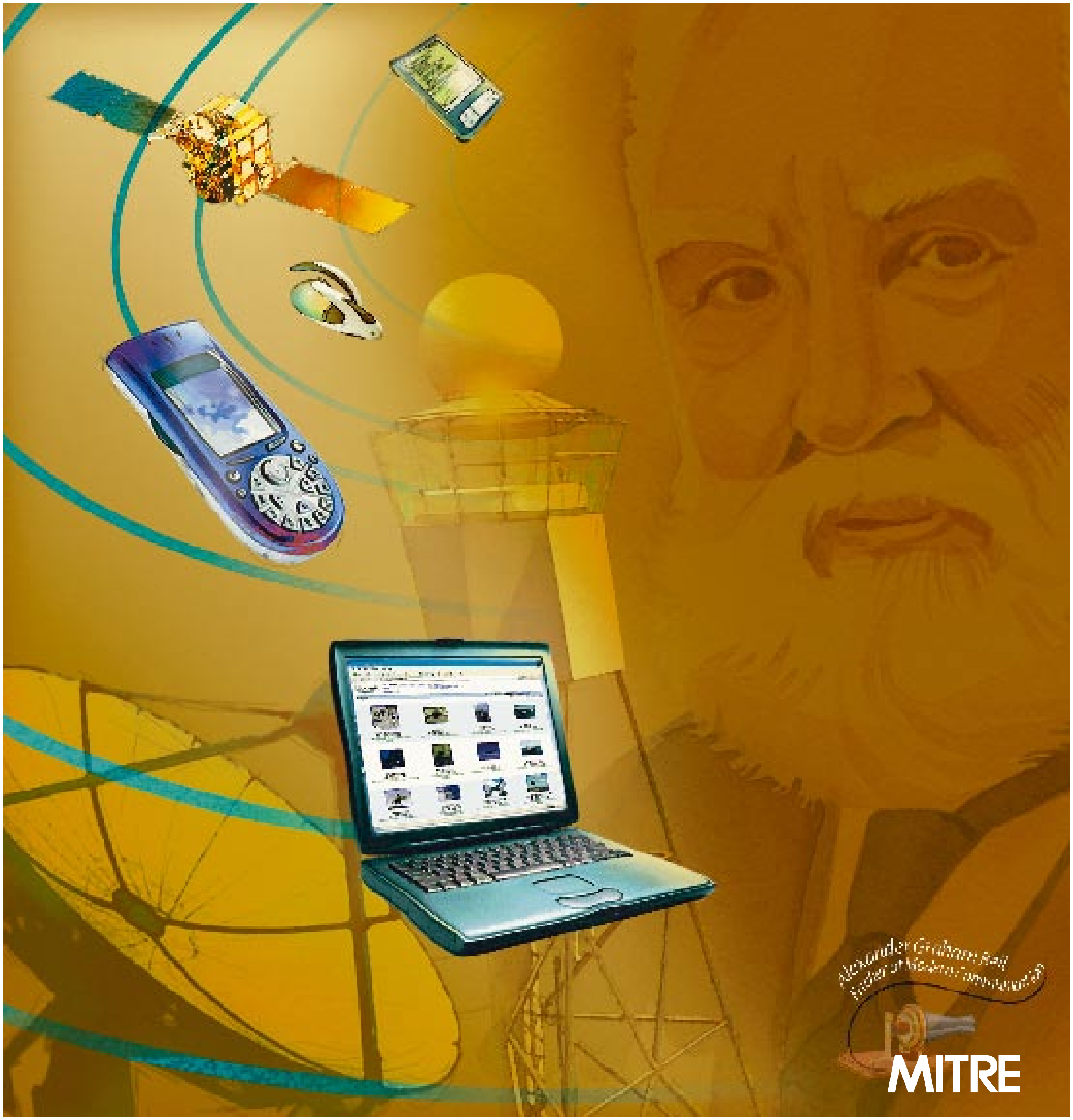
Transforming Communications

THE EDGE

MITRE's Advanced Technology Newsletter

Fall 2005 | Volume 9 | Number 2 **www.mitre.org/edge**



Intro

Introduction by *Marc Richard & Dave Roth*

Guest Editors

What Alexander Graham Bell accomplished in 1876 with the very first phone call, summoning Thomas A. Watson from several rooms away, seems modest today in the Information Age. The goal Mr. Bell pursued so tirelessly, however, is the same one that MITRE pursues today: transforming communications to make information sharing as fast, easy, and reliable as possible.

MITRE's contributions to transforming communications for the 21st century are as varied as our sponsors' needs. For the Department of Defense, transforming communications means net-centric operations in which everyone from the command center to the battlefield can share pertinent information on demand. The Federal Aviation Administration is looking for efficient, cost-effective communications that will solve the problems it sees looming in the future—which include limited spectrum for wireless communications. Other customers, such as the Coast Guard and Customs and Border Patrol, have needs similar to the DOD—dependable connections with staff in the field no matter what the environment.

MITRE teams throughout the corporation are working on communications systems that are needed in the near term, as well as on systems that require cutting-edge technologies that won't be ready to implement for a few more years. Our expertise in a variety of technologies—from networks to sensors to quantum cryptography—enables us to help sponsors solve their communications problems.

The articles in this issue illustrate the wide range of our capabilities and the importance of the problems we are working on. For example, the burgeoning industry of wireless communications depends on a finite resource—the electromagnetic radio frequency spectrum. As commercial interests gain more of the spectrum for their own use, government agencies are scrambling to find enough for such critical jobs as flight testing.

Another key issue for all communications systems today is information assurance. We work to secure both the networks and the data sent on those "pipes." We help a number of customers with everything from developing new technology to sorting out organizational issues, such as creating policies on when to share information and with whom.

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In This Issue

Spectrum Is Critical to Aviation and Weapon Systems Superiority

By Darrell E. Ernst

The fierce competition for electromagnetic radio frequency spectrum affects the transformation of all kinds of communications, from commercial cell phones to military actions.

The competition didn't begin until the late 1980s, when the telecommunications industry introduced far-reaching strategic plans to make wireless data communications an inexpensive consumer commodity. For its plans to come to fruition, however, the industry needed more of the spectrum than it was licensed to use. Since the spectrum is a finite public commodity, the government has the responsibility to apportion its use to suit the best interests of the public. The telecommunications industry successfully convinced the government that the services it wanted to provide were important enough to garner it a greater portion of the spectrum.

To accommodate the telecommunications industry, the government auctioned off some of the spectrum that was formerly used by the Department of Defense (DOD) for weapon support systems and high technology research and development. However, the same developments in information technology that are driving the consumer telecommunications market are also driving growth in the technical capabilities of aviation systems, military weapon systems, and weapons research and development (as well as many other critical communications systems). Just when the DOD—and other government agencies, such as the Federal Aviation Administration (FAA)—need additional spectrum to capitalize on these increased capabilities, they find themselves having to make do with less.

Spectrum is vital for aeronautical testing—of both military and commercial aircraft. To safely test new designs, the aircraft industry employs telemetry. Aeronautical telemetry is the use of radio transmissions to remotely measure and analyze the systems and safety of aircraft. Monitoring such a wealth of data requires a healthy chunk of spectrum. A lack of adequate available spectrum will seriously curtail the use of telemetry, leading to increased costs, higher risks, test delays or cancellations, longer acquisition cycles and time-to-market impacts, and fewer test points, leading to reduction in test quality.

