Chapter Three

MEETING MILITARY DEMAND WITH COMMERCIAL SATELLITES: CONTACT AND EVALUATION

Commercial communications have undergone extraordinary growth, and the advent of the Internet, new consumer services such as direct-to-home satellite television, and international agreements to open telecommunications markets offer many opportunities to develop profitable new services.[1] In Chapters Four, Five, and Six we will examine the various dimensions of communications supply from commercial satellites. First, we review international cable and satellite systems and their applications in the communications market. Second, we set out the satellites and network systems we intend to evaluate and the criteria against which we evaluate them.

CONTEXT: INTERNATIONAL COMMERCIAL COMMUNICATIONS SYSTEMS

Terrestrial Systems and Networks

Earthbound transoceanic communications are carried by undersea cables that connect most of the world's principal cities. Revolutionary advances in commercial submarine cable systems now permit enormous capacity between major telecommunications hubs. In 1988, the first-generation fiber-optic cable—TAT 8—was laid, with the capacity for 22,000 simultaneous voice calls.[2] By 1993,

[1]These agreements include the 1997 World Trade Organization agreement to open national telecommunications markets to foreign competition.

[2]Assuming each call is allocated 12.8 Kbps.

second-generation systems, with far more capacity, were being laid—TAT 12/13 across the Atlantic and TPC 5 across the Pacific. These systems can transmit 5 Gbps on two fibers, with an additional 5 Gbps of capacity in reserve in case of failures in the main cables. The latest transatlantic and trans-Pacific cables have been designed to employ multiple wavelengths or "colors" simultaneously on each fiber, with each "color" providing 2.5 Gbps capacity.[3] These cables have been laid in optical network rings that can route calls around breaks in the cables without interrupting communications. Over the next several years, new cables with capacities ranging from 40 to 100 Gbps or more are planned across the Atlantic and Pacific oceans. Figure 3.1 illustrates some of the systems that have been deployed, and notes their capacities on a logarithmic scale (with each major division signifying an order of magnitude increase). The capacity of these cables has far surpassed that of large-capacity satellites in service today.

Sufficient capacity is typically available on these cables for the military to use without owning them. However, cables do not provide service to remote areas or for mobile operations. Microwave relays may be useful in some cases, but require time to set up and must be protected. Communications relays on unmanned air vehicles (UAVs), useful for some applications, may be vulnerable to enemy air defenses and require time to set up the infrastructure for flight operations. Hence, the military has a continuing need for satellite communications.

Satellite Systems and Applications

The global satellite communications market has grown remarkably since the first commercial satellite attained full operational capability in 1965. That satellite, Early Bird,[4] was used to carry voice and television traffic between the United States and Europe. Early Bird capitalized on many design features of the Syncom satellites first

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[3]Not all of this capacity need be "lit" upon installation. Often, one or two "colors" are "lit" at commencement of service, with equipment added to the terminal ends to light additional colors as needed. This has the benefit of making capacity upgradeable without changing the submerged cable.

[4]Also known as INTELSAT I (see Martin, 1996).

