



# **X-57 and Whirl Flutter Discussion**

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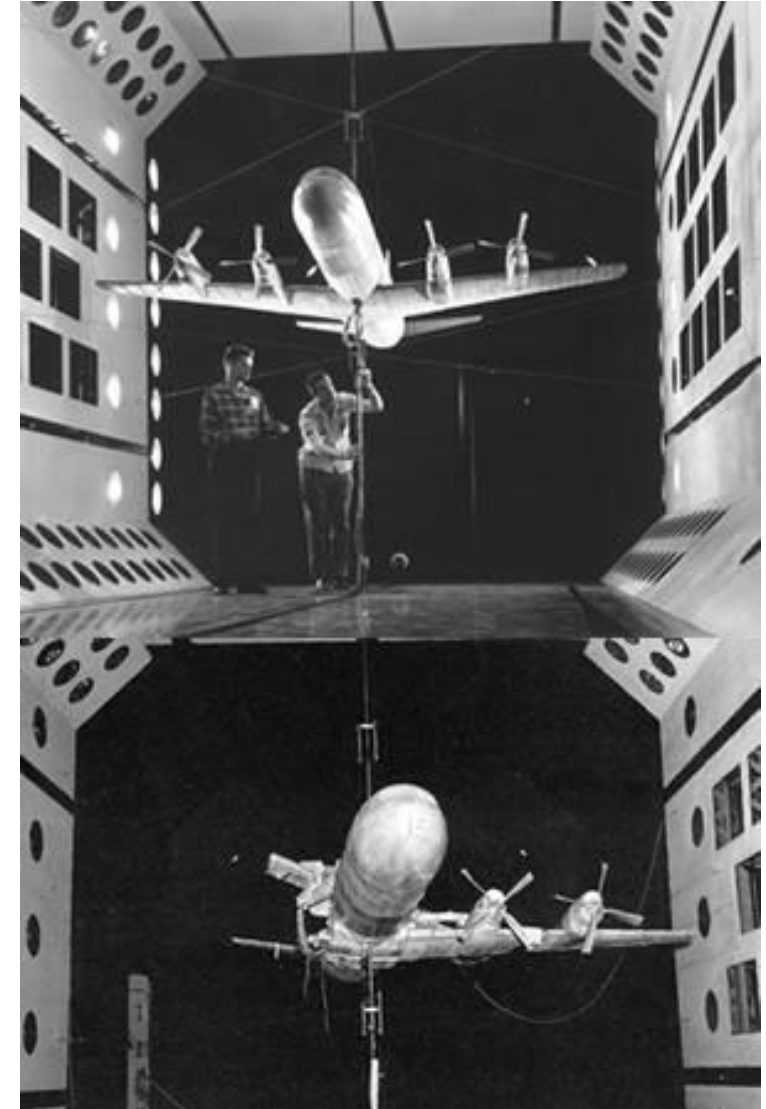
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# Whirl Flutter Background



- Whirl flutter is most commonly associated with Lockheed's Electra fatal mishap
- Research, testing and new analysis techniques seemed to solve the issue (1960s)
- Propeller propulsion is still an area of interest today
  - Advanced propellers a current area of CFD research
  - Electrically enhanced propulsion seems to be an area of interest in the industry
- Whirl flutter research seemed to cap out in the 1960s, yet our computational capabilities have greatly increased



