MHM-11

VOLUME ONE

HISTORY of the

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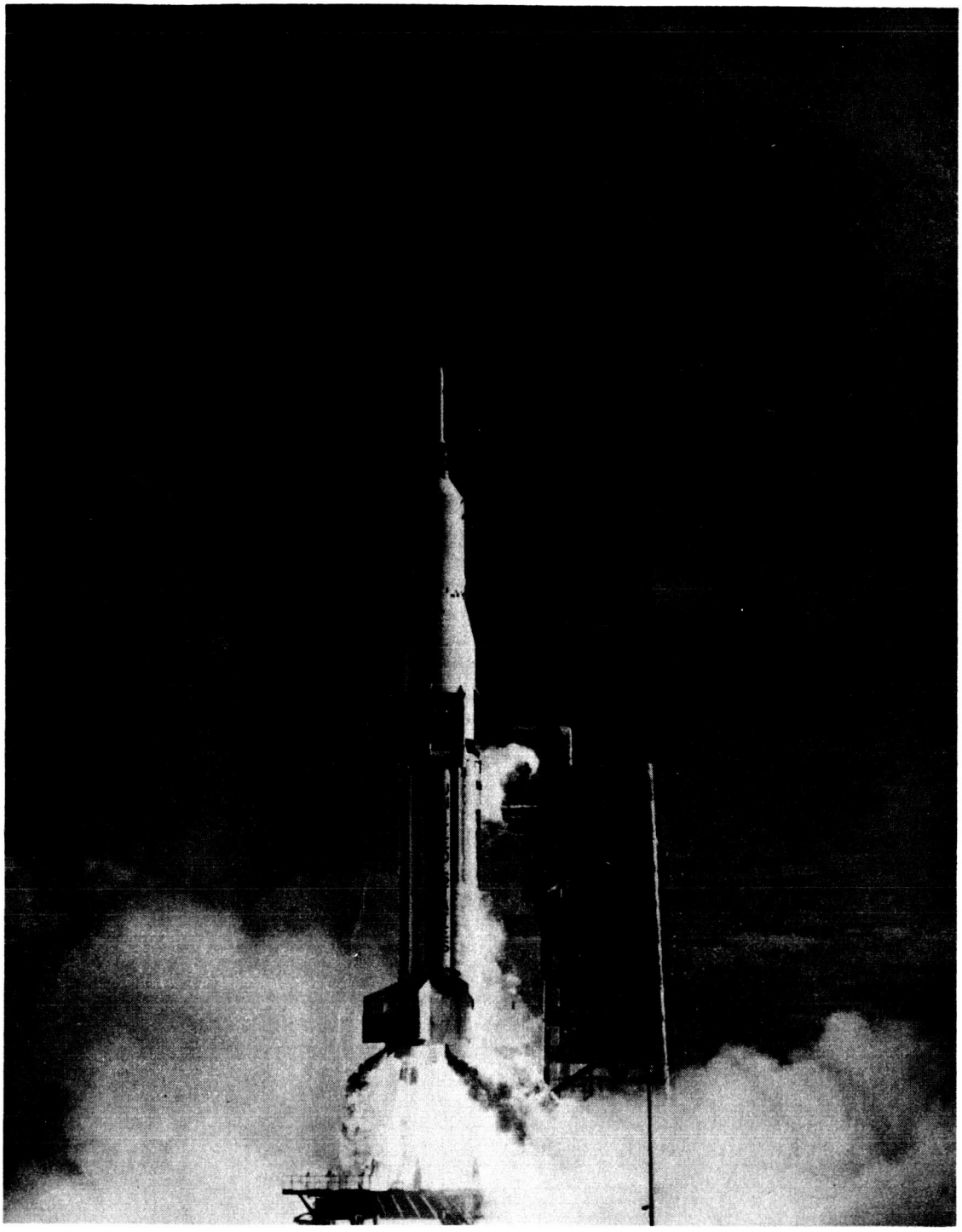

SUCCESSFUL PROGRAM ENDS

The tenth and final Saturn I launch vehicle, SA-10, roars off the pad at Kennedy Space Center on July 30, 1965, to climax a program that began in 1958.

MSFC Historical Monograph No. 11

(MHM-11)

HISTORY OF THE GEORGE C. MARSHALL SPACE FLIGHT CENTER FROM JANUARY 1 THROUGH DECEMBER 31 1965

VOLUME ONE

by

Leo L. Jones
A. Ruth Jarrell

MSFC Historical Office

Management Services Office
George C. Marshall Space Flight Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Huntsville, Alabama

April 1968

FOREWORD

This is the tenth periodic history of the George C. Marshall Space Flight Center. It covers the period January 1 - December 31, 1965, and records our most important activities in support of the National Aeronautics and Space Administration.

Our principal mission is to develop the launch vehicles for advanced space exploration. The immediate part of this objective is to provide the Saturn vehicles for manned lunar landing and return, a major national goal before 1970.

If it is true that one studies the past in order to know the future, then we are confident that this report will be of interest and help to those engaged in space exploration.

Wernher von Braun
Director

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PREFACE

Entitled Marshall Historical Monograph Number 11, this is the tenth in a series of histories about the George C. Marshall Space Flight Center. Prior to this present publication the periodic histories were published semi-annually. This is the first MSFC history covering a full year. The following pages document the most historic events at the Center during the Calendar Year 1965.

The historical background of the Center's scientific group goes back more than three decades prior to activation of MSFC and is related in Marshall Historical Monograph Number 1 (MHM-1), Historical Origins of the George C. Marshall Space Flight Center. The story of the Center's first year of operation is contained in MHM-2, History of the George C. Marshall Space Flight Center: July 1 - December 31, 1960, and MHM-3, History of the George C. Marshall Space Flight Center: January 1 - June 30, 1961. The history of the Center's second year of operation is contained in MHM-4, History of the George C. Marshall Space Flight Center: July 1 - December 31, 1961, and MHM-5, History of the George C. Marshall Space Flight Center: January 1 - June 30, 1962. The history of the third year of operation is contained in MHM-6, History of the George C. Marshall Space Flight Center: July 1 - December 31, 1962, and MHM-7, History of the George C. Marshall Space Flight Center: January 1 - June 30, 1963. The history of the Center's fourth year of operation is in MHM-8, History of the George C. Marshall Space Flight Center: July 1 - December 31, 1963, and MHM-9, History of the George C. Marshall Space Flight Center: January 1 - June 30, 1964. MHM-10, History of the George C. Marshall Space Flight Center: July 1 - December 31, 1964, is the history of the Center for the six-month period immediately preceding this first annual history.

Except for MHM-1 our previous MSFC histories consist of three volumes for each six months of operation. Volume I contains the text plus an appendix of chronological events for all the major programs. In Volume II are the unclassified documents that support Volume I. These documents

are referenced at appropriate places in the text. Volume III contains classified information and technical progress reports supporting the program histories in Volume I. Volume III is not published for general distribution but is retained in historical archives at MSFC and at NASA Headquarters in Washington, D. C. This first annual history likewise consists of Volumes I, II, and III.

Appropriate portions of this history have been read and approved by the Center's Office of Deputy Director, Technical; Deputy Director, Administrative; Management Services; Purchasing; Financial Management; Industrial Operations; and Research and Development Operations.

Our office gratefully acknowledges the valuable assistance and advice of the many individuals who contributed to the preparation of this study. It is imposssible here to acknowledge every person who provided information and other help. The list would represent most of the offices and laboratories of the Marshall Center, as well as a number of persons outside the Center. Appreciation is extended to Mrs. Helen S. Dunlap of the Historical Office who typed and retyped major portions of the history and performed indispensable filing and clerical and editing chores during its preparation.

April 18, 1968

David S. Akens,
Chief Historian

MARSHALL MILESTONES
Calendar Year 1965

January 27	- MSFC completed negotiations with Douglas Aircraft Company for the eight remaining Saturn IB S-IVB stages and a set of ground support equipment.
	- The Center awarded a contract for construction of a 20,000-square-foot addition to the Central Communication Facility, Building 4207.
February 1	- MSFC announced major revisions in the Saturn V S-II stage program which included cancellation of one ground test stage, substitution of another, transfer of the all-systems stage from Santa Susana to Mississippi Test Facility, and assignment of the facilities checkout stage directly to Kennedy Space Center.
	- NASA amended Chrysler Corporation's S-I/IB contract to provide prelaunch checkout support at Kennedy Space Center. The amendment added $6.3 million to the cost of the contract.
February 16	- SA-9, the eighth Saturn I vehicle launched by NASA, performed perfectly and placed an Apollo boilerplate spacecraft and the first Pegasus satellite into separate orbits.
In February	- MSFC awarded a $1.2 million contract for expansion of the Central Computer Facility at Slidell, Louisiana, which serves Michoud Assembly Facility and Mississippi Test Facility.
	- Workmen completed the brick-and-mortar portion of the J-2/S-IVB Test Facility at MSFC.
	- NASA modified the Rocketdyne H-1 engine contract to include uprating the H-1 from 188,000 to 200,000 pounds of thrust for Saturn IB application.
	- Computation Laboratory personnel completed occupancy of extensions to Building 4663.

