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

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Briefing Prepared for STTR Proposers

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PM: Dr. Dan "Animal" Javorsek, Col, USAF

STTR OBJECTIVE

Determine whether the current air combat cockpit environment impacts pilot cognitive performance and/or physiological sensor performance; quantify the effects; and demonstrate potential mitigation strategies

PROGRAM OUTCOMES

- How this is currently done:
  - EM fields and radio waves in cockpits are not currently monitored
  - Little effort has been made to shield pilots from these fields
  - Potential impact of these fields on cognition have not been assessed
- Impact if successful:
  - From 1993 – 2013, Spatial Disorientation in US Air Force pilots accounted for 72 Class A mishaps, 101 deaths, and 65 aircraft lost
  - If RF and EM fields are shown to impact pilot cognitive performance, proper emissions controls could be used to mitigate these effects
  - Improved performance could give US pilots a competitive advantage

STTR MOTIVATION

- Recent research has demonstrated that human brains sense electro-magnetic (EM) fields, and that this process is "jammed" by radio frequency (RF) waves, impacting brainwaves and behavior
- Current cockpits are flooded with RF noise from on-board emissions, communication links, and navigation electronics, including strong magnetic fields from audio headsets and helmet tracking technologies
- These fields may influence cognitive performance including task saturation, misprioritization, complacency and Spatial Disorientation
- Pilots often report minor cognitive performance challenges during flight

PROGRAM OVERVIEW

- **Phase I:** Demonstrate technical feasibility and proof of concept for 1) measurement of EM fields and RF signals present in combat representative cockpits and 2) empirical determination of potential impacts on aircrew neurophysiology and physiological sensor performance
- **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
- **Phase III:** Transition successful mitigation strategies and technologies to both commercial customers and DoD acquisition partners

ICEMAN – Heilmeier Questions

H1: What are you trying to do?

- Determine whether the current air combat cockpit environment impacts pilot cognitive performance and/or physiological sensor performance; quantify the effects; and demonstrate potential mitigation strategies

H2: How is it done today, and what are the limits of the current practice?

- EM fields and radio waves in cockpits are not currently monitored
- Little effort has been made to shield pilots from these fields
- Potential impact of these fields on cognition have not been assessed

H3: What's new in your approach and why do you think it will be successful?

- ICEMAN will empirically determine whether ambient magnetic fields and RF noise in a typical cockpit environment have an impact on pilot cognitive performance, and whether potential effects can be mitigated
- 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

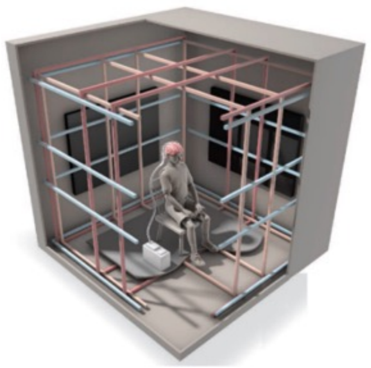
H4: Who cares? If you are successful, what difference will it make?

- From 1993 – 2013, SD in US Air Force pilots accounted for 72 Class A mishaps, 101 deaths, and 65 aircraft lost
- If RF and magnetic fields are shown to impact pilot SD or cognitive performance, proper shielding could be used to mitigate these effects, and resulting improved cognitive performance could give US pilots a competitive advantage
- 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

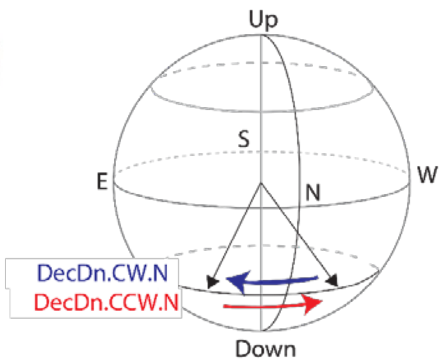
H5: What are the risks? What are the mid-term & final exams?

