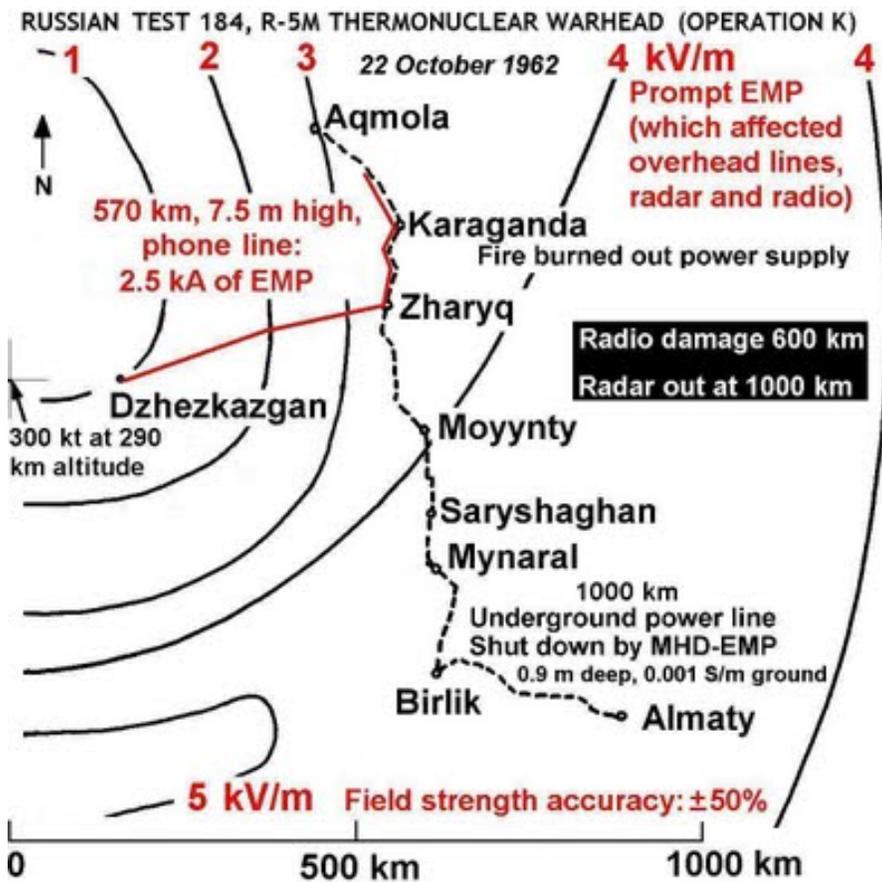


# Nuclear weapons test effects: debunking popular exaggerations that encourage proliferation

'I did not think, I investigated.' - Wilhelm Röntgen, discoverer of X-rays in 1895, answering Sir James Mackenzie-Davidson's question in 1896: 'What did you think?' J. J. Thomson in 1894 discovered visible evidence of X-rays: glass fluorescence far from a cathode ray tube. But his expert opinion was that it was unimportant! 'Science is the organized skepticism in the reliability of expert opinion.' - Richard Feynman in Lee Smolin, *The Trouble with Physics*, Houghton-Mifflin, 2006, p. 307.

Wednesday, March 29, 2006

## EMP radiation from nuclear space bursts in 1962

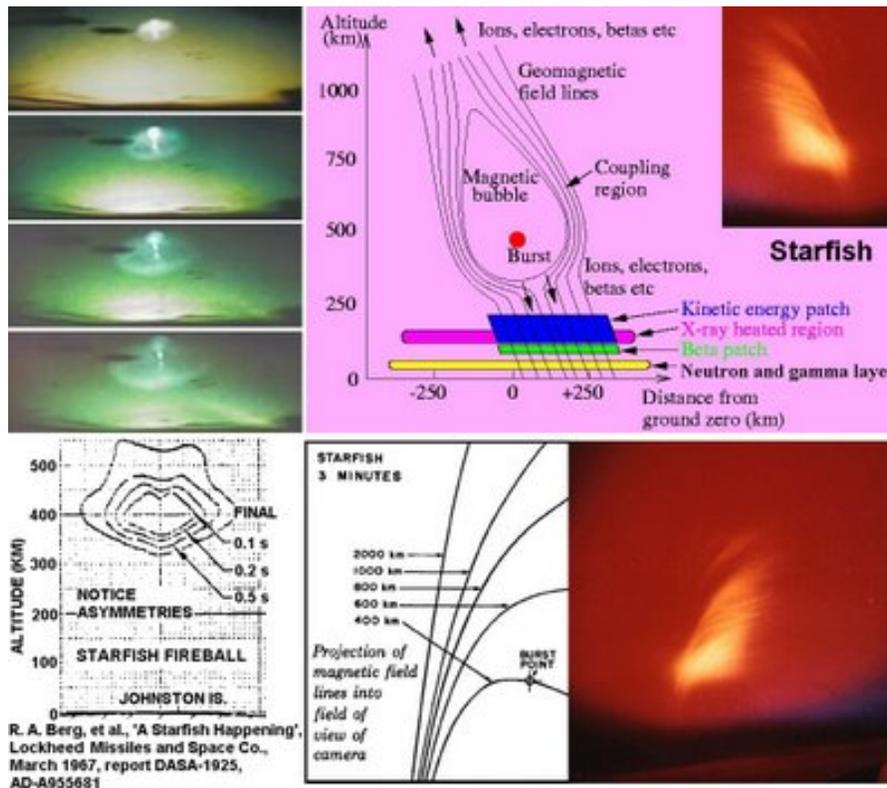


**Above:** USSR Test '184' on 22 October 1962,

'Operation K' (ABM System A proof tests) 300-kt burst at 290-km altitude near **Dzhezkazgan**. Prompt gamma ray-produced EMP induced a current of 2,500 amps measured by spark gaps in a 570-km stretch of 500 ohm impedance overhead telephone line to Zharyq, blowing all the protective fuses. The late-time MHD-EMP was of low enough frequency to enable it to penetrate the 90 cm into the ground, overloading a shallow buried lead and steel tape-protected 1,000-km long power cable between Aqmola and **Almaty**, firing circuit breakers and setting the **Karaganda** power plant on fire.

In December 1992, the U.S. Defence Nuclear Agency spent \$288,500 on contracting 200 Russian scientists to produce a 17-chapter analysis of effects from the Soviet Union's nuclear tests, which included vital data on **three underwater nuclear tests in the arctic**, as well three 300 kt high altitude tests at altitudes of 59-290 km over Kazakhstan. In February 1995, two of the military scientists, from the Russian Central Institute of Physics and Technology, lectured on the

electromagnetic effects of nuclear tests at Lawrence Livermore National Laboratory. The Soviet Union had first suffered electromagnetic pulse (EMP) damage to electronic blast instruments in their 1949 test. Their practical understanding of EMP damage eventually led them, on Monday 22 October 1962, to detonate a 300 kt missile-carried thermonuclear warhead at an altitude of 300 km (USSR test 184). That was at the very height of the Cold War and the test was detected by America: at 7 pm that day, President John F. Kennedy, in a live TV broadcast, warned the Soviet Union's Premier Khrushchev of nuclear war if a nuclear missile was launched against the West, even by an accident: 'It shall be the policy of this nation to regard any nuclear missile launched from Cuba against any nation in the Western hemisphere as an attack by the Soviet Union on the United States, requiring a full retaliatory response upon the Soviet Union.' That Russian space missile nuclear test during the Cuban missiles crisis *deliberately* instrumented the civilian power infrastructure of populated areas, unwarned, in Kazakhstan to assess EMP effects on a 570 km long civilian telephone line and a 1,000 km civilian electric power cable! This test produced the worst effects of EMP ever witnessed (*the more widely hyped 1.4 Mt, 400 km burst STARFISH EMP effects were trivial by comparison, because of the weaker natural magnetic field strength at Johnston Island*). The bomb released  $10^{25}$  MeV of prompt gamma rays (0.13% of the bomb yield). The 550 km East-West telephone line was 7.5 m above the ground, with amplifiers every 60 km. All of its fuses were blown by the induced peak current, which reached 2-3 kA at 30 microseconds, as indicated by the triggering of gas discharge tubes. Amplifiers were damaged, and lightning spark gaps showed that the potential difference reached 350 kV. The 1,000 km long Aqmola-Almaty power line was a lead-shielded cable protected against mechanical damage by spiral-wound steel tape, and buried at a depth of 90 cm in ground of conductivity  $10^{-3}$  S/m. It survived for 10 seconds, because the ground attenuated the high frequency field, However, it succumbed completely to the low frequency EMP at 10-90 seconds after the test, since the low frequencies penetrated through 90 cm of earth, inducing an almost direct current in the cable, that overheated and set the power supply on fire at Karaganda, destroying it. Cable circuit breakers were only activated when the current finally exceeded the design limit by 30%. This limit was designed for a brief lightning-induced pulse, not for DC lasting 10-90 seconds. By the time they finally tripped, at a 30% excess, a vast amount of DC energy had been transmitted. This overheated the transformers, which are vulnerable to short-circuit by DC. Two later 300 kt Soviet Union space tests, with similar yield but low altitudes down to 59 km, produced EMPs which damaged military generators.



Above: the **STARFISH** (1.4 Mt, 400 km detonation altitude, 9 July 1962) detonation, seen from a

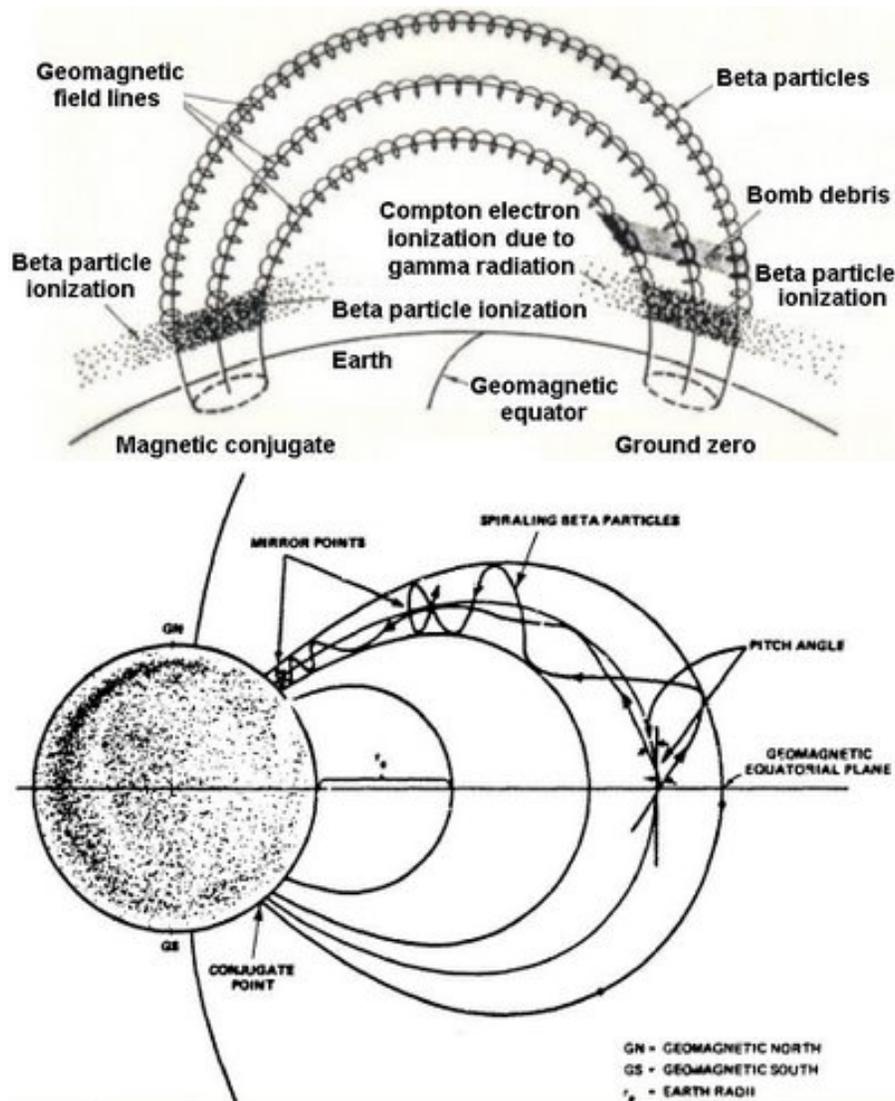
mountain above the low-level cloud cover on Maui, consisted of a luminous debris fireball expanding in the vacuum of space with a measured initial speed of 2,000 km/sec. (This is 0.67% of the velocity of light and is 179 times the earth's escape velocity. Compare this to the initial upward speed of only 6 times earth's escape velocity, achieved by the 10-cm thick, 1.2 m diameter steel cover blown off the top of the 152 m shaft of the 0.3 kt **Plumbbob-Pascal B** underground Nevada test on 27 August 1957. In that test, a 1.5 m thick 2 ton concrete plug immediately over the bomb was pushed up the shaft by the detonation, knocking the welded steel lid upward. This was a preliminary experiment by Dr Robert Brownlee called 'Project Thunderwell', which ultimately aimed to launch spacecraft using the steam pressure from deep shafts filled with water, with a nuclear explosion at the bottom; an improvement of Jules Verne's cannon-fired projectile described in **De la Terre à Lune**, 1865, where steam pressure would give a more survivable gentle acceleration than Verne's direct impulse from an explosion. Some 90% of the radioactivity would be trapped underground.) The film: 'shows the expansion of the bomb debris from approximately 1/3 msec to almost 10 msec. The partition of the bomb debris into two parts ... is shown; in particular the development of the "core" into an upwards mushroomlike expansion configuration is seen clearly. The fast moving fraction takes the shape of a thick disc. Also the interaction of the bomb debris with the booster at an apparent distance (projected) of approximately 1.5 km is shown.' (Page A1-38 of the quick look report.)

In this side-on view the fireball expansion has a massive vertical asymmetry due to the effects of the device orientation (the dense upward jetting is an asymmetric weapon debris shock wave, due to the missile delivery system and/or the fact that the detonation deliberately occurred with 'the primary and much of the fusing and firing equipment' vertically above the fusion stage, see page A1-7 of the quick look technical report linked here): 'the **STARFISH** test warhead was inverted prior to the high-altitude test over Johnston Island in 1962 because of concerns that some masses within the design would cause an undesirable shadowing of prompt gamma rays and mask selected nuclear effects that were to be tested.' (April 2005 U.S. Department of Defense **Report of the Defense Science Board Task Force on Nuclear Weapon Effects Test, Evaluation, and Simulation**, page 29.). The earth's magnetic field also played an immediate role in introducing asymmetric fireball expansion as seen from Maui: 'the outer shell of expanding bomb materials forms ... at ... 1/25 to 1/10 sec, an elongated ellipsoidal shape with the long axis orientated along the magnetic field lines.' (Page A1-12 of the quick look report.)

The **STARFISH** test as filmed from Johnston Island with a camera pointing upwards could not of course show the vertical asymmetry, but it did show that the debris fireball: 'separated into two parts ... the central core which expands rather slowly and ... an outer spherically expanding shell ... The diameter of the expanding shell is approximately 2 km at 500 microseconds ...' (William E. Ogle, Editor, **A 'Quick Look' at the Technical Results of Starfish Prime**, August 1962, report JO-600, AD-A955411, originally secret-restricted data, p. A1-7.) Within 0.04-0.1 second after burst, the outer shell - as filmed from Maui in the Hawaiian Islands, had become elongated along the earth's magnetic field, creating an ellipsoid-shaped fireball. Visible 'jetting' of radiation up and southward was observed from the debris fireball at 20-50 seconds, and some of these jets are visible in the late time photograph of the debris fireball at 3 minutes after burst (above right).

The analysis of **STARFISH** on the right was done by the Nuclear Effects Group at the Atomic Weapons Establishment, Aldermaston, and was briefly published on their website, with the following discussion of the 'patch deposition' phenomena which applied to bursts above 200 km: 'the expanding debris compresses the geomagnetic field lines because the expansion velocity is greater than the Alfven speed at these altitudes. The debris energy is transferred to air ions in the resulting region of tightly compressed magnetic field lines. Subsequently the ions, charge-exchanged neutrals, beta-particles, etc., escape up and down the field lines. Those particles directed downwards

are deposited in patches at altitudes depending on their mean free paths. These particles move along the magnetic field lines, and so the patches are not found directly above ground zero. Uncharged radiation (gamma-rays, neutrons and X-rays) is deposited in layers which are centered directly under the detonation point. The *STARFISH* event (1.4 megatons at 400 km) was in this altitude regime. Detonations at thousands of kilometres altitude are contained purely magnetically. Expansion is at less than the local Alfvén speed, and so energy is radiated as hydromagnetic waves. Patch depositions are again aligned with the field lines.'



The Atomic Weapons Establishment site also showed a Monte Carlo model of *STARFISH* radiation belt development, indicating that the electron belt stretched a third of the way around the earth's equator at 3 minutes, and encircled the earth at 10 minutes. The averaged beta particle radiation flux in the belt was  $2 \times 10^{14}$  electrons per square metre per second at 3 minutes after burst, falling to a quarter of that at 10 minutes. As the time goes on, the radiation belt pushes up to higher altitudes and becomes more concentrated over the magnetic equator. For the first 5 minutes, the radiation belt has an altitude range of about 200-400 km and spans from 27 degrees south of the magnetic equator to 27 degrees north of it. At 1 day after burst, the radiation belt height has increased to the 600-1,100 km zone and the average flux is then  $1.5 \times 10^{12}$  electrons/m<sup>2</sup>/sec. At 4 months the altitude for this average flux (plus or minus a factor of 4) is confined to altitudes of 1,100-1,500 km, and it is covering a smaller latitude range around the magnetic equator, from about 20 degrees north to about 20 degrees south. At 95 years after burst, the remaining electrons will be 2,000 km above the magnetic equator, the latitude range will be only plus or minus 10 degrees from the equator, and the shell will only be 50 km thick.

When *STARFISH* was detonated: 'The large amount of energy released at such a high altitude by the detonation caused widespread auroras throughout the Pacific area, lasting in some cases as long as 15 minutes; these were observed on

both sides of the equator. In Honolulu an overcast, nighttime sky was turned into day for 6 minutes (*New York Times*, 10 July 1962). Observers on Kwajalein 1,400 nautical miles (about 2,600 km) west reported a spectacular display lasting at least 7 minutes. At Johnston Island all major visible phenomena had disappeared by 7 minutes except for a faint red glow. The earth's magnetic field [measured at Johnston] also was observed to respond to the burst. ... On 13 July, 4 days after the shot, the U.K. satellite, Ariel, was unable to generate sufficient electricity to function properly. From then until early September things among the satellite designers and sponsors were "along the lines of the old Saturday matinee one-reeler" as the solar panels on several other satellites began to lose their ability to generate power (reference: *The Artificial Radiation Belt*, Defense Atomic Support Agency, 4 October 1962, report DASA-1327, page 2). The *STARFISH* detonation had generated large quantities of electrons that were trapped in the earth's magnetic field; the trapped electrons were damaging the solar cells that generated the power in the panels.' (Defense Nuclear Agency report DNA-6040F, AD-A136820, pp. 229-30.)



Above: the conjugate region aurora from *STARFISH*, 4,200 km from the detonation, as seen from Tongatapu 11 minutes after detonation. (Reference: W. P. Boquist and J. W. Snyder, 'Conjugate Auroral Measurements from the 1962 U.S. High Altitude Nuclear Test Series, in *Aurora and Airglow*, B. M. McCormac, Ed., Reinhold Publishing Corp., 1967.) A debris aurora caused by fission product ions travelling along magnetic field lines to the opposite hemisphere requires a burst altitude above 150 km, and in the *STARFISH* test at 400 km some 40% of the fission products were transported south along the magnetic force field into the conjugate region (50% was confined locally and 10% escaped into space). The resulting colourful aurora was filmed at Tongatapu (21 degrees south) looking north, and it was also seen looking south from Samoa (14 degrees south). The *STARFISH* debris reached an altitude of about 900-km when passing over the magnetic equator. The debris in the conjugate region behaves like the debris remaining in the burst locale; over the course of 2 hours following detonation, it simply settles back down along the Earth's magnetic field lines to an altitude of 200 km (assuming a burst altitude exceeding 85 km). Hence, the debris is displaced towards the nearest magnetic pole. The exact 'offset distance' depends simply upon the angle of the Earth's magnetic field lines. The ionisation in the debris region is important since it can disrupt communications if the radio signals need to pass through the region to reach an orbital satellite, and also because it may disrupt radar systems from spotting incoming warheads (since radar beams are radio signals which are attenuated).

In the Pacific nuclear high altitude megaton tests, communications using ionosphere-reflected high frequency (HF) radio were disrupted for hours at both ends of the geomagnetic field lines which passed through the detonation point. However, today HF is obsolete and the much higher frequencies involved do not suffer so much attenuation. Instead of relying on the ionosphere and conducting ocean to form a reflecting wave-guide for HF radio, the standard practice today is to use microwave frequencies that penetrate right through the normal ionosphere and are beamed back to another area by an orbital satellite. These frequencies can still be attenuated by severe ionisation from a space burst, but the duration of disruption will be dramatically reduced to seconds or minutes.

'Recently analyzed beta particle and magnetic field measurements obtained from five instrumented rocket payloads located around the 1962 *Starfish* nuclear burst are used to describe the diamagnetic cavity produced in the geomagnetic field. Three of the payloads were located in the cavity during its expansion and collapse, one payload was below, and the fifth was above the fully expanded cavity. This multipoint data set shows that the cavity expanded into an elongated shape 1,840 km along the magnetic field lines and 680 km vertically across in 1.2 s and required an unexpectedly long time of about 16 s to collapse. The beta flux contained inside the cavity was measured to be relatively uniform throughout and remained at  $3 \cdot 10^{11}$  beta particles/cm<sup>2</sup> s for at least 7 s. The plasma continued to expand upward beyond the fully expanded cavity boundary and injected a flux measuring  $2.5 \cdot 10^{10}$  beta particles/cm<sup>2</sup> s at H + 34 s into the most intense region of the artificial belt. Measured 10 hours later by the Injun I spacecraft, this flux was determined to be  $1 \cdot 10^9$  beta particles/cm<sup>2</sup> s.' - Palmer Dyal, 'Particle and field measurements of the *Starfish* diamagnetic cavity', *Journal of Geophysical Research*, volume 111, issue A12, page 211 (2006).

Palmer Dyal was the nuclear test Project Officer and co-author with W. Simmons of **Operation DOMINIC, FISH BOWL Series, Project 6.7, Debris Expansion Experiment**, U.S. Air Force Weapons Laboratory, Kirkland Air Force Base, New Mexico, POR-2026 (WT-2026), AD-A995428, December 1965:

'This experiment was designed to measure the interaction of expanding nuclear weapon debris with the ion-loaded geomagnetic field. Five rockets on *STARFISH* and two rockets on *CHECKMATE* were used to position instrumented payloads at various distances around the burst points. The instruments measured the magnetic field, ion flux, beta flux, gamma flux, and the neutron flux as a function of time and space around the detonations. Data was transmitted at both real and recorded times to island receiving sites near the burst regions. Measurements of the telemetry signal strengths at these sites allowed observations of blackout at 250 MHz ... the early expansion of the *STARFISH* debris probably took the form of an ellipsoid with its major axis oriented along the earth's magnetic field lines. Collapse of the magnetic bubble was complete in approximately 16 seconds, and part of the fission fragment beta particles were subsequently injected into trapped orbits. ...

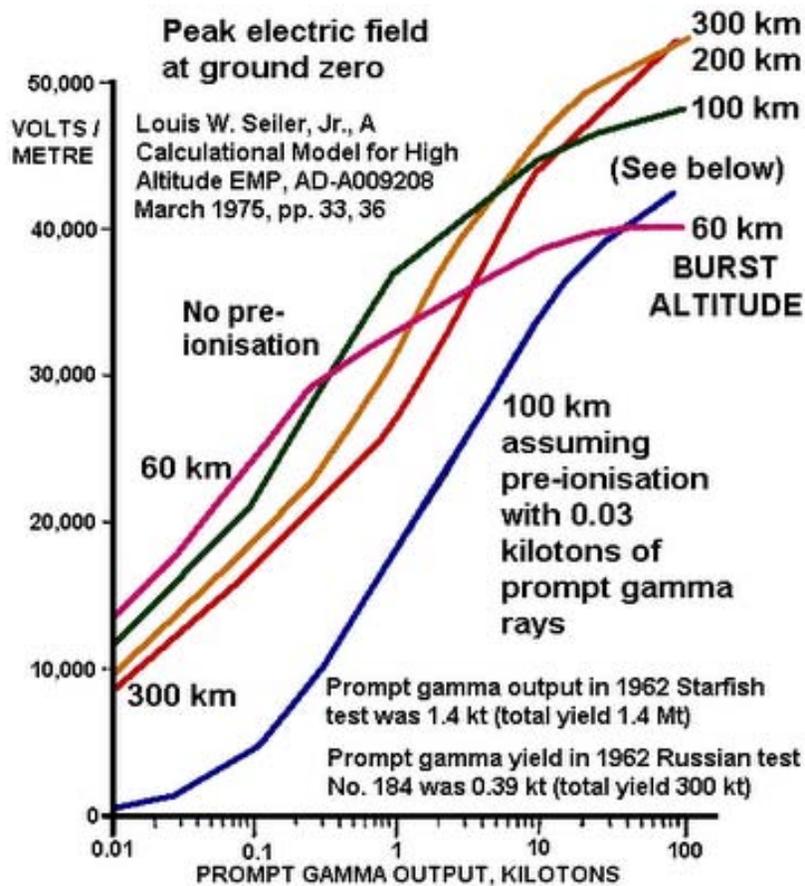
'At altitudes above 200 kilometres ... the particles travel unimpeded for several thousands of kilometres. During the early phase of a high-altitude explosion, a large percentage of the detonation products is ionized and can therefore interact with the geomagnetic field and can also undergo Coulomb scattering with the ambient air atoms. If the expansion is high enough above the atmosphere, an Argus shell of electrons can be formed as in the 1958 and 1962 test series. ... If this velocity of the plasma is greater than the local sound or Alfvén speed, a magnetic shock similar to a hydro shock can be formed which dissipates a sizable fraction of the plasma kinetic energy. The Alfvén velocity is  $C = B/(4\pi \cdot \rho)^{1/2}$ , where ...  $B$  is the magnetic field ... Since the *STARFISH* debris expansion was predicted and measured to be approximately  $2 \times 10^8$  cm/sec and the Alfvén velocity is about  $2 \times 10^7$  cm/sec, a shock should be formed. A consideration of the conservation of momentum and energy indicates that the total extent of the plasma expansion proceeds until the weapon plasma kinetic energy is balanced by the  $B^2/(8\pi)$  magnetic field energy [density] in the excluded region and the energy of the air molecules picked up by the expanding debris. ... An estimate of the maximum radial extent of the *STARFISH* magnetic bubble can be made assuming conservation of momentum and energy. The magnetic field swept along by the plasma electrons will pick up ambient air ions as it proceeds outward. ...'

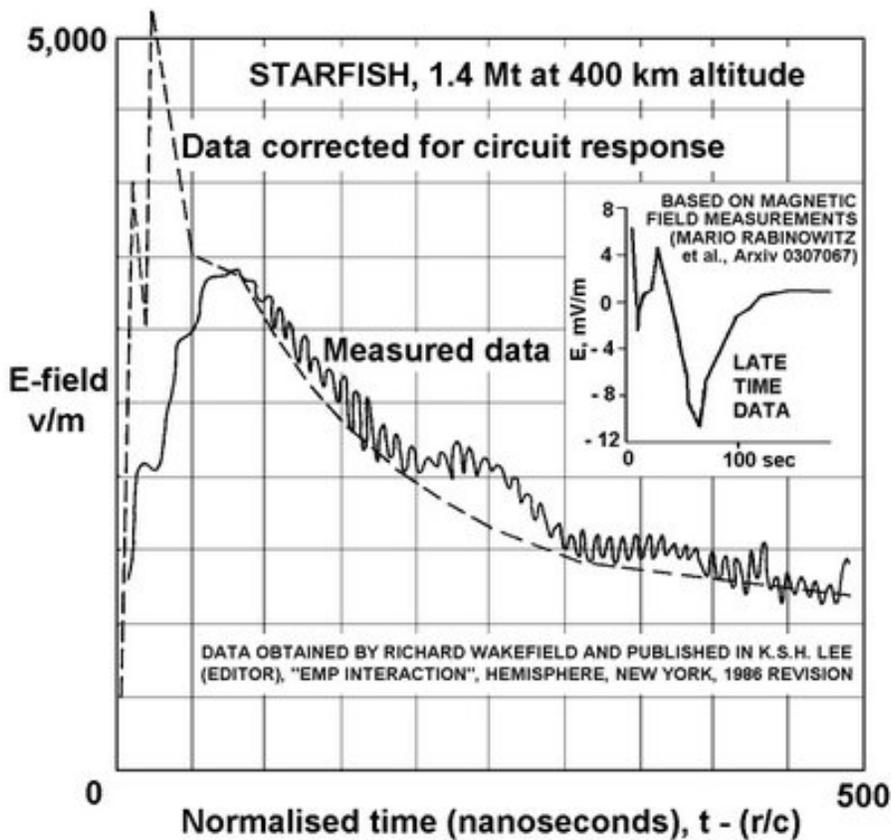
Conservation of momentum suggests that the initial outward bomb momentum,  $M_{\text{BOMB}}V_{\text{BOMB}}$  must be equal to the momentum of the total expanding fireball after it has picked up air ions of mass  $M_{\text{AIR IONS}}$ :

$$M_{\text{BOMB}}V_{\text{BOMB}} = (M_{\text{BOMB}} + M_{\text{AIR IONS}})V,$$

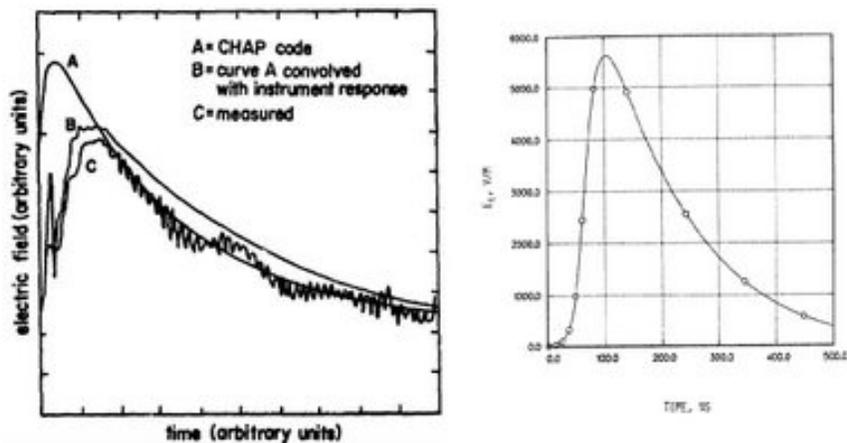
where  $V$  is the velocity of the combined shell of bomb and air ions. The expansion of the ionized material against the earth's magnetic field slows it down, so that the maximum radial extent occurs when the initial kinetic energy  $E = (1/2) M_{\text{BOMB}}V_{\text{BOMB}}^2$  has been converted into the potential energy density of the magnetic field which stops its expansion. The energy of the magnetic field excluded from the ionized shell of radius  $R$  is simply the volume of that shell multiplied by the magnetic field energy density  $B^2/(8\{\text{Pi}\})$ . By setting the energy of the magnetic field bubble equal to the kinetic energy of the explosion, the maximum size of the bubble could be calculated, assuming the debris was 100% ionized.

For *CHECKMATE*, they reported: 'Expansion of the debris was mostly determined by the surrounding atmosphere which had a density of  $4.8 \times 10^{10}$  particles/cm<sup>3</sup>.

