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Innovative Approach for Developing Spacecraft Interior Acoustic Requirement Allocation

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INCE

Outline

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- Process of Allocation
- Fan/Pump Package Sound Power Measurement and Source Sound Power Characterization
- Acoustic Models
- The Effects of Noise Control Treatment (NCT) on Allocated Noise Source Sound Power Levels (PWLs)
- Conclusions and Future Work

List of Acronyms

- ARS: Air Revitalization System
- CM: Crew Module
- CPP1: Coolant Pump Package 1
- ECLSS: Environmental Control and Life Support System
- EFT-1: Exploration Flight Test 1
- HSIR: Human-Systems Integration Requirements
- KSC: Kennedy Space Center
- MAJ: Manual Area Junction
- MPCV: Multi-Purpose Crew Vehicle
- NCT: Noise Control Treatment
- PWL: Sound Power Level
- SPL: Sound Pressure Level

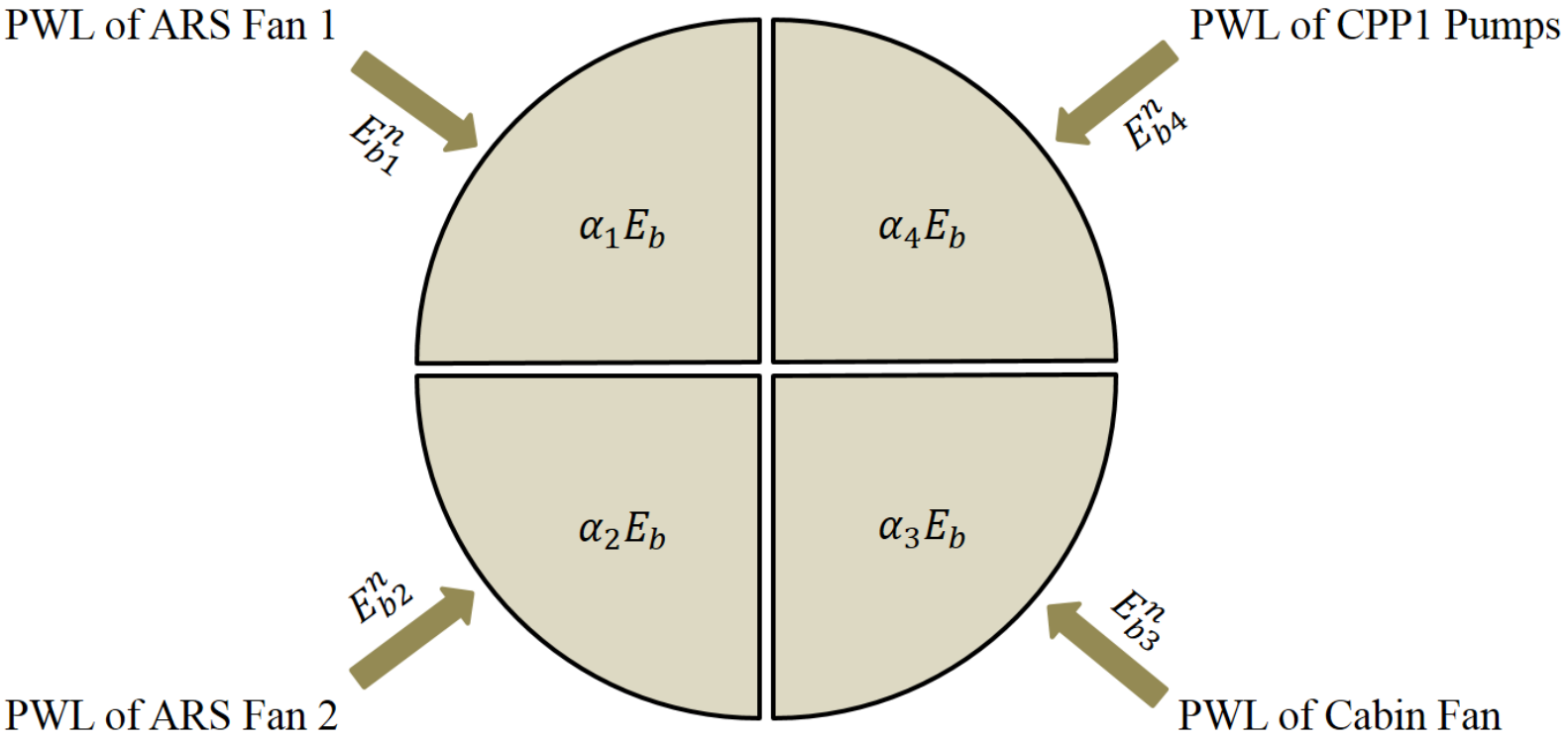
About Orion

Introduction

- Orion cabin continuous noise SPLs are subjected to limits specified in the HSIR. Major noise sources in the Orion CM are located in ECLSS; the contribution of ECLSS to cabin continuous noise SPL is limited by NC-50.
- NC-50 is an integrated vehicle level requirement. Emitted SPL of a hardware item (i.e. noise source) is dependent on its test environment. Therefore, for verification of stand-alone hardware end items, allocated requirements in the PWL metric are more appropriate. PWL is also needed as inputs to acoustic models (both SEA and FE).
- "Source" sound power is used in both test and analysis. ARS and Cabin fans are connected with ductwork. The source power of the fans are free from the effects of ductwork. Measured inlet/outlet sound powers are subject to the effects of ductwork.
- The sound power of CPP1 pumps is radiated directly to ECLSS bay without any duct work. Therefore, the radiated sound power is the source sound power of the pumps.
- Allocation is based on innovative application of PIM, which is used to obtain the gains from noise source sound powers to the acoustic energies of receivers, i.e., the cavities of cabin habitable volume.
- Both SEA and Hybrid SEA-FE models of Orion MPCV are used for analysis.

