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# Presenting



**Gregor Veble Mikić**  
Flight Physics Lead



# Designing for a sustainable future of aviation

Gregor Veble Mikić



01

Joby's mission



# Cities are getting bigger and more congested

Urbanization and under-funded infrastructure remain powerful trends

Sustainable mobility is more critical than ever



**4.6B/yr**

hours wasted in traffic in the top 15 U.S. metros

**29%**

CO2 emissions attributable to transportation sector in U.S.

**70%**

global population will be living in cities by 2050



# Aerial ridesharing unlocks the third dimension of urban transportation

## Sustainable

all-electric aircraft,  
zero operating emissions

## Fast

5X faster than driving  
in major metros<sup>1</sup>

## Scalable

exponential scaling of routes at a  
fraction of the infrastructure cost



# Downtown LA to LAX in 8 mins

Departure	DTLA
Arrival	LAX
Drive Time	23 Minutes
Flight Time	8 Minutes



# Hollywood to Palm Springs in 52 mins

Departure	HWD
Arrival	PSP
Drive Time	2 hrs 22 min
Flight Time	52 Minutes





# Massive untapped market opportunity

A dark-themed map of Los Angeles and its surrounding areas, showing a network of roads and water bodies. Two flight paths are overlaid on the map: a blue path and a yellow path. The blue path starts near the coast, loops around the San Gabriel Valley, and then extends southeast towards the desert. The yellow path starts near the coast, loops around the San Gabriel Valley, and then extends southeast towards the desert, following a similar but slightly different route than the blue path. The paths are thick and clearly visible against the dark background.

**300+** aircraft

Market  
opportunity  
of **\$500M+**  
per year in  
LA alone



# Designed for daily life

We are building a revolutionary, cost effective, and clean global transportation system to fulfill our vision of **saving a billion people an hour a day**