MITRE has a long history of working on spectrum issues for the DOD, FAA, and other government agencies. We've advised the government and various multiagency committees on ways to balance use of the spectrum and use it as efficiently as possible. For example, we've been a leader within the International Consortium for Telemetry Spectrum, a voluntary organization set up to facilitate information exchange among interested parties, and have presented our studies at numerous national and international forums to gain support for worldwide telemetry spectrum augmentation.

Today, MITRE's Center for Advanced Aviation System Development is actively assisting the FAA in addressing its spectrum challenges. For example, we're providing the sponsor with technical solutions that would allow it to deploy a wireless airport network without interfering with commercial satellites and other users of the band within which the system would operate. For the DOD, MITRE is working on many different spectrum-related efforts, including the Joint Tactical Radio System program, the Air Force's Airborne Network concept, and the Army's Future Combat System. We are also providing technical policy support to the Office of the Secretary of Defense, the Defense Information Systems Agency's Defense Spectrum Office, and the Defense Test Resource Management Center.

Spectrum decisions made today will determine how telemetry testing will be conducted in the future. Our economic impact studies on the DOD's need for more spectrum frequencies show that the amount of spectrum now allocated for telemetry is not sufficient to meet the growing requirements. The aeronautical weapons development

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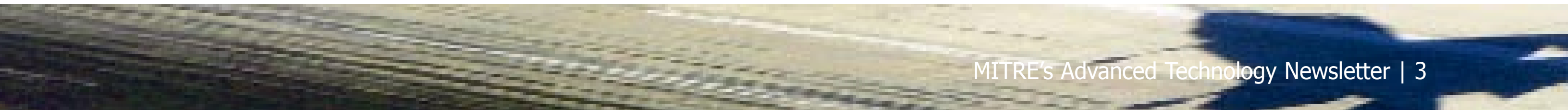


Continued from page 3

Spectrum Is Critical to Aviation and Weapon Systems Superiority

community will run out of spectrum needed for development and testing of aeronautical vehicles in the near future.

In seeking a solution to its sponsors' spectrum problems, MITRE has proposed a three-pronged strategy: (1) protect the sponsors' remaining spectrum against further encroachment, (2) develop new technologies for improving the efficiency of telemetry, (3) pursue initiatives to meet long-term growth in telemetry needs.

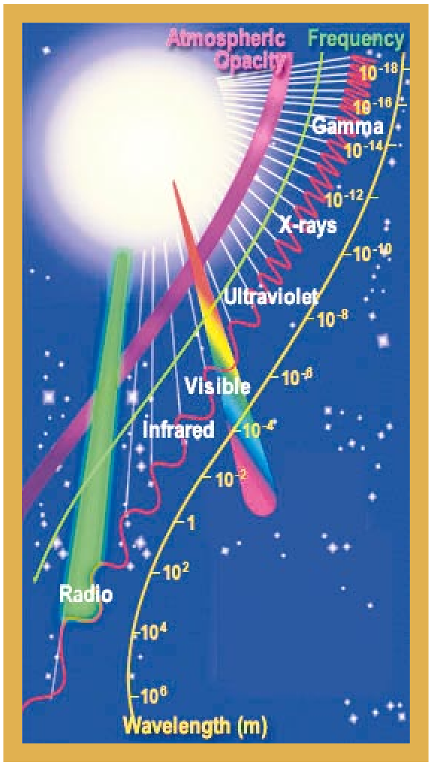
MITRE established a watch program to support the first prong of the strategy. We will identify, analyze, and report to the sponsor potential threats to its bands of interest along with a recommended set of actions. We are supporting the second prong of the strategy by helping sponsors operate science and technology programs and by conducting assessments of candidate technologies. To address the third prong, we are projecting spectrum growth requirements, building an economic model showing the realistic consequences of inadequate spectrum access, and addressing the technical challenges of using spectrum frequencies above 3 GHz. For example, our analysis to date shows that serious consequences would probably occur if the DOD requirement for an additional 650 MHz of telemetry spectrum is not met.

Currently, telemetry is conducted in specific frequency bands below 3 GHz. Spectrum below 3 GHz, however, is in great demand and fully allocated for various uses, so any additional bandwidth will need to be found at higher frequencies. MITRE has played a key role in the identification of technological requirements and limitations at frequencies above 3 GHz and in the assessment of technologies that could be used to facilitate the use of these bands.

Many problems are encountered at higher frequencies. For example, increased atmospheric absorption reduces the effective range of telemetry links. It is more difficult to design practical small form-factor telemetry transmitters at higher frequencies because high-power transistors are not available above 15-16 GHz. Also, antenna beam widths narrow as frequency increases, which complicates acquisition and tracking of the vehicle under test. And fading effects become more complicated as frequencies increases.

In our research, we have described the technological developments that are needed to overcome these potential problems and the limitations of both current technology and anticipated technology developments. This information will help sponsors scope out the portion of spectrum that should be sought for near-term use and help them establish science and technology programs to develop needed technologies.

Our nation—and, indeed, the globe—faces the challenge of properly husbanding a limited resource so that all may profit from it. We are contributing our technical knowledge both to help the government wisely use the spectrum available and to discover creative methods of opening up more of the spectrum to use.



MITRE's comprehensive spectrum stewardship strategy has led to a proposal before the International Telecommunications Union for a worldwide allocation of telemetry spectrum and a substantial research program to identify and develop needed technologies. It also proposes the establishment of a program to develop a net-centric test data communications system that will be capable of meeting the demand for ever-increasing quantities of data.

If the entire strategy is adopted and successful, the United States' testing of new weapons systems will be able to keep up with the increasing capabilities of these systems. And the testing of new commercial aircraft will be able to keep up with demand.

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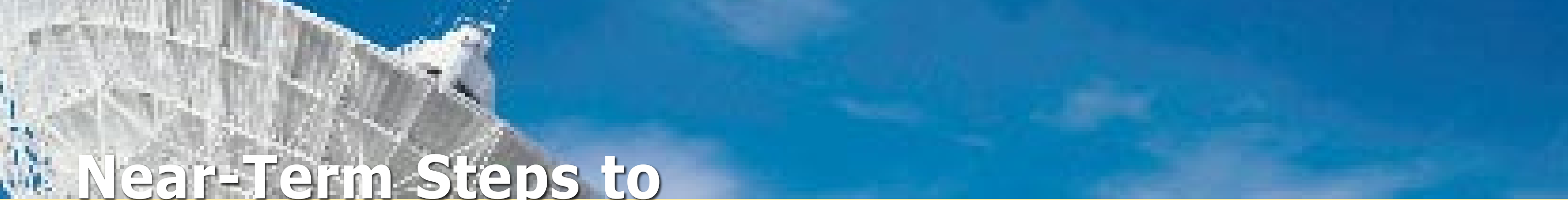

Near-Term Steps to Transforming Communications

By George Borrelli, Brian Crow, Shane Morrison, Robert Taylor, Darrell Trasko, Thomas Ullrich, and Robert Wood

MITRE's vision for transforming the communications capabilities of its sponsors is a bold one that reaches far into the future. But this vision will not be reached in one giant stride. It will be reached in small steps, each one an incremental success in the ongoing evolution of communications.

