Distributed Electric Propulsion Commuter Airliner Design Challenge

Background

Distributed Electric Propulsion (DEP) is an emerging aircraft design concept that has the potential to improve aircraft performance in a number of areas, including efficiency, takeoff and landing performance, emissions, noise abatement, safety, and ride quality. DEP also has the potential to enable new novel control systems. DEP can encompass any number of aircraft configurations and propulsion integration options. For this design challenge, a key component of DEP is an electrically powered propulsor unit, which can be a propeller, ducted or unducted fan, transverse fan, or any other motor-driven device that adds momentum to the flow. A propulsor may be used to provide thrust directly or may be used as an aerodynamic enhancement device (for example, increasing lift or reducing drag). One concept is the DEP wing in which the propulsors provide span-wise distribution of the propulsive stream and enhanced lift capability; however, other distribution arrangements may also be used. Another key component of DEP is a separate power source (e.g. batteries, fuel cells, turboelectric generators) providing electricity to the motors. An important advantage of distributed propulsion is that the propulsors are separate from the power source, allowing the designer to place the propulsor where it is most needed on the airframe. Another advantage is that propulsors can be operated independently, or even shut down during part of the mission.

Design & Mission Requirements

For this design challenge, a commuter aircraft mission was chosen to explore the benefits of applying DEP technology. DEP technology has the potential to enable new capabilities and enhance mission performance in a number of ways, depending on how the technology is applied. The design concepts must make significant use of DEP. The main source of thrust for the concept may come from DEP or a combination of DEP and conventional propulsion devices (turboprops, turbofans, etc.). The challenge for the design team is to determine the most advantageous application of DEP for their aircraft and to justify their selection. The mission requirements listed below should be considered the minimum thresholds. Proposed designs should significantly outperform a conventional turboprop aircraft of similar size and mission in one or more key areas (e.g. cruise efficiency, takeoff & landing performance, operating cost, emissions, noise abatement, safety) through the application of DEP. Design teams will need a solid understanding of DEP technology and an awareness of current state-of-the-art DEP research. They must decide how to apply DEP in a way that will make their design attractive to a potential customer (domestic and foreign airlines, cargo carriers, governments, etc.) when compared to a turboprop aircraft that only meets the threshold requirements. For example, if takeoff and landing performance is targeted, the proposed design should use DEP to significantly exceed the TOFL requirement while at least meeting all the other requirements. In addition, the team must justify their design choice by describing the intended market for the aircraft and why the market will choose their design over a conventional turboprop that only meets the 3000 ft. requirement. The team should also address how application of DEP is advantageous over a conventional high lift wing in their design. As with any new aircraft, teams should consider development cost and risk, FAA certification, and passenger acceptance. The aircraft should be ready for operational service by 2025.

Although DEP is compatible with a number of power sources, the requirement for this design is a turboelectric generator system. Batteries may be used to supplement power to the system if needed.

The focus of this design challenge is meant to be the propulsor integration and usage, not the evaluation and selection of the power source. Not all propulsors are required to operate during the entire duration of the mission.

Mission Requirements:

