Lockheed Aircraft Corporation

ADVANCED DEVELOPMENT PROJECTS

BURBANK, CALIFORNIA

REPORT NO. SP-1236

DATE August 1, 1967

COPY NO. — 8 —

MODEL B-52H/D-21B

TITLE OPERATIONAL LIMITS AND CHARACTERISTICS DURING MATED FLIGHT AND LAUNCH

PREPARED BY C. R. Cantrell, Jr.

M. D. Cassidy

Reviewed by J. R. McMaster

REVIEWED BY Ben R. Rich

APPROVED BY Clarence L. Johnson
Vice President
Advanced Development Projects

REVISIONS

DATE	PAGES AFFECTED

BEST COPY AVAILABLE

Approved for Release: 2018/11/16 C05116417

Lockheed · CALIFORNIA COMPANY

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

TABLE OF CONTENTS

FORM 5767A-2

FIGURE INDEX

FORM 5767A-2

Lockheed · CALIFORNIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

I. SUMMARY

The B-52H airplane's demonstrated capabilities enable it to carry and launch the D-21B drones, with acceptable reductions to its performance and handling qualities.

To insure structural integrity of the D-21B's and their attachments, more restrictive flight limits are imposed on the B-52H while carrying one or two D-21B's, as follows:

1. The calibrated airspeed, CAS, is limited to 250-265 knots, a function of altitude, and the true Mach number to 0.8. See Figure 3.
2. The maneuver load factors are limited to the range +1.6 to +0.5 "g" at all gross weights.
3. The aft center-of-gravity limit is moved forward. See Figure 6.

The following estimated characteristics are based on extensive wind tunnel and analytical work on the D-21B drone, a brief B-52 flight simulator study of the launch and Boeing flight experience with the AGM-28 Hound Dog and dummy Skybolt missiles:

FORM 5767A-2

1. The B-52H's take-off performance will not be significantly affected with one and possibly even two D-21B's.

2. Climb speed reduction and added drag while carrying drones will increase the time to climb by as much as 23% with two drones or 19% with one drone and two pylons, compared to the clean configuration, at max. flight weight. The penalties are smaller at lower weights. Cruise range of the clean B-52H is reduced by 17% with two drones, 10% with one drone and two pylons and 3% with two pylons, at the same fuel loading. With all effects included, the unrefueled range with two D-21B's, no launch, is reduced from a typical 7640 n. miles to 4220 n. miles.

3. There will be only small degradations in the B-52H's handling qualities with the D-21B's, largely due to the asymmetry when flying with one drone.

4. Launch of the D-21B will result in acceptable transient responses of the B-52H.

5. The D-21B's and/or their rocket boosters can be jettisoned throughout the mated flight envelope.

FORM 5767A.2

II. INTRODUCTION

This report is intended to familiarize flight test personnel with the estimated characteristics of the B-52H/D-21B system. It also documents and discusses all flight limitations imposed on the B-52H due to carrying the drones.

The estimated characteristics include effects of the D-21B's on the B-52H's flying qualities and performance and its response to launch of the drones. The D-21B's complete launch and boosted flight trajectories are presented. Characteristics of emergency jettison of the drone and/or its rocket booster are discussed.

Extensive wind tunnel and analytical work has been devoted to the design and development of the D-21B, including wind tunnel tests mated to and separating from the B-52. Because the B-52 has demonstrated excellent capabilities as a carrier and launcher aircraft, no wind tunnel and only limited analytical work has been extended to the B-52H with pylons and drones. Rather, B-52 experience with similar stores has been reviewed to establish its suitability to carry and launch the D-21B. In particular, Boeing's flight experience with the AGM-28 Hound Dog and dummy Skybolt missiles was utilized to estimate effects of the D-21B on the B-52H. A brief flight simulator study of the B-52's response to launch of the D-21B was conducted, and the results are presented.

III. DESCRIPTION OF THE SYSTEM

The B-52H/D-21B system serves as a carrier and launch platform for the D-21B drone. The range capability of the B-52H allows global mission coverage while operating out of one base.

Configuration

The B-52H/D-21B system utilizes the B-52's two 25,000 pound hardspots located on the wings between the inboard nacelles and the fuselage at wing station 218. Specially designed pylons carry the D-21B, similar to the AGM-28 Hound Dog and Skybolt missiles, X-15 and NASA's lifting body installations.

The installation of two D-21B's on the B-52H is shown in Figure 1. The drones are carried in a normal flight attitude. The vertical tail has minimum vertical clearance with the aft lower surface of the B-52H wing. It is carried far enough forward to allow normal operation of the B-52H wing flaps, with no flap cut-outs. Ground clearance is minimum, requiring the ventral fin on the D-21B's booster rocket to fold to one side. Special care must therefore be taken in ground operation, take-off and landing. A landing can be made with the folding rocket fin in the down position. The fin will be torn off and all significant damage should be confined to the fin and its attachment structure.

Pylon Attachment

The inboard profile, Figure 2, shows in more detail the D-21B and pylon. The drone is attached to the pylon by three explosive bolts; two forward on a yoke straddling the fuselage and one aft on the fuselage top centerline.

Umbilical connections between the pylon and the D-21B carry command, control, D-21B system evaluation information, power and air conditioning air between the B-52H and the drone. During mated flight and until moments before launch the systems within the D-21B are monitored and checked in order to assure the highest probability of mission success. The two Launch Control Officers (LCO), one for each D-21B, are responsible for the operation of the D-21B systems through mated flight, launch, boost, and into cruise where the D-21B will eventually exceed command range.

Weight

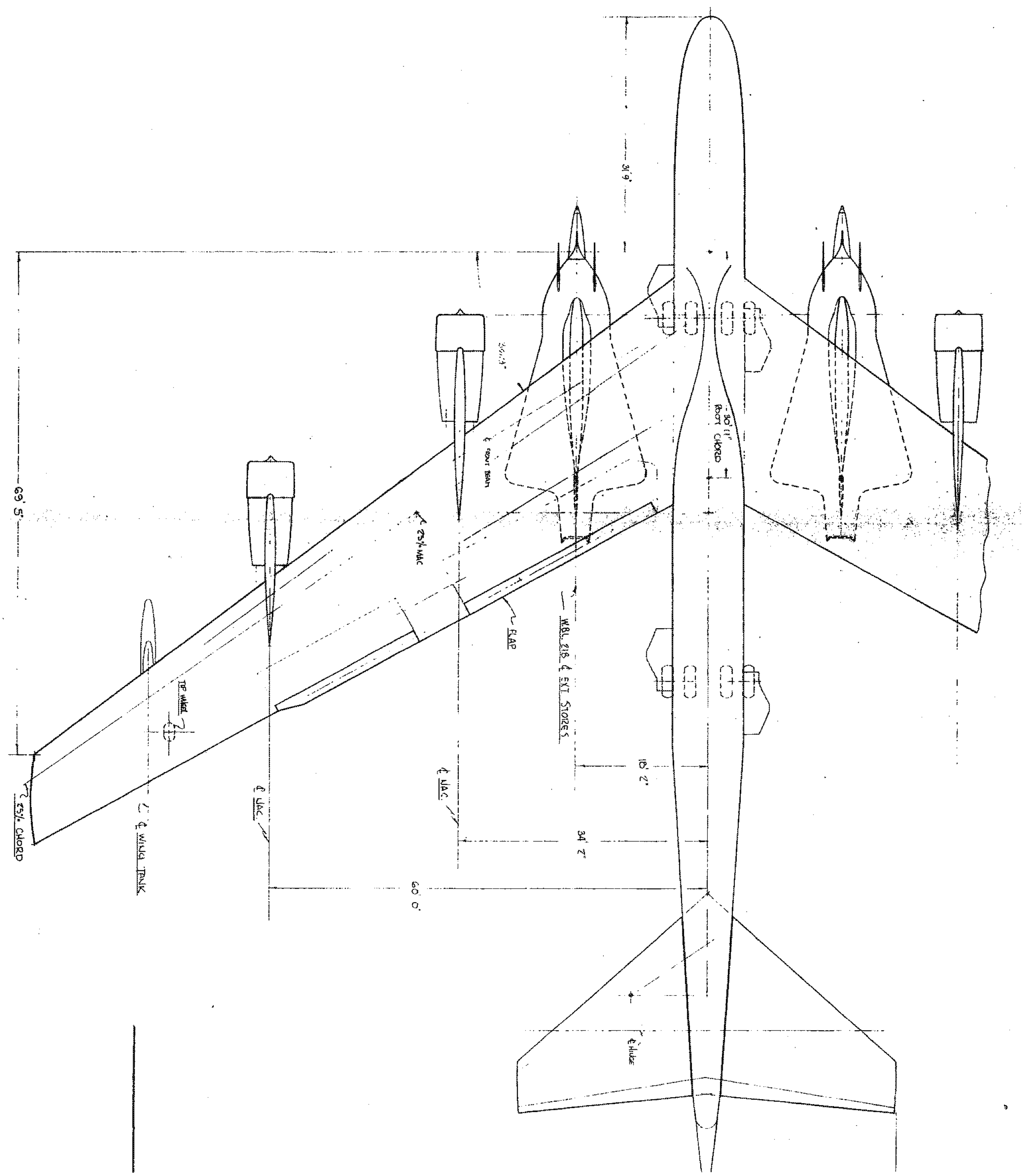
The following weight changes are incurred in converting a B-52H to the B-52H/D-21B system. These numbers are subject to change and not intended for detailed weight and balance calculations.

