Transonic Aerodynamic Characteristics of A Proposed Wing Body Reusable Launch Vehicle Concept

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A proposed wing body reusable launch vehicle was tested in the NASA Marshall Space Flight Center 14X14-inch trisonic wind tunnel during the winter of 1994. This test resulted in the vehicle's subsonic and transonic, Mach 0.3 to 1.96, longitudinal and lateral aerodynamic characteristics. The effects of control surface deflections on the basic vehicles aerodynamics including a body flap, elevons, ailerons, and tip fins are presented.

As an outcome of NASA's 1993 Access to Space study, a more in-depth follow on study was undertaken. Three candidate reusable launch vehicle configurations which would provide reusable single stage to orbit capability were selected. A wing body configuration was one of these candidate concepts, the other two concepts being a vertical lander and a lifting body. The wing body configuration was a direct outgrowth of the access to space option three reference single stage to orbit rocket vehicle. This vehicle matured during the subsequent reusable launch vehicle (RLV) study into the vehicle which was tested. Initially, the vehicles aerodynamic characteristics were determined using aerodynamic prediction codes. To obtain a better fidelity in the aerodynamic data, a series of scale models of the proposed wing body vehicle were tested at the NASA Marshall Space Flight Center (MSFC) and the NASA Langley Research Center (LaRC). The vehicle was tested at low subsonic and hypersonic conditions at LaRC and at subsonic, transonic, and supersonic conditions at MSFC. The results of the transonic testing in MSFC's 14-Inch Trisonic Wind Tunnel (TWT) facility are presented herein.

A .004 scale RLV wind tunnel model was tested during the winter of 1994 at the NASA Marshall Space Flight Center 14X14-inch trisonic wind tunnel (TWT). The subsonic and transonic, Mach 0.3 to Mach 2.0, aerodynamic characteristics of the WB001 reference wing-body vehicle were determined. This wind tunnel test provided aerodynamic data for the basic vehicle, wing and body contributions, and control surface increments. The data derived from this test were used to construct an aerodynamic database for flight mechanics and structural loads studies on the wing body vehicle.

The WB001 vehicle is generically a wing-body combination. The body consists of a drooped nose followed by a cylindrical core section 28.55 ft in diameter, full scale, with a total body length of 185.6 ft, full scale. The wing is a NACA-0010 airfoil at the root linearly varying to a NACA-0012 airfoil at the tip with a 54 degree leading edge sweep, 3.5 degrees of dihedral, and an aspect ratio of 1.91. Control surfaces for this configuration consist of ailerons, elevons and tip fins.

The vehicle is longitudinally stable and can be trimmed at both subsonic and transonic Mach numbers. This assumes a vehicle center of gravity at 68.6% body length or 127.32 feet aft of the nose. At subsonic Mach numbers, the vehicle is stable in trim for all control deflections. The vehicle for the subsonic Mach range can be trimmed at the desired angle-of-attack for entry, approximately 15 degrees. This trim angle is accomplished through various control surface deflections, see figure 84. The vehicle for the transonic Mach range, Mach 0.95 to 2.0, has stable trim points but not at the desired angle-of-attack, approximately 15 degrees angle-of-attack. It can be extrapolated from the current data trends that for a larger elevon deflection between 20 and 30 degrees, the vehicle will be neutrally stable at the desired trim point of 15 degrees.

The WB001 vehicle is laterally unstable for the subsonic and transonic Mach range. The tip fin deflections provide a trim angle range of approximately 1 to 2 degrees, therefore, larger tip fins and deflectable surfaces are desirable. Enlarging the tip fins by an approximate geometric factor of 3 to 4 should result in the vehicle being neutrally stable.

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Introduction:

- Vehicle Configuration
- Wind Tunnel Description
- Test Summary
- Results and Conclusions
- Follow-Ons
- Data Availability

Vehicle Configuration:

- Generic Wing Body Configuration
- Length = 185.6 ft
- Drooped Nose
- Core Diameter = 28.55 ft
- Wing Span = 93 ft
- NACA-0010 to NACA-0012 Airfoil
- 54 Degree Leading Edge Sweep
- 3.5 Degree Dihedral
- Aspect Ratio = 1.91

