National Aeronautics and
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Brief Overview of Subsonic Single Aft Engine (SUSAN) Transport Aircraft Concept and Trade Space Exploration

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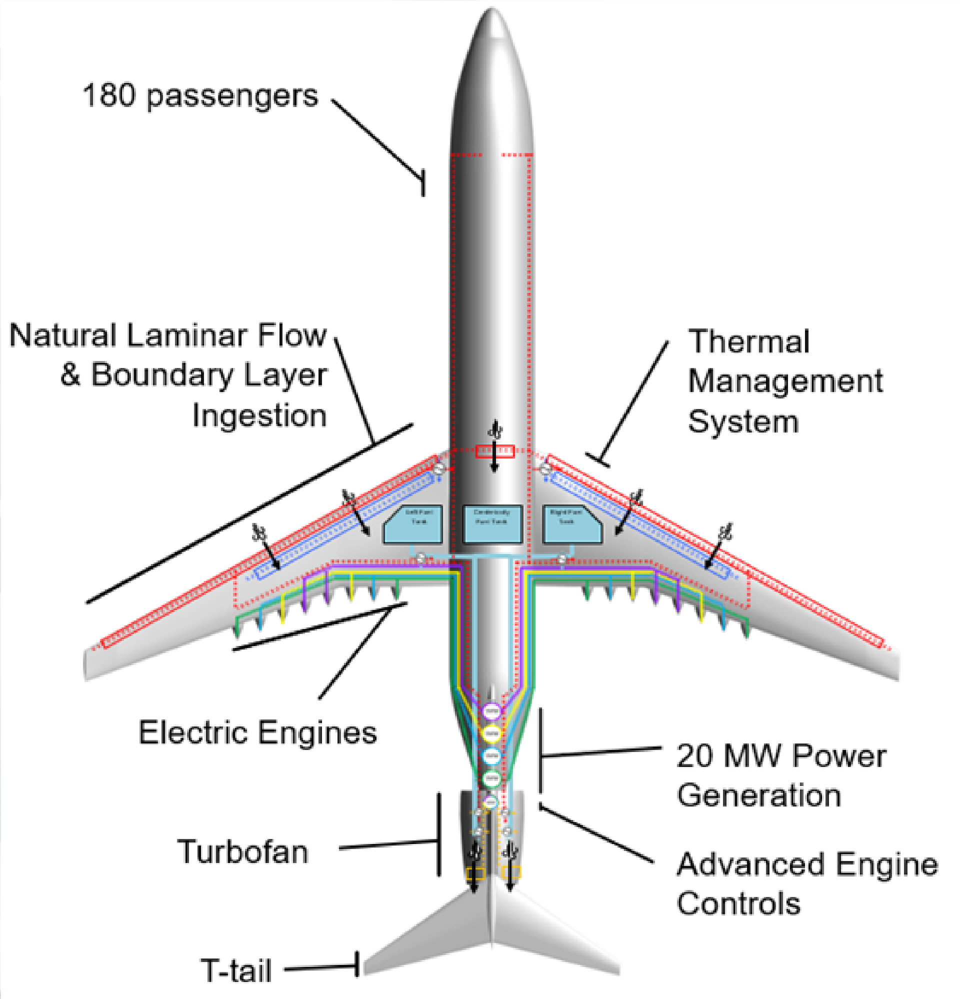
Introduction

- International Civil Aviation Organization (ICAO) has established two aspirational goals for international aviation
  - A 2% annual fuel efficiency improvement through 2050
  - Carbon neutral growth from 2020 onwards
- Aviation growth is driven by continued cost reduction while maintaining extremely high
1 safety standards
- The SUSAN Electrofan concept is intended to address both key drivers in aircraft design

