SBIR PHASE II · IN-HELMET NOISE DOSIMETRY

FROM ESTIMATES TO ACTUALS

Integrated in-helmet noise dosimetry for military aircrew hearing conservation programs

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DISCLOSURE

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AGENDA · LEARNING OBJECTIVES

WHAT WE'LL COVER

01 **Operational gap:** Protection estimates VS objective at-ear exposure monitoring

02 **Validation:** Measured dosimetry vs. reference equipment…lab and in flight

03 **Operational impact:** Mission effectiveness, comfort, health & readiness

LEARNING OBJECTIVE 01

Describe how integrated in-helmet noise dosimetry addresses the gap in objective at-ear exposure monitoring for military aircrew hearing conservation.

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CURRENT STATE · THE ESTIMATE STACK-UP

TODAY, "PROTECTION" IS A SERIES OF ESTIMATE

Helmet/passive cup attenuation

Ear-plug protection

Platform noise levels

Exposure time & flight profiles

Crew position

Accumulated variability of uncertain protection **is enormous** — and devastating over time.

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"ESTIMATED" EFFECTIVENESS · INSERTED DEVICES

EAR PLUGS — OF EVERY TYPE

They deliver huge variability in both protection and comfort

FOAM PLUGS

Notorious for poor insertion and protection, occlusion of comm clarity, and aircrew discomfort. (Navy 2004/5 Flight Deck Survey)

CEPS

Comfort and insertion similar to foam. Adequate for comms but risky — can work out on mission.

CUSTOM MOLDED

"Better" insertion results — but worse attenuation results than CEP's or properly inserted foamies (USAARL and AFRL study data).

These devices **don't provide repeatable, trusted protection** across the range of high-noise applications!

AFTER DECADES OF MANDATED USE

HERE'S WHAT WE ACTUALLY KNOW

PROTECTION

Inserted ear devices provide a **highly unpredictable** level of additional protection in a noise environment.

EXPOSURE

We know **very little** about the variable mission noise driven by platform, mission length, and flight profiles flown.

 # 1 **Hearing loss & tinnitus remain the top disability in the VA.**

So — what might we start doing with **actual noise-exposure data** for every airman, on every mission, in every position, in every platform?

THE OPPORTUNITY · WITH ACTUAL DATA

WHAT "ACTUALS" WOULD LET US DO

01 **Verify expected protection** – by helmet type, confirm each crewmember's passive + active attenuation every flight

02 **Learn mission-profile dependencies** – warfighters don't lose hearing in combat; they lose it in training.

03 **Reduce double protection** – Pilots HATE wearing plugs!! Allow many missions without it, still monitoring for overdosing

04 **Inform crew-cycle & rest** – targeted noise "rest" mitigates damage for overdosed fighters.

Use actual noise data to **protect long-term hearing health** while learning to manage noise exposure across the training space.

LEARNING OBJECTIVE 02

Analyze the correlation of in-helmet dosimetry against against **standard reference dosimeters** — across across controlled laboratory and operational flight- flight-test environments.

A MULTI-PHASE PLAN TO PROVE THE CONCEPT

THE SYSTEM

An integrated noise-dosimetry system inside an ANC-based earcup — analyzes data in real time, stores or streams to memory, and monitors noise both at the ear and in the environment.

01 Component characterization

Microphones & speakers

02 Sub-assembly testing

Earcups, faceplate and cavity

03 Full system integration

ANC hardware and On-board DSP

04 Lab testing and flight trials

Correlate to reference dosimeters

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COMPONENT · SUB-ASSEMBLY · SYSTEM VALIDATION

CHARACTERIZE EVERY ELEMENT

MICROPHONES

Sensitivity, frequency response, far-field accuracy, overload limits

Unit-to-unit variability vs. reference microphones

DRIVERS

Frequency response, distortion, earcup performance

Variability and behavior in sealed vs. open conditions

EARCUPS

Transfer functions (driver → mic, driver → ear)

Seal, cavity acoustics & mic placement effects

Passive response, ANC interaction, comm-signal impact

Why? Understand commercial components vs. lab-reference component variation — defining system responses that afford **Acoustic Response Correction Factors (ARCF)** .

