

# Vibroacustica di Lanciatori Spaziali: Problematiche e Metodi

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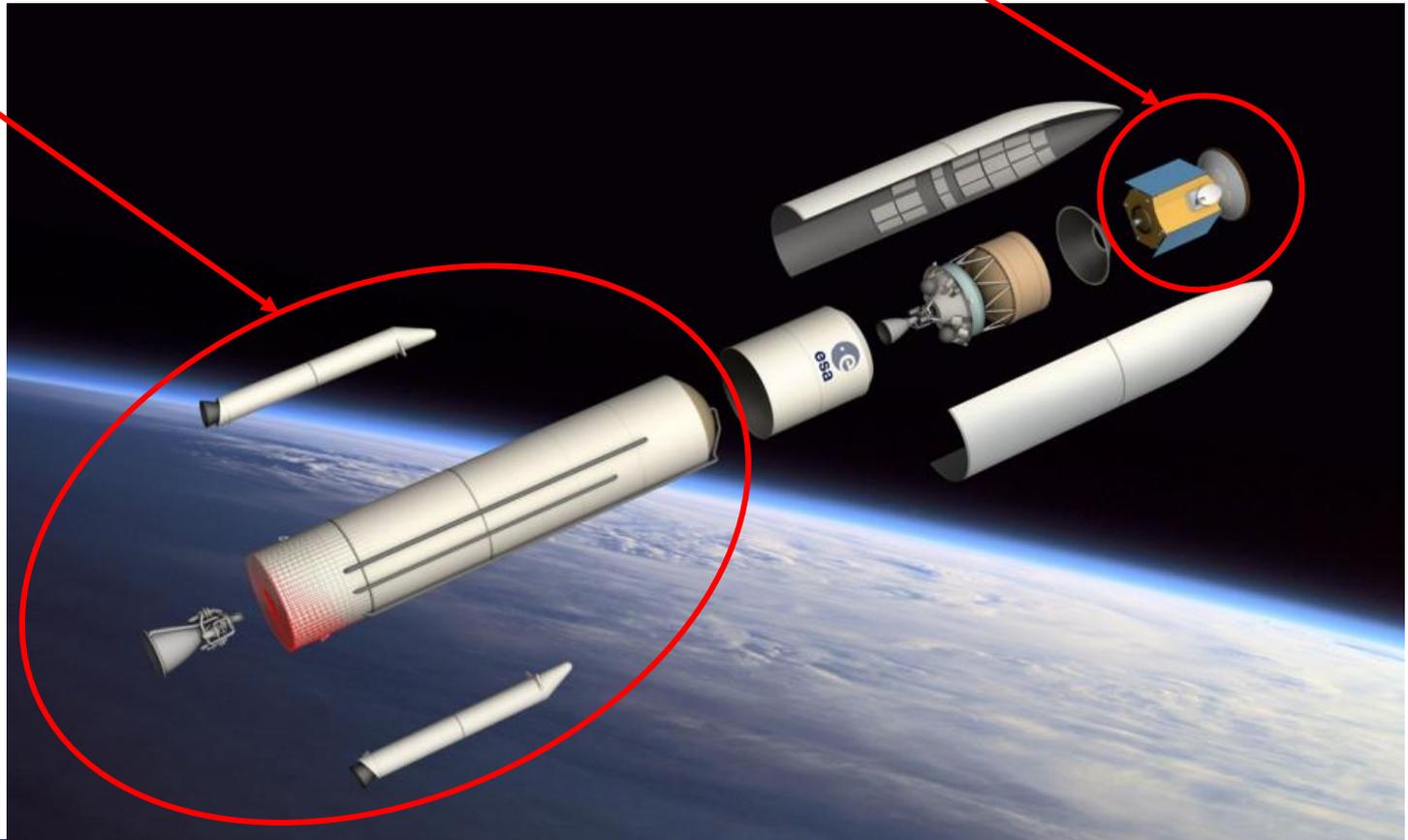
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# Cosa sono...?

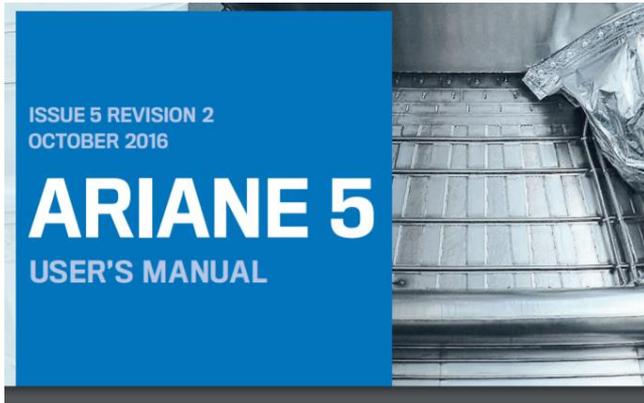
In astronautica, il lanciatore è un veicolo propulso da un particolare tipo di motori detti **endoreattori**.

È il mezzo usato per inviare nello spazio un certo **carico utile**



# Come è fatto?

Curiosità:  
Esistono i  
MANUALI...



