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Re: Health Effects of 5G Telecommunication Infrastructure

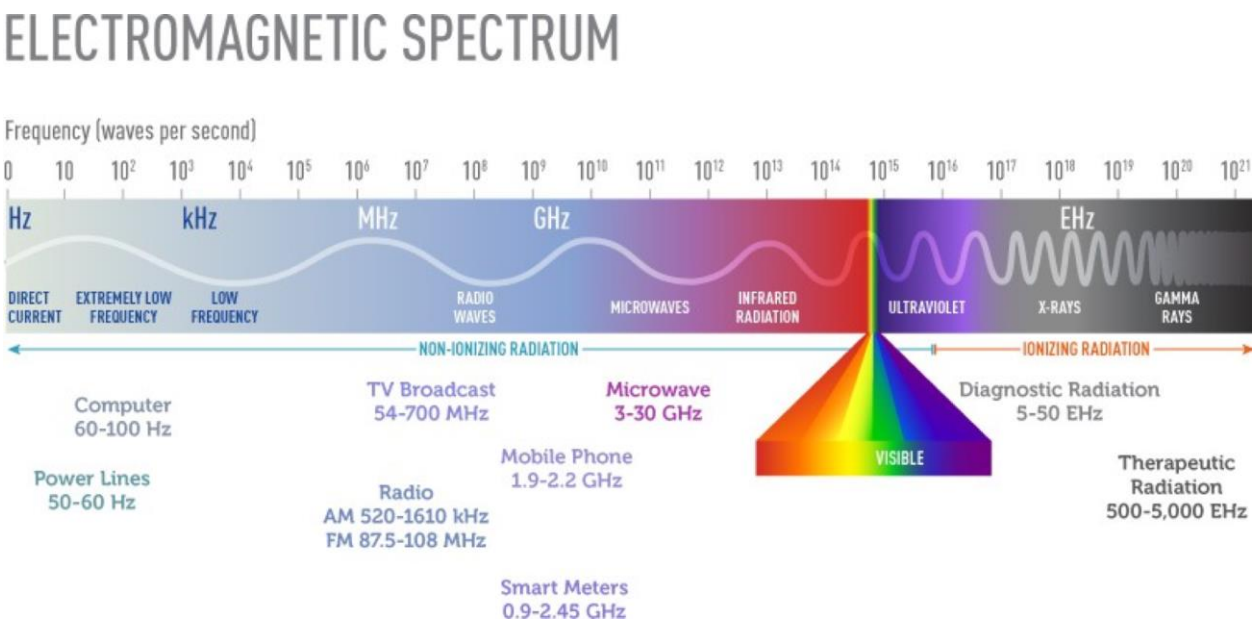
I have been asked by the CTIA to address any concerns over possible health effects related to 5G telecommunication infrastructure.

My name is Eric Swanson. I am a professor of theoretical physics at the University of Pittsburgh. I have published more than 100 papers on biophysics, nuclear physics, and condensed matter physics and given approximately 250 academic talks in 25 countries over a thirty-year career. I am the founder of the American Physical Society Topical Group on Hadronic Physics and an elected Fellow of the American Physical Society. I am also the author of *Science and Society* (Springer), *Applied Computational Physics* (Oxford University Press), and many newspaper and magazine op-eds and articles.

Because this report will be addressing issues concerning electromagnetic fields I would like to say a few words about what this is. Electromagnetic fields are waves that are created by moving charges (usually electrons) that traverse space at the speed of light. These waves are the *simplest phenomena known in the universe* and the physics related to them is well established. Waves only have three basic characteristics: frequency (how many times the wave oscillates per second), amplitude (the "height" of the wave), and polarization (we are most familiar with this via polaroid sunglasses). The figure below shows the "electromagnetic spectrum", which is just a representation of the names that we apply to different frequencies of radiation. Notice that visible light is part of the spectrum. Other familiar parts are UV radiation at slightly higher frequency than visible light, x-rays at even higher frequency, and microwaves and radio waves at lower frequency.

