Extended Line of Sight

In Vietnam, the DCPG has pioneered in the use of an elevated relay station to monitor a field of sensors and to transmit the information to an Infiltration Surveillance Center (ISC). The ISC also transmits commands to the sensors and to the other distributed elements via the same relay. The "relay" was initially an EC-121 aircraft equipped to operate in a manual, voice mode. From the IOC of the system, an automatic data relay was also provided and it has been the mainstay of the system operation ever since. Because of the cost and vulnerability of the EC-121, a drone light aircraft (Beech Debonaire—"Pave Eagle") was developed and equipped with the digital relay package, providing a much less expensive elevated line of sight. The orbiting aircraft, however, makes it somewhat difficult to use directional antennas for improving the reception from the sensor field, and a further development in the direction of an extended line of sight at low cost would be the use of high-altitude balloons. (S)

In Vietnam, ARPA has provided some two dozen balloons for use at altitudes of 1000 to 1500 feet above ground level, largely for communications at division level. A balloon has much longer time on station and much lower operating cost than does even a light aircraft. Further, it can certainly work at 40,000 feet and perhaps even as high as 100,000 feet when properly staged. A balloon can readily be provided with a large directional antenna to improve the bandwidth of a communications system or to provide antijam capabilities. In any case, an extended line of sight from an elevated platform is the key to many of the systems of the future. It is just not possible to obtain real-time communication of the required bandwidth without this line of sight, and many capabilities become economical with it. Therefore, there should be intensive, committed technological development of balloons and a data relay adequate for this purpose. A balloon with a tether is widely regarded as a hazard to air navigation, but in fact, the tether can be avoided by the use of warning systems such as were employed in World War II over London. Alternatively, a free balloon can remain on or near station by use of propellers driven by gasoline engines. The comparison between a

New Ideas

Following the meeting discussed above by the editor, I drew together some of my thoughts, as well as some comments I had made about the battlefield of the future. The items I have selected for emphasis seem to offer a significant advance in our future military capabilities. (S) powered free balloon and an aircraft depends very much on the design wind speed. At 100 knots, the skin drag alone on a 500-kg (load) balloon produces a lift-to-drag ratio of about 11, while low-speed aircraft can very well obtain a comparable *L/D*. (S)

Time-shared, Highly Directive Communication and Control System

It is ridiculous, of course, to assign a distinct frequency channel to every possible talker in a system. The commercial telephone system uses shared trunks with time-shared access by digital address (the dial telephone). The DCPG sensors, from the first, shared 31 frequency channels, with 27 sensors distinguished by code on each. The sensors and the relay platform have used omnidirectional antennas, even though the sensor location was fixed and known to the computer. (S)

One can obtain a much better communication system (with longer life for the sensors, less susceptibility to jamming, and greater communication capacity) by the use of a phased-array antenna on the relay and possibly by the use of directional antennas on the sensors. In addition, if the ISC or other central organization would initiate communication, either on call by the sensor or in a polling mode, the relay antenna could be pointed electronically in the direction of the particular sensors by means of steering information stored in the computer. If the sensor wished to initiate communication, a pilot tone could be used to attract the attention of the computer, which could then establish the highly directional communication as before. (S)

The BASS (Battle Area Surveillance System) recently deployed by the DCPG in South Vietnam is a first step toward a centralized communications system for mating sensors to users, providing accurate location of long-range patrols by LORAN retransmission and providing remote firing of Claymore mines. I believe that experience with this system will show the great operational utility and low initial and continuing cost of such a communication and control system. Its further development might be in the direction of a computer-controlled, time-shared, phased array in order to provide antijam capability, reduce the cost and size of sensors, and provide more functions. Such a system could then be installed as readily on an aircraft as on a balloon, since compensation for platform altitude and position could readily be accomplished at negligible increase in investment or workload. (S)

