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BuAer Report AE-61-4

Fundamentals of Design of Piloted Aircraft Flight Control Systems

Volume II, Addendum 1

DYNAMICS OF THE AIRFRAME

This publication shall not be carried in aircraft on combat missions or when there is a reasonable chance of its falling into the hands of an unfriendly nation, unless specifically authorized by the Operational Commander.

PUBLISHED BY DIRECTION OF
THE CHIEF OF THE BUREAU OF AERONAUTICS

FEBRUARY 1953

The material of this addendum forms part of Report AE-61-4II, which together with Report AE-61-4I, has been written under BuAer Contract NOas 51-514(c), "Fundamentals of Design of Piloted Aircraft Flight Control Systems." These form part of a series of manuals being written for the purpose of providing a unified approach to problems of control system design.

For the sake of securing as wide a distribution as possible, Report AE-61-4I, "Methods of Analysis and Synthesis," which is Volume I of this series, and the part, "Dynamics of the Airframe" (Vol. II), of AE-61-4II which precedes this confidential addendum, have been issued in an unclassified status, in accordance with one of the general intents of the series to provide a source of information to be used by engineers in bridging the gap between their collegiate training and the more advanced topics of system engineering.

Since the figures of this addendum contain classified data, they could not be included in the body of this Report, but are presented here in order to include the maximum usable information available at this time. Because of the disparity in level of classification, no mention of this addendum has been made in the body of this Report, but the information herein is to be considered in conjunction with the contents of Chapter IV.

The numerical values and the ranges of values of derivatives shown on the following charts are estimates, based on trends shown by flight tests, wind tunnel tests, and theory; they apply only to fighter type piloted aircraft of today and the near future. They do not apply to missile configurations where the wing is quite small compared to the body, for in these configurations the range of values of non-dimensional derivatives can become very large. (Pitkin, Marvin, and Ankenbruck, Herman O., "Estimation of Range of Stability Derivatives for Current and Future Pilotless Aircraft," NACA Research Memorandum, RM L7E29, Langley Memorial Aeronautical Laboratory, Langley Field, Va., October 8, 1947.)

The following notation has been used in the graphs of this portion of this Report:

A solid line (————————) has been used for straight wing aircraft; a broken line (— — — —), for swept wing; and a dotted line (------) for delta wing.

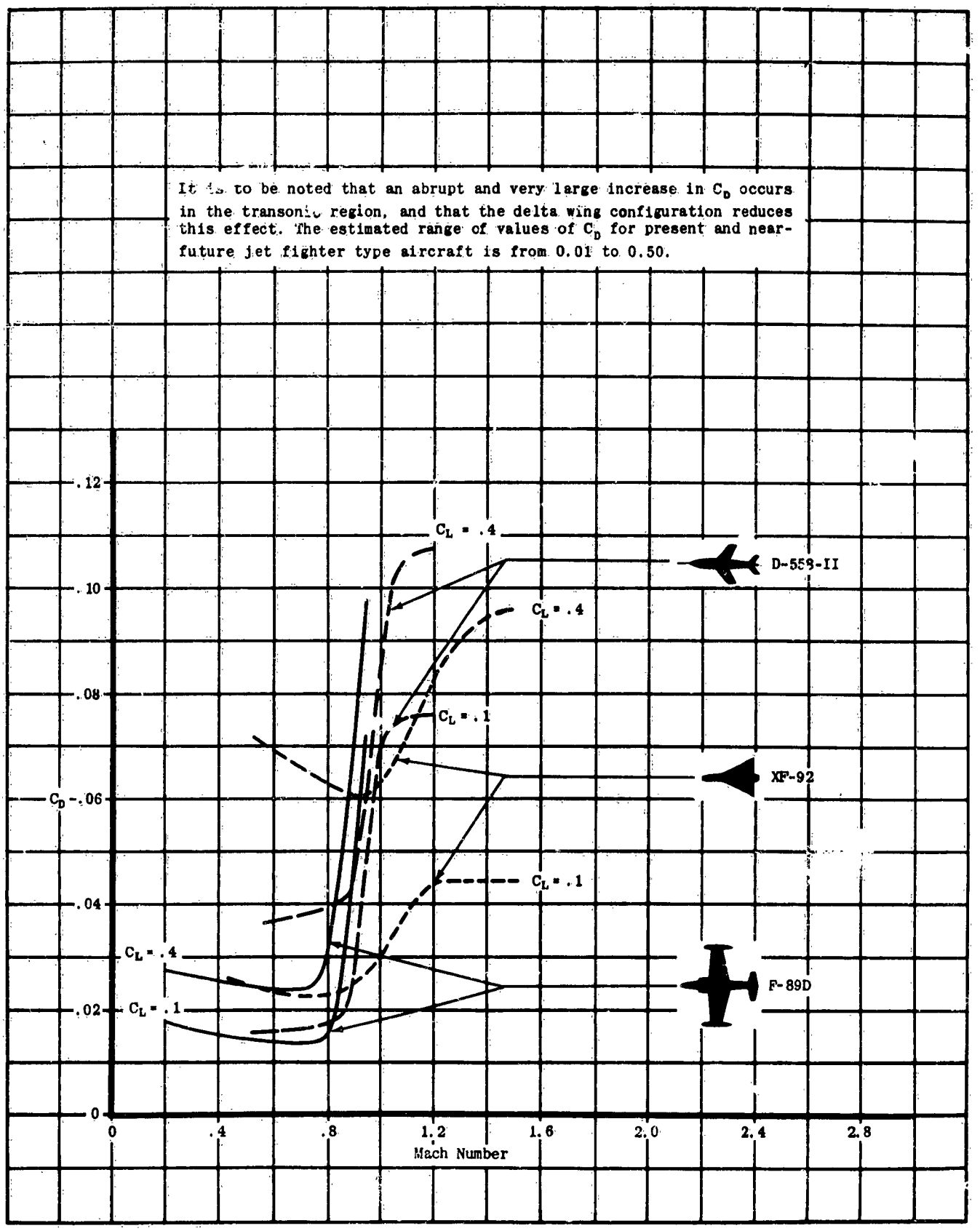

Figure A-1 Variation of C_D with Mach Number for Several High Speed Jet Aircraft

It may be seen that C_{D_u} is approximately zero up to the critical Mach number region at which point it rises abruptly to large positive values, but that the abruptness of the rise and the magnitude which C_{D_u} attains are much less for the delta wing configuration. The estimated range of values of C_{D_u} for present and near-future jet fighter type aircraft is from -0.01 to 0.50.

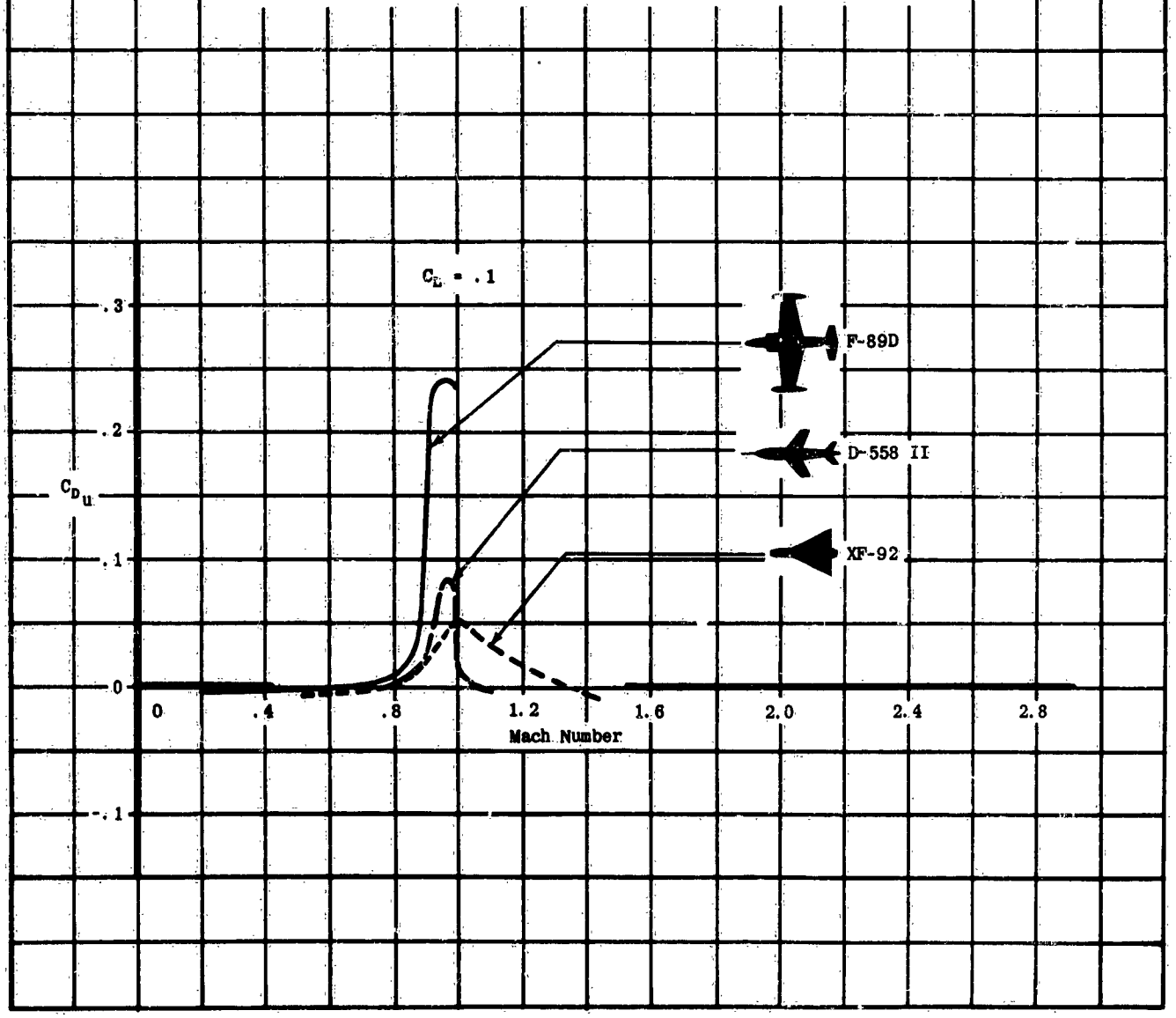

Figure A-2 Variation of C_{D_u} with Mach Number for Several High Speed Jet Aircraft

The values for all three airframe configurations show large variations with Mach number in the transonic region. The level of values in the low subsonic region is primarily a function of the equilibrium lift coefficient. The estimated range of values of C_{D_α} for present and near-future jet fighter type aircraft is from 0.02 to 0.20.

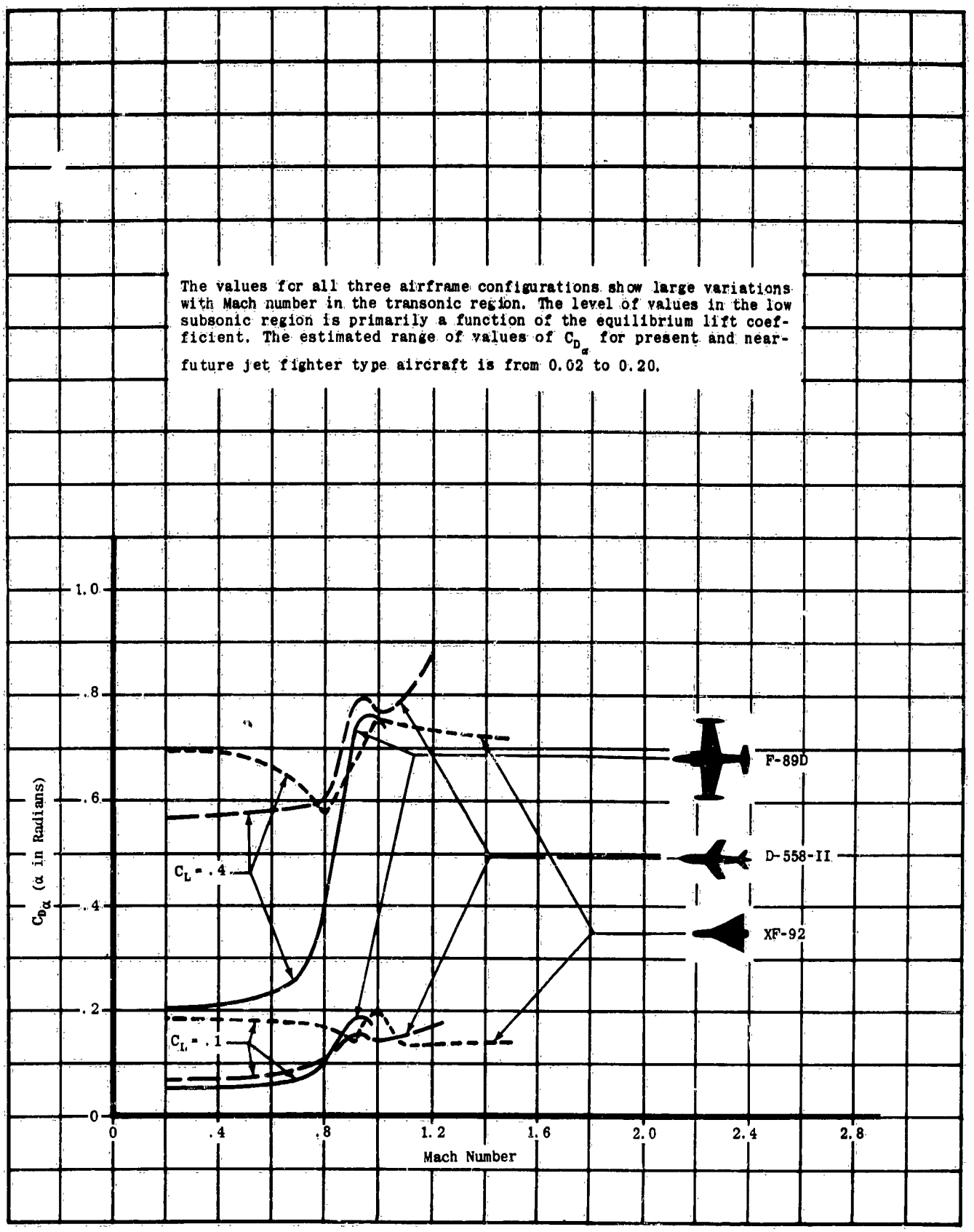

Figure A-3 Variation of C_{D_α} with Mach Number for Several High Speed Jet Aircraft