When it comes to human health concerns there is an important distinction between different parts of the spectrum. While I could explain this in terms of physical concepts, it is probably more useful to appeal to things we all know. UV radiation can be harmful because it can cause sunburns and skin cancer. X-rays and the higher frequency gamma rays can be even more harmful (at sufficient doses X-rays can cause cancer and gamma rays can kill people outright). Alternatively, we can happily spend days or months under indoor lighting with no chance of getting sunburn or skin cancer. The reason for this is that visible light is *below* the threshold frequency for causing damage to molecules in our cells. This threshold is referred to as the ionization threshold: electromagnetic waves that can break DNA bonds are called *ionizing* and electromagnetic waves that cannot break bonds are called *nonionizing*. The electromagnetic fields emitted by a cell phone and wireless infrastructure are nonionizing radiofrequency (RF) fields.

The frequencies used by 4G cellphones are around 2 GHz (this means two billion oscillations per second). These frequencies are about one million times lower than UV frequencies, which places them well on the safe side of the ionization threshold. 5G cellphones and infrastructure operate at RF frequencies that are approximately 30000 times below the ionizing threshold.



In the USA, 5G wireless infrastructure and 5G-capable cellphones are regulated by the Federal Communications Commission. All new equipment is tested and must comply with safety limits that have been set by the FCC. The FCC adopted the RF emission regulations based on standards recommended by international standards setting bodies such as the National Council on Radiation Protection and the Institute of Electrical and Electronics Engineers. It did so after consulting with federal health and safety organizations such as the FDA, Environmental Protection Agency, Occupational Safety and Health Administration, and National Institute for Occupational Safety and Health to develop "consensus" regulations. Together, these bodies have assessed thousands of scientific studies concerning possible health effects of nonionizing radiation. Animal tests and other studies indicate that thermal effects start to be felt at an energy deposition rate of approximately 100W/kg (this is called the *specific absorption rate*, or SAR)[1]. The FCC mandates that the general public be exposed to no SARs greater than 1.6 W/kg. In fact, according to the FCC, typical exposures near cellphone towers are hundreds or thousands of times lower than this figure. The FCC also mandates that *maximum permissible exposure* (called MPE, this is a measurement of the energy deposition rate by area) be lower than approximately 1 mW/cm^2.[2]

[1] For comparison, the heating pad I use to warm my arthritic knees is rated at 50W. I estimate it warms about 1 lb of my body, so this rather pleasant heating corresponds to a SAR of 100W/kg.
[2] FCC 13-39 (March 2013), Appendix A.

The consensus of the world-wide health and government health and safety organizations is that non-ionizing fields at the levels allowed by the FCC regulations are safe. For example, federal agencies responsible for regulating the safety of cell phones and wireless infrastructure and leading cancer and health research institutions in the United States have not found any link between electromagnetic fields allowed by the FCC regulations and cancer or other adverse health effects:

The Federal Communications Commission (FCC): "As discussed above, radiofrequency emissions from antennas used for cellular and PCS transmissions result in exposure levels on the ground that are typically thousands of times below safety limits. These safety limits were adopted by the FCC based on the recommendations of expert organizations and endorsed by agencies of the Federal Government responsible for health and safety. Therefore, there is no reason to believe that such towers could constitute a potential health hazard to nearby residents or students." [3]

The Food and Drug Administration (FDA): "Based on our ongoing evaluation of this issue, the totality of the available scientific evidence continues to not support adverse health effects in humans caused by exposures at or under the current radiofrequency energy exposure limits." [4]

National Cancer Institute: "… although many studies have examined the potential health effects of non-ionizing radiation from radar, microwave ovens, cell phones, and other sources, there is currently no consistent evidence that non-ionizing radiation increases cancer risk in humans." [5]

American Cancer Society: "At ground level near typical cellular base stations, the amount of RF energy is thousands of times less than the limits for safe exposure set by the US Federal Communication Commission (FCC) and other regulatory authorities … Some people have expressed concern that living, working, or going to school near a cell phone tower might increase the risk of cancer or other health problems. At this time, there is very little evidence to support this idea." [6]

Other worldwide health and safety organizations are in accord:

European Commission, Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) (2015): "Overall, the epidemiological studies on mobile phone RF EMF