These steps come in many different flavors: discovering brand new technologies, implementing new technologies, employing fielded technologies in new and better ways, conceiving new programs, and employing innovative ways to acquire systems. The following are some examples of efforts MITRE is engaged in for each of these categories of transformational steps.

Discovering New Technologies

Phones, computers, PDAs—everything is going wireless. For a military whose success is becoming more and more dependent on how quickly it can strike a target and move on to the next one, reliable wireless communication is crucial to maintaining its mobility.

Experts have picked multi-input multi-output (MIMO) systems as one of the next big revolutions in wireless communications technology. Most R&D and commercial research outfits developing MIMO systems have targeted their efforts on fixed indoor high-speed wireless local area networks (WLANs), which rely on dense multipath non-line-of-sight environments to achieve high data rates. However, the military has been slow to adopt MIMO because MIMO-based WLANs experience performance degradation whenever there is line-of-sight transmission, multiple access interference, or jamming—issues likely to be present on a battlefield.

MITRE has taken on the challenge of fortifying MIMO for military use. By designing space-time algorithms that exploit a two-way (feedback) MIMO channel, our researchers believe they can make MIMO systems capable of maintaining high capacity in all environments. If successful, this project will contribute to the development of a tactical radio system that will give our military and intelligence forces constant high-speed wireless network connectivity in every environment, be it rural or urban, outdoor or indoor.

Implementing New Technologies

Breakthroughs in communications technology are exciting events. But sometimes achieving the breakthrough is not the most arduous part of the process. It can take as much ingenuity to implement new technologies as to discover them.

The latest in extensible markup languages, XML, allows users to define, transmit, validate, and interpret many types of data among many types of applications. Thus, it is a crucial cornerstone of the military's vision of net-centric communications. The promise of interoperability that XML provides, however, will likely be a false one, unless the language is implemented in a consistent and reliable manner across all systems.

To ensure such consistency and reliability, the XML software for each system needs to be fully tested to guarantee its compatibility. MITRE is developing a formal standard testing process that will ensure XML systems are fully functional in their operational environment. Once MITRE has perfected its testing system, the military will be able to implement XML with full confidence throughout the Department of Defense.

Employing Technologies in Better Ways

During the early liberation of Iraq, Marine units advanced so quickly that they moved beyond the range of the data radios they relied on for battlefield information. To

Continues on page 6

Continued from page 5

Near-Term Steps to Transforming Communications

keep up with their advancing troops, commanders and staff had to displace the servers processing the battlefield data and reestablish them closer to the front lines. The need to break down and set up the servers led to potentially hazardous gaps in situational awareness.

By outfitting all-terrain vehicles with components of the data radio servers and transmitters, the system could become just as mobile as the troops it supported. The Marine Corps christened the project the Command and Control On-the-move Network Digital Over-the-horizon Relay (CONDOR) Capability Set. MITRE is providing technical engineering support to the CONDOR Project Officer at the Marine Corps Systems Command.

The Marine Corps is equipping ground vehicles to serve as mobile housing for elements of the CONDOR radio system. The first vehicle is known as the "Gateway." It acts as a node for the data radio network. The Gateway frees the Marine Operating Force Commanders from the frequent need to break down and set up servers. The second vehicle, the "Point of Presence Vehicle," keeps Marines connected to the network no matter how far and fast they advance. The third vehicle, the "Jump C2," maintains communications during system displacement, ensuring that Marine Operating Force Commanders maintain situational awareness at all times.

Employing Fielded Technologies

You won't find cell phone towers on the mountain peaks of the Caucasus or fiber optic cable beneath the sands of sub-Saharan Africa. But as it prepares to fight terrorism wherever it may raise its head, the U.S. European Command (USEUCOM) needs to extend its communication abilities to the edges of its domain.

USEUCOM has enlisted MITRE to help it design a system that could be quickly deployed to austere locations in order to span gaps in its communication capabilities. After an investigation of USEUCOM's current communication systems, we prototyped a cost-effective, lightweight, high-performance, easily deployed satellite communications system capable of supporting voice, video, and data transmissions.

The prototype system had to meet several goals: be capable of deployment within 72 hours of mission notification; be simple enough to be manned by a single operator; and be transportable via commercial or military air transport. MITRE designed a prototype system that integrates IP-based baseband equipment with a commercial Ku-band satellite terminal. The terminal weighs 86 pounds and integrates an antenna, radio frequency electronics, satellite modem, and a global positioning system receiver into a suitcase-like module. The operator controls the terminal using a laptop computer and Web browser connected to the terminal via an Ethernet port. USEUCOM's reach can now extend into the most hostile terrain in order to uproot terrorists.

Conceiving New Programs

We are in the middle of an information explosion that is radically changing the way the military operates. To take full advantage of this situation, communications systems must be able to pass information to all destinations. Unfortunately, current communications systems do not support seamless connectivity.

One promising solution is the intelligent communications gateway. A gateway is the part of a network that provides automated interfaces to another network or system using different message formats and/or communications protocols. By employing a gateway, systems using different communications capabilities can exchange information without requiring modifications to the existing systems.

MITRE is laying the groundwork in several ways for the evolving use of gateways. We are developing and investigating a layered communications architecture modeled on the Internet that will increase the ability of communications systems to incorporate gateways. Also, MITRE is striving to foster commonality among gateway

MITRE's advancements in communications are helping to collect ever-more-detailed battlefield intelligence and deliver it in real-time to the frontline warfighter.

developers to stem the development of redundant gateway programs. Meanwhile, we are assisting the Air Force in creating a consolidated Objective Gateway Program and Data Strategy that will guide their adoption of the technology.

To enhance efficiency and interoperability among Tactical Data Network platforms, MITRE is guiding the Air Force and Navy in the Common Link Integration Processing (CLIP) program. One of our tasks is to help develop fully interoperable data network processing modules that are reusable across most platforms. These data network platforms, gateways, and even the Joint Tactical Radio System will be able to integrate CLIP modules as key interoperability enablers. As CLIP matures and is adopted by many platforms, the need for stopgap gateway solutions will be greatly reduced.

Employing Innovative Acquisition

Our troops in the field need to be nimble and quick to win their objectives. Likewise, the military acquisition process needs to be nimble and quick in equipping forces with the communications capabilities they need to succeed.

At times, however, the pace of communications technology outruns even the most determined efforts by the military acquisition process to keep up. One such case is the Air Force's plan to replace its Ground Mobile Forces (GMF) terminals, developed in the 1970s as the tactical ground segment for the Defense Satellite Communications System. The Ground Multiband Terminal (GMT) acquisition program will replace GMF with wideband satellite communications terminals that will access both military and commercial space segments at C, X, Ku, and Ka bands and provide a huge increase in data rate throughput capability.

The traditional development contract the Air Force initially employed for the acquisition program was unable to achieve the desired result in a timely manner. The Air Force then decided to obtain the technology it needed "off the shelf." Instead of relying on a single contractor to develop the technology from scratch, the Air Force, with MITRE's guidance, will enlist industry sources to modify and integrate existing products into the GMT system. To date, several companies have demonstrated their capability and willingness to participate in the acquisition program source selection by showing candidate GMT terminals. The GMT capability is needed quickly, as it is designed to be fielded in synchronism with new satellites entering service in 2007.

The GMT effort represents a new paradigm of using commercial-off-the-shelf products to respond quickly to the DOD's needs.