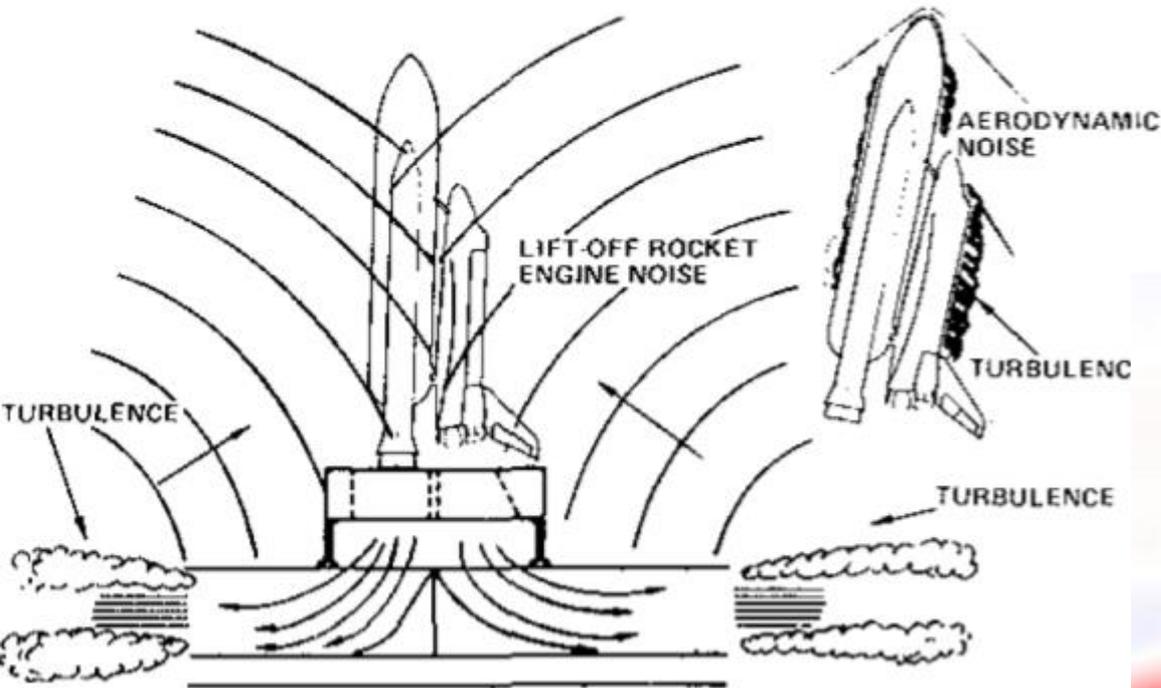
Payload e  
Fairing

Sistema  
propulsivo  
secondario

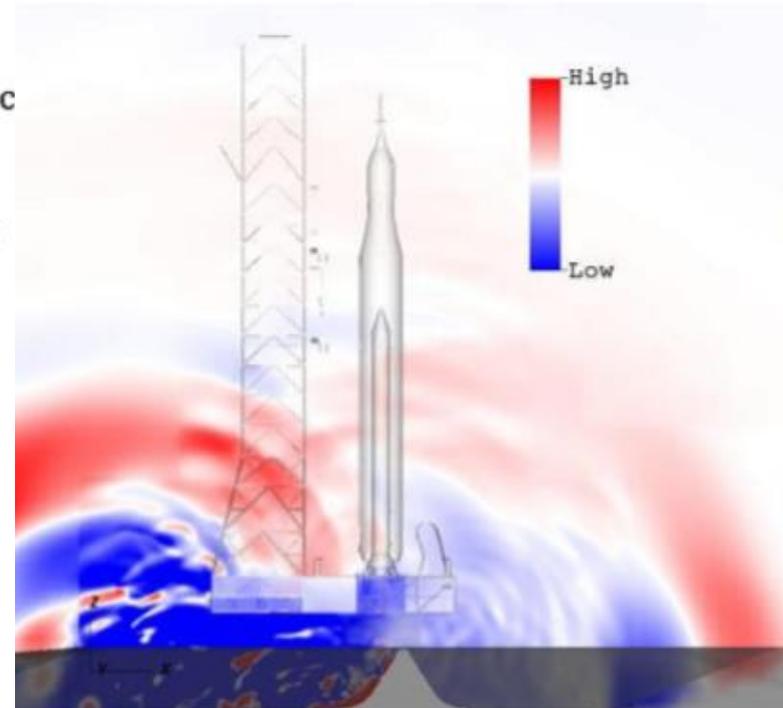
Sistema  
propulsivo  
principale



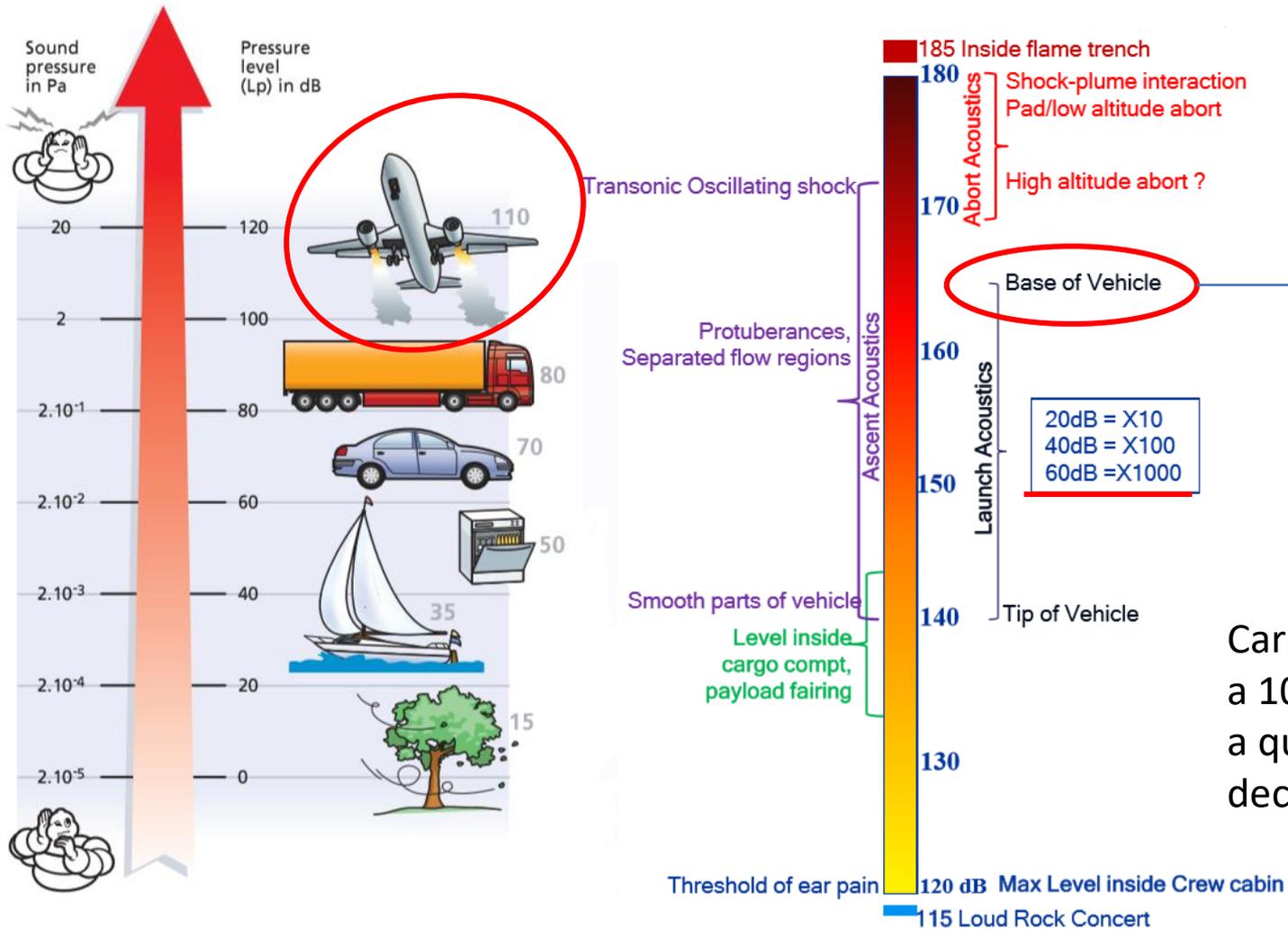
# Problematiche al Lancio



- Forti Carichi Aero-Acustici ed Onde d'urto
- Livelli di vibrazioni pericolosi per carichi, elettronica e sottosistemi (50% failure!)
- Rumore in Ambiente circostante