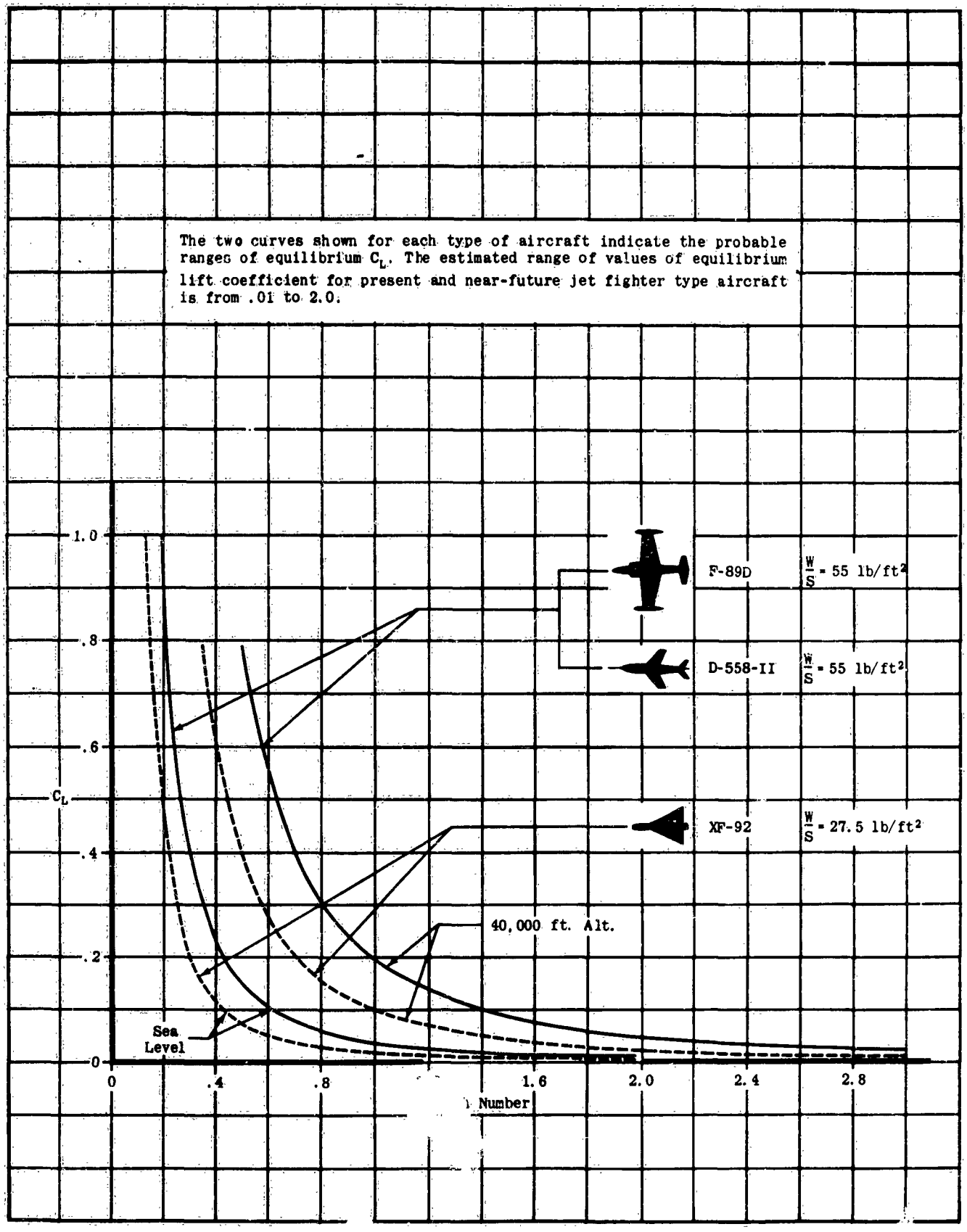

Figure A-4 Variation of Equilibrium Lift Coefficient for Level Flight with Mach Number for Several High Speed Jet Aircraft

The variation with Mach number is influenced considerably by the airframe geometry. The estimated range of values of C_{L_u} for present and near-future jet fighter type aircraft is from -0.1 to 0.3.

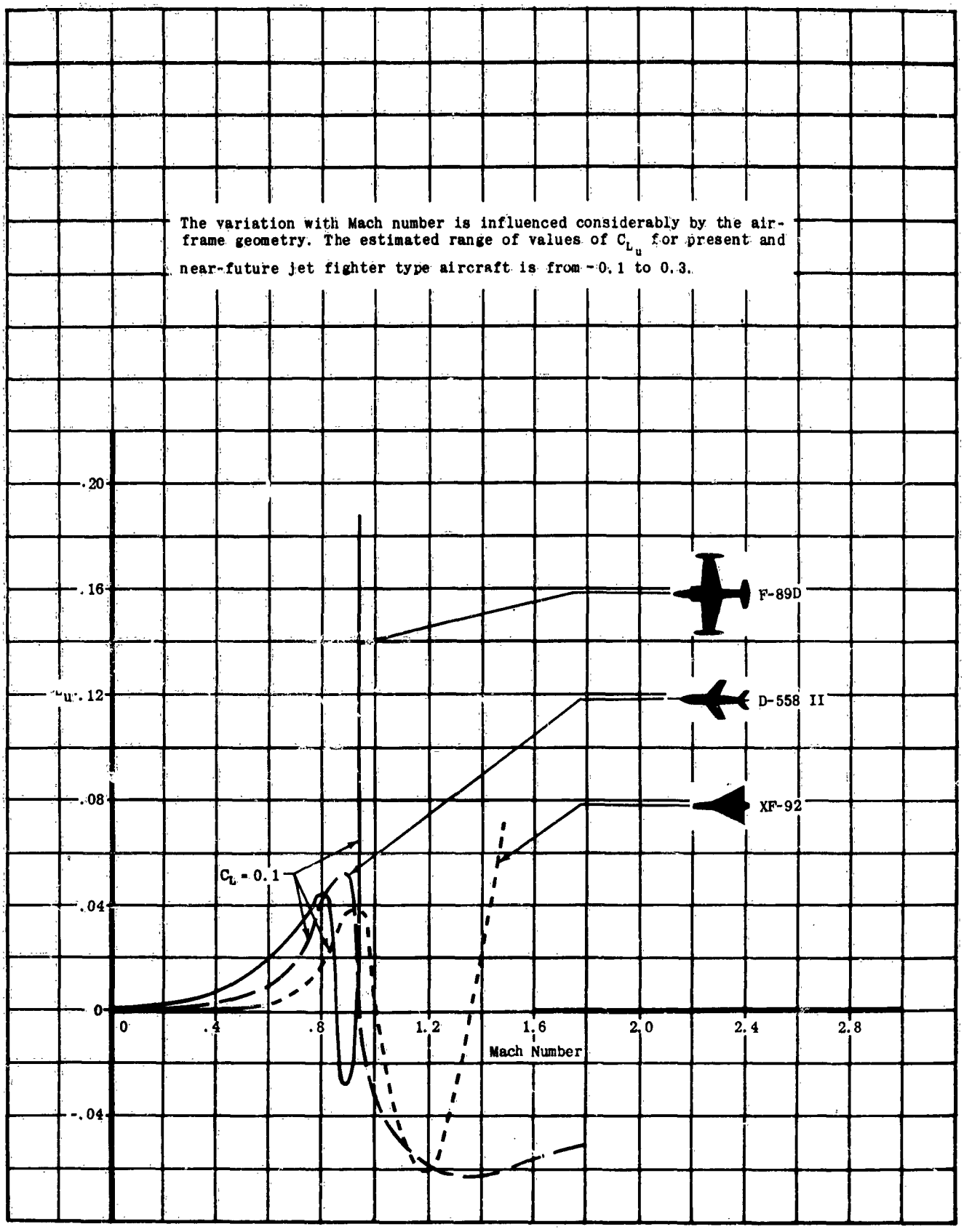

Figure A-5 Variation of C_{L_u} with Mach Number for Several High Speed Jet Aircraft

