# 2.0 Communications

## 2.1 Information Technology—An Overarching Concern

With widespread proliferation of advanced military weaponry and capability, what differentiates one nation's force from another's may be their relative usage of modern information technology. Clearly the USAF will have to deploy advanced global communications networks in order to have the kind of sophisticated information environment that will be commonplace in the near future. However, at first glance it is not evident that the networking that the USAF will be able to project into the field will measure up to the broadband capability that may be accessible to the average user in any developed nation in the world.

The information industry is moving massively and quickly towards architectures that depend intimately upon broadband communications. Two current trends that fuel this thrust are the client/server model of distributed computing and the move towards increasing use of multimedia information. Shrink-wrapped software will be available everywhere that depends upon high speed communications connectivity. This is the environment with which Air Force personnel will become familiar when working in their homes and in their permanent bases. The question is whether they will have to give up this bandwidth-rich environment when they are deployed to forward positions. If so, then the USAF will be isolated from the natural technology of the information industry, and this has strong implications for strategy, tactics, and training in the future.

Information Technology will be the differentiator in business and in the military. The Air Force must ride the commercial wave. The pace of information technology is faster than the typical acquisition cycle. Open interfaces and standards will dominate. Information technology will be ubiquitous in the world; entities will gain the advantage through skilled use of the technology, rather than through development of unique technology.

## 2.2 Projecting the Future in Communications

The future in communications arises from the interplay of a number of factors with differing time constants:

Exponential technology evolutions (e.g., Moore's Law)

The evolution of standards (e.g., ISDN)

Economic flywheels (e.g., investment in infrastructure)

Market chaos and fashion

Some technology is predictable. Moore's law predicts the exponential decline of transistor price and the exponential increase of computer power. There is a similar law for the capacity of optical fiber systems. Compression technology gives steady advances in bandwidth efficiency.

Advances in standardized infrastructures, such as ISDN and ATM, are also predictable. They happen over many years, as the technology must be developed and popularized. We could predict now that ISDN will rapidly disseminate over the next several years as an improved access method for Internet and other digital networks. ATM will take five to ten years to become a ubiquitous platform for high speed multimedia communication. Right now we foresee ATM being the technology of choice for LANs, for wireless access, and for backbone carriers. However, it appears that a future version of TCP/IP (version 6, or its progeny) will be the main protocol for packet networks. There will be many conversions between IP and ATM.

Another factor in how the future evolves is the economic flywheel. For example, it will require tens of billions of dollars to wire the US for broadband access. This will take perhaps a decade to accomplish.

Finally, market forces, serendipity, invention, and fashion form a fertile chaos from which many futures could coalesce. This is so important that it cannot be overstated. Simply put:

We do not know the future uses of networks—they are inherently unpredictable. The growth of the Internet is an example of this unpredictability. The exponential growth is the envelope of a number of rising new applications, the first of which was electronic mail and the most recent of which is the web. None was foreseen, yet all together they continued a predictable, exponential growth.

## 2.3 Laws of Networks

The law of network traffic—it doubles annually.

The law of network value—the value of a network grows with each addi-tional user

It is well known that data traffic on computer networks has been growing exponentially. Reliable statistics are kept on the traffic on the Internet backbone that show a steady 100% annual growth rate over the last decade. Since this is the largest computer network in the world, such statistics are rather compelling in thinking about how to project the natural growth of data traffic in Air Force networks. However, there is a complication—the Internet also shows a 100% growth rate in number of host computers. (The growth of actual users is not known.) Thus it is possible that the growth in traffic in the Internet is entirely due to the continual expansion in the number of connected computers. In Air Force networks we would not expect such a growth of computers.

Statistics on the growth of data traffic in fixed-user-population networks are much harder to come by. However, one comprehensive study at the Lawrence Berkeley Labs shows that in their own network they experienced a 100% annual growth rate over a period of years when their size, in terms of computers and people, remained relatively fixed. The same is true of statistics compiled for the corporate network of Bellcore.

