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SATURN IB SA-217 REFERENCE LAUNCH VEHICLE JANUARY 1968

By Space Vehicle Systems Branch
Propulsion and Vehicle Engineering Laboratory

NASA

George C. Marshall
Space Flight Center,
Huntsville, Alabama

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By

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ABSTRACT

This document contains a definition of a reference Saturn IB launch vehicle designated SA-217.

The Saturn IB SA-217 is a projected reference vehicle, based on Saturn IB SA-212, incorporating the latest proposed product improvements. The two-stage payload capability of this vehicle to a 100-nautical-mile circular orbit is 44,965 pounds. The Saturn IB SA-217 launch vehicle is to be used as the baseline vehicle for advanced studies requiring the use of the standard or modified Saturn IB launch vehicle. This vehicle definition does not necessarily represent approved changes to any specific vehicle.

This document supersedes the Saturn IB SA-213 Reference Launc Vehicle, described in memorandum R-P&VE-DIR-65-92.

GEORGE C. MARSHALL SPACE FLIGHT CENTER

TECHNICAL MEMORANDUM X-53686

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Compiled By

Space Vehicle Systems Branch
Advanced Studies Office

PROPULSION AND VEHICLE ENGINEERING LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

ACKNOWLEDGMENT

Specific appreciation is expressed to the Advanced Studies Office and other elements within the Aero-Astrodynamics Laboratory and to the participating elements of the Propulsion and Vehicle Engineering Laboratory for the many necessary technical contributions to this report. The individuals involved are too numerous to name but special recognition is warranted to J. P. Hethcoat and B. W. Shelton, R-P&VE-AV, and R. Marmann, R-P&VE-VAW, for their diligent efforts in providing and directing technical disciplines of this study.

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SATURN IB SA-217 REFERENCE LAUNCH VEHICLE
JANUARY 1968

SUMMARY

This document contains a definition of a reference Saturn IB launch vehicle designated SA-217.

The Saturn IB SA-217 is a projected reference vehicle incorporating the latest product improvements. The improvements were primarily in the reduction of weight in both stages. S-IB stage weight was reduced by using lighter materials and structural redesign. Incorporating the J-2S engine into the S-IVB stage resulted in the reduction of overall stage weight as well as providing increased performance. No changes were made in the Instrument Unit or in vehicle instrumentation. The resulting performance analysis indicates a payload capability of 44 965 pounds into a nominal 100-nautical-mile-circular orbit.

Where changes are not specifically indicated, current design data of the Saturn IB SA-212 launch vehicle are assigned. The Saturn IB SA-217 launch vehicle is to be used as the baseline vehicle for advanced studies requiring the use of the standard or modified Saturn IB launch vehicle.

It may be stated that although this vehicle definition does not necessarily represent approved changes to any specific vehicle, all anticipated changes and product improvements are technically feasible and are within the current state-of-the-art.

SECTION I. INTRODUCTION

Many technical studies and analyses are conducted to define probable future improved or uprated versions of the Saturn IB launch vehicle. As these projected concepts are for vehicles beyond present production commitments, it is necessary that some reasonable "at end of commitment" configuration be used as a baseline. The purpose of this document is to define such a baseline configuration. This enables the future improved or uprated vehicle to be referenced from a common denominator.

Many nominal product improvements are expected as production and engineering assessments continue. In order to determine the state of the Saturn IB at the end of the present production commitment it is necessary to investigate the planned and estimate the anticipated changes that would occur in time. This was done with the contributions of the many responsible organizations at MSFC to assign the best estimate for this baseline configuration.

This report contains the description of the baseline launch vehicle to which all future Saturn IB improvement or uprating studies are to be referenced. This baseline launch vehicle, designated SA-217, is an estimated projection of the current identified Saturn IB SA-212 vehicle with certain assigned product improvement items. Where specific Saturn IB SA-217 data are unavailable, SA-212 data have been assigned due to the similarity of the SA-212 and SA-217 launch vehicles. This concept vehicle is to be used for comparison purposes in advanced studies involving the use of a standard or modified Saturn IB and does not necessarily represent approved changes to the vehicle.

The technical data and descriptions contained in this report are those generally required to enable uprating analyses of vehicles to be performed. If additional or more specific information is needed it should be obtained directly from the responsible MSFC organization.

Redefinition, changes or updating of the baseline launch vehicle description is the responsibility of the Advanced Studies Office (R-P&VE-A). Addenda to this document or reissue of the vehicle description will be issued periodically as required.

In Section II is the general description of the reference launch vehicle with its nominal flight trajectory and aerodynamic characteristics. Stage weights and mass characteristics reflecting the product improvement items are also given.

Contained in Section III are the descriptions of the baseline S-IB and S-IVB stages and the Instrument Unit. Propulsion data for the H-1 and the J-2S engines are included.

SECTION II. BASELINE VEHICLE DESCRIPTION

A. Configuration Description

The Saturn IB SA-217 launch vehicle consists of an S-IB stage utilizing eight 205 000-pound-thrust (sea level) LOX/RP-1 H-1 engines, an S-IVB stage utilizing a single LOX/LH_2 J-2S engine, a vehicle Instrument Unit, and an Apollo shaped payload as shown in Figure 1. The S-IVB J-2S engine vacuum thrust varies from 216 012 pounds to 266 012 pounds as the mixture ratio varies from 4.5:1 to 5.5:1.

B. Stage Weights and Mass Characteristics

The product improvement items included in the detailed weights for the Saturn IB SA-217 are given in Table 1. These product improvements reflect the items which could be incorporated into the stages with minor changes and costs. Detailed weights for the S-IB stage, S-IB/S-IVB interstage, the S-IVB stage, and the Instrument Unit are given in Tables 2 through 5, respectively. Separation weights are given in Tables 6 and 7. The product improvement items have been incorporated into these weights. The mass characteristics during vehicle flight are given in Table 8.

Vehicle weight and center-of-gravity shift during first and second stage flight are given in Figures 2 and 3, respectively. Moments of inertia during first and second stage flight are shown in Figures 4 and 5, respectively.

C. Trajectory

The flight trajectory of the SA-217 two-stage launch vehicle to a 100-nautical-mile circular earth orbit is presented in Tables 9 and 10. A 90-degree launch azimuth measured from north toward east was used. Maximum dynamic pressure (max q) occurs at 77.4 seconds. Vehicle longitudinal acceleration versus time for the first stage flight is shown in Figure 6.

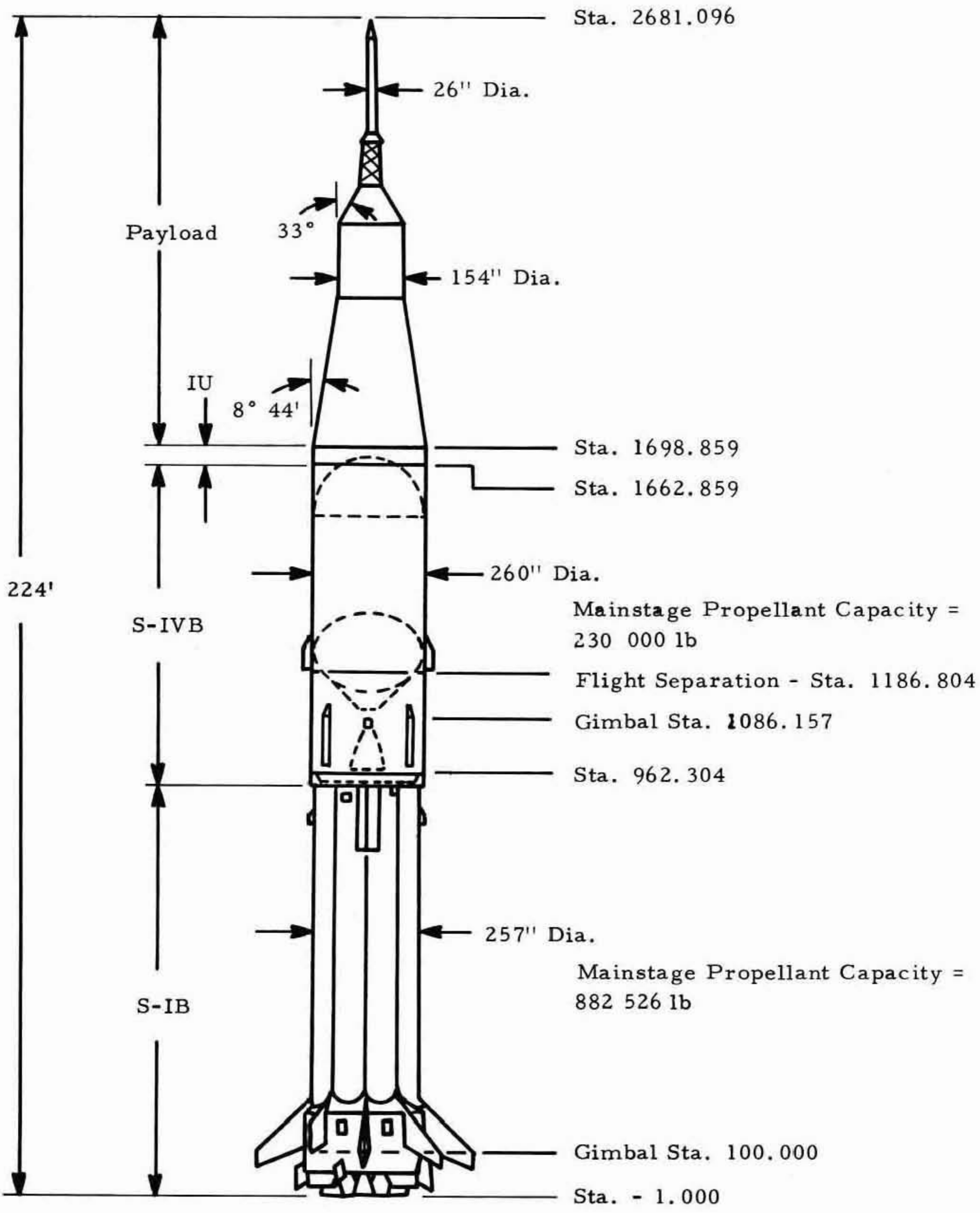

FIGURE 1. SATURN IB VEHICLE CONFIGURATION (SA-217)

Ref: R-P&VE-VAW, 2/12/65.

TABLE 1. SATURN IB SA-217 PRODUCT IMPROVEMENTS

Item	Weight Savings (lb)			
TOTAL VEHICLE WEIGHT SAVINGS				- 4 059
Total S-IB Stage Weight Savings			-2 589	
Use of Titanium Fasteners in Thrust Structure		- 615		
Redesign of Flexible Flame Curtains		- 154		
Redesign of Slosh Baffles and Supports		- 815		
Redesign of Gimbal Joints on Outboard Engines		- 546		
Forward and Aft 70-inch LOX Tank Support Fittings Milled for Weight Savings		- 213		
Decrease in Engine Thermal Protection		- 246		
Total S-IVB Stage Weight Savings			-1 470	
Dry Stage Savings		- 1 034		
Thermoconditioning Panel Improvements	- 164			
Low-density Encapsulating Material	- 250			
Use of Minimum Weight Attaching Parts	- 79			
Reduction of Forward Dome Internal Insulation	- 235			
** Remove Pneumatic System	- 156			
** Remove Chilldown System	- 160			
Remove J-2 Engine	- 3 489			
Install J-2S Engine	+ 3 800			
** Remove Ullage System (Three Rockets)	- 285*			
** Remove Solid Motor Separation System	- 16*			
Residuals Savings		- 260		
** LOX Depletion Cutoff	- 260			
Other Items		- 176		
** Ullage Propellant	- 176*			

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* These weights are a result of removing three solid ullage motors (477 pounds total).

** Weight saving associated with using the J-2S.

TABLE 2. S-IB STAGE DETAILED DRY WEIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Item	Weight (lb)		
S-IB Stage Structure			51 439
Fuel Container		5 475	
Skin (Including Welds)	3 888		
Ring Frames, Stringers, Longerons, Struts and Tie Rods	563		
Forward Bulkhead	444		
Aft Bulkhead	215		
Anti-slosh Devices	355		
Miscellaneous	10		
Oxidizer Container		12 653	
Skin (Including Welds)	10 259		
Ring Frames, Stringers, Longerons, Struts and Tie Rods	765		
Forward Bulkhead	450		
Aft Bulkhead	546		
Anti-slosh Devices	616		
Miscellaneous	17		
Structure Forward of Tanks (Extension of Container Sides, Transition, etc.)		6 474	
Skin (Including Welds)	1 765		
Ring Frames, Stringers, Longerons, Struts and Tie Rods	1 077		
Beams and Shear Panels	2 687		
Fittings	580		
Brackets, Doublers, Gussets, etc.	307		
Cutouts and Associated Structure	56		
Miscellaneous	2		

TABLE 2. - Continued

Item		Weight (lb)
Structure Aft of Tanks (From Container to Thrust Frame or Equivalent)		5 326
Skin (Including Welds)	2 709	
Ring Frames, Stringers, Longerons, Struts and Tie Rods	1 781	
Fittings	332	
Brackets, Doublers, Gussets, Etc.	486	
Cutouts and Associated Structure	10	
Miscellaneous	8	
Thrust Structure		10 559
Skin (Including Welds)	380	
Ring Frames, Stringers, Longerons, Struts and Tie Rods	3 256	
Beams and Shear Panels	5 155	
Fittings	209	
Brackets, Doublers, Gussets, etc.	1 511	
Cutouts and Associated Structure	29	
Miscellaneous	19	
Fairings and Associated Structure (Includes Insulation)		2 922
Forward Fairings, Hardware, Insulation	479	
Center Fairings	500	
Tail Fairings	1 615	
Air Intakes	67	
Cable Conduits	186	
Ice Shields	75	
Nonmoveable Aerodynamic Control Surfaces		4 024
Basic Structure	3 117	
Leading Edge	461	
Trailing Edge	162	
Secondary Structure	163	
Miscellaneous	121	

TABLE 2. - Continued

Item	Weight (lb)		
Base Heat Protection		3 869	
Tail Heat Insulation	3 266		
Flame Shield	139		
Fire Wall	464		
Paint and Sealer		137	
Paint and Sealer	137		
S-IB Stage Propulsion System and Accessories			25 521
Liquid Rocket Engine and Accessories (NAA Equipment)		15 494	
Liquid Rocket Engine and Accessories (CCSD Equipment)		1 024	
Purge System	174		
Engine Seal Drain Line Hardware	18		
Hydraulic System	673		
Ignition and Cutoff System	119		
Miscellaneous	40		
Fuel System		4 408	
Fill and Drain System	108		
Distribution or Suction System	2 231		
Transfer System	569		
Vent System	69		
Tank Pressurization System	1 249		
Antivortex Devices	166		
Bubbling System	16		
Oxidizer System		4 595	
Fill and Drain System	91		
Distribution or Suction System	2 134		
Replenishing System	65		
Transfer System	775		

TABLE 2. - Continued

Item	Weight (lb)		
Vent System	249		
Tank Pressurization System	1 068		
Antivortex Devices	205		
Bubbling System	8		
S-IB Stage Equipment and Instrumentation			4 395
Structure (for Equipment and Instrumentation)		208	
Environmental Control System - Equipment		375	
Fire Control System	297		
Compartment Temperature Control System	78		
Guidance System		8	
Accelerometers	5		
Wiring, Cables, (Including Clamps, Hardware, etc.)	3		
Control System Electronics		132	
Signal Processors	25		
Wiring, Cables (Including Clamps, Hardware, etc.)	107		
Tracking, Navigation, and Observation Equipment		32	
Transponders	23		
Antennas	4		
Wiring, Cables (Including Clamps, Hardware, etc.)	5		
Telemetry and Measuring Equipment		1 504	
Structure (Attaching Hardware, Supports, etc.)	288		
Telemeters	59		
Signal Processors	35		
Multicouplers	3		
Amplifiers	33		