Zero operating emissions



5 seats  
1 pilot 4 passengers



10+ years in development



150 miles max range



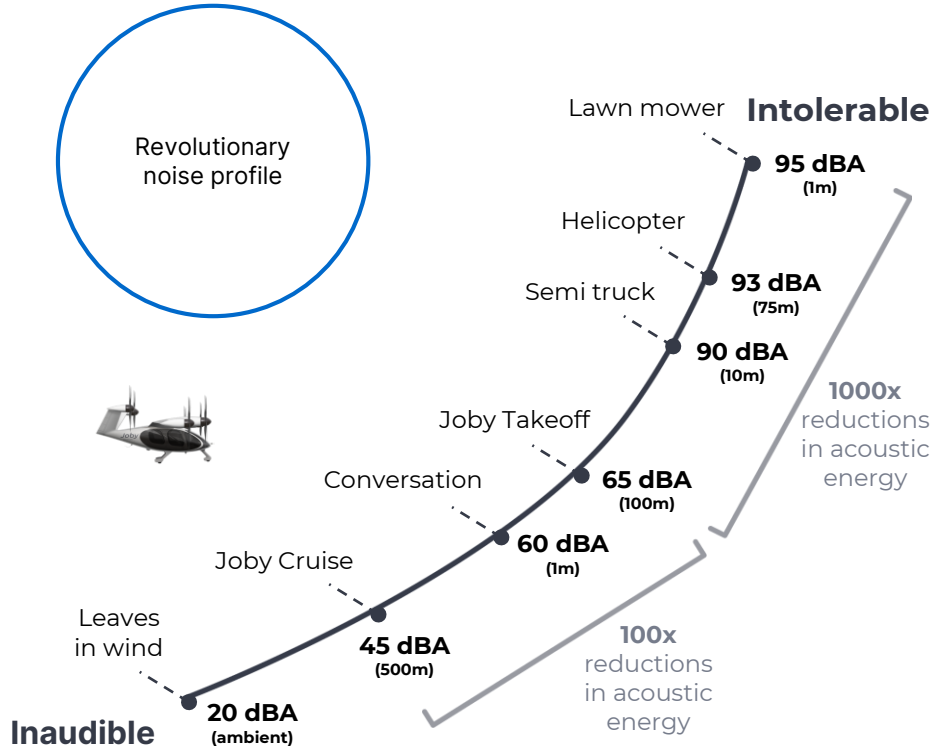
Vertical takeoff and landing



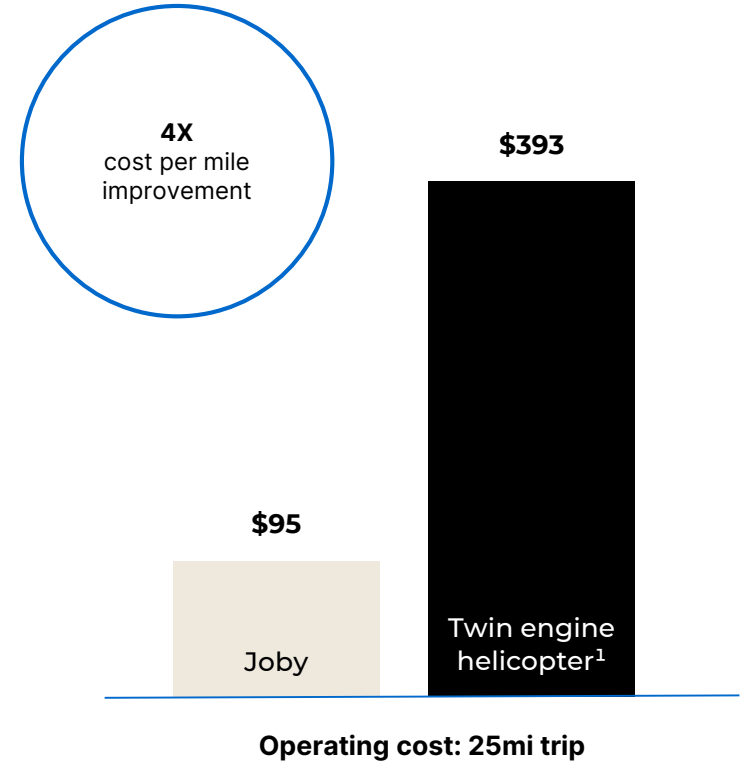
200 mph top speed



# 100x quieter than a helicopter



# at a fraction of the cost



<sup>1</sup>. Aircraft cost calculator (Sikorsky S-76C+) - Based on 120 mph helicopter block speed



Breakthrough enabling technology:

