Military Communication: The Chaos Factor

Detonation of a thermonuclear device in space over North American may interrupt the operation of electronic equipment and communications gear. The military could lose control over the many nuclear-equipped bases around the world.

by Roger Allan

IN JULY, 1962, the U.S. Military detonated a 1.4 megaton hydrogen bomb 248 miles above Johnson Atoll in the Pacific. While the test was successful, and the military learned what they wanted about the effect of such blasts on radar and radio signals, there were a series of odd occurences which intrigued a number of physicists. 800 miles away in Hawaii, for instance, burglar alarms had rung, street lights had failed and circuit breakers had popped open in power lines. Investigation showed that similar unexpected side effects of the blast had occurred in a number of electrical systems on islands in a 1000 mile radius of the blast. While the blast was expected to momentarily upset the ionosphere, these sorts of occurences did not fit the presuppositions of the military scientists.

Today, after investigation, the cause is known as the electromagnetic pulse (EMP), and potentially is the most serious and grave danger to the U.S. military's command, control and communication (C^3) capability — forcing it into a situation whereby the military commanders would not have the system to communicate and hence to control the worldwide U.S. military forces, resulting in an all-out nuclear war or surrender: a Hobson's choice between "using it or losing it."

All nuclear explosions produce electromagnetic pulses. However, only high-altitude bursts produce pulses whose effects extend far beyond the radius of direct destruction. Because the high-altitude source region exists between 20 and 40 km, and because this source region can extend many thousands of kilometers in diameter, the area of EMP coverage on the ground in relatively large. Typically, the maximum effects occur in the source region at a burst height between 40 and 400 km.

At these high altitudes, gamma rays produced in the first few milliseconds of a nuclear explosion can travel hundreds of kilometers before encountering electrons in atmospheric molecules. For a 10 megaton burst at an altitude of 400 km, this region of collision is about 3000 km in diameter and 10 km thick. The Compton electrons — those scattered by the gamma rays and named for the discoverer of this effect, Arthur H. Compton — are accelerated by these collisions, encounter the earth's magnetic field and are deflected, producing a transverse electric current. This current in turn sets up the electromagnetic pulses, which radiate downward toward the earth as EMP's.

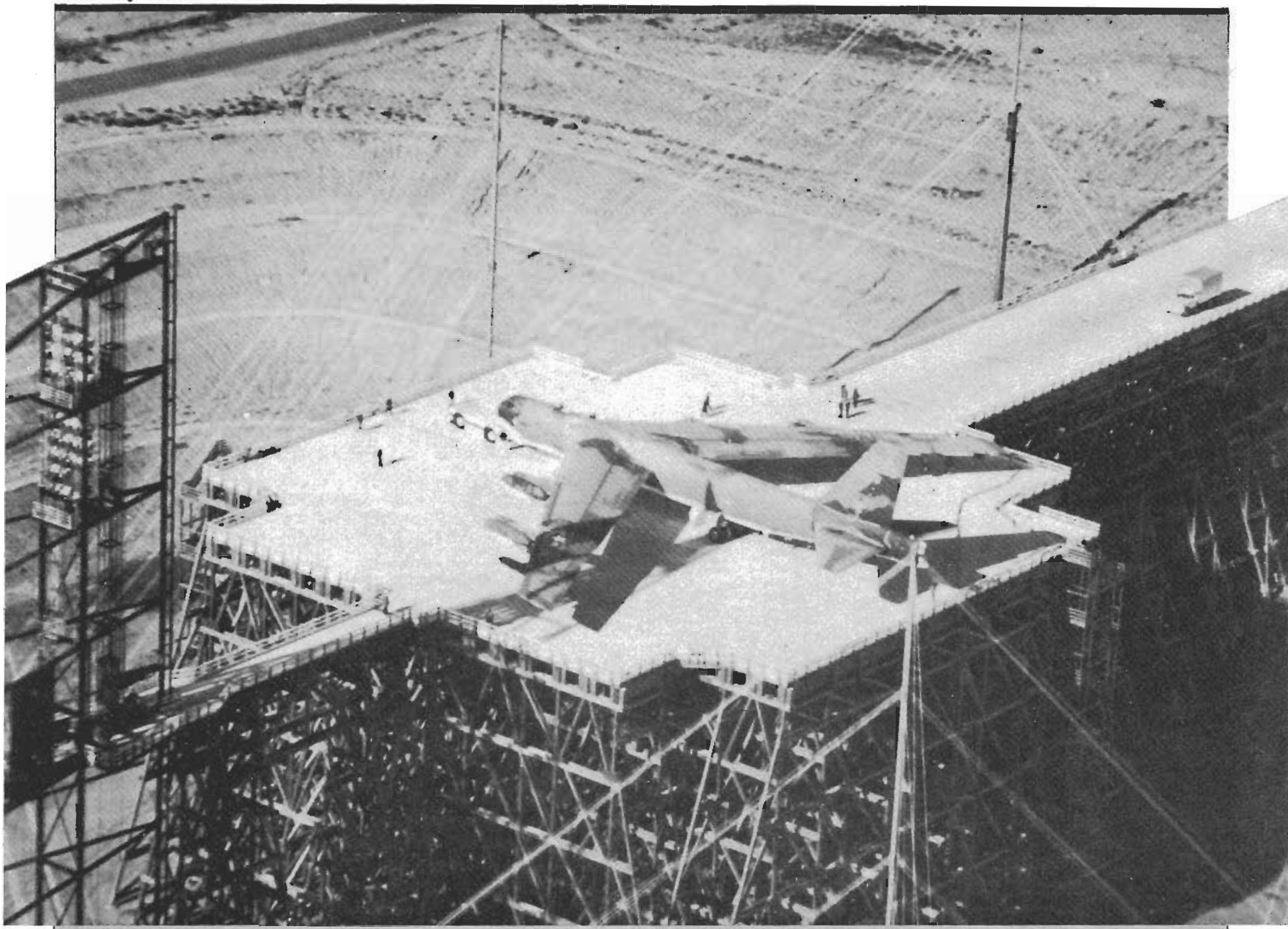
The EMP's rise very rapidly, reaching a peak field in only about 10 nS, then tail off in about 1 microsecond. As a result of this sharply peaked waveform, the power of the EMP's is spread over a broad band of frequencies.