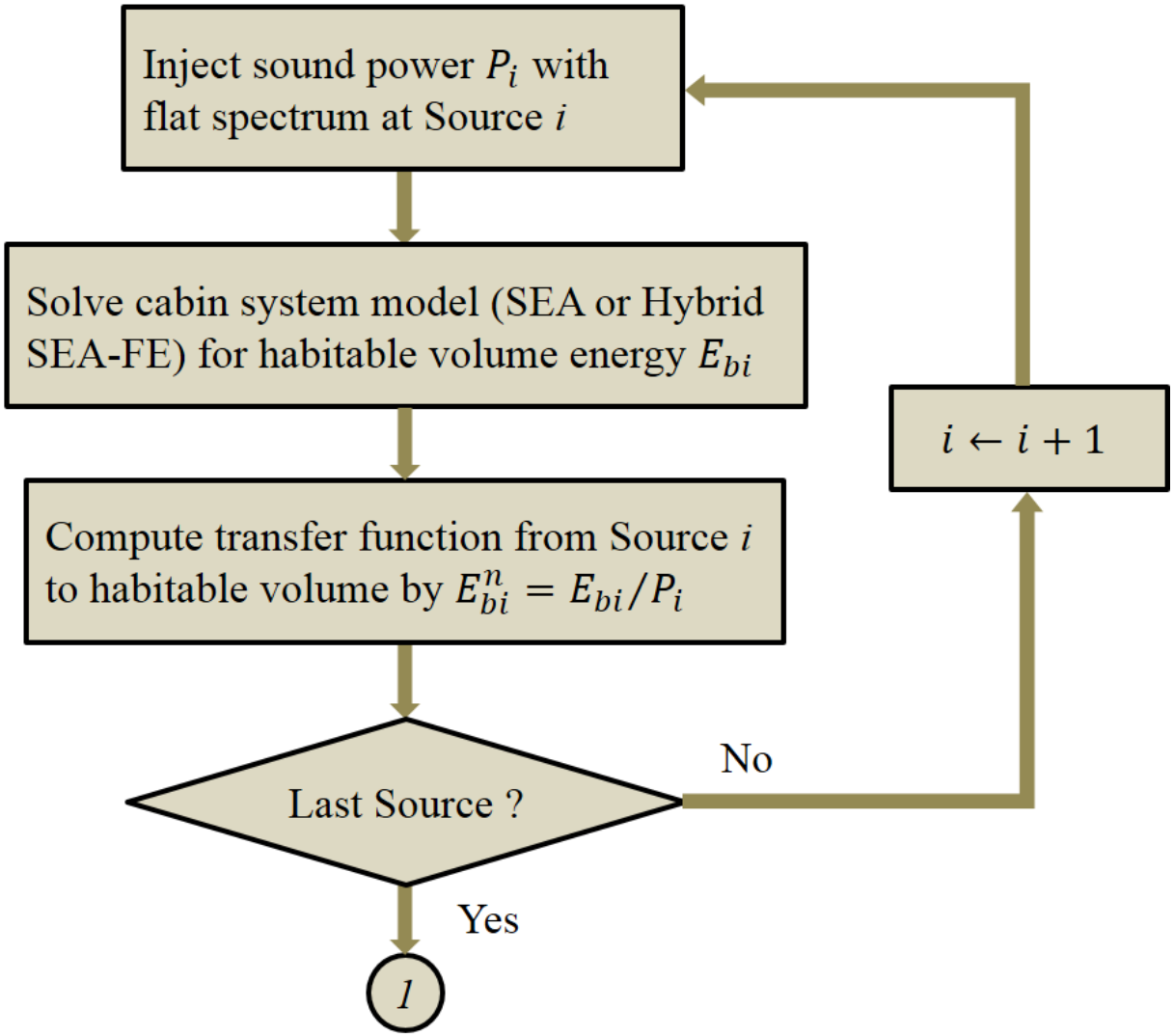
Noise Source Contributions to Habitable Volume Total Energy

- E_b is the total energy to maintain NC-50, the required SPL limits, in cabin habitable volume.
- E_b and α's are frequency dependent
- E_{bi}^n is obtained using PIM.