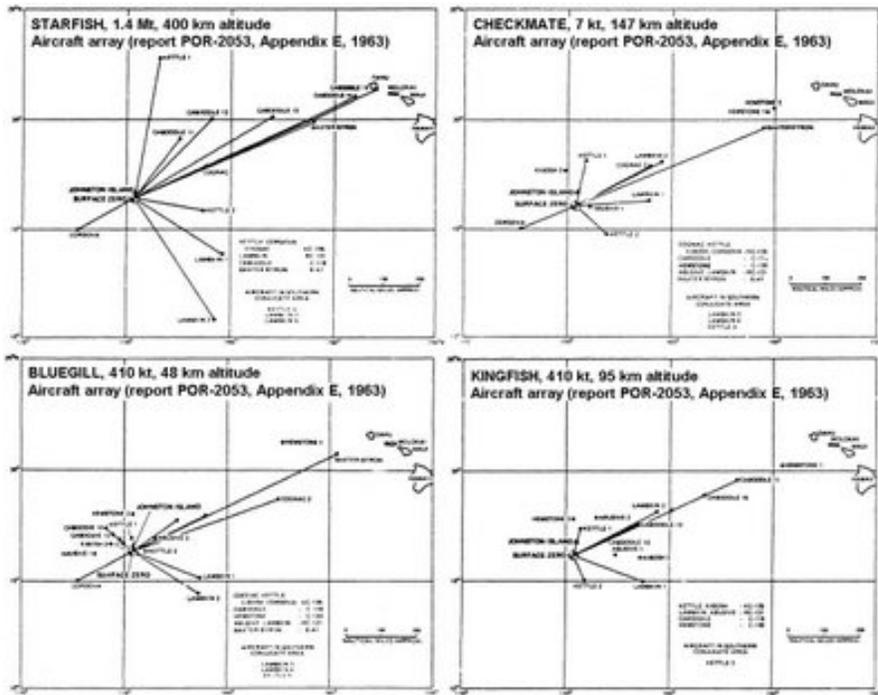




Richard L. Wakefield's curve above, although it suffers from many instrument problems, explained EMP damage on Hawaii some 1,300 km from the burst point - see map below. Dr Longmire explained Wakefield's curve by a brand new EMP theory called the 'magnetic dipole mechanism' - a fancy name for the deflection at high altitudes of electrons by the Earth's natural magnetic dipole field. The original plan for the *Starfish* test is [declassified here](#), and the first report on the effects is [declassified here](#). The zig-zag on the measured curve above is just 'ringing' in the instrument, not in the EMP. The inductance, capacitance, and resistance combination of the electronic circuit in the oscilloscope used to measure the EMP evidently had a natural resonance - rather like a ringing bell - at a frequency of 110 MHz, which was set off by the rapid rise in the first part of the EMP and continued oscillating for more than 500 ns. The wavy curve from the instrument is thus superimposed on the real EMP.

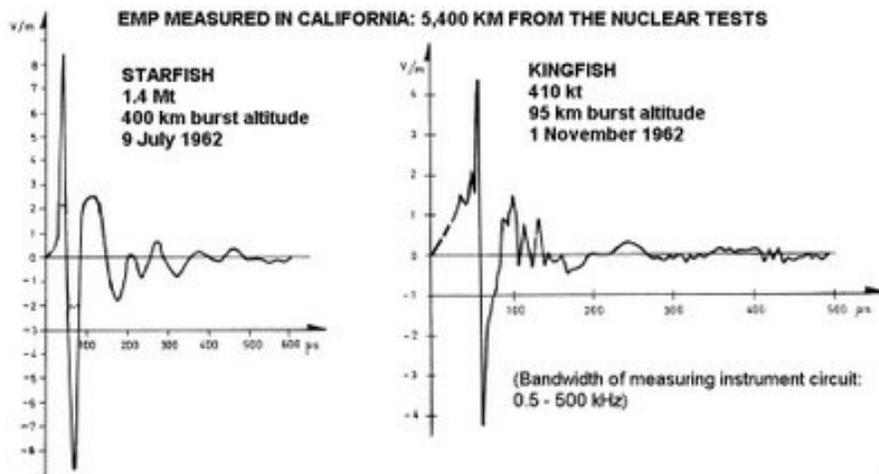


Above: raw data released by America so far on the Starfish EMP consists of the graph on the left based on a measurement by Richard L. Wakefield in a C-130 aircraft 1,400 km East-South-East of the detonation, with a CHAP (code for high altitude pulse) Longmire computer simulation for that curve both with and without instrument response corrections (taken from Figure 9 of the book [EMP Interaction, online edition](#)), and the graph on the right which is Longmire's CHAP calculation of the EMP at Honolulu, 1,300 km East-North-East of the detonation ([page 7 of Longmire's report EMP technical note 353, March 1985](#)). By comparing the various curves, you can guess the correct scales for the graph on the left and also what the time-dependent instrument response is.



Above: locations of test aircraft which suffered EMP damage during Operation Fishbowl in 1962. In testimony to 1997 U.S. Congressional Hearings on EMP, Dr. George W. Ullrich, the Deputy Director of the U.S. Department of Defense's Defense Special Weapons Agency (now the DTRA, Defence Threat Reduction Agency) said that the lower-yield Fishbowl tests after Starfish 'produced electronic upsets on an instrumentation aircraft that was approximately 300 kilometers away from the detonations.' The report by Charles N. Vittitoe, 'Did high-altitude EMP (electromagnetic pulse) cause the Hawaiian streetlight incident?', Sandia National Labs., Albuquerque, NM, report SAND-88-0043C; conference CONF-880852-1 (1988) states on page 3: 'Several damage effects have been attributed to the high-altitude EMP. Tesche notes the input-circuit troubles in radio receivers during the *Starfish* [1.4 Mt, 400 km altitude] and *Checkmate* [7 kt, 147 km altitude] bursts; the triggering of surge arresters on an airplane with a trailing-wire antenna during *Starfish*, *Checkmate*, and *Bluegill* [410 kt, 48 km altitude] ...'

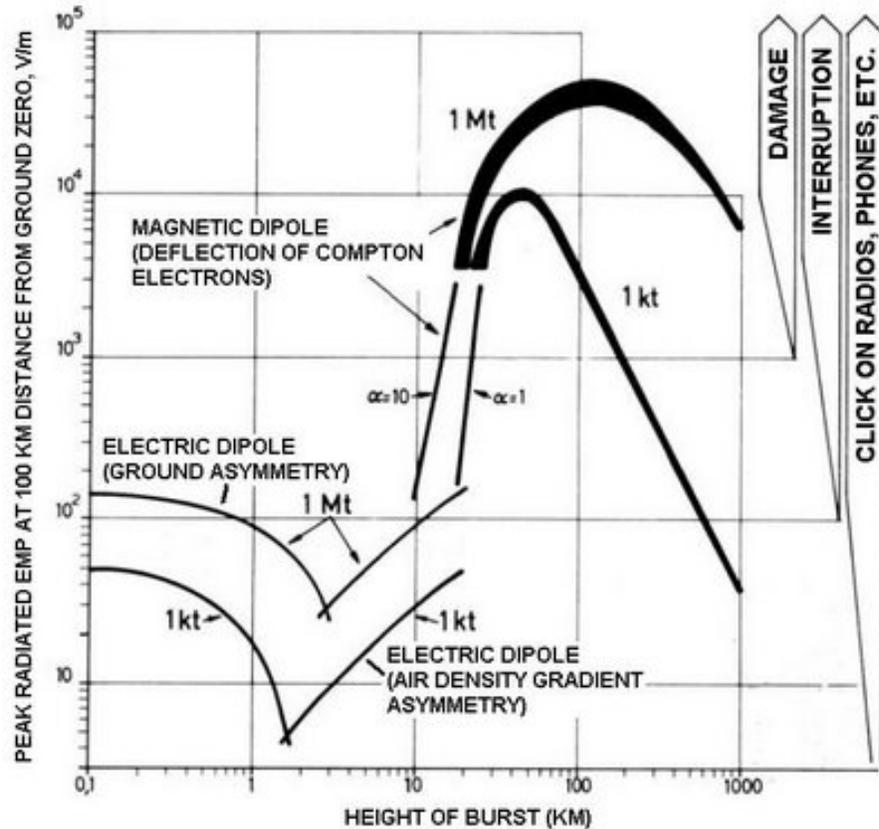
Below are the prompt EMP waveforms measured in California, 5,400 km away from *Starfish* (1.4 Mt, 400 km altitude) and *Kingfish* (410 kt, 95 km altitude) space shots above Johnston Island in 1962:



Crook, G. M., et al., 'Distant electromagnetic observations of the high altitude nuclear detonation of July 9, 1962', *Journal of Geophysical Research*, volume 68, p. 1781 (1963)  
 'How radio can plot high altitude nuclear blasts', *Electronics*, volume 36, p. 28 (January 11, 1963)  
 Vittitoe, C. N. 'Electromagnetic pulse generation from a high-altitude gamma ray source', SC-DC-70-4900, Sandia Laboratories (1970)

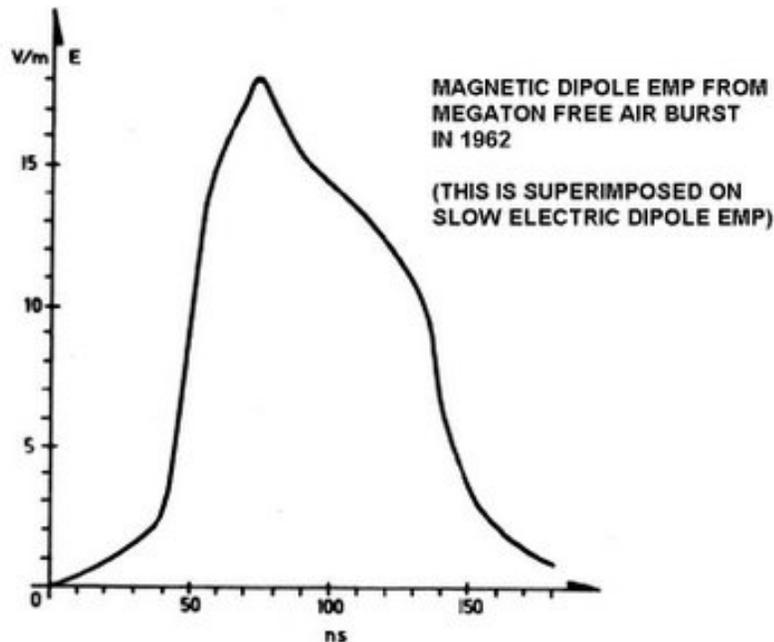
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It is surprising to find that on 11 January 1963, the American journal *Electronics* Vol. 36, Issue No. 2, had openly published the distant MHD-EMP waveforms from *all five* 1962 American high altitude detonations *Starfish*, *Bluegill*, *Kingfish*, *Checkmate*, and *Tightrope*: 'Recordings made during the high-altitude nuclear explosions over Johnston Island, from July to November 1962, shed new light on the electromagnetic waves associated with nuclear blasts. Hydrodynamic wave theory is used to explain the main part of the signal from a scope. The results recorded for five blasts are described briefly. The scopes were triggered about 30 micro-seconds before the arrival of the main spike of the electromagnetic pulse.'

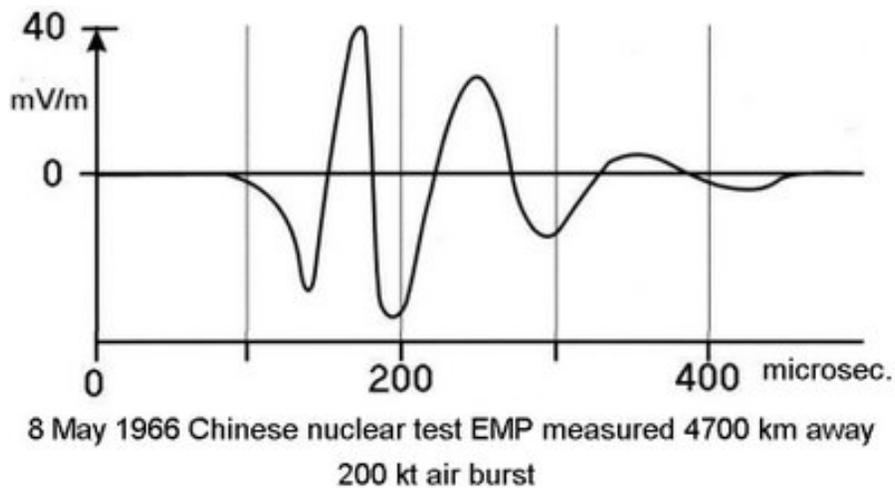


Above: if we ignore the late-time MHD-EMP mechanism (which takes seconds to minutes to peak and has extremely low frequencies) there are three EMP mechanisms at play in determining the radiated EMP as a function of burst altitude. This diagram plots typical peak radiated EMP signals from 1 kt and 1 Mt bombs as a function of altitude for an observer at a fixed distance of 100 km from ground zero. For very low burst altitudes, the major cause of EMP radiation is the asymmetry due to the Earth's surface (there is net upward Compton current due to the ground absorbing downward-directed gamma rays). This is just like a vertical 'electric dipole' radio transmitter antenna radiating radio waves horizontally (at right angles to the direction of the time-varying current) when the vertical current supplied to the antenna is varied in time. Dolan's DNA-EM-1 states that a 1 Mt surface burst radiates a peak EMP of 1,650 v/m at 7.2 km distance (which falls off inversely with distance for greater distances). As the burst altitude is increased above about 1 km or so, this ground asymmetry mechanism becomes less important because the gamma rays take 1 microsecond to travel 300 metres and don't reach the ground with much intensity; in any case by that time the EMP has been emitted by another mechanism of asymmetry, the fall in air density with increasing altitude, which is particularly important for bursts of 1-10 km altitude. Finally, detonations above 10 km altitude send gamma rays into air of low density, so that the Compton electrons have the chance (before hitting air molecules!) to be deflected significantly by the Earth's magnetic field; this 'magnetic dipole' deflection makes them emit synchrotronic radiation which is the massive EMP hazard from space bursts which was discovered by Dr Conrad Longmire after the Starfish test on 9 July 1962. After the Starfish EMP was measured by Richard Wakefield, the Americans started looking for 'magnetic dipole' EMP from normal megaton air bursts dropped from B-52 aircraft (at a few km altitude to prevent local fallout). Until then they measured EMP from air bursts

using oscilloscopes set to measure EMP with durations of tens of microseconds. By increasing the sweep speed to sub-microsecond times (nanoseconds), they were then able to see the positive pulse of 'magnetic dipole' EMP even in sea level air bursts at relatively low altitude, typically peaking at 18 v/m at 70 nanoseconds for 20 km distance as in the following illustration from LA-2808:

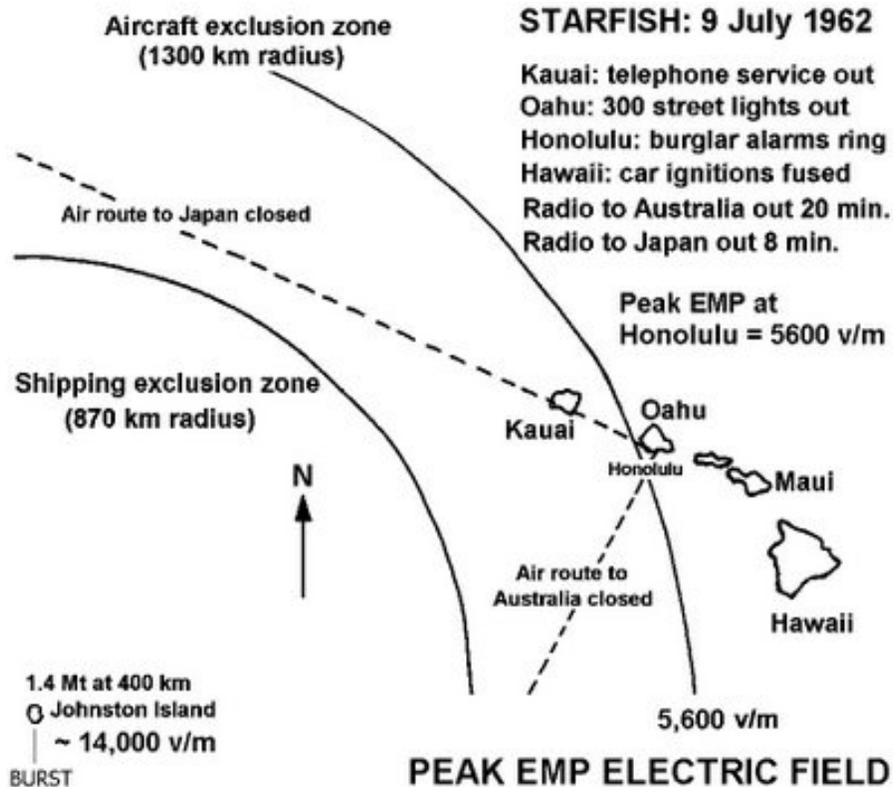


J. K. Theobald, Fast electromagnetic signals produced by nuclear explosions in the troposphere, LA-2808, Los Alamos Scientific Lab (1963)



Above: the long-duration, weak field electric-dipole EMP waveform due to vertical asymmetry from a typical air burst, measured 4,700 km from the Chinese 200 kt shot on 8 May 1966.

Because of Nobel Laureate Dr Hans Bethe's errors in predicting the wrong EMP mechanism for high altitude bursts back in 1958 (he predicted the electric dipole EMP, neglecting both the magnetic dipole mechanism and the MHD/auroral EMP mechanisms), almost all the instruments were set to measure a longer and less intense EMP with a different polarization (vertical, not horizontal), and at best they only recorded vertical-looking spikes which went off-scale and provided zero information about the peak EMP. In 1958 tests *Teak* and *Orange*, there was hardly any information at all due to both this instrumentation problem and missile errors.



Above: the American 1.4 Mt *Starfish* test at 400-km, on 9 July 1962, induced large EMP currents in the overhead wires of 30 strings of Oahu streetlights, each string having 10 lights (300 streetlights in all). The induced current was sufficient to blow the fuses. EMP currents in the power lines set off 'hundreds' of household burglar alarms and opened many power line circuit breakers. On the island of Kauai, EMP closed down telephone calls to the other islands despite the 1962 sturdy relay (electromechanical) telephone technology, by damaging the microwave diode in the electronic microwave link used to connect the telephone systems between different Hawaiian islands (because of the depth of the ocean between the islands, the use of undersea cables was impractical). If the Starfish Prime warhead had been detonated over the northern continental United States, the magnitude of the EMP would have been about 2.4 times larger because of the stronger magnetic field over the USA which deflects Compton electrons to produce EMP, while the much longer power lines over the USA would pick up a lot more EMP energy than the short power lines in Hawaiian islands, and finally the 1962 commonplace electronic 'vacuum tubes' or 'triode valves' (used before transistors and microchips became common) which could survive 1-2 Joules of EMP, have now been completely replaced by modern semiconductor microchips which are millions of times times more sensitive to EMP (burning out at typically 1 microJoule of EMP energy or less), **simply because they pack millions of times more components into the same space, so the over-heating problem is far worse for a very sudden EMP power surge (rising within a microsecond). Heat can't be dissipated fast enough so the microchip literally melts or burns up under EMP exposure, while older electronics can take a lot more punishment.** So new electronics is a million times more vulnerable than in 1962.

'The time interval detectors used on Maui went off scale, probably due to an unexpectedly large electromagnetic signal ...' - **A 'Quick Look' at the Technical Results of Starfish Prime**, 1962, p. A1-27.

The illustration of Richard Wakefield's EMP measurement from the *Starfish* test is based on the unclassified reference is K. S. H. Lee's 1986 book, **EMP Interaction**. (The earlier, 1980, edition is now [online here](#) as a 28 MB download, and it

contains the *Starfish* EMP data.) However, although that reference gives the graph data (including instrument-corrected data from an early computer study called 'CHAP' - *Code for High Altitude Pulse*, by Longmire in 1974), it omits the scales from the graph for the time and electric field, which need to be filled in from [another graph declassified separately in Dolan's DNA-EM-1](#). Full calculations of EMP as a function of burst altitude are also online in pages 33 and 36 of Louis W. Seiler, Jr., *A Calculational Model for High Altitude EMP*, report [AD-A009208](#), March 1975.

The recently declassified report on *Starfish* states that Richard L. Wakefield's measurement - the only one at the extremely high frequency that measured the peak EMP with some degree of success, was an attempt to measure the time-interval between the first and secondary stage explosions in the weapon (the fission primary produces one pulse of gamma rays, which subsides before the final thermonuclear stage signal). Wakefield's report title is (taken from page 44 of the [declassified \*Starfish\* report](#)):

*Measurement of time interval from electromagnetic signal received in C-130 aircraft, 753 nautical miles from burst, at 11 degrees 16 minutes North, 115 degrees 7 minutes West, 24,750 feet.*

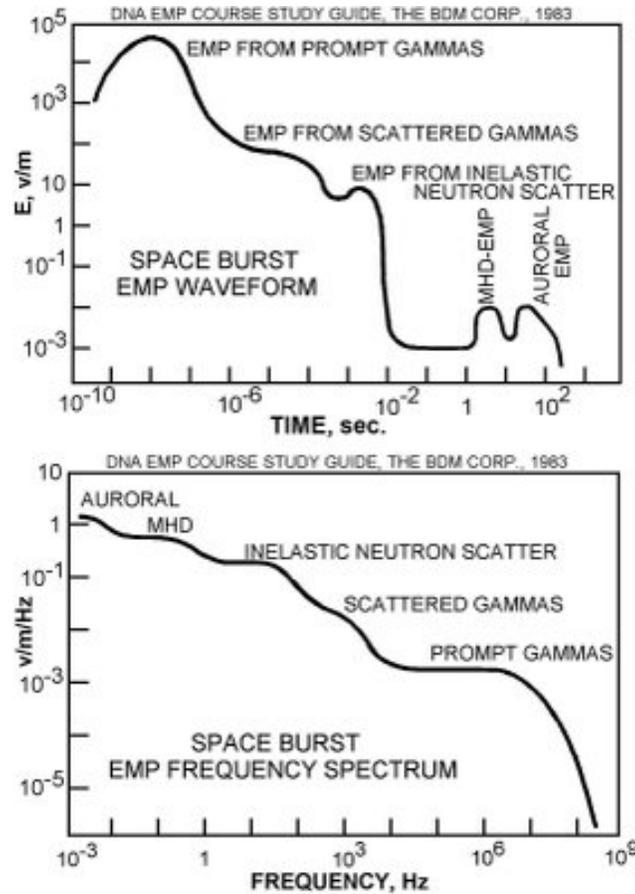
There is really no wonder why it remains secret: the *title alone* tells you that you can measure not just the emission from the bomb but the *internal functioning* (the *time interval* between the primary fission stage and secondary thermonuclear stage!) of the bomb, just by photographing an oscilloscope with a suitable sweep speed, connected to an antenna, from an aircraft 1,400 km away flying at an altitude of 24,750 feet! The longitude of the measurement is clearly in error as [it doesn't correspond to the stated distance from ground zero](#). Presumably there is a typing error and the C-130 was at 155 degrees 7 minutes West, not 115 degrees 7 minutes. This would put the [position](#) of Wakefield's C-130 some 800 km or so South of the Hawaiian islands at detonation time. The report also shows why all the other EMP measurements failed to measure the peak field: they were almost all made in the ELF and VLF frequency bands, corresponding to rise times in milliseconds and seconds, not nanoseconds. They were concentrating on measuring the magnetohydrodynamic (MHD) EMP due to the ionized fireball expansion displacing the Earth's magnetic field, and totally ignored the possibility of a magnetic dipole EMP from the deflection of Compton electrons by the Earth's magnetic field.

Notice that the raw data from *Starfish* - without correction for the poor response of the oscilloscope's aerial orientation and amplifier circuit to the EMP - indicates a somewhat lower peak electric field at a later time than the properly corrected EMP curve. The true peak was 5,210 v/m at 22 nanoseconds (if this scale is correct; notice that [Longmire's reconstruction of the Starfish EMP at Honolulu using CHAP gave 5,600 v/m peaking at 100 ns](#)). The late-time (MHD-EMP) data for *Starfish* shown is for the horizontal field and is available online in Figure 6 of the arXiv filed report [here](#) by Dr Mario Rabinowitz.

Dr Rabinowitz has also compiled a paper [here](#), which quotes some incompetent political 'off the top of my head' testimony from clowns at hearings from the early 1960s, which suggests that *Starfish Prime* did not detonate over Johnston Island but much closer to Hawaii, but the burst position was accurately determined from theodolite cameras to be 16° 28' 6.32" N and 169° 37' 48.27" W ([DASA-1251 which has been in the public domain since 1979 gives this, along with the differing exact burst positions of other tests; this is not the position of launch or an arbitrary point in Johnston Island but is the detonation point](#)). The coordinates of Johnston Island launch area are 16° 44' 15" N and 169° 31' 26" W (see [this site](#)), so *Starfish Prime* occurred about 16 minutes (nautical miles) south of the launch pad and about 6 minutes (nautical miles) west of the launch pad, i.e., 32 km from the launch pad (this is confirmed on page 6 of the now-declassified *Starfish* report [available online](#)).

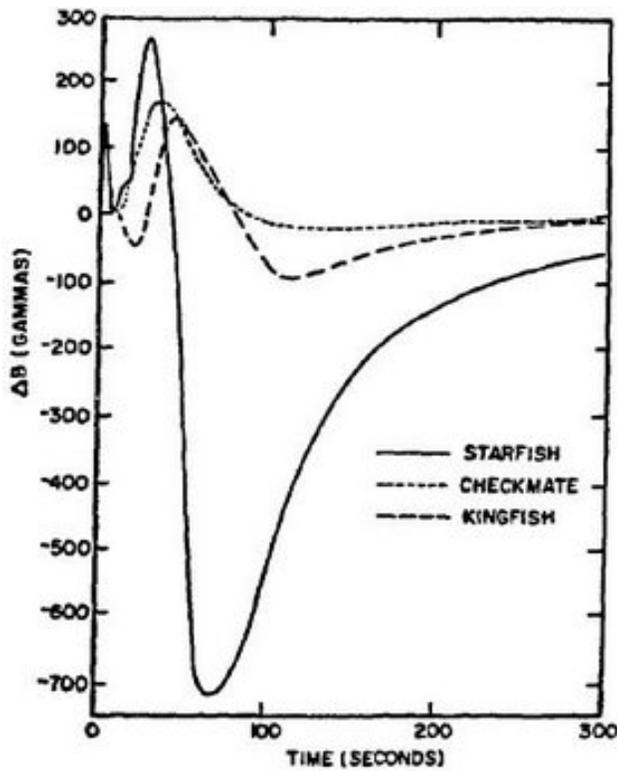
Hence, *Starfish Prime* actually detonated slightly *further away from Hawaii than the launch pad*, instead of much closer to Hawaii! The detonation point was around 32 km south-south-west of Johnston Island, as well as being 400 km up. It is however true as Rabinowitz records that the 300 streetlights fused in the Hawaiian Islands by *Starfish* were only 1-3% of the total number. But I shall have more to say about this later on, particularly after reviewing extensive *Russian EMP*

experiences with long shallow-buried power lines and long overhead telephone lines which Dr Rabinowitz did not know about in 1987 when writing the critical report.



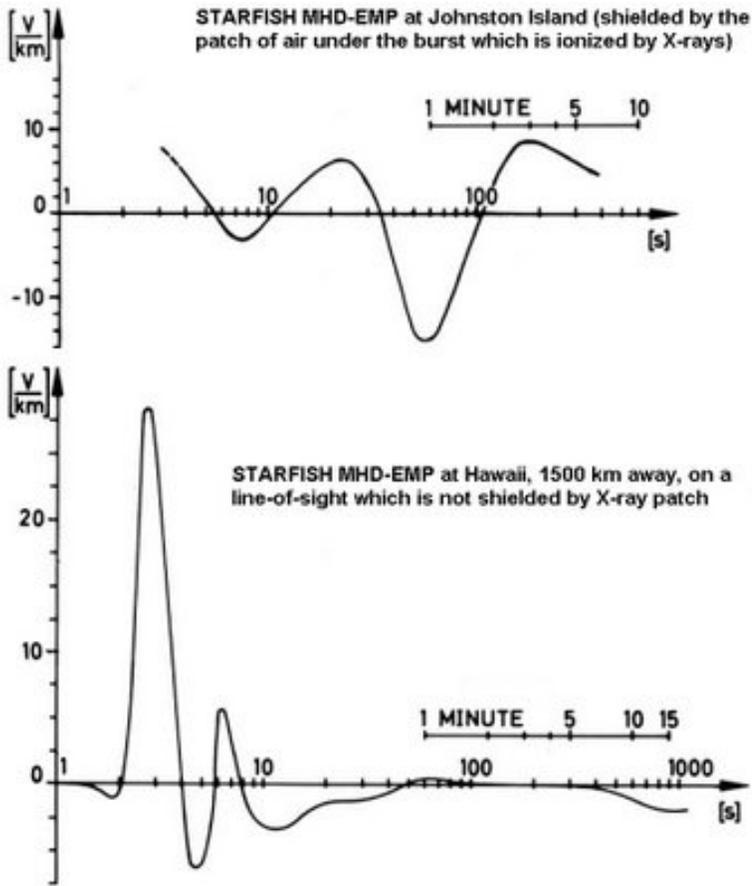
Above: EMP waveform for all times (logarithmic axes) and frequency spectra for a nominal high altitude detonation (P.

Dittmer et al., *DNA EMP Course Study Guide*, Defense Nuclear Agency, DNA Report DNA-H-86-68-V2, May 1986). The first EMP signal comes from the prompt gamma rays of fission and gamma rays released within the bomb due to the inelastic scatter of neutrons with the atoms of the weapon. For a fission weapon, about 3.5% of the total energy emerges as prompt gamma rays, and this is added to by the gamma rays due to inelastic neutron scatter in the bomb. But despite their high energy (typically 2 MeV), most of these gamma rays are absorbed by the weapons materials, and don't escape from the bomb casing. Typically only 0.1-0.5% of the bomb energy is actually radiated as prompt gamma rays (the lower figure applying to massive, old fashioned high-yield Teller-Ulam multimegaton thermonuclear weapons with thick outer casings, and the high figure to lightweight, low-yield weapons, with relatively thin outer casings). The next part of the EMP from a space burst comes from inelastic scatter of neutrons as they hit air molecules. Then, after those neutrons are slowed down a lot by successive inelastic scattering in the air (releasing gamma rays each time), they are finally captured by the nuclei of nitrogen atoms, which causes gamma rays to be emitted and a further EMP signal which adds to the gamma rays from decaying fission product debris. Finally, you get an EMP signal at 1-10 seconds from the magnetohydrodynamic (MHD) mechanism, where the ionized fireball expansion pushes out the earth's magnetic field (which can't enter an electrically-conductive, ionized region) with a frequency of less than 1 Hertz, and then the auroral motion of charged particles from the detonation (spiralling along the earth's magnetic field between conjugate points in opposite magnetic hemispheres) constitutes another motion of charge (i.e. an time-varying electric current) which sends out a final EMP at extremely low frequencies, typically 0.01 Hertz. These extremely low frequencies, unlike the high frequencies, can penetrate substantial depths underground, where they can induce substantial electric currents in very long (over 100 km long) buried cables.

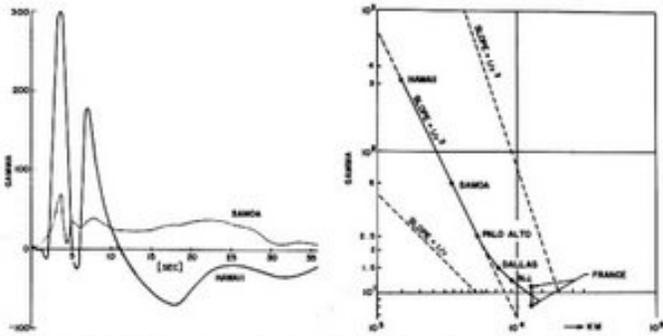


Chavin, S., Crevier, W. F., Kilb, R. W., and Longmire, C. L., "MHD-EMP Code Simulation of Starfish," MRC-R-516, Mission Research Corporation, August, 1979.