- Risks: This exploration may determine that the magnetic field and radio wave environment of military aircraft cockpits has no quantifiable or reproducible effect on pilots and aircraft crew, negating the need for further work in this area
- Exams: Demonstration of accurate quantification of ambient magnetic field and RF noise in a typical cockpit, demonstration of reproducible effects of these electromagnetic stimuli on brain activity, physiology, and/or behavioral responses, and demonstration of mitigation strategies

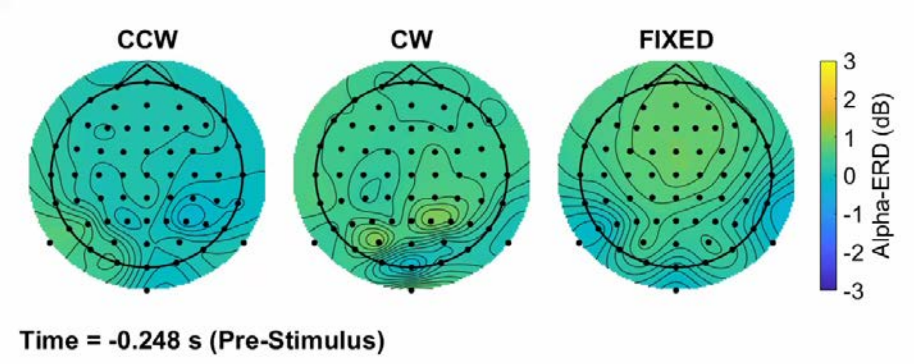
DARPA Prior Research in Human Magnetoreception



Experimental Chamber



Magnetic Field Rotations

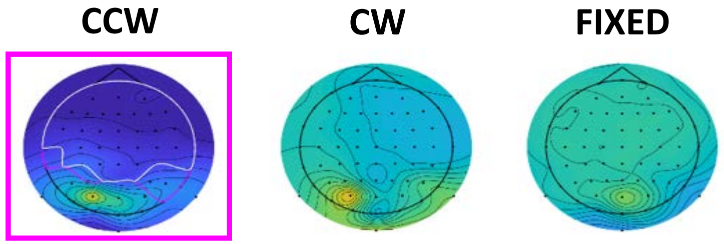


EEG Alpha Wave Response (Alpha-ERD)

Key Finding: Human brains respond to geomagnetic stimuli, as shown by a strong, repeatable drop in amplitude of EEG alpha waves (8-13 Hz) following magnetic field rotation.

"Transduction of the Geomagnetic Field as Evidenced from Alpha-band Activity in the Human Brain," Wang et al., *eNeuro*, March 18, 2019

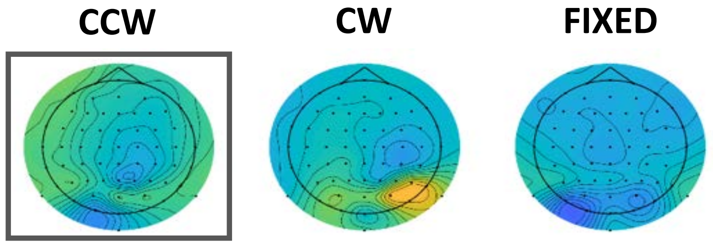
Follow-on results: Preliminary data showed that continuous RF exposure inhibited a polarity-sensitive magnetic response in human brain. DARPA RadioBio study funded to explore magnetoacoustic mechanism of RF absorption by magnetite and transduction through ultrasound-activated ion channels.