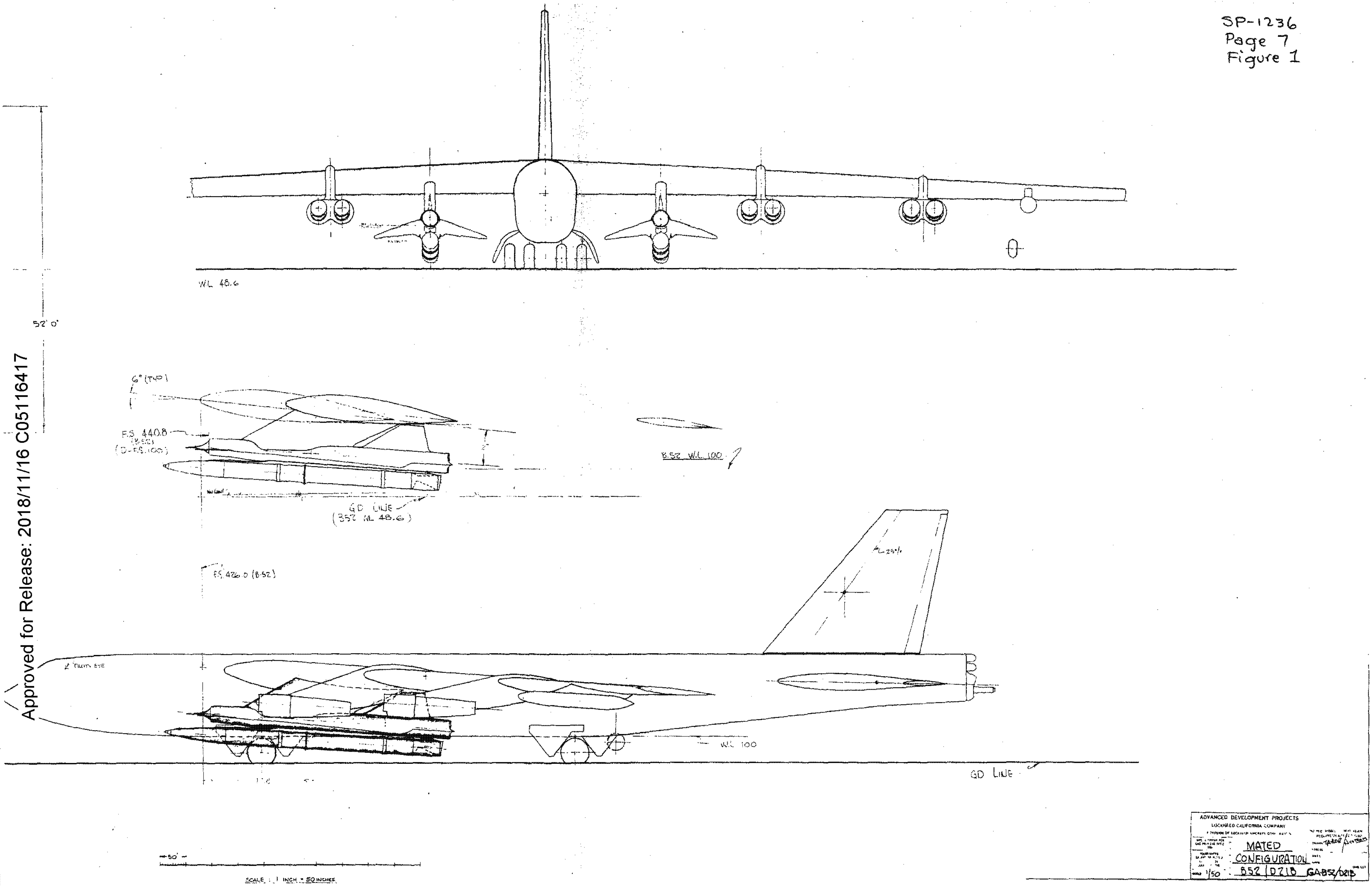
- net change in B-52H weight for equipment added and deleted and installation of two pylons: + 5078 lbs.

FORM 5767A-2

. weight of each D-21B and booster	+24,410 pounds
. total weight added	+53,898 pounds
. location of each D-21B weight addition is at	(-) 5.5% MAC and 218" off centerline of the B-52H

FORM 5767A-2


31' 9"
69' 5"
ROOT CHORD
FRONT BEAM
25% MAC
FLAP
W.B.L. 218 ℄ EXT STORES
18' 2"
34' 2"
60' 0"
℄ MAC
TIP WHEEL
℄ WING TRUNK
25% CHORD



Approved for Release: 2018/11/16 C05116417

Figure 2. Inboard Profile of D-21B

(To Be Provided)

FORM 57674-2

Approved for Release: 2018/11/16 C05116417

IV. B-52H/D-21B OPERATING LIMITATIONS

The carrying of one or two D-21B's requires additional limits on the airspeed, maneuver load factors and aft center-of-gravity of the B-52H, compared to the clean configuration. With the D-21B pylons only, the B-52H flight limits are unaffected.

Limit Airspeed

B-52H limit airspeeds in terms of calibrated airspeed (CAS) are presented in Figure 3. Calibrated airspeed closely approximates indicated airspeed (IAS), since they differ only by the instrument and position errors. The limit speeds in terms of true Mach number are shown in Figure 4.

Figure 3 shows that the B-52H with one or two D-21B's is limited to a CAS of 250-265 knots and a true Mach number of 0.8. These are structural limits, primarily for the attachment of the D-21B's to their pylons. This CAS limit is considerably below the "best climb speed" of the clean configuration (310 KIAS at MRT and 295 KIAS at NRT). This has a significant effect on the climb performance, as discussed in Section VI of this report.

The nominal launch Mach number is seen to be on the 0.8 limit. There are adequate safety margins, however, for a normal Mach number tolerance.

Maneuvering Load Factors

The maneuvering load factor limits of the B-52H are presented in Figure 5. The reduced limits of +1.6 and +0.5 "g" with one or two D-21B's are due to structural attachments of the drones.

