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Military Use of Satellite Communications
John M. Ruddy

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Military Use of Satellite Communications

John M. Ruddy

Dr. Ruddy is Vice President of The MITRE Corporation's Washington C^3 Center. He has been working at MITRE since 1973, focusing on satellite communications programs such as Milstar. He has served as technical director of MITRE's Strategic Communications Division, where he was substantively involved in program initiatives in areas such as monolithic microwave integrated circuits, wideband high-frequency communications, and lower-cost, low-earth-orbit military satellite communication system alternatives. Dr. Ruddy has also contributed to MITRE's Strategic Defense Initiative architecture program. Before coming to MITRE, Dr. Ruddy was a staff member at MIT's Lincoln Laboratory, and worked as an institutional research analyst for Baerwald & DeBoer and Newberger, Loeb & Company in New York City. In 1972, Dr. Ruddy cofounded Astech, Inc., a company that developed proprietary consumer telephone products using power line carrier technology; he holds several patents in this area.

Oettinger: I'd like to introduce John Ruddy of The MITRE Corporation. And, again, his biography has been in your hands for some time, so I won't recap that.

Ruddy: I'm not going through a long briefing. I have some charts and I hope to use them only to generate some interest and some conversation with you, as opposed to me just lecturing. Hopefully, that will keep both sides of the table awake at this hour in the afternoon. Unlike the previous speaker I don't have any golf jokes. Actually I never learned to play golf. I caddied once when I was too young and I developed an extreme dislike for the game. On the other hand, I went to a parochial high school and I counterbalanced that by spending my afternoons in a pool hall. However, there aren't very many funny pool jokes, so I'll just go into my main subject.

I presume all of you not only read the papers about the recent events in Desert Storm but you also watched them on television. That was a marvelous example of worldwide connectivity of the broadest kind, using satellites for the communications medium. It's not something that we could have had 10 or 15 years ago. It's something that will become more and more ubiquitous as time goes on. We'll be receiving satellite signals directly into our homes, in fact. Some of us do now. But where does the military really fit into all of this? I thought I'd start first by talking a little about what kind of communications the military has.

Oettinger: Could I break in for a moment? You have the advantage. You have notes; you know what you're going to say.

Ruddy: I have notes but that doesn't mean I know exactly what I'm going to say.

Oettinger: You said that 10 years ago, one couldn't have done this. Let me try to make you say that a bit more precisely, so I can enlighten the following question. When the last hoopla in Egypt and Israel took place about 1973, there were complaints that news reporting was asymmetric between the Egyptian and Israeli sides. And if I remember correctly, at the time it had relatively little to do with politics and a good deal more to do with the fact that the news on the Israeli side could be relayed, maybe via an earth station, in Haifa, or Greece, or something. You couldn't get it out from the Egyptian side, but that says to me two things — we're talking almost 20 years ago. You could do some of it, but it had limitations.

Ruddy: Correct.

Oettinger: Could you say a little about what has changed?

Ruddy: One thing that has changed is that every time I remember something now, it usually happened 50 percent longer ago than I thought. It must be something that happens to everyone. But seriously, the reality is that technology has changed. And it's changed our life in the following way: It's made things cheaper and smaller. As a result of making things cheaper and smaller, technology is available to more and more people.

We did do things like that before 1970. We had a super high frequency (SHF) satellite system for the military that could handle up to a megabit or so. It was called the Initial Defense Communications Satellite Program (IDCSP), and it was followed by another program called TACSAT, which was for tactical satellite communications. But those were primarily military. There were commercial analogs, but really the first real commercial analog was the SYNCOM, which was a relatively thin line system. It wasn't until we got into the INTELSAT arena, which then created the infrastructure that supported the satellite communications industry in this country — Hughes, Ford-Aerospace, RCA, (now GE Aerospace) — that we were able to expand into markets which would include what we call DOMSATS and regional satellites.

We now have entrepreneurs who buy their own satellites, getting investors to come in. For example, there is a satellite, called Pan-American Satellite, which was bought on speculation, if you will. The services were sold. They used those communications services during the Panama operation and I believe they also sold services during Just Cause to the military. I suspect there are lots of other people that have found that rather interesting. More and more people will actually speculate on putting transponders into space, betting that there are people who will want these services because there is equipment that they can buy and use. Motorola has just announced that they want to have a cellular telephone using a satellite system and sell that service worldwide. They'll have to invest upwards of $2 to $4 billion to do that, but I can assure you there's a lot of money if it's successful. They'll very likely recoup that investment rapidly.

There is also an interesting question about dual-use technology — the military's developments filtering into the commercial world, and the commercial world's developments filtering back into the military (figure 1). Who's leading what? Is the military ahead of the civilian area, or is the civilian ahead of the military? The answer is "yes" to all those questions, depending on "what." The military has an interesting set of needs. Most of them, except for the first one, are things that we would find in civilian applications or commercial applications. Not too many family households or businesses have a need for commanding and controlling nuclear-capable forces, but . . .

Student: But, some of us wish they had.

Ruddy: Yes; however, all of the communications listed here below relate to communications that most of us use or are familiar with — primarily data transfer. Most of us are now people who are computer-literate. We have computers on our desktops and access to files that are remote, and so do the military.

AUTODIN is a digital network. AUTOVON is a voice network. AUTOSEVOCOM is a secure voice network. In both the civilian world and the commercial world, secure voice networks are becoming important because you want to keep financial transactions and information away from unfriendly or unsavory people.

Wideband networks — television and imagery are major users of that service for broadcasting information, or for accessing large databases to transfer large blocks of information. Wideband networks exist on the civilian side, for example, with NASA, (National Aeronautics and Space Administration). The DOD (Department of Defense) is not the only organization that has imagery that has to be remoted around for study or access. As for command and control, while we don't generally sail around with ships ourselves, there are ships at sea — tankers and cargo carriers — that make use of satellite communications in order to be rerouted in real time to some other location, providing economic advantage. That capability, in fact, is what has led to the market for INMARSAT. This is a capability that Admiral Tuttle* used during Operation Desert Shield to help ships moving back and forth with supplies. The command was able to communicate directly with those ships that were delivering goods to the desert.

Student: Could I hear that again?

*Vice Admiral Jerry O. Tuttle.

Community	Purpose/Users	Type	Service	Data Rate
Nuclear Capable	C^2 for SIOP Forces, Nat'l Cmd. Auth., CINCs	Mobile, fixed	BLOS	Low
Def. Comm. Sys. & Special Suppport	Autodin, Autovon, Autosevocom, Diplomatic, White House	Fixed, Transportable	BLOS	Medium
WWMCCS	Nat'l Cmd. Auth. & CINC networks and C^2 for all forces, early warning	Fixed, Transportable	BLOS	Medium
Wideband	High data rate trunking (Intel)	Fixed	BLOS	High
Ground Mobile Forces	C^2 Army, Air Force, Marine ground operations	Mobile, Transportable	LOS, BLOS	Low
Fleet Ops	C^2 Navy ship, sub	Mobile	LOS, BLOS	Low
Air Ops	C^2 Air Force air ops; SAC, TAC, MAC, Security Service	Mobile	LOS, BLOS	Low

LOS – Line Of Sight
BLOS – Beyond Line Of Sight

Source: MITRE, 1991.

Figure 1

Military User Communities: General Communications Needs

Ruddy: INMARSAT.

Oettinger: Let me just interject. In the first or second year of this seminar, there was an account by a fellow from Mobil or Exxon, who talked about their handling of one of the oil embargoes and the use of satellites and other means to essentially reroute the stuff on the high seas. One of the reasons the embargo made very little difference was that the cargoes essentially would just be rerouted. Unembargoed oil moved to the U.S., embargoed oil then moved into places that weren't embargoed, and it was almost a wash. There's a fairly good record of that by one of the participants, if you want to pursue it.*

*A. K. Wolgast, "Oil Crisis Management," in *Seminar on Command, Control, Communications and Intelligence, Guest Presentations, Spring 1980*. Program on Information Resources Policy, Harvard University, Cambridge, MA, 1980.

Student: Have they gotten better about plugging the gaps south of 20 degrees south, where you operate even though there's nothing there?

