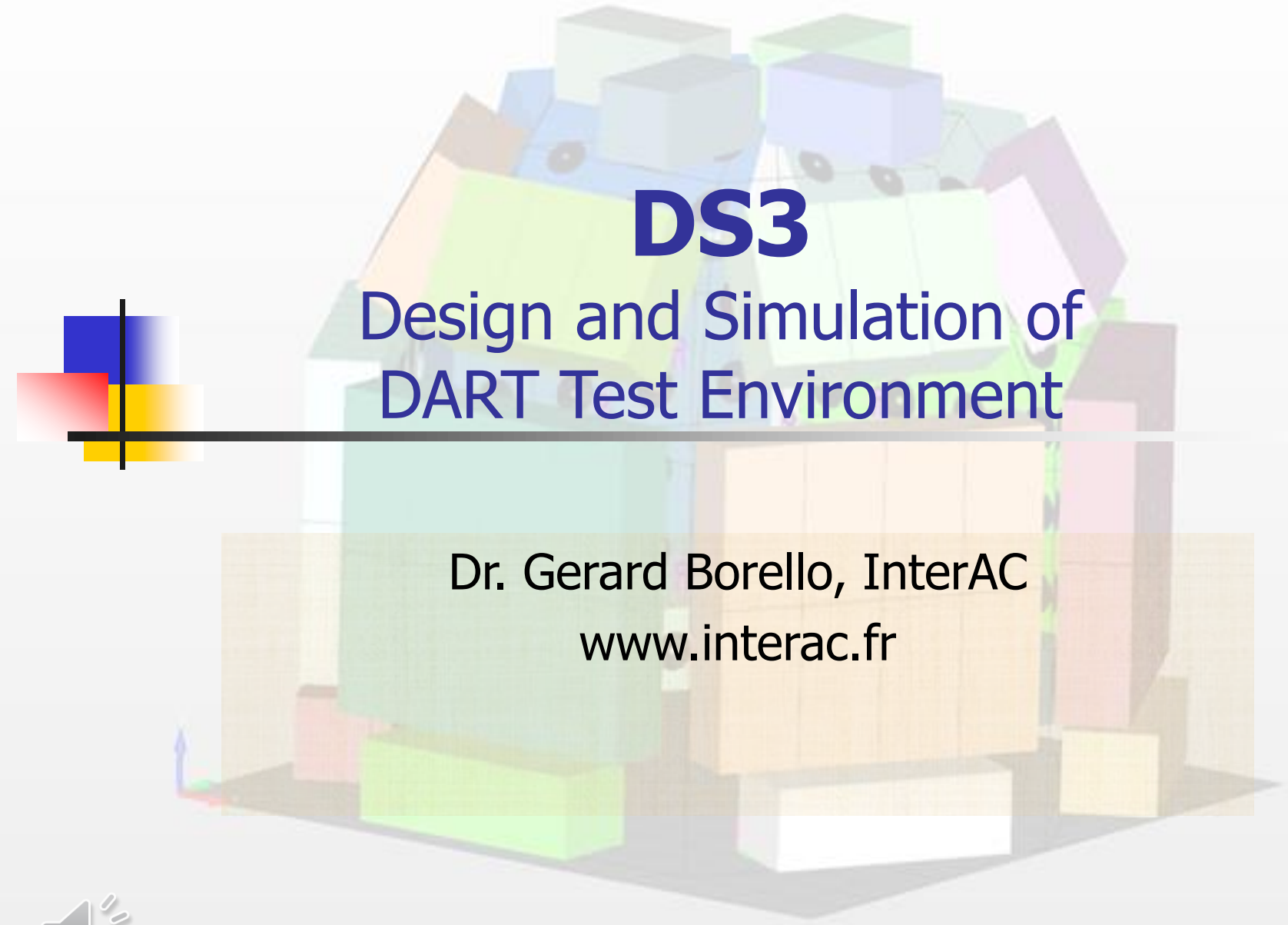


DS3

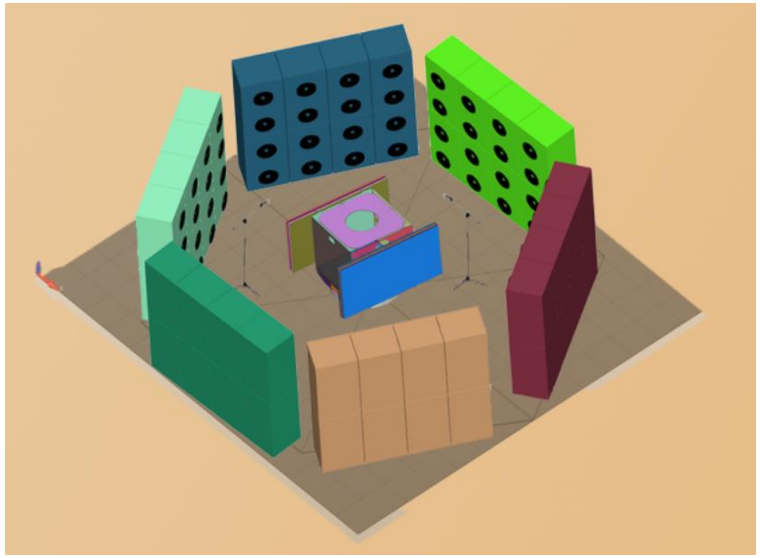
Design and Simulation of DART Test Environment

Dr. Gerard Borello, InterAC

www.interac.fr

DART Test System

- DART is an acronym for **Direct Acoustic Radiation Transfer**
- It refers to a specific type of acoustic qualification test of payloads, named DFAN, DFAX or DFAT in technical literature, the latter being the most popular but now registered as a trademark
- DART is an alternate solution to **reverberant chamber test** for acoustic qualification of spacecraft to random noise generated at launcher lift-off
- DART hardware is made of a swarm of high-powered loudspeakers located at a distance from the payload test specimen as sketched in here below picture