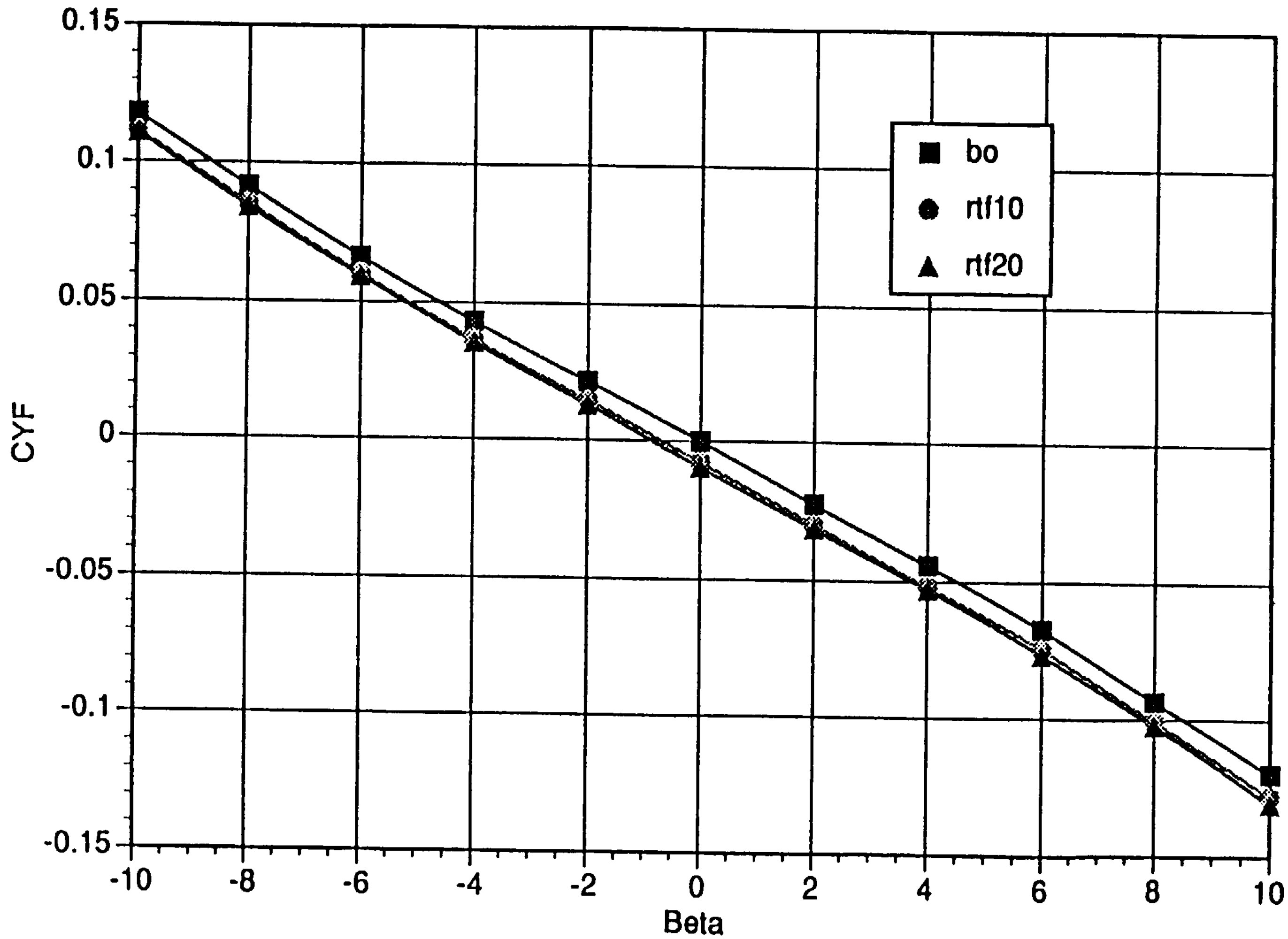
Wind Tunnel Description:

- 14X14-Inch Trisonic Wind Tunnel
- 14X14-Inch Test Section
- Mach Range 0.3 to 5.0
- Intermittent Blow Down Type Tunnel

