HR001120S0019-18: Impact of Cockpit Electro-Magnetics on Aircrew Neurology (ICEMAN)

MODERNIZATION PRIORITIES:
Biotechnology

TECHNOLOGY AREA(S):
Bio Medical, Human Systems

OBJECTIVE:
Determine if the current air combat cockpit environment impacts cognitive performance and/or physiological sensor performance; quantify the effects; and demonstrate potential mitigation strategies.

DESCRIPTION:
Current cockpits are flooded with radio frequency (RF) noise from on-board emissions, communication links, and navigation electronics, including strong electromagnetic (EM) fields from audio headsets and helmet tracking technologies. Pilots often report minor cognitive performance challenges during flight, and from 1993 to 2013, spatial disorientation in US Air Force pilots accounted for 72 Class A mishaps, 101 deaths, and 65 aircraft lost. It has been hypothesized that the cockpit RF and EM fields may influence cognitive performance including task saturation, misprioritization, complacency and Spatial Disorientation. However, EM fields and radio waves in cockpits are not currently monitored, little effort has been made to shield pilots from these fields, and the potential impacts of these fields on cognition have not been assessed.

Recent DARPA-funded research has demonstrated that human brains sense magnetic fields, like those used by animals for navigation, and that this process is "jammed" (i.e., disrupted) by radio waves (RF), impacting brainwaves and behavior. Furthermore, recent findings were the first to show that even weak RF fields and "earth strength" magnetic fields have measurable, reproducible effects on human brainwaves and unconscious behavior in a controlled environment. Current tactical audio headsets project magnetic fields up to 10 times earth strength, the effects of which can now be measured experimentally in a similar controlled environment. However, a need exists to assess these effects within a typical cockpit environment. Furthermore, as research efforts are increasingly seeking to assess aspects of human performance and cognitive state characteristics (e.g., cognitive workload, stress, and trust) within operational environments such as cockpits, a need exists to determine what effect, if any, the cockpit RF/EM environment may have on physiological sensor function and efficacy.

The DARPA Impact of Cockpit Electro-Magnetics on Aircrew Neurology (ICEMAN) STTR effort aims to 1) measure and manipulate the ambient EM field and RF noise in a typical cockpit, 2) measure potential effects of these electromagnetic stimuli on brain activity, physiology, and behavioral responses, and physiological sensing systems, and 3) demonstrate potential strategies to mitigate negative effects on aircrew neurology and sensor function.

PHASE I:
Demonstrate technical feasibility and proof of concept for measurement of EM fields and RF signals present in combat representative cockpits and empirical determination of potential impacts on aircrew neurology and physiological sensor performance. In Phase I, performers will be expected to investigate and provide a comprehensive summary of EM fields and RF signal equipment present in representative military cockpits, including Alternating Current (AC) and Direct Current (DC) EM fields from radar sources, active RF frequency bands, and signal intensity levels that are likely to exist in cockpit environments. If possible, performers are encouraged to collect initial representative measurements of fields and RF bands (i.e., 9 kHz - 1 GHz) for aircraft on the ground using existing and/or prototype sensing equipment (e.g., RF probes, spectral analyzers, search-coils, gauss meters). Due to the limited scope of Phase I no Government Furnished Equipment (GFE) will be provided but performers are encouraged to consider representative commercial aircraft (such as those with weather radars, typical avionics, and military-style helmets or headsets). The results of these measurements could be used to develop technical specifications for more sophisticated sensing equipment such as custom antenna systems to be developed in Phase II in support of more precise measurements. These measurements could also be used to develop a methodology for reproducing and modulating cockpit ambient EM/RF fields in a controlled laboratory setting such as an anechoic chamber. Finally, performers should develop a detailed methodology for how measurements will be conducted in Phase II, accounting for testing with and without human subjects, addressing considerations such as RF absorption by various tissues in the human body and brain.

At the end of Phase I, performers will need to demonstrate feasibility of conducting human subjects research (HSR) in both controlled laboratory settings and in real aircraft while controlling for confounding factors, particularly those present in live flight (e.g., gravitational loading, visual cues, geomagnetism, and stress). Detailed experimental design guidelines must be developed, and a draft Institutional Review Board (IRB) protocol should be outlined in the Phase I final report. A detailed protocol will be required as part of the Phase II proposal submission.

i. Schedule/Milestones/Deliverables Phase I fixed payable milestones for this program should include:

- Month 1: Conduct kickoff meeting and finalize Phase I work plan based on PM feedback
- Month 6: Submit report summarizing in-situ measurements of magnetic and RF fields of representative aircraft or aircraft equipment (headsets, helments, avionics equipment, etc.)
- Month 12: Complete development of Phase II methodology and submit Phase I Final Report

Phase I deliverables: Reports summarizing 1) Magnetic and RF fields present in cockpits, 2) Phase I in situ cockpit EM/RF measurements if available, 3) Phase II sensor suite technical specifications, 4) Phase II experimentation plan, 5) Phase II draft IRB protocol.