March 1	- S-IC-T, the all-systems test stage of the Saturn V booster, rolled out of Manufacturing Engineering Laboratory ahead of schedule, moved to the static test stand, and was erected for static firing.
March 15	- Bendix Corporation, the stabilized platform contractor for Saturn IB and Saturn V, delivered the first ST-124M platform to MSFC.
March 17	- Technicians at Kennedy Space Center erected the SA-8 vehicle in Launch Complex 37B and began systems tests.
March 31	- NASA gave final approval to the International Business Machines contract covering instrument units for Saturn IB and Saturn V vehicles.
In March	- MSFC's Propulsion and Vehicle Engineering Laboratory began using its new Load Test Annex, a structural test facility.
April 1	- The S-IB-1 performed its first static firing of 35 seconds.
	- NASA authorized Rocketdyne to increase the H-1 engine's power from 200K to 205K and modified the engine contract accordingly.
April 7	- The Apollo Program Director forwarded to MSFC an amendment authorizing transfer of $5 million to the Saturn IB program for Saturn IB/Centaur design.
April 9	- The MSFC S-IC Static Test Stand became operational with the first firing of S-IC-T.
April 13	- Chrysler test personnel static-fired the S-IB-1 stage a second time at MSFC. This full-duration firing was the stage's final acceptance test.
April 16	- The first five-engine test of S-IC-T occurred ahead of schedule. The firing lasted 6.5 seconds.
April 24	- North American Aviation personnel performed the first S-II Stage "battleship" cluster ignition test at Santa Susana Field Laboratory.
In April	- Distinguished visitors to MSFC included Mrs. Esther Peterson, Special Assistant to the President, and Walt Disney, noted cartoonist and motion picture producer.

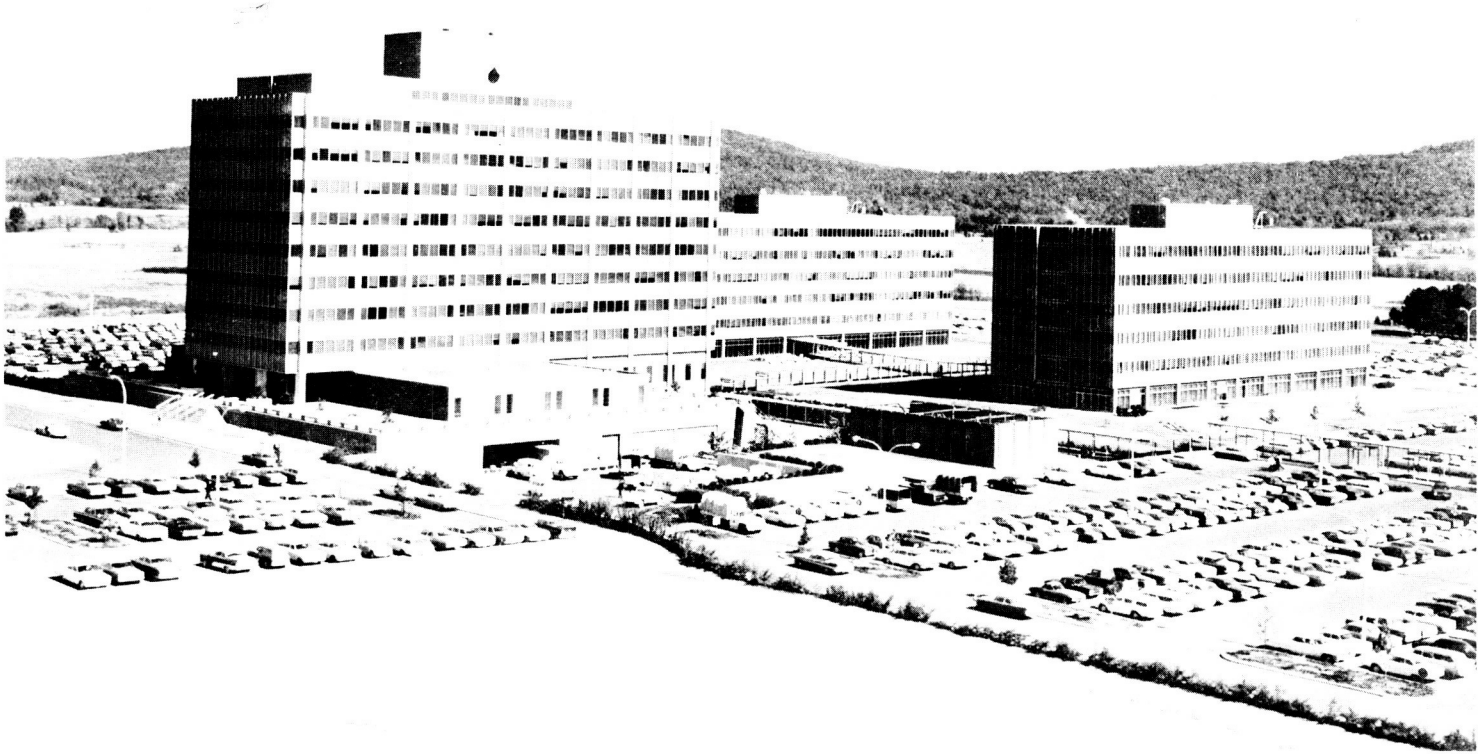
May 14	-	The S-IVB battleship stage ended a series of Saturn IB configuration tests at Sacramento in preparation for conversion to the Saturn V configuration.
May 19	-	In an election Lodge 1858, American Federation of Government Employees won exclusive recognition at MSFC as bargaining agent for Center civil service workers.
May 25	-	KSC launched SA-8, the ninth successful Saturn I. The vehicle accomplished all assigned missions and orbited the second Pegasus satellite.
May 27	-	The Saturn IB dynamic test vehicle completed its "total vehicle test" program at MSFC.
In May	-	Industrial Operations assumed responsibility for activation of Mississippi Test Facility with appointment of Jackson M. Balch as Manager of that facility. With Balch's appointment came abolishment of the MTF Planning Board and MTF Working Group.
	-	The Saturn V GSE Test Facility was finished at MSFC.
June 1	-	The Navy AKD Point Barrow, converted to a Saturn stage transporter, was officially made available to NASA.
In June	-	MSFC took beneficial occupancy of the Components Test Facility at Huntsville.
July 1	-	Frank L. Williams became director of the Advanced Systems Office, successor to the Future Projects Office, following resignation of Dr. H. H. Koelle to return to Germany. James T. Shepherd succeeded Williams as assistant to the Director.
July 2	-	Kennedy Space Center awarded a $6.7 million contract for adapting LC-37B to Saturn IB use.
July 8	-	The F-1 Engine Test Stand at MSFC became operational with its first engine firing.
July 20	-	The S-IB-2 stage completed a successful series of static tests at MSFC with a 2½-minute full-duration firing.

July 30	- SA-10, in the final flight test of the Saturn I program, performed flawlessly and placed in orbit the third Pegasus meteoroid detection satellite. The flight ended NASA's Saturn I program without a mission failure.
In July	- Michoud Operations became Michoud Assembly Facility and Mississippi Test Operations was renamed Mississippi Test Facility, at the direction of NASA Headquarters.
	- MSFC announced establishment of the Mission Operations Office in Industrial Operations to manage the Center's preflight and flight activities in the Apollo/Saturn program.
	- Following completion of Building 4202, the last of three buildings in the MSFC headquarters complex, personnel began moving into the building.
	- Rocketdyne initiated development of a J-2 engine capable of 230,000 pounds of thrust.
	- Rocketdyne completed flight rating tests (FRT) for the J-2 engine.
August 2	- MSFC conducted the first successful ignition test of the MSFC S-IVB Battleship. The test lasted 2.1 seconds.
August 5	- The first full-duration firing of S-IC-T occurred at MSFC for 143.6 seconds.
August 8	- S-IVB-201, second stage for the first Saturn IB flight vehicle, underwent a full-duration firing of 452 seconds. The test marked completion of the first fully automatic checkout, propellant loading, and firing.
August 9	- North American accomplished a full-duration S-II Battleship cluster firing at Santa Susana which was terminated manually after 385.6 seconds.
	- Chrysler shipped S-IB-1 to Kennedy Space Center for use in launch facilities checkout and then for flight.

August 17	-	The first two-burn full-duration firing of the S-IVB battleship at Sacramento Test Center lasted 170 and 320 seconds, respectively.
August 18	-	Technicians at Kennedy Space Center erected the Saturn IB facilities checkout vehicle in LC-34 and began checkout of the launch facilities.
August 20	-	The Saturn V S-IVB battleship test program was concluded with a two-burn test for 170 and 360 seconds.
August 31	-	The new Super Guppy aircraft performed its maiden flight test at Mojave, California.
September 4	-	NASA modified Chrysler's S-I/IB contract in the amount of $4.1 million to cover design development, testing, and mechanical GSE.
September 8	-	Douglas Aircraft Company technicians removed the S-IVB battleship from Beta I stand at Sacramento and shipped it to Tullahoma, Tennessee, for engine environmental testing.
September 9-10	-	Hurricane Betsy caused heavy damage to Michoud Assembly Facility buildings and equipment and beached the Saturn barge Promise on a levee.
September 15	-	The MSFC S-IVB battleship fired for 400 seconds, a full-duration test.
September 19	-	S-IVB-201 arrived at Kennedy Space Center aboard the SS Steel Executive.
September 29	-	During ultimate load testing at Seal Beach the S-II-S structural test stage ruptured and disintegrated at about 138 per cent limit load, thus demonstrating optimum design and verifying the structural integrity of the stage.
	-	Technicians at Kennedy Space Center completed the Saturn IB vehicle checkout of LC-34.
September 30	-	Workmen at Seal Beach completed all work on the S-II-T stage.
In September	-	NASA modified the Boeing contract by $4.5 million to provide services in connection with systems engineering and integration of mechanical ground support equipment.