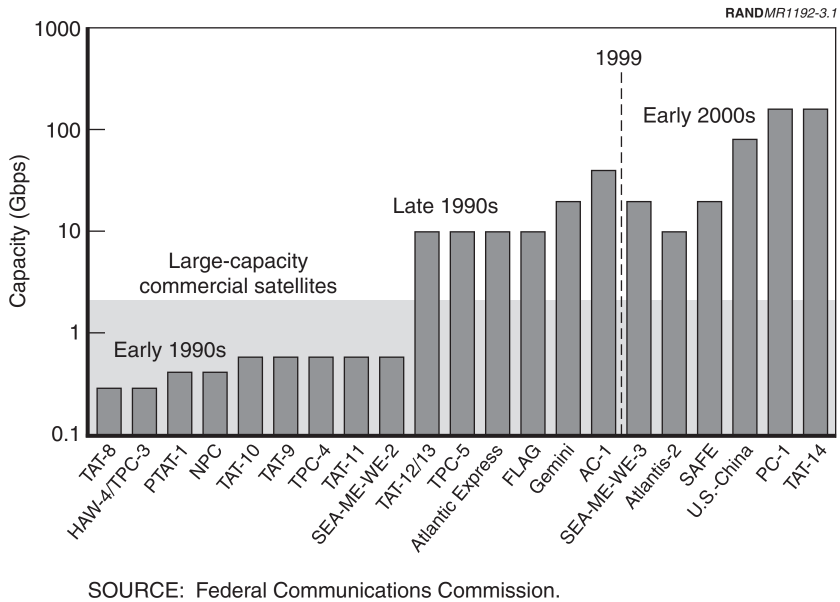

Figure 3.1—Major Submarine Cables in Use and Under Development

launched for the DoD in 1963. Domestic satellite communications began in 1974 with the launch of Westar I. Satellite weight, power, transponder[5] number and capacity, and the number of fixed and movable beams have increased steadily over the years.

Commercial communications satellites today are in low earth orbits (LEOs), medium earth orbits (MEOs), and geosynchronous earth orbits (GEOs). Iridium and Globalstar are examples of current LEO systems, and the proposed Teledesic system is another.[6] Most commercial communications satellites are in geosynchronous earth orbit—at 35,700 km altitude.

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[5]Transponders, also referred to as repeaters, receive, amplify, and retransmit signals between users at separate ground stations. They are the "working" or moneymaking part of the satellite.

[6]Their orbital altitudes are 770 km, 1400 km, and (planned to be) 1300 km, respectively.

In geosynchronous earth orbit, the satellites appear to be stationary when viewed from the earth.[7] In general, this is seen as an advantage, because a ground antenna can be pointed at the satellite once and remain in contact. The disadvantage is that it takes between one-quarter and one-half of a second to travel to the satellite and back. This delay time—or latency—is noticeable in voice conversations. There has also been concern that latency could prove troubling for Internet protocols that must receive confirmation of packet receipt.[8] Satellites at LEO and MEO have less latency, but require that a constellation of satellites be built to ensure that any given point on the ground always has at least one in view. This adds to the cost of the space segment.

We will not consider LEO satellite constellations further in this report for two reasons. First, only three such satellite constellations, Iridium, Globalstar, and ORBCOMM, exist; the remainder are proposed at this point. Second, these are narrowband (low-data-rate) systems intended primarily for paging or voice. The focus of our research has been on wideband systems capable of sending voice, video, and data. If a wideband system such as Teledesic is deployed, its use should be considered by the military. We will note the effect such a system might have on commercial capacity in the next chapter.

Prior to launch, satellites go through a lengthy coordination process with the International Telecommunications Union (ITU) and the nations that are in view of the satellite. The ITU serves as an arbiter and administrator for those nations that have agreed to coordinate their use of the communications spectrum with others.[9] This includes virtually all nations. However, the ITU has reported some instances of noncompliance with ITU guidelines. The major penalty for not coordinating use of the spectrum is interference with other commu-

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[7]In fact, some stationkeeping is needed to maintain position. When fuel runs out, the satellite begins to develop a "figure 8" pattern or a "wobble," necessitating the use of more complex and expensive ground antennas to track the satellite.

[8]The concern is that packets would be assumed lost because of the delay in confirmation. Packets would be resent, again be assumed lost, and be resent in an endless loop, eventually bogging down the system. The emergence of "Internet protocol (IP) over satellite" suggests the problem is manageable.

[9]Nations, not individuals or companies, file with the ITU for spectrum assignments.

nications users. Most nations, therefore, see it as in their best interest to coordinate their spectrum usage[10] to ensure that a satellite in a specific orbital position (or "slot") will not interfere with previously established users of a given frequency band. In addition, coordination establishes a satellite as the acknowledged user of a specific band in a slot.[11]

The ITU will allocate spectrum for specific orbital slots to those nations filing on a first-come/first-served basis for the useful life of the satellites, without respect to whether these systems will be used by commercial or government entities. The filing nations then coordinate their intended use of these frequencies with the nations that will be in view of the satellite. The nations in view of the satellite can raise objections if use of these frequencies by satellites will interfere with other uses within their borders. If the coordination process is successfully completed, then the respective nations agree to allow satellite operations to commence. However, this does not grant the nation operating the satellite any implied landing rights—approval to receive or transmit signals must be obtained separately from each host-nation government.