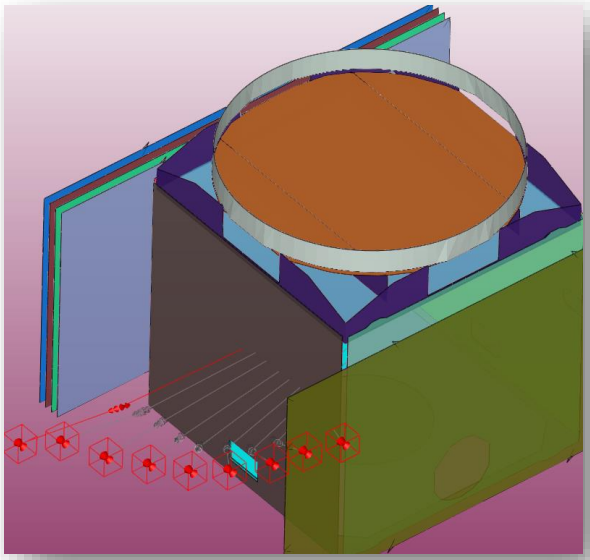


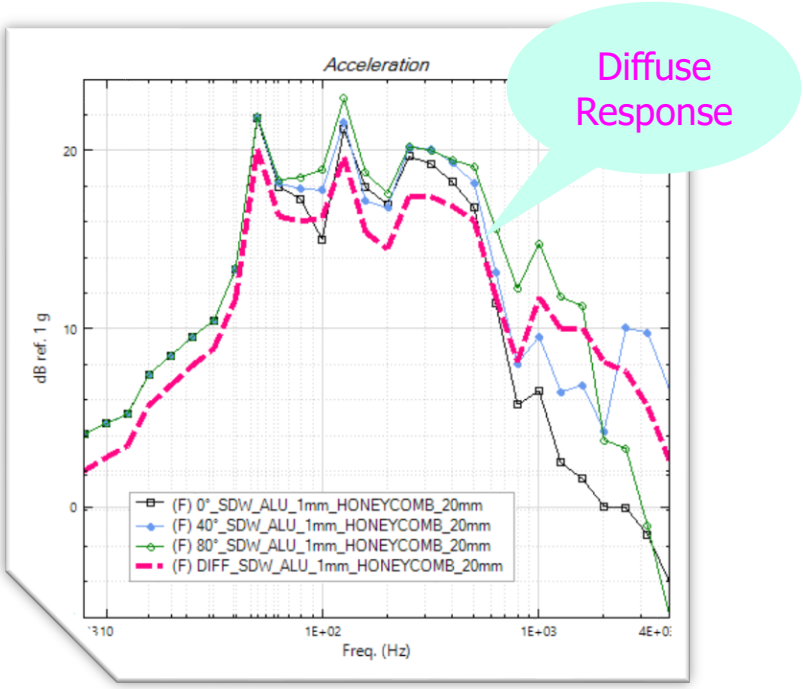
Benefits and Risks of DART Tests

- **Benefits**:
  - **Lowering qualification cost**
    - Tests performed on Payload integration site avoid transportation to an external test center equipped with reverberant chamber
  - **Accurate control of Sound Pressure Levels (SPL)** at set of predefined microphone locations
- **Risks**:
  - **SPL outside controlled points specific** to DART Setup
    - **Phase interference** due to radiation of correlated speakers
    - **Acoustic wave distribution** differs classical reverberant chamber to which payload structural response is sensitive (see next slide)
  - **Loss of the Universality of Test Responses**
    - **Extra variance in acoustic qualification**: Expected vibrational difference between a given DART configuration and reference levels provided by reverberant chamber tests
    - **Required update** of past numerical/experimental expertise for deriving actual lift-off qualification levels of spacecraft

