xEMU Suit Integrated Audio Communications System: Ambient and EVA Pressure-Test System Performance

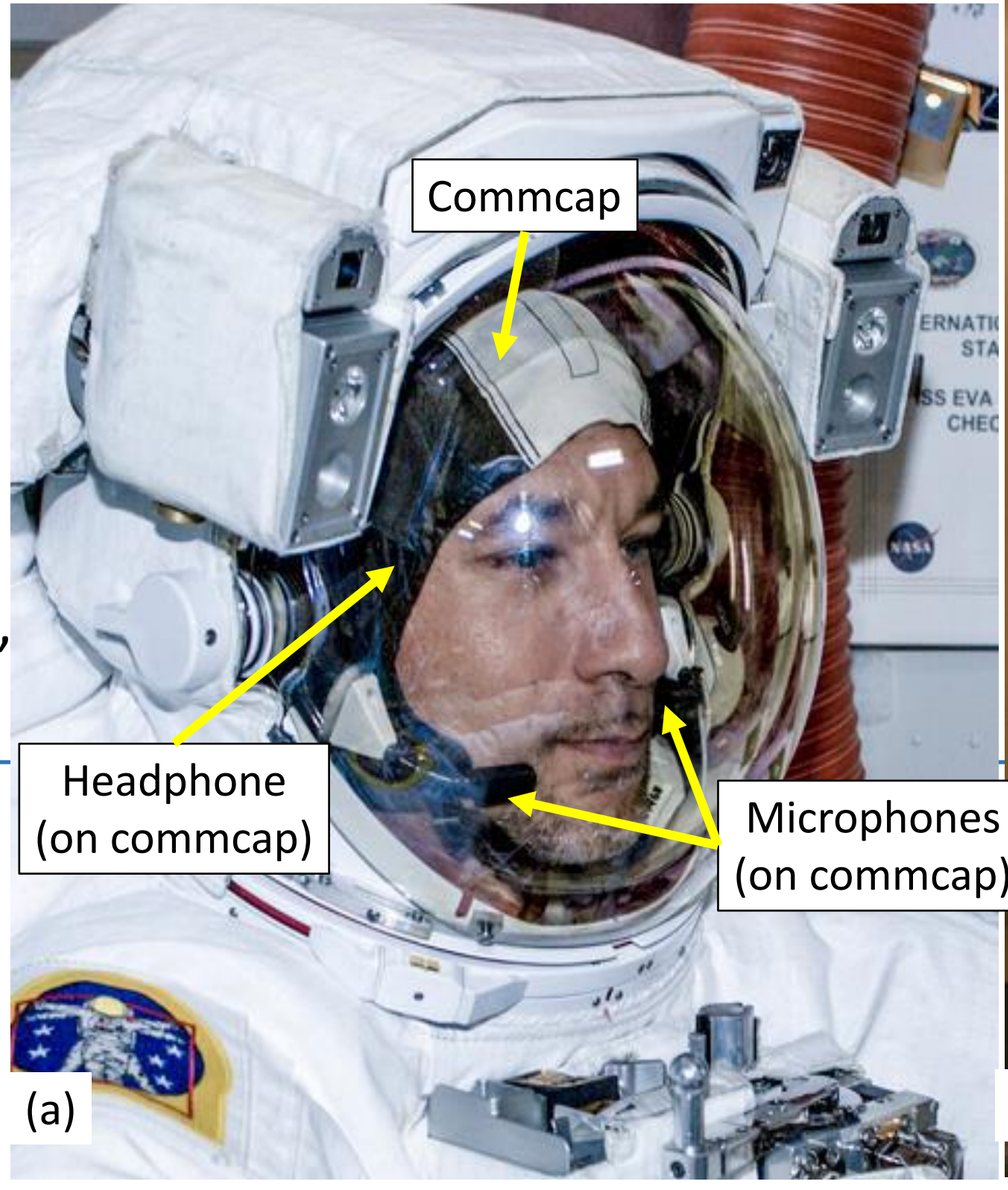
Steven Shawn Smith (GeoControls/Amentum) & Alan Turner (Leidos/KBR)

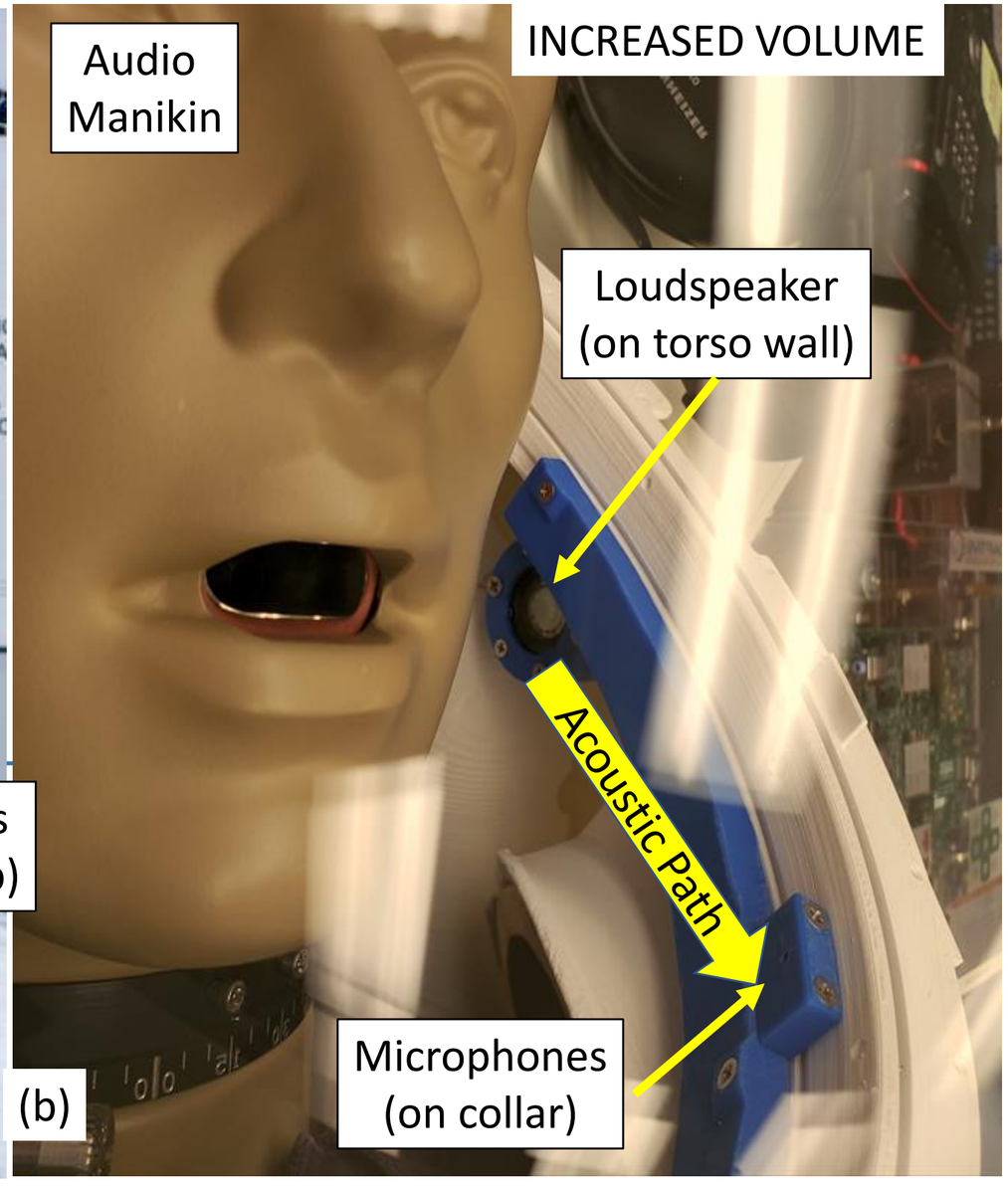
Spacecom2025



Closed vs. open acoustic path

“Physical Commcap”

