

A mini case study: the X-1

The first “research airplane”



NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/gallery/photo/index.html>
NASA Photo: EC72-3431 Date: 1947 Photo by: USAF photo by Lt. Robert A. Hoover

X-1 in flight

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



Aerospace and
Ocean Engineering

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 damned 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
 - sought “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, sought 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 18gs
 - 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)



Design Issues/Requirements IV

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

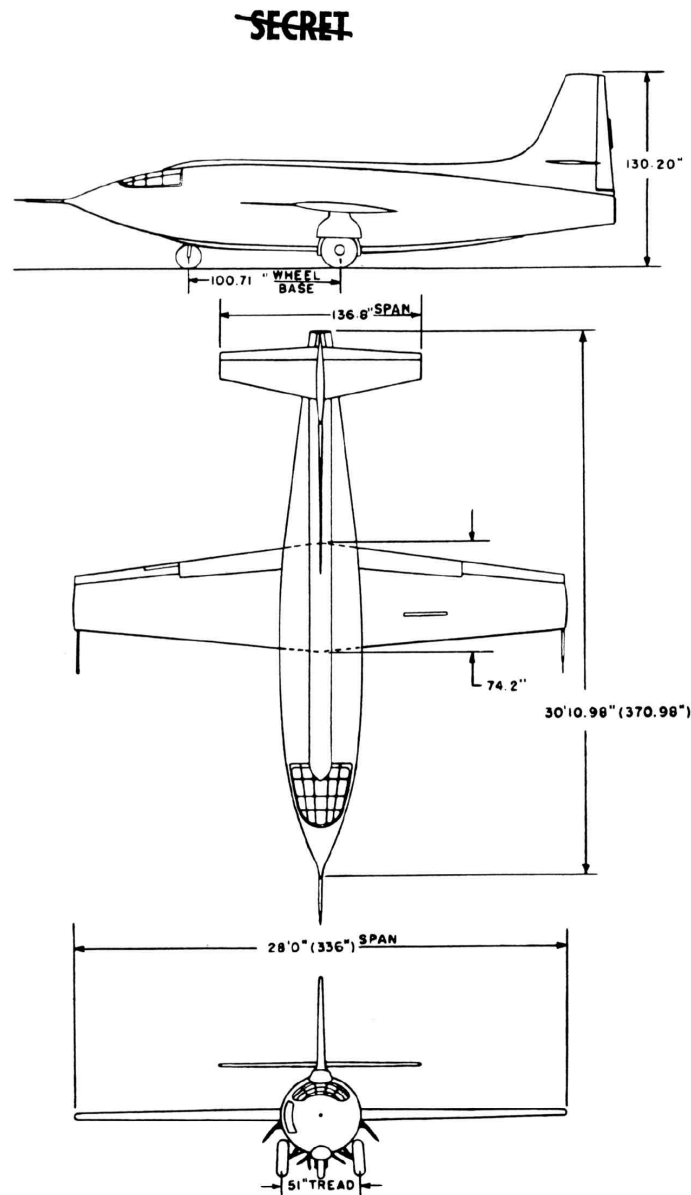
- theoretical advantages known
- applying this technology to an already extremely complicated design would introduce unnecessary additional risk

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



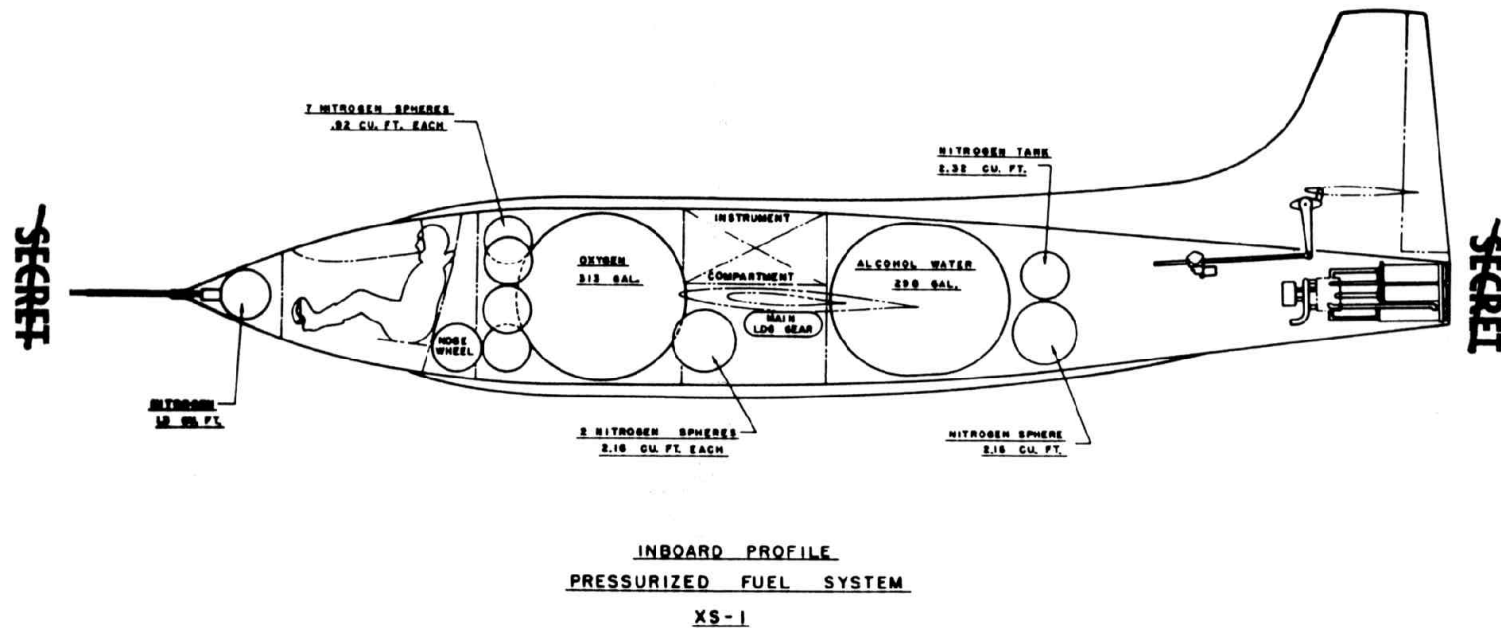
Three View Drawing of XS - 1



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~~SECRET~~

The Inboard Profile



source: "Meeting the Challenge of Supersonic Flight",
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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/>