EMP's may affect an area of 500 to 800 miles or more, depending on the height and yield of the burst. A typical one-megaton warhead can produce peak fields within this area of 50,000 V/m. The instanteous power density over this area is very high — typically about 6 MW/m², or 4000 times the radiation power received from the sun. However, since the pulse is of short duration, the total energy received is relatively small — about 0.6 J/m².

Any conductor within the very large area of EMP effects will act as an antenna to pick up the electromagnetic pulses. Long distance power transmission lines are particularly effective in picking up the lower-frequency components of the pulse. The magnitude of the current pulse induced in such power lines is highly variable, depending on the location and orientation of the line relative to the burst and the size and height of the burst. In a worst case scenario, peak voltages can be 3 MV, peak amperages 10 KA, and peak power 30,000 MW. This is two orders of magnitude above the design capabilities of virtually all power transmission lines and, thus, more than enough to trip current fault sensors and damage insulation. Despite these very high powers, total energy in a current pulse would not be extremely large (generally on the order of thousands or tens of thousands of joules) because of the microsecond duration of the induced pulse.

The voltage and amperage of such EMP-induced currents are comparable to those of the very largest lightning bolts, and the rise times of the currents (a few hundred nanoseconds) are considerably faster than those of lightning bolts. A far more significant difference between EMP's and lightning is that the EMP's are induced simultaneously throughout the entire grid and not just at a single locality.

Low frequency effects of EMP's can also induce large currents and voltages in long-distance communications and telephone links, while the high-frequency components would be picked up by circuits within electronic and electrical ap-



An EMP test facility in Nevada. A B-52 bomber is supported on a wooden trestle held together by 250,000 wooden pegs. The electrical system produces very high power nanosecond pulses for testing the effect of EMP on aircraft. (Photo courtesy of U.S. Air Force).

paratus of all sorts, even so far as destroying the microcomputers in automobiles and aircraft.