[3] FCC RF Safety FAQ https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#Q15 (last accessed March 11, 2019).
[4] FDA Statement, Statement from Jeffrey Shuren, M.D., J.D., Director of the FDA's Center for Devices and Radiological Health on the National Toxicology Program's report on radiofrequency energy exposure, Nov. 1, 2018, https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm624809.htm.
[5] National Cancer Institute, "Cell Phones and Cancer Risk" Factsheet (2019), https://www.cancer.gov/about-cancer/causes-prevention/risk/radiation/cell-phones-fact-sheet (last accessed March 11, 2019).
[6] American Cancer Society, "Cellular Phone Towers", https://www.cancer.org/cancer/cancer-causes/radiation-exposure/cellular-phone-towers.html (2018) (last accessed March 11, 2019).

exposure do not show an increased risk of brain tumours. Furthermore, they do not indicate an increased risk for other cancers of the head and neck region." [7]

World Health Organization (2006): "Recent surveys have indicated that RF exposures from base stations and wireless technologies in publicly accessible areas (including schools and hospitals) are normally thousands of times below international standards . . . From all evidence accumulated so far, no adverse short- or long-term health effects have been shown to occur from the RF signals produced by base stations." [8]

Health Canada (2014): "The Panel has concluded that the balance of evidence at this time does not indicate negative health effects from exposure to RF energy below the limits recommended in the Safety Code." [9]

United Kingdom Health Protection Agency Independent Advisory Group on Non-Ionizing Radiation (HPA) (2012): "In summary, although a substantial amount of research has been conducted in this area, there is no convincing evidence that RF field exposure below guideline levels causes health effects in adults or children." [10]

Swedish Council for Working Life and Social Research (2012): "Extensive research for more than a decade has not detected anything new regarding interaction mechanisms between radiofrequency fields and the human body and has found no evidence for health risks below current exposure guidelines." [11]

Norwegian Institute for Public Health (2012): "The studies have been performed on cells and tissues, and in animals and humans. The effects that have been studied apply to changes in organ systems, functions and other effects. There are also a large number of population studies with an emphasis on studies of cancer risk. The large total number of studies provides no evidence that exposure to weak RF fields causes adverse health effects." [12]

Similarly, the **Institute of Electrical and Electronics Engineers' International Committee on Electromagnetic Safety** (IEEE/ICES), which is one of the expert organizations that the FCC relies on in setting its RF emission standard, analyzed 52 years of studies and concluded that "the weight of scientific evidence supports the conclusion that there is no measurable risk associated with RF

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[7] European Commission, Scientific Committee on Emerging and Newly Identified Health Risks, Opinion, "Health Effects of Exposure to EMF," (2015) (available at https://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_041.pdf).

[8] World Health Organization, "Electromagnetic fields and public health: base stations", (2006), https://www.who.int/peh-emf/publications/facts/fs304/en/ (last accessed March 11, 2019).

[9] Health Canada, "A Review of Safety Code 6 (2013): Health Canada's Safety Limits for Exposure to Radiofrequency Fields," (2014) (available at https://rsc-src.ca/sites/default/files/SC6_Report_Formatted_1.pdf).

[10] Health Protection Agency, "Health Effects from Radiofrequency Electromagnetic Fields, Report of the Independent Advisory Group on Non-Ionising Radiation," (2012) (available at https://www.ncbi.nlm.nih.gov/nlmcatalog/101602435).

[11] Ahlbom A., *et al.*, Swedish Council for Working Life and Social Research, "Radiofrequency Electromagnetic Fields and Risk of Disease and Ill Health: Research during the last ten years," (2012) (available at http://www.fas.se/pagefiles/5303/10-y-rf-report.pdf).

[12] Norwegian Institute of Public Health, Report 2012:3, "Low-level radiofrequency electromagnetic fields, an assessment of health risks and evaluation of regulatory practice, (2012) (available at http://www.fhi.no/dokumenter/545eea7147.pdf).

exposures"[13] even at levels five times higher than that permitted by the FCC. In short, *the consensus of the scientific community is that the scientific evidence does not support any link between exposure to regulated RF and adverse health effects.*

