from both the market-driven and government sectors. By combining the products of commercial and government developments, a highly flexible set of communication assets can be assembled to meet the information demands of tomorrow's warfighters.

An important architectural challenge will be to develop a common framework within which such a highly flexible set of communication assets can interconnect freely and automatically. Another challenge will be to manage the transition to this highly interconnected architecture from today's less interconnected systems.

5. MANAGING THE TRANSITION TO FUTURE SYSTEMS

The path toward implementing future Milsatcom systems involves a relatively high degree of uncertainty. Clearly, the information requirements of the warfighter are growing and changing, but the degree of this growth and change is less clear. Both the overall information carrying capacity and the average user data rate in Milsatcom systems will need to increase from what is typical today, but by how much? There is also great uncertainty in the developing technologies of many the market-driven systems that have been proposed. Such systems as Iridium, Odyssey, GlobalStar, and Teledesic have promised great things, but the technologies involved, the international cooperation required, and the market demand for their services have yet to be proven. The actual utility of such systems to the DoD user community remains unclear.

Because of these uncertainties, any workable future Milsatcom architecture must incorporate a high degree of flexibility. This flexibility must encompass deployment possibilities, data rates, coverage patterns, switching and routing, and other technical parameters. It must also include programmatic flexibility, allowing for unanticipated or disappointing developments in technology, changing budgetary pressures, and changing procurement environments. It would be a mistake to plan rigid program developments for the next 20 years without allowing the freedom for making key technical and programmatic decisions at future points along the development path.

Some choices are already clear, though. For example, commercial technology and services will unquestionably play an increasingly important role in DoD Satcom architecture, and this should be included in development plans rather than used as a stopgap measure. Commercial systems should be preferred over government-developed ones whenever they meet DoD requirements economically. This will sometimes mean leasing commercial services and sometimes mean buying off-the-shelf commercial systems. (It should be noted that government ownership of highly used assets is usually less expensive than long-term leasing of commercially owned assets.) Dedicated military Satcom systems should be procured only when commercial alternatives are not adequate to meet requirements or do not do so economically. This will typically be the case for systems that offer robust protection, survivability, and assured access, but there are many DoD Satcom requirements that do not need high levels of protection and assuredness of immediate access.

Figure 7 shows a conceptual path from today's DoD Satcom usage toward future systems. Some of the ongoing requirements will be served by similar systems in the future, while some types of communications will migrate to new and different systems. Many of these future systems should follow commercial or commercial-like acquisitions.

Figures 8 through 11 show the evolution toward future systems in more detail. Figure 8 shows some of the characteristics of current, transitional, and objective systems for highly protected and highly survivable Satcom. This is one area where government acquisition is clearly still necessary because even the most advanced commercial technologies do not provide survivable and highly protected communications. A transitional system, available sometime in the middle of the next decade, should provide greatly increased data carrying capacity over today's Milstar II design. It should also include provisions for efficient data (packet switched) communications and greater antenna adaptivity. Crosslink capacities should be increased as well. In the further term, much greater data capacities should be achievable through spatial frequency reuse, and crosslinks to systems in other frequency bands could be considered.

Figure 9 shows a transition pathway for services at X-band and military Ka-band. This is an area that is ripe for using commercial-like acquisition procedures. A transitional system should include transponded capacity at both X- and Ka-bands for medium to large size user terminals. If commercial technologies mature rapidly, particularly those for emerging systems in the commercial Ka-band, the military satellites could incorporate these technologies in the nearby military Ka-band. This could result in small, transportable terminals that could access either commercial or military Ka-band satellite assets. (This would involve commercial-like processing and switching, not the highly robust processing used in the Milstar system.) These transition systems should be able to provide flexible antenna coverage and some degree of frequency reuse. A modest degree of protection could also be achieved through antenna discrimination and the use of antijam modems with transponded satellites. In the further term, data rates in the tens of kbps to the low Mbps range could be supported via commercial-like processed waveforms. This would support a dynamic mix of terminal sizes. It might also be possible to achieve a common waveform among X-band, Ka-band, and EHF systems (depending on technical and fiscal considerations). High data rates could be supported via satellite transponders, and this would provide backward compatible service for legacy terminals as well. These systems could possibly have crosslinks with EHF and UHF spacecraft.