Center-of-Gravity

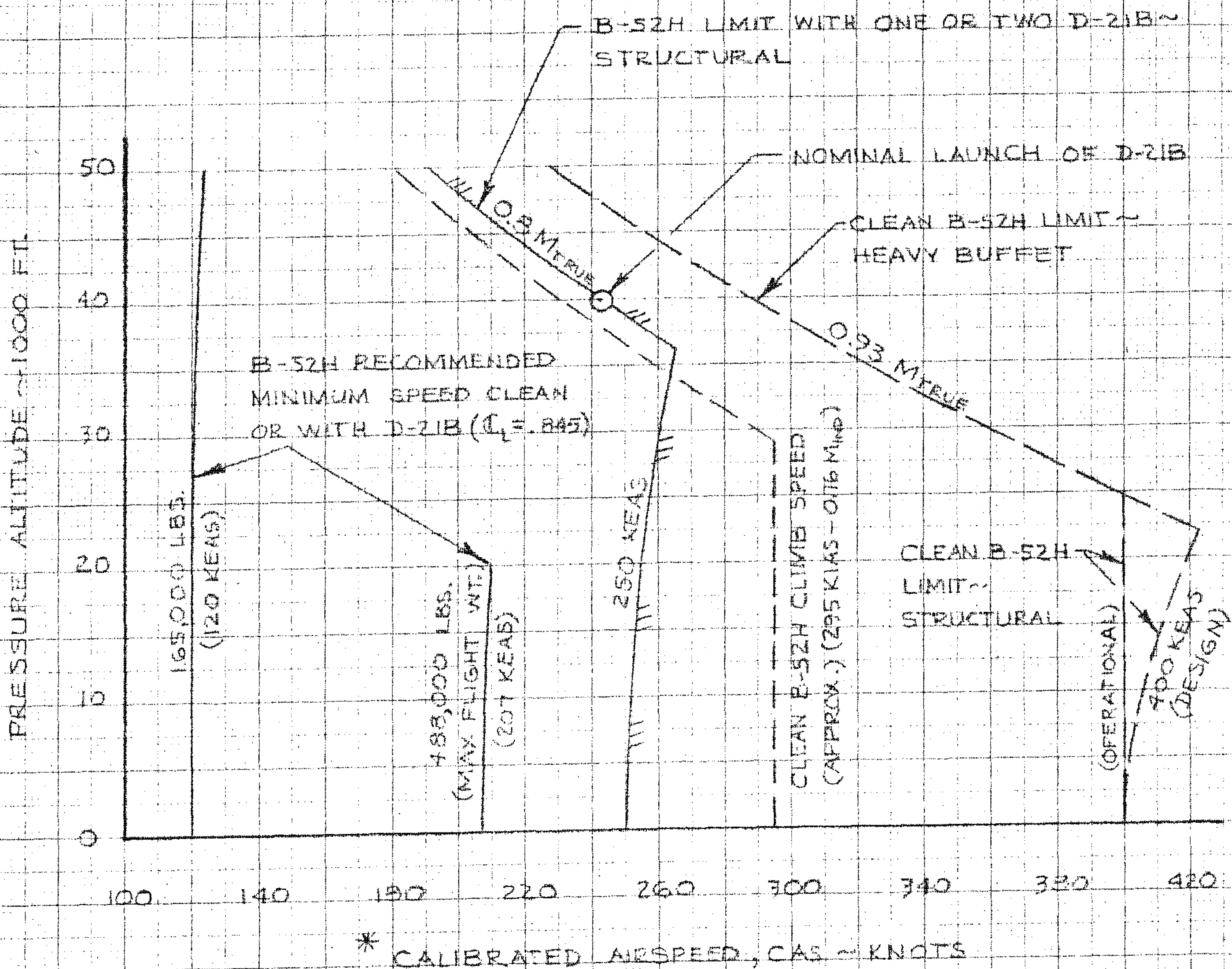
Center-of-gravity limits are presented in Figure 6. With one or two D-21B's the forward limit is unchanged, but the aft limit is moved significantly forward. This is necessary so that the B-52H's aft limit of 35% MAC is not exceeded when the drones are dropped.

Figure 3

B-52 H LIMIT SPEEDS ~ CALIBRATED AIRSPEED

FLAPS AND GEAR UP

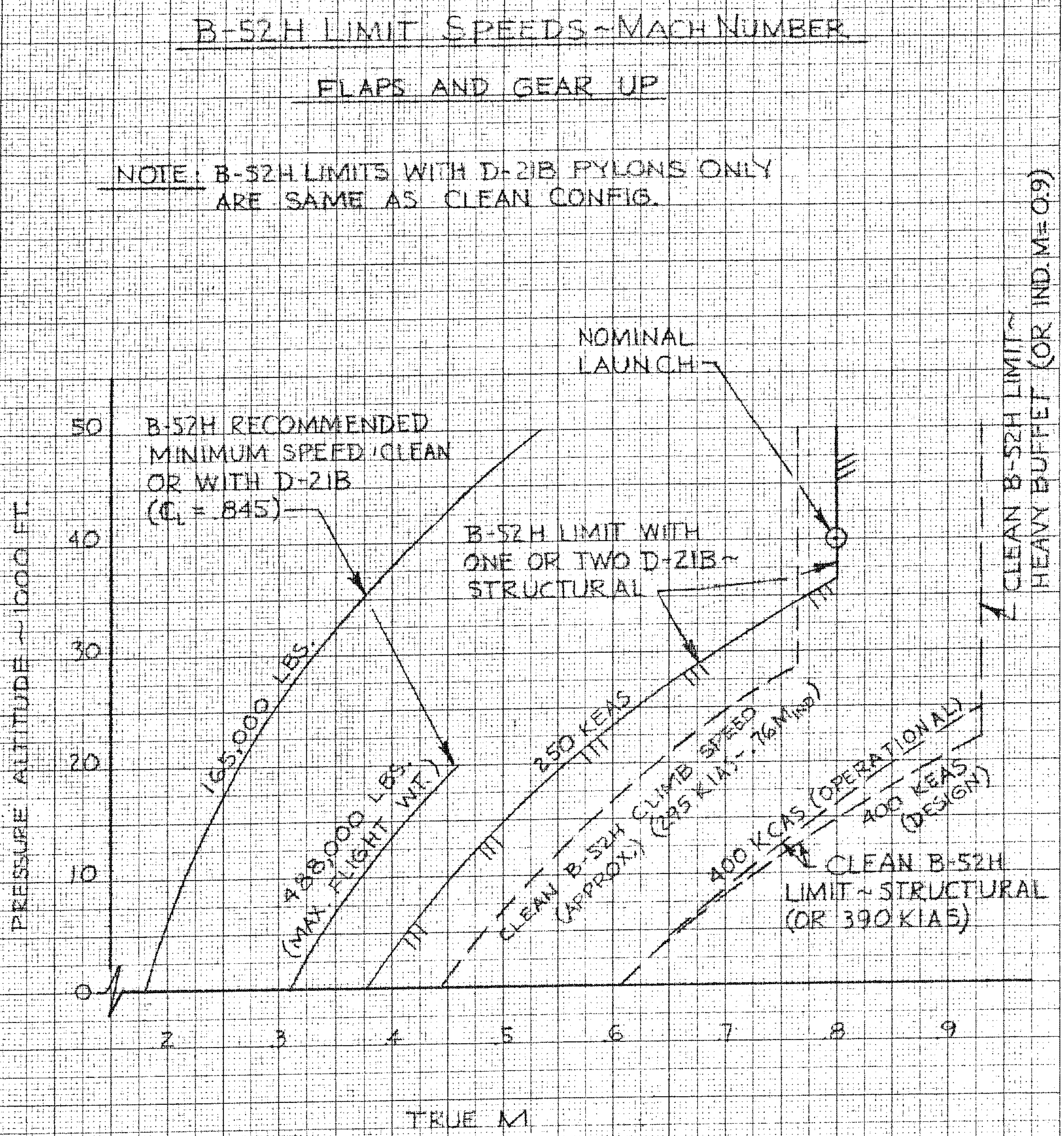
NOTE: B-52H LIMITS WITH D-21 B PYLONS ONLY ARE SAME AS CLEAN CONFIG.