October 6	-	During dedication of its new Huntsville plant, IBM symbolically turned over to MSFC the first Saturn IB instrument unit.
October 8	-	The first S-IC-T firing in automatic configuration occurred at MSFC for a scheduled duration of 45 seconds.
October 20	-	S-IU-201, the first Saturn IB vehicle's instrument unit, arrived at Kennedy Space Center aboard the barge Palaemon.
October 26	-	The S-IB-3 successfully performed a 2½-minute static firing at Huntsville.
October 28	-	Rocketdyne delivered to Chrysler at Michoud the first two H-1 engines uprated from 200K to 205K.
In October	-	Construction of Saturn V Launch Complex 39's Pad A ended at Kennedy Space Center.
November 9	-	Prestatic checkout of S-IB-4 ended at Michoud with no significant problems.
November 30	-	Chrysler completed assembly of S-IB-5 at Michoud.
In November	-	NASA announced the J-2 engine production contract would be amended to add 48 engines. NASA also asked Rocketdyne, the engine contractor, to provide 52 additional J-2 engines for delivery in 1967 and 1968.
December 1	-	The S-IVB-202 achieved all objectives during its full-duration acceptance firing which ended the acceptance test series for the stage.
December 13	-	The MSFC Medical Center opened for business.
December 14	-	Workmen at MSFC unloaded S-IB-4 from the barge Palaemon, moved it to the static test tower, and installed the stage in the tower for acceptance firings.
December 17	-	Qualification testing of the J-2 engine at 200K level, which began on December 2, ended successfully at Santa Susana.

December 17	-	NASA Headquarters announced management assignments for the Apollo Applications Program (AAP), which MSFC would share with Manned Spacecraft Center and Kennedy Space Center. MSFC created the Experiments and Applications Office in Industrial Operations to manage the Center's portion of AAP.
December 22	-	MSFC awarded to Aero Spacelines, Inc., a one-year contract for use of the new Super Guppy aircraft in transporting rocket cargoes, including the S-IVB stage and instrument unit. The $1.6 million contract also provided for continued services of the smaller Pregnant Guppy.
December 26	-	Kennedy Space Center technicians installed an Apollo spacecraft atop SA-201 at LC-34, completing the vehicle for launch as the Apollo Saturn 201 (AS-201).
December 30	-	NASA increased the Chrysler S-I/IB contract by $18.9 million to cover additional systems engineering.
In December	-	Chrysler completed the clustering of propellant tanks for S-IB-6 at Michoud Assembly Facility.



HEADQUARTERS AREA

The MSFC headquarters complex is seen in this low aerial view in the Fall of 1965.

CHAPTER I: ADMINISTRATIVE HIGHLIGHTS

MAJOR PROGRAMS

Development and production of Saturn launch vehicles to support NASA's Apollo Program continued to be MSFC's primary job. Calendar Year 1965 saw completion of one launch vehicle program, development maturity of two other vehicle systems, and early work in advanced space systems. Completed with 100 per cent success was the 10-vehicle Saturn I program. Saturn IB and Saturn V progressed past many major development milestones. And program definition work began on Apollo Applications and Voyager planetary exploration programs.

Three operational Saturn I launches with Pegasus payloads in the February--July period rounded out the first phase of the Apollo-Saturn program. The Pegasus satellite bonus missions provided NASA with three earth-orbiting micrometeoroid detectors that returned continuing data on the incidence of potentially hazardous meteoroids likely to be encountered by Apollo astronauts.

In the Saturn IB program, MSFC and contractors verified the vehicle design through components and systems qualification and ground tests in preparation for flight tests. Accomplishments in 1965 included completion of the battleship and dynamic test programs, static-test and acceptance of both stages for the first flight vehicle, and functional checkout of the first flight instrument unit. By the end of the year the first launch facility was ready and the first flight vehicle (SA-201) was waiting on the launch pad. Both stages of the second vehicle had been tested and accepted for flight, the third vehicle was nearly ready, and production of later stages continued on schedule.

Saturn V progress during 1965 included significant milestones in development, ground testing, and production of all three stages, the engines, and the instrument unit. Important progress also was made in

buildup and activation of facilities and ground support equipment (GSE) for this launch vehicle designed to carry men on the moon voyage. S-IC, S-II, and S-IVB stages underwent full-duration static firings. The instrument unit also completed ground development and qualification test programs. The F-1 engine, having completed flight rating tests in 1965, moved steadily toward 1966 flight qualification. The J-2 engine program progressed through flight rating and flight qualification test programs. Hardware production and delivery were generally on schedule in all portions of the program except the S-II stage and GSE development. Highlights at Huntsville included rollout and static firing of S-IC-T ahead of schedule and completion of the first flight booster, S-IC-1.

NASA Headquarters announced on December 17, 1965, the management assignments for the Apollo Applications Program. MSFC shared these assignments with the two other Office of Manned Space Flight centers, Manned Spacecraft Center and Kennedy Space Center. Marshall would be responsible for development and procurement of Saturn IB and Saturn V launch vehicles and for integration of experiments into the lunar excursion module, instrument units, and S-IVB stages. Apollo Applications missions would begin as soon as Saturn vehicles and Apollo spacecraft were no longer needed for the Apollo lunar landing program.

MANAGEMENT ACTIVITIES

An exceptionally busy administrative year at MSFC saw establishment of several new offices, a number of key personnel changes, and a continuing transition of the Center's role in the national space program. The trend was toward increased industrial management, with emphasis on plans for future space transportation and exploration systems.

DIRECTORY CHART
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

DATE: NOVEMBER 1, 1965

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EXECUTIVE ASSISTANT		876-1126
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VEHICLE & MISSION ANAL OFC	H O RUPPE	876-2658
APOLLO EXTENSION SYS OFC	P J de FRIES	876-4711
*ADVANCED STUDIES OFC (ASTR)	F E DIGESU	842-3230
*ADVANCED STUDIES OFC (P&VE)	E E GOERNER	876-8976
*ADVANCED STUDIES OFC (AERO)	H F THOMAE	876-6543

*CO-LOCATED

TECHNICAL SYSTEMS OFFICE (R-S)

DIRECTOR	L RICHARD	877-3760
TECHNICAL SYSTEMS COUNCIL	W LUCERO	877-2087
VEHICLE SYSTEMS GROUP	W KISTLER	877-3780
GROUND SYSTEMS GROUP	G TURNER	877-3783
SYSTEMS VERIFICATION GROUP		877-2060
SYSTEMS DYNAMICS GROUP		877-3770
SUPPORT SYSTEMS GROUP		876-9356

TECHNICAL STAFF OFFICE (R-TO)

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ASSISTANT TO DIRECTOR	H R LUDEWIG	876-6585
SYSTEMS REQUIREMENT GR	J V KLIMA	876-0264
TECHNICAL STAFF FUNCTIONS	H E ATTAYA, JR	876-6780

OPERATIONS MANAGEMENT OFFICE (R-OM)

DIRECTOR	W S FELLOWS	876-2748
DEPUTY DIRECTOR	W F McCARTNEY	877-8538
TECHNICAL ASSISTANT	W B LONG	876-6689
VEHICLE SUPPORT OFFICE	E W KING	876-8985
PROGRAM CONTROL OFFICE	F E NAPPER	876-3208
BUDGET GROUP	J C FRYMAN	876-1724
CONTRACTS GROUP	G W STURDIVANT	876-5503
FACILITIES GROUP	P C READ	876-1830
MANPOWER GROUP	W R SELF	876-2051
OPER ANAL & MGT SUPP OFC	W W ZBINDEN	876-2249
ADMINISTRATIVE OFFICER	J R ELLIS, JR	876-3397

AERO-ASTRODYNAMICS LABORATORY (R-AERO)

DIRECTOR	E D GEISSLER	876-4643
DEPUTY DIRECTOR	O C JEAN	876-1422
ASSISTANT DIRECTOR		876-4711
PROJECTS OFFICE	L L McNAIR	876-1222
TECH & SCIENTIFIC STAFF		876-1101
SYSTEMS CONCEPTS PLN OFFICE		876-4711
RESOURCES MANAGEMENT OFFICE	R Q BUTLER	876-4211
AEROSPACE ENVIRONMENT OFC	W W VAUGHAN	876-1238
AERODYNAMICS DIVISION	W K DAHM	876-4566
DYNAMICS & FLIGHT MECH DIV	H J HORNE	876-4446
FLIGHT EVAL & OPER STUDIES DIV	J P LINDBERG	876-2701
ASTRODYNAMICS & GUID THEORY DIV	C D BAKER	876-1524
ADVANCED STUDIES BRANCH	H F THOMAE	876-6543

ASTRIONICS LABORATORY (R-ASTR)

DIRECTOR	W HAEUSSERMANN	876-1642
DEPUTY DIRECTOR	H W KROEGER	876-3815
ASSISTANT DIRECTOR	O A HOBERG	876-4264
ASSISTANT FOR OPERATIONS	J B E CHASE	876-4705
ASSISTANT PROGRAM DEV	W P HORTON	876-0887
RESOURCES MANAGEMENT OFC	R D KRUIDENIER	876-5905
ADMINISTRATIVE GROUP	M L JENSEN	876-0181
IU PROJECT OFFICE	F WEBER	876-4326
ADVANCED STUDIES OFFICE	F E DIGESU	842-3230
SYSTEMS ENGINEER OFFICE	J L MACK	876-4264
GUIDANCE & CONTROL DIV	F B MOORE	876-3420
INSTRUMENTATION & COMM DIV	O A HOBERG	876-2941
ELECTRICAL SYS INTEGRATION DIV	H J FICHTNER	876-2436
FLIGHT DYNAMICS BRANCH	J HOSENTHIEN	877-2151
APPLIED RESEARCH BRANCH	J C TAYLOR	877-2168
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PROTOTYPE DEV BRANCH	W ANGELE	876-4525

COMPUTATION LABORATORY (R-COMP)

