

# Vibro-Acoustic Analysis of Percussion Instrument and Experimental Verification

## 打擊樂器聲振耦合分析與實驗驗證

振動與聲學技術聯盟



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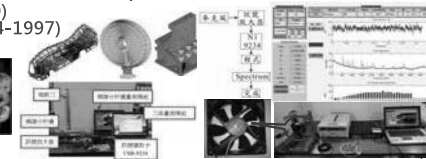
Homepage: <http://140.127.6.133/lab>



# 王栢村教授簡歷與研究主題



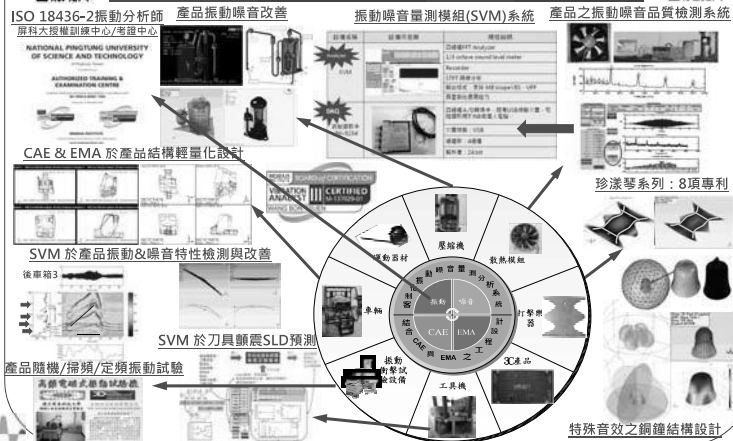
- 現職：**
  - 國立屏東科技大學
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  - 中華民國振動與噪音工程學會
    - 理事長(2014~2016)
  - 研發長(2011-2014)
  - 工學院院長(2007-2010)
  - 主任秘書(2003-2005)
  - 推廣教育中心主任(2001)
  - 機械工程系系主任(1997-2000)
  - 技術合作處研究發展組長(1994-1997)
  - 機械工廠主任(1991-1994)



- 專長：**
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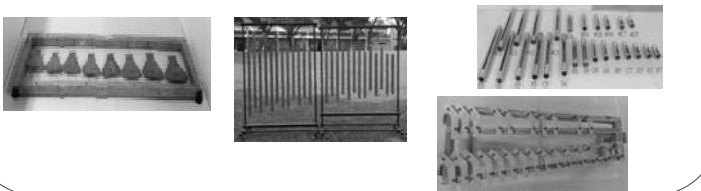
# 【振動噪音產學技術聯盟】推廣核心技術

## Fundamental knowledge → Domain knowledge



# Outline

1. Introduction
  - Percussion instruments
2. Virtual Testing for Percussion Instrument Design
  - FEA & EMA for virtual testing
3. New Percussion Instruments Developed by VAL/NPUST
  - Harmonic sound
  - Chord sound
4. Development of Tuned Percussion Instruments
  - Vibro-Acoustic Analysis
5. Conclusions and Future Works



# Categories of musical instruments

- Idiophone 體鳴 樂器【打擊樂器】
- Membranophone 膜鳴 樂器【打擊樂器】
- Chordophone 弦鳴 樂器【弦樂器】
- Aerophone 氣鳴 樂器【管樂器】



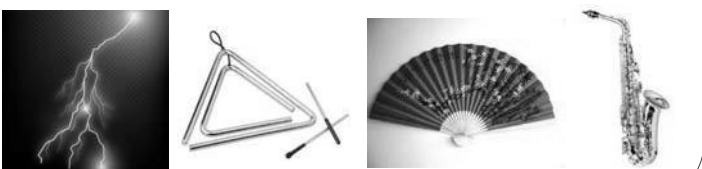
# Percussion Instruments

- The classification of percussion instruments
  - tuned or pitched (有調)
  - Un-tuned or unpitched (無調)