Sensitivity of Sandwich Wall to Incidence

- RMS acceleration is predicted here with SEA+ software under acoustic plane wave incidence (0°, 40°, 80°) and Diffuse in 1/3rd octave bands for a payload sandwich (alu skin 1 mm, core 20 mm)
- Potential variation of RMS acceleration lies in between 2 to 10 dB from diffuse field prediction





DS3 Software for DART Risk Analysis

- **Numerical Simulation of DART Sound field at any location**
  - **Direct Solve** from input spectral voltages to local SPL
  - **Inverse Solve** from specified SPL to required input spectral voltages to be applied to the various loudspeakers

→ Prediction of interferential acoustic field (include reflections from the ground)

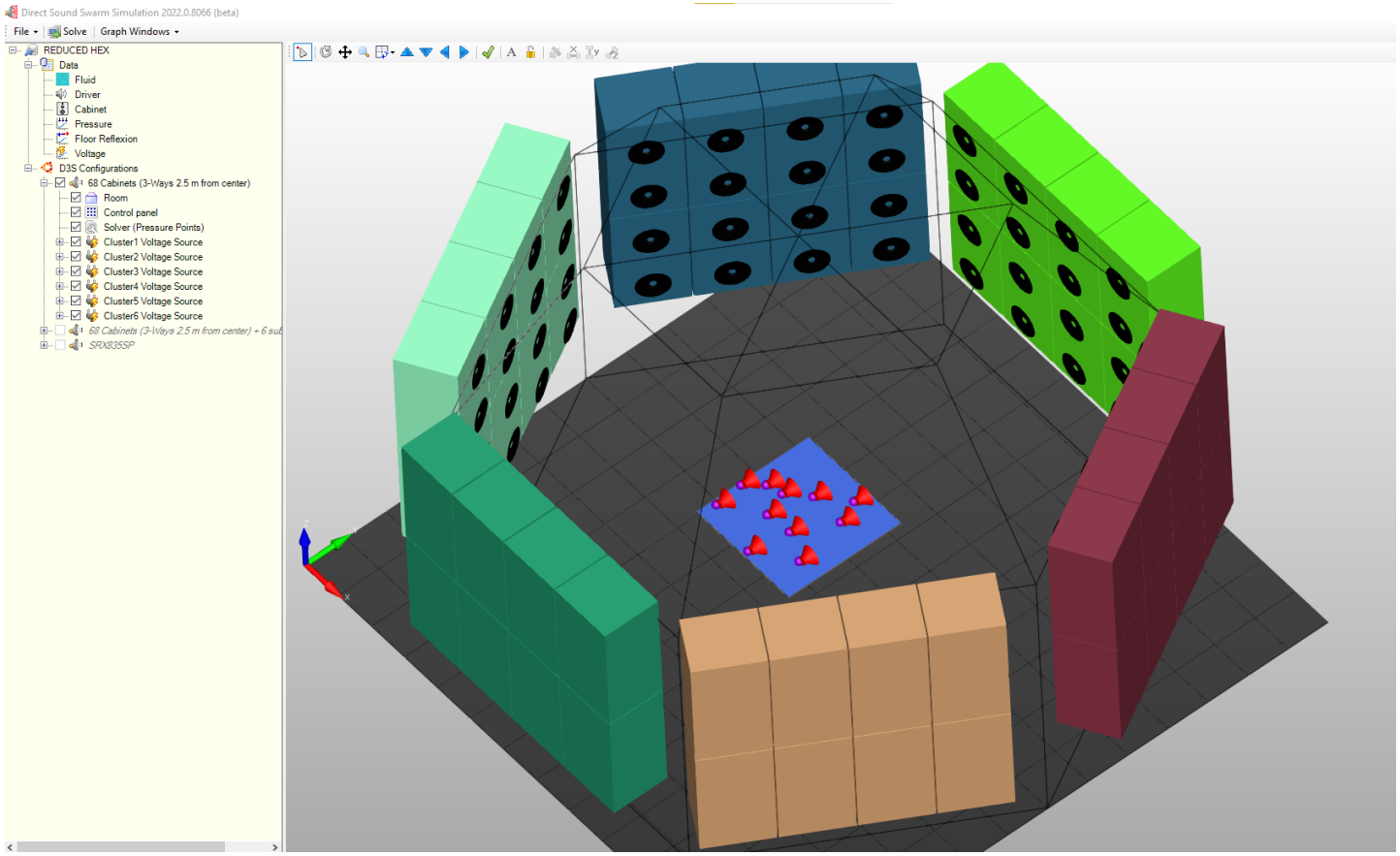
- **Numerical Analysis of Propagating Waves by the DART Swarm**
  - **2D-FFT of SPL distribution on reference movable panel surface**
  - Export as incident wave distribution to analyze vibrational response to DART sound field