TABLE 2. - Continued

Item	Weight (lb)	
Auxiliary Equipment	6	
Antennas	241	
Racks	225	
Distributors	56	
Power Dividers	1	
Sensors	44	
Separate Power Supply	15	
Wiring, Cables (Including Clamps, Hardware, etc.)	436	
Plumbing	28	
Transducers	34	
Propellant Utilization System		163
Structure (Attaching Hardware, Supports, etc.)	74	
Computers	14	
Sensors	23	
Wiring, Cables (Including Clamps, etc.)	52	
Electrical System		1 064
Structure (Attaching Hardware, Supports, etc.)	44	
Main Power Supply	116	
Distributors	122	
Junction Boxes	5	
Wiring, Cables (Including Clamps, Hardware, etc.)	777	
Range Safety Equipment		739
Structure (Attaching Hardware, Supports, etc.)	272	
Receivers and Decoders	16	
Controls	3	
Explosive Devices	98	

TABLE 2. - Concluded

Item	Weight (lb)		
Antennas	251		
Power Dividers	3		
Wiring, Cables (Including Clamps, Hardware, etc.)	40		
Emergency Detection System	56		
Pneumatic System		115	
Tanks, Tubing, Valves, Accumulator, Bottles, and Supports, etc.)	115		
Separation System		55	
Controls, Sequencing Equipment, and Wiring	55		
TOTAL S-IB STAGE SA-217 ASSIGNED DRY WEIGHT			81 355

Ref: Based on R-P&VE-VAW-67-102, 7/19/67

TABLE 3. S-IB/S-IVB INTERSTAGE WEIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Item	Weight (lb)		
Total Dry Weight-S-IB/S-IVB Interstage			5 383
S-IB/S-IVB Interstage Structure		4 393	
Interstage Structure	4 289		
Paint and Sealer	35		
Heat and Flame Protection	69		
Equipment and Instrumentation		990	
Environmental Control System	14		
Telemetering and Measuring Equipment	8		
Range Safety Equipment	8		
Separation System	916		
System for Total Vehicle	44		
Residual and Reserve Propellants			1 075
Retrorocket Propellant		1 075	
INTERSTAGE AT GROUND IGNITION			6 458

Ref: Based on R-P&VE-VAW-67-102, 7/19/67

TABLE 4. S-IVB STAGE DETAILED DRY WEIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Item	Weight (lb)	
S-IVB Stage Structure		12 117
Structure, Propellant Container	8 538	
Structure Forward of Tanks (Extension of Container Sides, Transitions, etc.)	1 079	
Structure Aft of Tanks (from Container to Thrust Frame or Equivalent)	1 425	
Thrust Structure	733	
Fairings and Associated Structure (Including Insulation)	180	
Paint and Sealer	48	
Ablative Insulation Thermolag	114	
Propulsion System and Accessories		5 691
Liquid Rocket Engine and Accessories	3 800	
Purge System for Stage Chilldown	120	
Fuel System	699	
Oxidizer System	785	
Stage Control System Hardware	287	
Equipment and Instrumentation		3 233
Structure (for Equipment and Instrumentation	322	
Environmental Control System Equipment	174	
Control System Electronics	109	
Telemetering and Measuring Equipment	1 045	
Propellant Utilization System	184	
Electrical System	344	
Range Safety Equipment	63	
Pneumatic System	113	
Spatial Attitude Control System	702	
Separation System	82	
Systems for Total Vehicle or Flight Stage	95	
TOTAL DRY WEIGHT - S-IVB STAGE		21 041

Ref: Based on R-P&VE-VAW-67-102, 7/19/67

TABLE 5. INSTRUMENT UNIT WEIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Item	Weight (lb)	
Instrument Unit Stage Structure		544
Interstage (Spacer) Vehicle Instrument Unit Structure	536	
Paint and Sealer	8	
Equipment and Instrumentation		3 202
Structure (for Equipment and Instrumentation)	29	
Environmental Control System - Equipment	756	
Guidance System	615	
Control System Electronics	202	
Tracking, Navigation, and Observation Equipment	24	
Telemetering and Measuring Equipment	289	
Electrical System	1 263	
Other	24	
TOTAL DRY WEIGHT - INSTRUMENT UNIT		3 746
Residual and Reserve Propellants		296
Air Bearing System Gas	30	
Environmental Control System Fluid	225	
Battery Fluids	41	
INSTRUMENT UNIT AT GROUND IGNITION		4 042

Ref: Based on R-P&VE-VAW-67-102, 7/19/67

TABLE 6. S-IB STAGE SEPARATION WEIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Item		Weight (lb)
S-IB Stage - Dry		81 355
Residual and Reserve Propellants		10 679
Fuel - Pressurization Gas	62	
Fuel - Bias	1 000	
Fuel - Trapped	3 890	
Oxidizer - Pressurization Gas	2 792	
Oxidizer - Trapped	2 874	
Nitrogen - Trapped	10	
Helium - Trapped	16	
Hydraulic Oil	28	
Fuel Additive	7	
Outboard Engine Thrust Decay Propellant		16
S-IB STAGE AT SEPARATION		92 050

Ref: Based on R-P&VE-VAW-67-102, 7/19/67

TABLE 7. S-IVB STAGE SEPARATION WEIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Item		Weight (lb)
S-IVB Stage - Dry		21 041
Residual and Reserve Propellants		2 089
Fuel - Pressurization Gas	345	
Fuel - Propellant Utilization Reserve	0	
Fuel Trapped - Tank	851	
Fuel Trapped - Lines and Engine	45	
Oxidizer - Pressurization Helium	155	
Oxidizer - Boiloff	173	
Helium - Pressurization Bottles	192	
Oxidizer Trapped - Tank	49	
Oxidizer Trapped - Lines and Engine	110	
APS Propellant - Usable	114	
APS Propellant - Trapped	8	
APS Pressurization - Helium	3	
Hydraulic Fluid	15	
Nitrogen - Hydrogen Reservoir	3	
Helium - Pneumatic System	11	
Hydrogen - Start Tank	1	
Environmental Control Fluids	14	
Dry Weight Separated with S-IB Stage		- 36
S-IVB STAGE AT SEPARATION		23 094

Ref: Based on R-P&VE-VAW-67-102, 7/19/67

TABLE 8. SATURN IB SA-217 REFERENCE LAUNCH VEHICLE FLIGHT STAGE SEQUENCING AND MASS CHARACTERISTICS SUMMARY

Item	Weight (lb)	Center of Gravity (Stations in in.)			Moment of Inertia (kg-m-sec^2)	
		x	y	z	Roll	Pitch
First Flight Stage at Ground Ignition	1 312 192	754.7	0.3	0.1	220 646	8 169 490
Thrust Buildup Propellant	- 14 176					
First Flight Stage at Lift-off	1 298 016	752.5	0.3	0.1	217 396	8 177 522
S-IB Mainstage Propellant (Capacity = 882 526 lb)	- 882 526					
S-IB Frost	- 1 000					
S-IB Gear Box Consumption (RP-1)	- 708					
S-IB Fuel Additive (Oronite)	- 26					
S-IB Inboard Engine Thrust Decay Propellant	- 2 194					
S-IB Seal Purge (N_2)	- 5					
S-IVB Frost	- 100					
First Flight Stage at Cutoff	411 457	1 167.6	0.9	0.2	44 240	4 084 754
S-IB Outboard Engine Thrust Decay Propellant to Separation	- 1 984					
First Flight Stage at Separation	409 473	1 172.4	0.9	0.2	43 799	4 026 560
S-IB Stage at Separation	- 92 050					
Interstage	- 6 458					
S-IVB Aft Frame	- 31					
S-IVB Separation System Components	- 5					
Second Flight Stage at Ignition	310 929	1 424.0	1.0	0.3	13 744	1 218 251
S-IVB Thrust Buildup Propellant	- 385					
S-IVB LH_2 Start Tank	- 4					
Second Flight Stage at Lift-off	310 540	1 424.0	1.0	0.3	13 744	1 218 066
S-IVB Mainstage Propellant (Capacity = 230 000 lb including FPR)	- 228 500					
S-IVB Auxiliary Propellant, Power Roll	- 6					
Launch Escape System	- 8 300					
Second Flight Stage at Cutoff	73 734	1 811.5	4.4	1.4	13 612	376 728
S-IVB Thrust Decay Propellant	- 133					
Second Flight Stage at Separation	73 601	1 812.7	4.4	1.4	13 612	375 092
S-IVB Stage at Separation	- 23 094					
Flight Performance Reserve Propellants	- 1 500					
Vehicle Instrument Unit	- 4 042					
Nominal Payload	44 965	2 109.3	0.2	1.0	4 333	43 848

Ref: R-AERO-XF, 11/20/67 and R-P&VE-VAW-67-159, 11/29/67

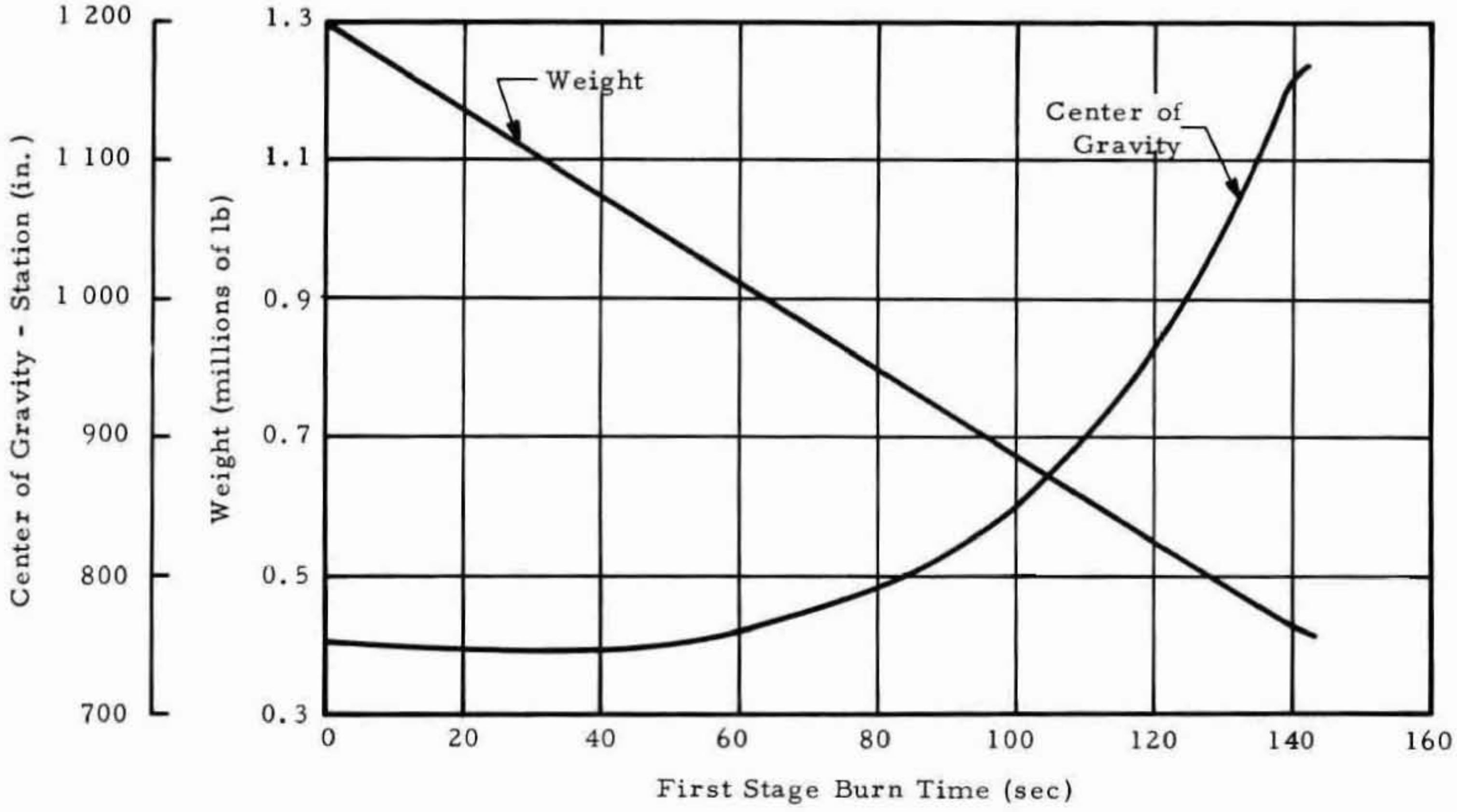

FIGURE 2. WEIGHT AND CENTER-OF-GRAVITY VARIATIONS DURING FIRST STAGE FLIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-AERO-XF, 11/20/67 and R-P&VE-VAW-67-159, 11/29/67

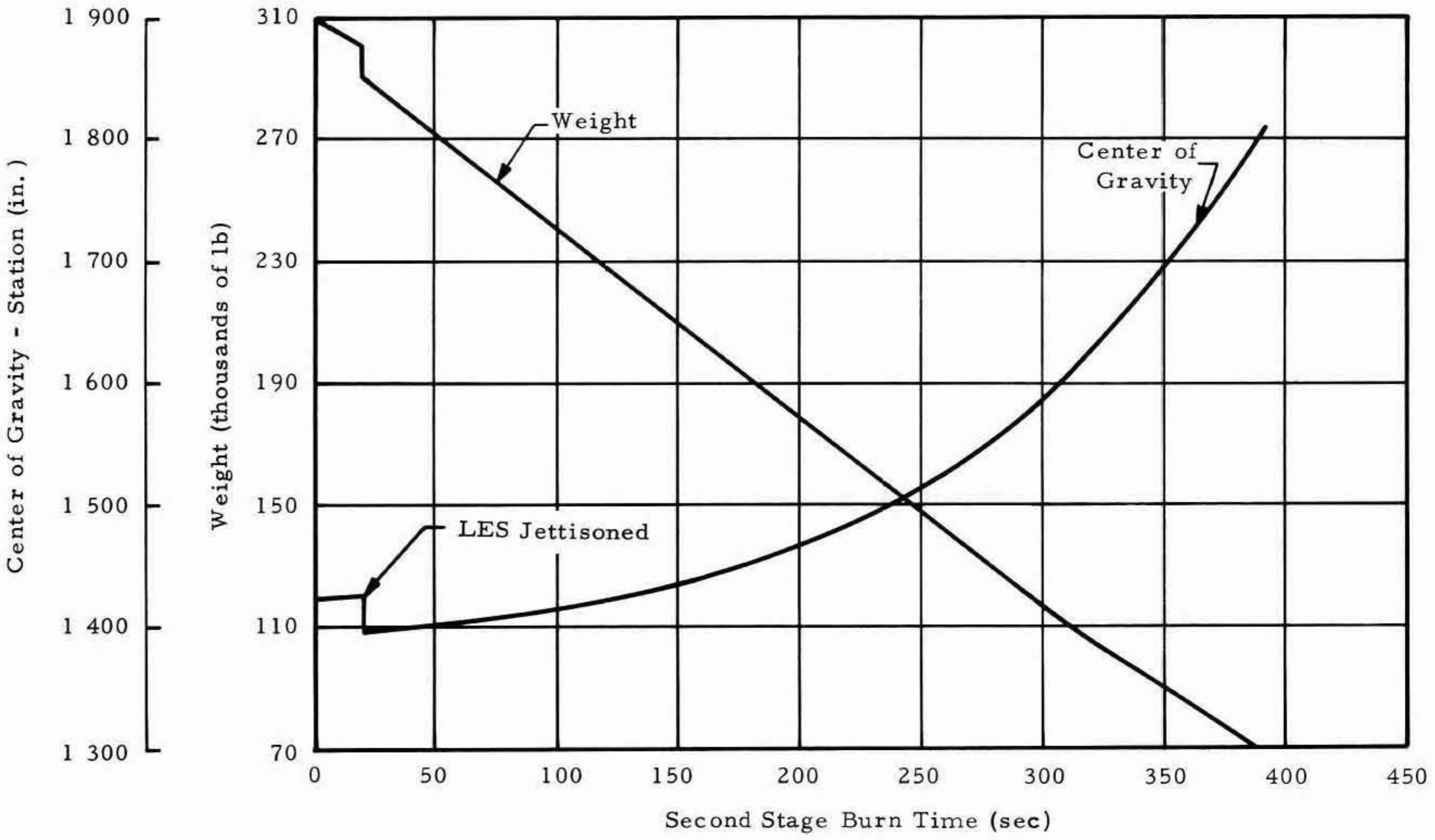

FIGURE 3. WEIGHT AND CENTER-OF-GRAVITY VARIATIONS DURING SECOND STAGE FLIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-AERO-XF, 11/20/67 and R-P&VE-VAW-67-159, 11/29/67