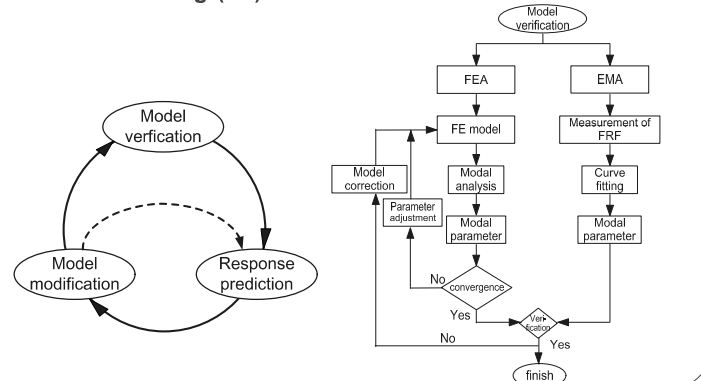
# 聲 (sound)

- Flow and Body interaction
  - 聲者，形氣相軋而成。
  - Flow - Flow：兩氣者，谷響雷聲之類。
  - Body - Body：兩形者，桴鼓叩擊之類。
  - Body - Flow：形軋氣，羽扇敲矢之類。
  - Flow - Body：氣軋形，人聲笙簧之類。

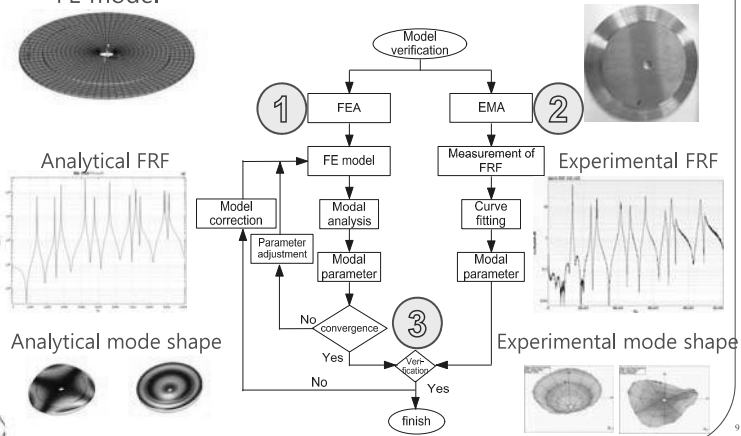


# 2. Virtual Testing for Percussion Instrument Design

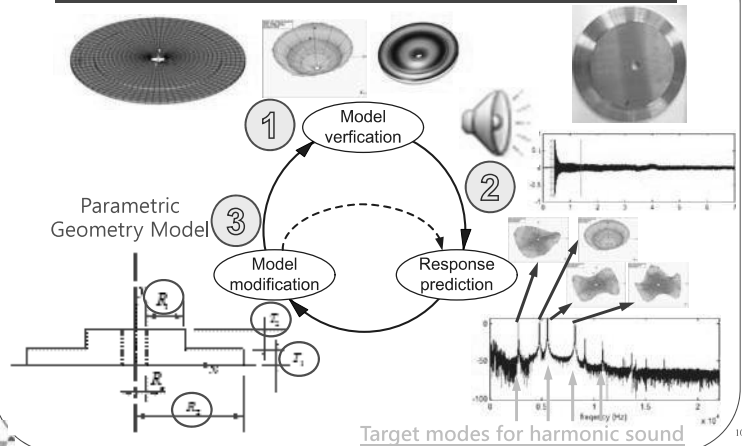
- Virtual Testing (VT)
- Model verification