The significance of EMP was only slowly learned and accepted by the military. In the late 1950's, both the United States and the Soviet Union commenced a series of atmospheric nuclear tests. The U.S. launched two in 1958, one at a height of 27 miles, the other at 48 miles. As a prelude to arms negotiations, the U.S. and U.S.S.R., in 1959, agreed to a moratorium on atmospheric testing, pending conclusion of negotiations for a limited test ban treaty. In 1961 the Soviets broke the moratorium and launched a series of atmospheric tests. The U.S. was caught flat-footed, and it took some time before they were ready and able to follow suit. The explosion on 8 July, 1962, which gave the first indication of EMP as mentioned, was one of this U.S. series. By the time the U.S. had finished its series and was analysing its data, considering what to do next, the Soviets launched a second series of tests described with 20/20 hindsight as "far more elegant" *viz a viz* EMP than the immediately previous US series. By the time the US was in a position to launch a second series which included primitive EMP tests, the limited test ban treaty had been signed. No further atmospheric tests have been conducted by either side in the subsequent 19 years.

The importance of this little piece of historical chronology is two-fold. First, the US conducted its tests in the Pacific, miles from anywhere, where electrical systems in neighbouring islands (even Hawaii) were relatively primitive by EMP standards, depending primarily on vacuum tubes and a few transistors. These, it has subsequently been learned, are ten million times less susceptible to EMP than are integrated circuits. Further, the ships used by the US Navy to carry the test monitoring equipment were of WW II vintage — their radars and communication gear likewise being primarily vacuum tube dependent. As such the total body of available data, that is, equipment and facilities which were effected by the EMPs and available for study, was relatively sparse. The Soviets, on the other hand, undertook their testing over south/central Siberia. While the population of such areas is slight, there are a number of cities and factories which had transistors and elementary circuits for use in communication and industrial control, along with military bases and their "state of the art" equipment. It is felt, again with 20/20 hindsight, that due to the Soviet population density and industry over which the tests were conducted, the Soviets were aware of EMP far earlier than the Americans, and that part of the design of their second series of tests was predicated on learning more about it.

Secondly, there is political thought that the Soviets hastened the signing of the test ban treaty, conceding a number of points during negotiations, such that they would be placed in the position of knowing about EMP effects while denying the US the testing procedure necessary for them to find out about them. This is demonstrated by the Mig-25 (Foxbat), a pillar of Soviet aerial defences which, at the time one was flown to Japan in 1976 by a defector, was considered by the Americans to be the best fighter-interceptor in the world. Inspection of the aircraft showed a number of points which puzzled the investigators. While the engines were state-of-the-art, the fuselage was constructed of steel rather than titanium, and its electronic circuitry, while of good design, including in the words of **Jane's All the World's Aircraft** (1981), its "high quality airborne computer," depended on vacuum tubes for those circuits located near to the aircraft's skin, and only depended on integrated circuits buried deep in the mainframe. Steel and vacuum tubes are far more EMP resistant than titanium and integrated circuits. The debate around this aircraft concerns whether or not the Soviet knowledge of EMP is so advanced that they are deliberately designing their aircraft to be EMP resistant, or whether the use of steel is due to Soviet industrial difficulties and the use of vacuum tubes due to the slow dissemination of integrated circuit technology through the military/industrial complex.

A third interpretation is that the defection was faked — being an instance of deliberate "misinformation".

The American failure to properly understand EMP for so many years, coupled with the Pentagon's inherent unwillingness to accept that their C^3 system would collapse within two or three minutes of a Soviet submarine launching a warhead into the appropriate area above central United States, has already cost billions of wasted dollars.

An example of such wastage is the **Safeguard** anti-ballistic missile defense system consisting of some 100 nuclear-tipped **Spartan** missiles located in silos at 12 fields primarily in northern Dakota. Upon a Soviet missile onslaught, the **Spartan** missiles would be fired, and when approaching a Soviet missle at a height of 160 km, would dissolve into a silent ball of nuclear fire, destroying the missile. Unfortunately, the explosion would also bathe the United Sates in an EMP pulse, destroying the military's C^3 system. The silos now stand empty, quiety filling with ground water. It appears that the Bell System, which is the Pentagon's prime contractor for C^3 systems, and which was the prime design contractor for the **Safeguard** system, had designed one system in such a fashion that if it had been successful (**Safeguard**) it would have destroyed the second system (C^3). **Safeguard** was declared operational on April Fool's Day, 1975, and stood down as non-operational 10 months later. It cost $5.7 billion.