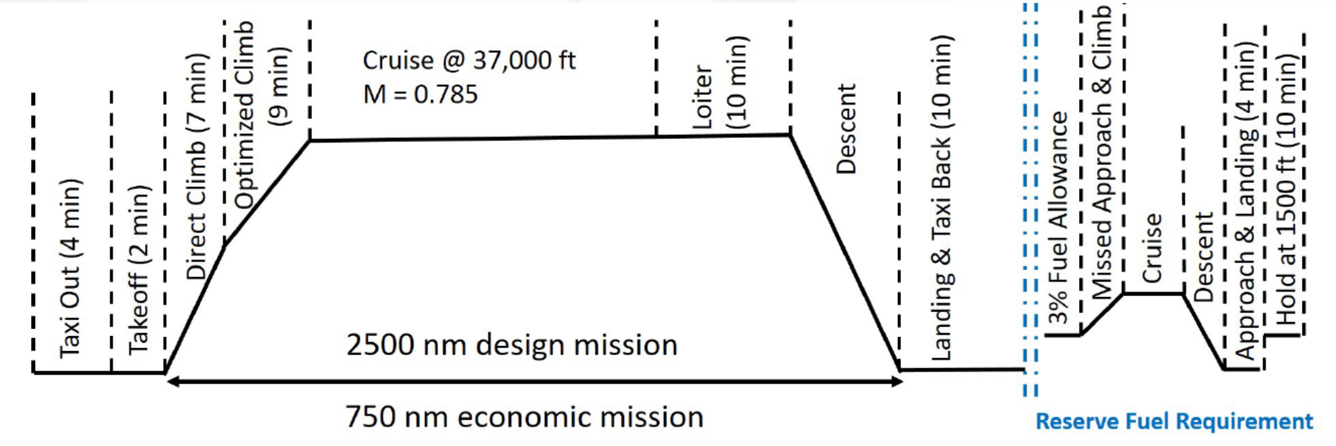
SUSAN Electrofan Aircraft Concept

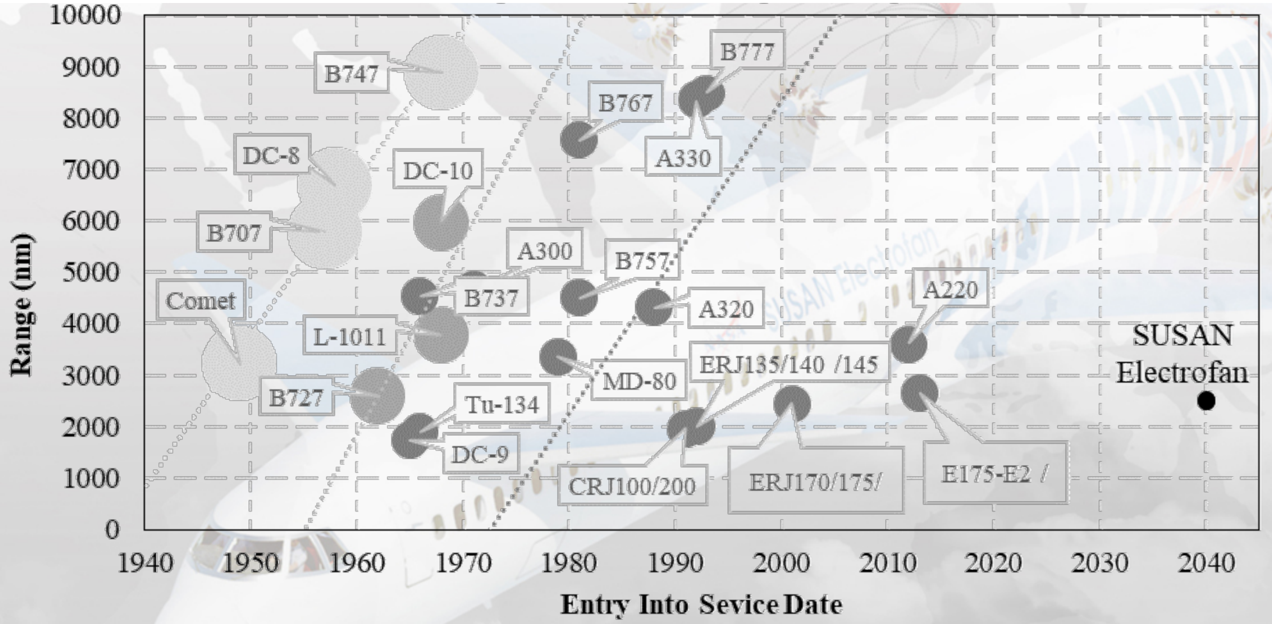
- The SUSAN Electrofan utilizes a 20 MW Electrified Aircraft Propulsion (EAP) system to enable
  - Single turbofan operation on a large transport category aircraft
  - Increased aerodynamic and propulsive efficiency through placement of electric engines
  - Optimized turbofan sizing and efficiency through control and electric boosting
  - Reduced control surface sizing through thrust augmentation



