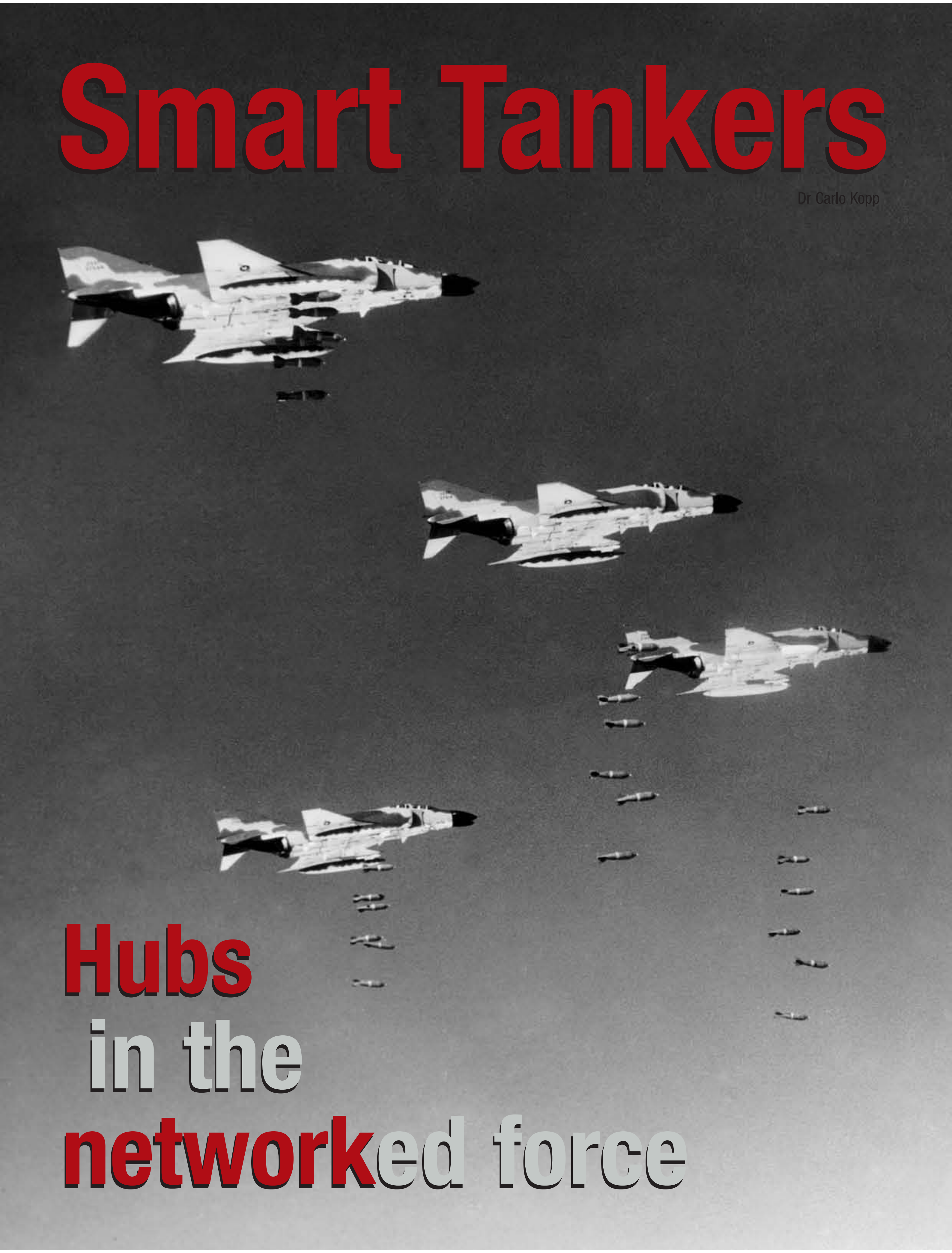
Smart Tankers

Dr Carlo Kopp



Hubs in the networked force

The term ‘Smart Tanker’ has emerged in recent years to describe the current US Air Force effort to introduce network and communications relay capability on some fraction of their existing KC-135R/T fleet. The idea of using larger aircraft as airborne communications relays is not new, but the manner in which the US Air Force is doing it is new. The driving impetus for the current Smart Tanker program is a shortage of available networking and communications bandwidth within the battlespace. This was first evident during the OEF campaign to defeat the Taliban and Al Qaeda in Afghanistan, and subsequently in the OIF campaign to oust Saddam Hussein. Both campaigns were the first to employ Killbox Interdiction techniques, in which persistent strike aircraft would orbit in areas of interest, termed ‘Killboxes’, and would be vectored to engage and destroy ground targets of interest.