Ruddy: Not with the geostationary satellites. You always run into that problem and that's why the military tends to have its own special systems. The U.S. military has a worldwide mission and that includes north of the 80th parallel. We have to include the polar areas as part of our connectivity.

Student: At 72 and 73 it's the same thing.

Ruddy: Right. So that's something that the military does have to take into account with its satellite communications systems. That also adds to their cost, because . . . yes, sir?

Student: Just a side comment. The Canadians intend to put up something called ELINK, an

Alaskan name, to take care of part of the northern hemisphere.

Ruddy: Yes, it is called ANIK, which is an SHF satellite — that's super high frequency. I think it's in the 7 or 8 gigahertz range, but I'm not sure. It may be 12 or 14 gigahertz; I've forgotten right now. However, it too is a geostationary satellite. They use it, and we use it. We also use RCA ALASKCOM to remote the data that comes from the early warning radars up north. We use commercial satellite services for that as opposed to military satellite service, in addition to other communications. Additional communications, by the way, is another difference that generally occurs in military communications, particularly U.S. military communications: We generally have more than one way and one technique to get from point A to point B. We call it dual phenomenology. If we're primarily using satellites, we will use high frequency (HF) networks as a backup to that, or we may use radio relays, or ground networks. There are certainly cases in which we can't use anything but satellites or HF radio, and they involve mobile platforms. It's very hard to plug fiber optic and coaxial cables into ships and planes and also have them be connected to the ground.

Oettinger: Another interjection, because I'm struck again by the simplicity and ease with which you portray some things which a decade ago were very difficult. If you look, for example, at General Paschall's* comments in his seminar, it was a major hassle. This notion that there is an alternative phenomenology, or alternative paths, and so on, was a major struggle. If you want to see an account of that struggle, read Paschall's presentation to this seminar. He was instrumental in initiating some of the early versions of these things. It also will give you a contrast to the rather special circumstances in Chuck's presentation**, where something got done in a matter of a couple of months because of enormous interest and enormous support. Whereas, in this area, we have talked in the past decade or two between the conception of something and its realization. In most areas that's kind of the norm.

Ruddy: Well, it generally does take us on the order of a decade to do almost anything for the military. That poses a real problem because we're usually at least two technology generations behind by the time we field something, and probably five generations behind by the time we decide to retire the system. That poses an interesting stress on being able to effect the kind of communications connectivity we want, and so on. I think our most recent experience with Desert Storm is going to change some of that. The reason for that is we were able to do in 30 to 60 days, as a result of cutting out all the bureaucratic folderol that generally exists, things that would normally have taken years to accomplish. If somebody needed a satellite terminal of a certain type on a ship, they got it. We followed all the legal niceties. By that I mean, we went through RFPs (requests for proposal) and so on, but it was done very much as it was described earlier, without all the surrounding folderol.

Oettinger: What made it easier? Was there a special emergency declaration authority of the President, or was this in ordinary legislation? What triggered that?

Ruddy: I think in this particular case, and I'm not an expert on it, it was the fact that the commander-in-chief in the field was given the power to marshal the resources. That's the first time we've had that since I can't remember when, and he had the direct authority to spend that money.

Student: That was based on the Presidential declaration. It had some interesting waivers. It allowed the call-up of 250,000 of the existing Marines, which triggered some interesting things.

Oettinger: Presidential national emergency powers were triggered somewhere along the line.

McLaughlin: The Food and Forage Act of 1861 was probably relevant to this.

Student: The Army needs to remember that one of the research experiments of the 1840s brought camels into Texas.

Oettinger: Before you take that one on, would you decode LOS and BLOS for us?

Ruddy: Oh, I'm sorry. Please interrupt me any time I lapse into jargon or acronyms. It's a hazard of our business. They stand for beyond line-of-sight and line-of-sight, and they mean exactly that. "Low data rate" means teletype or a single voice channel. In this sense, I mean it only in terms of how the particular user uses it. It's your telephone. There may be a satellite or some other communications systems that's supporting it (it may be thousands of

*Lee Paschall, "C³I and the National Military Command System," in *Seminar on Command, Control, Communications and Intelligence, Guest Presentations, Spring 1980.* Program on Information Resources Policy, Harvard University, Cambridge, MA, 1980.

**See preceding presentation by Charles L. Stiles in this volume.

telephones) and there may be an aggregate data rate that's very high. "Medium" in our jargon generally means things like the T1 carrier, which was referred to earlier. It means 1.5 megabits of data per second. "High" is generally what we associate with imagery and other sorts of intelligence information sent between one place and another. Yes, sir?

Student: I'm a little bit confused. You're talking about FLEETOPS and a low data rate. My understanding is that a lot of it is really a high data rate. They use satellite communications with data compression.

Ruddy: Not really. The Navy's primary satellite communications system is a UHF (ultrahigh frequency) satellite called FLEETSAT. The basic teletype channel bandwidth is 25 kilohertz (kHz) with a bottom data rate of 75 bits per second teletype. The Navy can push through that satellite channel maybe upwards of 20 kilobits per channel. FLEETSAT also has 5 kHz channels for use by the Air Force and Army. These channels support 75 bits per second.

Student: You're talking about a whole different scale then for ELF (extremely low frequency) and VLF (very low frequency).

Ruddy: ELF is extremely low frequency (and bandwidth). You're talking about data rates about 1 bit per second or less. That's an emergency system to communicate with the submarines. It's a doomsday system.

Oettinger: You need only one message.

Ruddy: Right. For example, the message might be, "Come up and do something".

The Navy people, however, as was mentioned earlier, want imagery now as part of how they perform the war. And in fact, the Navy did get imagery; it required putting different satellite terminals on some of the ships that they had. Some of those satellite terminals were military and some were commercial. So these are changing. In the past, they were voice and data channels; in the future, there will be very high rate data channels for the transmission of imagery for use with those expensive faxes.

Here's the term line of sight. I put this chart (figure 2) together just to give you some sense of frequencies used. I don't know how technical we need to get here, but these are the things that interest me. If you start nodding off, I'll go onto another subject. But we really do deal from direct current to daylight in the military, literally. ELF is essentially down to direct current, and fiber optic is the daylight. There is interest in using laser communications for satellites, as well as for ground communications and secure ground communications between Army units. There's a story told about that operation in Panama where they couldn't get some information across the river and they would have died just to have two little laser communications links that you could buy commercially, just to shoot some data across.

Oettinger: Let me just interpret this. Another metaphor for that would be a hair to a fire hose, in terms of information carrying capacity. There are places where hair is efficient; there are places where a fire hose is efficient, or it's all you can get. So there's that whole range. That's all behind the technical point.

Ruddy: In World War II, most of the communication was line-of-sight, and with a little bit of beyond-line-of-sight at HF. The line-of-sight was the hand-held walkie-talkie type of thing.

Oettinger: In World War II, they did have radio; I mean, they did have telephones.

Ruddy: In World War II, they used a lot of wireline telephones. They even had the kind of telephones that you used to see in the movies, those that soldiers answered while they were sitting in the foxhole. That was the kind of communications they had. That is very inhibiting in terms of performing rapid operations. You can't transport them. Even if you had the capability to move yourself with great speed, when you got there, you'd have nobody to talk to. It would take you time to set up an HF radio, and the HF radio medium is very unreliable. It depends on the ionosphere: there are times of the day when it's extremely unreliable. There are times of the day when it is reliable, but it's most reliable over long distances, say, several thousand kilometers, not several hundred miles. That creates a problem.