*Photo Credit: NASA*

# X-57 Objectives and Tecnam P2006T/Wing Overlay



## Primary Objective

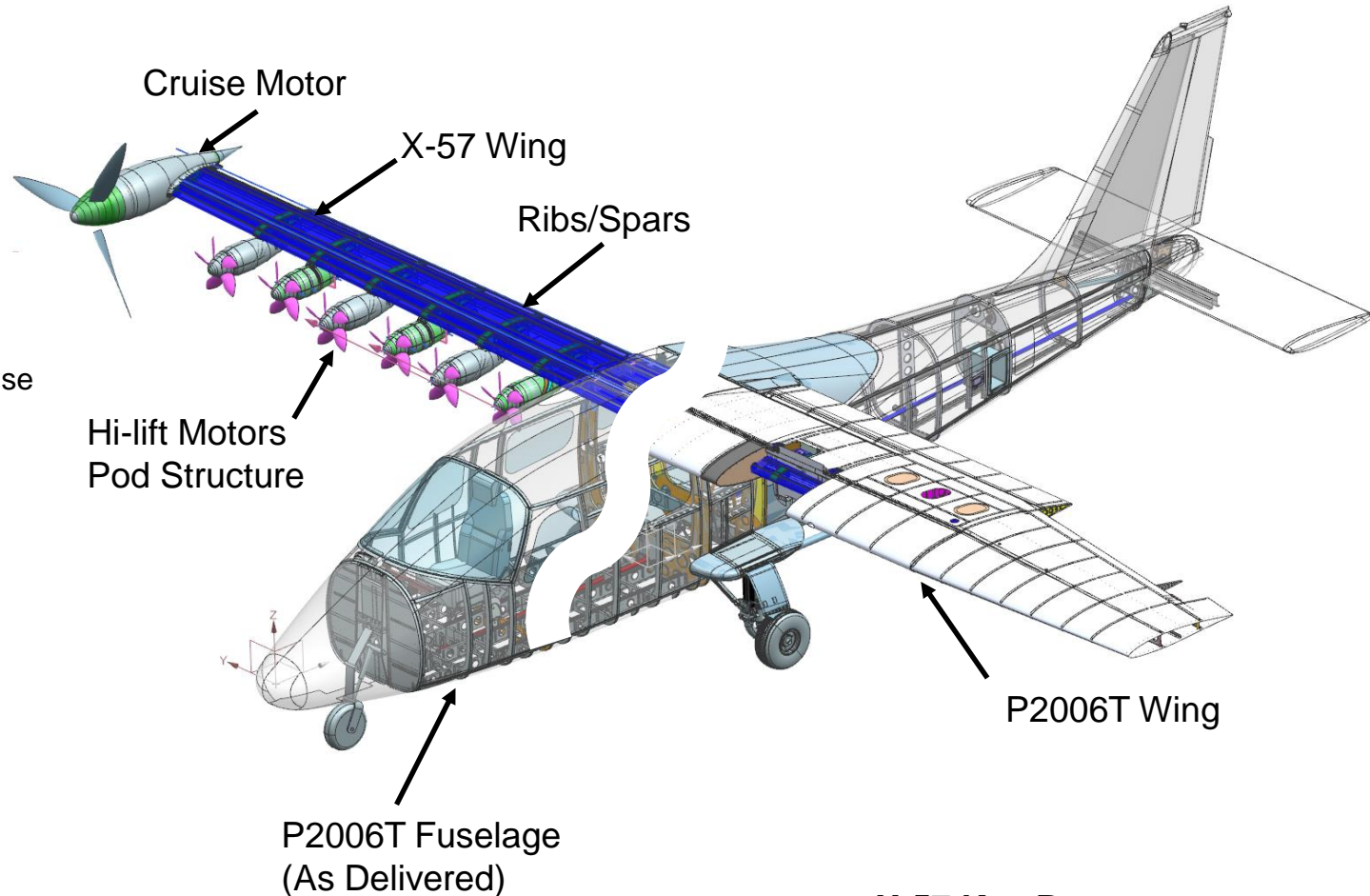
- Goal: 5x Lower Energy Use (Compared to Original P2006T @ 175 mph)
  - Internal Combustion Engine vs Electric Propulsion Efficiency changes from 28% to 92% (~3.3x)
- Synergistic Integration
  - Propulsion airframe integration provides higher cruise motor efficiency and cruise optimized wing

## Derivative Objectives

- ~30% Lower Total Operating Cost
- Zero In-flight Carbon Emissions

## Secondary Objectives

- 15 dB Lower community noise
- Flight control redundancy and robustness
- Improved ride quality
- Certification basis for Distributed Electric Propulsion (DEP) technologies



**X-57 Key Partners:**  
NASA ARFC, NASA LaRC  
Empirical Systems Aerospace (ESAero)  
Xperimental LLC, CA.

# X-57 Project Approach



Mod 1



Ground validation of DEP high lift system

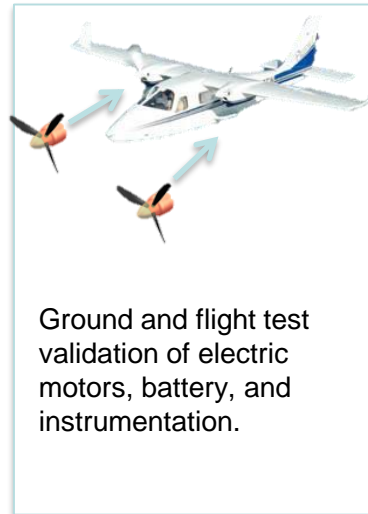


Flight testing of baseline Tecnam P2006T

Goals:

- Establish Baseline Tecnam Performance
- Pilot Familiarity

Mod 2

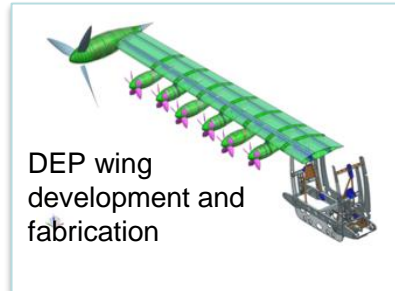


Ground and flight test validation of electric motors, battery, and instrumentation.