Persistent strike techniques are designed to defeat rapidly moving or ‘emerging’ targets; both categories are time critical. Any delay in vectoring the strike aircraft to the target could result in a moving target lost, or a moving target travel into an area that is off limits for a strike. A unique class of target has been terrorist leaders, detected on the move between hides.

If the strike aircraft cannot exploit the opportunity to strike while it exists, that opportunity may be lost and not re-emerge, or arise again months later. In strategic terms, it boils down to ‘kill the target while you can’.

Targeting data for such strikes was provided by a combination of Special Forces teams on the ground, UAVs such as the RQ-1A Predator and Gnat, and in OIF, by advancing elements of the ground force. When opportunities arose, data was gathered by reconnaissance satellites and Senior Span U-2 aircraft then relayed by satellite links to analysts in the US. UAVs would collect static optical and radar snapshots along with real-time video imagery, relayed over communications links to ground stations. Analysts explored the data and then called in air strikes.

What was clear by the end of OIF was that strike aircraft could pounce on targets and kill them within minutes of receiving a vector. The time to collect, analyse and distribute the targeting data became the bottleneck. In practical terms, this ‘inverted’ the established relationships between the information gathering and analysis phases of the targeting cycle, and the engagement phase of the targeting cycle.

Conventional thinking during the 1980s and 1990s was that the required digital connectivity and link capacity could be provided by the US Air Force’s constellation of communications relay satellites.

This proved to be unrealistically optimistic for a variety of reasons. The first was the available capacity of the satellites. Combat operations typically result in geographically localised ‘hot spots’ in demand for satcom channels and channel speed. As a result, at any time 90% of satcom capacity demand could and often did end up falling on 10% of the available number of relay satellites. Designed to provide global connectivity, the US Air Force constellation could not cope with high-density demand in localised areas of operations. This proved to be the problem that crippled both the Iridium and Teledesic Low Earth Orbit satellite schemes commercially - the potentially best revenue generating areas were concentrated over a small geographical extent, leaving much of the orbital network idle most of the time.

The problem of finding capacity to support large numbers of low speed channels was exacerbated by the large demands imposed by transmission of high-resolution radar and optical imagery, and realtime video. The latter proved to be exceptionally useful for locating fleeting and emerging targets, yet consumes far more bandwidth than other traffic types. Again this problem is analogous to that seen in commercial, cabled digital networks.

While the US did its best to improvise by leasing channels on commercial satellites, this was not a good long-term proposition as commercial systems are not designed for the high jam resistance of military modulations and protocols.

The third problem was that satellite links have latency problems; the time delay for a signal to bounce off a satellite in Medium Earth Orbit (MEO) or Geostationary Earth Orbit (GEO) is a factor of ten or more greater than the time to bounce off a repeater which is tens of miles away. While tolerable for voice, it creates a variety of problems for various digital protocols.

Satellites thus provide a tremendous capability to provide ‘skinny pipe’ digital connectivity over a global footprint, but are much less effective at providing ‘fat pipe’ digital connectivity in local areas of operations.

Airborne relays for digital communications offer an opportunity to escape this ‘bandwidth bottleneck’. Aircraft or UAVs, via the simple expedient of physical proximity to an area of operations, can provide much better available link capacity and much lower link latency delays.

The first modern airborne communications relays were a handful of KC-135A tankers modified under the Combat Lightning program to support strike operations over North Vietnam. These aircraft were used to extend the communications footprint of College Eye EC-121 AEW&C and Rivet Top EC-121 ELINT aircraft. The Combat Lightning aircraft were crewed by SAC personnel seconded from EC-135 command post units in the US, and are credited with playing a critical role in alerting fighters crews to inbound MiGs and SAMs (US Air Force).