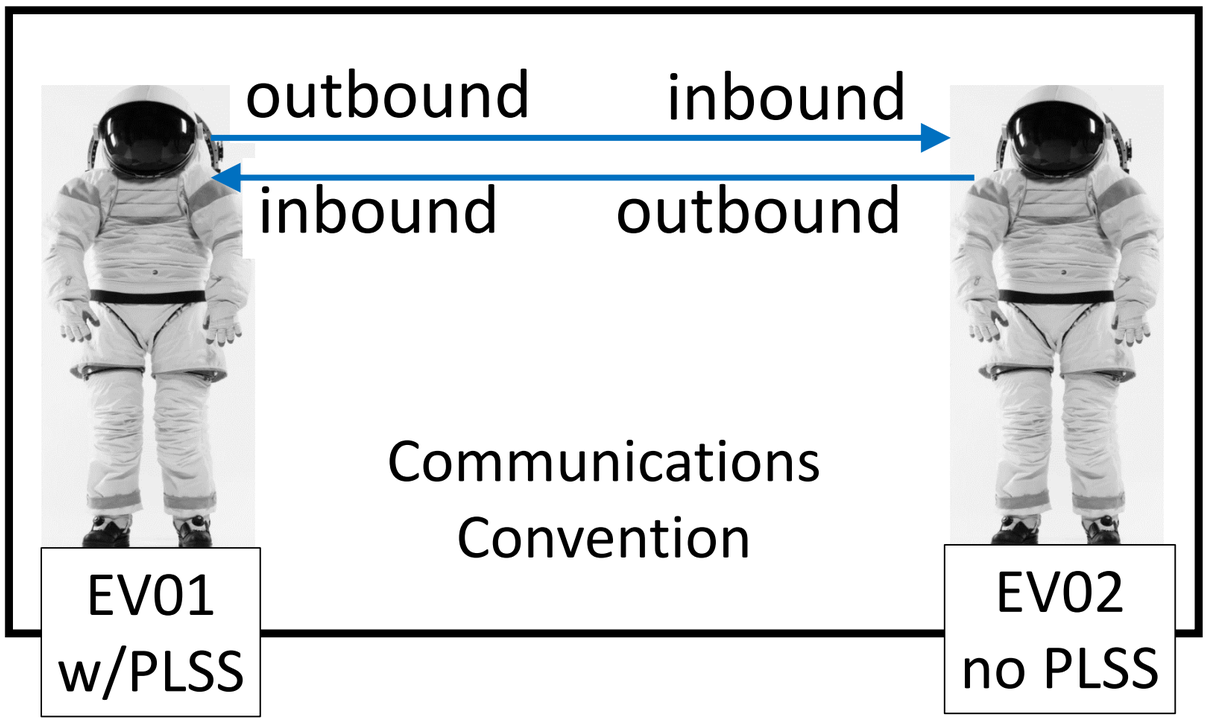




“Exploded Commcap”

xEMU Thermal-Vacuum Test Objectives

- First test w/2 xEMUs & measurement microphones
  - 5 simulated EVAs (temp., pressure)
  - confirm functionality of AEC, VOX, AGC
  - single-ended, conversational, full-duplex communications
  - quality/performance and speech intelligibility test signals, plus operational phrases
  - Q: How does PLSS affect comms?

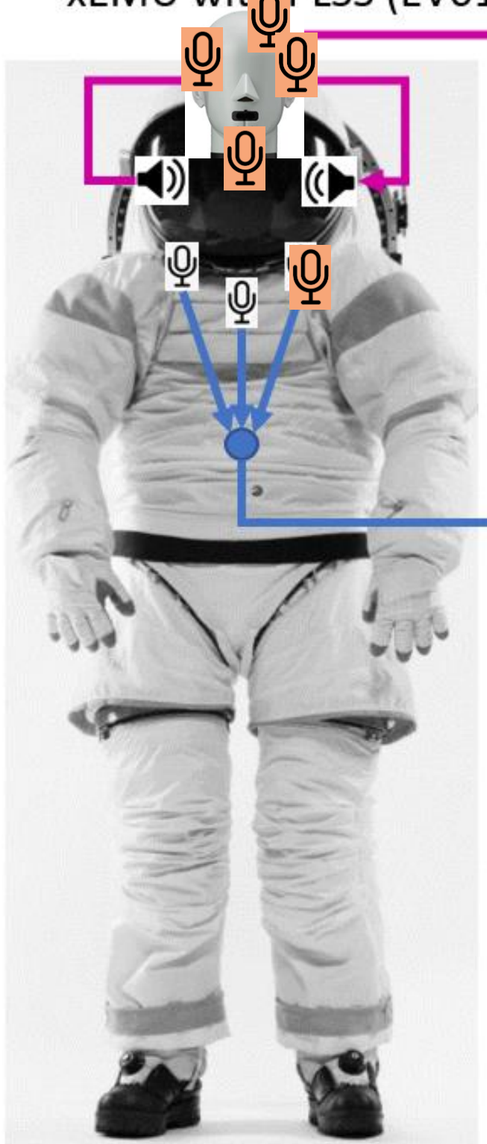


2-suit comms system w/MCC/HLS/ISS in

COMMCAP FREE

= calibrated measurement microphone

xEMU with PLSS (EV01)



LEGEND
- Digital
- Analog
- Ancillary Analog
- O-scope Monitor
- 701 Standin
- D-class switch amp

dB
f (Hz)

MCC/ISS/HLS

CH1 CH2 Master CH1 CH2

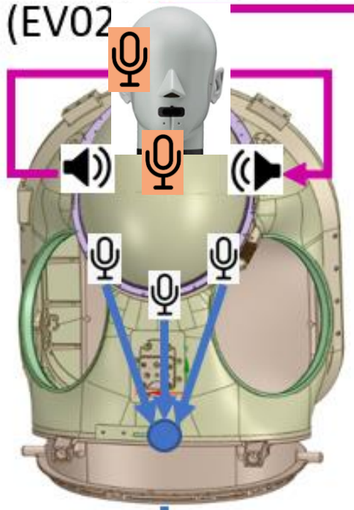
Mixer/ router

Monitor/tune signal levels

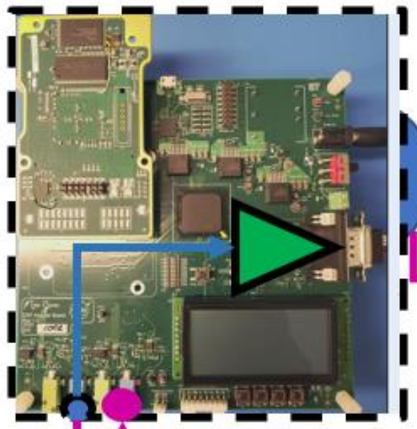


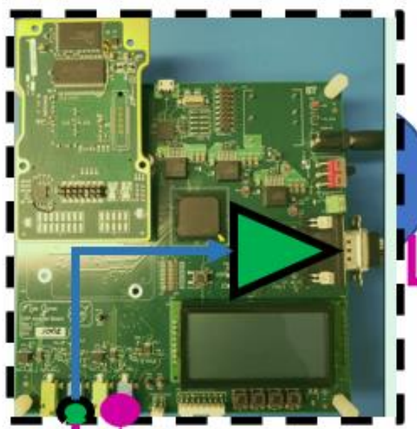
1 2 3 4

xEMU HUT or xEMU PGS w/K-bottles & vacuum pumps (EV02



dB
f (Hz)





3 1 4 2

xEMU radio stand-in test board w/full audio function

Physical Criss-cross

xEMU radio stand-in test board w/full audio function

Key Audio/Acoustics Concepts

- Suit is a filter (speakers, suit volume, noise sources)
- Three interacting acoustic regions: HUT, Helmet, PLSS
- Acoustic Echo Canceller (AEC)
  - prevents echo and feedback
  - eliminates commcap
  - multiband adaptive system
  - models how suit filters (changes) inbound signals, subtracts
  - blocks inbound signals from outbound comms (speech, tones)
  - passes signals created inside suit
    - crewmember speech (good)
    - PLSS noise (not good)

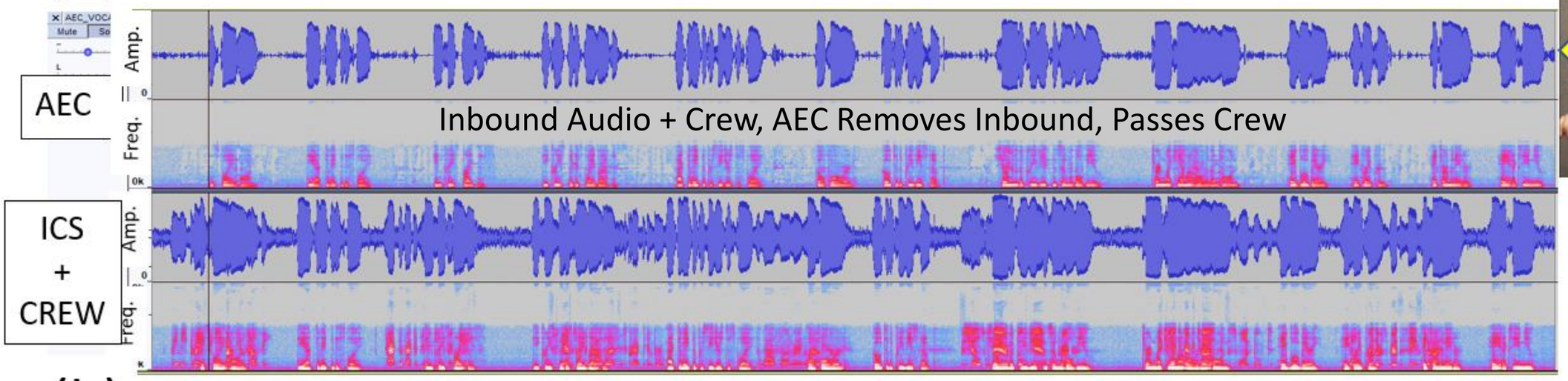
AEC for Comms: Outbound from suit



AEC blocks inbound signals from exiting via outbound comms

COMMCAP FREE

(a)



(b)