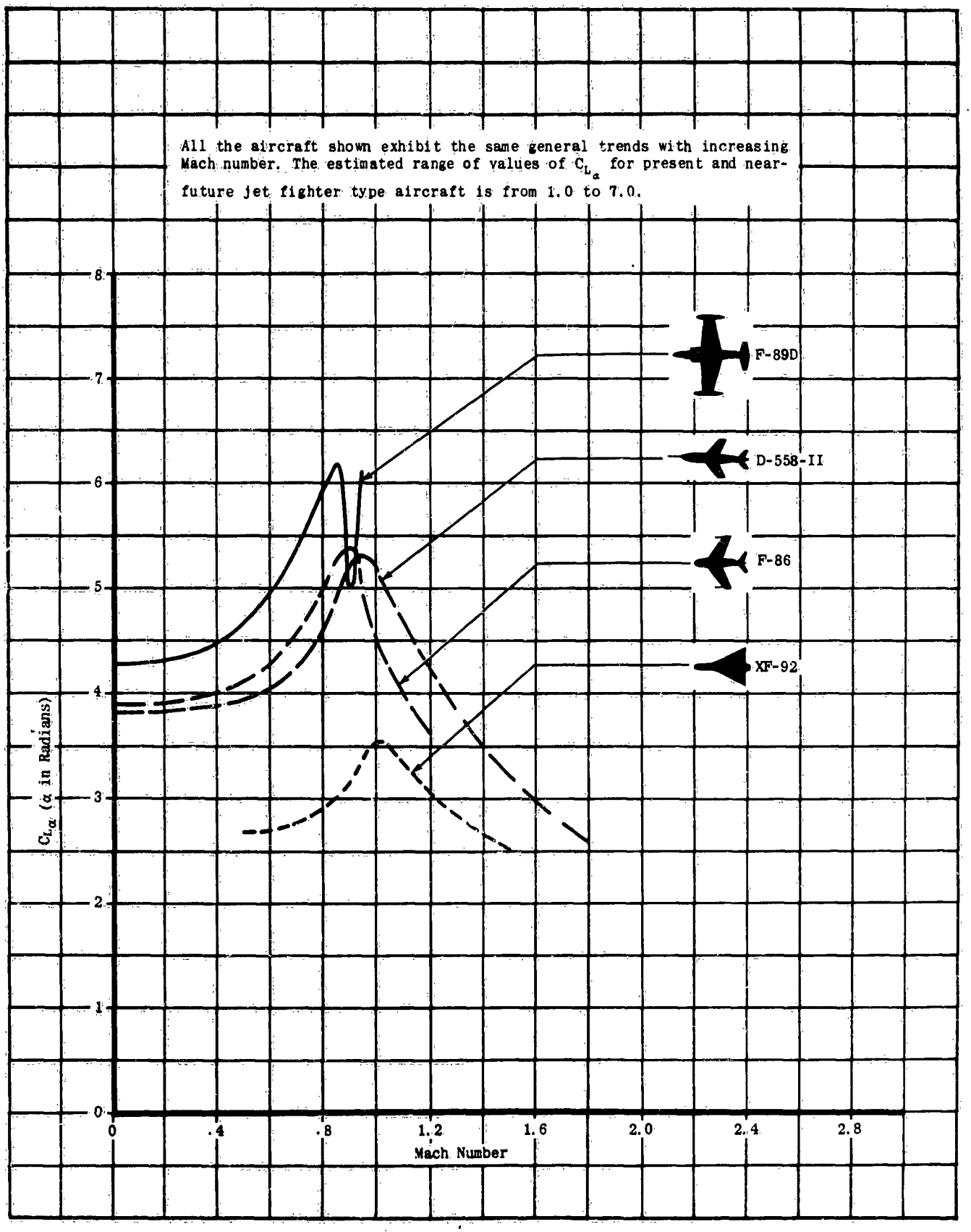

Figure A - 6 Variation of C_{L_α} with Mach Number for High Speed Jet Aircraft

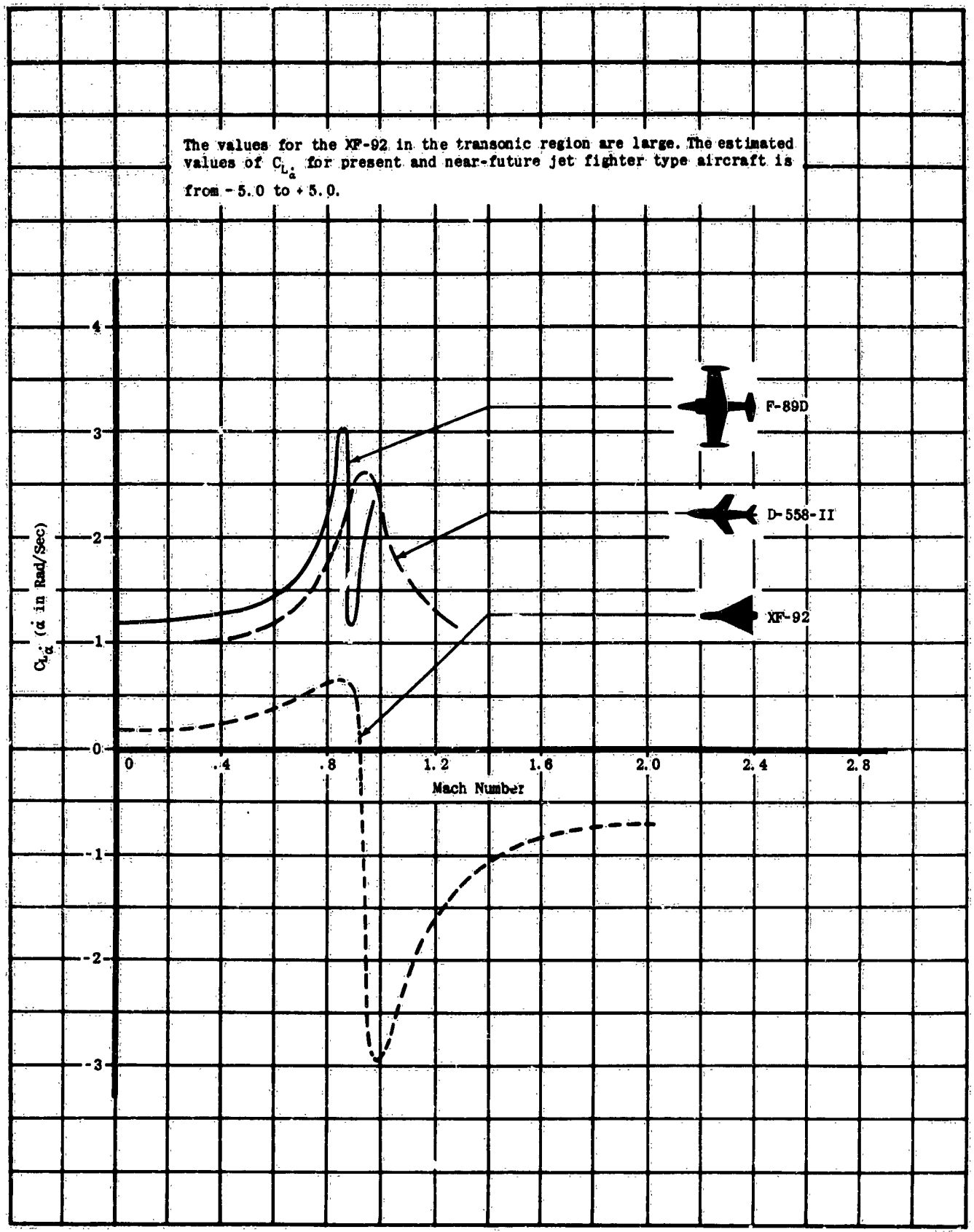

Figure A-7 Variation of $C_{L_{\dot{\alpha}}}$ with Mach Number for Several High Speed Jet Aircraft

The estimated range of values of C_{L_q} for present and near-future jet fighter type aircraft is from 0 to 8.

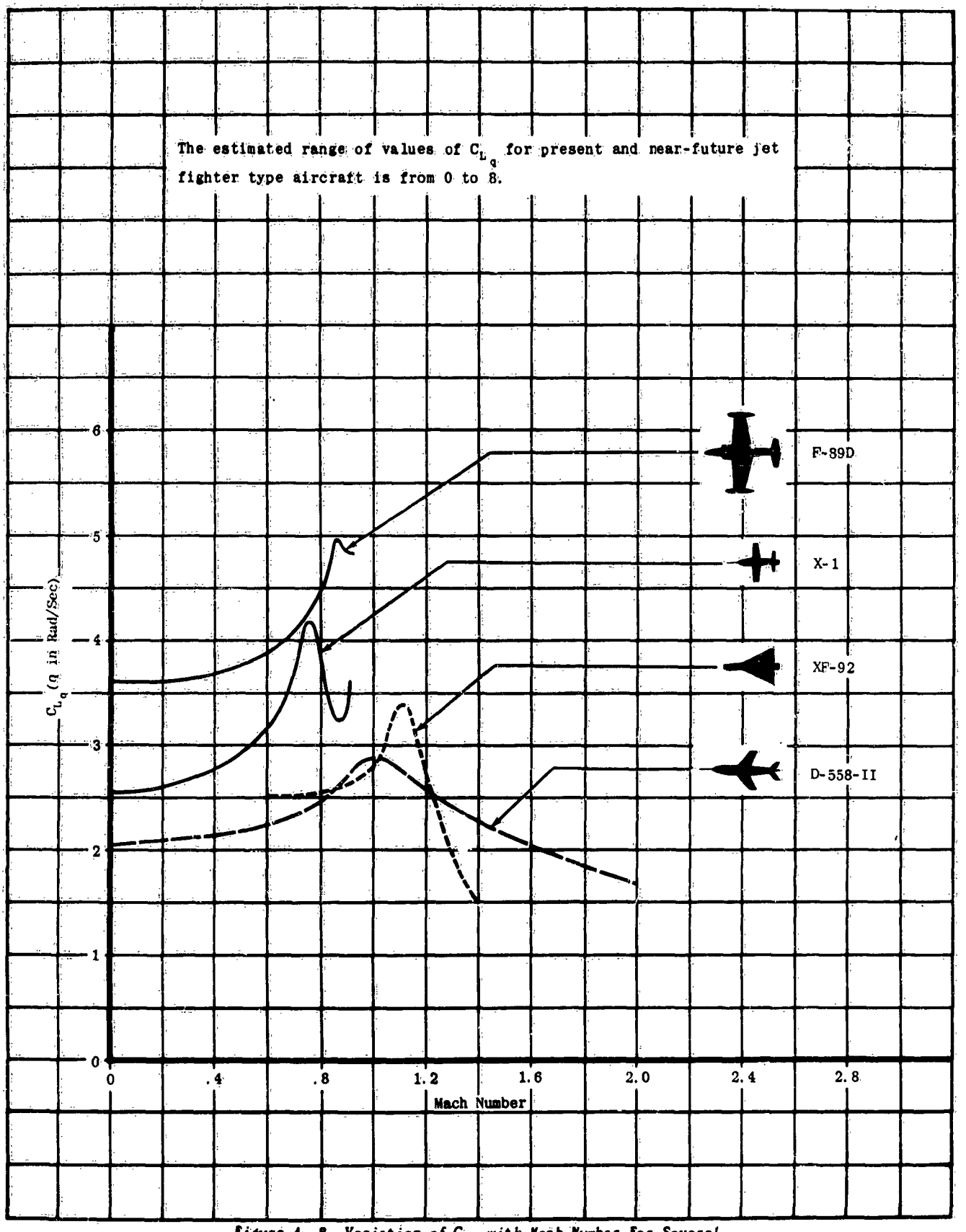

Figure A-8 Variation of C_{L_q} with Mach Number For Several High Speed Jet Aircraft

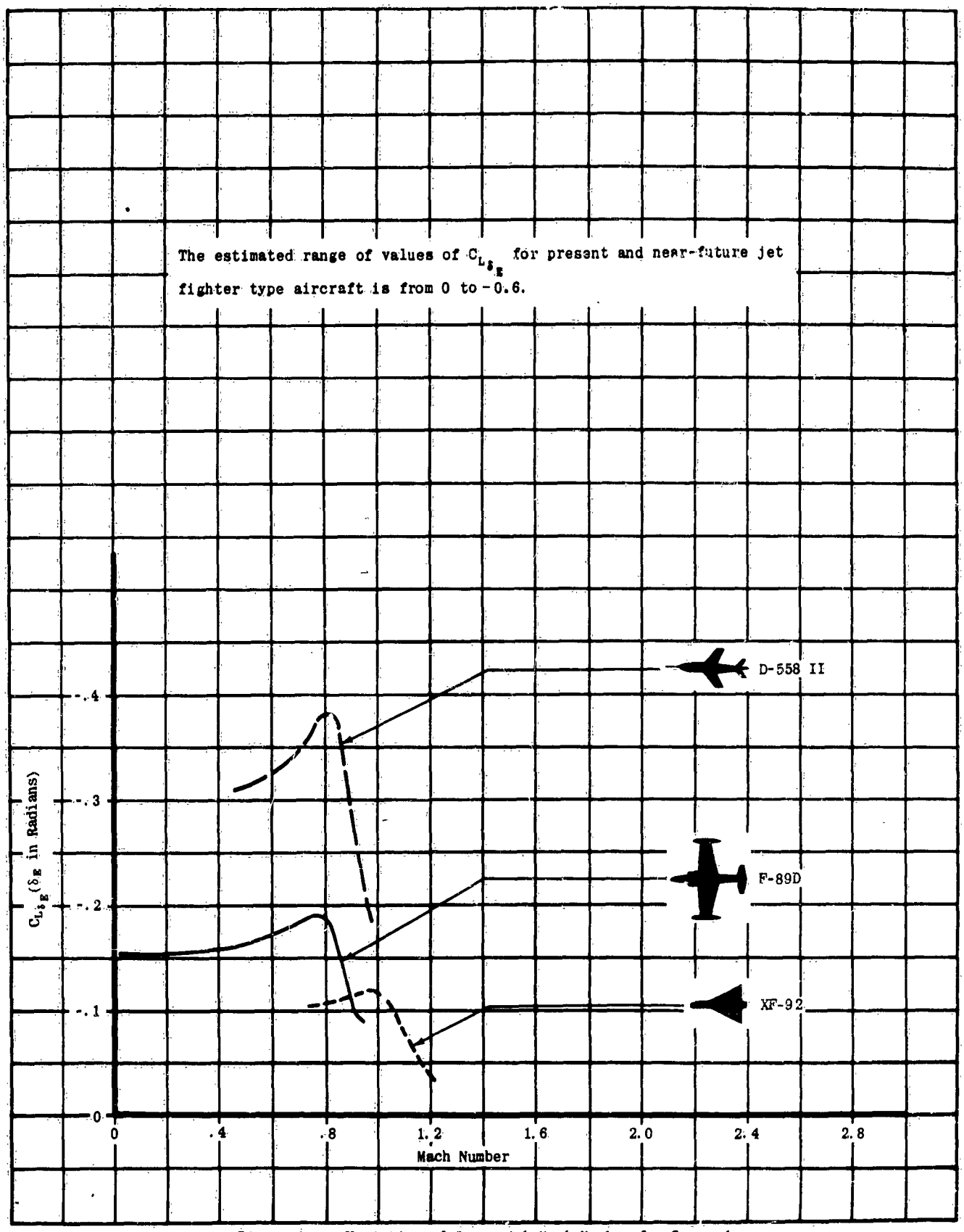

Figure A-9 Variation of $C_{L_{\delta_E}}$ with Mach Number for Several High Speed Jet Aircraft

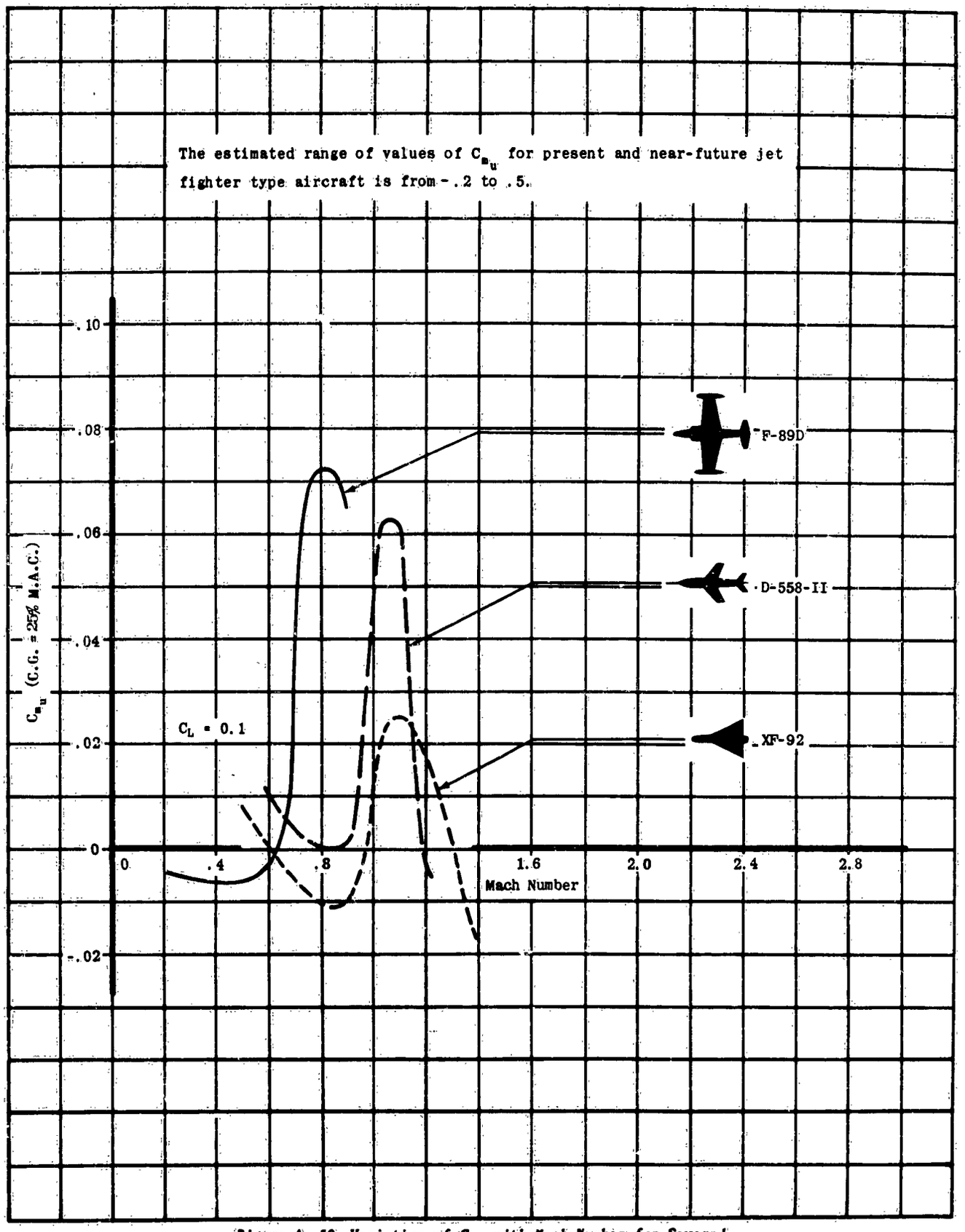

Figure A-10 Variation of C_{m_u} with Mach Number for Several High Speed Jet Aircraft

