The foundations of thermally based RF standard setting

Taken from PhD dissertation, The Procrustean Approach: Setting Exposure Standards for Telecommunications Frequency Electromagnetic Radiation

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Introduction

Since the 1950s there has been an ongoing controversy regarding the possibility of unintended health hazards from exposure to non-ionizing radiation emissions from radiofrequency and microwave (RF/MW - hereafter referred to as RF) technology, from military radar to telecommunications. In response to these concerns, recommended human exposure limits (or guidelines) have been developed by the Institute of Electrical and Electronics Engineers (IEEE) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) which is promoted by the World Health Organization's International EMF Project (IEMFP). These limits, although differing in detail, are founded on the same literature base and deem that the primary hazard to be considered in setting human RF exposure limits is thermal. This is defined as an immediate, excessive and harmful rise in body temperature as a consequence of exposure to high-level RF/MW emissions. Possible hazards from long-term environmental level (low intensity) RF exposures at power levels that do not cause obvious tissue heating have been deemed by these organizations as being not established and therefore outside the scope of standard setting. In fact the thermal limitations were declared by the IEEE's standards setting body, the International Committee on Electromagnetic Safety (ICES) in 2003 in a series of papers published in *Bioelectromagnetics Supplement 6.* These papers were to serve "as a scientific basis for the IEEE C95.1 standard revision" and to be a "valuable reference on the subject for many years to come". ICES claims that these papers establish a number of "guiding principles" to be used in RF standard setting hereafter. These so called principles state that only established adverse effects [thermal] can be used as a basis for setting maximum exposure limits. In addition they claim that nonthermal effects are not established and that none of the reported nonthermal effects are proven adverse to health.[1]

In like manner, ICNIRP chairman Paolo Vecchia stated at a November 2009 ICNIRP Workshop in Salzburg Austria that "long term effects cannot form the basis of ICNIRP's Guidance".[2] Vecchia's statement is of concern as one of the primary goals of the ICNIRP workshop was to "develop a shared vision among agencies on the approach to evaluating scientific evidence for health risks from NIR[3] exposure Guidance" [4] Taken together, IEEE and ICNIRP statements plainly illustrate a significant limitation in their ability to conduct an adequate risk assessment on human health hazards from RF exposures when it comes to evaluating long-term, low-intensity (non-thermal or athermal) data. This is not a

[1] C-K. Chou, J. D'Andrea, 'Reviews of the Effects of RF Fields on Various Aspects of Human Health: Introduction', *Bioelectromagnetics, Supplement 6*, 2003, pp. S5-S6

[2] Vecchia, P., "The ICNIRP perspective of NIR health risks: facts, uncertainties, public perception and need for action", ICNIRP workshop: "Evaluation and Communication of Scientific Evidence and Uncertainty - Towards a Consistent Terminology in Non-Ionizing Radiation" Salzburg, Austria, Nov. 23-24, 2009.

[3] Non Ionizing Radiation. This term encompasses both Extremely Low Frequency (ELF) and RF/WM exposures.

[4] http://www.icnirp.de/RiskAssessment/RiskAssessment.htm, Accessed Nov. 29, 2009.

recent controversy. Aleksandr Presman from the Department of Biophysics, Moscow University and author of the seminal work, *Electromagnetic Fields and Life* (1970) wrote of the large volume of Soviet research that found RF biological effects occurring in many life-forms at exposure intensities far below those which could cause thermal harm. It was mentioned that much of this data did not fit the strict restrictions of the heat theory being developed by Western standard setters.[5]

In the early 1980's research policy analyst Dr. Nicholas Steneck in the U.S. wrote of the many restrictions being placed on U.S. RF bioeffects research by vested interests. According to Steneck:

> The overwhelming [scientific] community commitment to thermal thinking severely limited the creativity of RF bioeffects research. Rather than attempting to learn from reports of athermal effects, the RF bioeffects community by and large devoted most of its attention to clarifying and proving what it already knew or to disproving claims believed to be false. This approach to research encouraged a single-mindedness that rigidly adhered to the thermal solution, a single-mindedness that can be seen in responses formulated when athermal effects were reported.[6]

Unfortunatlly, as mentioned previously, this rigid approach still prevails in both the IEEE and ICNIRP a quarter century after Steneck made his observations with many nations unquestionably accepting their version of science for their national RF standards.

As a sizeable amount of scientific data continues to accumulate that does not conform to the thermal restrictions, some of which is reviewed in the BioInitiative Report[7], it was inevitable that thermally restricted RF standards would come under increasing pressure to change and open up the standard setting process to include biologically relevant research data in order to better protect human health against low-intensity, long-term exposures.

For example, on September 2, 2008 the European Parliament overwhelmingly voted to recommend tighter safety standards for cell phones based on growing evidence of a link between brain tumours and cell phone use.[8] In making its recommendations the EU noted that "the limits on exposure to electromagnetic fields [0Hz to 30 GHz] which have been set for the general public are obsolete" and that the existing standards "do not address the issue of vulnerable groups, such as pregnant women, newborn babies and children". The EU parliament then called upon the EU Council to amend its exposure limit recommendations "in order to take into account the Member States' best practices and thus to set stricter exposure limits for all equipment which emits electromagnetic waves in the frequencies between 0.1 MHz and 300 GHz".[9]

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[5] V. Presman, *Electromagnetic Fields and Life*, Plenum Press, New York-London, 1970.See Foreword by V. Parin.

