I1.03 Net-Zero Charging Infrastructure Design for Electric Aircraft

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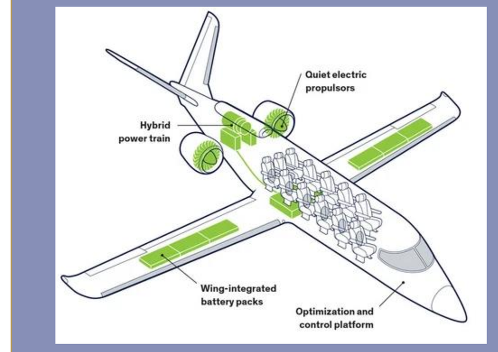
Problem Statement

- Propose a design solution for the establishment of a Net-Zero Charging Infrastructure for airports of a comparable size to Austin-Bergstrom International Airport (ABIA).
- Explore battery swapping and mega-charging solutions for promoting sustainable air travel.

Project Motivation

- The purpose is to lessen the carbon emissions of airplanes that run on fossil fuels as aviation accounts for 30% of global carbon footprint.
- The team will study and simulate the appropriate battery swapping and mega-charging needs under turn-around time constraint.



Project Objectives

- Reduce battery inventory level by utilizing M/G/s/s Erlang-B queue model for EA aircraft wait and leave.
- Reduce mega-charging waiting time by utilizing M/M/s/∞ Erlang-C queue model for EA turn-around time.
- Minimize the annualized cost of the battery swapping and mega-charging facilities over the course of a year.

Design Approach

Define → Measure → Analyze → Improve → Control

Define
- Project Statement
- Project Purpose
- Project Objectives
- Statement of Work (SOW)

Measure
- Simulation Testing
  - Probability of Leaving
  - Length of Charging Queue
  - Spare Batteries Available
  - Probability of Charging (Wait Time)
- Average Aircraft Arrival Rate
- Charger Cost ($60k - $350k)

Analyze
- Limited EA development and battery cost component data
- Most up-to-date EA modelling information
- EA Model: Eviation Alice
- Battery: Beta Technologies

Improve
- Battery Swapping & Battery Mega-Charging
- Optimize wait times for battery charging
  - EA layover time
  - Wait / leave time
- EA Layover Constraint: 45 minutes
- Cost: TBD

Control
- Further EA research
- Stream of communication with EPRI
- Enhance Net-Zero Battery queuing model

Measure

Simulation Testing – Queueing Model
M/G/s/s - Battery Swapping Process
M/M/n/∞ - Mega-Charging Process

Probability of Blocked Swap

$$B(s)=\Pr\{X=s\}=\frac{\frac{(\lambda_b/\mu_b)^s}{s!}}{\sum_{k=0}^{s}\frac{(\lambda_b/\mu_b)^k}{k!}}=\frac{\frac{\theta^s}{s!}}{\sum_{k=0}^{s}\frac{\theta^k}{k!}}$$

Length of Charging Queue

$$E[N_b]=\sum_{k=0}^{s}k\Pr\{X=k\}=\frac{\lambda_b}{\mu_b}\left(1-\Pr\{X=s\}\right)=\theta\left(1-B(s)\right)$$

Probability of Mega-Charging Waiting

$$C(n,s)=\frac{\frac{(B(s)\lambda_b/\mu_d)^n}{n!(1-B(s)\lambda_b/(n\mu_d))}}{\sum_{k=0}^{n-1}\frac{(B(s)\lambda_b/\mu_d)^k}{k!}+\frac{(B(s)\lambda_b/\mu_d)^n}{n!(1-B(s)\lambda_b/(n\mu_d))}}$$

Total Mega-Charging Service Time

$$t_{schg}=t_q+t_c=\frac{C(n,s)}{n\mu_d-\lambda_d}+\frac{1}{\mu_d}$$

Future Plans

- Once battery swap and mega-charging models are verified and validated, they will be implemented over medium-large sized airports.
- Sizing for Energy Capacity of Wind Turbine and Photovoltaic System for Net-Zero airport (Spring 2025).
- Cost Minimization of Net-Zero Infrastructure for EA (Spring 2025).

Human Factors/Ethics

- Electricity Safety Factor
- Shipping and handling of battery
- Swapping Battery Weight
- Mega Charger Safety Guideline

- Climate Justice - Net-Zero Emissions
- Environmental Justice - Noise Reduction
- Power Resilience - Less Maintenance

Analyze

Battery Manufacturer & Developer	Battery Name & Tech
Electro Aero	Electro Aero RAPID 240
Beta Technologies	Beta Charge Cube
Pipistrel	Pipistrel SkyCharge M20

Future Customers

- All Airports
- Electric Manufacturers
- Aviation Battery Manufacturers
- Mega-Charging System Manufacturers

Team Members

Alejandra Guardiola (left), Javier Guerrero (middle), Lauren Cravy (right)

References Information

Doctor, F., Budd, T., Williams, Paul. D., Prescott, M., & Iqbal, R. (2022). Modelling the effect of electric aircraft on airport operations and infrastructure. Technological Forecasting and Social Change, 177(121553), 121553. https://doi.org/10.1016/j.techfore.2022.121553