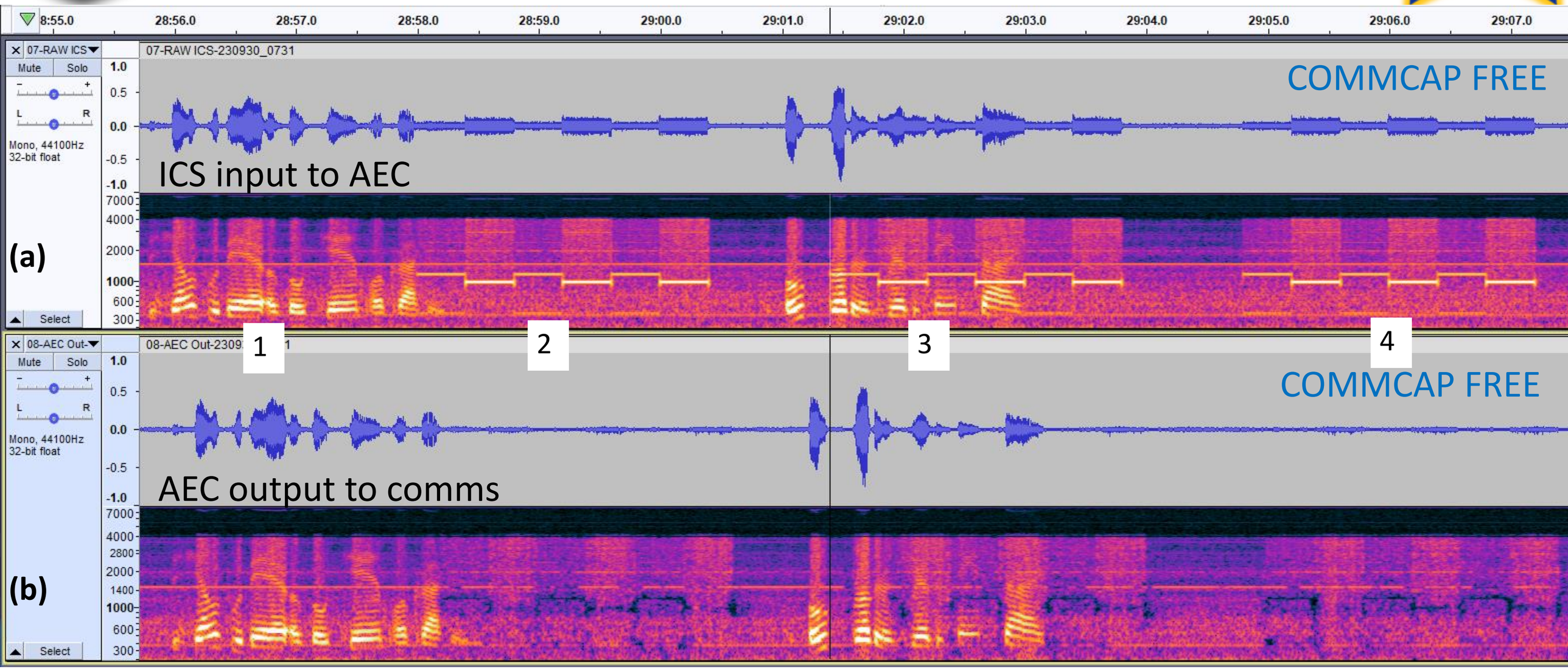
Time



AEC blocks inbound signals from exiting via outbound comms, passes crew voice (+ suit noise)

COMMCAP FREE

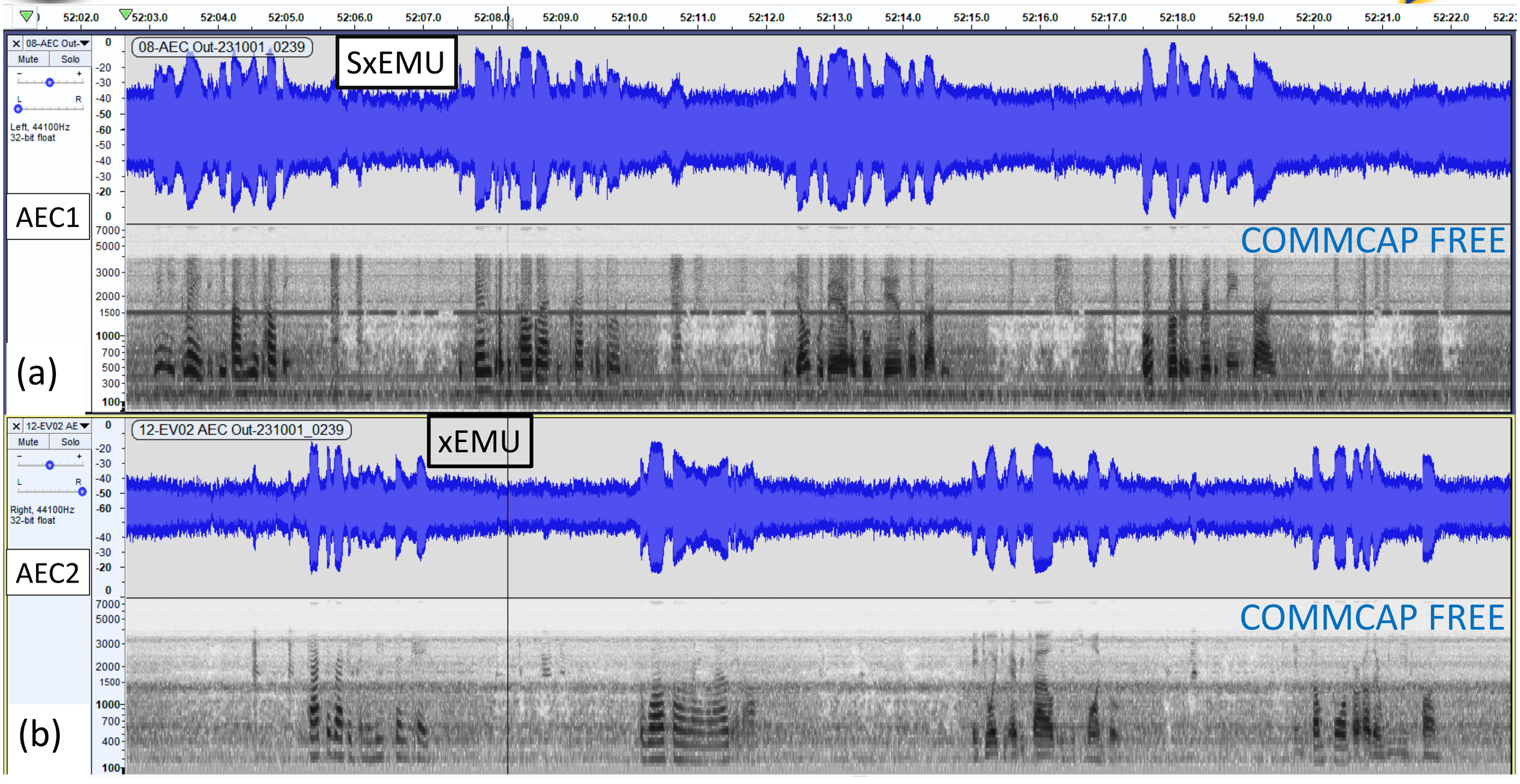
C&W tones: inbound w/transients



Ambient noise may vary as AEC adapts to broadband (transient) signal

AEC Conversation w/PLSS + Absorption

Time



xPLSS noise, AEC disruption, no absorption

Time (hh:mm:sec) →

SxEMU Left Ear

3D HUT Left Ear

SxEMU AEC out to comms loop

3D HUT out to comms loop

02-EAR Left-230615_1206 Unknown contact w/suit or test article mechanical noise

(1) EV01 (w/PLSS) Manikin Ear

DSP Bandlimited noise from comms loop (lab noise + conversation

SxEMU PLSS fan/ducts on

09-EV02 EAR Left-230615_1206

(3) EV02 Ear hearing EV01

DSP Bandlimited noise from comms loop (lab noise + conversation

08-AEC Out-230615_1206

3D HUT ICS output gained for 85 dBA EIS max is distorted version of xEMU fan/duct noise w/content above $f_{Nyquist}$ due to amplifier chip/issue