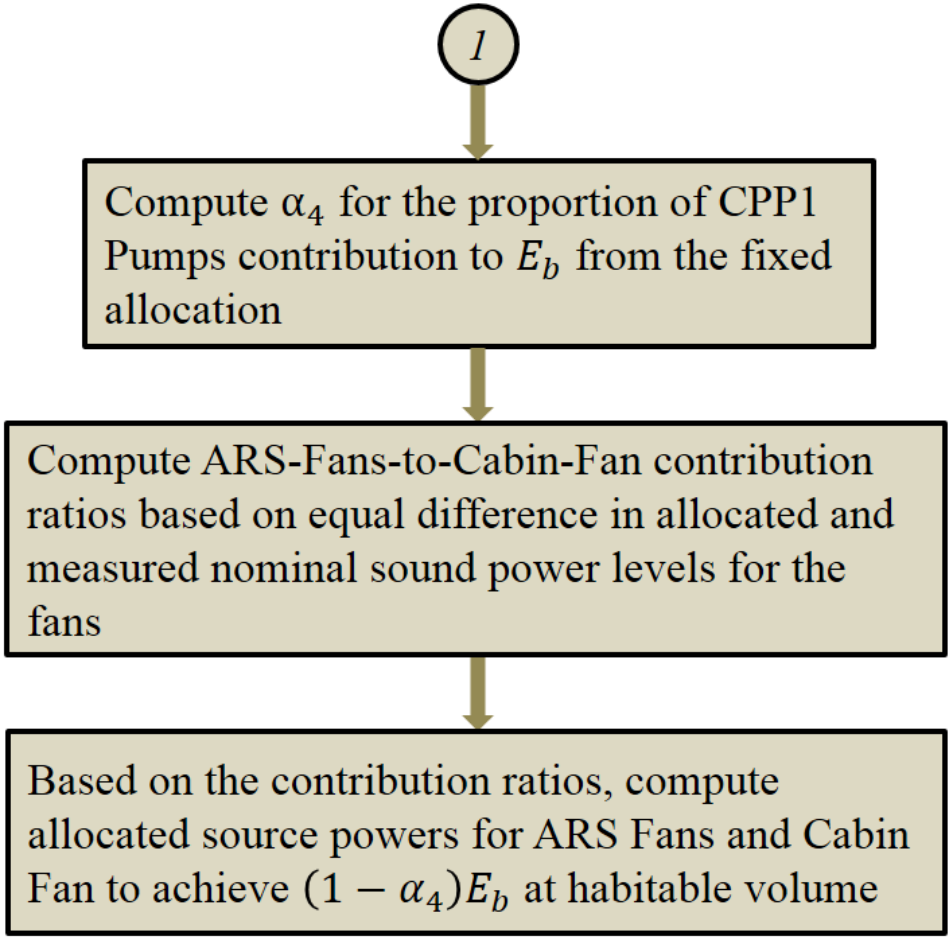


Process of Allocating Noise Source Sound Power

Based on Power Injection Method

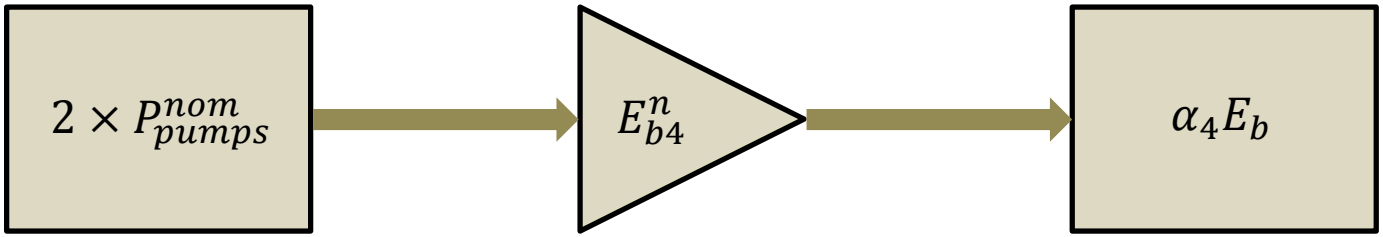


Process of Allocating Noise Source Sound Power



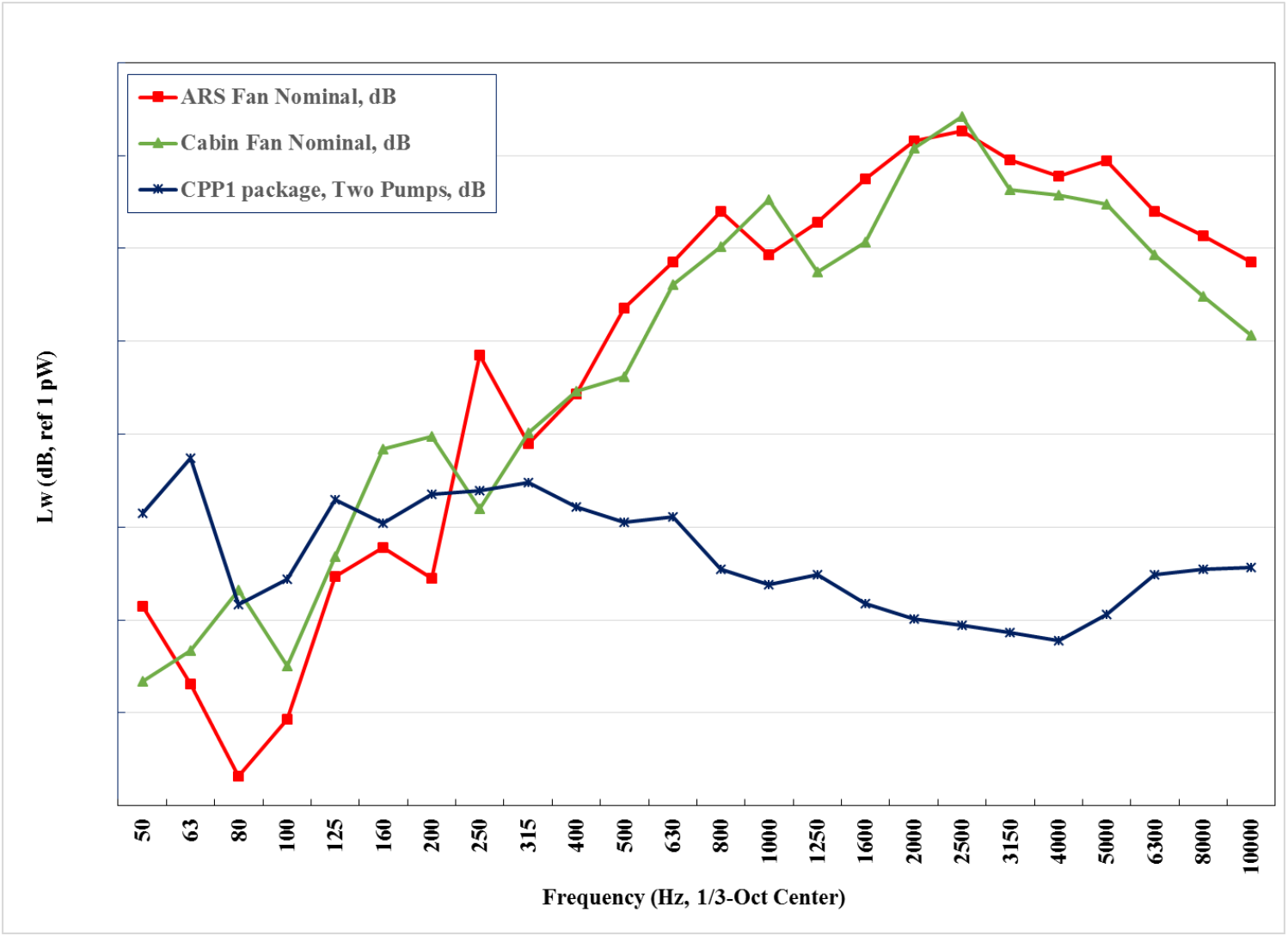
Allocation of CPP1 Pumps Sound Power

- P_{pumps}^{nom} is measured sound power of **two** pumps at nominal operating point.
- Fixed allocation is 3 dB above the sound power of 2 pumps, i.e., $2 \times P_{pumps}^{nom}$
- α_4 is derived from the fixed allocation
- The allocation of CPP1 does not require the usage of model as it is fixed at 3 dB above the measured PWL at all frequency bands.