[6] N. Steneck, *The Microwave Debate*, MIT Press, 1984.

[7] BioInitiative Working Group, C. Sage, D. Carpenter., Eds. *'Bioinitiative Report, A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)*, Aug. 31, 2007,, http://www.bioinitiative.org/index.htm, Accessed Nov. 29, 2009.

[8] Institute for Health and the Environment-SUNY at Albany, "European Parliament Recommends Stricter Safety Limits for Cell Phones, http://www.marketwire.com/press-release/The-Bioinitiative-Working-Group-901580.html, Accessed Nov. 20, 2009.

[9] Mid-Term Review of the European Environment and Health Action Plan 2004-2010, Sept. 4, 2008, http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P6-TA-2008-0410+0+DOC+XML+V0//EN, Accessed Nov. 20, 2009.

In order to better understand why we have come to this juncture in RF standard setting it is helpful to briefly look at history so hopefully we won't be condemned to just go on repeating old misconceptions. In a world of ever-increasing RF exposures where the potential human costs of continuing those misconceptions are enormous, especially for our children, do we dare get it wrong?

The early days

[Note: Part of the following is drawn from the seminal work of Nicholas Steneck, *The Microwave Debate*, 1984]

By the end of the 19th Century the many incremental discoveries and advances in wireless telegraphy (in 1896 referred to as telecommunications) heralded in the birth of the modern electronic age. Along with the revolutionary inventions by Edison, Marconi and Tesla, just to name a few of the many pioneers, came a large number of entrepreneurs wanting to capitalise on of the new technological revolution. Their contributions to the field consisted of an amazing array of electro-therapeutic devices that it was claimed could cure practically every disease known to man. By 1894 it was estimated that over 10,000 medical practitioners in the U.S. were regularly using some form of electro-therapeutic device to treat their patients and by 1900 most doctors in the United States had at least one electrical therapy device in their office, all totally unregulated and with no scientific validity as to their effectiveness. None of these devices at that time utilised high frequency microwaves but their widespread use, coupled with extravagant advertising in popular publications of the day, brought calls for the need for standards to control the use and marketing of these devices. This resulted in the passage of the Federal Pure Food and Drugs Act of 1906 and the publication of the Flexner Report in 1910 that established science as the basis for medicine and clinical education. Electrotherapy was declared scientifically unsupportable and was legally barred from clinical practice[10]. Although the Flexner Report eliminated a wide range of very dubious therapeutic devices, the acceptance of using radiofrequency as a therapeutic medium soon was on the ascendancy with the rapid development of radio technology that took off in the early 1920s. This era saw an amazing proliferation of businesses established to manufacture radio sets, and in many cases starting up their own transmitting stations as well. Companies sprang up in many countries, manufacturing radio components and marketing them nationally and globally through new trade magazines and catalogues.[11] It was seen as a wondrous technology and following on from the earlier electrotherapy craze, a new breed of entrepreneurs soon found new therapeutic applications for the technology in name of diathermy. By the 1930's diathermy, using radiowaves to heat tissue as a therapy, was widely accepted as a beneficial new use of RF technology by the medical fraternity and it was used to treat everything from backaches and muscle pain to cancer.

There were warnings, however, as early as 1928 when Helen Hosmer from the Albany Medical College warned General Electric (GE) that their employees should use "extreme care" when working on radiowave apparatus due to the risk of extreme heating. In 1930 GE commissioned additional research at the Albany Medical College which consisted of

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[10] B.H. Lipton, Electroanalgesia: Historical and Contemporary Developments, Section 3.2.11, *Electroanalgesia in the 20th Century United States*, DeMontfort University press, 1998, http://www.drgordongadsby.talktalk.net/page11.htm, Accessed Nov 18, 2009.

[11] T. White, United States Early Radio History, http://earlyradiohistory.us , Accessed April 7, 2006

exposing patients to RF heating. Some of the subjects complained of headaches, nausea, and/or dropping of blood pressure during exposure. As these symptoms were also reported during illnesses that cause fever, the GE researchers were not overly concerned. They reported that the patients did "not appear to be greatly distressed or fatigued when the maximum temperature is maintained for one hour and then allowed to return to normal while the patient is well blanketed." The researchers concluded that using the technology was safe provided caution was taken in its application.[12] The heating ability of RF fitted in well with the view amongst many physicians at the time that artificially produced fevers could help cure diseases, fevers being associated with the body's natural curing mechanism. By 1930 research on the therapeutic use of radiowave-induced fevers was widespread in the U.S. and other countries. The next decade saw international conferences on the topic and hundreds of articles were published extolling the beneficial uses of diathermy heating. Diathermy had become big business with a widespread viewpoint by the medical fraternity that the only bioeffect of radiofrequency exposure was a simple heating effect. The possibility of bioeffects not related to heating were considered unlikely even though no research had been done investigating this possibility and as diathermy treatments were brief there was no apparent need to investigate the possible effects of chronic (long-term) exposures. In 1935 the American Medical Association's Council on Physical Therapy (CPT) ruled that all bio-effects from diathermy RF exposure, regardless of frequency used, were simply a heating effect. The AMA, took the position that unless indisputable scientific evidence were found to the contrary the only bio-effect of RF exposure was heating.

