A BRIEFING MEMORANDUM: What We Know, Can Infer, and Don't Yet Know about Impacts from Thermal and Non-thermal Non-ionizing Radiation to Birds and Other Wildlife — for Public Release

Albert M. Manville, II, Ph.D., C.W.B.[1]; Principal, *Wildlife and Habitat Conservation Solutions, LLC*[2]*;* Adjunct Professor, Johns Hopkins University's Krieger School of Arts and Sciences, DC Campus[3]; and former U.S. Fish and Wildlife Service agency lead on avian-structural impacts — including from radiation

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Introduction

There continues to be an active yet unsettled controversy about current radiation safety standards and their effects on humans and wildlife (www.livingplanet.be), most especially (1) with the exponential growth of ultra-high frequency (UHF) microwave radiation of electromagnetic fields (EMF) ranging from 900 MHz to 2500 GHz. The 900 and 1800 MHz fields are commonly used in communication devices such as cellular (cell) telephones, their antennas, related "smart" phones, digital "smart meters," computer wi-fi communication systems, and other sources of point-to-point and Internet communication. Much less attention is being paid to (2) frequency modulated (FM) impacts on migratory birds, including bandwidths ranging from 70 to 110 MHz also briefly discussed in this memo.

However, as concluded in this memo, the impacts from radiation especially at the non-thermal level (thermal effects are generally pretty clear) have already been well documented. Most scientists consider non-thermal effects as well established even though the implications are not fully understood. For example, in the June 2016 *Scientific American Blog* (Portier and Leonard 2016), in response to the question, *"do cell phones cause cancer?"* The authors response was clear: *"probably, but it's complicated. The degree of risk almost certainly depends on the length and strength of exposure — but we still don't know how significant the actual danger is."* These same issues pertain to impacts to wildlife from both thermal and non-thermal effects emitted from cellular (cell) communication towers and FM antennas (discussed in detail beyond). The radiation effects on wildlife need to be addressed by the Federal Communications Commission (FCC), the Environmental Protection Agency (EPA), the Department of Commerce, the U.S. Fish and Wildlife Service (FWS) and other governmental entities.

Focusing in the remainder of this memo primarily on wildlife impacts, radiation effects can be characterized as *"near-field"* (near the source of radiation), *"far-field"* (some distance from the source) or *"intermediate."* Negative reports of near-field (i.e., very close to power sources such as on or very near cellular antennas and antenna arrays) thermal radiation effects (capable of heating tissue) on laboratory animals and wildlife have been published in the scientific literature since at least 1950. An example includes Clark 1950, cited in Tanner 1966. Much of the controversy about effects involves *"far field,"* non-thermal, low-level radiation impacts on humans, laboratory animals and wildlife. These are effects that can occur further away from the peak source of radiation (i.e., the tower antennas) due to signal attenuation, signal interference from objects and water droplets in the air, and other physical obstructions and disturbances. As concluded by Beason and Semm (2002), non-thermal effects had been the most difficult

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[1] C.W.B. = Certified Wildlife Biologist, accredited and recognized by The Wildlife Society

[2] email at whcsllc006@verizon.net

[3] email at amanvil1@jhu.edu

to explain because the mechanism by which they affect biological tissue was usually unknown or unclear. With much more current research and recent discoveries, the explanations are becoming much clearer as new research results become available and causality becomes more evident.

For human exposures, however, the FCC has operating rules. These rules require that power to cell and other broadcast towers must be turned off when workers are on and/or climbing the towers — due to health impacts and safety concerns from the thermal radiation.

Complicating the issue is the fact that there currently are no standards for wildlife exposure, including by the licensing and regulatory rules and procedures of the FCC. Other than a letter from the Interior Department's (DOI) Director of the Office of Environmental Policy and Compliance to the Commerce Department's National Telecommunications and Information Administration (NTIA; USDOI 2014) — Attachment A involving effects of tower collisions and non-thermal radiation on migratory birds which I authored — neither DOI nor the FWS have any policy or quasi policy that currently addresses radiation effects to migratory birds. Arguably, "effects" need to be determined by the EPA, which has no funding for this, and regulated as part of a National Environmental Policy Act (NEPA) site review for a proposed cell tower, including both thermal and non-thermal effects.