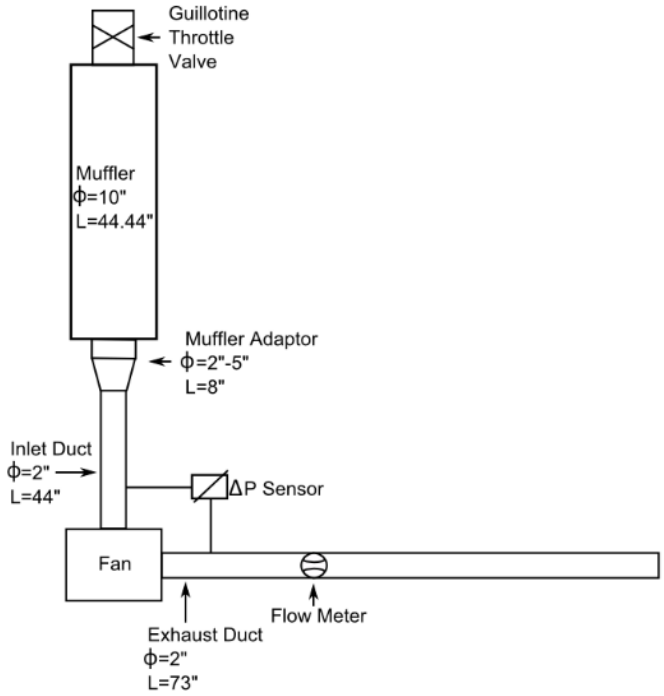
Allocated Sound Power Transfer Function

Source PWLs of Fans/Pumps at Nominal Operating Points



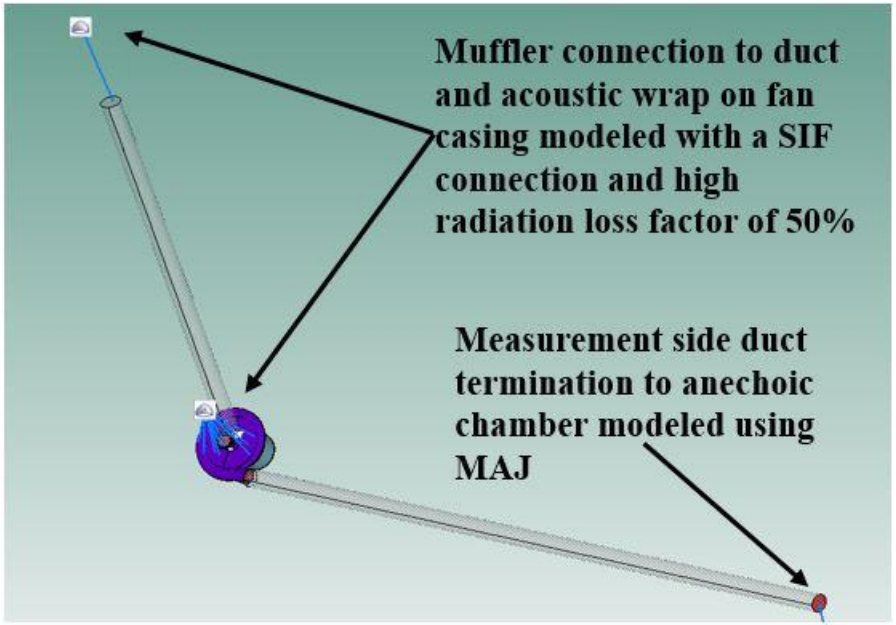
ARS Fan Exhaust Sound Power Measurement Setup

Fan Sound Power at JSC ANCL Anechoic Chamber

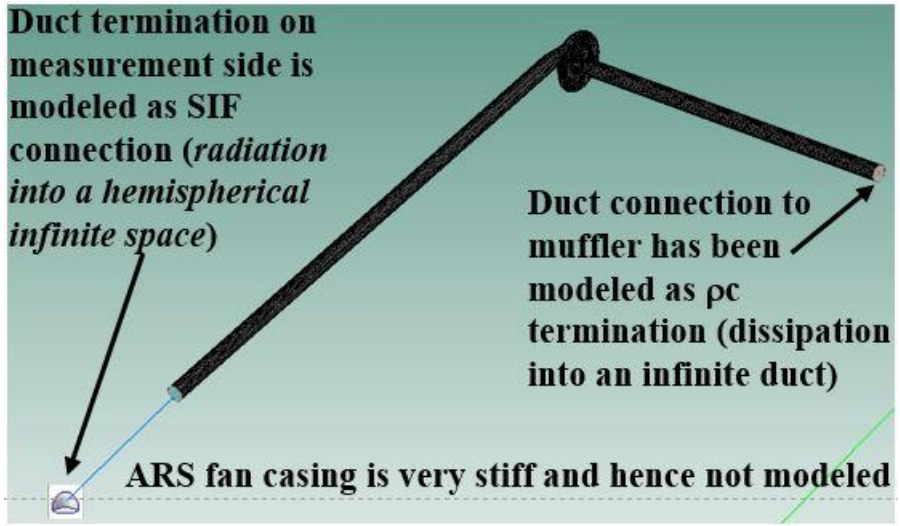


Models of ARS Fan Source Sound Power Characterization

SEA Model, for > 1,600 Hz



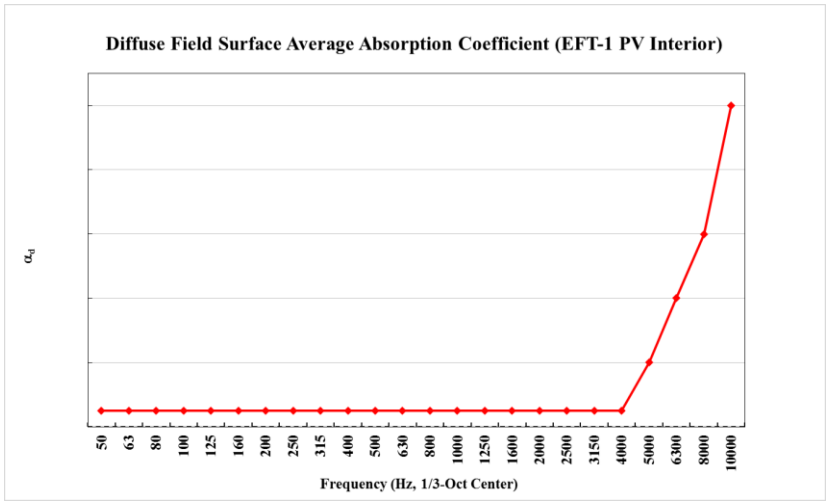
FE Model, for ≤ 1,600 Hz

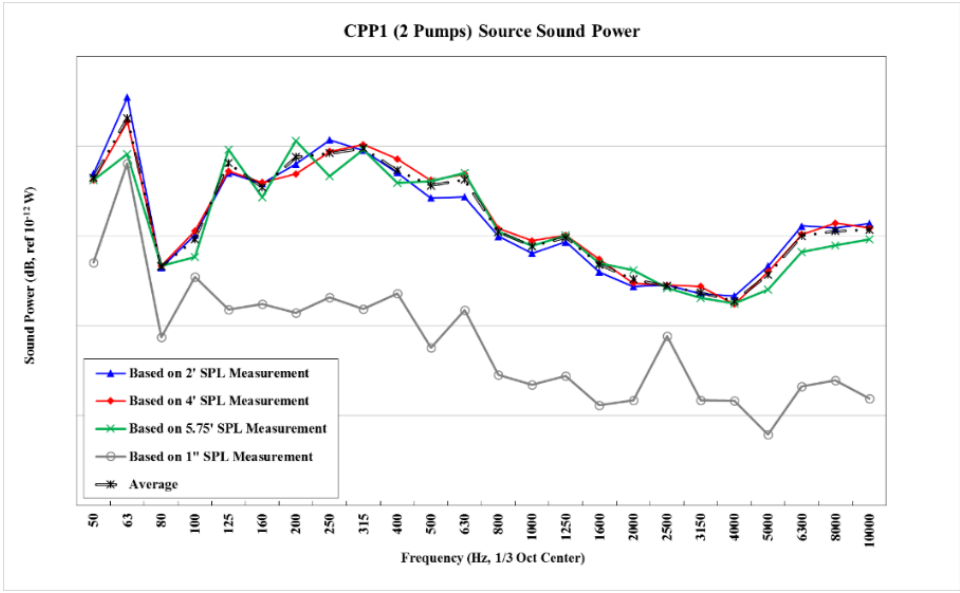


CPP1 SPL Measurement and Source Sound Power Characterization

- SPLs were measured from several distances from CPP1 inside EFT-1 at KSC.
- Source sound power was derived using the Eyring equation assuming hemispherical radiation.