The Pentagon is now asking Congress for another anti-ballistic missile system, also to operate outside the earth's atmosphere, but dependent on non-nuclear warheads.

A further indication of the fuzziness surrounding EMP thinking is that the **Safeguard** system itself was EMP proof — continuous steel shields being wrapped around critical equipment including the radars, emplaced interceptors and computers.

While this is the most expensive EMP fiasco, there had been other, earlier, ones which during the late 60's had forced the Pentagon to admit, albeit grudgingly, that EMP was a subject worthy of research. Commencing in the late 1960's, the Nuclear Defense Agency, the Pentagon's prime research organization, started to upgrade EMP research priority, such that by 1971 it was running at about 250 million dollars per year. This rate slowly rose from that level until the early 1980's when, in an unprecedented request, the Pentagon asked Congress for 7.4 *billion* dollars to be directed over the next five years on EMP research. The request, at time of writing, is still pending.

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The urgency represented by the Pentagon's request lay in EMP's effect on the military's C^3 capability and hence its ability to wage war. Very little of it has been EMP proofed, primarily because of the number of connections involved. Customarily, lightning and surge arrestors do not work due to the fast rise times of the surges. Components can be designed such that a connection is EMP proofed, but this would require the retro-fit of Faraday shields around equipment and these special connections in every circuit throughout the entire command structure. Even so much as a single unproofed wire coming into, say, a computer could result in the destruction of that computer's entire memory. It is therefore not a question of "plugging" most holes and hoping the system will still have sufficient redundancy that it will continue to function, but rather the necessity of "plugging" every hole or the whole lot fails. The retro-fit cost has been conservatively estimated at 250 *billion* dollars spread over the remainder of the decade.

The rulebooks of war say that the President has 43 different ways of sending out what is known as an Emergency Action Message (EAM) to the strategic US nuclear forces. This is sometimes referred to as the "call to arms." Essentially, and in very broad generalities, the President faced with the reality of an incoming Soviet missile strike has two choices — to fight an instantaneously ordered, all-out, massive counterstrike involving every weapon at his disposal, or he can try to fight a limited, but protracted nuclear war, trying to keep the casualties down, trying not to end humanity: what the current Vice-President once described as a "winnable" nuclear war. An all-out strike is relatively easy to wage: a single order received by the various components of the world-wide strategic forces telling them to fire, which they then do. But a protracted war is a very different organizational problem. A monumentally vast number of orders have to be cut, transmitted, received coherently and executed within very tight time parameters. This requires a very wide array of totally secure and unjammable communication nets, operating within very tight time parameters and essentially error free. With the recognition of EMP, it appears that the US C^3 networks would cease to function in very short order (a matter of minutes), not only isolating the President from the military, but isolating each and every small unit of the military from each other. In other words, there would be a thousand commanders of the thousand Minuteman silos not knowing what on earth is going on or what to do about it: to fire or not to fire. Some would fire, some wouldn't. But the important point is that there would be no cohesion, no operational plan surrounding their actions — they'd be fighting a nuclear war blindfolded. A thousand little gods. It is this that has the military worried. In the light of this problem, in 1982, the Secretary of Defense, Caspar Weinberger, called together a high-level, service-wide "strategic connectivity executive review board" to "wrestle" with the problem of designing a communications system better able to survive the effects of nuclear war. To date, its major finding has been to support the Pentagon's request for EMP research money.

The most unreliable portion of C^3 is the ground-based communication links. For one thing, the amount of EMP picked up and delivered to sensitive electronic equipment depends on the length of the collector. The short antenna of an FM radio picks up hardly anything. A global communications web of copper wires, microwave towers, switching centres and command posts picks up a great deal. Moreover, the sheer size of such a network makes it almost impossible to test it exhaustively for hardness to the effects of EMP, and the few tests carried out have not been encouraging.

An example of this is the Autovon network, a high-priority system built by Bell Systems for the government. It is supposed to be "nuclear bombproof". In 1975 a section of it, specifically a switching centre, was tested as to its EMP resistant capabilities. It turned out it had none, stopped dead, and took four and a half days to get working again. Autovon, the Pentagon's major C^3 ground link, has hundreds of such switching centres.