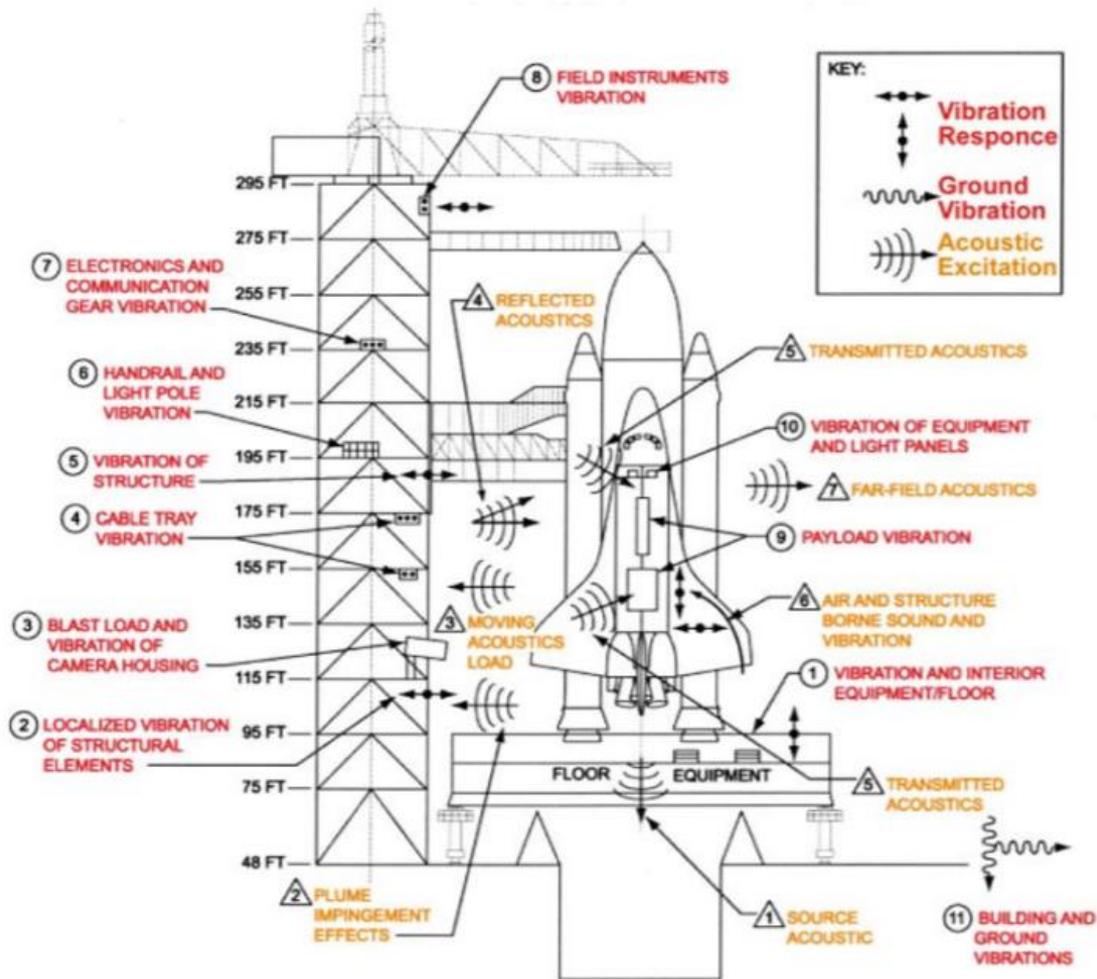


# Carichi a Lift-Off: Confronti



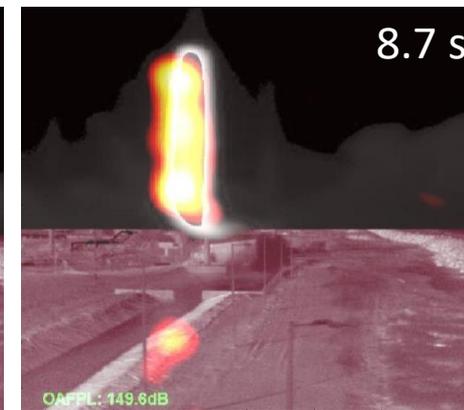
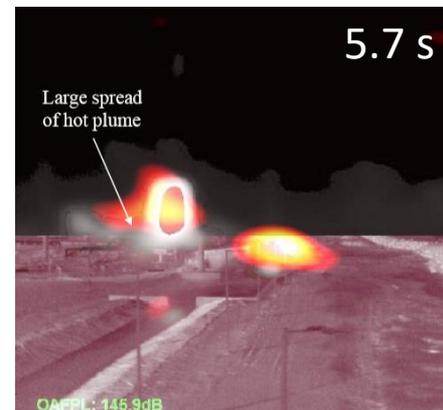
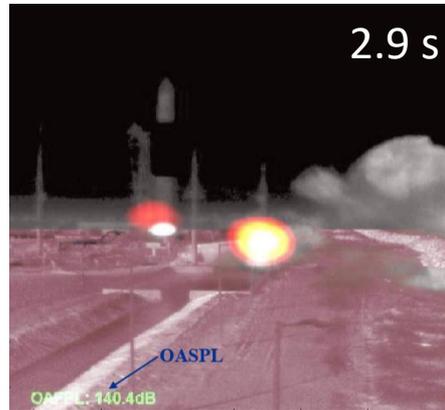
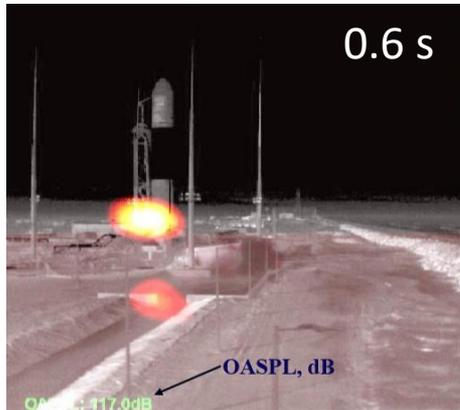
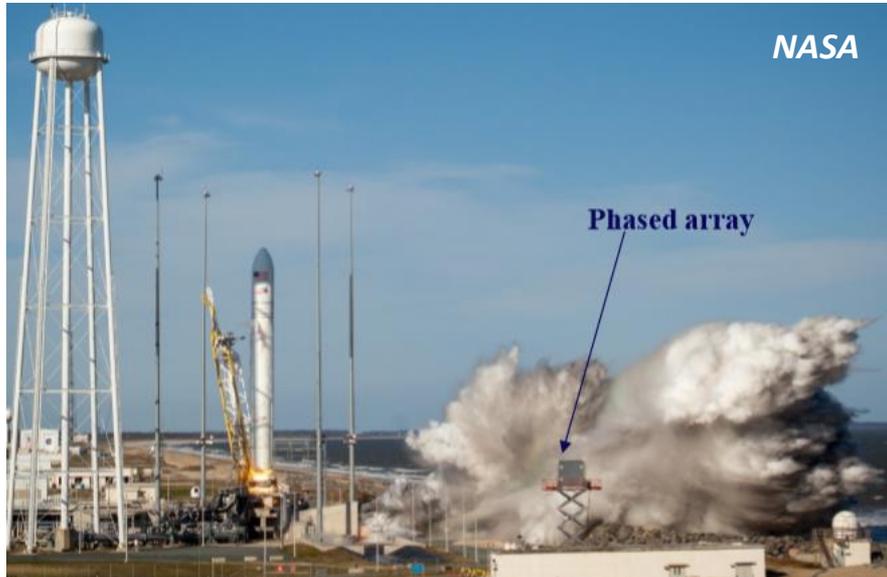
Carichi acustici da 100 a 1000 volte superiori a quelli di un aereo in decollo

# Overview sistemi “colpiti”

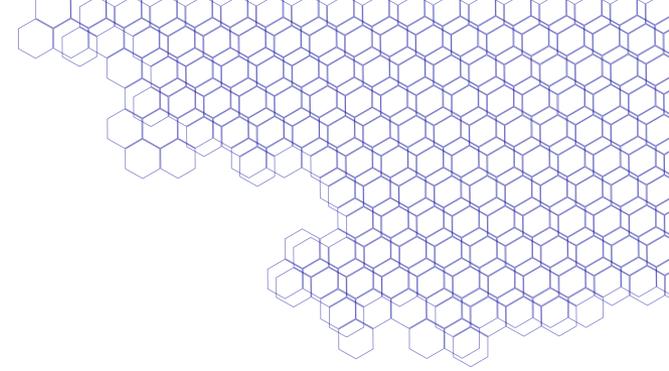


+ FATICA Acustica per lanciatori riutilizzabili (es. SpaceX, Blue Origin ecc)