Commercial satellites carry voice, video, and data between fixed and some mobile users. Satellites have transponders and a "bus" that performs "housekeeping functions" such as providing power, control, and stationkeeping. Transponders (repeaters) receive, amplify, and retransmit signals. Today, commercial satellites use C-band transponders with global, hemispheric, and zonal beams, and Ku-band transponders with spot beams to provide connections between users (Figure 3.2).

Global and hemispheric beams are used for applications (such as telephony) requiring access to broad regions. Zonal and spot beams

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[10]International Telecommunications Union (1997).

[11]Some orbital slots are claimed but vacant. This can happen when a nation has filed an intention to commence services with the ITU, but has not yet bought a satellite. These are sometimes referred to as "paper satellites." Though contrary to ITU agreements, this may be a way to claim a piece of spectral real estate for future use or sale to others.

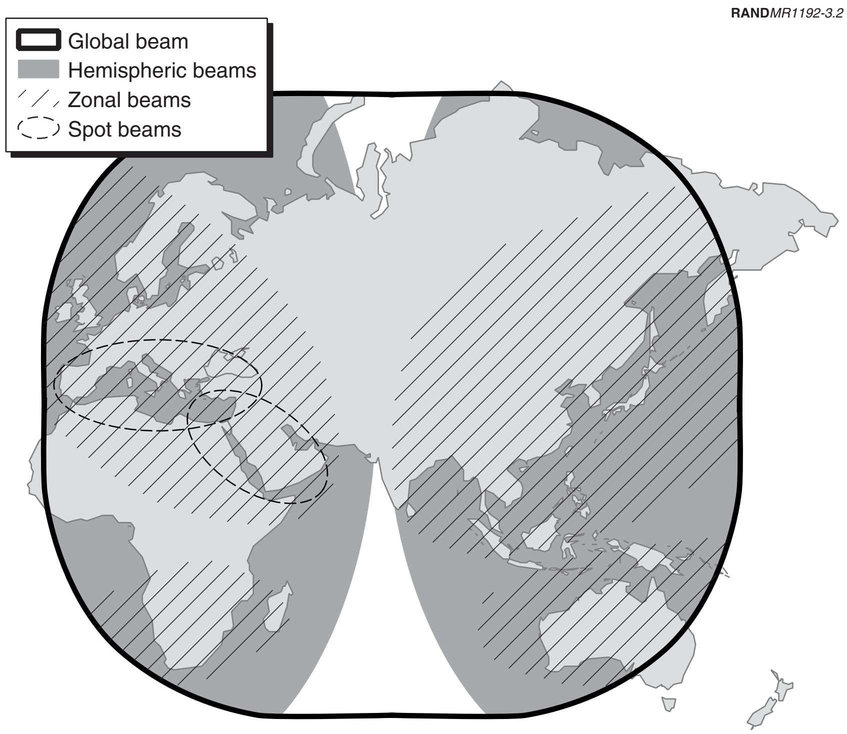

Figure 3.2—Exemplar Satellite Beam Patterns

provide focused coverage for applications such as video and data.[12] A satellite might have each type of beam, with transponders using the same frequencies in several beams simultaneously. Interference is avoided by physically separating and polarizing the beams.

To discriminate between satellites using the same frequencies, the satellites are spaced 2 degrees apart; this implies that only 180 satellites using each band could be in geosynchronous orbit at any one

[12]Reducing the size of the spot concentrates transponder power. For example "direct-to-home" television uses high-powered transponders in spot beams in small home dishes.

time.[13] Existing and planned satellites, if all were in operation, would more than fill the available slots.[14] However, many will be used as spares or retired once new satellites are launched. Also, some companies have begun to locate several satellites (sometimes five or more) in the same orbital slot.[15]

In addition to C- and Ku-bands, S-, L-, and Ka-bands are of interest to commercial users. The S- and L-bands are primarily used for mobile telephony (e.g., to ships at sea) and messaging. Although Ka-band has been experimented with for some time, technical challenges have delayed commercial use.[16] Ka-band is attractive because it has been assigned a large bandwidth by the FCC—making "broadband" or high-data-rate services possible. Also, the first groups filing for allocations were able to propose systems without having to coordinate with established users.[17] Some military satellites use X-band frequencies with low susceptibility to atmospheric attenuation and limited commercial use[18]—meaning less competition for orbital slots.