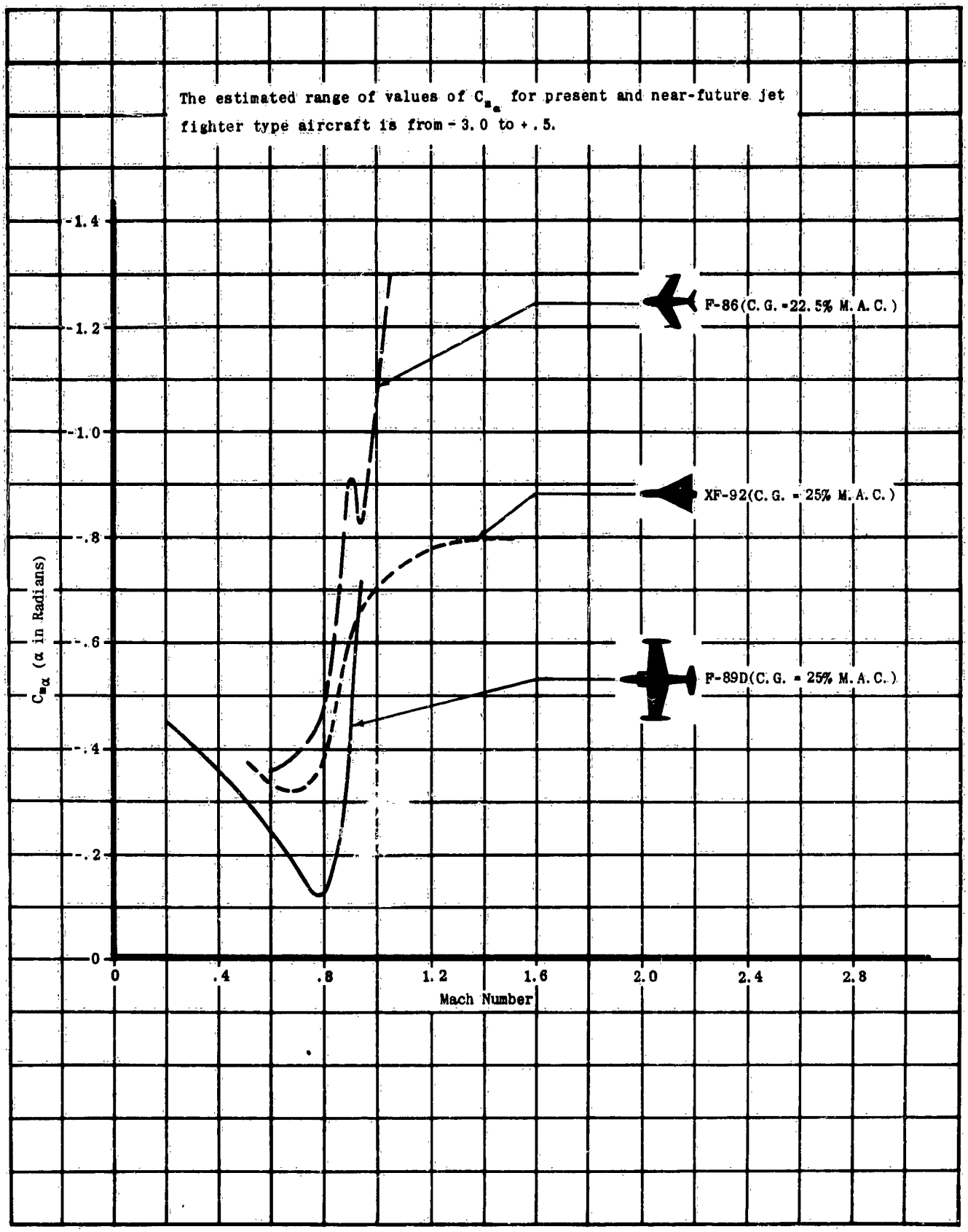

Figure A - 11 Variation of C_{m_α} with Mach Number for Several High Speed Jet Aircraft

For the XF-92, positive values are attained in the transonic and supersonic region. Although data concerning the performance of the other airplanes in the transonic region are scarce, it is probable that some of these configurations would exhibit positive values also. The estimated range of values of $C_{m_{\dot{\alpha}}}$ for present and near-future jet fighter type for present and near-future jet fighter type aircraft is from -10 to +3.

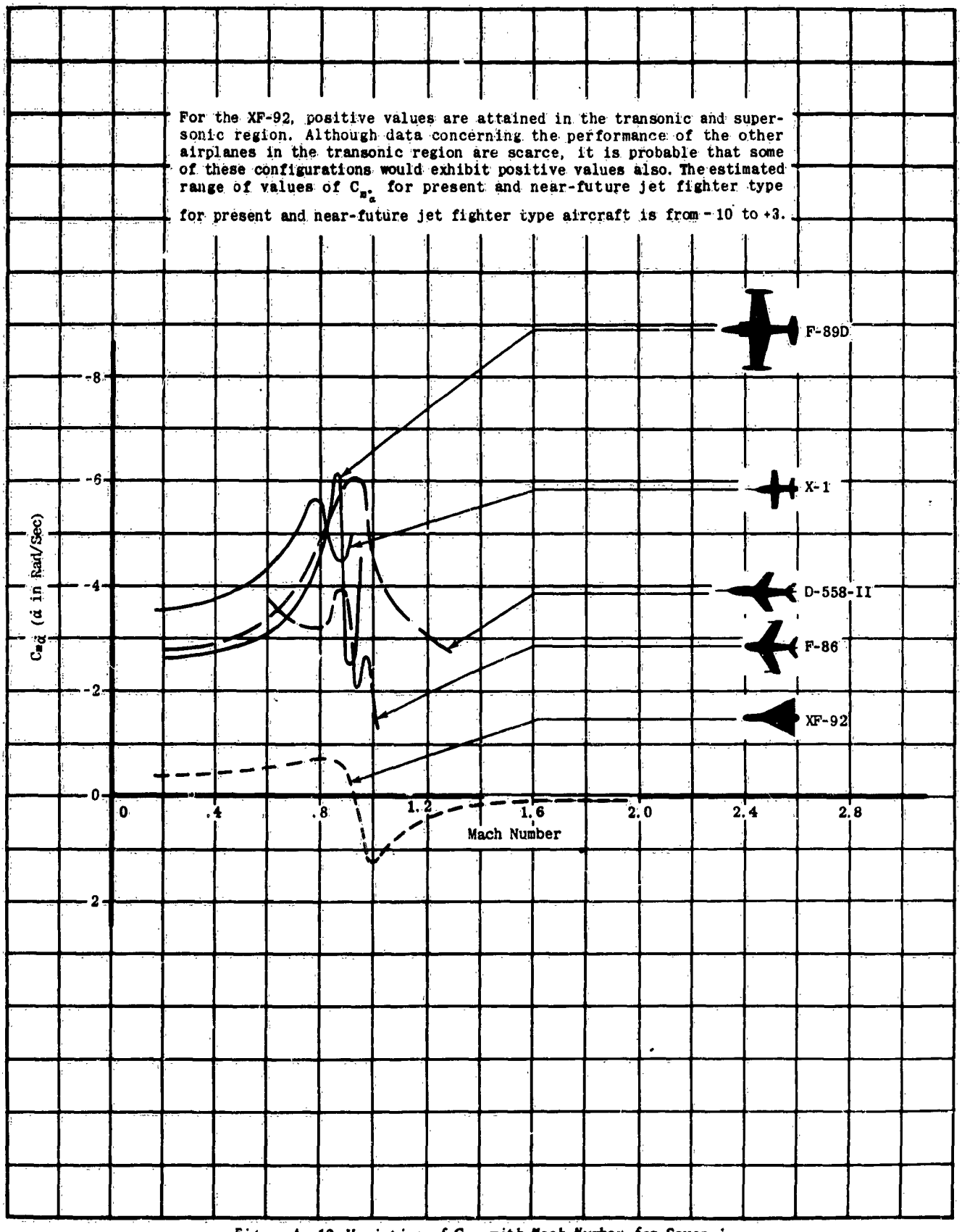

Figure A - 12 Variation of $C_{m_{\dot{\alpha}}}$ with Mach Number for Several High Speed Jet Aircraft

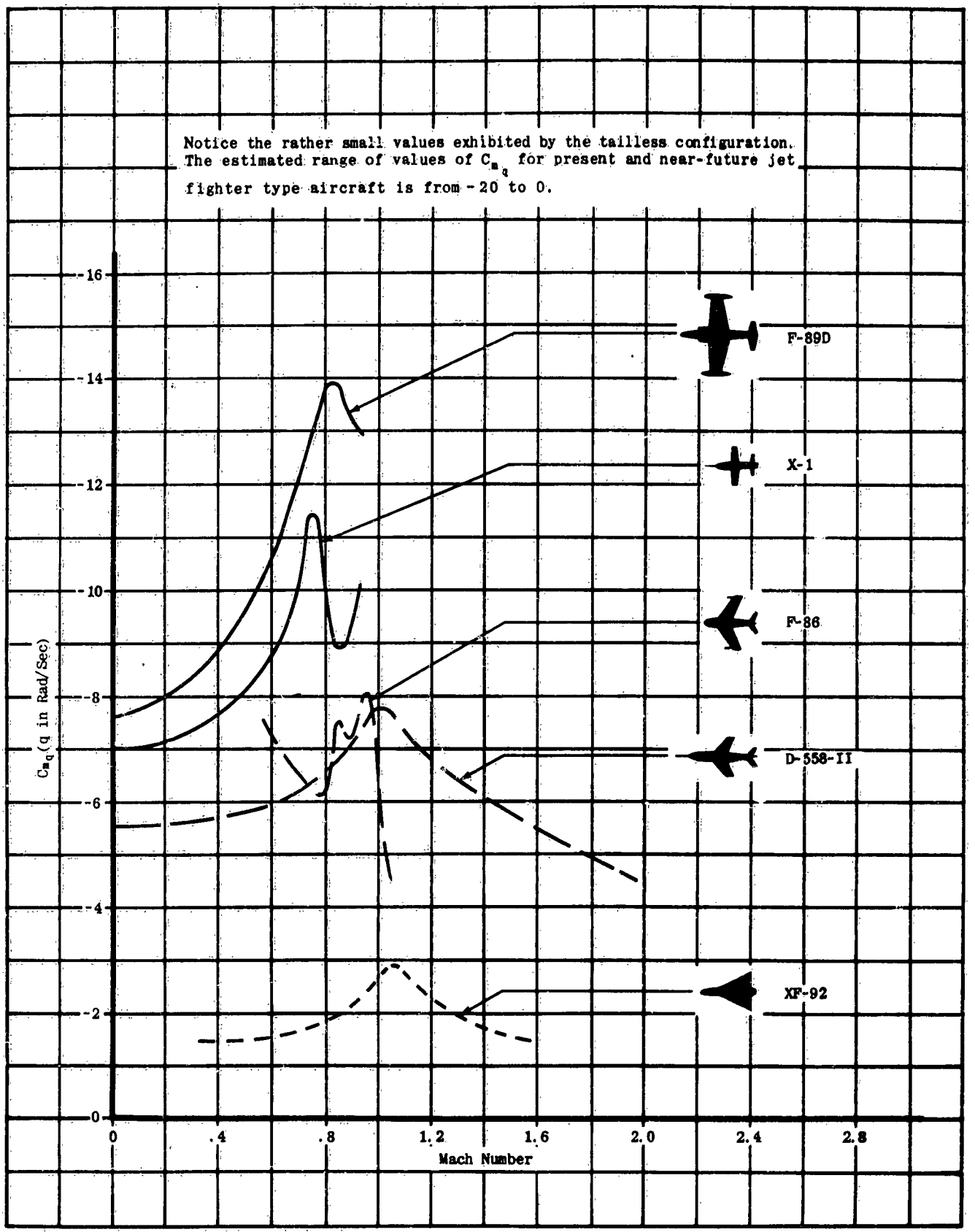

Figure A - 13 Variation of C_{m_q} with Mach Number for Several High Speed Jet Aircraft

