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INDEX FOR AERODYNAMIC DATA FROM THE BUMBLEBEE PROGRAM

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Bumblebee Aerodynamics Data Program

1. Introduction

The Bumblebee program, initiated in 1945 by the U. S. Navy Bureau of Ordnance, was designed to provide a supersonic guided missile defense for the fleet. Such a program required research, and exploratory and engineering development efforts in many technologies, including supersonic aerodynamics. The Johns Hopkins University Applied Physics Laboratory was assigned the task of leading this effort in the various technologies and proceeded to establish programs to acquire sufficient knowledge to accomplish the required goal.

The Aerodynamics program included a fundamental research effort in supersonic aerodynamics as well as a design task in developing both test vehicles and prototypes of tactical missiles.

Much of the material to be cited in this document contributed to the development of the three surface-launched Navy missiles, namely, the ramjet-powered Talos, the rocket-powered Terrier with tandem booster, and the dual-thrust, rocket-powered Tartar.

Meanwhile, as technology progressed, improvements were introduced to the missile systems to keep them abreast of new threats. Such improvements required continuing aerodynamic investigations throughout the intervening period. Standardization of components of the Terrier and Tartar resulted in their replacement with Standard Missile Extended Range and Standard Missile Medium Range, respectively.

During this period of missile development, many tests were run to provide aerodynamic data needed for definition of the missile configurations. Sufficient time was not always available, however, to analyze fully <u>all</u> of the data and provide research reports, design charts, etc., which could prove useful for other organizations interested in supersonic aerodynamics. Nevertheless, a considerable amount of information transfer was achieved through Navy-sponsored symposia, meetings of the Bumblebee Aerodynamics Panel, and publication of classified documents.

During the past year, the NASA Langley Research Center expressed an interest in a possible transfer to NASA of some of the unpublished data from the Bumblebee program which might be useful to NASA in carrying out its planned Missile Aerodynamics Research Program.

2. Objective of Present Program

The objective of this current effort is to provide NASA Langley Research Center with sufficient information on the aerodynamic studies conducted in the Bumblebee program and on the availability of the data so that NASA can ascertain which data are relevant to their planned programs and then to devise a system for transferring the selected data to NASA.

3. Approach

To perform the task of providing information from data acquired over a period of more than 30 years, the following approach was used.

First, a survey was made of the major advanced and engineering development programs: Talos, Terrier, Tartar, Typhon LR, Typhon MR, Standard Missile ER, Standard Missile MR, and Triton; the exploratory missile development programs: IRRSAM (integral rocket ramjet), TARSAM (thrust-augmented rocket), SCRAM (supersonic-combustion ramjet); and the aerodynamics research programs: Downwash Program, Wing-Body Interference Program*, Generalized Missile Study, Hypersonic Configuration Study, Planar Configuration Study, and Wrap-Around Surface Project. This survey reviewed the aerodynamic work of a parametric nature rather than that related to a specific configuration because NASA's goal is to provide a broad-based data package to potential users.

In cooperation with NASA personnel, the following list of topics was selected as NASA program categories for which relevant Bumblebee aerodynamics data should be sought.

A. Wing-Tail Interference

B. Tail-Controlled, Supersonic Rocket Configurations with Low Aspect Ratio Wings

C. Supersonic Airbreathing Missile Configurations

D. Wing or Tail Panel Loads and/or Flow Field Surveys

E. Hypersonic Missile Configurations

F. Unique Missile Configurations

With these topics in mind, data from the relevant BB programs were catalogued as to configurations tested, including parametric variations, range of test conditions (Mach number, angle of attack, roll attitude, control surface incidence), type of data collected (axial force, normal force, side force, pitching moment, yawing moment, rolling moment, surface loads and moments, pressures, flow field surveys), present availability of the data, and a listing of documents containing any parametric analyses of the data. In addition, suggestions are made of data sets for which further analyses could profitably be made if approved by NASA.

A separate section has been prepared for each of the topics A-F listed above and these sections are presented as Appendices A-F.

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* This program has been well-documented in the open literature and has not been included in the present survey. See Chapter 5, Vol. VII of High Speed Aerodynamics and Jet Propulsion, Princeton University Press, 1957, for listing of References.

4. Conclusions and Recommendations

This relatively limited survey of the aerodynamic data acquired in the Bumblebee missile program has uncovered several areas in which the existing data could be useful to NASA, Langley in its Missile Aerodynamics program.

Since many of the references listed in each Appendix as Reports on Data Analyses are single APL file copies, the following procedure is recommended for transfer of such data:

1. NASA, Langley personnel review this document and ascertain which portions of it will be most useful to the NASA research program.

2. A NASA representative spends some time at APL/JHU examining the file copies of the documents listed as Reports on Data Analyses and selects those reports which should be reproduced and delivered to NASA.

3. APL proposes a Task covering the reproduction and delivery of these documents.

Having satisfied any such immediate needs, we may then look to Tasks of longer range which might involve further analyses and correlations of data in a format desired by NASA. Such Tasks are suggested briefly at the end of each subsection of each Appendix. It is planned to submit a preliminary proposal giving further details on these potential Tasks under separate cover.

5. Conversion Table

The units used in this report are those of inches and feet, and are easily converted to the international system of units.

To convert from	to	multiply by
inch	meter	.0254
feet (U.S. Survey)	meter	.3048

Appendix A - Wing-Tail Interference

I. Bumblebee Reverse Roll Investigation

Configurations tested: See Figs. A-I-1, A-I-2, and A-I-3.

Test Conditions:

Mach Number	- $M = 1.73$
Angle of attack	- $2° \leq \alpha \leq 10°$
Roll attitude	- $\phi = 0, 22\frac{1}{2}°, 45°$
Reynolds Number	- $Re = 6 \times 10^6$/ft.
Flipper incidence	- $i_F = -5°, 0°, +5°$

Type of Data Collected:

Rolling Moment

Availability of Data:

Single hard copy of following reports in APL/JHU files:

1. APL/JHU CF-788, LSL Report 69, "Investigation of Roll-Reversal Effects on Generalized Missile Configuration at M = 1.73 in the 19 X 27.5-Inch Nozzle for the Johns Hopkins University," J. Post, September 1947.

2. APL/JHU CF-789, LSL Report 69-1, same title, J. Post, November 1947.

3. APL/JHU CF-1157, OAL Report 69-2, same title, J. Post, December 1947.

Reports on Data Analyses:

1. "Experimental Investigations of Roll-Reversal Effects for Generalized Missile Configurations at Supersonic Velocities," A. R. Eaton, Jr., published in APL/JHU TG 10-4, 1948 Bulletin of the Bumblebee Aerodynamic Symposium, November 4-5, 1948.

2. Data analyses also given in the Data Reports above.

Suggestions for Further Analyses:

Above analyses sufficient for NASA purposes.

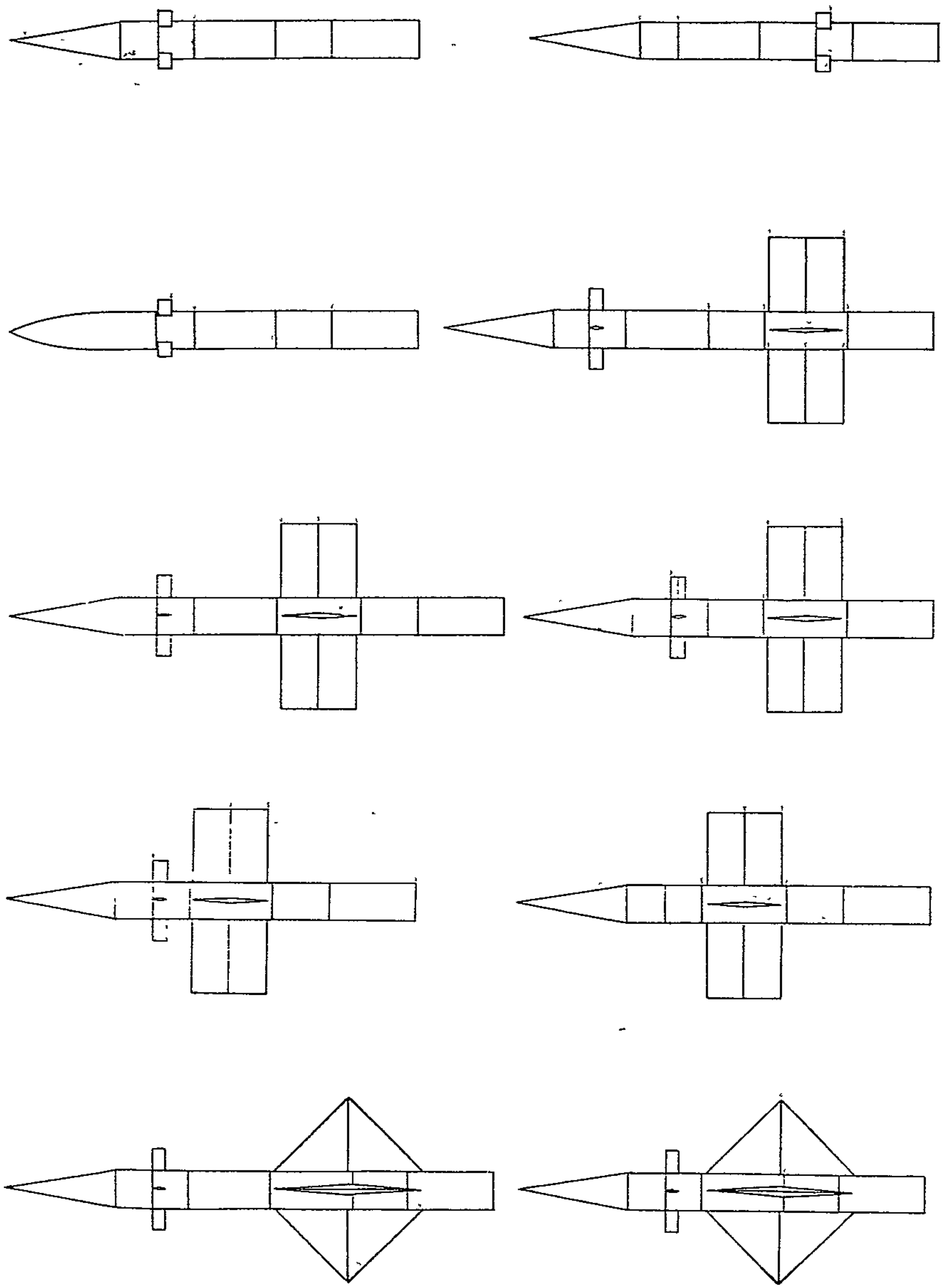

Fig. A-I-1 Configurations Used in Static Rolling-Moment Tests - Series 1

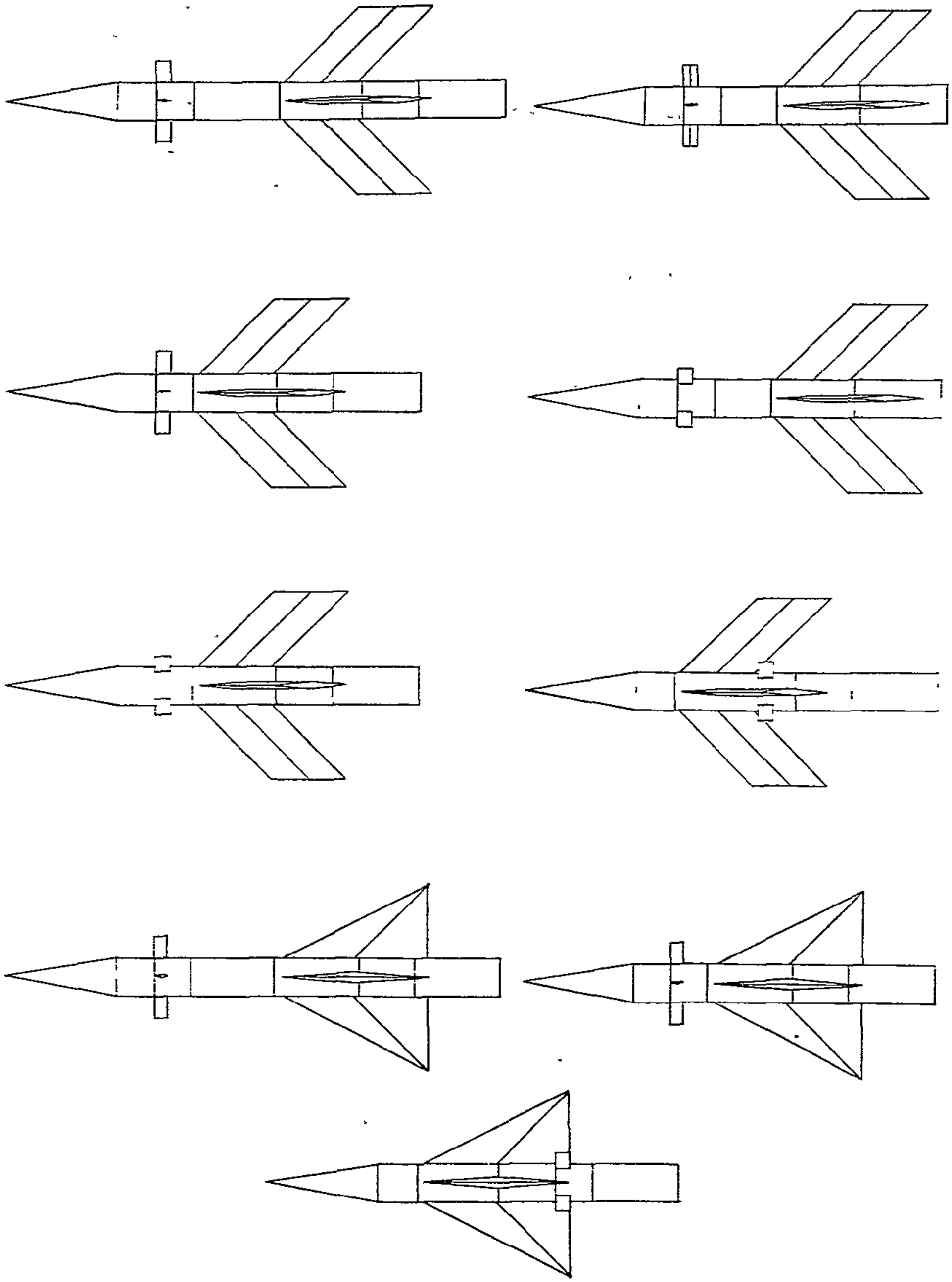

Fig. A-I-1 (Cont'd)

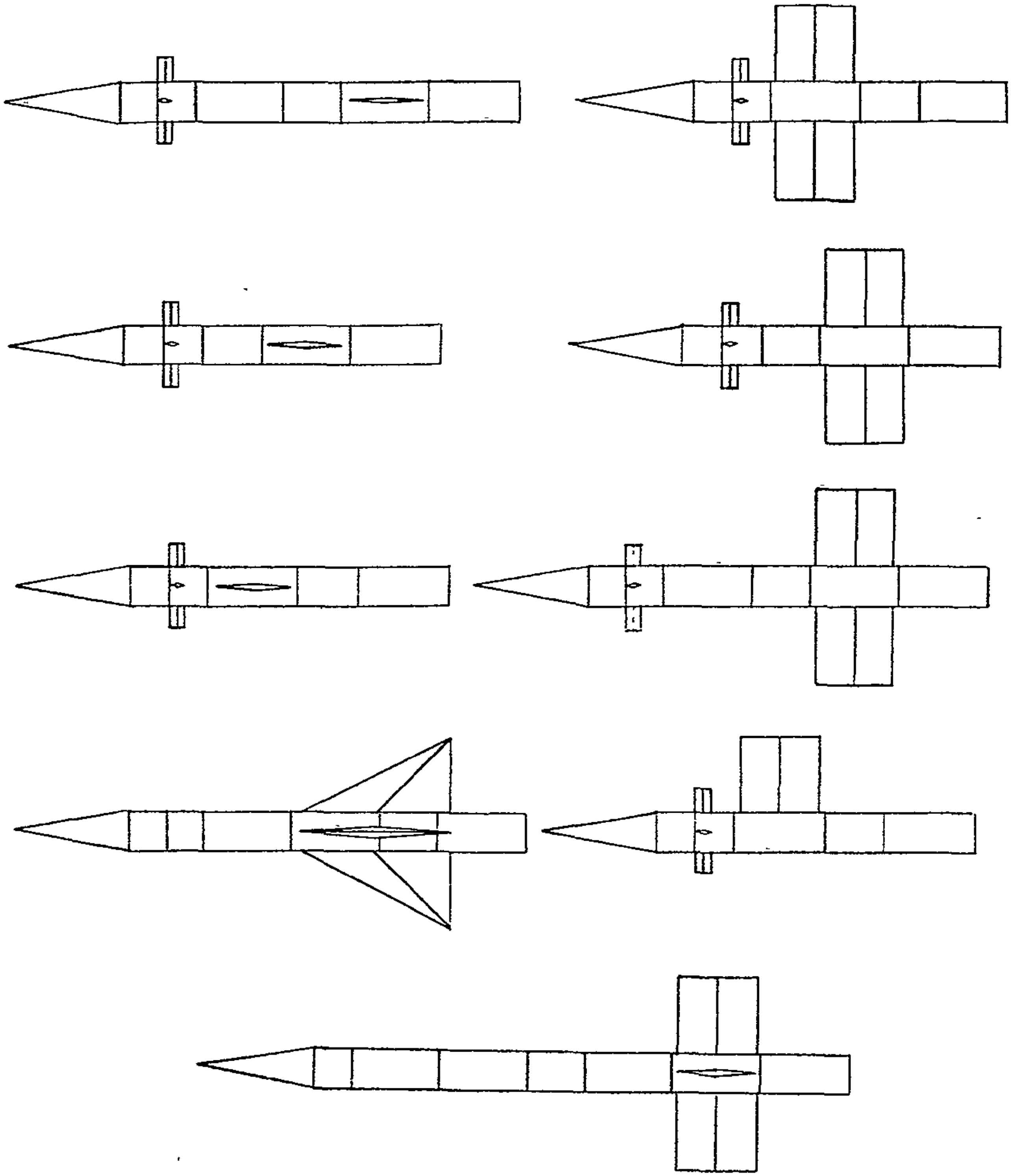

Fig. A-I-2 Configurations Used in Static Rolling-Moment Test - Series 2

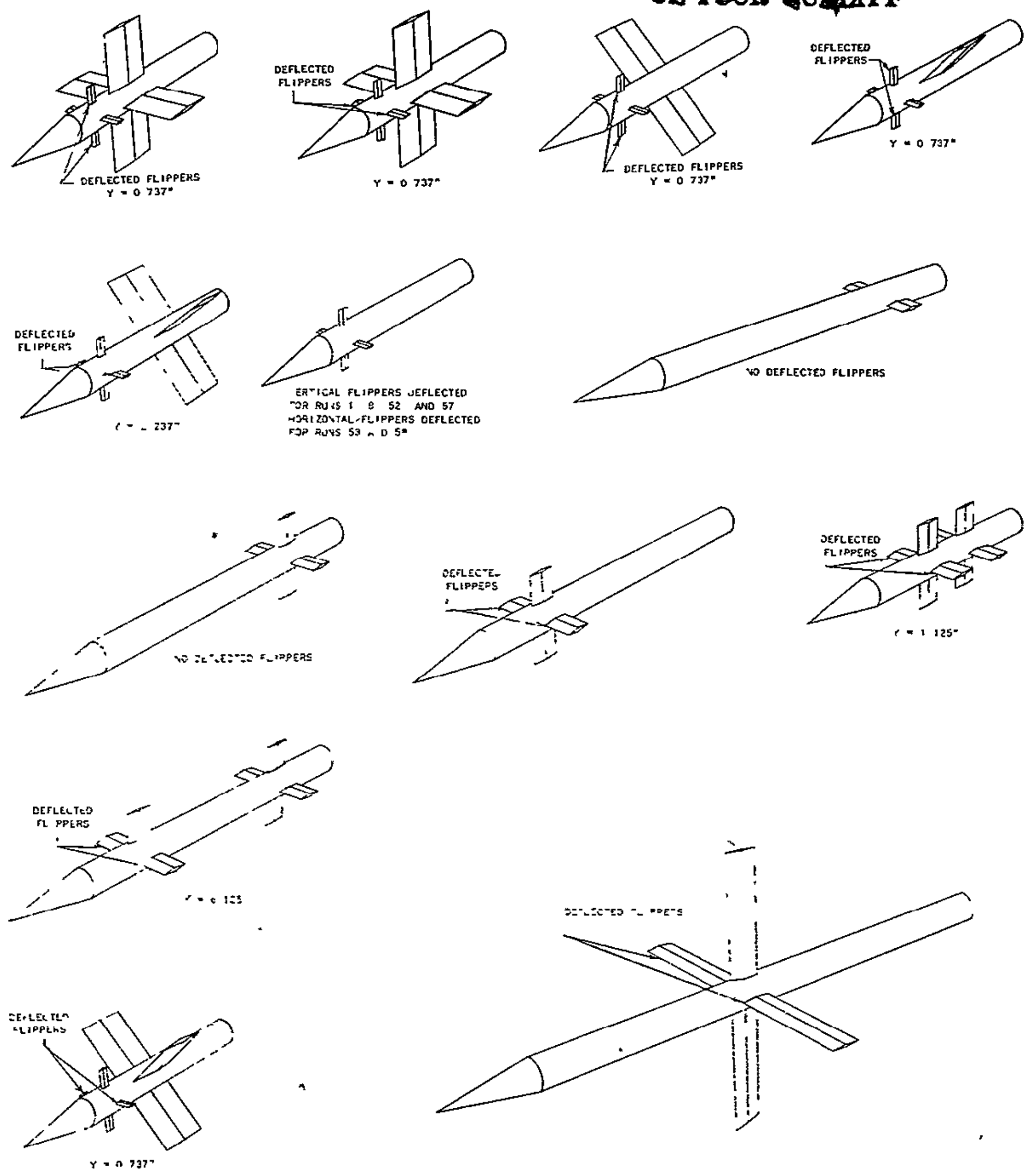

Fig. A-I-3 Configurations Used in Static Rolling-Moment Tests - Series 3

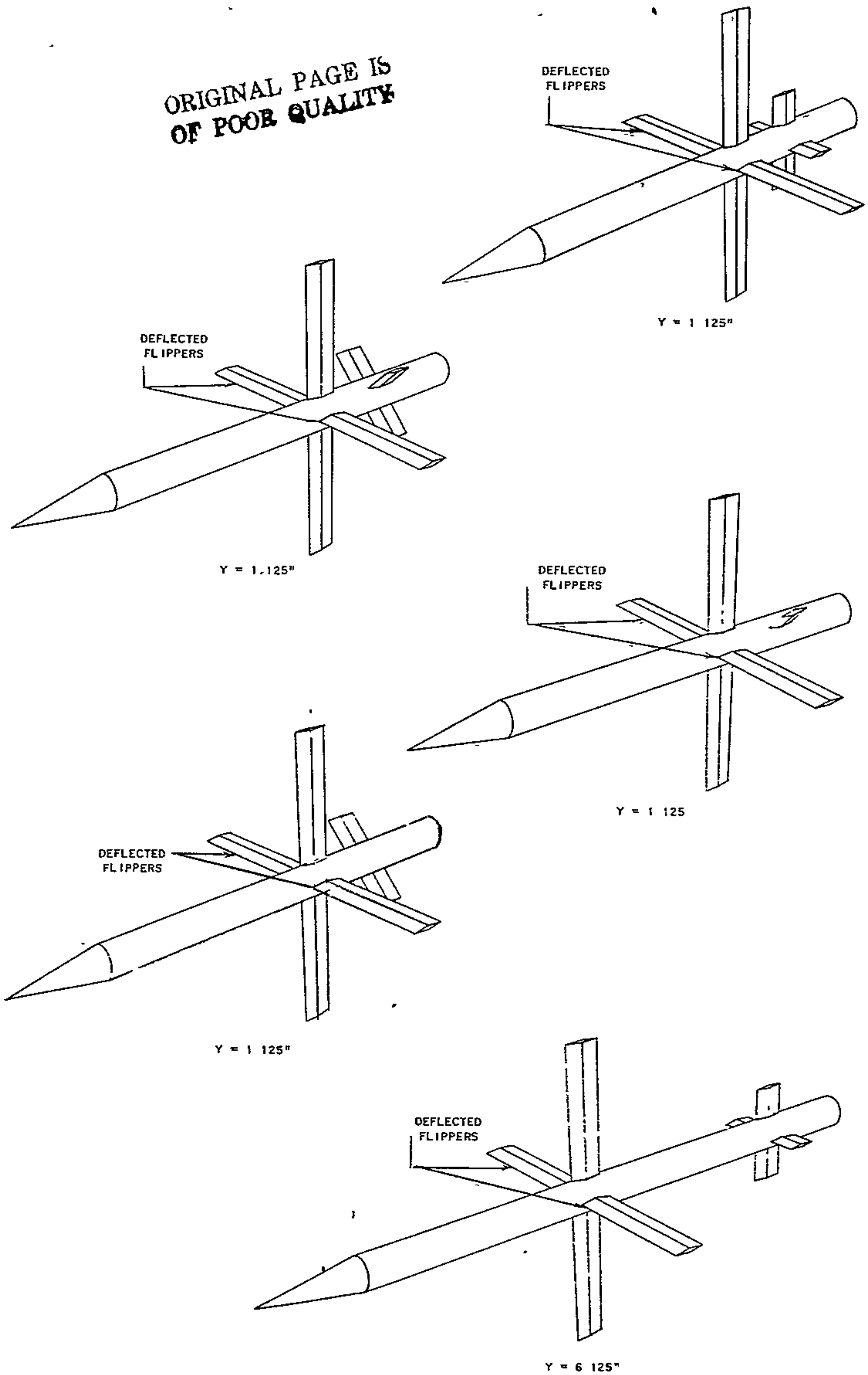

Fig. A-I-3 (Cont'd)

Appendix A - Wing-Tail Interference (Cont'd)

II. Bumblebee Downwash Program

Configurations tested:

See Figs. A-II-1 and A-II-2. Series 1 and 2 differed in body length and nose shape which showed minimum effect.