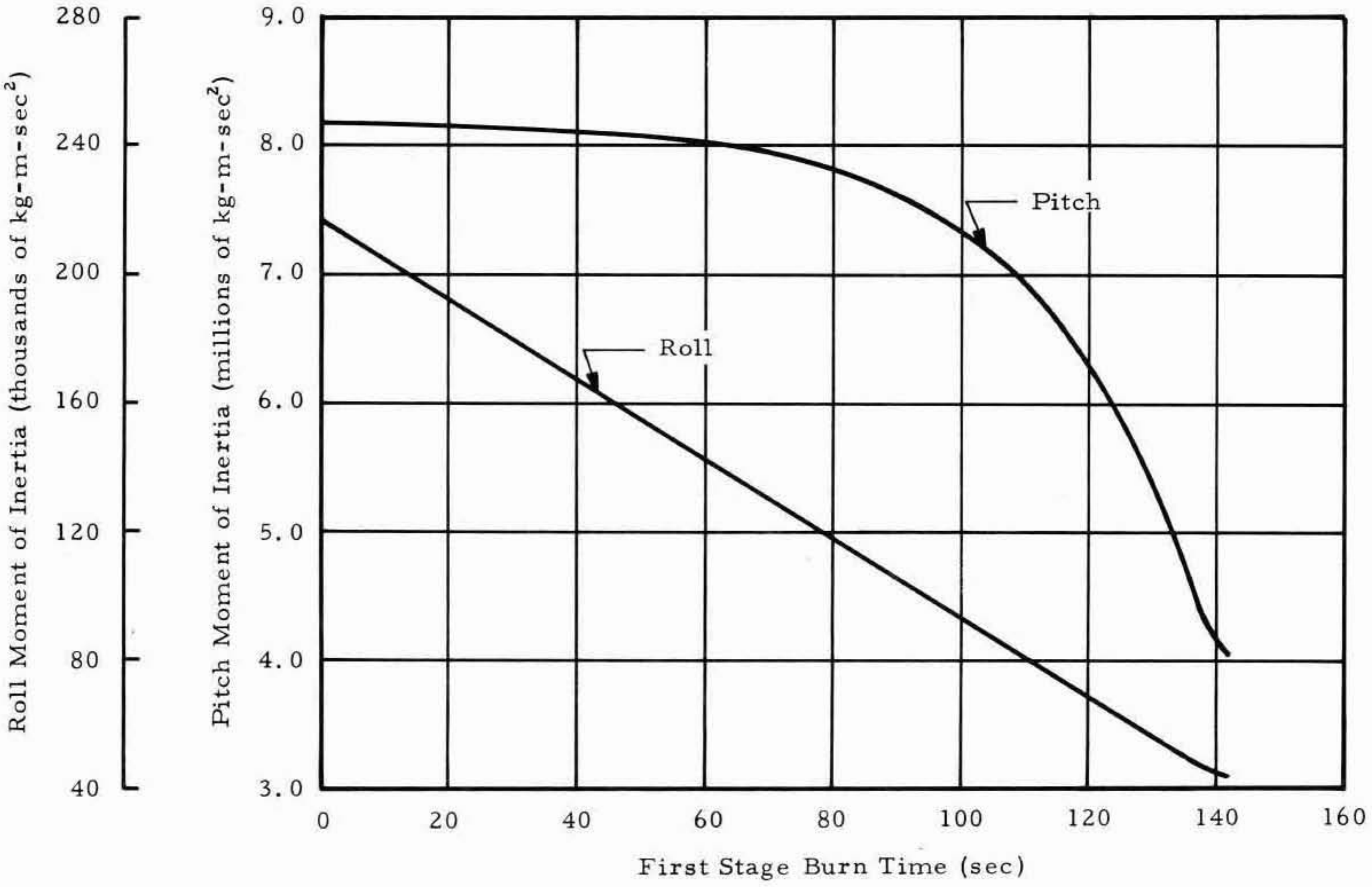

FIGURE 4. MOMENTS OF INERTIA VARIATIONS DURING FIRST STAGE FLIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-P&VE-VAW-67-159, 11/29/67

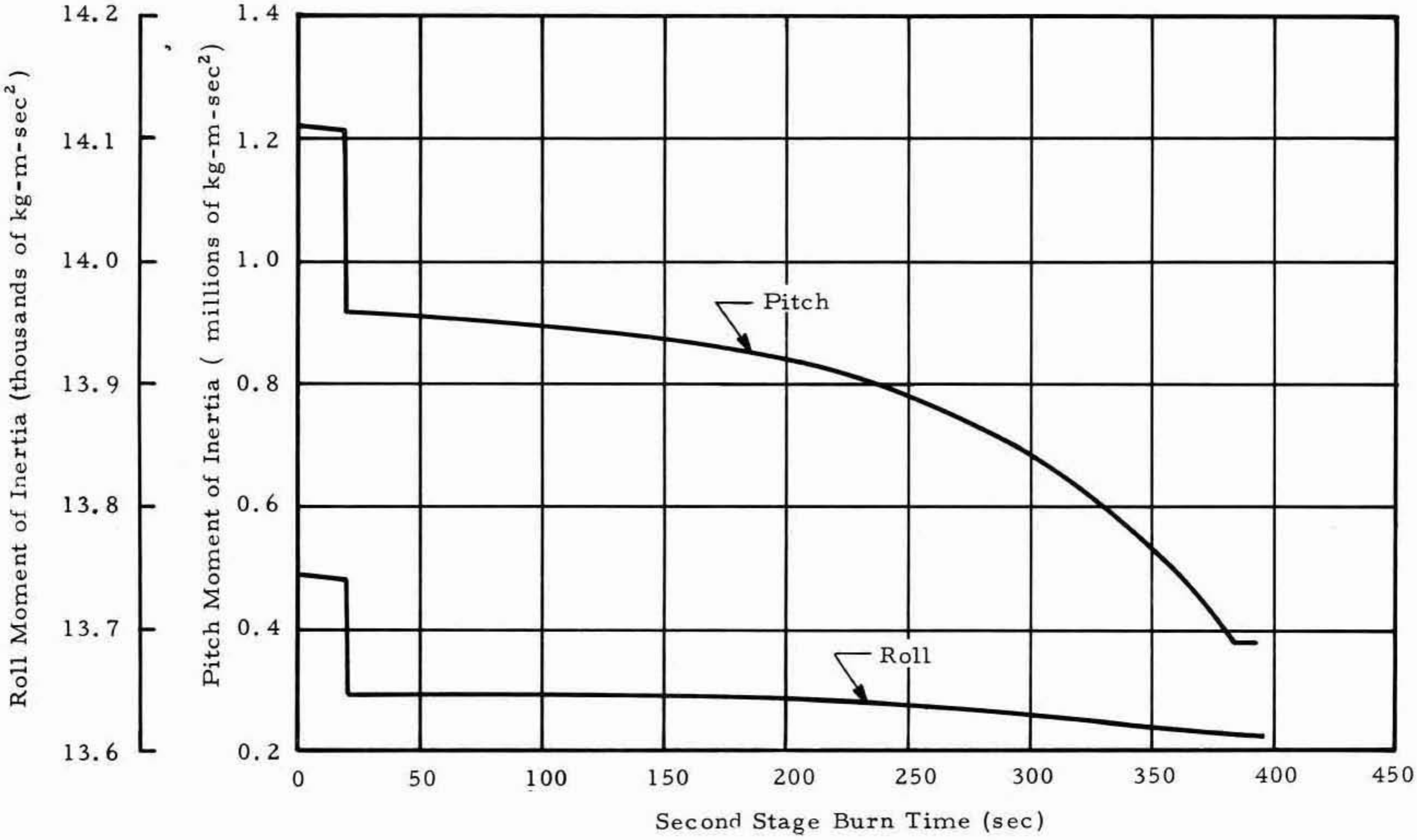

FIGURE 5. MOMENTS OF INERTIA VARIATIONS DURING SECOND STAGE FLIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-P&VE-VAW-67-159, 11/29/67

TABLE 9. FLIGHT TRAJECTORY, SATURN IB SA-217 LAUNCH VEHICLE

Item	Time (sec)	Relative Velocity (m/sec)	Flight Path Angle - Theta R (deg)	Weight (lb)	Thrust (lb)	Longitudinal Acceleration (m/sec^2)
Lift-off	0.000	0.000	90.000	1 298 016.2	1 640 000.0	12.30
	5.000	13.601	89.773	1 266 884.8	1 640 730.5	12.68
	10.000	28.825	89.767	1 235 753.5	1 643 045.4	12.99
	15.000	45.614	89.067	1 204 622.1	1 647 061.0	13.31
	20.000	64.015	87.075	1 173 490.8	1 652 855.1	13.62
	25.000	84.476	84.806	1 142 359.4	1 660 451.6	14.07
	30.000	107.172	82.502	1 111 228.0	1 669 838.3	14.48
	35.000	132.224	80.254	1 080 096.7	1 680 910.3	14.92
	40.000	159.876	78.098	1 048 965.3	1 693 487.7	15.40
	45.000	190.327	76.051	1 017 834.0	1 707 310.0	15.91
	47.422	206.136	75.101	1 002 756.0	1 714 356.8	16.17
	50.000	223.780	74.115	986 702.6	1 722 050.2	16.46
	55.000	260.943	70.658	955 571.3	1 737 276.4	17.03
	60.000	301.628	67.114	924 439.9	1 752 498.7	17.30
	65.000	343.590	63.534	893 308.5	1 767 190.8	17.48
10 Kilometers	69.584	386.259	60.261	864 767.4	1 779 786.4	18.39
	70.000	390.406	59.966	862 177.2	1 780 879.0	18.48
Drop Weight 1	70.000	390.406	59.966	861 077.2	1 780 879.0	18.50
	75.000	444.121	56.478	829 945.8	1 793 253.6	19.59
Q Maximum	77.417	472.654	54.838	814 897.5	1 798 652.1	20.13
	80.000	505.060	53.127	798 814.5	1 803 946.0	20.74
14 Kilometers	80.382	510.032	52.877	796 433.8	1 804 685.3	20.83
	85.000	573.598	49.952	767 683.1	1 812 680.8	21.95

TABLE 9. - Continued

Item	Time (sec)	Relative Velocity (m/sec)	Flight Path Angle - Theta R (deg)	Weight (lb)	Thrust (lb)	Longitudinal Acceleration (m/sec^2)
	90.000	650.066	46.977	736.551.8	1 819 325.1	23.23
	95.000	734.818	44.212	705 420.4	1 824 053.3	24.58
	100.000	828.106	41.659	674 289.0	1 827 334.1	25.99
	105.000	930.199	39.314	643 157.7	1 829 558.2	27.47
	110.000	1 041.356	37.166	612 026.3	1 821 042.6	29.03
	115.000	1 162.017	35.203	580 895.0	1 832 011.4	30.71
	120.000	1 292.772	33.415	549 763.6	1 832 629.6	32.54
	125.000	1 434.371	31.787	518 632.2	1 833 017.3	34.56
	130.000	1 587.757	30.310	487 500.9	1 833 257.1	36.80
	135.000	1 754.131	28.971	456 369.5	1 833 404.5	39.34
	140.000	1 935.036	27.760	425 238.2	1 833 495.5	42.24
Engine Cutoff	140.242	1 944.203	27.705	423 729.6	1 833 498.9	42.39
End Decay	140.242	1 944.203	27.705	423 729.6	916 729.6	21.19
Begin Decay	143.242	1 995.228	27.027	414 390.2	0.0	-0.00
Separation	143.242	1 995.228	27.027	310 534.2	0.0	-0.00
End Coast	148.742	1 971.401	25.786	310 534.2	0.0	-0.04
End Atmos.	148.742	1 971.401	25.786	310 534.2	0.0	-0.04
Ignition	148.742	1 971.401	25.786	310 534.2	-0.0	-0.00
End Buildup	149.003	1 971.386	25.733	310 453.5	266 012.0	8.40
	158.000	2 009.677	24.127	304 893.1	266 012.0	8.55
	168.000	2 056.215	22.410	298 712.6	266 012.0	8.73
Drop Weight 1	168.742	2 059.836	22.286	289 953.8	266 012.0	8.99
	178.000	2 109.203	20.782	284 232.0	266 012.0	9.17

TABLE 9. - Continued

Item	Time (sec)	Relative Velocity (m/sec)	Flight Path Angle - Theta R (deg)	Weight (lb)	Thrust (lb)	Longitudinal Acceleration (m/sec^2)
	188.000	2 166.584	19.234	278 051.4	266 012.0	9.37
	198.000	2 228.162	17.764	271 870.8	266 012.0	9.59
	208.000	2 293.928	16.373	265 690.2	266 012.0	9.81
	218.000	2 363.883	15.060	259 509.7	266 012.0	10.04
	228.000	2 438.042	13.823	253 329.1	266 012.0	10.29
	238.000	2 516.430	12.661	247 148.5	266 012.0	10.55
	248.000	2 599.086	11.571	240 967.9	266 012.0	10.82
	258.000	2 686.067	10.551	234 787.4	266 012.0	11.10
	268.000	2 777.445	9.598	228 606.8	266 012.0	11.40
	278.000	2 873.310	8.710	222 426.2	266 012.0	11.72
	288.000	2 973.769	7.883	216 245.6	266 012.0	12.05
	298.000	3 078.951	7.114	210.065.1	266 012.0	12.41
	308.000	3 189.006	6.402	203 884.5	266 012.0	12.78
	318.000	3 304.109	5.742	197 703.9	266 012.0	13.18
	328.000	3 424.456	5.133	191 523.3	266 012.0	13.61
	338.000	3 550.274	4.572	185 342.8	266 012.0	14.06
	348.000	3 681.819	4.055	179 162.2	266 012.0	14.55
	358.000	3 819.380	3.581	172 981.6	266 012.0	15.07
	368.000	3 963.285	3.148	166 801.0	266 012.0	15.63
	378.000	4 113.904	2.753	160 620.5	266 012.0	16.23
	388.000	4 271.654	2.394	154 439.9	266 012.0	16.88
	398.000	4 437.009	2.070	148 259.3	266 012.0	17.58
	408.000	4 610.507	1.778	142 078.7	266 012.0	18.35