Accurate Multiple-Use Low-Cost Theater Navigation System

The utility of a navigation system in weapon delivery has been demonstrated by the F–4D's of the 25th Tactical Fighter Squadron, which deliver bombs and DCPG sensors by LORAN in all weather. Position accuracy is 30 meters DEP. In level bombing from 10,000 feet during March–April 1969, actual bomb craters have exhibited about 70 meters CEP. Toward the goal of a low-cost theater navigation system, the DCPG system has demonstrated a LORAN retransmission unit in some of its sensors, which retransmit the 100-khz LORAN time signals on VHF, where they can then be retranslated back to 100 khz and used in a standard LORAN computer to determine with some tens-of-meters accuracy the location of the sensor involved. (S)

An early theater-navigation system to LORAN accuracy can be based on the LORAN retransmission system, and is, in fact, proposed in the IV Corps, using the BASS as a central communications facility. Thus, any patrol can carry a LORAN retransmission unit, which costs just a few hundred dollars, and have its position determined with very high accuracy by periodic polling from the central computer. (S)

The LORAN retransmission system should be used for early applications of accurate navigation, as will be discussed, including the high-precision delivery of missiles, projectiles, and the like. For the future, LORAN retransmission has the disadvantage that fairly long integration time may be required and that (relatively inexpensive) accelerometers would be required to determine in this way the position of a moving vehicle. (S)

For the future, instantaneous position determination at an adaptive data rate should be obtained by the means of a microwave, line-of-sight, time-difference system, such as the Air Force QRC–334 (or equivalent). The QRC–334 system can produce 10 independent position determinations per second per vehicle to a precision on the order of 10 feet over a hundred miles or more. This technique can readily be expanded to a theater-wide, multiple-use system; such a low-cost, precise system would have great utility. (S)

In general, such a theater navigation system could use three or four transmitters elevated on balloons or on light drone aircraft and weighing but a few pounds each. These transmitters would be spaced perhaps a hundred miles apart and would reradiate pulsed microwave signals from a central station. Any vehicle, patrol, or other echelon that wished to determine its position would have only a beacon, which would retransmit a pulse upon receipt of the pulse from any of the balloon-borne (or airborne or satellite) transmitters. The receipt of this pulse at the central computer, via the transmitting/relay stations, would then allow a measurement of the time differences of arrival of the relayed pulses at the vehicle, and a simple computation (especially simple if the vehicle is being tracked and if its previous position is known approximately) can determine the position to an accuracy on the order of 10 feet. The position of the relay balloons or aircraft would be determined with respect to standard vehicle-type beacons placed on the ground, so that there would be no necessity for accurate station-keeping of the relay platforms. The position of each vehicle could then be communicated to it at an appropriate rate, if desired. Hundreds of vehicles in midcourse flight could have their positions updated every 10 seconds, while a dozen vehicles within a few seconds of impact (artillery shells, bombs, etc.) could receive this service at a 10 per second rate. (S)

Remote TV or IR Imaging

Very often on the battlefield, one would like to emplace a fixed TV or IR camera or to be able to transmit for a short time a picture from a moving vehicle. For instance, it would be desirable to use a TV camera to monitor critical road passes or supply transfer sites, but such a TV picture would not be required at all times. The communications system could be alerted by sensor indications and a picture requested (perhaps at a normal TV frame rate, but just for a few frames) whenever trucks or other activity was felt to be within the field of view. In addition, for intelligence purposes, sampling is often perfectly adequate and the TV transmission could be set up on a sampled basis by the computer in order to avoid obtaining excessive amounts of excessively accurate information. (S)

Further, one can have a drone (probably a helicopter) forward air controller which could aid in the delivery of ordnance, say, laser-guided bombs against AAA, command posts, check points, trucks, or other targets. The extended line of sight and the time-shared highly directive communication and control system could then request TV imagery from such forward air controllers at an appropriate rate. (S)