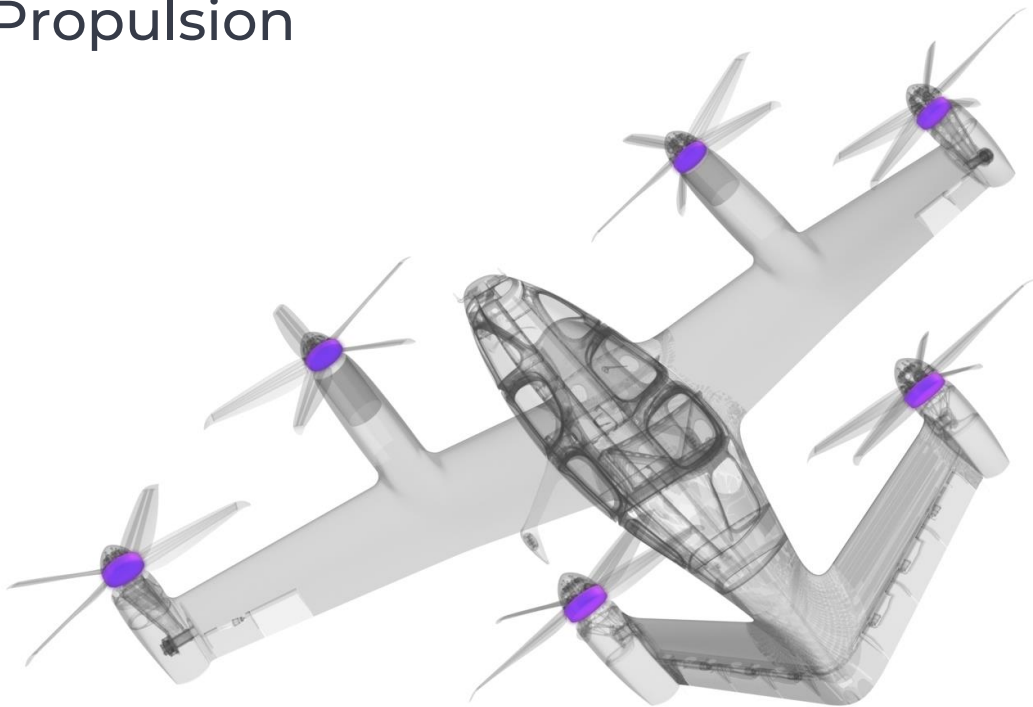
# Distributed Electric Propulsion

**Distributing multiple smaller and simpler electric motors across the aircraft enables:**

**Safety:** No single points of failure across aircraft systems

**Acoustics:** Electric motors enable a reduced sound profile

**Economics:** Reduced maintenance downtime; savings on fuel costs



# Designed for safety with high levels of redundancy

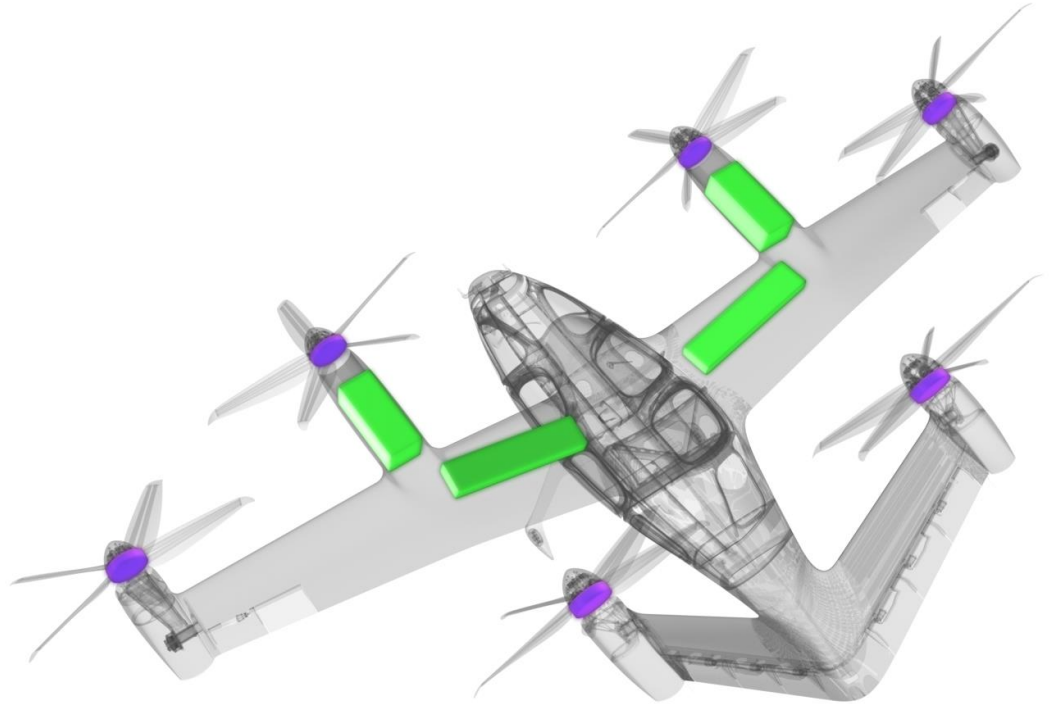
6 propellers – can fly safely with the loss of any one propeller

