Innovation Award

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Auditory Systems Lab

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Innovation:
A Test Battery for Effects of Hearing Protection on Auditory Situation Awareness: **"DRILCOM"**

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MY PLEA: Could we spend >10% of the time on development of the ASAF as we have on the NRR and its more recent aliases?

Auditory Situation Awareness Factor

A performance rating scheme needed for HPEDs & TCAPS and a "stimulus" suggestion to start:

ASAF = DRILCOM

ASAF = f(D , R-I , L , COM)

D: Detection
R-I: Identification / Recognition
L: Localization
COM: Communication

MOTIVATIONS FOR THE INNOVATION

1. **NIHL and tinnitus** are the most common disabilities reported by the Veterans Administration, with expenses >$1.2 billion/yr and $135 million spent on hearing aids alone in 2009 (VA Admin Office of R&D, 2010).
2. **Loss of Auditory Situation Awareness** can result in severe injury or death when threats, critical audio signals, or communications are unheard, unidentified, or non-localizable, especially to military personnel, first responders and workers in dynamic environments such as road construction.
3. **Compromised Tactical Ability, Survivability and Lethality** pose a liability to one's safety as well as that for other personnel. This stems from permanent hearing loss, AND/OR Situation Awareness loss.

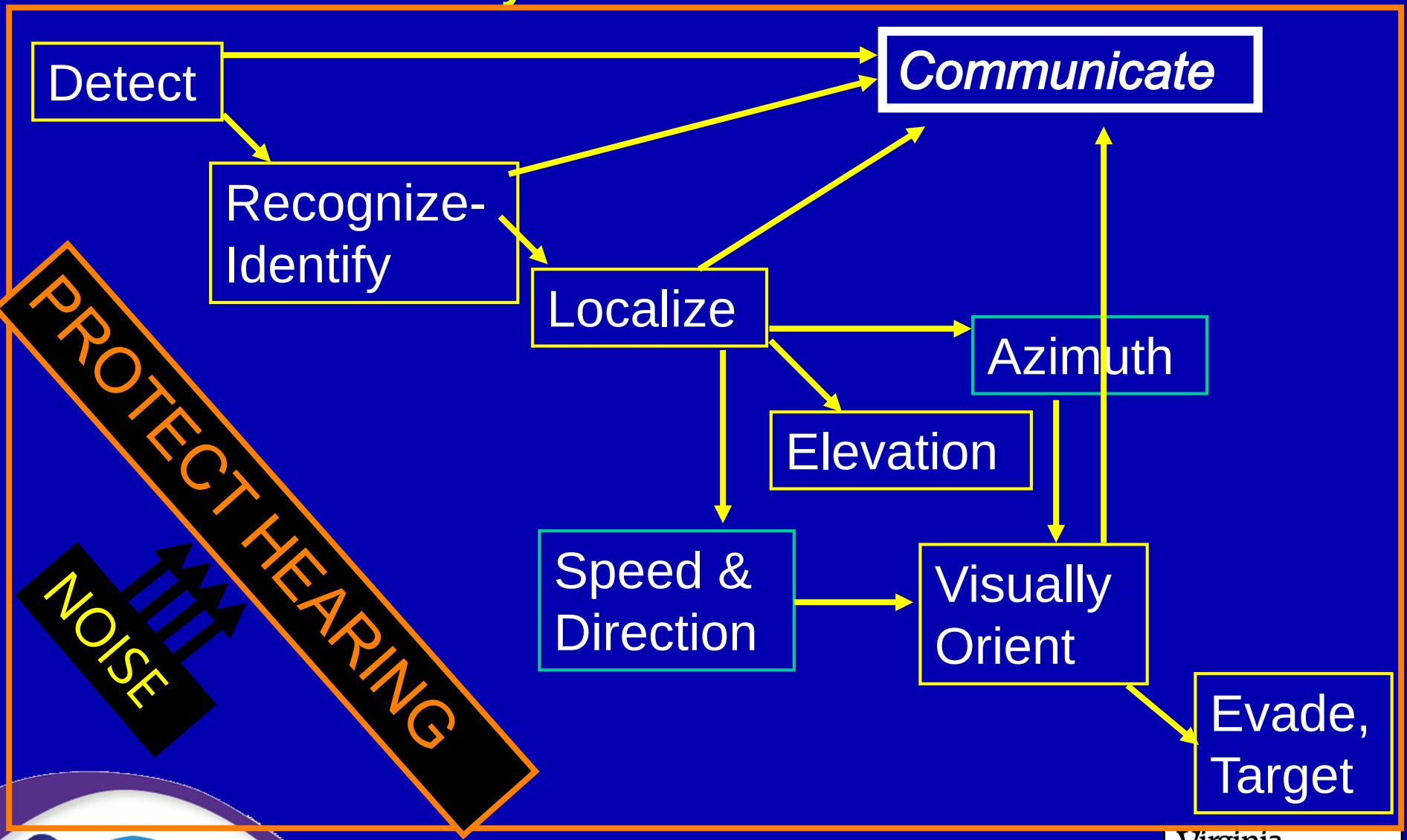
MAJOR CONTRIBUTIONS OF THE INNOVATION

- Use of the DRILCOM test battery will accrue to the prevention of NIHL and tinnitus by rendering deployed HPDs and TCAPS which are more user-acceptable in terms of their capabilities for providing Auditory Situation Awareness.
  - If a soldier or worker believes that a protector is compromising his/her ability to hear critical sounds or communications, particularly those with life-threatening implications, they will remove the protector even in the face of hazardous noise exposure including gunfire.

3 Major Beneficiary Groups for Situation Awareness Testing and Design Improvements

- **Military personnel**, including combat soldiers as well as other operations support personnel, whose lives are often at stake when their hearing of auditory threats, signals and communications, etc. is compromised.
- **Civilian workers in dynamic environments,** such as road construction, railroads, or near material handling equipment, who must avoid/evade moving vehicles and other equipment.
- **Civilians in recreational settings,** who may need protection or earphones for hunting, ATV operation, jogging, and spectator events, while having the need for situation awareness to facilitate their activity and their safety.

LEADING UP TO THE INNOVATION:
A Systems View of Human Tasks that support Auditory Situation Awareness



FINAL Virginia Tech Auditory Situation Awareness Test Battery
based on the DRILCOM Framework*

4 Individual Hearing Task Elements Tested:

ASAF = f(D , R-I , L , COM)

Detection
R-Identification
Localization
COMmunication

*Developed for the U.S. DoD Hearing Center of Excellence.