Component breakdown configurations were also used.

Test Conditions:

Series 1 - M = 1.5, 2.0
$-8° \leq \alpha \leq +8°$
$\phi = 0°$
Tail incidence = 0°, 3°, 6°, 9°

Series 2 - M = 1.5, 2.0, 2.5
$-4° \leq \alpha \leq +25°$
$\phi = 0°, 15°, 30°, 45°$
Wing and tail incidences = 0°, 5°, 10°, 20°

Types of Data Collected:

Series 1 - Five-component stability and control (no drag).

Series 2 - Five-component stability and control (no drag).
Three-component wing and tail loads and moments.

Availability of Data:

The following wind tunnel data reports are in APL/JHU files:

Series 1 - OAL 154, -1 through -4, "Wind Tunnel Investigation of Downwash Behind Wings of Rectangular Planform at Mach Numbers 1.50 and 2.0."

Series 2 - OAL 264, -1 through -10, "Generalized Investigation of Downwash Behind Wings of Rectangular Planform at Mach Numbers 1.50, 2.00 and 2.50."

Analysis Reports:

Series 1 - APL/JHU CM-609, "Wing-Body-Tail and Wing-Body Inter action effects for Rectangular Surfaces at Supersonic Velocities," G. M. Edelman, May 1950.

Series 2 - NAVORD Report 3146, Proceedings of the U. S. Navy Symposium on Aeroballistics, April 1953, Paper entitled "Wing-Body and Wing-Body-Tail Interaction at Supersonic Speeds for Generalized Missile Configurations at High Angles of Attack," G. M. Edelman, APL/JHU

Suggestions for Further Analysis:

A complete analysis of the Series 2 data would provide NASA with very useful information that could be integrated into its Wing-Tail-Interference Program.

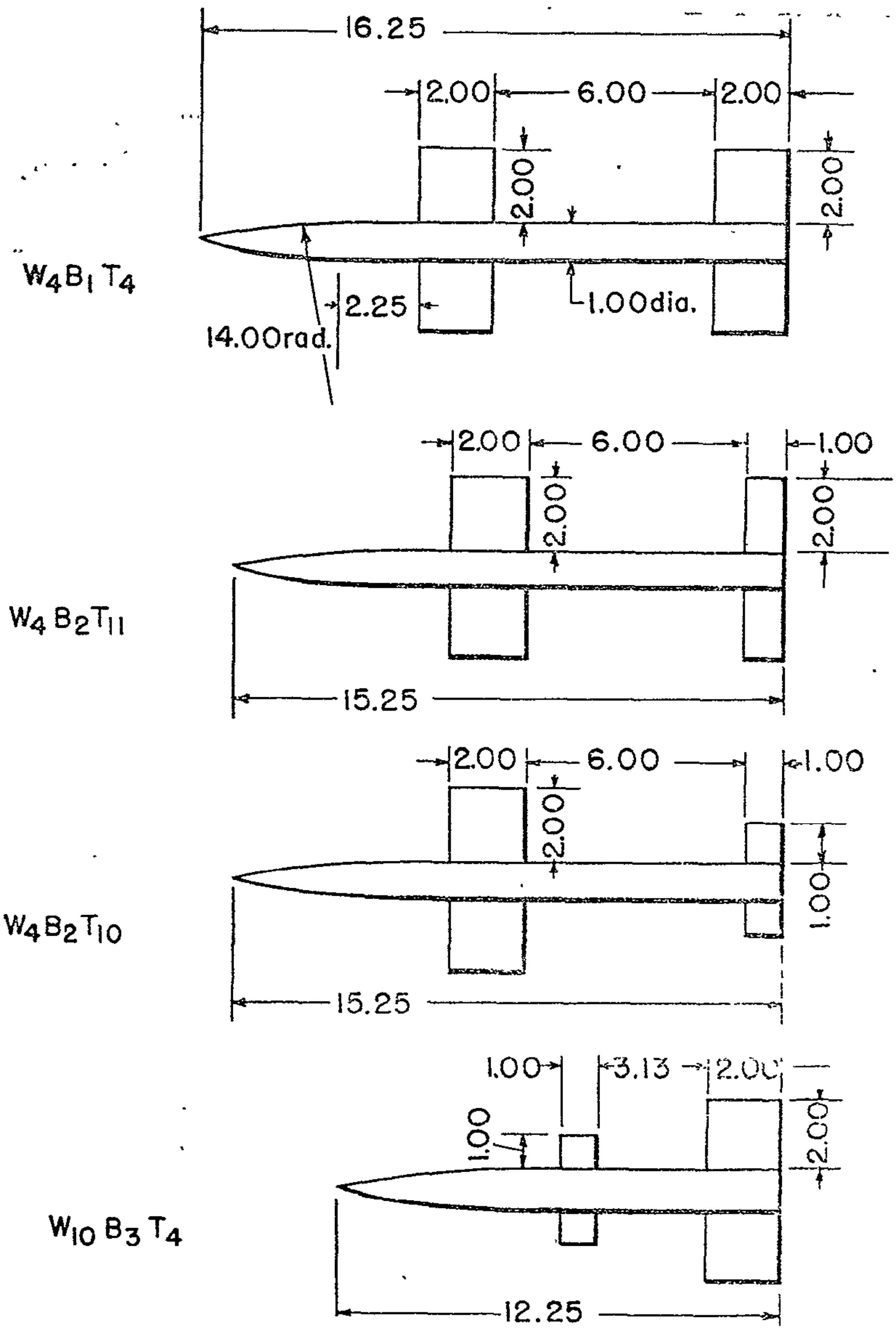

Fig. A-II-1 . Configurations Used in Downwash Program - Series 1

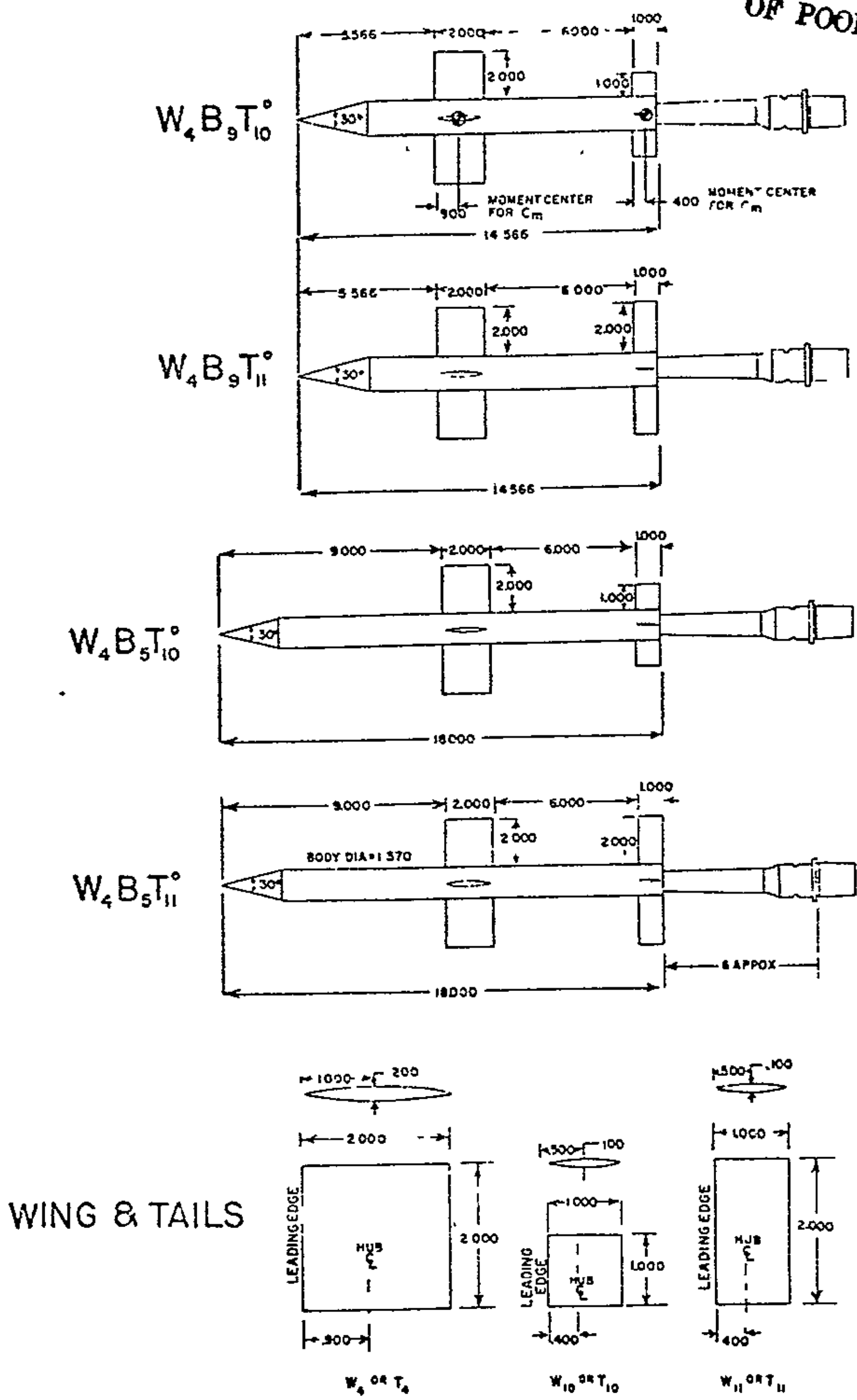

Fig. A-II-2 Configurations Used in Downwash Program - Series 2

III. Bumblebee Generalized Missile Study (GMS)*

Configurations tested:

See Figs. A-III-1 through A-III-5.
Note that not all configurations were tested for the test conditions listed below. The majority of the data were obtained for a 30° cone-cylinder body in combination with a number of rectangular wings with single panel aspect ratios varying from 0.25 to 1.33.

Test Conditions:

Mach Number - M = 1.50, 1.88, 2.00, and 3.23

Angle of Attack - α = -4° to 25°

Roll Attitude - ϕ = 0°, 15°, 30°, 45°

Wing Incidence - i_W = 0°, 10°, 20°

Tail Incidence - i_T = 0°, 10°, 20°

Reynolds Number -	M	Re/ft
OAL -	1.5	6.36×10^6
OAL -	2.0	7.56×10^6
NOL -	3.24	2.28×10^6

Type of Data Collected:

Stability models - Normal force, pitching moment, side force, yawing moment, and rolling moment.

Wing & Tail Hinge-Moment Model - Panel normal force, hinge moment, and spanwise bending moment.

Flow Survey - Data were obtained which completely defined the local flow at an axial station nearly three diameters behind the wing.

Availability of Data:

Single copy of the following OAL and NOL wind tunnel test reports in APL/JHU files:

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* Carried out by McDonnell Aircraft Corporation (MAC) under APL subcontract.

1. OAL 289 Series:

   a. "Investigation of Induced Roll and Longitudinal Stability Characteristics of a Generalized Missile Model at Mach Numbers 1.5 to 2.0."

OAL Report 289, -1, -2, -3	6/23/53
OAL Report 289-4, -7, -8, -10	8/5/55
OAL Report 289-5, -6, -9	1/28/55
OAL Report 289-11, -12, -13, -23, -24	8/16/55

   b. "Survey of the Flow Field Around a Generalized Missile Model at Mach Number 2.00."

OAL Report 289-14, -18, -19	4/19/56

2. NOL Series:

   a. WTR-316:

   "Generalized Missile Study: Static Stability and Control Wind Tunnel Data of the GMS Models at Mach Numbers of 1.88 and 3.23," NAVORD Report 4431, 2/24/58.

   b. WTR-354:

   "Generalized Missile Study: Tail Hinge Moment and Force Data for the GMS Models at a Mach Number of 3.24," NAVORD Report 4432, 12/2/58.

3. Wind Tunnel data reports per se are not available for the following tests; however, data plots are on file at APL in the form of MAC internal memoranda.

   a. OAL 465, -1, -4 Stability and control tests at M = 1.5 and 2.0. (MAC Memos AGM-20,-21, -25).

   b. OAL 465-3 Tail panel force and moment test at M = 1.5. (MAC memo AGM-24)

   c. NOL-WTR 403 Wing panel force and moment test at M = 3.24. (MAC memo AGM-30)

See Appendix D for more detailed information on wing and tail panel force and moment data.

<u>Reports on Data Analyses</u>:

1. "Generalized Missile Study - First Annual Report," A. R. Krenkel, APL/JHU CF-1996, May 29, 1953.

2. "Recent Developments in the Generalized Missile Study Program," A. R. Krenkel, APL/JHU TG 14-19, August 1953.

3. "Supersonic Induced Rolling Moment Characteristics of Cruciform Wing-Body Configurations at High Angles of Attack," APL/JHU CM-929, J. F. Mello, K. R. Sivier, Jan. 15, 1958.

4. "Supersonic Stability and Control Characteristics of Cruciform Wing-Body Configurations at High Angles of Attack," APL/JHU CM-950, J. F. Mello, J. Woods, June 15, 1959.

5. "Investigation of Very Low Aspect Ratio Cruciform Fins as a Means of Increasing the Body Lift Effectiveness of Supersonic Missile Configurations at High Angles of Attack," NAVORD Report No. 5904, Proceedings of the Fourth U. S. Navy Symposium on Aeroballistics, K. R. Sivier, May 1, 1958.

6. "Investigation of Normal Force Distributions and Wake Vortex Characteristics of Bodies of Revolution at Supersonic Speeds," APL/JHU CM-867, J. F. Mello, April 2, 1956.

The following MAC internal memoranda are also on file at APL/JHU.

1. MAC-AGM-29, "Analysis of the Normal Force and Pitching Moment Characteristics of GMS Configurations Having Cruciform Dorsals of Very Low Aspect Ratio," J. Woods, June 28, 1957.

2. MAC-AGM-33, "Analysis of the Normal Force Distributions on the Aftbody of a Cruciform Wing Plus Body Configuration at M = 2.00," J. Woods, May 2, 1958.

3. MAC-AGM-32, "Analysis of the Two-Dimensional Static Pressure Data Obtained on Cylinder Alone and Cruciform Finned-Cylinder Configurations in Supersonic Cross Flow," J. Woods, November 29, 1957.

<u>Suggestions for Further Analysis</u>:

1. Some selected sets of panel data may be of value to NASA in validating theoretical methods. A review of the NASA theoretical programs could be made so that data would be chosen over the ranges of validity of the theory. (See also Appendix D.)

2. A correlation of present NASA data in the Wing-Tail Interference program and the data in the GMS program could be carried out.

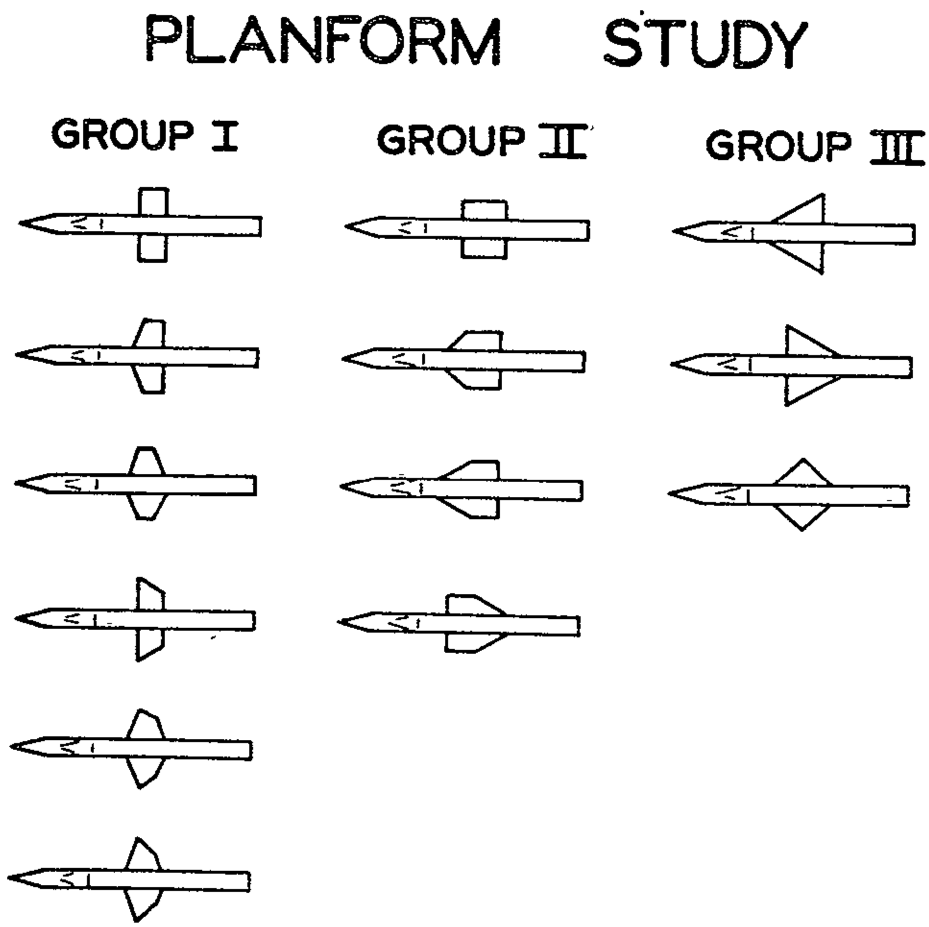

Fig. A-III-1 Generalized Missile Study - Wing Planform Configurations

GMS

MODEL GEOMETRY

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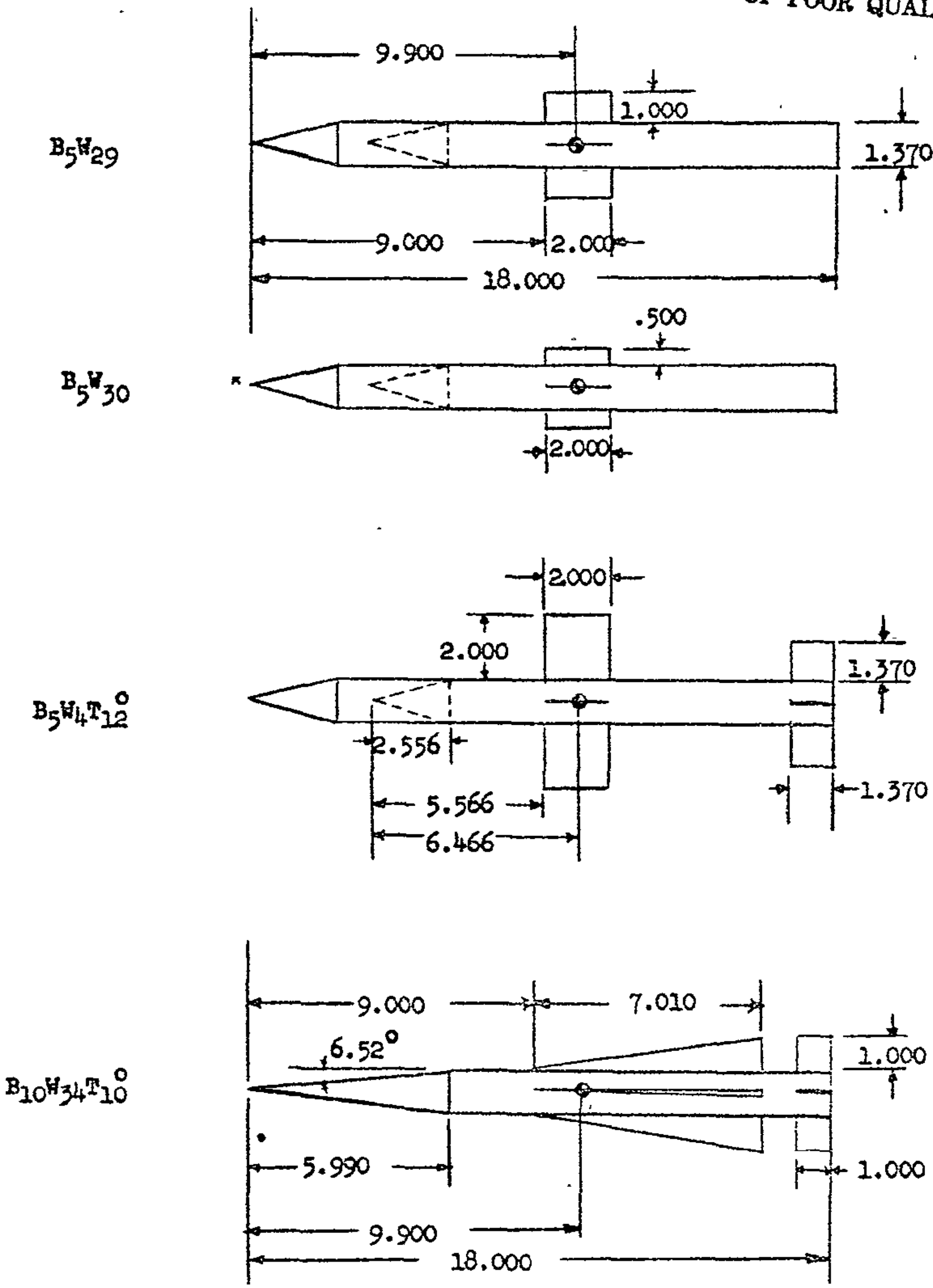
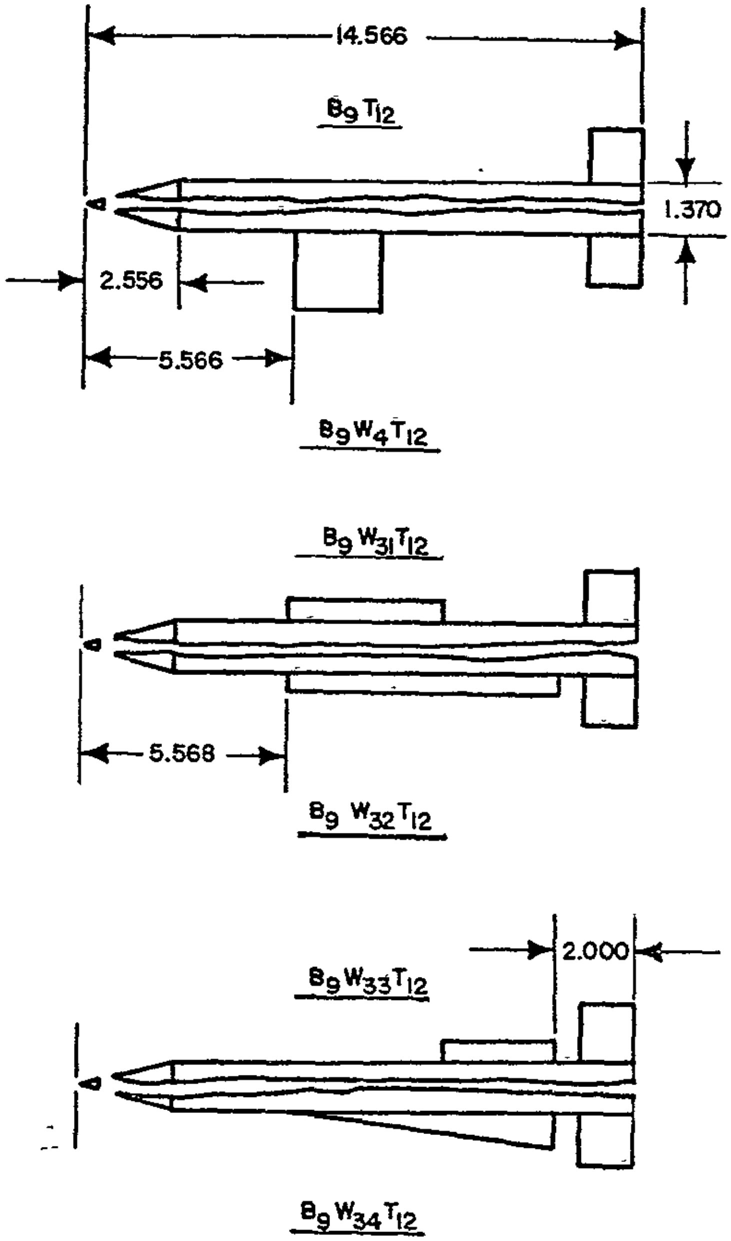


NOTES: Phantom outlines indicate B_9 nose location.
All dimensions are in inches.