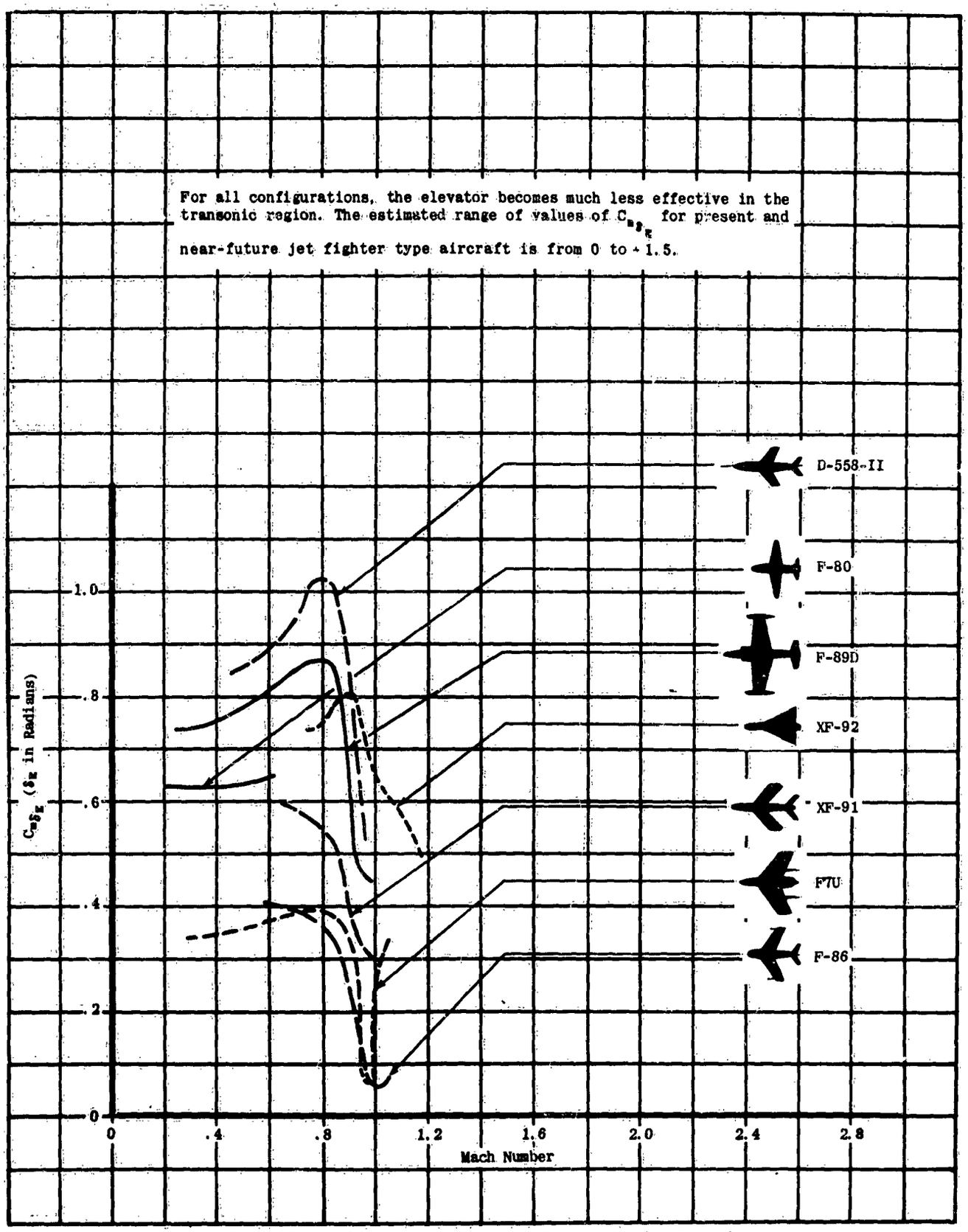

Figure A-14 Variation of $C_{m_{\delta_E}}$ with Mach Number for Several High Speed Jet Aircraft

Drake concludes that decreasing C_{y_β} improves the overall flight behavior.

(Drake, H.M., "The Effect of Lateral Area on the Lateral Stability and Control Characteristics of an Airplane as Determined by Tests of a Model in the Langley Free-Flight Tunnel," NACA Advance Restricted Report, ARR L5L05, Langley Memorial Aeronautical Laboratory, Langley Field, Va., February 1946.)

There is no apparent correlation between C_{y_β} values and wing planform type. The estimated range of values of C_{y_β} for present and near-future jet fighter type aircraft is from -.1 to -1.5.

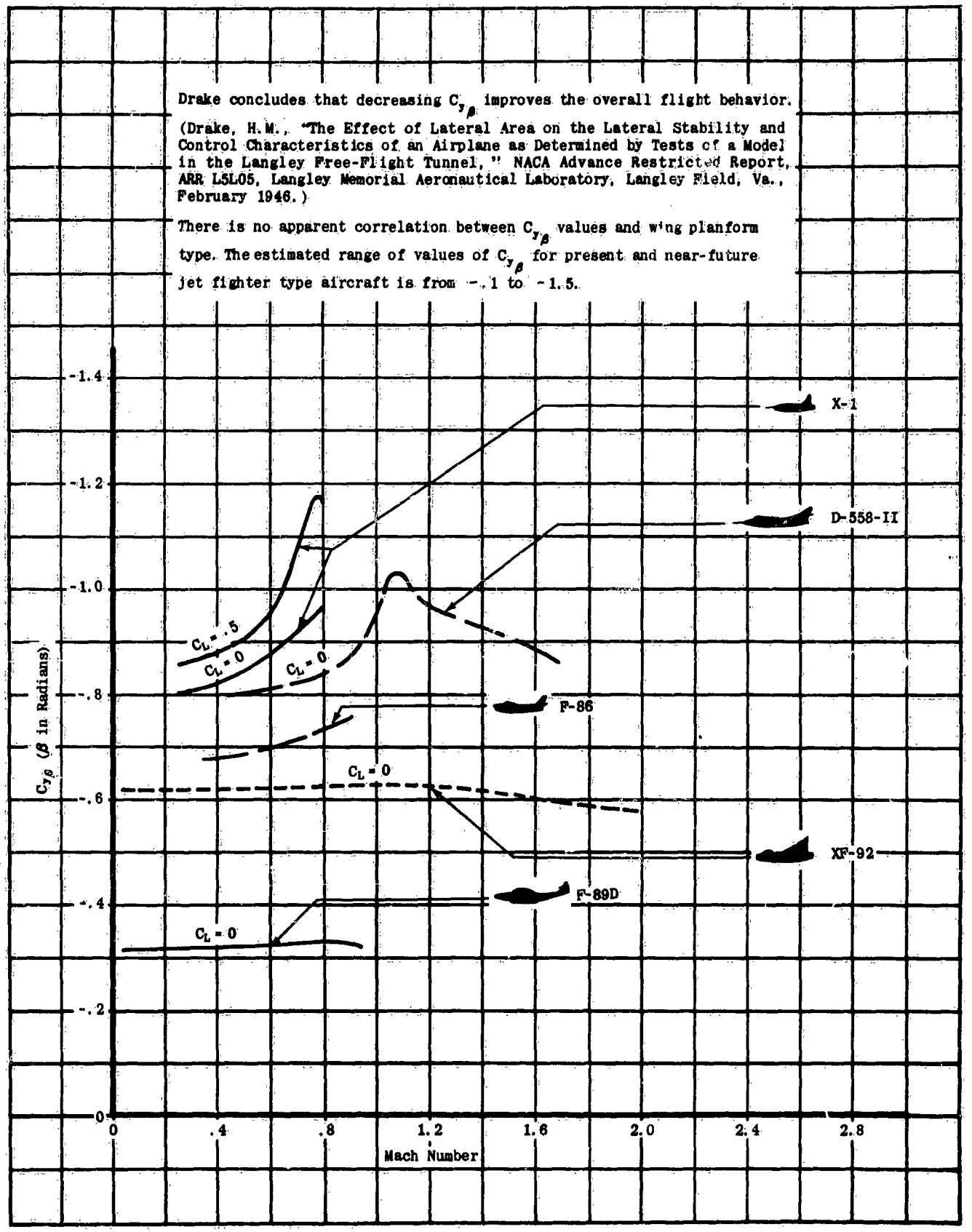

Figure A - 15 Variation of C_{y_β} with Mach Number for Several High Speed Jet Aircraft

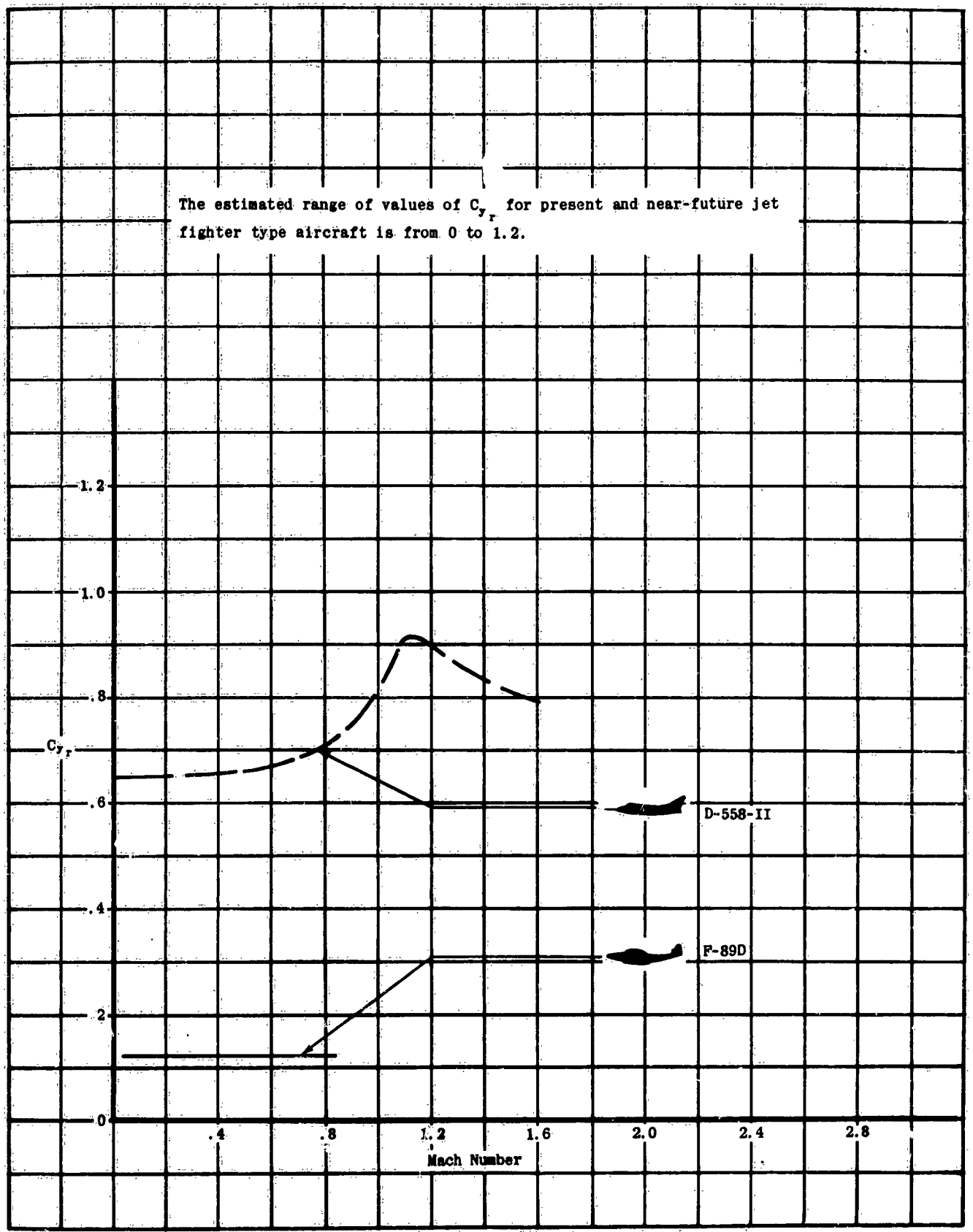

Figure A - 16 Variation of C_{y_r} with Mach Number for Several High Speed Jet Aircraft

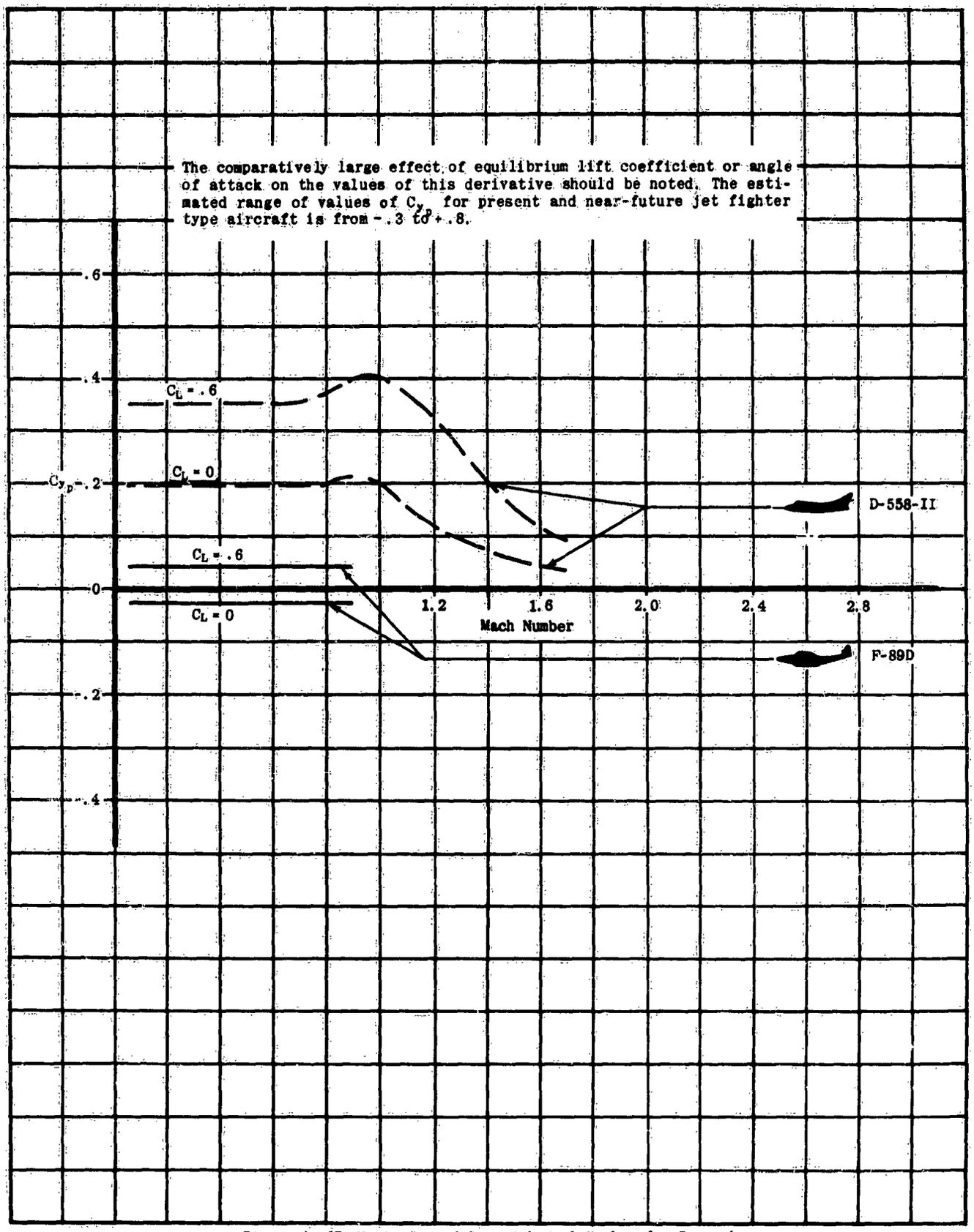

Figure A-17 Variation of C_{y_p} with Mach Number for Several High Speed Jet Aircraft