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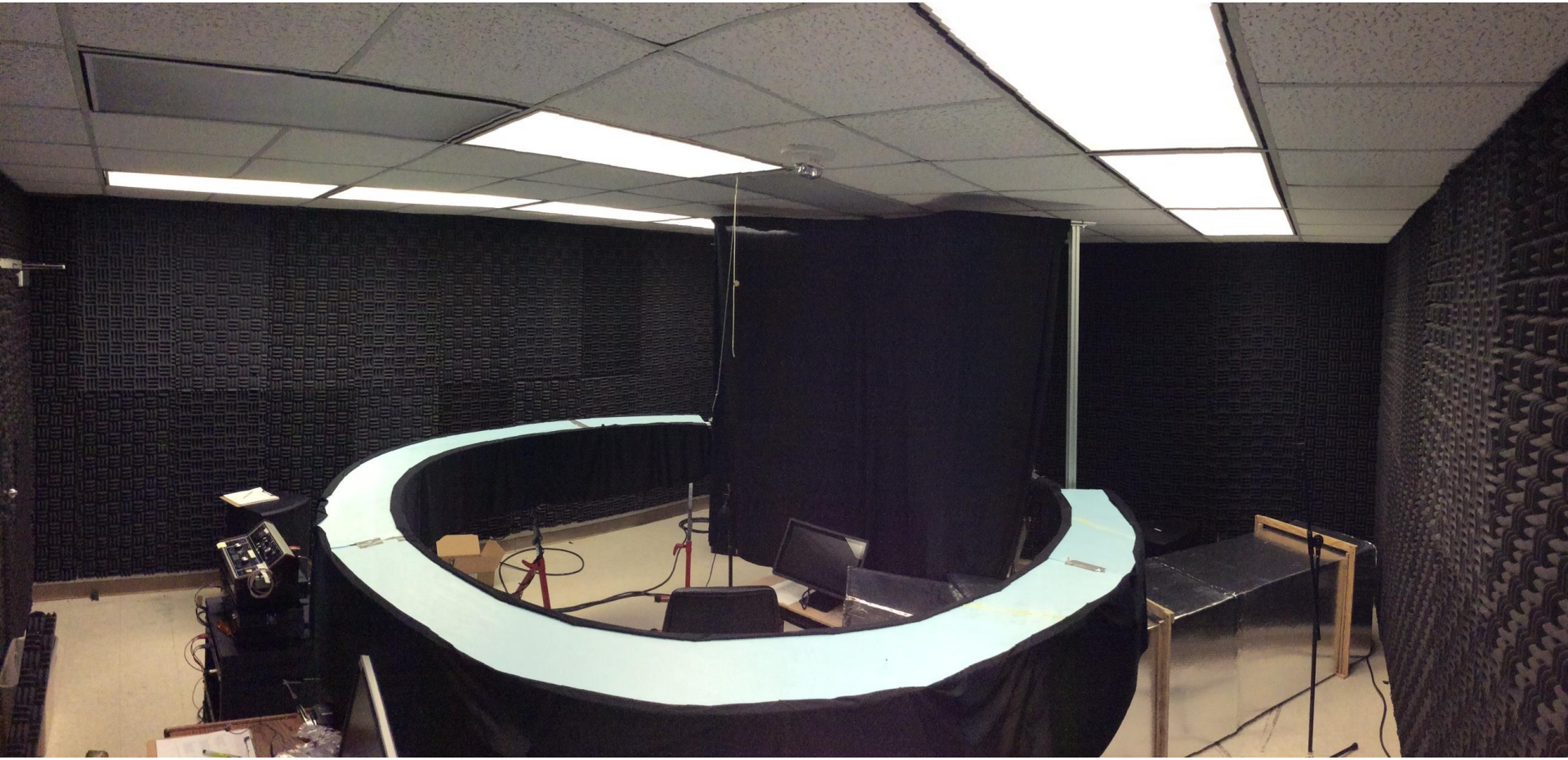