The medium that has changed how we perform warfare is satellite communications. It's basically the ability to have reliable communications anytime to anywhere, with almost any data rate. And it operates from UHF up to EHF, which is 300 megahertz, up to about 40 gigahertz in frequency. It encompasses both military-only satellite communications and commercial satellite communications. There was a tremendous amount of use made of satellite communications in Desert Storm. I cannot

Line Of Sight (LOS)		
Band	**Propagation**	**Commercial Technology Available**
HF (3 - 30 MHz)	Groundwave	Yes
VHF (30 - 300 MHz)	LOS	Yes
UHF (300 - 3000 MHz)	LOS	Yes
SHF (3 GHz - 30 GHz)	LOS	Yes
EHF (30 - 300 GHz)	LOS	No

Beyond Line Of Sight (BLOS)		
Band	**Propagation**	**Commercial Technology Available**
ELF (3 - 300 Hz)	Groundwave	No
VLF (3 - 30 kHz)	Groundwave	Yes
LF (30 - 300 kHz)	Groundwave	Yes
MF (300 - 3000 kHz)	Groundwave	Yes
HF (3 - 30 MHz)	Skywave	Yes
VHF (30 - 300 MHz)	Meteor burst	Yes
UHF (300 - 3000 MHz)	SATCOM	Yes
SHF (3 - 30 GHz)	Tropo, SATCOM	Yes
EHF (30 - 300 GHz)	SATCOM	No
Terrestrial: fiber optic, coax cable, twisted pair		Yes

Source: MITRE, 1991.

Figure 2

Some Military Related Communications Technologies

tell you how much came in and out of the theater in terms of data rate and so on, but I can tell you that almost all of the communications in and out were by satellite communications, and no other way. They made use of INTELSAT, DSCS*, any SAT. And if they could have gotten more, they would have. And that is going to change the way the military commanders feel they're going to have to run their war. They want that imagery; they want all that other intelligence information; they want to be able to communicate with their forces in the field reliably at long distances. There are all sorts of special missions that require reliable communications and so on, and that medium provides one of the best means for doing that.

The other thing that is special about the military is that it often has characteristics that are required, and they aren't often things that you would see with civilian technology because they're not necessary (figure 3). One of them, security, is something that is happening in the civilian world as well for

*Defense Satellite Communications System.

Service Characteristics

- Anti-jam
- Low probability of intercept/exploitation
- Robust in presence of propagation disturbances
- Security

Equipment Characteristics

- Ruggedized for adverse environments
- Hardened against nuclear events

Source: MITRE, 1991.

Figure 3

Special Military Needs

reasons of privacy, but is really important in the case of a conflict with a technological sophisticated power. And by the way, people were very concerned that the Iraqis would jam our communications capability, and that they would have sappers or some other things to take out critical communications nodes. We were very fortunate to have one of the most inept enemies we could have ever tripped across as an adversary. They did everything wrong that I'm aware of in the communications area, and they did nothing of any substance to disrupt our communications.

Oettinger: Does that go back also to what I said earlier about the Soviets? Because if the Soviets had been so disposed then I presume they could have made intelligence available or jammed us.

Ruddy: Well, yes, they should have had the technical capability to jam some of our communications links.

Stiles: They couldn't make it work. The French built a command and control system for Iraq, and, of course, the French had to evacuate so they had nobody there to perform maintenance on their system. They were there for eight years, those technicians in Iraq, helping to build that system. It's very funny, the point he makes about the Soviets. The Egyptians, of course, had long occupancy by the Soviets and they had SU-5s, SU-7s, Soviet MIG aircraft, and so forth. The Soviets built their aircraft so they were more easily maintainable in the field. They were field-strippable, like a rifle. But when the Soviets were at base and the Egyptians would get a spare part, they would just go over to a little room, and a hand would come out. They'd put the part in the hand and the hand would give them a part to put back — no thinking, no anything whatsoever, no ability to reason. The Soviets did not train them very well.

Ruddy: It also raises fundamental issues about how tall the Soviet is.

Student: But I think there's more. The interest in using INMARSAT and INTELSAT only became possible since this was all the world against two nations. Had it been two competing people who had large shares of an INMARSAT or an INTELSAT, then they could have brought in the agreement which says they can't be used for combat. The whole place would have been up the creek, thumbing their noses.

Stiles: You get Duane Andrews* here and you tell him that. No matter what, Duane Andrews says commercial satellites can be used for military and we're going to spend a lot of money on selling them.

Student: But you've got to read the agreement! That's assuming you can enforce international law. You can't enforce it by turning off parts of the transponders.

Ruddy: They can do that. They can turn off the ones you think you're going to be in.

Student: As a matter of fact, it doesn't matter whether you go to court or not. You can't talk.

Ruddy: Even though we had everyone behind us, we were very careful using those international assets. In the case of INMARSAT, the information transfer had to do with transportation of goods. It did not have anything to do with war fighting, per se. The war fighting per se stuff was mostly done over our own assets. So that is a concern, and probably one of the lessons that Congress isn't going to learn is that this is likely to rear its head in the next conflict. People learned what effect it had on the Iraqis, and they're going to want to do it to us if they can.

Oettinger: This being antijam?

*See presentation in this volume by Duane P. Andrews, Assistant Secretary of Defense for C³I.

Ruddy: That's right. That's using noise, electronic noise, to interfere with our communications.

Another very important characteristic that we like to have is what's called "low probability of intercept," When we transmit our signals, we don't want other people to know we're present or what we're saying. And I'll leave it to your imagination why and when that is important.

"Hardened against nuclear events" refers to conflicts with super powers, with the Soviets, and it has to do with people setting off nuclear weapons high in the ionosphere in order to disrupt communications and other electronics equipment. As a result of that disruption, it affects the communications links that go up and down from the satellites, and you don't get information through unless you have properly designed your satellites and your signalling structure to do so. And in the case of some of our military systems, we have done this. A significant portion of our satellite communications for the military are really commercial analogs. They operate on ruggedized equipment and on a military satellite, but it's a channel that looks very much like a commercial satellite channel. Security is very important. We want to deny information to the enemy. We don't want them listening to our open communications lines. I'm sure if you've read the newspaper recently, or *Time* magazine or *Newsweek*, you know that the Iraqis were able to uncover where we were going with our aircraft because our pilots had this very bad habit of speaking in the open. They provided intelligence information in the field to the adversary.

Student: Excuse me, does that mean we need to fix the KY-28s?

Ruddy: They need to use it. There's a switch.

Student: We have a lot of them saying, "I don't have time to wait for it to sync before I talk."

Ruddy: If you're asking if the equipment could be better, the answer is yes, better, in the sense that our crews will use it. They complain about the quality of the voice, and they complain about the amount of time it takes to communicate. But they could also handle the communications in the open a little differently than they do, as well.

The other thing is that for military systems, the equipment itself is physically different. It has to be: It operates in very extreme environments. We do not operate it in rooms. We don't wander around Harvard Square using it. It has to operate from Thule, Greenland, in the desert, even though the military takes a lot of hits and spends a lot of money, and people sometimes waste it, they know what they're doing. Most of their equipment worked very well in the desert, and it usually works very well in the North Pole, as well. And the commercial stuff does not, by the way.

McLaughlin: I did notice that there are incentives for the commercial manufacturers to ruggedize the stuff themselves. I once refereed an argument between a guy from DOD and a computer manufacturer. The computer manufacturer was saying that DOD wanted him to meet a tech spec. "My laptop — it's dropped in the airport; it's thrown around baggage carousels. If it's a performance spec, I can beat it, O.K. But, gee, ruggedized equipment is a big selling point to me for commercial equipment."

Stiles: I guess I would argue that GPS (Global Positioning Satellite) is a hand-held receiver. It can tell you wherever you are within four or five feet. The U.S. bought them because they're very handy for people in navigation. There's one thing about your little laptop. If you leave it up at the front of your pickup truck, when you come back, it's melted. I promise you, it's melted. So the military does have some justification for its specifications. In the desert, it's melted.

Ruddy: The problem is they do not know a priori where the next war is going to be. If it's in the jungle, it has to be protected against fungus and all sorts of things. And if it isn't, it won't work. Yes?

Student: I want to voice a known complaint with milspecs (military specifications), particularly for communications equipment and electronics. There's an idea of buying something for the whole service, or the whole Navy, or for the Air Force and the Navy, and it's very ruggedized for certain characteristics which are really inapplicable in other very specific applications. You wind up with something that can handle five degrees of angle in an environment where it takes ten or twenty, and all of a sudden it crashes, or you have something overbuilt.