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COMPONENT · SUB-ASSEMBLY · SYSTEM VALIDATION

CHARACTERIZATION RESULTS

MICROPHONES

Internal (at-ear) microphone

- Highly consistent → single-point calibration sufficient

External microphone

- Accurate at low frequencies; less accurate at high frequencies
- May require multi-point, frequency-dependent calibration

DRIVERS

Low variability and distortion → minimal impact on dosing accuracy

EARCUPS

Transfer functions (driver → mic, driver → ear)

Seal, cavity acoustics & mic placement effects

Passive response, ANC interaction, comm-signal impact

SYSTEM IMPLICATION

Standard ANC calibration provides a strong foundation for an integrated ANC-based dosimetry system, with only minor residual errors requiring ARCF correction.

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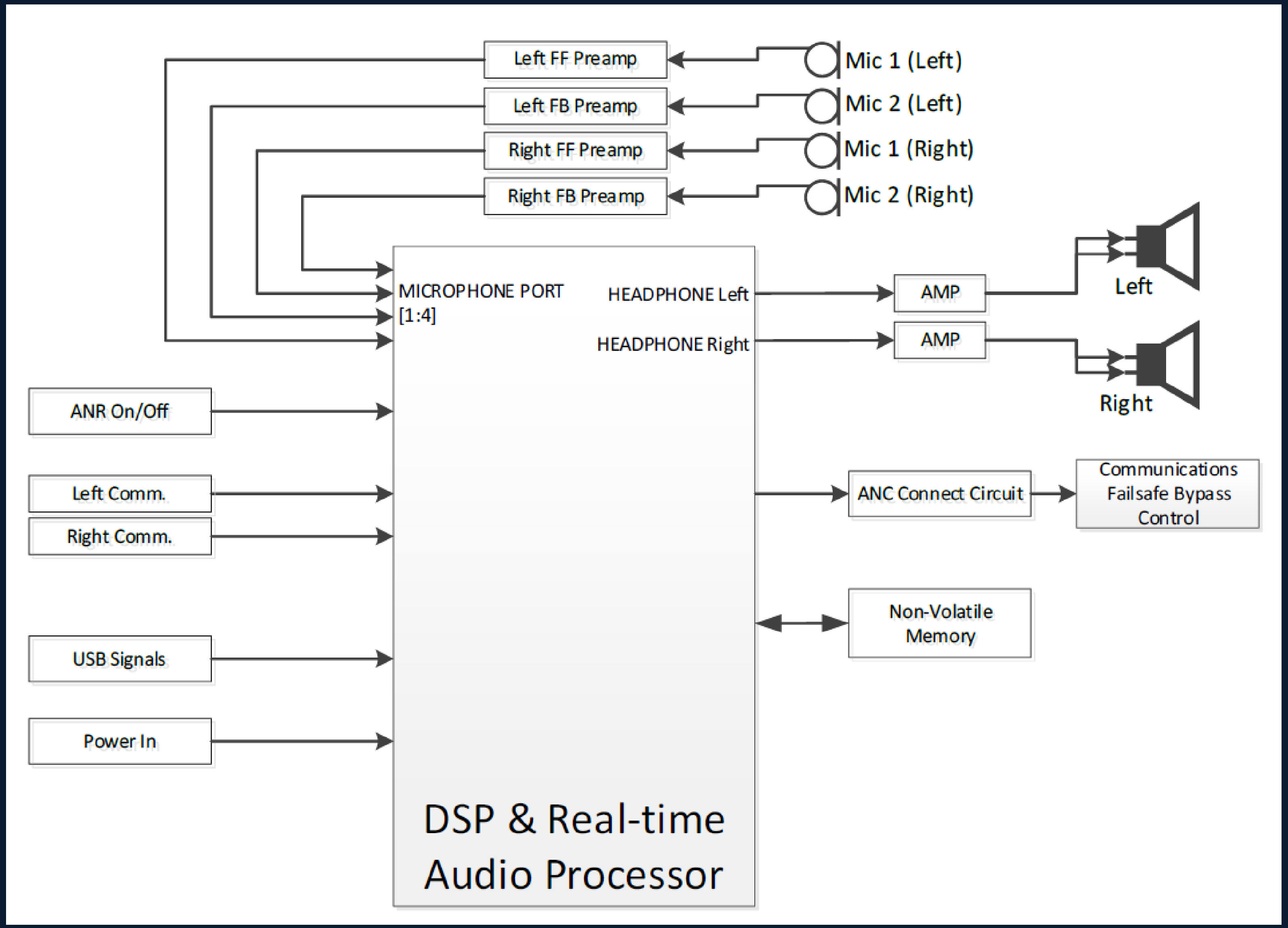
Key Hardware and Software Design