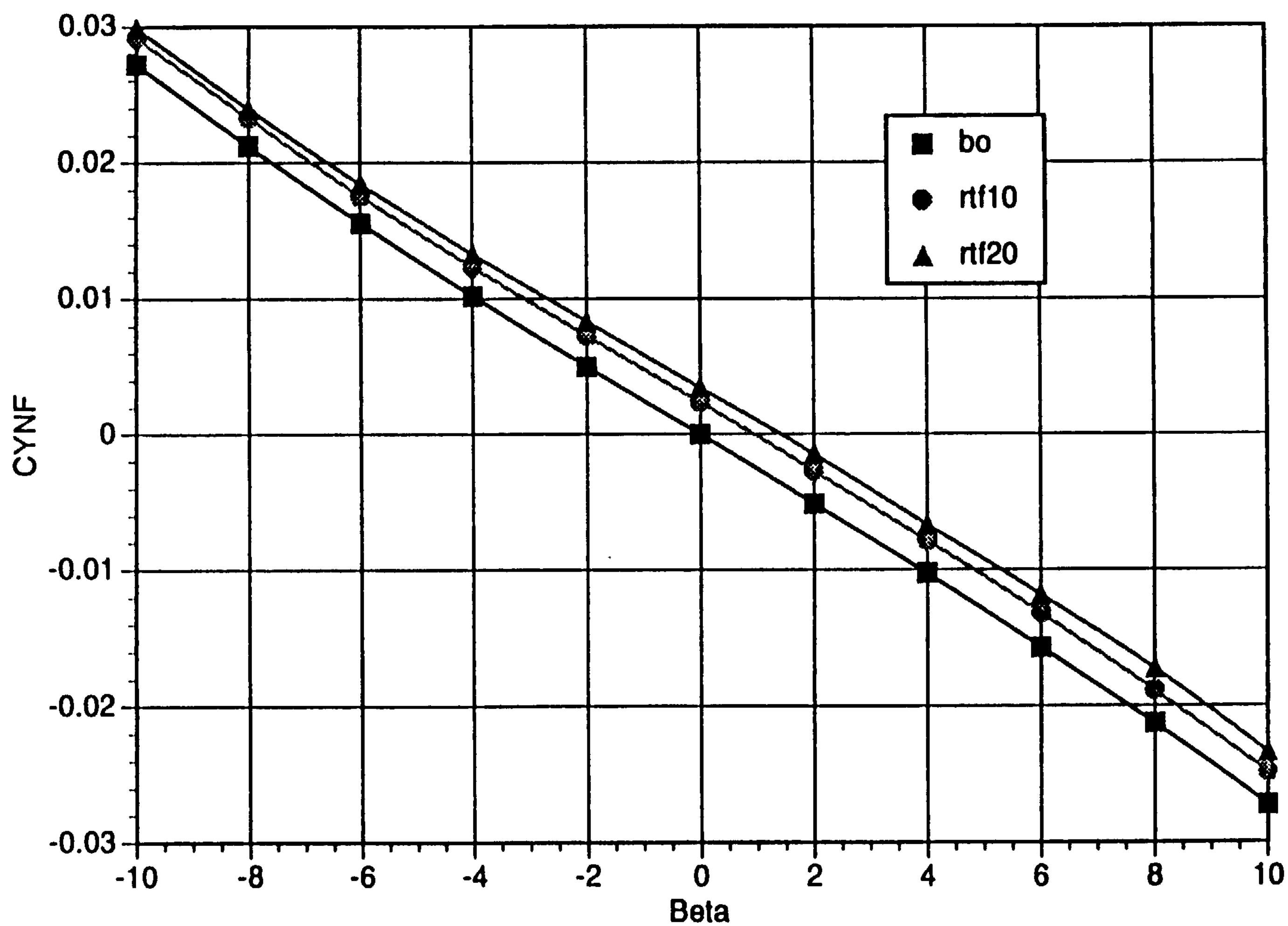
Test Summary:

- Static Stability Aerodynamic Characteristics
- Mach 0.3 to 1.96
- Basic WB001 Vehicle
- Elevon, Aileron, Body Flap Deflections (-10°)
- Tip Fin Deflections (10°, 20°)

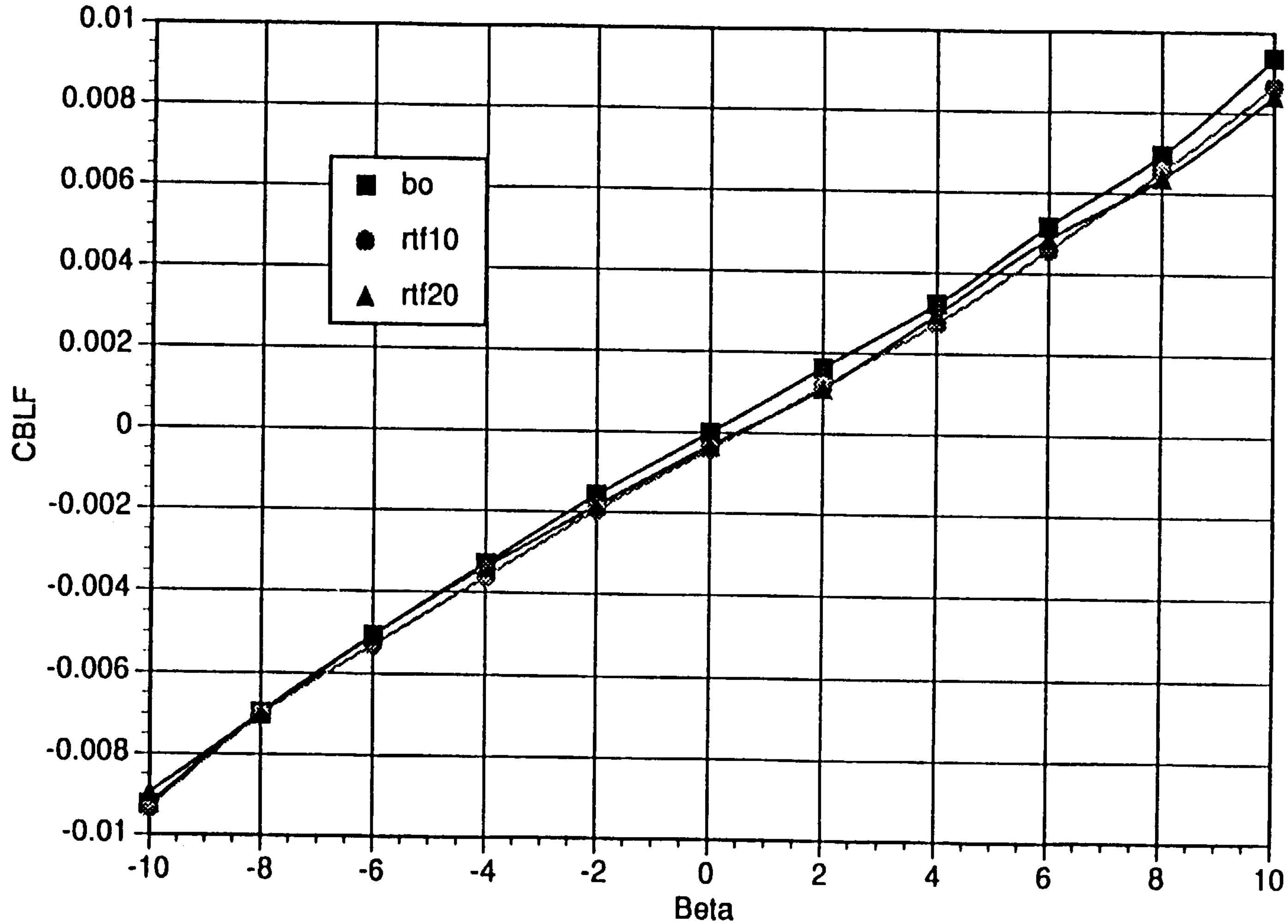
WB001 Tip Fin Control Deflections Mach 1.10