Ruddy: You're right. That's a good point. Let me answer it in a few ways. One of them is that I think the military could be better in the way it does buy some things. There's no doubt about that. They tend to get a little binary. For example, we have systems that have to have some portion of them nuclear-hardened, but we end up nuclear-hardening everything and it's not strictly necessary. The military people are not stupid and they are dedicated; but they operate in an environment that you wouldn't believe. They operate with Congress. It's just terrible. They'll get beat on the head for that $80,000 fax, which I'm sure everybody read about. If they had said, "Okay, we give up," and had thrown the idea away and bought commercial faxes, they would have been beat over the head for not having faxes that worked in the desert. The same group that says, "You shouldn't do this," will tell you, "You shouldn't do that," and it happens day in and day out. You really have to understand the environment the military lives in. They go schizoid because they get told one thing on Monday and then something else on Thursday.

Oettinger: It depends if he's running for reelection and looking after his district or . . .

Ruddy: . . . or whatever.

Stiles: I guess I would argue with you. The military has erred. I'm not one to castigate the military, but they probably attempted nuclear effects because there are so few people who really understand that technically. I know, for example, at a company where I was vice president, we designed a memory system for the B-2. With the rad-hardened specs we had, it would probably have been dead hours before the damn memory ever failed, and the cost curve was like this. I would think that was probably the biggest mistake, bigger than nuclear, because there are so few people who understand that technology. In Desert Shield, as I say, your nice little great computer in front of that pickup truck would have melted. I promise you. It would just be a blob, as were these hand-held GPS receivers.

Student: I got blown away for saying that we ought to go with the hardened thing. It will also work when you put the jitter on the satellite because this other stuff is cheaper. That means you've got to buy four times as much of the stuff that's hardened . . . I don't understand it.

Ruddy: "Everything in moderation" is a phrase that one hears often, and I think it applies to buying military things as well. You can go overboard with the specs, and they often do. This can happen with nuclear hardening, when they don't take a balanced view. They define a "reasonable" worse case environment and say, "That's it." I can't imagine every B-2 flying in that environment, to be frank about it. They don't approach the problem from what I call a statistical point of view. What is the likelihood that something's going to happen? At what level should I really set the nuclear hardness at so that X percent of them will get through in this kind of generalized environment and leave it at that? That would drop the cost of things in development significantly, although not quite so much in production. The effect in production is primarily in the generation of technology that you are permitted to use when your equipment is hardened against nuclear effects.

Oettinger: Let me just translate the last few sentences for some of our laymen here, because this is an extremely important point. I think this is one of the areas where the laity is probably more at fault than the military, by virtue of the notion of looking for certainty. We've created more crimes in looking for certainty — vaccines, military, and so forth. The notion of saying, "It worked most of the time, but occasionally, it won't," is anathema to most lay decision makers. The notion that nothing is perfect, and that for perfection is paying through the nose, is something that is very difficult to get across, especially when your budget is such that you have to argue. The path of least resistance is to say, "Yes, you know I'm going to try to give you perfection," and then the costs go up by factors of from two to one hundred because of this funny game. We see it over and over again. There's a good history, for example, of vaccine testing that Tom Schelling here at the Kennedy School did some years ago. So this point that you make is one that really runs very profoundly in the relationship between all technical people and all laity. The schism there causes an awful lot of money to be misspent.

Ruddy: Oh, yes. Every one of us in this room cannot guarantee that we will be someplace tomorrow, with 100 percent certainty — not one of us, maybe not even the next five minutes. Yet we insist on that for other things, and it's very expensive.

As I was saying, the main problem with the nuclear hardening is not the cost of buying it; that maybe adds 10 to 20 percent. Now that's not trivial, but it's not three times the amount. It costs a lot to develop it, but what really costs is the technology that you're permitted to use because you have to test the integrated circuits you want to use, and so on. The newest ones and the latest ones have not been verified that they are nuclear-hardened, so you cannot use them in your system. You're usually a generation to a generation-and-a-half behind just going out of the starting blocks when you're developing nuclear hardened systems.

Now, nuclear-hardened communications systems are the communications analog of the bomb itself. It does no good to have a deterrent that you have no control over, and you have no control over that deterrent unless you can communicate with it, at least one way. Doctrine has changed over the last 20 years, insisting that perhaps we need to control it two ways — that we have to have information coming back from the platform as well as telling it to go. This has to happen in a rather severe environment, with everything happening at the same time, with some probability. It costs money. We've done a reasonably good job of it. We've managed to convince our adversary that we are capable of managing our deterrent. It's been very successful. I think we will probably still need it for the foreseeable future because their nuclear weapons haven't gone away and more may be arising in other places. There may be more reasons to have positive control of our forces than in the past.

I've been primarily talking about satellites. Why? Because it's the only medium I know of that provides you all of these capabilities at once (figure 4). You get beyond line-of-sight; you get to talk to anywhere. You can talk worldwide if you put the satellites in the right places. You can reach isolated areas, even if you have a ground infrastructure. The richest ground infrastructure in the world is here in the United States; but there are places in the United States you cannot get to. You have to get to them by HF or VHF radio, or some other means, or as many people do now — by satellite. How else to get to mobile platforms, particularly if they're at great distances? And the other benefit is that it's easier to expand the service. It costs you nothing. The satellite is up there already. All you have to do is put the terminal there. There's no other infrastructure to add except the user's equipment.

- Beyond line of sight communications
- Worldwide coverage
- Service to isolated areas
- Reliable connectivity to mobile platforms
- Rapid and easy expansion to new locations

Source: MITRE, 1991.

Figure 4

Why Satellites?

Oettinger: Before you leave that, I'd like to clear up one point. All of these are clear advantages; at least another element is that satellites until now, have had an unpleasant echo problem, which has caused some substitution of fiber optics. What progress then has there been for eliminating that drawback?

Ruddy: Primarily, the improvements are coming as we go to more and more digital communications, and that's the direction of the civilian world. And that's the primary reason that we will get reliable and nonecho type of communications. You'll still have the delay. We can't make things go faster than the speed of light, but we will get rid of some of that echo. Yes, sir?

Student: How much has the cost gone down on the commercial side?

Ruddy: I should have had a ready answer. I should have anticipated that question. I believe it's several orders of magnitude in cost. The transponders — there's dollars per megahertz, per year, in space. It's gone down probably about an order of magnitude. What's really gotten cheap is the user's equipment. The first INTELSAT terminals cost on the order of five to ten million dollars, in 1970 dollars. That's a lot. Now Walmart has a satellite communications terminal — not the same kind of data rate — but now Walmart can have one in every one of its stores for inventory control.

Student: About $10,000?

Ruddy: They're about $10,000, transmit and receive. That's three orders of magnitude just for the equipment. That's a little flip because they don't do the same thing, but nevertheless, you couldn't have had theWalmart terminal in 1970. You can have it today. And that creates access and access creates need.

Student: I'll raise the question. Why doesn't the commercial world go entirely to satellites?

Ruddy: The commercial world does things for reasons of cost.

Student: Right, it's costly.

Ruddy: And it has to do with the tariff structure.

Oettinger: That's a more accurate point. It has to do with price and tariff structure because costs in engineering terms, fiber and so on, have also gone down. But you have a regulatory structure, which puts a disjunction between costs seen by the supplier and the prices that are charged. You get all sorts of weird anomalies. That's a subject for a whole other course, which you're welcome to come and take.

Stiles: That's why INTELSAT was formed. Because the smaller countries couldn't afford to pay the tariff costs. It's probably one of the more successful organizations. It's an outstanding organization of 50 or 60 nations. All talked together; all worked together; all shared costs.

Oettinger: Careful! It's a money pump from the U.S. to the rest of the world.

Ruddy: It's amazing that that many people could get together and do anything that complex.

Oettinger: It's COMSAT, you know: a U.S. enterprise with an international veneer. You look pretty, do the work, and you get things done.

Ruddy: The purpose of this chart is just to give you a flavor of the kinds of capabilities that satellites provide and who they provide them to. (figure 5). I have a mirror image chart from the military to indicate that the military commercial enterprises use satellites for essentially the same class of service, but for different reasons (figure 6). We're all familiar with that. Even if you're on cable, you're getting it from satellite down first. It's broadcast up; then it comes down to a cable head and gets fed into your home. Musak in the elevator comes by satellite. The telephone is another example, particularly calling overseas. That's something that is lost on our Congress, in terms of how they support satellite technology in this country. It's because we have such a rich infrastructure on the ground here, with microwave towers, cables ... fiber optics has replaced almost everything. They have long lines. It has become cost-competitive now to install new fiber optics for the tail circuits, that is, circuits from the central office to your home. And it will soon become advantageous to replace existing twisted-pair wires with fiber optics, and that means broadband information in and out of the home will become possible. And that will open up other markets.