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All of the Above

An intercontinental ballistic missile (ICBM) rumbling out of a silo hidden in a Montana wheatfield may strike some as an image left over from the Cold War. But ICBMs still serve as a vital component in our nation's strategic deterrence weapons system. What *is* a relic from the past is the communications network linking our ICBM command centers. The Hardened Inter-site Cable system, an extensive network of buried copper cables designed to survive a nuclear attack, was originally installed in the 1960s.

The Air Force Space Command has asked MITRE to conduct an analysis of the command and control communications network for the ICBMs. MITRE will evaluate the sustainability, survivability, efficiency, and security of the system, investigating both the system's current needs and its needs decades into the future.

In our plans to upgrade both the bandwidth and usefulness of the network, we are leaving no stone unturned. Digital subscriber lines, ultra-wideband (wire and wireless), optical fiber, free space optical, WiMax, and satellite communications are all being investigated for their suitability to convey ICBM commands in a time of crisis. Even with systems of the past, MITRE never stops looking toward the future.

How the Global Information Grid Is Transforming Communications for the Warfighter

By Marc Richard
and Dave Roth

Achieving a decisive military advantage through end-to-end communications and universal situational awareness is the idea behind net-centric operations. The Department of Defense's (DOD's) vision is to connect everyone from the commander to the warfighter in the field, who operates at "the tactical edge." Achieving net-centricity depends on the supporting infrastructure of the DOD's Global Information Grid (GIG).

The GIG is a network of networks—a complex system that links hundreds of information system elements to enable the rapid exchange of information among the U.S. services, the Intelligence Community (IC), and multinational allies. The GIG involves more than just technology. Rather, it is a globally connected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand. It comprises most of the DOD's information systems, software, and services, and supports the DOD and IC in peace time and during conflicts.

The GIG is a reality today. For example, its power was evident in the early days of Operation Iraqi Freedom, when U.S. and multinational forces took networking to a new level in warfare. They used a combination of networks that were linked by gateways to provide a remarkable degree of situational awareness and understanding—leading to mission success, particularly in SCUD missile suppression. In this effort, friendly forces had to fully leverage their intelligence, surveillance, and reconnaissance (ISR) assets and use combat aircraft in nontraditional missions, such as ISR. Warfighters were able to succeed on the ground and in the air by being connected over robust communications networks—including terrestrial radio systems, satellite radio systems, airborne data links, SIPRNET, and various information and command and control systems. Engineers and operators worked together to construct gateways that connected previously incompatible systems, such as Link-16 and Situational Awareness Data Link. Many other systems were connected as part of the GIG—including Battlefield Universal Gateway Experiment (or BUG-E), which connected local area networks and wide area networks with a wide array of information and command and control tools.

GIG users (people, processors, sensors, etc.) are either producers of information or consumers of information. Producers "publish" their information to the shared information space provided by the GIG, and consumers can access this data by searching and retrieving, or subscribing to the data. All users can get the relevant information they need (subject to security classifications) at any time. They can search databases that they couldn't search before because of difficulties with connections and compatibility. As new data is published, its availability becomes known to those subscribers needing that information, thereby enriching their situational awareness.

The GIG will continue to evolve and grow into the future as users' needs change and as new technologies emerge. At the heart of the GIG is an Internet-like communications network that provides the underlying connectivity among the users of the

GIG. The DOD is in the process of significantly upgrading its overall communications network, including its terrestrial infrastructure, satellite systems, and tactical radio systems. MITRE is supporting these upgrades in many different areas, including acquiring new systems, upgrading fielded systems, and investigating new technologies. In all cases, the use of commercially available products is a key consideration.

Terrestrial Infrastructure

To support the DOD's need for net-centric operational capabilities, the terrestrial infrastructure required a significant upgrade to remove network capacity as a limiting factor in the design of new capabilities. Network planners from the Defense Information Systems Agency (DISA) envisioned a quantum leap in capability over the DOD's existing terrestrial communications infrastructure. DISA is revamping its switched transport network and Internet Protocol (IP) terrestrial networks to provide a robust, optical network foundation for the warfighter. The new Defense Information Services Network-Next Generation, which is based on the Global Information Grid-Bandwidth Expansion (GIG-BE), will provide a secure and reliable platform to enable worldwide net-centric operations for intelligence, surveillance and reconnaissance and command and control information sharing. The state-of-the-art IP infrastructure will use an optical core network with physically diverse, ultra-high-speed routers to connect key DOD assets. This DISN optical and IP infrastructure will support new and evolving applications, such as multicasting, voice and video over IP, and IP collaborative planning.

Creating the GIG-BE required procurement and installation of state-of-the-art optical fiber and IP equipment. This procurement was particularly challenging because not only did it have to be executed in a very aggressive government procurement cycle, but the DOD needed it to be put into operation much faster than normal commercial telecommunications are set up. Teamed with government counterparts, MITRE staff helped write the functional specifications for the network and acted as technical advisors to the source selection boards, all of which contributed to a successful contract award in record time.

As the network is activated, we are providing optical engineering support, working with government counterparts to resolve numerous technical challenges, and meeting critical implementation milestones. MITRE is providing systems engineering support to DISA in the transition from legacy closed networks to a common network infrastructure capable of providing unclassified and classified service to meet the future warfighter's needs. With widespread use of the Internet and ever increasing network speeds, users have come to expect reliable and efficient data access. We are helping DISA to develop the strategies and deploy the technologies to provide the same reliability and efficiency to the warfighter in the field.

While the DOD optical fiber network heavily leverages commercial technologies, it is also unlike a commercial network in that it makes use of several different types of fiber. To guarantee that the bandwidth promised by this network is realized, MITRE is researching performance issues that arise from the use of such a nonhomogenous network of fiber.

Mobile Systems

The most important attribute of the GIG is the rich, robust connectivity it will provide to anybody connected to the common network. Obviously, it is much easier to build this for an office environment with a stable infrastructure than it is for the highly mobile elements of the military. In today's military mobile environment, existing legacy communication systems (and applications) were tailored for very specific needs. Different radios, waveforms, and networking protocols are the rule, so much

Continues on page 10

Continued from page 9

How the Global Information Grid Is Transforming Communications for the Warfighter

preplanning is required to provide connectivity among different communities of interest.

In addition to the abundance of non-compatible legacy radio systems, waveforms, and networking protocols in use, another major challenge in this environment is available bandwidth. In an office, workstations are supported with various local area networks (e.g., Ethernet) that connect to the Internet through high speed connections. Data rates are not a major issue. In the mobile environment, however, all communications require mobile wireless connections. Current DOD radios provide only limited data rates on the order of dial-up connections in the 1970s and 1980s—much less than in today's office environment. It's one thing to receive a text message—and even that is not guaranteed on the battlefield—but downloading photographs and maps cannot be accomplished in a reasonable time period. In addition, as vehicles maneuver on the battlefield, wireless connections are continuously broken and re-established. This results in a very difficult application environment on the "tactical edge." Improved mechanisms and applications are required to better share and re-use available network connections.