By the late 1940s, however, enough evidence had accumulated to indicate that diathermy, and in particular the short wave (microwave) frequencies being increasingly used, could selectively elevate internal body temperatures without the patients feeling the increase due to the pain receptors being located in the skin (thus the possibility of internal damage with no warning until after the event). In addition there was evidence from animal studies that areas with insufficient blood flow to remove excess heat, such as the eyes and testicles, could be damaged. As cataracts took some time to form after exposure, this meant that delayed bio-effects existed. As far as the supposed exposure thresholds for thermal damage, researchers from the University of Iowa found that testicular damage to rats occurred at power levels below these thresholds, causing the researchers to suggest that "damages may result in part from factors other than heat". These concerns, and the obvious implications over the possibility of litigation against physicians who used diathermy machines, led to the abandonment of medical diathermy by the mid 1950s.[13] However the legacy of the previous widespread medical use of diathermy was a general medical opinion that any hazards of RF exposure were solely from excessive heating of human tissue and any other possible effects not related to heating (non-thermal) were considered unlikely.

Early research focuses on heating

It was well known that uncontrolled heating outside the doctor's surgery, such as occupational heat stress, from whatever source (such as the sun), could have serious consequences, such as fatigue, increased pulse rate and heat stroke. For this reason the U.S. Navy's Bureau of Medicine and Surgery in July 1930 started an investigation of

[12] N. Steneck, *The Microwave Debate*, MIT Press, 1984, p. 27.
[13] Steneck, pp. 78-79.

possible heat based health hazards posed by powerful new 80 MHz radio transmitters being used. Personnel who were working in the vicinity of these transmitters reported symptoms that clearly indicated body heating was taking place such as an unpleasant warmth and sweating of the feet and legs, general body warmth and sweating, drowsiness, headaches, pains about the ankles, wrists, and elbows, weakness, and vertigo. What the Navy needed to know was the severity of the symptoms and if they could lead to permanent damage. The study consisted of six volunteers who were required to stand near an active transmitter until it became unbearable. The tests found that the volunteer's body temperature did increase a few degrees and that there were drops in blood pressure, however all symptoms disappeared when the transmitter was turned off with no apparent lasting ill health effects. Subsequent tests on the subjects did find that symptoms came on faster and recovery was slower, indicating a possible cumulative effect from repeated exposure, but this was simply dismissed as all subjects returned to apparent normal after the tests. Possible long-term effects were not a factor in the tests. As for possible dangers to human health posed by the new transmitters, the conclusion of the Navy investigators was that, as long a proper precautions were undertaken, "from a practical point of view there are none". Precautions would be to keep exposure to a minimum, use protective screening wherever possible, and keep workrooms well ventilated. The Navy's results seemed to confirm that the effects felt by the test subjects were similar to those felt by workers in high-temperature environments. By the mid 1930s a clear consensus began to emerge that the dangers from RF radiation were from heat induced stress, which was not an unreasonable trade-off, given the significant benefits of the technology and that thermal effects were considered tolerable and reversible if kept within reasonable levels, the control of which was considered easily manageable.[14]

In 1942, a year long U.S. Navy test on 45 personnel who worked with radar including blood tests, physical exams and case histories, reported finding no evidence of significant effects. Some radar operators reported headaches, warming of the extremities and a flushed feeling. As these did not persist after exposure it was considered just a transitory thermal effect with no need for concern, especially as the average power of the units was about the same as some diathermy machines. A similar study by the Aero Medical Laboratory in Boca Raton, Florida in 1945 of 124 servicemen reached essentially the same conclusion. The investigators also made a comparison with maximum radar power levels being in the order of that used in diathermal therapy.[15]

In 1947 the Mayo Clinic in Rochester, Minnesota was able to access a new short-wave microwave generator from the military and their studies confirmed that the higher microwave frequencies provided an effective tool for inducing heating. They could be more easily focused than the older radiowave diathermy units and were more easily absorbed by the body. The microwaves could be readily directed to specific parts of the body. They announced that "Heating by microwaves offered the promise of considerable usefulness in the practice of physical medicine."[16] The important issue now became one of studying just how the body disposed of excess heat and what microwave levels could be tolerated in various parts of the body without causing adverse effects from heating. It was known that the blood circulatory system was the principle mechanism to remove

[14] Steneck, pp. 27-29.
[15] Steneck, pp. 29-30.
[16] Steneck, p.31.

excess heat from the core of the body to the surface, where sweating and evaporation then remove the heat. Two areas of the body, the eyes and testes, however, do not have efficient cooling systems and research had found in the 1940s that infrared, ultraviolet and ionizing electromagnetic radiation could produce cataracts. Therefore the question was could microwaves also produce the same bio-effect in these parts of the body?