DIRECTOR	H HOELZER	876-3147
DEPUTY DIRECTOR	C L BRADSHAW	876-3115
ASSISTANT DIRECTOR	C PRINCE	876-5146
DATA SYSTEMS ENGINEERING OFC	J T FELDER	876-2890
RESOURCES MANAGEMENT OFFICE	R L WESSON	876-2822
DATA CENTER DIVISION	W H FORTENBERRY	876-1404
ENGINEERING COMPUTATION DIV	C P HUBBARD	876-1907

MANUFACTURING ENGINEERING LABORATORY (R-ME)

DIRECTOR	W R KUERS	876-1402
DEPUTY DIRECTOR	M P SIEBEL(ACT)	876-7186
ASST DIR FOR ADVANCED PROJ	H F WUENSCHER	876-6365
TECHNICAL ASSISTANT	M E NOWAK	876-4743
TECHNICAL ASSISTANT	W G CRUMPTON	876-2440
PROJECTS DEV OFFICE	H F WUENSCHER	876-6044
MFG ENGR LIAISON OFFICE	P H MAURER	877-2187
RESOURCES MANAGEMENT OFC	D T WALTERS	876-5389
MFG RESEARCH & TECH DIV	J P ORR	876-4546
MANUFACTURING DEV DIV	O K EISENHARDT	876-3910
PLANNING & TOOL ENGR DIV	W J FRANKLIN	876-2544
PLANT ENGINEERING BRANCH	W R POTTER	876-4914
INDUSTRIAL SUPPORT BRANCH	C A SWANSON	876-4859

PROPULSION & VEHICLE ENGINEERING LABORATORY (R-P&VE)

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DEPUTY DIRECTOR	F A HELLEBRAND	876-7164
ASSISTANT DIRECTOR	H R PALAORO(ACT)	876-0714
ADVANCED STUDIES OFC	E E GOERNER	876-8976
RESOURCES MGT OFFICE	C J RIEGER	876-4340
PROJECTS OFFICE	W A BROOKSBANK, JR	876-0081
MATERIALS DIVISION	W R LUCAS	876-2636
STRUCTURES DIVISION	G A KROLL	842-3500
PROPULSION DIVISION	H G PAUL	876-7928
VEHICLE SYSTEMS DIV	J O ABERG(ACT)	876-1777
SATURN V DYN TESTING	J O LYSAGHT	876-1403
SATURN IB DYN TESTING	C E WATSON	876-8412

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RELIABILITY ASSURANCE DIV	R L CHANDLER	876-2166
QUALITY ENGINEERING DIV	W L BRIEN	876-3766
ANALYTICAL OPERATIONS DIV	R W HENRITZE	876-2591
VEHICLE SYSTEMS CHECKOUT DIV	C O BROOKS	876-2040
SYS C/O COMPUTER SOFTWARE	C G RILEY	876-2107

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SPECIAL PROJECT OFC	J A DOWNEY III	876-4424
RESEARCH PROGRAM OFC	C G MILES, JR	876-6046
PHYSICS & ASTROPHYSICS BR	J B DOZIER, JR	876-1865
NUCLEAR & PLASMA PHY BR	R D SHELTON	876-4071
SPACE THERMODYNAMICS BR	G B HELLER	876-4024
SCIENTIFIC FLIGHT PAYLOADS BR	E A MECHTLY	876-1141

TEST LABORATORY (R-TEST)

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DEPUTY DIRECTOR	B R TESSMANN	876-4943
SPECIAL ASSISTANT	H C DYER	876-0733
SPECIAL ASSISTANT	J A HAUTH	876-0733
ADMINISTRATIVE OFFICE	W H DODD	876-1312
ADVANCED FAC PLANNING OFC	J B CARRINGTON	876-3405
MISSISSIPPI TEST FAC PLANNING & SPECIAL PROJ OFC	T E EDWARDS	876-2990
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SYSTEMS TEST DIVISION	D H DRISCOLL	876-4010
COMPONENTS & SUB-SYS TEST DIV	W L GRAFTON	876-1441
TEST INSTR & CONTROL DIV	W H SIEBER	876-6478
TECHNICAL SUPP DIVISION	W E MARSALIS	876-2602

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ASSISTANT DIR FOR ENGR	W A MRAZEK	876-4248
EXECUTIVE ASSISTANT	R E PACE, JR	876-6249
RESIDENT MANAGER, KSC	B MONTGOMERY	876-4950

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DEPUTY CHIEF	J R McCOMBS	876-6954
SPECIAL PROJECTS OFFICE	J H HYER	876-9985
STAGES BRANCH	E H EUBANKS	876-6060
ENGINES BRANCH	T L BURTON	876-1827
INSTRU UNIT, GSE & PAYLOADS BRANCH	E B CRAIG	876-8459
CONTRACT MANAGEMENT BR	S H JONES	876-2656
HUNTSVILLE-MICH OFC	C W DORNING	876-8194

FACILITIES PROJECTS OFFICE (I-FP)

CHIEF	A V DALY	876-4436
PROGRAMS BRANCH	B R FLEMING	876-4676
ENGINE FACILITIES BRANCH	C A BAUER	876-3440
SATURN I & IB FAC BRANCH	H P LLOYD	876-8584
SATURN V FACILITIES BR	C L WEBB	876-2456
INDUSTRIAL PROPERTY BR	V L LOONEY	876-8936
GEN SPT & TECH FAC BR	C L WEBB	876-2456

PROJECT LOGISTICS OFFICE (I-PL)

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PROGRAM SUPPORT BRANCH	W L KENNEDY	876-3616
PROPELLANTS & PRESS BR	R D WALKER	876-6932
TRANSPORT BRANCH	C D DeNEEN	877-2593

RESOURCES MANAGEMENT OFFICE (I-RM)

CHIEF	C E ANDRESSEN, JR	876-7242
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CONFIGURATION MGMT GR	W JEANCON	877-3801
BUDGET & PROG PLAN GR	C WILLIAMS	876-5618
SCHEDULING GROUP	A B CLAYTON	876-6547
PROG MGMT INFO GROUP	M L BULLINGTON	876-5568
ADMINISTRATIVE GROUP	S O HOLDSAMBECK	876-3619

SATURN I/IB PROGRAM OFFICE (I-I/IB)

MANAGER	L B JAMES	876 3774
DEPUTY MANAGER, OPERATIONS	W TIER	877-3995
DEPUTY MANAGER, MANAGEMENT	W F LaHATTE	877-3910
ASSISTANT MANAGER	G B HARDY	876-3277
MANAGEMENT SUPPORT OFC	E S GOBER	876-0938
DAC RESIDENT MGT OFFICE HUNTINGTON BEACH, CALIF	L R HALL	876-2154
KSC RESIDENT MGT OFFICE CAPE KENNEDY, FLA	T J LEE	876-7931
PROGRAM CONTROL OFFICE	M JOHNSON	876-0846
SYSTEMS ENGINEERING OFC	F E VREULS	876-9657
TEST OFFICE	J E FIKES	876-0844
RELIABILITY & QUALITY OFC	W W LUCE	876-5689
FLIGHT OPERATIONS OFC	J E FIKES(ACT)	876-0844
S-I & S-IB STAGE PROJECT	A W THOMPSON	876-2763
S-IVB(IB) STAGE PROJECT	J C McCULLOCH	876-0923
INSTRUMENT UNIT PROJECT	W K SIMMONS, JR	876-4134
IBM RESIDENT MGT OFFICE	L E POWELL	842-3940
VEHICLE GSE PROJECT	P DUNLAP, JR	876-8256
GE RESIDENT MGT OFFICE	F N BEASON	842-3304

SATURN IB/CENTAUR PROGRAM OFFICE (I-SC)

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DEPUTY MANAGER		876-2148
ASSISTANT TO MANAGER		876-2148
MANAGEMENT SUPPORT	J L DEW	876-9282
RESIDENT REP, KSC		
PROGRAM CONTROL	J C SWEARINGEN	876-9242
QUALITY & RELIABILITY	E HENNING	876-9252
SATURN BOOSTER & VEH GSE	J CHAMBERS	876-9538
SATURN CENTAUR STAGE	W A FERGUSON	876-0012
VOYAGER PAYLOAD INTEGRATION	C H CHAMBERS	876-9561
SYSTEMS ENGINEERING	R ISE	876-1043

SATURN V PROGRAM OFFICE (I-V)

MANAGER	A RUDOLPH	876-6216
DEPUTY MANAGER, OPERATIONS	J B BRAMLET	876-1558
DEPUTY MANAGER, MANAGEMENT	J T MURPHY	877-2672
ASSISTANT MANAGER	J E BRADFORD	876-2536
KSC RESIDENT OFFICE	J P MURPHY (AC 305)	867-4976
MANAGEMENT SUPP OFFICE	E H HARTLEIN(ACT)	876-2244
PROGRAM CONTROL OFFICE	B H SNEED	876-1949
SYSTEMS ENGINEERING OFFICE	L B BELL, JR	877-2905
TEST OFFICE	H D BURNS	876-6940
RELIABILITY & QUALITY OFFICE	J W MOODY	876-1729
FLIGHT OPERATIONS OFFICE	A D ROWAN	877-3127
S-IC STAGE PROJECT	M W URLAUB	876-2507
S-II STAGE PROJECT	S YARCHIN	876-3448
S-II RESIDENT OFFICE DOWNEY, CALIF	W K GENGELBACH (AC 213)	923-8111 EXT 6187
S-IVB STAGE PROJECT	R E GODFREY	876-6936
INSTRUMENT UNIT PROJECT	F DUERR	876-3777
VEHICLE GSE PROJECT	S E SMITH	876-6215

ENGINE PROGRAM OFFICE (I-E)