Fig. A-III-2



(ALL DIMENSIONS ARE IN INCHES)

DRAWINGS OF THE GMS CONFIGURATIONS SHOWING PRINCIPAL DIMENSIONS

Fig. A-III-3

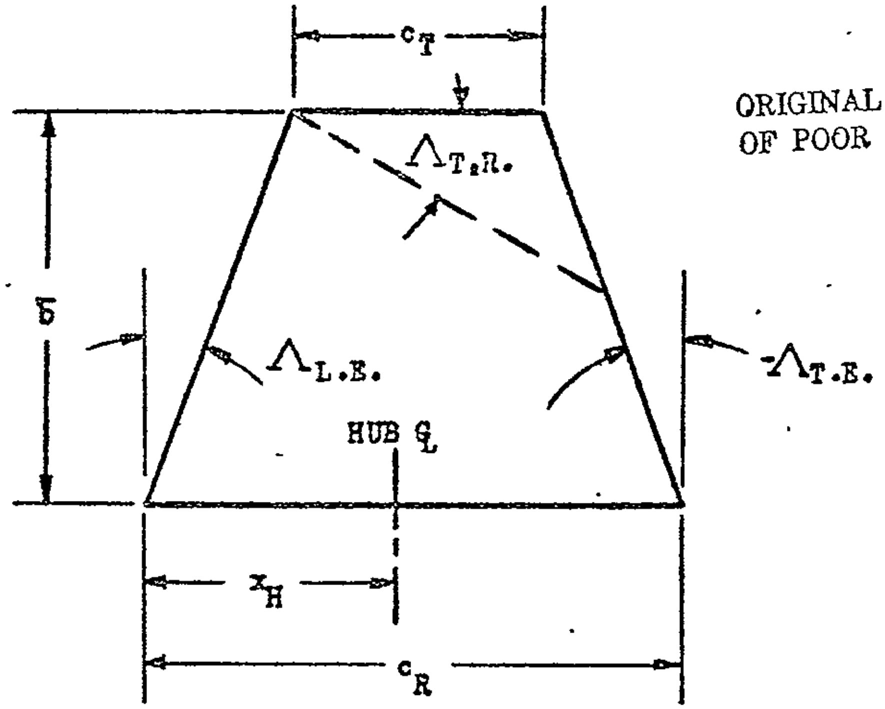


TABLE I

GMS WING DIMENSIONS

Wing	$\bar{b}$	c_R	c_T	x_H	$\Lambda_{L.E.}$	$\Lambda_{T.E.}$	$\Lambda_{T.R.}$	S_W (in.^{2})	$AR_{EXP.}$	AR
W_4	2.000	2.000	2.000	.900	0°	0°	0°	4.000	1.000	2.635
W_{12}	2.577	2.000	0	.835	0°	0°	30°	4.000	1.660	[illegible]
W_{13}	1.451	3.313	3.313	1.280	0°	0°	0°	4.807	.438	1.220
W_{14}	2.000	2.728	1.272	1.281	20°	-20°	0°	4.000	1.000	2.457
W_{15}	2.340	2.728	0	1.281	20°	-20°	30°	3.996	1.370	3.121
W_{16}	2.000	2.364	1.636	1.272	20°	0°	0°	4.000	1.000	2.566
W_{17}	2.350	4.070	0	2.720	60°	0°	0°	4.782	1.155	2.434
W_{18}	2.350	4.070	0	1.350	0°	-60°	0°	4.782	1.155	2.434
W_{19}	1.451	4.564	2.051	2.692	60°	0°	0°	4.799	.439	1.151
W_{20}	2.070	4.140	0	1.960	45°	-45°	0°	4.285	1.000	2.976
W_{21a}	1.451	4.036	2.585	2.222	45°	0°	0°	4.804	.438	1.206
W_{22}	1.451	4.564	2.051	1.872	0°	-60°	0°	4.799	.439	1.151
W_{23}	2.554	2.728	0	1.281	20°	-20°	45°	4.003	1.630	3.574

All wings have 6% thick modified double wedge airfoils, ($a = 1/3$), except wing W_4 which has 10% thick biconvex airfoil, and wings W_{19} and W_{22} which have 5% thick modified double wedge airfoils

Fig. A-III-4

GMS

BODY CONFIGURATIONS

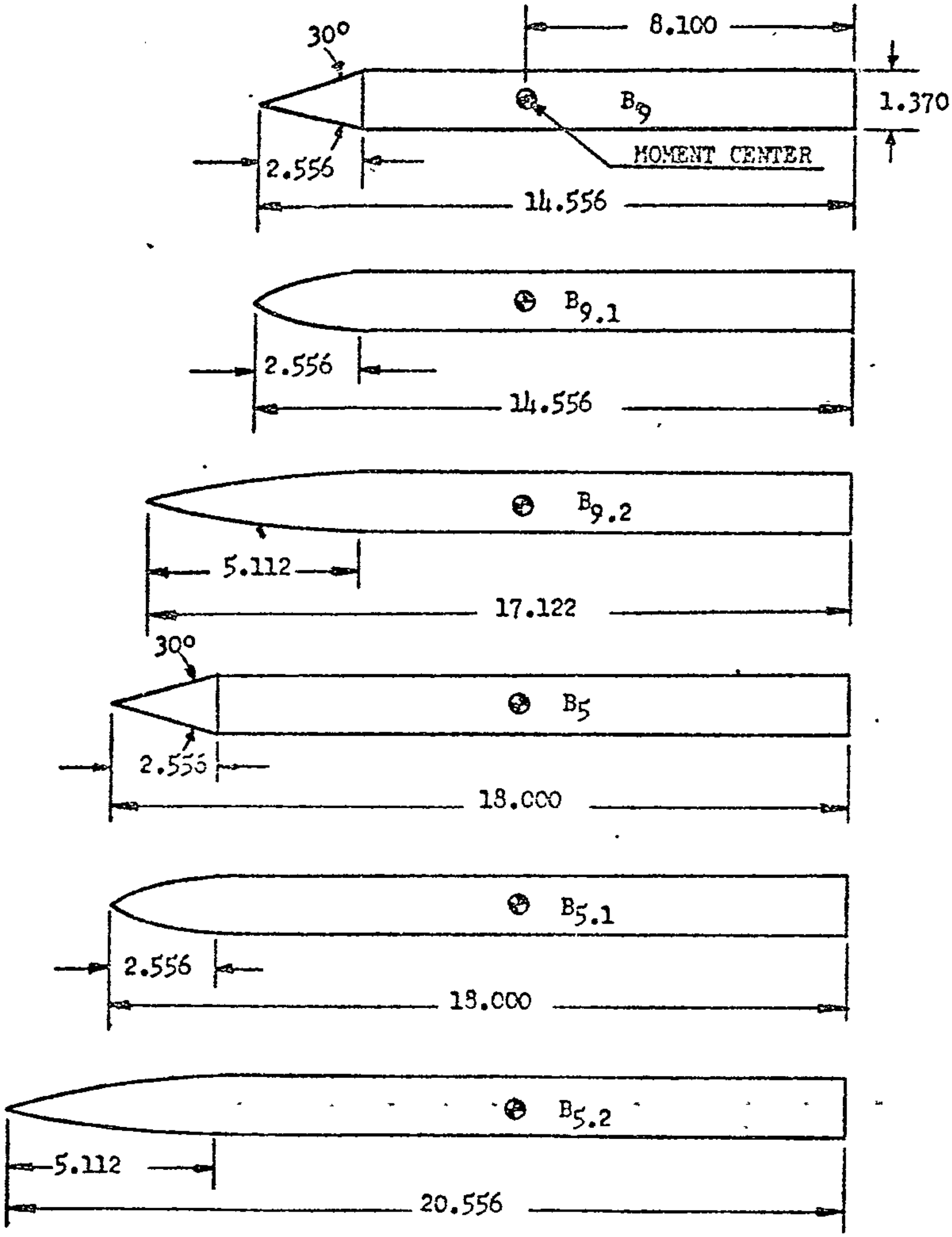


Fig. A-III-5

Appendix A - Wing-Tail Interference (Cont'd)

IV. Miscellaneous Empirical Studies of Tail Effectiveness

In addition to the planned research programs discussed previously, several empirical correlations of data (from many available missile programs) were carried out and published by the Bumblebee program in the following reports:

1. "Supersonic Downwash Configurations for Composite Configurations," R. J. Volluz, Ordnance Aerophysics Laboratory, Paper given at Bumblebee Aerodynamics Symposium, 4-5 November 1948, APL/JHU TG 10-4.

2. "Empirical Evaluation of Missile Tail Effectiveness at Supersonic Speeds," E. R. Hinz, Consolidated Vultee Aircraft Corporation, San Diego, California, April 1951, published as APL/JHU CM-652.

3. "Empirical Predictions of Tail Effectiveness at High Angles of Attack at Supersonic Speeds," J. DeBevoise and P. I. Dickey, Consolidated Bultee Aircraft Corporation, San Diego, California, May 1953, published as APL/JHU CF-2024. (This report extended the work of CM-652 to higher angles of attack---24°.)

Single hard copies of each report are held in the APL/JHU files.

Appendix B - Tail-Controlled Supersonic Configurations with Low-Aspect Ratio Wings

I. Terrier Program

As noted in the introduction to this report, the Aerodynamics program at APL/JHU over the past thirty years or so included a fundamental research effort in supersonic aerodynamics as well as a design task in developing both test vehicles and prototypes of tactical missiles. The Terrier, low-aspect-ratio, tail-controlled missile was one of these designs.

Configurations tested: See Figs. B-I-1 through B-I-4.

Typical parametric variations in missile configuration considered in this program are shown in Fig. B-I-1. Additional full configuration drawings are shown in Figs. B-I-2 through B-I-4.

As part of the Terrier program, various spin-off studies were made. One such study considered the use of reverse dart wings as shown in Fig. B-I-4.

Through the years, data have been collected on approximately 40 dorsal (strake) designs, 30 different bodies, 4 wings, and at least 2 tails. The body total length to diameter ratio varied from 9.7 to 13.8. Nose geometries included tangent and secant ogives, von Karman, and combination designs.

Test Conditions:

Mach Number - $M = 1.5$ to 5.0

Angle of Attack - $\alpha = 0°$ to $45°$

Roll Attitude - $\phi = 0°, 22.5°, 45°, 67.5°, 90°$. ϕ cuts at constant α.

Tail Incidence - $i = 0°, 5°, 10°, 15°, 20°, 25°, 30°$

Reynolds Number - $Re = 3$ to 12×10^6/ft.

Type of Data Collected:

Longitudinal and lateral five component stability and control. Tail panel loads and moments. Full and breakdown configurations.

Availability of Data:

Voluminous amounts in APL/JHU files.

Reports on Data Analyses:

This is a partial listing that typifies the type of information available.

Body Alone

1. APL/JHU CF-2806, "An Empirical Method of Predicting Normal Force and Center-of-Pressure Characteristics for Bodies of Revolution at Angles of Attack up to 24 Degrees at Supersonic Mach Numbers," P. T. Pilon, 8 May 1959.

Body-Tail

2. APL/JHU CF-3009, "The Supersonic Aerodynamic Force and Moment Characteristics of a Body-Tail Missile-Type Configuration and Its Component Surfaces," P. T. Pilon, November 30, 1962.

Full Configuration

3. BBA-1-156, "Supersonic Aerodynamic Characteristics of a Series of High-Lift, Low-Aspect-Ratio, Reverse-Dart Wings at Angles of Attack up to 20°," H. Ginsberg, January 29, 1960.

4. BBA-1-180, "Supersonic Longitudinal Stability, Control, and Trim Characteristics at Angles of Attack up to 24° of a Series of Body-Wing-Tail Configurations Having High-Lift, Low-Aspect-Ratio, Reverse-Dart Wings," H. Ginsberg, 8 June 1960.

5. BBA-TE-007-60, "Supersonic Lateral Stability, Control, and Trim Characteristics of a Series of Body-Wing-Tail Configurations Having Low-Aspect-Ratio, Reverse-Dart Wings at Angles of Attack up to 25 Degrees," H. Ginsberg, 30 November 1960.

6. APL/JHU CF-3032, "Supersonic Aerodynamic Stability, Control, and Trim Characteristics of the Terrier HT Missile (U)," L. E. Tisserand, 4 June 1963 (Confidential).

7. APL/JHU CF-3033, "Supersonic Aerodynamic Stability, Control, and Trim Characteristics of the Terrier BTN Missile (U)," L. E. Tisserand, 10 June 1963 (Confidential).

8. Paper #31, Vol. II, Proceedings of the 9th Navy Symposium on Aeroballistics, May 9-11, 1972 at APL/JHU, "Aerodynamic Characteristics for Computer Simulations of Three-Dimensional, Six-Degree-of-Freedom Missile Flights (U)," L. E. Tisserand (Confidential).

Note:

1. See Appendix D for information on individual surface aerodynamic characteristics.

Suggestions for Additional Analyses:

Since the publication of the noted analysis reports, more wind tunnel data have been obtained for some configurations. The following studies are indicated.

1. Body alone - Ref. 1.

   Extend analysis to higher Mach numbers and angles of attack ($M = 5.0$, $\alpha = 40°$).

2. Body-tail - Ref. 2.

   Extend analysis to higher Mach numbers and angles of attack ($M = 5.0$, $\alpha = 40°$).

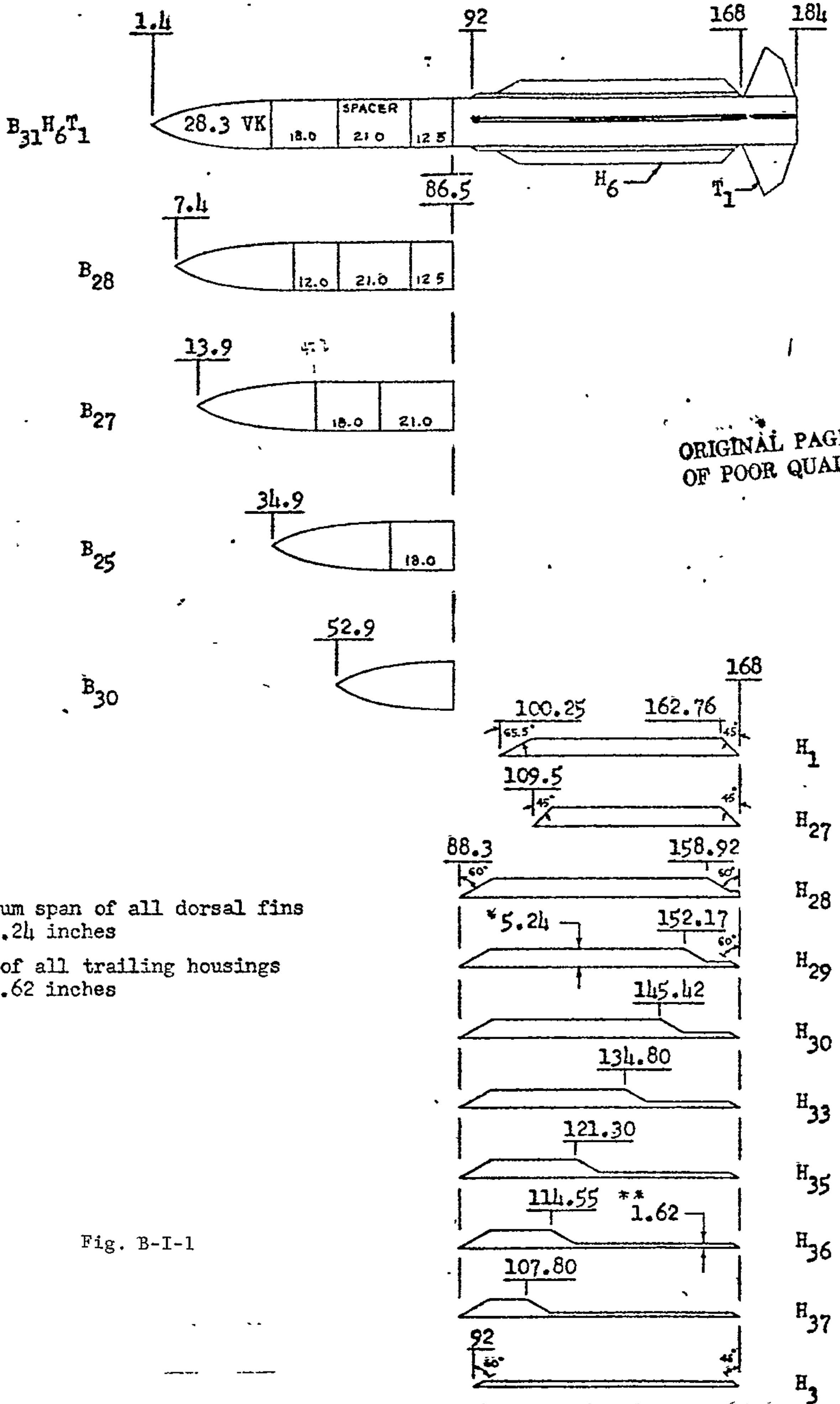
3. Full configuration, reverse dart wing - Refs. 3, 4, and 5.

   a. Report on wing alone data (in presence of body) is complete. Possible condensation of results into a few graphs.

   b. Summary report on effects of sweep, area, span, and longitudinal location on longitudinal stability and control should be made with the data presented.

   c. Summary report on effects of sweep, area, span, and longitudinal location on lateral stability and control at high angle of attack should be made with the data presented.

   d. Analysis of recently acquired data at higher Mach numbers and angles of attack (M to 5.0, α to 40°) should be carried out and the results summarized for inclusion in Items b and c.



mum span of all dorsal fins
5.24 inches

of all trailing housings
1.62 inches

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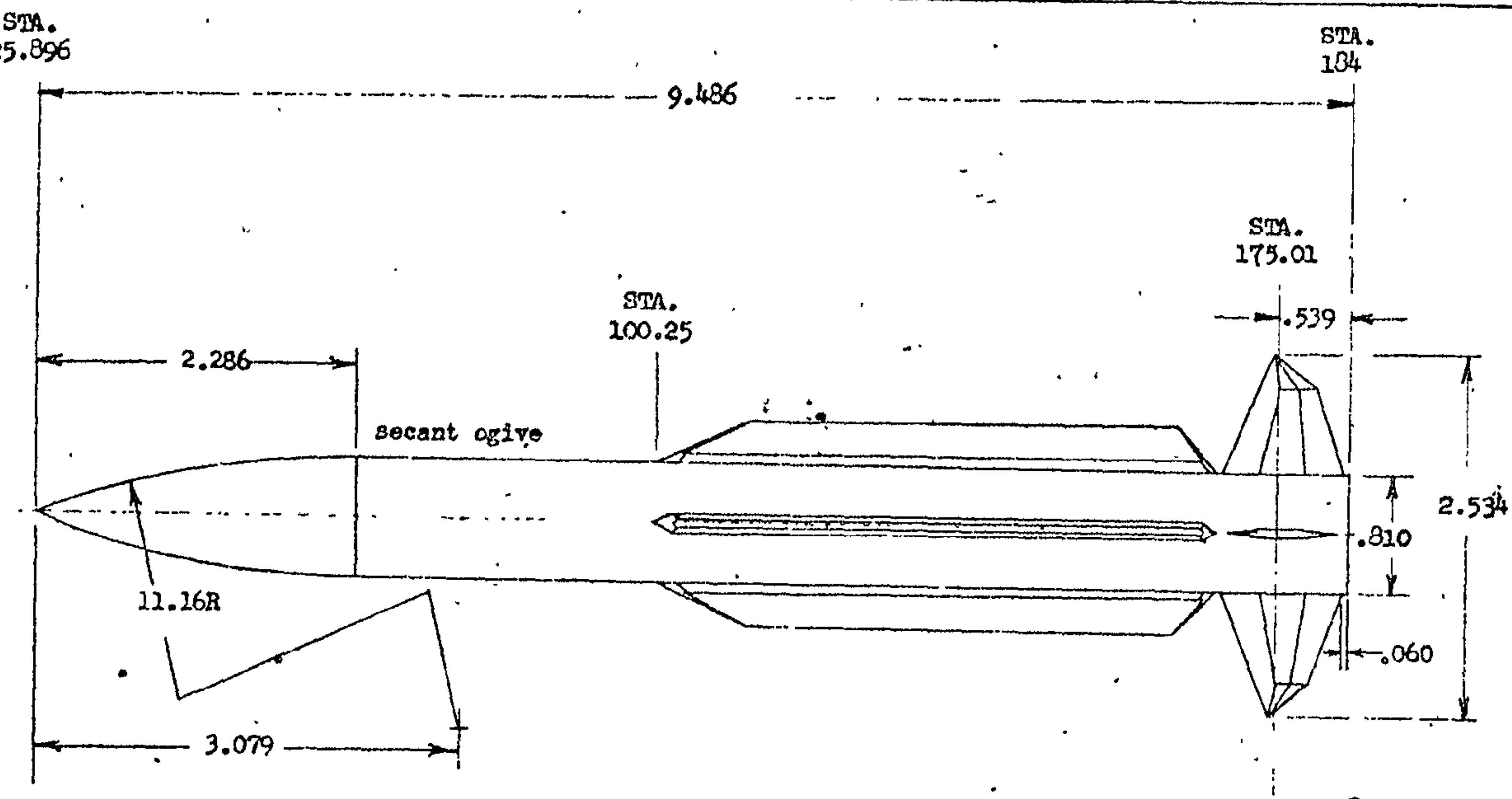
Fig. B-I-1

TERRIER Configurations Tested in HST 065-5
All dimensions are in inches (full missile scale)



CONFIGURATION $B_1 H_1 T_1$

$\phi = 0^o$

4 DORSALS

FIG. B-I-2 GENERAL ARRANGEMENT SKETCH OF THE 0.06-SCALE ADVANCED TERRIER (BT) MODEL

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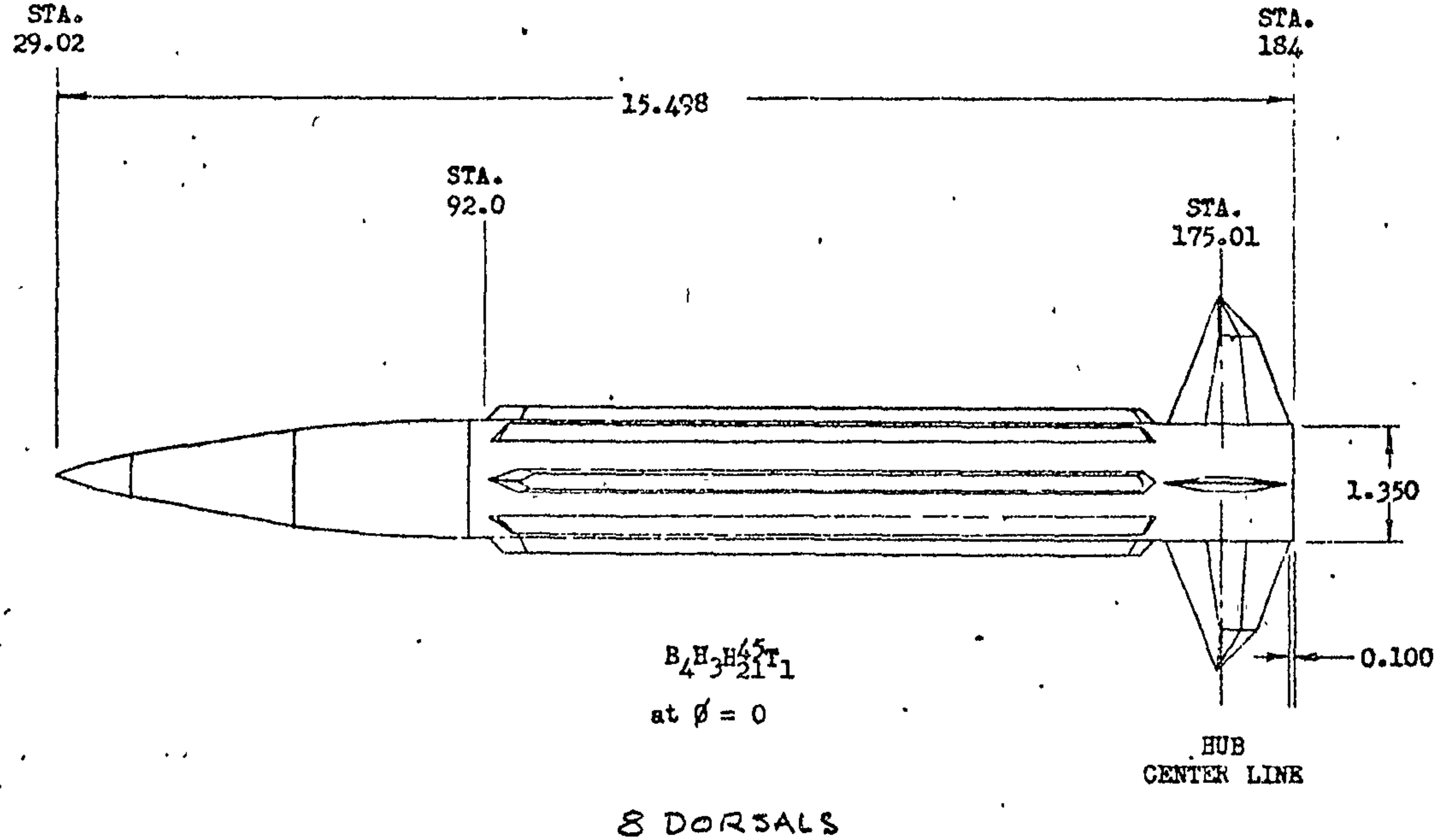
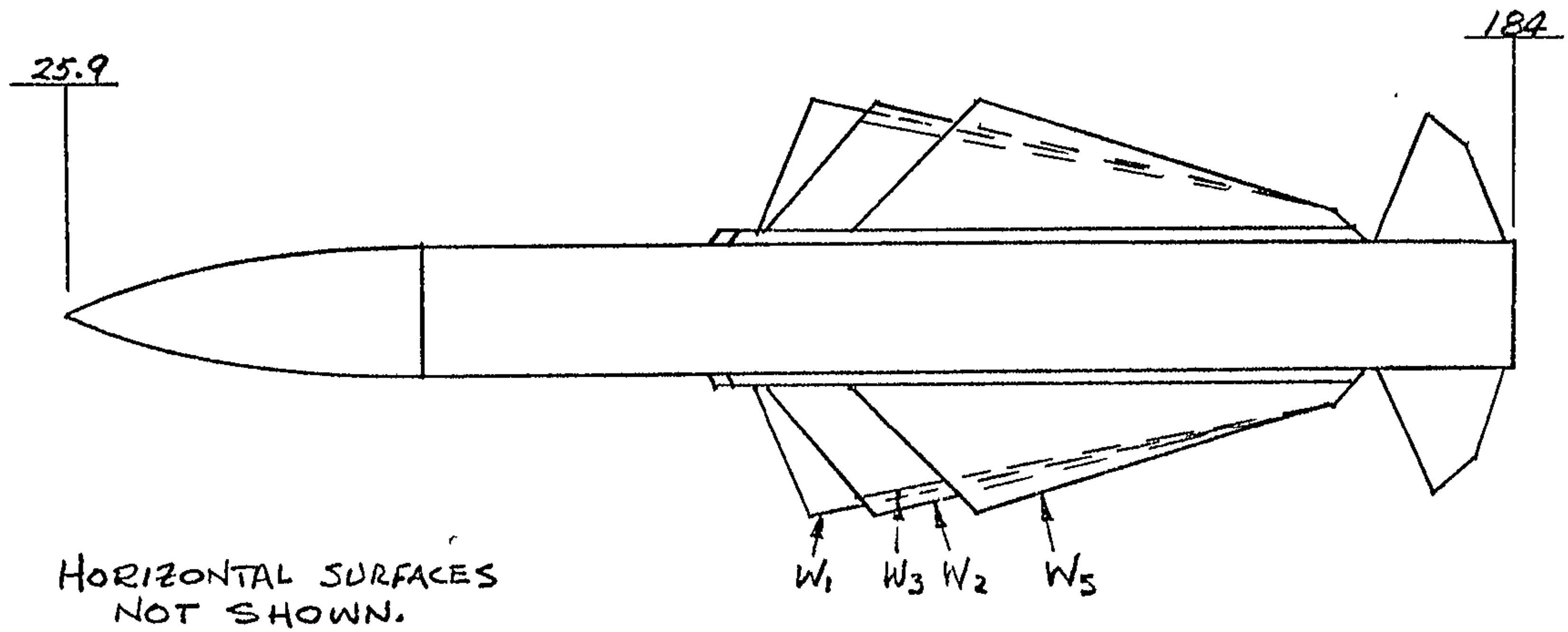


Fig. B-I-3 GENERAL ASSEMBLY SKETCH OF THE 1/10-SCALE

TERRIER

REVERSE DART WINGS



$B_1 W_x T_1$

FIG. B-I-4

Appendix B - Tail-Controlled Supersonic Configurations with Low-Aspect Ratio Wings (Cont'd)

II. Other Programs

The Tartar and Typhon MR programs provide much data on configurations similar to those tested in the Terrier program, but over a Mach number range covering the subsonic and supersonic regimes.