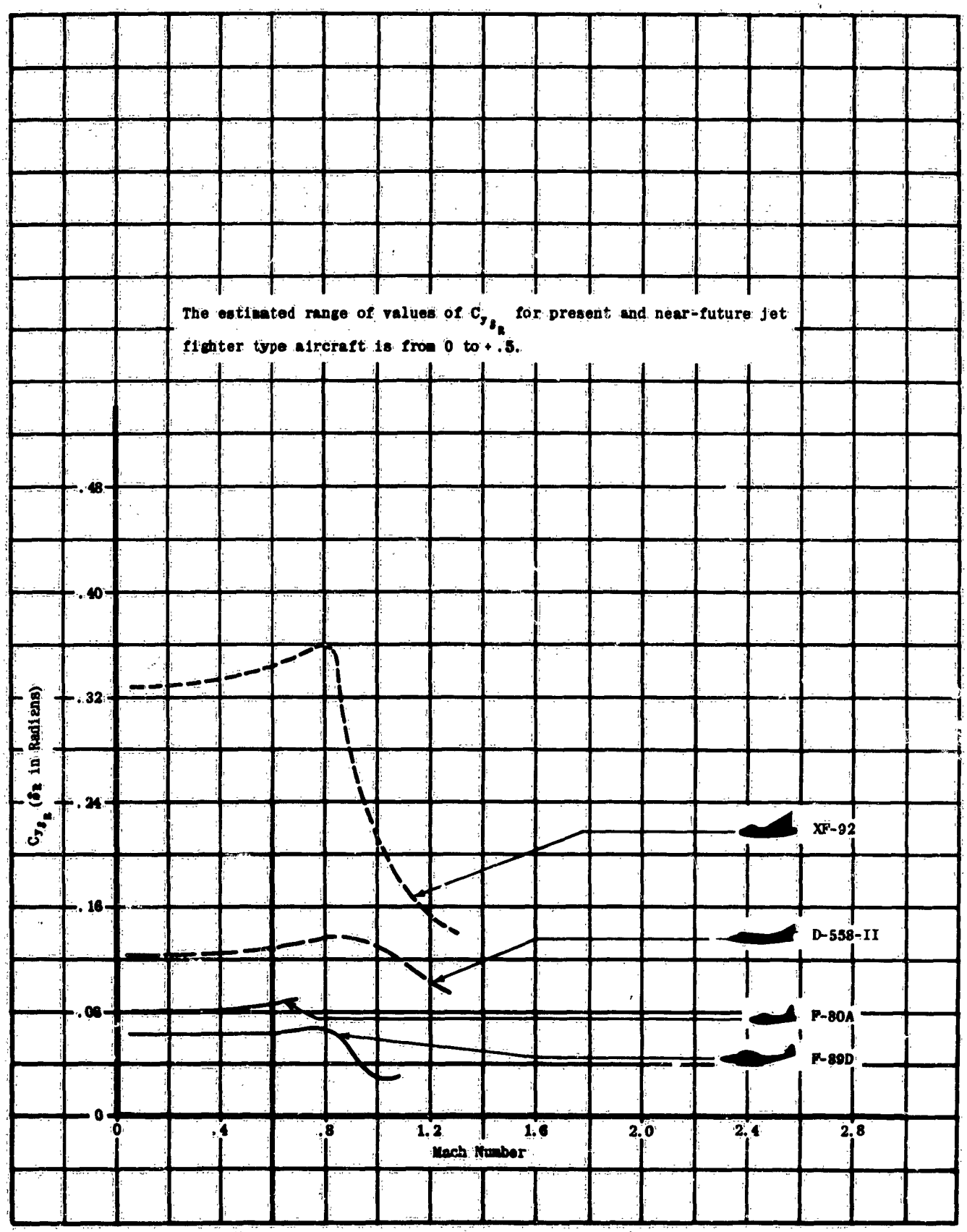

Figure A - 18 Variation of $C_{y_{\delta_R}}$ with Mach Number for Several High Speed Jet Aircraft

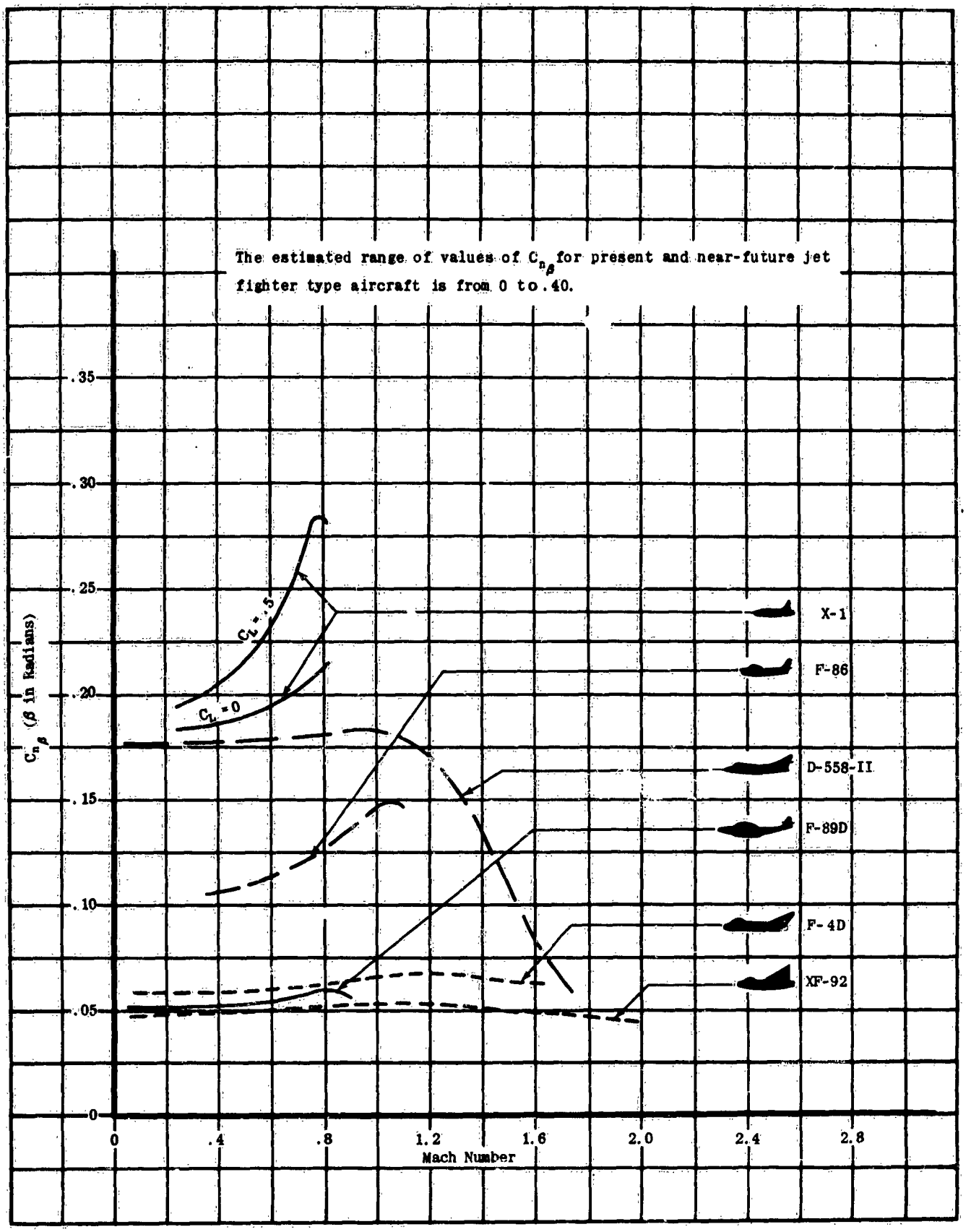

Figure A-19 Variation of C_{n_β} with Mach Number for Several High Speed Jet Aircraft

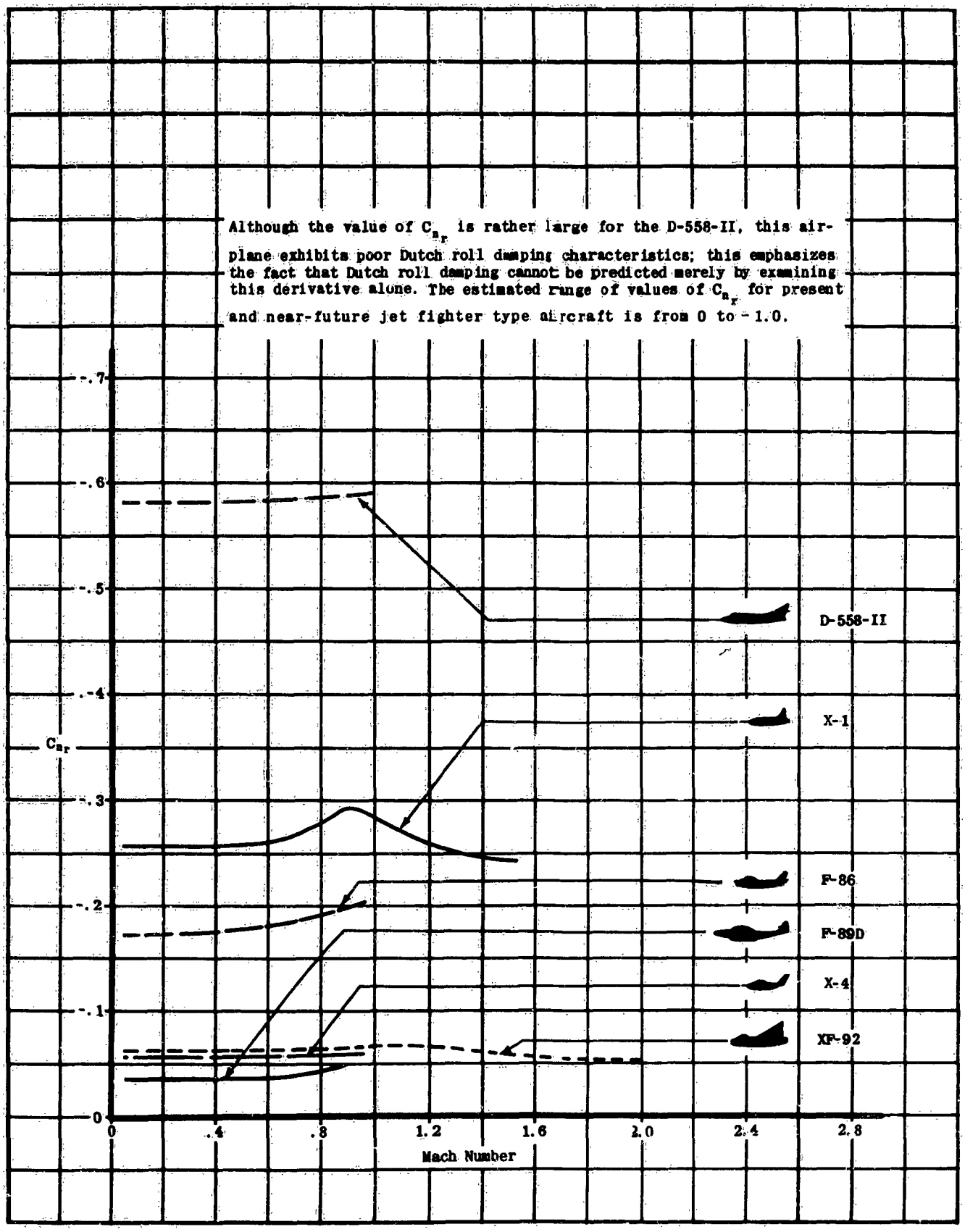

Figure A-20 Variation of C_{n_r} with Mach Number for Several High Speed Jet Aircraft