MANAGER	L F BELEW	876-2350
DEPUTY MANAGER	W D BROWN	876-5022
ASSISTANT MANAGER	J BURKS	876-2817
MANAGEMENT SUPPORT OFFICE	P C WATSON	876-1352
RESIDENT MGT OFFICES		
EDWARDS ROCKET BASE, CALIF	R GROENEVELD	714-762-5161 EXT 822041
ROCKETDYNE, CANOGA PARK, CAL	E W JOHNSON	213-346-9662 EXT 2841
PRATT & WHITNEY, WEST PALM BEACH, FLORIDA	W B FRY	876-9069
PROGRAM CONTROL OFFICE	H W HAENISCH	877-8169
SYS ENGINEERING OFFICE	J H WAITE	876-0654
TEST OFFICE	C M MITCHELL	877-3004
RELIABILITY & QUAL OFFICE	A STEINBERG	876-0671
RL-10 ENGINE PROJECT	R D STEWART	876-7178
J-2 ENGINE PROJECT	F M DRUMMOND	876-0675
H-1 ENGINE PROJECT	T P SMITH	876-2902
F-1 ENGINE PROJECT	S F MOREA	876-3033
SPACE ENGINE PROJECT	J M JACKSON	877-8274

MICHOUD ASSEMBLY FACILITY (I-MICH)

MANAGER	G N CONSTAN	255-52601
DEPUTY MANAGER	J L STAMY	255-52604
ASSISTANT MANAGER	M S HARDEE	255-52602
NASA AUDIT OFFICE	S SMITH	255-52567
CONTRACTS OFFICE	M S HARDEE	255-52631
FINANCIAL OFFICE	W M BAILEY	255-52637
LABOR RELATIONS OFC	F M TYVOLL	255-52603
COUNSEL OFFICE	L J CONNORS	255-52603
DOCUMENTATION OFFICE	H H QUINTON	255-53455
FACILITIES OFFICE	E L JENSEN	255-52583
PUBLIC AFFAIRS OFFICE	J M FUNKHOUSER	255-52605
PROGRAMS OFFICE	A O FRYE, JR	255-53444
ENGINE OFFICE	J W HILL	255-52563
S-I/IB STAGE OPER OFC	H H STEVENSON	255-52577
S-I/C OPER OFFICE	R J NUBER	255-52573
SUPPORT OPER OFFICE	H B ABERNETHY, JR	255-52611
COMPUTER OPER OFFICE	R L REEVES	255-56401
ASST FOR QUAL ASSUR & REL	A G SMITH	255-53401
QUALITY ENGR OFFICE	H W FOWLER, JR	255-54761
PRODUCT CONT ENGR OFC	R L RIEMER	255-52615
RELIABILITY OFFICE	H L WILLIAMS	255-53418

MISSION OPERATIONS OFFICE (I-MO)

MANAGER	F A SPEER	876-9142
ASSISTANT, TECHNICAL	W G CLARKE	876-9142
ASSISTANT FOR PLANNING	S C BARTLEY	876-9161
ORSO REPRES MGR STAFF	W H BYNES (AC 202)	963-5919
OPERATION OFFICE	H F KURTZ	876-9189
OPR SUPP REQUIREMENTS OFC	H F KURTZ(ACT)	876-9189
FLIGHT CONTROL OFFICE	C W CASEY (AC 713)	483-3101

MISSISSIPPI TEST FACILITY (I-MT)

MANAGER	J M BALCH	688-2121
DEPUTY MANAGER	**H F AUTER	688-4354
ASST MANAGER (ACTIVATION)	G E ARTLEY	688-3541
ASST MGR (CONSTR & INST)	**F A FRECH	688-2121
EXECUTIVE ASSISTANT	**F A FRECH	688-2121
COUNSEL	E L LING	688-2164
LABOR RELATIONS OFC	F M TYVOLL	688-3144
PUBLIC INFORMATION OFC	M R HERRING	688-3341
MANAGEMENT SUPP OFC	W H DEARING	688-4092
PROJECTS CONTROL OFC	**H F AUTER	688-4354
OPERATIONS ENGR OFFICE	W L GRAFTON(ACT)	688-3541
CONTRACTS OFFICE	W J McKINNEY(ACT)	688-3680
SITE SUPPORT OFFICE	E W KING	688-3111
NASA AUDIT OFFICE	J W SPERANCE	688-4609

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Organizational Changes

With the Saturn I program completed, Saturn IB well into production, and Saturn V in the final design and testing phase, emphasis at MSFC began shifting to future space programs. Claiming most attention was the Apollo Extension Systems program, which later in the year was to be renamed Apollo Applications Program.

In March 1965 NASA named MSFC project manager of the three-stage Saturn IB/Centaur launch vehicle system, which NASA had proposed in December 1964 for use in post-Apollo missions. Foremost among these proposed missions was Voyager, the project for scientific exploration of the planet Mars. In May 1965 MSFC established the Saturn IB/Centaur program office in Industrial Operations, to manage this vehicle program.[1]

Later in 1965 NASA decided to suspend development of the Saturn IB/Centaur and to use the Saturn V as the Voyager launch vehicle. In October NASA assigned MSFC the Saturn V launch vehicle system responsiblility for the Voyager project. The Center on December 1 assigned overall management responsibility for Saturn V/Voyager to Industrial Operations, with technical support from Research and Development (R&D) Operations. On December 17, 1965, the MSFC Director announced creation of the Experiments and Applications Office in Industrial Operations. This new office, to be opened January 1, 1966, would manage MSFC's portion of the Apollo Applications Program, including Voyager and the S-IVB Orbital Workshop.[2]

During 1965, because of these changing circumstances and new assignments, MSFC transferred numbers of personnel from R&D Operations to program management in Industrial Operations. The Center also transferred large amounts of in-house work to contractors. In connection with these changes,

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1. Memo, Office of Director, MSFC, to Distribution, subj., "Saturn IB/Centaur Project and Personnel Announcement," May 7, 1965.

2. Memos, Office of Director to Distribution, subj., "Assignment of Responsibilities for the Saturn V/Voyager Project," Dec. 7, 1965; and Office of Director to Addressees, subj., "Creation of Experiments and Applications Office," Dec. 17, 1965.

NASA prepared to transfer 200 civil service spaces from MSFC to Manned Spacecraft Center, Houston, Texas, where Apollo spacecraft program responsibilities were increasing. MSFC established a retraining program for employees desiring reassignment to MSC.[3]

MSFC reorganized its R&D Operations staff to conform to the Center's new mission status. During June and July the following offices were created: the Advanced Systems Office, succeeding the Future Projects Office as the focal point for all advanced planning; the Technical Systems Office, to support the Apollo program in launch vehicle technical matters; the Technical Staff, to assist the R&D Operations Director with technical problems; and the Operations Management Office, to provide administrative support and coordination with Industrial Operations. Concurrently with the July 1 establishment of these last two offices, R&D Operations abolished its existing Resources Management and Saturn/Apollo Systems Offices.[4]

Meanwhile, Industrial Operations made two top echelon changes: appointment of Karl Heimburg, Test Laboratory Director, to the dual office of Assistant Director for Industrial Operations, to assist in activation of Mississippi Test Facility (MTF); and assignment of Dr. W. A. Mrazek to full-time capacity as Assistant Director for Engineering. This latter appointment relieved Dr. Mrazek of dual-role responsibilities as Chief Engineer for Saturn I/IB and Saturn V vehicles.[5]

Industrial Operations assumed responsiblity for activation of MTF in May 1965 with the appointment of Jackson M. Balch as Manager, replacing William C. Fortune. With Balch's appointment came abolition of the MTF Planning Board and MTF Working Group, the Huntsville-based unit that

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3. Memo, Office of Director to All Employees, subj., "Marshall's Changing Role in the Space Program," Aug. 13, 1965.

4. Memo, Director, R&D Operations, to Distribution, subj., "R&D Operation Staff Reorganization," July 22, 1965.

5. Memos, Office of Director to Distribution, subj., "Mississippi Test Facility," May 4, 1965; and Director, Industrial Operations, to Distribution, subj., "Realignment of Duties of Assistant Director for Engineering, Industrial Operations," June 3, 1965.

planned and initiated buildup of the rocket test facility. Balch had formerly served as Assistant Deputy Director, Technical, at MSFC.[6] Fortune was reassigned to a new NASA job on the West Coast.

Two significant organizational name changes occurred in July when MSFC's Michoud Operations became Michoud Assembly Facility (MAF) and Mississippi Test Facility became the official name of what had been Mississippi Test Operations. These changes came at the direction of NASA Headquarters.[7]

Also in July MSFC announced creation of the Mission Operations Office within Industrial Operations. The objective of this office was to manage the Center's involvement in preflight and flight activities in the Apollo/Saturn program.[8]

Marshall established an important new staff office during 1965 with creation of the Manpower Utilization and Administration Office. This office combined the functions of the Personnel Office with manpower planning and community affairs.

Appointment and Reassignments

Air Force Colonel Samuel Yarchin became manager of the S-II Stage Project Office in February, succeeding E. W. Neubert, on detail since 1963 from the post of Associate Deputy Director, Technical.

In May the position title of Associate Chief Counsel for Patent Matters was changed to Patent Counsel.

S. R. Reinartz became acting manager of the Saturn IB/Centaur Project Office upon creation of this office in May.

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6. Memo, Office of Director to Distribution, subj., "Mississippi Test Facility," May 4, 1965.

7. MSFC Circular 7-65, subj., "Redesignation of MSFC Organizational Elements," July 6, 1965.

8. Memo, Office of Director to Distribution, subj., "Creation of Mission Operations Office," July 23, 1965.

In June Dr. H. H. Koelle announced his resignation as Director, Future Projects Office, effective July 1, 1965. Dr. Koelle returned to Germany to join the faculty of the Technical University of Berlin.