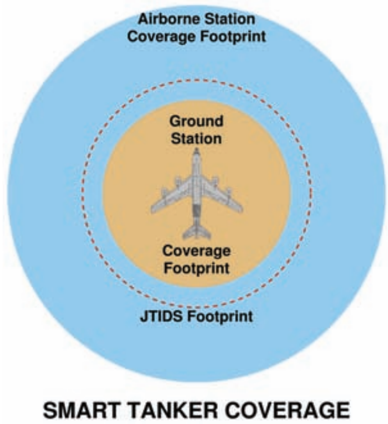
High-flying UAVs make for excellent communications relay platforms, with a better footprint than a Smart Tanker due to station altitudes of 60,000 ft or better. The drawback is that a large payload may force the commitment of a whole UAV with all of its operating costs. DARPA and the US Air Force initiated the development of the ABN payload for the Global Hawk some years ago, but the absence of recent reports suggests this program is no longer funded.

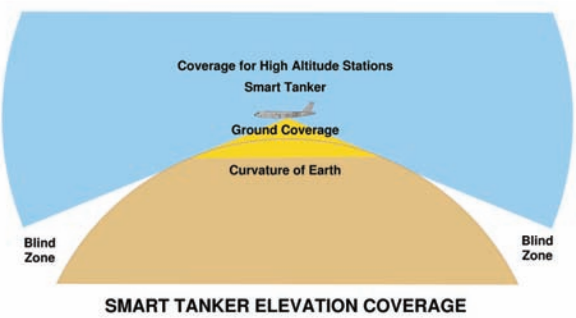
Airborne Relays and Pseudolites

The term 'pseudolite' (contracted from 'pseudo-satellite'), coined during the 1990s, described aircraft or UAVs equipped with relay packages similar to those on satellites but designed to service a much smaller geographical footprint using much faster communications channels.
The idea of using aircraft as communications relays to support military operations dates back to the 1960s, when the US Air Force developed and deployed a wide range of EC-135 variants to support Strategic Air Command nuclear strike forces, then comprising B-52s and Minuteman Inter Continental Ballistic Missiles. These systems were to provide a survivable communications network in the event of a nuclear war. Subsequently, this model was applied to supporting air operations in Vietnam.
The latter case study presents a good example, as the problems encountered and solved, albeit with the technology of four decades ago, are similar to the problems faced today.
The KC-135 Combat Lightning and EC-130 airborne communications relays orbited areas of operation to provide wide area VHF/UHF coverage primarily for supporting air force operations. The seven Combat Lightning KC-135s were specifically tasked as relays to support fighter operations over North Vietnam, providing extended radio footprint coverage for up to three EC-121 College Eye AEW&C aircraft and a single EC-121K Rivet Top ELINT aircraft, with KC-135 relay orbits usually situated over the Gulf of Tonkin. Numerous sources credit the Combat Lightning relays with playing a critical role in defeating NVA MiG and SAM operations.
By the 1990s the RAF in the UK initiated a program to put JTIDS/Link-16 relays on some of their tanker fleet, to provide a bigger coverage footprint for their E-3D AWACS, but also to allow these tankers to broadcast their fuel state and location to fighters flying nearby CAPs.

Technical Considerations for Airborne Relays

Two key issues arise with all airborne relay and pseudolite systems. The first is the aircraft's station altitude, as this determines the geographical footprint that can be covered.
Communicating with stations on the ground, the radio horizon sets the basic limit on range. At altitudes of around 20 kft this is around 150 NMI, at 36 kft around 240 NMI, at 50 kft beyond 250 NMI; with the caveat that distances close to the radio horizon begin to experience various problems resulting from signal bouncing off the earth's surface interfering with the signal received along light of sight.
Communicating with airborne stations, the radio horizon still imposes a hard limit, and problems can arise when the signal grazes the horizon. But distances of up to 400 NMI become feasible, which is the cited range limit for the Combat Lightning relay system.
In context, a satellite system covers a footprint of thousands of miles in diameter, while an airborne system covers a low altitude or ground footprint of up to 400 NMI diameter, and an airborne vehicle footprint of up to 800 NMI.
The US Air Force and DARPA did recognise this and when the RQ-4A Global Hawk High Altitude Long Endurance UAV program was launched, initiated a program to develop a communications relay payload, the Airborne Communications Node (ACN), which effectively launched the first military pseudolite program.
To date, ACN has not materialised, although the Global Hawk makes a superb vehicle for this purpose because of its station altitude and endurance.
Persistence on station is of course the second big issue for airborne relay systems. The longer the vehicle is on station, relative to the transit time to station, the better return on investment the user gets. The better the endurance of the airframe, the better the persistence.
Another important issue is the capacity of the airframe to support the power, cooling and antenna 'farm' requirements of the relay package to be used. In practical terms, fast digital links require bigger antenna packages than voiceband channels, and pushing out hundreds of Watts or more of radio power puts more demand on cooling and power than does a 50-Watt voice radio.
Survivability in contested airspace is yet another consideration, as this favours either HALE vehicles such as Global Hawk or faster conventional aircraft. While neither can survive a close encounter with an Su-27, both can make it difficult for the Sukhoi to get close enough for a shot.
In practical terms the two most viable options for relay systems today are either HALE UAVs or large / fast jet transports with good endurance and good subsonic dash speed.