Undebatable, however, is the exponential growth of cell phone technologies with an estimated 7 billion cell phones now available worldwide to a human population of 7.4+ billion (NPR March 2016 news report based on 2015 data). With this growing cell phone use and the communication systems that transmit and receive the signals from them, as well as the paucity of government regulatory oversight, this memorandum very briefly summarizes some of the major studies and take-aways conducted primarily on laboratory animals and wildlife, especially migratory birds. The issue represents a growing and troubling concern since migratory birds are in decline (at least 36% of which are in trouble species-wide in North America [USFWS 2008]), and which face additional uncertain impacts from non-ionizing, thermal and non-thermal radiation (Manville 2015, 2016).

Tests on laboratory animals such as chicken embryos, mice and rats are used as surrogates to predict harm to humans, protected migratory birds and other wildlife which, for practical, ethical and legal reasons in the United States would not otherwise be subjected to laboratory studies on impacts from radiation. Furthermore, scientists generally do not want to perform harmful experiments on either humans or protected wildlife such as migratory birds. Studies on the negative effects of non-thermal radiation to wild birds in Europe are clearly relevant as predictors of what will/is likely/is happening to wild birds in North America — the Bald Eagle as such as example due to its population growth and growing proximity to existing and proposed cell towers. That is why the published research results from European avian studies are so troubling.

Biological Systems and EMF

Living systems operating in animals support a variety of oscillatory electrical and/or biochemical activities which have been well documented to be affected by EMF. However, the direct relationship between electromagnetic radiation and wildlife health continues to be complicated and in cases involving non-thermal effects, still unclear. We know, for example, that brain waves are electrical, the heartbeat is electrical, the cell membrane has an electric field potential, cell division is electrically influenced, communication between neurons is electrical, and all of the hormonal and enzymatic activities are electrically regulated. Even the chemical-mechanistic model of the human and animal anatomy is essentially an electromagnetic model, because all chemical reactions involve the sharing, trading, or exchange of electrons at the elemental level (www.livingplanet.be) as explained by scientist J. Everaert in his website.

As J. Everaert further explains, there are studies showing frequency-specific biological effects, and studies demonstrating that a high frequency signal modulated at certain low frequencies, or a signal that is pulsed, has more harmful effects than an unmodulated, steady carrier wave (www.livingplanet.be).

Early Studies on EMF in the Microwave Bandwidth

Dating back to at least 1950, Tanner (1966, citing Clark 1950) concluded that much had been published on effects of microwave radiation on body tissues and animals, but most of the early experiments were concerned with the production of heat and its physiological effects. Tanner et al. (1967) looked briefly at the effects of microwave radiation on domestic chickens, and concluded that thermal effects were manifested by a rise in temperature of the irradiated birds, which were accompanied by physiological responses based on intensity and duration of the radiation field — escape or avoidance — but that non-thermal effects that impacted other physiological systems were more difficult to discern. Tanner (1966) and Tanner et al. (1967) discovered that birds' feathers are known to have piezoelectric properties, capable of conducting EMF/RF deep within bird body cavities. This finding can help, in part, explain increased bird sensitivity to EMF/RF radiation. In this early research, however, it remains unclear if thermal and non-thermal effects were adequately differentiated.

Wasserman et al. (1984) conducted field studies on 12 flocks of migratory birds subjected to various combinations of microwave power density and duration under winter conditions at Monomet, MA, with birds from 2 additional flocks serving as controls. Increased levels of aggression were noted in some of the irradiated birds suggesting effects, but calling for further study.