# Identificazione Sorgenti



# Qualifica Hardware Spaziale

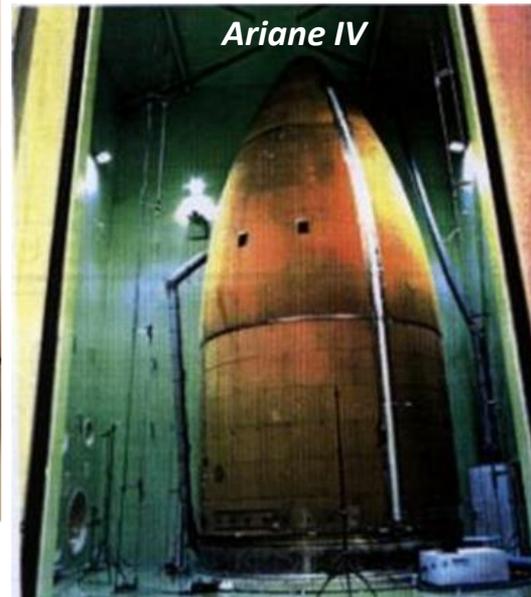


NASA

Reverberant Acoustic Test Facility  
NASA Plum Brook Station



NASA



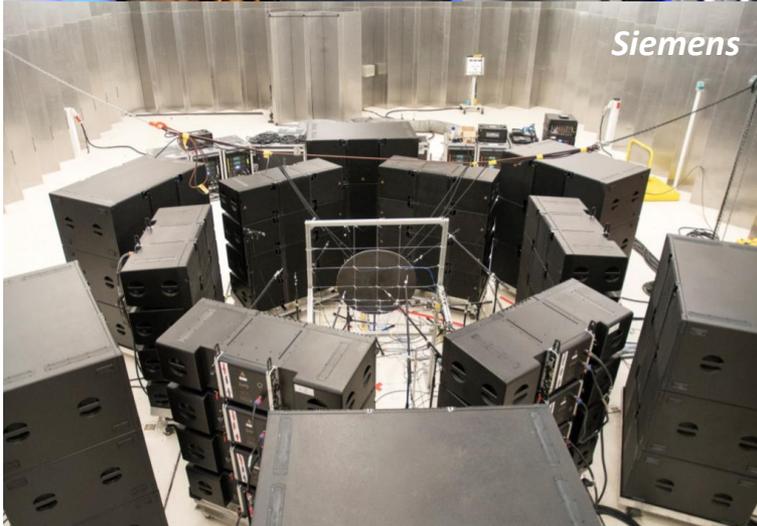
Ariane IV



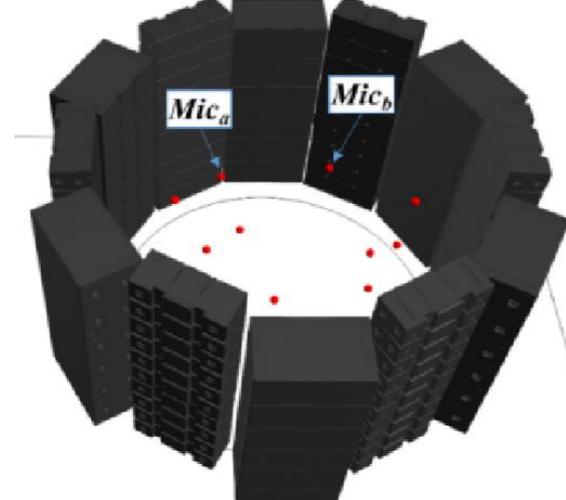
Ariane V

- Richieste facility di grandi dimensioni
- Costi elevati e poca flessibilità di operazione

# Qualifica Hardware Spaziale: “novità”



- Costi relativamente ridotti flessibilità di operazione
- Complessità di controllo operativo



Siemens

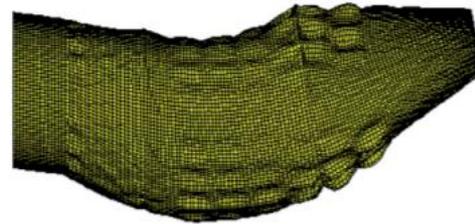
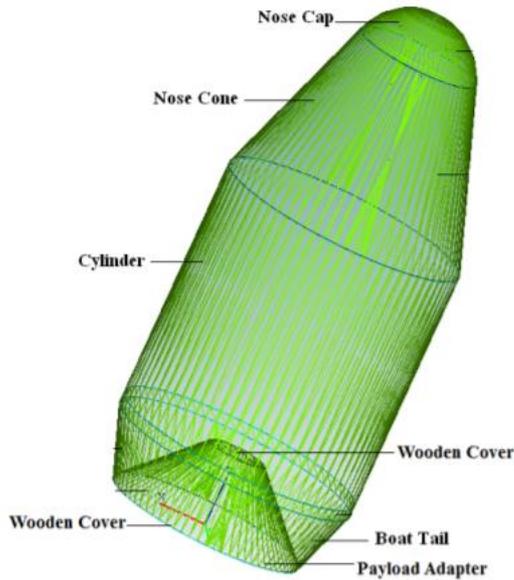
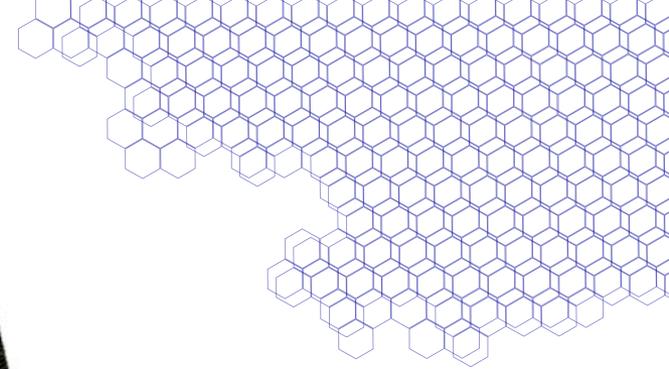
$$S_{uu} = \hat{H}^\dagger S_{yy}^{REF} (\hat{H}^\dagger)^H$$

Carico di Riferimento

Carico Simulato

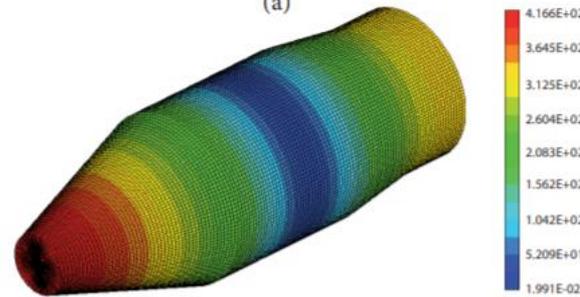
Matrici di Controllo

# Metodi di Analisi (1)

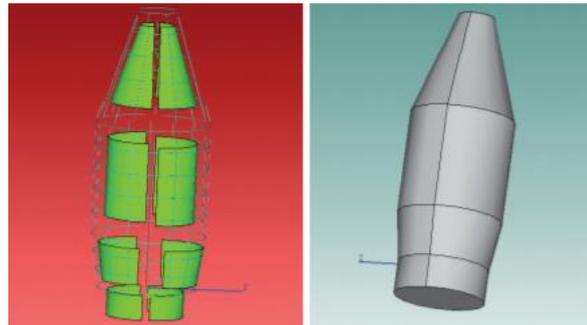


Modi Strutturali

FEM/BEM



Modi Acustici



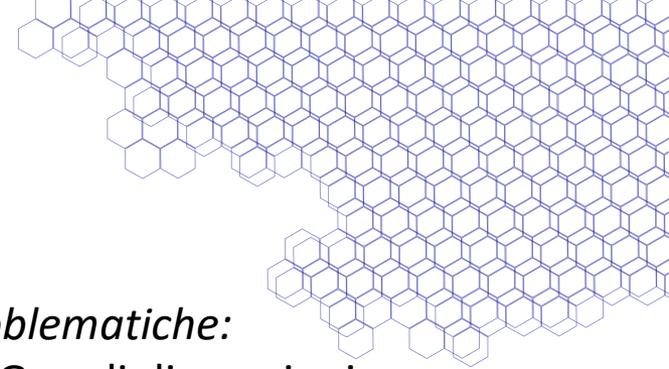
Suddivisione in  
Sottosistemi  
Scambio di Energia