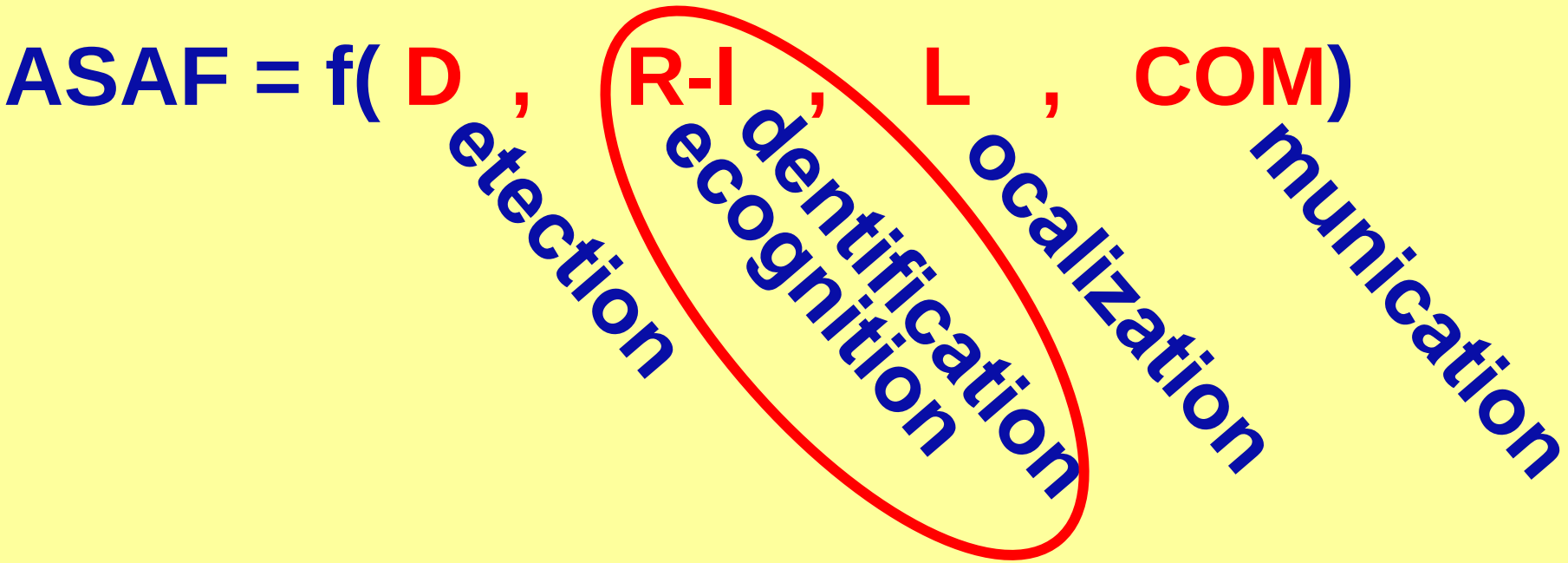
DRILCOM Auditory Situation Awareness
Hemi-Anechoic Test Room