TABLE 9. - Concluded

Item	Time (sec)	Relative Velocity (m/xec)	Flight Path Angle - Theta R (deg)	Weight (lb)	Thrust (lb)	Longitudinal Acceleration (m/sec^2)
	418.000	4 792.762	1.518	135 898.2	266 012.0	19.18
	428.000	4 984.478	1.287	129 717.6	266 012.0	20.09
	438.000	5 186.462	1.084	123 537.0	266 012.0	21.10
	448.000	5 399.652	0.909	117 356.4	266 012.0	22.21
	458.000	5 625.141	0.759	111 175.8	266 012.0	23.44
Thrust Shift	462.454	5 729.859	0.701	108 423.1	216 012.0	19.52
	468.000	5 838.509	0.610	105 674.7	216 012.0	20.03
	478.000	6 042.187	0.464	100 719.1	216 012.0	21.01
	488.000	6 256.641	0.337	95 763.6	216 012.0	22.10
	498.000	6 482.908	0.229	90 808.1	216 012.0	23.31
	508.000	6 722.203	0.141	85 852.5	216 012.0	24.65
	518.000	6 975.965	0.070	80 897.0	216 012.0	26.16
	528.000	7 245.911	0.017	75 941.4	216 012.0	27.87
Engine Cutoff	532.454	7 371.885	-0.000	73 734.2	216 012.0	28.71
Separation	532.454	7 371.885	-0.000	49 007.2*	-0.0	-0.00
Boost Impact	487.049	109.928	-89.677	103 856.0	-0.0	-10.39

Ref: Preliminary Flight Trajectory, R-AERO-XF, 11/20/67

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* Separation weight less IU weight (4 042 lb) = 44 965.2 pounds net payload

TABLE 10. FLIGHT TRAJECTORY, SATURN IB SA-217 LAUNCH VEHICLE

Item	Time (sec)	Altitude (m)	Inclination (deg)	Dynamic Pressure (kg/m^2)	Mach
Lift-Off	0.000	0.00	28.361	0.000	0.0000
	5.000	33.07	28.361	11.131	0.0392
	10.000	138.53	28.361	49.523	0.0832
	15.000	323.93	28.361	121.954	0.1320
	20.000	597.18	28.361	234.234	0.1859
	25.000	966.44	28.361	393.967	0.2463
	30.000	1 441.63	28.361	605.737	0.3141
	35.000	2 032.18	28.361	869.913	0.3898
	40.000	2 748.23	28.361	1 183.533	0.4746
	45.000	3 600.22	28.361	1 537.820	0.5698
	47.422	4 064.97	28.361	1 719.839	0.6202
	50.000	4 599.13	28.361	1 918.313	0.6772
	55.000	5 752.19	28.361	2 314.893	0.8005
	60.000	7 062.60	28.361	2 697.434	0.9417
	65.000	8 526.93	28.361	2 994.498	1.0965
10 Kilometers	69.584	10 000.03	28.361	3 214.315	1.2619
	70.000	10 140.09	28.361	3 231.617	1.2783
Drop Weight 1	70.000	10 140.09	28.361	3 231.617	1.2783
	75.000	11 909.98	28.361	3 387.210	1.4957
Q Maximum	77.417	12 824.23	28.361	3 408.935	1.6123
	80.000	13 845.08	28.361	3 381.888	1.7435
14 Kilometers	80.382	14 000.00	28.361	3 373.145	1.7634
	85.000	15 952.32	28.361	3 164.289	2.0078
	90.000	18 237.63	28.361	2 734.807	2.2600
	95.000	20 706.36	28.361	2 271.166	2.5165

TABLE 10. - Continued

Item	Time (sec)	Altitude (m)	Inclination (deg)	Dynamic Pressure (kg/m^2)	Mach
	100.000	23 362.92	28.362	1 843.424	2.7947
	105.000	26 211.89	28.362	1 466.596	3.1018
	110.000	29 257.45	28.362	1 138.600	3.4315
	115.000	32 504.33	28.363	857.723	3.7693
	120.000	35 958.02	28.363	631.525	4.1206
	125.000	39 625.68	28.364	456.055	4.4864
	130.000	43 516.68	28.364	325.009	4.8766
	135.000	47 642.45	28.364	230.160	5.3170
	140.000	52 017.70	28.365	164.842	5.9043
Eng. Cutoff	140.242	52 236.32	28.365	162.154	5.9369
End Decay	140.242	52 236.32	28.365	162.154	5.9369
Begin Decay	143.242	54 951.86	28.365	123.686	6.1620
Separation	143.242	54 951.86	28.365	123.686	6.1620
End Coast	148.742	59 802.90	28.365	67.101	6.2486
End Atmos	148.742	59 802.90	28.365	67.101	6.2486
Ignition	148.742	59 802.83	28.365	0.000	0.0000
Eng. Buildup	149.003	60 026.55	28.365	0.000	0.0000
	158.000	67 570.58	28.365	0.000	0.0000
	168.000	75 595.81	28.365	0.000	0.0000
Drop Weight 1	168.742	76 176.61	28.365	0.000	0.0000
	178.000	83 254.82	28.364	0.000	0.0000
	188.000	90 563.17	28.364	0.000	0.0000
	198.000	97 528.46	28.364	0.000	0.0000
	208.000	104 158.16	28.364	0.000	0.0000
	218.000	110 459.60	28.363	0.000	0.0000
	228.000	116 440.00	28.363	0.000	0.0000

TABLE 10. - Continued

Item	Time (sec)	Altitude (m)	Inclination (deg)	Dynamic Pressure (kg/m^2)	Mach
	238.000	122 107.07	28.363	0.000	0.0000
	248.000	127 467.89	28.362	0.000	0.0000
	258.000	132 530.01	28.362	0.000	0.0000
	268.000	137 300.66	28.362	0.000	0.0000
	278.000	141 787.32	28.361	0.000	0.0000
	288.000	145 997.29	28.361	0.000	0.0000
	298.000	149 938.13	28.360	0.000	0.0000
	308.000	153 617.14	28.360	0.000	0.0000
	318.000	157 042.03	28.360	0.000	0.0000
	328.000	160 220.56	28.359	0.000	0.0000
	338.000	163 160.43	28.359	0.000	0.0000
	348.000	165 869.49	28.358	0.000	0.0000
	358.000	168 355.97	28.358	0.000	0.0000
	368.000	170 628.26	28.357	0.000	0.0000
	378.000	172 694.80	28.357	0.000	0.0000
	388.000	174 564.60	28.356	0.000	0.0000
	398.000	176 246.87	28.356	0.000	0.0000
	408.000	177 751.36	28.355	0.000	0.0000
	418.000	179 088.29	28.355	0.000	0.0000
	428.000	180 268.47	28.354	0.000	0.0000
	438.000	181 303.42	28.353	0.000	0.0000
	448.000	182 205.55	28.353	0.000	0.0000
	458.000	182 988.20	28.352	0.000	0.0000
Thrust Shift	462.454	183 302.22	28.352	0.000	0.0000
	468.000	183 658.54	28.352	0.000	0.0000

TABLE 10. - Concluded

Item	Time (sec)	Altitude (m)	Inclination (deg)	Dynamic Pressure (kg/m^2)	Mach
	478.000	184 193.69	28.351	0.000	0.0000
	488.000	184 600.21	28.351	0.000	0.0000
	498.000	184 890.23	23.350	0.000	0.0000
	508.000	185 077.00	28.350	0.000	0.0000
	518.000	185 174.46	28.350	0.000	0.0000
	528.000	185 198.38	28.349	0.000	0.0000
Eng. Cutoff	532.454	185 189.70	28.349	0.000	0.0000
Separation	532.454	185 189.70	28.349	0.000	0.0000
Boost Impact	487.049	0.00	28.178	729.202	0.3169

Ref: Preliminary Flight Trajectory, R-AERO-XF, 11/20/67

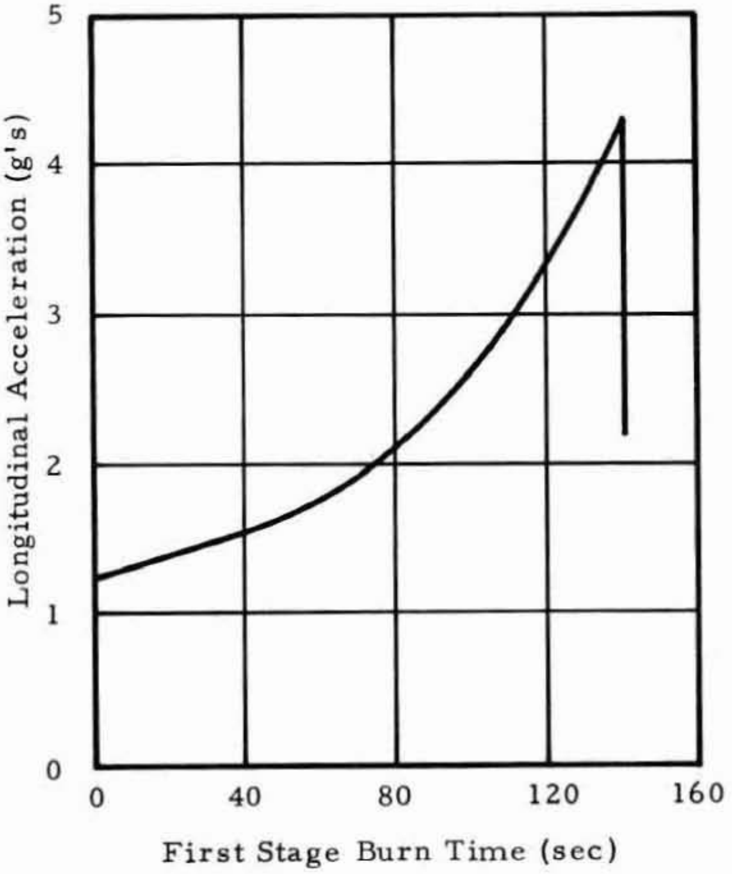

FIGURE 6. LONGITUDINAL ACCELERATION AS A FUNCTION OF FLIGHT TIME, FIRST STAGE FLIGHT, SATURN IB SA-217 LAUNCH VEHICLE

Ref: Preliminary Flight Trajectory, R-AERO-XF, 11/20/67

D. Aerodynamics

Assigned aerodynamic force distributions for the Saturn IB SA-217 launch vehicle are given in Figures 7 through 17. Definitions of coefficients and symbols are as follows:

α - angle of attack

C_A - total axial force coefficient, $\alpha = 0°$

C_{AF} - fore body axial force coefficient, $\alpha = 0°$

$C_{A_{BASE}}$ - base axial force coefficient

$C_{A_{F+S}}$ - fin and shroud axial force coefficient

$C_{A_{LES+CM}}$ - Launch Escape System (LES) plus Command Module (CM) axial force coefficient

D_{ref} - reference diameter = 257 in.

C_N - normal force coefficient

$C_{N\alpha}$ - normal force coefficient gradient, $(\alpha < 2°)$

$C_{N\alpha_{F+S}}$ - fin and shroud normal force coefficient gradient

$C_{N\alpha_{LES+CM}}$ - LES plus CM normal force coefficient gradient

$\frac{d(C_{N\alpha})}{d(X/D)}$ - local normal force coefficient gradient, $(\alpha < 2°)$

C_P/D - center of pressure, calibers from Station 100

X/D - distance from vehicle Station 100, calibers

$\frac{d(CA)}{d(X/D)}$ - local axial force coefficient, $\alpha = 0°$

$\frac{d(C_N)}{d(X/D)}$ - local normal force coefficient

C_{D_o} - drag coefficient at $\alpha = 0°$

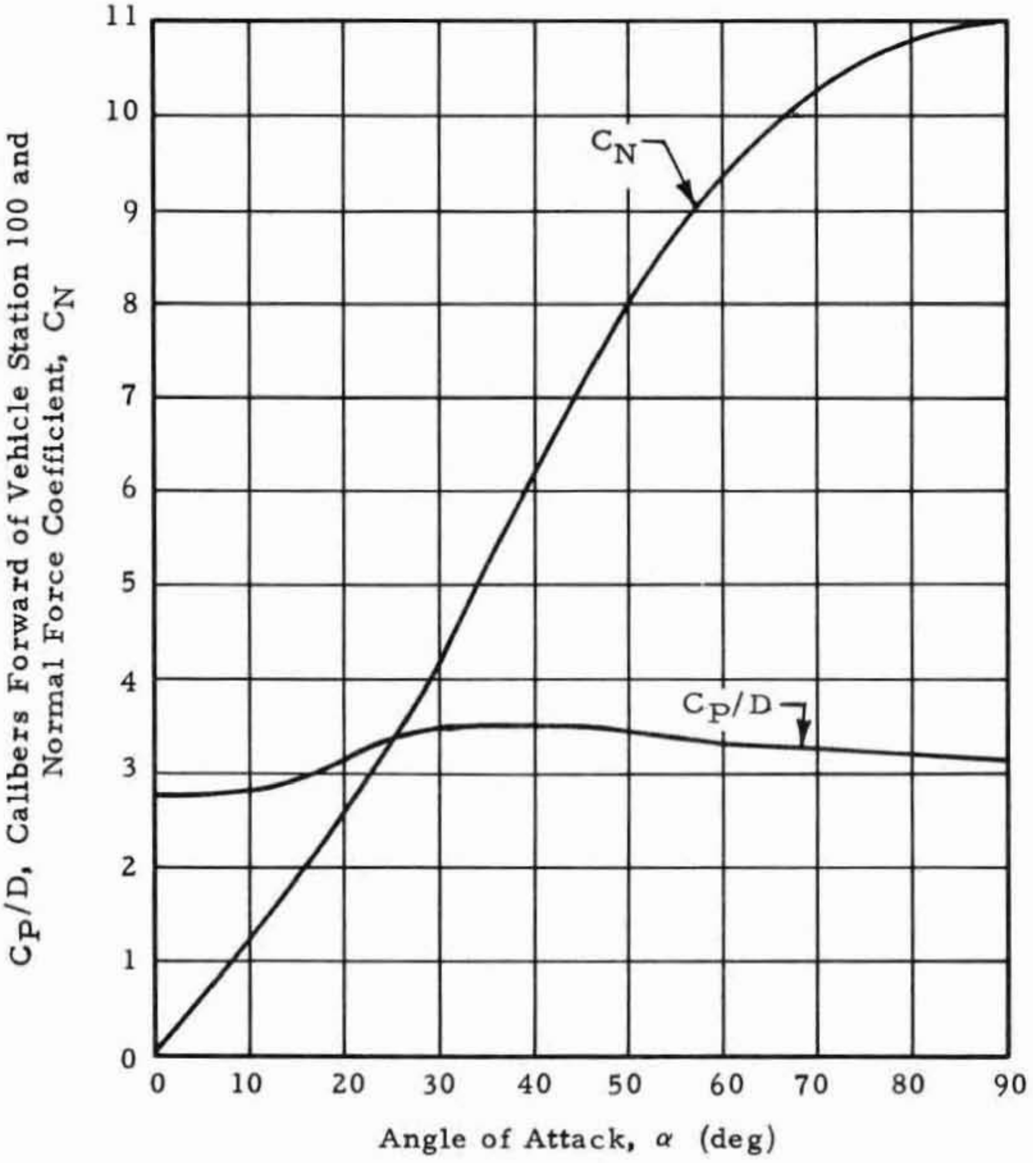

FIGURE 7. ASSIGNED VARIATION OF NORMAL FORCE COEFFICIENT AND CENTER OF PRESSURE WITH ANGLE OF ATTACK AT LIFT-OFF, REFERENCE DIAMETER = 257 IN., SATURN IB SA-217 LAUNCH VEHICLE