The DOD's Joint Tactical Radio System (JTRS) is the program intended to address these two challenges. JTRS is a software-defined, multi-mode, programmable, multi-channel, tactical wireless radio system. Different hardware sets are being developed to meet different environmental conditions (e.g., vehicular, aircraft, handheld, etc.), but one set of IP-based communications waveforms is being developed for all the different hardware sets. The intention is to ensure interoperability through the use of these common waveforms. When operational, JTRS will implement new wideband, networked waveforms that will leverage commercially available protocols and increase the bandwidth provided to mobile users. MITRE is supporting the Assistant Secretary of Defense (NII) in developing policy, the Joint Staff in the evolution of JTRS requirements and concepts of operation, and several Program Offices in procuring JTRS hardware and waveforms. MITRE is also supporting a new office that was recently put in place to oversee the entire JTRS program: the JTRS Joint Program Executive Office.

In addition to working on DOD acquisition programs, MITRE is conducting research on some of the technical challenges of the mobile tactical radio environment. One research team is addressing a well-known problem with the Transmission Control Protocol (TCP) currently used by the DOD. Because the TCP uses IP addresses to identify a transport layer connection, if a node changes its address, its connection breaks. We are investigating a possible solution called the Host Identity Protocol (HIP), which allows transport layer connections to be identified using long-term Host Identifiers rather than IP addresses. With HIP, transport connections can be preserved even if IP addresses change.

We are also investigating ways to improve mobile connectivity by dealing with the scarcity of available frequency spectrum. Certain parts of the spectrum are better suited to specific environments than others, so the challenge facing GIG transport layer designers is to develop systems and protocols that will most effectively use (and re-use) the available spectrum while still ensuring the security of the links. We are investigating the ability of a radio to "cognitively" employ electromagnetic spectrum; that is, it will be able to "change the way it operates" depending on the environment it is in to make the most efficient use of the spectrum available.

Satellite Systems

As described above, the Internet Protocol plays a big role in transforming communications. This is due to a number of factors, including its far-reaching commercial acceptance as the common

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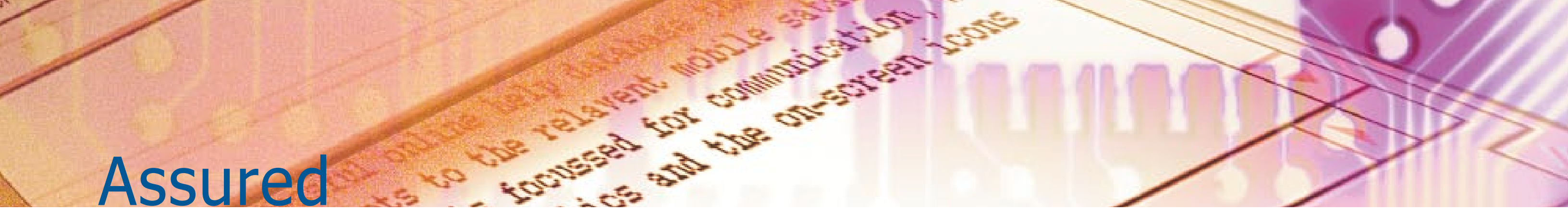


Assured Information Sharing

By Bill Neugent

Much of MITRE's work in transforming communications systems focuses on the networks that sponsors use to exchange information. Just as important, however, to MITRE and its sponsors is managing the information to be shared among agencies. And critical to both the "pipes" and the data is information assurance.

As the need to share data becomes increasingly important in the fight against terrorism and in conducting the war in Iraq, we are helping our sponsors find ways to ensure that information is available to our own people and allies and is protected from the enemy.

Sharing data becomes more complicated in situations that involve many diverse organizations, such as partners in a war—the U.S. services and coalition forces—or the many agencies defending the country against terrorism—from the Border Patrol to the local police. In these situations the "need to know" becomes the "need to share."

MITRE teams are working on a broad range of projects to provide the security that enables sharing information. Our work ranges from developing new technology to helping sponsors sort out organizational issues, such as developing policies on when to share and with whom. Many problems remain, some technological, some organizational or cultural. But there is a huge push from the government to bring down barriers.

In this article we discuss a few of the areas we are working on, such as making information accessible and discoverable, creating sharing policies, and monitoring how information is used.

Making information discoverable to soldiers in the field means more than making it accessible, although that's also critical. The data has to be on a server that the soldier can access. But the access only counts if the soldier can then understand the data. Is the metadata compatible between systems? Does it point the way to the coordinates or description the soldier needs?

For example, the intelligence community (IC) is building a data exchange standard to help its various agencies share information about terrorists. The Terrorist Watchlist Person Data Exchange Standard combines practices from several agencies into one accepted practice, which will make the data issued from all agencies discoverable by each other. This is just one example of what is needed among the Department of Defense (DOD, IC, and Department of Homeland Security) groups.

In the past, there was a real feeling of "ownership" of information by various groups and a reluctance to share it openly. After September 11, the government asked all the agencies to come up with common solutions to information sharing—new systems, governance, and processes. MITRE and its sponsors have been working on these issues, pursuing programs in what is called secure, cross-boundary, or cross-domain information sharing.

MITRE has been investing resources in an initiative called XBIS (Cross-Boundary Information Sharing), designed to explore approaches to cross-boundary information sharing and make recommendations. A team looked at many dimensions of sharing: social and cultural, as well as data, security, and the enterprise architecture. Rather than thinking of security as a wall, we started thinking of it as a web of relationships and resources. Sharing is the result of networking, building relationships, and fusing information. Now we're looking at translating these concepts into security measures.

Continues on page 12

Continued from page 11

Assured
Information Sharing

New Capabilities

The need for common practices and standards among groups is obvious. Intel analysts deal with reams of information coming in from all over the world. They don't necessarily know the value of certain bits of information to the warfighter in Iraq, so the challenge for analysts is to make their information available to users even when they can't gauge its value.

The users have to be able to search and pull what they need when they need it. One of the best ways to promote sharing is a take-off from the commercial world: Allow analysts from different organizations access to one another's information through a search engine. Since late 2004, thousands of military and intelligence community personnel have been doing that, using a MITRE-designed technology called the Multi-Domain Dissemination System (MDDS).

In the past, long-standing rules restricted people from searching multiple networks because the networks operated at different classification levels. These barriers—as much organizational as technical—forced analysts to hunt for information that should have been available but dwelled just out of reach, a sure recipe for creating frustration and information gaps.

MDDS allows intelligence providers and analysts to "browse down" through the databases of both intelligence community and military computer networks, allowing the analysts to produce more detailed, accurate reports.

As part of Operation Enduring Freedom, Marines in Afghanistan talk to local citizens during a security operation.

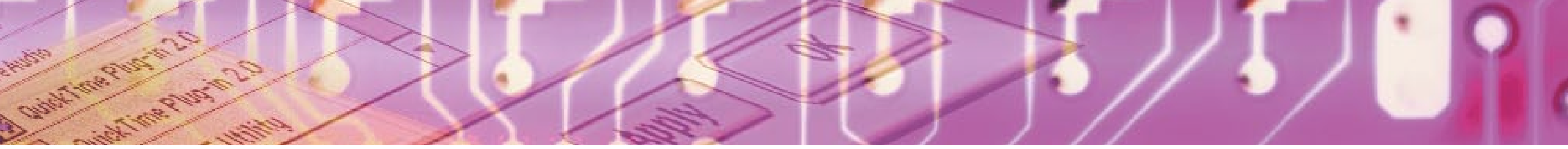
Because MITRE doesn't manufacture or sell products, we advised a commercial company that was building a similar product and then worked with the Defense Intelligence Agency to get MDDS approved and operational. That's one way the DOD and IC can achieve security quickly, adapting commercial products to their security needs.