The Standard Missile ER and MR programs have provided data over slightly extended ranges in Mach number and angle of attack.

Appendix C - Supersonic Airbreathing Configurations

This Appendix will include only those supersonic airbreathing configurations with side-mounted inlets which are of interest to NASA. There are available many data reports on configurations with nose inlets such as Talos and Typhon LR.

I. Bumblebee Integral Rocket-Ramjet Surface-to-Air Missile Program (IRR-SAM)

Configurations tested: See Fig. C-I-1.

Using the basic configuration of Fig. C-I-1, tests were made with two (2) longitudinal locations of the inlets, two (2) total body lengths, two (2) low aspect ratio wing chords, and two (2) tails of similar planform.

Test Conditions:

Mach number - M = 0.5 to 4.0

Angle of Attack - $-8° < \alpha < 25°$

Roll Attitude - ϕ = -45°, +45° (also roll cuts at constant α)

Tail Incidence - i = -0°, -10°, -20°

Reynolds Number - Re = 2.5 to 12 X 10^6 per ft.

Type of Data Collected:

Six-component stability, control, and drag data on full configurations and breakdowns (except body alone, which exists from other programs).

Availability of Data:

Single hard copy of following reports in APL/JHU files.

1. NOL Test WTR 943, "Static Stability and Control of the Integral Rocket-Ramjet Surface-to-Air Missile (IRR-SAM) at Mach Numbers of 2.76 and 4.00," 1966.
2. General Dynamics/Convair HST-TR-199-0, "A High Speed Wind Tunnel Test of the 1/10-Scale Integral Rocket-Ramjet Missile Model," 1967.
3. NOL Test WTR 1066, "Side Inlet Configuration Stability and Control Test at Mach 2.77, 3.5, and 4.11," 1969.

Reports on Data Analyses:

1. Paper No. 3, Vol. II, Proceedings of the 9th Navy Symposium on Aeroballistics, May 9-11, 1972, at APL/JHU, "Aerodynamic Characteristics of Missile Configurations with Side-Mounted Ramjet Inlets (U)," W. H. Rauser (Confidential).

Single hard copies of the following internal memoranda in APL/JHU files.

1. BBA-AS-003-68, "Component Effects of Inlets and Boundary-Layer Diverters on the Longitudinal Stability Characteristics of a Body Aft-Inlet Configuration at Mach Number 2.77 (U)," W. H. Rauser, 12 July 1968 (Confidential).

2. BBA-AS-007-68, "Longitudinal Static Stability and Control Characteristics at Mach 0.5 for an Aft-Entry Ramjet Missile with Blocked Inlets (U)," W. H. Rauser, 22 August 1968 (Confidential).

3. BBA-AS-003-69, "Longitudinal Static Stability and Control Characteristics at Mach 2.77 for Side-Inlet Configurations of Varying Body Length and Inlet Location (U)," W. H. Rauser, 11 March 1969 (Confidential).

4. BBA-AS-010-69, "Component Effects of Tails, Dorsals, and Side-Mounted Inlets at Mach 2.77 (U)," W. H. Rauser, 15 July 1969 (Confidential).

5. BBA-AS-012-69, "Longitudinal and Static Stability and Control Characteristics at Mach 2.01 and 4.11 for a Side-Inlet Configuration (U)," W. H. Rauser, 12 August 1969 (Confidential).

6. BBA-2-70-003, "Longitudinal Static Stability and Control Characteristics for a Side-Inlet Configuration at Mach 0.9, 1.1, and 1.5 (U)," W. H. Rauser, 10 February 1970 (Confidential).

7. BBA-2-70-016, "Longitudinal Static Stability and Control Characteristics of a Side-Inlet Configuration at Mach 2.77 (U)," W. H. Rauser, 28 July 1970 (Confidential).

Suggestions for Further Analyses:

The data analyses given in the above internal memoranda could be consolidated into a single summary report presenting the characteristics of the basic configuration and the observed effects of the parametric variations of model components.

INTEGRAL ROCKET RAMJET – IRRSAM

(180 INCH LENGTH CONFIGURATION)

Note: 1/10-Scale Model Used. Full-Scale Stations Given.

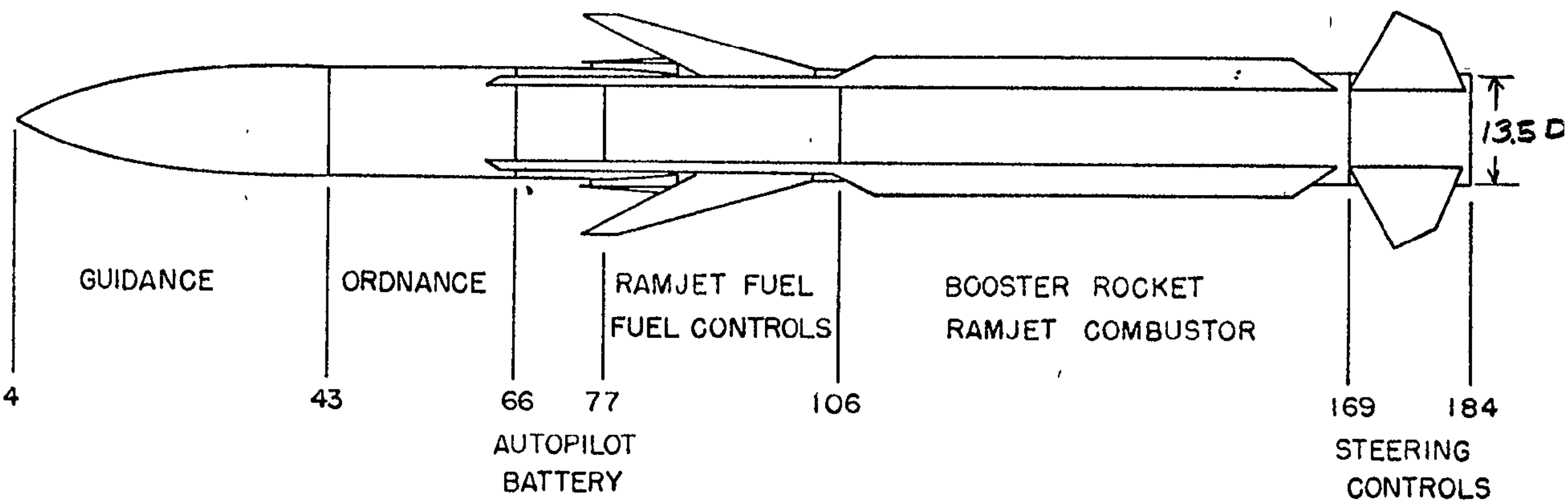


Fig. C-I-1 IRR-SAM Configuration

Appendix C - Supersonic Airbreathing Configurations (Cont'd)

II. Bumblebee Thrust-Augmented-Rocket, Surface-to-Air Missile Program (TAR-SAM)

Configurations tested: See Fig. C-II-1.

This is the basic TAR-SAM configuration for which most of the data apply. Some data are available for this configuration with a delta planform tail surface.

Test Conditions:

Mach Number - M = 3.0, 4.0

Angle of Attack - α = -4° to 20°

Roll Attitude - ϕ = 0°, 22.5°, 45°, 90° and ϕ cuts at constant α.

Tail Incidence - i = +15°, +10°, 0°, -5°, -10°, -15°, -20°

Reynolds Number - Re = 8.5 to 12 X 10^6 per ft.

Type of Data Collected:

Six-component stability, control, and drag data on full configuration and breakdowns. Control surface normal force, hinge moment and bending moment.

Availability of Data:

Single copy of following wind tunnel reports in APL/JHU files.

1. General Dynamics/Convair HST-TR-258-0, "Wind Tunnel Test of a 2/9-Scale ATP Force Model," 1968.

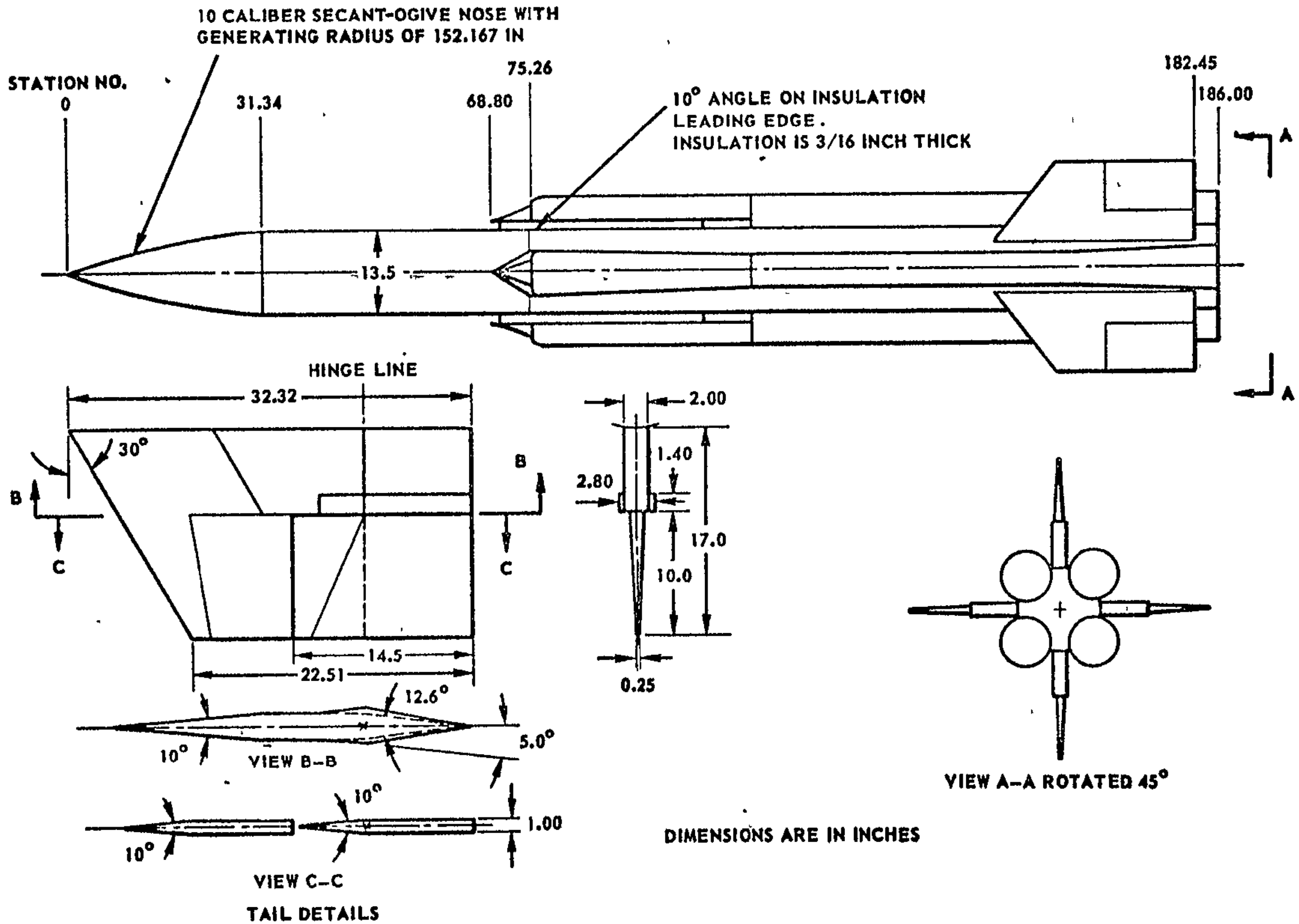
2. General Dynamics.Convair HST-TR-272-0, -1, "Wind Tunnel Tests of a 2/9-Scale ATP TTV-2 Force Model," 1969.

Reports on Data Analysis:

1. "TAR-SAM ER External Aerodynamic Characteristics," APL/JHU TG-1109, R. J. Vendemia, Jr., April 1970 (Confidential).

Suggestions for Additional Analysis:

Above analysis provides a complete description of TARSAM aerodynamic characteristics.



TAR-SAM

FIG. C-II-1

Appendix C - Supersonic Airbreathing Configurations (Cont'd)

III. Triton

Configurations tested:

Examples of several concepts of the Triton missile are given in Fig. C-III-1.

Test Conditions:

Mach Number - $M = 2.0$ to 4.8

Angle of Attack - $\alpha = -8°$ to $12°$

Roll Attitude - $\phi = 0°, 10°, 20°, 90°$

Tail Incidence - $i_T = 0°, -5°$

Reynolds Number - $Re = 7$ to 12×10^6/ft.

Type of Data Collected:

Longitudinal and lateral stability and control, drag, and panel loads and moments. Full configuration and breakdown.

Availability of Data:

Following is a partial list of wind tunnel data reports on file in the APL/JHU Document Library.

OAL Tests:

1. 346, -1, "Stability, Control, and Drag Tests of Several 1/32-Scale Asymmetric Triton Models at Mach Number 2.00 and 2.50."
2. 460-2, "Lift, Drag, and Stability Tests of Several 1/24-Scale Triton Configurations at Mach Number 2.5."
3. 388, -1 through -11, "Stability, Control, and Drag Tests of 1/20 and 1/32-Scale Triton Models at Mach Numbers 2.0, 2.5, and 2.77."
4. 532, -1 through -5, "Stability, Control, and Drag Tests of Several 1/21-Scale Triton SN-1 Configurations at Mach Numbers 2.23, 2.50, and 2.77."

Reports on Data Analyses:

The following list of APL/JHU internal memoranda exemplifies the type of information available.

1. APL/JHU, TRCM-1-56-30, "Stability and Control Characteristics of the Triton SN-1 Missile," T. A. McCarty, December 13, 1956.

2. APL/JHU, TRCM-1-56-24, "Aerodynamic Data for the Triton SN-1 Missile at Mach Numbers of 2.5, 2.77, 3.24, and 4.10," T. A. McCarty, October 15, 1956.

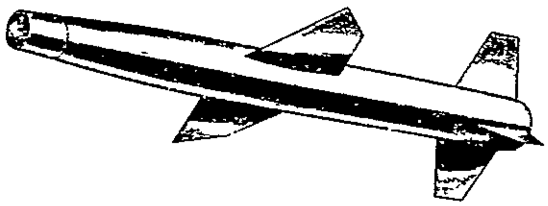
3. APL/JHU, TRCM-1-56-13, "Triton SN-1 Wind Tunnel Data for OAL Test 532 at a Mach Number of 2.77," T. A. McCarty, August 29, 1956.

4. APL/JHU, TRCM-1-57-10, "Triton SN-1, Summary Cross Plots of Axial and Normal Force Data as Functions of Angle of Attack, Elevator Deflection and Mach Number," I.D.V. Faro, May 23, 1957.

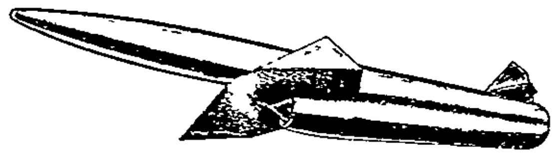
Suggestions for Additional Analyses:

It may be of use to compile enough summary graphs for several of the Triton configurations to depict adequately the aerodynamic characteristics of this type of airbreather design.

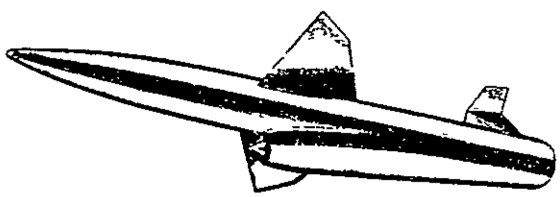
Nose Inlet



Underslung Inlet
Low Wing



Underslung Inlet
Mid Wing



Two Side Mounted
Engines

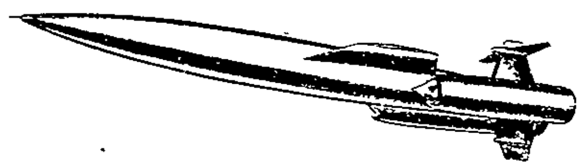


Fig. C-III-1, Evolution of Triton Aerodynamic Configuration

Appendix D - Panel Loads and Flow Field Surveys

I. Roll Reversal Investigation - Flow Inclination

As part of the Roll Reversal Investigation (see Appendix A-I), flow inclination measurements were made at various positions aft of differentially deflected roll flippers.

Configurations tested, test conditions, etc., are given in Appendix A-I and will not be repeated here.

Results of the flow inclination study are given in Data Reports 2 and 3, and the noted Data Analysis Report given in Appendix A-I.

Appendix D - Panel Loads and Flow Field Surveys (Cont'd)

II. Bodies of Revolution - Normal Force Distributions and Wake Vortex Characteristics

This is part of the Generalized Missile Study. See Appendix A-III.

Configurations tested:

See Figs. D-II-1 through D-II-4. Most test data were obtained for cone-cylinder models.

Test Conditions:

Series 1. Force and Moment Tests

Mach Number - M = 1.5, 2.00
Angle of Attack - α = -4° to 23°
Roll Attitude - ϕ = 0°, 15°, 30°, 45°
Reynolds Number - Re = 6.36 and 7.56 X 10^6/ft.

Series 2. Static Pressure Tests

Mach Number - M = 2.0
Angle of Attack - α = 0°, 4°, 8°, 12°, 16°, 20°, 23°
Roll Attitude - ϕ = 0°, 10°, 25° at each α
Reynolds Number - Re = 7.56 X 10^6/ft.

Series 3. Flow Survey Tests

Mach Number - M = 1.5, 2.0
Angle of Attack - α = 0°, 4°, 8°, 12°, 16°, 20°, 23°
Roll Attitude - ϕ = not applicable
Reynolds Number - Re = 6.36 and 7.56 X 10^6/ft.

Type of Data Collected:

Series 1. Normal force and pitching moment for bodies shown in Fig. D-II-1.

Series 2. Static pressure distribution for configuration shown in Fig. D-II-2.

Series 3. See Fig. D-II-3 and 4 for body design. Qualitative definition of body leeward wake. Local flow field completely defined at M = 2.0.

Availability of Data:

A copy of the following wind tunnel reports on file at APL/JHU.

1. OAL 289 Series:

   a. "Investigation of Induced Roll and Longitudinal Stability Characteristics of a Generalized Missile Model at Mach Numbers 1.5 and 2.0."

OAL Report 289, -1, -2, -3	6/23/53
OAL Report 289-4, -7, -8, -10	8/5/55
OAL Report 289-5, -6, -9	1/28/55
OAL Report 289-11, -12, -13, -23, -24	8/16/55

   b. "Survey of the Flow Field Around a Generalized Missile Model at Mach Number 2.0."

OAL Report 289-14, -18, -19	4/19/56

Reports on Data Analyses:

Following report on file at APL/JHU.

1. APL/JHU Report CM-867, "Investigation of Normal-Force Distributions and Wake Vortex Characteristics of Bodies of Revolution at Supersonic Speeds," John J. Mello, 2 April 1956.

Suggestions for Further Analyses:

Above report presents a partial analysis of the subject study.

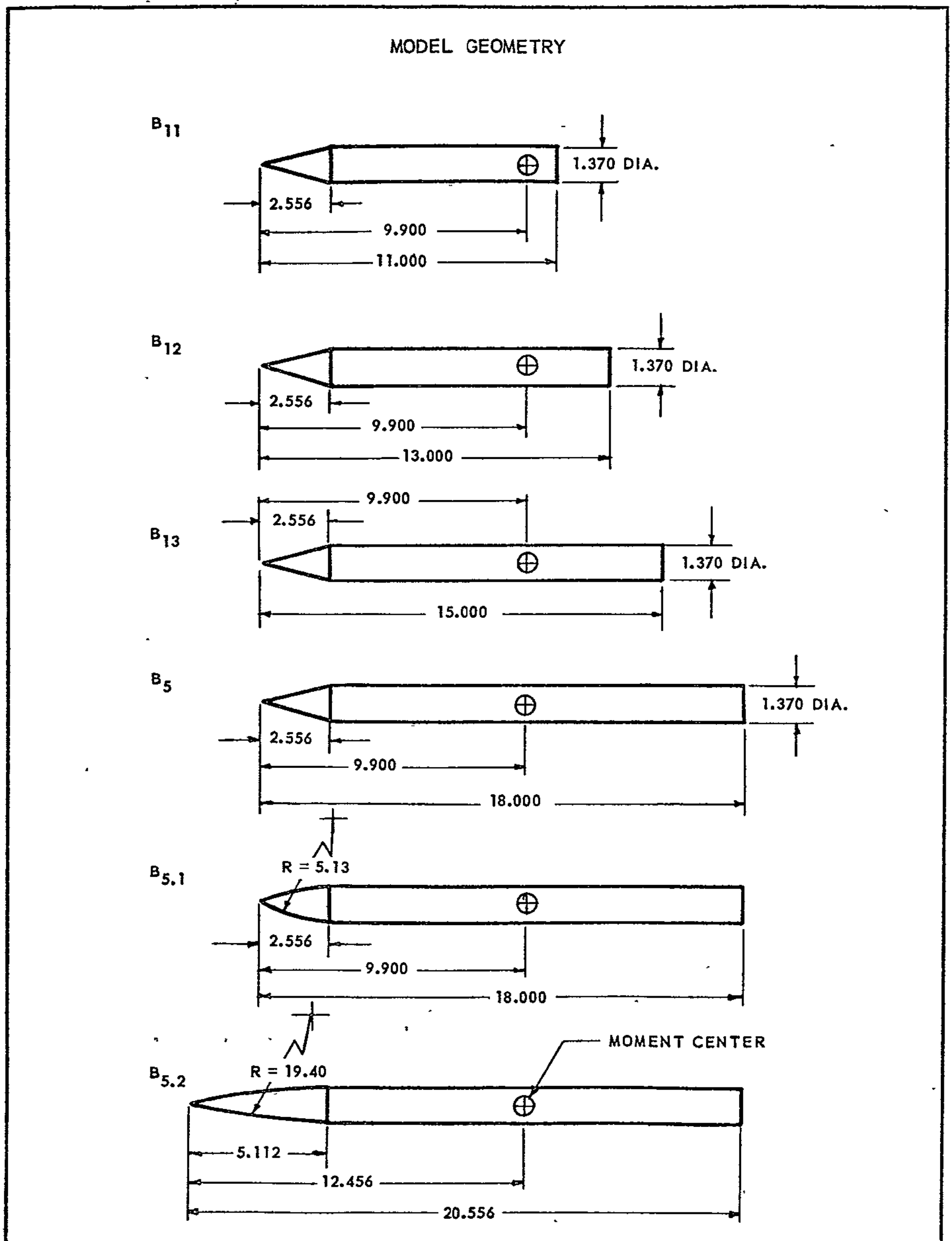
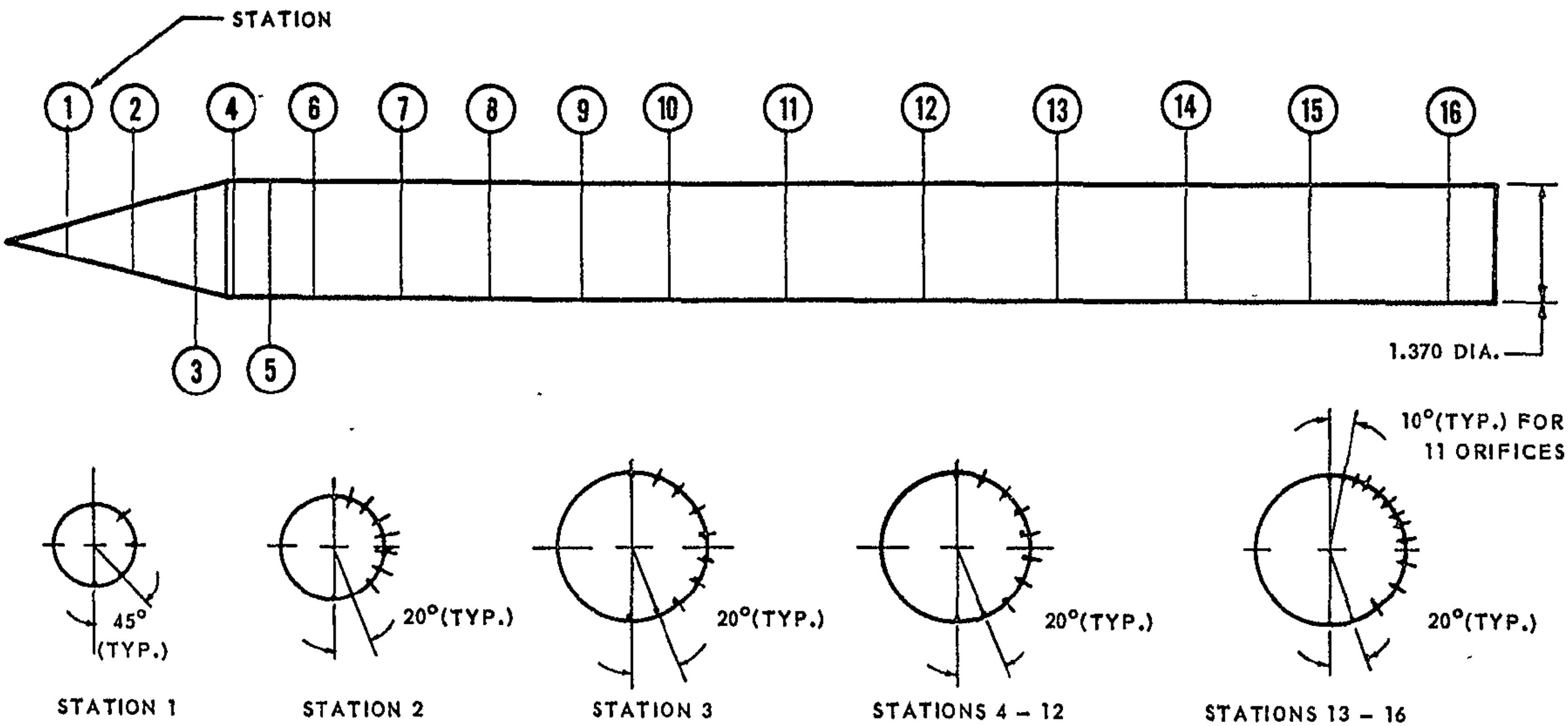