Ref: NASA TMX-53348, 10/13/65

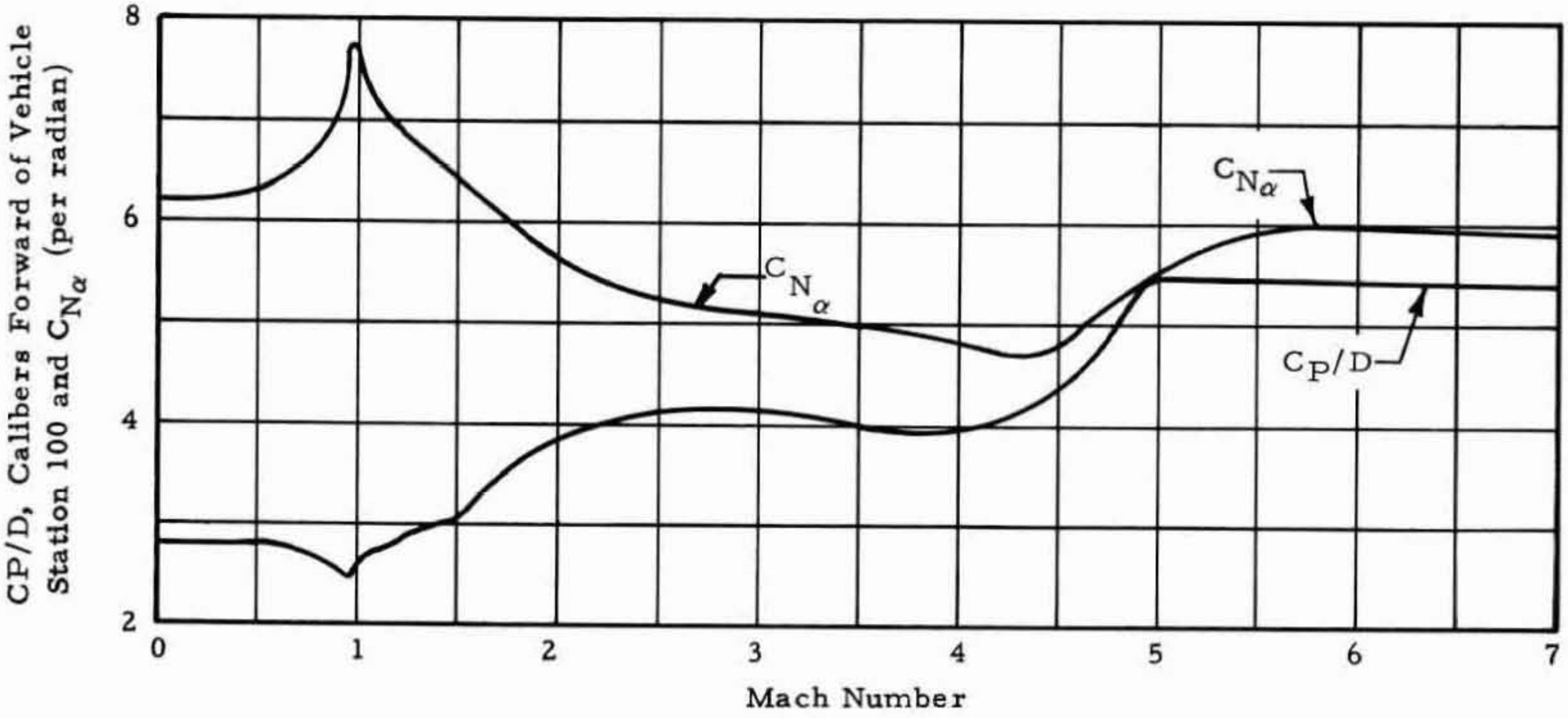

FIGURE 8. ASSIGNED VARIATION OF NORMAL FORCE COEFFICIENT GRADIENT AND CENTER OF PRESSURE WITH MACH NUMBER, REFERENCE DIAMETER = 257 IN., $\alpha = 0°$, SATURN IB SA-217 LAUNCH VEHICLE

Ref: NASA TMX-53348, 10/13/65

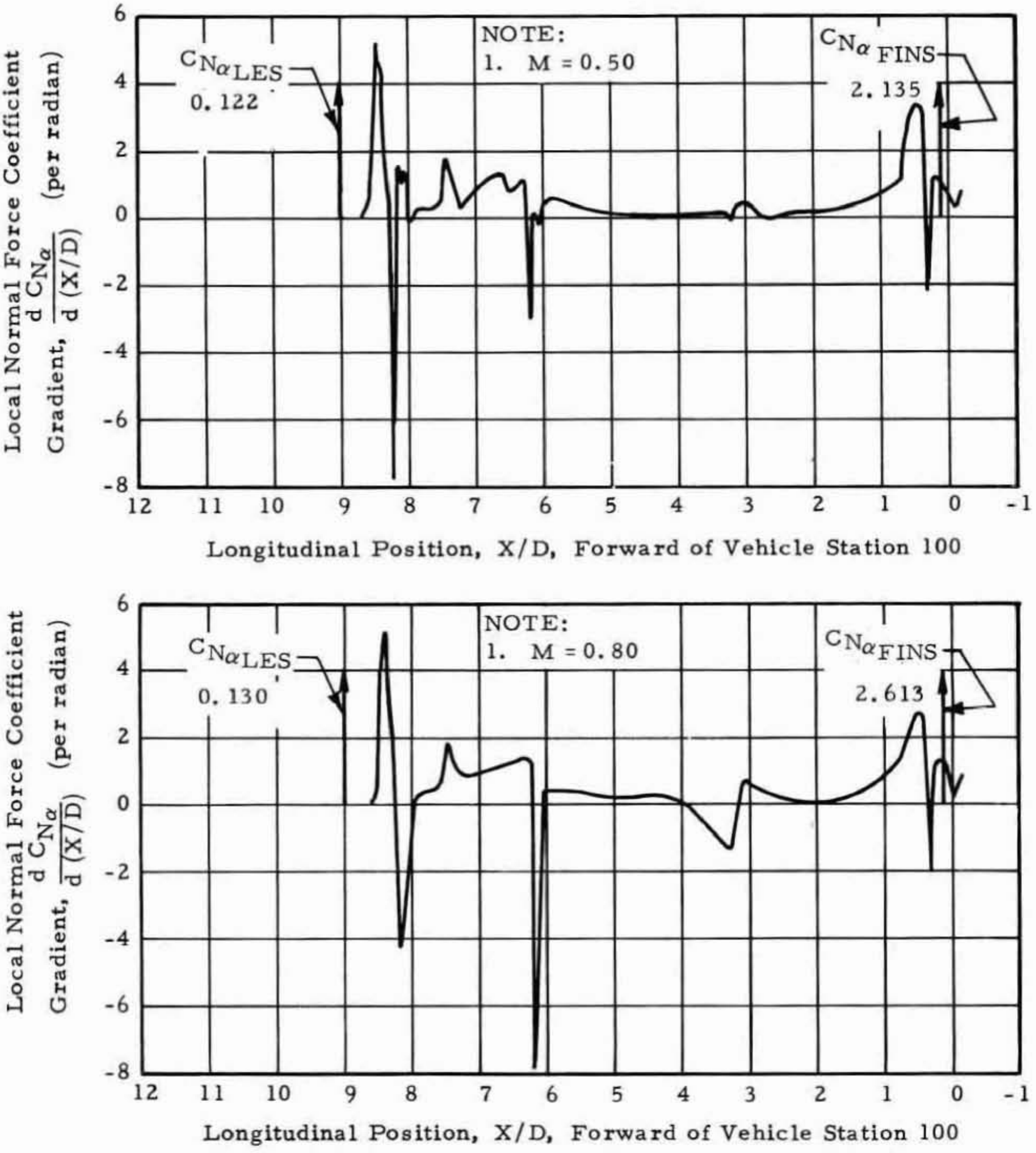

FIGURE 9. ASSIGNED DISTRIBUTION OF LOCAL NORMAL FORCE COEFFICIENT GRADIENT, REFERENCE DIAMETER = 257 IN., $\alpha = 0°$, SATURN IB SA-217 LAUNCH VEHICLE

Ref: NASA TMX-53348, 10/13/66

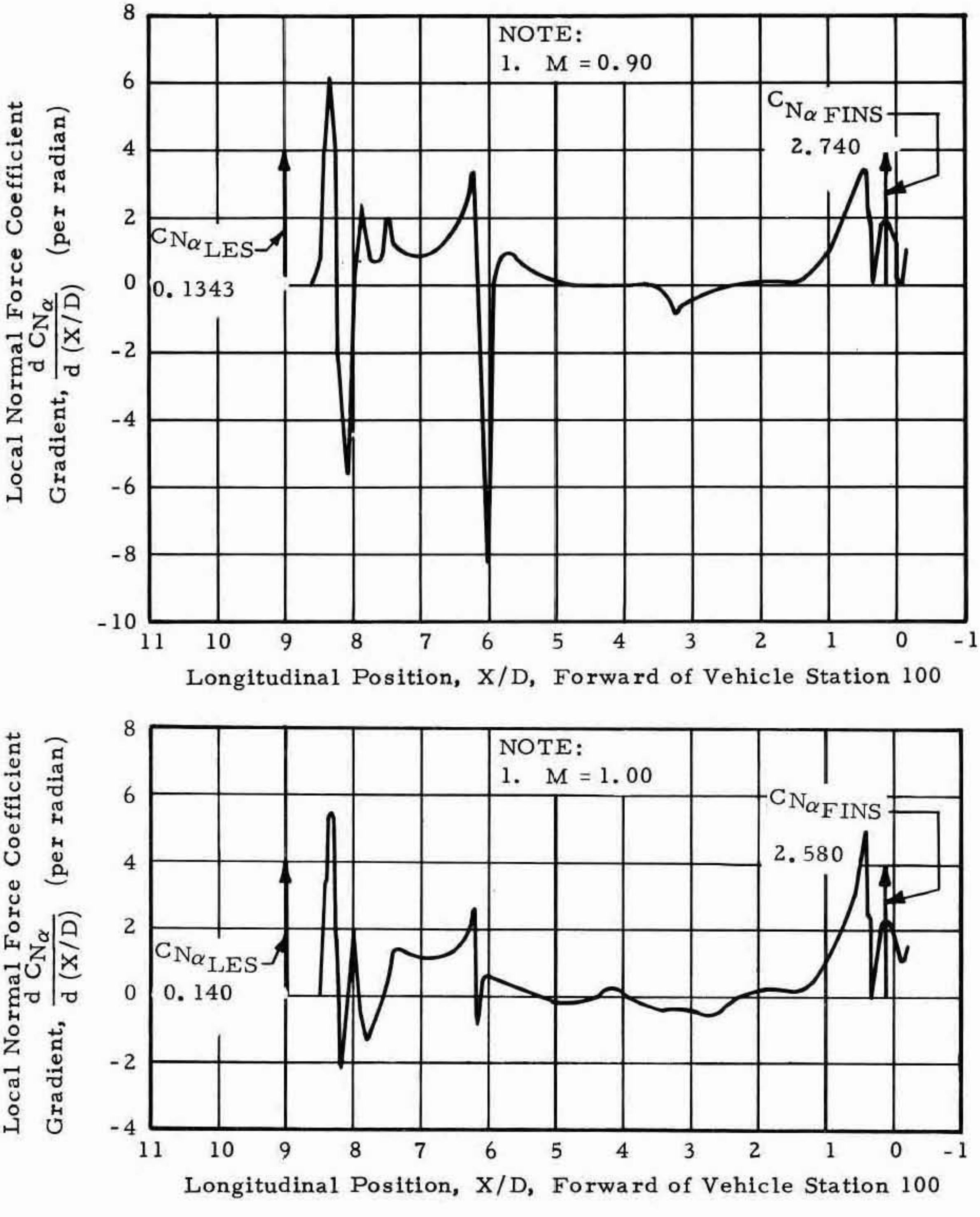

FIGURE 10. ASSIGNED DISTRIBUTION OF LOCAL NORMAL FORCE COEFFICIENT GRADIENT, REFERENCE DIAMETER = 257 IN., SATURN IB SA-217 LAUNCH VEHICLE

Ref: NASA TMX-53348, 10/13/65

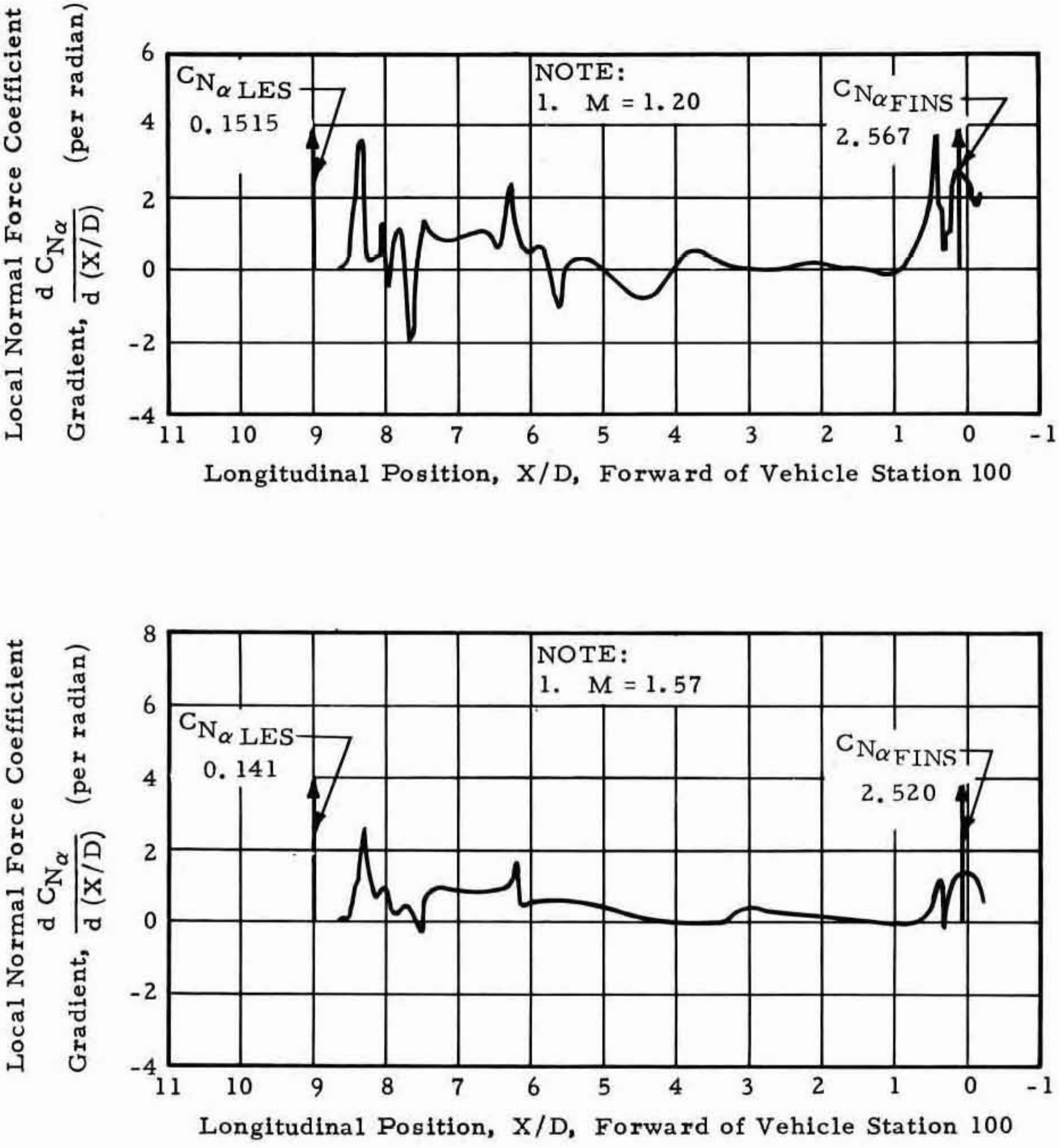

FIGURE 11. ASSIGNED DISTRIBUTION OF LOCAL NORMAL FORCE COEFFICIENT GRADIENT, REFERENCE DIAMETER = 257 IN., SATURN IB SA-217 LAUNCH VEHICLE