* CAS = IAS + INSTR. ERROR + POSITION ERROR

FORM 5278A

Figure 4



FORM 5278A

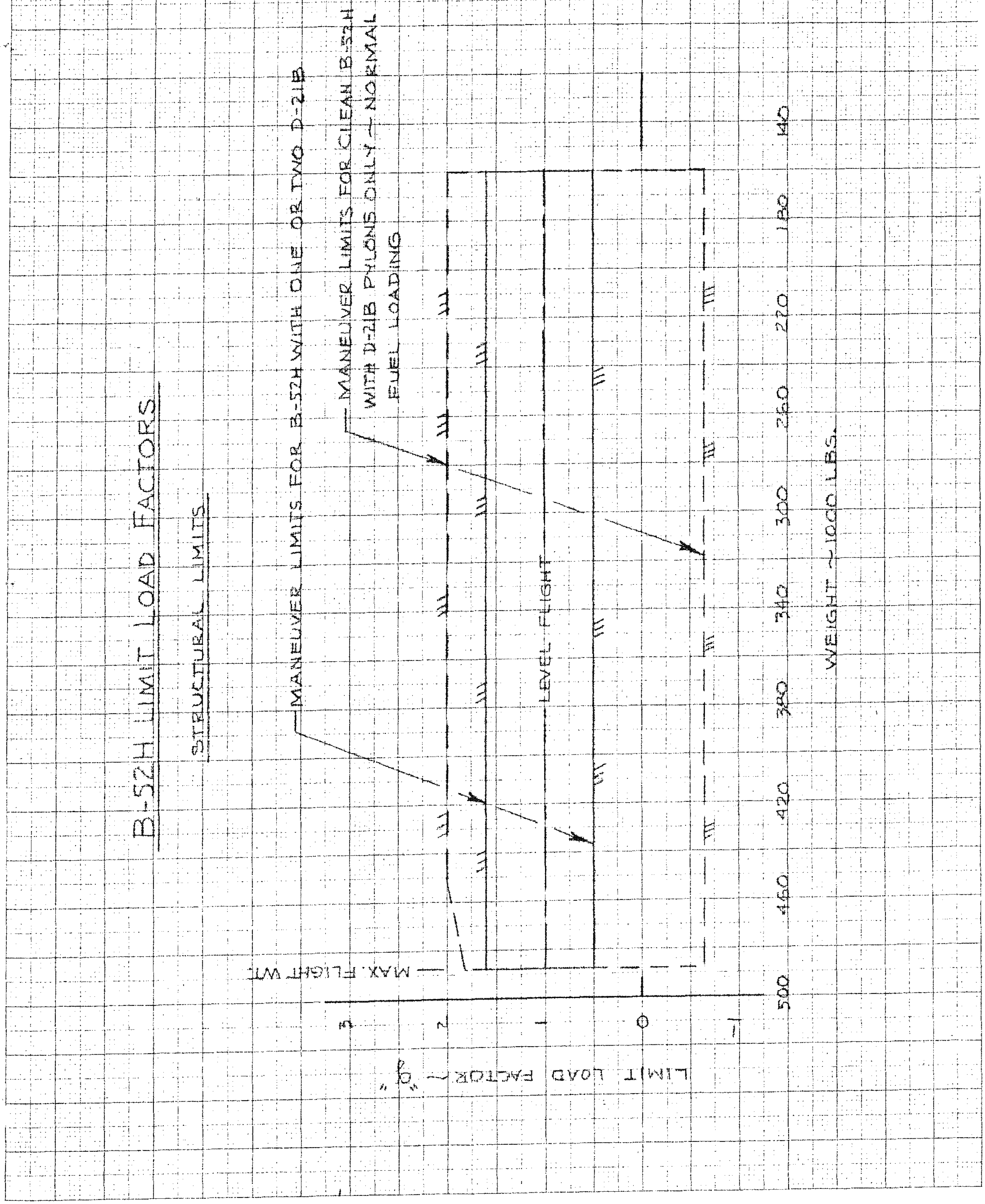
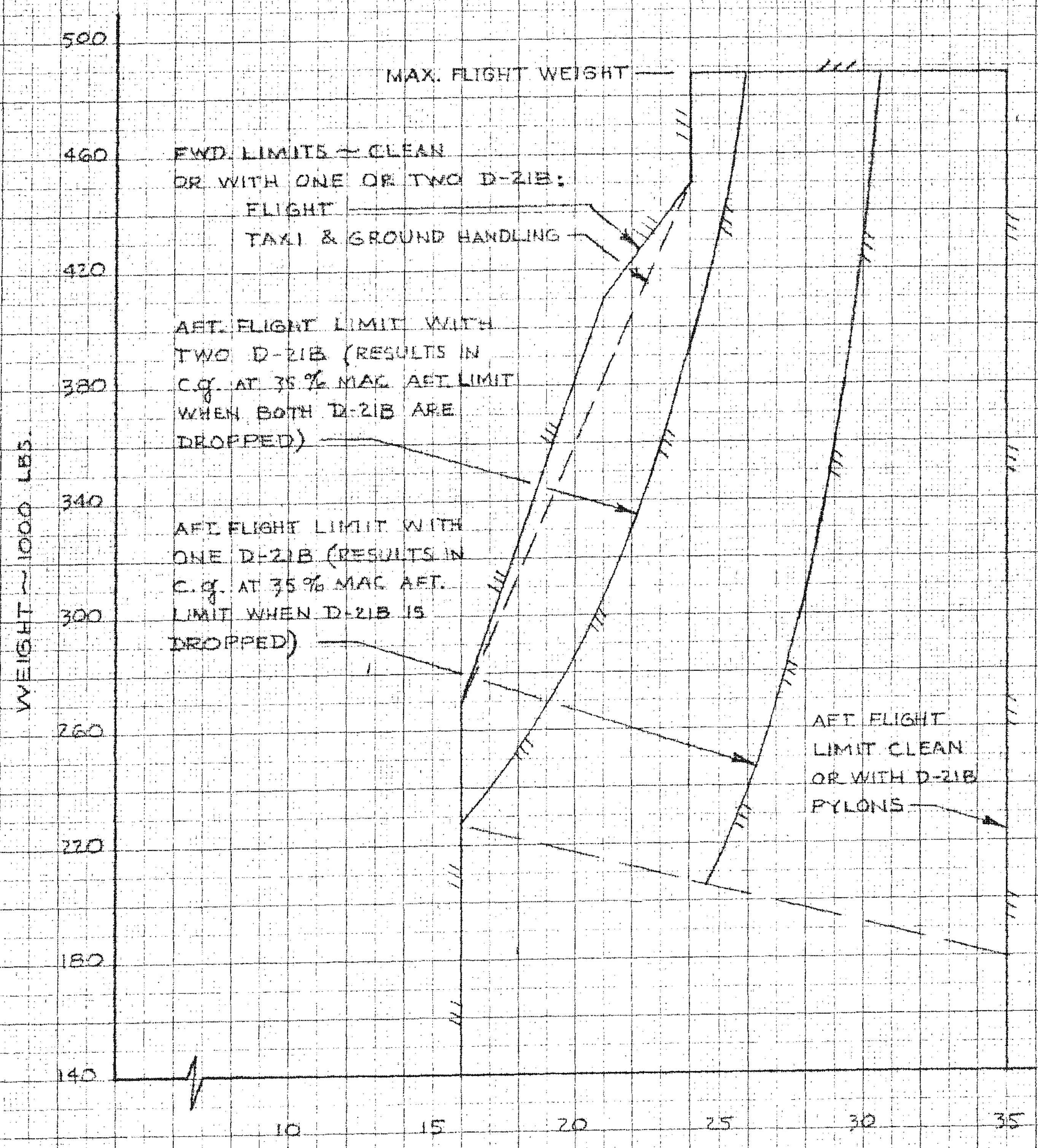


Figure 5

Approved for Release: 2018/11/16 C05116417

Figure 6

B-52H CENTER-OF-GRAVITY LIMITS



FORM 5278A

V. B-52H/D-21B FLIGHT CHARACTERISTICS

The demonstrated performance, stability and control capabilities of the B-52H are sufficient to provide satisfactory operation with D-21B's added. Since the B-52's have shown satisfactory characteristics with similar stores such as X-15, Hound Dog and Skybolt, no detailed performance, stability and control analysis were made. The following observations are based on rough estimates and a review of Boeing's flight experience with the Hound Dog and Skybolt missiles.

