HSR AERODYNAMIC PERFORMANCE STATUS AND CHALLENGES

HSR Aerodynamic Performance Technology Management Team

Bill Gilbert, NASA LaRC
Tony Antani, McDonnell Douglas
Doug Ball, Boeing
Rob Calloway, NASA LaRC
Phil Snyder, NASA ARC

Presentation at First Configuration Aerodynamics Workshop
NASA Langley Research Center, Virginia
February 27, 1996
Presentation Outline

- Introduction
- Aero impact on HSR
- Goals and Targets
- Progress and Status
- Remaining Challenges
- Summary

HSR Technology Development Charter

Technology Development

- Develop:
  - Methods
  - Processes
  - Database
  - Fundamental Knowledge

To:
- Improve Performance
- Knowledge
- Reduce Design Cycle Times
- Improve Results
- Reliability
- Reduce Risk

Motivation

- Allow Industry To Be More Nimble
  In Reacting To The Marketplace

Airplane Development

Tests
- Does Industry Want It?
- Is It "Cost" Effective?
- Is It Quick?
- Is It Reliable?
- Acceptable econ. & environ.?
ROAD AHEAD IS STEEPER & SLIPPERY!

- Aeroperformance has delivered on promises to date
- Future gains will be more difficult and will require excellent teamwork within Aero and in HSR
- Materials/Structures & Propulsion have encountered major problems in achieving needed gains
  - Aero is being asked to provide more help in meeting the takeoff noise goals
- As a result, pressure on aero to do even better will increase!
  - We’ll be squeezed to get every last drop of performance possible!
  - But we must maintain our confidence level in the performance gains we predict

Aerodynamic Performance Objectives & Impact

Develop and validate design & analysis methods & database to:
- Maximize low speed and cruise performance with acceptable S&C; help reduce community noise
  - Impacts on TOGW:
    - 1-count drag reduction: 7K lbs @M2.4; 1K lbs @ M0.9
    - 10% increase in highlift L/D gives about - 1.5 dB at C/B.
    - SLFC potential large gain(8%!), if feasible

- Provide good F/Q in a certifiable, safe airplane with low noise ops capability - essential to ensure viable, flyable product

- Soften sonic boom - goal feasible, not validated yet
**GOALS AND TARGETS**

DON’T LOSE SIGHT OF THEM

---

### CONFIGURATION AERODYNAMICS LOGIC DIAGRAM

<table>
<thead>
<tr>
<th>95</th>
<th>96</th>
<th>97</th>
<th>98</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image.png" alt="Diagram" /></td>
<td><img src="image.png" alt="Diagram" /></td>
<td><img src="image.png" alt="Diagram" /></td>
<td><img src="image.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

- **CFD Method Develop**
- **Tech Cat Definition**
- **Level 2 MS**
- **Level 3 MS**
- **Level 4 Activity**

- **Cruise Anal Meth**
- **Full Cond F & M**
- **LW Aerostat Analyses**
- **Viscous Aerostat Analyses**
- **Optimized Aeroelastic Concept**

---

![Diagram](image.png)
Aerodynamic Performance
Configuration Aerodynamics

Technical Performance & Technology Readiness Level

Key
- Subsonic
- Supersonic

Notes:
- Full scale values
- Updated per Tech Audit for Ref H platform (9/95)
- TCA per TI (1/96)

Current Status *
* Includes Technology gate to date
- 6.3 TCA (.092)
- 6.5 Ref H optimized design
- 6.1 Ref H linear design

Most likely Projections
- 9.1 TCA (.092)
- 8.7 Ref H

Note: Aero
- met this goal
w/ 8.64

4.3.2 High Lift Technology Logic Flow Diagram

Note: Number at upper corner is Level 3 milestone number.
Number at lower corner is Level 4 milestone number.
* Interfaces with other program elements described in sections 3.14-15.
Progress and Status

**Configuration Aerodynamics** - Developed database to satisfy Level 2 milestone "Ref H Assessment"; validated nonlinear aero optimization methods and a large aerodynamic performance gain via optimization.

**High Lift** - Downselected to preferred high-lift system concept; satisfied Level 2 milestone for HEAT 1 aeroacoustic tests.

