A mini case study: the X-1
The first "research airplane"

In honor of the 50th anniversary of the 1st manned supersonic flight
October 14, 1947

W.H. Mason
The Need:

- Understand the “sound barrier”
  - but bullets traveled at supersonic speeds
- Adverse Flight Characteristics at High Speeds
  - pilots killed as high speed fighters became uncontrollable in dives
- No theory or wind tunnel simulation available

Skipping WT and going straight to flight violates every rule
The Army Air Force

• Ezra Kotcher at Wright Field, Dayton, Ohio
  – proposes rocket powered airplane in 1939
    » nope
• World War II developments by Germans, British
  – time to rethink
    » yes
• By early 1944: Rocket powered, 2 minutes at altitude
The NACA

• John Stack, early 1930s
  – proposes propeller driven compressibility research vehicle (560 mph)
• By 1942: Yes at NACA Langley, No at NACA Headquarters
  – still wanted $M = 0.8 - 1.0$
• Early 1944: High Speed Panel
  – Eastman Jacobs: should be supersonic!
• *The NACA Position*: jet powered, low transonic speed
Air Force/Navy/NACA Combine forces

• March 1944
  – big disagreement:
    » NACA/Navy: Low transonic
    » Army Air Force: Supersonic

• April - May 1944
  – NACA Vehemently opposed to rocket power
    » Mel Gough: “No NACA pilot will ever be permitted to fly an airplane powered by a dammed firecracker”
    » Also:
      • not enough endurance
      • not relevant enough to real airplanes
By December 1944:

Requirements

• speed well above the critical Mach number
• duration at 35K: > 2 minutes
• flexible to permit a variety of wing and tail surfaces
• space for 400 lbs of instrumentation

Compromise:

• takeoff and climb with a turbojet
• use a rocket for high speed
The clash of cultures

NACA
- study problems in painstaking depth & detail
- ponder problem, rendering an unimpeachable verdict
  - sough “truth”
  - methodical, thorough, very cautious [time consuming]

Air Force (recall we are at war!)
- prompt, pragmatic solutions
- accepted risk
- fast programs
- did not pursue perfection, sough expedient way to get job done
- problem solvers, not seekers of “the truth”

Confusion over who would take the lead
More Politics

- **Aeronautics:**
  - Pre war perception:
    - » NACA Preeminent
  - War:
    - » British and Germans are way ahead of NACA

- **Where to fly?**
  - AAF: Muroc
  - NACA: Langley

- **Program Organization:**
  - Air Force will buy the airplane
  - NACA will test and “reduce the data”

- **John Stack, NACA:** Rockets won’t last long
  - with Navy, get a jet: the D-558 program
Finally: The Airplane

- Robert Woods (Bell A/C) and Ezra Kotcher (AAF, Wright Field)
  - November 1944:
    » Rocket Engine: 2 minutes endurance, 800 mph @ 35K feet
    » Safe and controllable up to $M = 0.80$
Design Issues/Requirements

• **Structures**
  – Stressed for 18\(gs\)
  – thin wings: 10% and 8% thick
    » tails 8% and 6% respectively

• **Propulsion**
  – jet: nope, best \(M = 0.9\) at \(sl\), slower fast with altitude
  – jet/rocket: too big/complicated
  – rocket: yes, now exactly which one?

**Design Decision: Pure Rocket Power**
Design Issues/Requirements II

The motor

- Aerojet “Rotojet” (the Cal Tech folks)
  - red fuming nitric acid and aniline
  - hypergolic!
  - ruled out: safety issue, plus behind schedule

- Reaction Motors Inc. XR-11
  - liquid oxygen and water diluted ethyl alcohol
  - safer
  - but: turbine driven pump problems
    » Bell: use high pressure nitrogen to feed engine
      (Stack objects), need 12 4800 psi nitrogen bottles
      (and spheres not efficient shapes to put in the plane)

Design Decision: XR-11 w/Nitrogen pressure feed
Design Issues/Requirements III

Air Launch vs Ground Takeoff

- NACA: Ground Takeoff
  - Data over widest range of conventional flight operations
  - Air Launch: Never be able to operate at Langley!
  NACA will lose control of the program (can’t divorce technical from political issues)
- Bell: Bob Woods: ground launch relevant to future aircraft
- Bell: Stanley/Hamlin:
  - safety
  - conserve fuel for high speed

Design Decision: System weight dictates air launch

(problems with pump & weight increase of nitrogen bottles)
The Aerodynamic Shape

- Bell engineers toured Industry/Government looking for info:
- At the AAF Ballistics Lab at Wright Field:
  How & Why the shape of a .50 cal bullet? (2491 mph!)
  - Ogival shape selected because in testing it produced the smallest dispersion pattern: proven to be stable at supersonic speed - the basis for the decision by Bell

Swept Wings

- theoretical advantages known
- applying this technology to an already extremely complicated design would introduce unnecessary additional risk

Design Decision: Ogival Shape w/Unswept wings
Finally: What it looks like - the 3-View

source:
“Meeting the Challenge of Supersonic Flight”, by James O. Young, Air Force Flight Test Center History Office, 1997
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Most Important NACA Contributions

• Horizontal tail $t/c$ less than wing $t/c$
  – thus compressibility effects on tail would occur above the Mach number for the wing effects: help maintain control

• Adjustable horizontal stabilizer
  – *would prove crucial*, elevator became ineffective and the stabilizer was used to provide the control as well as trim!

This leads to the use of “all flying tails” on US jets. Yeager says this *is* the contribution, and gives US a 5 year lead!

• Mount horizontal tail high on the vertical tail, out of the wing wake
Hardware

• Contract: March 16, 1945
• Rollout: December 27, 1945 (WOW!)
• First flight (a glide): January 25, 1946
• Supersonic flight: October 14, 1947 - the 50th flight

the key information source: “Meeting the Challenge of Supersonic Flight”, by James O. Young, Air Force Flight Test Center History Office, 1997

for more info and a complete bibliography:
http://www.hq.nasa.gov/office/pao/History/x1/