A development pathway for UHF systems is shown in Figure 10. The developments for EHF, X-band, and Ka-band systems described above are expected to consume significant financial resources in the near term, and thus the UHF transition plan shown here is unambitious in the near term to conserve money. The transitional UHF systems would be functionally similar to the current UHF follow-on system, which could be supplemented with emerging commercial personal communication service technology for secure (but nonassured) access.

In the further term, assured access handheld service could be provided at UHF through geosynchronous (GEO) satellites with large, deployable antennas; signal processing and routing; and cellular frequency reuse. Such GEO UHF systems offer several substantial advantages over low to medium earth orbit (LEO/MEO) systems. A primary advantage is that GEO systems can provide netted communications more efficiently. A single circuit access for each beam that contains net members is sufficient, and the static beam coverage areas do not need to be constantly rearranged. In contrast, commercial LEO/MEO designs are based on point-to-point connectivity, requiring a dedicated circuit for each net member. This is extremely inefficient (and needlessly expensive) for nets containing many users who are relatively inactive. A further advantage of GEO systems is that they can easily support supplementary higher data rate services (e.g., 64 kbps) to terminals with simple, nontracking directive antennas such as helixes. This is not practical with LEO/MEO systems because directive antennas would need to track moving satellites.

Projecting future DoD use of commercial systems currently involves a great deal of uncertainty. The outcomes of the many proposed systems are difficult to predict because they differ so markedly from previous systems, with many system designs entailing high technical, regulatory, and market risks. In spite of these uncertainties, however, a broad path for development can be laid out, as shown in Figure 11. DoD must remain flexible as technologies and systems evolve, judging commercial claims objectively and critically, but must also be ready to take advantage of commercial opportunities whenever they are shown to be a viable and economical way to meet mission needs. In the near to intermediate terms, those opportunities lie in emerging low data rate personal communication service (PCS) systems at L/S-band, and in emerging medium data rate systems at Ka-band. In each area, technical and market forces must play out to some degree before we can identify those initiatives that will become viable systems and will meet DoD needs cost effectively. Evolving commercial satellite communications will certainly play an important role in the emerging DoD communication infrastructure.

6. BUILDING INTERCONNECTION

The highly interconnected communication systems of the future will rely heavily on intelligent architectures that are designed to support a heterogeneous mix of users and communication applications. The current Satcom systems were designed with many fewer types of applications in mind. However, efforts have begun to take today's systems and connect them together to begin to support the types services that today's warfighters are already coming to expect. The connectedness of Milsatcom systems will undoubtedly continue to grow with time. In the nearer term of next-generation Satcom systems, interconnectivity will generally have to be accomplished through gateways and teleports, while in the further term, crosslinks and processing with onboard data switching and routing will complement gateway terminals to support higher degrees of connectedness.

Figure 12 depicts this situation graphically. With the continued development of ISDN, ATM, and TCP/IP standards, it is reasonable to expect that these technologies will be used to form backbone links of a communication infrastructure that will connect many different types of users, including, in the future, Satcom users. Gateways and teleports will be developed to connect Satcom users from several different Satcom systems to such a backbone, where their data can be routed to widely dispersed destinations. This type of interconnection should begin to be available somewhat before the advent of highly crosslinked and data switched Satcom systems. Such gateways and teleports can apply to both military and commercial systems, and have the potential to offer a moderate degree of interconnection by themselves. As more Satcom systems offer direct crosslinking, processing, and data switching, these technologies can work together with existing gateways to provide a more seamless interconnectivity. Ultimately, both types of interconnection technology can be useful and complementary.