From such published data we suggest the hypothesis that the natural growth of data traffic in networks is exponential, and that the annual expansion is of the order of 100%. This reflects the intuitive understanding of communications managers that network traffic grows exponentially in a network with available capacity, and that the traffic growth only decreases when the network approaches saturation, discouraging users from further expansion of their usage.

The important conclusion here is that the natural growth is exponential, and that *at any given time we do not know the future uses that will continue the exponential pattern.*

For example in the last few years the popularity of the client/server architecture has fostered the growth of distributed computing, and the emergence of multimedia has begun to cause bandwidth demands to escalate. The sudden popularity of the World Wide Web and the Mosaic hypertext user interface has begun a new underlying exponential thrust on Internet traffic, just as older interfaces seem to be reaching saturation. There is no reason to think that similar new traffic stimulants will not continue to appear in the future.

It is also important to say that this strong exponential growth is characteristic only of data traffic—not of traditional voice traffic, which grows only at about 6% per year. Thus the amount of Air Force traffic which is analog voice would not be expected to grow with time.

The value of a network increases nonlinearly with the number of users. This fact seems intuitively obvious when considered. Every user has his value increased by being able to access every other connected user. The more people you can communicate with, the more value you have. However, this proposition is often overlooked in the consideration of network security, where the idea is often to communicate with as few people as possible. These factors must be traded off, with explicit consideration being given to the value of increased communication connectivity.

## 2.4 Pricing of Commercial Communications Facilities

The price of commercial communications has decreased over time, both because of technology and because of emerging competition. Moreover, the price of capacity on a per-bit basis decreases with the band-width being purchased. Between these two factors, it is possible to effect an exponential expansion of communications capacity over time at a fixed price.

Historically in the United States the pricing of communications has decreased annually at approximately an 11% rate. On bandwidth, the general rule of thumb is that price per bit decreases as the square root of bandwidth. More accurately, the data suggests a guideline of price being proportional to the 0.6 power of the bandwidth.

Putting these two factors together, it is evident that twice as much capacity can be purchased for about 1.5 times the initial price, and that after about three years the price will have dropped about this amount. Thus without spending any more money, capacity can be doubled about every three years.

This exponential growth at fixed price is an attribute of commercial facilities that might not be shared by Air Force facilities, such as military satellite capacity. In the latter case it is not evident that either changing technology or emerging competition would serve to decrease prices so dramatically over time. This serves as another argument for the Air Force to ride the commercial market wherever possible in the purchase of long haul communications capacity.

## 2.5 Commercial Fiber Technology, 1994-2000

Commercial fiber technology provides an already powerful communications medium, and one that is growing in reach and bandwidth. Today's standard transmission systems send 2.5 Gbps per fiber on a single wavelength. Technology is rapidly enabling further exploitation of the intrinsic fiber bandwidth, which is perhaps 1000 times greater than that utilized currently. Wavelength multiplexing enables more channels to coexist with a fiber, while higher speed electronics enables higher speed transmission on each channel. By the year 2000, systems will probably use 10 Gbps as the standard speed per channel, with wavelength multiplexing of 4 or

8 channels on a fiber. Erbium-doped fiber amplifiers make upgrades of existing systems easy, since only distant transmitters and receivers have to be changed in order to increase capacities.

The bottom line of all this technological progress is that fiber is providing the cheapest medium for broadband communications, and that in the future it will become even more inexpensive on a per-bit basis. There is no question that fiber will be absolutely the least expensive way to get information from point A to point B. Therefore, when looking to future long haul communications alternatives for the USAF, commercial fiber must receive first consideration. Other media should be used only when fiber is infeasible.