Each motor is redundant and powered by two separate inverters

Each inverter is wired to a separate battery pack

4 isolated and redundant battery packs on board

Motor continues to function if an inverter or pack fails



**Our aircraft has no single points of failure across aircraft systems**



# Joby's three keys to success

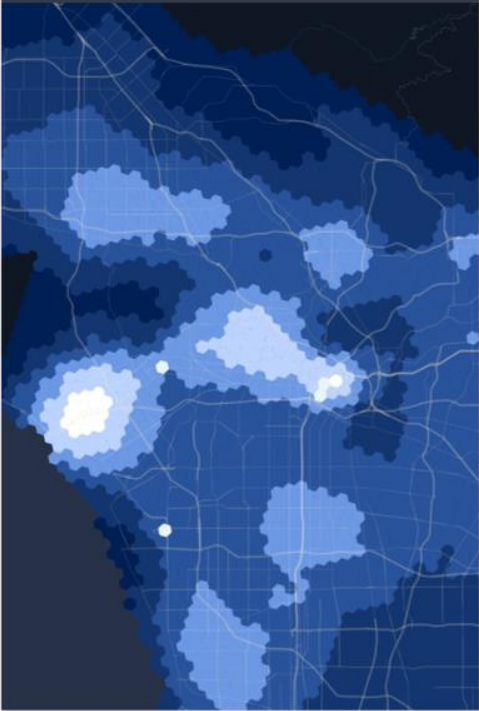
Right Aircraft, Certified



Scaled Production



Go to Market





**2021**  
Ongoing flight  
testing

**2023**  
Production facility  
online

**2020**  
Certification basis

**2022**  
Pre-certification  
operations

**2024**  
Commercial  
service launch







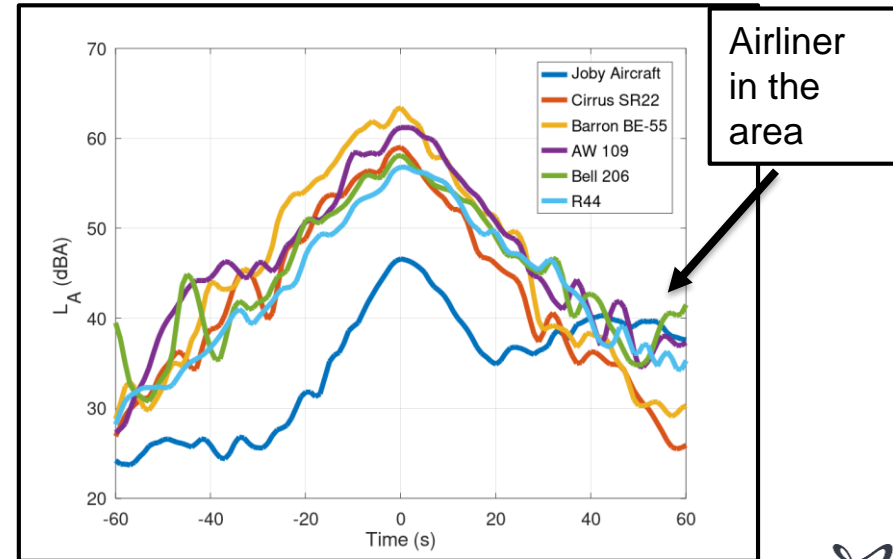
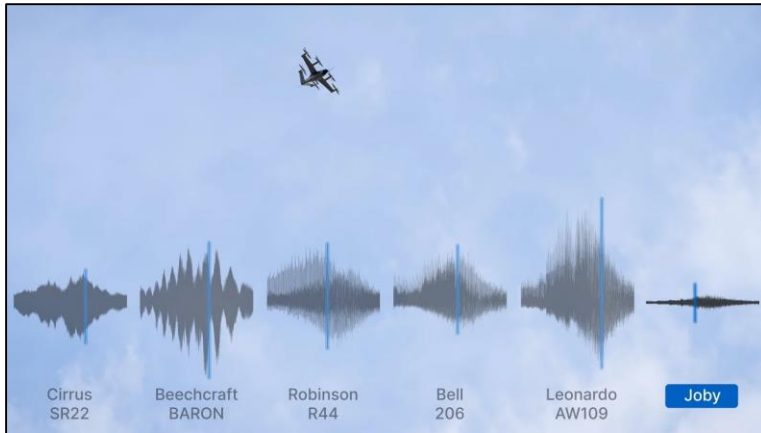
# Joby Design for Low Noise