MODEL GEOMETRY
B11
1.370 DIA.
2.556
9.900
11.000
B12
1.370 DIA.
2.556
9.900
13.000
9.900
2.556
B13
1.370 DIA.
15.000
B5
1.370 DIA.
2.556
9.900
18.000
B5.1
R = 5.13
2.556
9.900
18.000
MOMENT CENTER
B5.2
R = 19.40
5.112
12.456
20.556

FIG. D-II-1

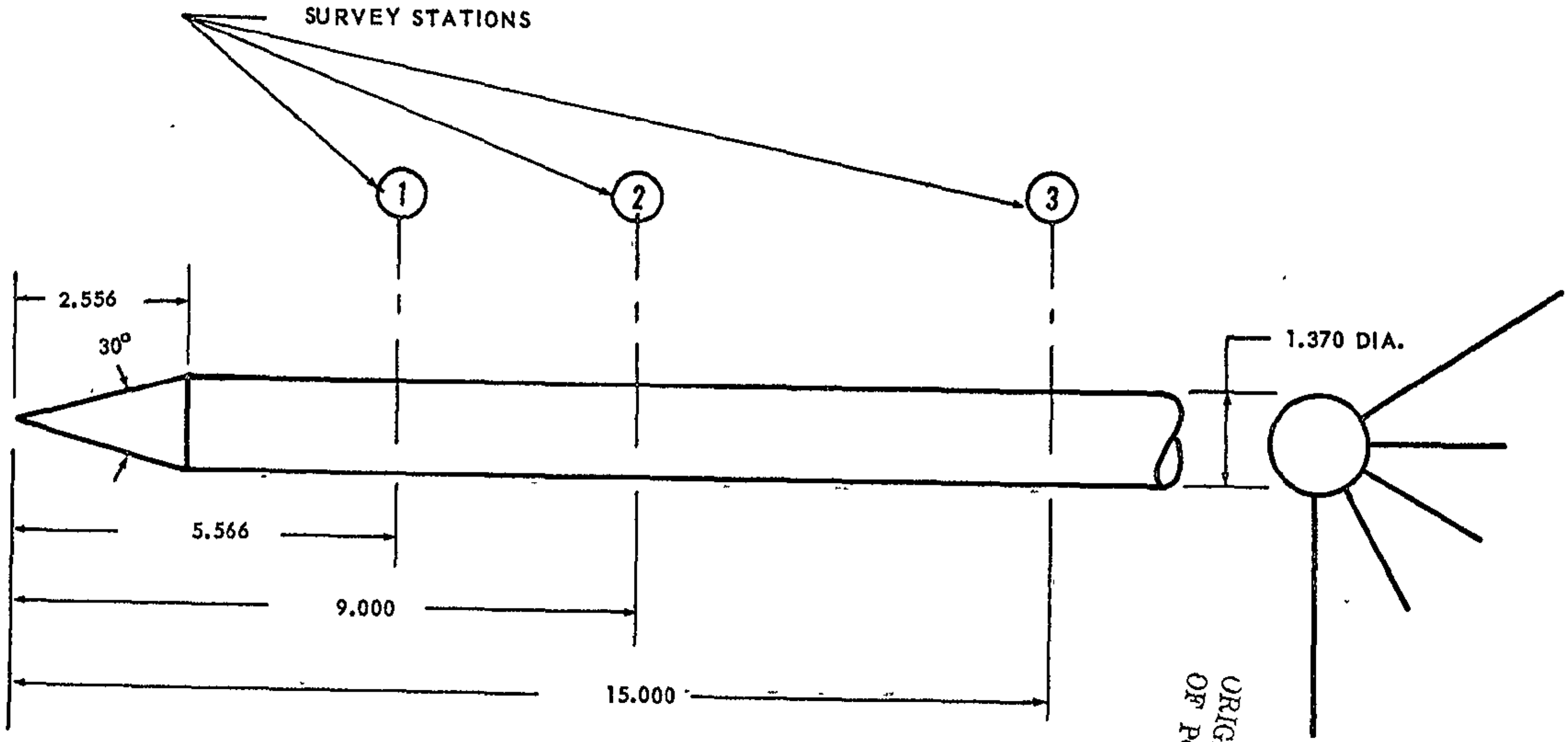
STATIC PRESSURE MODEL GEOMETRY



STATION	X (INCHES)	ORIFICE	STATION	X (INCHES)	ORIFICE	STATION	X (INCHES)	ORIFICE
1	.750	1–5	7	4.566	51–59	13	12.066	105–119
2	1.500	6–14	8	5.566	60–68	14	13.566	120–134
3	2.250	15–23	9	6.566	69–77	15	15.000	135–149
4	2.620	24–32	10	7.566	78–86	16	16.566	150–164
5	3.066	33–41	11	9.000	87–95	BASE	17.00	—
6	3.566	42–50	12	10.566	96–104			

Fig. D-II-2

FLOW SURVEY MODEL GEOMETRY

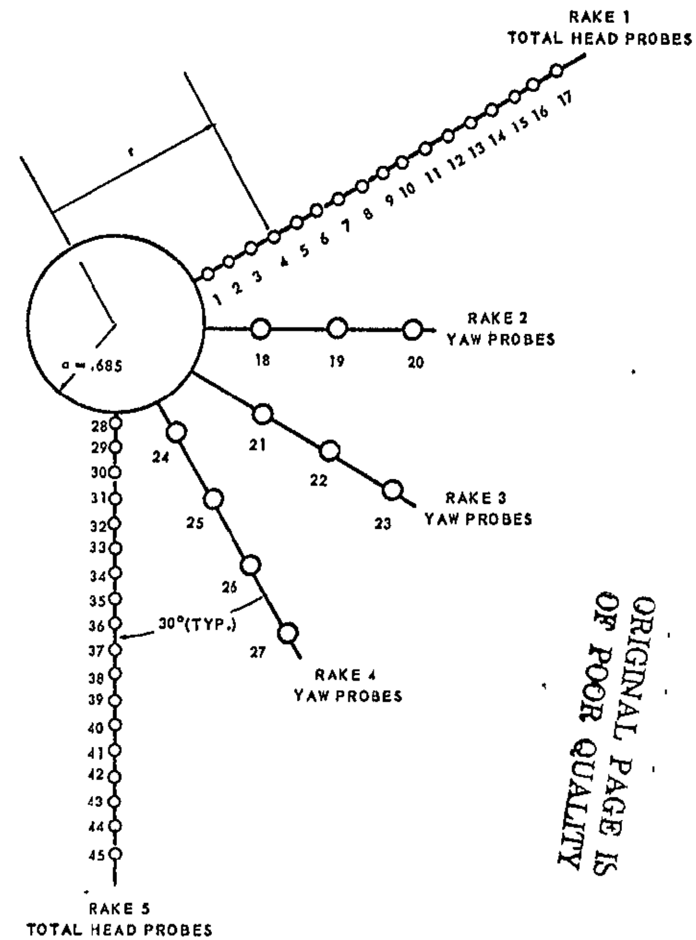


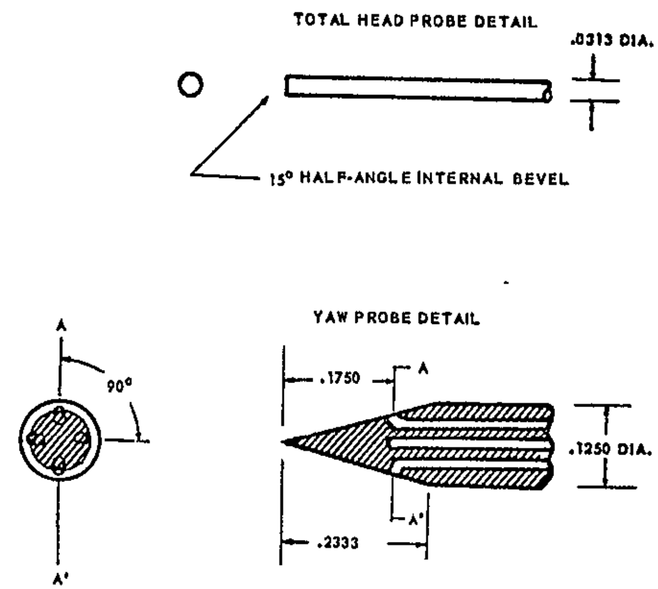
NOTE: ALL DIMENSIONS IN INCHES EXCEPT AS NOTED

Fig. D-II-3

FLOW SURVEY INSTRUMENTATION DETAIL

PROBE NUMBER	r/a	PROBE NUMBER	r/a
1	1 247	24	1.393
2	1 539	25	2 269
3	1 831	26	3.144
4	2 123	27	4 020
5	2 414	28	1 001
6	2 706	29	1 393
7	2.998	30	1.685
8	3 291	31	1 977
9	3 582	32	2.269
10	3 874	33	2.561
11	4 166	34	2 853
12	4 458	35	3.144
13	4 750	36	3 436
14	5 042	37	3.728
15	5 334	38	4 020
16	5 626	39	4 312
17	5 918	40	4 604
18	1 685	41	4 896
19	2 561	42	5 188
20	3 436	43	5 480
21	1 977	44	5 772
22	2 853	45	6 064
23	3 728		





NOTES:
1. ALL DIMENSIONS IN INCHES EXCEPT AS NOTED
2. TOTAL HEAD AND YAW PROBE DETAIL SCALE 5:1

Fig. D-II-4

Appendix D - Panel Loads and Flow Field Studies (Cont'd)

III. Very Low Aspect Ratio Lifting Surfaces

Configurations tested: See Fig. D-V-1.

Test Conditions:

Mach Number - $M = 1.5$ to 3.87

Angle of Attack - $\alpha = 0°$ to $24°$

Roll Attitude - $\phi = 0°, 22.5°, 45°$ (and ϕ cuts)

Reynolds Number - $Re = 3$ to 7×10^6 per ft.

Type of Data Collected:

Total configuration and breakdown normal force, pitching moment, side force, yawing moment, rolling moment. Wing normal force and center of pressure.

Availability of Data:

A copy of each of the following wind tunnel data reports is in APL/JHU files.

1. Convair, A Division of General Dynamics Corporation, Ordnance Aerophysics Laboratory, OAL Report No. 449, 449-1, Housing-Load and Center of Pressure Tests of a 1/10-Scale Advanced Terrier (VT) Model at Mach Numbers 1.50 and 2.50, by D. P. Cumming and R. C. Raedeker, February 1956.

2. Convair, A Division of General Dynamics Corporation, Ordnance Aerophysics Laboratory, OAL Report No. 449-2, Dorsal Load and Center of Pressure Tests of a 1/10-Scale Advanced Terrier Model at Mach Number 2.50, by M. D. Bennet and A. L. Taylor, July 1956.

3. Convair, A Division of General Dynamics Corporation, Ordnance Aerophysics Laboratory, OAL Report No. 449-3, Dorsal Load and Center of Pressure Tests of a 1/10-Scale Advanced Terrier Model at Mach Number 1.50, by M. D. Bennet and R. B. Lawrence, October 1956.

4. Convair, A Division of General Dynamics Corporation, Ordnance Aerophysics Laboratory, OAL Report No. 449-4, 449-5, Dorsal Load and Center of Pressure Tests of a 1/10-Scale Advanced Terrier Model at Mach Numbers 1.50 and 2.50, by E. R. Wilson and E. J. Martin, September 1957.

5. Convair, A Division of General Dynamics Corporation, Ordnance Aerophysics Laboratory, OAL Report No. 509-1, Dorsal Load and Center of Pressure Tests of a 1/10-Scale Tartar I Model at Mach Number 1.50, by M. D. Bennet and C. J. Essmeier, May 1956.

6. U. S. Naval Ordnance Laboratory, White Oak, Maryland, Preliminary Data from NOL WTR 296, "Dorsal Load and Center of Pressure Tests of a 1/10-Scale Advanced Terrier Model at Mach Number 2.50, 3.24, and 3.83," 1955.

7. U. S. Naval Ordnance Laboratory, White Oak, Maryland, Preliminary Data from NOL WTR 377, "Dorsal Load and Center of Pressure Tests of a 1/10-Scale Advanced Terrier Model at Mach Number 3.24," 1957.

Reports on Data Analysis:

1. "An Aerodynamic Study of Very-Low-Aspect Ratio Nearly Rectangular Lifting Surfaces at Supersonic Speeds," APL/JHU CM-931, H. H. Hart, February 1958. (See attached Abstract of this report.)

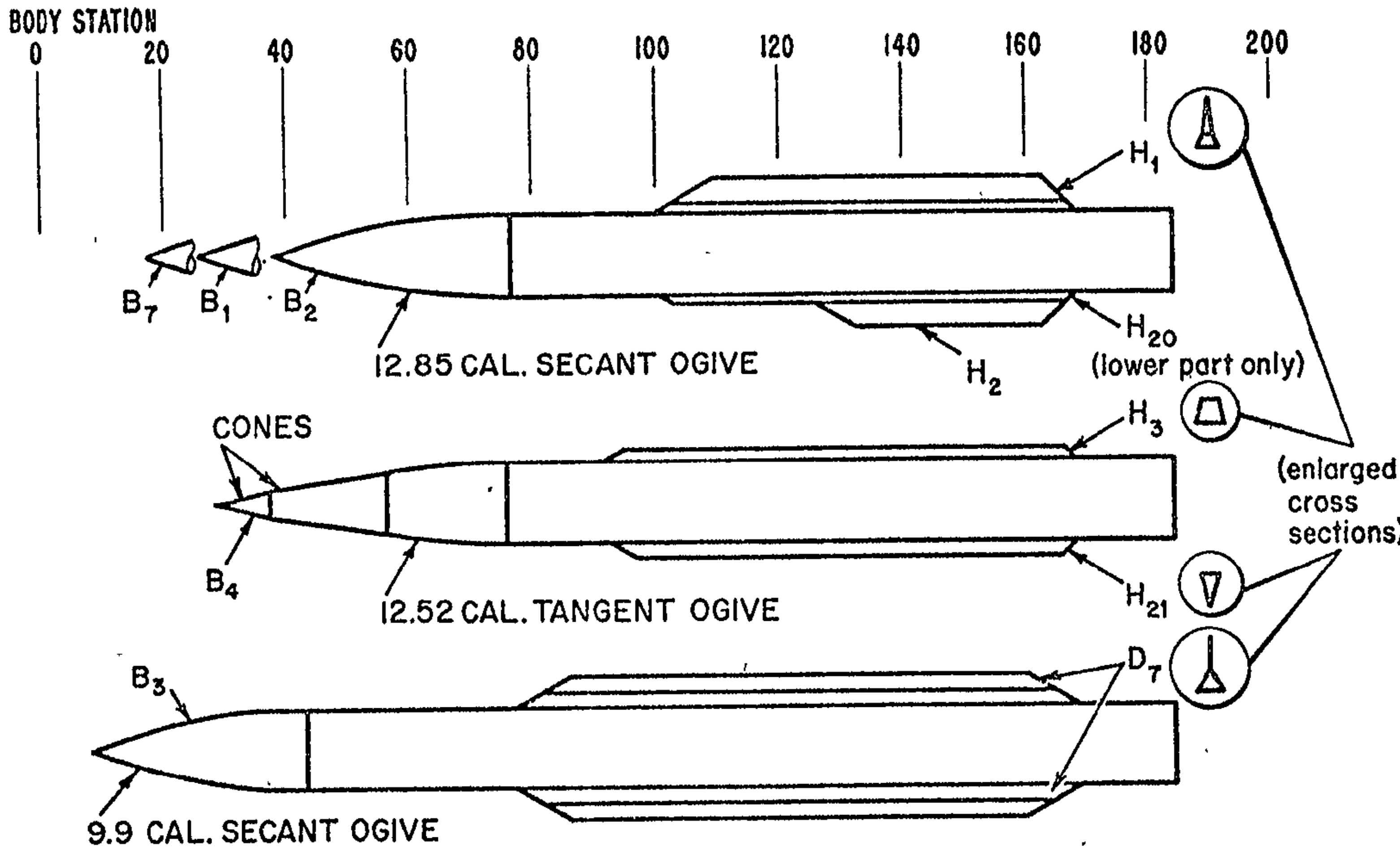
Suggestions for Additional Analyses:

Since the writing of the noted Data Analysis report, a considerable amount of test data on many additional low-aspect ratio surfaces (dorsals) have been obtained. For example, see the model configurations in Appendix B. Additional analyses of these data would certainly supplement and possibly expand the scope of the initial study. It should be noted, however, that no direct measurements of panel loads were made in these additional tests.

APL/JHU CM-931, "An Aerodynamic Study of Very-Low-Aspect Ratio Nearly Rectangular Lifting Surfaces at Supersonic Speeds," H. H. Hart, February 1958.

ABSTRACT

A study has been made of the aerodynamic behavior in supersonic flow of very-low-aspect-ratio, nearly rectangular lifting surfaces attached to certain bodies of revolution. The results of this study are given herein. The objectives of the presentation are: first, to give the reader an understanding of the basic aerodynamic phenomena influencing these surfaces, and second, to provide sufficient detailed information to permit engineering estimates of (a) the aerodynamic loading on such wings and (b) the effect of the wings on configuration stability and maneuverability. These low-aspect-ratio wings are studied in all roll attitudes at angle of attack up to 24 degrees over a range of Mach numbers from 1.50 to 3.87. Interference effects considered are those of the body on the wing, of the wing on the body, and of one wing on another. Among the geometrical parameters considered are aspect ratio, span-to-body diameter ratio, and length of nose ahead of the wings. The approach is primarily empirical, and a considerable body of test data has been correlated and assembled into design charts (presented in the Appendix). However, existing theory has not been ignored, and theoretical methods of calculation have been used where applicable and not unreasonably complex.



SKETCHES OF BODIES AND LOW-ASPECT-RATIO WINGS USED IN WIND-TUNNEL TESTS

FIG. D-III-1

Appendix D - Panel Loads and Flow Field Surveys (Cont'd)

IV. Bumblebee Generalized Missile Study (GMS) - Wing and Tail Panel Forces and Moments

Configurations tested:

1. Wing Panel - Fig. D-IV-1
2. Tail Panel - Figs. D-IV-2 and D-IV-3

Test Conditions:

1. Wing Panel

   Mach Number - $M = 3.24$
   Angle of Attack - $\alpha = 0°$ to $24°$
   Roll Attitude - $\phi = -90°$ to $+45°$
   Wing Incidence - $i_W = 0°, 10°, 20°$
   Reynolds Number - $Re = 2.28 \times 10^6/ft.$

2. Tail Panel

   Mach Number - $M = 1.5$ and 3.24
   Angle of Attack - $\alpha = 0°$ to $26°$
   Roll Attitude - $\phi = 0°$ to $-90°$
   Tail Incidence - $i_T = 0°, 10°, 20°$
   Reynolds Number - $Re = 6.36$ and $2.28 \times 10^6/ft.$

Type of Data Collected:

Panel normal force, hinge moment, and spanwise bending moment.

Availability of Data:

The following reports are on file at APL/JHU.

1. Wing Panel

   a. MAC Memo. AGM-30, "Transmittal of Wind Tunnel Data for NOL Test WTR 403, M = 3.24, GMS," Thomas Lowe, Jr., August 21, 1957 (Data plots only).

2. Tail Panel

   a. MAC Memo AGM-24, "Transmittal of Wind Tunnel Data for OAL Test 465-3, M = 1.50, GMS," D. E. Bachmann, September 24, 1956 (Data plots only).

b. NOL WTR-354, "Generalized Missile Study: Tail Hinge Moment and Force Data for the GMS Models at a Mach Number of 3.24," NAVORD Report 4432, December 2, 1958.

Reports on Data Analyses:

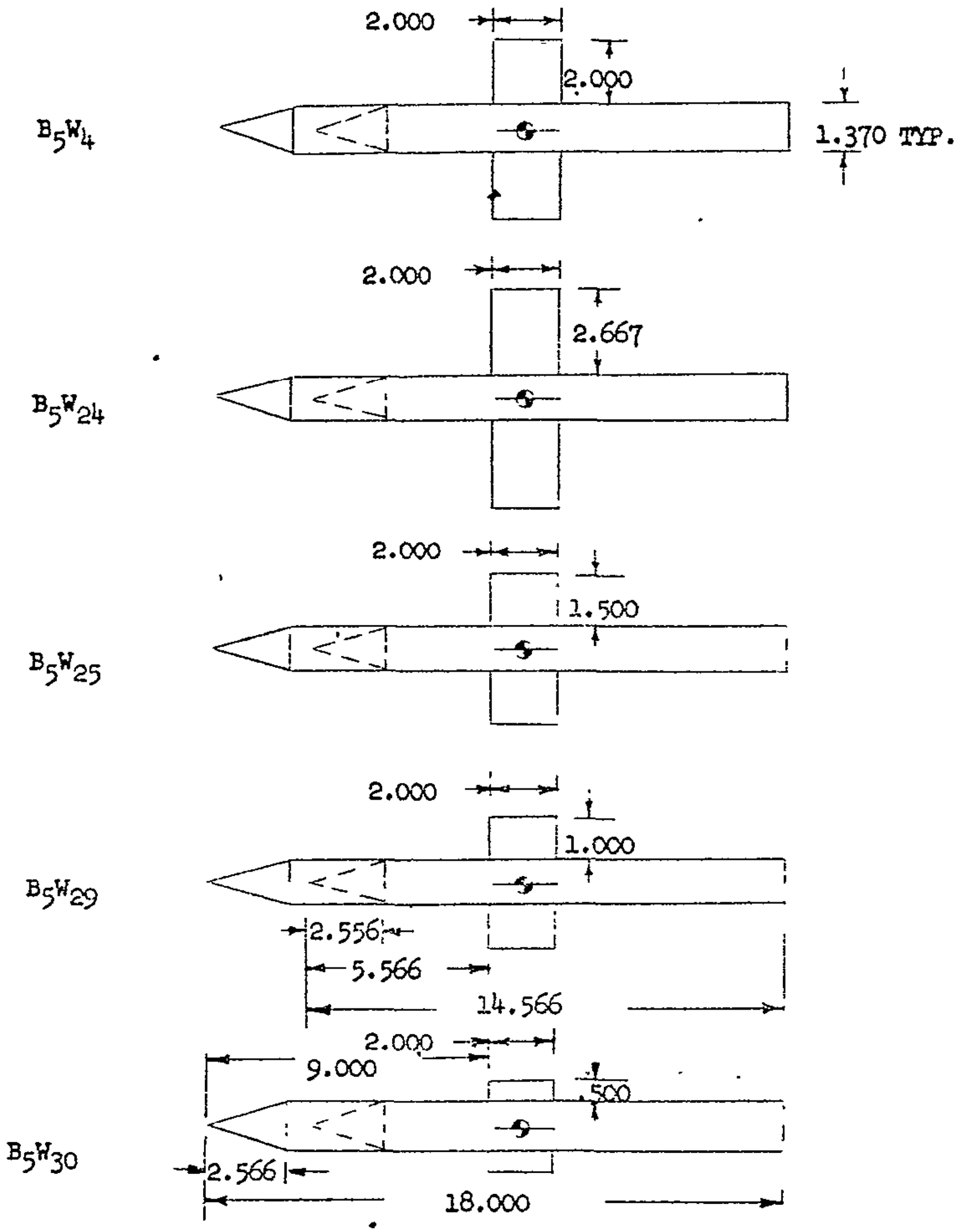
None available.

Suggestions for Additional Analysis:

As noted in Appendix A, these wing and tail panel data may be of use to NASA in validating theoretical methods. Also, a correlation of present NASA data in the Wing-Tail Interference Program with these wing and tail panel data could be carried out.