Localization test azimuthal speaker ring and frontal elevation speakers under curtains; wind noise generator to right.

EXAMPLE
of
1 of 4 Subtasks in the DRILCOM Framework:

Recognition/Identification



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Examples of Signal Forced Choice Triads
(subjects trained to listen to all 3 signals, then pick the position of the target signal)

- SNR: -10, 0, 10
  - Signal at 70 dBA; pink noise was 80, 70, 60 dBA
- Vehicle noise
  - Military tank track noise
  - Heavy truck driving in and stopping
  - Jake (engine compression) brake
- Gunshot noise
  - Handgun firing with a silencer
  - Semi-automatic pistol shots
  - Incoming mortar shell






R/I: Examples of Signal Forced Choice Triads

(subjects listened to all 3 signals in a Triad, then pick the position of a stated target signal)

- SNR: -10, 0, 10 for all Triads
  - Signal at 70 dBA; pink noise was 80, 70, 60 dBA
- TRIAD: Footsteps sound
  - Footsteps in snow 
  - Footsteps in leaves 
  - Footsteps in gravel 
- TRIAD: Gun cocking sounds (high-freq clicks, pops)
  - AK-47 being cocked 
  - Bolt action rifle being cocked 
  - Jackhammer working 

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Localization Test Subtasks

- Stimulus signal included interaural time cues (<1000 Hz) and interaural level cues (>3000 Hz)
  - frequencies spanned 100 – 8000 Hz:
    - 104, 295, 450, 737, 2967, 4959, 7025 and 7880 Hz
  - slight frequency offset was to yield aural dissonance
  - 1 second duration
  - Background pink noise of 40 dBA and 75 dBA
    - Signal: low (50 dBA), high (85 dBA); S/N fixed at +10
- Two-part test:
  - 360° azimuth with speakers at 30° separation, dummy targets in-between (12 speakers, 24 targets)
  - Frontal elevation test with speakers separated at 0°, 330°, and 30° in azimuth, and 0, +30° in elevation with dummy targets at +15° and 45° in elevation (6 speakers, 12 targets – see schematic slide)

QuickSIN Test for COMmunications Testing

- Pass-through sound transmission testing only.
  - Radio communication is covered by other MIL-STDs (e.g., 1472G, Sec 5.3.1.6, 5.3.1.8.1; 1474E, 4.3)
- Typical scenarios for adjacent pass-through communications:
  - Listener and speaker in quiet.
  - Listener and speaker in noise.
- QuickSIN:
  - It measures SNR loss at different, pre-recorded S/N ratios (includes the talker's voice in quiet and in noise).
  - Prior used by AFRL in Whispr report (2008) on TCAPS testing.)
  - Efficient and easily calibrated.

"Proof-of-Concept" Experiment was performed using DRILCOM

- To ascertain the **sensitivity** of DRILCOM to inter-device and device vs. open-ear changes.
- To ascertain the ASA **diagnosticity** of DRILCOM in different ASA tasks.
- To determine whether DRILCOM's independent variable conditions, and measurements obtained, yielded statistical-significance with a small subject sample.
- Dr. Kichol Lee was experimenter on all test conditions.
  - 700 total test conditions run.