## Model Verification

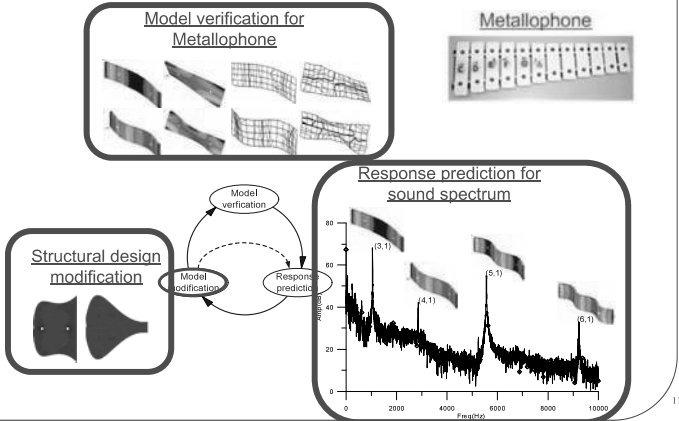


## Geometry Design for Different Notes



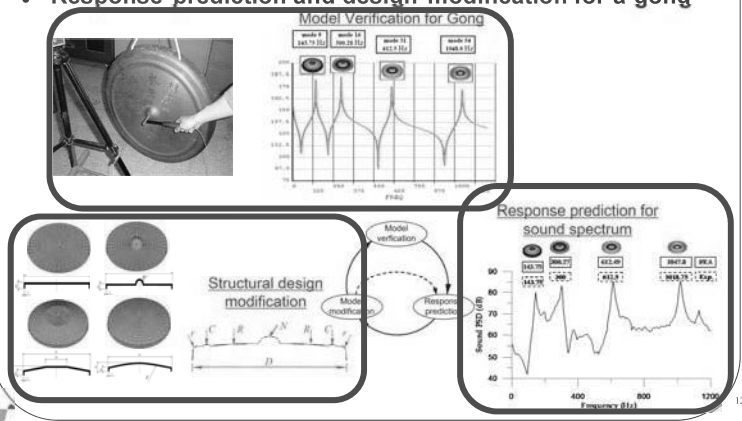
## 2-1 Metallophone Analysis

- Response prediction and design modification for metallophone plate

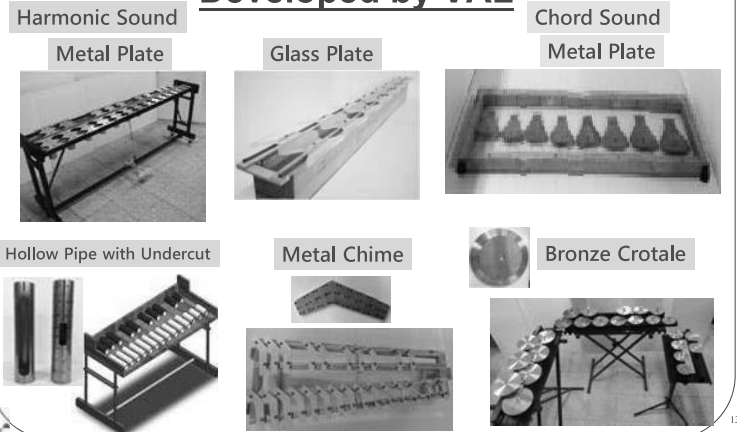


## 2-3 Copper Gong Analysis

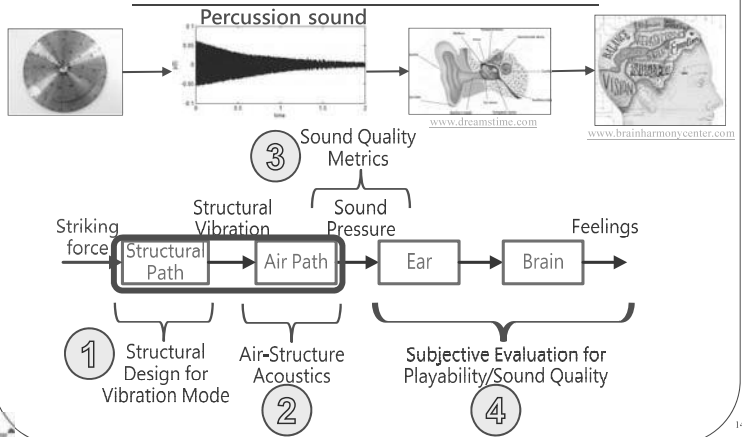
- Response prediction and design modification for a gong



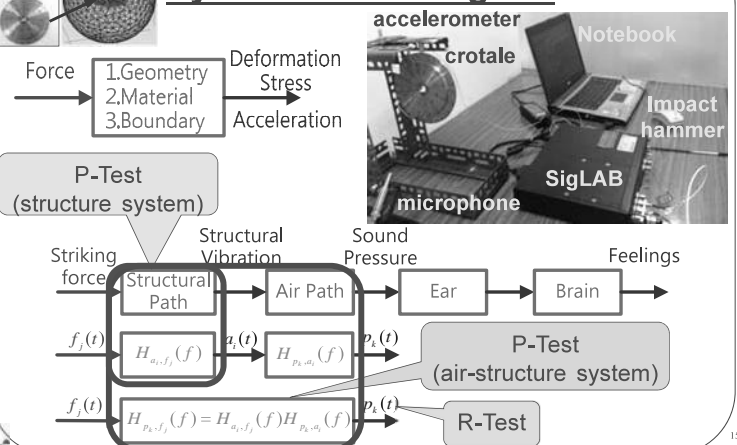
## 3. New Percussion Instruments Developed by VAL