RF_Off
t = +0.5 s
Significant Response

VS

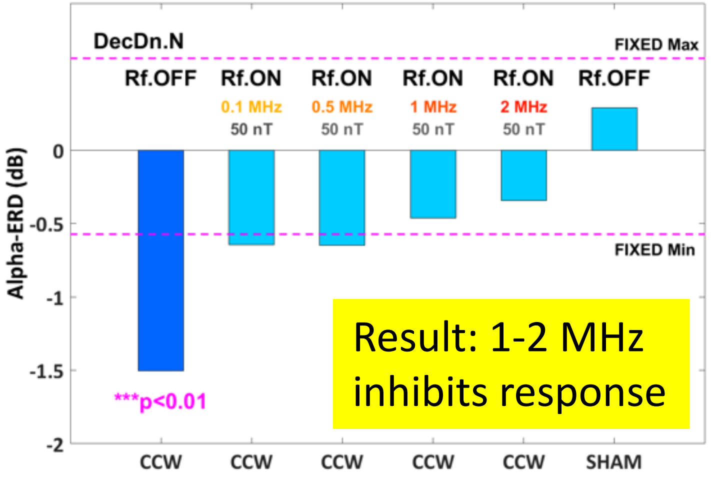
RF_On
t = +0.5 s
Response Inhibited



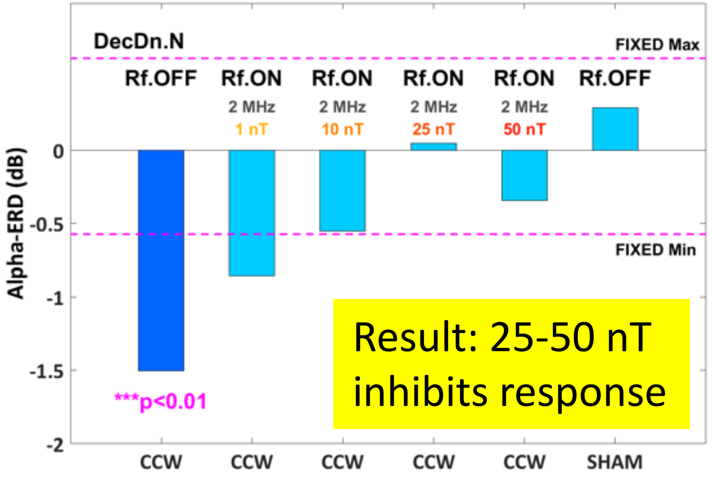
DARPA RadioBio Approach: Test for RF inhibition of human magnetoreception using (1) model-predicted RF parameters for exposure and (2) improved experimental/analytical methods from published study.

RF Inhibition of Human Magnetoreception

RF Test #1 (N = 1): Vary RF freq at constant amp



Rf Test #2 (N = 1): Vary RF amp at constant freq



Outcome:
Identified RF frequency and amplitude ranges strongly inhibiting magnetic response

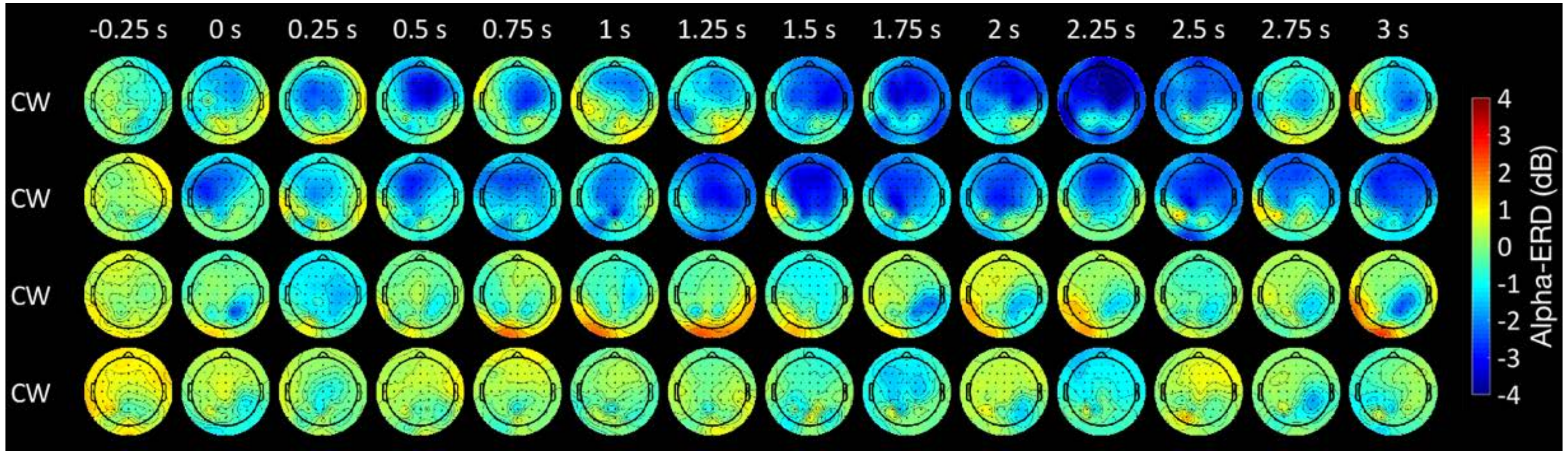
RF Test #3 (N = 1): Varying amplitudes (No RF, 0.1 nT, 1 nT, and 10 nT) at 10 MHz