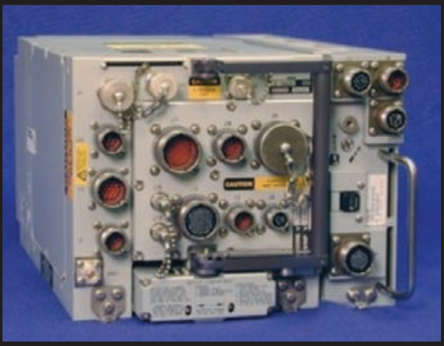


Smart tankers provide potentially large coverage footprints when communicating with other airborne stations at medium and higher altitudes. For station altitudes between 30,000 ft and 40,000 ft the ultimate range can be as great as 400 nautical miles. Conversely, coverage for low flying stations and ground forces or warships is limited by the radio horizon to no more than about 250 nautical miles, with quality degradation frequently arising due to the shallow elevation angles of the ground station line of sight to the Smart Tanker. The timing behaviour of some protocols, for instance JTIDS/MIDS, can impose further limits on usable footprint (Author).

Smart Tankers

The idea of reviving the Combat Lightning model using modern digital relay equipment must be credited to the US Air Force, under the leadership of Gen John Jumper, who has been an aggressive proponent of this model. The concept envisaged by the US Air Force is that some aerial refuelling tankers would be equipped as relays for the new Joint Tactical Radio System (JTRS) and a range of established and legacy protocols.
The model hinges on the ubiquity of tankers that are always orbiting in proximity to the battlespace – refuelling fighters, bombers and ISR platforms. Ergo, if the tankers are always going to be there, why not install digital communications relay packages in the tankers and have them perform concurrently as pseudolites to support air / sea / ground assets in the area?
In part, an imperative for pursuing this model has been the ongoing series of delays in the UAV world. The Global Hawk is arriving later than hoped, and the smaller RQ-1 Predator is less suited to the role. Thus was born the US Air Force SMART (Scalable, Modular, Airborne, Relay Terminals) tanker program and its ROBE (Roll-on Beyond Line of Sight Enhancement) equipment package.
The ROBE concept was devised by the US Air Force Command and Control, Intelligence Surveillance and Reconnaissance Center (AFC2ISRC), at Langley Air Force Base, VA by a team led by Major Jack Cheney and Captain Kjall Gopaul of the Tactical Datalink Office of AFC2ISRC. Gen Jumper and SecAF Roche were briefed in January 2002, followed by an accelerated acquistion cycle, which resulted in the first proof-of-concept demonstrator flown in October 2002 at Eglin AFB in Florida.
The aim of the ROBE effort is to acquire 20 ROBE packages and modify 40 KC-135R tankers to carry them – to permit all systems to be in use at any time regardless of the depot status of the KC-135Rs.
The configuration of the baseline ROBE system comprises a Multifunctional Information Distribution System (MIDS)-Low Volume Terminal 3 (LVT-3) for Link-16 network access, an AN/ARC-210 satellite radio for worldwide data transfers, a Global Positioning System receiver for navigation and precision clocking, and a modified laptop computer. The computer acts as the protocol gateway and as the central processing element of the suite, which is networked using an internal Mil-Std-1553B bus. The total weight of the system is 140 lb, in four stackable shock-resistant cases. The package is handled as would a 463L pallet, using standard cargo floor tie-downs. At the time of writing forty KC-135Rs at McConnell, Grand Forks and Fairchild AFBs had been modified to carry ROBE.
The modifications to the tankers are minimal. Three new antennas are fitted, to support JTIDS/MIDS, the UHF satcom, and the GPS. Interface panels are added on the main deck to provide antenna feed access, and electrical power.
The MIDS-LVT network terminal is a compact low cost derivative of the Rockwell-Collins FDL datalink, but is designed to be installed in tactical aicraft as the replacement box for the existing TACAN/VOR/DME system, using the original antenna configuration, with provisions to fit a replacement TACAN transceiver in the terminal. The cited transmit power levels for the MIDS-LVT are 200, 50 and 1 Watt, with a cited optional 'High Power Amplifier' interface delivering 1 KiloWatt. The terminal has Mil-Std-1553B, Ethernet and X.25 interfaces.