Hearing Condition Variable (Devices) for DRILCOM Experiment

Peltor ComTac III™

INVISIO X50™

Honeywell QuietPRO+™

Etymotic EB15LE™

Combat Arms™

Plus the OPEN EAR for comparison.

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DRILCOM Proof-of-Concept Experiment:

All 4 Subtests were investigated
with 5 devices and the Open Ear.

Objective performance measures were specific
to each of the 4 subtests.

Measures also included
"% worse/better than open ear" in all cases
to provide a robust, common-ground metric.

DRILCOM Proof-of-Concept Experiment:

Final Report with Data Set
was submitted to
DoD Hearing Center of Excellence
in early January, 2016

Release of full set of performance results will be a DoD decision.

Overall, the DRILCOM test battery showed high sensitivity to auditory situation awareness performance differences between devices, and between devices and the open ear, with statistically-significant discriminations.

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FUTURE OF THE INNOVATION: Recommendations for DRILCOM application

- To thoroughly evaluate advanced HPDs and TCAPS prior as to ASA effects, ***prior to*** their selection and deployment.
- To provide an objective means for feedback into the design and development cycle, guiding manufacturers and providing in-process checks-and-balances.
- To match an advanced HPD or TCAPS to specific Military Operational Specialties (MOS) requirements or Mission Tactical Requirements (MTR), or hearing critical industry jobs.
- Because DRILCOM consists of 4 orthogonal, independent tests, stimuli and conditions can easily be modified to better represent certain hearing critical job requirements.
- DRILCOM could be applied as a training tool for personnel ASA training, with further development.

FUTURE OF THE INNOVATION: Recommendations for DRILCOM application

- The DRILCOM Final Report, submitted to the DoD Hearing Center of Excellence in January, 2016, includes individual product test results from the proof-of-concept experiment. We've requested that it be disseminated to manufacturers, *if not military-restricted.*
- With considerable additional work and careful military criteria-setting, minimum performance requirements perhaps could be established for different classes or types of HPDs and TCAPS.
- Discussions have begun regarding whether a DRILCOM-like test for Auditory Situation Awareness should be moved toward a formal Standard. At least one Program Manager has proposed that.

DRILCOM Test Battery System Cost Estimate

- TDT equipment for Detection and Localization tests: $4000
- CD player, audiometer, etc. for COMmunication test: $2500
- COM microphone & recorder $800
- Signal Speakers (w/ integral amps): $2000
- Background noise system (power amp, loudspeakers): $4400
- Audio rack with patchbays: $600
- PC with two monitors (experimenter & subject): $2000
- Sonex™ 3-in foam for walls (630 sq ft) $2500
- Custom-fabricated steel mounting structure: $1500
- Daily Calibration equipment (RTA & mics): $8000
- **Total: $28,300**

**Does not include labor cost for VT-ASL custom-programmed LabView and MatLab software.*

DRILCOM Test Battery Testing Time (per subject, for 1 device and open ear)

• Screening/qualification	**60 min**
• **D**etection test:	**80 min***
• **R**ecognition**/I**dentification test:	**20 min**
• **L**ocalization test:	**20 min**
• **COM**munication test:	**20 min**
• **Total time:**	**140 min**

*Detection test time can be shortened considerably if number of source directions is reduced.

WHERE DOES THE INNOVATION STAND?

- The HPD & TCAPS performance data are now in from several studies, and some warrant serious concern – we as hearing conservationists have responsibility to collectively address this fact,
- An objective, device-sensitive, repeatable ASA test battery is now available,
- Comprehensive stimulus materials, protocols, and parameter-specific measures are in place,
- Hardware and audio apparatus for the battery is configured, some available off-the-shelf,
- The tests are largely automated via software control/scoring programs,
- Proof-of-concept data are in hand for DRILCOM,
- **Therefore, we offer DRILCOM for evaluating HPDs and TCAPS for Auditory Situation Awareness effectiveness.**.