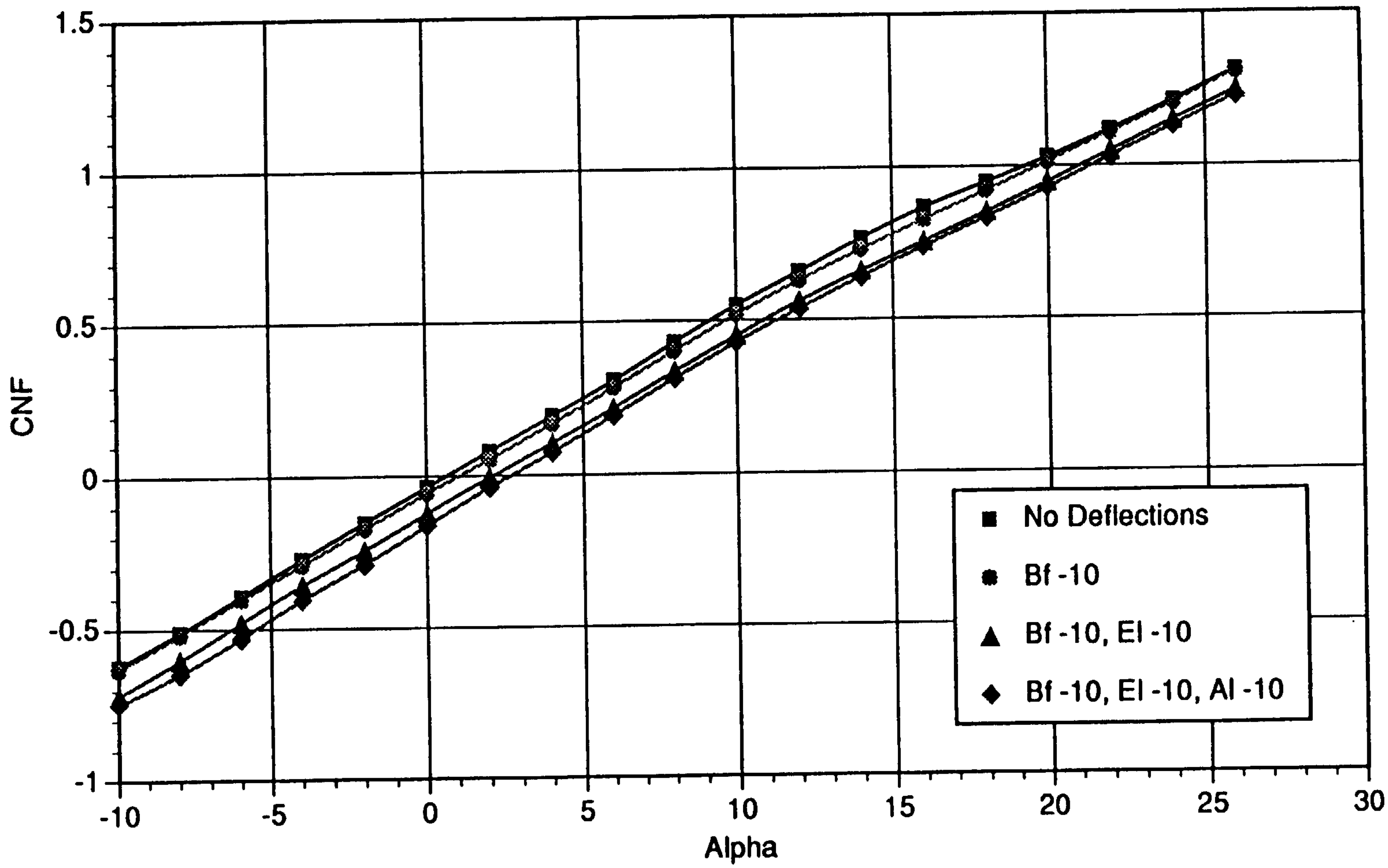
WB001 Tip Fin Control Deflections Mach 1.10