## 4. Development of Tuned Percussion Instruments



## System Block Diagram



## Theoretical formulation for vibro-acoustic analysis

- The structure-only system which equations can be expressed as follows:

$$[M_s]\{\ddot{u}\} + [C_s]\{\dot{u}\} + [K_s]\{u\} = \{F_s\} + [R]\{p\}$$

- The air-path system equations can be expressed as follows:

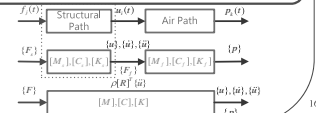
$$[M_f]\{\ddot{p}\} + [C_f]\{\dot{p}\} + [K_f]\{p\} = \{F_f\} - \rho_0[R]^T\{\ddot{u}\}$$

- The integrated fluid-structure system equation can be derived as follows:

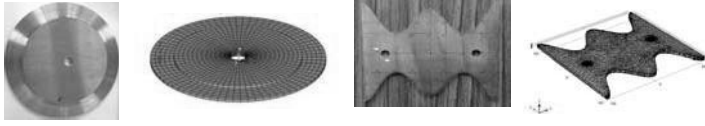
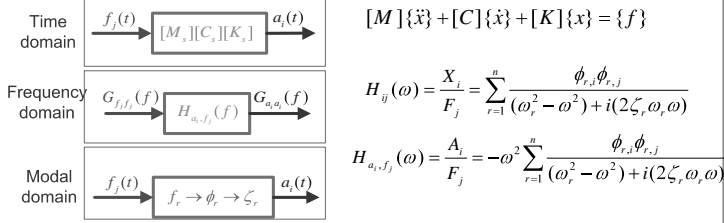
$$\begin{bmatrix} [M_s] & 0 \\ \rho_0[R]^T & [M_f] \end{bmatrix} \begin{Bmatrix} \{\ddot{u}\} \\ \{\ddot{p}\} \end{Bmatrix} + \begin{bmatrix} [C_s] & 0 \\ 0 & [C_f] \end{bmatrix} \begin{Bmatrix} \{\dot{u}\} \\ \{\dot{p}\} \end{Bmatrix} + \begin{bmatrix} [K_s] & -[R] \\ 0 & [K_f] \end{bmatrix} \begin{Bmatrix} \{u\} \\ \{p\} \end{Bmatrix} = \begin{Bmatrix} \{F_s\} \\ \{F_f\} \end{Bmatrix}$$

- or in the simple expression:

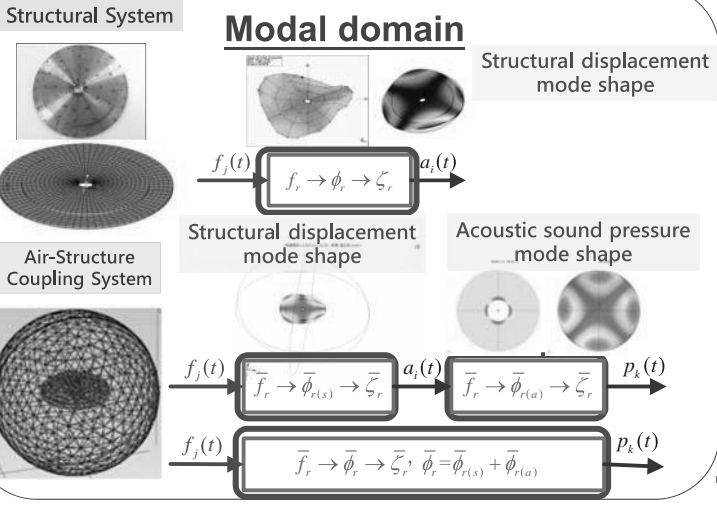
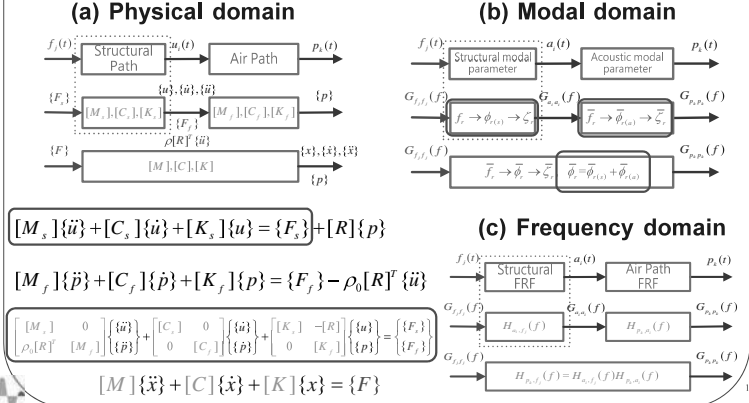
$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{F\}$$