Research at Northwestern University Medical School in 1947 that focused microwaves directly on the eyes of dogs reported no adverse effects. The researchers said that if the same held true for humans then "this method should be a safe and excellent means for the application of localised heat to the eye." A research team from the State University of Iowa exposed rabbits to either one brief high power exposure or several low power exposures to microwave and found significant effects. The rabbits given one brief/high power exposure began to develop cataracts three days later. The rabbits given several low-power exposures developed cataracts as long as 42 days later. The researchers wrote that their findings should not in any way discourage the use of microwaves for diathermy but did note "that precautionary measures may be of value to workers and patients frequently exposed to the radiations of microwave generators." When the researchers turned their efforts to the testes they also found evidence of tissue damage and they again issued precautionary advice: "precautions should be taken by those working in the field of high energy electromagnetic generators and by those giving treatments with microwave generators." [17]

The research up to the 1950's focused on using brief exposures to high (acute) RF levels in animal studies in order to better understand the thermo-regulatory mechanisms in the body (how the body handled RF induced heating). Low intensity human volunteer studies (using exposure levels that did not cause an obvious heating effect) were not conducted and the emphasis on high level thermal effects was to set the pattern for all future research that formed the foundations of both IEEE C95.1 and ICNIRP's RF guidelines.

Post WW II to the Cold War

During WWII radar and other RF/MW emitting equipment had power outputs that were roughly equivalent to the power outputs of diathermy equipment, typically in the tens to hundreds of watts. A direct comparison to diathermy devices was therefore possible – and since diathermy was thought to be beneficial, the hazards therefore were considered minimal, provided precautions were undertaken. By the 50s, however, new radar systems had outputs in the millions of watts and within the decade their power outputs had increased a thousand-fold more. At these power levels comparisons to diathermy were no longer relevant and by the early 1950s evidence started coming out that there may be adverse health consequences for those working with the new systems.

In October 1951 a microwave technician employed by the Sandia Corporation visited the company's medical director, Dr. Frederic Hirsch, complaining of blurred vision, which Hirsch diagnosed as bilateral cataracts and acute inflammation of the retina. Subsequent investigations by Dr. Hirsch found that the technician routinely exposed his head to the antenna radiations when checking to see if it was generating properly. Hirsch estimated the power level to be about 100 mW/cm2. In his report Hirsch recommended that the

[17] Steneck, pp. 32-33

case was useful "as a means of recalling the attention of ophthalmologists, industrial physicians, and microwave operators to the potentialities of microwave radiations in order that the use of this form of energy will be accompanied by appropriate respect and precautions".[18]

In 1952 an investigation by Dr. John McLaughlin at Hughes Aircraft found numerous cases of internal bleeding in Hughes workers, as well as possible cataract formation amongst employees working with radar. Further investigation by McLaughin of both civilian and Air Force personnel working with radar uncovered two reports of leukaemia amongst a group of 600 radar workers and reports of jaundice and headaches in personnel working with microwave equipment. McLaughlin also conducted a literature search that indicated thermal effects may not be the only mechanism causing bio effects and wrote up a report to Hughes that was made public in February 1953. McLaughlin's report clearly stated his case that hazards may exist with exposure to microwaves. It was this report that caused Hughes Aircraft to ask its military clients for research to verify, or not, McLaughlin's findings. Within two months two major military sponsored conferences were convened and a full-scale effort to study the microwave effects issue was created.[19] Even at that early stage a list of potential problems that were to prove to be endemic to the RF standard setting process were raised at the 1953 Navy conference at the Bethesda Naval Hospital. The list is as follows:

- Extrapolation from animal exposure studies to the human body was difficult.
- Research findings interpreted by one researcher as evidence of effects can be interpreted by another as evidence of no effects. This subjective interpretation would therefore affect the standard setting process
- How can an objective interpretation of the data be done by an expert body when that body is of necessity made up of people from the same sector?
- Exposure data collected under field conditions were difficult to control and were usually not replicable.
- There were no outside observers to staff a neutral board with the necessary technical understanding to conduct an objective review, therefore both researcher and reviewed may represent the same school of thought.
- Once a standard is set, some exposed people would then be able to take legal action for perceived harm from previous exposures over that limit. This sets up an incentive for not reducing exposure levels below previously accepted levels.
- There is the problem of basic philosophies on who is to be protected, from what and to what extent.
- Also discussed at the Bethesda conference were other issues, such as funding constraints, peer group pressure and implications of experimental results all having an impact on the course of science progress.[20]

If these points were followed through in the subsequent Tri-Service Program the progress of standard setting may have been far different that what eventuated. As it turned out, however, these concerns were largely ignored in subsequent standard work.

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[18] P. Brodeur, *The Zapping of America*, W.W. Norton & Co., 1977, p. 26.
[19] Steneck, op. cit., p. 34.
[20] Steneck, p. 46.

As a direct result of the 1953 McLaughlin report the Air Force's Air Research and Development Command directed the Cambridge Research Centre to investigate the biological aspects of microwaves with the aim to determine tolerance levels for both single and repeated exposures.[21] Once tolerance dosages were worked out with experimentation then appropriate exposure standards could be set. As time was to tell however, setting "appropriate" standards would prove not to be that straightforward. The navy also commenced investigations to establish the amount of RF induced heating energy that the human body could absorb and eliminate through normal body functions. Using only calculations an exposure level was initially set at 100mW/cm2. Biophysicist Herman Schwan, working at the University of Pennsylvania, and employee of the Navy from 1947 to 1951, disagreed with that level. Schwan's re-calculations showed that the 100mW/cm2 level was more than twenty times greater than what the body could dissipate. Schwan then recommended a 10mW/cm2 level, based on his thermal model to limit temperature rise.[22] Schwan's 10 mW/cm2 calculated value was supported by experimental data showing that the threshold for eye cataracts was greater than 100mW/cm2, therefore giving a 10 fold factor of safety against a biological effect of considerable interest at that time.[23] By 1960 all three branches of the U.S. military, as well as their industrial contractors, had concluded that the 10 mW/cm2 level was a safe level of exposure to prevent excessive tissue heating. This later became the basis for the first ANSI C 95.1 microwave standard in 1966, which Schwan was instrumental in drafting as chairman of the C95.1 committee.