More Recent EMF Studies on Birds, Other Wildlife and Laboratory Animals in the Microwave Bandwidth

There is an increasing body of published laboratory research that finds DNA damage at low intensity exposures — well below levels of thermal heating — which may be comparable to far field exposures from cell antennas. This body of work would apply to all species, including migratory birds, since DNA is DNA, whether single-strand or double helix. The first study to find such effects was conducted by H. Lai and N.P. Singh in 1995 (Lai and Singh 1995). Their work has since been replicated (e.g., Lai and Singh 1996, as well as in hundreds of other more recent published studies), performed in at least 14 laboratories worldwide. The take-home message: low level transmission of EMF from cell towers and other sources probably causes DNA damage. The laboratory research findings strongly infer this relationship. Since DNA is the primary building block and genetic "map" for the very growth, production, replication and survival of all living organisms, deleterious effects can be critical.

The entire thermal model and all FCC categorical exclusions for all of the devices we see today, rests on the incorrect assumption that low-level, non-ionizing non-thermal radiation cannot cause DNA breaks because it is *"so low-power"* (B. Levitt and H. Lai, Comments Filed Jointly to FCC, ET Docket No. 13-84, 2013). These issues need to be adequately addressed by the appropriate authorities including the FCC, EPA and FWS. Currently they are not.

In laboratory studies by T. Litovitz (2000 pers. comm.) and DiCarlo et al. (2002) from the standard 915 MHz cell phone frequency on domestic chicken embryos showed that radiation from extremely low levels (0.0001 the level emitted by the average digital cellular telephone) caused heart attacks and deaths in some embryos. Controls, however, were unaffected (DiCarlo et al. 2002). In replicated experiments, similar results were obtained by Grigor'ev (2003) and Xenos and Magras (2003). These findings are important since similar evidence exists for lethal and injurious impacts to wild birds in Europe from cell

tower radiation, and based on anecdotal reports from the U.S., are very likely also occurring in North America (Manville 2016).

In field studies on wild birds in Spain, Balmori (2005) found strong negative correlations between levels of tower-emitted microwave radiation and bird breeding, nesting, roosting and survival in the vicinity of electromagnetic fields. He documented nest and site abandonment, plumage deterioration, locomotion problems, and death in Wood Storks, House Sparrows, Rock Doves, Magpies, Collared Doves, and other species. While these species had historically been documented to roost and nest in these areas, Balmori (2005) did not observe these symptoms prior to construction and operation of the cell phone towers. Results were most strongly negatively correlated to proximity to antennas and Stork recruitment and survival. Twelve nests (40% of his study sample) were located within 200 m of the antennas and never successfully raised any chicks, while only 1 (3.3%), located further than 300 m, never had chicks. Strange behaviors were observed at Stork nesting sites within 100 m of one or several cell tower antennas. Those birds that the main beam impacted directly (i.e., electric field intensity/EFI > 2 V/m) included young that died from unknown causes. Within 100 m, paired adults frequently fought over nest construction sticks and failed to advance the construction of the nests with sticks falling to the ground while nests were being constructed. Balmori (2005) reported that some nests were never completed and the Storks remained passively in front of cellsite antennas. The electric field intensity was higher on nests within 200 m (2.36 ± 0.82 V/m) than on nests further than 300 m (0.53 ± 0.82 V/m). However, the EMF levels, including for nests < 100 m from the antennas, were not intense enough to be classified as thermally active. Power densities need to be at least 10 mW/cm2 to produce tissue heating of even 0.5 C (Bernhardt 1992).

Balmori and Hallberg (2007) and Everaert and Bauwens (2007) found similar strong negative correlations among male House Sparrows and electromagnetic radiation in their studies. In another review, Balmori (2009) reported health effects to birds which were continuously irradiated. They suffered long-term effects including reduced territorial defense posturing, deterioration of bird health, problems with reproduction, and reduction of useful territories due to habitat deterioration.

Beason and Semm (2002) demonstrated that microwave radiation used in cell phones produces non-thermal responses in several types of neurons of the nervous system of Zebra Finches. The brain neurons of anesthetized birds were tested with a 900 MHz carrier, modulated at 217 Hz. Stimulation resulted in changes in the amount of neural activity by more than half of the brain cells with most (76%) of the responding cells increasing their rates of firing by an average 3.5-fold as opposed to controls — a clearly definitive study showing non-thermal effects. The other responding cells exhibited a decrease in their rates of spontaneous activity suggesting potential effects to humans using hand-held cell phones affecting sleep (Borbely et al. 1999). The Beason and Semm (2002) theoretical model could also help explain why birds may be attracted to cell towers, an important theoretical premise that they previously hypothesized in regard to Bobolinks (Semm and Beason 1990).