MITRE teams are studying numerous capabilities for information sharing to see how they might meet our sponsors' needs, from metadata-based release policy to access control, to monitoring systems.

One way to make sure data is accessible to others is to use new protocols and standards, such as XML, which enable sharing across and within security levels. Many government agencies, as well as the medical and finance communities, have created flexible sharing systems using XML firewalls. Other possibilities for secure data management are: write to share, tear-line production, time stamping, and integrity wrapping.

Monitoring

Another way to make people feel more comfortable about putting their information on shared systems is to create efficient monitoring systems. How do we track information we've made available and monitor how it is used? Also, how do we know what information was valuable to users and what wasn't, so that we can share



more of what's useful? Monitoring serves many purposes, from detecting malicious insiders to measuring users' satisfaction with information available.

We are helping the DOD and IC find better monitoring methods. The new trend is to "Let them have the information but keep an eye on them." Take the risk, but manage it. Ways of monitoring include watermarking data, fingerprinting it, or putting a beacon on it that tells you where it went.

This is probably the biggest technological gap when it comes to enabling information sharing: creating monitoring systems that reflect the different needs of the users. For example, the monitoring requirements for counter-intelligence information will be different from those of law enforcement or medical information. This variety has to be built in.

Sharing Policies

We're also involved in discussions among agencies on coming up with accepted sharing policies. These decisions can be very complex, particularly when different levels of classification are involved and when sensitive defense networks and civilian networks intersect. The latter usually are not as well protected as the DOD and IC networks. Thus, deciding who owns data and who can view it and use it is often as difficult as creating the technology that enables sharing. MITRE has come up with some recommendations for policy-based sharing standards.

The theme of our recommendations is let the mission determine the rules for releasing data. Today, the process is overly reliant on humans to make every call. Whoever controls sensitive data gets to determine whether or not to give it to someone else for the other group's purposes. This can be a slow process that doesn't work well during a crisis.

MITRE has recommended a policy that optimizes gain and loss. First you ask, "What are the benefits to the mission if the information is shared and what are the risks if the information—or the means by which it was collected—are compromised?" Then you ask, "Who gets to decide?" There's no one answer; it depends on the mission. The biggest barrier is trust. The process of getting stakeholders together to create the policy is critical—it represents the "relationship" part of the web.

The MITRE team working on this project also discussed it with the Markle Foundation, a non-partisan, non-profit organization that advises the government on issues of IT that concern national security and healthcare. For example, the Markle Task Force invented the Systemwide Homeland Analysis and Response Exchange Environment.

The government continues to push for more and more sharing among agencies—for ways to bring down the stovepipes, both technical and cultural. MITRE will continue to work closely with sponsors on various initiatives to protect both networks and information shared among government and civilian agencies. Our projects range from trusted computing architectures to cryptography, to Digital Rights Management, and our research looks ahead to newly emerging technologies that might provide the answers in the future.

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Aviation Seeks Future Solution to Ground-to-Air Information Exchange

By Frank Buck and Dean Lamiano

Air travel has rebounded strongly from its post-September 11 slump, and it is expected to grow rapidly over the next few years. For the airline industry, that's good news — but also a source of concern for the Federal Aviation Administration (FAA) and other civil aviation authorities. Because there are more planes in the air, more communications capabilities between air traffic control systems and airborne systems are needed to coordinate the safe and efficient routing of flights. MITRE and the FAA are projecting that if there are no changes in the way air traffic controllers and pilots communicate, the growth of the National Airspace System (NAS) won't keep pace with the growing volume of air traffic. This could result in groundings and delays.

This outcome could be changed, however, through some of the new technologies that the FAA and research companies such as MITRE are studying. In the future, networked digital links could be used to efficiently exchange information (e.g., routes, four-dimensional trajectory information, weather notifications, and traffic advisories). This information exchange could make the communications spectrum, and the controllers that use it, more productive. According to a study done by MITRE's Center for Advanced Aviation System Development (CAASD), controllers spend between one-third and one-half of their time talking or listening on a voice channel. If controllers could be freed from routine voice communications tasks, such as handoffs and frequency changes, they could have more time to address more strategic air traffic management tasks, ensuring safe separation at all times with greater air traffic volume.

To make such improvements a reality, the civil aviation authorities in Europe and the United States initiated a Future Communications Study. The study is being conducted by major organizations charged with shaping the future of air travel, including the FAA, Eurocontrol, NASA, and CAASD.

The purpose of the study is to identify and evaluate possible solutions that would allow both the United States and Europe to accommodate all actual and anticipated growth in air traffic by 2030 and come up with a blueprint for the communications systems needed to handle it. The study's constituents are looking for an answer that will be affordable for the United States, Europe, and the airlines and will serve as a model for other countries.

The answer must be a globally accepted one because many airlines fly over many different countries' airspace. In search of a solution, MITRE is studying flexible avionics architectures to try to find cost-effective mechanisms

Aviation is a global industry, and changes in one country's procedures affect many other countries. To talk about improvements to existing communications systems, the aviation industry initiated the Future Communications Study, which is being conducted by many organizations, including the FAA, Eurocontrol, NASA, and MITRE.

to support multiband/multimode avionics that could operate with multiple communications technologies.

CAASD is providing support to the FAA in a number of ways. First, we compared future concepts of operation published by U.S. and international bodies and helped define operational services necessary for the study. In addition, we have provided analysis and assessments of key technical issues and developed a joint understanding on the timing of the implementation of needed services in the air traffic management environment. We are also assessing capacity needs through modeling aircraft traffic and resulting communications needs.

There are many possibilities for consideration by the aviation community. In general, potential solutions fall into two broad categories: (1) using existing technology to make better use of remaining space on the spectrum, and (2) exploring emerging technology that can make a wider range of information available for pilots and controllers to exchange.

Meanwhile, technologies to expand the range of information available to pilots—such as VHF Digital Link Mode (VDL-2), which was developed in the early 1990s—are currently being deployed as a way of providing data communications to aircraft for the airlines' operational needs. This can help pilots make more informed decisions that allow them to reduce flight times, delays, and fuel consumption—which benefits all aviation stakeholders.

CAASD has also developed VDL-3, which allows both digital voice and data to be transmitted simultaneously over the same frequency using a single radio. MITRE worked with the FAA and the International Civil Aviation Organization to standardize VDL-3, and we also worked with avionics vendors to certify and develop a commercially viable product.

Other similar technologies being investigated include global broadband aviation solutions; wide area network standards, such as 802.16 and 802.20 (WiMax); and aviation-specific technologies, such as Broadband VHF. Any new technology will be required to support both voice and data communications and must be capable of supporting both existing and emerging operational concepts.

The hope is that MITRE's efforts can form the basis of a long-term strategy for enhancing air-to-ground communications to support growing traffic. To reach this goal, MITRE continues to contribute its technical expertise and experience to the aviation community worldwide.

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The Future: Bringing Down Barriers to Wireless Communications

By Anne Cady, Richard Games, Ed Palo, Jason Providakes, and Glenn Roberts

People told this issue's cover boy, Alexander Graham Bell, that it was impossible to send the human voice over a wire. Today, wireless mobile devices have revolutionized the way we get information and communicate. Could Bell have imagined this when he helped start the communications revolution?