Airspeed Calibration

The airspeed, altitude and Mach number position errors will be affected by carrying D-21B's on either side, since the airflow over the static ports will be affected by the drones. The additional position error for one D-21B may be as much as the error for the clean airplane, and the increment may be doubled for two D-21B's.

Longitudinal Stability and Control

It is expected that the addition of the D-21B's will move the B-52H's neutral stability point forward in terms of % MAC. The aft center-of-gravity limits with drones are also moved forward, however (Figure 6), more than the estimated forward movement of the neutral stability point. Therefore, the longitudinal flying qualities in terms of

FORM 5767A.2

"speed stability" (stick force vs. speed) and "maneuvering stability" (stick force vs. load factor) will not be appreciably affected at permissable center-of-gravity locations.

For trim, the AGM-28 missiles require a small nose-down stabilizer increment. Additional nose-down trim can be expected to be required for the D-21B's, but well within the B-52H's trim capability. For take-off, the stabilizer trim settings determined for the clean airplane from the Flight Handbook can be used. The trim shift due to the drone(s) can be compensated by elevator control or manual trimming as required. Flight experience may derive an increment of stabilizer trim for take-off with one and two D-21B's.

Lateral-Directional Stability and Control

Based on the AGM-28 and Skybolt flight tests, the lateral-directional effects of carrying one D-21B can be easily compensated by spoiler and rudder deflections. To minimize these control deflections with one D-21B it is recommended that for take-off, landing and for best long range cruise, lateral trim be accomplished by asymmetrical fuel loading and directional trim by asymmetrical thrust. The unbalanced drag of one D-21B at 150 knots IAS is approximately 500 pounds. Hence it can be balanced by about 250 pounds thrust on an inboard engine or 150 pounds on an outboard engine. Asymmetrical fuel loading and thrust are optional for launch while carrying one D-21B.

Lateral-directional trim with one D-21B will not be a problem during normal operations. With an inoperative outboard engine and/or lateral or directional control malfunction, however, minimum airspeeds must be approached with caution.

The mated drones cause a loss of local lift on the B-52 wing, and this reduces the damping in roll. Roll rates can therefore be expected to be increased by 20% or more, based on AGM-28 experience.

Also based on AGM-28 missile tests, the Dutch Roll stability of the B-52H with D-21B's will be degraded. The time to damp Dutch Roll oscillations to half amplitude was increased 4 to 5 seconds with AGM-28's. Similar or greater time increments can be expected with D-21B's.

Buffet

The effect of the D-21B's on buffet characteristics can only be determined by flight test. However, the reduced limit Mach number of 0.8 with drones should prevent a high-speed buffet problem. The low-speed buffet margins were not significantly affected by the AGM-28 missiles and should not be by the D-21B's.

Aerial Refueling

Aerial refueling with one AGM-28 was accomplished without difficulty.

VI. EFFECTS ON B-52H PERFORMANCE

One or two D-21B's significantly affect the B-52H's climb and cruise performance, partly because the climb speed must be reduced. This airplane's great performance capability, however, still permits impressive operations with the drones. Estimated performance effects are presented here to give an initial appreciation of their magnitude.

Take-off

At take-off airspeeds the drag of one D-21B and two pylons is low (750 pounds at 150 knots IAS), and it is expected that the Flight Handbook take-off performance of the clean airplane can be achieved. This was the experience with two AGM-28 missiles. For take-off with two D-21B's, flight test experience may establish a small increase in EPR setting to achieve comparable performance to the clean airplane.

Climb

With one or two D-21B's, the B-52H's rate of climb is reduced both by drone drag and the reduced limit airspeed of 250-265 knots CAS. The best climb speeds of the clean configuration are 310 knots IAS at MRT and 295 knots IAS at NRT. Above approximately 34,000 feet the B-52H with drones can climb at the clean airplane's best climb Mach number of 0.76. With pylons only, the best climb speeds can be maintained at all altitudes.

The estimated effects on climb performance are summarized below. The tabulated numbers are percent loss in rate of climb, compared to the clean configuration at best climb speed, 8 engines, MRT or NRT from the Flight Handbook. The same percentages apply as increases in time, distance and fuel to climb, compared to the clean configuration:

Climb speed 250-265 knots, CAS (S. L. to approximately 34,000 feet):

Initial Climb Wt., 1000 lbs:	160	240	320	400	480
With 2 D-21B, %	12	14	15	19	23
With 1 D-21B, 2 pylons, %	9	10	13	15	19
With 2 pylons, % *	1.5	1.5	1.5	2	2

*at best climb speed, clean configuration

Best climb Mach number 0.76 (above approximately 34,000 feet):

Initial Climb Wt., 1000 lbs:	160	240	320	400	480
With 2 D-21B, %	18	21	23	26	-
With 1 D-21B, 2 pylons, %	11	13	14	15	-
With 2 pylons, %	3.5	4	4.5	5	7.5

FORM 5767A.2

Cruise

The estimated percent loss of cruise range at the same fuel loading, compared to the clean airplane, is as follows:

With 2 D-21B, %	17
With 1 D-21B, 2 Pylons, %	10
With 2 pylons, %	3

An example mission for the clean B-52H and with two D-21B's, no launch, is presented on the following page.

Lockheed · CALIFORNIA COMPANY

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

EXAMPLE RANGE MISSION, B-52H

Reference: Flight Handbook, T.O. 1B-52H-1-1

	CLEAN		WITH 2 D-21B NO LAUNCH	
Operating wt.	198,692		198,692	
2 D-21B's	---		53,898	
Zero fuel wt.	198,692		*252,590	
Fuel	289,308		235,410	
Max. flight wt.	488,000		488,000	
**Climb @ MRT: fuel	11,300		13,900	
dist.		90 n. mi.		110 n. mi.
Initial cruise wt.	476,700		474,100	
End cruise wt.	228,623		282,521	
***Cruise @ .76M @ "Cruise Ceil.": fuel	248,077		191,579	
dist.		7500		4060
Descent: fuel	1,000		1,000	
dist.		50		50
Landing wt.	227,623		281,521	
Reserve fuel (10% initial)	28,931		28,931	
Zero fuel wt.	198,692		252,590	
Total Distance, n. mi.		7640		4220

* includes ballast fuel to keep c.g. within limits

** penalty for 2 D-21B's = 23% compared to clean

*** penalty for 2 D-21B's = 17% compared to clean, exclusive of reduced cruise fuel

VII. NORMAL LAUNCH OF D-21B

The Mach number and altitude for normal launch of the D-21B drones have been selected as 0.8 Mach and 40,000 feet, from level flight of the B-52H. This Mach number and altitude provides a high starting point for the drones' boost trajectory and is well within the envelope of satisfactory flight characteristics of the B-52H with mated D-21B's.

The background of wind tunnel and flight simulator tests, the B-52H's response to launch and the D-21B's launch and boost trajectories are described in the following paragraphs.