SEA

*Problematiche:*

- Grandi dimensioni
- Problemi di alta e bassa frequenza
- Costo computazionale

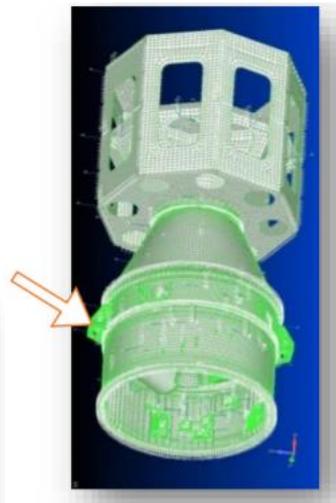
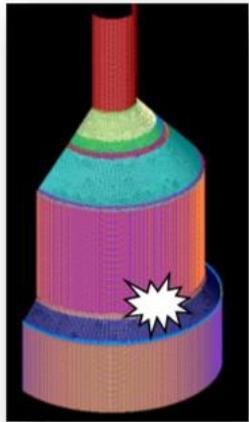
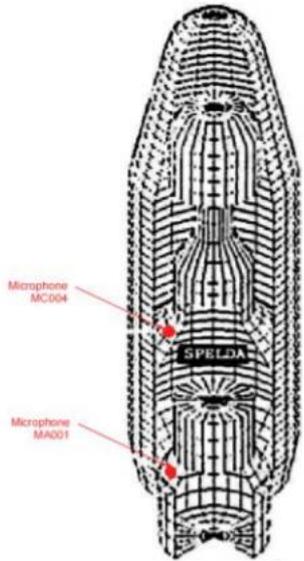
# Metodi di Analisi (2)