Frank L. Williams, formerly assistant to Dr. von Braun, became Director of the Advanced Systems Office on July 1. This new office succeeded the Future Projects Office; it consolidated the Future Projects Office mission with the total future planning and advanced systems work for all elements of the Center. Following Williams as assistant to Dr. von Braun was James T. Shepherd, former Assistant Director for Facilities Engineering.

Other appointments to newly created offices included: Ludie Richard, Director, Technical Systems Office; K. K. Dannenberg, Director, Technical Staff; W. S. Fellows, Director, Operations Management Office; Dr. F. A. Speer, Manager, Mission Operations Office; and Dr. J. C. McCall, Director, Experiments and Applications Office.

Fred B. Cline, since March 1964 the Acting Director of P&VE Laboratory, was named Director of this laboratory effective July 18, 1965.

Keith Wible was named Chief of the Manpower Utilization and Administration Office upon creation of this office in July. Wible had served since 1961 as Assistant Manager of Michoud Operations.

Dr. Rudolf F. Hoelker, a member of the original Project Paper Clip rocket development team from Germany, resigned as a division chief in the Aero-Astrodynamics Laboratory. Dr. Hoelker left Huntsville to join the staff of NASA's new Electronics Research Center, Boston, Massachusetts.

Dr. O. H. Lange, a key official of MSFC since the Center's creation, resigned in September to become Chief Scientist of the Army's Nike X Project Office. Dr. Lange, former Director of the Saturn Systems Office, served his last two years at MSFC as Assistant Director for Scientific and Technical Analysis.

Dr. J. P. Kuettner, former Deputy Director of the Saturn/Apollo Systems Office at MSFC, received temporary assignment in September 1965

to become Chief Space Scientist of the National Weather Satellite Center. This Center is a function of the Environmental Science Services Administration (ESSA), which replaced the Weather Bureau.

E. C. Andressen, Jr., formerly Deputy Director, Executive Staff, was named Chief of the Resources Management Office, Industrial Operations, effective October 18, 1965.

Cost Reduction

MSFC continued for the second year the effort at reducing costs while improving efficiency. The Cost Reduction and Value Engineering (CRAVE) Office directed this effort in-house and monitored the cost reduction programs of 11 major NASA contractors. MSFC had a Fiscal Year 1965 cost reduction goal of $42 million; actual savings reported to Headquarters and accepted as valid, however, amounted to $56.6 million for this period.[9] MSFC was host on May 25 to a Cost Reduction Seminar attended by 300 persons representing nine NASA centers and 13 contractors. Participating also was Brooks C. Preacher, Director, NASA Office of Cost Reduction. In October Aubrey Smith was named Chief of CRAVE Office, succeeding W. S. Fellows.

Technology Utilization

MSFC's technology utilization program assumed a growing importance as more and more space technology became applicable to industrial uses. The Center transmitted reports on innovations and advancements to private industry, institutions, and other government agencies through its Technology Utilization Office, a part of Management Services Office.

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9. The FY 1965 figures are the only available final figures relevant to Calendar Year 1965. Data obtained from Enclosure to Letter from Dr. George E. Mueller, OMSF, NASA, to Dr. von Braun, Aug. 5, 1965.

Support Contracts

In January 1965 MSFC renewed for one year a $2.1 million contract with Telecomputing Services, Inc., for operation of computers and data transmission equipment at MAF and Slidell, Louisiana.

On March 1 MSFC announced selection of nine companies to provide support services for Center laboratories and offices. These firms were chosen following the 1964 decision to consolidate support and engineering services under one contract for each major organizational element of MSFC. Cost of the nine contracts effective March 1, 1965, for a one-year period was approximately $58.5 million, and total number of personnel about 4,700. Contracts were awarded as follows: Astrionics Laboratory, Sperry Rand Corporation, $12.6 million; Propulsion and Vehicle Engineering Laboratory, Brown Engineering Company, $12.3 million; Test Laboratory, Vitro Corporation, $4.1 million; Manufacturing Engineering Laboratory, Hayes International Corporation, $6.8 million; Aero-Astrodynamics Laboratory, Northrop Space Laboratories, $3.9 million; Quality and Reliability Assurance Laboratory, Spaco, Inc., $7 million; Facilities and Design Office, Rust Engineering Company, $700,000; Management Services Office, RCA Service Company, $5 million; Technical Services Office, Management Services, Inc., $3.9 million.

At MAF, MSFC awarded the firm of Mason-Rust a 10-month contract effective through December 1965 covering support services at the new Saturn booster assembly site. This contract extension provided engineering and housekeeping services for the period at a cost of $10.9 million.

In July MSFC awarded to General Electric Company an $8.1 million contract modification for support to Computation Laboratory. This was a one-year extension of the contract originally awarded in 1964.

In December MSFC renewed the portion of the General Electric Apollo support contract covering support services to MTF. This renewal, valued

at $42.9 million, called for a one-year provision of technical and plant services at the test facility.[10]

New Medical Center

During 1965 MSFC decided to establish its own medical service program, since the Center's needs had overtaxed the occupational health capability provided by the Army for all Redstone Arsenal organizations. Through a subcontract with Aerojet-General Corporation under the RCA support contract, MSFC employed three doctors and made plans for a new medical center building. On June 7 NASA Headquarters approved $220,000 for the project, and the same month MSFC awarded a contract to Greenhut Construction Company for construction of a Medical Center addition to Building 4729 (Technical Services Office). Basic construction ended in November. The Medical Center opened for business on December 13, 1965.[11]

Manned Flight Awareness

The Manned Flight Awareness program at MSFC is an effort to assure the safety of Apollo astronauts by encouraging all personnel to do their jobs well. Early in 1965 this office transferred from R&D Operations to Industrial Operations because of the program's concentration upon the private industrial firms most responsible for building reliable Saturn vehicles. A noteworthy event toward this objective was outfitting of a mobile display van illustrating the importance of perfect workmanship.

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10. MTF, Historical Report, Jan. 1--Dec. 31, 1965, pp. 5 and 73.

11. Memos, Facilities and Design Office to H. H. Gorman, Deputy Director, Administrative, subj., "Weekly Activities," June 11, 1965; Purchasing Office to Gorman, subj., "Weekly Activities," June 11, 1965; and Management Services Office to Gorman, subj., "Weekly Activity Report," Dec. 17, 1965.

Dr. von Braun and IO Director E. F. O'Connor dedicated this vehicle at MSFC March 31 before it began its visits to Saturn contractor plants across the country.

Drives and Campaigns

A charity fund drive combining the United Givers Fund and Joint Fund campaigns was organized at Redstone Arsenal with MSFC's participation in the fall of 1965. This first trial effort was named Combined Federal Campaign (CFC) and featured a "one-time-only" drive for all charity and health purposes. Employees were able, for the first time also, to give through payroll deduction. The CFC ended in November with MSFC personnel participation exceeding 85 per cent and total contributions from Center employees reaching $125,766; gifts by contractors and their personnel raised the total to $135,500.

MSFC and other government and civil agencies began in August 1965 a "Campaign for Courteous Driving," emphasizing personal courtesy to reduce the rising rate of traffic accidents on the Arsenal. One aspect of this safety campaign was the reporting of observed incidents of road courtesy and the awarding of official certificates for these acts.

In an effort to reduce records file space in use at MSFC, a program called "Operation Cleanup" began in July. This campaign aimed at disposing of inactive and unneeded documents. MSFC's files representing about 80,000 cubic feet were to be reduced 25 per cent or 20,000 cubic feet. The result of Operation Cleanup, reported in December, was that 11,346 cubic feet--equivalent to 1,134 five-drawer file cabinets--had been vacated at the Center.[12]

A drive to reduce excessive paper work, "Operation Papermill," came late in this period. The Center Director urged employees to help eliminate

12. Memo, Management Services Office to Gorman, subj., "Weekly Activity Report," Dec. 17, 1965.

production of unnecessary documents. Approximately 270 million pieces of paper went into MSFC documents in 1965.[13] This drive was incomplete at the end of 1965.

GENERAL FACILITIES*

Building 4202, the last of the three buildings in the MSFC headquarters complex, was under construction at the beginning of this report period. On June 10, 1965, there was a final inspection of all parts of the structure except the cafeteria and basement equipment rooms. Early in July, with only grassing and landscaping work remaining to be completed, the first of about 600 personnel began moving into Building 4202.

Construction of a $1.8 million addition to Building 4610 (P&VE Laboratory) proceeded on schedule throughout the year after initiation in December 1964. By the end of 1965 this project was 70 per cent complete.

Extensions to three wings of Building 4663 (Computation Laboratory) were completed in December 1964 and January 1965. Personnel completed occupying these additions by early February 1965.[14] A $52,890 addition to Building 4663 began in February and ended late in 1965 for the Huntsville Operations Support Center (HOSC). Personnel of the new Mission Operations Office occupied this annex to support Apollo launch and flight operations.

The Center awarded a $339,620 contract on January 27, 1965, for construction of a 20,000-square-foot addition to the Central Communications Facility, Building 4207. The building was almost complete by the end of 1965, with beneficial occupancy expected the first week in January 1966.[15]

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13. Public Affairs Office, Marshall Star, Dec. 8, 1965, p. 4.

14. Memos, Facilities and Design Office, to Gorman, subj. "Weekly Activities Report," Jan. 8 and June 18, 1965.

15. Memo, Management Services Office to Gorman, subj., "Weekly Activity Report," Dec. 30, 1965.

* Facilities directly supporting the launch vehicle programs are covered in the applicable chapters of this history.