7. TOMORROW'S SYSTEMS: FLEXIBLE, ROBUST, INTERCONNECTED

In a changing world, DoD will have a wide range of missions, many of which will require rapid (and perhaps unanticipated) deployment to regions of the world that are not supported by a communications infrastructure adequate to support the missions. Many of these deployments will be unique in their requirements for mobility, capacity, and types of communication services. Consequently, an architecture required to support tomorrow's DoD Satcom services needs to be extremely flexible. It must offer highly protected and survivable service; it must provide significantly increased data capacities; and it must be able to support a high degree of interconnectivity, both with other Satcom systems and with terrestrial communication systems. This architecture should incorporate a cost-effective mix of military and commercial technologies and frequencies. The EHF band is critical for supporting needs for protected and mobile communication. UHF, X-, and Ka-bands are well suited for providing assured access communication. Commercial systems and frequency bands will offer an increasingly valuable as-needed capability for noncritical communications.

The acquisition of Satcom systems should be increasingly like typical commercial acquisitions. They should rely increasingly on already developed technologies that can be ordered "off the shelf" with little or no modification. This will not always be possible given military requirements, but it should be done where it is possible.

Finally, the implementation plans for future Milsatcom systems need to accommodate growing requirements and evolving technology without large programmatic disturbances. The rapid development of technology for electronic communication and computing can enable great advances in how our warfighters get the job done, but only if it is channeled through an adaptable and open-ended architecture and implementation plan.

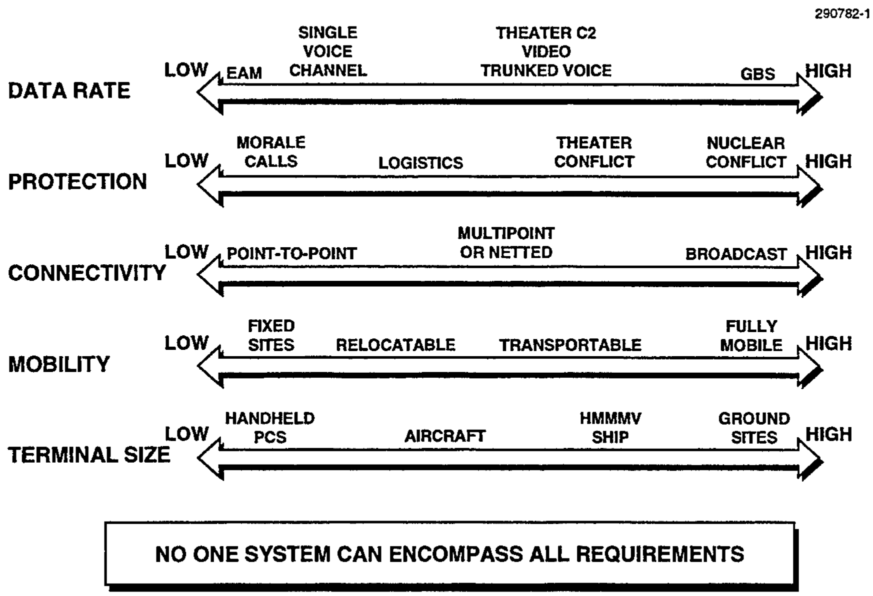

Figure 1. Requirements diversity.