Design and Simulation of DART Systems

- DS3 has two major capabilities: **Design** & **Simulation**
- **Design** for building your **own DART** system
  - **DS3** simulates the **electromagnetic** behavior of swarm of speakers from input voltage to delivered acoustic environment
  - **Loudspeakers** are modeled in **DS3** by their Thiele's parameters, easy to retrieve from simple electro-magnetic impedance measurement
  - **Any suitable speaker on market** place can be used in **DS3** to build a model of the DART setup

DS3 Software User Interface

- Windows App, 3D GUI and relational database for object properties accessed through tree-browser.
- Various configurations may be created from Browser.

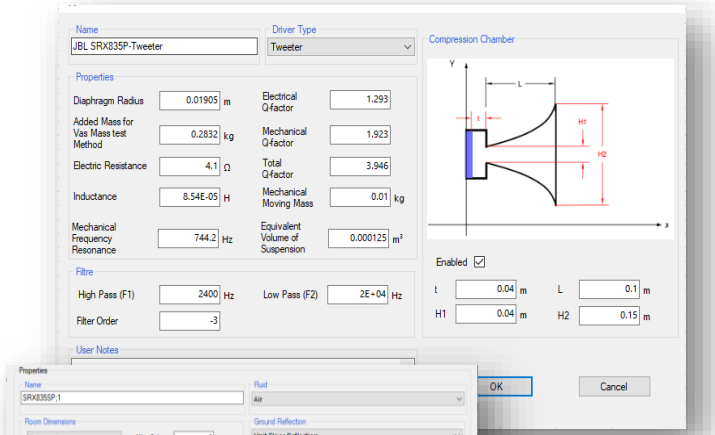


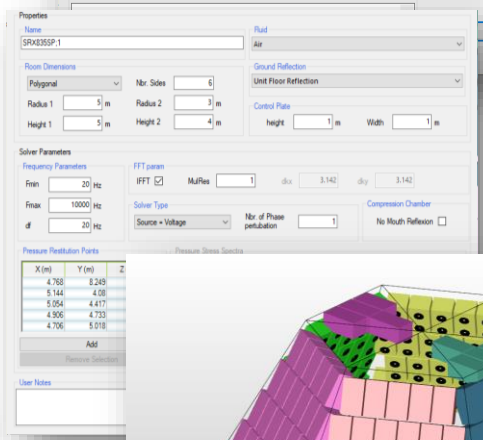
Design and Simulation of DART Systems: the DS3 Model