(2) EV01 (w/PLSS) Comms output

12-EV02 AEC Out-230615_1206

(4) EV02 Comms Output

AEC blocking inbound lab speech sent by xEMU AEC

AEC blocks incoming fan/duct noise from xEMU

AEC failure

Time

100 200 500 1k 2k

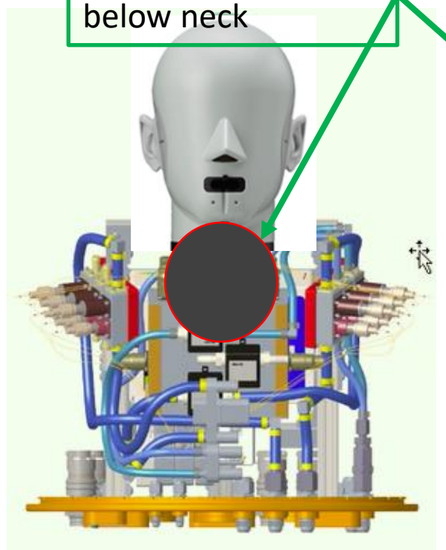
Hz

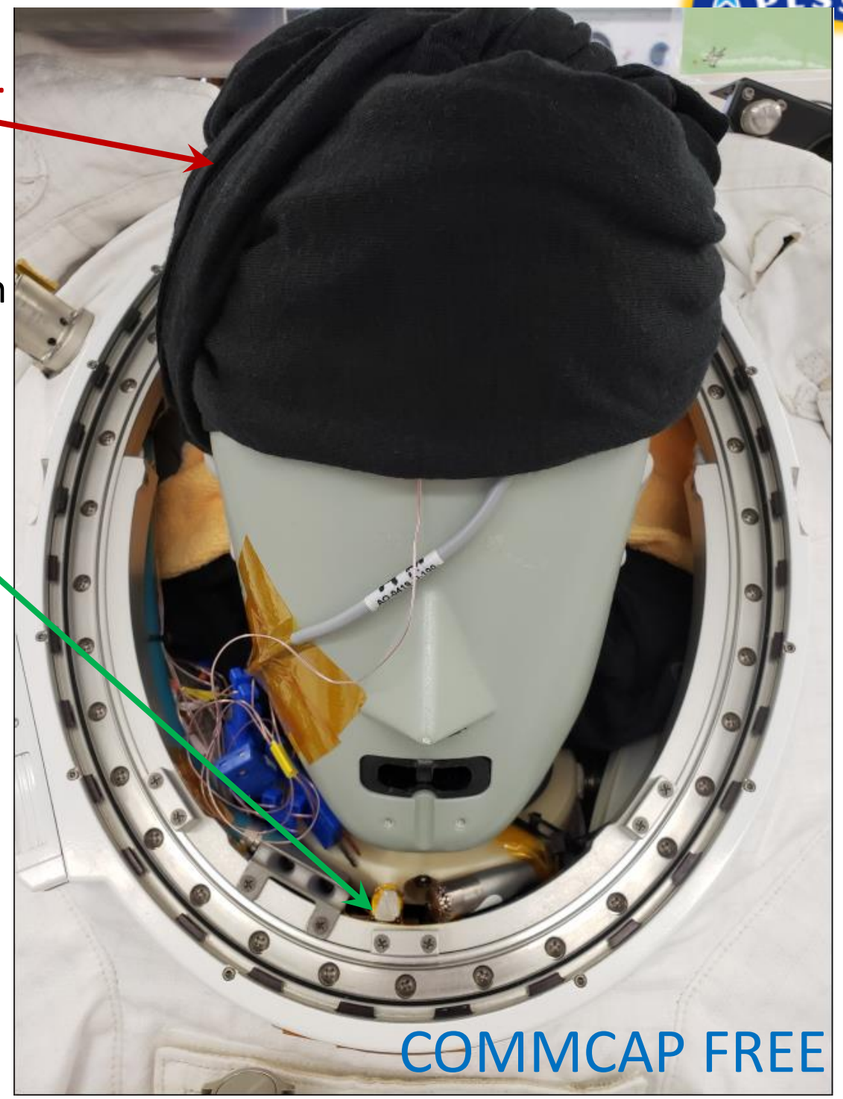
Acoustic absorption to continue test

INDEX/RUN ORDER	Skullcap Absorber	Collar Absorber	Neck pillow Absorber TERRYCLOTH NO TCU	LAN-XI xEMU Left Ear w/A wt. and 1/12th octave Drum to diffuse field equalization
01/01	X	X	X	86.1 dBA
02/02	X	X		86.9 dBA
03/06	X		X	87.4 dBA
04/07	X			89.3 dBA
05/04		X	X	89.4 dBA
06/03		X		90.0 dBA
07/05			X	91.1 dBA
08/08	NONE	NONE	NONE	92.5 dBA
09 ADDITIONAL 07/11/2023	X	X	X	86.7 dBA

Max attenuation 92.5-86.1 = 6.4 dBA

* Removal of O_2 inlet/splitter gives approx. 3 dBA additional reduction
* Helmet + full Absorbers w/transmission of lab fan noise, no inbound audio noise, ambient SPL = 56.5 dBA

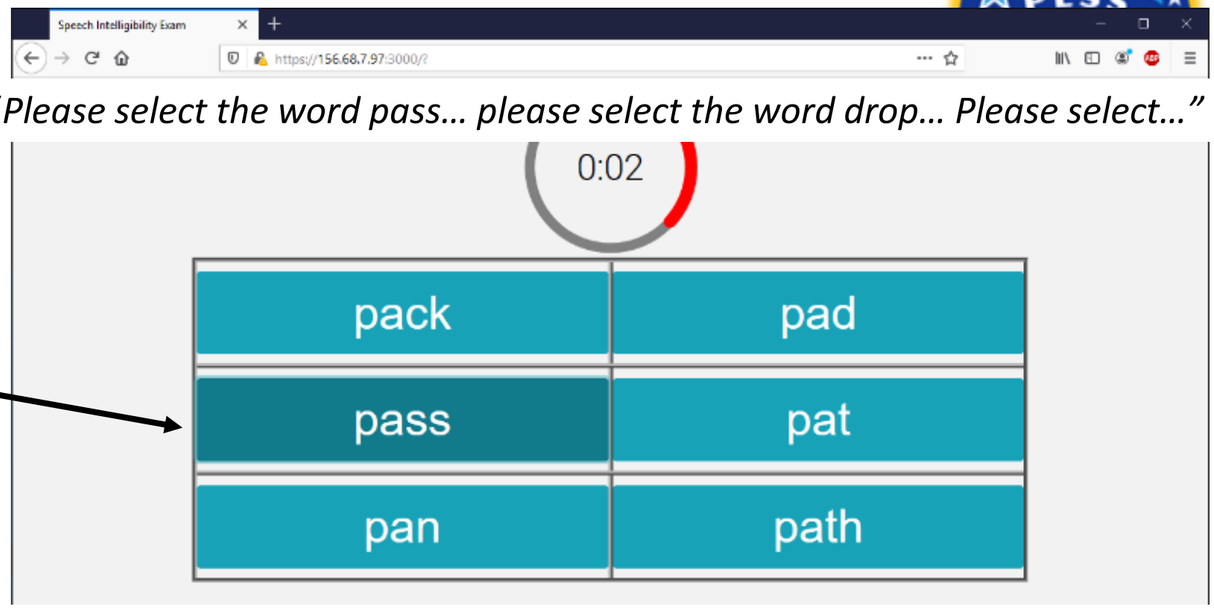




Absorption improvised to facilitate additional testing –
Not authentic match of human absorption (hair, LCVG, etc.)

Speech Intelligibility

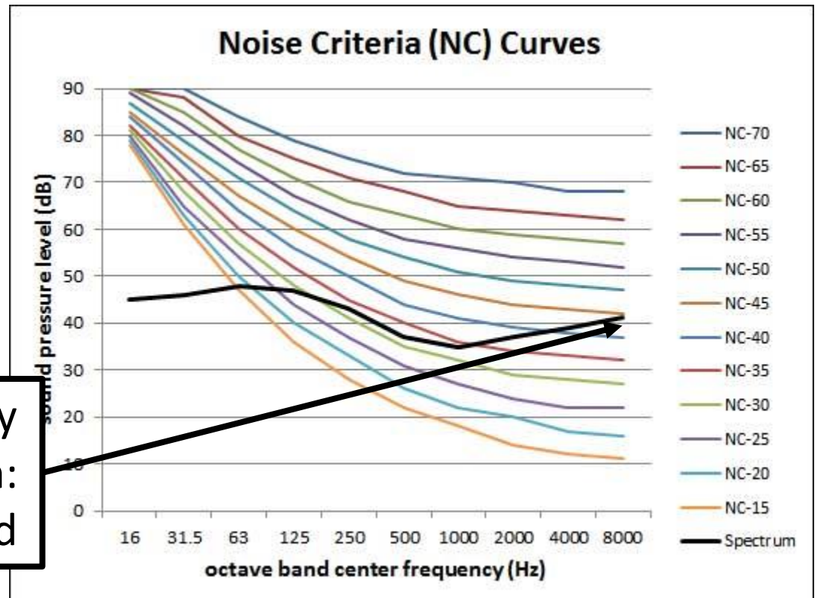
- Target: >90%
- Modified Rhyme Test (**ANSI/ASA S3.2-2009**)
  - Battery of short words from multiple talkers
  - Listener jury picks best word from a list
  - Statistics account for guessing



"Please select the word pass… please select the word drop… Please select…"