Wind Tunnel and Flight Simulator Tests

To substantiate satisfactory separation characteristics, the air loads were measured on a model of the D-21B drone while mated to and separating from a B-52 model in the wind tunnel at the launch Mach number of 0.8. These loads were then used in a digital computer program to analyze separation and boosted flight trajectories.

Since the B-52 has demonstrated satisfactory launch of a variety of vehicles, including the X-15 airplane, the air loads on the B-52 model were not measured in the D-21B mated and separation wind tunnel

FORM 5767A-2

tests. The response of the B-52 to the center-of-gravity shift and weight loss during launch of the D-21B has been studied, however, in a B-52 flight simulator.

The flight simulator tests were conducted by a qualified B-52 pilot in the Boeing simulator at Wichita. The results in terms of maximum values of the B-52's response are presented in Figure 7. Cases 5 and 6 of Figure 7 are for the simultaneous launch of two D-21B's, and are not operational conditions. For one typical case, Case 4, time histories of the B-52's load factor and control column position are presented in Figure 8a. The roll angle and wheel position are shown in Figure 8b. It is seen that the load factor of the B-52 can go through a significant excursion. It should be noted that all of the load factor excursions in Figure 7 are well within the structural capabilities, designed by gusts, of the basic B-52H and B-52H/D-21B systems.

It is evident from Figure 8a that the pilot moved the control column forward to counteract the initial nose-up response and then made relatively small corrections as the B-52 damped out. This general procedure is recommended for the actual launches. Too rapid control movement can easily get "out-of-phase" with the B-52's response in pitch and roll.

The pilot who made the simulator flights felt that the responses were satisfactory, and that no "pre-trimming" of the B-52 was necessary.

D-21B Launch and Boost Trajectories

The drone's launch and initial boosted flight trajectory is presented in Figure 9. The trajectory has been derived from the digital computer program mentioned above. It is seen that the D-21B drops straight down relative to the B-52, the booster ignites at 5 seconds after launch, and the drone's autopilot starts a pull-up 10 seconds after launch. The drone will pass through the launch altitude about 7000 feet ahead of the B-52 if the latter continues on the launch heading.

To get out from under the D-21B's straight ahead flight path, it is recommended that the B-52 turn after launch and move one or two miles to the side of the drone's track. Launch course should then be resumed to minimize telemetry range to the D-21B. The turn should not be initiated until the LCO has observed booster ignition in his periscope, to insure coverage for the cameras on the B-52.

Figure 10 presents the D-21B's complete boosted flight trajectory and initial cruise. This trajectory is relative to earth, therefore B-52 locations are also spotted. For normal booster jettison from the drone, it is seen that the booster case will fall approximately 17 miles ahead of the B-52.

It is recommended that the B-52 continue on course, after the turn out to the side, until the drone is out of telemetry range. If a destruct signal is sent to the drone, the B-52 should reverse course to avoid falling debris.

Tolerances on Flight Conditions at Launch

Flight safety is not sensitive to launch flight conditions, but the D-21B's boosted flight performance will be affected by variations in launch Mach number and altitude. The target launch conditions must therefore be established with reasonable care.

The launch conditions are:

Target (true)	Tolerance
M = 0.80	± .02
h = 40,000 Ft.	± 500 Ft.
Load Factor = 1.0	± .1

The procedure recommended in the Flight Handbook for holding Mach number accurately should be followed. This is to calculate and fly the corresponding indicated airspeed (IAS).

B-52H RESPONSE TO D-21 LAUNCH

B-52H Flight Simulator Study

Summary of Max. Values

CASE	LAUNCH* CONDITION	PILOT NOTICE	LOAD FACTOR "g"	PITCH ANGLE Deg.	CONTROL COLUMN Deg.	ELEVATOR Deg.	ROLL ANGLE Deg.	WHEEL Deg.
1	One D-21B B-52H c.g. @ 27.75%	None	1.2 0.25	2 -2	13.5 (push)	9.7	3 -5.7	0 -66
2	One D-21B B-52H c.g. @ 27.75%	Count-down	1.25 0.25	1.7 -2.5	10.5	9.1	1.9 -1.9	0 -46
3	One D-21B B-52H c.g. @ 35%	None	1.4 0	3.2 -3.3	12.6	9.7	2.5 -0.7	6 -60
4	One D-21B B-52H c.g. @ 35%	Count-down	1.25 0.6	1.7 -2.6	10	9	3.7 --	3 -39
5	Two D-21B ** B-52H c.g. @ 35%	None	1.8 0	4.9 -3.8	18	11	--	--
6	Two D-21B ** B-52H c.g. @ 35%	Count-down	1.2 0.4	1 -2.5	13.3	10.1	--	--

* c.g. shown is after release

All cases: B-52H Wt. = 270,000 lbs., D-21B Wt. = 24,000 lbs. (each)
Mach No. = 0.8, Altitude = 40,000 ft.

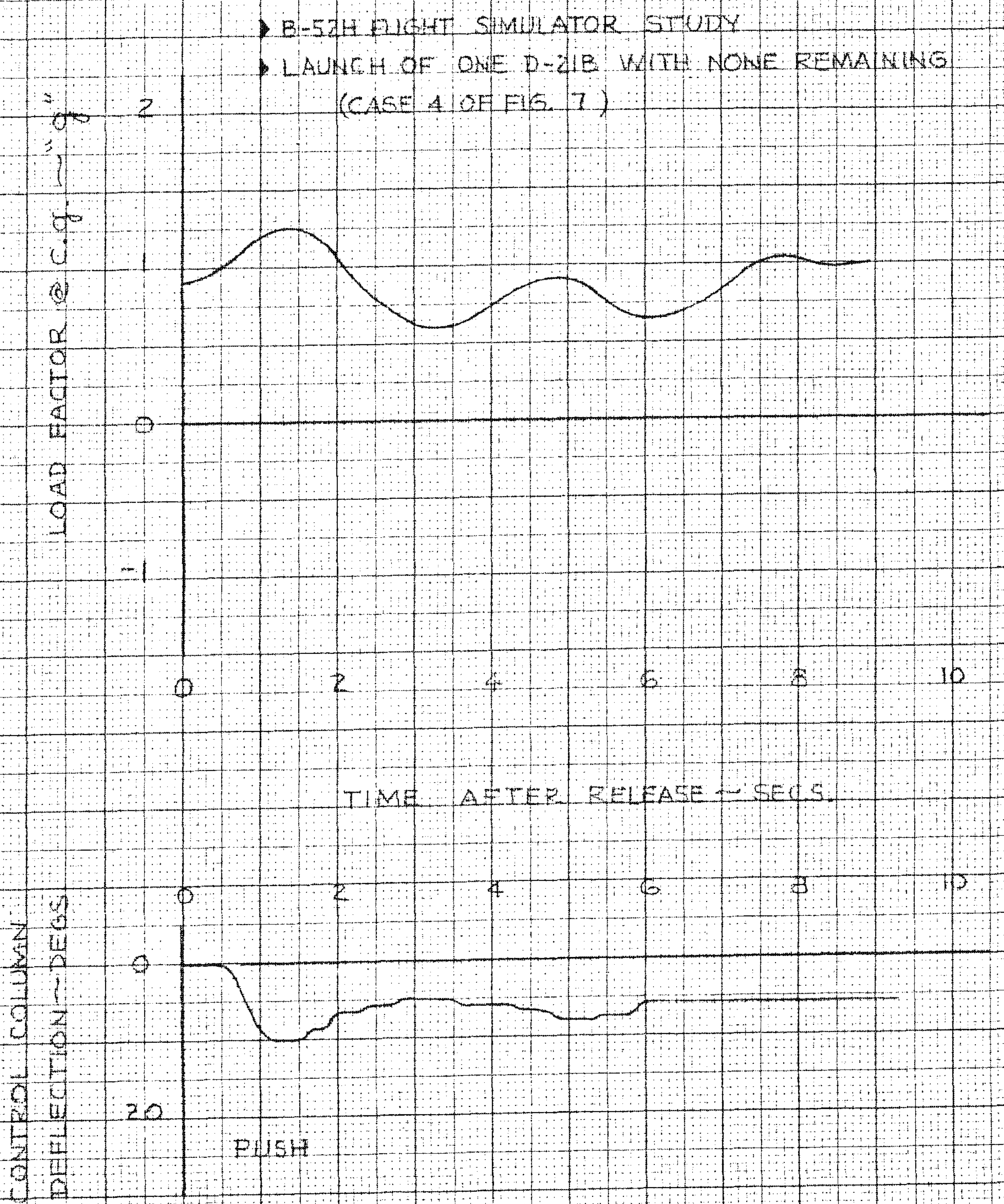
** Not an operational condition.