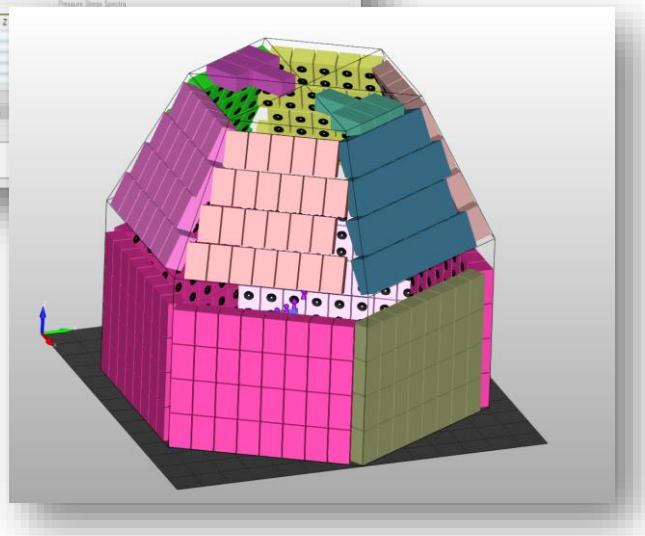
- **Simulation** for Analyzing Field Response
  - **Quick DS3 setup modeling** by arranging speaker drivers in cabinet cluster
  - **Prediction of all system parameters** such as:
    - Electric consumption required for reaching given SPL
    - Voltage and current spectra of all speakers
    - Velocity spectra of speaker diaphragm levels at controlled points for a set of discrete controllers (independent random signals driving the sub-set of cabinets)
    - Radiated power from both DS3 cabinet swarm and from individual cabinets
    - Dense mapping of SPL on a movable rectangle associated to 2D-FFT
    - Impulse audio responses in time domain

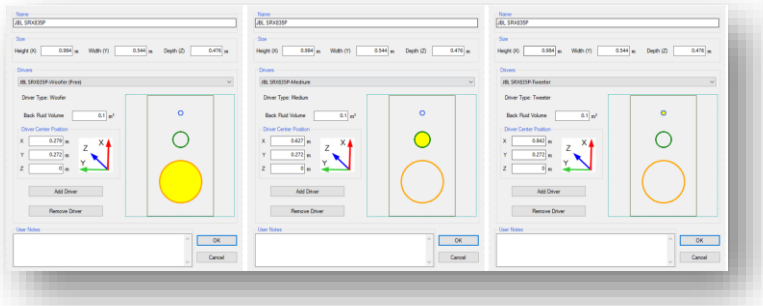
Building Models in the 3D-GUI of DS3

- **Defining** Electro-magnetic **drivers**
  - Input of their **Thiele's Parameters**
  - Adding **compression chamber** and **horn** to some drivers
- **Creating cabinets** containing required drivers
- **Associating** Cabinets to control voltage signals
- **Automated** generation of DART-type configuration from parametric geometry