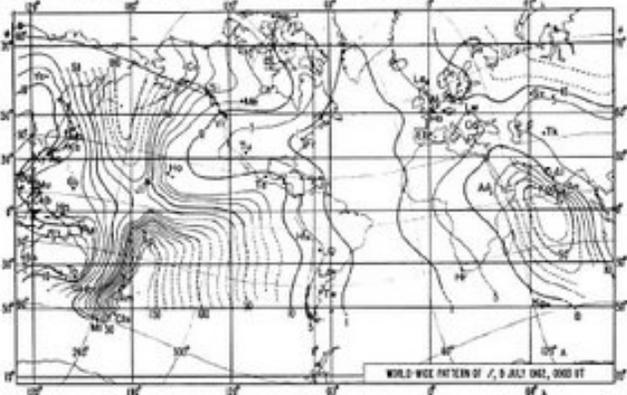
Above: the late-time magnetohydrodynamic EMP (MHD-EMP) measured by the change in the natural magnetic field flux density as a function of time after American tests *Starfish* (1.4 Mt, 400 km burst altitude), *Checkmate* (7 kt, 147 km burst altitude) and *Kingfish* (410 kt, 95 km burst altitude) at Johnston Island, below the detonations. The first (positive) pulse in each case is due to the ionized (diamagnetic) fireball expanding and pushing out the earth's magnetic field, which cannot penetrate into a conductive cavity such as an ionized fireball. Consequently, the pushed-out magnetic field lines become bunched up outside the fireball, which means that the magnetic field intensity increases (the magnetic field intensity can be defined by the concentration of the magnetic field lines in space). Under the fireball - as in the case of the data above, measured at Johnston Island, which was effectively below the fireball in each case - there is a patch of ionized air caused by X-rays being absorbed from the explosion, and this patch shields in part the first pulse of MHD-EMP (i.e., that from the expansion of the fireball which pushes out the earth's magnetic field). The second (negative) pulse of the late-time EMP is bigger in the case of the *Starfish* test, because it is unshielded: this large negative pulse is simply due to the auroral effect of the ionized fission product debris rising and moving along the earth's magnetic field lines. This motion of ionized fission product debris constitutes a large varying electric current for a high yield burst like *Starfish*, and as a result of this varying current, the accelerating charges radiate an EMP signal which can peak at a minute or so after detonation.



Above: the measured late-time MHD-EMP at Hawaii, 1,500 km from the Starfish test, was stronger than at Johnston Island (directly below the burst!) because of the ionized X-ray patch of conductive air below the bomb, which shielded Johnston Island. The locations of these patches of ionized air below bursts at various altitudes are discussed in the [blog post linked here](#).



Maximum MHD-EMP at 3-5 seconds after STARFISH, 1.4 Mt at 400 km altitude, 9 July 1962 (burst was 1,500 km from Hawaii and 3,400 km from Samoa)



Global magnetic field disruption at 2 minutes 51 seconds after STARFISH  
 H. A. Bomke, et al., 'Near and distant observations of the 1962 et al Johnston Island high-altitude tests', *Journal of Geophysical Research*, vol. 69, p. 3125 (1964)  
 H. A. Bomke, et al., 'The nature of worldwide geomagnetic disturbances', *Journal of Geophysical Research*, vol. 71, p. 2777 (1966).

Above: correlation of global measurements of the Starfish MHD-EMP late signal which peaked 3-5 seconds after detonation.

The 3-stages of MHD-EMP:

1. Expansion of ionized, electrically conducting fireball excludes and so pushes out Earth's magnetic field lines, causing an EMP. This peaks within 10 seconds. However, the air directly below the detonation is ionized and heated by X-rays so that it is electrically conducting and thus partly shields the ground directly below the burst from the late-time low-frequency EMP.
2. A MHD-EMP wave then propagates between the ionosphere's F - layer and the ground, right around the planet.
3. The final stage of the late-time EMP is due to the aurora effect of charged particles and fission products physically moving along the Earth's magnetic field lines towards the opposite pole. This motion of charge constitutes a large time-varying electric current which emits the final pulse of EMP, which travels around the world.

MHD-EMP has serious effects for long conductors because its extremely low frequencies (ELF) can penetrate a lot further into the ground than higher frequencies can, as proved by its effect on a long buried power line during the nuclear test of a 300 kt warhead at 290 km altitude on 22 October 1962 near Dzhezkazgan in Kazakhstan (as part of some Russian ABM system proof tests). In this test, prompt gamma ray-produced EMP induced a current of 2,500 amps measured by spark gaps in a 570-km stretch of overhead telephone line out to Zharyq, blowing all the protective fuses. But the late-time MHD-EMP was of special interest because it was of low enough frequency to enable it to penetrate the 90 cm into the ground, overloading a shallow buried lead and steel tape-protected 1,000-km long power cable between Aqmola and Almaty, firing circuit breakers and setting the Karaganda power plant on fire. *The Russian 300 kt test on 22 October 1962 at 290 km altitude (44,84° N, 66,05° E) produced an MHD-EMP magnetic field of 1025 nT measured at ground zero, 420 nT at 433 km, and 240 nT at 574 km distance. Along ground of conductivity 10<sup>-3</sup> S/m, 400 v was induced in a cable 80 km long, implying an MHD-EMP of 5 v/km.*



Above: the incendiary effects of a relatively weak but natural MHD-EMP from the [geomagnetic solar storm of 13 March 1989](#) in saturating the core of a transformer in the Hydro-Quebec electric power grid. Hydro-Quebec lost electric power, cutting the supply of electricity to 6 million people for several hours, and it took 9 hours to restore 83% (21.5 GW) of the power supply (1 million people were still without electric power then). Two 400/275 kV autotransformers were also damaged in England:

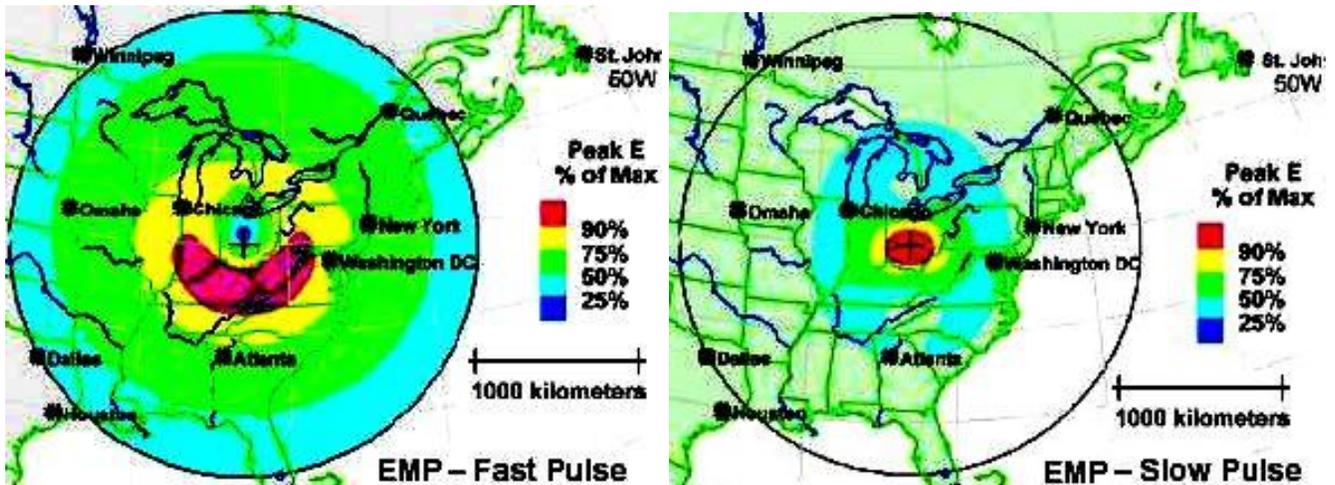
'In addition, at the Salem nuclear power plant in New Jersey, a 1200 MVA, 500 kV transformer was damaged beyond repair when portions of its structure failed due to thermal stress. The failure was caused by stray magnetic flux impinging on the transformer core. Fortunately, a replacement transformer was readily available; otherwise the plant would have been down for a year, which is the normal delivery time for larger power transformers. The two autotransformers in southern England were also damaged from stray flux that produced hot spots, which caused significant gassing from the breakdown of the insulating oil.' - [EMP Commission report, 'Critical National Infrastructures', 2008, page 42.](#)

A study of these effects is linked [here](#). Similar effects from the Russian 300 kt nuclear test at 290 km altitude over Dzhezkazgan in Kazakhstan on 22 October 1962 induced enough current in a 1,000 km long protected underground cable to burn the Karaganda power plant to the ground. [Dr Lowell Wood testified on 8 March 2005 during Senate Hearings 109-30 that these MHD-EMP effects are:](#) 'the type of damage which is seen with transformers in the core of geomagnetic storms. The geomagnetic storm, in turn, is a very tepid, weak flavor of the so-called slow component of EMP. So when those transformers are subjected to the slow component of the EMP, they basically burn, not due to the EMP itself but due to the interaction of the EMP and normal power system operation. Transformers burn, and when they burn, sir, they go and they are not repairable, and they get replaced, as you very aptly pointed out, from only foreign sources. The United States, as part of its comparative advantage, no longer makes big power transformers anywhere at all. They are all sourced from abroad. And when you want a new one, you order it and it is delivered - it is, first of all, manufactured. They don't stockpile them. There is no inventory. It is manufactured, it is shipped, and then it is delivered by very complex and tedious means within the U.S. because they are very large and very massive objects. They come in slowly and painfully. Typical sort of delays from the time that you order until the time that you have a transformer in service are one to 2 years, and that is with everything working great. If the United States was already out of power and it suddenly needed a few hundred new transformers because of burnout, you could understand why we found not that it would take a year or two to recover, it might take decades, because you burn down the national plant, you have no way of fixing it and really no way of reconstituting it other than waiting for slow-moving foreign manufacturers to very slowly reconstitute an entire continent's worth of burned down power plant.'

## MEASURED ELECTROMAGNETIC PULSE (E.M.P.) EFFECTS FROM SPACE TESTS

'The British Government and our scientists have ... been kept fully informed ... the fall-out from these very high-altitude tests is negligible ... the purpose of this experiment is of the greatest importance from the point of view of defence, for it is intended to find out how radio, radar, and other communications systems on which all defence depends might be temporarily put out of action by explosions of this kind.' – *British Prime Minister Harold Macmillan, Statement to the House of Commons, 8 May 1962.*

'Detonations above about 130,000 feet [40 km] produce EMP effects on the ground ... of sufficient magnitude to damage electrical and electronic equipment.' – Philip J. Dolan, editor, *Capabilities of Nuclear Weapons*, U.S. Department of Defense, 1981, DNA-EM-1, c. 1, p. 19, originally 'Secret – Restricted Data' (declassified and released on 13 February 1989).



Above: area coverage by the first (*fast* or 'magnetic dipole mechanism') peak EMP and by the second (*slow* or 'magneto-hydrodynamic, MHD-EMP, mechanism') for a 10-20 kt single stage (pure fission) thin-cased burst at 150 km altitude. Both sets of contours are slightly disturbed from circles by the effect of the earth's slanting magnetic field (the burst is supposed to occur 500 km west of Washington D.C.). Notice that the horizon range for this 150 km burst height is 1,370 km and with the burst location shown that zaps 70 % of the electricity consumption of the United States, but if the burst height were 500 km then the horizon radius would be 2,450 km and would cover the entire United States of America. This distance is very important because the peak signal has a rise time of typically 20 ns, which implies a VHF frequency on the order of 50 MHz, which cannot extend past the horizon (although lower frequencies will obviously bounce off the ionosphere and refract and therefore extend past the horizon). However if you simply increase the burst altitude, you would then need a megaton explosion, to avoid diluting the energy and hence the effects by increasing the area coverage.

### NOBEL LAUREATE FAILED TO PREDICT THE SEVERE EMP MECHANISM

In October 1957, Nobel Laureate Dr Hans A. Bethe's report, "Electromagnetic Signal Expected from High-Altitude Test" (Los Alamos Scientific Laboratory report LA-2173, secret-restricted data), predicted incorrectly that only a weak electromagnetic pulse (EMP) would be produced by a nuclear detonation in space or at very high altitude, due to vertical oscillations resulting from the downward-travelling hemisphere of radiation. This is the 'electric dipole' EMP mechanism and is actually a trivial EMP mechanism for high altitude bursts.

*Hardtack-Teak*, a 3.8 Mt, 50 % fission test on 1 August 1958 missile carried to 77 km directly over Johnston Island, gave rise to a powerful EMP, but close-in waveform measurements failed. This was partly due to an error in the missile which caused it to detonate above the island instead of 30 km down range as planned (forcing half a dozen filmed observers at the entrance to the control station to duck and cover in panic, [see the official on-line U.S. Department of Energy test film clip](#)), but mainly because of Bethe's false prediction that the EMP would be vertically polarised and very weak (on the order of 1 v/m). Due to Bethe's error, the EMP measurement oscilloscopes were set to excessive sensitivity which would have sent them immediately off-scale:

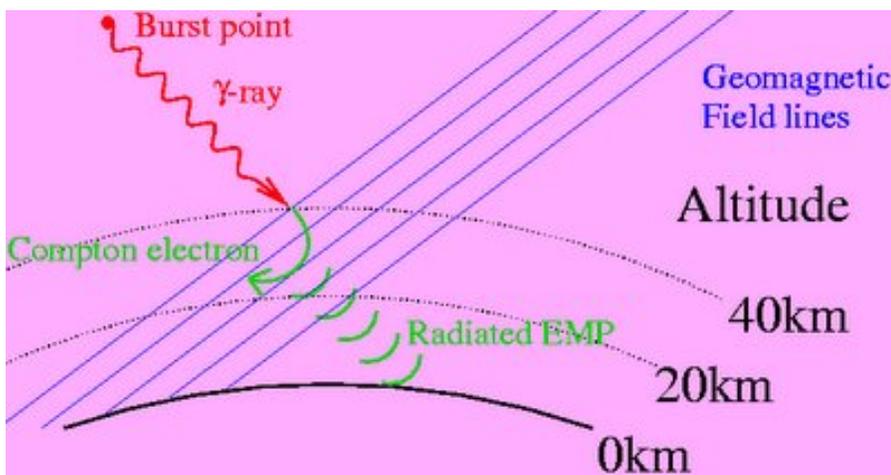
'The objective was to obtain and analyze the wave form of the electromagnetic (EM) pulse resulting from nuclear

detonations, especially the high-altitude shots. ... Because of relocation of the shots, wave forms were not obtained for the very-high-altitude shots, *Teak* and *Orange*. During shots *Yucca*, *Cactus*, *Fir*, *Butternut*, *Koa*, *Holly*, and *Nutmeg*, the pulse was measured over the frequency range from 0 to 10 mega-cycles. ... Signals were picked up by short probe-type antennas, and fed via cathode followers and delay lines to high-frequency oscilloscopes. Photographs of the traces were taken at three sweep settings: 0.2, 2, and 10 micro-sec/cm.

'The shot characteristics were compared to the actual EM-pulse wave-form parameters. These comparisons showed that, for surface shots, the yield, range and presence of a second [fusion] stage can be estimated from the wave-form parameters. EM-pulse data obtained by this project is in good agreement with that obtained during Operation Redwing, Project 6.5.' - F. Lavicka and G. Lang, *Operation Hardtack, Project 6.4, Wave Form of Electromagnetic Pulse from Nuclear Detonations*, U.S. Army, weapon test report WT-1638, originally Secret - Restricted Data (15 September 1960).

However, the Apia Observatory at Samoa, 3,200 km from the *Teak* detonation, recorded the 'sudden commencement' of an intense magnetic disturbance – four times stronger than any recorded due to solar storms – followed by a visible aurora along the earth's magnetic field lines (reference: A.L. Cullington, *Nature*, vol. 182, 1958, p. 1365). [See also: D. L. Croom, 'VLF radiation from the high altitude nuclear explosions at Johnston Island, August 1958,' *J. Atm. Terr. Phys.*, vol. 27, p. 111 (1965).]

The expanding ionised (thus conductive, and hence diamagnetic) fireball excluded and thus 'pushed out' the Earth's natural magnetic field as it expanded, an effect called 'magnetohydrodynamic (MHD)-EMP'. But it was on the 9 July 1962, during the American *Starfish* shot, a 1.4 Mt warhead missile-carried to an altitude of 400 km, that EMP damage at over 1300 km east was seen, and the *Starfish* space burst EMP waveform was measured by Richard Wakefield. Cameras were used to photograph oscilloscope screens, showing the EMP pickup in small aerials. Neither Dr Bethe's downward current model, nor the MHD-EMP model, explained the immense peak EMP. In 1963, Dr Conrad Longmire at Los Alamos argued that, in low-density air, electrons knocked from air molecules by gamma rays travel far enough to be greatly deflected by the earth's magnetic dipole field. Longmire's theory is therefore called the 'magnetic dipole' EMP mechanism, to distinguish it from Bethe's 'electric dipole' mechanism.



[Illustration credit: Atomic Weapons Laboratory.]

Dr Longmire showed that the successive, sideways-deflected Compton-scattered electrons cause an electromagnetic field that adds up coherently (it travels in step with the gamma rays causing the Compton current), until 'saturation' is reached at ~ 60,000 v/m (when the strong field begins to attract electrons back to positive charges, preventing further increase). It is impossible to produce a 'magnetic dipole' EMP from a space burst which exceeds 65,000 v/m at the Earth's surface, no matter if it is a 10 Mt detonation at just 30 km altitude over the magnetic equator. The exact value of the saturation field depends on burst altitude. See pages 33 and 36 of Louis W. Seiler, Jr., *A Calculational Model for High Altitude EMP*, report

AD-A009208, March 1975.

Many modern nuclear warheads with thin cases would produce weaker EMP, because of pre-ionisation of the atmosphere by x-rays released by the primary fission stage before the major gamma emission from the fission final stage of the weapon. An EMP cannot be produced efficiently in ionised (electrically conducting) air, as that literally shorts out the EMP very quickly. This means that many thermonuclear weapons with yields of around 100 kilotons would produce saturation electric fields on the ground of only 15,000-30,000 v/m if detonated in space. [More about this, see Dr Michael Bernardin's testimony to the U.S. Congress:](#)

'I speak as a weapons designer with specialized knowledge in electromagnetic pulse. Since 1996, I have been the provost for the Postgraduate Nuclear Weapon Design Institute within the laboratory chartered with training the next generation of nuclear weapon designers. The issue to be addressed this morning is the impact of a high-altitude nuclear detonation over the United States to the civilian and military infrastructure. A high-altitude nuclear detonation would produce an electromagnetic pulse that would cover from one to several million square miles, depending on the height of burst, with electric fields larger than those typically associated with lightning. In such an event, would military equipment deployed within the area of EMP exposure be seriously impaired? Would civilian communications, the power grid and equipment connected to the power grid catastrophically fail? The answers to these questions depend on three elements: One, the types of threat weapons deployed; two, the EMP produced by these weapons; and three, the effects that are caused by EMP. The Defense Intelligence Agency (DIA) and the Central Intelligence Agency (CIA) identify current and projected nuclear weapon threats and provide inputs to the Department of Energy nuclear design labs, Los Alamos and Livermore National Laboratories, who model foreign nuclear weapons. The labs each have over 25 years of experience in performing this type of modeling. The weapon models serve as a basis for associated EMP threat assessments. For the purpose of EMP assessment, it is convenient to group the threat weapons into the following five categories: One, single-stage fission weapons; two, single-stage boosted weapons; three, nominal two-stage thermonuclear weapons with yields up to a few megatons; four, two-stage thermonuclear weapons with yields over a few megatons; and five, special technology thermonuclear weapons. ...The ionization shorts out the EMP, limiting its value to typically 30,000 volts per meter. High-energy x-rays are also produced by the exploding weapon and can enhance the ionization in the high-altitude EMP source region. This source of ionization was largely ignored in EMP assessments until 1986. The inclusion of the X-rays lowered the assessed values of the peak field for many weapons. Note in graphic three that the thermonuclear weapon consists of two stages, a primary stage, which is typically of relatively low yield and is used to drive the secondary stage, which produces a relatively large yield. Each weapons stage produces its own EMP signal, but the primary stage gamma rays, after they go out, leave behind an ionized atmosphere from their EMP generation that is present when the secondary stage gamma rays arrive a moment later. Thus, the **primary stage can degrade the EMP associated with the secondary stage.**'

Dr William Graham, the President and CEO of National Security Research, then testified:

'By way of background, I have worked in EMPs since 1962, when I was a lieutenant at the Air Force weapons lab, handed a dataset taken from the last atmospheric and Pacific exoatmospheric nuclear test series, and asked to try to explain some very strange-looking phenomena that had been observed. Fortunately, we had the benefit of colleagues at Livermore, Los Alamos and other places in doing this, and the theory of high-altitude EMP, and, in fact, all EMP was developed over the next decade or so. Interestingly, though, like many important scientific discoveries, the intense electromagnetic pulse produced by the exoatmospheric nuclear weapon explosion was discovered by accident. It was first observed both directly and by its effects on civilian systems during the exoatmospheric nuclear test series we had conducted, primarily the *Fishbowl* series [tests *Starfish*, *Checkmate*, *Bluegill*, *Kingfish*] in the beginning of the 1960s. However, the theory that was being used at the time to predict the effect had been incorrectly derived by a Nobel laureate [*Bethe*] actually and caused all of the instrumentation on monitoring those exoatmospheric tests to be set at far too low a scale, far too sensitive a level, so that the data on the scope tended to look like vertical lines. We couldn't see the peak amplitudes that were being produced, and it was Conrad Longmire of Los Alamos National Laboratory who, after looking at the data, figured out what was really happening.'

In those same U.S. Congressional Hearings of October 1999, Dr Lowell Wood, of Lawrence Livermore National Laboratory, explained the effects of EMP as then known from **Starfish** test experience:

'I am grateful for the invitation to appear today. Like Dr. Graham, my esteemed senior colleague, I also commenced EMP studies in 1962, as my graduate advisor Willard Libby had recently retired from a long term of service as the Commissioner of the Atomic Energy Commission, and he assigned me EMP analysis problems kind of as exercises for the students, as he was then very keenly concerned by them.

'Indeed, electromagnetic pulses, EMP, generated by high-altitude nuclear explosions have riveted the attention of the military nuclear technical community for more than three and a half decades since the first comparatively modest one very unexpectedly and abruptly turned off the lights over a few million square miles of the mid-Pacific. This EMP also shut down radio stations and street-lighting systems, turned off cars, burned

out telephone systems and wreaked other technical mischief throughout the Hawaiian Islands nearly 1,000 miles distant from ground zero.'

However, Dr Wood is not very specific when mentioning damage to radio stations and telephone systems. [Dr John Malik notes on page 31 of Herman Hoerlin's Los Alamos National Laboratory report LA-6405, \*United States High Altitude Test Experiences:\*](#)

'*Starfish* produced the largest fields of the high-altitude detonations; they caused outages of the series-connected street-lighting systems of Oahu (Hawaii), probable failure of a microwave repeating station on Kauai, failure of the input stages of ionospheric sounders and damage to rectifiers in communication receivers. Other than the failure of the microwave link, no problem was noted in the telephone system. No failure was noted in the telemetry systems used for data transmission on board the many instrumentation rockets.

'There was no apparent increase in radio or television repairs subsequent to any of the Johnston Island detonations. The failures observed were generally in the unprotected input stages of receivers or in rectifiers of electronic equipment; transients on the power line probably caused the rectifier failures. There was one failure in the unprotected part of an electronic system of the LASL Optical Station on top of Mount Haleakala on Maui Island. With the increase of solidstate circuitry over the vacuum-tube technology of 1962, the susceptibility of electronic equipment will be higher, and the probability of more problems for future detonations will be greater. However, if detonations are below line-of-sight, the fields and therefore system problems will be much smaller.'

In addition to the July 1962 Hawaiian experience of EMP induced equipment failures - including some anecdotal evidence of car ignition systems fusing (modern microprocessor controlled vehicles would be more vulnerable), some severe Russian EMP damage occurred in 'Operation K' (ABM System A proof tests) of 1962. On 22 October – during the Cuban missile crisis – Russia detonated a 300-kt missile-warhead at 290-km altitude. Prompt EMP fused 570 km of overhead telephone line west from Zharyq, then MHD-EMP started a fire at the Karaganda power plant and shut down 1,000-km of buried civilian power cables between Aqmola and Almaty. Russian Army diesel electricity generators were burned out by EMP, after 300-kt tests at altitudes of 150 km on 28 October and 59 km on 1 November.

America produces two classified reports on nuclear weapons effects: a 'red book' of foreign threats and a 'blue book' of its own nuclear weapons radiation output data. See page 27 of the candid April 2005 U.S. Department of Defense [Report of the Defense Science Board Task Force on Nuclear Weapon Effects Test, Evaluation, and Simulation](#). Page 29 says:

'The flux or fluence of prompt gammas, neutrons and X-rays is by no means isotropic about the burst point of a high-altitude detonation. Clumps of materials (thrusters, gas bottles, propellant tanks, firing units, etc., for example) surround a warhead in a non-symmetric fashion and make radiation output estimation inherently three-dimensional. In realistic situations, some warhead components will shield the prompt radiations from other components, creating a large shadow cone in a preferential direction.

'For example, the *Starfish* test warhead was inverted prior to the high-altitude test over Johnston Island in 1962 because of concerns that some masses within the design would cause an undesirable shadowing of prompt gamma rays and mask selected nuclear effects that were to be tested. In another example, a nuclear driven kinetic kill warhead (that destroys a reentry vehicle with steel pellets) will have a very low yield-to-mass ratio, which will greatly suppress the X-ray output. The Russians reported on their 1962 high-altitude testing of such a device at an *International Conference on Electromagnetic Effects* in 1994 held in Bordeaux, France.'

This is far more candid than the older data released [here](#) and [here](#).

In addition, in [testimony to 1997 U.S. Congressional Hearings](#), Dr. George W. Ullrich, the Deputy Director of the U.S. Department of Defense's Defense Special Weapons Agency (now the DTRA, Defence Threat Reduction Agency) [said:](#)

'... Enrico Fermi ... prior to the Trinity Event, first predicted that nuclear explosions were capable of generating strong electromagnetic fields. ... A less well known effect of high altitude bursts, but also one with potentially devastating consequences, is the artificial 'pumping' of the Van Allen belt with large numbers of electrons. The bomb-induced electrons will remain trapped in these belts for periods exceeding one year. All

unhardened satellites traversing these belts in low earth orbit could demise in a matter of days to weeks following even one high altitude burst. ...

'One of our earliest experiences with HEMP dates back to the resumption of atmospheric nuclear testing in 1962 following a three year testing moratorium. *Starfish Prime*, a 1.4 megaton device, was detonated at an altitude of 400 kilometers over Johnston Island. Failures of electronic systems resulted in Hawaii, 1,300 kilometers away from the detonation. Street lights and fuzes failed on Oahu and telephone service was disrupted on the island of Kauai. Subsequent tests with lower yield devices [410 kt *Kingfish* at 95 km altitude, 410 kt *Bluegill* at 48 km altitude, and 7 kt *Checkmate* at 147 km] produced electronic upsets on an instrumentation aircraft [presumably the KC-135 that filmed the tests from above the clouds?] that was approximately 300 kilometers away from the detonations.

'Soviet scientists had similar experiences during their atmospheric test program. In one test, all protective devices in overhead communications lines were damaged at distances out to 500 kilometers; the same event saw a 1,000 kilometer segment of power line shut down by these effects. Failures in transmission lines, breakdowns of power supplies, and communications outages were wide-spread.

'... a 50 kiloton (KT) weapon detonated at a 120 km altitude (75 miles) can produce electron densities several orders of magnitude higher than the natural electron environment in low earth orbit. These elevated electron densities can last for months to years and significantly increase the total ionizing dose accumulated by space assets that transit these belts. This increase in total dose accumulation can dramatically shorten the lifetime of satellite systems. Projected lifetimes of up to ten years can be reduced to a mere two months after such an event.

'EMP does not distinguish between military and civilian systems. Unhardened systems, such as commercial power grids, telecommunications networks, and computing systems, remain vulnerable to widespread outages and upsets ... While DoD hardens assets it deems vital, no comparable civil program exists. Thus, the detonation of one or a few high-altitude nuclear weapons could result in devastating problems for the entire U.S. commercial infrastructure. Some detailed network analyses of critical civil systems would be useful to better understand the magnitude of the problem and define possible solution paths.'

However, **some claim that EMP is an exaggerated threat.** It is true that the 300 streetlights which failed on Oahu were only a small fraction (around 1-3 %) of the total number of streetlights in the Hawaiian islands, but you have to remember that the small size of the islands meant that the conductors were similarly limited in size. The Russian experience of tests over land shows that the worst effects occur in electrical and electronics equipment connected to very long power transmission or telephone lines, which did not exist in the Hawaiian Islands. In addition, the threat is worse today than in 1962 because a microchip is a million times more vulnerable to a power surge than the thermionic valves in use in electronics in 1962.

The claim <http://www.alternet.org/story/25738/> makes about EMP from a 10-20 kt fission bomb being proportionately weaker than that from the 1.4 Mt *Starfish* test is blatant nonsense. The formula for EMP, even neglecting saturation, shows that the peak electric field varies as the square root of the weapon yield divided by the distance from the burst. Hence, a 100-fold increase in yield only increases the EMP at a given distance by a factor of 10, even when you neglect saturation.

When you include saturation, the difference is even less. Saturation introduces an exponential limiting of the form:  $E = Y[1 - \exp\{-(X/Y)^2\}]^{1/2}$ , where  $X$  is peak EMP predicted by the simple law that ignores saturation, and  $Y$  is the saturation field ( $Y \sim 60,000$  v/m). (When  $X$  is very large, the exponential disappears so this formula reduces to the saturation value  $E=Y$ , but when  $X$  is very small, the formula reduces to  $E=X$ , the weak field limit. The reason for the square and square root powers appearing instead of just  $E = Y[1 - \exp\{-(X/Y)\}]$ , is actually due to the fact that for the time of peak EMP, the *air conductivity at that time is proportional to the square-root of the Compton current*. I'll return to this mathematical model in a later post. In the meantime see the full calculations of EMP as a function of burst altitude online in Louis W. Seiler, Jr., *A Calculational Model for High Altitude EMP*, report [AD-A009208](#), **March 1975**.)

Still another factor you have to take account of is that Philip J. Dolan's formerly classified *Capabilities of Nuclear Weapons*, DNA-EM-1, chapters 5 and 7, show that the prompt gamma yield fraction was only 0.1% for *Starfish* but can be 0.5% for less efficient low yield pure fission devices, depending on the design.

Hence a 10-20 kt fission weapon, because it has a thinner case than a massive x-ray coupled 1.4 Mt thermonuclear weapon (*Starfish*), would result in up to 5 times as much prompt gamma ray energy release per kiloton of yield, which causes the peak EMP. Taking all factors into account, it is easy to design a 10-20 kt fission weapon which produces

exactly the same peak EMP as *Starfish* if you reduce the burst altitude slightly (the area covered will still be massive). Another plus is that, because you are only dealing with a single stage design, there is no danger of pre-ionisation of the atmosphere.

If gamma or x-rays from the first stage deposit much energy in the atmosphere, they will cause ionisation and hence a rise in conductivity of the air, which will literally 'short out' much of the Compton current for the EMP from the second pulse of gamma rays (see Dr Bernardin's comment, quoted above). Dr Mario Rabinowitz was censored out in the early 1980s, after he wrote a paper {by email dated November 19, 2006 6:42 PM he kindly confirms to me: 'I actually did this work in the very early 80's. The forces that be suppressed release of my EPRI report, and prevented publication of my work until 1987. I even have a galley of my paper in Science which managed to get through their tough review process. It was about a week before being published, when it was killed.'}.

Dr Bernardin rediscovered this in a classified report dated 1986 and refined the calculations to quantify precisely how primary stage gamma and x-rays reduce the main EMP by pre-ionizing the atmosphere. Dr Rabinowitz **independently published in 1987 giving a general discussion of it in his less weapons-sensitive - unclassified - report which was published in an IEEE journal**, where he notices also that you can't use several EMP weapons or they will interfere with each other, reducing the total EMP.