5G telecommunication technology seeks to increase data rates by a factor of 100 over 4G networks (to 1Gbps or higher), decrease latency (time wasted in establishing communication) by a factor of 50 or more, and increase user density drastically (up to one mobile device per 10 square feet). These capabilities will enable smart city technology, the "internet of things", mobile service on airplanes, remote medicine, and the machine-to-machine communication required for the robotic cars of the future. It will achieve these things by placing low power small cell wireless infrastructure close together and by employing more of the electromagnetic spectrum (specifically, the spectrum near 30 GHz). Because 30 GHz radiation is nonionizing and the emissions from cell phones and small cell wireless infrastructure are regulated by the FCC's exposure standards that have withstood the test of time, there is no reason to believe there is a risk of adverse health effects. In addition, one can estimate MPE levels by using published data concerning the size of 5G small cell wireless infrastructure and their power ratings (these are also regulated by the FCC). The result is an MPE that is approximately 500 times below the FCC limit. Thus, 5G technology presents no substantial risk to the general public, and certainly does not present risk that current regulations cannot manage.

The National Toxicology Program Rat and Mouse RFR Studies

The National Toxicology Program conducted a study of the effects of cellphone radiofrequency radiation (RFR) in rats[14] and mice[15]. The study was generally negative for adverse health effects. There was no finding of a carcinogenic effect in male mice, female mice, or female rats. There were a few elevated results for glioma and heart schwannoma (tumor of the heart) in some male rats under specific exposures well above what federal standards allow for cell phones. The findings for these tumors were weak and the authors of the NTP study disavowed the suggestion that their study demonstrated anything regarding human health effects[16]. Overall, the NTP study in fact supports the scientific consensus that there are no adverse human health effects from RFR. The U.S. Food and Drug Administration agreed, concluding, after the release of the NTP study, that "the totality of the available scientific evidence continues to not support adverse health effects in humans caused by exposures at or under the current radiofrequency exposure limits."

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[13] Institute of Electrical and Electronics Engineers, International Committee on Electromagnetic Safety (SCC39), "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300 GHz," (2006).

[14] "Toxicology and Carcinogenesis Studies in Hsd:Sprague Dawley SD Rats Exposed to Whole-body Radio Frequency Radiation at a Frequency (900 MHz) and Modulations (GSM and CDMA) used by Cell Phones", M.E. Wyde *et al*., NTP TR 595 (November, 2018).

[15] "Toxicology and Carcinogenesis Studies in B6C3F1/N Mice Exposed to Whole-body Radio Frequency Radiation at a Frequency (1900 MHz) and Modulations (GSM and CDMA) used by Cell Phones", M.E. Wyde *et al*., NTP TR 596 (November, 2018).

[16] Specifically, the NTP cautioned that their "findings should not be directly extrapolated to human cell phone usage." The U.S. Food and Drug Administration explained: "We agree that these findings should not be applied to human cell phone usage."

The weak elevated findings for glioma and heart schwannoma in male rats are questionable given some obvious flaws in the study:

- The study was based on exposing male and female rats to levels of RFR at levels far greater than permitted by the FCC for human use, and for periods of time much greater than typical human use. Testing of those animals was compared to testing of control groups of rats and mice that were not exposed. Notwithstanding the extremely high exposure levels and time periods, no adverse findings were found in the male mice, the female mice, or the female rats. Although adverse health effects were observed in some of the exposed male rats, it is very difficult to find a plausible biological explanation for a sexual difference in the incidence of health effects. Given that the male and female rats were subject to equal amounts of RFR exposure, this suggests that the higher incidence among males was attributable to something other than RFR. And the absence of health effects among male or female mice is also noteworthy.

- The NTP study reports that rats that were exposed to RFR *lived longer* than the control group which was not exposed to RFR. As the authors note, since cancer is associated with ageing, the higher cancer rate among the exposed rats may be explained by the very fact that they lived longer, not by the fact that they were exposed to RFR: "If malignant gliomas or schwannomas are late-developing tumors, the absence of these lesions in control males in the current study could conceivably be related to the shorter longevity of control rats in this study."[17] And the data reflects that most of the tumors in the exposed group of male rats developed *after* the control rats had already died. Thus, the control rats died before they had the opportunity to develop glioma.

- The disparity between male and female rats might also be explained by the type of rats that were studied. Sprague-Dawley rats (the type used in the NTP study) are known to produce tumors at a high and variable rate[18]. A different study[19] examining cancer rates in Sprague-Dawley rats found that tumor incidence varied greatly depending on the commercial source of the rats. The authors "stressed the need for extreme caution in evaluation of carcinogenicity studies conducted at different laboratories and/or on rats from different sources."