Ref: NASA TMX-53348, 10/13/67

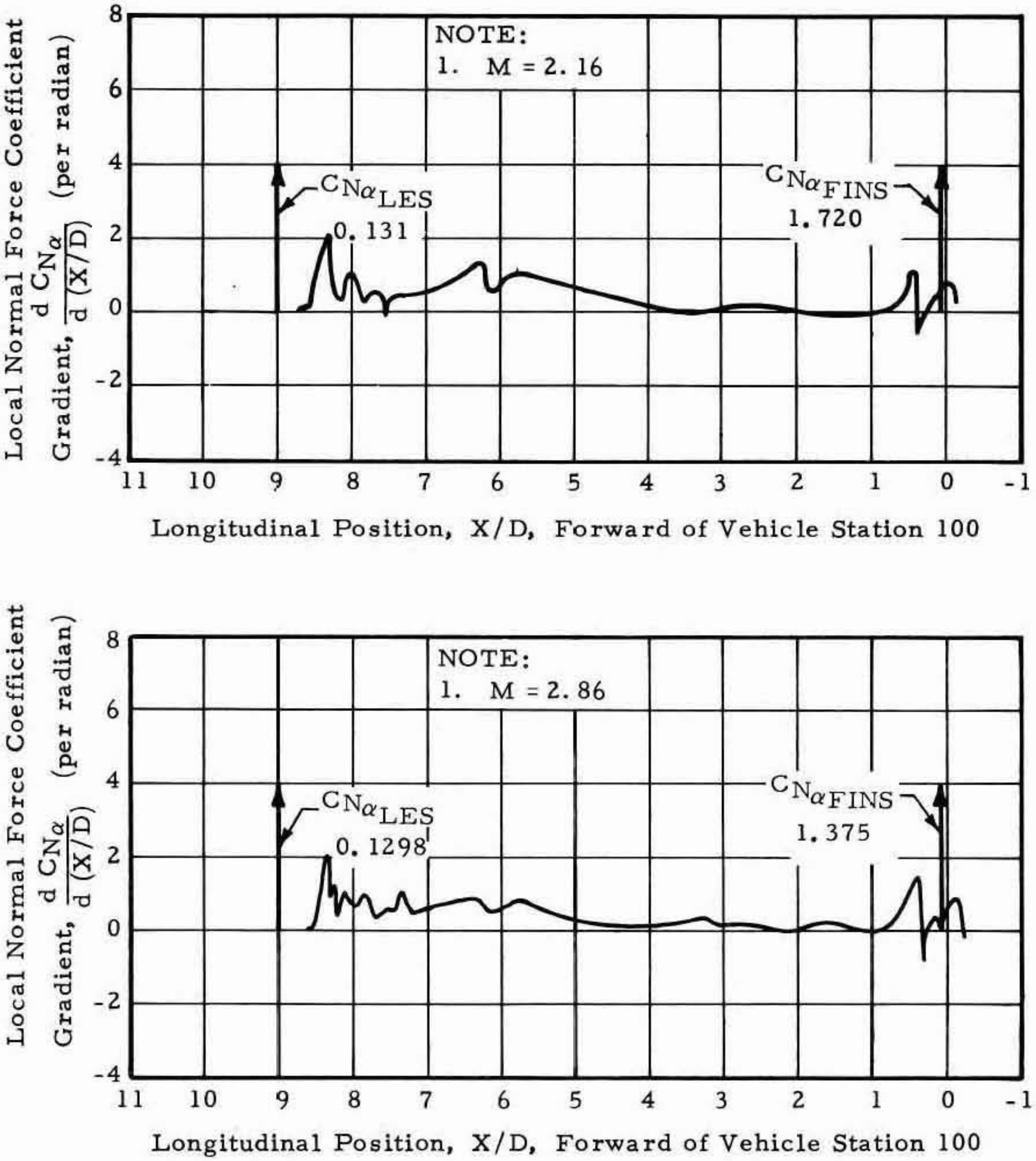

FIGURE 12. ASSIGNED DISTRIBUTION OF LOCAL NORMAL FORCE COEFFICIENT GRADIENT, REFERENCE DIAMETER = 257 IN., SATURN IB SA-217 LAUNCH VEHICLE

Ref: NASA TMX-53348, 10/13/65

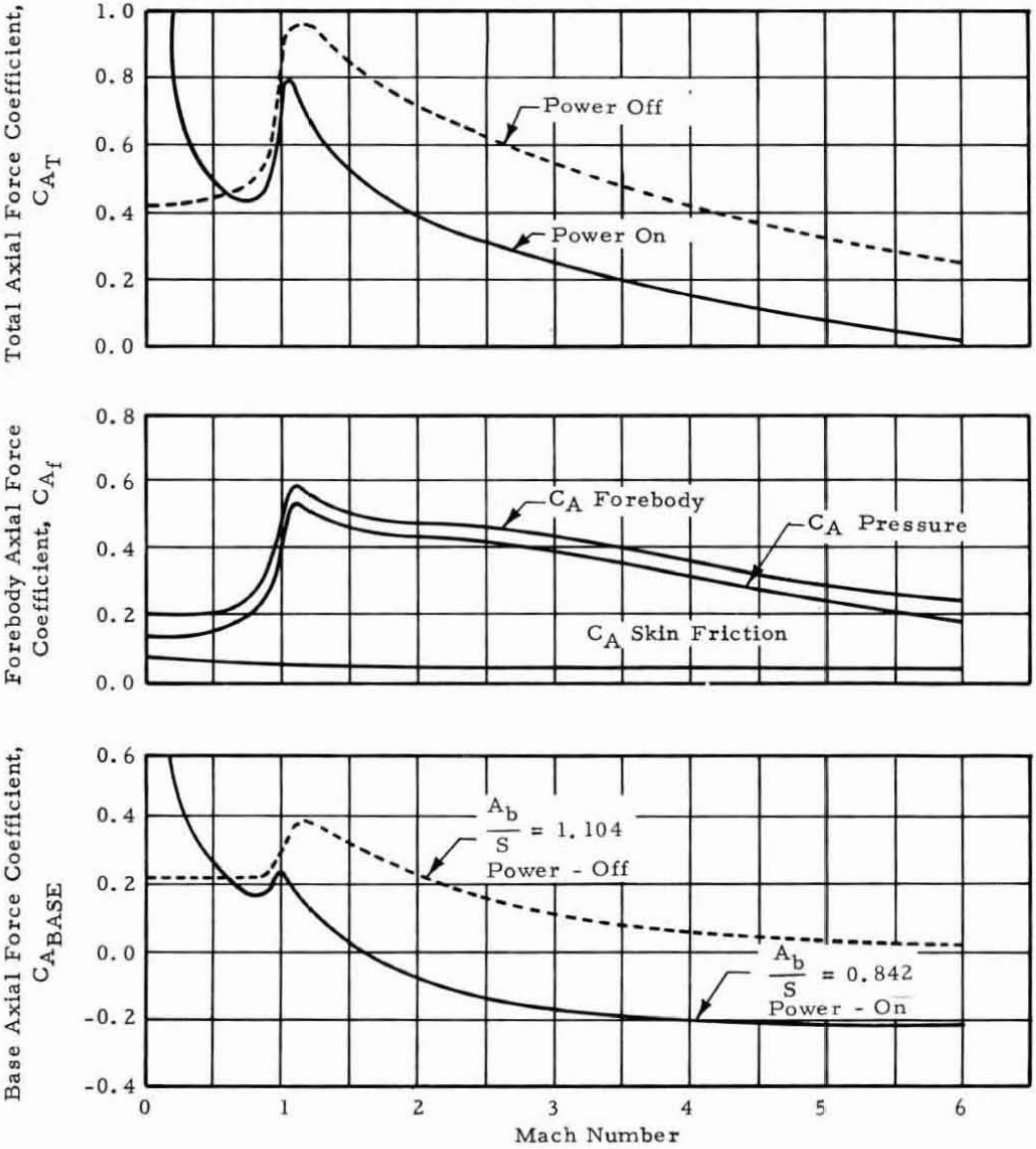

FIGURE 13. ASSIGNED VARIATION OF AXIAL FORCE COEFFICIENT WITH MACH NUMBER, REFERENCE DIAMETER = 257 IN., α = 0°, SATURN IB SA-217 LAUNCH VEHICLE

Ref: NASA TMX-53348, 10/13/65

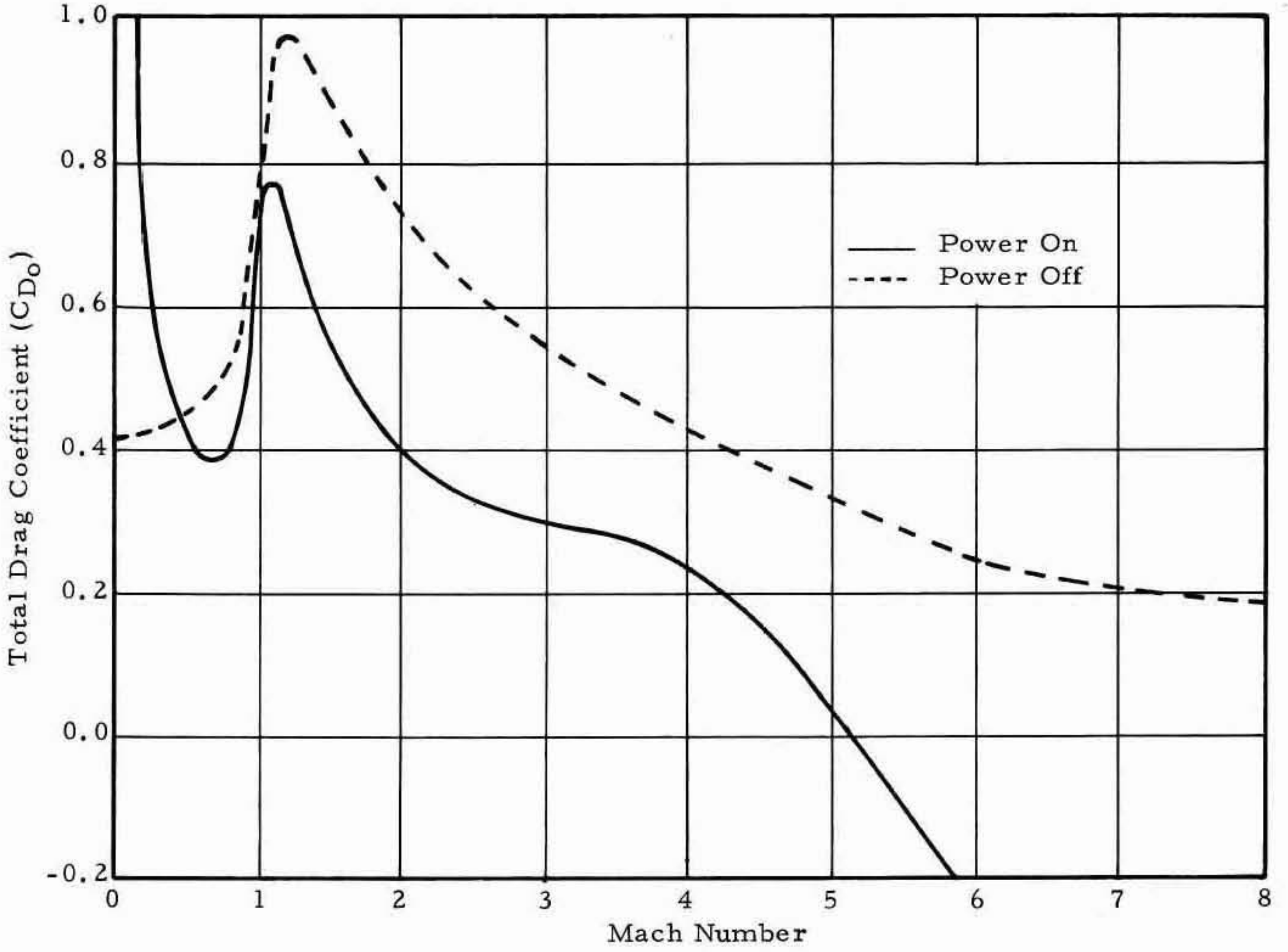

FIGURE 14. ASSIGNED VARIATION OF TOTAL DRAG COEFFICIENT WITH MACH NUMBER, $\alpha = 0°$, REFERENCE DIAMETER = 257 IN., SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-AERO-AD-66-37, 9/2/66

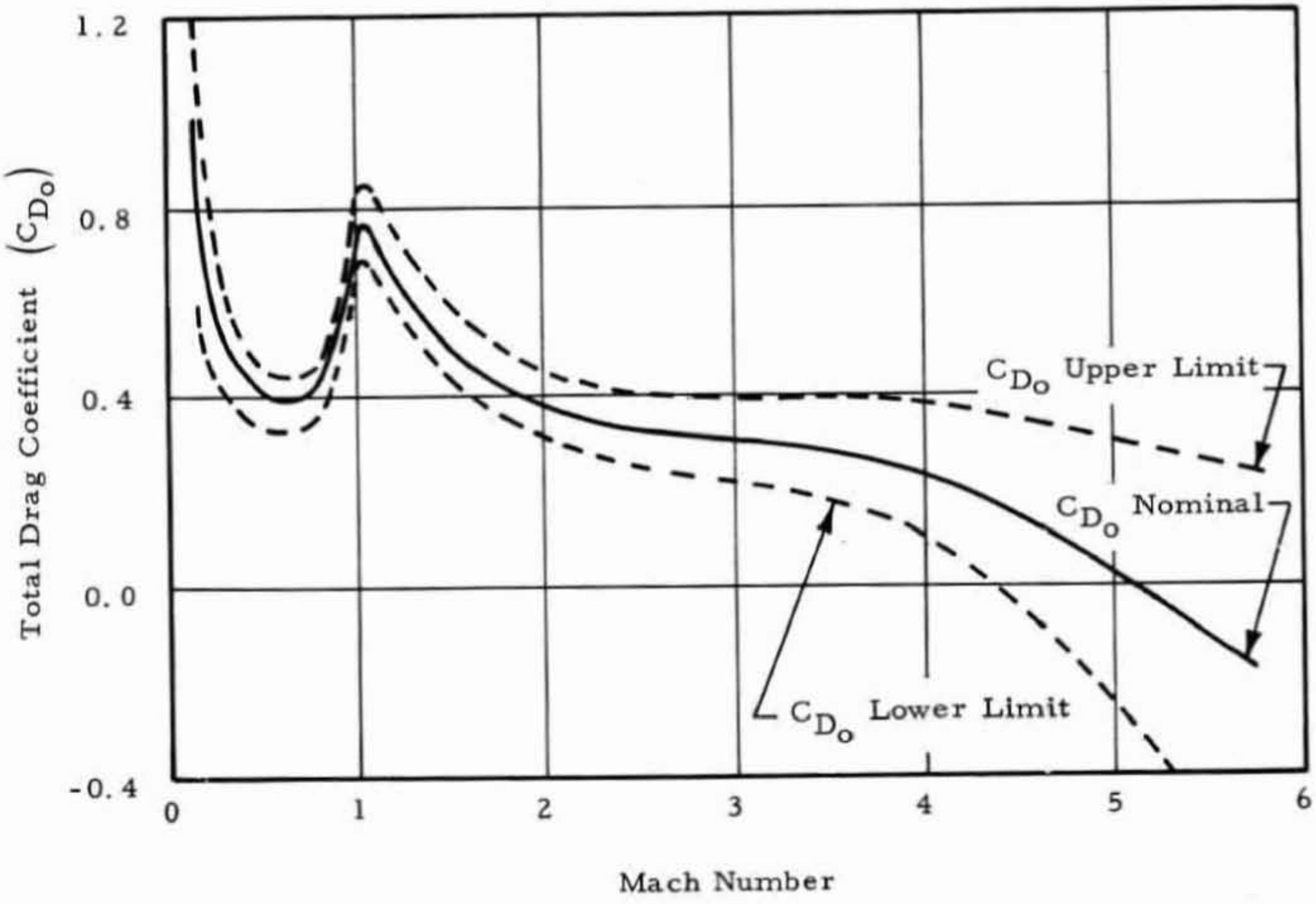

FIGURE 15. ASSIGNED DEVIATIONS OF TOTAL DRAG COEFFICIENT, REFERENCE DIAMETER = 257 IN., SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-AERO-66-37, 9/2/66