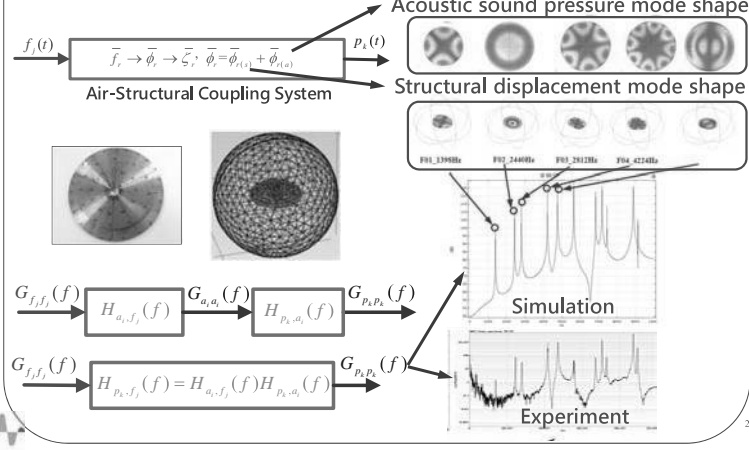
# System block diagram for Structure-only System



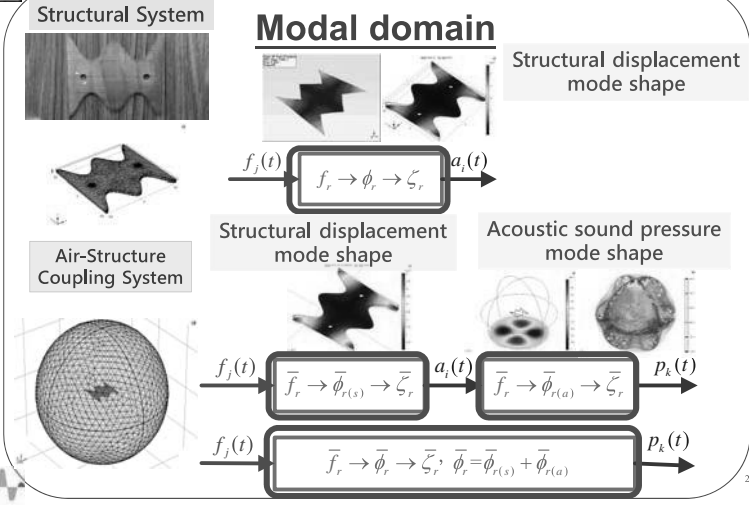
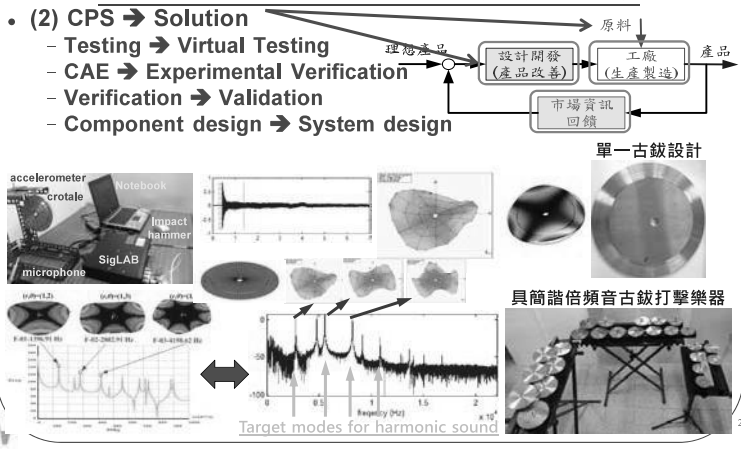
# System block diagram for air-structure analysis