MITRE is working on a number of transformation programs for sponsors, including research designed to improve communications 10 or more years ahead. To look at what the future holds, *The Edge* editors sat down with MITRE's chief engineers to discuss critical communications problems facing our customers and the possible solutions to be found in emerging technologies.

Much of the commercial world has already moved from fixed, wired networks to point-to-point wireless communication via a fixed infrastructure. For many of our government sponsors, however, the communications transformation means moving out of fixed infrastructure into ad hoc wireless networks—being mobile and flexible.

This move is key to the Department of Defense vision of net-centric warfare—in which everyone can exchange information in near-real time—and to a lot of other government agencies, such as the Department of Homeland Security. The elements of robust wireless communications—including mobility, adaptability, reliability, security, and management—are written into the future plans of the Federal Aviation Administration as well. Whether the goal is improving air traffic control, equipping the modern warfighter with better communications tools, gathering intelligence, or protecting the nation's borders, government agencies want advances that will expand and improve networks, stretch the bounds of wireless connectivity, and ensure the security of information passing through the communications infrastructure.

The ubiquity of wireless devices is evident on the streets of almost any town in America, where everyone seems to be on his or her cellphone or PDA. Connectivity is getting better all the time, and most people expect reliable service and instant access. But move to a less structured environment and the problems of wireless communications are obvious. Whether in the middle of Baghdad or in the aftermath of Hurricane Katrina, the limits of wireless and mobile communications can lead to deadly situations.

Today's wireless capabilities are limited by many factors, from available technology to the physical environment—such as the ones our troops face in Iraq and Afghanistan. These environments create huge challenges, explains Jason Providakes, chief engineer for the Washington Command, Control & Communications Center. First there's the heat and sand; then there are signal barriers, such as the buildings of downtown Baghdad and the dense caves of Afghanistan, which block signals or bounce them around.

For military ground forces, the challenge can be summed up in the phrase, "the last tactical mile." It's critical that the front-line soldier on the move remain connected to the network—including others at the tactical edge, as well as to air and ground support—while operating in these challenging environments.

MITRE is pursuing many ways to improve wireless communications for our sponsors, both in our work programs and in our research.

Spectrum As wireless communications proliferate, a critical dilemma facing users all over the world—civilian, government, military, and commercial aviation—is the finite capacity of the radio frequency (RF) spectrum on which wireless depends. (*See the article on page 3 for more on spectrum.*) For example, the future of aviation air-to-ground communication is driven by spectrum availability and the need for greater productivity, says Glenn Roberts, chief engineer for the Center for Advanced Aviation System Development. While we can buy time by slicing the spectrum into thinner wedges, he says, the key to the future is to move to new technologies and find ways to automate and share spectrum.

One emerging technology we are studying—which will help with

A key concept of net-centricity throughout the Department of Defense is interoperability. To be able to share information across units, services, and with allies, all communications systems must be able to "talk" to each other—for example, by using the same standard software protocols.

spectrum limitations—is free space optical communication. Free space optical communication transmits data from primary fiber-optic lines through the air to a user by means of lasers. Although it offers high bandwidth relatively inexpensively, its links are susceptible to degradation from atmospheric conditions such as fog, and they require direct lines of sight. Therefore, the challenge is to provide optimal communications bandwidth without giving up all-weather RF reliability. To overcome these limitations, MITRE is researching ways to improve free space optical technology. It is vital for airborne networks and for helping small autonomous networks link together via satellite or ground infrastructures—thus bridging the gap caused by the inability to scale mobile networks.

"It's an immense challenge," says Ed Palo, chief engineer in the Center for Air Force Command & Control Systems. A start has been made with the Joint Tactical Information Distribution System (JTIDS/Link 16), which creates digital links across a number of platforms, says Palo, but it lacks an Internet-like protocol, which would increase its flexibility, connectivity, and applicability to evolving net-centric applications.

Antennas Another technology area that needs improvement to support wireless, mobile communications is antennas. Getting the right antenna for the environment is a major hurdle—especially at a reasonable price. Particularly in ground mobile tactical applications, the typical one-piece omni-directional antenna has limitations, such as data collisions, jamming, and signal fading. Adaptive antennas, however, can mitigate multipath signal fading, as well as filter out background noise and other interference, intentional or unintentional.

MITRE is working with adaptive array antennas—a circle or grid of numerous antennas whose outputs can be combined to point in desired directions in phases, and even to become "smart" enough—given the right kind of digital signal processing system—to keep adjusting the antenna to the right direction by knowing only the signal.

What makes the problem particularly vexing for on-the-move networks—airborne or on the ground—is that they call for two antennas that can point to each other on the fly and constantly adjust. In the airborne environment, the problems are compounded by the limitations in the number, size, and location of available antenna apertures. Experiments are under way at MITRE to address these problems.

Another challenge MITRE is working on for the future is building an airborne network, which the Air Force and the civil aviation community could use with all flight platforms to communicate air-to-ground and air-to-air using satellite links. For example, all warplanes in a theater would be able to exchange information in near-real-time through the airborne network. The critical challenge here is the speed at which these network nodes move around in relation to each other and to mobile and stationary units on the ground.

Interoperability A key concept in the DOD, one which supports net-centric warfare, is interoperability. To be able to share information across units and services, and with allies, systems must be able to "talk" to each other. Interoperability is also critical to many other government organizations; for example, in matters of homeland security, military and intelligence units share information with Customs and Border Patrol and often with state agencies.

On the battlefield, when net-centric warfare is the norm, each soldier will have a mobile wireless communication device—for example a software radio, satellite phone, or PDA. Their devices will automatically detect who else is near and how to connect. The resulting networks won't need any physical configuration in advance—unlike, for example, most current military networks, which are pre-configured, with information flowing through routers and switches

Continues on page 18

Continued from page 17

The Future: Bringing Down Barriers to Wireless Communications

MITRE is researching a number of technologies to improve communications for warfighters in the field, such as self-healing (or self-forming) networks. These networks will find ways to route information around a disabled section of the network, making sure warfighters are connected at all times.

at pre-determined places. The new networks automatically connect when wireless-equipped soldiers come into range of each other, enabling timely communication, accessibility of networked services and data, and uninterrupted connectivity.

MITRE and many other research organizations are exploring ways to accomplish such on-the-fly, interoperable networks, looking at various techniques called mesh networks, ad hoc networks, or self-forming networks.

An ad hoc network is a collection of communication devices (or nodes) created to communicate with no fixed infrastructure available or pre-determined organization of available links. These networks, which can be built around any wireless technology, are common in the military but are also appropriate for other uses that require temporary networks. Small ad hoc networks have been created and tested in the field but there's still a lot of work to be done in the areas of theory, research, and prototypes, says Palo. One significant issue is scale, and the protocols available so far don't scale well to create the large networks the military needs.

Another future technology we are researching is "self-healing" (or self-forming) networks. These are networks that can learn how to route information when one part of the network is disabled or unavailable. A self-healing network has the advantage of keeping people connected at critical times, without the need to drag extensive support personnel to the front line to fix problems.