Road network improvement on the MSFC complex of Redstone Arsenal continued in 1965 with award of a $1.6 million contract early in May. The contract was for seven miles of roadway and several interchanges, to divert and speed traffic through the Center. This project, conducted under the supervision of the Army Corps of Engineers, was well along at the end of 1965 but still far from completed.

Hurricane Betsy damage at Michoud Assembly Facility was considerable. The damage report showed damage of $2.1 million to buildings and grounds, and program impact cost of $1 million. Two repair contracts totalling $1.6 million were awarded for general roof, building, and cleanup work. These repairs were largely complete at the end of this period.

Other MAF construction projects during 1965 included a $1.9 million contract for construction of a Contractor Services Building; a $2.1 million expansion of the Slidell Computer Operations building; a new cafeteria at Slidell, costing $163,000; and a $417,959 extension to the Saturn marine docks.[16]

At Mississippi Test Facility NASA and support personnel began moving in January into the new Office and Administration Building. About 750 government and contractor personnel completed occupation of this multi-storied building in April 1965. Most of MTF's roads, railroads, utilities, docks, and grounds were completed and placed in service during the year. Acquisition of land at a cost of more than $18 million was completed. Placed in service was the navigation lock and bridge complex as well as the facility's 7½-mile main canal system.[17]

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16. Michoud Assembly Facility, Hist. Rpt., Jan. 1--June 30, 1965, pp. 2 and 48-49; and July 1--Dec. 31, 1965, pp. 2-3, 21, and 43.

17. MTF, Hist. Rpt., Jan. 1--Dec. 31, 1965, pp. 1 and 11-13. For further details on both MAF and MTF, see Vol. II of this history.

PERSONNEL

The number of civil service personnel employed by MSFC at all locations when this report period began was 7,649. When the period ended MSFC had 7,515 civil service employees plus 37 on military detail. Of this number 6,827 were at Huntsville and 688 at government and contractor facilities outside the Huntsville area. The Center's civil service employees earned total salaries exceeding $82 million during 1965.

MSFC support contractor personnel at the beginning of the report period totalled approximately 8,200. This number included 4,334 who worked at MSFC/Huntsville, 2,517 at other locations in Huntsville, and 1,341 situated outside the Huntsville area. At the end of 1965 support contractor personnel at all locations numbered 9,228, including 4,152 at MSFC/Huntsville, 1,544 at other Huntsville locations, and 3,532 at government installations outside Huntsville--principally at MAF and MTF.[18]

MAF had more than 11,000 employees in all categories when the period began. The number reached 11,862 at mid-year and receded to 10,651 by the end of 1965. The year-end total included 279 civil service workers and 1,159 support contract personnel, all included in the total MSFC figures in the preceding paragraphs. Most other MAF personnel were prime vehicle contractor employees: 5,925 Boeing and 3,288 Chrysler personnel.[19]

At MTF, where a rapid transition from construction to activation status was taking place, employees in all categories numbered about 2,700 when the period started. Peak employment of 6,299 came in August and by the year's end MTF's work population had risen to approximately 4,800. NASA civil service personnel of 115 and support contractor personnel

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18. Executive Staff, "MSFC Manpower Status Summary as of January 8, 1965," and "MSFC Contractor Status Summary as of December 31, 1964;" and Manpower Utilization and Administration Office, "MSFC Manpower Status Summary, December 31, 1965," and "MSFC Contractor Status as of December 31, 1965." (Note: Personnel working "outside the Huntsville area" include employees at MAF and MTF)

19. MAF, Hist. Rpt., Jan. 1--June 30, 1965, pp. 37-38, and July 1--Dec. 31, 1965, p. 42.

numbering about 2,300 are included in the MSFC totals cited earlier in this section. Other workers at MTF included 1,200 construction personnel, 850 prime vehicle contractor personnel, and 118 Corps of Engineers employees.[20]

Awards

Honors for outstanding achievement came from independent organizations to two key MSFC officials. Dr. von Braun received in July the 1965 AIAA Louis W. Hill Space Transportation Award at the second annual meeting of the American Institute of Aeronautics and Astronautics. The Director was cited for his personal contributions and leadership in the development of space launch vehicles. In November Dr. W. R. Lucas, Chief of the Materials Division, P&VE Laboratory, received the annual Hermann Oberth Award presented by the Alabama Section of AIAA. This award was for Dr. Lucas' accomplishments in the field of rocket materials research.

MSFC presented sustained superior performance awards to 52 employees. Cash awards totalling $17,975 went to these employees for tangible savings of $1,211,156. Eleven employees received outstanding performance ratings. Ten Purchasing Office employees shared a $500 group achievement award. Two persons received cash special service awards for outstanding accomplishments. In December Dr. von Braun presented superior achievement awards totalling $48,250 to 494 MSFC employees for their work in various projects, including completion of the Saturn I program and Pegasus project, assembly and static test of S-IC-T, rollout of S-IC-1, and static test of the S-IVB battleship. The Director also presented certificates of merit to 43 top management personnel for their contributions to accomplishment of these milestones.

In the Center's suggestion program, 1,038 suggestions were received and 222 were adopted, for estimated first-year savings of $267,750.

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20. MTF, Mississippi Test Facility Construction of Facilities Bi-Weekly Activity Report, Rpt. No. 61, Nov. 29--Dec. 13, 1965, p. 13.

Suggesters received $13,260 in awards for adopted suggestions. The largest suggestion award, $980, went to William S. Porter, Saturn V Program Office, and Richard H. Jackson and Edward T. Mallory, Executive Staff, for their suggestion concerning the machine programming of the Program Operation Plan. NASA Headquarters approved for MSFC employees 23 invention awards totalling $8,850. Three employees received Presidential Citations during 1965. There were 903 MSFC letters of appreciation and 301 letters of commendation presented to Center employees. NASA honorary service awards went to 1,568 employees, as follows: 14 employees for 30 years, 232 for 20 years, 281 for 15 years, 375 for 10 years, and 666 for one year.[21]

Equal Opportunity

MSFC's Equal Employment Opportunity (EEO) Office continued during 1965 to promote job and community opportunities for minority groups. The Center took action in several areas of the EEO program, including housing, community coordination, school assistance, program publicity, recruiting, summer employment, surplus property distribution, and training. At Huntsville 20 of the 75 persons (26 per cent of the total) employed in the President's Youth Opportunity Campaign (YOC) were Negroes. At MTF a total of 300 young people were employed in the YOC program; two thirds of these persons were Negroes. There were 91 permanent Negro employees at MSFC when the current report period ended. This number was 1.2 per cent of the Center's total civil service work force.[22]

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21. Memo, Executive Secretary, Incentive Awards Committee, to David S. Akens, Historical Office, MSFC, subj., "Incentive Awards Program Data--Historical Report," Feb. 16, 1966.

22. MSFC, "1965 Report to the Administrator Regarding the Equal Employment Opportunity Program;" and "MSFC Equal Employment Opportunity Program Quarterly Report, October--December 1965."

Housing

To its Huntsville government and contractor personnel MSFC issued 795 "809" FHA housing eligibility certificates during 1965. These certificates were issued to 299 employees at Michoud Assembly Facility and to 292 at Mississippi Test Facility. Under Section 809 of the National Housing act, NASA helps secure housing for essential government and contractor employees by guaranteeing home loans through FHA in communities where federal programs have had unusual impact.[23]

Employee Activities

Redstone Arsenal Lodge 1858, American Federation of Government Employees (AFGE), won exclusive recognition at MSFC following an election on May 19 in which more than 2,300 employees voted. About 2,000 voted in favor of making AFGE the exclusive bargaining agent for Center civil service workers.

Also in May, Marshall Athletic, Recreation and Social Exchange (MARS) elected Adas Verble, Jr., to succeed Jim Hiers as MARS president. The new president announced that MARS had a new charter enabling employees to participate in activities of the association planned or underway.

SPECIAL EVENTS

A visitor to MSFC in April was Mrs. Esther Peterson, Special Assistant to the President and Assistant Secretary of Labor. Mrs. Peterson's two-day visit had to do with the President's program for equal employment

23. Information furnished Sept. 15, 1967, by Lonnie Stokes, Community Affairs Office, Manpower Utilization and Administration Office, MSFC.

VISITOR IN TEST AREA

Mrs. Esther Peterson, special assistant to the President, was a visitor to the Center April 1, 1965. Karl Heimburg, Test Laboratory Director, here comments on a point of interest.

for women. She addressed women supervisors and employees, toured the Center, conferred with Dr. von Braun, and held a press conference.

Walt Disney, the noted cartoonist and motion picture producer, visited the Center, also in March. Disney and a party of his associates toured MSFC facilities on a three-day orientation visit that took them also to the NASA Manned Space Flight installations at Houston, Texas, and Cape Kennedy, Florida.

An Alabama state government delegation including Governor George C. Wallace and about 90 legislators and other high state officials came to MSFC on June 8. Accompanied by about 50 newspaper editors, the state group also toured Redstone Arsenal and Huntsville, and witnessed a Saturn V booster static test at MSFC. NASA Administrator James E. Webb, who came to Huntsville to help host the Alabama officials, saw his first firing test of the "moon rocket" first stage.

Following completion of the 10-vehicle Saturn I program with the launch of SA-10 on July 30, Dr. von Braun praised MSFC employees for their efforts in this successful program. He addressed several hundred employees in Morris Auditorium to offer his congratulations for the first 100 per cent successful NASA launch vehicle program and to ask for renewed efforts in Saturn IB and Saturn V programs. A telegram from the Administrator and a later visit by Manned Space Flight Associate Administrator George E. Mueller also brought accolades to Marshall workers for their achievements.