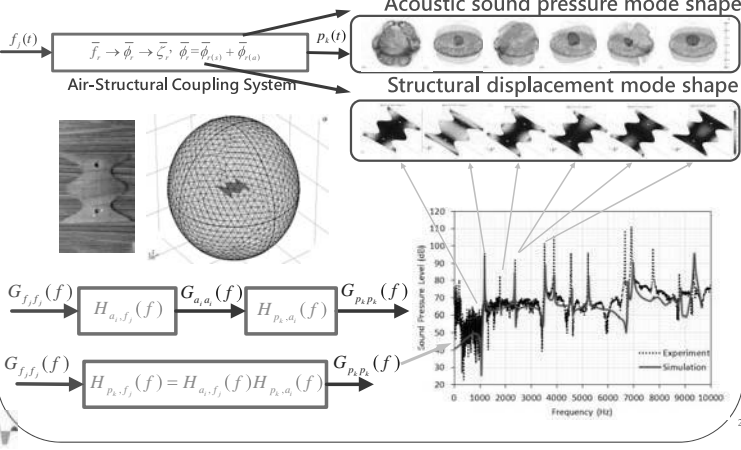
# Characteristics of Percussion Sound



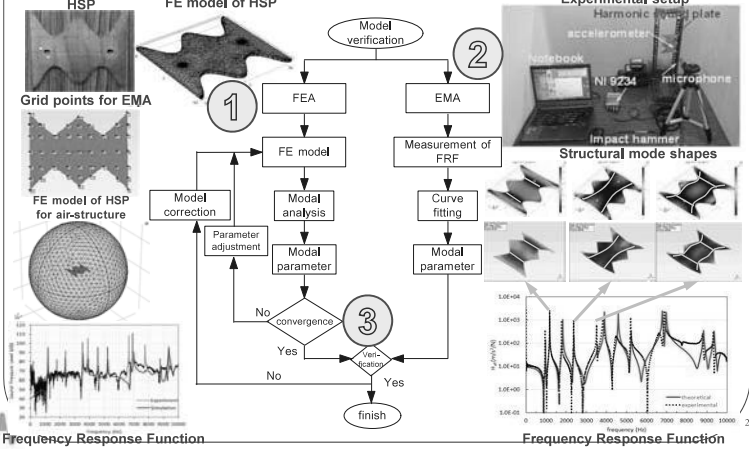
# Design for Crotales with Harmonic Sound