Student: Fiber optics are immune to some of the radiation and the nuclear effects that you were talking about earlier.

Broadcast (One-to-Many)

- Home Box Office, Showtime, etc.
- Muzak

Point-to-Point

- Telephone (analog and digital)
- Video conferencing
- Bank/financial networks
- Computer networks
- Airline reservation networks

Many-to-One

- Data bank services
- Very small aperture terminals (VSAT)

Source: MITRE, 1991.

Figure 5

Commercial Use of Satellites

Ruddy: So we don't need satellites for telephones in the United States, and we're so egocentric, we assume nobody does. But that's not true — Africa, the Sino-Soviet land mass — just go around the world, and almost everybody needs it except us and Europe. Yes?

Student: You could bring back the cellular phones' transmissions by a satellite, instead of a local microwave transmission.

Ruddy: Well, the cellular telephone idea that Motorola* has is really a dual phone. It will operate on the standard line-of-sight cellular telephone in metropolitan areas. If you look at Cellular One's and NYNEX's coverage zones, there's a lot of places where you can't use your cellular telephone and it will be quite some time before the investment will be available to expand out even further than it is now. If you want to provide that kind of service to people, there are people who would like to have it and who will use it. They're called salespeople. The only way to do it right now is by satellite or by radio or by driving to a phone. That's a very unsatisfac-

*Iridium.

Broadcast (One-to-Many)

- EAM dissemination
- Force direction

Point-to-Point

- Wideband data nets
- Tactical theatre
- NCA/CINC Internets

Many-to-One

- Force reporting
- Intelligence

Source: MITRE, 1991.

Figure 6
Military Use of Satellites

tory medium. So that is one reason why the Motorola idea may actually sell. Also there are needs for lots of data bank transfers. That's many-to-one, one-to-one, some-to-some, in broadcast. And the military has the same kinds of service. The broadcast of one to many — that's the most important one. It is the deterrence to the Soviets, or has been. That's the EAM, which means emergency action message — force direction. Telling people they have to do something. From the commander to the forces using point-to-point data networks. We have them all over the place in Europe, waiting for the Russians to come, and we used them in Saudi Arabia and the Kuwait theater of operations. And many-to-one, that's the information from people in the field back to the commander, so he knows the status of his forces. That's the intelligence portion. It shows what weapons are left, indicates damage assessment, and things of that nature. It's very important to keep pressure on the adversary.

There are significant differences between commercial and military needs, and also many similarities (figure 7). What's important for the military is to decide which services they do provide, which are appropriate to use on commercial satellites, and which must have a military component to them. A major difference for the military is the worldwide mission. We have to operate above the temperate zone. So we have orbits other than geostationary, which are the ones you are familiar with. The Russians have an orbit that they use called Molniya, which is a highly inclined elliptic orbit that provides far northern hemisphere-type of coverage. We also have such orbits for polar coverage.

Commercial people have found satellite communications to be a very good business, so they have lots of satellites up there taking up lots of spectrum. They're looking for ways to utilize that spectrum more fully. They're going to use narrower and narrower beams, and they make use of things like dual polarization. That's just a technical term for saying you can send an electric wave up this way into the transponder, and then you send it up the other way, and you can use two transponders, one for each polarization. The military does not make a lot of use of the total available spectrum, even though they have lots of intelligence needs and lots of imagery. Their needs pale in comparison to the amount of data that's flowing around the world on commercial systems. But, the kinds of data that flow are really the same — voice, teletype, data bank transfers. Once you're in the digital system, you can't tell what it is, so it doesn't matter; it's just how you organize the various channels together. And that's not a very substantive difference.

As for terminals, it used to be that the military was the only one running around with mobile terminals. The mix of large and small and fixed and transportable antenna were similar for commercial and militaries. Now the commercial world has mobile terminals as well. For example, there are those shipboard INMARSAT terminals that they leased to the Navy during Desert Storm.

With regard to grade of service, commercial has to be as close to perfect as you can get. Military should be good. It does not have to be perfect, you don't have to be able to recognize your Aunt Tillie. You can recognize people by secure codes. In fact, that's much better than listening to the voice, but it's hard to get users to buy off on that. Yes?

Student: Could you define grade of service a little bit more specifically?

Ruddy: AT&T toll quality for voice, if it's a voice circuit — very clear, no noise, like that Sprint commercial where you can hear the pin drop.

Student: I was going to say, I'm not sure it's that clear.

Ruddy: It's not hi-fi. In terms of data transfer, a user can specify what grade of service he wants,

Coverage	Commercial	Military
	DOMSATS: National boundaries INTELSAT: Nearly worldwide (no polar coverage)	Worldwide including the polar regions
Orbit	Geostationary	Geostationary and other
Orbit utilization	High	Low
Spectrum utilization	Fairly high	Low
Capacity	Mix of high/low data rates	Mix of high/low data rates
Terminals	Diverse mix of large to small antennas, a few mobile	Diverse mix of large to small antennas, many mobile
Grade of service	Very good (toll quality)	Good
Reliability	Very high (on orbit spares)	Moderate
Security	Desirable	Mandatory
Anti-jam	Not required	Highly desirable
Anti-intercept	Not required	Desirable
Physical survivability	Not required	Desirable

Source: MITRE, 1991.

Figure 7

Comparison of Commercial and Military SATCOM Systems

which has to do with how many errors in his data he is willing to accept. It's called the bit-error-rate, and it affects how much power he takes out of the transponder when he transmits his information. He pays for different grades of service. That has to be pretty good on a military system, but military and civilian systems both have error-correcting codes. That's a way of adding redundant information into the transmission in order to correct any errors that might have occurred. You can detect the errors, and then you correct them.

Reliability is very high for civilian systems. The reason it's higher for civilian than for military is because the military has more than one way to transmit. If a commercial company's circuit goes down for an extended period of time, customers lose money and that's the last time they use that service.

Oettinger: I'm wondering whether you're not objective. It seems to me that we're seeing a civilian move toward some diversification, at least for some of the major users — airlines, banks, and so on. You're saying quality is more moderate per circuit in the military because you're getting high reliability in the aggregate.

Ruddy: In the aggregate, yes. Here, you might describe it the same way, but the service that the user sees has to be very high. If the quality of his transponder goes down, or his channel, he has to be switched to another channel automatically. Occasionally you see it happen when you're watching television, and you lose the picture. It could either be a problem at the cable end, or it could be a problem with the satellite transponder. They try to correct that very quickly, and it's expensive to make reliability very high.

In the case of security, it's certainly desirable in civilian systems, or certain civilian systems. It's mandatory in military systems, even though they don't have it on all the military systems.

Antijam, anti-intercept, and physical survivability are not characteristics that you associate with commercial needs, but they are characteristics that are generally necessary for military operation. These are all things that cost money.

Student: Thinking about physical survivability, doesn't that really depend on the commercial use you're talking about? The thing I have in mind is the problem in New Jersey and Boston a couple of months ago. The trunk to Manhattan disrupted the financial markets. I mean, we're talking about physical survivability. Maybe we're talking about a different scale, but I think there is a necessity for physical survivability in the commercial market.

Ruddy: Physical survivability has to do with the thing itself. Reliability is different. What I'm thinking about here is the satellite itself. What you're talking about is that I might have more than one satellite. I would put what you're talking about in the reliability row, as opposed to the survivability row. It's a question of definition. For example, I don't know exactly what the circumstances were with that trunk loss. I'm very surprised they didn't have another way of routing through.

Student: They did, but it took about three hours.

Ruddy: I don't know how long they were out. They were out several hours, as I recall, and it should have been faster than that.