*So nuclear terrorism using EMP from one single-stage low-yield fission weapon is really a very real threat.* Unfortunately, Dr Lowell Wood **did not explain these facts when asked** so the media ignored the reports vague (i.e., unscientific, as in: *lacking actual nuclear test data to validate claims*) warning of EMP:

'Wood refused, however, to respond to questions about whether weapons capable of doing such damage are technologically possible and within reach of so-called "rogue" states and terrorists he said might pose a threat. "You seriously don't expect answers in an unclassified [setting] to those sorts of questions?" he said.'

The media justifiably reported this poor answer under the banner **'Plausibility of EMP Threat Classified, Expert Says'**. Why should the media believe severe claims without seeing hard nuclear test evidence and rigorous mathematical physics to back them up?

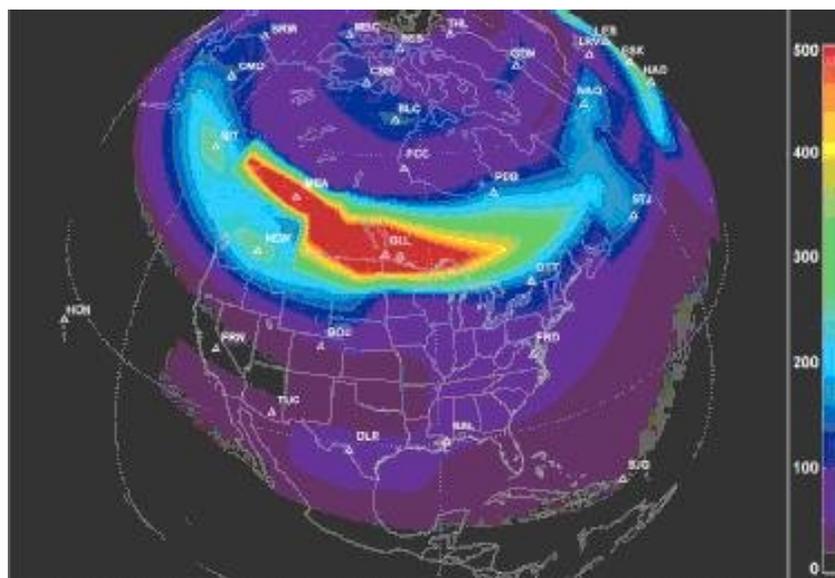
See the recent non-technical U.S. Congress sponsored discussion: **Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, Volume 1: Executive Summary, July 22, 2004**. This unclassified volume of the report doesn't contain any science, but it does have colourful maps with circles to illustrate how much of America would be covered by EMP for different heights of burst and so forth. The **accompanying 2004 EMP hearings** discuss the politics, such as an outrageous threat allegedly made by the Soviet Ambassador to the U.S., **Vladimir Lukin, who said to the Americans in Vienna in May 1999: 'we have the ultimate ability to bring you down [by EMP]'**. (It was this alleged threat, or warning, or whatever you'd call it, that prompted the new American congressional EMP concerns.)

Appendix A of the July 2004 Commission EMP report quotes from Thomas C. Schelling's Foreword to Roberta Wohlstetter's book *Pearl Harbor: Warning and Decision*, Stanford University Press, 1962, p. vii:

'[There is] a tendency in our planning to confuse the unfamiliar with the improbable. The contingency we have not considered looks strange; what looks strange is therefore improbable; what seems improbable need not be considered seriously.'

This is true. Even when Hitler mobilized 100 divisions at the Soviet Union's border in 1941, Stalin was dismissive of all reports of preparations being made by the Nazis to invade the Soviet Union (this was because of the Nazi-Soviet peace-pact of 1939, creating a false sense of security to the USSR). Herman Kahn has explained in *On Thermonuclear War* (1960) how Pearl Harbor, Oahu, Hawaii (appropriately by coincidence also the centre of unpredicted EMP damage in the

1962 *Starfish* nuclear test) was supposedly immune from attack, because it was shallower than the textbook-stated minimum water depth for a torpedo. The Japanese simply made special torpedoes to use in the attack on the U.S. Pacific Fleet in 1941. (Even when America received advanced warning of the attack, its wishful thinking simply dismissed the warning as an error, so no warning was passed on, and the scale of the tragedy was maximised.)



Geomagnetic field disturbance conditions, dB/dt (nT/min) over North America at time 7:45 UT on March 13, 1989

Source: Metatech Corporation, Applied Power Solutions

Above: the 2004 Commission report on EMP includes this map of the EMP from the solar storm on 13 March 1989 which had effects similar to a weak MHD-EMP and the auroral EMP (caused by a fraction of the debris fireball and charged particle radiation which moves along magnetic field lines between conjugate points in different hemispheres). For example, the 1989 event overloaded and caused the collapse of Quebec Hydro power supply grid. Page 12 says:

'During the Northeast power blackout of 1965, Consolidated Edison generators, transformers, motors, and auxiliary equipment were damaged by the sudden shutdown. In particular, the #3 unit at the Ravenswood power plant in New York City suffered damage when the blackout caused loss of oil pressure to the main turbine bearing. The damage kept that unit out of service for nearly a year, and more immediately, complicated and delayed the restoration of service to New York City.'

There is a 2004 U.S. Army review of EMP by Thomas C. Riddle online: **NUCLEAR HIGH ALTITUDE ELECTROMAGNETIC PULSE – IMPLICATIONS FOR HOMELAND SECURITY AND HOMELAND DEFENSE**. There is also a U.S. Army EMP protection Technical Army (TM 5-590) [here](#), and Dr Glen A. Williamson who was at Kwajalein Atoll when *Starfish* was detonated in 1962, has an informed page about EMP protection [here](#).

But it is not even all one-sided doom and gloom! Lawrence Livermore National Laboratory in its February 1992 Energy and Technology Review was considering 'EMP warheads for nonlethal attacks of targets with sensitive electronics.' So it is even possible that the Allies could be the first to use this new effect for peaceful and safe conflict resolution, as I suggested in the November 1994 issue of *Electronics World*.

Pages 19-21 of **A 'Quick Look' at the Technical Results of *Starfish Prime***, August 1962 states:

'At Kwajalein, 1400 miles to the west, a dense overcast extended the length of the eastern horizon to a height of 5 or 8 degrees. At 0900 GMT a brilliant white flash burned through the clouds rapidly changing to an expanding green ball of irradiance extending into the clear sky above the overcast. From its surface extruded great white fingers, resembling cirro-stratus clouds, which rose to 40 degrees above the horizon in sweeping arcs turning downward toward the poles and

disappearing in seconds to be replaced by spectacular concentric cirrus like rings moving out from the blast at tremendous initial velocity, finally stopping when the outermost ring was 50 degrees overhead. They did not disappear but persisted in a state of frozen stillness. All this occurred, I would judge, within 45 seconds. As the greenish light turned to purple and began to fade at the point of burst, a bright red glow began to develop on the horizon at a direction 50 degrees north of east and simultaneously 50 degrees south of east expanding inward and upward until the whole eastern sky was a dull burning red semicircle 100 degrees north to south and halfway to the zenith obliterating some of the lesser stars. This condition, interspersed with tremendous white rainbows, persisted no less than seven minutes.

'At zero time at Johnston, a white flash occurred, but as soon as one could remove his goggles, no intense light was present. A second after shot time a mottled red disc was observed directly overhead and covered the sky down to about 45 degrees from the zenith. Generally, the red mottled region was more intense on the eastern portions. Along the magnetic north-south line through the burst, a white-yellow streak extended and grew to the north from near zenith. The width of the white streaked region grew from a few degrees at a few seconds to about 5-10 degrees in 30 seconds. Growth of the auroral region to the north was by addition of new lines developing from west to east. The white-yellow auroral streamers receded upward from the horizon to the north and grew to the south and at about 2 minutes the white-yellow bands were still about 10 degrees wide and extended mainly from near zenith to the south. By about two minutes, the red disc region had completed disappearance in the west and was rapidly fading on the eastern portion of the overhead disc. At 400 seconds essentially all major visible phenomena had disappeared except for possibly some faint red glow along the north-south line and on the horizon to the north. No sounds were heard at Johnston Island that could be definitely attributed to the detonation.

'Strong electromagnetic signals were observed from the burst, as were significant magnetic field disturbances and earth currents.'

Update: The DVD called *Nukes in Space: the Rainbow Bombs (Narrated by William Shatner)*, contains an interview comment by Dr Byron Ristvet of the U.S. Defense Threat Reduction Agency who states that either the 1958 *Teak* or *Orange* shot caused unexpected EMP induced power cuts on Oahu in the Hawaiian Islands:

*'As it was, one of those two high altitude shots [Teak and Orange, August 1958] did affect the power grid on Oahu, knocking out quite a bit of it. That was unexpected.'*

Oahu is 71 km long by 48 km wide, and power cables could have picked up significant EMP, especially the MHD-EMP effect caused by fireball expansion. However, this is surmise. Why is the U.S. Defense Threat Reduction Agency being coy over their EMP effects data? Which test did this? Why not say "*TEAK* knocked out part of the power grid on Oahu"? Why secrecy?

Obviously the one factor against 3.8 Mt *TEAK* causing damage in Hawaii was that the burst altitude of only 77 km was below the horizon as seen from Hawaii, cutting off the highest frequencies of the EMP from reaching Hawaii, although the rising fireball later appeared over the horizon as it gained sufficient altitude. However, a [very useful Norwegian report on EMP](#) seems to state that *TEAK* in 1958 had some similar effects to those from *STARFISH*:

['Spesielle sikringer som skulle beskytte disse lamper ble ødelagt. Ved en eksplosjon samme sted i 1958 p•a. 4 Mt i en høyde av 77 km \(Teak\) ble det ogs•ngitt at det oppsto feil p•lektrisk utstyr i Hawaii \(24\).'](#)

[\['Special protection that would protect these lamps was destroyed by an explosion on the same place in 1958 of yield approximately 4 Mt and burst height of 77 km \(Teak\), and it was also indicated that it resulted in malfunctions to electrical equipment along roads in Hawaii \(24\).'\]](#)

Reference (24) is to two reports: *EMP threat and protective measures*, US Office of Civil Defence, report TR-61 A, US OCD (1971) and *EMP and associated effects on power, communications and command and control systems*, report JES-107-1M-12-63, Joslyn Electronic Systems (1963).

Another example: the sanitized report ITR-1660-(SAN), *Operation Hardtack: Preliminary Report, Technical Summary of Military Effects Programs 1-9*, DASA, Sandia Base, Albuquerque, New Mexico, 23 September 1959, sanitized version 23 February 1999.

On page 347 of ITR-1660-(SAN), the first American measurement of high altitude EMP was made not at *Starfish* in 1962 (which Dr Conrad Longmire claimed), but at the 2 kt *Yucca* test in 1958. (The *Teak* shot EMP measurements failed because the shot went off directly overhead instead of 20 miles downrange due to a missile guidance error.) They only measured the beta ionisation which affects radio/radar transmissions for hours, but it is the brief high frequency EMP which causes physical damage to equipment. Although *Yucca* was of too low yield to cause EMP damage, oscilloscopes in 1958 did record the intense, high frequency magnetic dipole EMP mechanism which caused the damage in the higher yield (1.4 Mt) *Starfish* test of 1962:

'Shot *Yucca* ... [EMP] field strength at Kusaie indicated that deflection at Wotho would have been some five times the scope limits... The wave form was radically different from that expected. The initial pulse was positive, instead of the usual negative. The signal consisted mostly of high frequencies of the order of 4 Mc, instead of the primary lower-frequency component [electric dipole EMP] normally received ...'

Another EMP cover up story - which comes from Glen Williamson who was on Kwajalein when *Starfish* was tested - is that the first surface burst in Nevada in 1951 (test *Sugar*) coupled EMP out of cables from the bomb to the control point, and on to the main power supply, then beyond it to Las Vegas, tripping circuit breakers:

'Right after WWII, during one Nevada test, circuit breakers, 90 miles away [Las Vegas], were tripped; thus giving early hints of EMP.'

Notice that there is some evidence of something like this in extracts from B. J. Stralser's 30 April 1961 EG&G Secret - Restricted Data report *Electromagnetic Effects from Nuclear Tests*. Previous Nevada tests were aircraft dropped free air bursts with no close-in cables to couple EMP into equipment. As soon as cable-controlled Nevada testing started, they found EMP returning in the cables would get into other circuits by cross-talk (i.e., mutual inductance, Ivor Catt's alleged area of excellence).

After the first bad EMP event in 1951, they switched over the Nevada Test Site's telephone system to run off diesel generators at shot times, to avoid EMP getting into the U.S. power grid. The Stralser report states that at the main power supply, 30 miles (50 km) from the detonation, technicians were warned over the loudspeaker system prior to each shot:

*'Stand by to reset circuit breakers.'*

Stralser also reports that protective measures like carbon block lightning protectors proved useless at the Nevada against the EMP from the cables: the EMP was so severe it would simply 'arc over' the power surge arrestor. Lead-tape shielded cables at out to 800 metres from Nevada tests with yields below 75 kt had their multicore conductors fused together by the heat of carrying thousands of amps of EMP current! The full Stralser report is unavailable at present, only a brief extract and summary of it can be found in the U.K. National Archives at Kew, in an originally 'Secret - Atomic' note (the British equivalent of the American 'Secret - Restricted Data' classification). The file is a British Home Office Scientific Advisory Branch report on the effects of nuclear detonations on communications technology. Dr R. H. Purcell was the chief scientific advisor in the Home Office at that time, and apparently he wrote the summary for the benefit of his scientists because it was of too high classification for them to see the full American report. A few years later, the summary was published - without the source (Stralser) report being disclosed - in the Home Office Scientific Advisory Branch magazine *Fission*

## Fragments.

### UPDATE (10 November 2008)

Various later posts add to the information on this post. The following section from the latest EMP post (mainly concerned with surface and air bursts, but including the following on high altitude bursts) is particularly important and relevant so the excerpt is being copied from that post to here:

<http://glasstone.blogspot.com/2008/11/radiation-and-emp-chapters-from-dolans.html>:

#### UPDATE ON HIGH ALTITUDE BURST EMP FIELD STRENGTH PREDICTIONS

An earlier post on this blog, 'EMP radiation from nuclear space bursts in 1962', attempted to document the vital scientific data concerning high altitude nuclear test EMP from American and Russian nuclear tests in 1962 (and some previous tests in 1958 that were not properly measured due to a theory by Bethe that led to instruments being set up to detect a radiated EMP with the wrong polarization, duration and strength). That post still contains valuable data and the motivation for civil defence, although a great deal has changed and much new vital technical information on high altitude EMP predictions has come to light since that post was written.

Dr Conrad Longmire, as stated in that post, discovered the vital 'magnetic dipole' EMP mechanism for high altitude explosions (quite different to Bethe's 'electric dipole' predictions from 1958) after he saw Richard Wakefield's curve of EMP from the 9 July 1962 *Starfish* test of 1.4 Mt (1.4 kt of which was prompt gamma rays) at 400 km altitude.

'Longmire, a weapons designer who worked in [Los Alamos] T Division from 1949 to 1969 and currently is a Lab associate, played a key role in developing an understanding of some of the fundamental processes in weapons performance. His work included the original detailed theoretical analysis of boosting and ignition of the first thermonuclear device. Longmire ... wrote *Elementary Plasma Physics* (one of the early textbooks on this topic). He also became the first person to work out a detailed theory of the generation and propagation of the [high altitude magnetic dipole mechanism] electromagnetic pulse from nuclear weapons.'

*Starfish* was however not the first suitable measured curve of the magnetic dipole EMP, which was obtained from the 2 kt *Yucca* test in 1958 and described in detail in 1959 on page 347 of report ITR-1660-(SAN), but no EMP damage occurred from that test and so nobody worried about the size and shape of that EMP which was treated as an anomaly: 'Shot Yucca ... [EMP] field strength at Kusaie indicated that deflection at Wotho would have been some five times the scope limits... The wave form was radically different from that expected. The initial pulse was positive, instead of the usual negative. The signal consisted mostly of high frequencies of the order of 4 Mc, instead of the primary lower-frequency component [electric dipole EMP] normally received ...' Longmire's secret lectures on the magnetic dipole EMP mechanism were included in his April 1964 Los Alamos National Laboratory report, LAMS-3073. The first open publication of Longmire's theory was in the 1965 paper 'Detection of the Electromagnetic Radiation from Nuclear Explosions in Space' in the *Physical Review* (vol. 137B, p. 1369) by W. J. Karzas and Richard Latter of the RAND Corporation, which is available in RAND report format online as report AD0607788. (The same authors had perviously in October 1961 written a report on Bethe's misleading 'electric dipole' EMP mechanism - predicting incorrectly an EMP peak electric field of only 1 volt/metre at 400 km from a burst like *Starfish* instead of 50,000 volts/metre which occurs in the 'magnetic dipole' mechanism - called 'Electromagnetic Radiation from a Nuclear Explosion in Space', AD0412984.) It was only after the publication of this 1965 paper that the first real concerns about civil defence implications of high altitude bursts occurred.

The next paper which is widely cited in the open literature is Longmire's, 'On the electromagnetic pulse produced by nuclear explosions' published in the January 1978 issue of *IEEE Transactions on Antennas and Propagation*, volume 26, issue 1, pp. 3-13. That paper does *not* give the EMP field strength on the ground as a function of the high altitude burst yield and altitude, but it does give a useful discussion of the theoretical physics involved and also has a brief history of EMP. In the earlier post on this blog, I extracted the vital quantitative information from a March 1975 masters degree thesis by Louis W. Seiler, Jr., *A Calculational Model for High Altitude EMP*, AD-A009208, pages 33 and 36, which had gone unnoticed by everyone with an interest in the subject. I also obtained Richard Wakefield's EMP measurement from the Starfish test which is published in K. S. H. Lee's 1986 book, *EMP Interaction*, and added a scale to the plot using a declassified graph in Dolan's *DNA-EM-1*, Chapter 7. However, more recent information has now come to light.

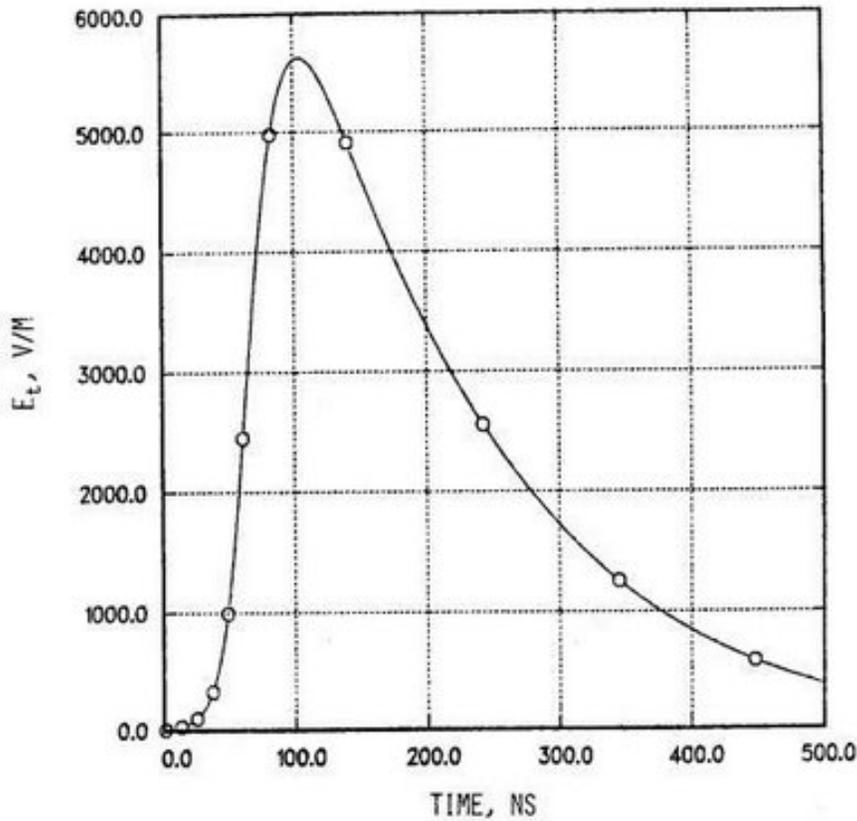
***The reason for checking these facts scientifically for civil defence is that the entire EMP problem will be dismissed by critics as a Pentagon invention for wasting time because of the alleged lack of EMP effects evidence or because of excessive secrecy being used as an excuse to not bother presenting the facts to the public in a scientific manner, with evidence for assertions ('extraordinary claims require extraordinary evidence' - Carl Sagan).***

The latest information on EMP comes from a brand new (October 24, 2008) SUMMA Foundation database of EMP reports compiled by Dr Carl E. Baum of the Air Force Weapons Laboratory and hosted on the internet site of the Electrical and Computer Engineering Department of the University of New Mexico:

***'Announcements. Update: Oct. 24, 2008 - We are pleased to announce that many of the unclassified Note Series are now on-line and is being hosted by the Electrical and Computer Engineering Department at the University of New Mexico. More notes will be added in the coming months. We appreciate your patience.'***

The first of these reports that needs to be discussed here is Note 353 of March 1985 by Conrad L. Longmire, 'EMP on Honolulu from the Starfish Event'. Longmire notes that: 'the transverse component of the geomagnetic field, to which the EMP amplitude is approximately proportional, was only 0.23 Gauss. Over the northern U.S., for some rays, the transverse geomagnetic field is 2.5 times larger.' For *Starfish* he uses 400 km burst altitude, 1.4 Mt total yield and 1.4 kt (i.e. 0.1%) prompt gamma ray yield with a mean gamma ray energy of 2 MeV. Honolulu, Hawaii (which was 1,450 km from the Starfish bomb detonation point 400 km above Johnston Island) had a magnetic azimuth of 54.3 degrees East and a geomagnetic field strength in the source region of 0.35 gauss (the transverse component of this was 0.23 Gauss).

Longmire calculates that the peak radiated (transverse) EMP at Honolulu from Starfish was only 5,600 volts/metre at about 0.1 microsecond, with the EMP delivering 0.1 J/m<sup>2</sup> of energy: 'The efficiency of conversion of gamma energy to EMP in this [Honolulu] direction is about 4.5 percent.' Longmire's vital *Starfish* EMP graph for Honolulu is shown below:

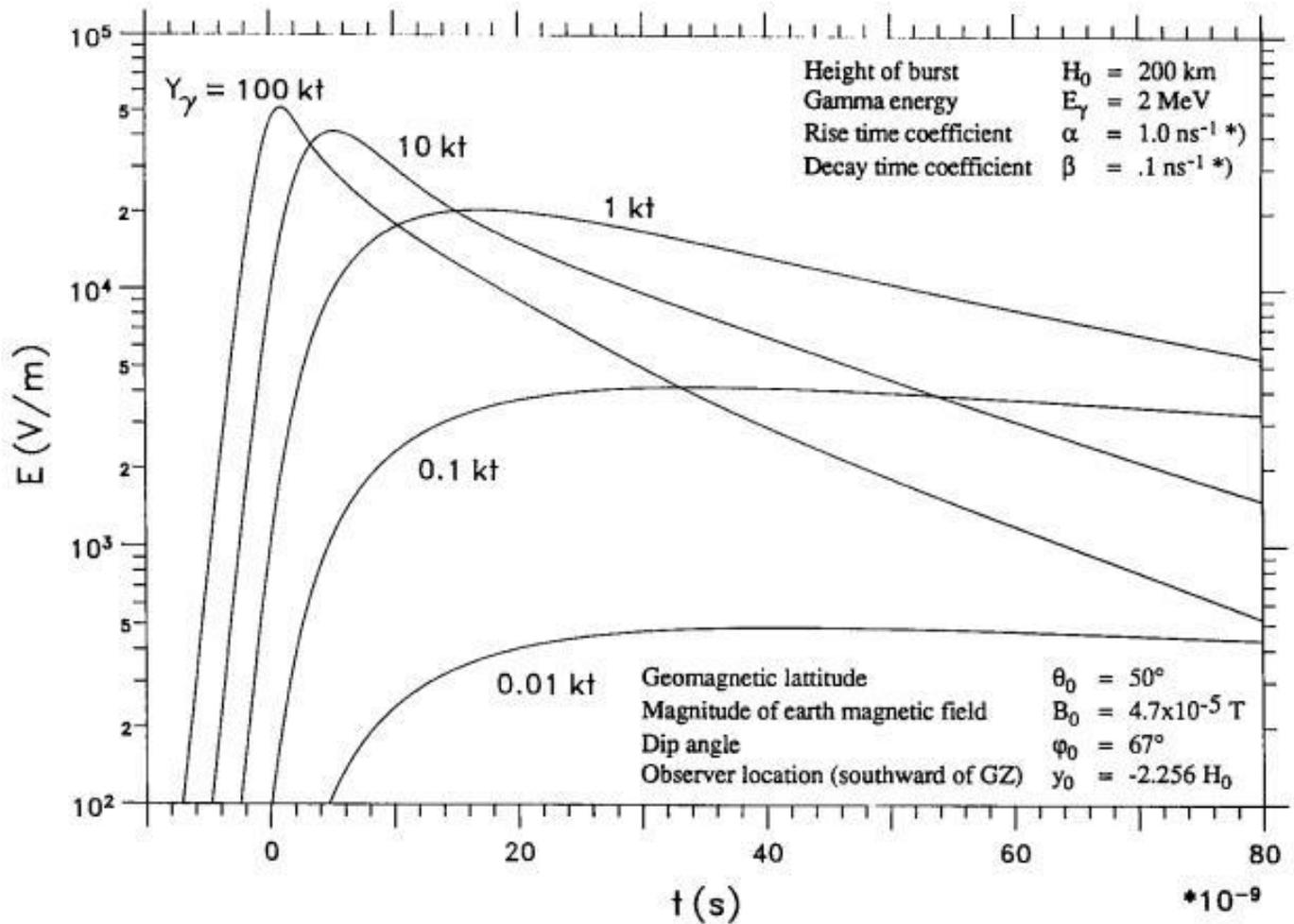


TRANSVERSE ELECTRIC FIELD AT HONOLULU

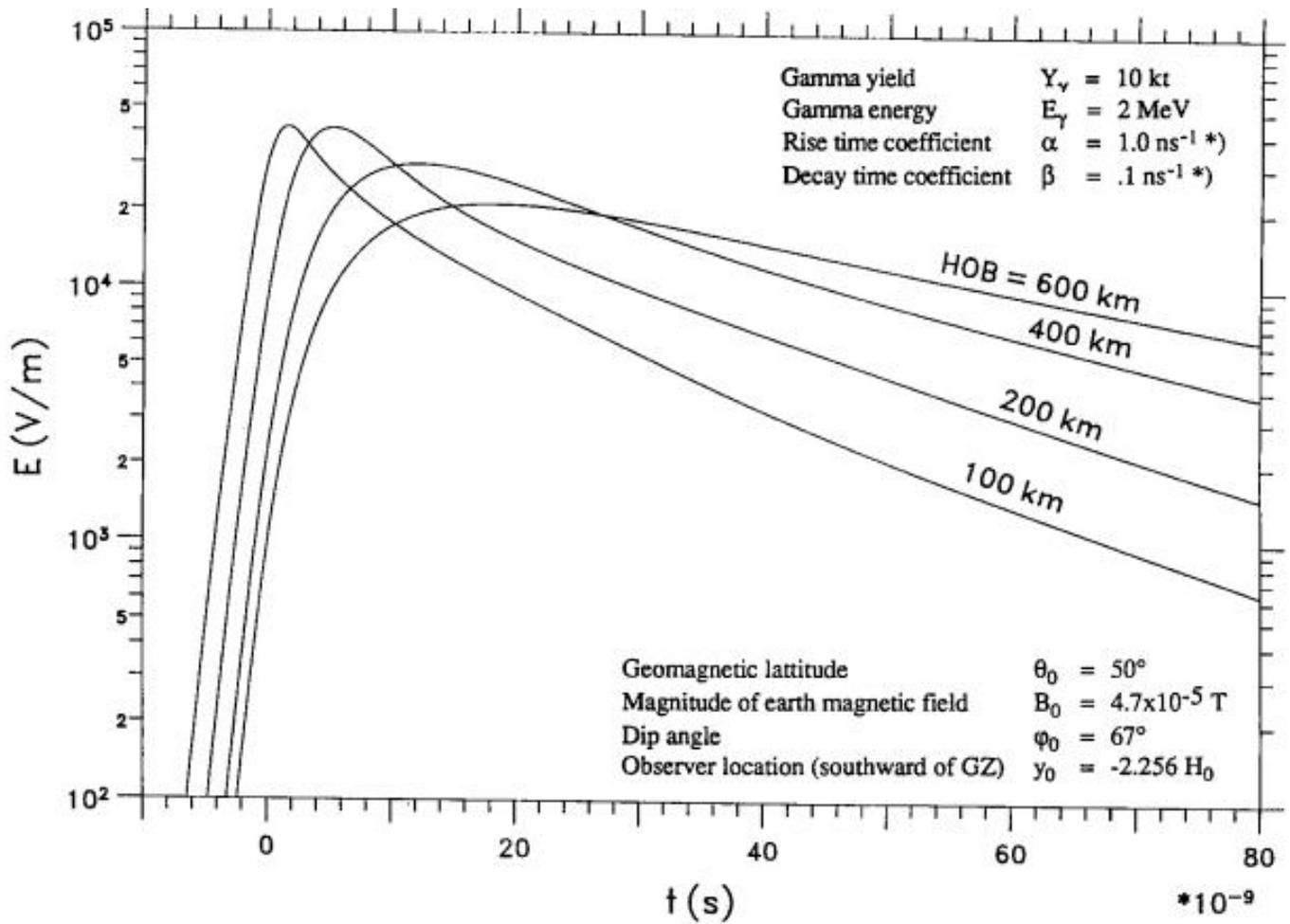
Longmire points out that much higher EMP fields occurred closer to the burst point, concluding on page 12: 'We see that the amplitude of the EMP incident on Honolulu [which blew the sturdy electric fuses in 1-3% of the streetlamps on the island] from the *Starfish* event was considerably smaller than could be produced over the northern U.S. ... Therefore one cannot conclude from what electrical and electronic damage did *not* occur in Honolulu that high-altitude EMP is *not* a serious threat.'

'In addition, modern electronics is much more sensitive than that in common use in 1962. Strings of series-connected street lights did go out in Honolulu ... sensitive semiconductor components can easily be burned out by the EMP itself,  $10^{-7}$  Joules being reportedly sufficient.'