SUSAN Operational Concept

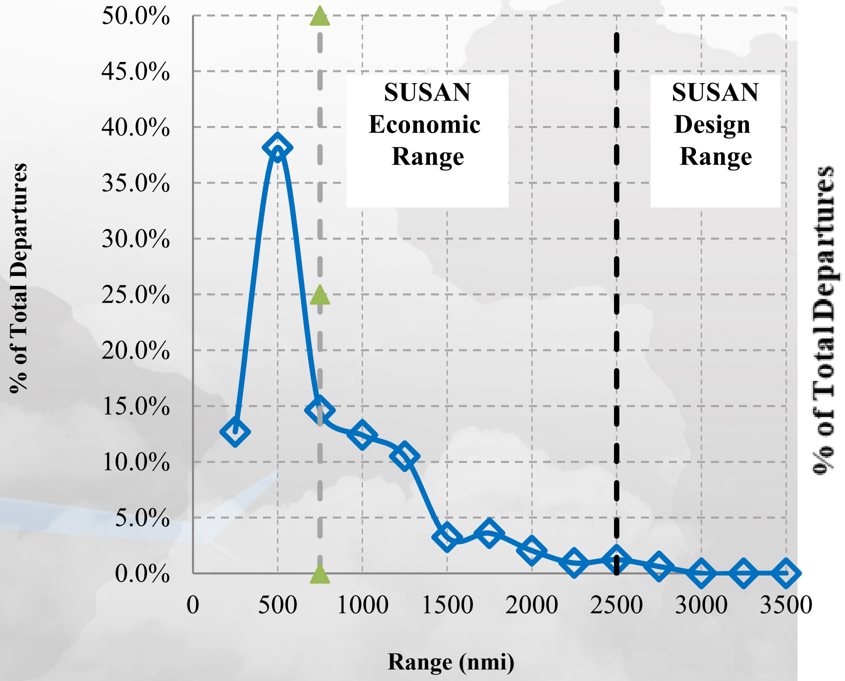
- Operates within current airspace constraints with a design range of 2500 miles, an economic range of 750 miles and a cruise speed of Mach 0.785
- Operates using current airport infrastructure with no battery charging or swapping required
- A single use battery powers the electric engines in case of turbofan failure
- Certification aspects are part of concept development