McLaughlin: It's a fine point. You have the Hillsdale fire at the Ameritech Illinois Bell switching center and, gee, Sears Roebuck was up. The First of Chicago was staying up. The stock market stayed up. They had a million people depending on data exchange. In theory, you don't care whether that particular switching center survives or not, if they can go over to another one immediately. That's system survivability. That's why he's looking now at your reliability. If I'm Illinois Bell, it sure makes a difference to me whether that physical equipment survives, but it doesn't necessarily to the customer if the customer has alternatives, which is why an awful lot of very large customers have multiple systems. American Airlines at one end of the switching center can be sent out via AT&T though Dallas/Fort Worth, with half of their system. The other half goes out Southwestern Bell to Tulsa and Oklahoma City and never the twain shall meet. And they, in theory, have at least 100 percent capacity in both of those systems and use them only 50 percent of the time. They use only 50 percent so that in case of massive failure in one, they switch everything over to the other. But every corporate communications manager says, "I go out and I buy this redundancy, this survivability, and I walk outside the building and AT&T, MCI, Sprint, and the local telephone company are all putting their fibers in the same trench."

Stiles: Let's make a point. In 1984, this country worried about the vulnerability of their military command and control system. They were seriously worried. They formed what they called the National Security Telecommunication Advisory Committee. Now, there is a subset of that called the Industry Executive Subcommittee, which was 32 companies in the communications business.

We were very worried about our national emergency preparedness communications in case of a nuclear attack. And by the way, it was very clear to us by the diversification of Ma Bell that you could not put it back together and you would not be able to communicate from the White House and from command and control systems. So what happened out of that? Now that the Russians have gone away, it drove the commercial industry to do more in terms of survivability. They recognized that during the earthquake out in California, you couldn't talk to anybody. What do you do about that? And so, this is an instance of the government doing real good, with the military driving the commercial industry to be more survivable for emergencies, such as the Hillsdale fire. This is a perfect case of where the military gets castigated all the time, but they are the ones who drove the commercial world, and now there's a committee that looks at nothing but standardization among that world.

Ruddy: Well, in the case of the military, there are only a few satellites up there, you know, not hundreds, but tens. Some of them are extremely important or may be extremely important, and they are carrying that deterrence traffic, if you will. You don't want that link to be broken. So there's a desire to have the satellite itself physically survivable in some way. And that, again, has to do with nuclear hardening and other things. That costs lots of money, which is why some of those military budgets are so big. But now the world has changed. How do they deal with that?

I just wanted to give you some idea of what systems the military has and does use, both on the military side and the commercial side (figure 8). This is commercial SATCOM and military SATCOM — low, medium, or moderate data rates, and high data rates and survivability needs. Now, for the most part, the mobile platforms don't have a particularly high survivability need in the sense of the communications survivability, and they are using nonsurvivable satellites. They don't have any or very much antijam and they are the UHF satellites, FLEET satellites, and Air Force satellite transponders. And there's a new system that the Navy is buying, which will be going up in a few years. It's called the UHF Follow-on, which has the great acronym of UFO. They lease services at a slightly higher frequency — L band — it's around 1,600 megahertz on the INMARSAT, which is supplied by an international mobile satellite consortium.

One of the things about these mobile platforms is that in order to talk to a satellite or to anything with electronics, you have to have an antenna. If you have to point the antenna on a moving platform, it can be very expensive, because you're pointing to some place in the sky while the platform is doing whatever it feels like. And you have to keep that antenna pointed in that direction. In the case of the UHF systems, you don't have to do that. They have what's called an omnidirectional antenna, and it looks up everywhere and it sees its satellite anywhere in the sky. So it has what's called an inexpensive, or cheap terminal, because it doesn't have that big expensive antenna system. But that also means that it doesn't have a lot of survivability features in terms of antijam.

When you start going to the microwave regime, you have DSCS, the Defense Satellite Communication System, and the domestic satellites, of which there are many varieties and flavors. You have to have those dish antennas that you see around. Some of them are very big. When you put them on an airplane, they can't be that big, but they still may be several feet in diameter underneath the radome and having that on an aircraft is very expensive. We don't buy too many of them. We'd like to buy more, but we don't. We would incur that same cost, whether or not we were going through a military system or a commercial system: It's just as expensive to do in either case. And that's for low and medium data rates.

Data Rate	Platform	Survivability	MILSATCOM	COMSATCOM
Low	Mobile	Low	FLEETSAT AFSAT UHF Follow-on	INMARSAT
Low – Med	Transportable Fixed	Low	DSCS	DOMSAT
		Mod	DSCS	
Med – High	Fixed Transportable	Low	DSCS	DOMSAT INTELSAT
		Mod	DSCS	
Low – Med	Mobile Transportable Fixed	High	MILSTAR	

Source: MITRE, 1991.

Figure 8

SATCOM Systems: Capabilities

As you get higher and higher in data rate, you really can't put those antennas on mobile platforms. It gets much harder to do because as you increase the data rate, it takes more energy to transmit information up to the satellite. That means you have to have higher power tubes, or higher power solid state amplifiers, and bigger apertures to get more energy up to and back from the satellites. They don't fit on airplanes anymore. To some degree, they don't even fit on ships. For example, you don't really want to have an antenna much wider than seven or eight feet on a large nuclear-powered aircraft carrier. Anything bigger than that gets the Navy captains upset about having this thing sitting on their superstructure. They'd like to keep it smaller than the six-footer.

Finally, we have what's called the Milstar system. It's a millimeter wave satellite system, that will be highly survivable, both in terms of jam resistance and physical survivability. MILSTAR makes use of mobile terminals as well as transportable, and it will operate at low to medium data rates. That means that it will operate from teletype up to about a one-megabyte data rate from a terminal. Now, I can use commercial satellites to provide service for some of these users, but not all, because I may have a need for moderate survivability. By that I mean antijam and I cannot get antijam properties from a commercial satellite. The same thing is true at higher data rates. If I want very high survivability, there is no commercial satellite system that can provide me that; even if I have it proliferated, it doesn't help.

Duane Andrews has a committee looking at that very question: "Where should I be spending what little money is going to be left in the '90s on satellite communications, in particular?" At my company, we have been taking a look to find out where we need military satellite communications and where we could do without them and one of the things that we did was try to map that into how much capacity we need for highly survivable satellites and moderately survivable satellites, and how much capacity we could get to satisfy people who don't need any survivability at all (figure 9). And the Ds and the Ns here have to do with whether or not you need satellite communications, because you don't need them for everything. The military, by the way, has missions other than fighting wars against the Iraqis. Some of this technology gets used in counternarcotics and counterterrorism.

Obviously, we use broadband communications for the transmission of intelligence information, as I mentioned earlier. However, depending on the threat environment, we don't need a lot of survivable communications to provide that. We can send all that imagery over commercial satellites, as long as no one is shooting at us. And if we have a general nuclear war, some of us might wonder why we're interested after that's happened,. But there are people who feel we should be interested. It becomes necessary, but you can't provide the same capacity in this situation as you can in these.

Oettinger: Out of necessity. I mean, there are arguments in terms of termination of hostilities.

Ruddy: For the lower data rate, yes. Absolutely. But you can also imagine for the higher data rates, running around looking for Scuds was interesting. It's probably just as interesting looking for SS-24s and 25s. But for force management, it is absolutely necessary, to terminate as well as to start hostilities. You have to be credible in both of those regimes in order to have a reasonable deterrence. And then it falls into what I call "fairyland," and that's reconstitution after a nuclear war.

Those are my charts. I'd be glad to answer any questions that you might have about any topic relating to those straight lines between blocks on command and control charts.

McLaughlin: John, you made a specific reference to small satellites. Do you see this as a growth industry?