GMS MODEL GEOMETRY

WING PANEL TESTS



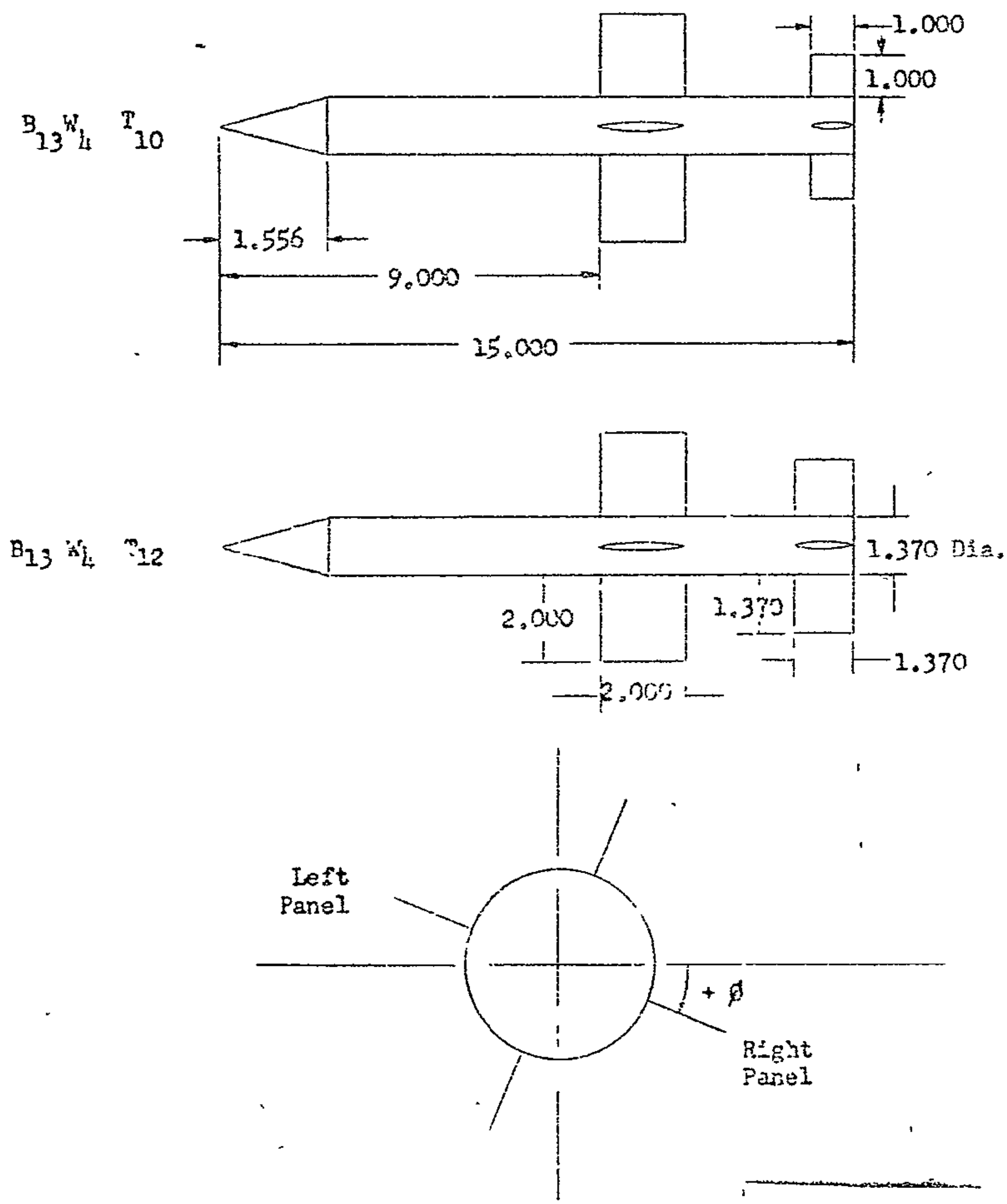
NOTES: 1. PHANTOM OUTLINE ILLUSTRATES B_9 NOSE LOCATION.

2. MOMENT REFERENCE 8.100 INCHES FORWARD OF MODEL BASE.

Fig. D-IV-1

MODEL GEOMETRY

TAIL PANEL TESTS



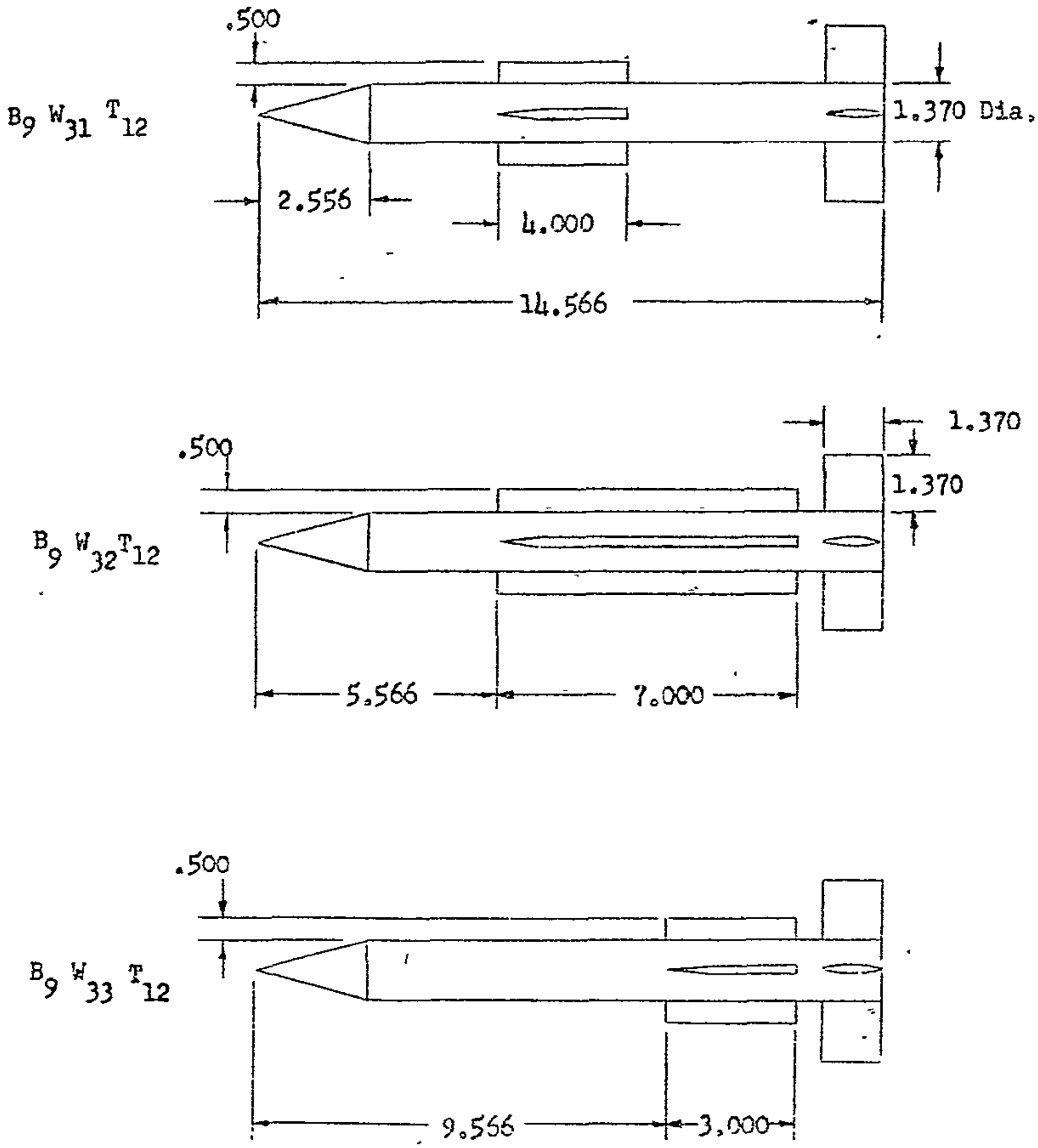
TAIL PANELS VIEWED LOOKING UPSTREAM

NOTE: ALL DIMENSIONS ARE IN INCHES

Fig. D-IV-2

MODEL GEOMETRY

TAIL PANEL TESTS



NOTE: ALL DIMENSIONS ARE IN INCHES

Fig. D-IV-3

Appendix E - Hypersonic Missile Configurations

I. Bumblebee Hypersonic Configuration Study

Configurations tested:

Series 1. Tail-Controlled, Straked Configurations (Cruciform and Triform, in-line and interdigitated) See Figs. E-I-1, -2, -3, -4, -5.

This series includes tests also on cruciform in-line configurations with various body lengths, nose shapes, strake sizes and longitudinal position, and tail thickness (thin and very thick delta wedges). Much breakdown data are also available, including data for tests with body and a single lifting surface.

Series 2. Tail-Controlled Delta-Winged Configurations (Cruciform) See Fig. E-I-6.

Series 3. Canard-Controlled Delta-Winged Configurations (Cruciform) See Fig. E-1-7.

Test Conditions:

Series 1. Mach Number - M = 4.4, 7.7

Angle of Attack - α = -4° to 36°, -5° to 25°

Roll Attitude - ϕ = -90° to +90°

Tail Incidence - i = 0°, -10°, -20°

Reynolds Number - Re = 12 X 10^6/ft, 3 X 10^6/ft

Series 2. Mach Number - M = 4.4

Angle of Attack - α = -4° to 36°

Roll Attitude - ϕ = o°, -45°

Tail Incidence - i = 0°, 20°

Reynolds Number - Re = 12 X 10^6/ft

Series 3. Mach Number - M = 4.4

Angle of Attack - α = 4° to +33°

Roll Attitude - ϕ = 90° to +90°

Canard Incidence 0°, 20°

Reynolds Number - Re = 12 X 10^6/ft

Type of Data Collected:

Five-component stability and control data for all Series. Extensive schlieren coverage is also available.

Availability of Data:

Single hard copies of the following data reports are available in APL/JHU files:

1. NOL WTR 783
2. NOL WTR 808
3. NOL WTR 1020
4. General Dynamics HST 137-0
5. General Dynamics HST 155-0

Reports on Data Analyses:

1. Paper No. 5 - 9th U. S. Navy Symposium on Aeroballistics, Proceedings published by APL/JHU, September 1972, "Low Aspect Ratio Wings in Hypersonic Flow," E. F. Lucero.

2. Paper No. 22 - 8th U. S. Navy Symposium on Aeroballistics, Proceedings published by Naval Weapons Center, China Lake, California, June 1969, "Wing-Tail Interference in Hypersonic Missile Configurations," H. H. Hart.

3. Paper given at 7th U. S. Navy Symposium on Aeroballistics, Proceedings published by Naval Missile Center, Point Mugu, California, as NMC Misc. Publ. MP-66-10, June 1966, "Hypersonic Delta-Wing-Body Interference," H. H. Hart.

4. Paper No. 3, 6th U. S. Navy Symposium on Aeroballistics, Proceedings published by David Taylor Model Basin, November 1963, "Some Factors Influencing the Aerodynamic Stability of Hypersonic Interceptor-Type Missile Configurations," H. H. Hart and J. C. Hagan.

5. Paper No. 7, 48th Bumblebee Aerodynamics Panel Meeting, Proceedings published as APL/JHU TG 14-43, September 1963, "Preliminary Results of APL Hypersonic Configuration Study," H. H. Hart and J. C. Hagan.

In addition to the above formal publications, the following internal memoranda (single hard copy in APL files) contain various portions of the analyses:

6. BBA-RE-010-64, "Longitudinal Stability Characteristics at M = 7.69 for Four Basic Hypersonic Missile Configurations," H. H. Hart and J. C. Lowndes, October 1964.

7. BBA-RE-011-64, "A Compilation of Cone and Cone-Cylinder Normal Force and Stability Characteristics at Hypersonic Speeds," J. C. Hagan, October 1964.
Also
BBA-RE-011a-64, "The Center of Pressure of the Afterbody of Cone-Cylinder Combinations at Hypersonic Speeds - An Addendum to BBA-RE-011-64."

8. BBA-RE-003-65, "Hypersonic Body-Tail Interference in the Horizontal Plane," H. H. Hart, March 1965.

9. BBA-RE-005-65, "Directional Stability Characteristics at M = 7.69 for Four Basic Hypersonic Missile Configurations," H. H. Hart and J. C. Lowndes, March 1965.

10. BBA-RE-007-65, "Stability and Control Characteristics at M = 4.36 for Four Basic Hypersonic Missile Configurations," H. H. Hart and E. W. Youngquist, December 1965.

11. BBA-RE-001-67, "Some Dorsal Fin-Tail Interference Effects in Cruciform Hypersonic Configurations at M = 7.69," H. H. Hart, February 1967.

12. BBA-RE-002-67, "Longitudinal and Roll Aerodynamic Characteristics of a Canard-Controlled Delta Wing Missile Configuration at Mach 4.36," J. J. Pasierb, February 1967.

13. BBA-RE-007-67, "Longitudinal Stability and Control Characteristics at M = 4.36 for Two Tail-Controlled Delta Wing Missile Configurations," H. H. Hart, August 30, 1967.

14. BBA-RE-009-67, "Longitudinal Stability and Control Characteristics of Four Canard-Controlled Delta-Wing Missile Configurations at Mach Number 4.36," W. H. Rauser, September 28, 1967.

15. BBA-RE-010-67, "Stabilizing and Control Efficiency of Canard and Tail Surfaces at M = 4.36," H. H. Hart, October 4, 1967.

16. BBA-RE-002-68, "The Effect of Nose Cone Angle on the Aerodynamic Characteristics of Cone-Cylinder Bodies at M = 7.69," H. A. Kirker, July 19, 1968.

17. BBA-2-70-014, "Hypersonic Configuration Study, Part I: Cone-Cylinders (U)," E. F. Lucero, 14 July 1970 (Confidential).

18. BBA-2-71-021, "Hypersonic Configuration Study, Part II: Body-Dorsal Configurations (U)," E. F. Lucero, 6 December 1971 (Confidential).

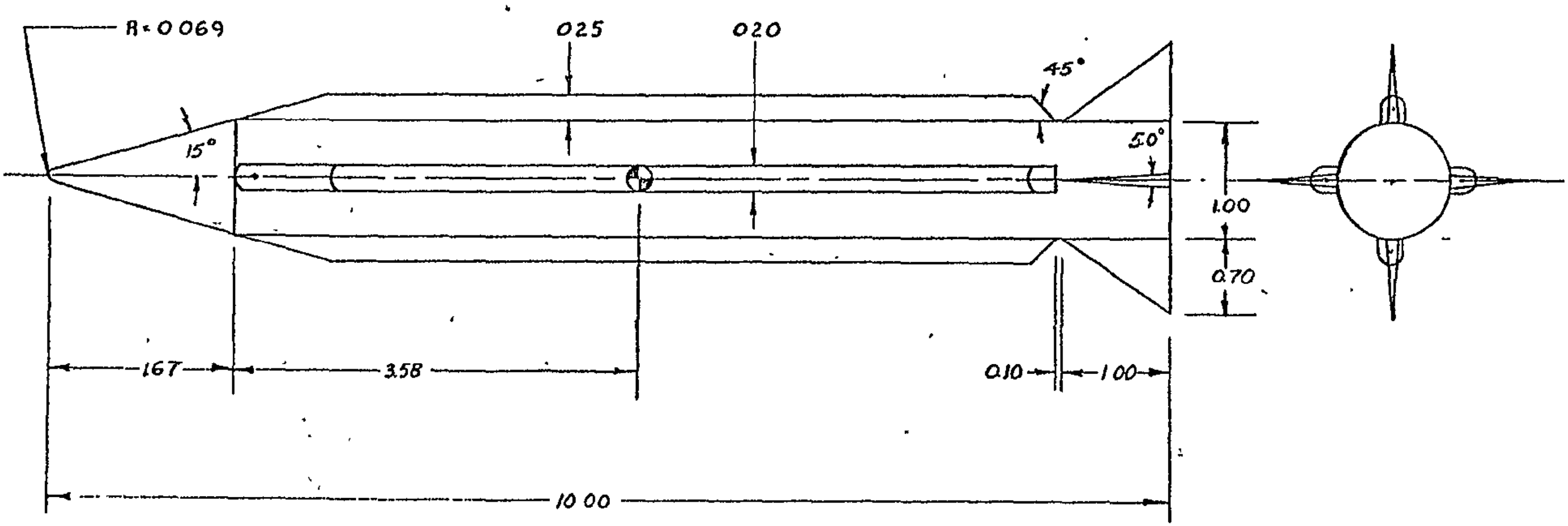
Suggestions for Further Analysis:

A summary document providing the conclusions from the many parametric variations, together with some design charts should be produced. The wealth of available data would require a substantial effort to produce such a document.

HYPERSONIC CONFIGURATION MODEL

CRUCIFORM CONFIGURATION WITH IN-LINE TAILS

$B_1D_1T_1$



Note: Dimensions are in body diameters

Fig. E-I-1

HYPERSONIC CONFIGURATION MODEL

CRUCIFORM CONFIGURATION WITH INTERDIGITATED TAILS

$B_1D_1T_1^{45}$

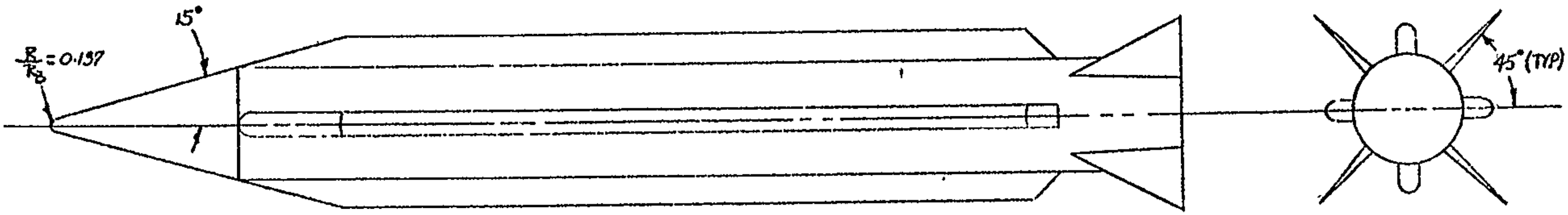


Fig. E-I-2

HYPERSONIC CONFIGURATION MODEL

TRIFORM CONFIGURATION WITH IN-LINE TAILS

$B_1^3 D_1 T_1$

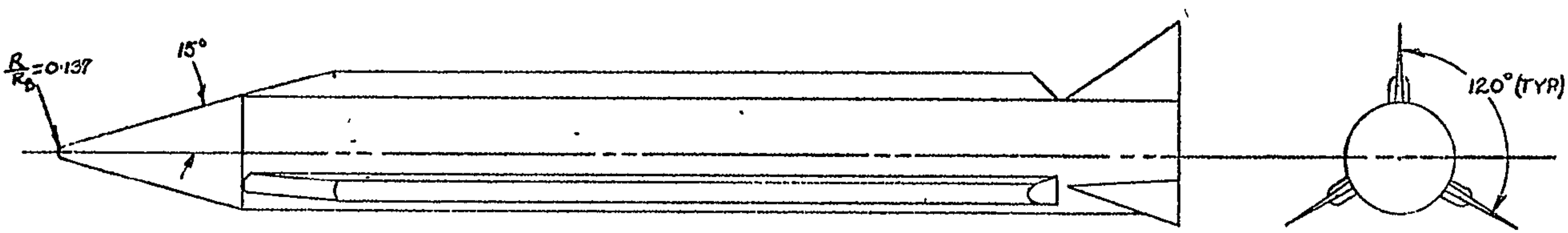


Fig. E-I-3

HYPERSONIC CONFIGURATION MODEL

TRIFORM CONFIGURATION WITH INTERDIGITATED TAILS

$B_1^3 D_1 T_1^{60}$

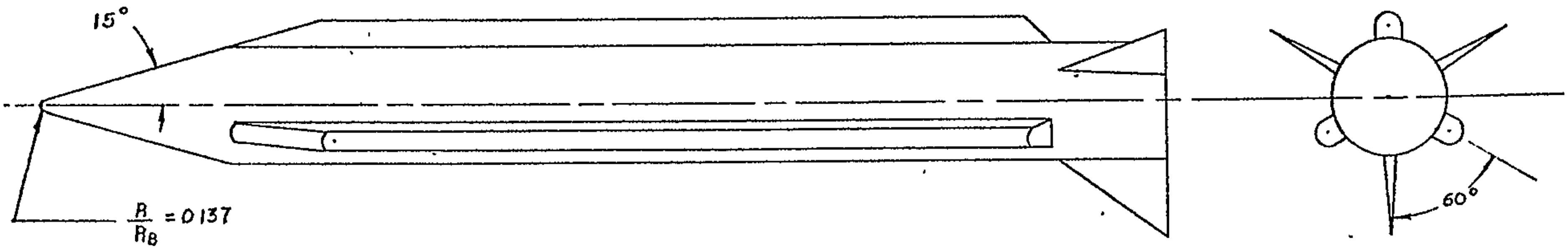


Fig. E-I-4

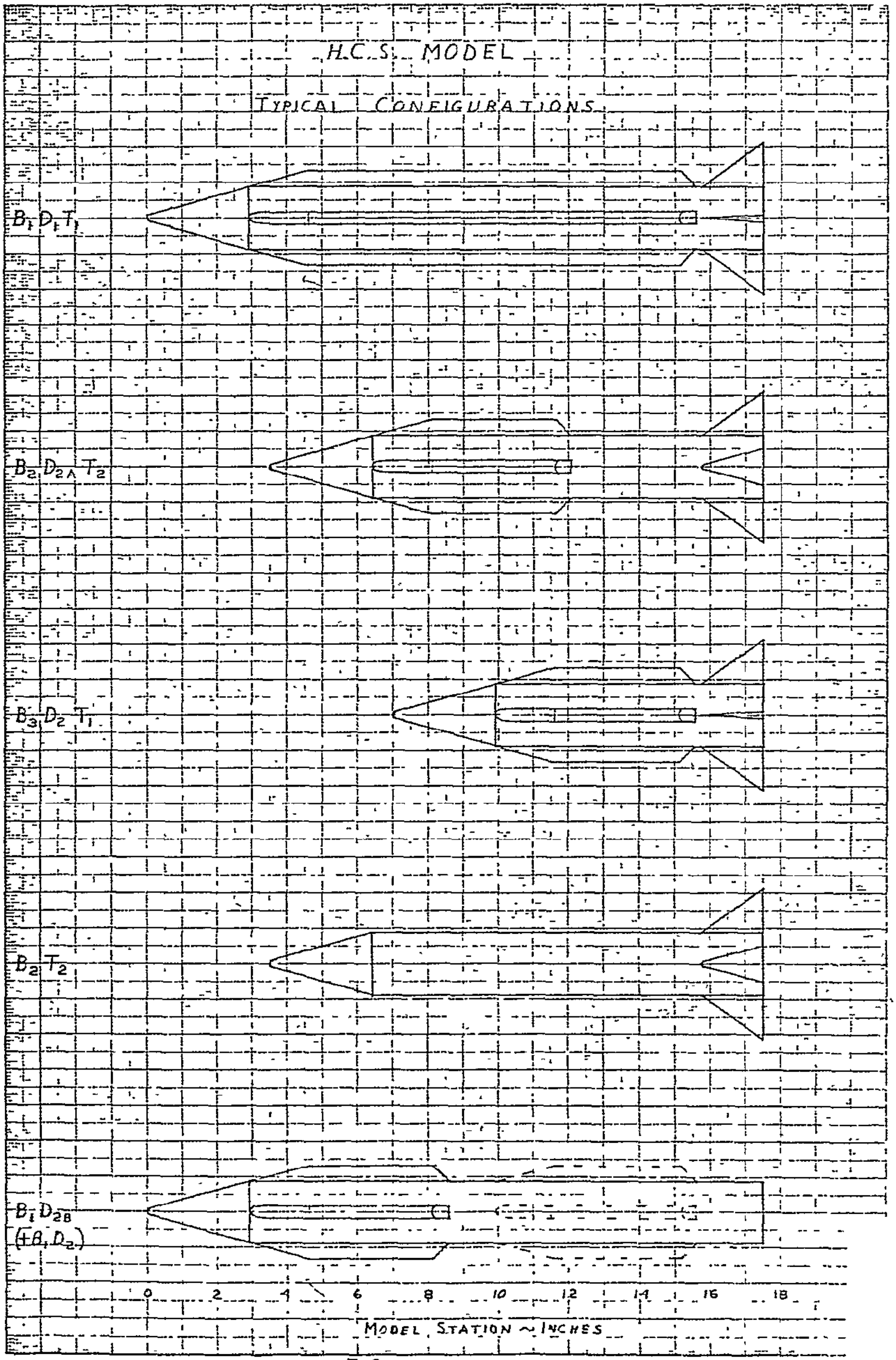
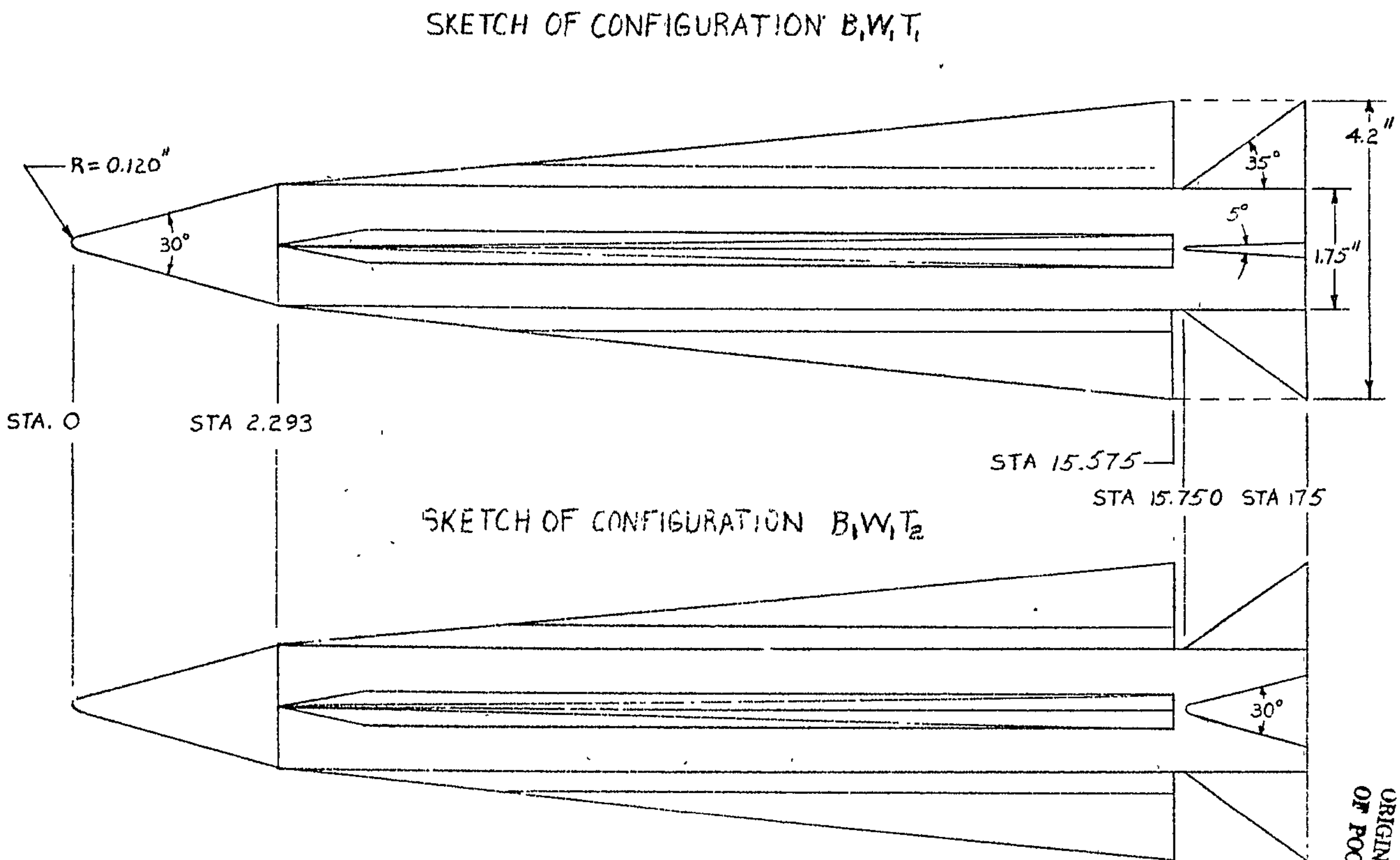