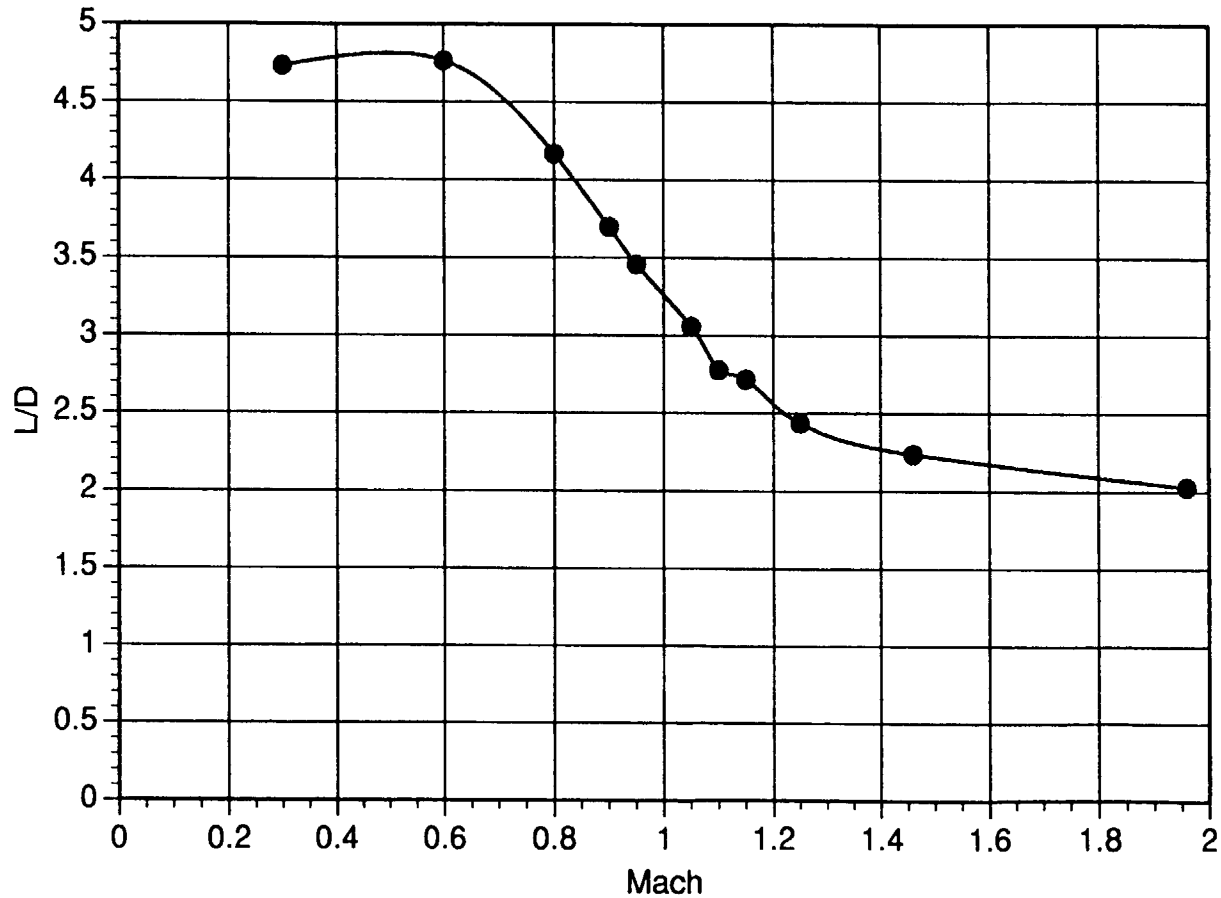
WB001 Tip Fin Control Deflections Mach 1.10