SP-1236
Page 26
Figure 7

Approved for Release: 2018/11/16 C05116417

Figure 8a

B-52H TIME HISTORY DURING D-21B LAUNCH



FORM 5278

Figure 8b

B-52H TIME HISTORY DURING D-21B LAUNCH

- B-52H FLIGHT SIMULATOR STUDY
- LAUNCH OF ONE D-21B WITH NONE REMAINING (CASE 4 OF FIG. 7)

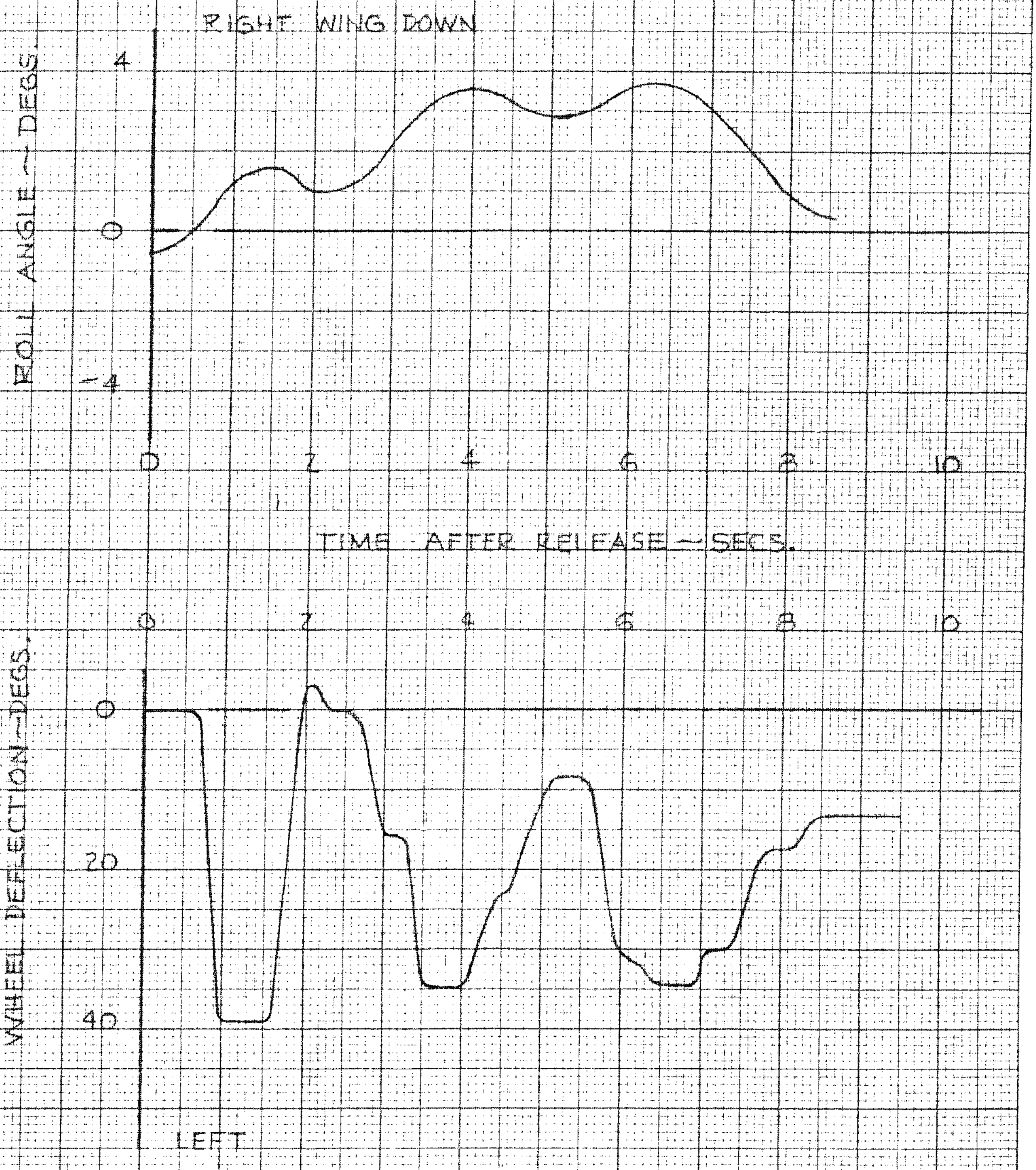
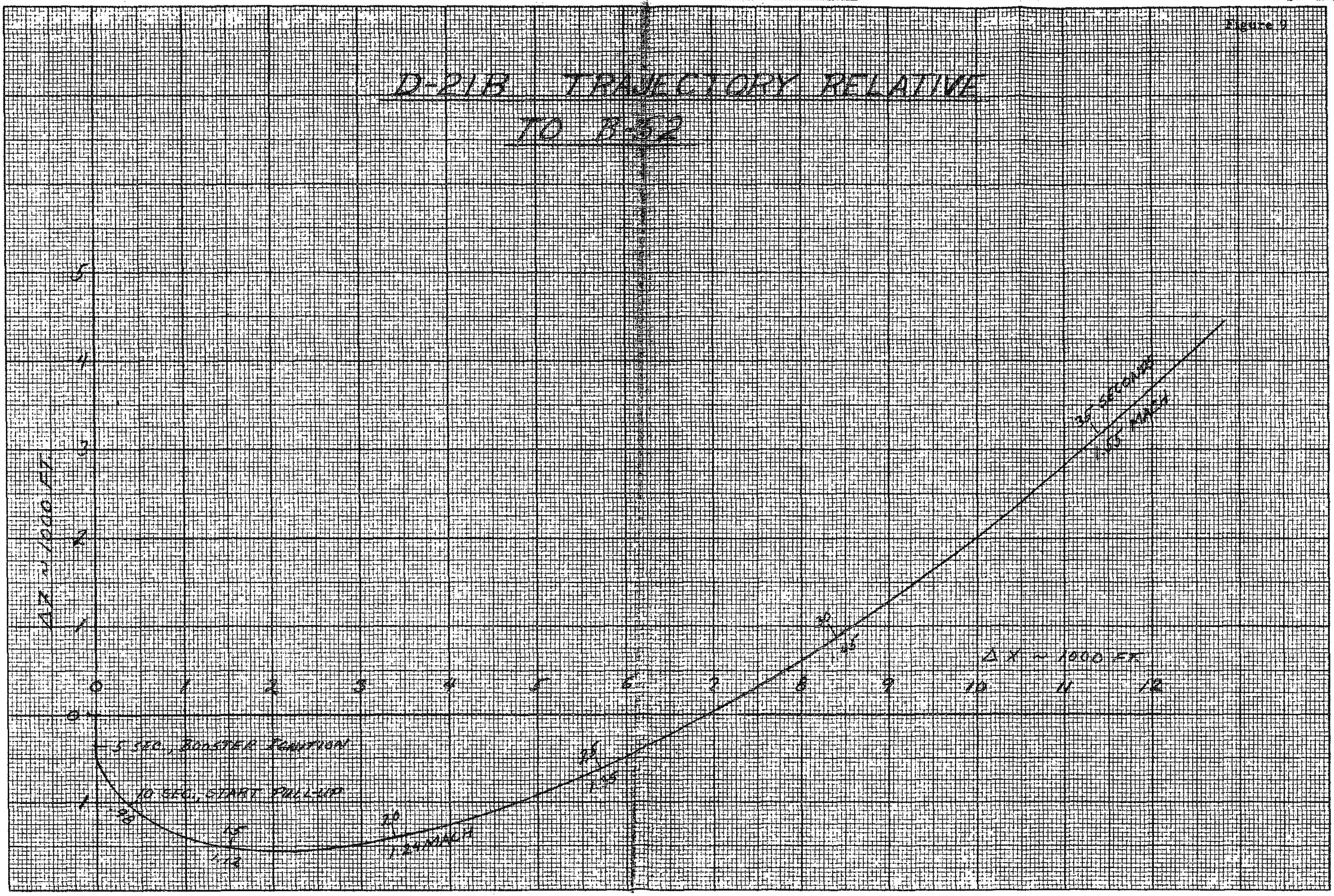