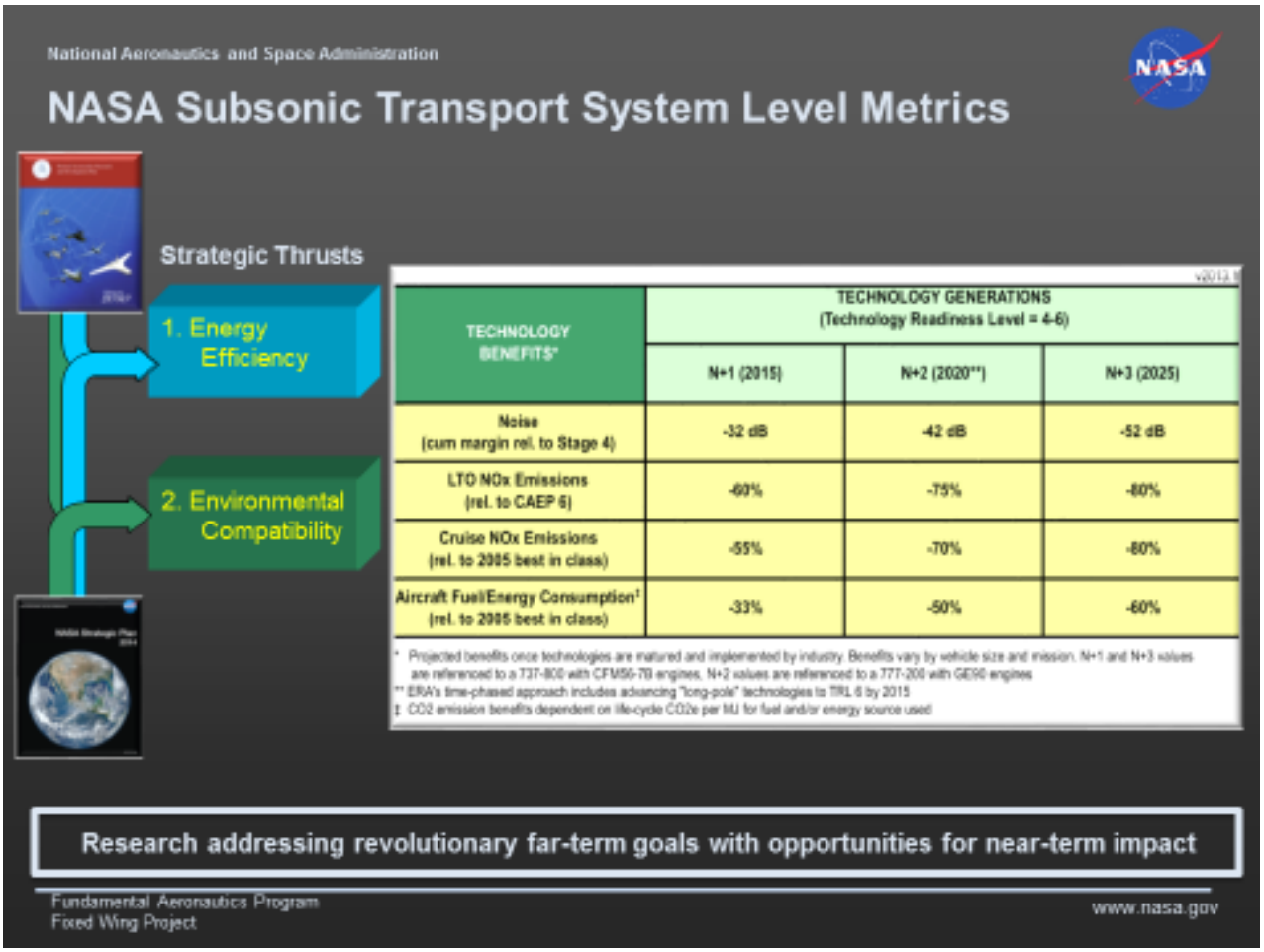
- Passenger capacity: 19 passengers with a 31-inch seat pitch. Assume a passenger with baggage weighs 225 lb.
- All-weather capability, including the ability to fly in icing conditions.
- Cruise Speed: 250 mph
- Service Ceiling: 28,000 ft.
- Range Requirement: The design concept should be capable of capturing at least 90% of the 19 passenger commercial commuter aircraft market. The design range should be compatible with that goal.
- Takeoff & Landing Field Length: No greater than 3000 ft. at maximum takeoff weight at sea level standard atmospheric conditions
- Reserve requirement: FAR fuel requirements for flight in IFR conditions
- Structural design criteria are +2.5/-1.0 g with a factor of safety of 1.5.

Written Report

The written report should include a discussion of both the hard requirements from the RFP and the derived requirements from the design team. The report should reference current DEP research and provide arguments supporting how and why the research is applicable to the team's concept. Discussion on which benefits of DEP were targeted and why is required along with a detailed discussion of the propulsion integration options and the rationale for the chosen configuration. The report should discuss the methodology for determining the power requirements of the electric motors and sizing the turboelectric generator system. Discussion of design tradeoffs should be emphasized, including trades to determine cruise speed & altitude, wing area, required power, aircraft geometry, etc. A comparison to existing aircraft that perform a similar mission should be included. The tools and methods used in the design and analysis should be briefly described, including formal methods, rules-of-thumb, and engineering judgment. The report should contain, at a minimum, the following:

- Dimensioned three-view drawing
- Internal arrangement drawing showing passenger arrangement and subsystem layouts
- V-n diagram
- Contour or Carpet plots showing trades between power and wing area
- Weight build-up table
- Table of key aerodynamic characteristics and performance parameters (e.g. L/D, cruise velocity, cruise altitude, energy consumption, rate-of-climb)
- Stability and control analysis
- Cost analysis, including aircraft development cost, production cost, and operation cost
- Safety discussion -- consider crashworthiness, propeller separation / fan bursts, fire containment, emergency egress

The report should also contain a discussion of the environmental impact of the concept. The community noise, aircraft energy consumption, CO2 emissions, and NOx emissions are all important factors to consider when discussing the viability of an aircraft concept. The table below shows the NASA projected environmental benefits of applying different generations of advanced technologies to different reference aircraft. Note that the dates correspond to a Technology Readiness Level (TRL) of between 4 and 6. The values in the table are not requirements, but reflect the environmental impact levels that NASA is targeting for future generations of aircraft. The values represent both the goals and technology assumptions to reach these goals. At a minimum, the report should contain a qualitative discussion of these environmental factors, the technology assumptions used in the concept, the potential impact of the concept on these factors, and how the potential impact compares with these NASA goals. If design team has specifically targeted an environmental benefit using DEP technology, then a more quantitative analysis would be expected.



TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6)		
	N+1 (2015)	N+2 (2020**)	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-32 dB	-42 dB	-52 dB
LTO NOx Emissions (rel. to CAEP 6)	-60%	-75%	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
Aircraft Fuel/Energy Consumption‡ (rel. to 2005 best in class)	-33%	-50%	-60%

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines. N+2 values are referenced to a 777-200 with GE90 engines
** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015
‡ CO2 emission benefits dependent on life-cycle CO2e per MJ for fuel and/or energy source used