Vision & Propulsion Airframe Integration (PAI) Challenges of Future Air Vehicles

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Propulsion Airframe Integration TIM
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Outline

NASA Aeronautics Context

Propulsion Airframe Integration

Traditional Subsonic “Fixed Wing” Markets

Emerging Aviation Markets

    Supersonic
    Vertical Lift (VL)

Concluding Remarks
NASA Aeronautics
NASA Aeronautics Vision for Aviation in the 21st Century

ARMD continues to evolve and execute the Aeronautics Strategy https://www.nasa.gov/aeroresearch/strategy

Global Sustainable

Transformative

U.S. leadership for a new era of flight
NASA Aeronautics Strategic Implementation Plan (SIP)
Mega Drivers and Strategic R&D Thrusts

**T1 Safe, Efficient Growth in Global Operations**
- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

**T2 Innovation in Commercial Supersonic Aircraft**
- Achieve a low-boom standard

**T3A ST Ultra-Efficient Commercial Vehicles**
- Pioneer technologies for big leaps in efficiency and environmental performance

**T3B VL Transition to Alternative Propulsion and Energy**
- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

**T4 In-Time System-Wide Safety Assurance**
- Develop an integrated prototype of an in-time safety monitoring and assurance system

**T5 Assured Autonomy for Aviation Transformation**
- Develop high impact aviation autonomy applications

Each Strategic Thrust has associated community outcomes – targeted impacts at 10, 20, and 30 years out.
NASA Aeronautics Priorities
from Congressional Briefing on President’s FY19 Budget Request (February 2018)

- Focus Topics
  - Low Boom Flight Demonstrator
  - Subsonic Aircraft Technologies
  - Hypersonic Technology
  - UAS Traffic Management and Urban Air Mobility
  - Air Traffic Management
  - System Wide Safety
  - Energizing the U.S. Aeronautics Innovation Pipeline

Focus Topic list indicative of ARMD priority areas
PAI critical for all vehicles
Propulsion Airframe Integration
integration of the key subsystems that most define the aircraft

• What system? For this presentation:
  – Vehicle system
  – Vehicle as a subsystem within the air transportation system
  – Vehicle as a system compromised of major subsystems
    • airframe, propulsion, control, communication, navigation, …

• Propulsion Airframe Integration
  – Integration of two major subsystems that most define what we see as the aircraft configuration externally, but also includes much that is internal
    • Example: fuel subsystem is internal, integrated within airframe and propulsion subsystems
  – Includes Propulsion Airframe Acoustics (PAA) challenges & opportunities
The Dawn of Propulsion Airframe Integration

1902 glider

1903 powered flight
"Current" Propulsion Airframe Integration
Subsonic Transport – under wing pylon mount

- Challenge
  - Efficient integration
  - Propulsion system growth for efficiency/noise
  - Nacelle weight/drag growth

- Design Process Advances
  - Isolated wing & nacelle
  - Wing with influence of nacelle
  - Simultaneous wing/nacelle
  - Simultaneous wing/nacelle/fan?

- Design Considerations
  - ground clearance, roll, nose gear collapse, water ingestion, rotor burst, loads/aeroelastics, ETOPS, engine out, full env operability, fuel system integ, secondary power extraction & distrib, etc

PAI IS HARD AND GETTING HARDER

Figure courtesy Brian Yutko

Schlosser et al. Chart 5
Overcoming the PAI Challenge
Subsonic Transport – options

1 – No physical size growth (outer mold line (OML)) compared to state-of-the-art (SOA) propulsion system
   - fits under existing low wing
   1.1) Small core, high efficiency without growing OML
   1.2) Partial hybrid system

2- Reduce physical size (OML) compared to SOA propulsion system
   - fits under existing wing with room for growth
   - more than 2 propulsors, equal or less number of cores than propulsors
   2.1) > 2 engines, propulsor to core 1:1, each smaller than equivalent twin
   2.2) Distributed propulsion system #fans > #cores. Explore trade space of propulsor distribution and power transmission (electrical or mechanical)
   Example: Boundary Layer Ingestion (BLI) tail cone thruster
           (to enable smaller thrust requirement for under wing engines)

3- Accept physical size (OML) growth compared to SOA propulsion system
   - doesn’t fit under existing wing, unless landing gear grows (weight/noise)
   - requires reconfiguration/relocation of propulsion, nontraditional airframe
   3.1) Over Wing Nacelle
   3.2) Fuselage Mount (side or above)
   3.3) High wing / Gull Wing
   3.4) **BLI** or flush mount w/diverter derivative of any pylon mounted configure above

Reference: 2017 Single-Aisle

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Overcoming the PAI Challenge
Subsonic Transport – opening a range of future possibilities?

- Sample Configuration Possibilities with unique PAI
  - Boeing BWB
  - Lockheed Martin HWB
  - Dzyne BWB

- Sample Configuration Possibilities with unique PAI including BLI
  - 180 Degree Distortion
    - NASA N3X
    - MIT/Cambridge SAX-40
  - 360 Degree Distortion
    - Boeing SUGAR
    - NASA STARC-ABL
    - Bauhaus Luftfahrht Propulsive Fuselage
So what about BLI?
Is there really a benefit when considering all the penalties?

- **Potential Benefits**
  - Variation, uncertainty in benefit, dependent on application and assumptions

### Historical Estimates of the benefit of BLI

[Bar chart showing historical estimates of the benefit of BLI with new results in 2018 ranging from 3-6% benefit.]

- Boeing BWB (Daggart, et al, 2003)
- Boeing BWB (Kawai, et al, 2006)
- MIT HWB (Plas, et al, 2007)
- UTRC TnW (Hardin, et al, 2012)
- Dispersal TnW (Isikveren, 2015)
- MIT D8 (Drela, 2017)
So what about BLI?
Is there really a benefit when considering all the penalties?

• Understanding details and minimizing penalties
  – Distortion Tolerant Fan
    fan efficiency, weight, ....
  
    See Arend, et al. AIAA 2017-5041
  
  – NASA GRC 8x6

  Inlet Flow Conditioning
  forward of or within inlet

    See Owens, et al. AIAA J. of Aircraft
    vol. 45, no.4. pp1431

    NASA LaRC 0.3m TCT
Propulsion Airframe Integration
Safe, Efficient, Quiet Vertical Lift Aircraft

“Traditional” helicopter design is already challenging and PAI fundamental

Wide range of concepts in development (Hirshberg, www.vtol.org, January 2018 lists 51!) up to and including in flight test that are even more challenging

NASA representative suite of reference vertical lift aircraft/missions for research

Propulsion Airframe Integration
Civil Supersonic Aircraft

Practical civil supersonic aircraft are emerging

Full vehicle shaping including PAI is critical for quiet, efficient supersonic flight

NASA Low Boom Demonstrator and several other aircraft concepts in development heading towards flight test
Concluding Remarks

• Exciting times in Traditional and Emerging Aviation Markets
  – Many opportunities … many challenges
  – Modern technology/capabilities lead to expanded design/trade space (but the devil is in the detail)

• NASA Aeronautics working on PAI Challenges and exploring opportunities across vehicle classes
  – External and internal integration challenges
  – Complexity of design, test, and analysis grows
  – Subsonic FW: PAI challenges may drive configuration change
    Vehicle-integrated BLI-propulsion warrants further study
  – Subsonic VL: PAI challenges in breadth and complexity of new configurations
  – Supersonic: PAI challenges inherent in low boom and conventional designs