PHASE II:

Develop next generation sensor suite capable of measuring the ambient EM/RF conditions in a military aircraft cockpit environment or a suitably similar analogue. This system must enable measurement of RF intensity vs frequency as well as RF absorption by various tissues in the human body and brain. These measurements will also be used to develop a methodology for reproducing and modulating cockpit ambient EM/RF fields in a controlled laboratory setting such as an anechoic chamber. Performers will validate these same EM/RF signals and magnetic field stimuli on human subjects in a controlled experimental setting and utilize physiological sensing and behavioral assays to quantify effects of signals on human magnetoreception, sensory perception, cognition, and behavior. Any effects of these fields on physiological sensors must also be assessed and characterized. Phase II will include human subjects research (HSR) in both controlled laboratory settings and in real aircraft while controlling for confounding factors, particularly those present in live flight (e.g., gravitational loading, visual cues, geomagnetism, and stress). Data collection should include testing in militarily relevant aircraft on the ground, in live flight, with and without radar, and during typical air combat flight maneuvers. Data collection should include and control for typical cockpit equipment such as radio headsets and electronics. Over the course of Phase II, performers will refine models, requirements, EM/RF measurement and generation prototypes, and experimental interventions.

The goal of Phase II experimentation will be to, not only identify any impacts of the cockpit EM/RF conditions that negatively impact pilot cognitive function or physiological sensor function, but also to develop and test various mitigation strategies to protect against these effects. Potential mitigation strategies could include methods for EM/RF shielding and attenuation. Prototype shielding systems will have to be tested in highly controlled settings as well as in live flight tests, accounting for potential confounding factors.

i. Schedule/Milestones/Deliverables Phase II fixed payable milestones for this program should include:

- Month 1: Conduct kickoff meeting and finalize Phase I work plan based on PM feedback
- Month 2: Finalize experimental design and submit IRB protocol
- Month 6: Complete Phase II EM/RF sensor suite development and conduct EM/RF measurement data collection in representative aircraft on ground, in flight, and during flight maneuvers
- Month 9: Complete Phase II EM/RF generation system development and begin lab-based testing
- Month 12: Begin HSR experimentation in laboratory and ground-based cockpit settings
- Month 18: Provide initial experimental findings and recommendations for potential mitigation strategies
- Month 24: Provide demonstration and results of non-HSR mitigation strategy experimentation
- Option Month 36: Provide demonstration and results of HSR mitigation strategy experimentation

Phase II deliverables: Reports summarizing (1) EM/RF sensing prototype technical specifications and functionality testing results, (2) cockpit EM/RF measurement experimentation, (3) EM/RF generation prototype technical specifications and functionality testing results, (4) HSR and non-HSR experimentation protocols and results.

PHASE III DUAL USE APPLICATIONS:

If this research and development effort reveals negative impacts of cockpit EM/RF environments on human cognitive function or physiological sensor performance, it is expected to generate interest from the commercial airline industry as well as other industries in which humans are exposed to similar EM/RF conditions. DoD/military applications include protection of performance optimization of aircrew, as well as other DoD personnel exposed to similar EM/RF conditions. Moreover, any successful mitigation strategies will be applicable and of interest to both commercial customers and DoD acquisition partners.

REFERENCES:

1) Poisson, R.J. and M.E. Miller, Spatial disorientation mishap trends in the U.S. Air force 1993-2013. Aviat Space Environ Med, 2014. 85(9): p. 919-24

2) Foxe, J.J. and A.C. Snyder, The role of alpha-band brain oscillations as a sensory suppression mechanism during selective attention. Frontiers in Psychology, 2011. 2

3) Using reference models of the human head for RF measurements: Beard, B.B. and W. Kainz, Review and standardization of cell phone exposure calculations using the SAM phantom and anatomically correct head models. Biomedical Engineering Online, 2004. 3

KEYWORDS:

Psychology, Radiobiology, Anatomy and Physiology, Stress Physiology, Life Support Systems, Bioinstrumentation, Biological Instrumentation and Engineering

TPOC USERS:

None