SATELLITE ALTERNATIVES AND EVALUATION CRITERIA

The military has several options to match supply and demand for military communications:

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[13]Advances in technology, higher frequencies, and precise coordination of beams may allow closer spacing in the future.

[14]Currently, there are 141 satellites in geostationary orbit broadcasting at C-band and 154 at Ku-band. An additional 59 C-band and 93 Ku-band are planned for launch over the next four years.

[15]Direct-to-home video broadcasters often place several satellites in a "hot bird" slot to accommodate a large number of homes or businesses with receive-only dishes.

[16]Ka-band is used on the National Aeronautics and Space Administration (NASA) Advanced Communications Technology Satellite (ACTS) and on Japanese test satellites. However, Ka-band signals suffer more than X- or Ku-band from degradation caused by rain.

[17]On May 9, 1997, the International Bureau of the Federal Communications Commission (FCC) awarded licenses for 13 proposed commercial Ka-band satellite systems.

[18]Frequencies between 240 and 340 MHz (ultra-high frequency, UHF), 7250 and 7750 MHz and 7900 and 8400 MHz (X-band), and 19.2 and 20.2 GHz and 29 and 30 GHz (Ka-band) are recognized for exclusive military use by the FCC within the United States.

- DoD could attempt to limit the amount of communications that U.S. forces use to match the amount that present, programmed, and planned military systems can provide;
- DoD could allocate more money for purchasing military-unique communications satellites;
- DoD could employ additional commercial communications to augment military systems.

We do not consider the first option further. Although it is unclear what future contingency needs will be, restricting the communications available to U.S. forces may make it difficult to have the real-time command and control envisioned in joint doctrine. The second option requires that more money be allocated to buy communications satellites—money that would need to come from an increase in DoD funding, a shift from other acquisition programs, or a shift from other accounts such as operations and support (O&S).

The third option requires more money, too. In addition, it requires DoD to develop concepts to employ systems that the military does not completely control. Currently, DoD appears to be satisfying about half of its satellite communications needs with commercial systems. Even if more military satellites are purchased, commercial systems would provide a valuable option for additional communications to meet demand growth or unexpected contingency surges.

In concept, the choices facing DoD are not only between military and commercial systems but also between owning and leasing (see Table 3.1). Ownership includes all rights and obligations pertaining to the hardware itself during and after its projected useful life and all rights of use for the same period. In addition, ownership requires an orbital slot with the appropriate spectrum allocation. Leases can include the right to use a specified satellite, transponder, or bandwidth for a specified amount of time. The hardware or service leased typically occupies or originates from a slot on which the owner has an established claim.

Table 3.1

DoD Satellite Communications Acquisition Options

Option	Military-Unique System[a]	Commercial System[a]
DoD ownership	DSCS MILSTAR UFO Gapfiller	Policy difficul-ties
DoD lease	LEASAT	INTELSAT PanAmSat Orion

[a]Exemplar systems.

Conceptually, four options are available to DoD:

- Purchase a DoD-unique satellite (using frequencies allocated to DoD, and perhaps with other DoD-unique features as well)
- Lease a DoD-unique satellite
- Purchase a commercial satellite (of an existing design, and employing frequencies allocated for commercial use)
- Lease a commercial satellite.

In fact, however, these options devolve down to purchasing a DoD-unique satellite or leasing a commercial satellite. U.S. policy assigns use of certain frequencies (such as a portion of X-band) to military satellites. Therefore, the current customers for commercial systems operating at these frequencies would be the U.S. military or U.S. allies. (This argument may hold only in the United States if commercial satellite providers move to X-band in foreign countries.) A commercially owned DoD-unique system would probably be leased for the life of the system, and the military would probably have to assume all of the capacity. We will treat this type of lease as a purchase.[19]

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[19]The military did lease the LEASAT system, which operated in the military UHF and X-bands, from Hughes between 1984 and 1996. The United Kingdom is considering leasing an X-band payload or services hosted on a commercial satellite. In the future, commercial Ka-band systems may be designed to be tunable over the military and

Similarly, current U.S. policy assigns primary use of commercial frequencies to commercial users—meaning that military use of these frequencies must be on a "noninterference" basis.[20] In principle, the military must yield to commercial users if the two uses interfere. In addition, if the military were to purchase a commercial satellite, it would need to buy from a company with an orbital spectrum allocation for a satellite on orbit or one soon to be launched.[21]

The options we will evaluate may thus be summarized as follows:

- DoD-unique satellite
- Whole commercial satellite
- Fractional commercial satellite—a transponder or fixed bandwidth lease
- Communications service agreements.