WB001 Mach 1.1



Wing Body Lift to Drag Ratio



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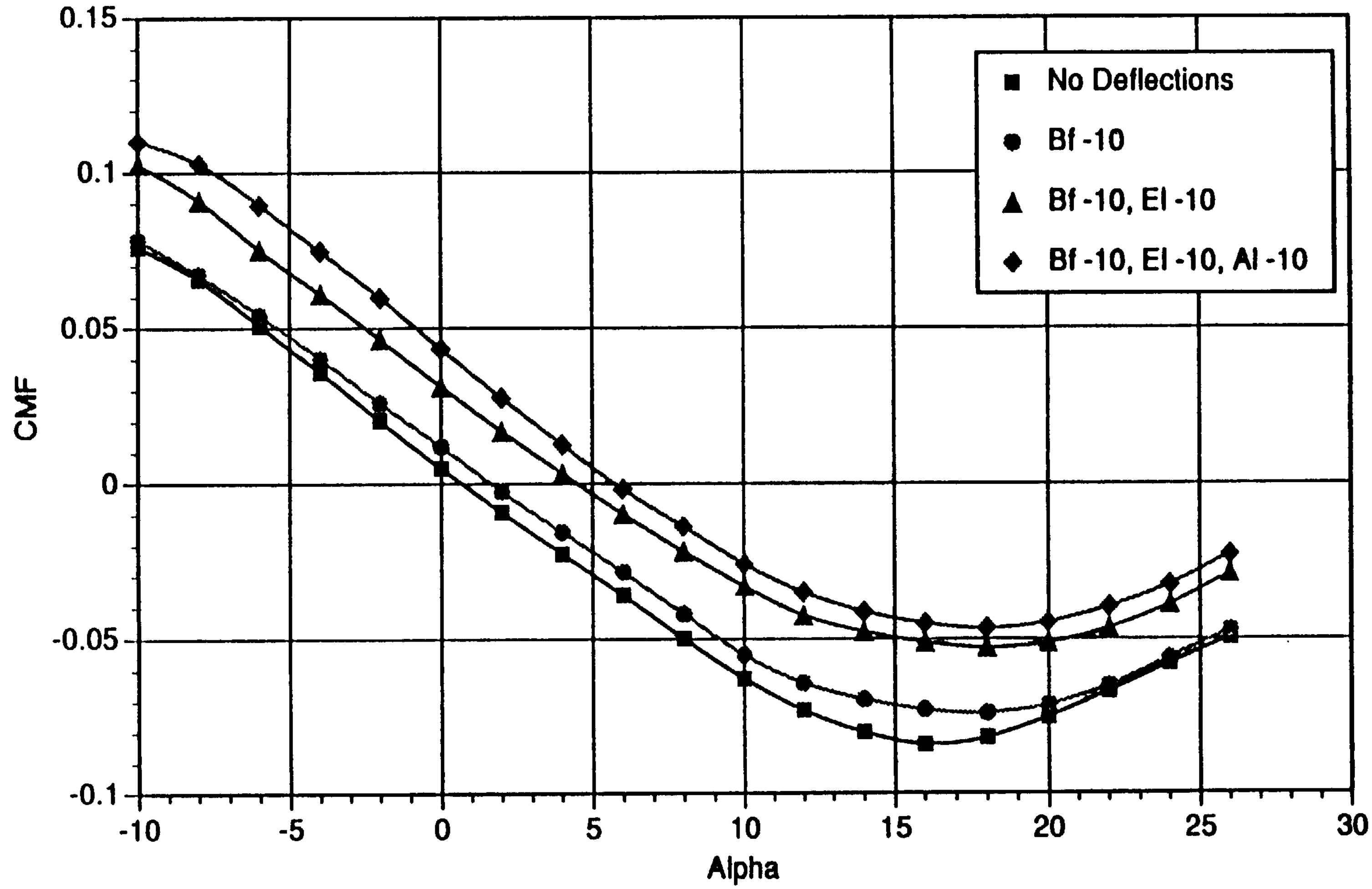
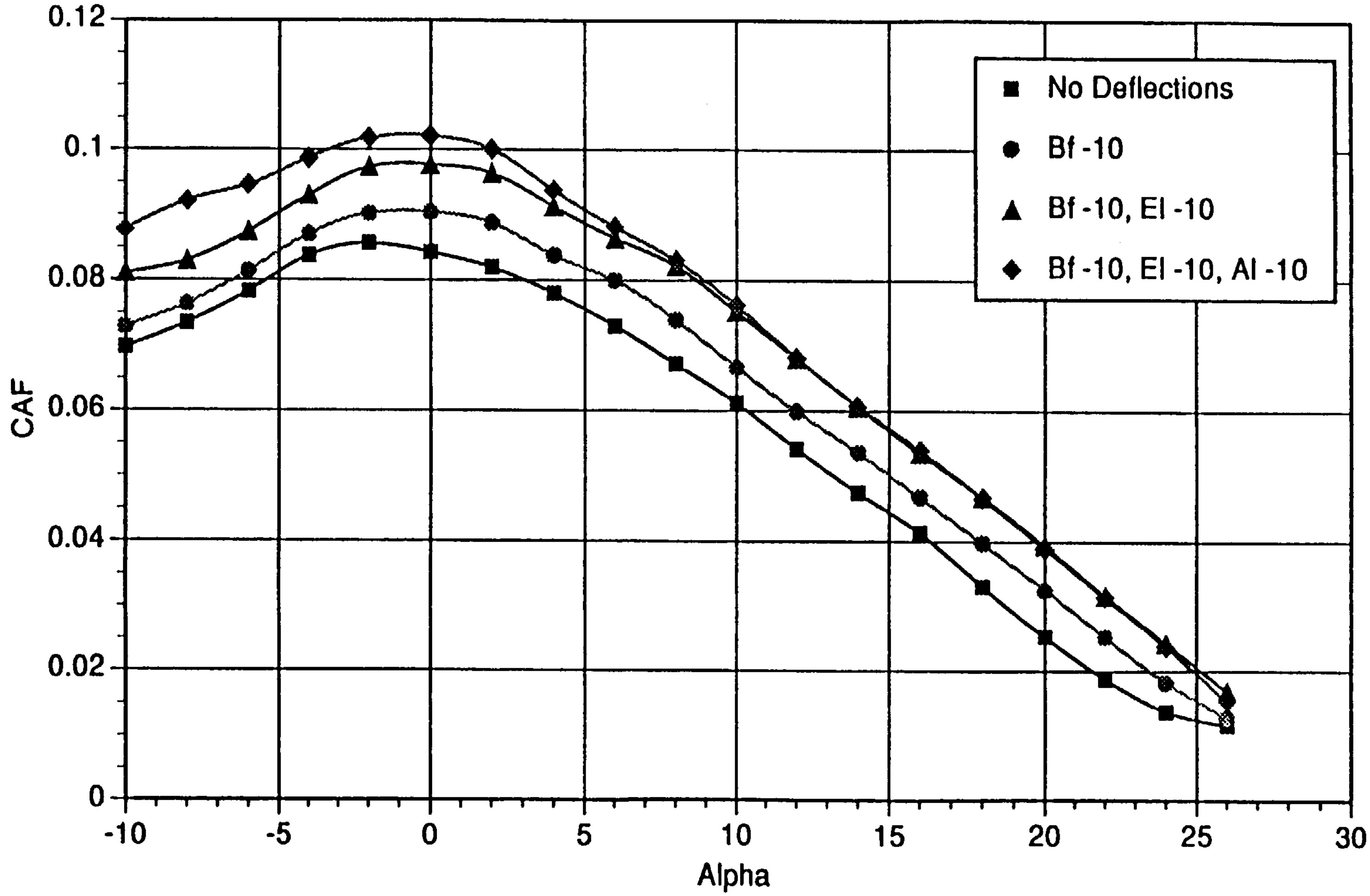
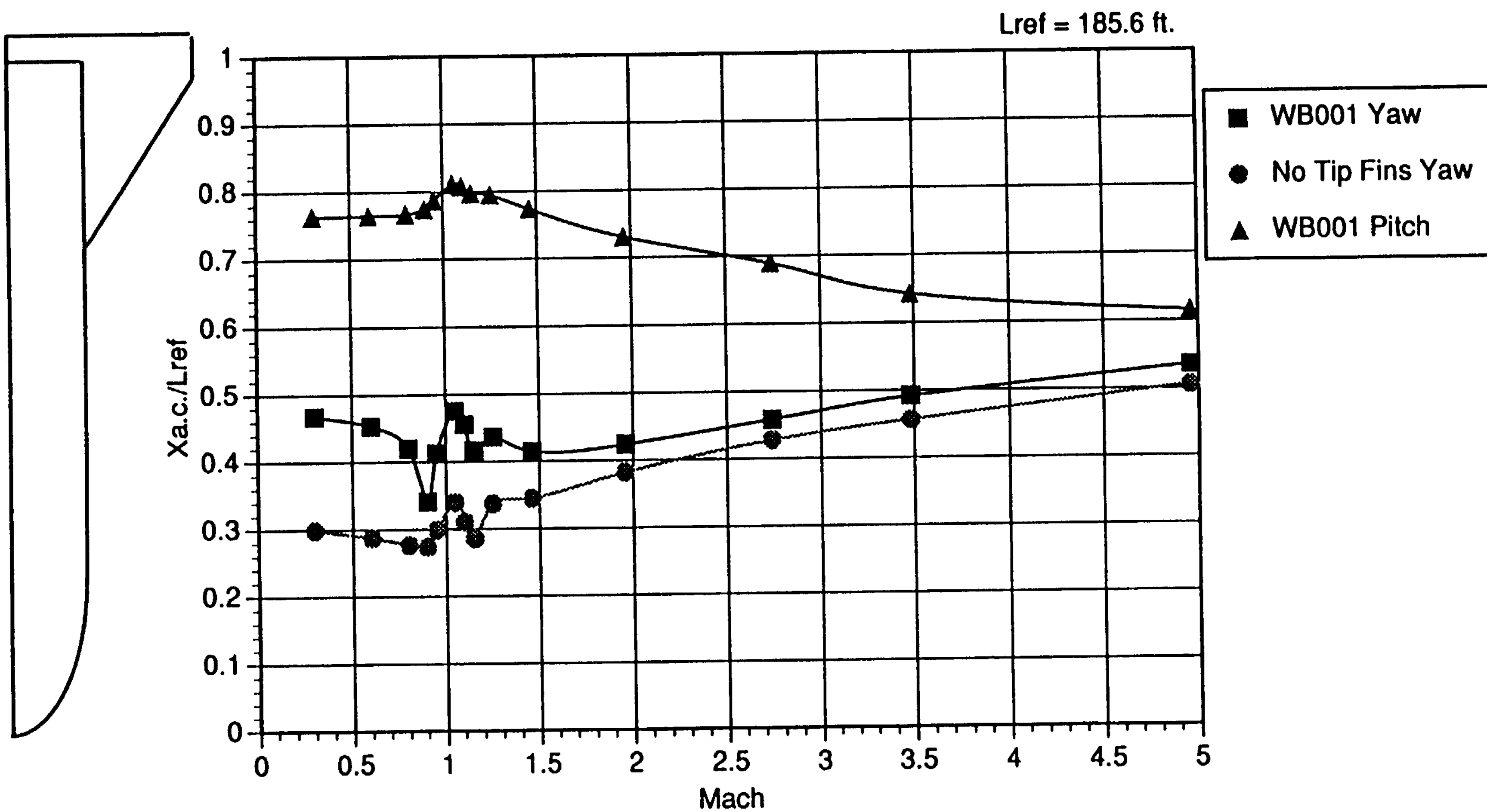