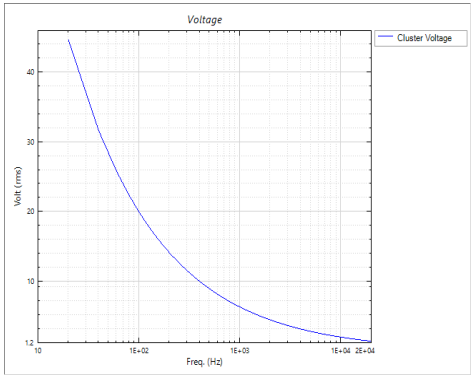


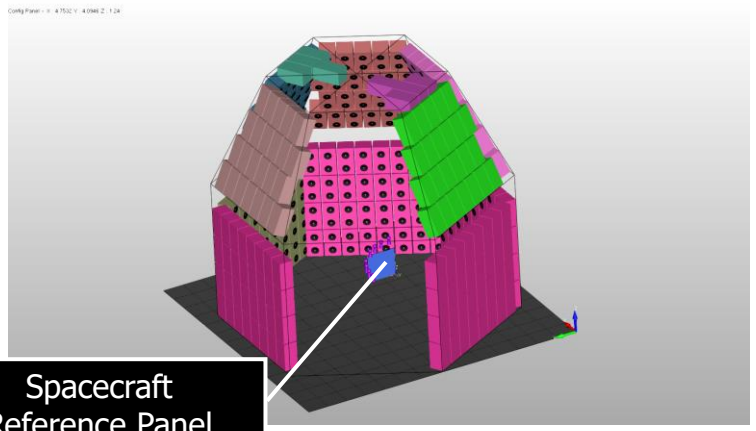




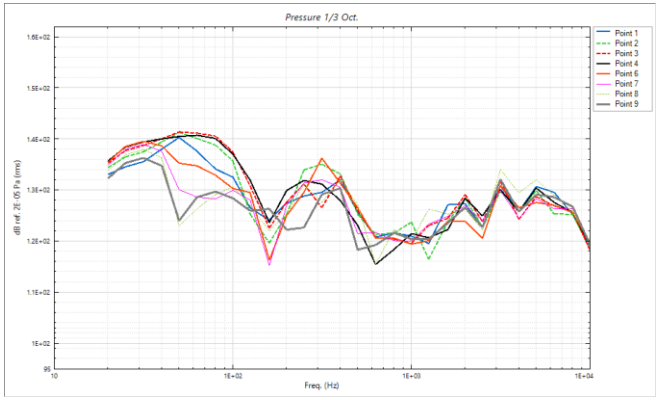
Analyzing DS3 Spectral Outputs

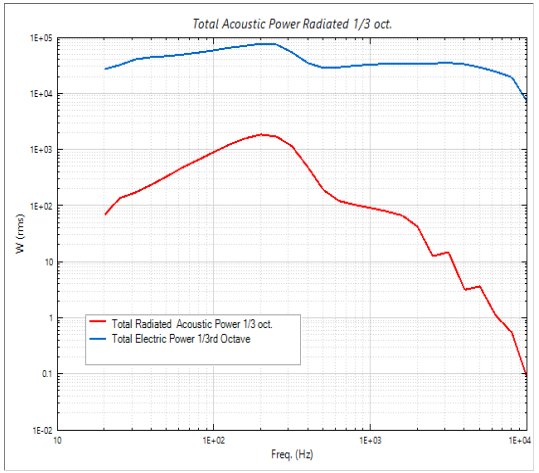
- Electric Voltage Input





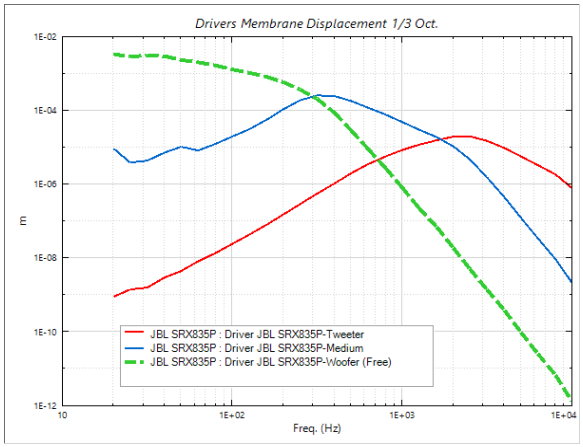
- SPL at controlled nodes, electric power and radiated acoustic power