Such a helicopter could be flown by command within the theater navigation system discussed above to a target area. It could then descend to a few-hundred-feet altitude, switch to its remotely viewed TV, and implant mines or sensors to an accuracy of a very few feet while relaying a TV picture of the target area. It is easy to show that such a helicopter and its control system more than pay for themselves in the increased effectiveness of the mines and sensors over delivery by aircraft with the usual CEP. (S)

Typically, the duty cycle (the fraction of time the TV is desired to be in operation) is relatively small for such applications, so that a separate channel may not be needed. Moreover, it should be noted that in case of largely one-dimensional motion expected along trails, roads, or waterways, a TV or IR sensor need scan only a single vertical line. The motion of the object itself will provide the second dimension of scan, although the resulting display will be compressed or expanded horizontally if the object's speed differs greatly from design speed. (S)

Remote-Guided Weapons in This Context

The accurate, multiple-use, low-cost theater navigation system can obviously be used for the delivery of bombs. In particular, the control unit on the existing Paveway laser-guided bomb could be modified to accept a time-difference setting, so that it can guide to a point at which the time differences in a fixed time-of-arrival system equal those which were set into the bomb. In this way, level bombing from 20,000 to 30,000 feet could deliver weapons with a CEP on the order of 20 to 30 feet; admittedly, the problem would be complicated by motion of the microwave time-of-arrival navigation system relay platforms. A more flexible scheme would be to use a beacon retransmitter in the bomb and a command system from the central computer for those bombs which are falling to a target, regarding the

SECRET

bomb as just another vehicle in the QRC–334 system. Most of the electronics and control would still remain common with the laser-guided bomb kit. (S)

Similarly, artillery shells could be given an accuracy on the order of 20 feet, independent of range, and indeed, with a terminal guidance system of this type, artillery shells could be fitted with a sabot and folding wings to provide a glide bomb of very long range, with better accuracy than one could ever expect from a single rocket-assisted projectile. (S)

Of course, ground-launched, pulse-jet, surface-to-surface cruise missiles could be used with a similar accurate theater navigation system and guided by the central computer according to a predetermined flight plan, including continuous maneuvering and terrain avoidance by the use of barometric altimeter and the preset flight plan. In this way, CEP's on the order of 20 to 50 feet could be obtained at very great ranges. This same system could be used for very accurate and flexible remote control of multiple photographic reconnaissance drones, reducing their present vulnerability by the provision of continuous, accurately controlled maneuver. (S)

Another advantage of the accurate midcourse navigation system of this type would be the very small region of uncertainty within which final target acquisition would be required for homing weapons. For instance, with a midcourse CEP of 2 miles and with reasonable g limitations on the missile or artillery shell, a region more than two miles across would have to be searched for the particular target. This in itself would then require a visibility of many miles and an adequate ceiling. It would also make active illumination from the missile difficult. Contrast this with a midcourse navigation CEP of 100 feet, which would then allow a region 200 feet in diameter to be searched for the point target, requiring only a few-thousand-foot visibility and no particular ceiling. Further, a small light or forward-fired flare from the missile would suffice for attack at night. In fact, the limitation on target acquisition is likely to be the reaction time of a man in designating via a light pen or a cursor the actual target position in the field of view, this requiring only about 2 sec for such a small uncertainty area and for a known direction of approach. (S)

The remote-guided weapon is related to items previously discussed, in that the remote TV is required for a time of not more than ten seconds. This allows the use of uncooled transmitters, highly directional antennas for the TV transmission, with their orientation fixed on the missile before launch, a highly directional antenna on the balloon or aircraft, providing the elevated line of sight which needs to be devoted to the final target acquisition for each missile or shell for only a few seconds and, thus, which need not be replicated. (S)

The important point is that such a remote-guided cruise missile can be extremely inexpensive, if it flies in the context of these other theater capabilities, which in themselves have other valuable applications. (S)