Adaptability Adaptability is a key concept when you're talking about mobile networks and limited airwaves for transmitting signals. Software radio is one technology that can help: it's a radio (or other wireless communicator) that can be programmed to use various RF waveforms. For military and civilian aviation, software radio can help bridge legacy and future technologies and allow for easier upgrades. The biggest impediment is creating affordable radios. And then the next step up is "smart radio" (or "cognitive radio"), which knows how to adapt to the spectral environment and dynamically change modulation and frequency to use unoccupied spectrum that avoids congestion and jamming.

Network-aware applications will also support adaptability. Software and network protocols developed for stationary networks often encounter serious deficiencies when moved to a tactical military environment. So we are looking to create "network-aware" applications that can operate equally well on the base and in the field.

Protocols Once different networks are connected, it is the software protocols that let them exchange information and govern how the networks behave. Better protocols are needed, however, to create the kind of airborne networks and net-centric environments envisioned by MITRE's customers.

The government is planning to roll out the new Internet Protocol Version 6 (IPv6), which will handle a much larger number of network addresses than the current IPv4, provide better security, and make it easier to deploy complex networks. Making the transition from IPv4 to IPv6, however, will require modification or replacement of millions of computers and network devices, as well as software applications that use Internet addresses. There is strong international demand for transitioning to IPv6, motivated largely by the vastly increased address space and the limited ability of IPv4 systems to handle growth in demand. The U.S. Department of Defense plans to start the transi-

While the commercial world has been very successful in moving from fixed, wired networks to wireless communications, most of these organizations don't deal with the kinds of environments that the military faces around the world. From the windy deserts of Iraq to the icy mountains of Afghanistan, the Department of Defense's communications equipment must work where there is no infrastructure whatsoever.

tion in 2008 and be fully operational in 2012. Other government agencies, including the FAA, are similarly working the IPv6 transition problem.

MITRE researchers are also looking at developing protocols governing information transport for aircraft moving across large distances; better wireless protocols that can predict connectivity, create location awareness and synchronization, and integrate with wired networks; as well as creating disruption-tolerant networks.

Network Management As the size and complexity of the networks grow, so does the management task. How do you determine what messages get priority? How do you keep information secure? For the airborne network, is there a limited number of clear entry and exit points—and how are they managed?

Managing a wide range of networks that must work together is a big challenge. Most government organizations, including the military, have multiple platforms, a dynamic wireless environment, IP-based networking systems, and non-IP-based legacy systems, plus the need to maintain security and quality of service. Services change frequently, have different release lifecycles, and change independently of the rest of the system.

Most organizations have accepted the constant change and are finding ways to deal with them. For example, the DOD's concept of netcentricity defies pre-planning since they can't determine ahead of time everything they'll need to know to have a working network for soldiers, aviators, and commanders in any situation. The trend is to create systems and protocols that can adapt, wherever and whenever they are deployed, and to make connections that are reliable and secure.

MITRE researchers are exploring a new approach to network design, hypothesizing that the strictly layered architectures that work for fixed wired infrastructures may not be effective in a highly unpredictable mobile network. The alternate approach, cross-layer design, calls for distributing the optimization solution across layers—physical, media access, and routing—so that functionality in different layers is intentionally interrelated. With this approach, any layer can share information with other layers and still be capable of being updated without having to update the entire system.

Security Security is an issue that weaves through all areas of wireless networks. It should be built into systems early on so that developers can consider issues such as risk management and bandwidth requirements. The goal is to create a system that obstructs jamming, prevents eavesdropping, reliably maintains its connections, and prevents intrusion.

MITRE is looking at a number of ways to ensure security (*see the article on page 11*). For example, the "black core" is an IP network that encrypts data coming in and decrypts it going out, so that data is protected throughout its complete journey, instead of being decrypted and reencrypted at each connection point.

Content We've touched here on just a portion of the work MITRE is doing in transforming communications. In addition to building the infrastructures that carry communication, we are also addressing the content of the communications—how to make sure people can quickly find what they need to know. For example, we are researching areas such as machine translation, data mining and extraction, matching metadata among systems that use different terminology, data visualization, complex behavior analysis, decision-making, and collaboration tools.

According to Richard Games, chief engineer for the Center for Integrated Intelligence Systems, "If you want to transform communication, you have to look at it holistically, and we are."

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The EDGE MP 04W0000122-04 The EDGE is published quarterly by The MITRE Corporation.

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Continued from page 10

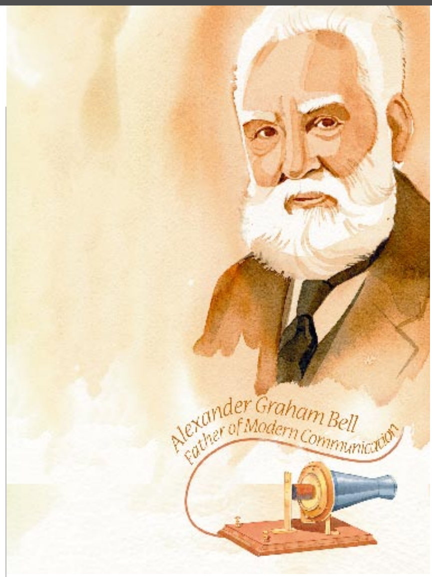
convergence layer for packet switching, the efficiency and flexibility attained through the use of packet switching compared to circuit switching, and the availability of standard applications that seamlessly interoperate using IP.

Most of today's military satellite communications (SATCOM) systems are basically stove-piped, circuit-based systems, that are not Internet protocol-friendly. Standard applications can't be run over many of today's SATCOM systems because they were designed with different applications and communication approaches in mind. Consequently, the DOD is in the process of developing and acquiring a fundamentally new SATCOM system to change this paradigm. The Transformational Communications Satellite (TSAT) system, when fully fielded, will provide an Internet-like backbone in space. This packet-switched approach will provide for more efficient use of the spectrum and more dynamic connectivity to users than do today's legacy circuit-switched services. The Air Force's Family of Advanced Beyond Line of Sight Terminals (FAB-T) will provide user connectivity to TSAT.

In addition to radio-frequency links, TSAT will employ laser communications. Compared with radio frequency links, the GIG's optical communications in space will employ smaller and lighter equipment and provide higher data rates and more effective use of frequency resources. Data rates will exceed 1 gigabit/second. An example of this tremendous increase in performance is that a TSAT can transmit a radar image from a Global Hawk unmanned aerial vehicle in less than a second, compared with the 12 minutes it takes for Milstar to transmit it today. MITRE is supporting the TSAT system in many areas, from overall systems engineering and terminal developments to researching fundamental technologies (e.g., free space optical propagation and terminal software architecture). MITRE also supports other efforts to provide transformational capabilities based on using IP for SATCOM systems, including the development of a new SATCOM waveform—the Net Centric Waveform—the use of commercial IP modems, and satellite performance enhancing proxies.

Conclusion

Implementing the GIG will take a number of years, but bit by bit it will increase the DOD's ability to conduct net-centric warfare. MITRE will continue to work on GIG programs for all the Services, investigate novel ways to improve the capability of fielded systems, and perform fundamental research to improve DOD's networking infrastructure. We will continue to work across the DOD on these efforts, providing technically objective systems engineering support to all aspects of the communications infrastructure (terrestrial, mobile, and satellite). Our mission is to support DOD's goal of providing an Intranet-like capability for warfighters, to enable secure interoperability and timely information sharing.



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This document has been approved for public release.

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