Special Thanks to:

DEPARTMENT OF DEFENSE
HEARING CENTER OF EXCELLENCE

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Thanks to Research Sponsors & Collaborators

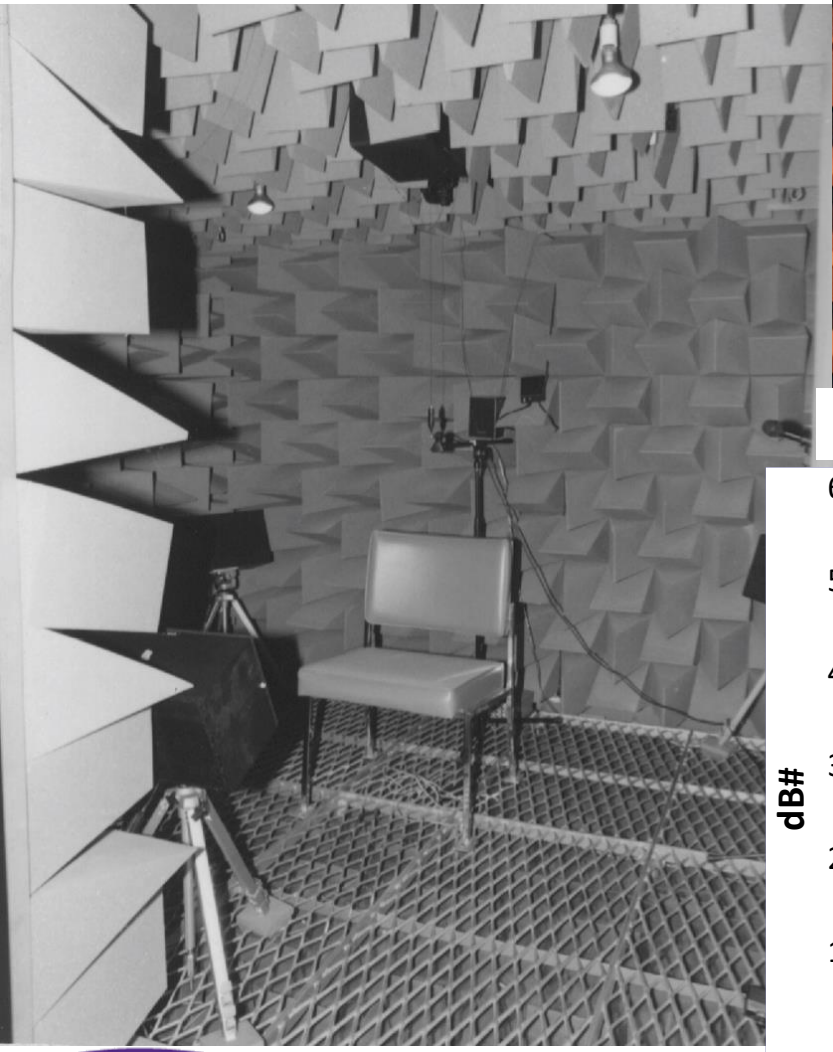
Auditory Situation Awareness & DRILCOM:

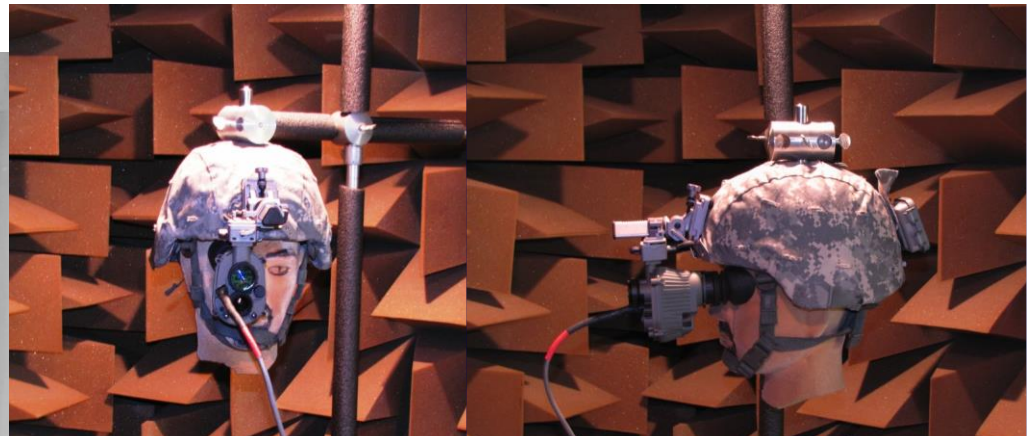
- DoD Hearing Center of Excellence, COL Mark Packer, Executive Director
- Office of Naval Research, Kurt Yankaskas, Program Mgr.
- NIOSH