Schwan's thermal model was based on his assumption that:

> [C]ell membranes are not likely to be affected directly by microwaves since fields of interest can only apply potentials across the membranes that are vanishingly small in comparison with potentials needed to yield significant membrane responses, and significant responses of biopolymers require field strength levels very much higher than those causing undue heating.[24]

This hypothesis, a valid assumption for the early 1950s, went on to become the only accepted mechanism for RF bio-effects in the U.S. and Western standards without ever being critically re-evaluated in light of subsequent research. It was a bio-effect that was readily observable in animal research. Alternative theories proposed later by Adey, Blackman, Frey and others that proposed other bio-effects that were not related to heating were largely ignored by the standard setting bodies[25]. This avoidance was apparently because these alternative theories undermined Schwan's 10 mW/cm2 thermal hypothesis and therefore threatened the very foundations of the U.S. military/industrial RF standard's risk assessment. To retreat from the 10mW/cm2 basis for standard setting and set a lower level to take into account other mechanisms would threaten the very

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[21] Steneck, p. 45.
[22] Steneck, pp. 49-50.
[23] J.M. Osepchuk, R.C. Petersen, 'Historical Review of RF Exposure Standards and the International Committee on Electromagnetic Safety (ICES)', *Bioelectromagnetics Supplement* 6, 2003, pp. S7-S16.
[24] H.P. Schwan, 'Physical properties of biological matter: some history, principles and applications', *Bioelectromagnetics*, vol. 3 no.1, 1982.
[25] For a review of the scientific literature on non-thermal RF biological effects and possible mechanisms of interaction see the BioInitiative Working Group, op.cit.

basis for the military's assurances of safety for civilian contractors developing the technology, personnel working with the equipment and other people exposed to radar emissions.

Conflicts of interest endemic

The problem right from the beginning was that the only organisation that had the resources, interest and authority to investigate the dangers from what was at the time primarily military equipment was the military itself. The medical community would have seemed a good candidate but there were concerns raised that many medical professionals were heavily committed, and were firm believers in the therapeutic uses of microwaves by diathermy machines. Thus a conflict of interest would have been inevitable if they were also charged with conducting research that may result in finding that diathermy level microwaves were a possible health hazard. Thus in the 1950s the emerging health effects issue was seen as a military problem, radar being primarily a military technology. An obvious conflict of interest with the military developing radar systems for national defense and evaluating the possible hazards of radar technology apparently went unchallenged. This conflict of interest was to prove to be a significant factor in subsequent RF standards development both in the U.S. and internationally. The issue of corporate conflict of interest with RF standard setting was also a problem right from the start of the research effort. As far back as 1953, Hughes Aircraft researcher John McLaughlin wrote of his concerns in a memo attached to his report, mentioned previously. McLaughlin claimed that the Raytheon corporation, a major manufacturer of diathermy equipment (and military contractor), was upset by the adverse publicity caused by the publication of reports of microwave cataracts and was putting pressure on the Navy to discontinue funding the research that had led to the reports.[26]

There was a conflict of interest within the military as well. On one hand the operational branches had as their mission an urgency to get new microwave radar equipment deployed in the field as an essential part of improving their defensive capabilities during the the Cold War with the Soviet Union. On the other hand, the services research branches' mission was concerned with the possible health hazard issue and basic research questions. When the first RF exposure guidelines were devised in the late 1950's the operational branches were not in favour of any restrictions that they perceived might be detrimental to their basic mission to provide an adequate defense for the nation.[27]

The Tri-Service Research Program

As an outcome of the two military conferences in 1953, by 1957 the military's newly created *Tri-Service Research Program* (1957-1960) was ready to start its stated mission to clear up any unknowns about microwave exposure and discover the basic mechanisms of microwave-tissue interactions. It was hoped that this would then lead to setting exposure standards to protect civilian and service personnel working on RF/MW generating equipment. The Air Force, however, not willing to wait for the program to come up with guidance, adopted its own 10mW/cm2 in-house exposure standard for RF/MW, based solely on Schwan's thermal calculations, one month before the program started in June

[26] Steneck, op cit, p. 35.
[27] Steneck, pp. 36-37.

1957.[28] As for the goals of the Tri-Service Program, a high ranking Air Force officer testified at a Senate hearing that the objectives were "to acquire through laboratory experimentation, a basis for validating protective criteria to insure a safe radiation environment for personnel at the least possible cost to military operations."[29] His testimony indicated that the Air Force saw the Tri-Service Program not as an open inquiry to investigate all possible mechanisms for RF/MW bio-effects, but simply to validate the Air Force's thermally based "protective criteria" which would not hinder technological development.