**Sonic Boom** - Achieved boom softening goals and acquired exceptional flight data for boom propagation methods validation.

**SLFC** - Transition prediction methods transferred to industry; SLFC flight experiment developed and underway.

**Flight Control** - Developed excellent full-envelope simulation and conducted piloted assessment of Baseline configuration.
Ref. H Flight Regimes and Maneuver Tasks Examined

- Optimal Trajectory
- VMAX OP Limit
- Vmin Limit

Descent
Emergency Descent
(Cabin Depressurization)

Stall Recovery
Straight-in Stalls
Turning Stalls
Engine-Out Stalls

Optimal Ascent Profile
Transition to Level Flight
Transonic Accel

Climb
Supersonic Cruise
Engine Unstart + Gust Upset Recovery
Inadvertent Speed Increase

Approach & Landing
Nominal Landings • Vertical & Lateral Offsets
Crosswinds • Go-Arounds • Engine Failures
Jammed Stabilizer • Reduced Visibility (Fog)

Takeoff
Standard Profile • Rejected Takeoff
Acoustic Profile / Power Level Reductions
Crosswind • Engine Failures

REMAINING CHALLENGES

- Increase Performance gains
  - within resources available
  - realizable in integrated vehicle

- Reduce Uncertainties
  - expected full-scale performance
  - confidence in design methods/concepts
CONFIGURATION AERODYNAMICS DESIGN:
GEOMETRY SHAPING ALLOCATIONS BY DISCIPLINE
Drag reductions projected for aero design at Mach 2.4

Performance:
9 to 10 counts drag reduction

Propulsion-Airframe Integration:
2 to 3 counts drag reduction

Payoff is Major:
- Performance gain gives weight savings equal to payload:
  Potential 16 drag count reduction = 80-100K lbs reduction in TOGW
  - Any additional saving expected to provide design margins for risk reduction

...But the road to improvement has challenges:
- Must simultaneously maintain good transonic performance
- Optimization techniques must include full configuration
- Aeroelastic effects must be accounted for
- Outside trades usually make the job more difficult (i.e. nacelle, empennage, landing gear bump size increases, etc.)
- Parasite drag penalties

CONFIGURATION AERO CHALLENGES

- Find the right complementary roles for NASA and industry to get best affordable technology into methods and airplane concepts while ensuring good, robust integration of these methods and concepts into the industry HSCT design capability.

- Begin to focus on best methods (narrow the field) to allow maturing them and improving their robustness, speed, and utility.

- Attach “belly buttons” to each key deliverable and hold them accountable for development and reporting -- within available resources -- don’t micromanage.
HIGH LIFT CHALLENGES

• Increased Performance
  – Leading edge suction increase to 94% (that’s a bunch!)
  – Accomplish gain with smaller/lighter system on TCA

• Reduced Uncertainty
  – Full scale Rn
  – Realistic system and aircraft geometry
  – Propulsion effects

FLIGHT CONTROL CHALLENGES

• Develop flight control laws to handle large spectrum of flight dynamics and the propulsion/flight control integration in HSCT.

• Help define right balance of inherent stability vs. control power for an HSCT.

• Continue providing high-fidelity look at the flight performance of the integrated technology baseline for HSR.
OTHER KEY CHALLENGES

- Limited resources -- tighter for Aero now

- Limited supercomputing time --
  - NAS oversubscribed (essential to use other supercomputing platforms where possible)
  - Essential for HSR AERO goals

- Wind tunnel facilities
  - availability and schedules
  - most effective use (quantity & quality)

IMPORTANCE OF TECHNOLOGY READINESS AND PERFORMANCE

![Graph showing technology readiness level (TRL) over time](image)
SUMMARY

• Great progress to date. Thanks from the TMT.
• While we are developing the technology, we must learn to operate as the HSR Team versus the Ames, Langley, Douglas, or Boeing Team.
• Each ITD team should play to the strengths of team members as you execute your plans.
• We must plan our work to be achievable within the time and resources available -- and then manage the effort accordingly -- watch products versus expenditures.
• We must understand and address the real vehicle integration and operational constraints -- need good real-time interaction with TI and other ITD’s.
• When we finish the HSR Program, U.S. industry should have the best HSCT design capability in the world....not NASA, but industry.