Acoustic System Design



- **Proven Hardware architecture** – based on COTS
- **Feed forward microphone** environment measurements*
- **Feedback microphone** at the ear measurements
- **Integrated Communications** can collect impact of system Communications

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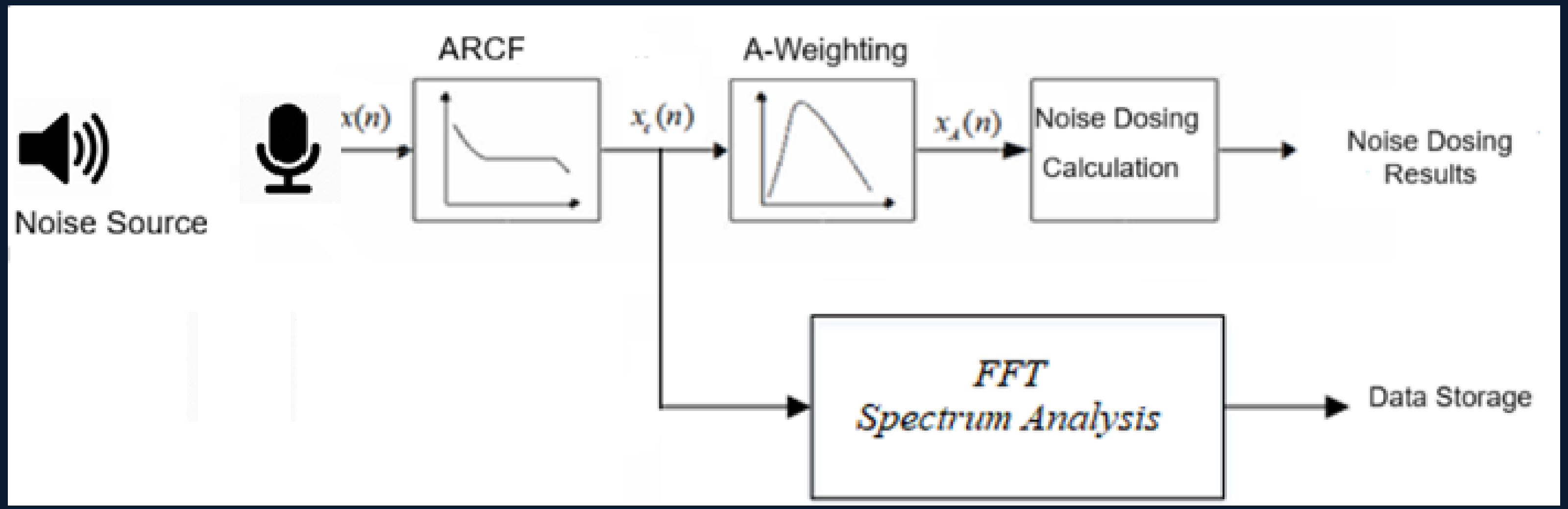
Key Hardware and Software Design

Software System Design



- **Alternating collecting & averaging data over 1 min**
  - At-ear and environmental metrics per side
- **Metrics saved per interval**
  - Dosing metrics (Noise level, Dose, Peak SPL, etc.)
  - Frequency spectrum
- **Impulse noise captured** contribution increment reduced

IN SCOPE · THIS PROGRAM

CONTINUOUS NOISE

Steady-state platform and mission exposure — the dose that accumulates over hours of flying. This is what in-helmet dosimetry measures.