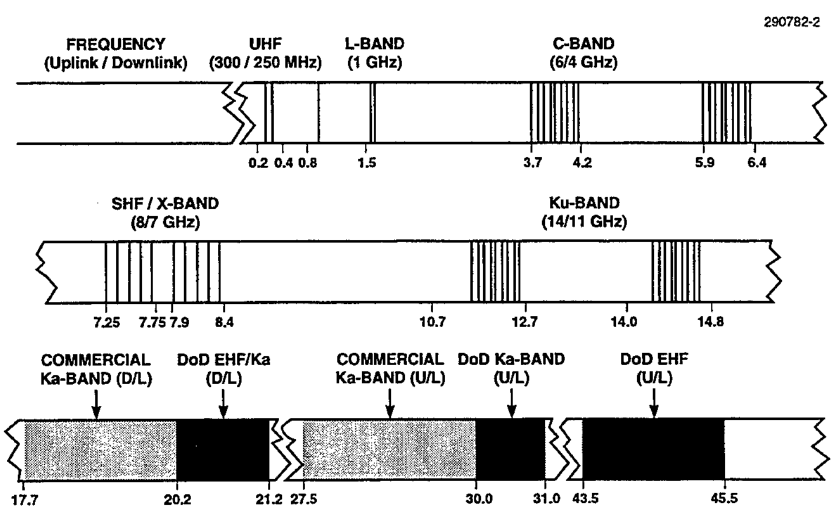

Figure 2. Satellite communications frequency plans.

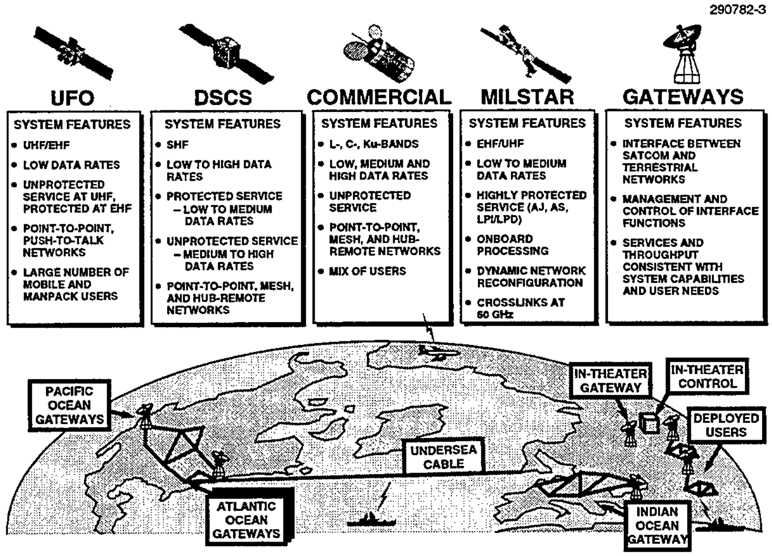

Figure 3. Current Satcom systems.

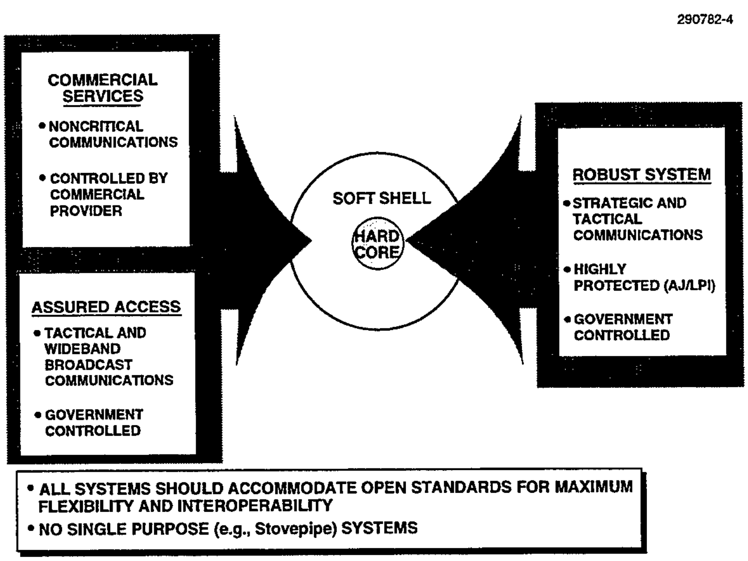

Figure 4. Partitioning of DoD Satcom.