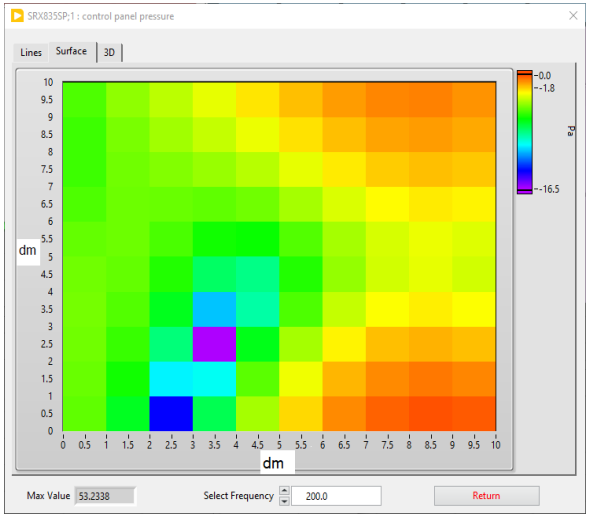


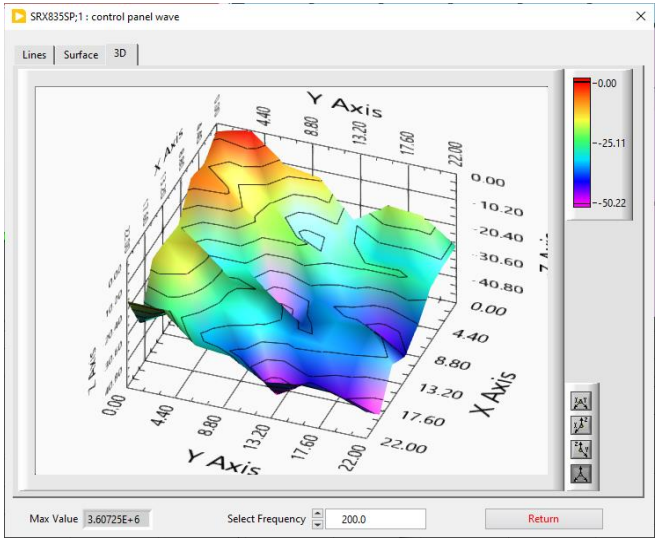
Analyzing DS3 Spectral and 2D-FFT Outputs

- **Motion of driver diaphragms**
  - RMS and 1/3rd octave spectra of
    - displacement
    - velocity
    - acceleration of diaphragms



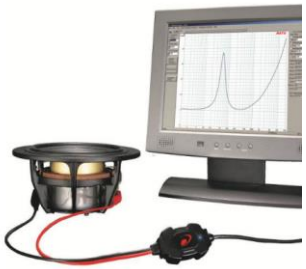
- **Payload Wall SPL mapping**
  - SPL distribution for selected frequency band
  - Mapping in wavenumber domain

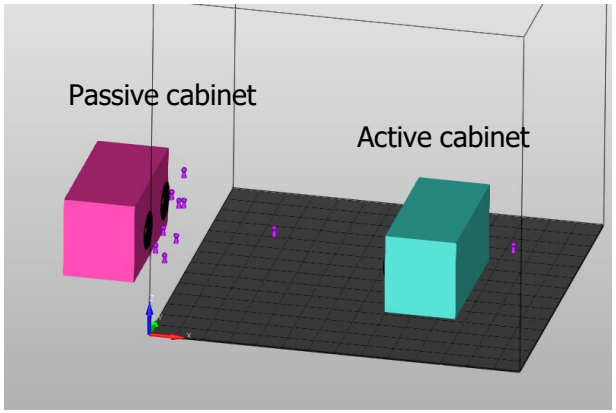


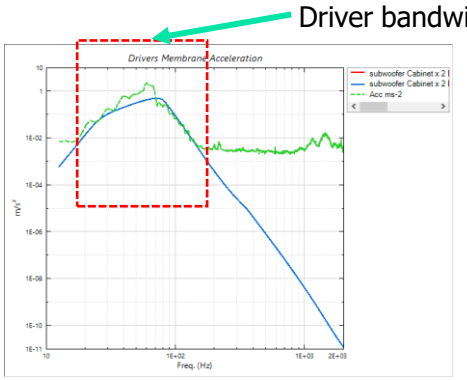


Validation of DS3 Simulation

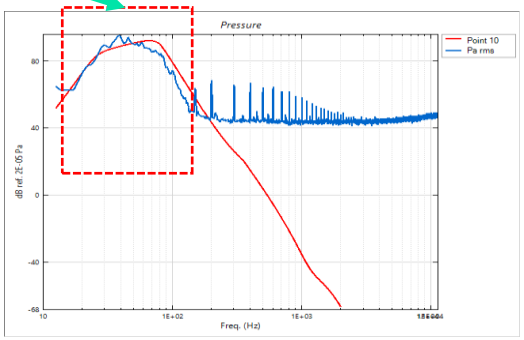
- Test campaigns with Airbus Defense and Space using set of JBL cabinets
- For both subwoofers and 3-Way JBL cabinets
  - Identification of Thiele's parameters of related drivers (Subwoofer, Woofer, medium and tweeter)
  - Simulation of subwoofer cabinet then, 3-ways cabinet
  - Cross-comparisons of measured and predicted SPL pressure at distance, directivity and diaphragm velocity
    - Single cabinet configuration
    - Two interacting cabinets (one passive, one active)