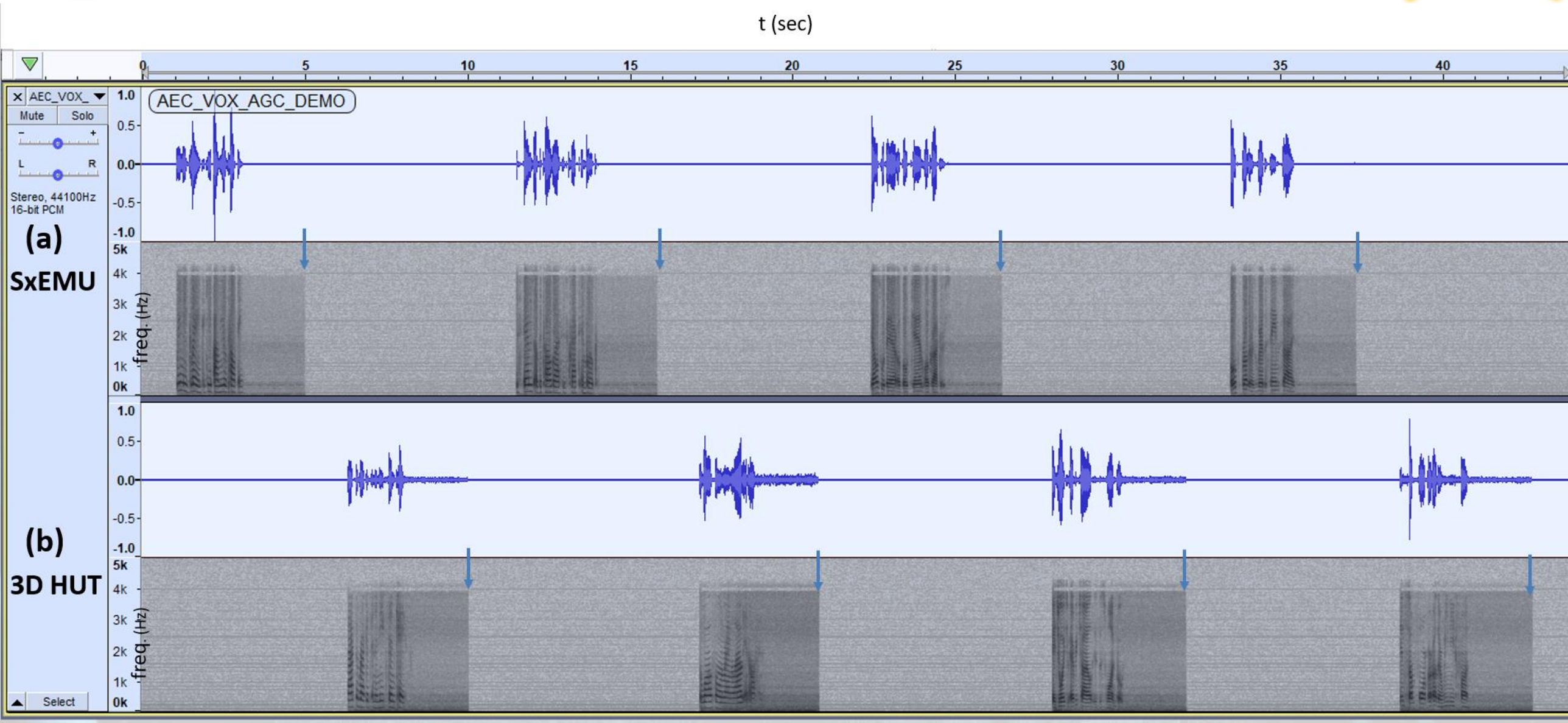
- Speech intelligibility, "bookend cases":
  - 63% w/PLSS– worst case – can only improve
  - 88% for "NC-52-like" low fan noise, like design specification
- Previous test (sans PLSS): low 90% range

NC-rating determined by highest-rated curve broken: NC45 in 8 kHz band



Graphic: Wikipedia

AEC Conversation + VOX/AGC, “NC-52-like”



Summary/Conclusions

- Audio: Commcap-free, full-duplex comms
  - Works @ expected “NC-52-like” conditions: 88% speech intelligibility
  - PLSS noise: 63% speech intelligibility
- PLSS: Best solution is a quiet PLSS
  - Too loud for crewmember > 85 dBA
  - Noisy PLSS = noisy outbound audio
  - Hearing protection doesn’t prevent noisy outbound comms
  - Disrupts AEC in other suit
  - Improvised absorption → mid to low 70 dBA for vacuum chamber
  - Solution(s):
    - Acoustical treatment of PLSS (fan, pump, turbulence)
    - Suit absorption
- Helmet:
  - Reflective, elliptical, driven directly by PLSS
  - Microphones at collar
  - Treatment: mic windscreens or alternate locations, acoustics