From its inception the over riding research effort in the Tri-Services program was to first find the mechanism of interaction. There was a level of intellectual bias here as any of the medical doctors who assisted in the effort firmly believed, because of diathermy, that the only possible adverse bio-effect from RF exposures was excessive thermal increases. Thermal considerations therefore easily became the main focus to the exclusion of any other possible bio-effect. This viewpoint was also shared by most of the biologists and engineers involved in the Tri-Service program and as a result the emphasis of the studies conducted for the program focused on examining in detail just what happens to biological systems with RF radiation exposures in the 10mW/cm2 to 100mW/cm2 range. Rats, rabbits, dogs and monkeys were the animals used in the exposure studies, with power densities in the 10 to 100 mW/cm2 range aimed at producing thermal effects. Power density levels in this range seemed to fall in a tolerable range that did not overwhelm the body's normal cooling system.[30]

One of the principal investigators, veterinarian Sol Michaelson from Rochester University, started out by testing animals to known high-level thermal doses of RF energy (165 mW/cm2) to establish the features of thermally caused bio-effects. Other experiments were designed to determine how the excess heat affected the animals' bodies. Unexpectedly, some of Michaelson's research indicated that high-level, short-term exposures produced effects could be duplicated by lower-level, longer-term exposures, - suggesting that duration of exposure may be a factor to consider. The Tri-Service Program concluded however, that the bio-effects of RF energy were only short term and reversible in nature and that the body's natural cooling system could, up to a point, protect it from the potential dangers of RF exposure. Therefore the task was to find the maximum level exposure that the natural defence against excess heat stress provided protection.[31]

Experiments to test the validity of the thermal-only viewpoint by conducting exposure studies below the presumed thermal level to see if any bio-effects still occurred were not done. As state previously, the emphasis with the Tri-Services studies was to clarify the thermal threshold for effects and not to look for other possible interactions that would only bring into question the Air Force's "protective criteria". As the Tri-Service Program progressed, those concerns expressed at the 1953 Bethesda conference on the necessity of independent review boards, objective interpretations and exploring conflicting points of view, etc., eventually disappeared.

As Nicholas Steneck pointed out in *The Microwave Debate*:

[28] Steneck, op. cit., p. 50.
[29] Brodeur, op. cit., p. 32.
[30] Steneck, op. cit., pp. 37-39.
[31] Steneck, p. 42.

> Conflicting points of view were passed over, scientific ambiguity was ignored, and contrasting philosophies left unexplored as a single-minded approach gradually crept in and came to dominate all decisions.[32]

This single-minded approach saw the Tri-Services program gradually come under the control of just one man, Colonel George Knauf, a military surgeon with experience on the latest high-powered radar systems. Knauf was initially placed in charge of the Tri-Service Program's effort at Rome Air Force Base in Rome, New York. Gradually, however, his interest in the program and enthusiastic statements about its progress led to him being assigned to head the entire program, essentially having the final say in issues of scientific interpretation and application. The emphasis on validating the Air Force's "protective criteria" was apparent in the 1957 statement by Knauf at a Tri-Services conference that "I think this might be a good time to say that up to date there has not been any effect produced or even hinted at power levels which remotely approach our established maximum safe exposure level." At the concluding Tri Services conference in 1961 Knauf enthusiastically said that: "I am indeed pleased to say that up to today we have not seen any research data which shakes our faith in the validity of this arbitrary safe exposure level, which we sponsored some five years ago."[33] Knauf's conclusions were not questioned by the military at all, as it gave closure to the earlier concerns raised by Laughlin at Hughes and others – all was well as long as the 10 mW/cm2 standard was not exceeded. The symptoms reported in the investigations on humans exposed to microwaves in the course of their work was considered as transitory, as symptoms appeared to disappear after exposure ceased. Knauf considered that only immediate permanent damage as a result of excessive heating as a significant biological effect. Minimal overheating was accepted because the body had the ability to cool itself. Testicular damage that could occur around the 10 mW/cm2 level was ignored and cataract damage was considered to occur only above the 100mW/cm2 level.[34]

Colonel Knauf's 'quick-fix' to the problem was what the military urgently needed considering the political climate that existed at that time. On October 4, 1957, the Soviet Union successfully launched Sputnik I, the world's first artificial satellite and then followed by another, the successful launch of Sputnik II on November 3rd 1957, carrying Laika, a dog, into orbit.[35] In comparison America's efforts were plagued with a series of failures and it was not until January 31 that they were able to successfully launch Explorer I, America's first satellite.[36] As acknowledged by NASA, the Soviet Sputnik achievements ushered in new political, military, technological, and scientific developments and marked the start of the space age and the American/Soviet space race [37]. What was also important about the Soviet space achievements was that it caused concern in the U.S. that the Soviet's proven ability to launch satellites meant that the Soviets now had the capacity

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[32] Steneck, p. 48.
[33] Steneck, p. 50.
[34] Steneck, p. 53.
[35] NASA,'Sputnik and the dawn of the Space Age', Oct. 10, 2007, http://history.nasa.gov/sputnik/index.html, Accessed Apr. 28, 2006.
[36] C.M. Green, M. Lomask, 'Vanguard – A History', NASA Historical Reference Collection, NASA History Office, NASA Headquarters, Washington, DC., 1970, Chap 12: 'Success – and After' http://history.nasa.gov/SP-4202/chap12.html, Accessed Apr. 28, 2006.
[37] NASA, 2007.