VEGA – FEM/BEM Accoppiato

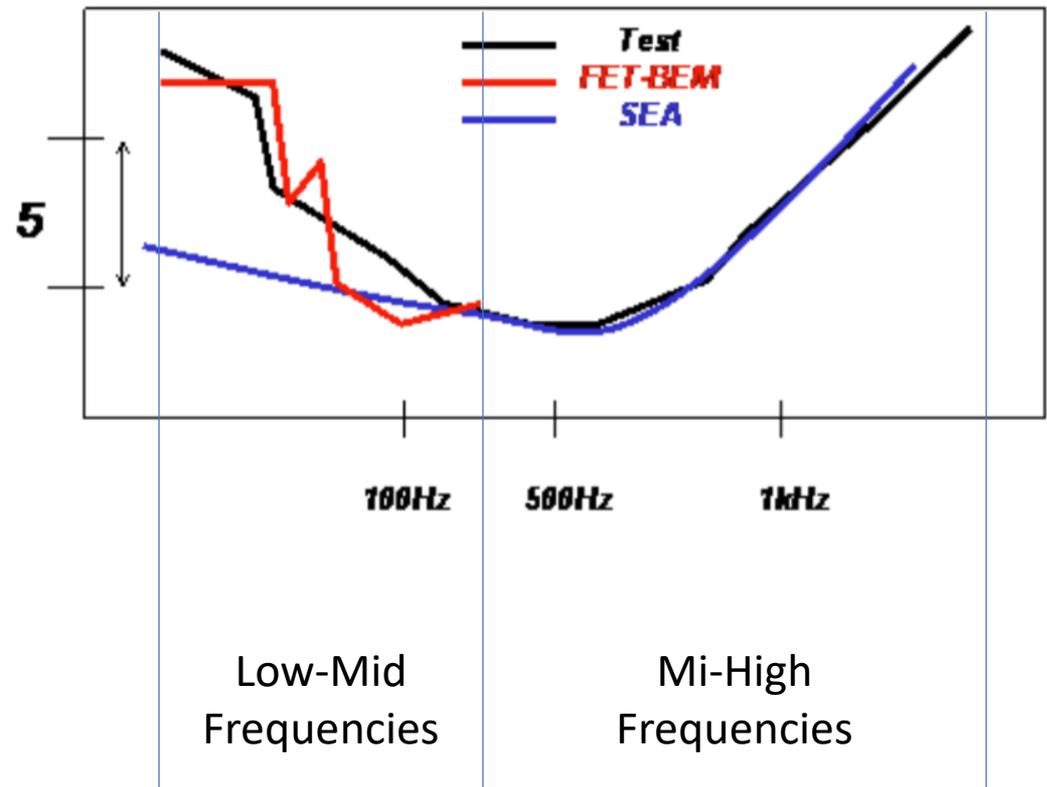
*Problematiche:*

- Grandi dimensioni
- Costo computazionale

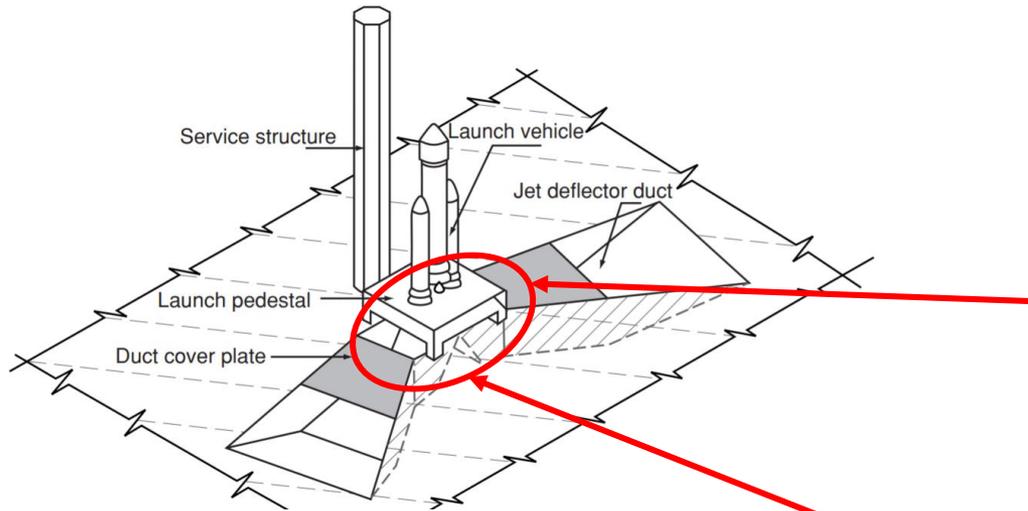


NR in dB

Prediction/test



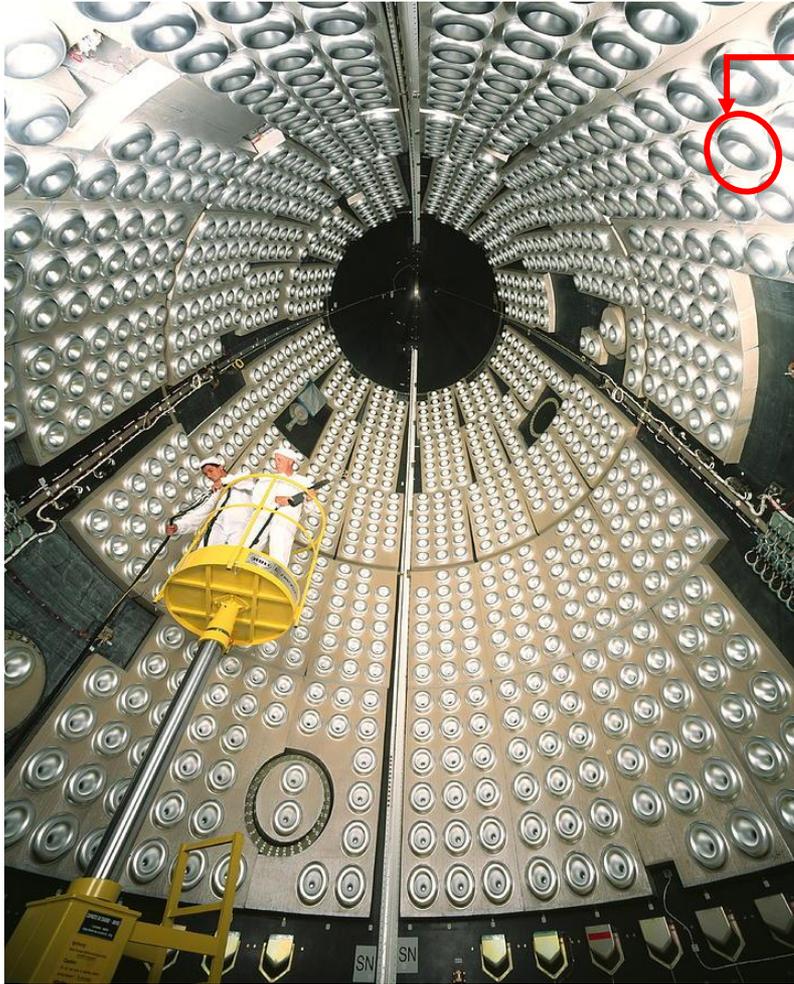
# Soluzioni Adottate: Water Injection



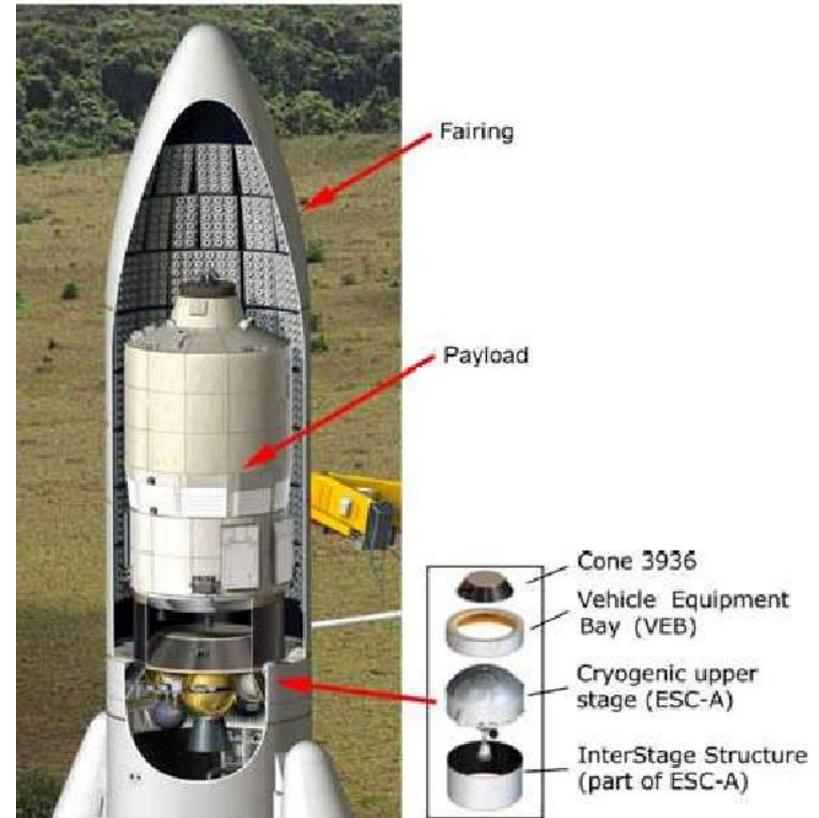
- Riflessione su tutte le strutture di contorno
- Efficace simultaneamente contro le varie sorgenti aeroacustiche di rumore (-8/12 dB)
- Due meccanismi: 1) riduzione temperatura tramite vaporizzazione; 2) Riduzione velocità getto tramite variazione di momento (fase liquida/solida)



# Soluzioni Adottate: Noise Control Material (1)

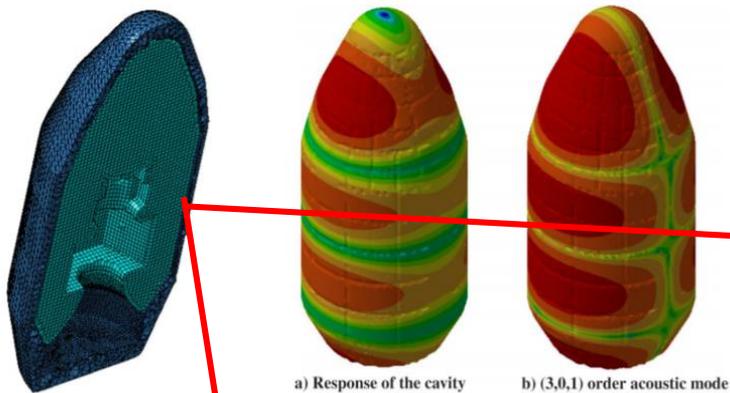


- Risonatori di Helmotz immersi in frame di materiale poroso (foam)
- Cavità riempita di Elio (non sempre)



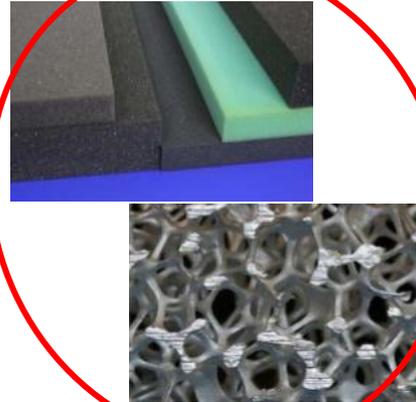
# Soluzioni Adottate:

## Noise Control Material: Risonatori di Helmholtz e Foam



a) Response of the cavity

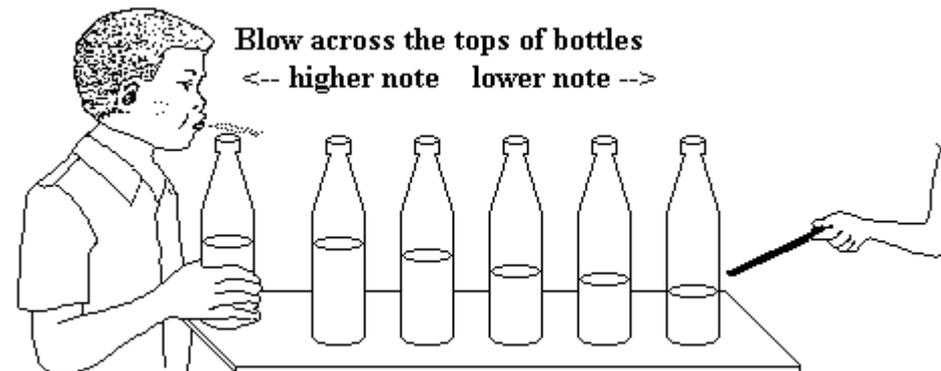
b) (3,0,1) order acoustic mode



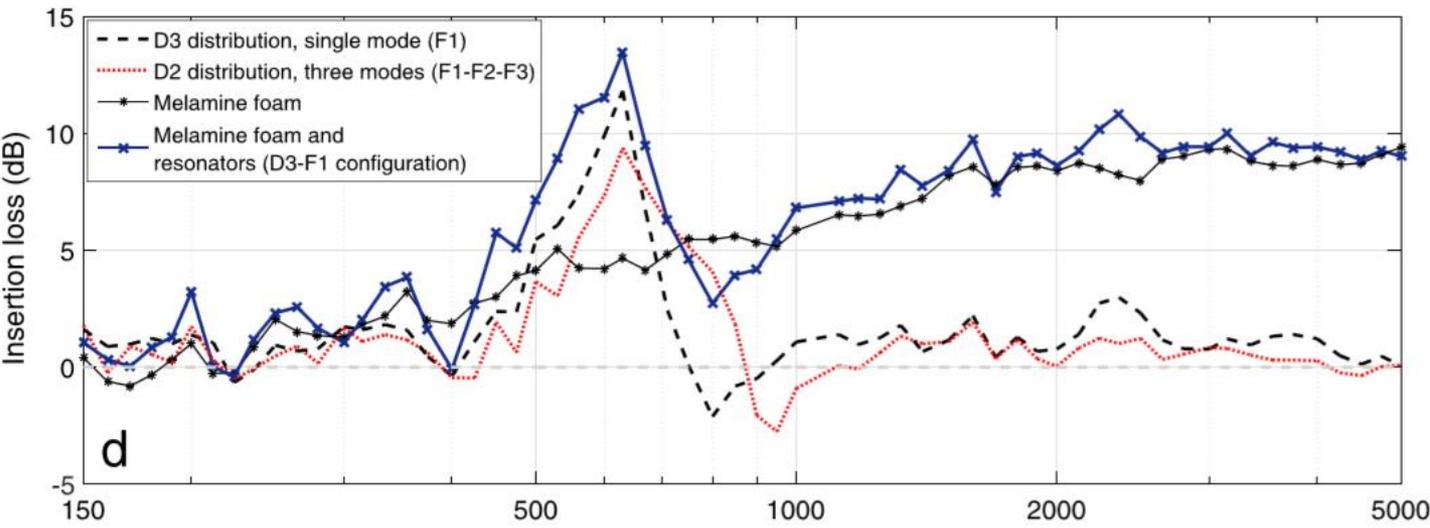
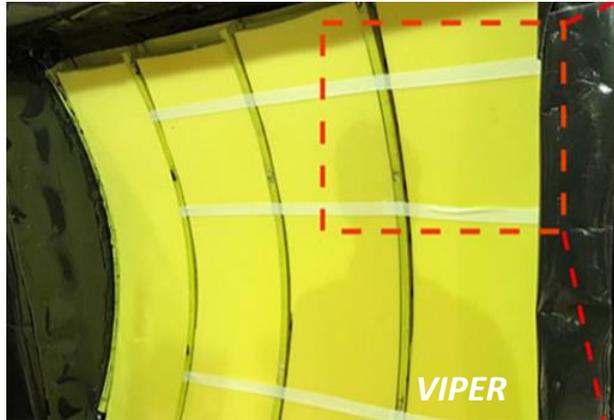
- Alto Assorbimento a frequenze medio alte
- Aggiunta di volume e massa



- Funziona ad una sola frequenza
- Aggiunta di volume e massa



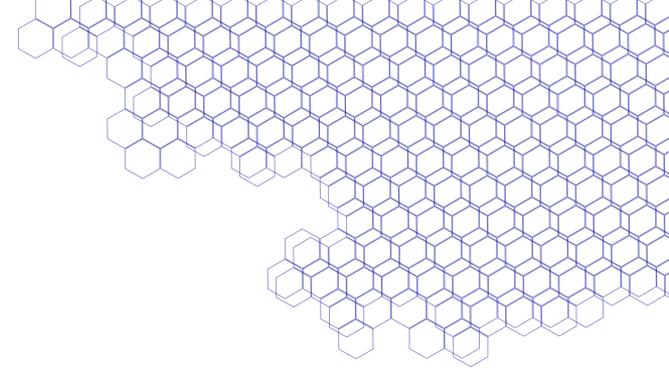
# Soluzioni Adottabili: Noise Control Materials



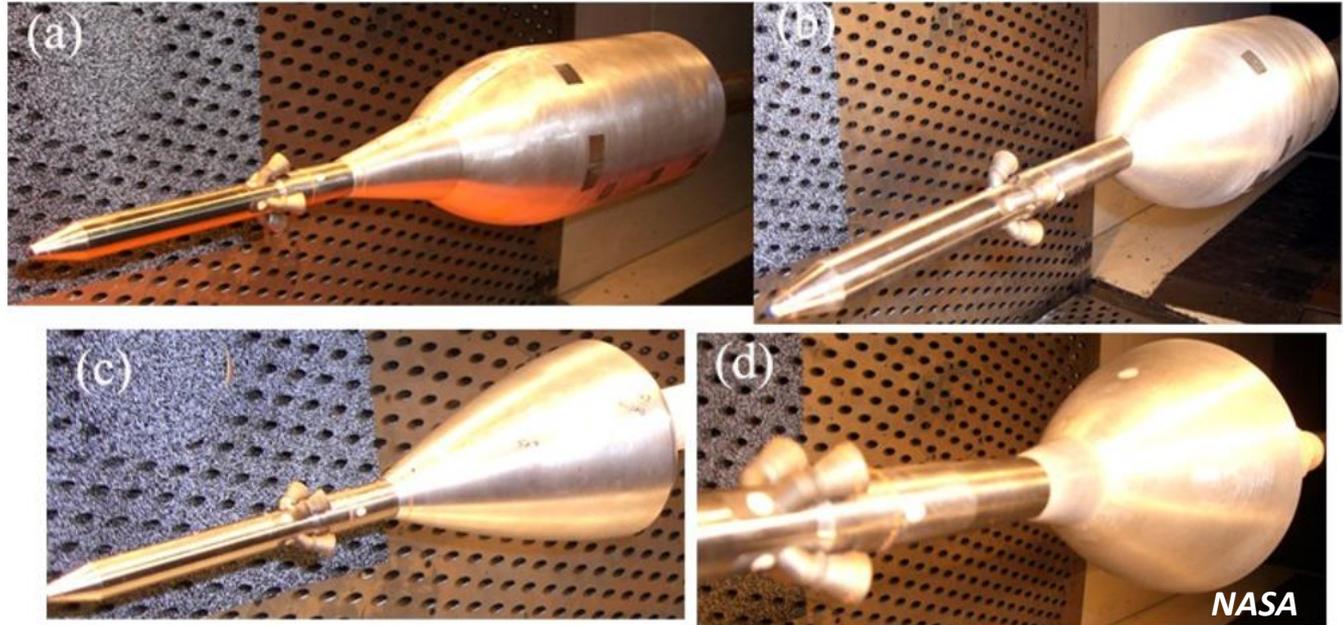
Risonatori meccanici prodotti con stampa 3D