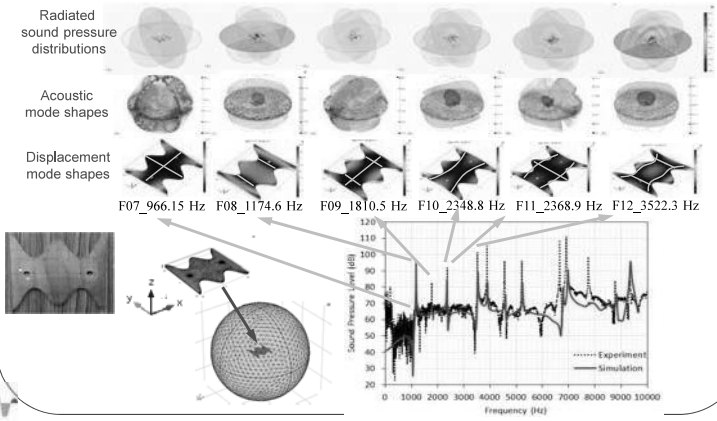
# Characteristics of Percussion Sound



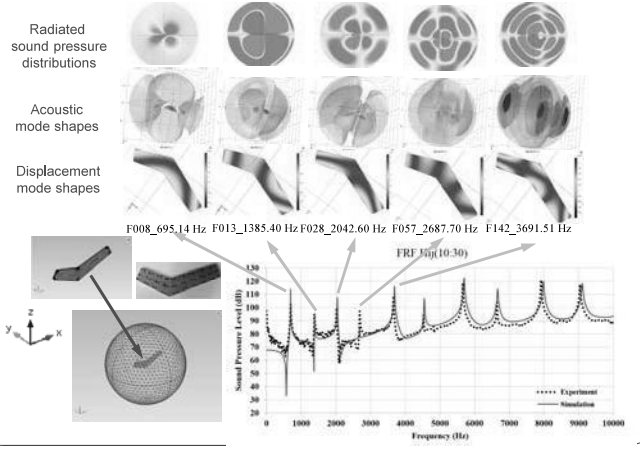
# Model Verification for HSP



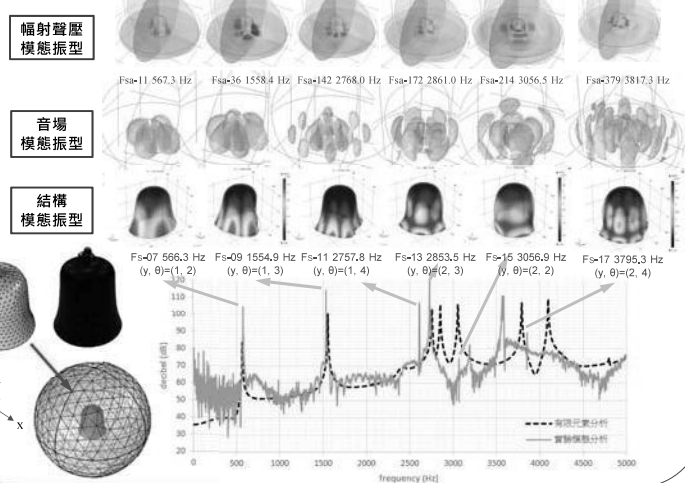
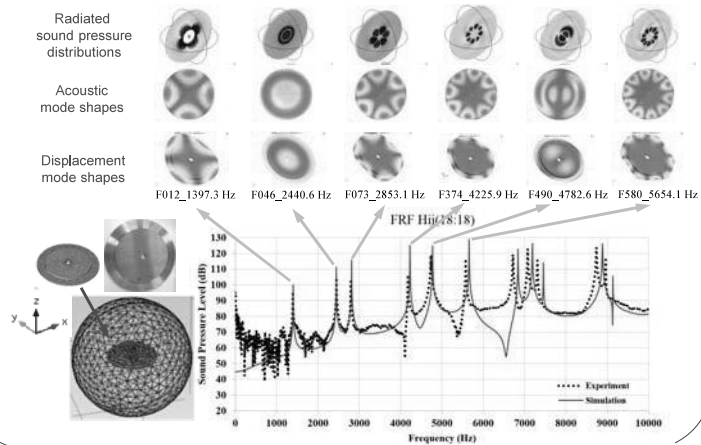
## Air-Structural FRF & mode shapes (animation) HSP



## Air-Structural FRF & mode shapes Steel Chimes Percussion Instrument



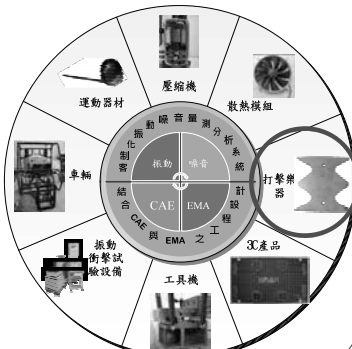
## Air-Structural FRF & mode shapes Crotale Percussion Instrument



## 5. Conclusions and Future Works

- Why I start to study musical instruments ?
  - Link to personal hobby
  - Close to life
- Why VAL get onto the percussion instruments ?
  - Structural vibration and acoustics
- Musical acoustics
  - very engineering
  - Interesting & Challenging
- Future works
  - New musical instruments
    - Lots to explore
  - Subjective evaluation
  - Commercial products

CAE/EMA/Vibration/Acoustics

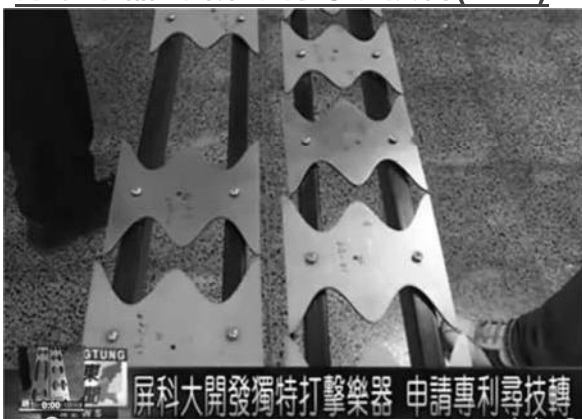


## Many more ...



www.quora.com

## 2016.03.24--屏東新聞 屏科大開發獨特打擊樂器 申請專利尋求技轉(3.12)



## Thank you for your attention.



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深耕：組建堅固信賴深耕  
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