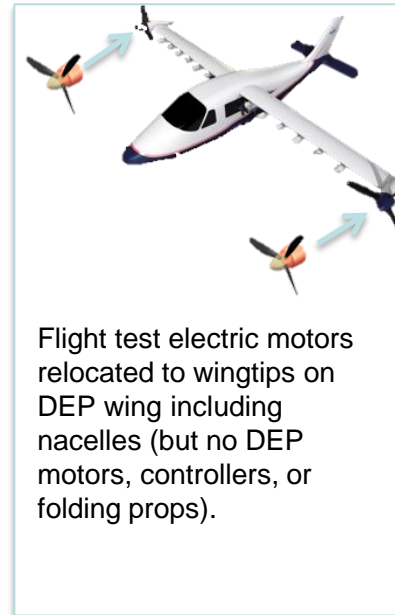
Goals:

- Establish Electric Power System Flight Safety
- Establish Electric Tecnam Retrofit Baseline

Mod 3



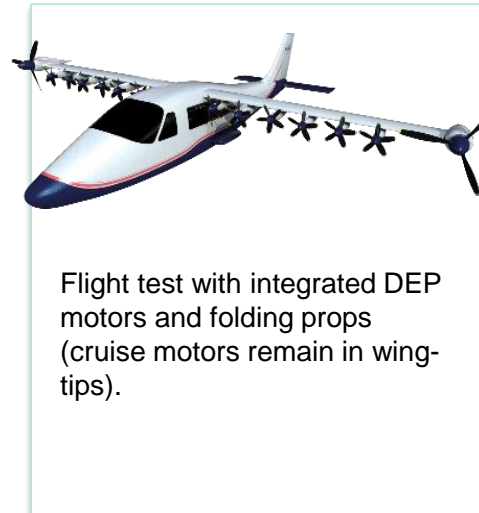
DEP wing development and fabrication



Flight test electric motors relocated to wingtips on DEP wing including nacelles (but no DEP motors, controllers, or folding props).

Achieves Primary Objective of High Speed Cruise Efficiency

Mod 4



Flight test with integrated DEP motors and folding props (cruise motors remain in wing-tips).

Achieves Secondary Objectives

- DEP Acoustics Testing
- Low Speed Control Robustness
- Certification Basis of DEP Technologies