In a meta-review of studies through 2008, and based on laboratory research they conducted, Panagopoulos and Margaritas (2008) determined maximum radiation distances for both cell phones and for communication towers, based on the Global System for Mobile Telecommunications (GSM) and the Digital Cellular System (DCS). This maximum radiation distance corresponds to an intensity around 10 mW/cm2 for both types of radiation in regards to the RF components — i.e., Bernhardt's (1992) threshold for thermal heating effects. Panagopoulos and Margaritas (2008) recorded an *"intensity window"* — a thermal effect — around 10 mW/cm2 RF exposure where bio-effects became even more severe than at intensities higher than 200 mW/cm2. This *"intensity window"* appeared at a distance of 20-30 cm from the cell phone antenna, corresponding to a distance of about 20-30 meters from a base station antenna. This could be considered a classic nonlinear effect and would apply to far field exposures. Since cell phone base station antennas are frequently located within residential areas where houses and workplaces are often situated at distances 20-30 m from such antennas, not to mention birds nesting and roosting close to

these antennas (e.g., Balmori 2005), humans, migratory birds and other wildlife may be exposed up to 24 hours per day.

Based on their research and meta-analyses, Panagopoulos and Margaritas (2008) concluded that large decreases in reproductive capacity were being caused by GSM and DCS radiation fields. This included extensive DNA fragmentation on reproductive cells of experimental animals induced by these fields, exerting an intense biological action able to kill cells, damage DNA, and dramatically decrease the reproductive capacity of living organisms, including populations of wild birds and insects. They cautioned, however, that the physical parameters of these radiations, including intensity, carrier frequency, pulse repetition frequency, distance from the antenna, and similar factors provided inconsistency and lack of standardization making it difficult to correlate specific thermal and non-thermal effects to specific types of radiation. Their take-away message, however, was clear: bio-effects to migratory birds, other wildlife, insects, laboratory animals and humans continue to be documented from thermal and non-thermal exposures, as well as effects from intermediate exposures between the near-field and far-field levels. All migratory birds are potentially at risk, whether they be Bald Eagles, Golden Eagles, Birds of Conservation Concern (USFWS 2008), Federally and/or State-listed bird species, other birds in peril regionally or population-wide, or birds whose populations are stable.

Cucurachi et al. (2013) reported on 113 studies from original peer-reviewed publications and relevant existing reviews. A limited number of ecological studies was identified, the majority of which were conducted in a laboratory setting on bird embryos or eggs, small rodents and plants. In 65% of the studies, ecological effects of RF-EMF (50% of the animal studies and about 75% of the plant studies) were found both at high as well as at low dosages. Lack of standardization and limited sampling made generalizing results from the organism to the ecosystem level very difficult. Cucurachi et al. (2013) concluded, however, that due to the number of variables, no clear dose–effect relationship could be found especially for non-thermal effects. However, effects from some of the studies reviewed were well documented, and certainly can serve as predictors for effects to wild, protected migratory birds and other wildlife in North America.

Engels et al. (2014) investigated *"electromagnetic noise"* emitted everywhere humans use electronic devices including from cell phones and their towers. While prior to their study on European Robins, no *"noise effect"* had been widely accepted as scientifically proven, the authors in this double-blind experiment were able to show that migratory birds are unable to use their magnetic compass in the presence of urban electromagnetic noise. The magnetic compass is integral to bird movement and migration. The findings clearly demonstrated a non-thermal effect on European Robins and clearly serves as a predictor for effects to other migratory birds including those in North America.

