Structural Requirements for Design and Analysis of 25% Scale Subsonic Single Aft Engine (SUSAN) Research Aircraft

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Outline

- SUSAN Overview
- Objective
- Structural Requirement Consolidation
- Loads Analysis Approach
- Atypical Structural Design Requirements
- Example application: SUSAN 25% Scale Vehicle
- Conclusions & Next Steps

SUbsonic Single Aft eNgine (SUSAN) Electrofan

- Regional jet transport aircraft concept
- Utilizes aft mounted single turbofan engine and underwing electrified aircraft propulsion
- Aims to reduce:
  - Fuel usage
  - Emissions
  - Cost

Objective

- Establish set of structural requirements
  - Conceptual design studies
  - Aircraft concepts and early design phases of experimental aircraft
- Consolidate applicable aircraft design loads & structural requirements
  - Enables rapid informed iterations on the structural design of the SUSAN aircraft

Structural Requirement Consolidation

- Extensive set of structural requirements come from FAA and NASA standards
- Consolidated applicable aircraft design loads and standards

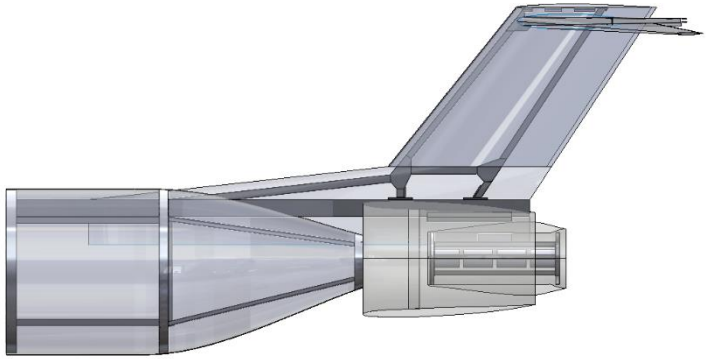
Standard/Document	Consolidated Requirements
FAA CFR Part 25	Loads and standards for SUSAN 180PAX
FAA CFR Part 23	Loads and standards for SUSAN 25% scale vehicle
NASA Armstrong AFG-7123.1-001	Factors of safety for SUSAN 25% scale vehicle; flight conditions that produce highest loads
NASA-STD-5020	Fitting factors, fastener analysis requirements,
NASA-STD-5001B	Fatigue and creep service life factor; buckling analysis requirements
DO-160G	Crash loads

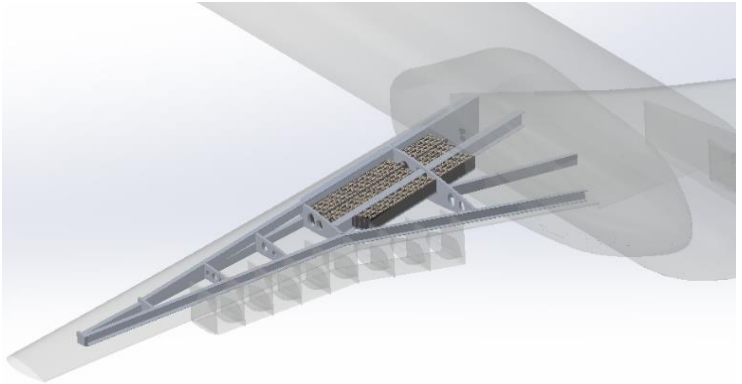
Loads Analysis Approach

- Identifying significant flight loads during key mission points:
  - Takeoff/landing
  - Cruise
  - Loitering
  - Maneuvering
- Focus given to the primary aircraft structural elements:
  - Fuselage structure
  - Wing structure
  - Engine/tail mount

Atypical Structural Design Requirements

- Aft engine mounted via pylon in-line with fuselage
  - Tail structure shares this mounting location
- Wing mounted electric engines
  - Impact to control surfaces, loads more distributed across the wing
- Battery pack and fuel storage in wings
  - Landing weight closer to takeoff weight