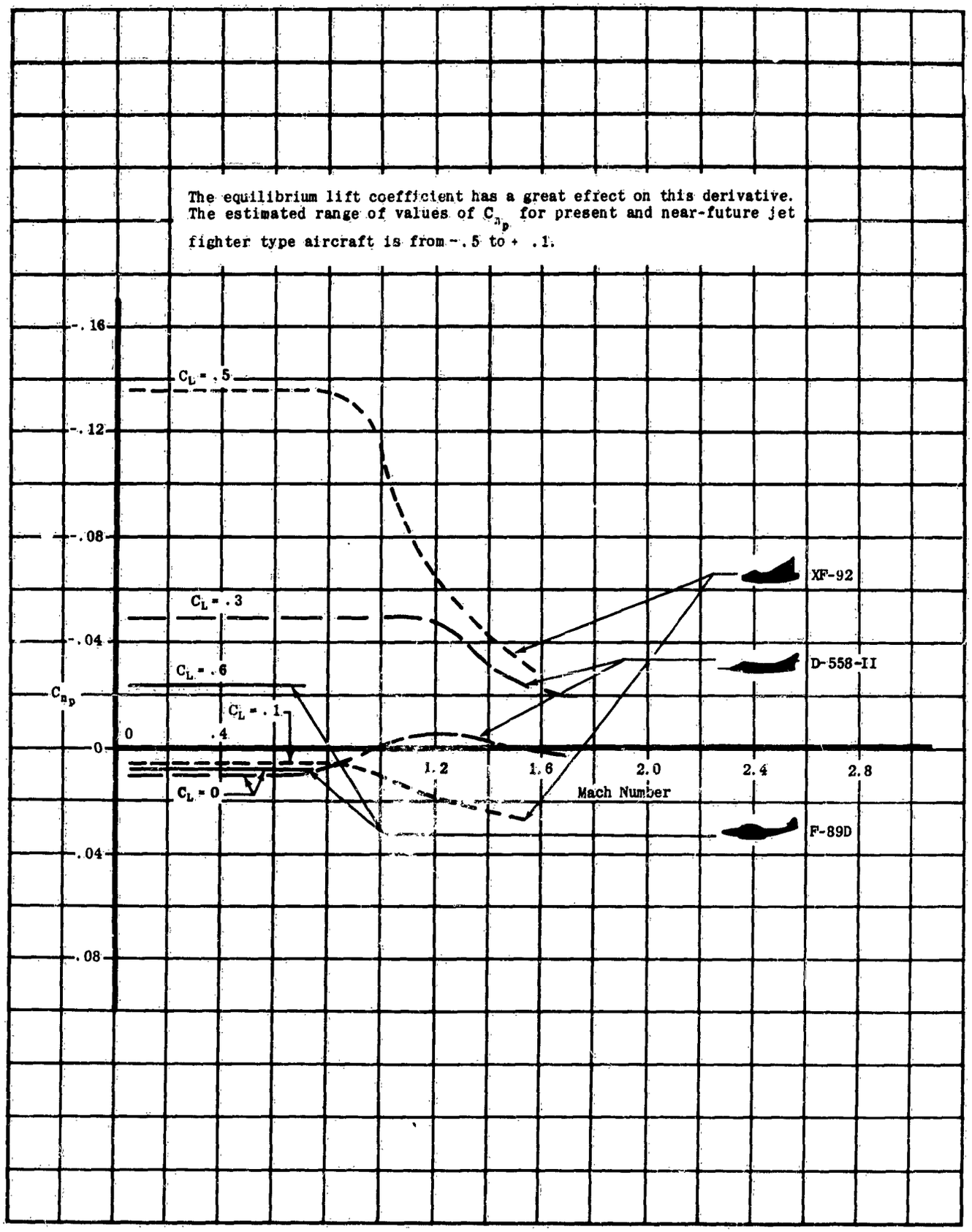

Figure A - 21 Variation of C_{n_p} with Mach Number for Several High Speed Jet Aircraft

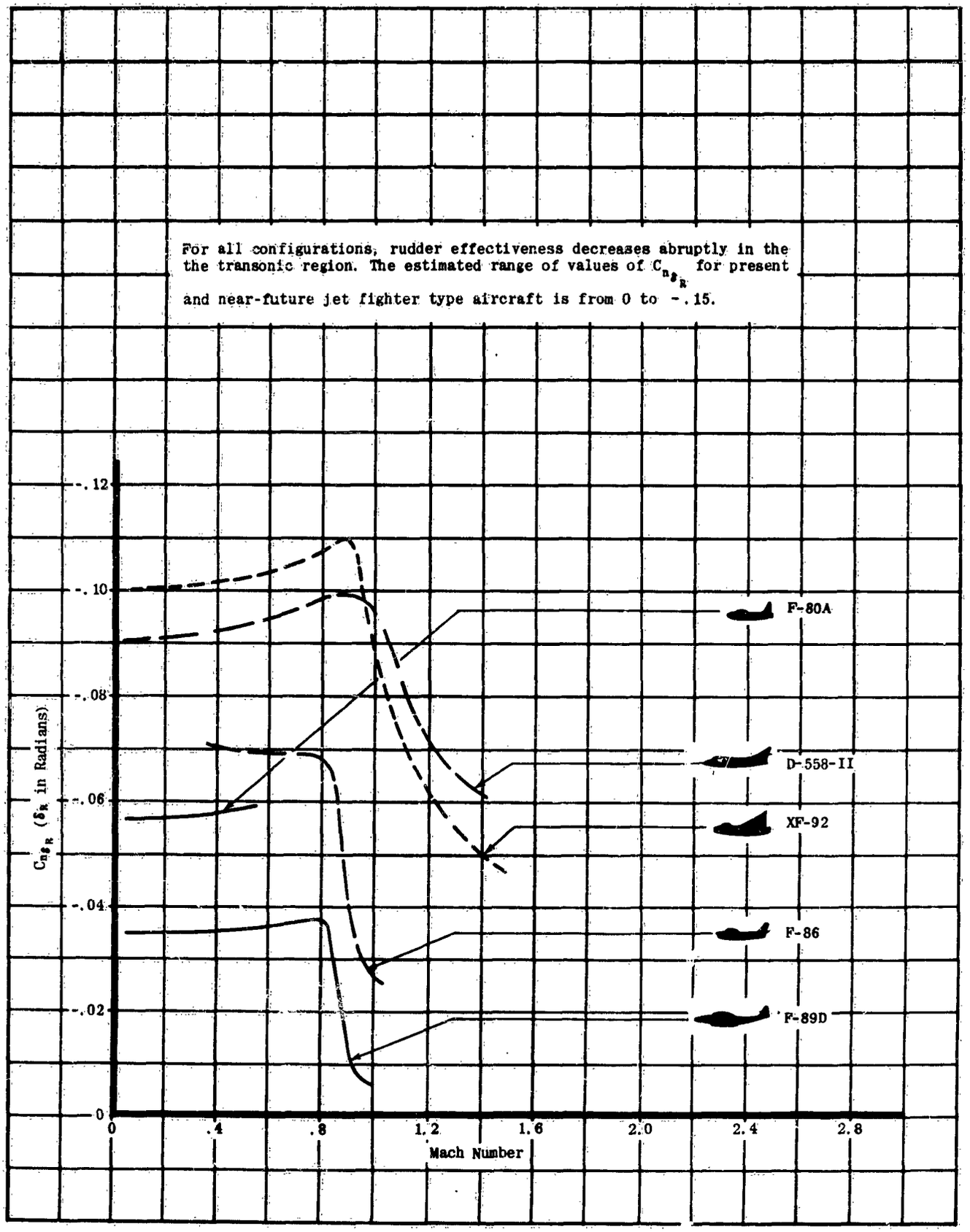

Figure A-22 Variation of $C_{n_{\delta_R}}$ with Mach Number for Several High Speed Jet Aircraft

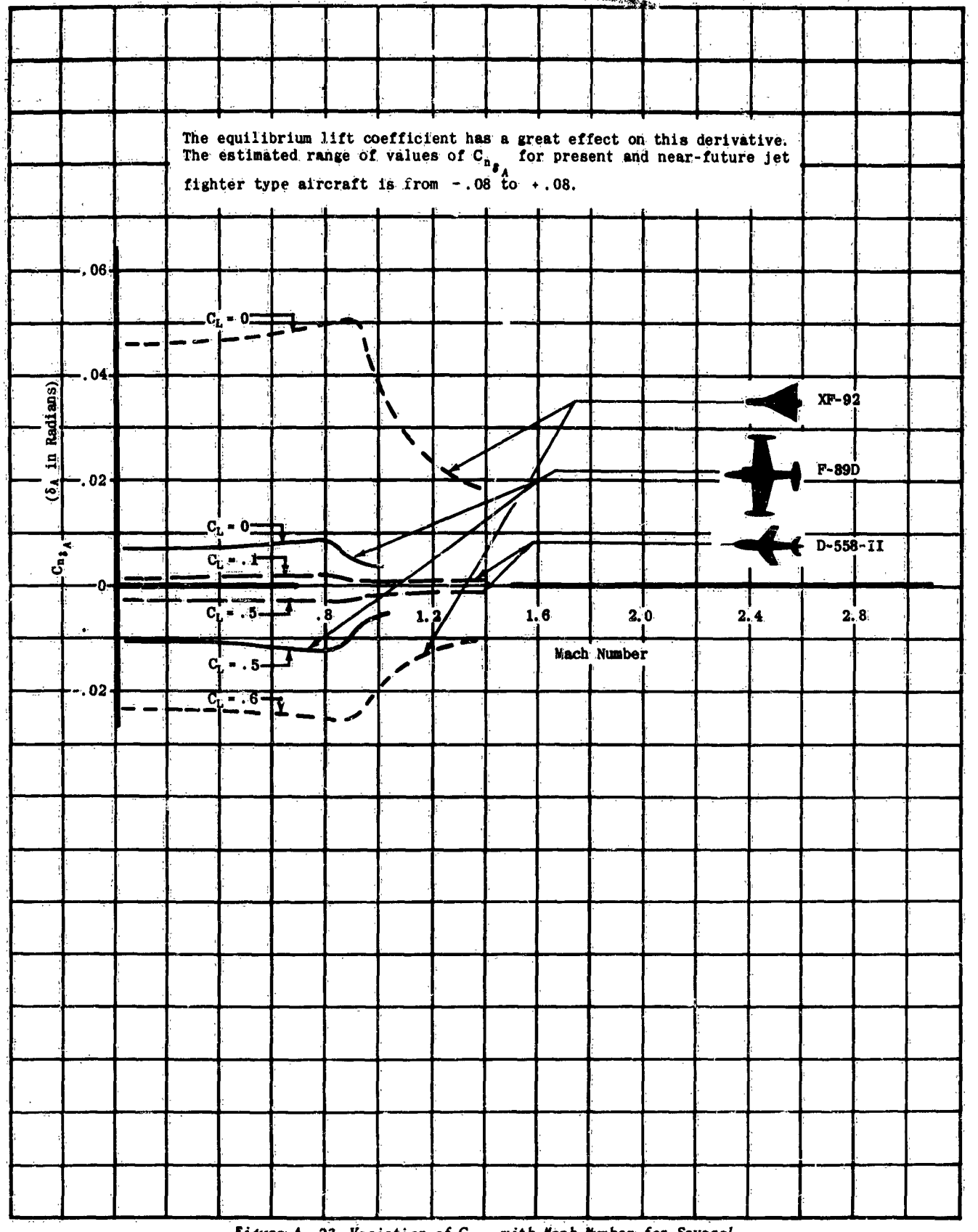

Figure A - 23 Variation of $C_{n_{\delta_A}}$ with Mach Number for Several High Speed Jet Aircraft

The equilibrium lift coefficient has a great effect on performance, especially for the delta wing configuration, but there is an abrupt decrease in its effect in the transonic range. The estimated range of values of C_{l_β} for present and near-future jet fighter type aircraft is from -.30 to +.06.

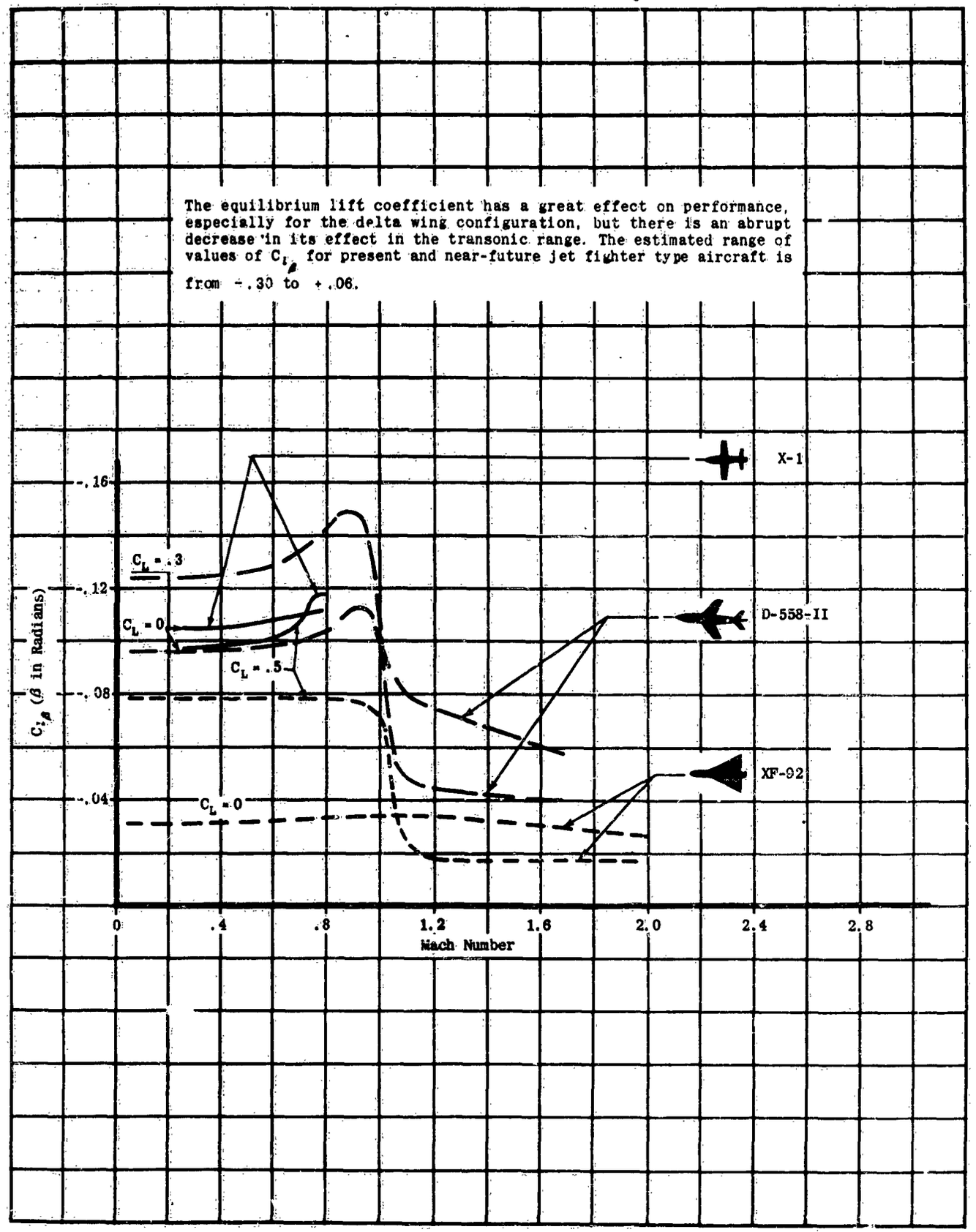

Figure A-24 Variation of C_{l_β} with Mach Number for Several High Speed Jet Aircraft

The equilibrium lift coefficient has a great effect on this derivative, an effect caused by the vertical tail contribution. The estimated range of values of C_{l_r} for present and near-future jet fighter type aircraft is from 0 to .4.