- The study found difficulty in consistently evaluating whether the test animals actually had diseases of a given type. This has been noted by an external referee, Dr. A.M. Michalowski,

[17] Page 15, "Effect of cell phone radiofrequency radiation on body temperature in rodents: Pilot studies of the National Toxicology Program's reverberation chamber exposure system", M.E. Wyde *et al.*, Bioelectromagnetics. 2018 Apr; 39(3):190-199. doi: 10.1002/bem.22116.
[18] "Editor in Chief of Food and Chemical Toxicology answers questions on retraction", A. Wallace Hayes, Food and Toxicology, 65 (2014) 394-395.
[19] "Comparison of Neoplasms in Six Sources of Rats", W.F. MacKenzie and F.M. Garner, JNCI, 50 (5) (1973), 1243-1257.

who suggested that the various working groups who examined the animals may have employed different sets of criteria in their evaluations. "Working list of limitations potentially impacting NTP study interpretations. Difficulty in achieving diagnostic consensus in lesions classifications of rare, unusual, and incompletely understood lesion association. Document appears to indicate that the second Pathology Working Group (PWG) empaneled to review and obtain lesion classification consensus, following the inability of the initial PWG to do so, may have reviewed different lesions sets."[20]

- Among other things, the study looked at the incidence of a tumor known as a schwannoma. Exposed male rats had a higher incidence of schwannomas of the heart. Yet the rats had their whole bodies irradiated with excessive amounts of RFR. If RFR contributed to the schwannomas, it is not immediately obvious why schwannomas would preferentially appear in the heart as opposed to other parts of the body that were exposed. Indeed, when one examines all schwannomas, not just the cardiac schwannomas, there does not appear to be a significant relationship to RFR.

All of these conclusions reinforce the NTP authors' own admonition that their studies do not establish a basis for concluding that RFR poses a health risk to humans.

The NTP study also suffers from a common methodological flaw known as the "problem of multiple outcomes." In short, the more variables that are simultaneously introduced into a test, the higher the likelihood of false positives. For example, if researchers decide to test whether a particular drug is effective at treating certain diseases, the more diseases they introduce into the testing, the more likely it is that the drug will *appear* to have been effective as to at least one of the diseases due to the effects of random sampling, i.e., a false positive. If an experiment has a 5% false positive rate, doing two experiments has a 9.8% chance of finding a false positive. Things rapidly get worse as more experiments are done—-performing 20 experiments yields a 64% chance of finding a false positive.

We find this phenomenon at work in the NTP study. In an attempt at thoroughness, the NTP study exposed four different groups of animals to two types of signal modulation (CDMA and GSM) at three different levels of exposure. Furthermore, the animals were examined for dozens of types of cancer. Statistically, the resulting multitude of subclasses being tested mean it is very likely that false positives occur.

Although there are well-established methods to overcome the "problem of multiple outcomes" (such as the Bonferonni method), the NTP authors did not apply any of them, thus exacerbating the problem of false positives. This problem was noted by an external referee (Dr. Michael S Lauer), who commented, "The low power implies that there is a high risk of false positive findings, especially since the epidemiological literature questions the purported association between cell phone exposure and cancer."[21]

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[20] Page 62, Ref. footnote 17.
[21] Page 36. Ref. footnote 17.

Finally, glioma is rare (the incidence rate in the USA is approximately 3 per 100,000 persons[22]), and it is expensive and difficult to perform experiments on a sufficient number of rats to obtain statistically reliable results. To test this, I have computed the relative likelihood for obtaining the experimental results observed by the NTP researchers. In the NTP study none of the control rats developed a glioma. However, if one examines the incidence of glioma in *all* NTP experiments (using data presented in Appendix D of Ref. 17) one finds a *lower incidence of glioma among rats exposed to RFR.* This could be interpreted of strong statistical evidence that RFR exposure actually *reduces* the incidence of glioma. This implausible result is yet another indication of the unreliable statistical significance of the NTP study conclusions.

Sincerely,

E.S. Swanson
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[22] The incidence for Sprague-Dawley rats is estimated to be 1.5%.