RF_Off

RF_On: 10 MHz, 0.1 nT

RF_On: 10 MHz, 1 nT

RF_On: 10 MHz, 10 nT



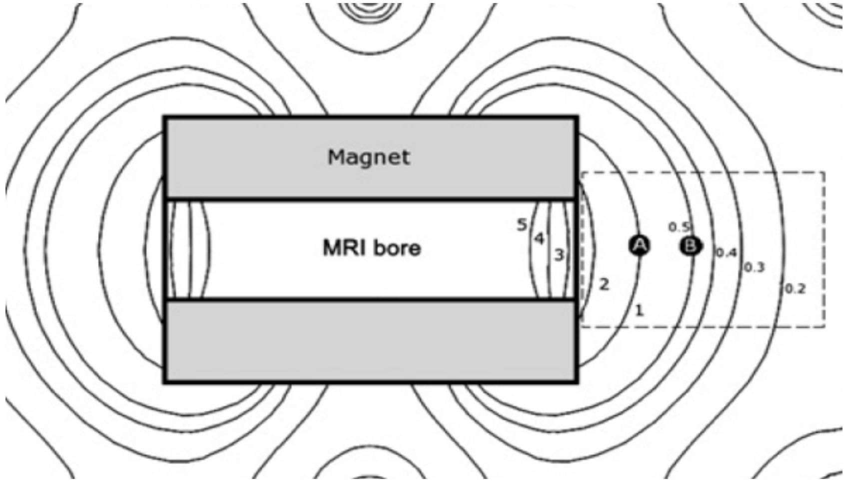
Outcome of Group Level Testing:

- RF Exposure #1: **2 MHz, 50 nT** to establish RF reception in human brain
- RF Exposure #2: **10 MHz, 1 nT** to test RF reception at low amplitude and higher frequency

Military Relevance

- Headsets and helmets in military and commercial aircraft generate magnetic fields of > 10 x Earth's field through the center of pilots' heads

- Pilot cognitive impact of such fields is unknown and may include changes to pilot sensory perception (including spatial orientation) and implicit behavior



Top view map of the 7 T MRI with calculated field lines of the static magnetic stray field Dots represent the positions of the subject for the exposure conditions. (Credit: L.E. van Nierop et al./Occup Environ Med)

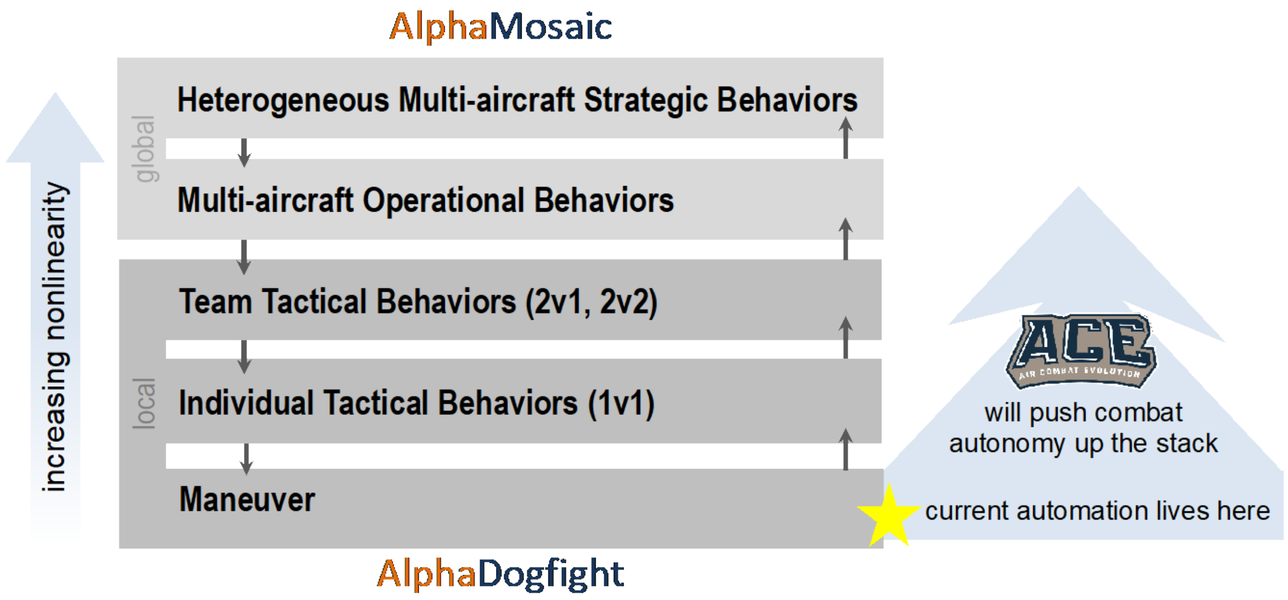
- MRI scanners apply intense static magnetic fields coupled with RF pulses in the 10 – 300 MHz range