Ruddy: That's a very interesting question to me because I like small satellites if they're thought about in a systems sense. Right now, with the exception of Motorola, they're being thought about in a technology sense. A commander would like to have control of his own communication resource or control of his own intelligence resource. As a result of that, he believes that if he could get one of these lightweight satellites, if he could afford it, he could launch it when he wanted, and so on. But what he forgets is that when he puts a small satellite up in a low-earth orbit, he gets it for ten minutes, and then an hour and a half later, he gets it for another ten minutes — not very satisfactory. So small sats have some utility, but not the way I see some people thinking about them. They have to be thought about in terms of 50 or 100 small sats as part of a system. Then you ask yourself, "Well, what's that system supposed to do? Does it really provide me with a capability that I can't get with these other larger satellites? Or is it because the control structure for allocating the communications resource that I currently have is so cumbersome that when I ask for

Mission/Activity	Threat Environment						
	Day–Day	Small Crisis	Small Regional (Convent.)	Large Regional (Convent.)	Regional (Nuclear)	Major War	General Nuclear War
Low intensity conflict	D	D	D	D	D	D	
Counter narcotics	D	D	D	D	D		
Counter terrorism	D	D	D	D	D	D	
Intelligence	D	D	D	D	D	D	N
Enhanced intelligence		D		N	N	N	N
Small force deployment	D	D	D	D	D	D	N
Large force deployment	D	D	D	D	D	D	N
Conventional force management	D	D	D	D	D	D	N
Reconnaissance		D	D	D	D	D	N
Warning/attack assessment	N	N	N	N	N	N	N
Nuclear force managment					N		N
Reconstitution				D	D	D	N

D – Desired
N – Necessary

☐ Commercial ▩ Commercial/Military ■ Military

Source: MITRE, 1991.

Figure 9

Qualitative Military Needs for Satellite Communications

it, I don't get it, because I'm too low on the priority list, and the only way for me to get that communications service is to buy it myself?"

I think a lot of the thrust toward small sats has to do with the inability to allocate resources dynamically to field commanders in a way they would like. While that doesn't mean you shouldn't have small sats, what it really means is that you ought to address the fundamental problem first, and then deal with small sats later, or deal with them by themselves, but don't mix the two things up. I believe there's a lot of mixing up going on right now about why people want them. There are a lot of technology people out there who are willing to sell anybody anything if they're willing to pay for it, because it's an interesting technology, they'll have a lot of fun working on it, and it may prove to be useful. But the fundamental problem is giving the people the resource when they want it, and that's not being addressed as strongly as it should be.

Oettinger: May I underscore that, because this is one of the core issues that you will find occurring, year after year in this seminar. You find there's no end to it, because that fundamental central authority has this delegation problem, and no matter how much you do by way of small sats or anything else, there will always be some set of things that needs to be done in common. For example, there is the pulling together of intelligence from a variety of sensors and systems and assuring that some guy in a tank or in a command post or in a regional air traffic control center has it. There is no escaping the need to address on a continuing basis the question of who has priority. But the minute you have the assets and you've got priority, you are going to fight with the other guy because he's persuaded that his need is the most critical. That problem will never, never go away. It's one of those things that tends to get suppressed because it's so unpleasant and political. And one always has the illusion that maybe if we spent a little bit of money or got a little bit of technical assistance, it would go away. It won't! The struggle between a subordinate and a superior is always there. The struggle among colleagues is always there. The fundamental issues never get addressed and so that's why that's a perennial problem.

Stiles: I'm going to argue. His point is well taken. He's right. Everybody comes around and wants his own little private satellite. They don't realize this involves physics. You tell people that it just doesn't work that way. Motorola has a program named Iridium. It will have 77 satellites in orbit, at a cost of two to four billion dollars. Lockheed won that contract. We believe that any place on the earth, you'll be able to talk on a cellular phone. A PBX in the sky is really what you have. You put a PBX up, you take a telephone exchange out here, and you put it up in the sky. You can talk anywhere in the world, except you always need a satellite to do something.

Ruddy: But that's a system in response to a need, a real need.

Stiles: Well, we think there's a real need.

Ruddy: There is a real need if they can provide it at a reasonable price.

Oettinger: But let me emphasize again the importance of his latter remark. I don't know of any PBX, or system ever invented where there isn't an argument over priorities under circumstances. And so we just simply shift the ground of the argument. I mean, that's all I was going to say. That argument's perennial; it's fundamental.

Student: My question is one of frequency and power management in terms of satellites. Could you talk a little about how frequencies are managed, who is in charge, who thinks they're in charge, how many folks are in charge, and how that has to do with resource allocation.

Ruddy: Okay, let me say something that might not please you very much since you're in the military, but . . .

Student: I know who's in charge!

Ruddy: I would describe resource allocation technology in our satellite systems in the following way right now: We have satellite systems from the 1970s and 1980s being controlled with 1960s control technology and philosophies. Something must be done about that, and it's not being addressed to the degree that it should because it has no technology sex appeal associated with it. It's important, it's key, it's critical, but it just lacks drama.

Student: I would add the fact that all the spectrum is more or less allocated. The folks who have pieces of it aren't going to give them up.

Ruddy: We don't do a good job with that on the military side.

Student: I'd like you to analyze both sides — the military and the civil side, because the FCC occasionally thinks that the international radio frequency board doesn't exist.

Ruddy: And it does. For example DSCS is an SHF system and operates at 7 and 8 gigahertz. All the commercial systems in the analogous frequency band, which operate on either side, C band and Ku band — 4 and 6 gigahertz and 12 and 14 gigahertz — consider those frequency resources precious and they ring the last bit per hertz out of any transponder they can get before they move on to another frequency regime. Not so in DOD. We have not wrung out anywhere near the amount of bits per hertz that we can get out of SHF. For example, we don't even put up more satellites, which would be the simplest way.

Student: We don't have frequency reuse.

Ruddy: Exactly right. We don't have frequency reuse. We use one circular polarization. We don't use opposite sense circular. We don't use opposite sense vertical and horizontal. We could literally take a satellite and double the bandwidth on that satellite for that spot in space just by doing one relatively simple thing.

Oettinger: The folks who are hungering for personal communication systems are getting their guns trained on every ounce of spectrum available, and I think the military sacred cows will be butchered one of these days, unless they get straightened out.

Student: There are standard emergency networks which have locked frequencies. They tend to get unhappy when there are mistakes. I once knocked off the Frankfurt air traffic control frequency, and I knew about that right away. The Germans were prepared, and they still are, to shoot anybody who gets on that frequency to make a potential threat to defense. That's why I asked the question about how in the heck are frequencies and power allocated? I know there's a difference between the civil and the military. I only know the theoretical way of the civilian side.

Oettinger: They're allocated the same way that every other resource is allocated, by political rank.

Ruddy: That's how the frequencies are allocated. It's hornswoggling. But there are things that can be done to alleviate some of these problems in Europe because they happen to use the same frequency band that DSCS does for their microwave line-of-sight. That creates part of the problem. But that's not everywhere. And you really have to think, do I change all my satellites because of one location on the earth, or do I deal with that?

You asked me another question about power. In civilian systems, the power and the terminals are controlled by a central user. In the military systems, there's always a crank, a knob you can turn on. And the operator drives everybody else off the air.

Student: Both the power and the frequency are generally fixed in civil systems.

Ruddy: But they can also be automatically controlled in some others.

Student: Through loading analyzers.

Ruddy: Right. There's a load analyzer on DSCS. There's no power control from central authority. On the other hand, there's too much central authority in terms of allocating the resource itself. They should be able to allocate a certain amount of power and spectrum to a user in the field, for him to use how he wants. Now, it takes a month. They've done much better since the Panama operation, which took several months to plan frequencies. They did much better with Desert Storm, but all they are doing is speeding up a manual process. They haven't changed the basic control philosophy, which has to be done in order to have more effective use of the system. The other thing has to do with this 100 percent business. What they also don't do enough of, in the military, is share resources when they have them to share, using demand-assigned multiple access techniques (DAMA). You know, "I will have my channel all the time because I need it all the time." And then they use it ten percent of the time. Nobody else can use that resource and nobody else knows it's not being used because we don't have analyzers to detect that. You know, it's a profligate waste of a very expensive resource.

The way to get around that is not to yell and scream. The way I would get around it is to charge for the service. I would have the services pay for their channel time and recover the cost of my satellites that way. That would be a marvelous way to get the wasteful users off, and it would also force them to look at DAMA.

