"Captain Miller's laser data link came to life as she took direct control of Risky 3's MMLR [multimission, long-range] uninhabited aircraft." So reads one of the you-are-there vignettes from the Air Force's future operating concept giving a view of USAF in 2035.

Over the past decade, aerial networks carrying battlespace communications have become coequal partners in many types of USAF missions. Airmen tap into a data network with a smartphone for location, navigation, communications, and the latest information, and the Air Force realizes that's the kind of reliable data connections needed in combat, too.

Battlespace communications are at the center of operating concepts—and they will be hotly contested.

"Historically, we had superiority in battlespace communications," said Lt. Col. Tim Wilcox, chief of operations integration in the Air Staff's A3 directorate. "I don't think we can count on that in the future."

Today, airpower depends on data flowing through the battlespace, but that wasn't always the case. The aerial layer scarcely existed until the late 1990s. A generation ago, airmen in Operation Desert Storm communicated mainly with voice over radio. A few big computers generated planning orders at air operations centers but they weren't linked to other computers.

Aerial layer networks began as small clusters. Some of the first networks consisted of tactical data links transmitting information between fighters and E-3 AWACS aircraft, for example.

The Link 16 data link debuted in the 1970s with large terminals at ground stations and aboard AWACS. Air Force F-15Cs then acquired the links, and by the 1990s, Link 16 reached a range of US and NATO fighters and airborne battle managers like JSTARS, Rivet Joint, and the NATO alliance's own AWACS aircraft.

Secure radio links also branched out from voice to data transmission. Ground communications links to air operations centers provided access to ISR assets transmitting data via SATCOM, such as the U-2, unmanned aircraft, and satellites. The aerial layer thus became a network with multiple entry points from relying on local links and space-based communications.

Networking created the structure for time-sensitive targeting, as first seen on a wide scale in NATO's Operation Allied Force in 1999. Link 16's ability to provide position location and reporting became a cornerstone of rapid strike against newly identified targets. Missions like hunting and destroying enemy surface-to-air missile batteries were highly dependent on links to pass identification and targeting information.

Wars in Afghanistan and Iraq saw airmen linking more aircraft and tapping into bigger pipelines of data at air and space operations centers. By the mid-2000s airmen had regular access to data carried by ad hoc aerial networks. A portfolio of tactical data links exchanged information between platforms and mission partners. They gradually extended those links to fighters, bombers, tankers, and of course, unmanned aircraft and controllers on the ground with handheld ROVER communications tools. The result was fast-moving intelligence, surveillance, recce—and a huge increase in rapid, flexible targeting.

COMMS THROUGH THE AERIAL LAYER

By Rebecca Grant
Technological advances are on the verge of opening up new horizons for military communication.
nect while airborne, then Tactical Quint establishes sockets of higher data-rate for rich sensor imagery. QNT (Quint Networking Technology) also ties in nodes for persistent threat detection.

Many links were rushed into place to meet immediate combat needs. From a tactical perspective, that was good, but there was no master plan.

“The Air Force’s information environment evolved and converged as individual mission needs dictated, rather than being designed,” recalled the USAF’s Flight Plan issued in May 2015.

This wasn’t a problem unique to USAF. In October 2009, the Joint Requirements Oversight Council approved plans for a Joint Aerial Layer Network, known as JALN, to concentrate on advanced combatant information exchange. The aerial layer networks (ALNs) also plug in to surface and space networks. JALN isn’t a single program. It’s a concept whose main goal is to provide reliable and secure links between aerial platforms without depending only on space.

Air Force work on its portions of the aerial layer lodged firmly within the JALN framework. In 2011, USAF signed out a vision for the aerial layer anticipating most platforms would have relay capability by 2024.

“ALN affects the soldier on the ground, the pilot in flight, or the satellite operator,” said Lt. Col. Todd Schug, who was the Air Staff chief of the airborne networking branch. “Think of a warfighter fighting in the hills of Afghanistan getting mission-critical data over ALN that tells him or her the enemy is just on the other side of [the] hill.”

Upgrading aerial layer networks is a constant process of mixing new and old. Efforts also focus on expanding capacity while protecting data. Interoperability is a big issue. “How do planes communicate with different link profiles?” Wilcox asked. Future plans call for extending Internet Protocol (IP) access “across the sky in a secure manner,” he said.

USAF is concerned now with “four capability gaps: communications, capacity, information sharing, and network management,” said Lt. Col. Karina DeGarto of A6, the Air Force’s Office of Information Dominance and Chief Information Officer. Hailing from the AWACS community, DeGarto is the Air Staff’s point person for the JALN/ALN initiatives.