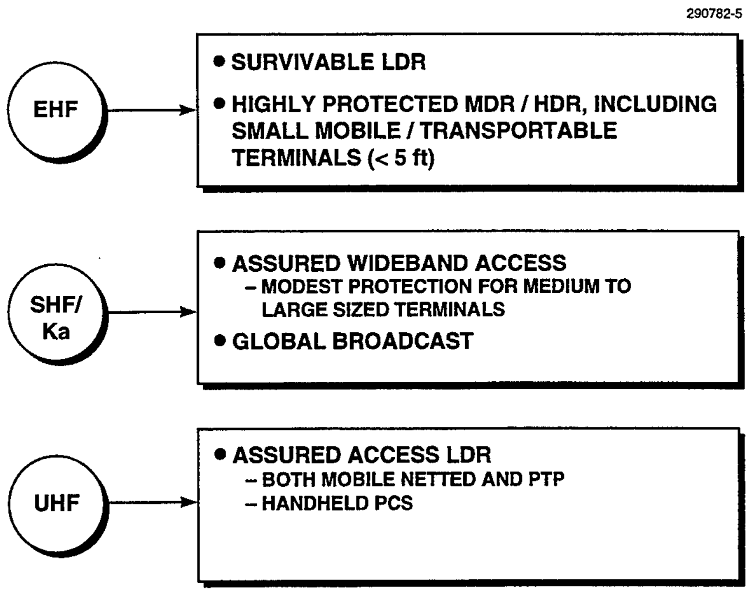

Figure 5. Roles of military Satcom bands.

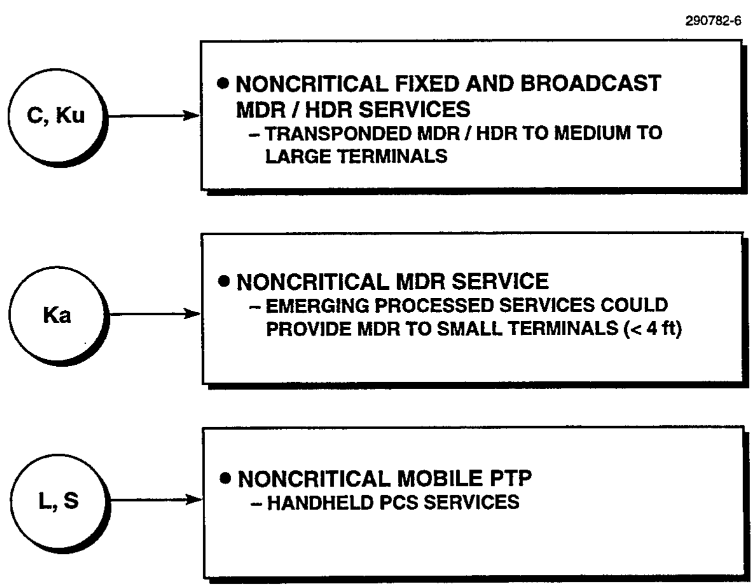

Figure 6. Roles of commercial Satcom bands.