OUT OF SCOPE · HERE

IMPULSE NOISE

Weapons fire and blast — a fundamentally different, high-peak measurement problem addressed separately.

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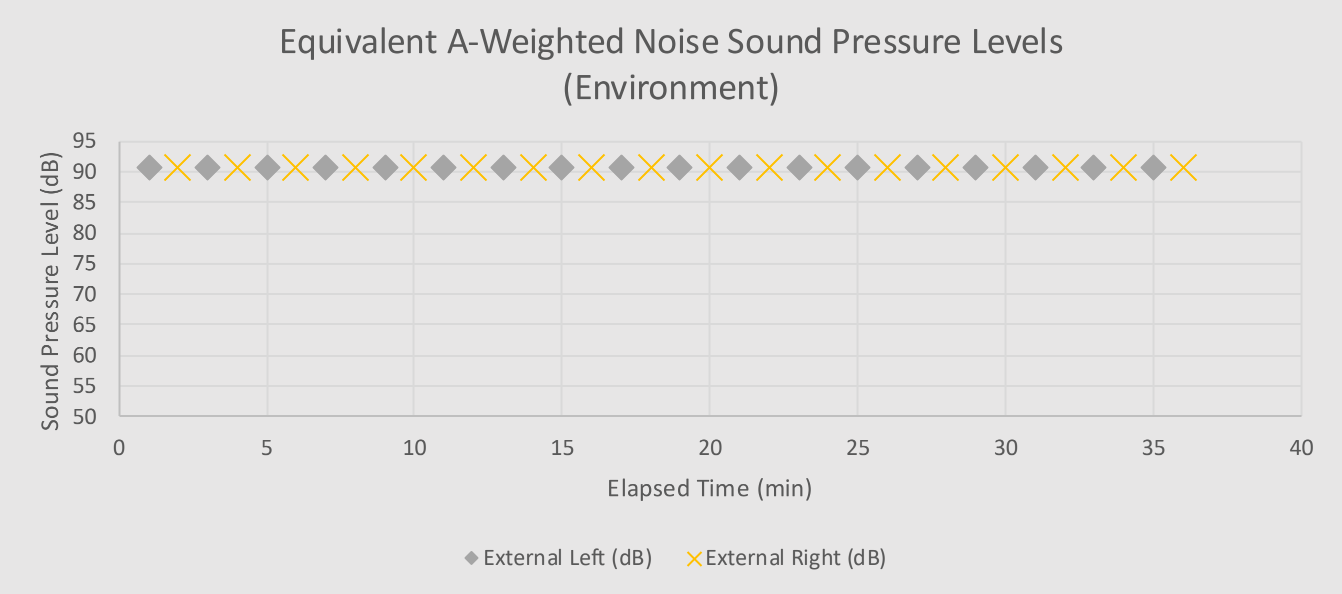
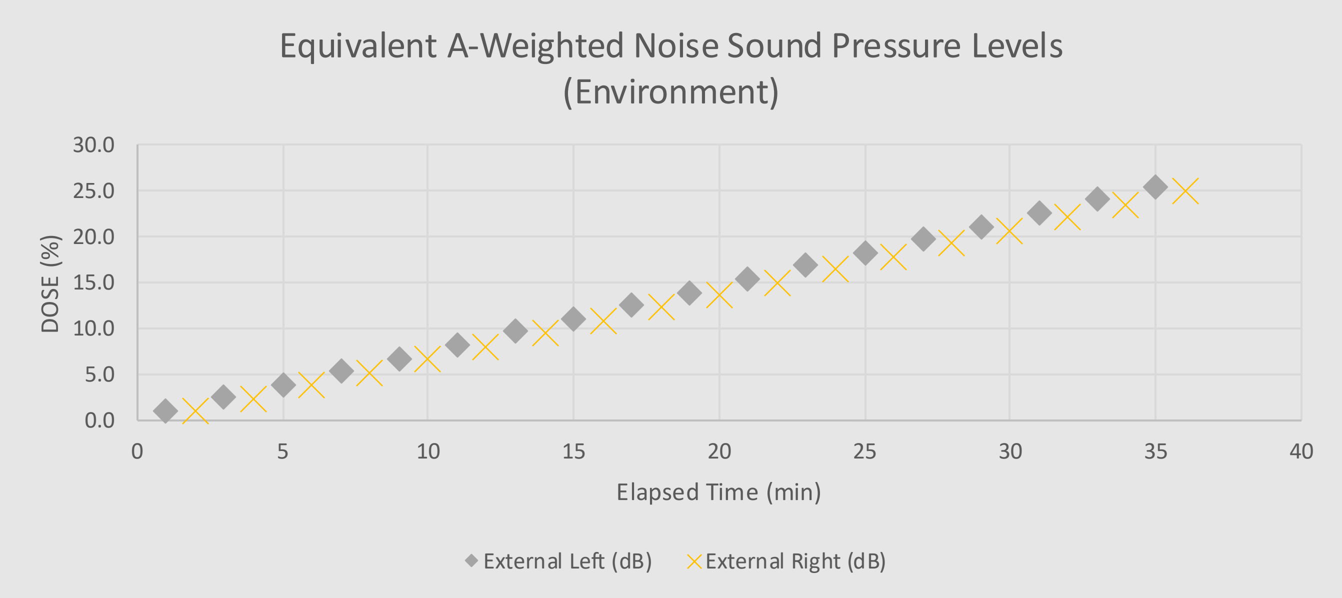
Verification