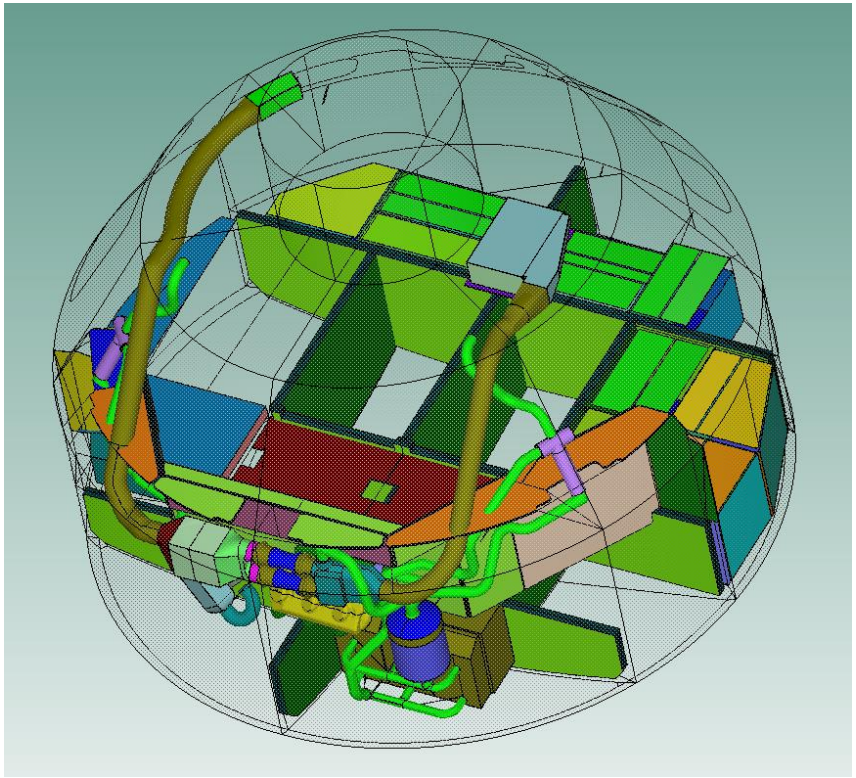
$$L_p(r) = L_w + 10log_{10}\left(\frac{Q}{4\pi r^2} + \frac{4}{R}\right)$$