Airborne MTI for Detecting Personnel and Vehicle Motion

There is now a general consensus that an elevated scanning MTI radar would be extremely valuable in providing overall theater surveillance. Such a PPI-type radar could provide complete surveillance of a theater 200 miles across every minute, as contrasted to a side-looking radar, which would require times in the order of hours to cover the theater, if indeed the resources were available. There is no doubt that the most effective means for mounting and utilizing such a radar is from a high-altitude balloon. There is also no doubt that adequate stabilization of the radar can be obtained in this way and that the operating cost for a balloon is at least two orders of magnitude below that for a usual high-flying aircraft. The operational capability of balloon-borne MTI radar operation remains to be demonstrated, and follow-on improvements in an operational system would presumably include the possibility of a powered balloon to replace a tethered balloon, thereby increasing the capability of the balloon lift and eliminating the small potential hazard to aircraft which the balloon tether implies. (S)

Advanced Mines and Target-Activated Munitions

Although hand-emplaced mines are standard in ground warfare, aerially emplaced mines were not available for use at the beginning of the Vietnam conflict. Land mines have two quite distinct functions: (*1*) To provide an obstacle or barrier in order to deny access for a time to a

SECRET

particular area, and (2) to be used as strike munitions against moving targets and, thus, to provide a higher kill probability than is possible with a contact-burst weapon [the vehicle-kill probability for an unguided weapon goes as $(R_k/\text{CEP})^2$, while for a strike mine the kill probability goes as (R_k/CEP) with R_k the kill radius and CEP the delivery error]. For CEP of 300 to 500 feet and for kill radii on the order of 20 feet, a strike mine can be 25 times as effective as the same weapon used as a bomb. (S)

It would be of extreme value to our ground forces to be able to emplace expeditiously a barrier (like a river). Mines far less detectable than the Gravel and the Dragontooth are possible by the use of nondrying glue, as proved with the so-called "noiseless button bomblet." An all-mechanical mine is possible with an infinite storage life, with an end-of-life timer operating by the slow ejection of a viscous fluid through a porous plug by means of a strong spring. Such mines can readily be built with the armed life ranging from 10 minutes to many months and with the variability in a given theater probably on the order of 10 percent. Certainly, such mines should be mixed with antidisturbance fuzed mines of a similar type, to prevent easy and cheap sweeping. (S)

The finite storage life of batteries and the concomitant requirement for refrigerated storage are extremely awkward and expensive features of many mines. A modicum of battery development—for instance, using wax-encapsulated electrolytes, so that the mine can be prepared for implanting simply by heating it beyond the melting point of the wax—would greatly improve the acceptability of this important munition. Remember the glass-encapsulated electrolyte of the World War II proximity fuze! Improved burying qualities, comparable to that of the deployable afterbody of the DCPG sensors, would greatly improve the effectiveness of antivehicular mines. Such characteristics might be obtained by a terrabrake, which remains folded against the sides of the mine case until the mine penetrates solid material, at which time a spring or small structural member's strength is overcome and the terrabrake opens to slow the mine. (S)

In any case, antivehicular and antipersonnel strike mines with short life, low-cost antivehicular mines, and low-cost, convenient, antipersonnel mines of long shelf life and long field life would provide an extremely effective capability for our forces. (S)

The Mark-36 Destructor, a magnetically fuzed 500-lb Navy shallow-water mine has been used by the tens of thousands in *land* interdiction in North Vietnam and Laos. This mine costs only some $500, including fuze. Its effectiveness against vehicles could be much increased by providing a "lifter charge" and a short delay fuze to allow the mine to be expelled from the ground and to burst in the air rather than underground.

Summary

The key to enhanced tactical capabilities at a bearable price seems to lie in the provision of theater support capabilities dependent on elevated relay platforms to provide computer-controlled communication, high-precision navigation and direction, and remote vision and MTI radar. Improved munitions—navigation-guided bombs, expanded use of laser-guided bombs, and wider understanding of the utility of strike mines—would further increase our capabilities for destroying defended targets in bad weather and at night.

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