Levitt and Lai (2010) reported numerous biological effects from cell tower radiation documented at very low intensities comparable to what the population experiences within 60–150 m distance from a cell tower, including effects that occurred in studies of cell cultures and animals after exposures to low-intensity RFR. These reported effects were genetic, growth, and reproductive in nature; they documented increases in permeability of the blood–brain barrier; showed behavioral responses; illustrated molecular, cellular, and metabolic changes; and provided evidence of increases in cancer risk — all applicable to migratory birds, other wildlife and to far field exposures in general. They cited published, peer-reviewed examples of effects that included:

Dutta et al. (1989) who reported an increase in calcium efflux in human neuroblastoma cells after exposure to RFR at 0.005 W/kg. Calcium is an important component in normal cellular functions.

Fesenko et al. (1999) who reported a change in immunological functions in mice after exposure to RFR at a power density of 0.001 mW/cm2. These results can serve as predictors for impacts to wild animals.

Magras and Xenos (1997) who reported a decrease in reproductive function in mice exposed to RFR at power densities of 0.000168— 0.001053 mW/cm2. The results also serve as predictors for reproductive impacts to wildlife.

Forgacs et al. (2006) who reported an increase in serum testosterone levels in rats exposed to GSM-like RFR at specific absorption rates (SAR) of 0.018— 0.025 W/kg. The results also serve as predictors for reproductive impacts to wildlife.

Persson et al. (1997) who reported an increase in the permeability of the blood–brain barrier in mice exposed to RFR at 0.0004– 0.008 W/kg. The blood–brain barrier is a physiological mechanism that protects the brain from toxic substances, bacteria, and viruses. These findings have clear applicability to wildlife including migratory birds.

Phillips et al. (1998) who reported DNA damage in cells exposed to RFR at the SAR of 0.0024– 0.024 W/kg. DNA is integral to the very function and survival of all living organisms, including migratory birds.

Kesari and Behari (2009) also reported an increase in DNA strand breaks in brain cells of rats after exposure to RFR at the SAR of 0.0008 W/kg. The results also serve as predictors for impacts to DNA in wildlife. And,

Belyayev et al. (2009) who reported changes in DNA repair mechanisms after RFR exposure at a SAR of 0.0037 W/kg. DNA is integral to the maintenance and repair of cells and cellular function in all animals. All sources from above were cited in Levitt and Lai (2010).

In a 2-year study conducted by the National Toxicology Program (NTP) of the National Institutes of Health (May 2016), NTP (Wyde 2016) reported partial findings from their $25 million study on cancer risk to laboratory rodents from cellphone radiation. The report summarizes a long-term exposure study to cell phone radiation, with statistically significant evidence of DNA damage from non-thermal exposure to cellphone radiation to laboratory mice and rats. Controlled studies on laboratory rats showed that cellphone radiation caused 2 types of tumors, glioma and schwannoma, the results which *"could have broad implications for public health."* The report has been characterized as a *"game-changer"* as it proves that non-ionizing, radiofrequency radiation can cause cancer without heating tissue. The researchers controlled the temperature of the test animals to prevent heating effects so the cancers were caused by a non-thermal mechanism. The report on the mice component of the study will be released at a later date. Not surprisingly, much of the media coverage contained considerable bias or "media spin" intended to create doubt about the study's important findings regarding cancer risk from exposure to cellphone radiation (Moskowitz 2016). The implications are troubling for migratory birds and other wildlife.

Likely Impacts to Migratory Birds from Frequency Modulated (FM) Signals

FM signals travel in line-of-sight paths, so antennas are located on the highest ground available to blanket an area wherever the target signal recipients are located, also providing convenient perches for migratory birds. FM digital (on/off) signals which simulate pulsed waves pose additional health concerns to migratory birds, especially from thermal heating which will be coupled with the UHF's from cell phone providers often colocated on the same antennas (e.g., see cellphonetaskforce.com; work of Dr. O. Johansson). This creates a very dangerous frequency potential for protected migratory birds such as Bald Eagles since

the length of the FM signal is about 6 feet, creating a full-body resonant effect for both humans and Bald Eagles — an Eagle wingspan extends to about 6 feet. Power levels for FM transmission (e.g., 6,000 Watts for a commercial radio station) are far higher than that for a colocated UHF antenna(s), exacerbating thermal heating effects.