The ARC-210 is the Rockwell-Collins modular radio system, available currently in at least sixteen configurations. In the ROBE system it is used to provide UHF band AFSatcom connectivity; an optional module is available to provide operation in the 2.5 GHz satcom bands. The radio supports CASS/DICASS, Have Quick and Have Quick II modulations in the UHF band.
The ROBE system provides, in networking terms, 'horizontal' connectivity to other JTIDS/MIDS network-equipped platforms within radio line of sight; and 'vertical' connectivity via satcom links to other US military facilities, including those in the continental US. Given the use of established JTIDS/MIDS and legacy satcom, ROBE is not a high speed system. Its purpose is to provide miminal capability (typically text messages) as quickly and cheaply as possible, globally. Each complete ROBE installation costs the US taxpayer around US$1.5M, with 20 ordered to date.
ROBE is designed to operate unattended, once the tanker crew turn it on it is left to run during the sortie until the aircraft returns. The fully automated gateway system running on the laptop computer manages the traffic and routes messages as required (refer NCW 101 this issue).
Future growth of the ROBE system is planned but to date funding has been scarce. Options include a remote control capability, allowing an operator elsewhere to configure and manage the gateway system, EPLRS / SADL to provide connectivity with Army ground forces, Link 11 and Link 22 for naval compatibility, and Mil-Std-3011 Joint Range Extension Application Protocol (JREAP) to support TCP/IP over global distances. In the longer term, ROBE systems will need to be compliant with the new JTRS network, using the high speed WNW waveform.
The ROBE system provides the US Air Force with much more than a basic JTIDS/MIDS network relay. As the system is integrated with satcom, it becomes feasible to use the system to relay messages from Headquarters elements in the US to combat aircraft orbiting in-theatre, and vice versa. If/when the JREAP upgrade is deployed, any similarly equipped system interfacing via the ROBE-equipped tanker will acquire global TCP/IP connectivity.

The ROBE demonstrator system during trials performed at Elgin AFB in 2002. The system integrates a laptop computer running gateway software, a MIDS/LVT netowrk terminal and an ARC-210 UHF satcom radio (US Air Force).



The ROBE system integrates two existing communications equipments, the MIDS-LVT terminal and the AN/ARC-210 UHF radio (Rockwell Collins).

The Future

The ROBE system is the first foray into genuine 'Smart Tanker' operations, providing a basic but very useful capability. Longer term, as JTRS and JREAP protocols mature, Smart Tankers will become effectively hubs in the networked force. This will produce two effects. The first is that tankers being large will be capable of hosting a large suite of networking equipment, including high speed gateways and high capacity links. Effectively the in-theatre bottleneck in digital connectivity will vanish, as the high availability of tankers and considerable throughput of tanker-borne networking equipment will plug the existing hole. The second effect is that tankers will become even more valuable targets, as killing a tanker not only starves patrolling fighters of fuel, but also knocks out a major digital networking hub.
There is little doubt that operational economics favour Smart Tankers over dedicated HALE UAV relay platforms, as the incremental cost of carrying even hundreds of pounds of networking payload is lesser than the cost of carrying it on a large UAV - this is despite the better coverage footprint achievable with a UAV at 60,000 ft.