In 2017, Joby built and tested ~10 prop designs to find the best balance with blade chord, tip speed, and airfoil for acoustics



# Numbers Don't Tell The Whole Story

- Numerical metrics (e.g. dBA) tell some of the story but our ears are not microphones. It is a mix of physiology and psychology (“Psychoacoustics”).
- We have released a few YouTube videos with actual sounds of the S4, but you really need to hear it with your own ears to understand how transformational the sound is.
- It isn't just that we are quieter – we sound much more pleasant and blend into the background.

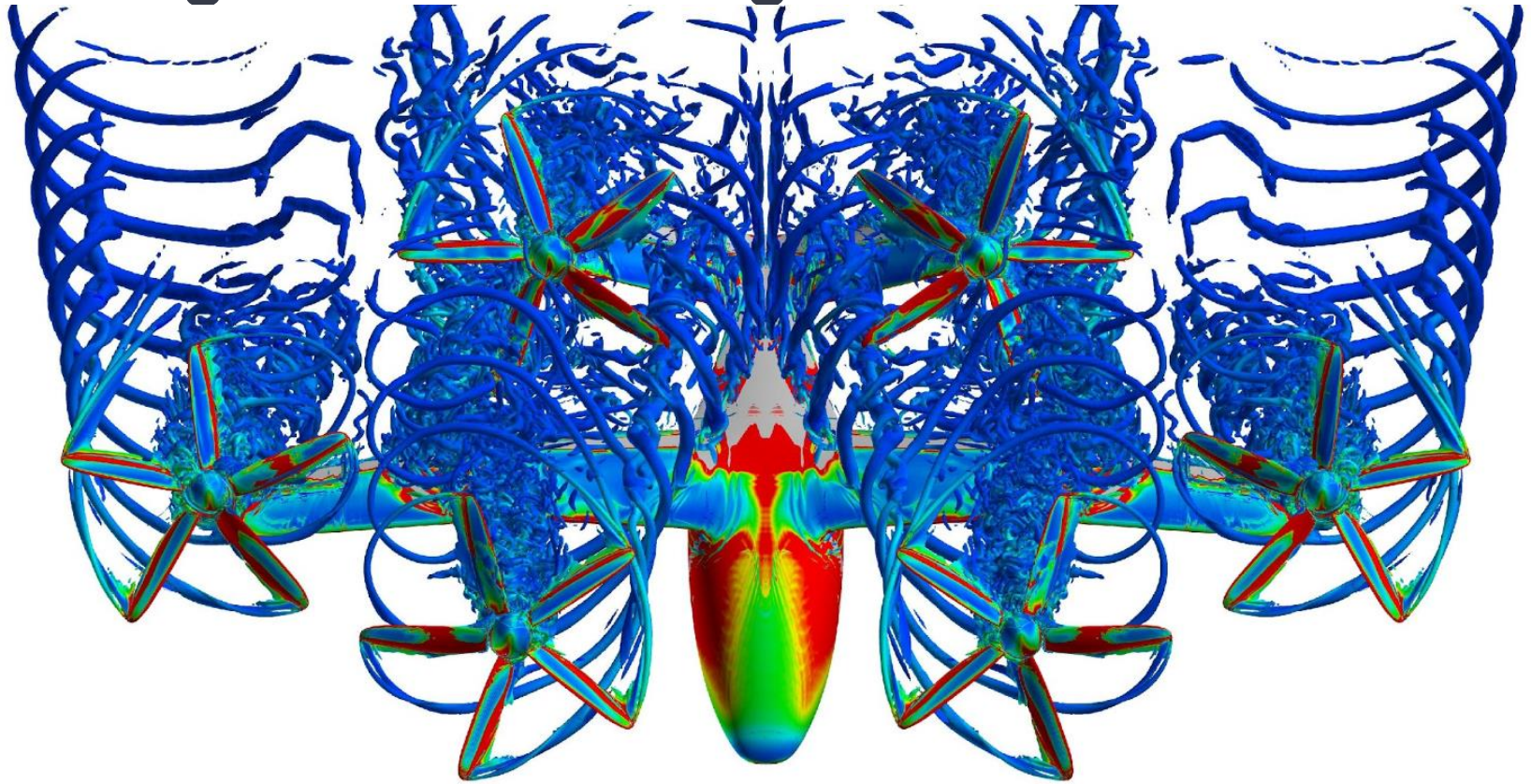


# NASA Advanced Air Mobility National Campaign

- NASA was at our Electric Flight Base in the second half of 2021 to perform a comprehensive acoustic survey of the pre-production aircraft.
- NASA conducted preliminary tests in November 2020 and found the grass was too loud (!) so we had to mow the field to create lanes for microphone array (see photo).