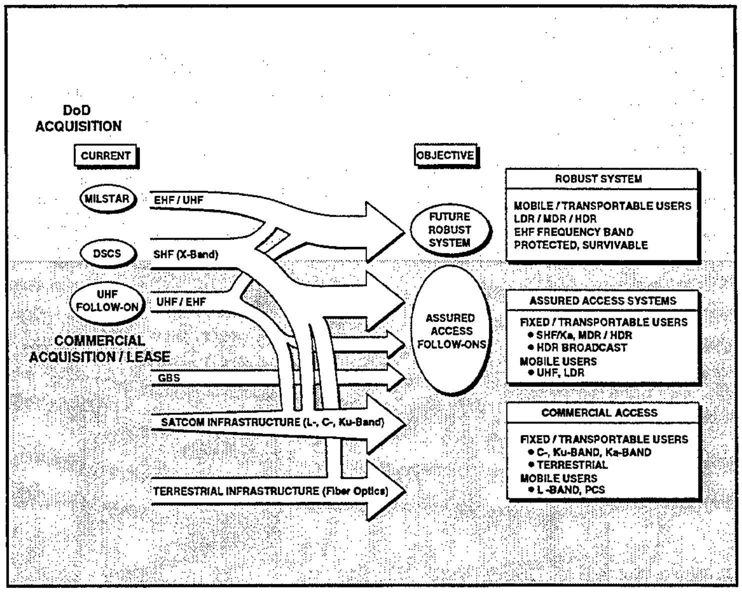

Figure 7. Illustrative DoD Satcom architecture evolution.

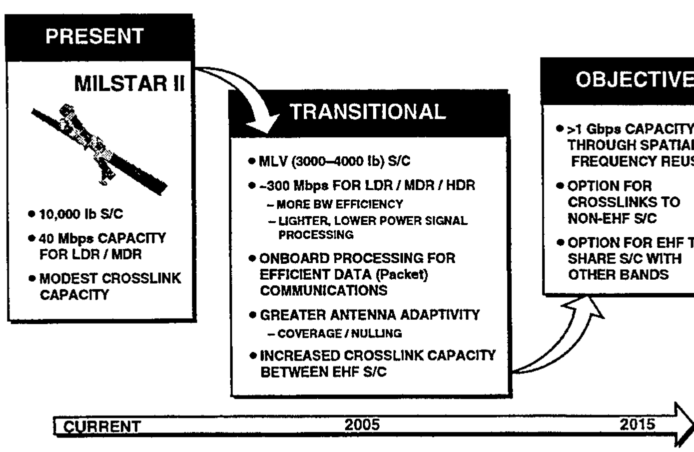

Figure 8. Architecture progression for robust Satcom at EHF.

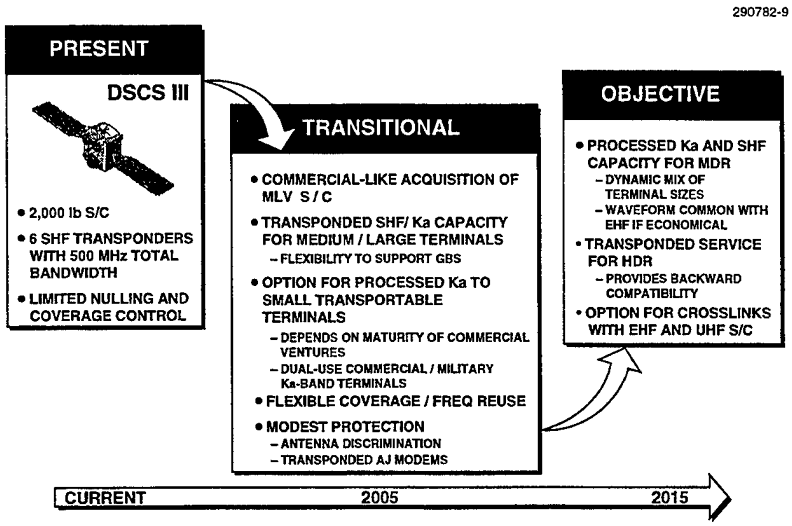

Figure 9. Architecture progression for assured access at SHF/Ka.