## 2.6 Fiber Deployment, 1994-2000

The expansion of fiber deployment throughout the world is extremely rapid. In 1992 the rate of fiber expansion within CONUS was at the speed of sound (total fiber miles divided by seconds in the year)! However, the fiber backbones across the US are temporarily overbuilt, and attention has turned to other parts of the world, including in particular Asia.

In the near future it is likely that every city in the world with a population of 100,000 will have access to fiber. Furthermore, every land mass on which the Air Force might have to operate will be connected by fiber. This includes every island where there are enough people to have a conflict.

In spite of the overwhelming proliferation of fiber, it appears likely that there will be deep communications “holes” that still exist in the year 2000. These holes will be principally in central Africa and South America. Thus it cannot be said that the world will have been glassed over, and fiber access cannot be assured everywhere.

## 2.7 Fiber and the USAF

Because of the bandwidth and economy of fiber, it will be the medium of choice for digital communications. Furthermore, commercial computing technology will evolve based upon the availability of fiber communications. Thus the USAF should plan to use fiber long haul systems wherever possible. To do otherwise would cut the USAF off from the technology and economy of commercial information systems.

Even though fiber will have reached every population node on earth, it is not evident that the forward locations that the Air Force must reach will have fiber access. Any such location might possibly be on the order of 100 miles from a fiber route, but these miles might pose an insurmountable barrier. They might be spanned by a satellite link, but once satellite has to be used for any link, the satellites might as well do the whole job—the point of fiber becomes moot.

It is possible to bridge the geographic gap to a fiber terminus by setting up a portable microwave link. There are occasions where this might be a useful strategy during the middle phase of a deployment, after satellite has served for the initial deployment into a “desert” environment.

Unfortunately, even given physical access to a fiber terminus, there are other problems. One is that the fiber access will be controlled by local governments. It might be necessary to reach a fiber terminus in an adjacent country. Furthermore, the fiber trunk might consist of a single line that could be disrupted or exploited by the enemy.

Thus, even though fiber must always be the medium of choice, it will not always be feasible to use. This presents a problem for the USAF, because their information usage and capabilities will naturally evolve with commercial technology based on expanding bandwidth. It will be necessary for the Air Force also to have information systems that use diminished bandwidth, and for preparation and training with these lesser capabilities.

## 2.8 Wireless

Some experts predict that as much as 80% of telecommunications in the year 2000 will use wireless access. Others, more pessimistic, say only about 30%. Either way, it will be a major factor in how telecommunications evolve. The following generations of wireless access are succeeding each other:

Analog cellular (AMPS)

Digital cellular

PCS (personal, low power transceivers)

There will be a number of tiers of wireless access. Several global satellite-based telephone networks will be in existence in the year 2000. Iridium and Globalstar are contenders, but so are a number of other alliances. It seems certain that some of them will survive, while others will not. The major question is whether the satellite service remains an expensive prestige item for the special business traveler or becomes a low cost mainstay of developing countries.

For the Air Force the existence of these low earth orbit (LEO) telephone networks poses problems. How much capacity do they have? What priority might the USAF get in the event of a conflict? Could the enemy be stopped from using them? For now the answers seem to be: not enough, not much, and no.

The alliance between Bill Gates and Craig McCaw to build a broadband, LEO network with about 600 satellites is especially interesting. They would have to dramatically change the economics of satellite technology. If anyone can do it, they can, but it is a difficult bet. If it existed, it would be most useful for military purposes, offering worldwide, broadband data access.

In addition to the PCS networks, there is currently an effort to build a PACS (personal access communication) access infrastructure, with simplified, high speed links connecting phones in buildings and in pedestrian areas to a multitude of low power base stations. Such technology might be typically provisioned in developing nations as an alternative to wired infrastructures. By the year 2000 it might be widely deployed, so that wireless access would exist in all but the most inaccessible areas of the earth.

The technology of wireless has been largely point-to-point or many-to-one until now. It is likely that much technology will be developed for wireless networking in the near future. Wireless LANs will provide instant infrastructure for quick provisioning of networks. Such capabilities will be obviously important to military operations.