H.C.S. MODEL
TYPICAL CONFIGURATIONS
$B_1 D_1 T_1$
$B_2 D_{2A} T_2$
$B_3 D_2 T_1$
$B_2 T_2$
$B_1 D_{2B}$
$(+B_1 D_2)$
0
2
4
6
8
10
12
14
16
18
MODEL STATION ~ INCHES

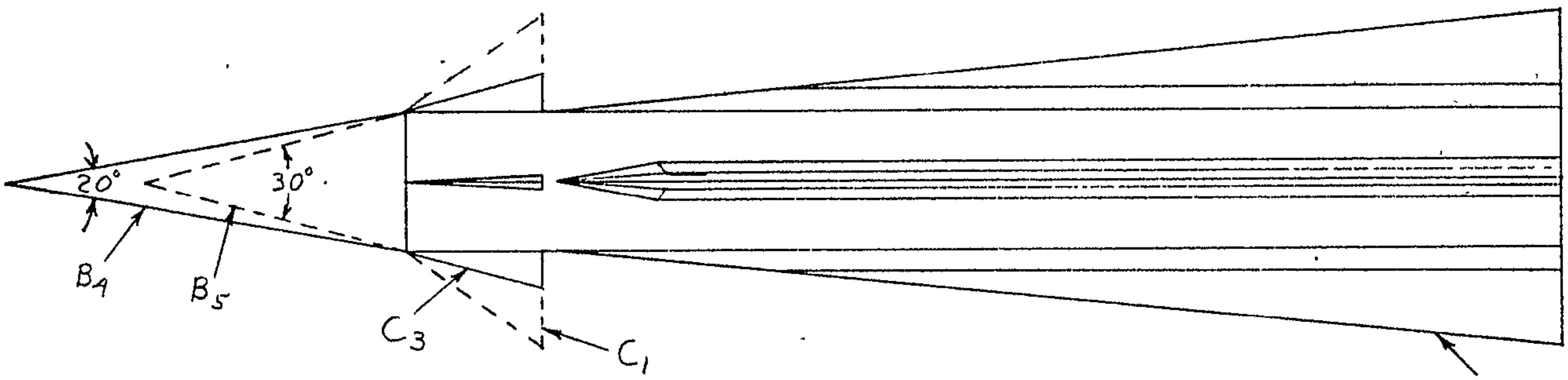
Fig. E-I-5



SKETCH OF CONFIGURATION $B_1W_1T_1$
R = 0.120"
30°
35°
4.2"
5°
1.75"
STA. 0
STA 2.293
STA 15.575
STA 15.750
STA 17.5
SKETCH OF CONFIGURATION $B_1W_1T_2$
30°

Fig. E-I-6

CANARD - CONTROLLED CONFIGURATIONS



NOTE. C_3^{45} ARE C_3 SURFACES ROTATED 45° AROUND BODY

Fig. E-I-7

Appendix E - Hypersonic Missile Configurations (Cont'd)

II. Bumblebee Supersonic Combustion Ramjet Program (Mod II SCRAM)

Configurations tested: See Figs. E-II-1, E-II-2, and E-II-3.

Test Conditions:

Mach Number - M = 4.36 and 7.69

Angle of Attack - $\alpha = 0°$ to $10°$

Roll Attitude - $\phi = 0°, 45°$

Tail Incidence - $i = 0°, 10°$

Reynolds Number - $Re = 12 \times 10^6$ per ft, M = 4.36
3×10^6 per ft, M = 7.69

Type of Data Collected:

Five-component stability and control data. Full configuration and breakdown. Engine force and moments.

Availability of Data:

Single copy of following reports in APL/JHU files.

1. General Dynamics/Convair HST-TR-202-0, -1, "Wind Tunnel Tests of a Mod II SCRAM Model at M = 4.36," 1967, 1968.

2. NOL Test WTR 989, "Hypersonic Research Model Simulation of Mod II SCRAM Stability and Control at Mach 7.69," 1967.

Reports on Data Analyses:

Copies of the following internal memoranda in APL/JHU files.

1. BBA-SC-005-67, "Longitudinal Stability and Control Characteristics of the Hypersonic Research Configuration Simulation of Mod II SCRAM at Mach 4.37 (U)," J. C. Hagan and E. W. Youngquist, 25 May 1967 (Confidential).

2. BBA-SC-011-67, "Longitudinal Stability and Control Characteristics of the Hypersonic Research Configuration Simulation of Mod II SCRAM at Mach 7.69 and a Comparison with Mach 4.37 Characteristics (U)," J. C. Hagan and E. W. Youngquist, 3 November 1967 (Confidential).

3. BBA-SC-012-67, "Experimental Stability Characteristics of a Single Normal Shock Duct Mounted on a Cone-Cylinder Body at Mach 4.37 and 7.69 (U)," J. C. Hagan, 12 December 1967 (Confidential).

4. BBA-3-71-001, "Analysis of Wind Tunnel Tests at M = 4.36 on Models Having Two Types of Simulated Mod II SCRAM Engine Pods (U)," R. J. Vendemia, Jr., L. S. Glover, and J. C. Hagan, 26 January 1961 (Confidential).

In addition, the following formal document was published on a portion of the analysis:

5. "The Simulation of Ramjet Configurations with Pod Inlets for Stability and Control Wind Tunnel Testing," J. C. Hagan (Confidential), Vol. 5, Proceedings of the 8th Navy Symposium on Aeroballistics, published by Naval Weapons Center, China Lake, California, June 1969.

Suggestions for Additional Analysis:

Above analyses provide a complete description of Mod II Scram aerodynamic characteristics for preliminary design purposes.

HYPERSONIC RESEARCH MODEL
SIMULATION OF MOD II SCRAM
WIND TUNNEL MODEL CONFIGURATIONS

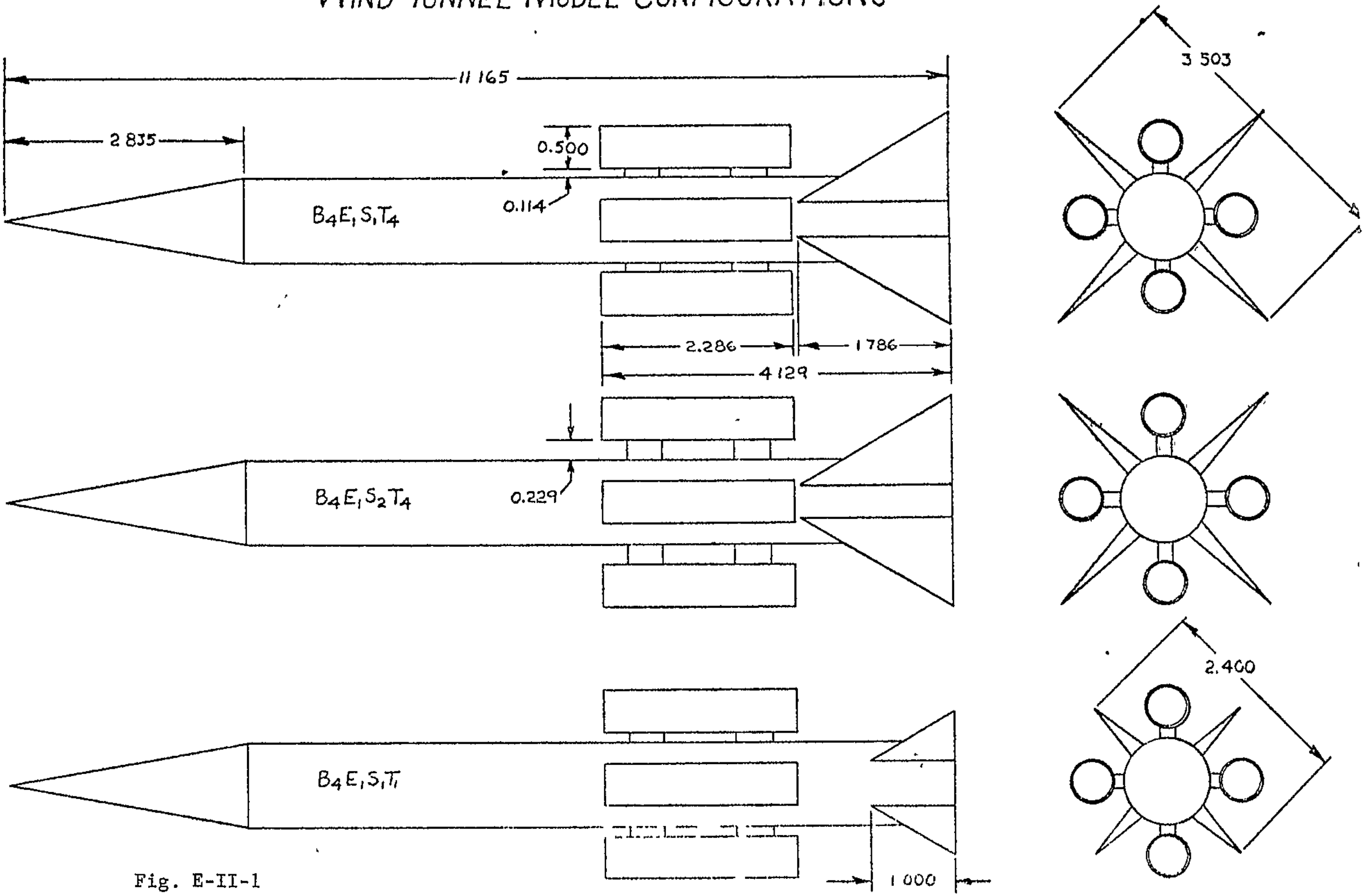


Fig. E-II-1

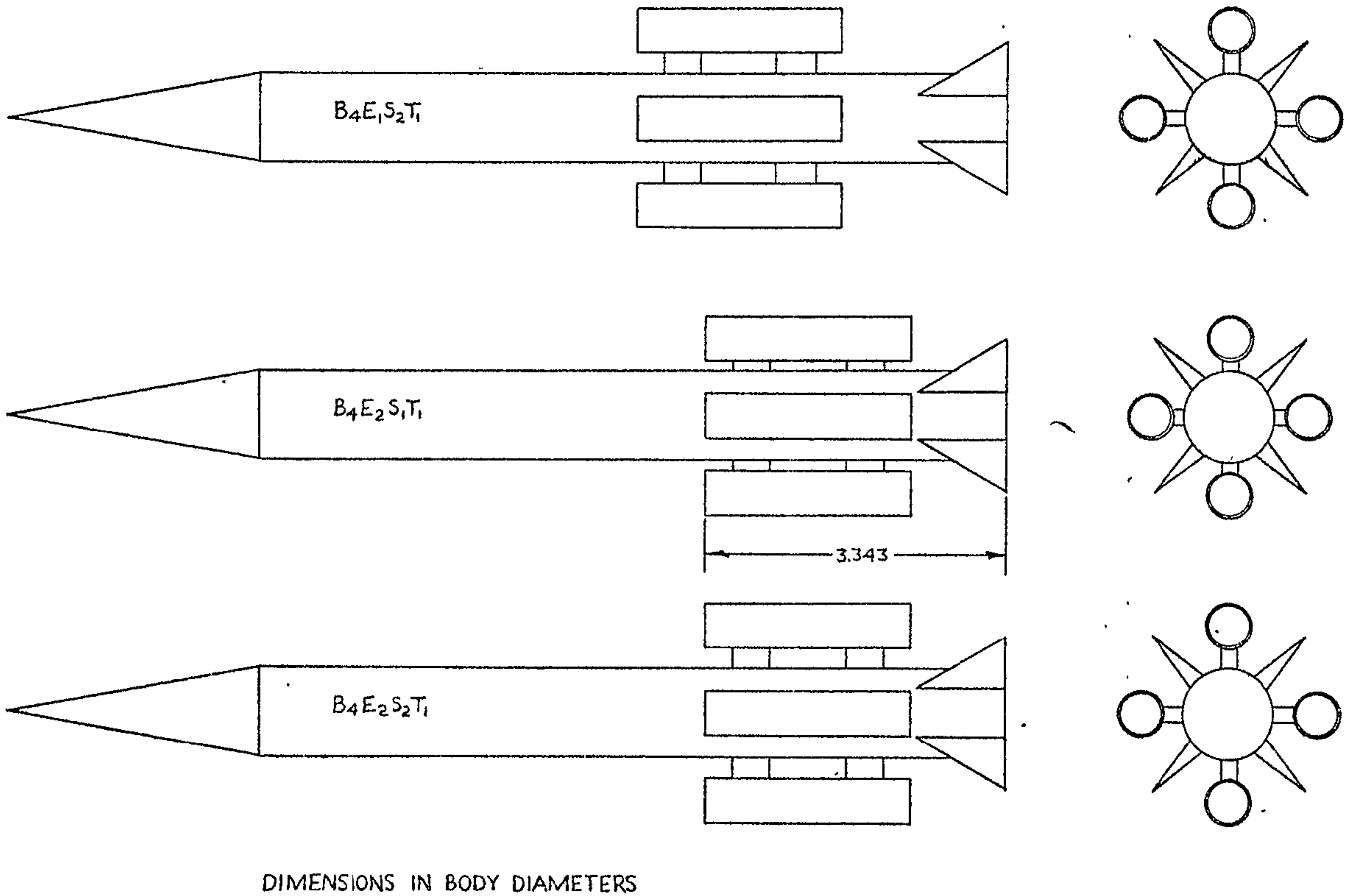
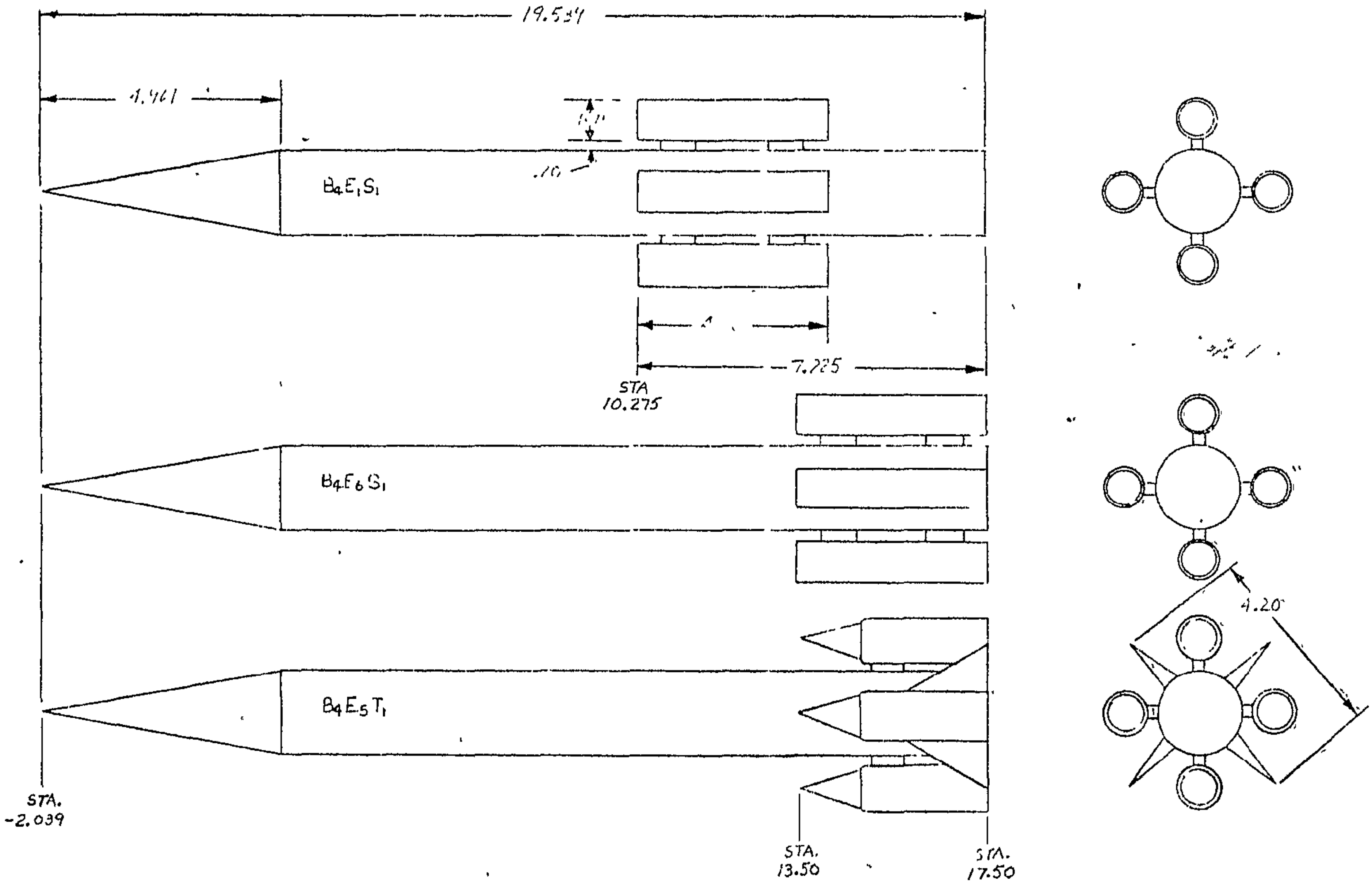


Fig. E-II-1 (Cont'd)

HYPERSONIC RESEARCH MODEL
SIMULATION OF MOD 2 SCRAM
WIND TUNNEL CONFIGURATIONS



DIMENSIONS IN INCHES - MODEL SCALE

Fig. E-II-2

HYPERSONIC RESEARCH MODEL
SIMULATION OF MOD 2 SCRAM
WIND TUNNEL CONFIGURATIONS

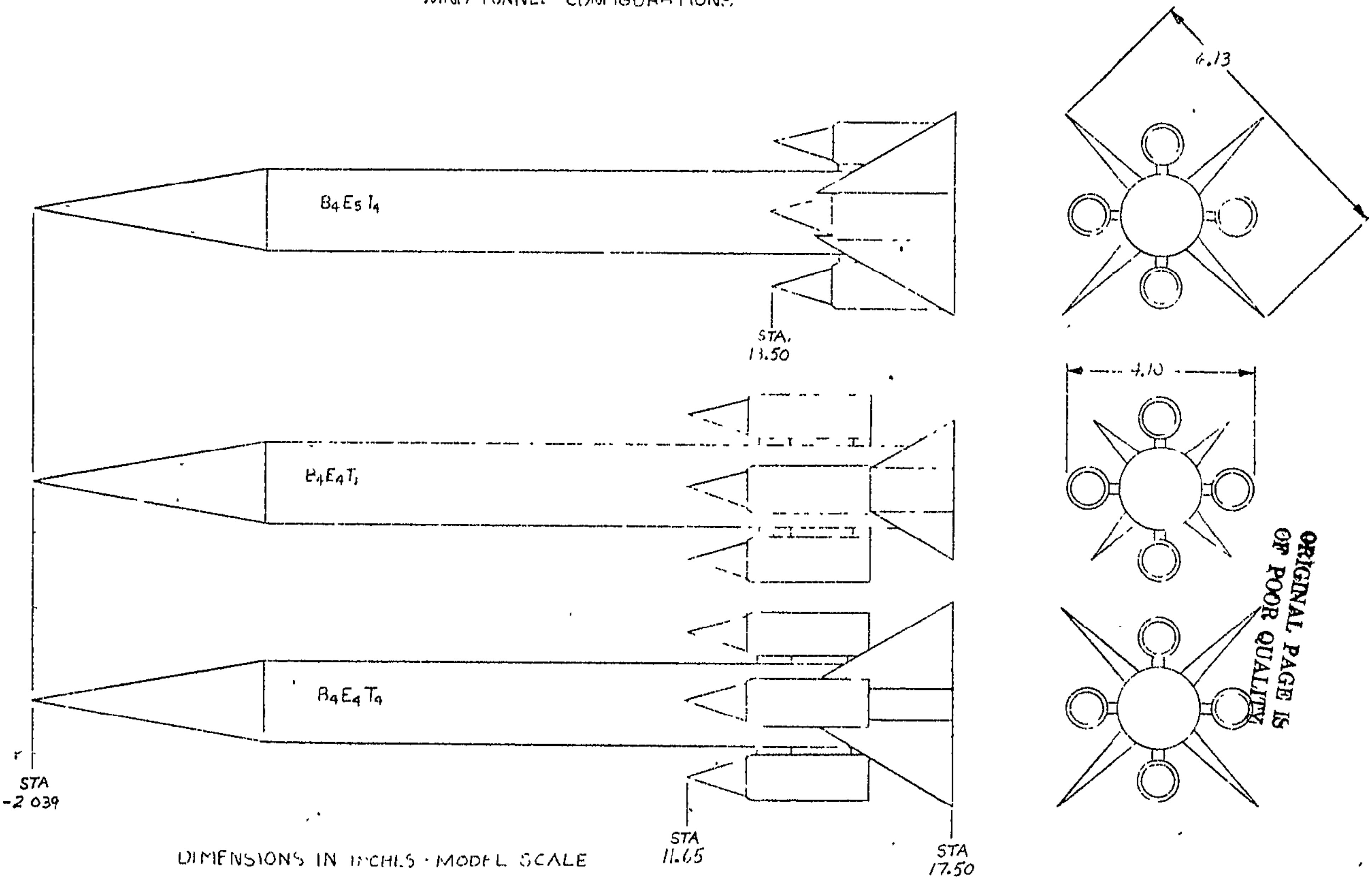


Fig. E-II-3

Appendix F - Unique Missile Configurations

I. Wrap-Around Surface Project (WASP)

Wrap-Around Surface Project configurations were tested at subsonic speeds with the objective of investigating the aerodynamic feasibility of using a bank-to-turn configuration incorporating wrap-around wing and tail surfaces. The relative effectiveness of curved versus planar surfaces was evaluated.

Configurations tested: See Figs. F-I-1, F-I-2, F-I-3.

Full, breakdown, and single wing and tail configurations were tested as were three wing positions.

Test Conditions:

Mach Number - M = 0.65 to 0.98 (majority of data obtained at M = 0.8)

Angle of attack - α = -15° to 15°

Roll Attitude - ϕ = 0° and 90° and ϕ cuts at constant α

Tail Incidence - i_p = -10°, 0°, 5°, 10° - horizontal surfaces
i_y = 0°, 5° - vertical surface

Reynolds Number - RE = 8 x 10^6/ft.

Type of Data Collected:

Five component stability and control, and drag. Oil flow visualization information on wings.

Availability of Data:

Copy of following data report in APL/JHU files (BFD Group).

General Dynamics/Convair - HST 361-0, -1.

Reports on Data Analyses:

1. Paper No. 11, 10th U. S. Navy Symposium on Aeroballistics, Proceedings published by Naval Surface Weapons Center, Dahlgren, Virginia, April 1976, "High Subsonic Aerodynamic Longitudinal Stability and Control Characteristics of Configurations Incorporating Wrap-Around Surfaces," E. F. Lucero.

In addition to the above formal publication, the following internal memoranda are on file at APL/JHU (BFD Group).

2. BFD-1-75-012, "Experimental Results at Mach 0.80 of the Effect of Body Cavity on the Longitudinal Stability and Control Characteristics of the Wrap-Around Surface Project (WASP) Configurations," E. F. Lucero, 9 June 1975.