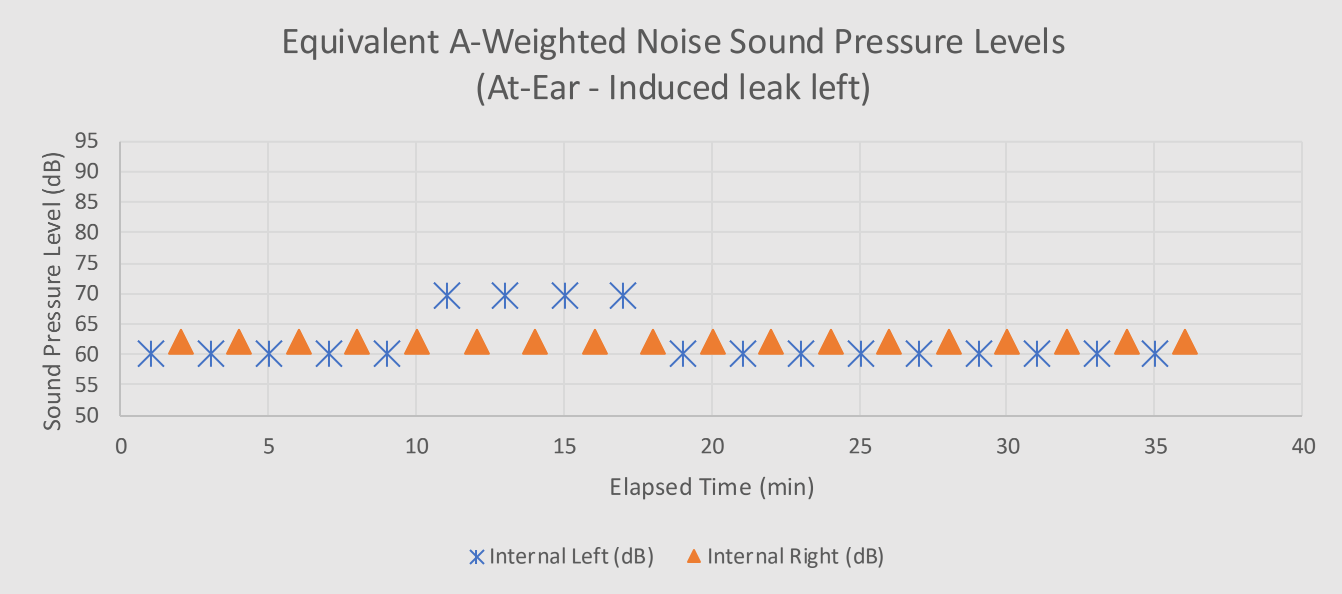
In-House Testing Results

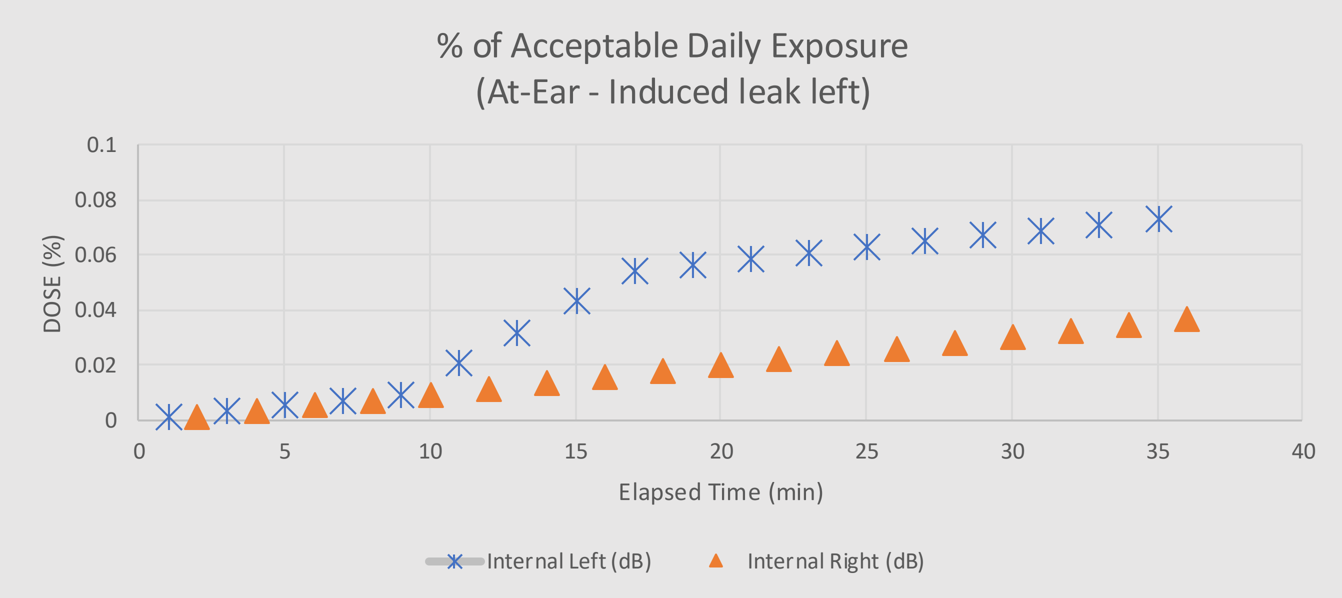
Environment measurements
~90dBA SPL





At-ear measurements
8-min leak induced on left side from min 10-17.





Overall Results: Deviation from Reference Sensor

Noise	Ext. L/R (dB)	At-Ear L/R (dB)
Pink	1.4/1.25	0.8/0.5
White	2.1/2.3	1.7/1.5
Cessna-172	0.03/0.05	0.1/0.15

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Verification

External Lab Testing Results

Method

Performed at Michael & Associates

- Installed on GRAS 45CB (>60dB Insertion loss)
- 95 dBA SPL at the earcup
- 30-min tests; leak induced starting at minute 10
- Perform tests with Pink, White, Brown, Cessna 172 cockpit, and simulated jet noise (In Flight, F-106A, Pilot, Cruise - 25000 Feet PA, .95M - IR Seeker Head-Up)

Summary

At-Ear:

- Good correlation

External:

- Higher delta with high-frequency content signals.

Deviation to Ref. Sensor	Ext. L/R	At-Ear L/R
Pink Noise	2.57 / 2.95	**0.7 / 0.03**
White Noise	7.5 / 7.96	**1.35 / 3.0**
Brown Noise	**0.0 / 1.6**	**0.78 / 0.06**
Airplane Noise (Cessna 172)	**0.0 / 1.5**	**0.7 / 0.5**
Simulated Jet Noise	**0.0 / 0.01**	**1.17 / 0.0**

ARCF

Simulations against the noise type vs. application of scalar and frequency-dependent ARCF.