Another tier of wireless will be the unlicensed spectrum used now by cordless phones. This technology will be much more widely used in the future. It is also quite possible that more spectrum will be available for “cooperating transceivers,” rather than being rigidly assigned through the Federal Communications Commission or its foreign equivalents.

Telephone and cable companies are also now rushing to use LMDS and MMDS technology for broadband broadcast. As of this moment, these are seen as quick start ways of getting into video access. The LMDS, at 28 Ghz, conflicts with the proposed satellite systems, such as Teledesic, but provides a great deal of potential bandwidth, whereas the MMDS at around 2 Ghz is easier technically and politically.

## 2.9 Network Security and Reliability

*Unbreakable* codes will exist as *standards* throughout the world (encryption techniques that are computationally infeasible to decrypt). This is a fact that NSA and other government organizations would like to prevent or ignore. However, the knowledge is already widespread, and the development of standards, cheap coders, and transparent interfaces will inevitably follow. This is both good and bad news. The good news is that security will become something that the Air Force shares with the commercial world. Its problems will no longer be unique. In fact, the Air Force might seriously consider at some time in the future the use of commercial security equipment and practices, instead of relying upon military techniques.

The bad news is that the enemy’s codes will be indecipherable. (Although other methods of exploitation will always exist.)

The Air Force will find some of the new techniques of cryptography useful, including digital signatures, integrity checks, authentication procedures, digital time stamping, and electronic money. Undoubtedly, one of the areas receiving work will be the authentication technology, where biometric techniques will become more prevalent.

Network integrity and security should be a high priority concern of the Air Force. The Air Force should know how to keep its own networks up and how to take down the enemy’s networks. Both will be very sophisticated technologies, and based upon past history the offense and defense will be well matched. It seems likely that will continue into the future, with hacker techniques keeping fully abreast of every firewall put in their face. Even national networks will be vulnerable to disruption by knowledgeable people.

## 2.10 Internet

The Internet will be of prime importance in the global information infrastructure. In fact, it will probably *be* the global infrastructure. At the current rate of growth the number of users equals the world’s population in the year 2003. However, some saturation will occur, and a reasonable estimate might be several hundred million users in the year 2000. All the earth except central Africa and South America will be heavily connected. The network itself will be diverse and robust. It will be hard to take down, both technically and politically. In a conflict both sides would make use of the network.

The number of people on Internet will be multiplied by their use of software agents or knowbots. Agents will watch for events, will combine services, and will effect transactions. They will have sets of privileges that will constrain their abilities to act.

The Internet will become a major conduit for business, and will carry electronic money in various forms. Thanks to new protocols, and a continuous expansion of backbone bandwidth, the Internet will carry an appreciable amount of real time traffic, including speech, video, and multimedia. Video mail may become a popular feature of the network.

A huge amount of information will be readily accessible on Internet. Not only digital libraries and documents of all sorts, but even arrays of sensors everywhere on earth will be on-line. You will be able to access the temperatures in rooms throughout a distant city, or monitor the traffic flow. Through actuators you will be able to effect complicated commands at a distance. In the distributed network the speed of light will become an important limitation.

People everywhere on earth will be empowered to broadcast on the Internet. It is likely that no happening will go undocumented on the Internet. In a conflict amateur video cameras will go on-line to broadcast through the Internet. Common personal computers will be powerful video servers.

A structure for information will evolve that gives powerful search capabilities. Browsers will be simulated, 3-dimensional point-of-view like some computer games of today. There will be execution environments embedded in HTML documents, so that actions may occur at a distance. This is a very important development in network use, which will have a major effect within a ten year horizon.

Every soldier might well attempt to make personal use of the Internet in a conflict, provided he or she could get access. If wireless infrastructure becomes relatively ubiquitous, this might be possible. A tremendous amount of information will be there for the taking—for either side.