FOURTH TO FIFTH

Just how is the Air Force putting the aerial layer technology to work? Collection and transmission of ISR data is a major component. Another priority is combat networks. Aerial layer techniques are particularly important to connect fighters. The technologies assisted with two big steps: creating a path for the fifth generation fighters to network with older, fourth generation aircraft, and building a communications link between F-22s and F-35s.

Scenarios for dealing with enemy aircraft place special demands on the aerial networking layer. It’s no exaggeration to say that air superiority will

MSgt. Zachary Swain, a tactical air command and control specialist with the Mississippi ANG, locates coordinates for a live-fire training operation during Exercise Southern Strike.
F-22s and F-35As fly in formation after completing the first integrated training mission over Eglin Training Range in November 2014.

depend as much on the links as on the fighters themselves. An air battle where Red fighters outnumber Blue US joint forces and allies will make information superiority all the more critical. Sharing information will permit aircraft to share tracks of Red fighters, decide on who takes the shot, and keep abreast of the unfolding battle. The B-2 and new Long-Range Strike Bomber will be participants in the aerial layer, too.

For the Air Force, the communication between fourth generation fighters and the new F-22 and F-35 is an especially critical section of the aerial network layer. “The F-35 and F-22, instead of speaking only to each other, need to speak backward to legacy aircraft,” said DeGarmo.

F-22 training with other forces has already shown the need for robust, secure links.

The challenge is how to modernize those fourth generation aircraft that will still be in the fight over the next decade. Link 16 created a solid standard but data needs and security concerns could both outpace older links in the future.

In joint terms, fourth-to-fifth generation connectivity falls under the heading of DARE: distribution, access, range extension. DARE delivers a tailored and scalable network transport capability across domains, according to the Joint Concept for Command Control of the Joint Aerial Layer Network.

What about sharing data between F-22 and F-35? Although both are fifth generation platforms in capabilities and survivability, they arrived just as IP-enabled networking was becoming de rigueur. Talking to each other demanded a new protocol that was both efficient and secure.

In December 2013, an experiment called Project Missouri—after the nickname of the “Show Me” state—proved they could. (The test was dubbed Project Missouri after Air Combat Command leadership challenged Lockheed Martin to “show me” the capability.)

“We successfully integrated an F-22 with a Rockwell Collins tactical radio for Link 16 transmit and receive capability, and two L-3 Communications devices to support encrypted and secure operations,” said Ron Bessire, who was then vice president of program and technology integration at Lockheed Martin Skunk Works. An F-22 flying from Nellis AFB, Nev., communicated with software on the F-35 avionics test aircraft, known as the Catbird. The test used an open system architecture. Hardware and software development took just seven months.

The end goal is for everything to communicate, noted DeGarmo. Under current budgets, the Air Force must prioritize networking upgrades to legacy platforms.

ON WITH JALN

The Air Force is playing a central role in aerial layer networks for joint operations, too. USAF is committed to providing both strategic direction and program funding for development of JALN.

“As airborne networking becomes increasingly important for future forces that will rely on effective communications for mission success,” the Defense Department “requires the ability to conduct information sharing among similar, and disparate platforms, provide access to the ground-layer high capacity backbone to extend DODIN [Department of Defense Information Networks] services to tactical edge users, and support combatant commanders and national leaders,” said the Air Force Information Dominance Flight Plan.

Of course, the aerial layer network is not isolated to the Air Force. Broken links could affect ground forces, too. Marines deployed in fixed sites had become “addicted to big-pipe, space-based systems,” said Lt. Gen. John A. Toolan Jr., commander, I Marine Expeditionary Force.

“We developed an overdependence on high-bandwidth communication systems and the contractors required to run them,” Toolan told National Defense Magazine in February 2014.

With JALN, specific airborne platforms can be repositioned to provide an airborne network for units on the ground. It’s not the main mission—rather, JALN becomes a target of opportunity. Aircraft equipped with the JALN relay capability will normally be tasked with other missions. Commanders may ask them to respond and contribute to the network as a secondary task or even pop them into JALN during a mission.

It’s about giving commanders a number of ways to form and reform aerial networks. Airborne assets aren’t the only way to do it, but they are appealing because of their rapid mobility and flexibility.

The guiding idea behind JALN is to reconnect tactical units with the network they need while carrying out operations. “When network demand exceeds supply and/or a capable adversary targets US forces’ communications, JALN airborne assets may be the only option that allows a JFC to ensure the highest priority missions operate with their full potential of net-enabled combat capabilities,” summarized the JALN joint concept.