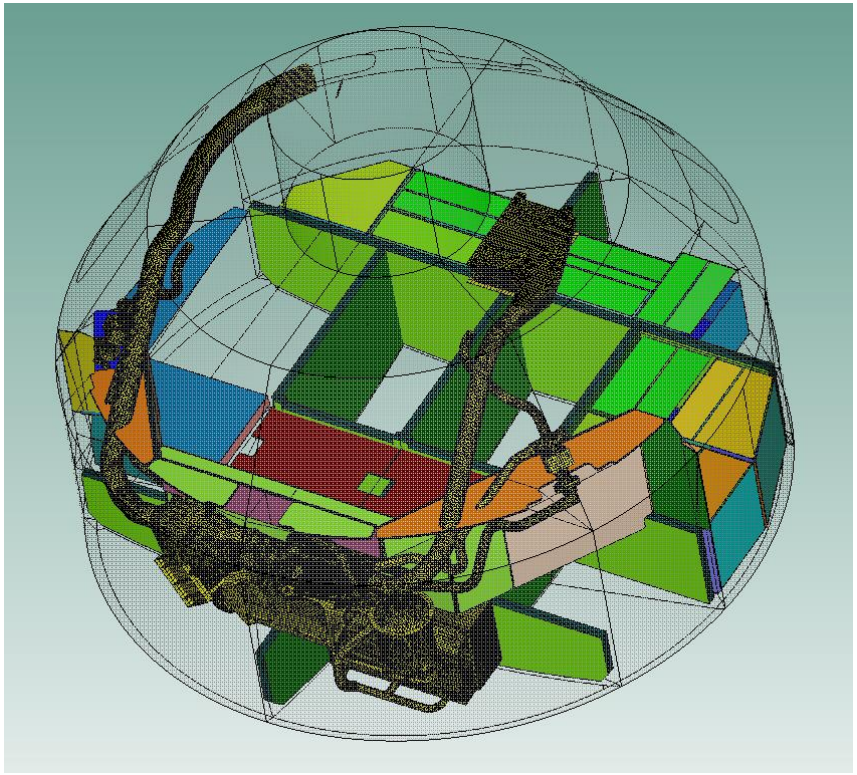


Orion Cabin System Models

SEA Model, for > 1,600 Hz

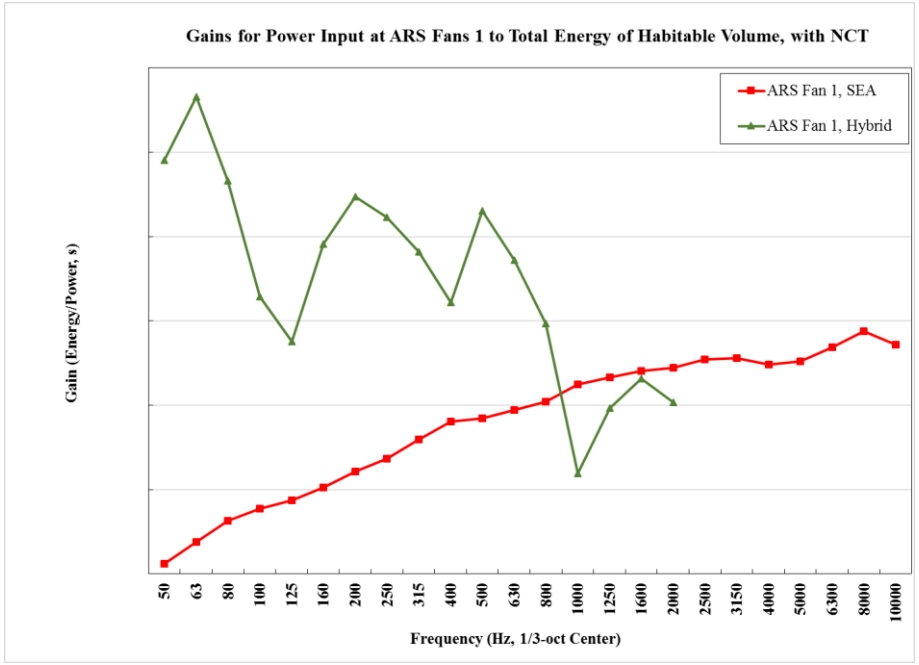


Hybrid SEA-FE Model, for ≤ 1,600 Hz

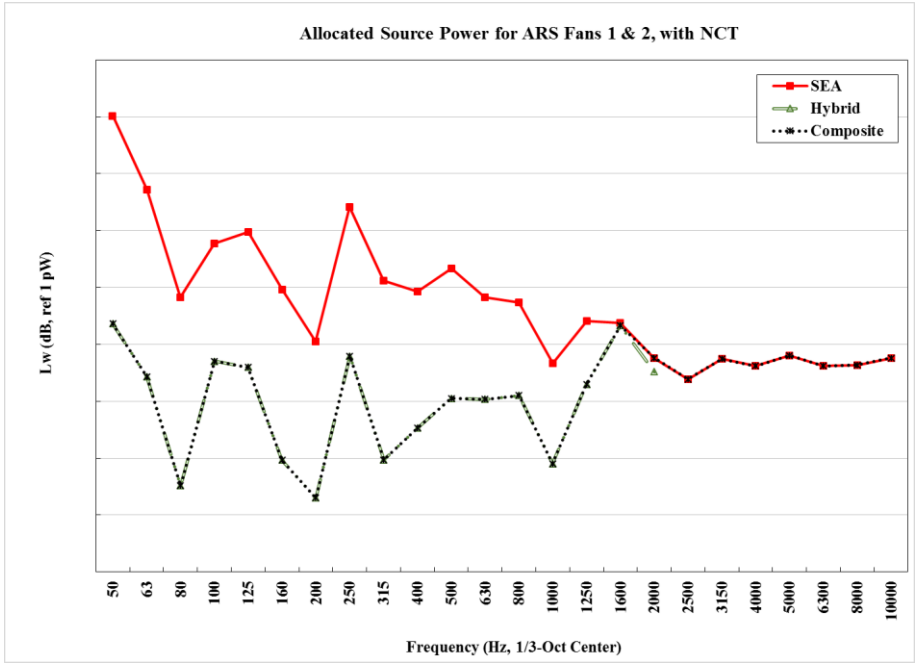


SEA vs. Hybrid SEA-FE

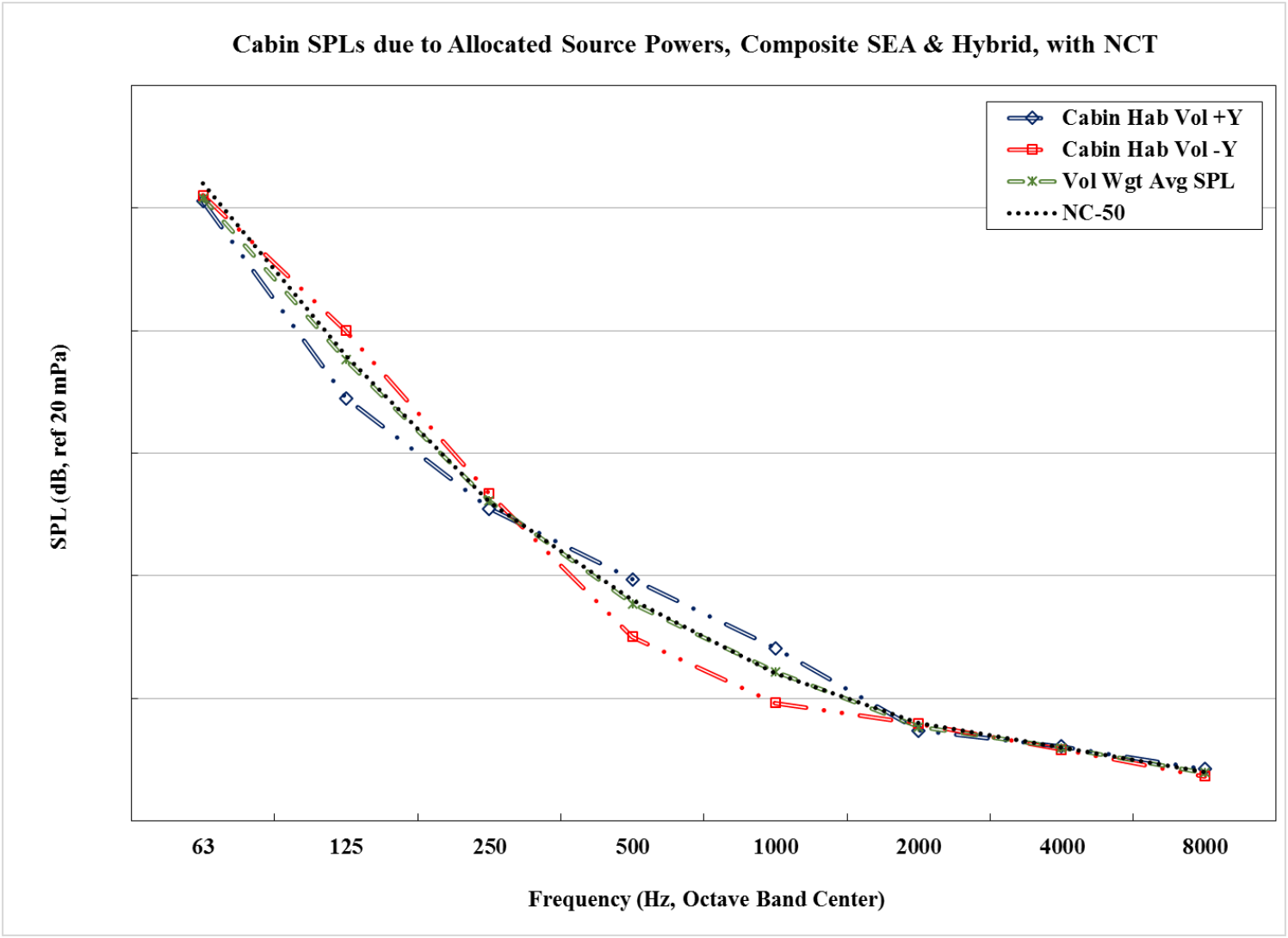
ARS Fan 1 Source-to-Receiver Gains



ARS Fans 1&2 Allocated Source Power

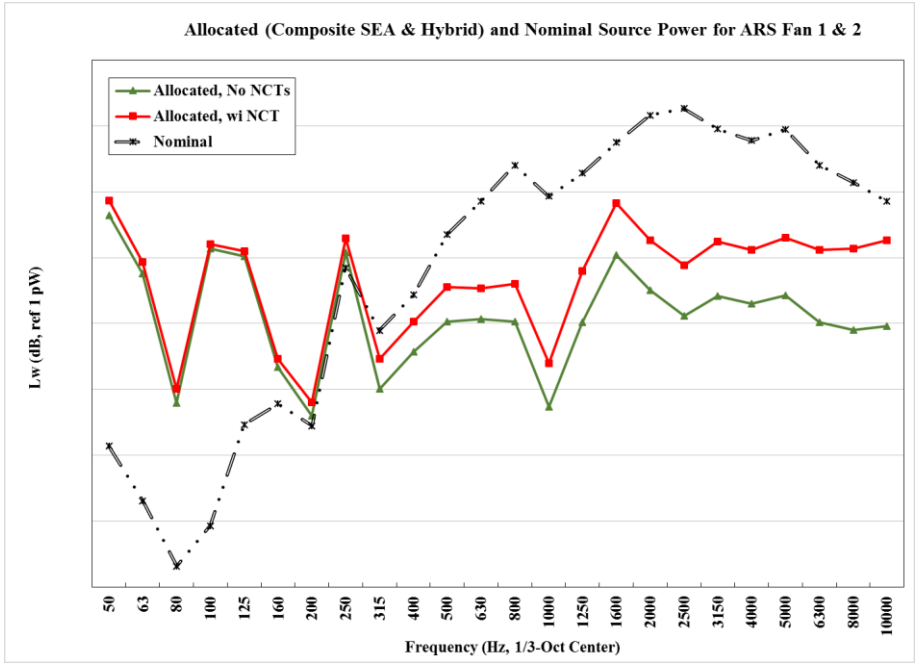


Cabin SPL due to Allocated Noise Source Powers

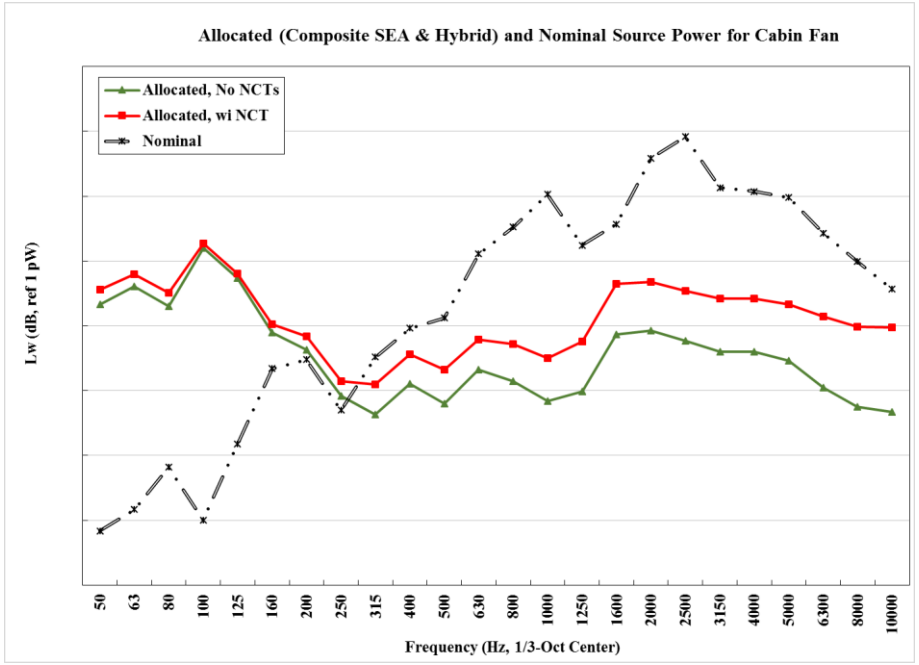


The Effect of NCT on Noise Source Powers

ARS Fans 1&2

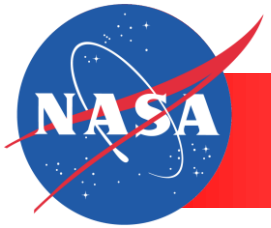


Cabin Fan



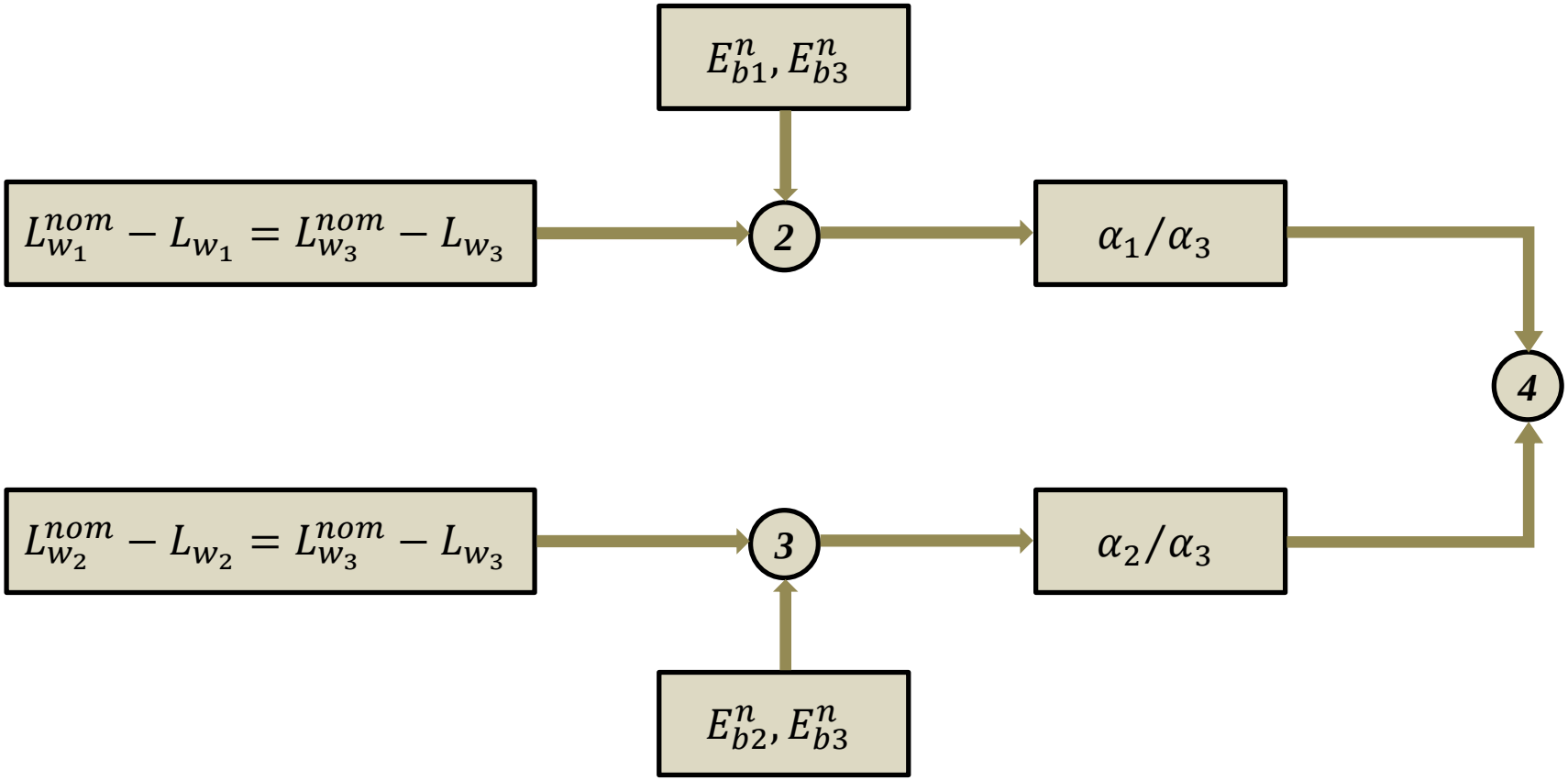
Conclusions and Future Work