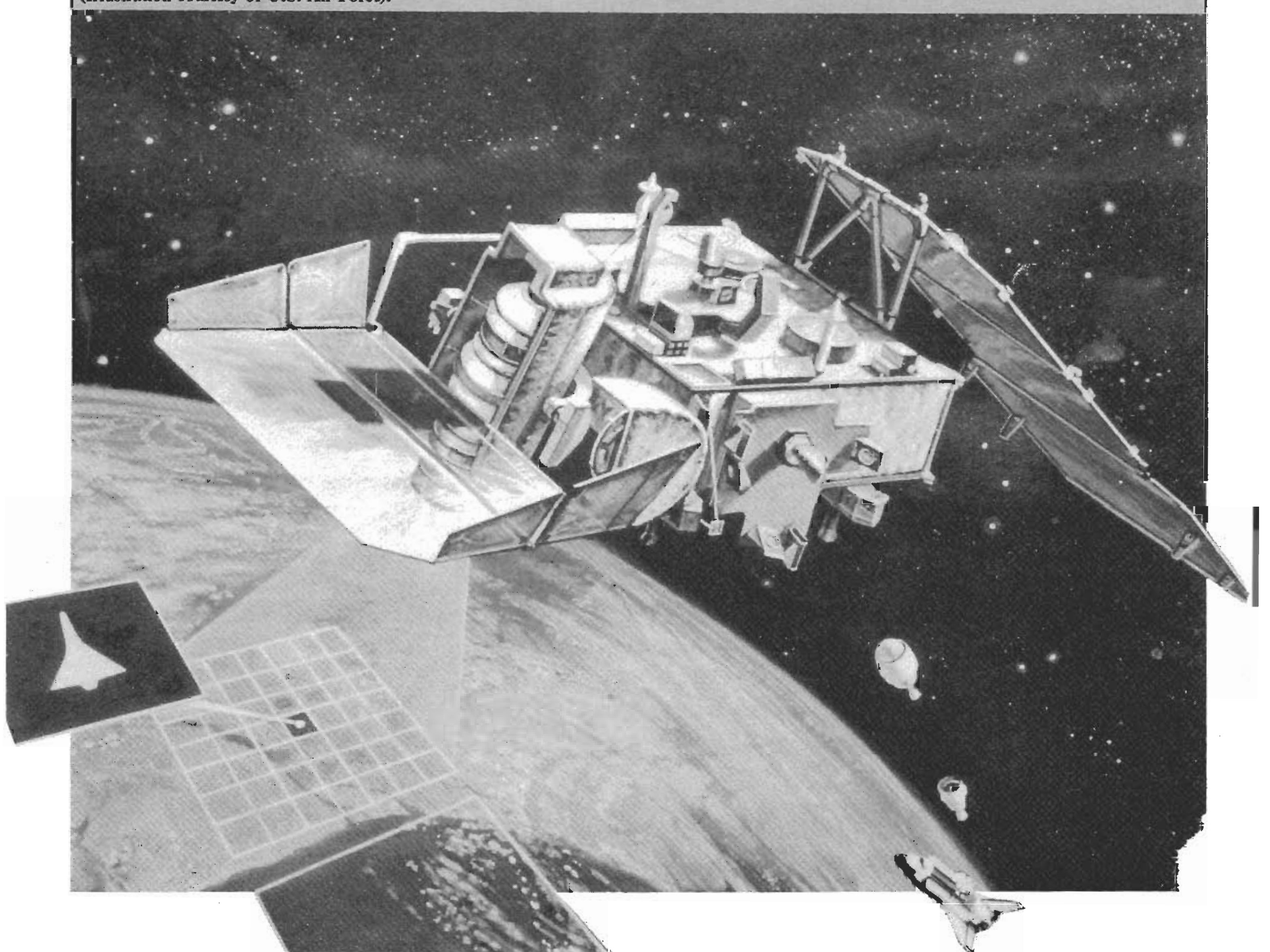
A second example of where EMP could destroy the US C^3 capability is at the Presidential/Pentagon interface. The Presidential airborne command posts are four specially designed Boeing 747s. Only one plane is EMP hardened. The other three, on call 15 days out of every month, have as many as 11,500 essential circuits that would fail if the planes were hit by an electric pulse from a nuclear burst thousands of kilometers away. The hull construction (windows, doors, cable connections) that would admit EMP will not be sealed until late 1983.