Mod 1

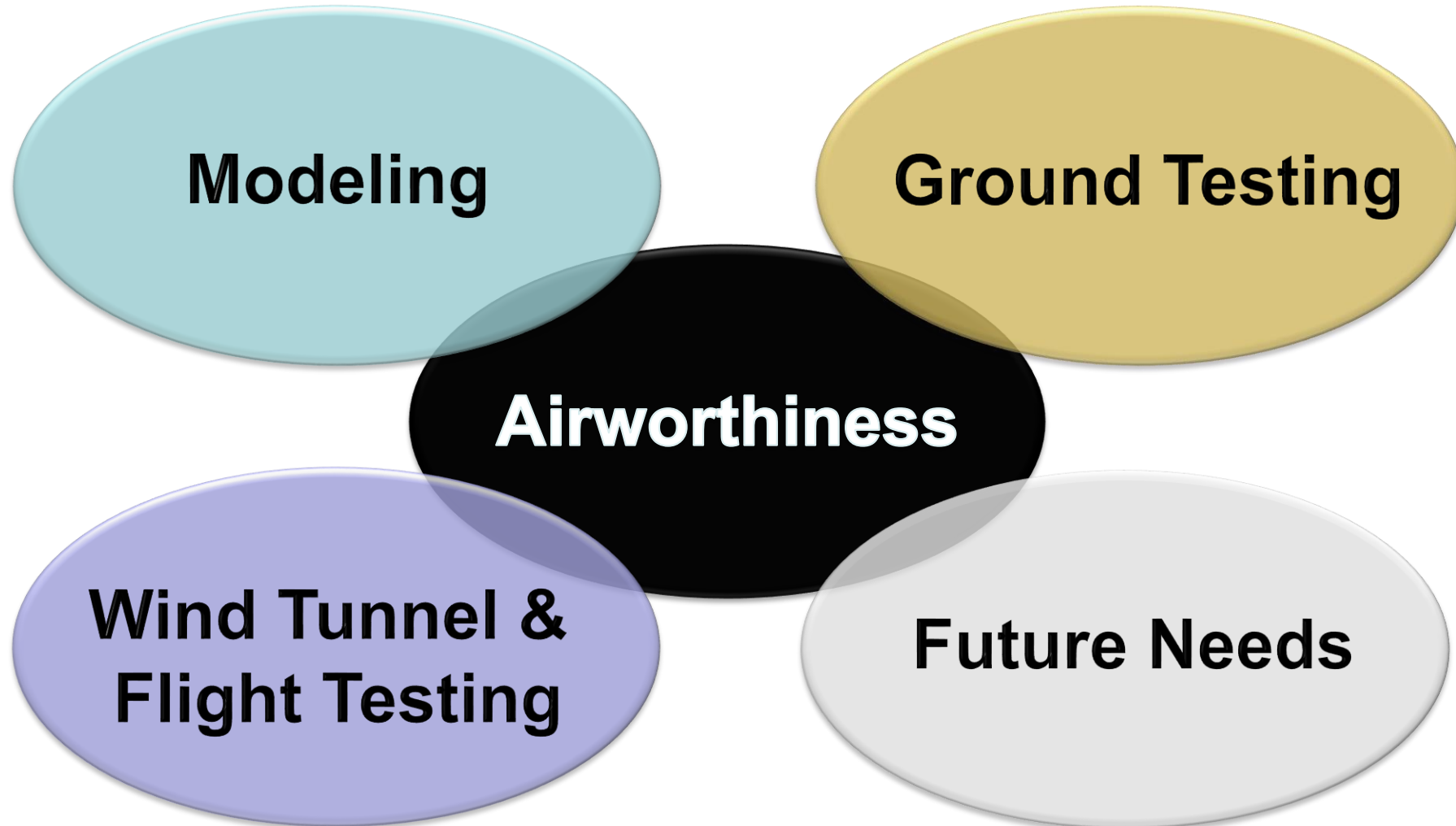
Mod 2

Mod 3

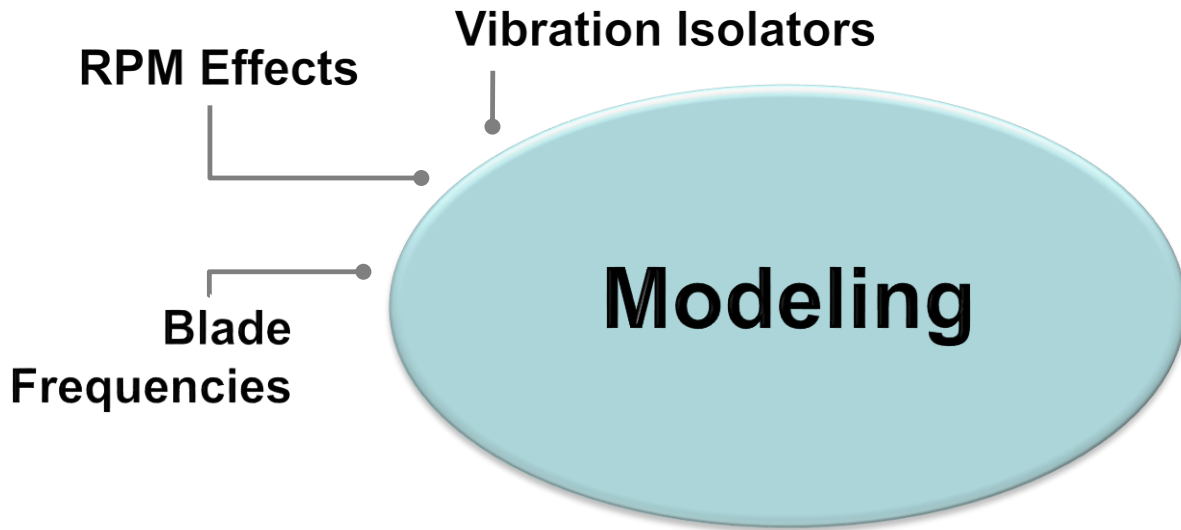
Mod 4

# Challenges Involving Whirl Flutter

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# Challenges Involving Whirl Flutter