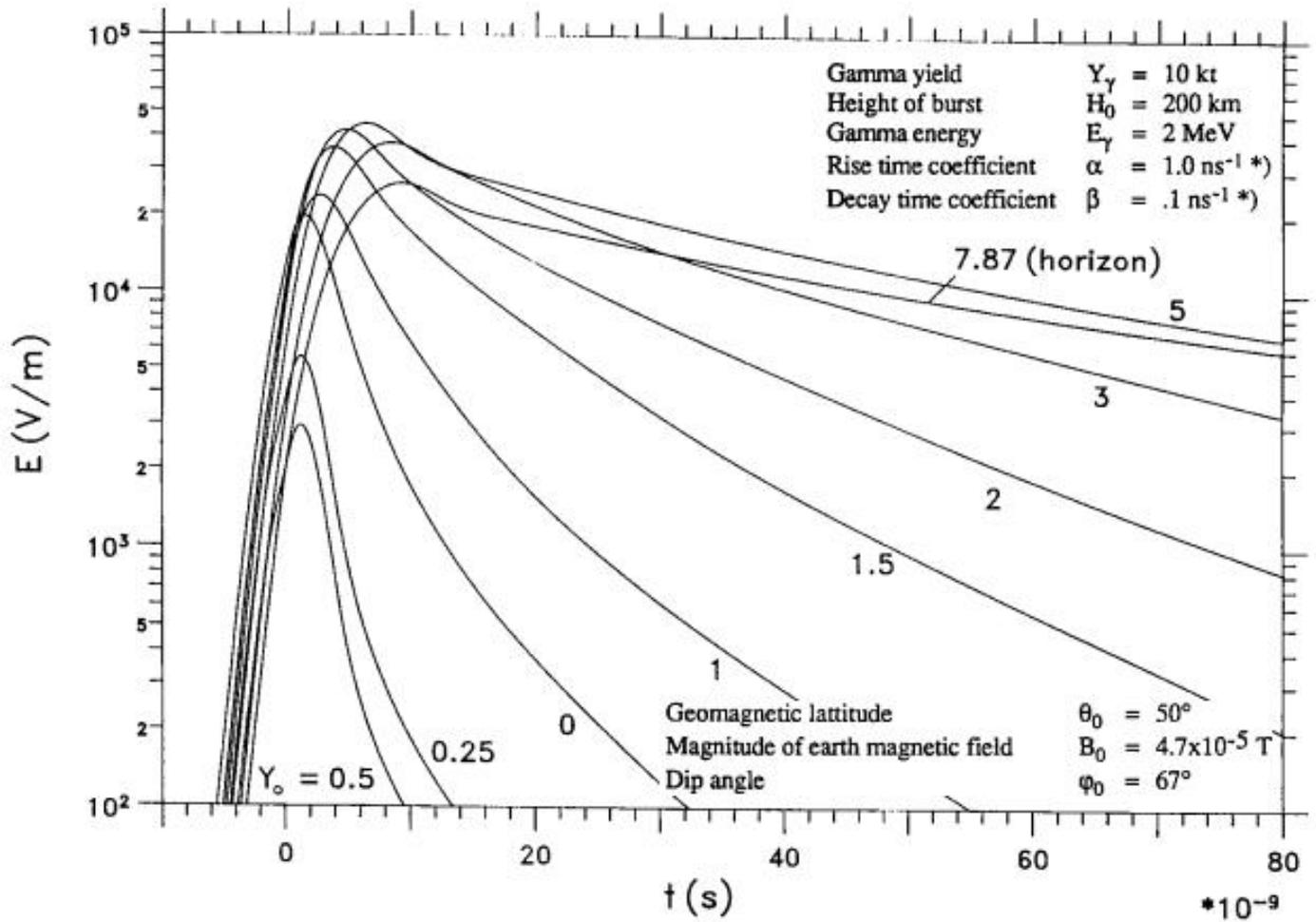
The next vitally important report deserving discussion here in Dr Baum's collection is [K. D. Leuthauser's \*A Complete EMP Environment Generated by High-Altitude Nuclear Bursts\*, Note 363, October 1992](#), which gives the following vital data (notice that 10 kt prompt gamma ray yield generally corresponds to a typical thermonuclear weapon yield of about 10 megatons):



Variation of total electric field with gamma yield

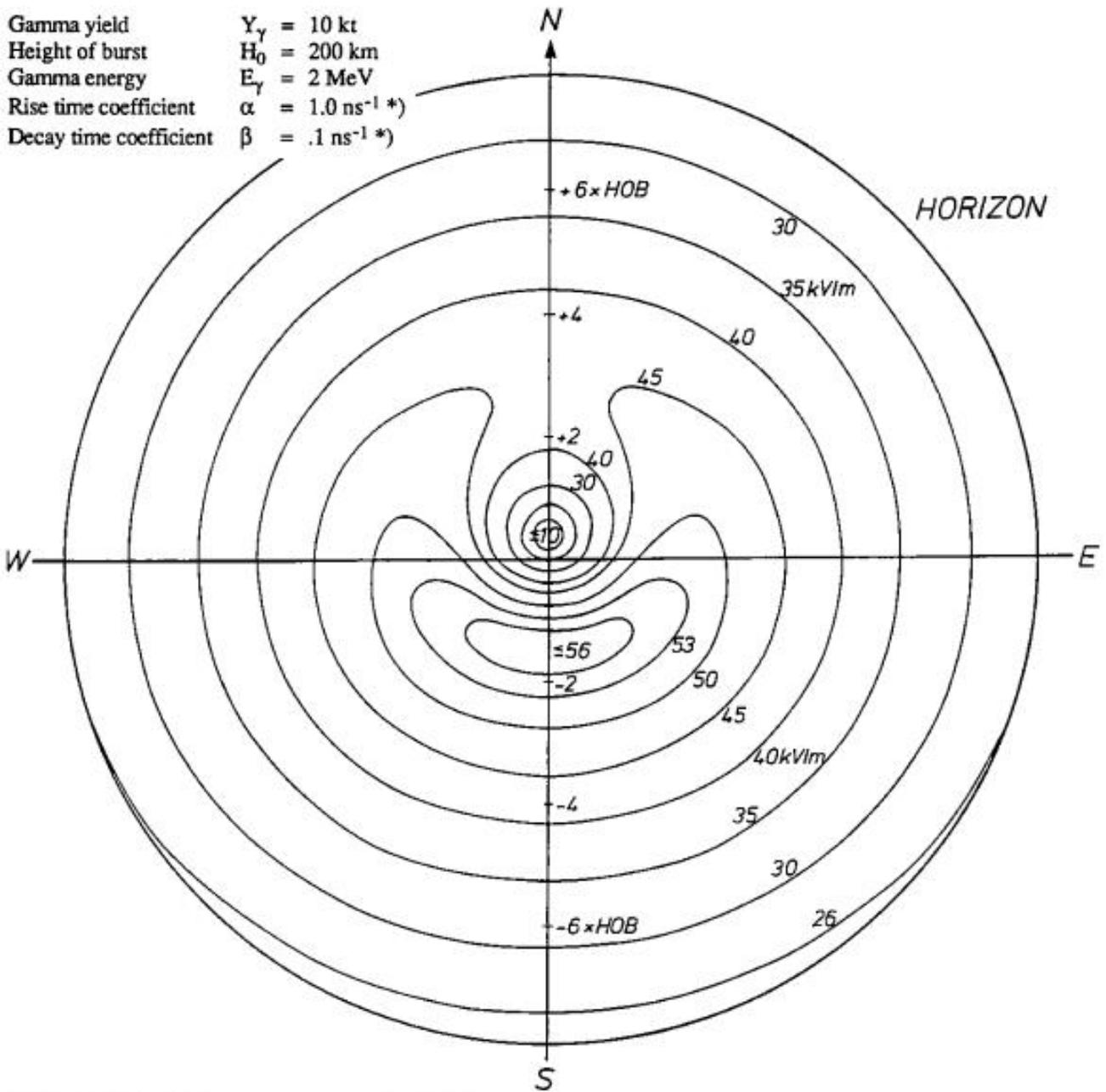


Variation of total electric field with height of burst



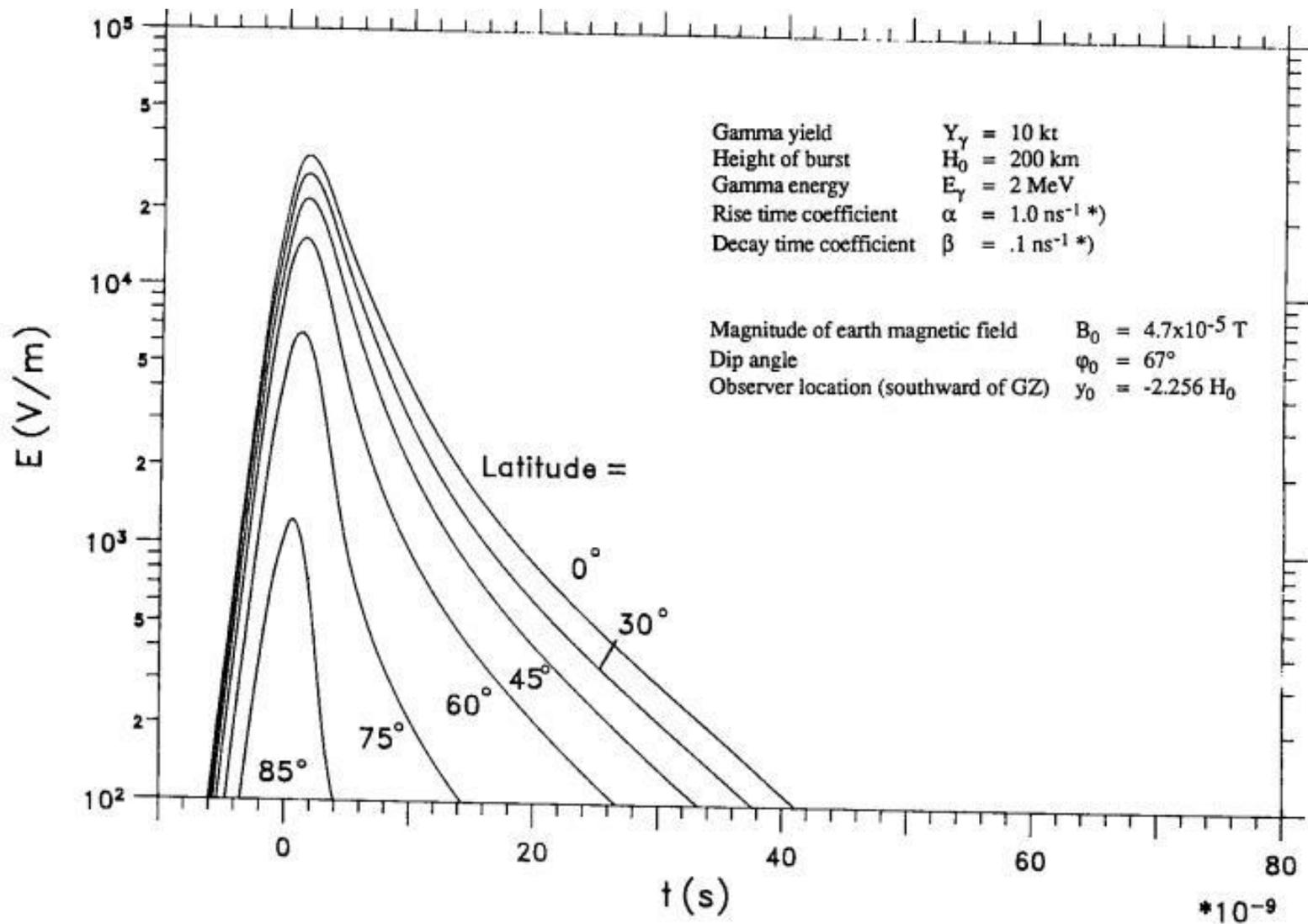
Total electric fields at various observer locations north of Ground Zero (in units of HOB = 200 km)

Gamma yield  $Y_\gamma = 10 \text{ kt}$   
 Height of burst  $H_0 = 200 \text{ km}$   
 Gamma energy  $E_\gamma = 2 \text{ MeV}$   
 Rise time coefficient  $\alpha = 1.0 \text{ ns}^{-1} *$   
 Decay time coefficient  $\beta = .1 \text{ ns}^{-1} *$



Geomagnetic latitude  $\theta_0 = 50^\circ$   
 Magnitude of earth magnetic field  $B_0 = 4.7 \times 10^{-5} \text{ T}$   
 Dip angle  $\phi_0 = 67^\circ$

Contour plot of peak electric field magnitudes



Total electric fields at Ground Zero ( $y_0 = 0$ )  
 for explosions at various geomagnetic latitudes

Quotations from some of the Theoretical Notes on EMP in Dr Carl E. Baum's database:

Theoretical Note 368:

Conrad L. Longmire, *Justification and verification of High-Altitude EMP Theory, Part 1*, Mission Research Corporation, June 1986, pages 1-3:

'Over the 22 years since the first publication of the theory of High-Altitude Electromagnetic Pulse (HEMP), there have been several doubters of the correctness of that theory. ... commonly, it has been claimed that the HEMP is a much smaller pulse than our theory indicates and it has been implied, though not directly stated in writing, that the HEMP has been exaggerated by those who work on it in order to perpetuate their own employment. It could be noted that, in some quarters, the disparagement of HEMP has itself become an occupation. ...

'... One possible difficulty with previous papers is that they are based on solving Maxwell's equations. While this is the most legitimate approach for the mathematically inclined reader, many of the individuals we think it important to reach may not feel comfortable with that approach. We admit to being surprised at the number of people who have wanted to understand HEMP in terms of the fields radiated by individual Compton recoil electrons. Apparently our schools do a better job in teaching the applications of Maxwell's equations (in this case, the cyclotron radiation) than they do in imparting a basic

understanding of those equations and how they work. ...

'The confidence we have in our calculations of the HEMP rests on two circumstances. The first of these is the basic simplicity of the theory. The physical processes involved, e.g., Compton scattering, are quite well known, and the physical parameters needed in the calculations, such as electron mobility, have been measured in relevant laboratory experiments. There is no mathematical difficulty in determining the solution of the outgoing wave equation, or in understanding why it is an accurate approximation. ...

'... the model of cycotron radiation from individual Compton recoil electrons is very difficult to apply with accuracy to our problem because of the multitudinous secondary electrons, which absorb the radiation emitted by the Compton electrons [preventing simple coherent addition of the individual fields from accelerated electrons once when the outgoing EMP wave front becomes strong, and therefore causing the radiated field to reach a saturation value in strong fields which is less than the simple summation of the individual electron contributions]. ...

'The other circumstance is that there is experimental data on the HEMP obtained by the Los Alamos Scientific Laboratory in the nuclear test series carried out in 1962. In a classified companion report (Mission Research Corp. report MRC-R-1037, November 1986) we present calculations of the HEMP from the *Kingfish* and *Bluegill* events and compare them with the experimental data. These calculations were performed some years ago, but they have not been widely circulated. In order to make the calculations transparently honest, the gamma-ray output was provided by Los Alamos, the HEMP calculations were performed by MRC and the comparison with the experimental data was made by RDA. The degree of agreement between calculation and experiment gives important verification of the correctness of HEMP theory.'

As stated in this blog post, [Theoretical Note TN353 of March 1985 by Conrad L. Longmire, \*EMP on Honolulu from the Starfish Event\*](#) calculates that the peak radiated (transverse) EMP at Honolulu from Starfish delivered only 0.1 J/m<sup>2</sup> of energy: 'The efficiency of conversion of gamma energy to EMP in this [Honolulu] direction is about 4.5 percent.'

He and his collaborators elaborate on the causes of this inefficiency problem on [page 24 of the January 1987 Theoretical Note TN354](#):

'Contributing to inefficiency ... only about half of the gamma energy is transferred to the Compton recoil electron, on the average [e.g., the mean 2 MeV prompt gamma rays create 1 MeV Compton electrons which in getting slowed down by hitting molecules each ionize 30,000 molecules releasing 30,000 'secondary' electrons, which uses up energy from the Compton electron that would otherwise be radiated as EMP energy; also, these 30,000 secondary electrons have random directions so they don't contribute to the Compton current, but they do contribute greatly to the rise in air conductivity, which helps to short-out the Compton current by allowing a return 'conduction current' of electrons to flow back to ions].'

Longmire also points out that Glasstone and Dolan's *Effects of Nuclear Weapons* pages [495](#) and [534](#) gives the fraction of bomb energy radiated in prompt gamma rays as 0.3 %. If this figure is correct, then 10 kt prompt gamma ray yield is obviously produced by a 3.3 megatons nuclear explosion. However, the Glasstone and Dolan figure of 0.3 % is apparently just the average of the 0.1 % to 0.5 % range specified by Dolan in [Capabilities of Nuclear Weapons, Chapter 7, Electromagnetic Pulse \(EMP\) Phenomena, page 7-1 \(Change 1, 1978 update\)](#):

'Briefly, the prompt gammas arise from the fission or fusion reactions taking place in the bomb and from the inelastic collisions of neutrons with the weapon materials. The fraction of the total weapon energy that may be contained in the prompt gammas will vary nominally from about 0.1% for high yield weapons to about 0.5% for low yield weapons, depending on weapon design and size. Special designs might increase the gamma fraction, whereas massive, inefficient designs would decrease it.'

Later related posts:

<http://glasstone.blogspot.com/2008/11/radiation-and-emp-chapters-from-dolans.html>

<http://glasstone.blogspot.com/2008/05/philip-j-dolans-formerly-secret.html>

<http://glasstone.blogspot.com/2006/04/teak-and-orange-each-38-mt-50-fission.html>

<http://glasstone.blogspot.com/2006/03/starfish-fireball-photograph.html>

*posted by nige @ 1:02 AM*

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### 20 Comments:

*At 10:52 PM,  Anonymous said...*

[http://en.wikipedia.org/wiki/Talk:Electromagnetic\\_pulse](http://en.wikipedia.org/wiki/Talk:Electromagnetic_pulse)

The EMP from a high air burst is never strong enough at the Earth's surface to do this. The strongest EMP was produced by the Hardtack-Teak shot, not the Starfish test. (Teak was 3.8 Mt and was detonated at 77 km. EMP field strength (but not area coverage) is maximised for a burst at 40 km altitude, so Teak at 77 km would have produced a stronger ground level EMP than Starfish at 400 km.) The prompt EMP electric field from Teak was not measured due to instrument failure, but the late-time magnetic field variation was measured in a laboratory which studies solar storms:

"... the Apia Observatory at Samoa recorded the 'sudden commencement' of an intense magnetic disturbance – four times stronger than any recorded due to solar storms – followed by a visible aurora along the earth's magnetic field lines (reference: A.L. Cullington, Nature, vol. 182, 1958, p. 1365)."

Since this EMP covered vast areas (though not as wide as those from Starfish), if the magnetic field was strong enough to wipe magnetic information off swipe cards, it would in 1962 have wiped magnetic audio and data tapes (a swipe card is just a plastic card with a strip of magnetic tape stuck on it). This didn't happen. If you think about it, the electromagnetic radiation which propagates is governed by Maxwell's equations (like visible light), and the magnetic field component of such a light velocity wave is given by:

$$B = E / c$$

Inserting the commonly used value for EMP of  $E = 50,000$  volts/metre for the prompt field with a rise time of about 20 nanoseconds, the magnetic field strength is seen to be  $B = 0.000167$  Teslas. This is only 2.9 times the natural magnetic field strength in Washington D.C. according to <http://www.vsg.cape.com/~pbaum/magtape.htm> which says the natural field there is 0.0000571 Testa. However, the ability to erase magnetic tape or credit card strip information depends on the field intensity in Orested not the field strength in Teslas:

"QUESTION: What is the danger that my tape will accidentally be erased?

"ANSWER: Standard open reel audio tapes have a coercivity of approximately 360 Oersteds. It takes an even greater magnetic field (approaching 900 Oersted) to completely erase a tape. For a comparison: The earth's magnetic field is 0.6 Oersted." - <http://www.vsg.cape.com/~pbaum/magtape.htm>

EMP can't directly wipe out magnetic information. However, it could wipe magnetic information indirectly, if it induced a large current in a long conductor which runs near magnetic tape. Any conductor carrying an induced pulse of electric energy creates a magnetic field around it, which can easily be much stronger than the magnetic field of the EMP in free space. For example, a long overhead power transmission line, subjected to 50,000 v/m peak EMP will typically give a

pulse with a peak of 1 million volts at 10,000 Amps. This will create tremendous magnetic fields. When these pulses go into transformers at the end of the power line, the transformer can explode or catch fire, but some of the energy is passed on before that happens, and can end up in home power systems. Any loop of cable connected to the mains will be a source of a powerful magnetic field which could wipe nearby magnetic tape, cards, and discs. 172.212.17.34 21:03, 30 March 2006 (UTC)

Microchips are vulnerable. In the 1950s and 1960s, America tested weapons at Nevada with yields up to 74 kilotons in air bursts and near surface bursts, which just produced 'clicks' on car radios. If you see B. J. Stralser's declassified 30 April 1961 EG&G report, Electromagnetic Effects from Nuclear Tests, you see that there is no damage to anything unless it was connected physically to a cable which had induced an EMP. Hence, in tower test, with cables running from bomb to control point 50 km away, after serious damage in a 1951 test they had to switch off mains power and go over to diesel generators at shot time. In the 1958 Teak test the 3.8 Mt bomb exploded 77 km directly over Johnston Island, producing a massive EMP, but again no portable radios were destroyed. In the 1962 Starfish test, and also three Russian tests, lots of things were damaged but only if they were connected to long wires. Portable radios working off batteries were OK. Although modern microchips are up to a million times more sensitive than valve/vacuum tube radios, the aerial size in a UHF cellular phone is really tiny compared to the long aerials of old HF valve/vacuum tube radios, so things balance out. I agree that anything you can fit in your pocket is not likely to be damaged by EMP, unless it is being recharged from the mains when the bomb exploded. (Batteries could only be damaged if they were being recharged at the time.) However, a safe, working cellular radio wouldn't be any use to you if the network (running from mains electricity) was zapped by EMP! 172.212.17.34 21:24, 30 March 2006 (UTC)

At 11:27 AM,  Anonymous said...

Dr Bernadin info:

[http://www.fas.org/spp/starwars/congress/1999\\_h/99-10-07bernardin.htm](http://www.fas.org/spp/starwars/congress/1999_h/99-10-07bernardin.htm):

Written Statement by Dr. Michael P. Bernardin

Provost for the Theoretical Institute for Thermonuclear and Nuclear Studies

Applied Theoretical and Computational Physics Division

Los Alamos National Laboratory

I have been employed in the nuclear weapon design division at Los Alamos National Laboratory since 1985 to work on nuclear weapon design, nuclear outputs, and high-altitude electromagnetic pulse (EMP) assessment. I discovered the impact of x-rays on EMP and quantified the impact of two-stage shadowing effects on it as well, revolutionizing the understanding of realistic EMP environments. From 1992 – 1995, I was the Laboratory Project Leader for the Joint DoD/DOE Phase 2 Feasibility Study of a High Power Radio Frequency (HPRF) Weapon. This study effort focused on the feasibility and effectiveness of developing an HPRF weapon for offensive purposes. Since 1996, I have been the Provost for a post-graduate nuclear weapon design Institute within the Laboratory, chartered with training the next generation of nuclear weapon designers. ...

The Defense Threat Reduction Agency (DTRA), through contractors that it employs, is the principal DoD organization for EMP assessment. Los Alamos also has a capability for assessing the large-amplitude portion of the EMP, and has provided the Joint Staff with independent EMP threat assessments since 1987. ...

For a 200-km height of burst, which might be appropriate for a hypothetical multi-Mt weapon, the horizon is located at

about 1600 km (or 1000 miles) from the point on the ground directly beneath the burst. For a 50-km height of burst, which might be appropriate for a 10-kt fission weapon, the horizon is located at about 800 km from the ground point beneath the burst. ...

[Very interesting: a 10 kt weapon would be best detonated at 50 km to produce the same (?) intensity of peak EMP on the earth's surface as a Mt weapon detonated at 200 km. Radius for damage from 10 kt burst at 50 km altitude is 800 km. Quite big!]

A characteristic amplitude of the electric field is 30,000 volts per meter (V/m) (Longmire, 1978). The intermediate-time component is defined as the portion of the pulse from one microsecond to one second, and it is produced primarily through prompt gamma rays that have been scattered in the atmosphere and by neutrons produced in the explosion. This component is characterized by a peak electric field value of 100 V/m (Radasky, 1988). The third component, the late-time component, is defined as the portion of the pulse beginning at one second and lasting up to several hundred seconds. It is produced primarily through the interaction of the expanding and rising fireball with the earth's geomagnetic field lines. This EMP component is characterized by a peak field of 0.01 V/m. ...

[The reason why this weaker MHD-EMP causes damage is that low frequencies can penetrate the topsoil and affect very long buried electric cables. Although the MHD-EMP field strength is tiny compared to 10 ns peak, the extra duration (1 peak second EMP is a time factor of 100,000,000 longer than 10 ns peak EMP) means that the energy deposited can be similar in both cases. However the MHD-EMP depends largely on the fission yield of the weapon, not the amount of prompt gamma ray energy which escapes from the weapon casing. Hence, bigger bombs - despite thicker cases - produce far more MHD-EMP energy. A low yield weapon, say 10 kt, with a thin case if burst at an appropriate altitude (50-150 km) may produce similar 10 ns peak EMP on the ground to 1 Mt burst at 300-500 kt, but it will produce much lower MHD-EMP effects.]

The ionization shorts out the EMP, limiting its value to typically 30,000 V/m.

High-energy x-rays produced by the exploding weapon can also enhance the ionization in the high-altitude EMP source region. This source of ionization was largely ignored in EMP assessments until 1986. Inclusion of the x-rays lowered the assessed values of the peak field for many weapons.

Note in graphic 3 that a thermonuclear weapon consists of two stages. The primary stage is typically of relatively low yield and is used to drive the secondary stage that produces a relatively large yield. Each weapon stage produces its own E1 EMP signal. But the primary stage gamma rays leave behind an ionized atmosphere from their EMP generation that is present when the secondary stage gamma rays arrive. Thus, the primary stage can degrade the EMP associated with the secondary stage.

Graphic 4 shows the spatial distribution of the peak EMP fields for a hypothetical weapon detonated over the United States. The directionality of the earth's magnetic field causes the largest peak-field region to occur to the south of the burst point. The larger numbers on the plot are peak electric field values, in thousands of volts per meter (kV/m), and the smaller numbers are distance increments in kilometers. Note that the peak field ranges from 12 to about 25 kV/m. ...

It is worthwhile reviewing the most famous of the EMP effects from U.S. atmospheric testing, namely the simultaneous failure of 30 strings of streetlights in Oahu during the Starfish event. Starfish was detonated at 400 km above Johnston Island in the Pacific on July 9, 1962. It had a yield of 1.4 Mt (about 115 times the yield of the bomb dropped on Hiroshima). Oahu was located approximately 1300 km from the designated ground zero of the burst, which was within line of sight of the detonation. A post-mortem following the event indicated that the failure of the strings of streetlights resulting from the Starfish event was due to damaged fuses. This event was analyzed by Charles Vittitoe, a Sandia National Laboratory scientist, in a report published in 1989 (SAND88-3341, April 1989). He notes that the observed damage is consistent with the magnitude and orientation of the EMP fields impinging on the streetlight strings that suffered damage. More importantly, he notes that the 30 strings of failed streetlights represented only about 1% of the streetlights that existed on

Oahu at the time. Thus, the effects were not ubiquitous. ...

## References

Barnes, P.R., et al, (1993). Electromagnetic Pulse Research on Electric Power Systems: Program Summary and Recommendations, Oak Ridge National Laboratory report ORNL-6708.

Longmire, C.L., (1978). On the Electromagnetic Pulse Produced by Nuclear Explosions, IEEE Transactions on Antennas and Propagation, Vol. AP-26, No. 1, p. 3.

Radasky, W.A., et al, (1988). High-Altitude Electromagnetic Pulse – Theory and Calculations, Defense Nuclear Agency technical report DNA-TR-88-123. See figure on page 2.

Vittitoe, C.N., (1989). Did High-Altitude EMP Cause the Hawaiian Streetlight Incident? Sandia National Laboratories report SAND88-3341.

*At 7:54 PM,  Anonymous said...*

The White House is now ignoring high altitude EMP threats in its current civil defence planning. They also ignore the likely scenario of an underwater burst in a harbor. They only consider a 10 kt gun type U-235 burst surface burst on land (in Washington D.C.). All the other scenarios are biological, chemical and radioactive ground-level attacks.

The study, marked "official use", is: <http://www.strac.org/Docs/Exdocs/National%20Planning%20Scenarios%20Feb%202006.pdf> :

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NATIONAL PLANNING SCENARIOS

Created for Use in National, Federal, State, and Local Homeland Security Preparedness Activities

February 2006

White House Homeland Security Council

[This is a 164 page book]

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## Introduction

The Federal interagency community has developed 15 all-hazards planning scenarios (the National Planning Scenarios or Scenarios) for use in national, Federal, State, and local homeland security preparedness activities. The Scenarios are planning tools and are representative of the range of potential terrorist attacks and natural disasters and the related impacts that face our nation. The objective was to develop a minimum number of credible scenarios in order to establish the range of response requirements to facilitate preparedness planning. Since these Scenarios were compiled to be the minimum number necessary to develop the range of response capabilities and resources, other hazards were inevitably omitted.

Examples of other potentially high-impact events include nuclear power plant incidents<sup>1</sup>, industrial and transportation accidents, and frequently occurring natural disasters. Entities at all levels of government can use the National Planning Scenarios as a reference to help them identify the potential scope, magnitude, and complexity of potential major events. Entities are not precluded from developing their own scenarios to supplement the National Planning Scenarios.

These Scenarios reflect a rigorous analytical effort by Federal homeland security experts, with reviews by State and local homeland security representatives. However, it is recognized that refinement and revision over time will be necessary to ensure the Scenarios remain accurate, represent the evolving all-hazards threat picture, and embody the capabilities necessary to respond to domestic incidents.

### How to Use the National Planning Scenarios:

#### Capabilities-Based Planning –

In seeking to prepare the Nation for terrorist attacks, major disasters, and other emergencies, it is impossible to maintain the highest level of preparedness for all possibilities all of the time. Given limited resources, managing the risk posed by major

events is imperative. In an atmosphere of changing and evolving threat, it is vital to build flexible capabilities that will enable the Nation, as a whole, to prevent, respond to, and

recover from a range of major events. To address this challenge, the Department of

Homeland Security (DHS) employs a capabilities-based planning process that occurs under uncertainty to identify capabilities suitable for a wide range of challenges and

circumstances, while working within an economic framework that necessitates prioritization and choice. As a first step in the capabilities-based planning process, the Scenarios, while not exhaustive, provide an illustration of the potential threats for which we must be prepared. The Scenarios were designed to be broadly applicable; they generally do not specify a geographic location, and the impacts are meant to be scalable for a variety of population and geographic considerations.

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## Scenario 1: Nuclear Detonation – 10-kiloton Improvised Nuclear Device

### Scenario Overview: General Description –

In this scenario, terrorist members of the Universal Adversary (UA) group—represented by two radical Sunni groups: the core group El-Zahir (EZ) and the affiliated group Al Munsha'a Al Islamia (AMAI)—plan to assemble a gun-type nuclear device using Highly Enriched Uranium (HEU) stolen from a nuclear facility located in Pakistan. The nuclear device components will be smuggled into the United States. The device will be assembled near a major metropolitan center. Using a delivery van, terrorists plan to transport the device to the business district of a large city and detonate it.

### Detailed Attack Scenario –

Current intelligence suggests that EZ may be working with AMAI to develop an Improvised Nuclear Device (IND). It is suspected that special training camps in the Middle East have been established for IND training. Some IND manuals have also been confiscated from suspected EZ operatives. The volume of communications between EZ and AMAI operatives has increased significantly in past two weeks.

EZ operatives have spent 10 years acquiring small amounts of HEU. Operatives acquired the material by posing as legitimate businessmen and by using ties to ideologically sympathetic Pakistani nuclear scientists. EZ plans to construct a simple gun-type nuclear device and detonate the weapon at a symbolic American location. EZ Central Command initiates the operation. To preserve operational effectiveness at all levels, compartmentalization and secrecy are required. Due to fears of penetration, EZ has become increasingly discreet in its decision-making process, with few operatives informed of the next target. Target selection, preparation, and acquisition are confined to a small number of terrorist operatives.

page 1-2:

This scenario postulates a 10-kiloton nuclear detonation in a large metropolitan area. The effects of the damage from the blast, thermal radiation, prompt radiation, and the subsequent radioactive fallout have been calculated (based on a detonation in Washington, DC), and the details are presented in Appendix 1-A. However, the calculation is general enough that most major cities in the United States can be substituted in a relatively straightforward manner. Enough information is presented in the appendix to allow for this kind of extrapolation<sup>1</sup>. The radioactive plume track depends strongly on the local wind patterns and other weather conditions. In a situation where the wind direction cycles on a regular basis or other wind anomalies are present, caution should be exercised in directly using the fallout contours presented in the appendix.

If the incident happened near the U.S. border, there would be a need for cooperation between the two border governments. Additionally, the IND attack may warrant the closure of U.S. borders for some period of time. If the detonation occurs in a coastal city, the fallout plume may be carried out over the water, causing a subsequent reduction in casualties. On the other hand, the surrounding water will likely restrict the zones that are suitable for evacuation. Bridges and tunnels that generally accompany coastal cities will restrict the evacuation, causing delay and an increase in the radioactive dose that evacuees receive. This delay may be substantial, and the resulting dose increase may drive a decision to shelter-in-place or evacuate-in-stages. This assumes that the authorities have an effective communication channel with the public.

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APPENDIX: Scenario Working Group

## Members

The Homeland Security Council receives interagency guidance via a number of Policy Coordinating Committees (PCCs). One of them is the Domestic Threat, Response, and Incident Management (DTRIM) PCC; the Scenarios Working Group (SWG) supports the DTRIM. The members of the SWG are as follows:

CHAIR: Janet K. Benini, Director of Response and Planning, White House Homeland Security Council

...