- We flew ~100 test points with our aircraft over an array of 58 microphones and generated hundreds of GB of data.
- Joby had 7 microphones co-located with NASA to validate our measurements.
- Preliminary report from NASA complete



# CFD Image of Wake During Transition



# 02

## Thinking aircraft

Considerations for future sustainable aircraft design



# What does the future hold?

- **The science and technology of eVTOL and sustainable aviation is solidifying, but there are ample opportunities for significant advances**
- **The configuration space is still very open**
- **Advances in low noise solutions will be shaping the designs**
- **Emissions free energy sources are likely to expand beyond batteries**



# What makes this impossible?



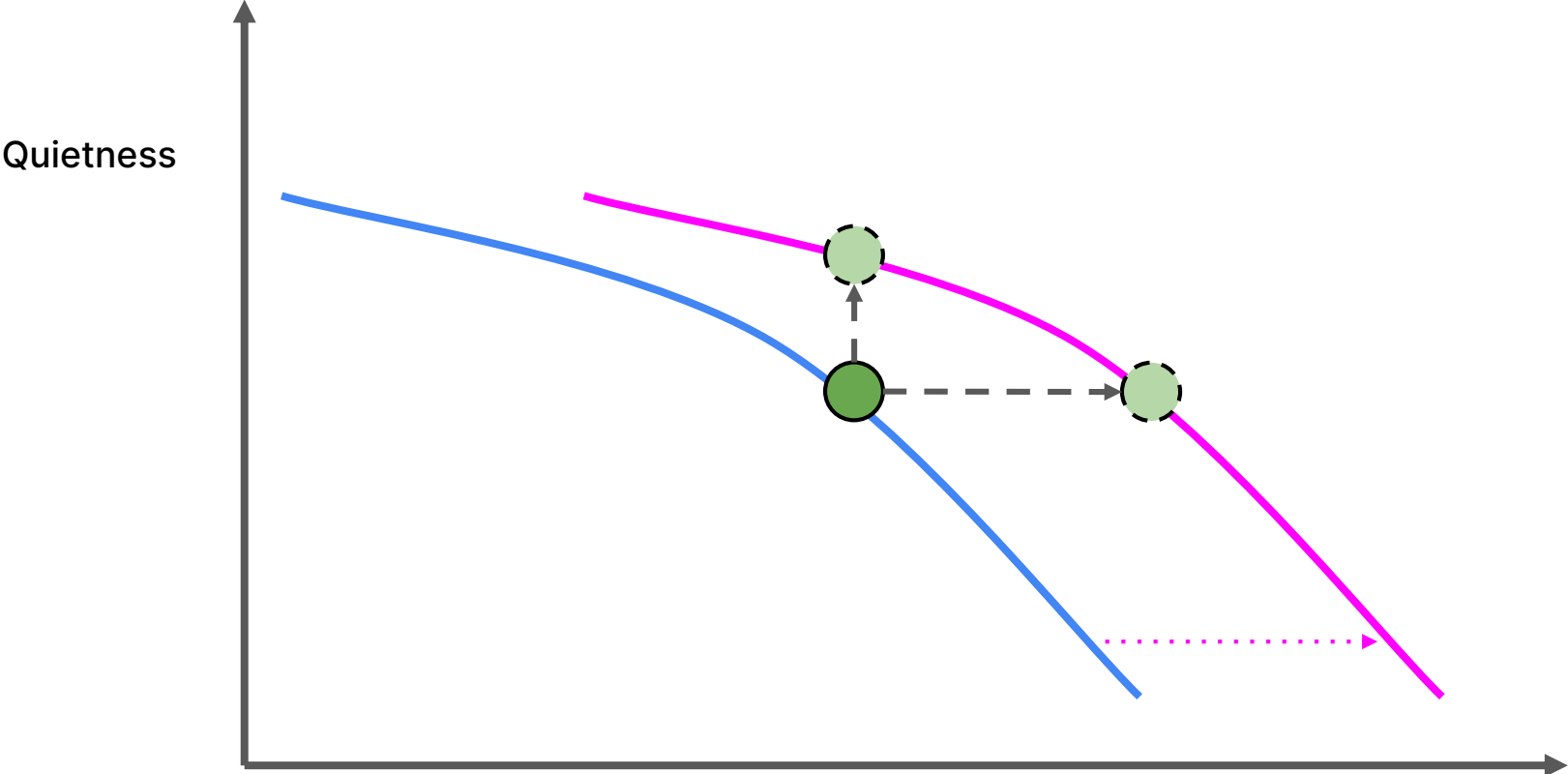
Original image: J.T. Csotonyi (Creative Commons Attribution [2.5 Generic license](#))