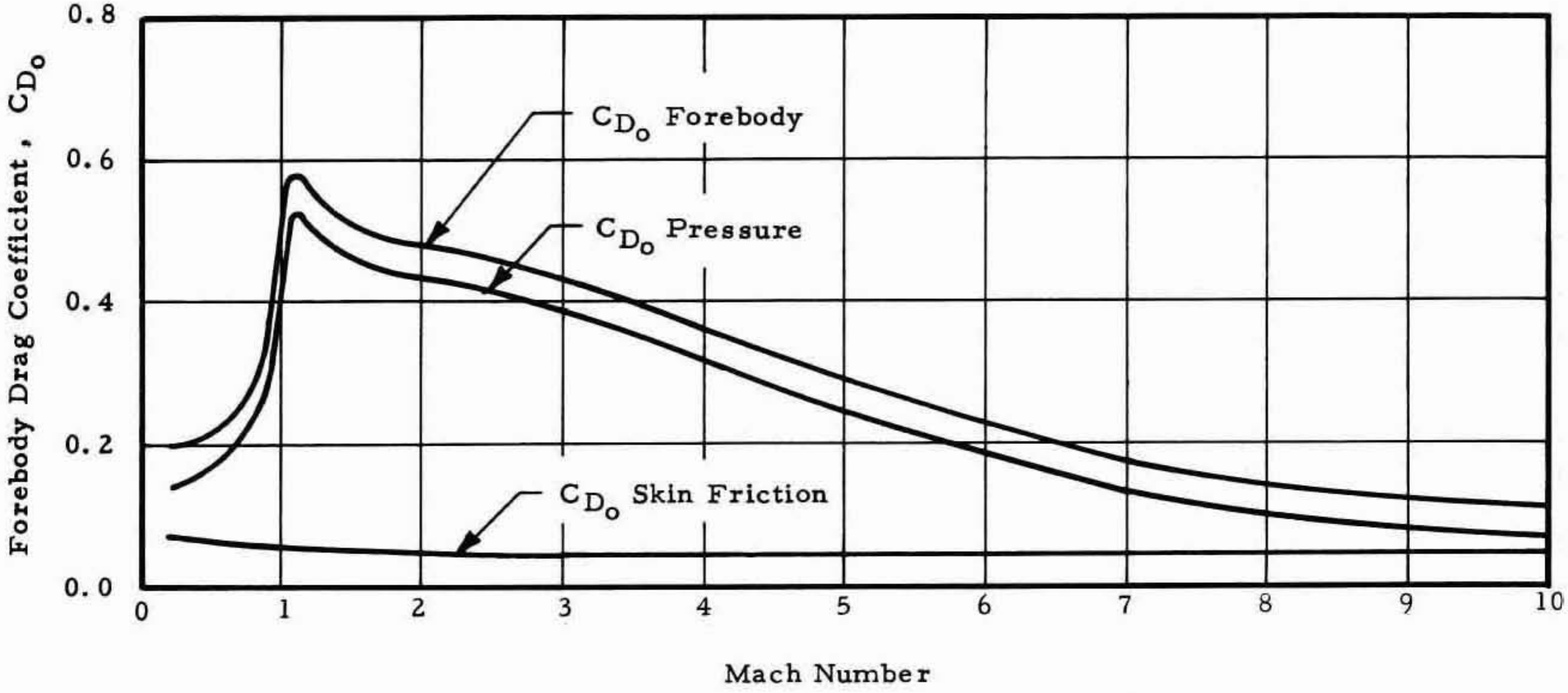

FIGURE 16. ASSIGNED FOREBODY DRAG COEFFICIENT VERSUS MACH NUMBER, REFERENCE DIAMETER = 257 IN., $\alpha = 0°$, SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-AERO-AD-66-37, 9/2/66

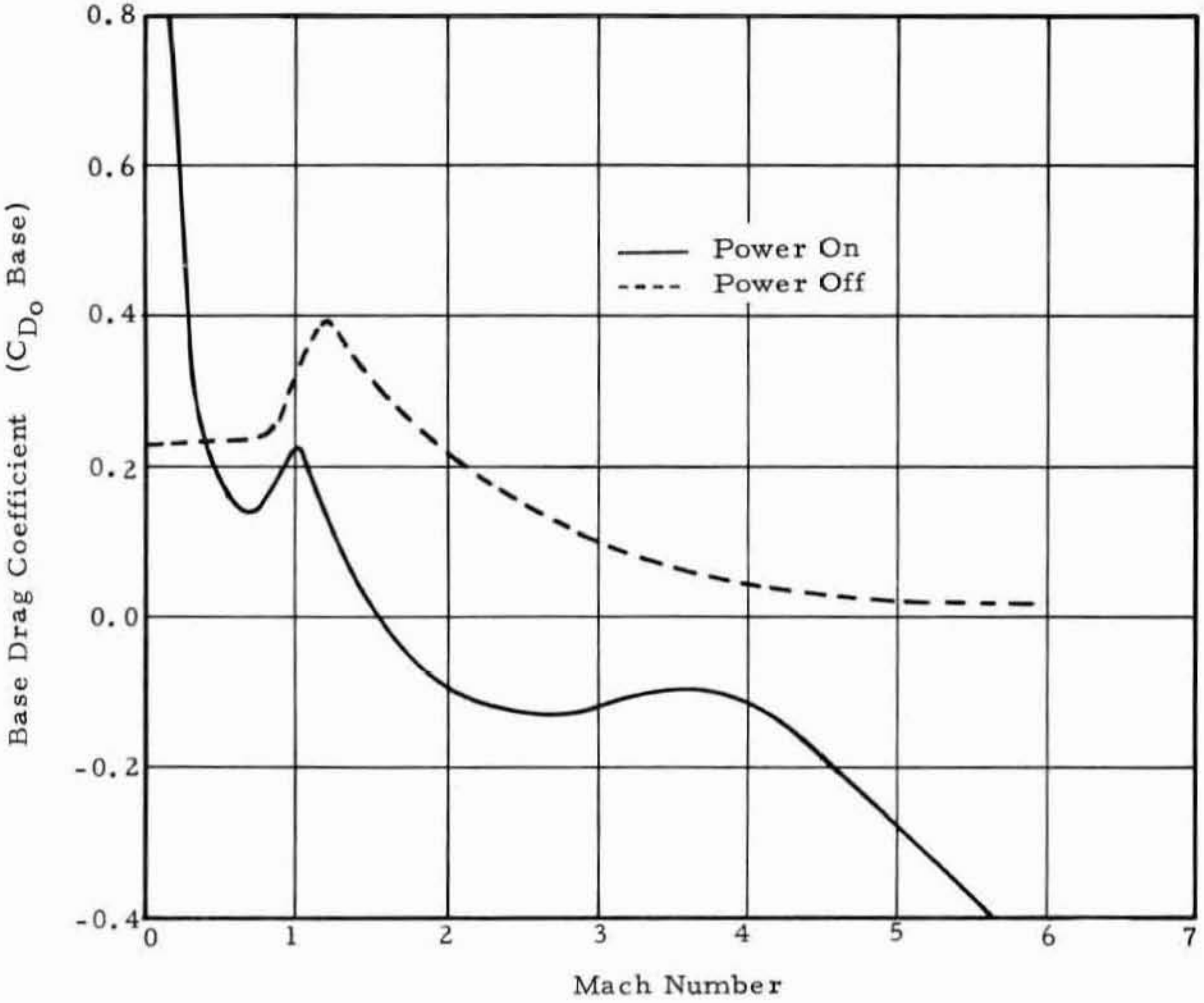

FIGURE 17. ASSIGNED VARIATION OF BASE DRAG COEFFICIENT WITH MACH NUMBER, REFERENCE DIAMETER = 257 IN., $\alpha = 0°$, SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-AERO-AD-66-37, 9/2/66

E. Flight Control

While the inboard engines of the S-IB stage are fixed, the outboard engines are equipped to gimbal in an 8-degree square pattern for vehicle directional control. The rigid body control analysis for the Saturn IB SA-217 considered flight times of t = 61.0 seconds (Mach 1.0), t = 68.8 seconds (max $q\alpha$), t = 76.0 seconds (approximately max q), and t = 136.0 seconds (just prior to inboard engine cutoff). These data are for Saturn IB SA-207 and subsequent, and have been assigned to Saturn IB SA-217 launch vehicle.

The standard cross wind disturbances, consisting of 95-percent probability of occurrence wind speed in the maximum wind months with the associated 99-percent shears, were used. In the 4- to 15-kilometer altitude region, a 9-m/sec gust was used in conjunction with the 99-percent shears. Both the shears and the gust were reduced by 15 percent in this altitude region.

Drift minimum control gains with angle of attack control were used. The natural frequency of the control loop was 0.2 hertz with a damping ratio of 70-percent critical. No control filters, actuator dynamics, or rate limits were considered.

Parameter variations in lateral center of gravity, center of pressure, nominal force coefficient, control gains, thrust and engine alignment were considered. The variations that produce the largest bending moment ($M_{B_{RSS}}$) at the maximum bending moment were used. The effects of nonlinear aerodynamics were considered in both the vehicle responses and bending moment coefficient.

Presented in Table 11 are the assigned peak vehicle responses for nominal control conditions and peak vehicle responses for $M_{B_{RSS}}$ conditions.

To include the effect of elastic body dynamics on the bending moments, the following procedure is employed. Add 7 percent of the value of the maximum bending moment at all stations except those for which the bending moment is less than 0.07 times the maximum bending moment. At these stations the bending moment should be doubled to include bending effects.

Values of angle of attack and gimbal angle versus flight time for nominal control conditions at maximum q are given in Figure 18. Values for angle of attack and gimbal angle for RSS bending moment conditions at maximum q are given in Figure 19.

TABLE 11. ASSIGNED PEAK VEHICLE RESPONSES, SATURN IB SA-217 LAUNCH VEHICLE

Time of Wind Peak (sec)	Nominal Conditions		$M_{B_{RSS}}$ Conditions		
	α_y (deg)	β_y (deg)	α_y (deg)	β_y (deg)	Station (m)
61.0	7.465	1.793	7.687	2.446	27
68.8	7.080	2.882	7.425	3.565	27
76.0	6.139	4.123	6.504	4.868	27
136.0	3.117	0.109	3.607	0.329	28

Ref: R-AERO-DCC-25-65, 6/16/65

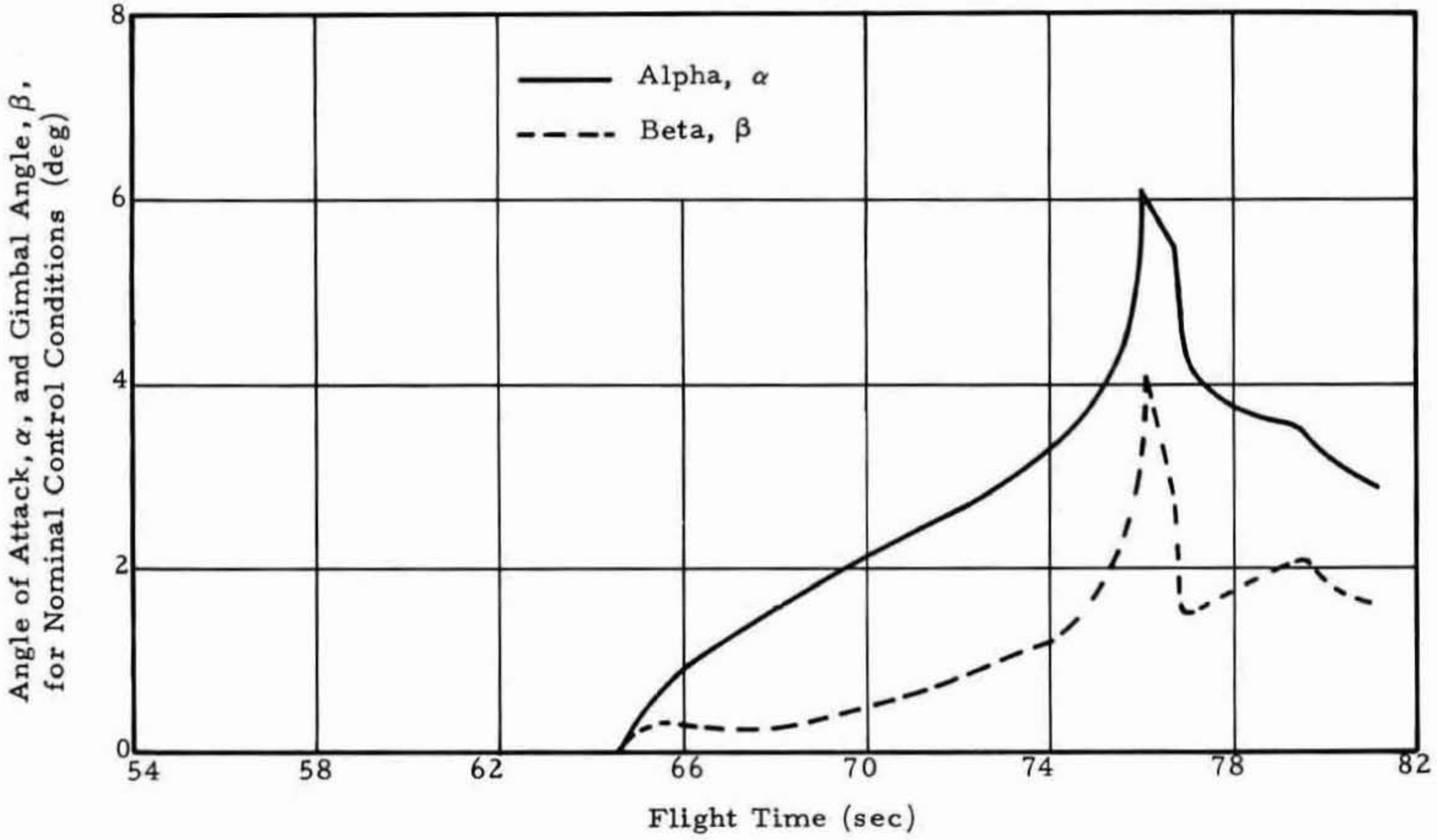

FIGURE 18. ASSIGNED ANGLE OF ATTACK AND GIMBAL ANGLE VERSUS FLIGHT TIME FOR NOMINAL CONTROL CONDITIONS, SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-AERO-DCC-25-65, 6/16/65