## ANOTHER REPORT:

<http://www.strac.org/Docs/Exdocs/NPS%20Attack%20Timelines%20Feb%202006.pdf>

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NATIONAL PLANNING SCENARIOS:  
Attack Timelines

Created for Use in National, State, and Local Homeland Security Preparedness Activities

February 2006

White House Homeland Security Council

[This 112 pages long book sets out in diary format the envisaged activities of the terrorists in assembling and detonating various types of weapons for each of the 15 attack scenarios detailed above. All the details certainly do make my hair stand on end. But they don't consider other nuclear attacks like underwater bursts in ships, of the kind Britain tested in Operation Hurricane, 1952. The radioactive effects of a shallow underwater burst are more important than those of a surface burst on land, because of the early high speed base surge and also the difficulty in decontaminating ionic wet fallout - it becomes chemically attached to surfaces unlike dry land burst fallout which can be swept away with a broom or hosed off.)

page 1-1

In this scenario, terrorist members of the UA group?represented by two radical Sunni groups: the core group El-Zahir (EZ) and the affiliated group Al Munsha?a Al Islamia (AMAI)?plan to assemble a gun-type nuclear device using Highly Enriched Uranium (HEU) stolen from a nuclear facility located in Pakistan. The nuclear device components will be smuggled into the United States. The device will be assembled near a major metropolitan center. Using a delivery van, terrorists plan to transport the device to the business district of a large city and detonate it.

...

At 10:15 PM,  nige said...

Dr Mario Rabinowitz has very kindly emailed me (19 November 2006 18:42) some corrections to this blog post which I will make when time permits.

At present, this comment will indicate the changes required.

The report by Mario mentioned with the date 1987 for publication in an IEEE journal (where he notices also that you can't use several EMP weapons or they will interfere with each other, reducing the total EMP) was actually done in:

"... the very early 80's. The forces that be suppressed release of my EPRI report, and prevented publication of my work until 1987. I even have a galley of my paper in Science which managed to get through their tough review process. It was about a week before being published, when it was killed.

"I'm sure many other scientists have encountered similar problems."

Well I have suffered problems of this sort myself.

The problem of censorship is precisely that it creates these priority issues.

Dr Bernadin was unaware of the work of Dr Rabinowitz because the latter was censored. It is extremely difficult to resolve such issues in a satisfactory way.

Dr Rabinowitz was generally at a disadvantage anyway by lack of access to classified nuclear test data and even declassified documents, which were not easy to find out about or obtain in the 80s.

Nigel Cook

At 12:53 PM,  nige said...

13 October 2007: updates

(1) Regarding the map showing USSR Test '184' on 22 October 1962 ('Operation K' (ABM System A proof tests), A 300-kt burst at 290-km altitude near Dzhzhkazan, the source for the information in the box that a radar installation 1,000 km away malfunctioned due to EMP and that radio receivers failed out to a distance of 600 km, is a summary briefing by General Vladimir Loborev (Director of the Russian Central Institute of Physics and Technology, CIPT, near Moscow), made at the June 1994 EUROEM Conference in Bordeaux, France.

It is not clear whether the effects were due to EMP received directly by the affected devices, or whether they were merely affected by power surges in long buried power lines or long overhead telephone lines connected to them.

However, see the later post <http://glasstone.blogspot.com/2006/08/nuclear-weapons-1st-edition-1956-by.html> for British Home Office Scientific Advisory Branch studies published in its restricted journal "Fission Fragments" on EMP effects to portable transistor-based battery powered radios (not connected to any external power line, external aerial, etc.):

"Fission Fragments", Issue No. 21, April 1977, pages 18-25:

On pages 20-24 there is an article by C. H. Lewis, MSc, The Effects of EMP, in Particular on Home Defence Communications which states:

'For a near ground-burst the downward component [of the outward Compton electron current in the air, produced by initial gamma radiation] is largely suppressed leaving the upward component to form what is virtually a conventional dipole aerial with a tremendously high current. ... Field strengths for a 5 Mt weapon may be about 20 kV/m at 3 miles, 5 kV/m at 5 miles and 1 kV/m at 8 miles, where blast pressure will be down to 2 psi. ... Consider first the possible effects on the power

system. Fortunately the super-grid (which is designed to work at 400 kV) is not thought to be particularly vulnerable, but perhaps 1/4 of the pulse energy picked up by the supergrid may be passed on by the distribution transformers with consequent current surges in the lower voltage systems of perhaps 20,000 amps. Thus although the supergrid may survive, the current surges in the distribution system may result in major system instability with consequent serious breakdown ... It will be remembered that system instability in 1965 resulted in a total black-out of the north-east U.S. for several days. ... Turning to communications ... transmitters appear to be vulnerable to EMP, which can generate peak currents in the aerials of medium wave transmitters (which may be of the order of 100 m long) of several kiloamperes. As a result there is a considerable risk of breakdown in the high voltage capacitors of the transmitters. Additionally, the continuity of broadcasting depends on power supplies, communication with the studio and the studio equipment. Ironically the ordinary domestic transistor receiver with ferrite rod aerials is likely to survive, but VHF receivers with stick aerials are vulnerable when the aerial is extended. ... At this stage the vulnerability of various devices may be considered. A 300 ft length of conductor may pick up between 0.1 and 40 Joules (1 Joule = 1 watt-second). According to US sources, a motor or transformer can survive about 10,000 J, electronic valves about 0.01 J. Small bipolar transistors are sensitive to about  $10^{-7}$  J and microwave diodes, field effect transistors, etc., are sensitive to about  $10^{-9}$  J. ... With a rise time of  $10^{-8}$  secs,  $10^{-8}$  J equates to 1 watt - well beyond the capacity of small transistors. Clearly, motors and transformers are likely to survive, thermionic valves are reasonably good, but transistors in general are vulnerable, whilst equipment using field effect transistors or microwave diodes is especially vulnerable.'

The remainder of that article discussed the effects of EMP on the British wired telephone system: 'The effect of any EMP pick-up in the system will be to cause flashover at one or more of a number of points - terminal boards, relay contacts, relay coil terminations, capacitors, etc. ... There are likely to be many domestic telephones connected in part by overhead lines, and these lines can pick up EMP currents, passing them into the exchange equipment. Because most telephone lines are underground, it is no longer Post Office policy to provide lightning protectors at the exchange or on subscribers premises. Within the exchange, all incoming cables are terminated at the Main Distribution Frame, and from this point the internal wiring to the exchange equipment is unshielded. In view of the tremendous amount and complexity of this internal wiring it appears that the major source of EMP pick-up may lie within the exchange. ... The limit of satisfactory direct speech transmission is about 25 miles and since this must include the subscribers lines to and from the exchange it is customary to provide "repeaters" (amplifiers [including inductance coils to prevent frequency-dependent distortion]) at intervals of 15 miles between exchanges.'

The next very interesting article in "Fission Fragments", Issue No. 21, April 1977, is at page 25: A. D. Perryman (Scientific Advisory Branch, Home Office), EMP and the Portable Transistor Radio. Perryman states: 'In an attempt to answer some of these questions [about EMP effects on communications] the Scientific Advisory Branch carried out a limited programme of tests in which four popular brands of transistor radio were exposed in an EMP simulator to threat-level pulses of electric field gradient about 50 kV/m.

'The receivers were purchased from the current stock of a typical retailer. They comprised:

- '1. a low-price pocket set of the type popular with teenagers.
- '2. a Japanese set in the middle-price range.
- '3. a domestic type portable in the upper-price range.
- '4. an expensive and sophisticated portable receiver.

'All these sets worked on dry cells and had internal ferrite aerials for medium and long wave reception. In addition, sets 2, 3 and 4 had extendable whip aerials for VHF/FM reception. Set 3 also had one short wave band and set 4 two short wave bands... .

'During the tests the receivers were first tuned to a well-known long-wave station and then subjected to a sequence of

pulses in the EMP simulator. This test was repeated on the medium wave and VHF bands. Set 1 had no VHF facility and was therefore operated only on long and medium waves.

'The results of this experimentation showed that transistor radios of the type tested, when operated on long or medium waves, suffer little loss of performance. This could be attributed to the properties of the ferrite aerial and its associated circuitry (e.g. the relatively low coupling efficiency). Set 1, in fact, survived all the several pulses applied to it, whereas sets 2, 3 and 4 all failed soon after their whip aerials were extended for VHF reception. The cause of failure was identified as burnout of the transistors in the VHF RF [radio frequency] amplifier stage. Examination of these transistors under an electron microscope revealed deformation of their internal structure due to the passage of excessive current transients (estimated at up to 100 amps).

'Components other than transistors (e.g. capacitors, inductors, etc.) appeared to be unaffected by the number of EM pulses applied in these tests.

'From this very limited test programme, transistor radios would appear to have a high probability of survival in a nuclear crisis when operated on long and medium bands using the internal ferrite aerial. If VHF ranges have to be used, then probably the safest mode of operation is with the whip aerial extended to the minimum length necessary to give just audible reception with the volume control fully up.

'Hardening of personal transistor radios is theoretically possible and implies good design practice (e.g. shielding, bonding, earthing, filtering etc.) incorporated at the time of manufacture. Such receivers are not currently available on the popular market.'

The effects of EMP on electronics can be amplified if the equipment is switched on, because the amplification of an EMP signal by an operating circuit will add extra power to the current surge. Damage also occurs when current passes the wrong way through transistors, overheating them (especially the transistors built into IC's since these have no effective heat sink available over the small time scale for nanosecond duration power surges).

(2) The 1963 secret American Defense Department film "High-Altitude Nuclear Weapons Effects - Part One, Phenomenology" (20 minutes), has been declassified.

It discusses in detail, including film clips and discussions of the sizes and quantitative phenomena of the tests, the effects of 1962 high altitude tests BLUEGILL (410 kt, 48 km altitude), KINGFISH (410 kt, 95 km altitude), and STARFISH (1.4 Mt, 400 km altitude).

This film is mainly concerned with fireball expansion, rise, striation along the Earth's natural magnetic field lines, and air ionization effects on radio and radar communications, but it also includes a section explaining the high altitude EMP damage mechanism.

Here is a summary of facts and figures from this film:

BLUEGILL (410 kt, 48 km height of burst, 26 October 1962): within 0.1 second the fireball is several km in diameter at 10,000 K so air is fully ionised. Fireball reaches 10 km in diameter at 5 seconds. By 5 seconds, the fireball is buoyantly rising at 300 metres/second. It is filmed from below and seen within a minute to be transforming into a torus or doughnut shape as it rises. The fireball has reached a 40 km diameter at 1 minute, stabilising at an altitude of 100 km some minutes later.

KINGFISH (410 kt, 95 km altitude, 1 Nov. 1962): fireball size is initially 10 times bigger than in the case of BLUEGILL. The KINGFISH fireball rises ballistically (not just buoyantly) at a speed 5 times greater than BLUEGILL. Its diameter (longways) is 300 km at 1 minute and it is elongated along the Earth's natural geomagnetic field lines while it expands. It reaches a maximum altitude of 1000 km in 7 or 8 minutes before falling back to 150-200 km (it falls back along the Earth's

magnetic field lines, not a simple vertical fall). The settled debris has a diameter of about 300 km and has a thickness is about 30 km. This emits beta and gamma radiation, ionizing the air in the D-layer, forming a "beta patch". Photographs of beta radiation aurora from the KINGFISH fireball are included in the film. These beta particles spiral along the Earth's magnetic field lines and shuttle along the field lines from pole to pole. Because magnetic field lines concentrate together as they approach the Earth's poles, the negative Coulomb field strength due to concentrated beta particles near the poles (where the magnetic field lines come close together) slows and reflects beta particles back. This is the "mirroring" effect discovered in Operation Argus in 1958. It only works effectively if the mirror point altitude is above 200 km, otherwise the beta particles will be rapidly absorbed by the atmosphere (after a few passes from pole to pole) before they can be reflected. Hence, only sufficiently high altitude nuclear explosions can create long-lasting "shells" of trapped electrons at very high altitude. To some extent, the trapping effect varies as the debris rises and sinks back in one explosion.

STARFISH (1.4 Mt, 400 km, 9 July 1962): the film shows STARFISH early fireball expansion effects. STARFISH produced an asymmetric fireball due to the missile which carried the fireball: a shock wave goes upward and another goes downward, while a small star-like remnant continues to glow at the detonation point (contrary to predictions!). Fireball expansion was resisted by geomagnetic back-pressure: the electrically conductive fireball gases exclude the Earth's magnetic fields, so the latter is displaced as the fireball expands. This is the "magnetic bubble" effect.

The film then explains the mechanism for the magnetic dipole EMP: prompt gamma rays are mainly absorbed between 25-30 km altitude, the Compton electrons being deflected by the Earth's magnetic field lines, emitting coherent EMP in the process. The film shows the damaging results by depicting an overhead powerline experiencing a powersurge and sparking.

Near the end of the film, there is an amazing and impressive speeded-up film showing the KINGFISH fireball (initially a large egg shaped fireball) rising and striating into a series of line-like filaments orientated along the Earth's magnetic field lines.

Other declassified films worth mentioning are "Fishbowl High-Altitude Weapons Effects" (1962, 28 minutes) which explains the instrumentation and shows the effects of each detonation on Pacific radio communications at different frequencies, and the lengthy set of four films "Starfish Prime Event Interim Report By Commander JTF-8", "Fishbowl Auroral Sequences", "Dominic on Fishbowl Phenomena" and "Fishbowl XR Summary" (1 hour 9 minutes in total).

Some highlights of these films: the high-altitude 1962 Fishbowl series involved 266 instrument stations: 156 stations on land, 80 stations aboard 10 ships, and 30 stations aboard 15 test aircraft. They mention the 3 high altitude Argus tests in 1958 and the Yucca (1.7 kt, 26 km), Orange (3.8 Mt, 43 km) and Teak (3.8 Mt, 77 km) tests of Hardtack in 1958. The 3 objectives of Fishbowl are stated to be:

1. ICBM acquisition problems for ABM radar installations after a nuclear explosion,
2. AICBM (Anti-ICBM) kill mechanism to use a nuclear explosion to destroy an incoming ICBM (by neutron and gamma radiation, shock wave, and thermal ablation phenomena),
3. Communications effects of high altitude explosions of various yields and burst altitude.

STARFISH HF radio effects lasted for 2 days over the Pacific.

CHECKMATE (7 kt, 147 km burst altitude) HF radio effects extended out to 700 km for 30 minutes.

KINGFISH HF radio effects extended to 2500 km radius for 2 hours.

BLUEGILL HF radio was blacked out over 1 minute over 200 km radius, and lesser effects lasted over this region for 2 hours. BLUEGILL also produced retinal burns to test rabbits.

VLF was relatively unaffected by the tests, LF was degraded, HF was extensively degraded as was VHF except for less

severe absorption. UHF line of sight was relatively unaffected, except where the signal path was through a fireball region.

On the silent films there is an especially good BLUEGILL torus film, and nice films of KINGISH auroral radiation emission from the fireball. There are also detailed films showing the STARFISH auroral fireball developing around the burst location, the striation of CHECKMATE fireball debris (a speeded up film) and some interesting films showing shock waves rebounding inside the TIGHTROPE fireball: explosive and implosive shock waves occur with the implosion shock wave bouncing off the singularity in the middle and transforming itself into an outward explosive shock wave.

*At 6:45 AM,  Corky Boyd said...*

Regarding the Starfish test, I performed an unsophisticated test of EMP myself.

I was a junior officer in the Navy at Pearl Harbor assigned to Pacific Fleet Headquarters.

I knew of the test and the countdown frequency. I purchased an inexpensive Hallicrafter SW radio to monitor the countdown, which used the ID of April Weather. There were numerous scrubbed missions and one disaster when the radar lost track of the Thor IRBM and it had to be destroyed at a very low altitude.

My test was to monitor the countdown, which was broadcast from Johnston Island at just slightly above 10 mhz. Near the countdown frequency was a VOA broadcast from California. My intention was to shift frequency shortly after detonation, which I did, and test reception.

When the detonation occurred, the sky, which was overcast, lit up in a brilliant yellow/chartreuse color. After about 45 seconds the edges of the chartreuse turned a deep red, which worked its way into the center of the light until it darkened about 5 to 7 minutes after the test. It was an awesome experience.

At the time of the detonation there was a zzzzzt sound for about a half second. There was no loss of signal from April Weather and when I changed frequencies to VOA it was coming in as clear as before.

My recollection was the test altitude was significantly higher than 400km now being reported. It appeared to be 35 to 40 degrees above the horizon. The countdown from launch to detonation (nudet in the vernacular) was slightly in excess of 13 minutes.

The news outlets in Hawaii reported some lights going out, but no widespread effects. There were also reports of EMP related problems in New Zealand, but very little else. My own test did not show any electric power interruption, or any loss of signal in the 30 meter band.

Thought you might be interested.

*At 3:30 PM,  nige said...*

"The news outlets in Hawaii reported some lights going out, but no widespread effects. There were also reports of EMP related problems in New Zealand, but very little else. My own test did not show any electric power interruption, or any loss of signal in the 30 meter band."

Hi Corky Boyd,

Thank you very much for your first-hand experience of the Starfish EMP. It is extremely extremely useful to have first-hand accounts.

I exchanged an email with Glen Williamson ( [http://www.williamson-labs.com/480\\_emp.htm](http://www.williamson-labs.com/480_emp.htm) ) who observed the same Starfish test from Kwajalein Atoll, 1500 miles away. He wrote, as he says on his site:

"I don't remember hearing of anything happening on Kwaj as a result of the shots. Of course, all of the technical facilities there were heavily shielded. Knowing that there were artifacts in Hawaii, I am surprised we didn't experience the same..."

- [http://www.williamson-labs.com/480\\_emp.htm](http://www.williamson-labs.com/480_emp.htm)

It does seem that EMP effects on 1962 electronics on small islands were few and far between after Starfish.

I've seen the declassified reports, and they all - from interim scientific report to the present day - give the Starfish burst altitude as 400 km. There is actual film of the Starfish device exploding, included in the set of films, "Starfish Prime Event Interim Report By Commander JTF-8", "Fishbowl Auroral Sequences", "Dominic on Fishbowl Phenomena" and "Fishbowl XR Summary" (1 hour 9 minutes in total).

These films do indicate that the burst altitude was correct: it was above the horizon as seen from Hawaii. The calculation is straightforward to determine the burst altitude, allowing for the Earth's curvature.

This business about the streetlamps and radios in Hawaii is a red-herring, it's true only 1-3% of streetlamps were put out (the uncertainty of 1-3% depends is just historical guesswork about how many streetlamps there were in Hawaii, it is known for sure that the number that had to have fuses replaced by engineers were 300 streetlamps in 30 overhead-connected strings of 10 lamps each) on the island Oahu. If you look at the size of the Hawaiian islands and compare to the Russian test, the overhead and buried power and communication lines were short in Hawaii. That, plus the electromechanical phone systems and valve/vacuum tube radios, was what limited damage as compared to what would happen if the test was repeated today over land.

The electromechanical relay phone switchboards and vacuum tube electronics were capable of surviving power surges a million times greater than microchips and other transistor-dependent devices.

In addition, for above ground power cables, the current induced by a fixed EMP fast (prompt gamma produced) pulse is almost directly proportional to the length of the line for line lengths of up to 100 km or so. Hence, even if a string of 10 streetlamps on Hawaii was say 1 km long, then you would get 100 times more current induced in 100 km or more of overhead power line over land. In the case of the slow (MHD) EMP, the situation is even more severe, with the cable length effect increasing the induced EMP for even bigger distances.

The vulnerability of solid state chip computer systems to EMP is a problem that was never investigated in Russian or American nuclear tests.

Certainly the MHD EMP is slow enough (several seconds rise time) that circuit breakers in protected power supplies could fully protect equipment from damage, but the microsecond surge spike in powerlines from the fast EMP (caused by prompt gamma rays) is supposed to be faster than many circuit breakers can respond to (they are chiefly designed to stop millisecond spikes due to lightning flashes, not microsecond spikes from a high altitude nuclear explosion). It seems that any protective equipment would reduce damage in threshold cases, by stopping at least part of the surge after the spike has passed. However, most portable (laptop) equipment that was not connected to the mains at the time of the explosion probably be unaffected because they are so small and so can't directly pick up much damaging current from the EMP: the wireless antennae they have are also small and tuned for 2.4 GHz, much higher than the predominantly HF signal of the EMP. Mobile cellular phones similarly now mainly work on microwave frequencies and are small enough to resist quite well fairly powerful EMP's of 5-20 kV/m.

So the major crisis of EMP would be damage to power stations and distribution, and its effects in turn on putting out computers and mobile phone network repeaters. There is also the problem of the electronic ignition failure of cars/

automobiles due to EMP, again due to the greater sensitivity of microchips to EMP than the kind of simple electronics (distributor system) used in electronic ignition systems in Hawaii in 1962.

Altogether, it seems that there are concerns for countries with long power lines and long phone lines, that depend on microchips, and neither of these concerns existed in the small sized Hawaiian islands back in 1962.

One example of this kind is the failure of the telephone system on the Hawaiian island of Kauai due to the EMP destroying the microwave link, which was the one piece of crucial equipment there back in 1962. I think it was supposed to have burned out a semiconductor diode.

Really, in discussing 1962 nuclear test EMP effects in a modern context, emphasis needs to be placed on the relative insensitivity of 1962 electronic systems in general, and the small size of the conductor cables involved in those small islands. The Russian experiences of detonating bombs over inhabited areas and fusing the phone lines while causing lead-shielded underground cables to pick up enough current to set the power station on fire by overloading heavy-duty transformer coils, shows the likely effects of high altitude explosions over large, inhabited land areas.

At 6:47 AM,  Corky Boyd said...

Nige,

It is possible I misread the Starfish test altitude, but my memory was that it was significantly higher than 250nm. A couple of items still make me question the officially reported altitude.

First the countdown from launch to detonation was over 13 minutes, which included burn time and coast. Seems excessive for a 250nm burst. Second, would a 250nm altitude burst be directly visible above the horizon from Kwajalein 1500nm away? Also from rough calculations (please check me) a 250nm high burst would be about 10 degrees over the horizon at Pearl Harbor about 700nm away. It appeared higher than that.

On the other hand, it doesn't make sense for the US to be deceptive on this. Surely the Soviets made their own measurements.

You sound as if you are well versed in physics. Would you run the numbers on the Kwajalein altitude and burn time scenarios?

I enjoy your discussions.

At 1:00 AM,  nige said...

Hi Corky,

The photos of the Starfish Prime fireball are shown on another post of this blog:  
<http://glasstone.blogspot.com/2006/03/starfish-fireball-photograph.html>

There is a comparison between photos of the fireball at 3 minutes after detonation, taken with an 80 mm Hasselblad camera aboard a Los Alamos instrumented KC-135 instrumentation jet above the clouds, 300 km horizontal distance from detonation.

The photo shows the burst location against the background stars which are also visible behind the fireball. There is film also from earlier times, before the fireball had expanded so much. Therefore, it looks to me as if the burst altitude was

accurately determined from careful measurements based on photos.

Visible effects of a nuclear detonation above the horizon were documented after the 1958 "Teak" nuclear test above Johnston Island at night, which was even more powerful than Starfish but was below the horizon as seen from the Hawaiian Islands (3.8 megatons, of which 1.9 megatons was from fission, at a burst altitude of 77 km).

There was little cloud cover at the time and a few people were able to photograph the "Teak" test. four very good quality amateur photos, taken at intervals of about 50 seconds, were even published in the Journal of Geophysical Research, vol. 65, 1960, p. 545).

Despite detonating below the horizon, the "Teak" explosion was immediately visible (within a fraction of a second) due to beta particle radiation streaming upward from the radioactive fireball and causing a bright aurora in the low density air above the detonation point. After a few seconds, when the fireball starting rising at a "ballistic" rate due to the fireball height exceeding the altitude over which the air density fell by an order of magnitude, the fireball itself rose above the detonation point and could be seen directly from Hawaii, despite the burst having occurred at only 77 km altitude.

So, could it be a case that the apparently high angle of the flash as seen through the cloud at Hawaii was just a result of beta radiation causing a bright aurora high above the burst point, as the photo taken at 3 minutes seems to show?

This effect of a glow far higher than the detonation point due to the passage of radiation upward, would also account for some of the visible effects from Starfish seen at Kwajalein Atoll.

I can't find any data on how long the rocket burned before the Starfish device exploded. The declassified films I obtained (which I will be transferring to Google Video as soon as possible), did indicate that the Starfish missile with its 1.4 megaton thermonuclear warhead, instrument pods, etc., was very heavy and the previous attempt to fire it failed about a minute after launch.

I don't know how long it is supposed to take to get such a missile up to 400 km. It will depend on the rocket thrust and the total mass of the missile including all the attached instrument pods which were ejected at different altitudes on the way up, to measure the effects at different distances from the fireball.

The film does make it clear that the missile was tracked carefully by both radar and by camera stations until the detonation occurred.

In the DVD "Nukes in Space" there are some conferences of President Kennedy discussing the nuclear tests in space in October 1962, and one of the major arguments was about "Uracca", a test planned for very high altitude (I think it was planned to be 7 kt at 1300 km altitude). That test had to be cancelled, and there is a discussion of that as follows in a technical report I found about the general effects of American high altitude tests:

"In any case, Dr. Webb, the NASA administrator at that time, prevailed upon Dr. Jerome Wiesner, the Chief Scientific Advisor to the President, and reportedly also directly upon President Kennedy to have future nuclear space experiments restricted to lower altitudes. This, in my personal opinion, highly emotional response led un-fortunately to the cancellation of the low-yield Uracca event, which was to be exploded at an altitude of 1300 km as proposed by LASL. The event, as planned, would have added less than 17% to the inventory of the artificial belts but would have increased our knowledge of near-space physics significantly."

- <http://www.fas.org/sgp/othergov/doe/lanl/docs1/00322994.pdf>

Thank you for the discussion, which is very interesting.

At 3:24 PM,  hilo boy said...

A minor comment. I was a high school student in Hilo (Hawaii) during Teak, and saw the burst. As I remember, there were two tests, separated by a week or maybe several weeks. The first one was unannounced and some of my friends were out, late at night, and were very frightened by what they saw. They weren't alone in that.

For the second test there was an official announcement. Many of the students in my high school, including me, drove over to Ka Lae (South Point) to watch the explosion, which we did indeed see.

As I remember, there were widespread reports of power outages for both tests. And also, as I remember, the authorities denied that the explosions could have had anything to do with them.

Of course this was 50 years ago and my memory may be faulty about anything except what I witnessed that night at Ka Lae.

At 7:30 PM,  nige said...

Hilo boy,

Thank you. Could you please describe what you saw, presumably the "Orange" test on 12 August of 3.8 Mt (50% fission) at 43 km altitude over Johnston Island? "Teak" was an identical weapon design detonated at 76.8 km altitude on 1 August.

According to Glasstone & Dolan's *Effects of Nuclear Weapons*, 3rd ed., 1977, Chapter 2:

"2.56 The TEAK explosion was accompanied by a sharp and bright flash of light which was visible above the horizon from Hawaii, over 700 miles away. Because of the long range of the X rays in the low-density atmosphere in the immediate vicinity of the burst, the fireball grew very rapidly in size. In 0.3 second, its diameter was already 11 miles and it increased to 18 miles in 3.5 seconds. The fireball also ascended with great rapidity, the initial rate of rise being about a mile per second. Surrounding the fireball was a very large red luminous spherical wave, arising apparently from electronically excited oxygen atoms produced by a shock wave passing through the low-density air (Fig. 2.56). [Fireball and red luminous spherical wave formed after the TEAK high-altitude shot. (The photograph was taken from Hawaii, 780 miles from the explosion.)]

2.57 At about a minute or so after the detonation, the TEAK fireball had risen to a height of over 90 miles, and it was then directly (line-of-sight) visible from Hawaii. The rate of rise of the fireball was estimated to be some 3,300 feet per second and it was expanding horizontally at a rate of about 1,000 feet per second. The large red luminous sphere was observed for a few minutes; at roughly 6 minutes after the explosion it was nearly 600 miles in diameter. ...

"2.60 Additional important effects that result from high-altitude bursts are the widespread ionization and other disturbances of the portion of the upper atmosphere known as the ionosphere. These disturbances affect the propagation of radio and radar waves, sometimes over extended areas (see Chapter X). Following the TEAK event, propagation of high-frequency (HF) radio communications (Table 10.91) was degraded over a region of several thousand miles in diameter for a period lasting from shortly after midnight until sunrise. Some very-high-frequency (VHF) communications circuits in the Pacific area were unable to function for about 30 seconds after the STARFISH PRIME event.

"2.61 Detonations above about 19 miles can produce EMP effects (§ 2.46) on the ground over large areas, increasing with the yield of the explosion and the height of burst. For fairly large yields and burst heights, the EMP fields may be significant at nearly all points within the line of sight, i.e., to the horizon, from the burst point. ...

"2.62 An interesting visible effect of high-altitude nuclear explosions is the creation of an "artificial aurora." Within a second

or two after burst time of the TEAK shot a brilliant aurora appeared from the bottom of the fireball and purple streamers were seen to spread toward the north. Less than a second later, an aurora was observed at Apia, in the Samoan Islands, more than 2,000 miles from the point of burst, although at no time was the fireball in direct view. The formation of the aurora is attributed to the motion along the lines of the earth's magnetic field of beta particles (electrons), emitted by the radioactive fission fragments. Because of the natural cloud cover over Johnston Island at the time of burst, direct observation of the ORANGE fireball was not possible from the ground. However, such observations were made from aircraft flying above the low clouds. The auroras were less marked than from the TEAK shot, but an aurora lasting 17 minutes was again seen from Apia. Similar auroral effects were observed after the other high-altitude explosions ..."

The earlier 2nd edition (1962 and massively corrected 1964 reprint) of that book contained a bit more information about the "Orange" test; it states that observers at Hawaii saw a grey cloud rise over the horizon about 1 minute after the detonation and disappear shortly thereafter. It would be interesting if you can recall what you saw of the explosion. Was there cloud intervening, or was the sky clear?

Both detonations were well below the horizon as seen from ground level at Hawaii. Because the long-range EMP that causes most of the damage is VHF frequency, it can't propagate around the horizon. The MHD-EMP is ELF and can get around the horizon, but the powerlines and phone lines in Hawaii probably were not long enough to pick up significant currents from MHD-EMP. I can't see how either "Teak" or "Orange" could have had much EMP effect out at Hawaii, because both shots were too low to allow VHF frequency EMP to propagate with sufficient strength (well past the horizon radius as seen from the burst point in those tests).

There were certainly effects on radio propagation due to enhanced atmospheric ionisation by beta particles (the ionosphere was used to bounce radio signals to and from Australia and America, etc.). But this is not EMP damage, and doesn't damage equipment or cause power losses, it just introduces noise (static) in long range radio signals, or phase shifts in the paths taken by the radio signals (due to bouncing off the ionosphere at a different altitude from normal when being ducted between the sea and the ionosphere).

But do you remember any specific EMP effects occurring after the 1962 "Starfish" test?

At 5:23 PM,  nige said...

More about the visible effects of 3.8 Mt "HARDTACK-ORANGE" at 43 km above Johnston Island in 1958:

"The dramatic display of southern lights [aurora] which TEAK generated raised considerable anxiety in Hawaii, but most observers in the islands were disappointed in ORANGE. One observer on the top of Mount Haleakala on Maui described the display as "... a dark brownish red mushroom [that] rose in the sky and then died down and turned to white with a dark red rainbow." While ORANGE was visible for about 10 minutes in Hawaii, it had little effect on radio communications."

- Page 142 of [http://www.dtra.mil/newsservices/publications/pub\\_includes/docs/DefensesNuclearAgency.pdf](http://www.dtra.mil/newsservices/publications/pub_includes/docs/DefensesNuclearAgency.pdf)

At 5:25 PM,  nige said...

The full title of that last linked reference above is:

"Defense's Nuclear Agency: 1947-1997", DTRA History Series, U.S. Defense Threat Reduction Agency, U.S. Department

of Defense, Washington, D.C., 2002.

At 3:00 PM,  nige said...