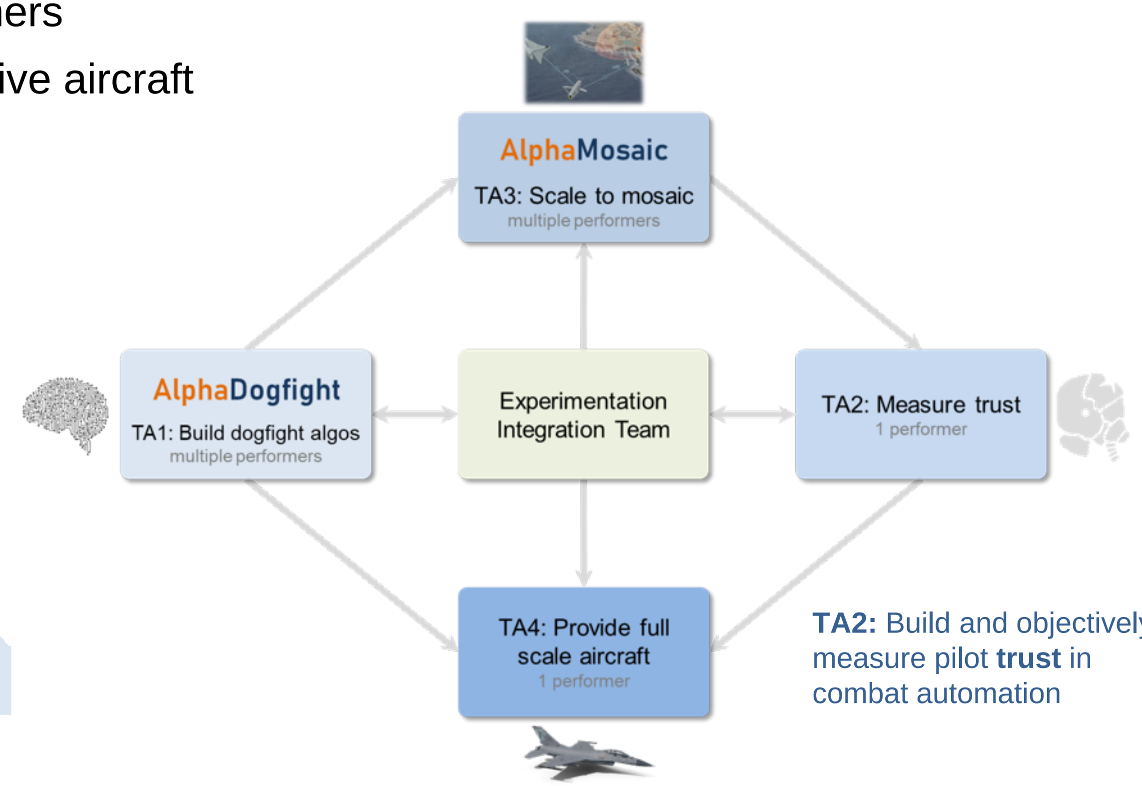
- Preliminary RadioBio MRI/magnetoreception case study demonstrated that MRI exposure disabled response to magnetic stimuli in participant for up to a full year (N = 1)

Relationship to PM Portfolio

- The ICEMAN STTR has the potential to impact and benefit from the Air Combat Evolution (ACE) program
- ACE objective: Demonstrate trusted, scalable, human-level autonomy for air combat, focusing on Within Visual Range (WVR) dogfighting artificial intelligence (AI), and scaling up to “Mosaic” warfare tactics
- ACE consists of 4 Technical Areas (TAs): AlphaDogfight (TA1), Trust (TA2), AlphaMosaic (TA3), Aircraft (TA4)

- TA2 involves air combat pilot physiological measurement to assess trust in the ACE dogfighting AI
  - ICEMAN will support ACE TA2 by assessing cockpit EM/RF impact on physiological sensor performance
  - Mature ICEMAN technologies may transition to ACE partners
  - ACE may enable access to pilots and combat representative aircraft





TA2: Build and objectively measure pilot **trust** in combat automation

Pre-Release One-on-One Phone Calls with PM

- Potential performers interested in scheduling a 15 minute one-one-one call with Dr. Javorsek should contact Ms. Jane Kim: jane.kim.ctr@darpa.mil

- Technical and programmatic questions can also be submitted to Dr. Anna Skinner: anna.skinner.ctr@darpa.mil