Simulation	Ext. L/R (Scalar ARCF)	Ext. L/R (Freq.-dependent ARCF)
Pink Noise	2.03 / 2.47	0.72 / 1.10
White Noise	6.91 / 7.10	1.33 / 1.25
Brown Noise	0.03 / 1.14	0.03 / 0.89
Airplane Noise (Cessna 172)	0.11 / 1.34	0.21 / 0.44
Simulated Jet Noise	0.23 / 0.35	0.29 / 0.25

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VALIDATION

FLIGHT TESTS

PLATFORM

General Aviation Aircraft

- Cirrus SR22
- Cessna 172
- Piper PA-23

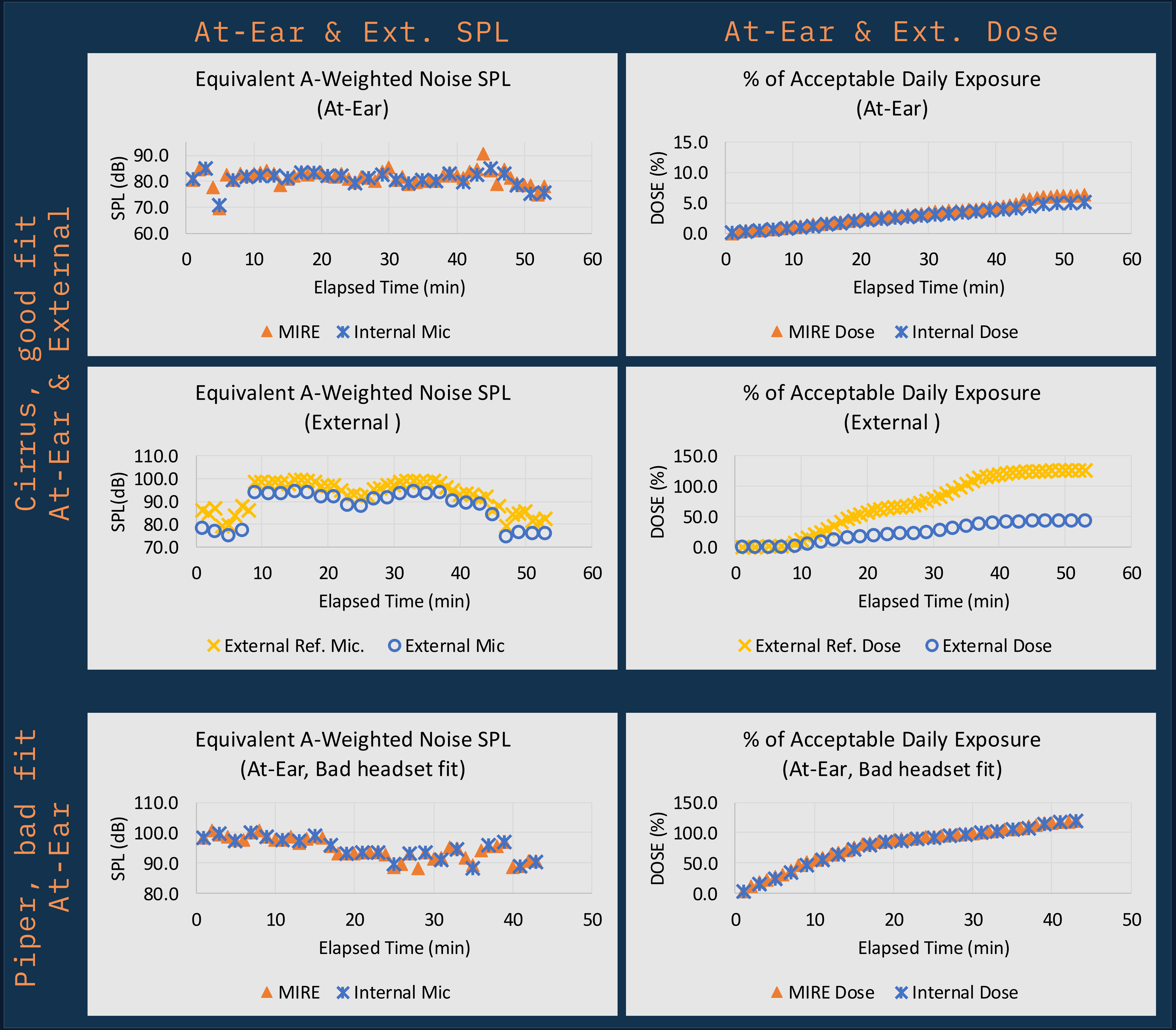
SORTIES

12 flights – 2 test subjects per flight

- Take-off, three speeds, landing
- includes active communication (cabin, radio, ATIS, etc.)