Another useful source of early unclassified and incomplete data on Starfish effects is:

[http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19640018807\\_1964018807.pdf](http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19640018807_1964018807.pdf)

NASA Technical Note: NASA TN D-2402, *The Effects of High Altitude Explosions*, by Wilmot N. Hess, Goddard Space Flight Centre, Greenbelt, Md., 1964.

It mentions the EMP radiated by electrons deflected by the Earth's magnetic field, but only under cover of the physics jargon "synchrotron radiation", and completely misses the important prompt gamma radiation induced VHF/UHF frequency microsecond duration EMP, mentioning on page 9 only inconsequential non-damaging minutes-long low frequency radiation from electrons trapped in radiation belts:

"A few minutes after Starfish, synchrotron radiation from the trapped electron was observed in Peru (Reference 15). This is the only effect of the artificial radiation belts that is observed on the ground for long periods.

Synchrotron radiation is the electromagnetic radiation given off when an electric charge is accelerated in a circle (Reference 16 - Schwinger, J., "On the Classical Radiation of Accelerated Electrons," *Phys. Rev.* v75, pp1912-1925, 15 June 1949). It was first observed as light emitted from a synchrotron electron accelerator. If the charged particles have  $V \ll c$ , then the radiation is emitted only at the cyclotron frequency and is called cyclotron radiation; but, when the particle is relativistic, many higher harmonics of the cyclotron frequency are emitted, too, and the radiation is called synchrotron radiation. The radio emission of the planet Jupiter in the 30 cm range is tentatively identified as being synchrotron radiation from trapped electrons with energies in the order of 5 to 100 Mev ..."

Much more usefully, it gives some of the early data from Starfish on the radiation belts it caused in space (mapped by early satellites' geiger counters) and some data on the degradation of solar cells on satellites due to the radiation damage from transversing the enhanced radiation belts due to the Starfish explosion. There are also various later, better papers on the subject, but as this is already available in full on the internet it is worth linking to right away.

At 7:34 PM,  nige said...

About the "Orange" test, Chuck Hansen's book "U.S. Nuclear Weapons", Orion Books, 1988, page 81 states (referencing Glasstone's Effects of Nuclear Weapons, Feb. 1964 revision pages 50-52, 82-3, which I don't have handy at present):

"The *Orange* fireball was also seen from Hawaii; about a minute later, a grayish-white radioactive cloud was seen low on the horizon, but it disappeared within four minutes."

At 11:56 AM,  nige said...

copy of a comment to:

<http://riofriospacetime.blogspot.com/2008/05/thunder-lightning-and-vog.html>

Beautiful pictures of volcanic lightning and of Saturn! It is certainly true that cosmic rays can trigger lightning bolts. There is a large electric potential between the Earth's surface and the ionosphere, which is at high altitude and hence low pressure air. This is similar to conditions in a Geiger-Muller tube, where you have low pressure gas and a strong electric field. Any

cosmic ray can potentially set off an electron avalanche, which in the absence of a quenching agent (Geiger-Muller tubes include some inert gases like helium, neon or argon which have filled outer-shells of electrons, in order to limit the size of the electron avalanche and thus quench each small discharge). Since there is little quenching gas in the Earth's atmosphere, you get major lightning bolts develop.

One pretty impressive lightning situation which demonstrates the connection between ionizing radiation and lightning, was lightning filmed around the periphery of the fireball from the "Mike" nuclear test on 1 Nov. 1952 at Eniwetok. The yield was 10.4 Mt, and the gamma rays set off at least five lightning flashes in the ionized air just around the fireball. All the lightning bolts were essentially vertical, from the scud cloud just above the fireball down to the lagoon water. This confirms that nuclear radiation, via causing ionization in the atmosphere, definitely can trigger a shorting of the natural vertical electric potential gradient in the atmosphere, resulting in a bolt of lightning:

<http://adsabs.harvard.edu/abs/1987JGR....92.5696C>

At 12:32 AM,  nige said...

The vital 1963 declassified films of the 1962 high altitude nuclear test effects (see my comment above) are available on YouTube:

Part 1: <http://youtube.com/watch?v=tdrirkDT2Y&feature=related> (20 minutes)

part 2: [http://youtube.com/watch?v=T6eLPLR\\_WPs&feature=related](http://youtube.com/watch?v=T6eLPLR_WPs&feature=related) (16 minutes)

To recap, here again is my review and summary of Part 1 (the association of nuclear test names to test events discussed in the film have to be deduced from the films of the explosions):

*The 1963 secret American Defense Department film "High-Altitude Nuclear Weapons Effects - Part One, Phenomenology" (20 minutes), has been declassified.*

*It discusses in detail, including film clips and discussions of the sizes and quantitative phenomena of the tests, the effects of 1962 high altitude tests BLUEGILL (410 kt, 48 km altitude), KINGFISH (410 kt, 95 km altitude), and STARFISH (1.4 Mt, 400 km altitude).*

*This film is mainly concerned with fireball expansion, rise, striation along the Earth's natural magnetic field lines, and air ionization effects on radio and radar communications, but it also includes a section explaining the high altitude EMP damage mechanism.*

*Here is a summary of facts and figures from this film:*

*BLUEGILL (410 kt, 48 km height of burst, 26 October 1962): within 0.1 second the fireball is several km in diameter at 10,000 K so air is fully ionised. Fireball reaches 10 km in diameter at 5 seconds. By 5 seconds, the fireball is buoyantly rising at 300 metres/second. It is filmed from below and seen within a minute to be transforming into a torus or doughnut shape as it rises. The fireball has reached a 40 km diameter at 1 minute, stabilising at an altitude of 100 km some minutes later.*

*KINGFISH (410 kt, 95 km altitude, 1 Nov. 1962): fireball size is initially 10 times bigger than in the case of BLUEGILL. The KINGFISH fireball rises ballistically (not just buoyantly) at a speed 5 times greater than BLUEGILL. It's diameter (longways) is 300 km at 1 minute and it is elongated along the Earth's natural geomagnetic field lines while it expands. It reaches a maximum altitude of 1000 km in 7 or 8 minutes before falling back to 150-200 km (it falls back along the Earth's magnetic field lines, not a simple vertical fall). The settled debris has a diameter of about 300 km and has a thickness is about 30 km. This emits beta and gamma radiation, ionizing the air in the D-layer, forming a "beta patch". Photographs of*

*beta radiation aurora from the KINGFISH fireball are included in the film. These beta particles spiral along the Earth's magnetic field lines and shuttle along the field lines from pole to pole. ...*

At 2:41 PM,  nige said...

Nobel Laureate Hans A. Bethe's report containing the wrong EMP mechanism for high altitude bursts (electric dipole instead of magnetic dipole) is:

H. A. Bethe, "Electromagnetic Signal Expected from High-Altitude Test", Los Alamos Scientific Laboratory report LA-2173, October 1957, secret-restricted data.

This report is significant because it predicted all three major parameters so wrongly that it prevented the magnetic dipole EMP being discovered for five years. It predicted (1) totally the wrong polarization (the direction antenna need to be pointed to detect the EMP), (2) completely the wrong rise time of the EMP (the oscilloscope time-sweep setting needed to show up the pulse on the display so it could be photographed; the pulse duration is tens of nanoseconds not tens of microseconds), and finally (3) the wrong intensity of the pulse (about 1 volt/metre was predicted instead of 10,000 or more volts/metre, so the oscilloscope pulse height settings were wrong by a factor of 10,000 and any instruments which did detect the pulse just gave vertical spikes extending off-scale, with no information whatsoever about the peak EMP or its duration.

These problems were only resolved after one instrument operated in an instrumentation aircraft operated in 1962 by Wakefield at Starfish was set with a very fast sweep and low intensity, so it managed to capture the EMP peak and duration successfully:

Richard L. Wakefield, "Measurement of time interval from electromagnetic signal received in C-130 aircraft, 753 nautical miles from burst, at 11 degrees 16 minutes North, 115 degrees 7 minutes West, 24,750 feet", Los Alamos Scientific Laboratory, pages 44-45 of Francis Narin's Los Alamos Scientific Laboratory compilation "A 'Quick Look' at the Technical Results of Starfish Prime", report AD-A955411, August 1962. (Figure 8 on page 45 gives the Wakefield EMP waveform measurement for Starfish, and is headed "EM Time Interval Signal on C-130 aircraft 753 Nautical Miles from Burst".)

At subsequent 1962 "Fishbowl" (high altitude) tests Kingfish, Bluegill and Checkmate, similar oscilloscope settings were used to obtain further successful waveform measurements of EMP:

John S. Malik, "Dominic Fishbowl Radioflash Waveforms", Los Alamos Scientific Laboratory report LA(MS)-3105, May 1964, Secret-restricted data.

John S. Malik and Ralph E. Partridge, Jr., "Operation Dominic Radioflash Records", Los Alamos Scientific Laboratory report LAMS-3019, November 1963, Secret-restricted data.

The two reports above are still classified, more than 35 years after being written.

At 1:45 PM,  nige said...

Update (26 Feb 2009): Vital fresh information on EMP from Starfish and other 1962 nuclear tests has been published and is reported on this blog in the new post:

<http://glasstone.blogspot.com/2009/02/how-emp-turned-off-1-3-of-streetlamps.html>

'The street lights on Ferdinand Street in Manoa and Kawaiui Street in Kailua went out at the instant the bomb went off,

according to several persons who called police last night.'

- *HONOLULU ADVERTISER* newspaper article dated 9 July 1962 (local time; reprinted in the Tuesday 21 February 1984 edition, celebrating the 15th anniversary of Hawaiian statehood to the U.S.A.).

At 11 pm on 8 July 1962 (local time, Hawaii), 300 streetlights in 30 series connected loops (strings) were fused by the EMP from the *Starfish* nuclear test, detonated 800 miles away and 248 miles above Johnston Island. This is approximately 1-3% of the total number of streetlights on Oahu.

In a much earlier blog post ([linked here](#)), the 1962 EMP damage effects from high altitude explosions (including three Russian high altitude tests of 300 kt each with differing altitudes of burst) were [examined in some detail](#).

Then, in a [more recent blog post \(linked here\)](#), freshly released information from Dr Carl Baum's EMP notes series was given and discussed, including [Dr Conrad Longmire's](#) investigation (Note 353 of March 1985, *EMP on Honolulu from the Starfish Event*) which assessed the EMP field strength at Hawaii, which peaked after 100 nanoseconds at 5,600 volts/metre.

Longmire stated on page 12 of his report:

'We see that the amplitude of the EMP incident on Honolulu [which blew the sturdy electric fuses in 1-3% of the streetlamps on the island] from the Starfish event was considerably smaller than could be produced over the northern U. S. ... Therefore one cannot conclude from what electrical and electronic damage did *not* occur in Honolulu that high-altitude EMP is *not* a serious threat. In addition, modern electronics is much more sensitive than that in common use in 1962. Strings of series-connected street lights did go out in Honolulu ... sensitive semiconductor components can easily be burned out by the EMP itself,  $10^{(-7)}$  Joules being reportedly sufficient.'

This 5,600 v/m figure allows definite correlations to be made between the observed effects and the size of the EMP field, which is a massive leap forward for quantitative civil defence assessments of the probable effects of EMP.

Now Dr Baum (who has an important and interesting overview of EMP [here](#), although it misses out some early important pieces of the secret history of EMP in the table of historical developments) has made available the [report by Charles N. Vittitoe](#), 'Did high-altitude EMP (electromagnetic pulse) cause the Hawaiian streetlight incident?', Sandia National Labs., Albuquerque, NM, report SAND-88-0043C; conference CONF-880852-1 (1988).

Vittitoe on page 3 states: 'Several damage effects have been attributed to the high-altitude EMP. Tesche notes the input-circuit troubles in radio receivers during the *Starfish* [1.4 Mt, 400 km altitude] and *Checkmate* [7 kt, 147 km altitude] bursts; the triggering of surge arresters on an airplane with a trailing-wire antenna during *Starfish*, *Checkmate*, and *Bluegill* [410 kt, 48 km altitude] ...'

This [refers to the KC-135 aircraft that filmed the tests from above the clouds, approximately 300 kilometers away from the detonations.](#)

The reference Vittitoe gives to [Dr Frederick M. Tesche](#) is: 'F. M. Tesche, *IEEE Transactions on Power Delivery*, PWRD-2, 1213 (1987). [This reference is [unfortunately wrong since there were only 4 issues of that journal published in 1987 and page 1213 occurs in issue 4 - in the middle of an article on EMP by Dr Mario Rabinowitz - that article being also available on arXiv.org and reviewed critically in a previous blog post here.](#)] The effects were reported earlier by G. S. Parks, Jr., T. I. Dayharsh, and A. L. Whitson, *A Survey of EMP Effects During Operation Fishbowl*, DASA [U.S. Department of Defense's Defense Atomic Support Agency, now the [DTRA](#)] Report DASA-2415, May 1970 (Secret - Restricted Data).'

Vittitoe then quotes Glasstone and Dolan's statement in *The Effects of Nuclear Weapons*:

'One of the best authenticated cases was the simultaneous failure of 30 strings (series-connected loops) of street lights at various locations on the Hawaiian island of Oahu, at a distance of 800 miles from ground zero.'

The detonation occurred at 11pm 8 July 1962 (local time) for Hawaii, so the flash was seen across the night sky and the failure of some street lights was observed. Vittitoe usefully on page 5 quotes the vital newspaper reports of the EMP damage, the first of which is the most important since it was published the very next day following the explosion:

'The street lights on Ferdinand Street in Manoa and Kawainui Street in Kailua went out at the instant the bomb went off, according to several persons who called police last night.'

- *HONOLULU ADVERTISER* newspaper article dated 9 July 1962 (local time; this amazing *Starfish* EMP effects article was reprinted in the Tuesday 21 February 1984 edition, celebrating the 15th anniversary of Hawaiian statehood to the U.S. A.).

A technical investigation was then done by the streetlights department into the causes of the 300 streetlight failures, and then on 28 July 1962, the *HONOLULU STAR-BULLETIN* newspaper article 'What Happened on the Night of July 8?' by Robert Scott (a professor at Hawaii University) reported that a Honolulu streetlight department official attributed the failure of the streetlights to blown fuses, due to the energy released by the bomb test being coupled into the power supply line circuits (see illustration above; the street lamps were attached to regular overhead power line poles, allowing EMP energy to be coupled into the circuit).

On 8 April 1967, *HONOLULU STAR-BULLETIN* newspaper published an article by Cornelius Downes about the blown fuses: 'small black plastic rings with two discs of lead separated by thin, clear-plastic washers.'

Vittitoe reports that the streetlight officials found that: 'The failure of 30 strings was well beyond any expectations for severe [electrical lightning] storms (where ~4 failures were typical).'

Vittitoe then gives a full analysis of the physics of how the EMP calculated by Longmire turned off the streetlights, and confirms that the EMP was responsible for the fuse failures.

Interestingly, Vittitoe co-authored the 2003 arXiv.org paper *Radiative Reactions and Coherence Modeling in the High-Altitude Electromagnetic Pulse* with Dr Mario Rabinowitz, who has kindly corresponded with me by email on the subjects of EMP and also particle physics (although Dr Rabinowitz did not mention this EMP paper he co-authored with Vittitoe!).

At 5:58 PM,  nige said...

*Literature references to EMP effects data from the three Russian EMP nuclear tests at high altitudes over Kazakhstan in October and November 1962:*

V. M. Loborev, "Up to Date State of the NEMP Problems and Topical Research Directions," *Electromagnetic Environments and Consequences: Proceedings of the EUROEM 94 International Symposium, Bordeaux, France, May 30-June 3, 1994*, edited by D. J. Serafin, J. Ch. Bolomey, and D. Dupouy, published in 1995, pp. 15-21. (Details of 1962 Russian high altitude nuclear test damage to the fuses in a 500 km long above-ground communications line, and to the insulation to a 1,000 km long buried power line, as well as diesel generators and radar systems).

Greetsai, V. N., A. H. Kozlovsky, M. M. Kuvshinnikov, V. M. Loborev, Yu. V. Parfenov, O. A. Tarasov, L. N. Zdoukhov, "Response of Long Lines to Nuclear High-Altitude Electromagnetic Pulse (HEMP)," *IEEE Transactions on EMC*, vol. 40, No. 4, November 1998, pp. 348-354. (Details of 1962 Russian high altitude nuclear test damage to two communication lines. Abstract: "During high-altitude nuclear testing in 1962 over Kazakhstan, several system effects were noted due to the high-altitude electromagnetic pulse (HEMP). In particular a 500-km-long aerial communications line experienced a failure due to the damage of its protective devices. This failure is examined in detail beginning with the calculation of the incident HEMP environments, including those from the early- and late-time portions of the HEMP. In addition, the currents and voltages induced on the line are computed and the measured electrical characteristics of the protection devices are presented. With this information it is possible to determine which portions of the HEMP environment were responsible for particular protection failures. The paper concludes with recommendations for further work required to understand the best ways to protect power lines from HEMP in the future".)

Howard Seguire (SeguireH@c3isky1.c3i.osd.mil), "US-Russian meeting – HEMP effects on national power grid & telecommunications", 17 Feb. 1995, is a report that gives data relevant to the USSR Test '184' on 22 October 1962, 'Operation K' (ABM System A proof tests) 300-kt burst at 290-km altitude near Dzhezkazgan. Prompt gamma ray-produced EMP induced a current of 2,500 amps measured by spark gaps in a 570-km stretch of overhead telephone line westwards from Zharyq, blowing all the protective fuses. The late-time MHD-EMP was of low enough frequency to enable it to penetrate the 90 cm into the ground, overloading a shallow buried lead and steel tape-protected 1,000-km long power cable between Aqmola and Almaty, firing circuit breakers and setting the Karaganda power plant on fire. Russian Army diesel electricity generators were burned out by EMP, after 300-kt tests at altitudes of 150 km on 28 October and 59 km on 1 November. Seguire's report gives many useful details, a few extracts from which follow:

"Lawrence Livermore National Lab (LLNL) hosted the Workshop on Atmospheric Nuclear Test Experience with the Russian Electric Power Grid, 14-15 Feb. Russian attendees were Professor (Maj Gen) Vladimir M. Loborev, Director, Russian Federal Ministry of Defense Central Institute of Physics and Technology (CIPT), Moscow; and Dr. (Colonel) Valery M. Kondrat'ev, Senior Scientist, CIPT. Dr. Lynn Shaeffer, LLNL, hosted the meeting. About 20 LLNL members attended. Other US attendees were Stan Gooch, STRATCOM; Chuck Lear, Silo-Based ICBM System Project Office, Hill AFB; Maj ValVerde, USSPACECOM; Balram Prasad, Defense Nuclear Agency (DNA); Mike Zmuda, Sacramento Air Logistic Center; two translators; and me. ...

"Question [asked to Loborev]: Based on your understanding of what the US has published, can US models be improved by Russian models and/or data? Answer: We follow world literature, in this area, assiduously. I suspect the US doesn't have close-in data on even the Soviet detonations. I'm convinced US-Russian specialists' discussions in this area would be absolutely beneficial to both sides with regard to improving methodologies. But this type of collaboration is in the bailiwick of higher ups in both our governments. Such could occur if they agreed. The fact that I'm standing before you and that you have some Russian scientists at the lab says that the process has begun, as President Yeltsin recently said. We both should pursue this through out respective chains. ...

"KONDRAT'EV – Formal paper (read by Kondrat'ev, with some difficulty)

- a. USSR EMP theory was developed 1961-62. The Ministry of Communications did EMP experiments on communications lines.
- b. The attached diagram [nuclear test of 23 October 1962] approximates a vu-graph used to discuss damages. Dimensions shown and information in the three boxes were provided verbally by Kondrat'ev and/or Loborev.
- c. Amplifiers, spaced 40-80 km apart were damaged as were spark gap tubes. The latter were commonly used to protect the system from lightning damage. Spark gaps saw more than 350 volts for 30-40 microsecs; parts of the line saw more than kiloamps, and the rise time was 30-40 microsecs – these were actual measurements.
- d. Experiments were set up specifically to study protection measures for critical items. We experienced fires from EMP and loss of communications gear. Seven-wire cables were common in telecommunications networks.
- e. Destruction of power supply at Karaganda. Fuses failed during the test, as they were

designed to do; actually, they burned. ...”

Russian EMP effects report PDF link:

[Seguine report on Russian EMP nuclear tests 1962](#)

[Corrected EMP effects illustration](#)

In testimony to the 1997 U.S. Congressional Hearings, “Threats Posed by Electromagnetic Pulse to U.S. Military Systems and Civilian Infrastructure; House of Representatives, Committee on National Security, Military Research and Development Subcommittee, Washington, DC, Wednesday, July 16, 1997” (Hon. Curt Weldon, Chairman of Military Research and Development Subcommittee), Dr. George W. Ullrich, the Deputy Director of the U.S. Department of Defense's Defense Special Weapons Agency, DSWA (now the Defence Threat Reduction Agency, DTRA) stated:

“Starfish Prime, a 1.4 megaton device, was detonated at an altitude of 400 kilometers over Johnston Island. Failures of electronic systems resulted in Hawaii, 1,300 kilometers away from the detonation. Street lights and fuzes failed on Oahu and telephone service was disrupted on the island of Kauai. Subsequent tests with lower yield devices [410 kt Kingfish at 95 km altitude, 410 kt Bluegill at 48 km altitude caused EMP problems, 7 kt Checkmate at 147 km] produced electronic upsets on an instrumentation aircraft [the KC-135 that filmed the tests from above the clouds] that was approximately 300 kilometers away from the detonations.

“Soviet scientists had similar experiences during their atmospheric test program. In one test, all protective devices in overhead communications lines were damaged at distances out to 500 kilometers; the same event saw a 1,000 kilometer segment of power line shut down by these effects. Failures in transmission lines, breakdowns of power supplies, and communications outages were wide-spread.”

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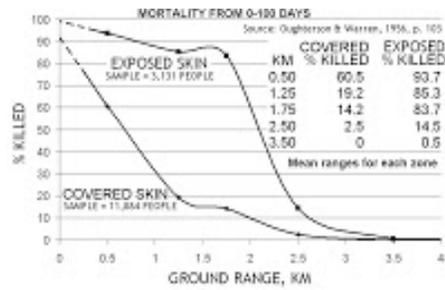
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‘Paradoxically, the more damaging the effect, that is the farther out its lethality stretches, the more can be done about it, because in the last fall of its power it covers vast areas, where small mitigations will save very large numbers of people.’

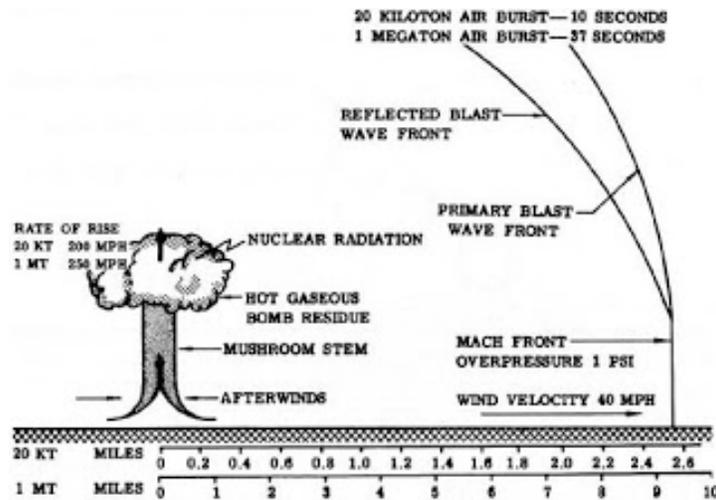
- Peter Laurie, *Beneath the City Streets: A Private Inquiry into the Nuclear Preoccupations of Government*, Penguin, 1974.

‘The purpose of a book is to save people [the] time and effort of digging things out for themselves. ... we have tried to leave the reader with something tangible – what a certain number of calories, roentgens, etc., means in terms of an effect on the human being. ... we must think of the people we are writing for.’

– Dr Samuel Glasstone, DSc, letter dated 1 February 1957 to Colonel Dent L. Lay, Chief, Weapons Effects Division, U.S. Armed Forces Special Weapons Project, Washington, D.C., pages 2 and 4, concerning the preparation of *The Effects of Nuclear Weapons*.



From Dr Glasstone's *Effects of Nuclear Weapons* (1962/64 ed., page 631): 'At distances between 0.3 and 0.4 mile from ground zero in Hiroshima the average survival rate, for at least 20 days after the nuclear explosion, was less than 20 percent. Yet in two reinforced concrete office buildings, at these distances, almost 90 percent of the nearly 800 occupants survived more than 20 days, although some died later of radiation injury. Furthermore, of approximately 3,000 school students who were in the open and unshielded within a mile of ground zero at Hiroshima, about 90 percent were dead or missing after the explosion. But of nearly 5,000 students in the same zone who were shielded in one way or another, only 26 percent were fatalities. ... survival in Hiroshima was possible in buildings at such distances that the overpressure in the open was 15 to 20 pounds per square inch. ... it is evident ... that the area over which protection could be effective in saving lives is roughly eight to ten times as great as that in which the chances of survival are small.'



'The evidence from Hiroshima indicates that blast survivors, both injured and uninjured, in buildings later consumed by fire [caused by the blast overturning charcoal braziers used for breakfast in inflammable wooden houses filled with easily ignitable bamboo furnishings and paper screens] were generally able to move to safe areas following the explosion. Of 130 major buildings studied by the U.S. Strategic Bombing Survey ... 107 were ultimately burned out ... Of those suffering fire, about 20 percent were burning after the first half hour. The remainder were consumed by fire spread, some as late as 15 hours after the blast. This situation is not unlike the one our computer-based fire spread model described for Detroit.'

- Defense Civil Preparedness Agency, U.S. Department of Defense, *DCPA Attack Environment Manual, Chapter 3: What the Planner Needs to Know About Fire Ignition and Spread*, report CPG 2-1A3, June 1973, Panel 27.

'It is true that the Soviets have tested nuclear weapons of a yield higher than that which we thought necessary, but the 100-megaton bomb of which they spoke two years ago does not and will not change the balance of strategic power. The United States has chosen, deliberately, to concentrate on more mobile and more efficient weapons, with lower but entirely sufficient yield ...'

- President John F. Kennedy in his television broadcast to the American public, 26 July 1963.

'During World War II many large cities in England, Germany, and Japan were subjected to terrific attacks by high-explosive and incendiary bombs. Yet, when proper steps had been taken for the protection of the civilian population and for the

restoration of services after the bombing, there was little, if any, evidence of panic. It is the purpose of this book to state the facts concerning the atomic bomb, and to make an objective, scientific analysis of these facts. It is hoped that as a result, although it may not be feasible completely to allay fear, it will at least be possible to avoid panic.'

– Dr George Gamow (the big bang cosmologist), Dr Samuel Glasstone, DSc (Executive Editor of the book), and Professor Joseph O. Hirschfelder, *The Effects of Atomic Weapons*, Chapter 1, p. 1, Paragraph 1.3, U. S. Department of Defense, September 1950.

'The consequences of a multiweapon nuclear attack would certainly be grave ... Nevertheless, recovery should be possible if plans exist and are carried out to restore social order and to mitigate the economic disruption.'

- Philip J. Dolan, editor of *Nuclear Weapons Employment FM 101-31* (1963), *Capabilities of Nuclear Weapons DNA-EM-1* (1972), and *The Effects of Nuclear Weapons* (1977), Stanford Research Institute, Appendix A of the U.S. National Council on Radiological protection (NCRP) symposium *The Control of Exposure to the Public of Ionising Radiation in the Event of Accident or Attack*, 1981.

'Suppose the bomb dropped on Hiroshima had been 1,000 times as powerful ... It could not have killed 1,000 times as many people, but at most the entire population of Hiroshima ... [regarding the hype about various nuclear "overkill" exaggerations] there is enough water in the oceans to drown everyone ten times.'

- Professor Brian Martin, PhD (physics), 'The global health effects of nuclear war', *Current Affairs Bulletin*, Vol. 59, No. 7, December 1982, pp. 14-26.

Dihydrogen monoxide is a potentially very dangerous chemical containing hydrogen and oxygen which has caused numerous severe burns by scalding and deaths by drowning, contributes to the greenhouse effect, accelerates corrosion and rusting of many metals, and contributes to the erosion of our natural landscape: 'Dihydrogen monoxide (DHMO) is colorless, odorless, tasteless, and kills uncounted thousands of people every year. Most of these deaths are caused by accidental inhalation of DHMO, but the dangers of dihydrogen monoxide do not end there. Prolonged exposure to its solid form causes severe tissue damage. Symptoms of DHMO ingestion can include excessive sweating and urination, and possibly a bloated feeling, nausea, vomiting and body electrolyte imbalance. For those who have become dependent, DHMO withdrawal means certain death.'

From the site for the petition against dihydrogen monoxide: 'Please sign this petition and help stop This Invisible Killer. Get the government to do something now. ... Contamination Is Reaching Epidemic Proportions! Quantities of dihydrogen monoxide have been found in almost every stream, lake, and reservoir in America today. But the pollution is global, and the contaminant has even been found in Antarctic ice. DHMO has caused millions of dollars of property damage in the Midwest, and recently California.'

In 1996, half a century after the nuclear detonations, data on cancers from the Hiroshima and Nagasaki survivors was published by D. A. Pierce et al. of the Radiation Effects Research Foundation, RERF (*Radiation Research* vol. 146 pp. 1-27; *Science* vol. 272, pp. 632-3) for 86,572 survivors, of whom 60% had received bomb doses of over 5 mSv (or 500 millirem in old units) suffering 4,741 cancers of which only 420 were due to radiation, consisting of 85 leukemias and 335 solid cancers.

'Today we have a population of 2,383 [radium dial painter] cases for whom we have reliable body content measurements. . . . All 64 bone sarcoma [cancer] cases occurred in the 264 cases with more than 10 Gy [1,000 rads],

while no sarcomas appeared in the 2,119 radium cases with less than 10 Gy.'

- Dr Robert Rowland, Director of the Center for Human Radiobiology, ***Bone Sarcoma in Humans Induced by Radium: A Threshold Response?***, Proceedings of the 27th Annual Meeting, European Society for Radiation Biology, Radioprotection colloquies, Vol. 32CI (1997), pp. 331-8.

Zbigniew Jaworowski, 'Radiation Risk and Ethics: Health Hazards, Prevention Costs, and Radiophobia', ***Physics Today***, April 2000, pp. 89-90:

'... it is important to note that, given the effects of a few seconds of irradiation at Hiroshima and Nagasaki in 1945, a threshold near 200 mSv may be expected for leukemia and some solid tumors. [Sources: UNSCEAR, *Sources and Effects of Ionizing Radiation*, New York, 1994; W. F. Heidenreich, et al., *Radiat. Environ. Biophys.*, vol. 36 (1999), p. 205; and B. L. Cohen, *Radiat. Res.*, vol. 149 (1998), p. 525.] For a protracted lifetime natural exposure, a threshold may be set at a level of several thousand millisieverts for malignancies, of 10 grays for radium-226 in bones, and probably about 1.5-2.0 Gy for lung cancer after x-ray and gamma irradiation. [Sources: G. Jaikrishan, et al., *Radiation Research*, vol. 152 (1999), p. S149 (for natural exposure); R. D. Evans, *Health Physics*, vol. 27 (1974), p. 497 (for radium-226); H. H. Rossi and M. Zaider, *Radiat. Environ. Biophys.*, vol. 36 (1997), p. 85 (for radiogenic lung cancer).] The hormetic effects, such as a decreased cancer incidence at low doses and increased longevity, may be used as a guide for estimating practical thresholds and for setting standards. ...

'Though about a hundred of the million daily spontaneous DNA damages per cell remain unrepaired or misrepaired, apoptosis, differentiation, necrosis, cell cycle regulation, intercellular interactions, and the immune system remove about 99% of the altered cells. [Source: R. D. Stewart, *Radiation Research*, vol. 152 (1999), p. 101.] ...

'[Due to the Chernobyl nuclear accident in 1986] as of 1998 (according to UNSCEAR), a total of 1,791 thyroid cancers in children had been registered. About 93% of the youngsters have a prospect of full recovery. [Source: C. R. Moir and R. L. Telander, *Seminars in Pediatric Surgery*, vol. 3 (1994), p. 182.] ... The highest average thyroid doses in children (177 mGy) were accumulated in the Gomel region of Belarus. The highest incidence of thyroid cancer (17.9 cases per 100,000 children) occurred there in 1995, which means that the rate had increased by a factor of about 25 since 1987.