Audio/Comms check outside
TVAC vacuum chamber in 3D-printed HUTS

COMMCAP FREE

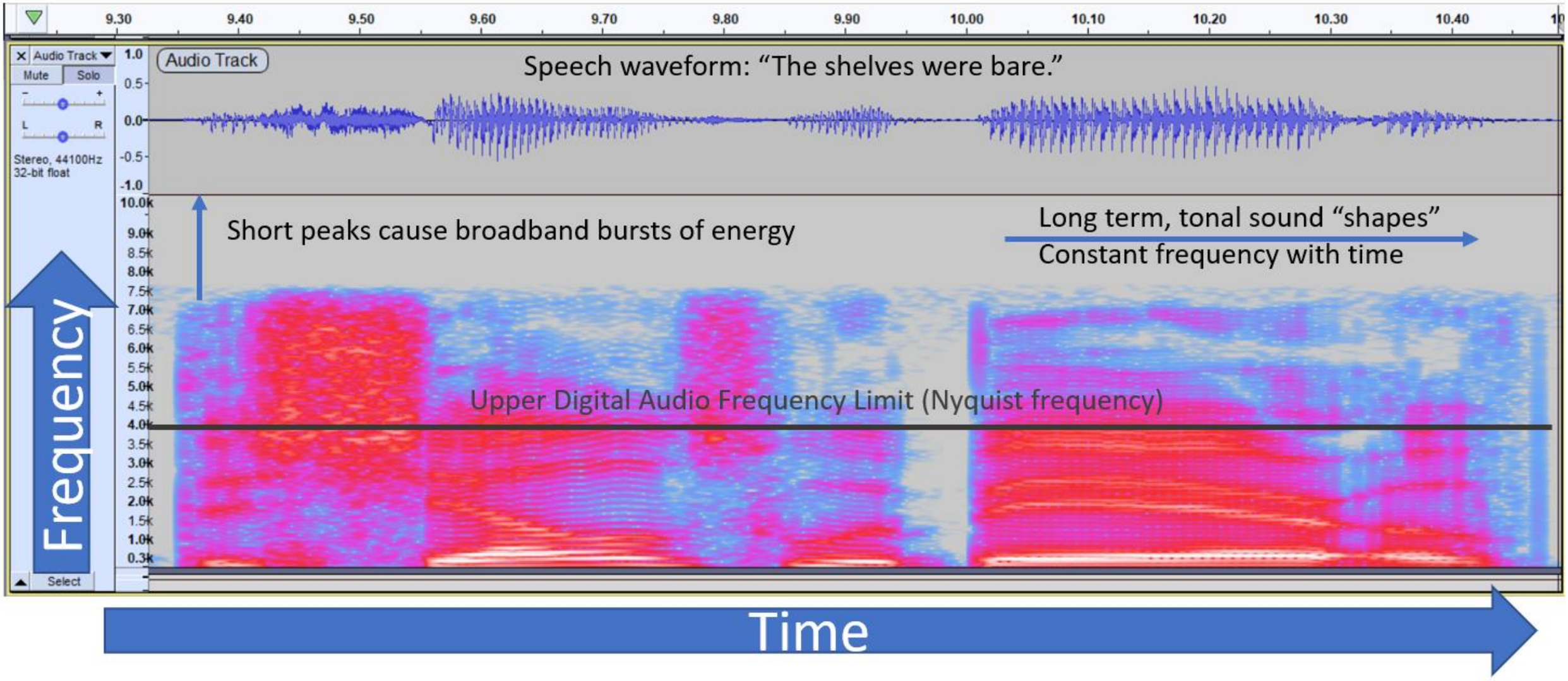
Q & A



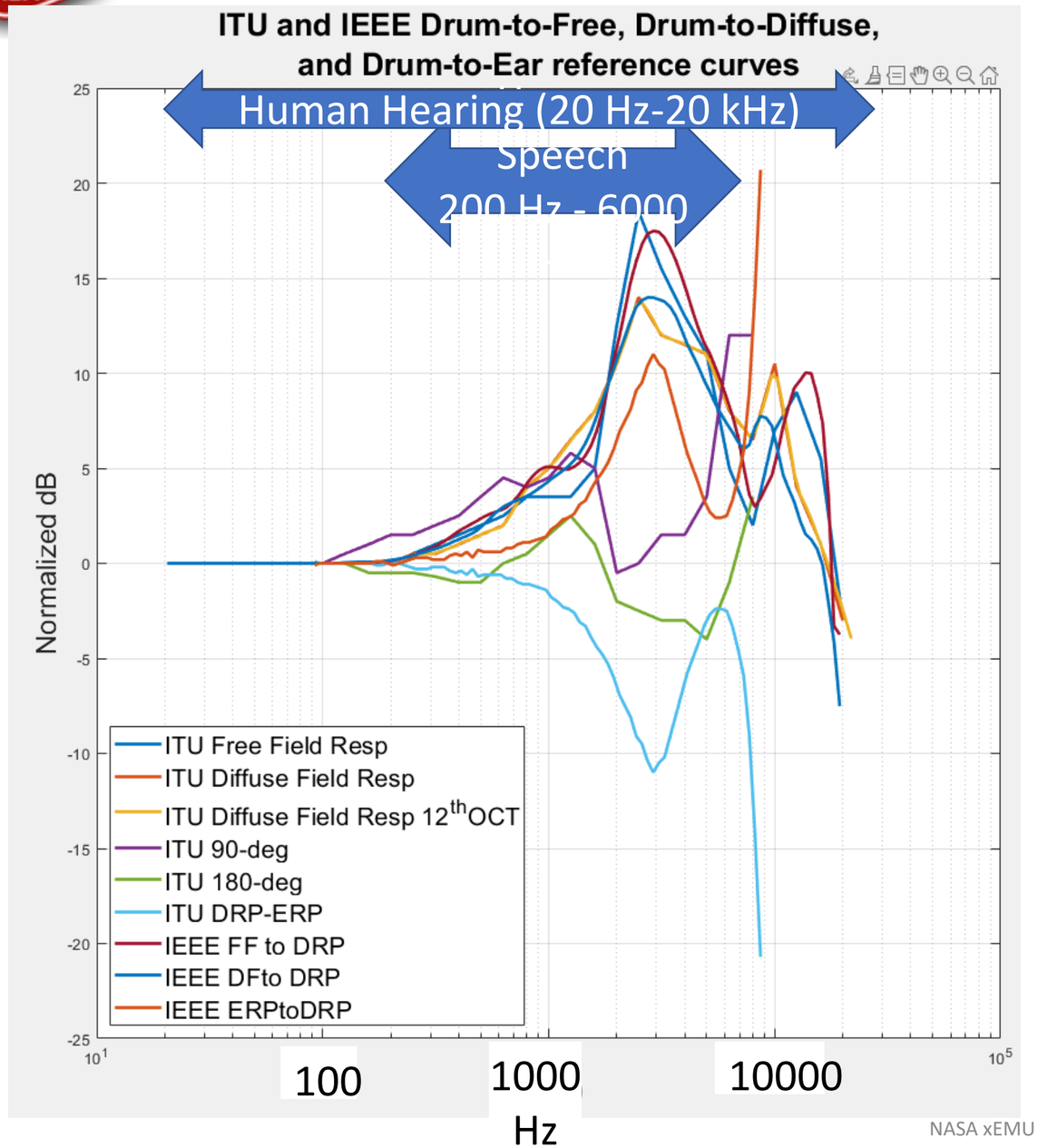
Contact Info:
Steven Smith, GeoControl Systems/Jacobs/NASA Audio Dev Lab
Suit audio/DSP/audio-acoustics
steven.s.smith@nasa.gov