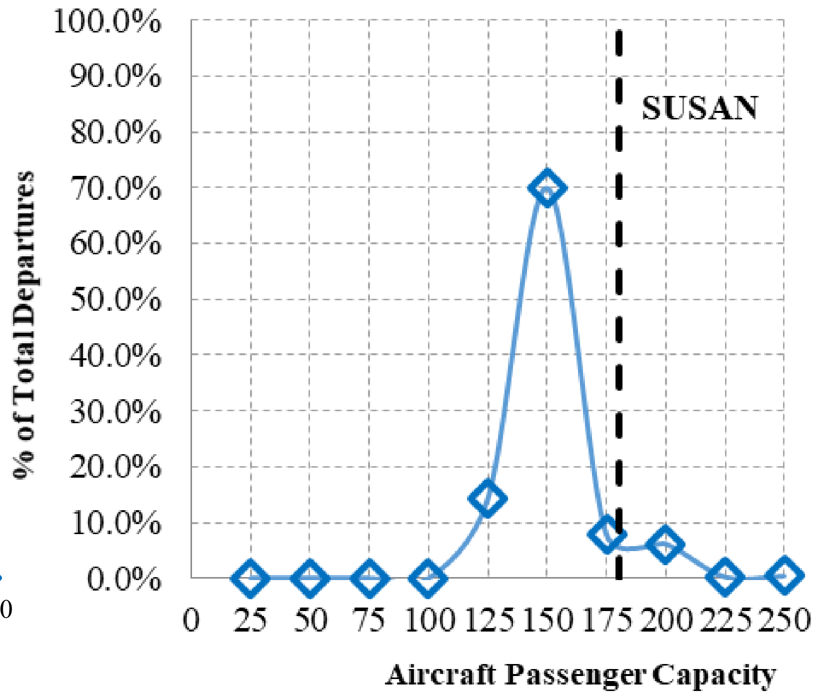




Market

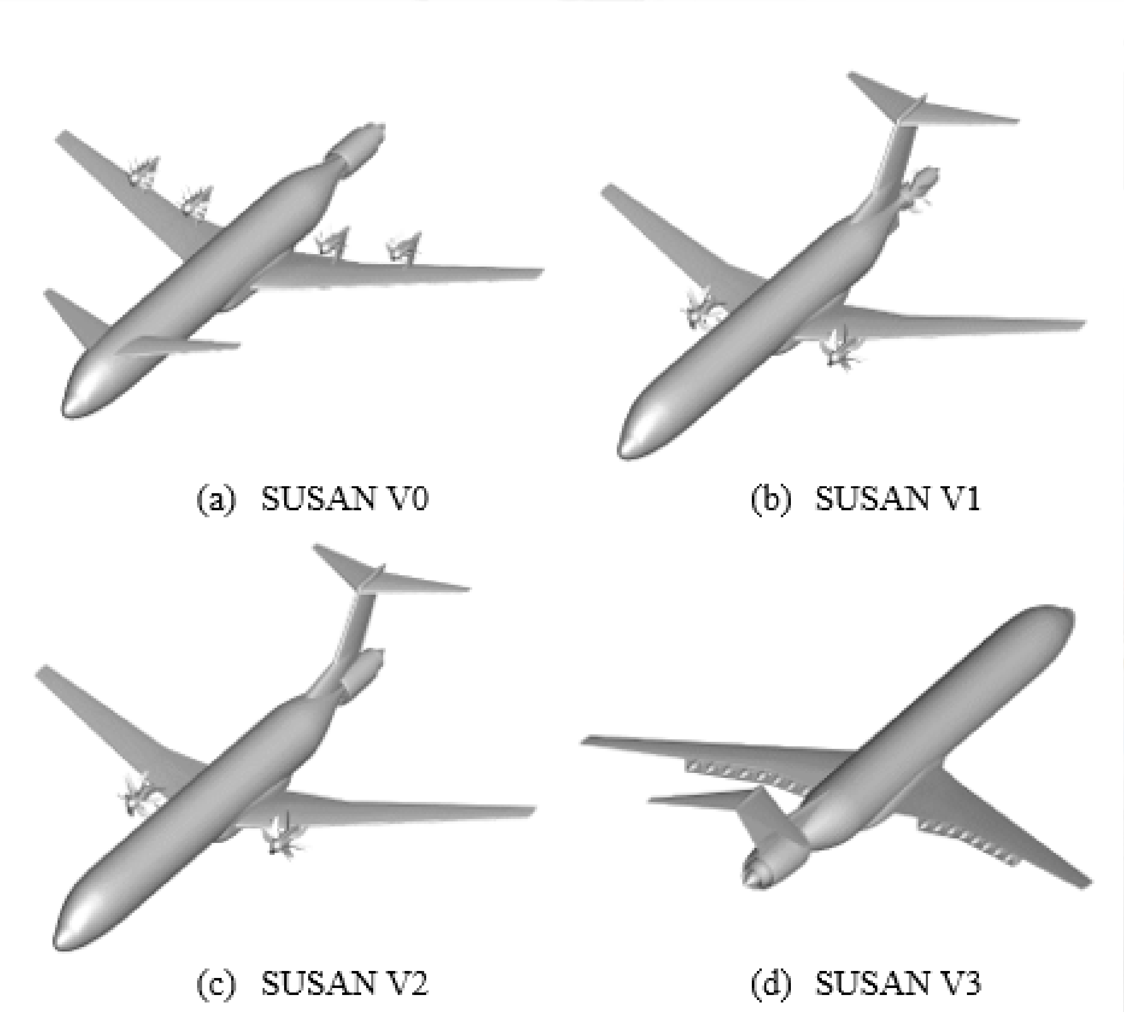
- SUSAN is designed to meet the needs of regional and domestic air carriers
- The range and passenger capacity requirement was determined from a primary analysis of three domestic U.S. airlines and two European regional carriers
- SUSAN meets the vast majority of the flight segment needs for these users