Modulated FM signals infuse the atmosphere with lower frequencies which become more bioactive, even at lower power intensities. These, in turn, coupled with a UHF cell phone frequency(s) will create greater thermal and non-thermal effects. Generally the approved level of power for an FM transmission antenna is considerable. The FCC does not measure the modulated signal, only the carrier signal (Levitt 1995). Let's evaluate a hypothetical FM antenna array, with a carrier signal of 104.9 MHz at 47 meters above ground level (AGL), and an effective radiated power of 6,000 Watts. Here, nesting, roosting, feeding and potentially breeding birds such as Bald Eagles using this hypothetical tower would almost certainly be affected by thermal heating, in addition to non-thermal impacts. These issues need to be assessed including through the NEPA review process (either an Environmental Assessment or an Environmental Impact Statement) by FCC and FWS.

The specific absorption rate (SAR) is the energy absorbed per unit of biological tissue, usually expressed in watts per kilogram or milliwatts per gram of tissue, and the SAR is used to focus on *"harmful effects"* to humans. SARs peak in the bands of 70 — 100 MHz (Cleveland 2001). However, as previously mentioned in this memo, there currently are no standards for wildlife exposure to RFR — both from FM and UHF radiation — including for Bald Eagles and all other protected migratory birds. These issues need to be addressed both by FCC and FWS.

Summary Recommendations

Levitt and Lai (2010) concluded that the obvious mechanism of effects from RFR are thermal (i.e., tissue heating) — which is what FCC bases its current radiation standards on, even if they are more than 30 years out of date and rejected both by the Department of Interior and Department of Commerce (USDOI 2014, Manville 2016) as incomplete. However, for decades, there have been questions about non-thermal (i.e., not dependent on a change in temperature) effects, whether they exist, and what specifically causes the effects to surface. The sources cited above should help dispel that doubt or at the very least show that non-thermal effects do indeed occur, have been well documented, and can have significant deleterious effects on migratory birds and other wildlife.

Practically, as Levitt and Lai (2010) concluded, we do not actually need to know whether RFR effects are thermal or non-thermal to set exposure guidelines. Most of the biological-effects studies of RFR that have been conducted since the 1980s were under non-thermal conditions, including the most recent NTP (2016) studies. In studies using isolated cells, the ambient temperature during exposure was generally well controlled. In most animal studies, the RFR intensity used usually did not cause a significant increase in body temperature in the test animals. Most scientists consider non-thermal effects as well established, even though the implications are not fully understood.

Scientifically, Levitt and Lai (2010) concluded that there are three rationales for the existence of non-thermal effects:

1. Effects can occur at low intensities when a significant increase in temperature is not likely.

2. Heating does not produce the same effects as RFR exposure.

3. RFR with different modulations and characteristics produce different effects even though they may produce the same pattern of SAR distribution and tissue heating.

There is virtually no non-thermal research to indicate what is safe for either humans or wildlife, including migratory birds which are highly sensitive to perturbations in ways humans are not (see previous citations). Unfortunately, there also is very little far-field, distance-to-safety research for wildlife — most especially for migratory birds — as this has not been studied with that focus in mind. What little EMF/RF field research on wildlife that has been conducted, its focus has been on behavior, mortality and reproductive outcomes (e.g., B. Levitt and H. Lai, Comments Filed Jointly to FCC, ET Docket No. 13-84, 2013; Balmori 2005, 2009; Balmori and Hallberg 2007; Everaert and Bauwens 2007; Engels et al. 2014; Wasserman et al. 1984; and Semm and Beason 1990).

In summary, we need to better understand, tease out, and refine how to address these growing and poorly understood radiation impacts to migratory birds, bees, bats, and myriad other wildlife. At present, given industry and agency intransigence (with the exception of the Interior Department and Department of Commerce both which are now beginning to address non-thermal radiation issues), massive amounts of money being spent to prevent addressing impacts from non-thermal radiation — not unlike the battles over tobacco and smoking — and a lack of significant, dedicated and reliable funding to advance independent field studies and better understand the etiology and consequences of impacts, we are left with few options. Currently, other than to proceed using the precautionary approach and keep emissions as low as reasonably achievable, we are at loggerheads in advancing meaningful guidelines, policies and regulations that address non-thermal effects. The good news: there appears to be an awakening at least within a significant segment the scientific community to the realization that these issues must be addressed — for the health of humans, wildlife and our environment — and DOI and the Department of Commerce are also beginning to address non-thermal effects to migratory birds.