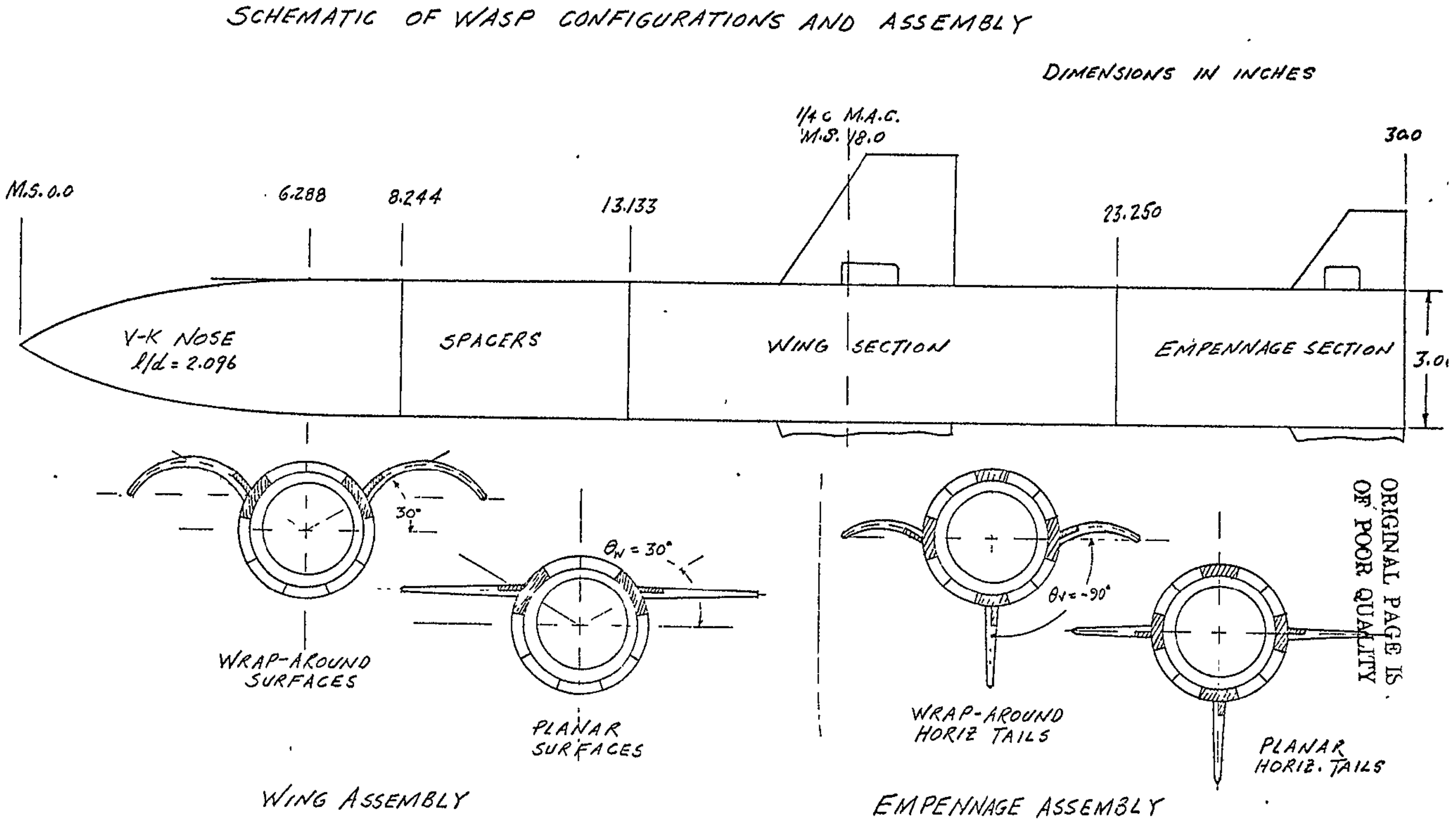
3. BFD-1-75-010, "Wrap-Around Surface Project (WASP) Studies - Analysis of Experimental Data on Lateral Stability and on Effects of Sideslip on Yaw and Roll Control, M = 0.8," E. F. Lucero, 30 May 1975.

4. BFD-1-75-006, "Experimental Study at M = 0.8 of the Aerodynamic Controllability of the Missile Configuration for the Wrap-Around Surface Project (WASP)," E. F. Lucero, 8 May 1975.

5. BFD-1-74-009, "Experimental Results of High Subsonic Aerodynamic Longitudinal Stability Characteristics of Bank-to-Turn Configurations Incorporating Wrap-Around Surfaces with Subsonic Sections," E. F. Lucero, 12 February 1975.

Suggestions for Additional Analyses:

- Above analyses plus a forthcoming APL-TG report provide a complete description of the Wrap-Around Surface configuration aerodynamic characteristics at subsonic speeds.



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OF POOR QUALITY

Fig. F-I-1

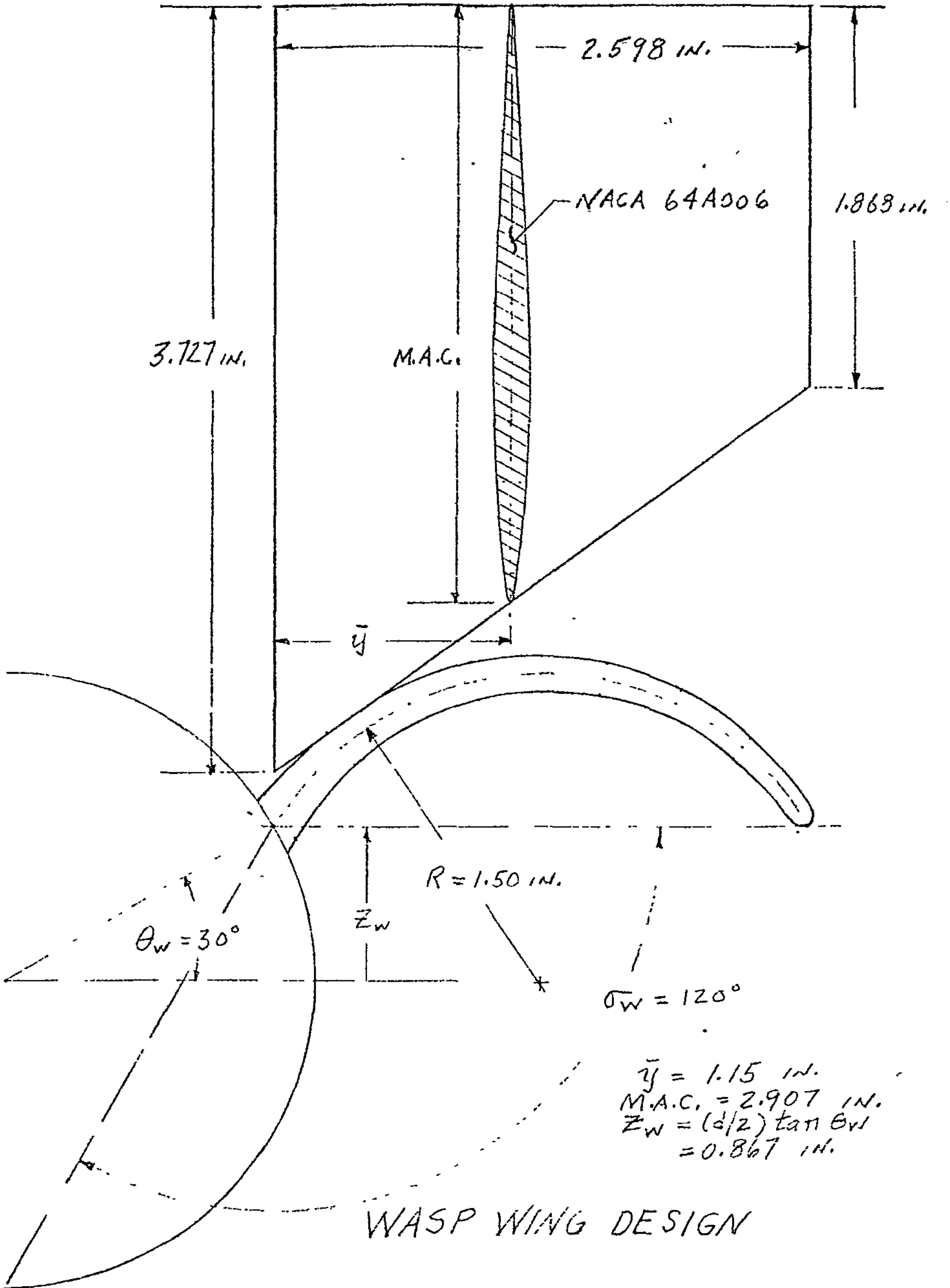
2.598 IN.
NACA 64A006
1.868 IN.
3.727 IN.
M.A.C.
$\bar{y}$
R = 1.50 IN.
$\bar{Z}_W$
$\theta_W = 30°$
$\sigma_W = 120°$
$\bar{y}$ = 1.15 IN.
M.A.C. = 2.907 IN.
$\bar{Z}_W$ = (d/2) tan θ_W
= 0.867 IN.
WASP WING DESIGN

FIG. F-I-2

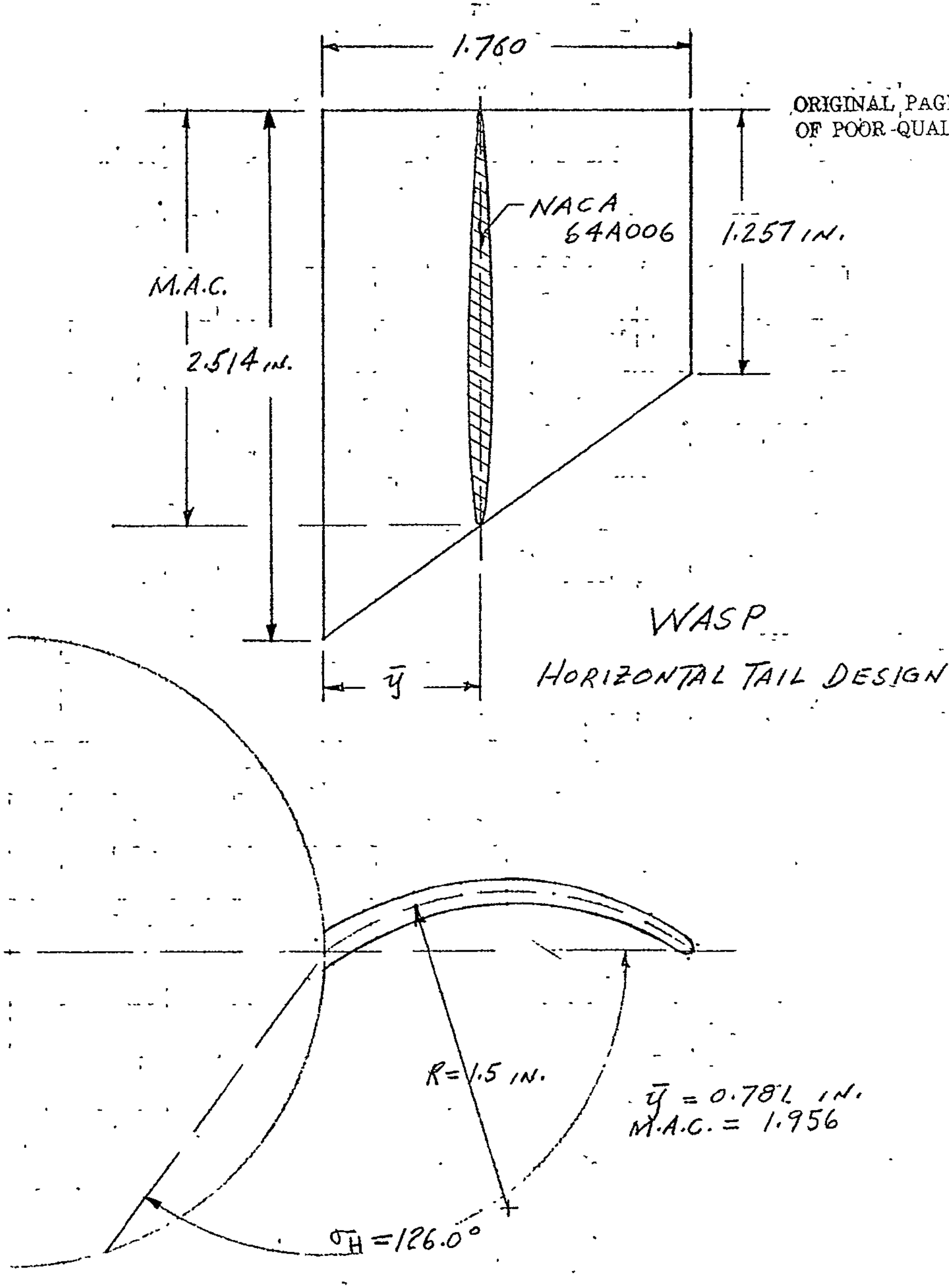
1.760
NACA
64A006
1.257 IN.
M.A.C.
2.514 IN.
ȳ
WASP
HORIZONTAL TAIL DESIGN
R = 1.5 IN.
ȳ = 0.781 IN.
M.A.C. = 1.956
σH = 126.0°

Fig. F-I-3

Appendix F - Unique Missile Configurations

II. Bumblebee Planar Missile Configuration

Configurations tested: See Figs. F-II-1, -2, -3

Test Conditions:

Mach Number - M = 2.5, 3.5
Angle of Attack - α = -4° to +20°
Roll Attitude - ϕ = 0° to 90°
Tail Incidence - i = 0°, -10°, -20°
Reynolds Number - Re = 3 to 5.5 x 10^6/ft.

Type of Data Collected:

Five-component stability and control data (no drag data).

Availability of Data:

A single hard copy of each of the following wind-tunnel test reports is available in the APL/JHU files.

1. NAVORD Report 6869, 11 January 1961.
2. NAVWEPS Report 6864, 13 September 1960.
3. NOL Test WTR 607, September 1960 (also published as NOL TR 61-31).
4. NOL Test WTR 669, March 1961 (also published as part of NOL TR 63-161).
5. NOL Test WTR 681, May 1961 (also published as part of NOL TR 63-161).

Reports on Data Analyses:

1. Paper No. 8, Fifth U. S. Navy Symposium on Aeroballistics, October 1961. Proceedings published by U. S. Naval Ordnance Laboratory, White Oak, Maryland, "High Angle-of-Attack Phenomena Associated with Supersonic Planar Configurations," H. H. Hart.
2. APL/JHU TG-923, "Supersonic Stability and Control Characteristics of Low-Aspect-Ratio Planar Configurations Designed for Large Maneuvers," H. H. Hart, August 1967.
3. APL/JHU TG-998, "Supersonic Interference Effects in Low-Aspect-Ratio Planar Configurations at Large Angles of Attack," H. H. Hart, July 1968.

Suggestions for Further Analyses:

The two TG reports probably contain sufficient analyses of the data for NASA needs.

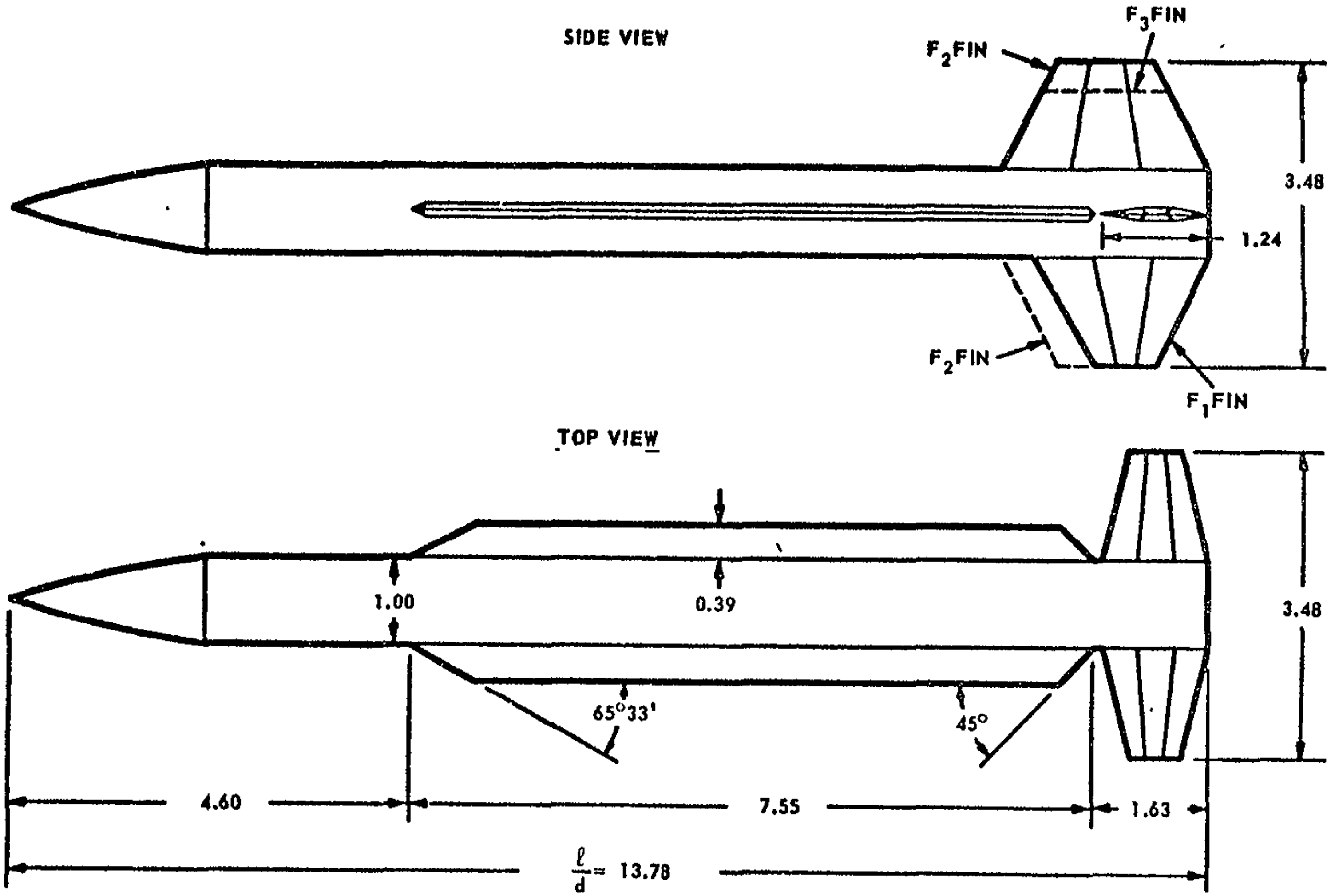

Fig. F-II-1 STRAKED PLANAR CONFIGURATION

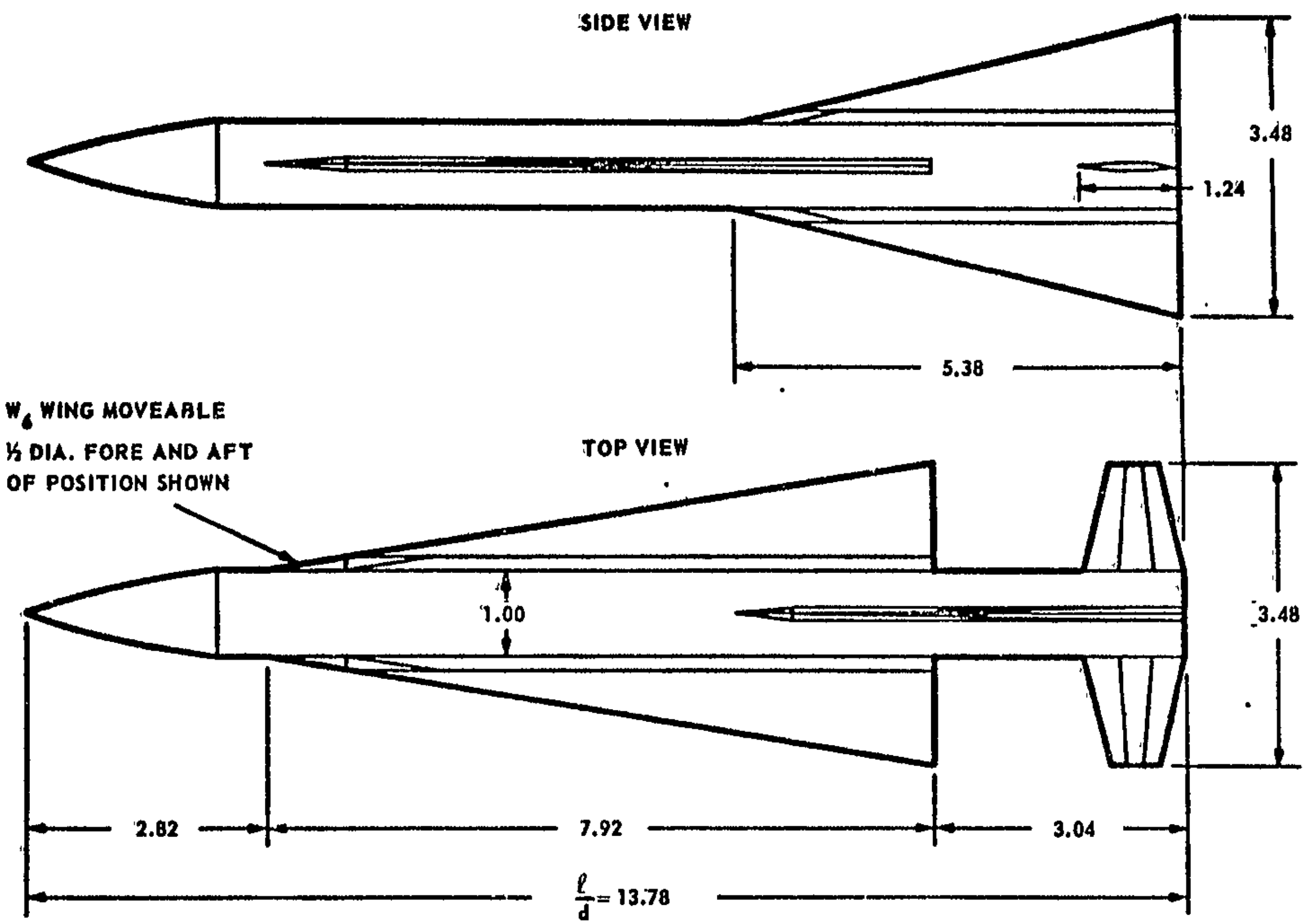

Fig. F-II-2 DELTA-WINGED PLANAR CONFIGURATION

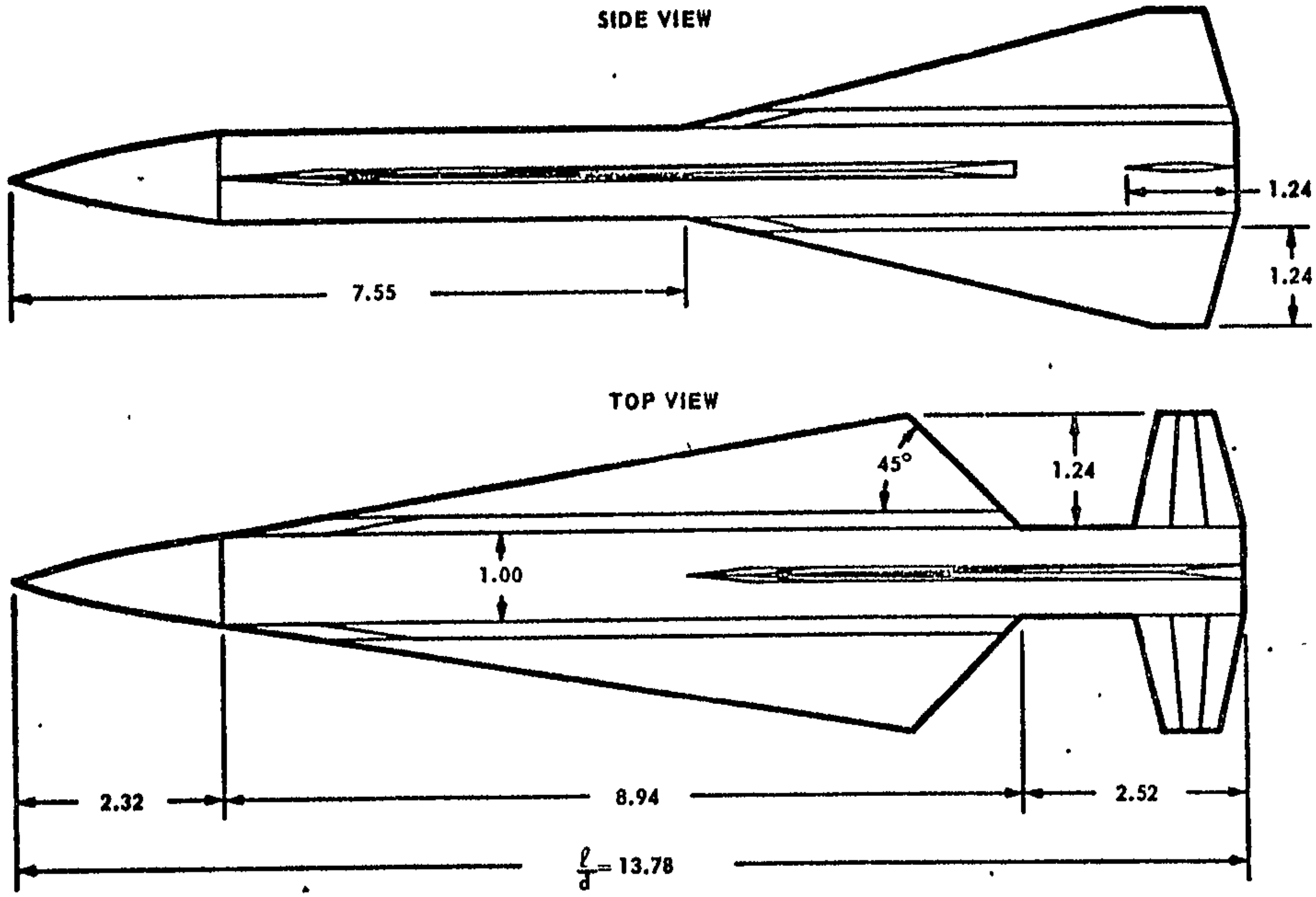

Fig. F-II-3 DART-WINGED PLANAR CONFIGURATION

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NASA CR-145347		
4 Title and Subtitle: Index for Aerodynamic Data From the Bumblebee Program		5 Report Date: April 1978
		6. Performing Organization Code
7 Author(s): L. L. Cronvich and G. A. Barnes		8 Performing Organization Report No.
9 Performing Organization Name and Address: The Johns Hopkins University, Applied Physics Laboratory, Laurel, Maryland 20810		10 Work Unit No.
		11 Contract or Grant No: L-60036A
12 Sponsoring Agency Name and Address: National Aeronautics and Space Administration, Langley Research Center, Hampton, VA 23665		13. Type of Report and Period Covered: Contractor Report
		14 Sponsoring Agency Code

15 Supplementary Notes

Langley Technical Monitors: Wallace C. Sawyer and Charlie M. Jackson, Jr.

16 Abstract

This index was prepared in order to facilitate dissemination of a large amount of fundamental aerodynamic missile data, which has been stored for a number of years at the Applied Physics Laboratory. Only an index of the data are presented in this report, but a list of reference documents and graphic illustrations of the various configurations provide sources of detailed data.

The Bumblebee program, initiated in 1945 by the U. S. Navy Bureau of Ordinance, was designed to provide a supersonic guided missile. The Aerodynamics program included a fundamental research effort in supersonic aerodynamics as well as a design task in developing both test vehicles and prototypes of tactical missiles.

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