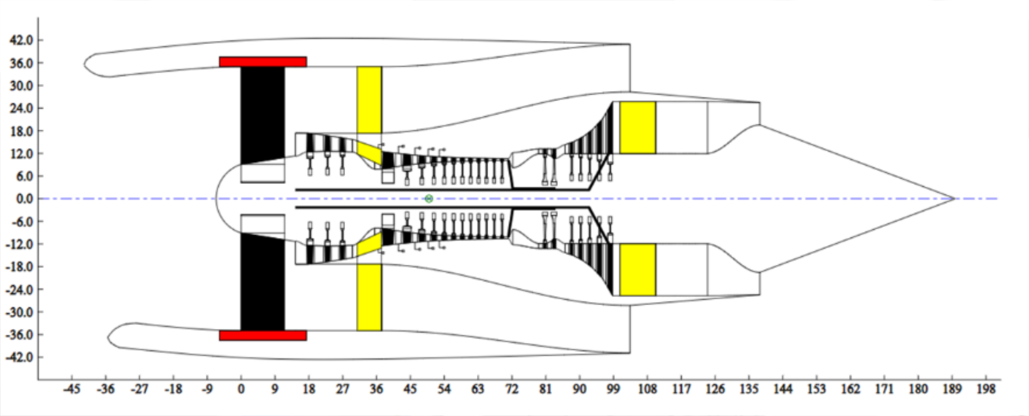
Aircraft Study Approach

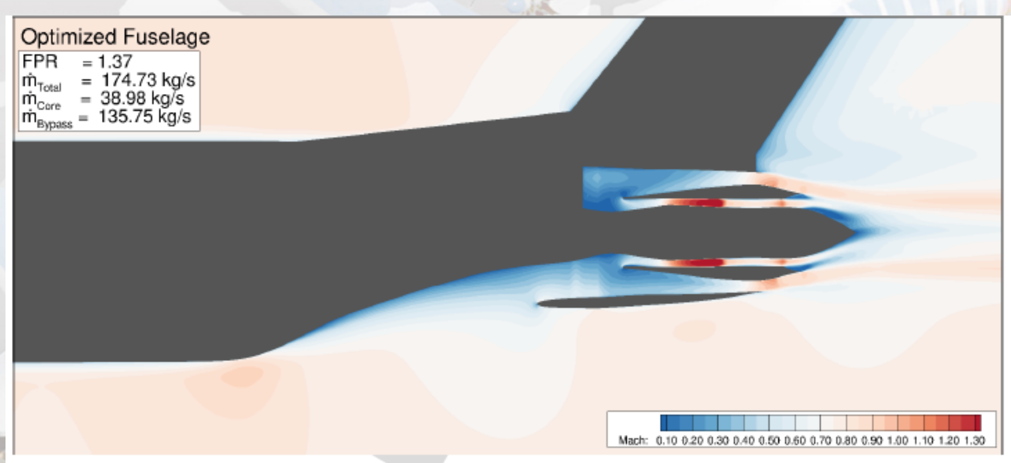
- Low and medium fidelity analysis is being conducted to trade aircraft configurations
- Subsystem trades are being conducted on the turbofan, wing, electric engine, power system, thermal system, and structure
- The SUSAN concept continues to evolve as the trades become more coupled



Turbofan

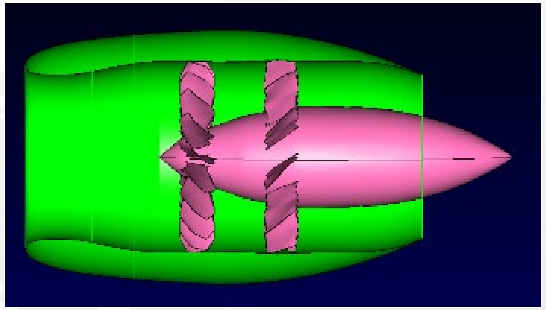
- The turbofan engine provides thrust and powers four 5MW electric generators (20MW total) to power the electric engines
- Trade studies are continuing to determine the optimal engine architecture
- Fuselage integration studies are being conducted to maximize the benefit of fuselage boundary layer ingestion

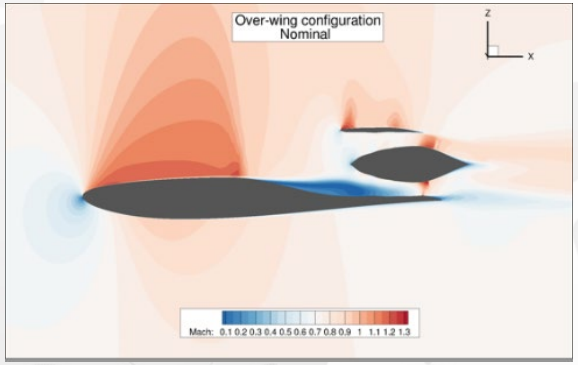


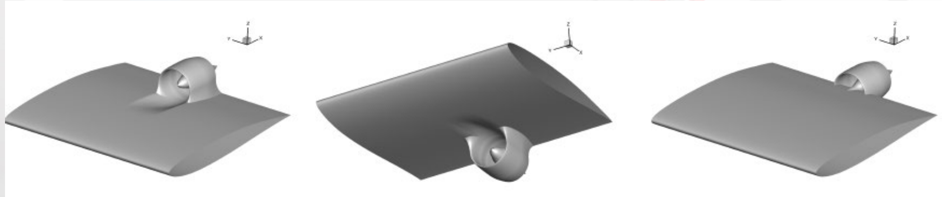


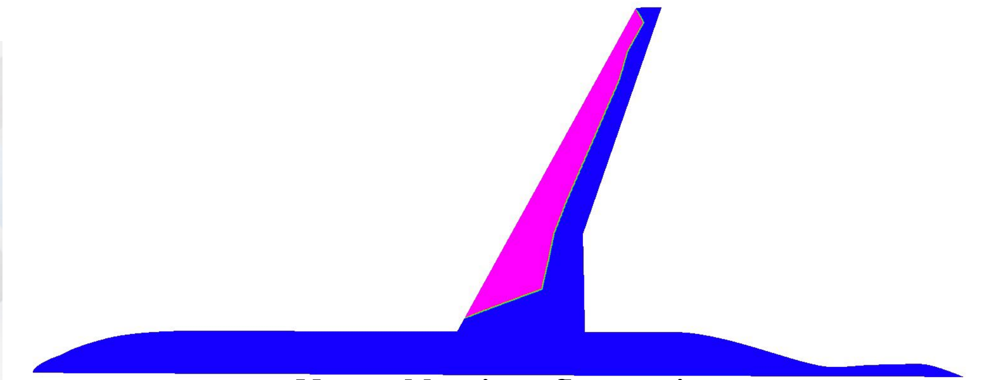
Wing and Electric Engines

- Ducted, unducted, single and dual fan row electric engines are being traded.
- Positioning of the electric engines on top of, below, and behind the wing are being considered.
- The wing is being optimized for natural laminar flow (NLF)
- Overall optimization of propulsive efficiency, wing shape, wing BLI, and NLF is an ongoing trade.