Next Steps

The following suggestions would help significantly advance the need to address effects/impacts from non-thermal radiation on migratory birds and other wildlife:

- We desperately need to conduct field research on thermal and non-thermal radiation impacts to wild migratory birds and other wildlife here in North America, similar to studies conducted in Europe. Specifically, the research focus should center on causality for *"near-field," "far-field"* and *"intermediate"* effects, ideally based on some standard, agree-upon radiation metrics. The metrics need to be consistent with standards for intensity, carrier frequency, pulse repetition frequency, distance from the antenna, and similar factors. The research must be based on peer-reviewed monitoring and testing protocols (e.g., upgrades to the Manville 2002 peer-reviewed research protocol submitted to the U.S. Forest Service for studies on cell towers in Arizona, and key methodologies used in studies previously referenced in this memo, among others). The research needs to be conducted by credible, independent third party research entities with no vested interest in the outcomes, and the results need to be published in refereed scientific journals, made available to the public.

- Studies need to be designed to better tease out and understand causality of thermal and non-thermal impacts from radiation on migratory birds. Results need to be carefully compared with findings from Europe and elsewhere on wild birds, and efforts need to be made to begin developing exposure guidelines for migratory birds and other wildlife based on dose-effect and other nonlinear relationships. We do not actually need to know whether RFR effects are thermal or non-thermal to develop and set exposure guidelines (Levitt and Lai 2013).

- To minimize deleterious radiation exposures, these guidelines should include use of avoidance measures such as those developed by the electric utility industry for bird collision and electrocution avoidance (APLIC 2006, 2012) — both publications which I co-authored. In the case of Bald Eagles, the communication tower guidelines refined and updated by FWS (Manville 2013) — and submitted to the FCC and industry — recommend one-mile disturbance free buffers during active nesting of Ferruginous Hawks and Bald Eagles, and 0.5-mile buffers around other active raptor nests, based on nest studies conducted by the Wyoming Ecological Services Field Office in that State; Guideline #5). Impacts must address collision mortality, crippling loss, and injury; mortality, injury, population viability and survivorship based on impacts from radiation; as well as disturbance and habitat fragmentation. The updated 2013 Service Guidelines were intended to be inclusive.

- Studies need to be conducted on the use of "faux" branches (i.e., metal arms that mimic pine or fir branches) on cell and/or FM towers intended to disguise the towers as trees, but provide nesting and roosting opportunities for migratory bird including Bald Eagles, which will almost certainly be impacted both by thermal and non-thermal radiation effects. Additionally, birds such as Bald Eagles and others are subject to possible impalement from the sharp metal arms, with enhanced chances of injury and death due to disturbance from tower maintenance. Even if these "faux" branches are not constructed, Eagles for example tend to use the tallest objects available for roosting, so impacts from roosting, feeding and breeding on the antenna supports all must be considered by FCC and FWS.

- Agencies tasked with the protection, management, and research on migratory birds and other wildlife (e.g., FWS, U.S. Geological Survey, National Park Service, U.S. Forest Service, Bureau of Land Management, and USDA Wildlife Services, among others) need to develop radiation policies that avoid or minimize impacts to migratory birds and other trust wildlife species. This means supporting — and where applicable — conducting research, and developing policies that help minimize radiation impacts.

- As Levitt and Lai (2010) concluded, we do not actually need to know whether RFR effects are thermal or non-thermal to set exposure guidelines. Most scientists consider non-thermal effects as well established, even though the implications are not fully understood.

- Given the rapidly growing database of peer-reviewed, published scientific studies (e.g., http://www.saferemr.com, School of Public Health, University of California, Berkeley), it is time that FCC considers thermal and non-thermal effects from EMR in their tower permitting, and incorporates changes into their rulemaking regarding "effects of communication towers on migratory birds."

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