'This rate increase was probably a result of improved screening [not radiation!]. Even then, the incidence rate for occult thyroid cancers was still a thousand times lower than it was for occult thyroid cancers in nonexposed populations (in the US, for example, the rate is 13,000 per 100,000 persons, and in Finland it is 35,600 per 100,000 persons). Thus, given the prospect of improved diagnostics, there is an enormous potential for detecting yet more [fictitious] "excess" thyroid cancers. In a study in the US that was performed during the period of active screening in 1974-79, it was determined that the incidence rate of malignant and other thyroid nodules was greater by 21-fold than it had been in the pre-1974 period. [Source: Z. Jaworowski, *21st Century Science and Technology*, vol. 11 (1998), issue 1, p. 14.]'

W. L. Chen, Y. C. Luan, M. C. Shieh, S. T. Chen, H. T. Kung, K. L. Soong, Y. C. Yeh, T. S. Chou, S. H. Mong, J. T. Wu, C. P. Sun, W. P. Deng, M. F. Wu, and M. L. Shen, 'Is Chronic Radiation an Effective Prophylaxis Against Cancer?', published in the ***Journal of American Physicians and Surgeons***, Vol. 9, No. 1, Spring 2004, page 6, available in PDF format here:

'An extraordinary incident occurred 20 years ago in Taiwan. Recycled steel, accidentally contaminated with cobalt-60 ([low dose rate, gamma radiation emitter] half-life: 5.3 y), was formed into construction steel for more than 180 buildings, which 10,000 persons occupied for 9 to 20 years. They unknowingly received radiation doses that averaged 0.4 Sv, a collective dose of 4,000 person-Sv. Based on the observed seven cancer deaths, the cancer mortality rate for this population was assessed to be 3.5 per 100,000 person-years. Three children were born with congenital heart malformations, indicating a

prevalence rate of 1.5 cases per 1,000 children under age 19.

'The average spontaneous cancer death rate in the general population of Taiwan over these 20 years is 116 persons per 100,000 person-years. Based upon partial official statistics and hospital experience, the prevalence rate of congenital malformation is 23 cases per 1,000 children. Assuming the age and income distributions of these persons are the same as for the general population, it appears that significant beneficial health effects may be associated with this chronic radiation exposure. ...'

'Professor Edward Lewis used data from four independent populations exposed to radiation to demonstrate that the incidence of leukemia was linearly related to the accumulated dose of radiation. ... Outspoken scientists, including Linus Pauling, used Lewis's risk estimate to inform the public about the danger of nuclear fallout by estimating the number of leukemia deaths that would be caused by the test detonations. In May of 1957 Lewis's analysis of the radiation-induced human leukemia data was published as a lead article in Science magazine. In June he presented it before the Joint Committee on Atomic Energy of the US Congress.' – Abstract of thesis by Jennifer Caron, *Edward Lewis and Radioactive Fallout: the Impact of Caltech Biologists Over Nuclear Weapons Testing in the 1950s and 60s*, Caltech, January 2003.

Dr John F. Loutit of the Medical Research Council, Harwell, England, in 1962 wrote a book called Irradiation of Mice and Men (University of Chicago Press, Chicago and London), discrediting the pseudo-science from geneticist Edward Lewis on pages 61, and 78-79:

'... Mole [R. H. Mole, *Brit. J. Radiol.*, v32, p497, 1959] gave different groups of mice an integrated total of 1,000 r of X-rays over a period of 4 weeks. But the dose-rate - and therefore the radiation-free time between fractions - was varied from 81 r/hour intermittently to 1.3 r/hour continuously. The incidence of leukemia varied from 40 per cent (within 15 months of the start of irradiation) in the first group to 5 per cent in the last compared with 2 per cent incidence in irradiated controls. ...

'What Lewis did, and which I have not copied, was to include in his table another group - spontaneous incidence of leukemia (Brooklyn, N.Y.) - who are taken to have received only natural background radiation throughout life at the very low dose-rate of 0.1-0.2 rad per year: the best estimate is listed as  $2 \times 10^{-6}$  like the others in the table. But the value of  $2 \times 10^{-6}$  was not calculated from the data as for the other groups; it was merely adopted. By its adoption and multiplication with the average age in years of Brooklyners - 33.7 years and radiation dose per year of 0.1-0.2 rad - a mortality rate of 7 to 13 cases per million per year due to background radiation was deduced, or some 10-20 per cent of the observed rate of 65 cases per million per year. ...

'All these points are very much against the basic hypothesis of Lewis of a linear relation of dose to leukemic effect irrespective of time. Unhappily it is not possible to claim for Lewis's work as others have done, "It is now possible to calculate - within narrow limits - how many deaths from leukemia will result in any population from an increase in fall-out or other source of radiation" [Leading article in *Science*, vol. 125, p. 963, 1957]. This is just wishful journalese.

'The burning questions to me are not what are the numbers of leukemia to be expected from atom bombs or radiotherapy, but what is to be expected from natural background .... Furthermore, to obtain estimates of these, I believe it is wrong to go to [1950s inaccurate, dose rate effect ignoring, data from] atom bombs, where the radiations are qualitatively different [i.e., including effects from neutrons] and, more important, the dose-rate outstandingly different.'

'What is Science?' by Richard P. Feynman, presented at the fifteenth annual meeting of the National Science Teachers Association, 1966 in New York City, and published in *The Physics Teacher*, vol. 7, issue 6, 1968, pp. 313-20:

'... great religions are dissipated by following form without remembering the direct content of the teaching of the great leaders. In the same way, it is possible to follow form and call it science, but that is pseudo-science. In this way, we all

suffer from the kind of tyranny we have today in the many institutions that have come under the influence of pseudoscientific advisers.

'We have many studies in teaching, for example, in which people make observations, make lists, do statistics, and so on, but these do not thereby become established science, established knowledge. They are merely an imitative form of science analogous to the South Sea Islanders' airfields - radio towers, etc., made out of wood. The islanders expect a great airplane to arrive. They even build wooden airplanes of the same shape as they see in the foreigners' airfields around them, but strangely enough, their wood planes do not fly. The result of this pseudoscientific imitation is to produce experts, which many of you are. ... you teachers, who are really teaching children at the bottom of the heap, can maybe doubt the experts. As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts.'

Richard P. Feynman, 'This Unscientific Age', in *The Meaning of It All*, Penguin Books, London, 1998, pages 106-9:

'Now, I say if a man is absolutely honest and wants to protect the populace from the effects of radioactivity, which is what our scientific fiends often say they are trying to do, then he should work on the biggest number, not on the smallest number, and he should try to point out that the radioactivity which is absorbed by living in the city of Denver is so much more serious ... that all the people of Denver ought to move to lower altitudes.'

A recent example of the pseudoscientific radiation 'education' masquerading as science that Feynman (quoted above) objected to in the 1960s was published in 2009 in an article called 'The proportion of childhood leukaemia incidence in Great Britain that may be caused by natural background ionizing radiation' in *Leukemia*, vol. 23 (2009), pp. 770-776, which falsely asserts - in contradiction to the evidence that the no-threshold model is **contrary** to Hiroshima and Nagasaki data: 'Risk models based primarily on studies of the Japanese atomic bomb survivors imply that low-level exposure to ionizing radiation, including ubiquitous natural background radiation, also raises the risk of childhood leukaemia. Using two sets of recently published leukaemia risk models and estimates of natural background radiation red-bone-marrow doses received by children, about 20% of the cases of childhood leukaemia in Great Britain are predicted to be attributable to this source.' The authors of this pseudoscience which is the opposite of the facts are R. Wakeford (Dalton Nuclear Institute, University of Manchester, Manchester, UK), G. M. Kendall (Childhood Cancer Research Group, Oxford, UK), and M. P. Little (Department of Epidemiology and Public Health, Imperial College, London, UK). It is disgusting and sinful that the facts about childhood leukemia are being lied on so blatantly for non-scientific purposes, and it is to be hoped that these leukemia investigators will either correct their errors or alternatively be banned from using scientific literature to promote false dogma for deception until they mend the error of their ways and repent their sins in this matter.

Protein P53, discovered only in 1979, is encoded by gene TP53, which occurs on human chromosome 17. P53 also occurs in other mammals including mice, rats and dogs. P53 is one of the proteins which continually repairs breaks in DNA, which easily breaks at body temperature: the DNA in each cell of the human body suffers at least two single strand breaks every second, and one double strand (i.e. complete double helix) DNA break occurs at least once every 2 hours (5% of radiation-induced DNA breaks are double strand breaks, while 0.007% of spontaneous DNA breaks at body temperature are double strand breaks)! Cancer occurs when several breaks in DNA happen to occur by chance at nearly the same time, giving several loose strand ends at once, which repair proteins like P53 then repair incorrectly, causing a mutation which can be proliferated somatically. This cannot occur when only one break occurs, because only two loose ends are produced, and P53 will reattach them correctly. But if low-LET ionising radiation levels are increased to a certain

extent, causing more single strand breaks, P53 works faster and is able deal with faster breaks as they occur, so that multiple broken strand ends do not arise. This prevents DNA strands being repaired incorrectly, and prevents cancer - a result of mutation caused by faults in DNA - from arising. Too much radiation of course overloads the P53 repair mechanism, and then it cannot repair breaks as they occur, so multiple breaks begin to appear and loose ends of DNA are wrongly connected by P53, causing an increased cancer risk.

1. DNA-damaging free radicals are equivalent to a source of sparks which is always present naturally.

2. Cancer is equivalent the fire you get if the sparks are allowed to ignite the gasoline, i.e. if the free radicals are allowed to damage DNA without the damage being repaired.

3. Protein P53 is equivalent to a fire suppression system which is constantly damping out the sparks, or repairing the damaged DNA so that cancer doesn't occur.

In this way of thinking, the 'cause' of cancer will be down to a failure of a gene like P53 to repair the damage.

Dr Jane Orient, 'Homeland Security for Physicians', *Journal of American Physicians and Surgeons*, vol. 11, number 3, Fall 2006, pp. 75-9:

'In the 1960s, a group of activist physicians called Physicians for Social Responsibility (PSR) undertook to "educate the medical profession and the world about the dangers of nuclear weapons," beginning with a series of articles in the *New England Journal of Medicine*. [Note that journal was publishing information for anti-civil defense propaganda back in 1949, e.g. the article in volume 241, pp. 647-53 of *New England Journal of Medicine* which falsely suggests that civil defense in nuclear war would be hopeless because a single burned patient in 1947 with 40% body area burns required 42 oxygen tanks, 36 pints of plasma, 40 pints of whole blood, 104 pints of fluids, 4,300 m of gauze, 3 nurses and 2 doctors. First, only unclothed persons in direct line of sight without shadowing can get 40% body area burns from thermal radiation, second, duck and cover offers protection in a nuclear attack warning, and G. V. LeRoy had already published, two years earlier, in *J.A.M.A.*, volume 134, 1947, pp. 1143-8, that less than 5% of burns in Hiroshima and Nagasaki were caused by building and debris fires. In medicine it is always possible to expend vast resources on patients who are fatally injured. In a mass casualty situation, doctors should not give up just because they don't have unlimited resources; as at Hiroshima and Nagasaki, they would need to do their best with what they have.] On its website, [www.psr.org](http://www.psr.org), the group boasts that it "led the campaign to end atmospheric nuclear testing."

With this campaign, the linear no-threshold (LNT) theory of radiation carcinogenesis became entrenched. It enabled activists to calculate enormous numbers of potential casualties by taking a tiny risk and multiplying it by the population of the earth. As an enduring consequence, the perceived risks of radiation are far out of proportion to actual risks, causing tremendous damage to the American nuclear industry. ... Efforts to save lives were not only futile, but unethical: Any suggestion that nuclear war could be survivable increased its likelihood and was thus tantamount to warmongering, PSR spokesmen warned. ...

'For the mindset that engendered and enables this situation, which jeopardizes the existence of the United States as a nation as well as the lives of millions of its citizens, some American physicians and certain prestigious medical organizations bear a heavy responsibility.

'Ethical physicians should stand ready to help patients to the best of their ability, and not advocate sacrificing them in the name of a political agenda. Even very basic knowledge, especially combined with simple, inexpensive

advance preparations, could save countless lives.'

Dr Theodore B. Taylor, *Proceedings of the Second Interdisciplinary Conference on Selected Effects of a General War*, DASIAC Special Report 95, July 1969, vol. 2, DASA-2019-2, AD0696959, page 298:

'I must just say that as far as I'm concerned I have had some doubts about whether we should have had a civil defense program in the past. I have no doubt whatsoever now, for this reason, that I've seen ways in which the deterrent forces can fail to hold things off, so that no matter what our national leaders do, criminal organizations, what have you, groups of people over which we have no control whatsoever, can threaten other groups of people.'

This point of Taylor is the key fact on the morality. Suppose we disarm and abandon nuclear power. That won't stop fallout from a war, terrorists, or a foreign reactor blast from coming. Civil defence knowledge is needed. Even when America has ABM, it will be vulnerable to wind carried fallout. No quantity of pacifist hot air will protect people against radiation.

British Prime Minister Maggie Thatcher, address to the United Nations General Assembly on disarmament on 23 June 1982, when she pointed out that in the years since the nuclear attacks on Hiroshima and Nagasaki, 10 million people were killed by 140 non-nuclear conflicts:

'The fundamental risk to peace is not the existence of weapons of particular types. It is the disposition on the part of some states to impose change on others by resorting to force against other nations ... Aggressors do not start wars because an adversary has built up his own strength. They start wars because they believe they can gain more by going to war than by remaining at peace.'

It is estimated that Mongol invaders exterminated 35 million Chinese between 1311-40, without modern weapons. Communist Chinese killed 26.3 million dissenters between 1949 and May 1965, according to detailed data compiled by the Russians on 7 April 1969. The Soviet communist dictatorship killed 40 million dissenters, mainly owners of small farms, between 1917-59. Conventional (non-nuclear) air raids on Japan killed 600,000 during World War II. The single incendiary air raid on Tokyo on 10 March 1945 killed 140,000 people (more than the total for nuclear bombs on Hiroshima and Nagasaki combined) at much less than the \$2 billion expense of the Hiroshima and Nagasaki nuclear bombs! Non-nuclear air raids on Germany during World War II killed 593,000 civilians.

On 29 October 1982, she stated of the Berlin Wall: 'In every decade since the war the Soviet leaders have been reminded that their pitiless ideology only survives because it is maintained by force. But the day comes when the anger and frustration of the people is so great that force cannot contain it. Then the edifice cracks: the mortar crumbles ... one day, liberty will dawn on the other side of the wall.'

On 22 November 1990, she said: 'Today, we have a Europe ... where the threat to our security from the overwhelming conventional forces of the Warsaw Pact has been removed; where the Berlin Wall has been torn down and the Cold War is at an end. These immense changes did not come about by chance. They have been achieved by strength and resolution in defence, and by a refusal ever to be intimidated.'

'The case for civil defence stands regardless of whether a nuclear deterrent is necessary or not. ... Even if the U.K. were not itself at war, we would be as powerless to prevent fallout from a nuclear explosion crossing the sea as was King Canute to stop the tide.' - U.K. Home Office leaflet, Civil Defence, 1982.

'Dr Edward Teller remarked recently that the origin of the earth was somewhat like the explosion of the atomic bomb...' – Dr Harold C. Urey, *The Planets: Their Origin and Development*, Yale University Press, New Haven, 1952, p. ix.

'But compared with a supernova a hydrogen bomb is the merest trifle. For a supernova is equal in violence to about a million million million million hydrogen bombs all going off at the same time.' – Sir Fred Hoyle (1915-2001), *The Nature of the Universe*, Pelican Books, London, 1963, p. 75.

'In fact, physicists find plenty of interesting and novel physics in the environment of a nuclear explosion. Some of the physical phenomena are valuable objects of research, and promise to provide further understanding of nature.' – Dr Harold L. Brode, The RAND Corporation, 'Review of Nuclear Weapons Effects,' *Annual Review of Nuclear Science*, Volume 18, 1968, pp. 153-202.

'It seems that similarities do exist between the processes of formation of single particles from nuclear explosions and formation of the solar system from the debris of a [4 x 10<sup>28</sup> megatons of TNT equivalent, type Ia] supernova explosion. We may be able to learn much more about the origin of the earth, by further investigating the process of radioactive fallout from the nuclear weapons tests.' – Dr Paul K. Kuroda (1917-2001), University of Arkansas, 'Radioactive Fallout in Astronomical Settings: Plutonium-244 in the Early Environment of the Solar System,' pages 83-96 of *Radionuclides in the Environment: A Symposium Sponsored By the Division of Nuclear Chemistry and Technology At the 155th Meeting of the American Chemical Society, San Francisco, California, April 1-3, 1968*, edited by Symposium Chairman Dr Edward C. Freiling (1922-2000) of the U.S. Naval Radiological Defense Laboratory, *Advances in Chemistry Series No. 93*, American Chemical Society, Washington, D.C., 1970.

Dr Paul K. Kuroda (1917-2001) in 1956 correctly predicted the existence of water-moderated natural nuclear reactors in flooded uranium ore seams, which were discovered in 1972 by French physicist Francis Perrin in three ore deposits at Oklo in Gabon, where sixteen sites operated as natural nuclear reactors with self-sustaining nuclear fission 2,000 million years ago, each lasting several hundred thousand years, averaging 100 kW. The radioactive waste they generated remained in situ for a period of 2,000,000,000 years without escaping. They were discovered during investigations into why the U-235 content of the uranium in the ore was only 0.7171% instead of the normal 0.7202%. Some of the ore, in the middle of the natural reactors, had a U-235 isotopic abundance of just 0.440%. Kuroda's brilliant paper is entitled, 'On the Nuclear Physical Stability of the Uranium Minerals', published in the *Journal of Chemical Physics*, vol. 25 (1956), pp. 781–782 and 1295–1296.

A type Ia supernova explosion, always yielding 4 x 10<sup>28</sup> megatons of TNT equivalent, results from the critical mass effect of the collapse of a white dwarf as soon as its mass exceeds 1.4 solar masses due to matter falling in from a companion star. The degenerate electron gas in the white dwarf is then no longer able to support the pressure from the weight of gas, which collapses, thereby releasing enough gravitational potential energy as heat and pressure to cause the fusion of carbon and oxygen into heavy elements, creating massive amounts of radioactive nuclides, particularly intensely radioactive nickel-56, but half of all other nuclides (including uranium and heavier) are also produced by the 'R' (rapid) process of successive neutron captures by fusion products in supernovae explosions. Type Ia supernovae occur typically every 400 years in the Milky Way galaxy. On 4 July 1054, Chinese astronomers observed in the sky (without optical instruments) the bright supernova in the constellation Taurus which today is still visible as the Crab Nebula through telescopes. The Crab Nebula debris has a diameter now of 7 light years and is still expanding at 800 miles/second. The supernova debris shock wave triggers star formation when it encounters hydrogen gas in space by compressing it and seeding it with debris; bright stars are observed in the Orion Halo, the 300 light year diameter remains of a supernova. It is estimated that when the solar system was forming 4,540 million years ago, a supernova occurred around 100 light years away, and the heavy radioactive debris shock wave expanded at 1,000 miles/second. Most of the heavy elements including iron, silicon and calcium in the Earth and people are the stable end products of originally radioactive decay chains from the space burst fallout of a 7 x 10<sup>26</sup> megatons thermonuclear explosion, created by fusion

and successive neutron captures after the implosion of a white dwarf; a supernova explosion.

How would a  $10^{55}$  megaton hydrogen bomb explosion differ from the **big bang**? Ignorant answers biased in favour of curved spacetime (ignoring quantum gravity!) abound, such as claims that explosions can't take place in 'outer space' (disagreeing with the facts from nuclear space bursts by Russia and America in 1962, not to mention natural supernova explosions in space!) and that explosions produce sound waves in air by definition! There are indeed major differences in the nuclear reactions between the big bang and a nuclear bomb. But it is helpful to notice the solid physical fact that implosion systems suggest the mechanism of gravitation: in implosion, TNT is well-known to produce an *inward* force on a bomb core, but Newton's 3rd law says there is an equal and opposite reaction force *outward*. In fact, you can't have a radially outward force without an inward reaction force! It's the rocket principle. The rocket accelerates (with force  $F = ma$ ) *forward* by virtue of the recoil from accelerating the exhaust gas (with force  $F = -ma$ ) in the *opposite* direction! Nothing massive accelerates without an equal and opposite reaction force. Applying this *fact* to the **measured  $6 \times 10^{-10} \text{ ms}^{-2} \sim$**  **Hc cosmological acceleration of matter radially outward** from observers in the universe which was **predicted accurately in 1996** and later observationally discovered in 1999 (by Perlmutter, et al.), we find an outward force  $F = ma$  and inward reaction force by the 3rd law. **The inward force allows quantitative predictions, and is mediated by gravitons, predicting gravitation in a checkable way (unlike string theory, which is just a landscape of  $10^{500}$  different perturbative theories and so can't make any falsifiable predictions about gravity).** So it seems as if nuclear explosions do indeed provide helpful analogies to natural features of the world, and the mainstream lambda-CDM model of cosmology - with its force-fitted unobserved *ad hoc* speculative 'dark energy' - ignores and sweeps under the rug major quantum gravity effects which increase the physical understanding of particle physics, particularly force unification and the relation of gravitation to the existing electroweak SU(2) x U(1) section of the Standard Model of fundamental forces.

Richard Lieu, Physics Department, University of Alabama, 'Lambda-CDM cosmology: how much suppression of credible evidence, and does the model really lead its competitors, using all evidence?', <http://arxiv.org/abs/0705.2462>.

Even Einstein grasped the possibility that general relativity's lambda-CDM model is at best just a classical approximation to quantum field theory, at the end of his life when he wrote to Besso in 1954:

'I consider it quite possible that physics cannot be based on the [classical differential equation] field principle, i.e., on continuous structures. In that case, nothing remains of my entire castle in the air, [non-quantum] gravitation theory included ...'

'Science is the organized skepticism in the reliability of expert opinion.' - Professor Richard P. Feynman (quoted by Professor Lee Smolin, **The Trouble with Physics**, Houghton-Mifflin, New York, 2006, p. 307).

Mathematical symbols in this blog: your computer's browser needs access to standard character symbol sets to display Greek symbols for mathematical physics. If you don't have the symbol character sets installed, the density symbol ' $\rho$ ' (*Rho*) will appear as 'r' and the ' $\pi$ ' (*Pi*) symbol will as 'p', causing confusion with the use of 'r' for radius and 'p' for momentum in formulae. This problem exists with Mozilla Firefox 3, but not with Microsoft Explorer which displays Greek symbols.

## About Me

Name: nige

Background info: <http://quantumfieldtheory.org/> <http://nige.wordpress.com/> Dynamics of energetic expansive processes in space etc. <http://www.math.columbia.edu/~woit/>





[wordpress/?p=273#comment-5322](http://www.math.columbia.edu/~woit/wordpress/?p=273#comment-5322). <http://www.math.columbia.edu/~woit/wordpress/?p=353&cpage=1#comment-8728>. <http://www.math.columbia.edu/~woit/wordpress/?p=215#comment-4082>.

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Mean yield of the 4,552 nuclear warheads and bombs in the deployed U.S. nuclear stockpile as of January 2007: 0.257 Mt.

Total yield: 1,172 Mt. For diffraction damage where damage areas scale as the two-thirds power of explosive yield, this stockpile's area damage potential can be compared to the 20,000,000 conventional bombs of 100 kg size (2 megatons of TNT equivalent total *energy*) dropped on Germany during World War II: (Total nuclear bomb blast diffraction damaged ground *area*)/(Total conventional blast diffraction damaged ground *area* to Germany during World War II) =  $[4,552*(0.257 \text{ Mt})^{2/3}]/[20,000,000*(0.0000001 \text{ Mt})^{2/3}] = 1,840/431 = 4.3$ . Thus, although the entire U.S. stockpile has a TNT *energy* equivalent to 586 times that of the 2 megatons of conventional bombs dropped on Germany in World War II, it is only capable of causing 4.3 times as much diffraction type damage area, because *any given amount of explosive energy is far more efficient when distributed over many small explosions than in a single large explosion! Large explosions are inefficient because they cause unintended collateral damage, wasting energy off the target area and injuring or damaging unintended targets!*

In a controlled sample of 36,500 survivors, 89 people got leukemia over a 40 year period, above the number in the unexposed control group. (Data: *Radiation Research*, volume 146, 1996, pages 1-27.) Over 40 years, in 36,500 survivors monitored, there were 176 leukemia deaths which is 89 more than the control (unexposed) group got naturally. There were 4,687 other cancer deaths, but that was merely 339 above the number in the control (unexposed) group, so this is statistically a much smaller rise than the leukemia result. Natural leukemia rates, which are very low in any case, were increased by 51% in the irradiated survivors, but other cancers were merely increased by just 7%. Adding all the cancers together, the total was 4,863 cancers (virtually all natural cancer, nothing whatsoever to do with radiation), which is just 428 more than the unexposed control group. Hence, the total increase over the natural cancer rate due to bomb exposure was only 9%, spread over a period of 40 years. There was no increase whatsoever in genetic malformations.

There should be a note here about how unnatural radioactive pollution is (not) in space: the earth's atmosphere is a radiation shield equivalent to being protected behind a layer of water 10 metres thick. This reduces the cosmic background radiation by a factor of 100 of what it would be without the earth's atmosphere. Away from the largely uninhabited poles, the Earth's magnetic field also protects us against charged cosmic radiations, which are deflected and end up spiralling around the magnetic field at high altitude, in the Van Allen trapped radiation belts. ***On the Moon, for example, there is no atmosphere or significant magnetic field so the natural background radiation exposure rate at solar minimum is 1 milliRoentgen per hour (about 10 microSieverts/hour) some 100 times that on the Earth (0.010 milliRoentgen per hour or about 0.10 microSieverts/hour). The Apollo astronauts visiting the Moon wore dosimeters and they received an average of 275 milliRoentgens (about 2.75 milliSieverts) of radiation (well over a year's exposure to natural background at sea level) in over just 19.5 days.*** It is a lot more than that during a solar flare, which is one of the concerns for astronauts to avoid (micrometeorites are another concern in a soft spacesuit).

The higher up you are above sea level, the less of the atmosphere there is between you and space, so the less shielding you have to protect you from the intense cosmic space radiations (emitted by thermonuclear reactors we call 'stars', as well as distant supernovae explosions). At sea level, the air above you constitutes a radiation shield of 10 tons per square metre or the equivalent of having

a 10 metres thick water shield between you and outer space. As you go up a mountain or up in an aircraft, the amount of atmosphere between you and space decreases, thus radiation levels increase with altitude because there is less shielding. **The normal background radiation exposure rate shoots up by a factor of 20, from 0.010 to 0.20 milliRoentgens per hour, when any airplane ascends from sea level to 36,000 feet cruising altitude.** (The now obsolete British Concorde supersonic transport used to maintain radiation-monitoring equipment so that it could drop to lower-altitude flight routes if excessive cosmic radiation due to solar storms were detected.) Flight aircrew get more radiation exposure than many nuclear industry workers at nuclear power plants. Residents of the high altitude city of Denver get 100 milliRoentgens (about 1 milliSievert) more annual exposure than a resident of Washington, D.C., but the mainstream anti-radiation cranks don't campaign for the city to be shut to save kids radiation exposure, for mountain climbing to be banned, etc.!

1994 revised Introduction to Kearny's Nuclear War Survival Skills, by Dr Edward Teller, January 14, 1994:

'If defense is neglected these weapons of attack become effective. They become available and desirable in the eyes of an imperialist dictator, even if his means are limited. Weapons of mass destruction could become equalizers between nations big and small, highly developed and primitive, if defense is neglected. If defense is developed and if it is made available for general prevention of war, weapons of aggression will become less desirable. Thus defense makes war itself less probable. ... One psychological defense mechanism against danger is to forget about it. This attitude is as common as it is disastrous. It may turn a limited danger into a fatal difficulty.'

Before 9/11, Weinberger was quizzed by skeptical critics on BBC News Talking Point on Friday, 4 May, 2001, **Caspar Weinberger quizzed on new US Star Wars ABM plans:**

'The [ABM] treaty was in 1972 ... The theory ... supporting the ABM treaty ... that it will prevent an arms race ... is perfect nonsense because we have had an arms race all the time we have had the ABM treaty, and we have seen the greatest increase in proliferation of nuclear weapons that we have ever had. We are up to 7,000 plus, the Russians are up to 6,900 plus. On intercontinental missiles the Russians have 23,000 nuclear warheads. So the ABM treaty preventing an arms race is total nonsense. ... I don't know how any networking is going to prevent North Korea from doing everything it can to get more nuclear weapons than they have now particularly when China and Russia are perfectly willing to sell them all of the technology required. Intelligence sources aren't going to prevent a country from doing it.

'You have to understand that without any defences whatever you are very vulnerable. It is like saying we don't like chemical warfare - we don't like gas attacks - so we are going to give up and promise not to have any defences ever against them and that of course would mean then we are perfectly safe. ...

'The Patriot was not a failure in the Gulf War - the Patriot was one of the things which defeated the Scud and in effect helped us win the Gulf War. One of two of the shots went astray but that is true of every weapon system that has ever been invented. ...

'The fact that a missile defence system wouldn't necessarily block a suitcase bomb is certainly not an argument for not proceeding with a missile defence when a missile that hits can wipe out hundreds of thousands of lives in a second. ...

'The curious thing about it is that missile defence is not an offensive weapon system - missile

defence cannot kill anybody. Missile defence can help preserve and protect your people and our allies, and the idea that you are somehow endangering people by having a defence strikes me almost as absurd as saying you endanger people by having a gas mask in a gas attack. ...

'My worry is when we have Russia and China being the most vociferous opponents of the plan to abandon the ABM treaty and go to a defensive system. Why are they so vociferous about their hatred of the idea of having a defensive system?

The answer, I am afraid is rather clear - it is because they have offensive plans that they think would be thwarted by a defensive system and so they are doing everything they can to try to block it. ...

***'Tensions are on the rise because very aggressive powers know that the one system that will never be defended against if we follow the ABM treaty ... are these nuclear and chemical warhead carrying missiles. Now if you tell an aggressive nation that is the one system weapons that is never going to be defending against - what are they going to do? They are going to make every effort to get that kind of system of weapons. That is what is happening and that is why there is an increased tension. The greatest force for proliferation is the ABM treaty.'***

'So that is why it seems to me that it is vital that we get rid of the ABM treaty concept as soon as possible and proceed with the construction of an effective defence to protect ourselves and our allies. ...

'President Bush said that we were going ahead with the defensive system but we would make sure that nobody felt we had offensive intentions because we would accompany it by a unilateral reduction of our nuclear arsenal. It seems to me to be a rather clear statement that proceeding with the missile defence system would mean fewer arms of this kind.

'You have had your arms race all the time ABM treaty was in effect and now you have an enormous accumulation and increase of nuclear weapons and that was your arms race promoted by the ABM treaty. Now if you abolish the ABM treaty you are not going to get another arms race - *you have got the arms already there* - and if you accompany the missile defence construction with the unilateral reduction of our own nuclear arsenal then it seems to me you are finally getting some kind of inducement to reduce these weapons.'

'The expression of dissenting views may not seem like much of a threat to a powerful organization, yet sometimes it triggers an amazingly hostile response. The reason is that a single dissenter can puncture an illusion of unanimity. ...

'Suppression of intellectual dissent can inflict large costs on society. Among those suppressed have been the engineers who tried to point out problems with the Challenger space shuttle that caused it to blow up. More fundamentally, suppression is a denial of the open dialogue and debate that are the foundation of a free society. Even worse than the silencing of dissidents is the chilling effect such practices have on others. For every individual who speaks out, numerous others decide to play it safe and keep quiet. More serious than external censorship is the problem of self-censorship.'

— Professor Brian Martin, University of Wollongong, 'Stamping Out Dissent', Newsweek, 26 April 1993, pp. 49-50

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