to launch ballistic missiles capable of reaching American cities. American military concerns at that time were that Soviet ballistic missiles were being developed, not to launch satellites, but as the best means for destroying the U.S. [38]

An obvious influence to decisions made during the running of the Tri-Services program and the acceptance of the Air Force's "protective criteria" was the creation of the Defense Advanced Research Projects Agency (DARPA) in 1958 as a response to the Soviet Union's launching of Sputnik. DARPA reported directly to the Secretary of Defense and was given a mission to assure that the U.S. maintained "a lead in applying state-of-the-art technology for military capabilities and to prevent technological surprise from her adversaries".[39] As a primary state-of-the-art technology being developed at the time was high-power early warning radar, discussions of possible adverse effects below the Air force's "protective criteria" would have been viewed with concern and as a threat to national defence (radar development) if allowed to continue. This was an era when a fear of the extent of the Soviet threat to America's very survival was paramount. Senator Joseph Mccarthy was making accusations that the U.S. Army and State Department had been infiltrated by Soviet agents. A communist army had taken over China and thousands of American soldiers had been killed fighting communist forces in Korea. There was an attempted communist takeover in Greece, and strong communist political movements in Italy and France. According to Stephen Kizner, author and veteran New York Times correspondent, during the 1950s the political leadership in the U.S. was "gripped by a fear of encirclement, a terrible sense that it was losing the postwar battle of ideologies".[40] There was, therefore, an urgency to develop and deploy globally new improved radar systems to detect any Soviet missiles launched over the Arctic Circle. Any consideration of non-thermal bio-effects from radar was seen as having the potential to adversely impact on systems development and deployment. This was stated by Michaelson when he admitted that if the U.S. adopted stringent RF standards, similar to the Soviets, "the harm that would be done to industry and the military would outweigh any proposed public-health benefit."[41]

By the time the Tri-Service Program was terminated in 1961, the thermal effects only viewpoint, as exemplified by Knauf and Schwan, was well on its way to becoming accepted as the only way that RF microwave exposure interacted with human body. The military's de-facto 10 mW/cm2 "protective criteria" was the favoured standard. The possibility of other biological effects not related to actual heating was clearly rejected in the Tri-Service program and, as more advanced radar was developed evidence for non-thermal effects came to be viewed as a threat to national security[42] and technological development.

Therefore, in consideration of the above, the foundations of the thermal effects only viewpoint in RF standard setting can be said to be based on two factors, ignorance and fear. That is - an ignorance of possible biological interactions other than what they

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[38] ABC TV (Australia), 'Space Race: Race For Satellites', Oct.15, 2006.
[39] DARPA website, http://www.darpa.mil/body/overtheyears.html, Accessed Aug. 26, 2008.

[40] S. Kinzer, *Overthrow: America's Century of Regime Change from Hawaii to Iraq*, Times Books, 2006.
[41] A. Marino, J. Ray, *The Electric Wilderness*, San Francisco Press, p. 16, 1986.
[42] R. Becker, *Cross Currents*, Jeremy P. Tarcher, Inc. Los Angeles, 1990, p. 299.

historically knew and fear of nuclear annihilation if they did not have the best possible defensive technology in place..

In consideration, even though there was an obvious vested interest in maintaining a thermal-effects only viewpoint, it is perhaps understandable that from the limited literature base at the time, combined with the 1950's Cold War fears, establishing RF exposure limits based solely on thermal considerations was the best that they could do.

Maintaining that limitation, however, for another half-century is altogether another matter.

IEEE's thermal paradigm spreads internationally

The foundations of the international effort to address both ionising and non-ionizing radiation protection can be traced back to the American Health Physics Society (HPS), founded in 1956, a year before the establishment of the U.S. Tri-Service Research Program mentioned previously. In the early 1960s an HPS committee was established to explore the need for an international health physics organization and through the work of this committee the International Radiation Protection Association (IRPA) was established in 1964 representing 15 health physics and radiation protection national societies.[43]

In 1971 WHO convened a working group meeting which recommended that the protection of humans from exposure to RF/MW should be a high priority. This led to a meeting of the 3rd International IRPA Congress in 1973 where the first session to address non-ionizing radiation protection was established. This was followed up in 1974 by the formation of a Working Group on non-ionizing radiation and in 1975 by a study group to review the field of non-ionizing radiation. In 1977, at the 4th IRPA International Congress, the International Non-Ionizing Radiation Committee (INIRC) was created and in 1981 a joint WHO/IRPA group issued the first Environmental Health Criteria for Radiofrequency and Microwaves. In 1988 Dr. Michael Repacholi was appointed Chairman of INIRC till 1992 when he became Chairman of INIRC's replacement, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) at the IRPA 7th International Congress[44]. ICNIRP then adopted Repacholi's 1984 IRPA proposal that the only health issue to address in standard setting were short-term effects due to the absorption of RF/MW energy of sufficient power to be converted to heat, based on the IEEE's RF standard philosophy. The frequency range of 10 MHz to 10 Ghz was selected with a basic restriction for whole-body Specific Absorption Rate[45] (SAR) derived from a SAR of 4 W/kg.[46] The ANSI/IEEE C95.1 1982 RF standard was referenced in Repacholi's 1984

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[43] IRPA, Foundation, http://www.irpa.net/index.php?option=com_content&task=blogcategory&id=178&Itemid=113 Accessed Sept. 6, 2008.