There are essentially four ways to harden the system. One, was mentioned above — retro-fit surge arrestors. The second is to increase the use of fibre optics which are unaffected by EMP. One of the reasons the Carter Administration cancelled the B-1 bomber was that its control and communications ability would be knocked out by EMP. A new bomber proposed by the Reagan Administration is to have as much of its system composed of fibre optics as possible. So also is the MX missile. Still, as mentioned in a previous article on integrated optics ("Light Memory", ETI, August 1982) no one has as yet designed an opto-electronic switch, and hence no fibre optic system can be considered EMP proof — the EMP affecting the system at the electrical-laser interface. None the less, the Pentagon is purchasing fibre optics in very large quantities and pressuring Bell Systems to hasten its fibre optic usage in main corridor telephone trunk routes such as the Washington to Boston corridor ("Fibre Optics", ETI, June 1982).

A third way is via the development of the Ground Wave Emergency Network (GWEN). The system, still under development, will consist of a grid of unmanned EMP hardened relay nodes operating at the LF Band. Network terminals will be located at major command centres, warning sensor sites and force element command posts. These terminals will have the capability to support two-way data communications in a nuclear environment.

A fourth way is to increase the use of satellite communication links in the military's total C^3 posture, and in fact the Pentagon relies on such satellite links for more than 70 percent of its long-haul communications. Half of this capacity is leased by the Pentagon from commercial vendors and half is provided by Pentagon-owned satellites such as those of the Defense Satellite Communications System. The Air Force is thinking of installing satellite ground stations at the phased-array radars just going into operation along the Massachusetts and California coasts. Plans are underway to equip the launch control centres of the 1000 *Minuteman* missile silos scattered across the American heartlands with satellite ground stations. At least 400 Navy ships have satellite links, and so on. While cost

An artist's concept of the Space Test Program satellite used for surveillance. These satellites, while effective, are vulnerable to anti-satellite weapons. (Illustration courtesy of U.S. Air Force).



is one of the reasons the Pentagon increasingly relies on satellites, a major reason is survivability. X-rays from a nuclear blast in space can produce a high voltage electric pulse in a satellite (called 'system generated EMP'). But unlike huge ground based networks, a satellite can be tested to ensure that EMP hardening procedures work. A factor against satellites is that they are vulnerable to Soviet satellite killers and the possibility of a direct nuclear hit. It is for this reason that the Strategic Satellite System proposed by the Air Force was scrapped. It was decided that a "proliferated" system was more survivable than a handful of "dedicated" emergency satellites which could be easily spotted and attacked. As such, dozens of US satellites whose primary mission lies elsewhere are equipped to send war messages. The Navstar Global Positioning Satellites, for example, carry an additional payload known as a single channel transponder for EAM signals.

Yet when all is said and done, executing an EMP attack against the United States with the chaos and pandemonium that would result, forcing the American President into a "use it or lose it" Hobson's choice, is simplicity itself. All that would be required is one thermonuclear bomb detonated high above the central United States, and the US power grid would shut down; all electrical appliances

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without a separate power supply stopping, commercial telephone lines going dead, military channels going off the air. Yet this is a worst case scenario, based on the calculation of physicists who in the early 1960's looked at a few unanticipated events surrounding a 248 mile high weapons test in the Pacific and wove them into a theory that predicts catastrophic events. Perhaps they were wrong.

It is precisely due to this uncertainty that the Defense Nuclear Agency has, for funding purposes, latched so carefully onto what is known as the Jackson Safeguards. In 1963 when the Limited Test Ban Treaty was on the Senate floor, Senator Jackson proposed four conditions for the Senate's acceptance of the treaty. The third of these calls for the US to maintain an "atmospheric test readiness capability", such that should the Soviets break the treaty, the US would be instantly capable of commencing exoatmospheric nuclear testing. The Defense Nuclear Agency is empowered to fullfill this criterion, and does so in part by the maintenance of a 165-person force on Johnson Atoll in the Pacific. Under their direction is a missile launch site with a thermonuclear warhead ready for installation and firing. Three days after the Soviets broke the test ban treaty, the US would have fired the missile, detonated the bomb exoatmospherically and determined once and for all whether the EMP threat is as great as believed, and whether the hardening procedures work.

Until then, or until a nuclear war occurs, a slight question mark remains. But only a slight one. ETI