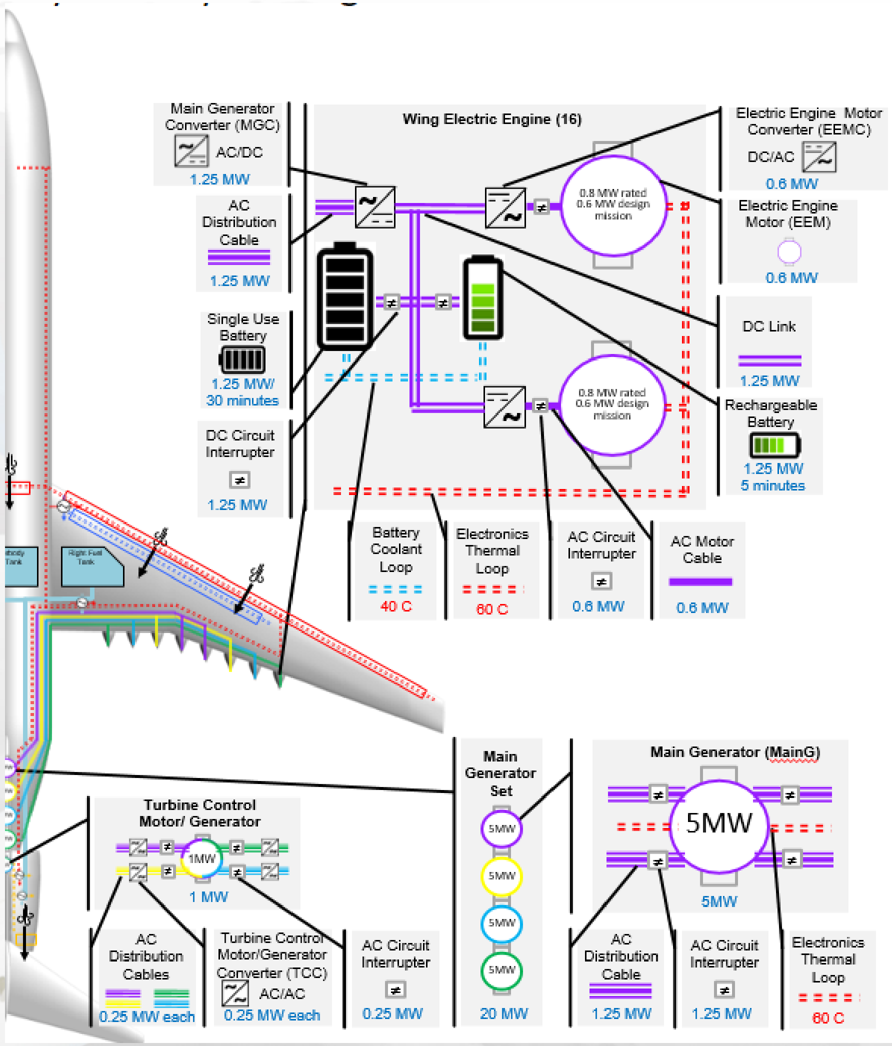




Natural laminar flow region

Power System

- Four 5 MW turbofan driven generators power the wing mounted electric engines
- Relatively small, in-flight rechargeable batteries are used for climb boost and to improve turbofan operability
- A single use battery provides power if the turbofan fails
- The power system must be extremely light weight and highly efficient to reduce aircraft mission energy use.



Power System Key Performance Parameters

- A range of key performance parameters have been established for each of the power components in the trade study
- Light weight and high efficiency must be simultaneously achieved at power ratings an order of magnitude above other aircraft power systems.