MEASURING

Internal and external microphone comparisons to reference dosimeter and overall dose levels.



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Verification

Summary of Flight Test Results

Details

At the ear results

- Closely correlated to the dosimeter

External results: Location variability

- Scalar vs. Frequency based ARCF
- lapel vs. shirt clip location

	At ear results	External results
Mean bias	+0.5 dB	-3.5 dB
Typical spread (1σ)	±1.5 dB	±1 dB
RMSE	~2.2 dB	~3.8–4.2 dB (bias-dominated)
Max deviation	~6–8 dB (rare, transient)	~6–7 dB
Outlier frequency (>4 dB)	<2%	~5% (mostly transitions)

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KEY FINDINGS · CALIBRATION & FREQ. BASED ARCF

WHAT THE DATA TOLD US

AT-EAR	Highly consistent → single-point calibration sufficient; best correlation to true ear exposure.
EXTERNAL	Accurate at low frequencies, less so at high — requires frequency-dependent calibration.
SYSTEM	Capable of monitoring continuous noise with or without communication signals present
SYSTEM	Essentially class-2 dosing measurements at the ear.

SYSTEM IMPLICATION

Proves that the acoustic system can provide active noise reduction, enhanced speech intelligibility, and monitor pilot dosing to enhance mission effectiveness and protect hearing.

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LEARNING OBJECTIVE 03

Discuss the operational impact of real-time individualized individualized noise-dose data on our

- **Warfighters:** Mission effectiveness, comfort and fatigue fatigue

- **Hearing-health management:** Both for short and long-term force readiness.

For the WARFIGHTER • **MISSION EFFECTIVENESS & COMFORT**

LET THEM FLY THEIR BEST MISSIONS

- **Improve intelligibility** — no occlusion, better comm fidelity than CEPs, ANR-driven intelligibility.
- **ANR: reduces fatigue & cognitive workload** — faster responses and better decisions
- **Eliminate ear inserts on most missions** — Improved Comfort, guided by dosing data and mission insights.
- **Fly with the protection they actually need** — nothing less, always more.

HEARING-HEALTH MANAGEMENT • **SHORT-TERM ACTIONS**

POST FLIGHT DOSING REVIEW - EVERY FLIGHT

Utilize AI-driven analysis of data to determine appropriate next steps

01 **Detect any TTS from a flight** – flagged by analysis, with aircrew follow-up.

02 **Fitment checks vs. known standard** – did the wearer get 90%+ of planned attenuation?

03 **Dual protection when planned** – for certain mission levels & durations.

04 **Next-flight & duty-cycle adjustments**– overdose effects can be partly recovered with noise rest.

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HEARING-HEALTH MANAGEMENT · **PREDICTED LONG-TERM EFFECTS**

Improve READINESS, RETENTION, and COST

READINESS

Fatigue management — overdosing will affect readiness

Sharper auditory fitness for better missions

Noise-based training knowledge — we create overexposure in training,

RETENTION

Hearing safety reduces reasons to exit

Properly protected, more experienced pilots stay in longer

Reduce COST

Lower training & replacement costs

Reduced VA costs for hearing disability

Better quality of life for retired aircrew

Help aircrews **fly safer**, the branches **train smarter**, and the VA **spend far less.**

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SUMMARY

FROM *Variable* PREDICTION to *Actual* NOISE Exposure *Management*

In-helmet dosimetry replaces estimated "protection" with **actual exposure.**

A **proven technique** , ready to scale into a military-grade capability.

Hundreds of thousands of service members benefit — on their jobs...and in their lives.

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QUESTIONS