WB001 Mach 1.1

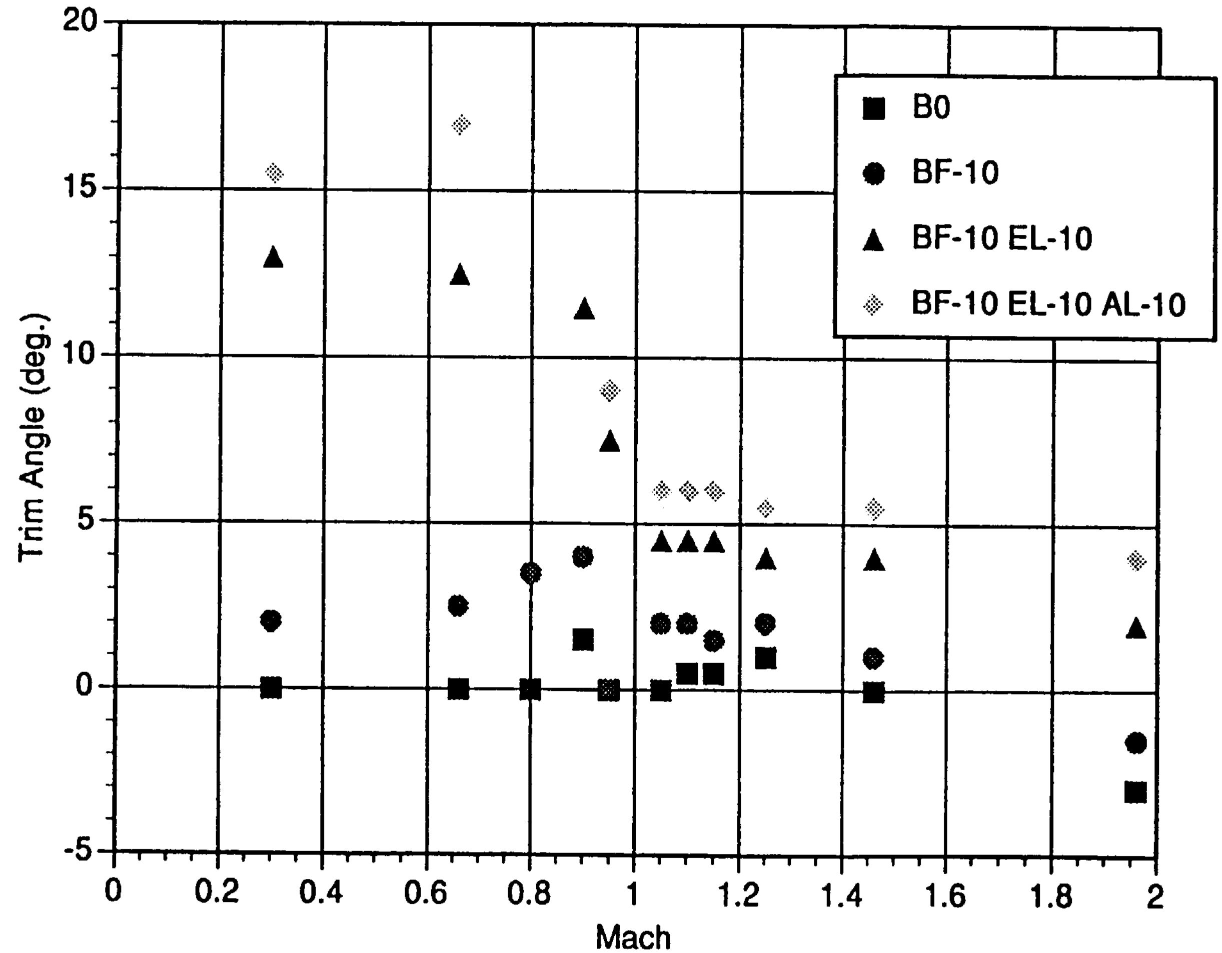


Wing Body Aerodynamic Center



Note: Under 3% Change in Pitch
Xa.c. for No Tip Fin Configuration

WB001 Trim Angle @ C.G. = 68.6%



Follow-Ons:

- Determine Supersonic Aerodynamic Char.
- Larger Elevon Deflections
- Vertical Tail
- Split V-Tail
- Larger Tip Fins (Factor of 3)

Data Availability

- Wing Body Transonic Aerodynamic Characteristics have been documented in NASA TM-XXXX
- This memo is available through NASA to interested parties
- The follow-on test will be documented in a forth coming NASA publication