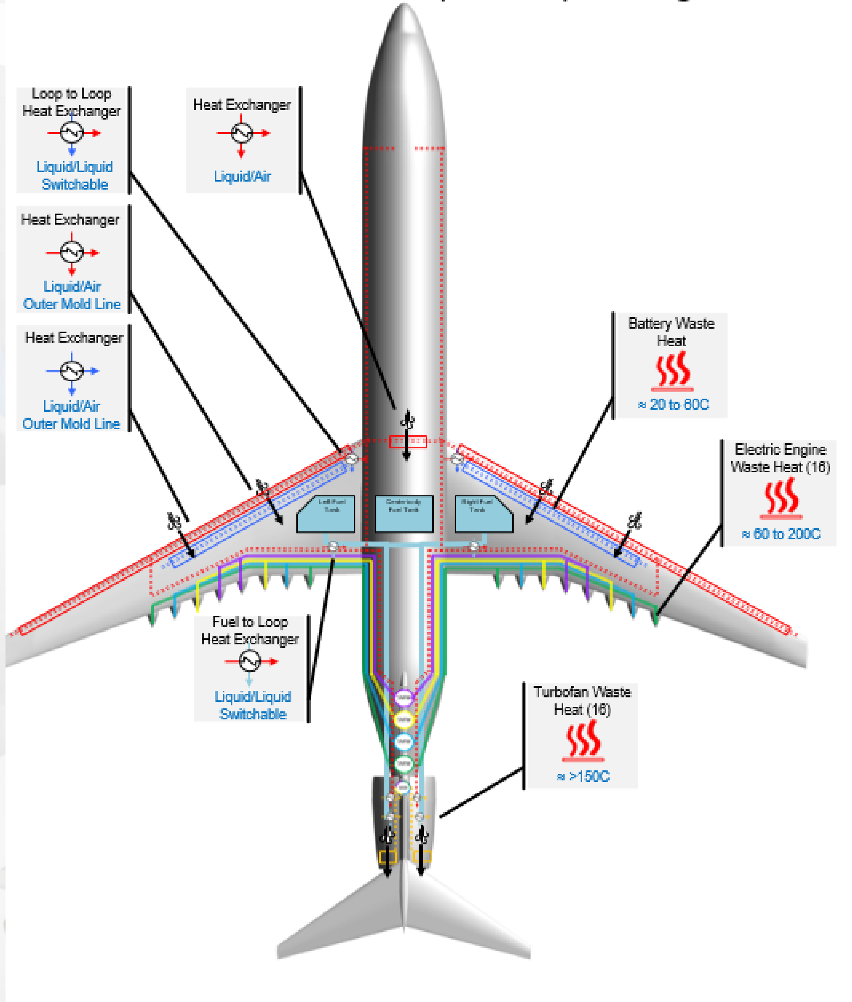
Table 3: Specific Power and Efficiency Ranges Being Evaluated for SUSAN EPS Components

	Weight				Efficiency			
	Nominal	Min	Max	Unit	Nominal	Min	Max	Unit
Electric Machines								
Main Generator	25	15	50	kW/kg	99%	98%	99.5%	%
Turbine Control Motor/Generator (TCMG)	20	10	30	kW/kg	99%	98%	99.5%	%
Electric Engine Motor (EEM)	20	10	30	kW/kg	98.5%	97%	99.0%	%
Power Conversion								
Main Generator Converter (MGC)AC to DC	30	20	40	kW/kg	99%	97%	99.5%	%
Turbine Control M/G Converter (TCC) AC to AC	15	10	20	kW/kg	98%	94%	99%	%
Electric Engine Motor Converter (EEMC) DC to AC	20	10	40	kW/kg	99%	97%	99.5%	%
Batteries								
Rechargeable Battery	500	200	1000	w-hr/kg	97%	90%	98.0%	%
Single Use Battery	1500	700	3000	w-hr/kg	90%	50%	98.0%	%
Cables								
AC Distribution Cable	2	0.5	10	kg/m/MW	0.040%	0.080%	0.020%	% loss/m
DC Distribution Cable	2	0.5	10	kg/m/MW	0.040%	0.080%	0.020%	% loss/m
Circuit Interrupters								
AC Circuit Interrupters	300	200	600	kW/kg	99.5%	99.7%	99.9%	%
DC Circuit Interrupters	150	100	300	kW/kg	99.5%	99.7%	99.9%	%