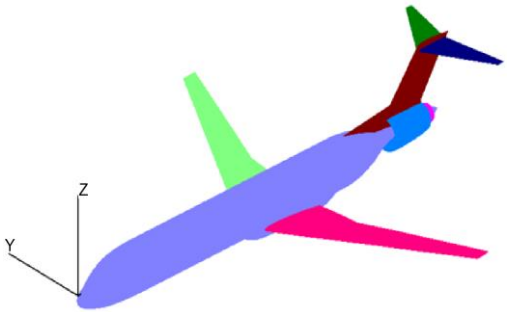




Research Testbed

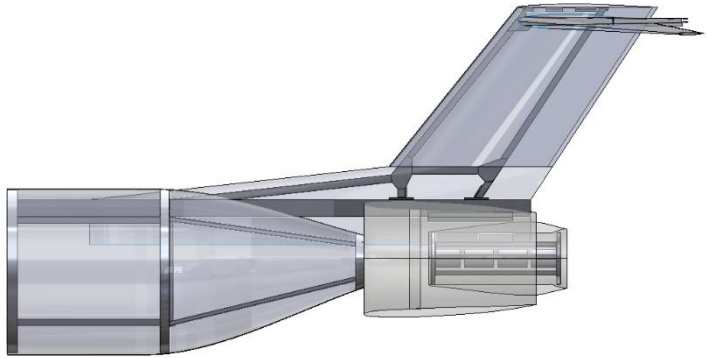
- Technical risk reduced through incremental validation of design concepts
- 25% scale flight research vehicle formulated to serve as remote piloted testbed for:
  - Integrated flight
  - Propulsion
  - Controls architecture
- Direct scale down of 180pax OML

Flight Conditions	
Condition	**Value**
SL	0 ft
Hc	10,000 ft
Vc	130 kt / 150 mph
W/MTOW	1,500 lb
S_{ref}	81.125 ft^2
V_{ref}	225.61 ft/s
ρ_{ref}	0.001755 $slugs/ft^3$



Example Application: SUSAN 25% Scale Vehicle

- Example application of key load elements for 25% scaled vehicle engine mount location
- Highlights major requirements assessed from consolidated standards



25% Scale Flight Research Vehicle – Engine Mount Example

- Individual load requirements for engine mount based on flight conditions that typically produce high loads

Load Case	Load or Load Factor Applied	Reference
Engine mount side load	Limit load factor of 1.33g in lateral direction (assumed to be independent of other flight conditions)	CFR 23 Part 363
Aerodynamic loads	These include horizontal and vertical gust loads of ±50 ft/s, symmetric maneuvering loads on vertical tail, air loads on rudder and elevators, and aerodynamic loads at the nacelle.	Combined requirements, CFR 23
Engine thrust	300 lb maximum thrust estimate	Project specification
Engine torque	Limit engine torque corresponding to maximum continuous power and propeller speed acting simultaneously with the limit loads (+3.8/–1.5)	CFR 23 Part 361
Combination of thrust with vertical and side loads	300 lb engine thrust, side limit load factor = 1.33g, vertical load factor = 3.8g (from maximum maneuvering load factor)	CFR 23
Gyroscopic and aerodynamic loads	Combination of 2.5 rad/s yaw velocity, 1.0 rad/s pitch velocity, normal load factor of 2.5g, maximum continuous thrust force, and aerodynamic loads that result from engine operation	CFR 23-Part 371
Unsymmetrical loading on horizontal tail (maneuvering)	100% of maximum loading from symmetrical flight conditions on one side; opposite side follows: % = 100 – 10(n – 1) where value may not be more than 80%.	CFR 23-Part 427
Maneuvering load on vertical tail surface	Yaw velocity assumed to be zero and airplane in unaccelerated flight; at speeds up to V_A, vertical surfaces must be designed to withstand sudden displacement of rudder control to maximum deflection. Airplane yaws to overswing sideslip angle of 22.5°. Aeronautical loads are determined from this maneuver.	CFR 23 Part 441

25% Scale Flight Research Vehicle – Engine Mount Example

- Specific cases/mission profile loading for engine mount
  - Combines individual load requirements to encompass range of load cases at specific mission points

Key Mission Points	Load or Load Factor Applied	Reference
Crash condition	3g, 6g, 9g, 1.5g, 4g loads applied up, down, forward, aft, and side, respectively. g-loads applied separately.	DO-160G / CFR 25 part 561
Engine-out condition	Does not lead to typical unsymmetric loads detailed in CFR 23. In the event of turbofan engine failure, primary batteries will provide electrical power to wing propulsors and allow for limited continuation of flight.	General
Takeoff/landing	Aerodynamic loads, engine thrust and torque, considerations for tail strike at aft engine (must check different angles of attack at landing)	Combined requirements
Cruise	Symmetrical vertical gusts in level flight (Gust of +/- 50 ft/s), thrust, engine torque, aerodynamic loads, 1g load factor	Combined requirements
Maneuvering (this will include load cases for airplane loitering)	Aerodynamic loads, engine thrust and torque, side loads on engine mount, gyroscopic loads, unsymmetrical loading, and maneuvering conditions on empennage	Combined requirements

Conclusions & Next Steps

- Consolidated applicable aircraft design loads and standards
  - FAA CFR Part 25
  - FAA CFR Part 23
  - NASA Armstrong AFG-7123.1-001
  - NASA-STD-5020
  - NASA-STD-5001B
- Rapid informed iterations of 25% scale structural design primary components:
  - Engine/tail mount
  - Fuselage structure
  - Wing structure

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