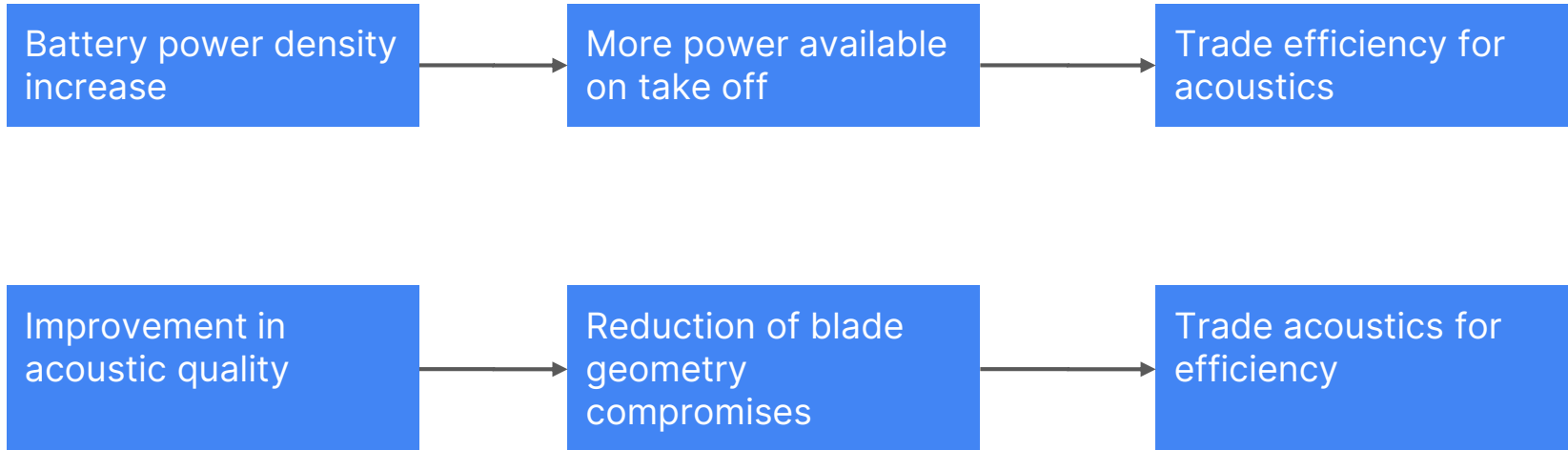




# Design tradeoffs



# Advances in other fields allow for better designs



# VTOL design exploration



Beier (Creative Commons Attribution-Share Alike 3.0 Unported)