- Effetti additivi con foam
- Buoni per problemi tonali
- Aggiunta di peso

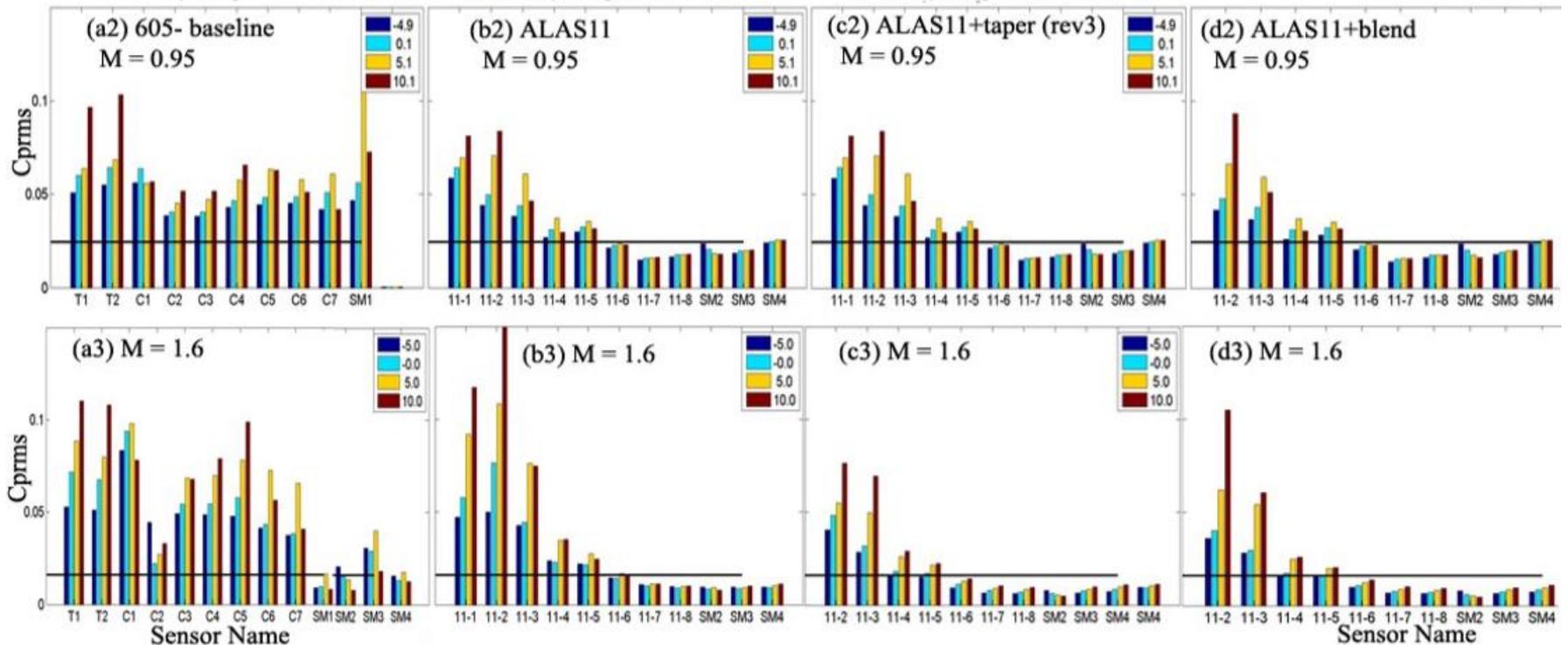
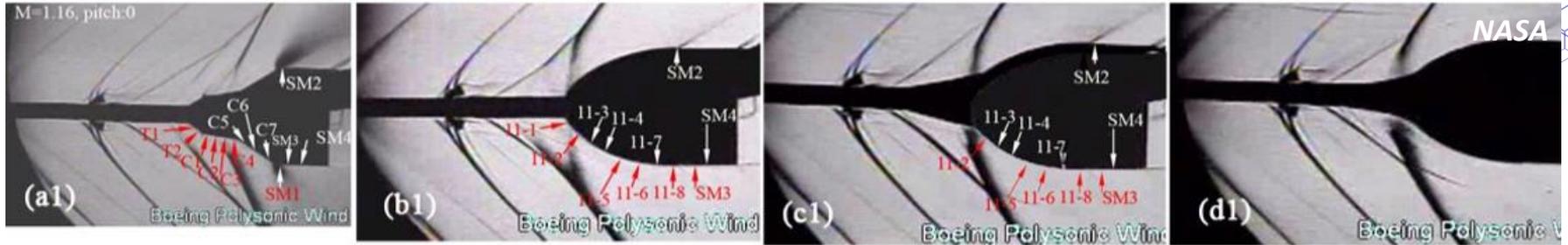
# Soluzioni Adottate: Ottimizzazione Forme (1)



**Real Engineering – What if the acoustic levels are too high?**  
MPCV Shape Optimization to Reduce Aero-acoustic environment

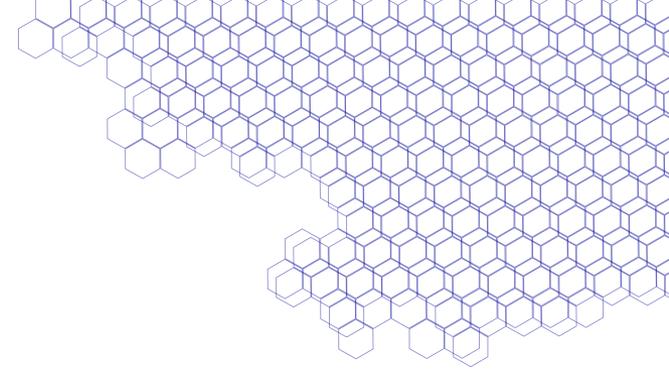


# Soluzioni Adottate: Ottimizzazione Forme (2)

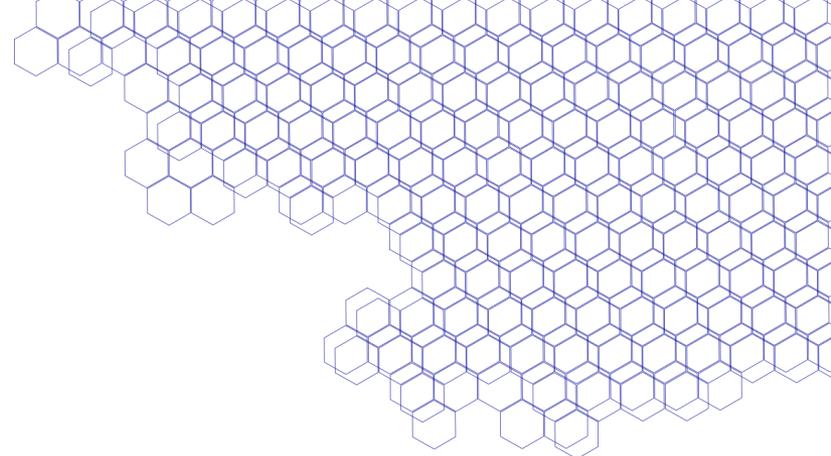
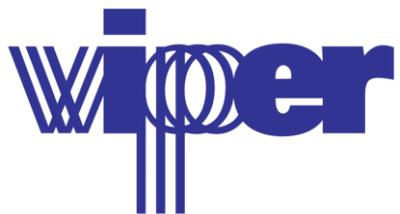


# Conclusioni

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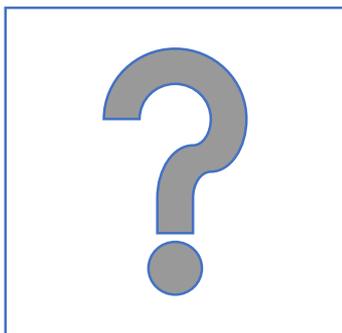


- I carichi a cui sono soggetti I lanciatori in fase di lancio e ascesa possono danneggiare le componenti strutturali ed i sottosistemi
- La simulazione predittiva e i test su scala reale/ridotta sono fondamentali
- La qualifica di hardware spaziale diventa oggi un problema e nuove tecnologie stanno emergendo (i.e. DFAX)
- I problemi di fatica acustica saranno dominanti con i nuovi lanciatori ri-utilizzabili
- L'ottimizzazione delle forme del fairing permette di ridurre i carichi in ascesa.



# Grazie per l'attenzione

## Domande



=  
146  
dB



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