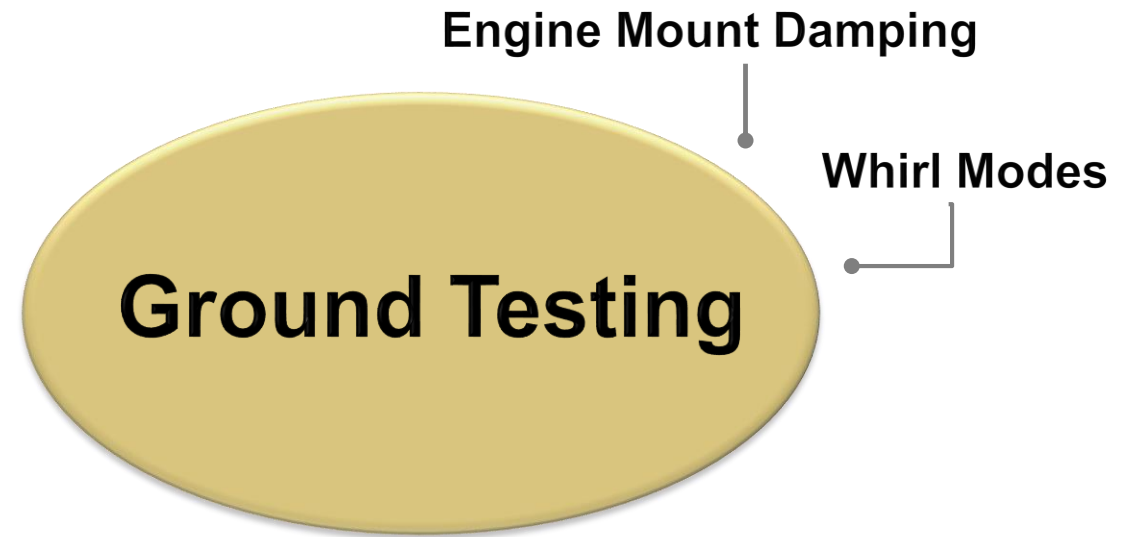


- Variable prop effects on whirl modes and flutter margins
- Electric motors have less vibrations, but motor mount dampers tend to stabilize whirl flutter
- Should blade frequencies effect flutter results?

# Challenges Involving Whirl Flutter



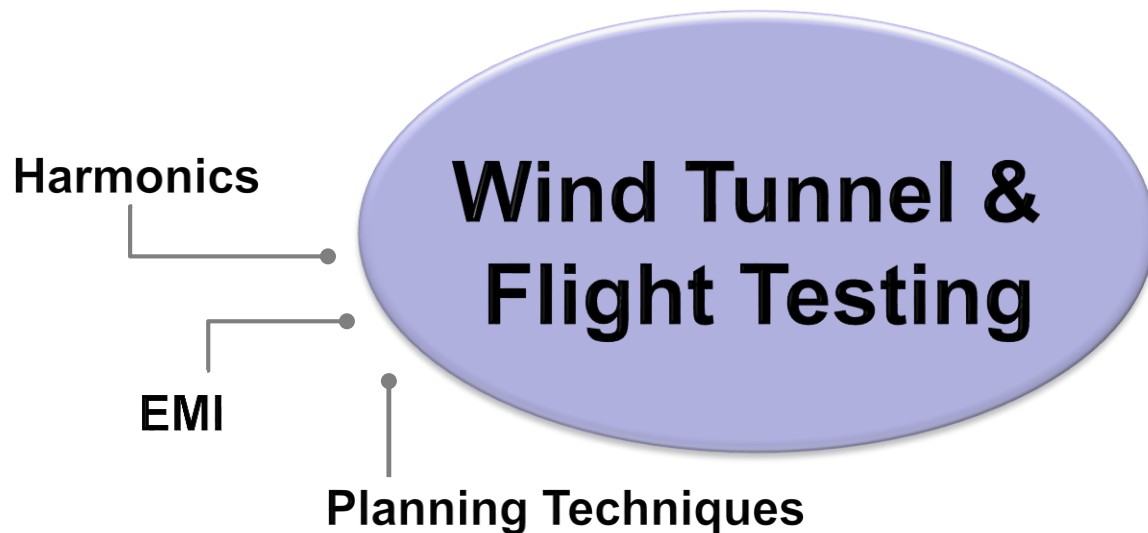
- Standard modal testing acquires pitch and yaw of prop system
- Gyroscopic whirl modes not included in ground testing
- Characterizing the damping of the engine mount requires environmental chamber testing