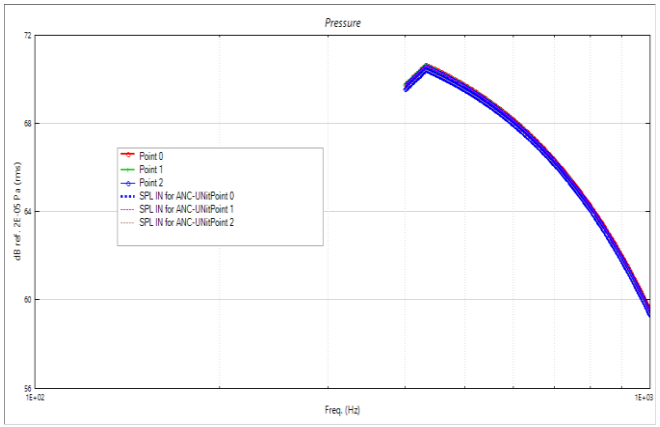
Driver Diaphragm acceleration in passive cabinet (predicted blue)



SPL at 2 m distance from active cabinet (predicted red and measured blue)

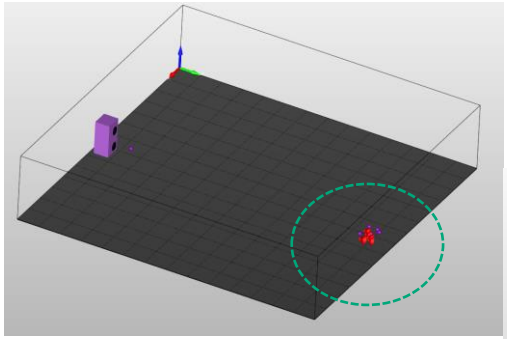
D3S Active Noise Control (**ANC**) Capabilities

- SPL is simulated at a set of distant points from a cabinet
- Voltage state at set of extra cabinets is identified by **ANC solver** for generating anti-sound at the set of previous distant points (same SPL but out-of-phase with SPL to cancel)

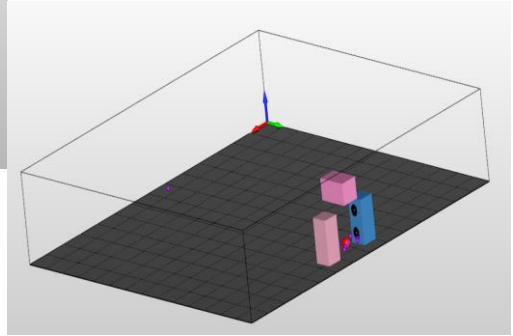


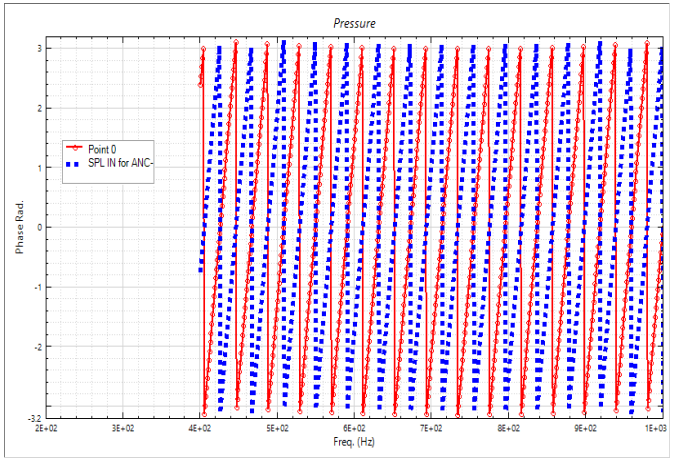
RMS moduli of Source and Anti-source signals

Generation of signal to cancel out



ANC cabinets to cancel out left SPLs





Phase or Source and Anti-source signals

Synthesis

- DS3 for DART Design & Simulation is an InterAC software
  - Calculation/test comparisons are based on measurements carried out in partnership with Airbus Defense and Space (ADS)
- For DART system modeling
  - from elementary electro-magnetic drivers parameters (Thiele's parameters)
  - by including drivers in user-defined cabinets
  - by creating cluster of cabinets from user-defined geometrical configuration
- For DART Design by solving both direct & inverse problems
  - Starting from voltage, it provides SPLs, diaphragm responses and electric currents
  - Starting from specified SPLs, it provides diaphragm responses, electric currents and voltages
  - For a given number of independent specified voltage signals between controllers, each associated to a subset of cabinets, it provides the random or deterministic response of the system for analyzing wave interference effects within the generated wave field
  - The latter correlated pressure wave-field can be exported in SEA+ software for computing effects of spacecraft response to the specific DART field
- For Anti-sound analysis and control
  - Allow investigation of potential ANC solutions based on anti-sound speakers
- For more information contact: info@interac.fr