Other Major Areas:

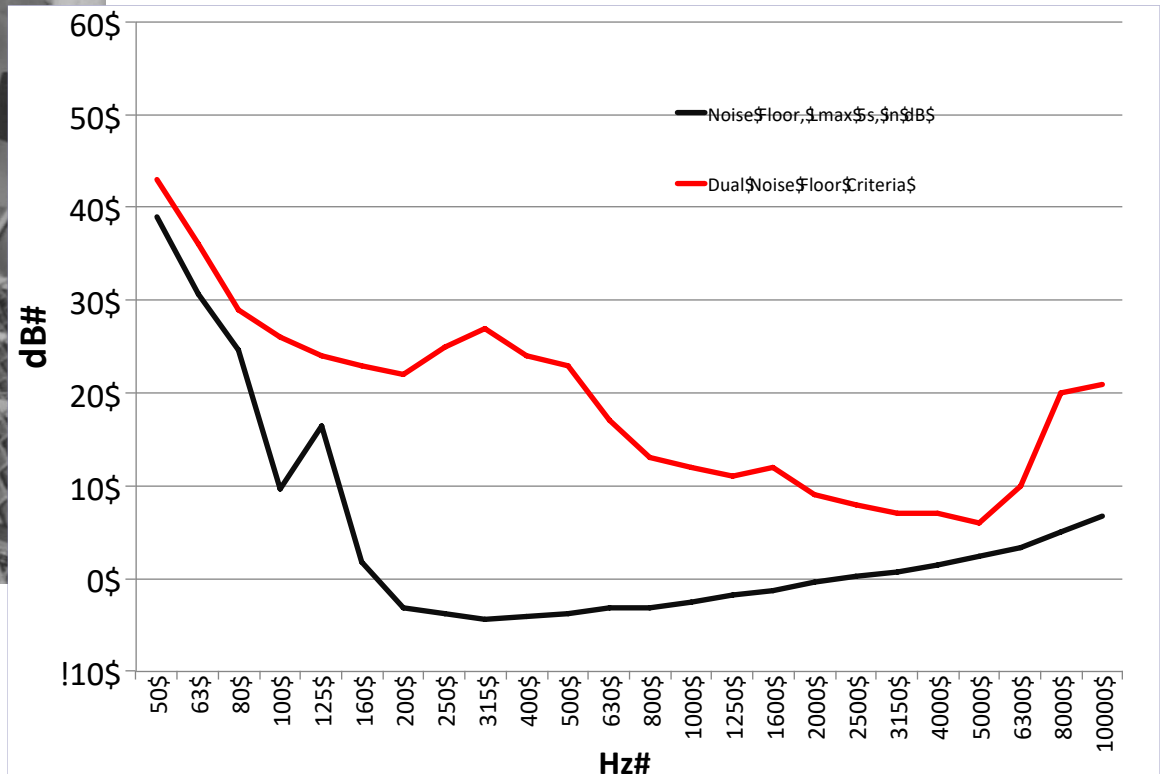
- Dan Gauger, BOSE Corp.
- Mead Killion, Etymotic Research, Inc.
- Jeffrey Goldberg, Custom Protect Ear
- Elliott Berger, AEARO-3M
- Bill Ahroon, U.S. Army Aeromedical Research Lab
- Lynne Marshall & Jeremy Federman, U.S. Navy Submarine Medical Research Lab
- Alton Burks, U.S. Bureau of Mines

Anechoic Chamber for Aural NonDetectability and Speech Intelligibility Experiments





Night Vision Goggle: Nondetectability (Stealth) Testing



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VT-Auditory Systems Lab: Team Members

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Kichol Lee, Ph.D., Research Professor & Research Manager of Auditory Systems Lab

John P. Keady, Ph.D., J.D., Adjunct Research Scientist of Auditory Systems Lab; external Ph.D. advisory committee member

Numerous doctoral and master's students in Human Factors Engineering

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