- A methodology for allocating the SPL limits of a spacecraft interior to the PWL limits of major noise sources was developed. The method is based on the PIM and controls the total acoustic energy of the spacecraft interior for maintaining the required SPL limits.
- The inlet/outlet PWLs of the ARS fan and cabin fan at nominal operating points were measured; while SPLs at different distances from the CPP1 pump were measured inside the EFT-1 flight vehicle. Both SEA and FE models of fan test ductwork were used to derive source's PWLs, and the Eyring equation was used to derive the source PWLs of CPP1 from measured SPLs.
- Both SEA and Hybrid SEA-FE were used for the allocation development. Representing ECLSS network using SEA instead of FE tends to under-predict the source-to-receiver gains and over-allocates the source powers for the fans.
- The effect of applying NCT to cabin surfaces is reduction of source-to-receiver gains and hence more lenient targets for noise sources in the mid-to-high frequencies. → Trade-off between developing quieter sources and more effective NCT in the cabin.
- Future work: development of ECLSS component noise targets/noise controls, and verification of allocation during Orion MPCV vehicle level acoustic tests.

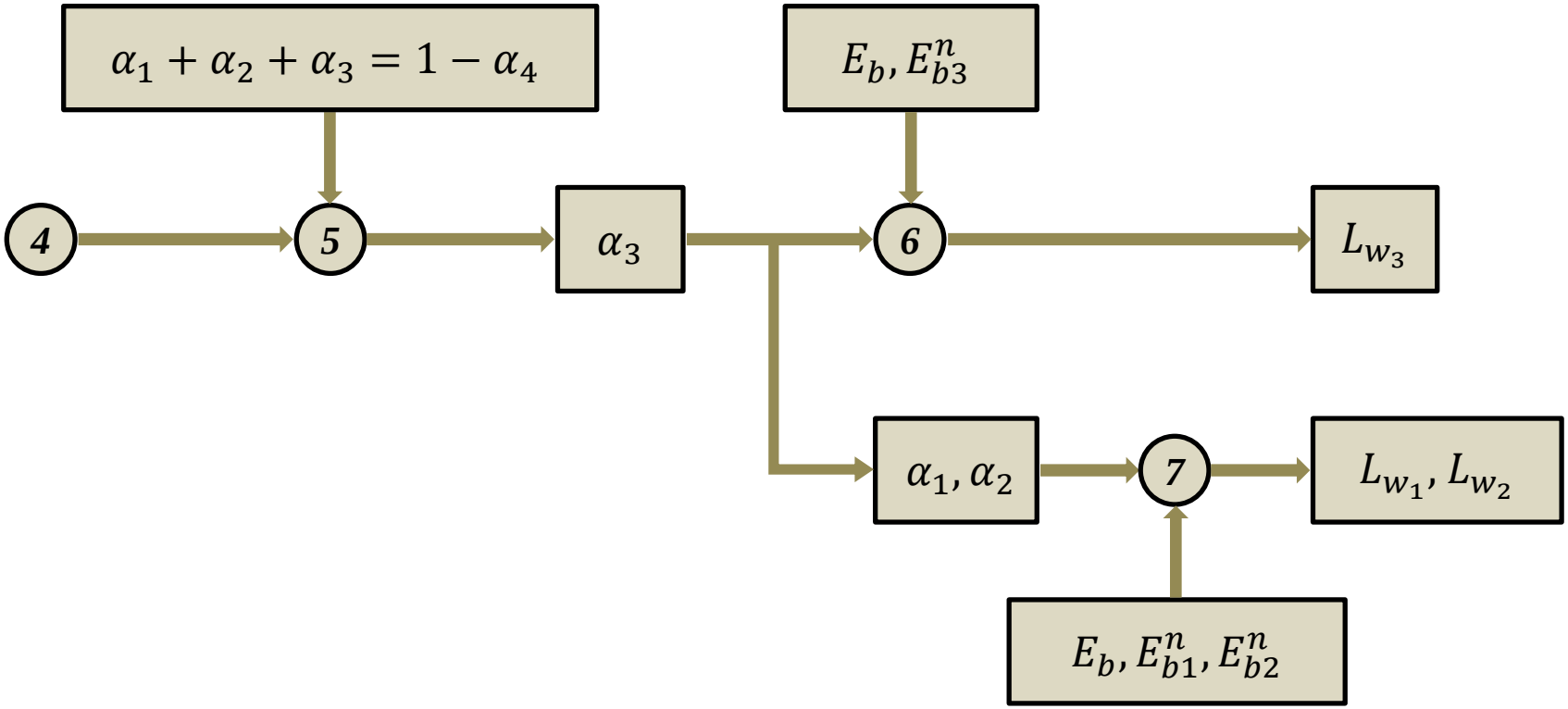


Backup

Allocations of ARS and Cabin Fans Sound Powers



Allocations of ARS and Cabin Fans Sound Powers



ARS Fan Source Sound Power