# Challenges Involving Whirl Flutter



- Flight test planning with variable speed motors and variable blade pitch
- Monitoring flight data with harmonics
- Monitoring flight data with EMI





# Challenges Involving Whirl Flutter

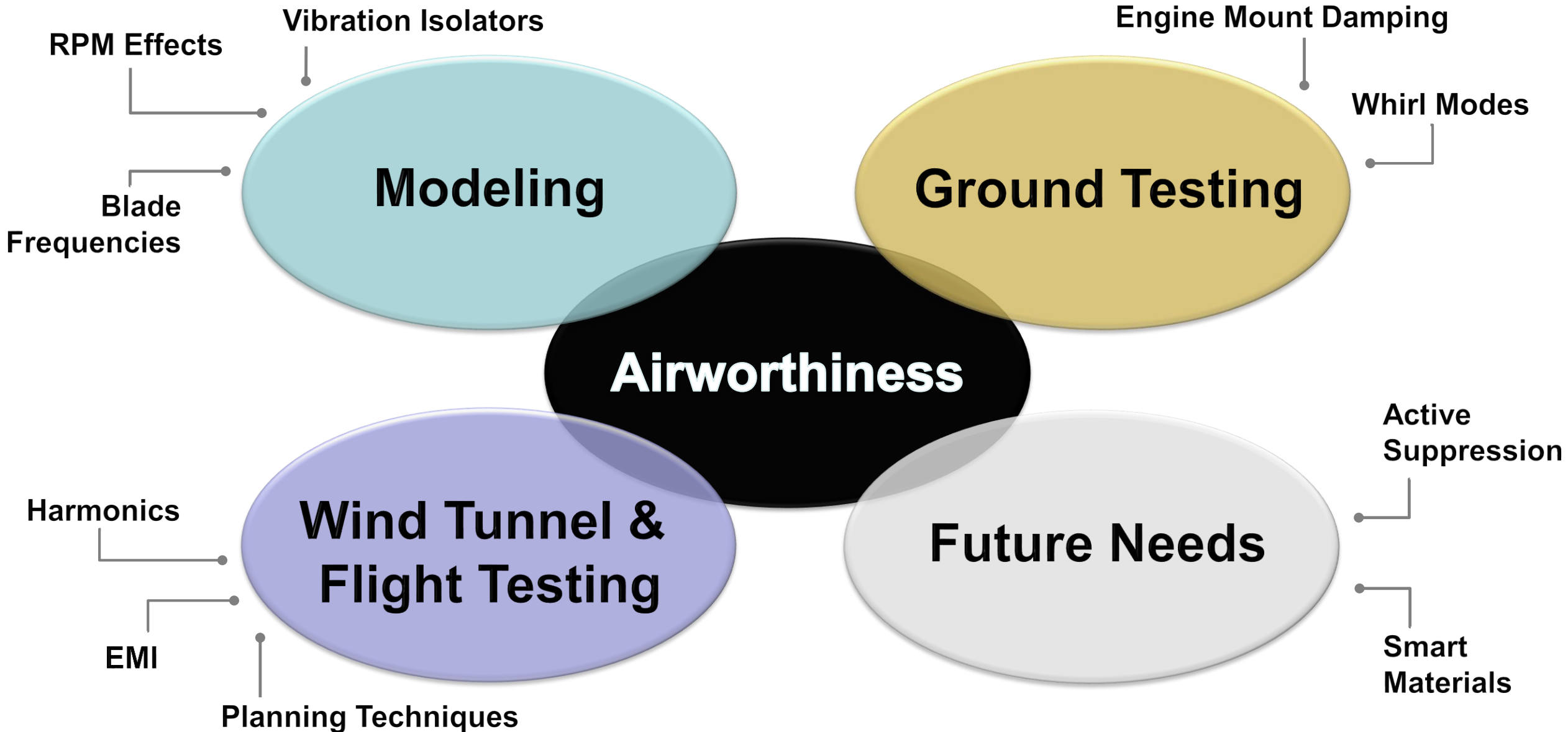
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- Are there future needs in the field?
- Can the aircraft industry benefit from active suppression or smart materials?



# Discussion: Challenges Involving Whirl Flutter





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**Thank you.**

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