Thermal System

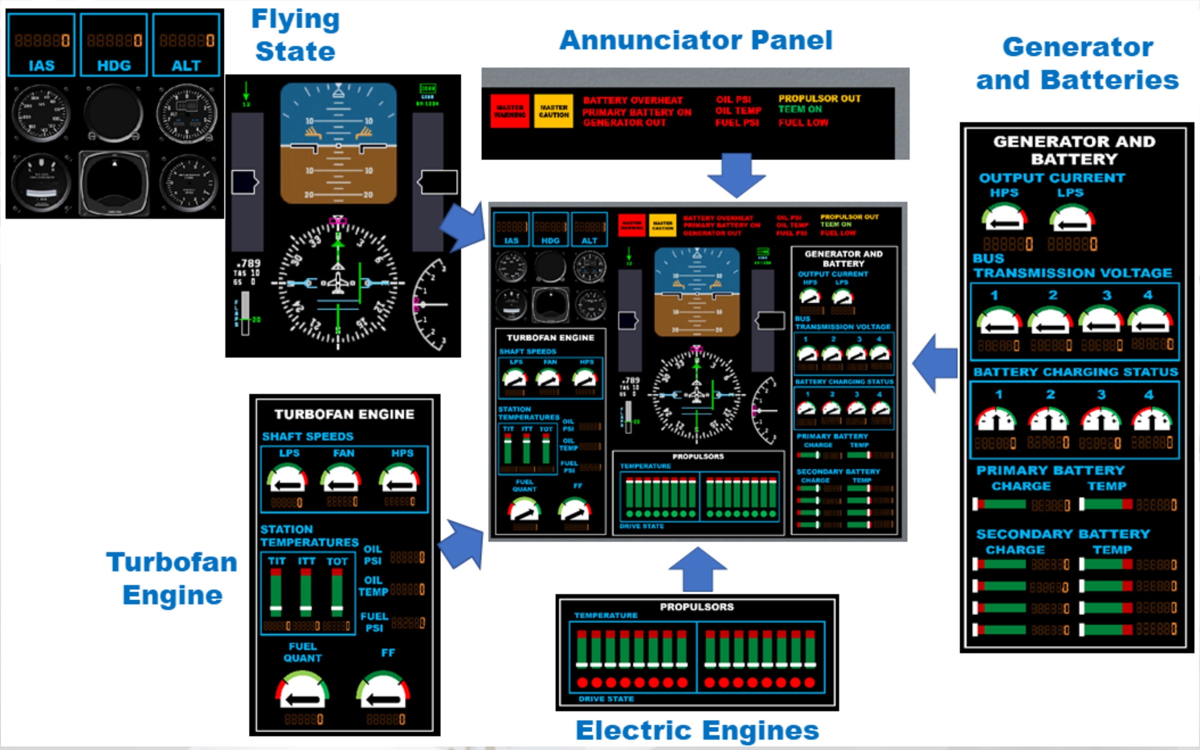
- The approach to minimize thermal management system mass, drag and power requirements consists of five elements:
  - Minimization of heat loads
  - Three loops operating at temperatures appropriate for their thermal loads
  - Use of waste heat from the engine to warm electrical systems on cold day conditions
  - Management of transient heat loads through heat capacitance of the fuel
  - Removal of heat using a combination of traditional heat exchangers and outer mold line cooling

SUSAN Electrofan Thermal System Layout Diagram



Control / Pilot Interface

- A flight simulation system for the SUSAN Electofan is being developed for two purposes
  - Mature the integrated flight, propulsion, and power control design
  - Create a cockpit design and receive feedback to improve the pilot interfaces



Conclusions

- The SUbsonic Single Aft eNgine (SUSAN) Electrofan trade study is being conducted to determine if a 50% emissions reduction can be achieved while retaining the range and speed of large transport aircraft
- The SUSAN concept uses 20MW EAP to enable aerodynamic, propulsive, and thermal efficiencies to reduce total mission energy.
- Reduced mission energy is combined with alternative fuels to further reduce emissions.
- The SUSAN concept operates within the constraints of the current airport, airspace, and economic systems.
- Although preliminary assessments are promising, substantial work is required to complete a closed concept with an understanding of benefits.

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Reference Papers

TITLE	Lead Author	Link to Paper
Subsonic Single Aft Engine (SUSAN) Transport Aircraft Concept and Trade Space Exploration	Ralph Jansen	https://arc.aiaa.org/doi/10.2514/6.2022-2179
Initial Regulatory and Certification Approach for the SUSAN Electrofan Concept	Casey L Denham	https://arc.aiaa.org/doi/10.2514/6.2022-2180
Conceptual Exploration of Aircraft Configurations for the SUSAN Electrofan	Timothy Chau	https://arc.aiaa.org/doi/10.2514/6.2022-2181
Tail-mounted engine Architecture and Design for the Subsonic Single Aft Engine Electrofan Aircraft	Arman Mirhashemi	https://arc.aiaa.org/doi/10.2514/6.2022-2182
Electrical System Trade Study for SUSAN Electrofan Concept Vehicle	Joe Haglage	https://arc.aiaa.org/doi/pdf/10.2514/6.2022-2183
Thermal Management System Trade Study for SUSAN Electrofan Aircraft	Nic Heersema	https://arc.aiaa.org/doi/10.2514/6.2022-2302
A Design Exploration of Natural Laminar Flow Applications for the SUSAN Electrofan Concept	Michelle N Lynde	https://arc.aiaa.org/doi/10.2514/6.2022-2303
High Fidelity Computational Analysis and Optimization of the SUSAN Electrofan Concept	Leonardo M. G. Machado	https://arc.aiaa.org/doi/10.2514/6.2022-2304
Conceptual Design of Propulsors for the SUSAN Electro-fan Aircraft	May-Fun Liou	https://arc.aiaa.org/doi/10.2514/6.2022-2305
Implementation Approach for an Electrified Aircraft Concept Vehicle in a Research Flight Simulator	Jonathan S Litt	https://arc.aiaa.org/doi/10.2514/6.2022-2306

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