DoD-unique satellites possess technical or operational capabilities of interest primarily to the military with no, or limited, commercial markets. We will assess DoD-owned satellites with characteristics similar to the proposed Gapfiller—a wideband satellite using military X- and Ka-band but with little jam resistance. DoD would control both the satellite payload and the bus, and could move spot beams or the satellite at will.

Whole commercial satellites currently on orbit might be leased to provide SATCOM services. (We assume that the satellites would be bought or leased on orbit so that an orbital slot assignment would be included.) In this case, the day-to-day management of satellite resources and operations would be performed by, or under the direct oversight of, DoD. The commercial satellites are presumed to utilize C-, Ku-, and Ka-band and have minimal protection.

Alternatively, DoD could lease some of the transponders on a commercial satellite or some portion of its bandwidth. The transponder/fixed bandwidth lease is similar to those leases and

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commercial Ka frequencies, making it technically possible for them to provide capacity to both types of users.

[20]DoD (1996).

[21]The commercial C- and Ku-bands have largely been allocated already.

services offered by INTELSAT and its signatories and other commercial companies such as PanAmSat and Orion. DoD could manage the bandwidth, but the satellite bus would be operated by an outside entity (typically the private entity that has title to the satellite).

Leases come with the appropriate spectrum assignment and right to transmit in that frequency (but not necessarily the right to transmit or receive from a ground terminal without first obtaining agreement from individual nations). In addition, DoD might be able to purchase the right to switch transponders between beams at will, or the right to reposition spot beams.

Finally, DoD might procure satellite communications through service agreements with commercial providers. These vendors might own the satellites or arrange for communications on other satellites. The vendor would be responsible for procurement, network management, and allocation of satellite time to DoD users—and might be able to offer variable amounts of bandwidth as user demand changes. In the case of service agreements, DoD would control neither the satellite bus nor its payload. Service agreements may be thought of as a special class of leases, where satellites and transponders may change without notice, and DoD may not know which specific ones are being used.

These types of commercial service agreements are only now emerging. COMSAT Corporation offers a Linkway service that allows users to establish a network of terminals from a given satellite. Customers may vary the total bandwidth they use on these terminals and are billed for the capacity they actually use. Hughes Global Services has a similar concept called "DemandNet," a concept that allows users to relocate one or more terminals and still receive service. Limited capacity is available today, but these concepts are a step toward giving a user access anywhere in the world, and billing "by the bit" rather than at a flat rate. User applications under discussion for Hughes Spaceway, Lockheed Martin Astrolink, Teledesic, and other systems may make more capacity with these features available.[22]

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[22]These systems are not yet in operation.

In evaluating the four options, we are interested not only in their ability to satisfy military demand in terms of quantity, but also along several dimensions of quality. The evaluation criteria we will use are those put forth in the Capstone Requirements Document. These criteria, which are defined in some detail in the following chapters, are as follows:

- **Capacity:** Will the option provide enough wideband throughput to meet the needs of fighting forces and their supporting infrastructure?
- **Coverage:** Will the option provide sufficient capacity in all areas needed?
- **Flexibility:** Will the option support the full range of military operations, missions, and environments?
- **Interoperability:** Will the option support the ability of all elements of the U.S. force and command structure to communicate with each other (and with allies)? Will the integration of satellites into the defense information infrastructure be transparent to users?
- **Access and control:** Will the option make the required communication services available and accessible when and where they are needed? Will DoD be able to plan, monitor, and operate the communication resources?
- **Quality of service:** Will the option provide communication channels meeting the appropriate industry standards or Mil-Specs (military specifications) for reliability, bit error rate, transmission throughput, outage responsiveness, and other appropriate factors?
- **Protection:** Will the option provide communication services that will survive attack and be robust to jamming?

In addition to the evaluations, we will consider operational concepts to mitigate shortfalls in commercial satellites or to operate combined military-commercial systems. If commercial systems are to provide future capacity, the military must use care not to introduce unintended vulnerabilities into DoD networks. That is, DoD must shift its focus from providing individual systems to the art and science of using communications for military operations.