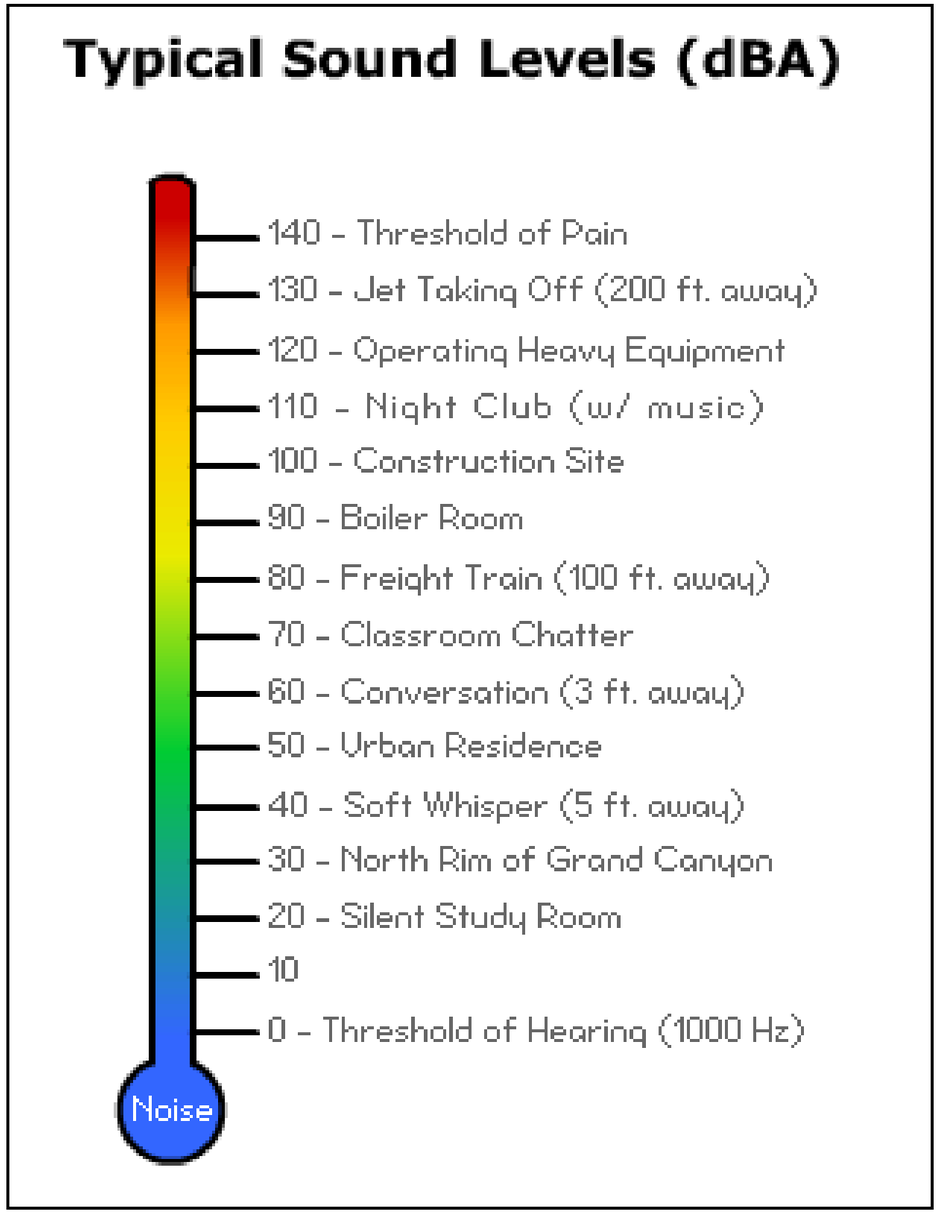
Data Presentation

- Spectrograms show frequency content over time



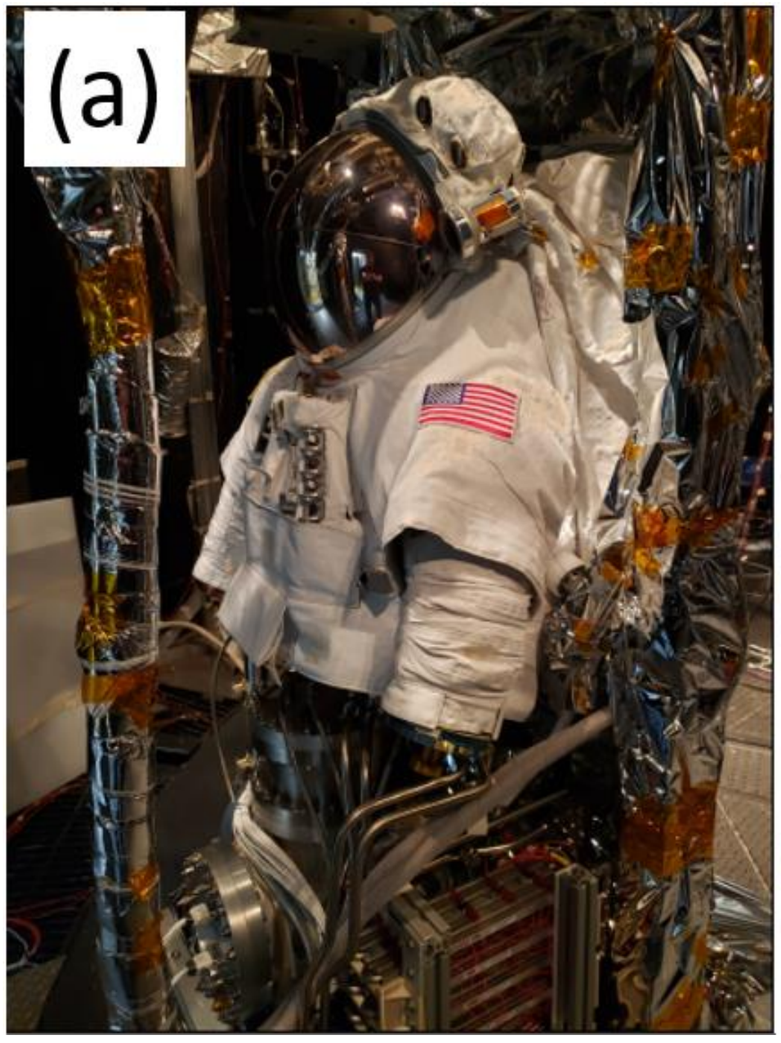
Sound Levels, corrections, bandwidth



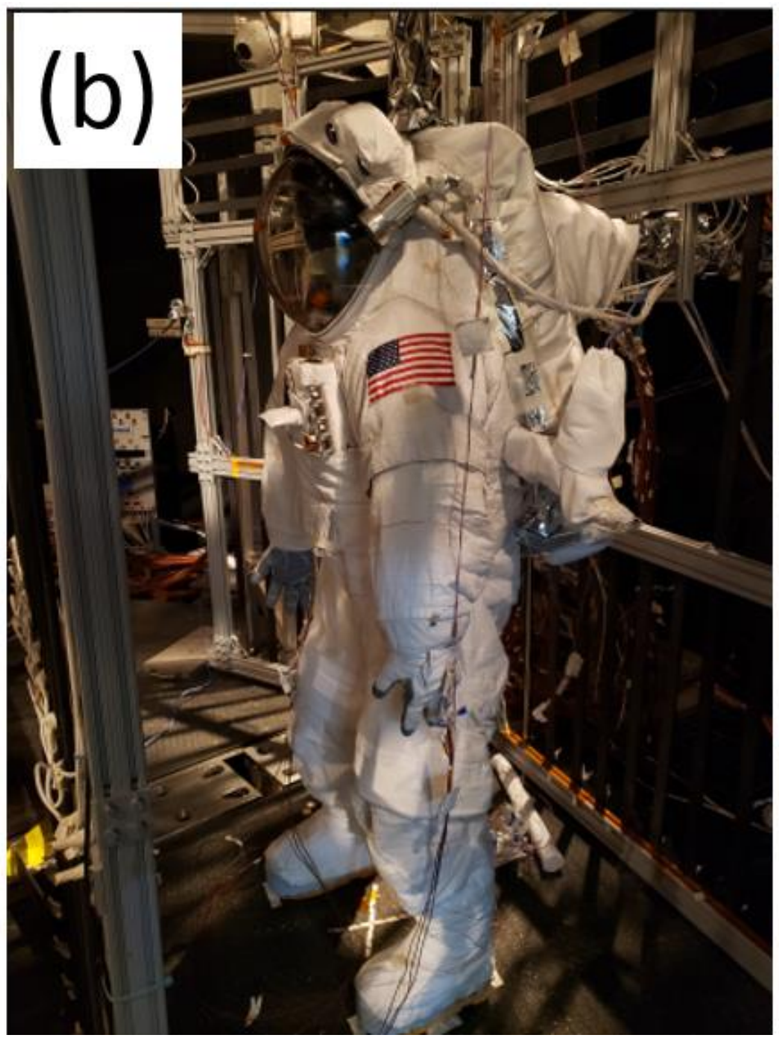


Source: OSHA Technical Manual (OTM) - Section III: Chapter 5 | Occupational Safety and Health Administration

Equipment: Suits



“Short” xEMU with Human Metabolic Simulator & PLSS



Second suit w/nitrogen and extensive thermocouples



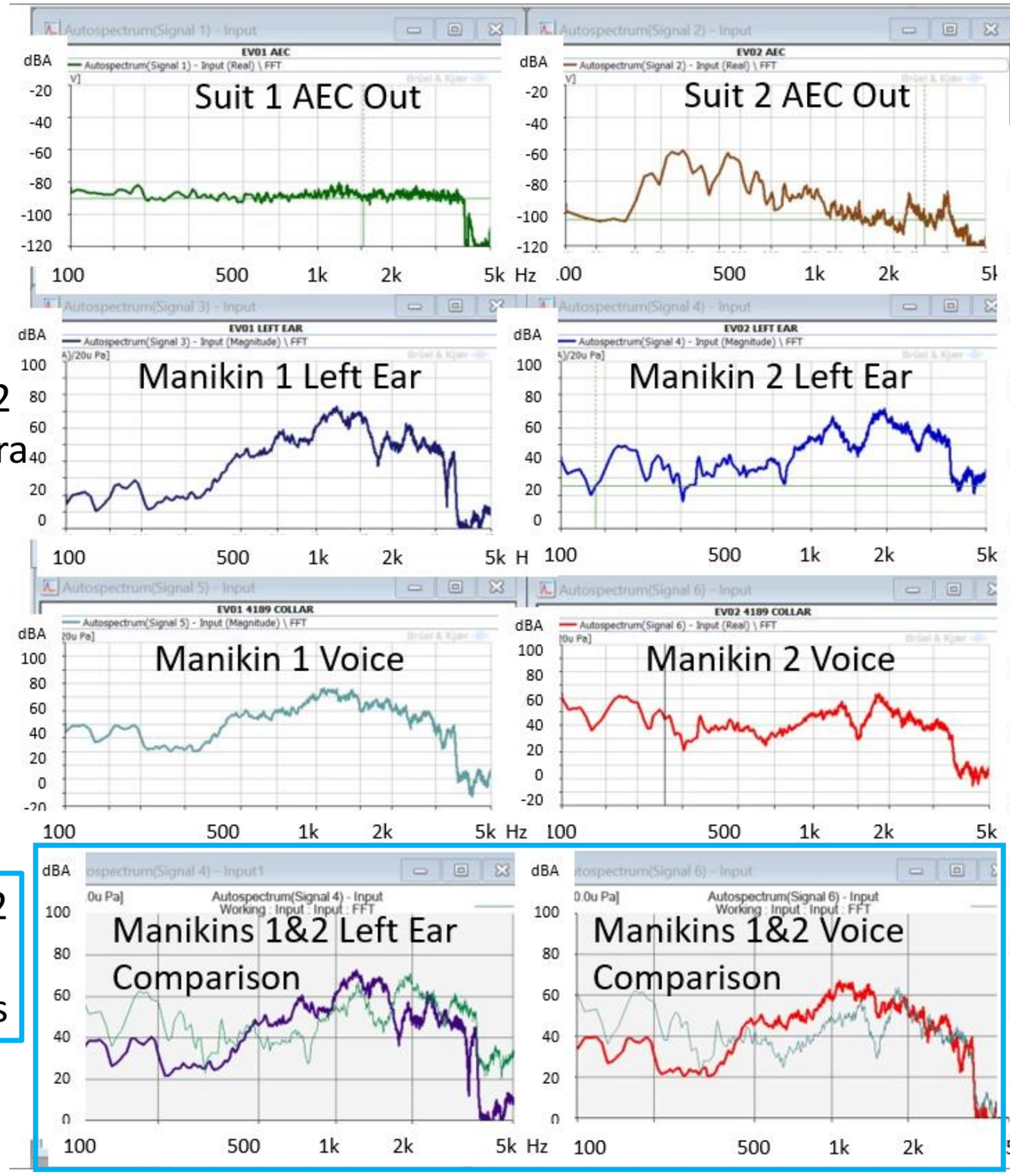
Audio test manikin with voice and measurement microphones