03

# How to think about acoustics



# What is a good metric?

## **Easily Explainable**

Quantifies human impacts - not a number on a log scale

## **Predictive of Response**

Considers propensity of activity to annoy and trigger complaints

## **Contextualized**

Factors in the masking potential of ambient soundscapes



Measure the  
Change

Estimate the  
Impact

Mitigate the  
Effects



# Measure the Change

## Site Research

Assess land use, demographics, community values

## Record Ambient Soundscapes

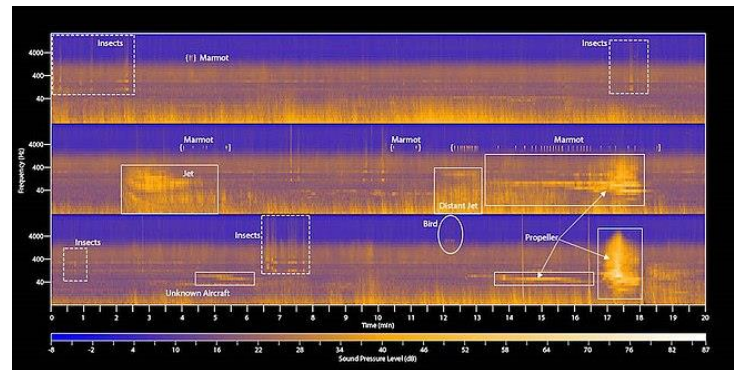
Collect data from relevant operating locations or proxies ASAP to account for seasonal adjustments

## Capture Aircraft Signatures

Continue collection of acoustic data, particularly at relevant approach conditions

## Simulate and Compute Resultant Soundscapes

Develop tool to simulate acoustic experiences at various distances/directions





# Estimate the Impact

## Complete Human Response to Noise Studies

Use acoustic simulations with relevant ambient soundscapes to better predict detection and annoyance

## Develop Analysis Capability

Tools for quantifying, for a specific site:

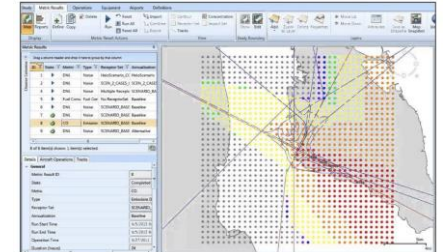
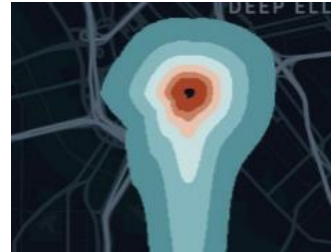
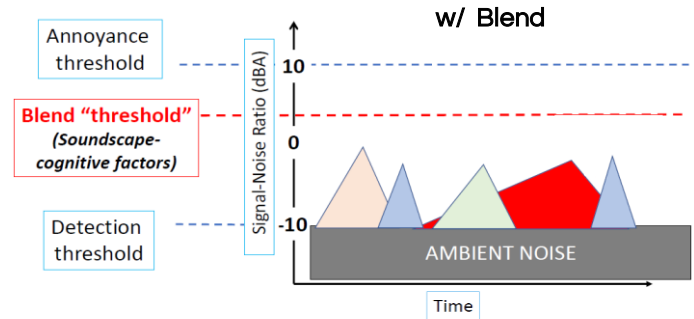
- % detect
- % disrupted
- % motivated by disruption

## Develop Data Visualization Capabilities

Tools for stakeholder engagement

## Utilize Existing Tools (Parallel Path)

Use noise hemisphere data in AEDT/AAM



# 04

## Looking forward

Targets for sustainable aviation



"The list of impossibilities for aviation could go on and on, and only as time and the unexpectedly brilliant development of flying progressed was it finally recognized that the most dangerous forecast in aviation is to predict the impossibility of something."

- Igor Sikorsky



# Emissions free aviation is possible





## Need for design tools

- Medium fidelity design tools
- High fidelity analysis tools that support early design exploration



Research direction driven by relevant physics, biology & psychology





# Rethinking noise

Acoustics is about perception and context