Oettinger: That's an interesting option because it may sound like taking something priceless — military needs are priceless — and putting a price on it and creating administrative difficulties. But the game played on the civilian side is essentially that, and it is the most remote thing you ever saw from any kind of free market. The price juggling is today one of the most marvelous meeting grounds of the free market and controlled economy thinking. The message is ultimately a price message, which is why the day-to-day user, you know, sort of doesn't know or care. But the way the prices are determined is about democratic-Soviet style, as opposed to pure Adam Smithian style, as you can imagine. It would be an interesting topic, if somebody gets tired of their term paper and wants to start afresh on another one. It would be an interesting thing to look at.

Student: On the subject of variable power and sharing, the brass did something smart for 20 years that I was in, with one of the systems that they assisted in the development of. It allowed, in a task force operation, one ship to come up with the UHF terminal and be able to feed other ships via the HF variable power, so the circuitry could take advantage of that.

Student: Not very fast, though.

Student: Not very fast when you come to the attack or rescue. It drove the Navy to look again at variable power transmitters on ships as far as HF was concerned, because it looked like we were just wide open and that was it.

Ruddy: It looked that way because it was.

Student: You could hear it coming for miles, but that was one thing that we were able to do to take advantage of all this technology.

Ruddy: But that was done in the field.

Student: Yes, that's true. It was driven by the operators.

McLaughlin: I want to pursue this line because we know a lot about these resource allocation issues. But they become less important as these resources become more abundant and cheaper. If we look at the computing world, we have a situation where we define computing as a resource that has gone from being scarce to being abundant. There's hardly a task that you don't do on computer because it's too expensive. There may be other reasons for not doing it, but it's certainly not because of lack of cheap computing power. In dealing with telecommunications companies, we used to build telecommunications systems to minimize communication, naturally. I mean, you climbed up or down off the network to avoid the expense of communicating. Now, communications has become a cheap good in the commercial world. We see in the commercial world that this changes the way people think about communications, and a lot of these resource allocation arguments in corporations have disappeared. Do you see any future where this becomes less of an issue in the military, or — Tony and I have this argument — are people going to make uses for it faster and faster?

Ruddy: I would say it probably acts like a wave, and sometimes it leads and sometimes it lags. It all depends. Certainly, the amount of the telecommunications resource that exists has gone up dramatically over the last 20 years. Its price, however you want to measure it, has gone down dramatically. The fact that people are able to build the infrastructures and charge for them indicates that there is a need. There are not too many telephone companies or carriers that are going out of business. There was a great fear that satellite communications would disappear with the advent of fiber optics, and what happened was the kind of users that were using the satellites changed. Because of that change, the market for satellites increased instead of decreased. It was the small user, not the big user, and there are a lot more small users than there are big users. I just think that the price will continue to go down, and that the demand will continue to go up, because there's a need for communications. There is more and more information that needs to be transferred with greater and greater data rates and amounts of data.

Oettinger: That's slightly different. Let's see whether John agrees or disagrees because I would have reacted to the question slightly differently. What I heard him say about the current state of the military suggests that the problem they face is a little bit like what you've described elsewhere in terms of the civilian fiber-to-the-home problem: In order to get to this Nirvana that you describe, they've got to go from a system that is antiquated but is written off — it's paid for — with a massive up-front upgrading and technology revamping thing. In these circumstances (that is, the military), the Congress and the taxpayer have to pay for the upgrade rather explicitly in a period of declining budgets. If they cross that threshold, then they can join the civilian world in terms of this horn of plenty? But I think, if I've interpreted what you said correctly, is that a system which is now 20 years old and no longer up to civilian standards, could move into the cornucopia era if somebody were willing to make the investment. Is that a correct interpretation?

Ruddy: I think the problem is endemic in government. We don't depreciate in order to rebuild. We have no sense of that for any of our infrastructure services, from local government to federal government. Unless you recover an investment, you can't continue to improve the infrastructure, and there's no concept of that in government. The bridges fall down first, then you build the bridge. You say, "Where do I get the money from?"

Student: I was just going to say, we don't necessarily look to capitalize it that way, but you do look at operational support costs.

Ruddy: The government does not really look at total costs when it develops systems. The development guys deal with their color of money one way; the log commands deal with it in another way; the users and the operationals deal with it in another way, and they do inefficient things on the whole because they're maximizing the utility of the money in their pockets. They'll do things that are not financially sensible because it's to their advantage to do it with their money. It happens all too often. There's a lot of life-cycle analysis, but there's no life-cycle synthesis.

Stiles: It's a lack of communications. There's nothing wrong with them. They're good people, all of them.

Ruddy: It's not that they're bad. They're doing exactly what the system is incentivizing them to do.

Oettinger: Careful, careful, careful, because I think that what you're arguing is an injustice to the government because it also describes what in actuality is what goes on in the private sector. There is a tremendous amount of talk about depreciation and amortization and economic costs, but in the last analysis, that's a budgetary tool used to bludgeon this department and everybody. Ultimately, what happens is that somebody at the top says, "You know, this week we favor this department," and then all the budgetary things get weighed in that direction. But the fact that the pieces are not added up in some meaningful way is just as true in most private enterprises.

McLaughlin: You're wrong.

Ruddy: I also disagree.

McLaughlin: You actually do have continuity and stockholdership in private enterprises. You may argue that it changes some from quarter to quarter, but as we've talked here before, if you come in as an assistant secretary, you can bet your average tenure is going to be two years. With congressmen, well, what's their typical horizon? It's the next election, O.K.? We know enough people in corporations moan about quarter to quarter, but these people have been there for 20 years, and they hope to be there another 20 years.

Oettinger: I know, but you've shifted the argument from resource allocation to continuity. I don't disagree with your point about continuity.

McLaughlin: Oh, because continuity makes a world of difference in the way you allocate resources. If you're going to be around for a few years, you allocate resources differently.

Stiles: Excuse me. It's not the service secretary's fault. It's not the people who are there for a short time who do the resource allocation. It's the government employees who have been there a long time who do, and I will tell you that we do totally cost our facilities. Every year, we go back to Congress with an agreed Corps of Engineers cost model that says this is how much it cost to build the building. This is how the building falls apart. And unless I put this much money in, it's going to fall apart. And I will lose my money in every year because operations and maintenance isn't a sexy thing, and it doesn't get funded. So we're back to real political resource allocation.

Ruddy: General Cassity* told me two weeks ago that he had a cost savings opportunity, but it would cost $3 million to upgrade the system. In the first year, it would save $2.8 million — just in the first year — but he could not get anybody to give him the $3 million.

McLaughlin: He'd find that much easier to sell at IBM or AT&T. You're much more likely to have had a budget delegated to you, so you actually have some control, as opposed to line-item reprogramming requiring congressional approval.

Oettinger: It's a matter of degree. We don't need to continue that argument here.

Ruddy: The bridge across the Charles River. We have lots of local examples of the problem — the roads, bridges, and public buildings, as opposed to private buildings.

Student: But, you know, your charts are very good. As a military man, I say that we're coming up on a very major decision, and that Milstar and DSCS are concepts that are going to function in architecture for the future years. And I'm not sure that the Department of Defense understands how this is going to work. I really don't think they do.

Ruddy: They don't.

Student: It's a concern of ours.

Ruddy: There are lots of alternatives, but they don't really know.

Student: They really don't. There are lots of alternatives but they really don't how they're going to do this, or how it's going to sort out. I really don't know. It's a good question, you know — Milstar versus DSCS.

Ruddy: Part of the problem is that we always pose things in either/ors. If you have to have more DSCS, you can't have any Milstar, and so forth. It's always either/or. That kills it. It's the American way; we don't do anything unless there's a crisis, and then we respond marvelously. We would have been bored negotiating with Saddam Hussein a year or two ago. Maybe he was impossible to negotiate with anyway, but I can't imagine this national psyche being able to deal with that. We'd much rather shoot him.

*Lt. Gen. James Cassity, Jr., USAF. Director, Command, Control and Communications systems for the Joint Staff.

McLaughlin: Well, you know, part of that is because the last time we had patience, we went through nine years in Vietnam. You know, we had an awful lot of the Johnson Administration people saying that we were so impatient. We want to get these wars over quickly. We never learned to suffer long wars, like the Victorians.

Oettinger: Ladies and gentlemen, any more questions? If not, let us thank John for joining us today.

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