[44] ICNIRP, Aim and Roots, 2007, http://www.icnirp.de/aim.htm , Accessed Apr. 2, 2008.

[45] The Specific absorption rate is a time derived compliance measurement expressed in watts per kilogram (W/kg) of the rate of energy absorption (or dissipation) in a volume mass of biological tissue (either 1 or 10 grams). This is essentially a calculation of the heat absorbed by tissue based on mathematical and artificial head models (for mobile phone compliance testing). SAR is the unit used in RF standards/guidelines to designate the threshold limits where adverse biological effects (heating) have been proven to occur when the human body is exposed to an RF field.

[46] R. Repacholi , 'Problems with Regulating Radiofrequency (RF) Radiation Exposure', IRPA 6, May 1984, pp. 1291-1294, http://www.2000.irpa.net/irpa6/cdrom/VOL.3/B3_96.PDF, Accessed Sept. 4, 2008.

proposal later adopted by ICNIRP[47]. In their historical review of the development of Western RF standards, IEEE C95.1 committee members Osepchuk and Petersen (2003) mention that C95.1 became the foundation for most contemporary RF standards (including ICNIRP) and was based on a simple thermally orientated biological endpoint of observed disruption of food motivated learned behavior in laboratory RF exposed animals.[48] A very influential book published in 1983 also supported the developing international thermal-effects-only paradigm and was supported by the North Alantic Treaty Organization (NATO) with Sol Michaelson (who played a central role on the development of C95.1 from the original 1950s Tri Services Project), being a major contributor to the publication. Michaelson's contribution laid out the thermal fundamentals and biological interactions of RF exposure.[49] Thus a significant amount of sharing of ideas had taken place between the IEEE C95.1 standard setters and the international development of ICNIRP's RF guidelines with a thermal emphasis unquestionably taken as the scientific basis for RF standard setting.

ICNIRP's power frequency exposure recommendations

The ICNIRP guidelines also include recommendations for extremely low frequency (ELF) fields which encompass mains power frequency electromagnetic fields (50 and 60 hertz). ICNIRPs emphasis for ELF exposures is on providing protection from short-term, immediate health effects from stimulation of peripheral nerves and muscles and shocks and burns caused by touching conducting objects at acute levels of exposure.[50] Similar to its RF/MW guidelines, ICNIRP members claim that it is not possible to include consideration of possible hazards from prolonged environmental ELF exposures because of what it calls insufficient data. As for the epidemiological evidence that consistently finds a connection between a number of diseases and low intensity ELF magnetic fields, including childhood leukaemia[51], ICNIRP dismisses this as unconvincing and insufficient. Such dismissal may on the surface appear to be objective expert opinion but an examination of ICNIRP's risk assessment processes finds, however, that power industry influence is endemic to the process. This influence appears to be aimed at ensuring economic protection for the industry against the need to spend enormous amounts of money on upgrading distribution networks as well as the risks of litigation if more restrictive limits were ever put in force.[52]

Conclusion

In examining the historical development of the thermally restricted RF standards, IEEE C95.1 and the RF guidelines promulgated by ICNIRP it is apparent that many subjective judgements, based on vested interests and limited knowledge melded together by Cold War political and military concerns lie at the very foundations of the thermal paradigm.

[47] Repacholi, 1984.

[48] J. Osepchuk, R. Petersen, 'Historical Review of RF Exposure Standards and the International Committee on Electromagnetic Safety (ICES)', *Bioelectromagnetics,* Supplement 6, 2003, pp. S7-S16.

[49] M. Grandolfo, S, Michaelson, A. Rindi, *Biological Effects and Dosimetry of Nonionizing Radiation: Radiofrequency and Microwave Energies*, NATO Advanced Study Institute on Advances in Biological Effects Dosemetry and NATO Scientific Affairs Division, Plenum Press,1983.

[50] Guidelines For Limiting Exposure To Time-Varying Electric, Magnetic, And Electromagnetic Fields (Up to 300 Ghz), *Health Physics*, April 1998, Vol. 74, No. 4.

[51] BioInitiative Working Group, op.cit.

[52] D. Maisch, ' Conflict of Interest & Bias in Health Advisory Committees: A case study of the WHO's Electromagnetic Field (EMF) Task Group, *JACNEM*, Vol. 25, No. 1, Apr. 2006, pp. 15 – 17.

In essence, the thermal limitations of the IEEE C95.1 RF standard and the ICNIRP RF Guidelines can be said to be little more than an outdated artefact from a half-century ago, maintained by a scientific elite who have longed staked their scientific credibility on maintaining that viewpoint. From their perspective, to retreat from that paradigm would be to admit that they had it wrong after all.

The reality that lies behind the rationale of the thermal standards/guidelines is that they have been designed and maintained in order to aid technological development. They also provide a rationale for the industry, and those promoting ever-increasing wireless development, to argue that the technology is perfectly 'safe' as emissions are well below the standard limits. To continue to claim, however, that RF/MW/ELF human exposure standards cannot consider low-intensity long-term effects is not only a gross insult to the very concept of providing adequate public health protection but also urgently needs to be replaced by biologically relevant exposure limits consistent with providing a level of protection that takes into consideration all the available scientific data.