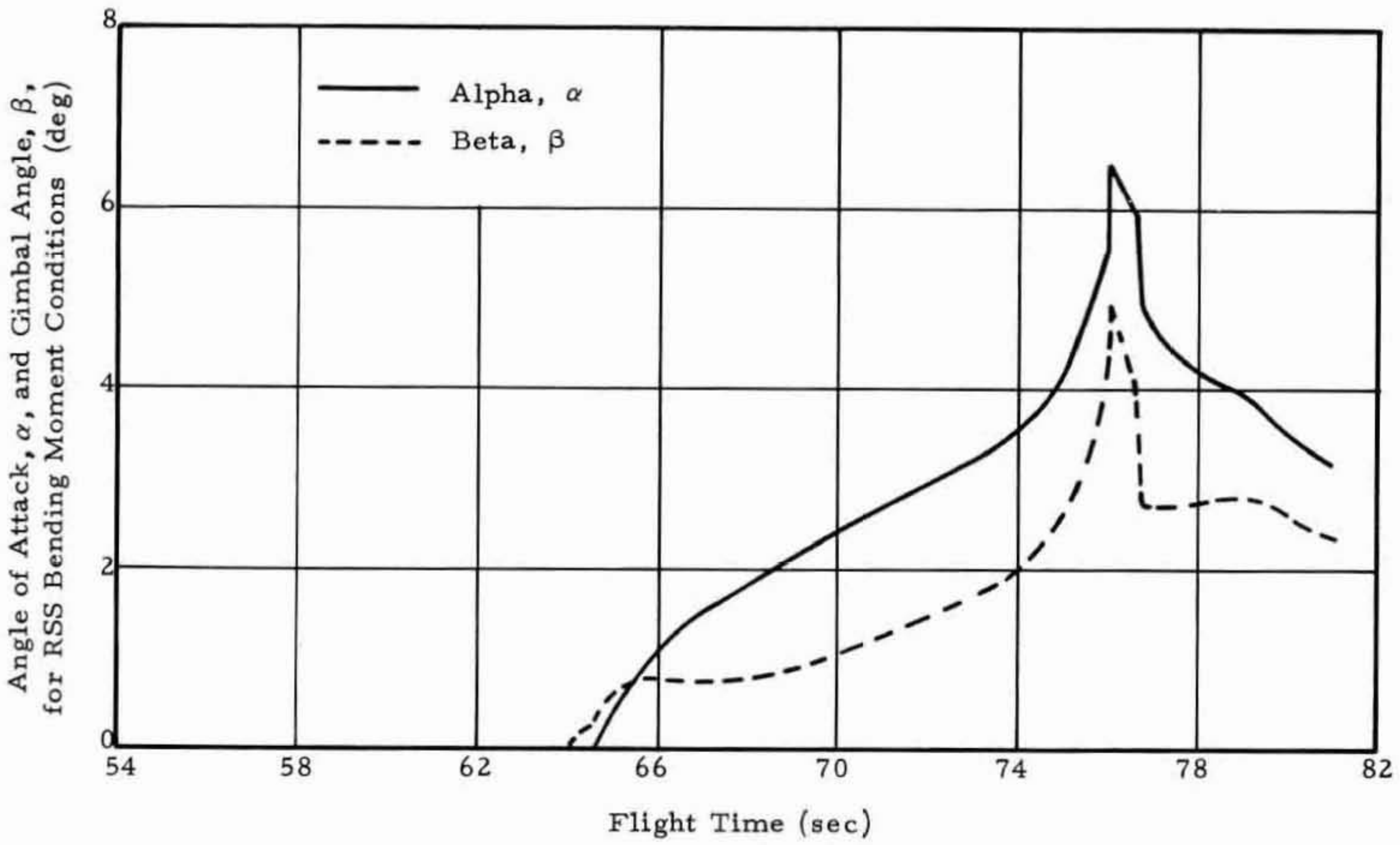

FIGURE 19. ASSIGNED ANGLE OF ATTACK AND GIMBAL ANGLE VERSUS FLIGHT TIME FOR RSS BENDING MOMENT CONDITIONS, SATURN IB SA-217 LAUNCH VEHICLE

Ref: R-AERO-DCC-25-65, 6/16/6

F. Structural Capability

Structural loads and capability data for the SA-217 launch vehicle have not been included in this report. Tension and compression loads may be determined using Table 12 and the loads for the S-IB and S-IVB stages as presented in MSFC Memorandum R-P&VE-SLL-212-63.

Safety factors of 1.4 and 1.25 ultimate shall apply to the manned and unmanned configurations, respectively. A safety factor of 1.1 yield shall apply to both configurations.

As acoustic and vibration data for the SA-217 are lengthy, they have been omitted from this description. Acoustic data are contained in MSFC Memorandum R-P&VE-SVE-64-22, dated February 4, 1964. The vibration data are contained in MSFC Memorandum R-P&VE-SLA-66-10, dated May 12, 1966.

TABLE 12. FUEL AND OXIDIZER TANK PRESSURE RANGES, BOTH STAGES, SATURN IB SA-217 LAUNCH VEHICLE

STAGE	TANK	MAX (PSIG)		MIN (PSIG)	
		GROUND	FLIGHT	GROUND	FLIGHT
S-IB	LO_2	54.3	47.8	40.6	32.8
	RP-1	17.7	21.5	14.9	19.0
S-IVB	LO_2	25.3	30.8	22.3	26.3
	LH_2	19.3	25.3	16.3	11.8

R-P&VE-PPA
3/7/68

SECTION III. BASELINE STAGE DESCRIPTION

A. S-IB Stage

1. Configuration Description. The S-IB stage consists of four 70-inch-diameter fuel containers mounted alternately with four 70-inch-diameter oxidizer containers around a 105-inch-diameter center oxidizer container. The containers are supported at the base by a thrust structure assembly to which are affixed the eight H-1 engines. A spider beam assembly provides attachment structure for the forward end of the containers and serves as an adapter for the S-IVB stage.

2. Structure. The S-IB stage structure consists basically of the thrust structure assembly, fins, tail assembly shroud, propellant containers, and spider beam assembly. The S-IB is fabricated primarily of an aluminum alloy to obtain maximum structural stiffness with minimum weight.

a. Thrust Structure Assembly. The thrust structure assembly consists of concentric inner and outer aft thrust rings, a forward thrust ring, eight outrigger assemblies with I-beam braces between outriggers, mounting pads for outboard and inboard engines and actuator attachment points. The basic functions of the thrust structure assembly are to provide mountings for the engines, to provide connections for the fins, and to transmit inertia and thrust loads.

b. Fins. Eight lightweight fins at the base of the S-IB stage are included to stabilize the vehicle in flight and to provide holddown points on the launch pad.

c. Tail Assembly Shroud. The tail assembly shroud encompasses the engine thrust structure and the engine compartment, forming an aerodynamic external surface. The shroud consists of eight forward and eight aft reinforced aluminum alloy panels mechanically fastened together. The aft shroud panels are corrugated while the forward panels have a smooth exterior surface. Conical fairings join the forward shroud panels to the propellant containers. Four skirts, each partially enclosing an outboard engine, are mounted on the aft end of the corrugated portion of the shroud. These skirts have a smooth aluminum alloy exterior and are reinforced with stiffeners. Each skirt has an air scoop attached.

d. Propellant Containers. The S-IB stage has nine cylindrical propellant containers made of an aluminum alloy. Eight 70-inch-diameter containers are mounted in a circular pattern around a 105-inch-diameter container. Four of the outer 70-inch-diameter containers and the center 105-inch-diameter container store liquid oxygen. The cylindrical portions of the propellant tanks are milled in segments and joined by welding. Hemispherical heads are welded to the cylinder to form the propellant tanks. Material thickness of the tanks is varied longitudinally with the larger thickness at the bottom decreasing upward with the decreasing stress conditions. Each propellant container has antislosh baffles.

e. Spider Beam Assembly. The spider beam assembly is made from aluminum alloy I-beams. The spider beam assembly connects the propellant containers at the upper end and transmits structural loads between the stages. It also supports the propellant tanks during fabrication, assembly and transportation in the horizontal position.

3. Propulsion Systems

a. H-1 Engine. The H-1 engine is a calibrated, single-thrust-chamber, fixed-thrust, bipropellant rocket engine. The thrust chamber is regeneratively cooled with fuel, and has an exhaust-nozzle expansion ratio of 8:1. The propellants, liquid oxygen and RP-1 fuel, are supplied to the thrust chamber by a turbopump. A gas generator, using the same propellants as the thrust chamber, powers the turbopump. Replenishing of propellants and fuel additive and the replacement of the solid propellant gas generator, initiators, ignitors, hypergol cartridge, and main LOX valve closing control valve are required for reusing the engine after ground test.

Each engine is attached to the vehicle structure by a gimbal assembly. The inboard engines are stabilized in their position by struts attached to the stabilizing lugs. The outboard engines have gimbal actuators attached to the gimbal outriggers permitting the outboard engines to gimbal in an 8-degree square pattern for vehicle directional control. Each installed engine contains propellant ducts, tanks, pneumatic supply for system purges, and electrical power.

The inboard engines are canted 3 degrees, and the outboard engines are canted 6 degrees to the stage centerline. Assigned H-1 engine data are given in Table 13.

b. Propellant Container Pressurization. The LOX tanks are pressurized by gaseous oxygen which is supplied by changing the liquid oxygen to a gas through use of a heat exchanger. The RP-1 tanks are pressurized by use of high-pressure nitrogen bottles.

4. Thermal Protection. Components in the aft engine compartment are protected from rocket exhaust heat after engine ignition by a heat shield, a flame shield and flame curtains. The heat shield encloses the bottom portion of the engine compartment and has cutouts to allow the engine nozzles to protrude. The outboard engine cutouts in the heat shield are large enough to allow for engine gimbaling. This excess opening is protected with a flexible flame curtain. The flame shield is supported by the aft end of the thrust structure. Exposed structural members in the tail skirt area are protected from the radiant heat of the engines by a coating of thermal insulation material.

B. S-IVB Stage

1. Configuration. The S-IVB stage is basically a 260-inch-diameter semimonocoque structure consisting of a cylindrical propellant container and quasi-elliptical ends, a thrust structure assembly, a forward skirt assembly, an aft skirt, and a S-IB/S-IVB interstage and fairing.

Dual propellant tanks, separated by a common quasi-elliptical bulkhead, are located within the propellant container. The liquid oxygen tank is located aft of the liquid hydrogen tank. A thrust structure assembly to which is mounted a J-2S engine is attached to the aft bulkhead of the propellant containers. A skirt assembly is attached to the aft end of the cylindrical portion of the propellant container. The S-IB/S-IVB interstage and fairing is connected to the aft skirt assembly. Another skirt assembly is attached to the forward end of the cylindrical portion of the propellant container and supports the vehicle Instrument Unit and payload.

TABLE 13. ASSIGNED H-1 ENGINE DATA, S-IB STAGE, SATURN IB SA-217 LAUNCH VEHICLE

Item	
Engine × Number	H-1 × 8
Thrust (lb)	
Sea Level	205 000 (I_{sp} = 263.4)
Altitude	229 000
Throat Area, A_t (in^2)	205.1
Expansion Area Ratio, ϵ	8:1
Mixture Ratio	2.23:1
Chamber Pressure, P_c (psia)	652.9
Weight Flow Rate, w_t (lb/sec)	778.3
Propellants	
Fuel	RP-1
Oxidizer	LOX
Gimbal Capability	± 8-degree square pattern
Start Capability	Single

Ref: R-P&VE-DIR-66-403, 8/1/66

2. Structure. The basic structure of the S-IVB stage consists of the forward skirt, liquid hydrogen tank, liquid oxygen tank, thrust structure, aft skirt and aft interstage.

a. Forward Skirt. The cylindrical forward skirt is of aluminum alloy and skin and stringer construction. It houses the various antennae, the forward umbilical plate, panels with telemetry and electrical equipment, and joins the S-IVB stage to the Instrument Unit.

b. Liquid Hydrogen Tank. The fuel tank consists of a cylindrical section 268.5 inches long and 260 inches in diameter with a quasi-elliptical forward bulkhead. A common bulkhead serves as the fuel tank aft bulkhead and LOX tank forward bulkhead. It is fabricated of aluminum alloy except for the aft bulkhead which is made of aluminum sheets and honeycomb core. The tank cylinder is formed of seven sheets of aluminum longitudinally welded and milled on the interior and internally insulated by a polyurethane foam reinforced material.

c. Liquid Oxygen Tank. The oxidizer tank is formed by the intersection of the aft liquid hydrogen tank bulkhead (common bulkhead) with the aft LOX bulkhead. The bulkheads have a spherical radii of 130 inches and intersect each other so that there are no cylindrical elements in the LOX tank.

d. Thrust Structure. The thrust structure consists of a 65.5-inch-high truncated cone with a top diameter of approximately 160 inches and a diameter of 28 inches at the engine connections. It is of aluminum alloy, skin-and-stringer-type construction, and is attached to the engine support fitting forming an integral unit. It is attached to the LOX tank bulkhead by means of a bolted joint.

e. Aft Skirt. The aft skirt is a cylinder 85.5 inches long with an outside diameter of 260 inches. It is made of aluminum alloy skin and stringer panels mechanically joined. The skirt contains the aft umbilical plate and houses panels with telemetry and electrical equipment. The skirt also supports the auxiliary propulsion system.

f. Aft Interstage. The aft interstage is a cylinder with a diameter of 260 inches, and a height of 224.5 inches. It is formed from aluminum alloy skin and stringer constructed panels. Also included as part of the interstage is a 27.4-inch aerodynamic fairing over the S-IB stage spider beam. The aft interstage supports the four S-IB stage retrorockets and separates with the S-IB stage.

3. Propulsion Systems.

a. J-2S Engine. Primary propulsion for the S-IVB stage is provided by a J-2S rocket engine which is a high-performance engine utilizing liquid oxygen and liquid hydrogen as propellants. The only fluids used in the engine are the propellants and helium gas. The extremely low operating temperature of the engine prevents the use of lubricants or other fluids. Assigned J-2S engine data are given in Table 14. Programmed mixture ratio shift is utilized in the S-IVB stage.

Propellant utilization is accomplished by passing liquid oxygen from the discharge side of the oxidizer turbopump to the inlet side through a valve driven by a servomotor.

The J-2S features a single tubular-walled, bell-shaped thrust chamber, and two independently driven, direct-drive turbopumps for liquid oxygen and liquid hydrogen. Both turbopumps are powered in series by a single gas generator, which utilizes the same propellants as the thrust chamber. An electrical control system which contains solid-state logic elements is used to sequence the start and shutdown operations of the engine.

The solid-propellant gas generator replaces the pressurized hydrogen spin bottle required to initiate turbopump operation for engine start. Up to three solid-propellant gas generators may be installed on the engine, enabling up to three starts. Upper and lower time limitations between engine starts and spin bottle conditioning prior to launch have been eliminated.

Welded tube joints are used to minimize leaks and to improve reliability. Dual (Naflex) seals incorporating an intermediate bleed from the low-pressure side are utilized at all separable hot-gas and propellant connections.

b. Propellant Container Pressurization. A heat exchanger located in the oxidizer turbopump turbine exhaust duct provides for pressurization of the vehicle oxidizer tank. Helium gas or liquid oxygen flows through the heat exchanger and is expanded for oxidizer tank pressurization. Gaseous hydrogen from the thrust chamber fuel manifold is utilized for fuel tank pressurization.

TABLE 14. J-2S ENGINE DATA, S-IVB STAGE, SATURN IB SA-217 LAUNCH VEHICLE

Item	Data
Engine × Number	J-2S × 1
Propellants	
Fuel	LH_2
Oxidizer	LOX
Programmed Mixture Ratio	
Nominal Thrust (lb)	241 012
First Step Thrust (lb)	266 012
Second Step Thrust (lb)	216 012
Nominal I_{sp} (sec)	433.5
First Step I_{sp} (sec)	430.4
Second Step I_{sp} (sec)	435.9
Nominal Mixture Ratio	5.0:1
First Step Mixture Ratio	5.5:1
Second Step Mixture Ratio	4.5:1
Nominal Chamber Pressure (psia)	1 119
First Step Chamber Pressure (psia)	1 235
Second Step Chamber Pressure (psia)	1 003
Expansion Area Ratio (ε)	40:1
Gimbal Capability	± 7.5-degree square pattern
Start Capability	Multiple (three starts)

Ref: R-P&VE-DIR-66-403, 8/1/66
R-P&VE-AV-66-215, 11/30/66

c. Auxiliary Propulsion System. Engines for the attitude control system use storable hypergolic propellants (MMH and N_2O_4). This system provides for pitch and yaw control during unpowered flight and roll control during powered and unpowered flight.

C. Instrument Unit

The launch vehicle guidance system and most of the instrumentation are packaged in the Instrument Unit which is located immediately forward of the S-IVB stage. The Instrument Unit is a cylinder 36 inches long and 260 inches in diameter. This cylinder forms a part of the vehicle load-bearing structure with interfaces to the S-IVB stage and spacecraft. The vehicle guidance and electrical equipment panels are mounted on the cylindrical structure.

January 16, 1968 APPROVAL TM X-53686

SATURN IB SA-217 REFERENCE LAUNCH VEHICLE JANUARY 1968

By

Space Vehicle Systems Branch
Advanced Studies Office

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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