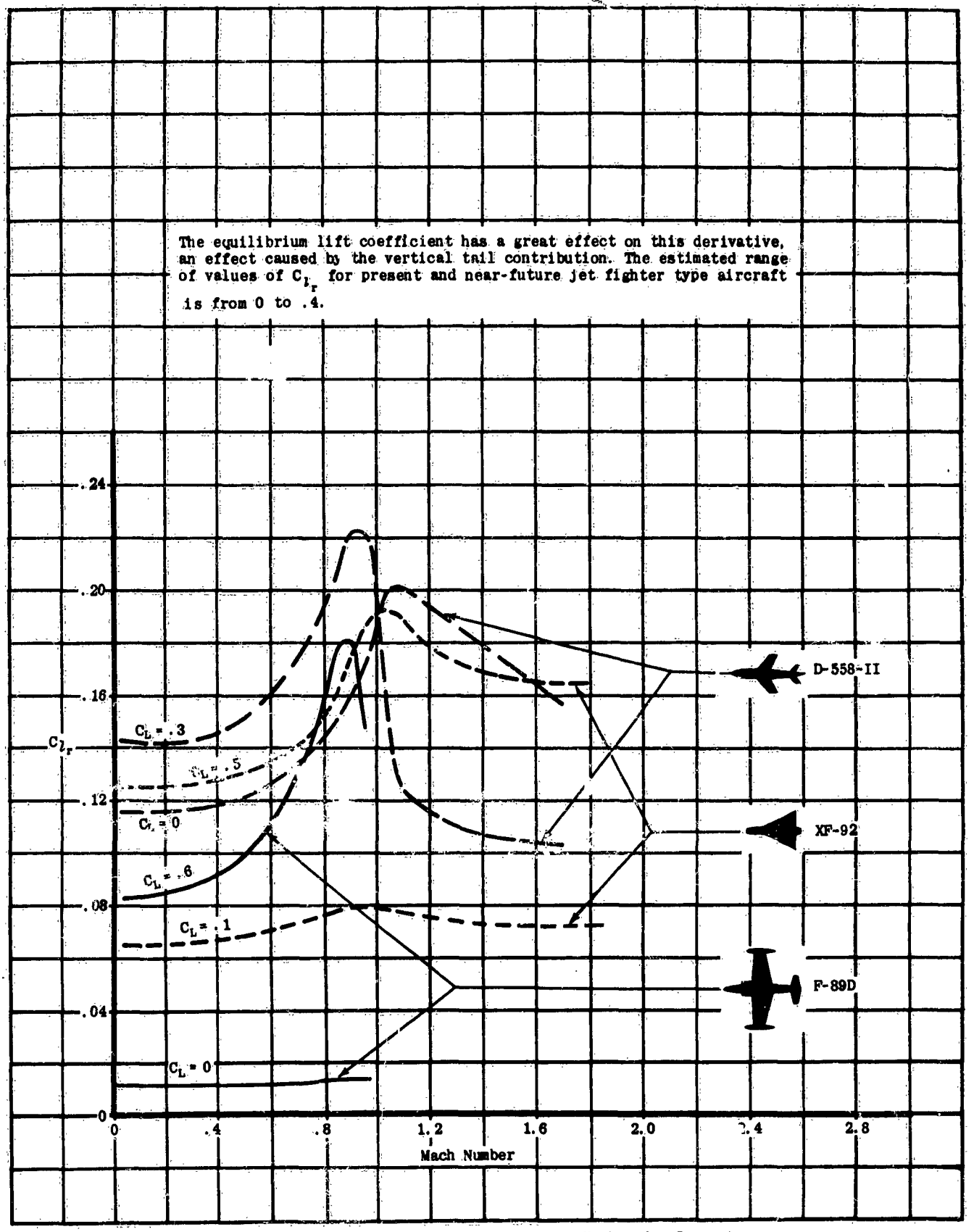

Figure A-25 Variation of Cl_r with Mach Number for Several High Speed Jet Aircraft

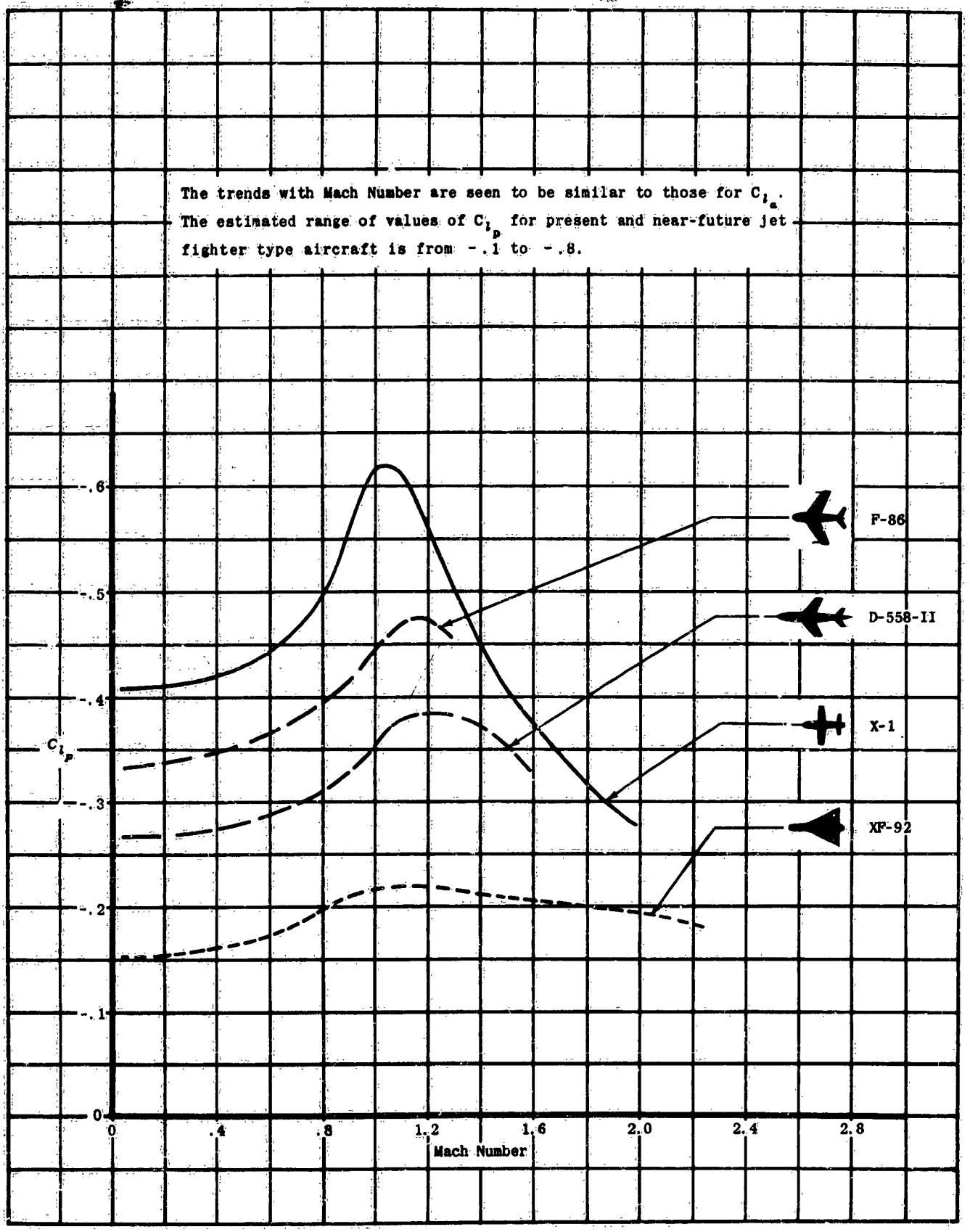

Figure A - 26 Variation of C_{l_p} with Mach Number for Several High Speed Jet Aircraft

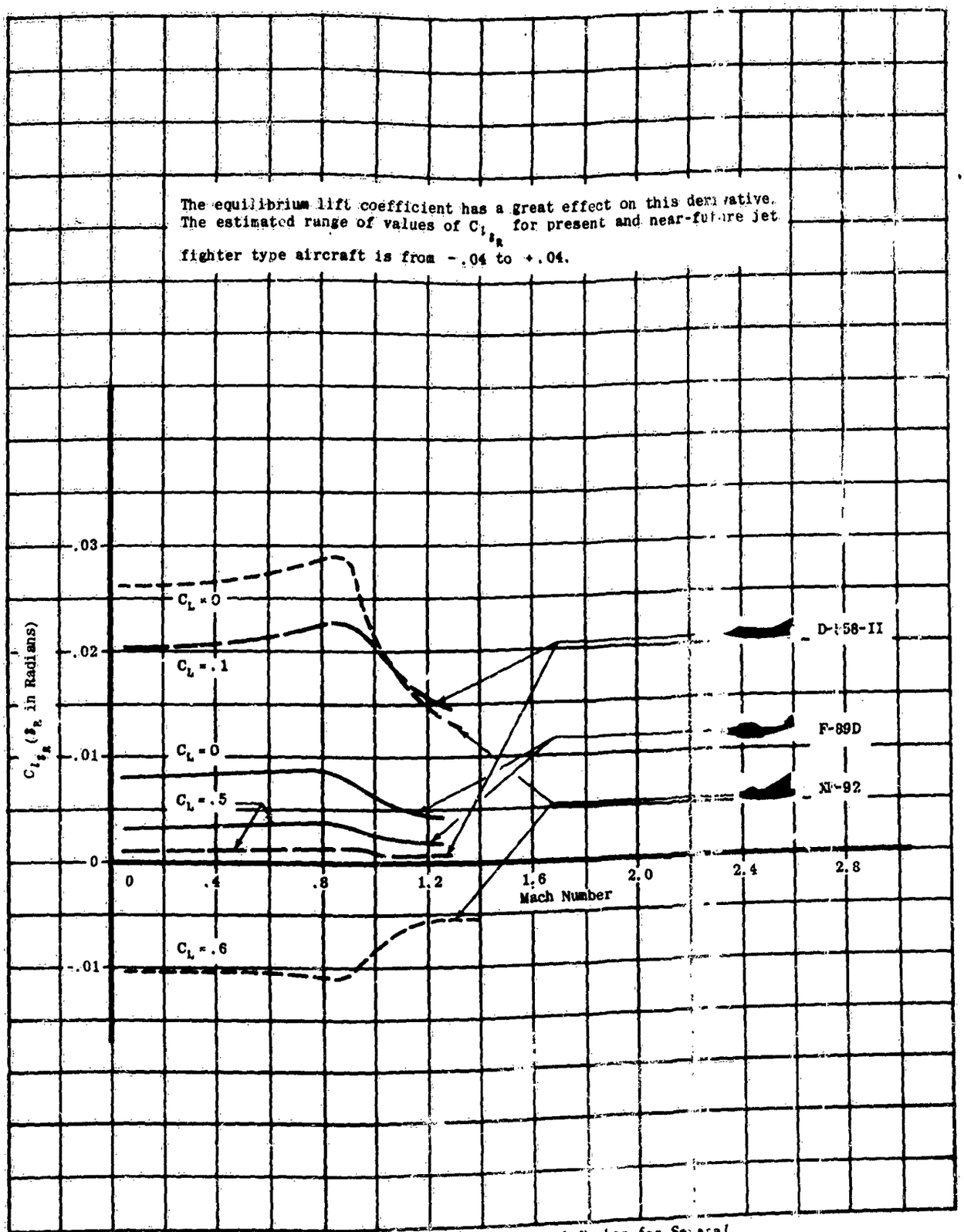

Figure A - 27 Variation of $C_{l_{\delta_R}}$ with Mach Number for Several High Speed Jet Aircraft