As such, part of the JALN concept is for joint force commanders to prioritize who gets up on the network and when. The future may include automated planning tools that take into account when certain units most need to latch onto the airborne relay.

“Priority joint forces must be able to continue net-enabled operations even in the face of overburdened infrastructure, difficult environments, or determined adversaries,” the joint concept acknowledged.

LASER AND BEYOND

How then, might USAF arrive at the point where the Captain Millers of the future operating concept really use lasers? Advanced waveforms like QNT and TTNT make the most of the radio frequency spectrum and improve data management. Next on the horizon are new ways to manipulate electromagnetic energy to carry messages.

“From the earliest days of laser development, researchers realized that light could outperform radio in terms of information speed and density,” summed up science writer Nicholas Gerbis in a “How Stuff Works” article. The tiny laser waves are packed more closely together. Laser printers, DVDs, bar codes—all take advantage of laser light’s ability to handle large quantities of information.

Technical problems restricted laser communications over greater distances and between ground-to-air and air-to-air nodes. Turbulence and other factors once generated bit errors, but steady experimentation and adaptive designs have overcome most obstacles. For example, Louthain’s work found value in the averaging effect of multiple beams and explored optimum angulation for those beams. Air Force Research Lab has worked on developing components to maintain links between high-speed aircraft even in strong turbulence.

NASA has scored successes, too. In October 2013, the Lunar Laser Communication system transmitted data from the moon to Earth at 622 megabits per second, compared to tens of megabits common in household connections. NASA’s Lunar Atmosphere and Dust Environment Explorer spacecraft hosted the payload, and the space agency called it the longest and most reliable lasercom link ever to function through the atmosphere. The link also debuted an error-correction pathway.

DARPA and AFRL have both funded research on adapting laser technology to communications in the aerial layer. Grouped together, fiber lasers increase power and refine out atmospheric disturbance. The lower power clusters open possibilities for laser beams to carry communications data. The technology “may also benefit low-power applications such as laser communications and the search for and identification of targets,” said DARPA Program Manager Joseph Mangano.

Time lines for laser communications differ for each mission area. NASA plans to conduct high-speed laser communications to GEO satellites in the next few years. Air-to-air laser communications have already been demonstrated by DARPA and others. As a result, “Air Combat Command may be able to provide requirements for laser communications applications within the next decade,” said Othana Zuch, spokesman for 377th Air Base Wing public affairs at Kirtland AFB, N.M.

By then, quantum computing may be changing encryption techniques. Quantum key distribution is emerging as a physics-based alternative to current techniques. International investment in QKD is on the rise. To keep pace, USAF labs are exploring potential capabilities and limitations of the technology for USAF applications.

But don’t count out the radio frequency spectrum. Recent experiments point to more methods for increasing data capacity. Engineers at the University of Southern California twisted polarized beams into a single spiral and sent 32 gigabits of data per second across about 10 feet of air. The rate was 30 times faster than typical wireless connections. Orbital angular momentum, discovered in the 1990s, lets multiple channels ride a single frequency, researcher Alan E. Willner told IEEE Spectrum in October 2014. Those ranges are short for airborne networks, but the premise holds potential. “A radio backhaul like that could be a huge pipe for data centers,” noted Willner.

**KEEP A BACKUP**

However promising the new communications technology, the Air Force must still ensure cross-domain dominance.

“We don’t want to go 100 percent network,” cautioned Wilcox. Airmen on missions need to react and adjust if the IP networks shut down. Network failure is especially problematic when weapons and sensors are disaggregated from the platform. A missile or unmanned craft drawing information from a network for updates to its mission could be in jeopardy. In the worst case, “you basically have a soft kill,” Wilcox explained.

Future progress in autonomous systems is another reason for improving the aerial network layer. A group of autonomous missiles, for example, may receive endgame updates from the aerial network layer as they seek their targets. Even with terminal guidance aboard, the aerial layer network will supply crucial target identification and permission and, ideally, transmit the final strike decision and impact information to assist in damage assessment.

One solution is to keep manned aircraft in proximity.

“If you sever beyond-line-of-sight links,” Wilcox continued, the air battle manager can control activity through line-of-sight communications. Voice carried over VHF and other radio bands can provide backup communications links. “You can’t abandon all the old ways of communicating just for new technology,” said Air Staff aerial layer network expert DeGarmo.

True agility will call on airmen to work with multiple communications pathways.

“The purpose of all this is to get the mission accomplished,” DeGarmo concluded. “The future is an interoperable communications network between airborne, terrestrial, and space forces.”