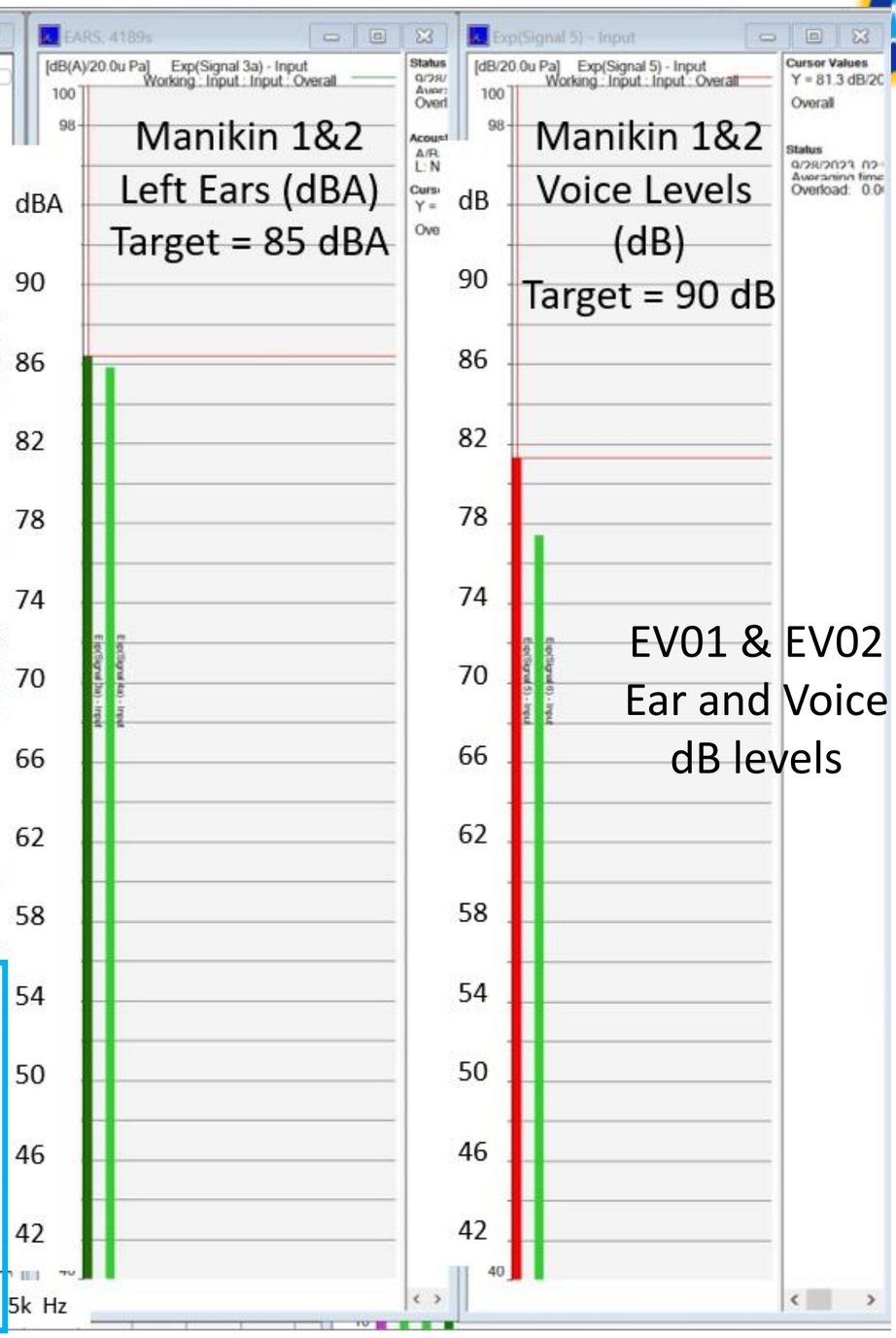
COMMCAP FREE

Operations/Monitoring

EV01 & EV02 Critical Spectra

EV01 & EV02 Spectral Comparisons



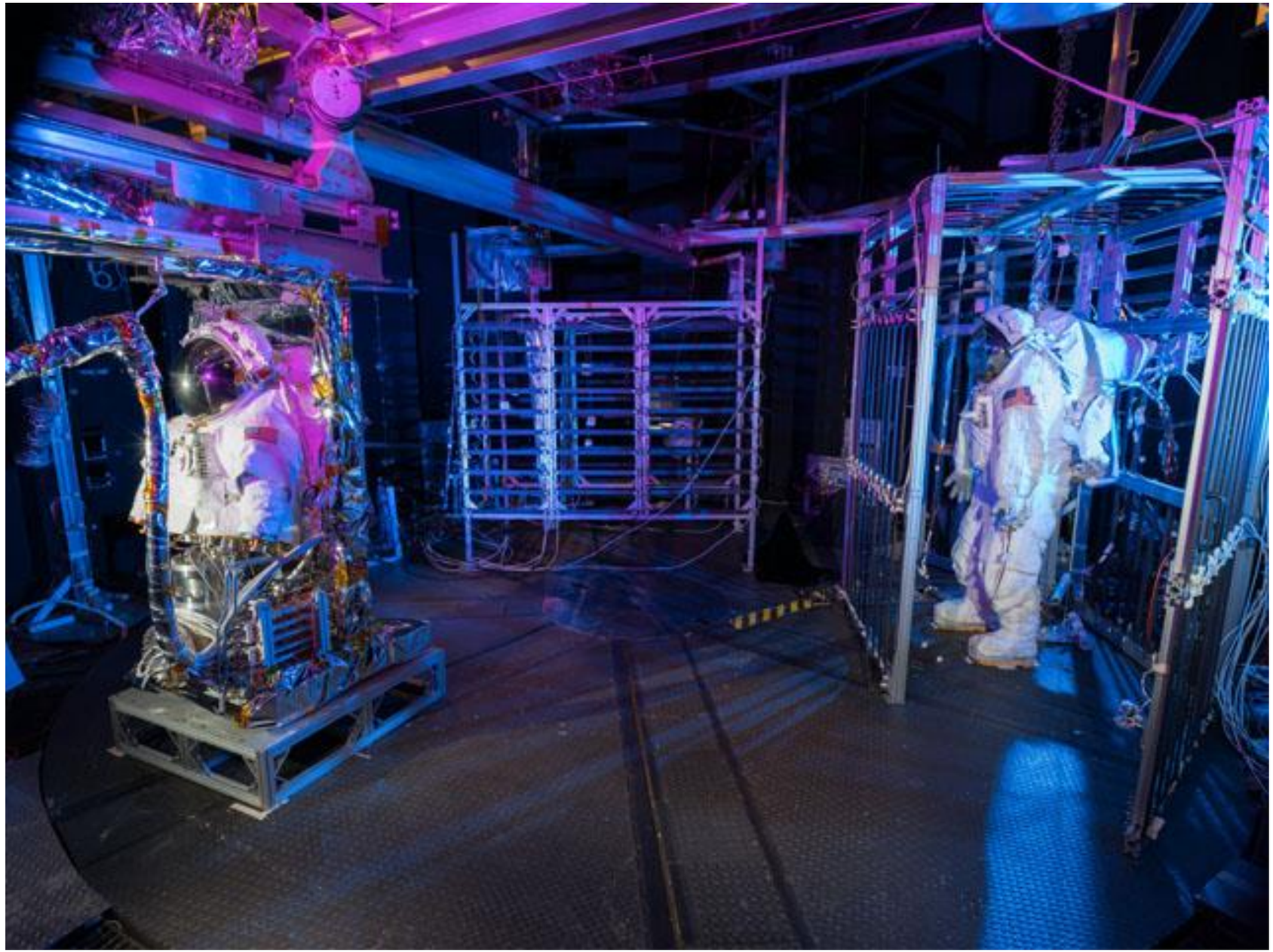


EV01 & EV02 Ear and Voice dB levels

Spec. Reqs.

	Objective	Status/Comment
1	The IAS provides two-way voice communications between two suits	Confirmed for full duplex hardline analog comms loop.
2	The IAS transmits and receives over a hardline interface	Analog hardline interface between suits tested. Radio UHF hardline interface requires two functional radios.
3	The AEC prevents inbound audio in the suit volume from exiting the suit in outbound comms by attenuating any inbound signals by at least 20 dBA	AEC cancellation of inbound comms exceeds 40 dB for an "NC-52-like" suit interior. Values of 15-20 dB were achieved with an active PLSS.
4	The AEC prevents suit-generated C&W tones from exiting the suit in outbound comms by attenuating any inbound signals by at least 20 dBA	C&W tones with sharp frequency transitions may cause artifacts in outbound audio. AEC attenuation affected by PLSS noise.
5	AEC functionality is not disrupted by inbound speech (xEMU or other) or C&W tones	C&W tones with sharp frequency transitions may cause artifacts in outbound audio.
6	The AEC in combination with all IAS/radio components functions nominally in the presence of PLSS fan and pump noise	PLSS noise far exceeds NC-52 specs. Audio system functioned in TVAC when acoustic absorption and additional amplification were incorporated. However, excessive PLSS noise/distortion may disrupt the AEC.
7	The AEC in combination with all IAS/radio components functions nominally in the presence of purge-valve noise	TBD from existing recordings. Note that broadband noise can cause AEC filters to re-adapt.
8	The suit's IAS can provide and limit comms speech SPL values at the crewmember's ears to 85 dBA	Radio "stand-in" test board required additional amplification and filtering to exceed ~75 dBA and reduce distortion. Limiting set manually — not governed by algorithm.
9	The suit's IAS can provide and limit C&W SPL values at the crewmember's ears to 95 dBA	Set on radio "stand-on" board manually — not governed by algorithm.
10	VOX and AGC work in accordance with accepted standards without dropping (leaving out) crewmember speech in the outbound audio	Manually set VOX and AGC perform accordingly for proper suit background noise levels.
11	The AGC is pressure-compensated/controlled	AGC currently operates at manually set level.
12	The IAS and overall suit acoustics meet NC-52 noise control standards	xPLSS fan/duct and water pump noise exceed NC-52 specifications without improvised acoustic absorption packages for testing (Figure 8, Figure 9). PLSS/suit noise abatement required.
13	The IAS achieves 90% or better speech intelligibility in accordance with ANSI/ASA S3.2-2009 standard for measuring speech intelligibility over communication systems	Intelligibility scores of 63% were obtained for MRT speech recorded in the SxEMU w/functional PLSS. Intelligibility scores of 88% were obtained for MRT speech recorded in the SxEMU in "NC-52-like" conditions (approx. 60 dBA background noise).
14	The suit's IAS meets functional requirements at pressures ranging from 3.5 psia to 25 psia	IAS as per Figure 3 demonstrated functionality from 4.3 to 14.7+4.3 psia.
15	AEC and system exhibit proper functionality for the don/doff case of two nearby xEMUs with helmets off	AEC/VOX/AGC function as expected when collocated and tested in both lab and B32 high bay with approx. 65-70 dBA of background fan noise (PLSS remains off while helmets off).

19



Official NASA Photo