Figure 9


D-21B TRAJECTORY RELATIVE TO B-52
ΔZ ~ 1000 FT.
ΔX ~ 1000 FT.
5 SEC., BOOSTER IGNITION
10 SEC., START PULL-UP
15
1.12
20
1.24 MACH
25
1.35
30
1.45
35 SECONDS
1.55 MACH

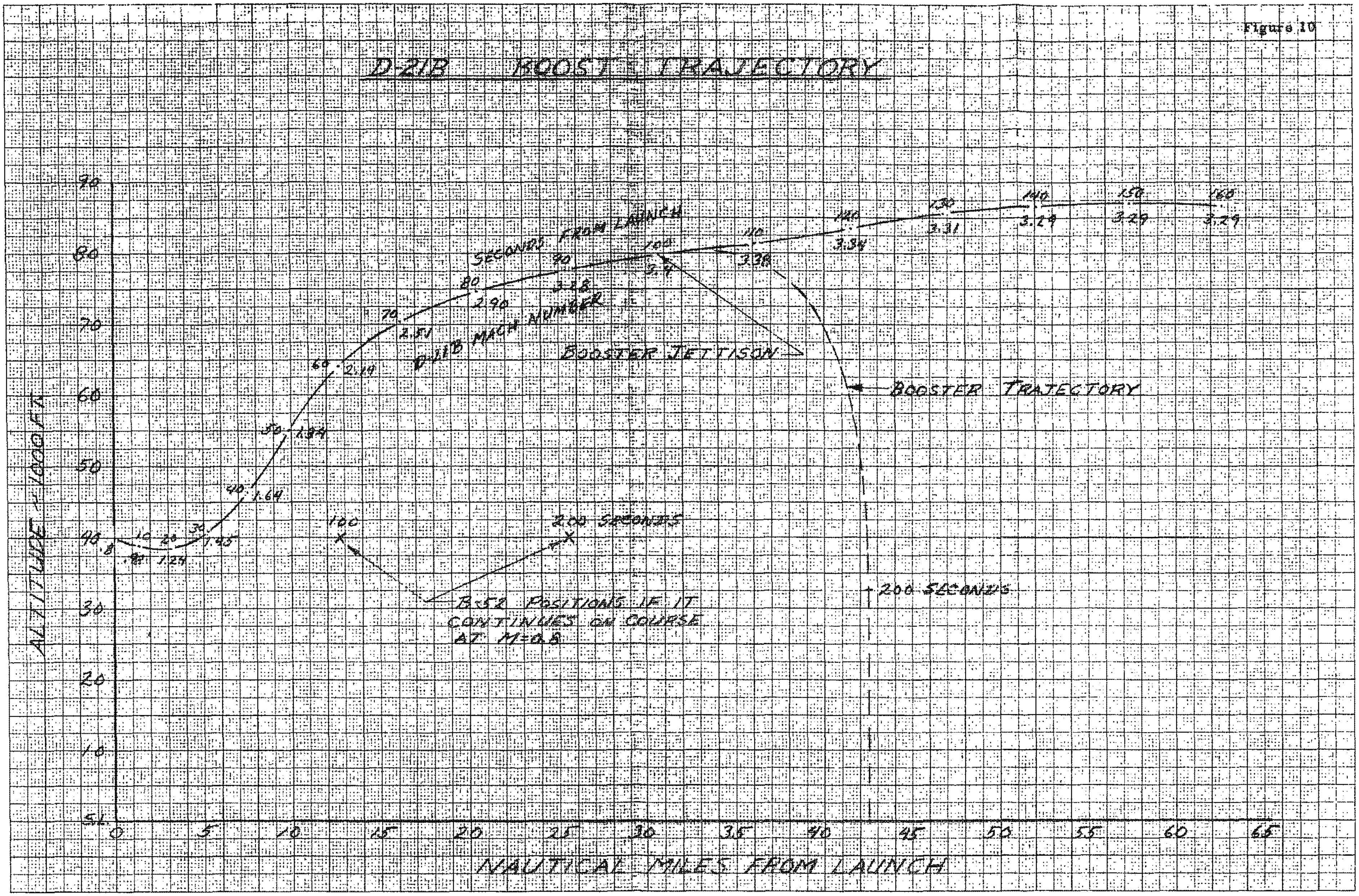


Figure 10
D-21B BOOST TRAJECTORY
ALTITUDE ~ 1000 FT
NAUTICAL MILES FROM LAUNCH
SECONDS FROM LAUNCH
D-21B MACH NUMBER
BOOSTER JETTISON
BOOSTER TRAJECTORY
200 SECONDS
B-52 POSITIONS IF IT CONTINUES ON COURSE AT M=0.8
100
200 SECONDS

Lockheed · CALIFORNIA COMPANY

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

VIII. EMERGENCY JETTISON OF D-21B

The D-21B/B-52H system has been designed to allow emergency jettison of a complete D-21B, a rocket booster only, or a drone without booster. As for the normal launch, separation trajectories have been analyzed in an IBM computer program, using wind tunnel-measured air loads on the drone. The characteristics of jettison in each drone configuration are discussed in the following paragraphs.

Jettison of D-21B with Booster

The drones with booster can be jettisoned, one at a time, throughout the mated flight envelope from level flight with flaps up. When jettison is commanded, the D-21B's elevons are automatically moved to 10 degrees trailing edge down using stored energy independent of the drone's basic hydraulic system. This elevon positioning assures positive and rapid separation.

Best jettisons are achieved at low indicated airspeeds and low B-52 weights where aerodynamic forces and moments on the drone are small. B52/D-21B center-of-gravity limits must be observed so that an emergency jettison does not leave the B-52H with an unsatisfactory center-of-gravity location.

FORM 5767A-2

Jettison of Booster Only

The booster can be jettisoned from the D-21B while the drone is still mated to the B-52H. Booster jettison can be accomplished throughout the D-21B/B-52H mated flight envelope, level flight, with B-52 flaps up or down. Here again minimum indicated airspeed yields safest jettison.

Jettison of D-21B Without Booster

Jettison of a D-21B without booster can be accomplished under the same conditions as jettison with booster. In this situation, however, impact of the D-21B's vertical tail against the lower surface of the B-52 wing can be expected. For this possibility, the B-52's lower wing surface has been reinforced in this area by the addition of a bumper plate scabbed onto the skin. The degree of vertical tail impact can be lessened by jettisioning at low indicated airspeed and at low B-52 weight.

The D-21B's 10 degrees down elevon for jettison has been conservatively chosen to assure safe separation, while recognizing the impact problem with the drone without booster. When flight-measured loads on the mated drone become available, the jettison elevon position will be reevaluated to find if the vertical tail impact problem can be reduced without compromising the general separation.