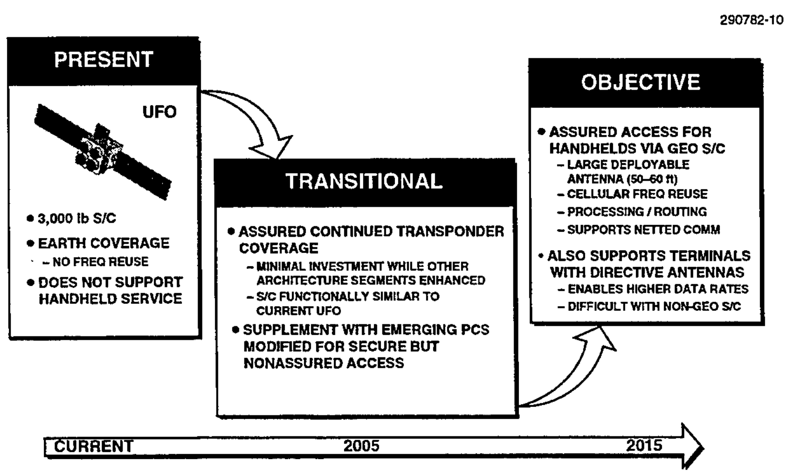

Figure 10. Architecture progression for assured mobile access at UHF.

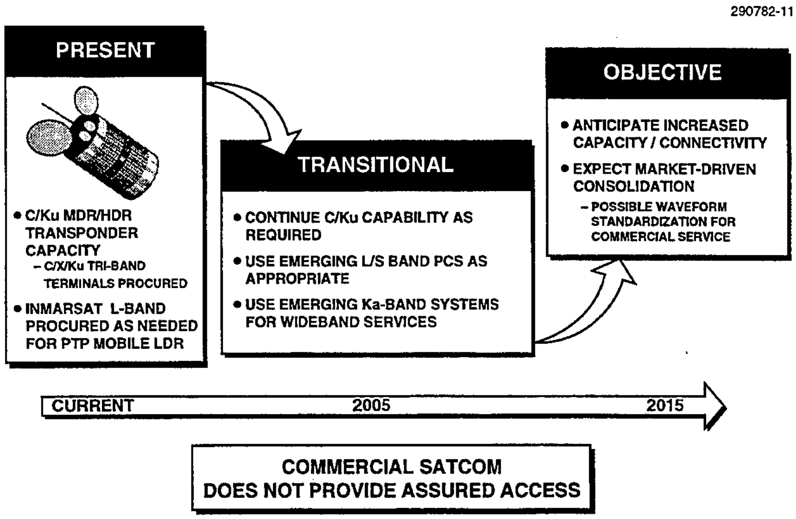

Figure 11. Commercial Satcom is key for noncritical services.

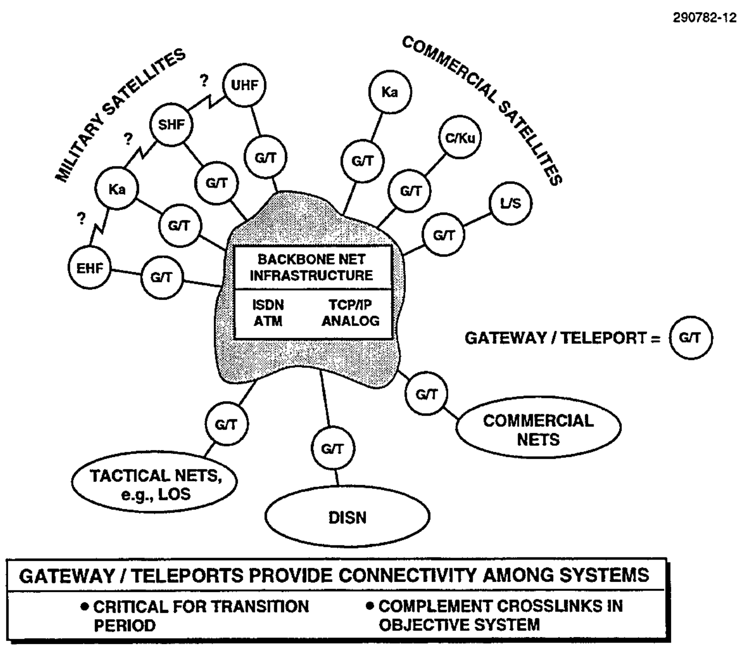

Figure 12. Architecture interconnectivity.

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