The Space Orientation Center proved to be an increasingly popular attraction to employees, their families and friends, and visitors from all 50 states and many foreign lands. Visitor attendance for the year was over 200,000, an increase of 37 per cent over 1964. An important addition to the outdoor rocket display in December was a complete Saturn I vehicle erected in a vertical position.

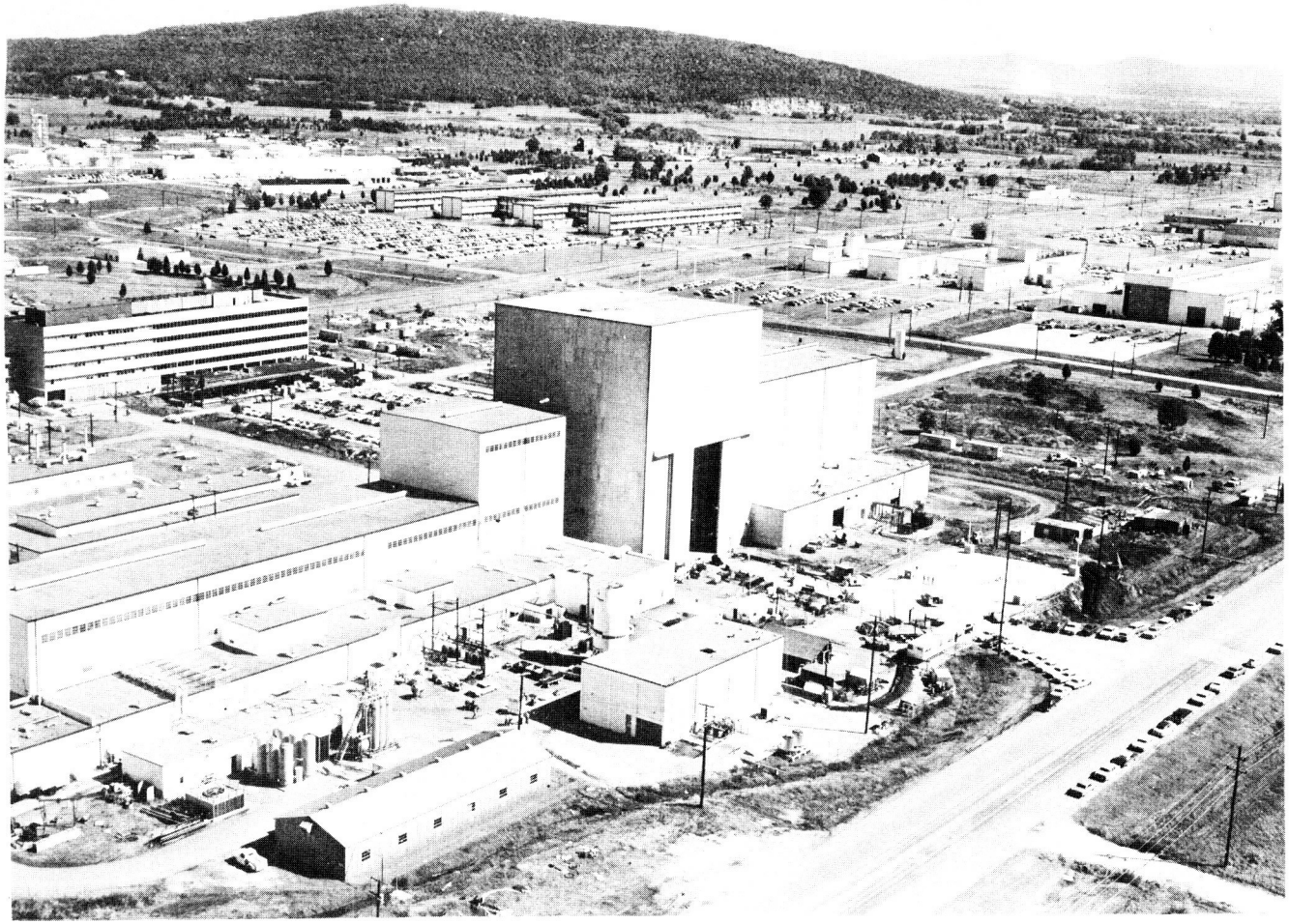
DISNEY VISITS CENTER

Walt Disney, right, famous movie maker, visited MSFC on April 13, 1965, to view rocket-making activities. Shown in the West Test Area with Disney are Karl Heimburg and Dr. Wernher von Braun.

FUNDING

During 1965 MSFC obligated a total of $1,756,209,000. Research and development (R&D) accounted for $1,576,907,000 of the total. Of the R&D obligation 85.2 per cent or $1,343,524,000 was allocated to prime contractors for production/fabrication of stages, engines, instrument units, and other major hardware. The remaining 14.2 per cent of R&D money was costed in-house by mission support contractors and minor contractors. Administrative operations (AO) required $141,423,000, or 8 per cent of the total obligated. Salaries for civil service personnel totalled $85,034,000 of the AO allocation. Construction of facilities took $37,879,000, which was 2.1 per cent of the total.[24]

24. Information supplied by Louis E. Snyder, Financial Management Office, MSFC, Feb. 18, 1966.



P&VE FACILITIES

Portions of the Propulsion and Vehicle Engineering (P&VE) Laboratory area are pictured here in October 1965. At left rear is the principal office building, Building 4610. The Load Test Annex is shown in the foreground.

CHAPTER II: SATURN I

The goal of the Saturn research and development (R&D) program is the development of a family of large boosters suitable for all phases of the Apollo program. In general, these are the Saturn I, Saturn IB, and Saturn V launch vehicles. The R&D program began in August 1958 and is expected to continue through completion of Saturn V development in 1968.

The first phase of the development program involved Saturn I. Until early 1960 the U. S. Department of Defense Army Ballistic Missile Agency managed Saturn I for the Advanced Research Projects Agency. The Saturn program has been managed by the Marshall Space Flight Center (MSFC) since its transfer to NASA in 1960, as part of the Apollo manned space effort.

The Saturn I project ended in July 1965. It included the SA-1 through SA-10 flight tests. The flight program was separated into two blocks of flights. Block I included suborbital flights SA-1 through SA-4. Block II included orbital flights SA-5 through SA-10.

Completed in the 1961 - 1963 period, the suborbital series of flights demonstrated the effectiveness of clustered engine techniques. The first orbital flight, SA-5, was launched in January 1964. The vehicle had an expected orbital lifetime of several years. SA-6 and SA-7, second and third orbital flights, occurred in May and September 1964, and had three- and four-day orbital lifetimes.[2] Each of the orbital flights demonstrated the use of cryogenic upper stages having liquid hydrogen (LH_2) as fuel,

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1. The research and development team directing the 1.5 million-pound-thrust booster development for ABMA was transferred as a unit to MSFC to continue the development program.

For the early history of the Saturn I see MSFC, Marshall Historical Monograph No. 1 (MHM-1), and MHM-2, Historical Origins of the George C. Marshall Space Flight Center, December 1960, pp. 58-80, and History of the George C. Marshall Space Flight Center, July 1 - December 31, 1960, pp. 42-47.

2. For details of the four suborbital flights and the first three orbital flights see MSFC, MHM-4, pp. 23-28; MHM-5, pp. 8-11; MHM-6, pp. 14-19; MHM-7, pp. 13-18; MHM-9, pp. 16-36, and MHM-10, pp. 23-30.

advanced guidance equipment concepts, and vehicle and payload compatibility. The payload of the first orbital flight (SA-5) resembled the Jupiter-type nose cones flown on Block I flights. The nose cone was ballasted with sand to simulate the weight of an Apollo spacecraft. SA-6 orbited the first boilerplate model of an Apollo (BP-13), and SA-7 orbited the second, BP-15.

Because of the phenomenal success of Saturn I's flight test program, NASA declared SA-7 and the remaining flights operational. The SA-8, SA-9, and SA-10 flights are described in the first part of this chapter. NASA elevated the status of passenger scientific payloads, Pegasus A, B, and C scheduled for these vehicles,[3] to prime objective payloads. Apollo boilerplate spacecraft BP-16, BP-26, and BP-9, were designated secondary payloads; they were modified to serve as shrouds to house the Pegasus satellites A, B, and C. The satellites would measure the number of penetrations through each of three selected thicknesses of material, store this information, and transmit it back to earth upon telemetered commands.

The Saturn I program ended July 30, 1965, with a perfect flight record without parallel in the entire history of launch vehicle development.

The second major section of this chapter summarizes the notable contributions of the Saturn I project to aeronautical and astronautical research.

SATURN FLIGHTS IN 1965

The Saturn flights occurring in 1965 included SA-9[4], SA-8, and SA-10. The vehicles for these flights differed only in minor technological

3. Initially, NASA had scheduled two Pegasus capsules as "bonus" or passenger missions for SA-9 and SA-8. In October 1963 the space agency cancelled Saturn I's operational flight use following SA-10 and consequently SA-10's prime mission. NASA then began considering various scientific missions for SA-10 and in March 1964 approved a Pegasus mission for SA-10.

MSFC, MHM-10, p. 44.

4. The SA-9 flight preceded the SA-8. This order of flight

improvements. Each had an S-I first stage, an S-IV second stage, an instrument unit (IU), and the dual payload consisting of a boilerplate Apollo spacecraft and Pegasus satellite.

The S-I stage measured 21.4 feet in diameter and 80.3 feet in length, weighed approximately 988,386 pounds when loaded with propellant, and was powered by eight H-1 rocket engines using liquid oxygen and kerosene (LOX/RP-1) fuel. Clustered in two groups of four and mounted to the thrust structure aft end, the engines provided 1.5 million pounds of thrust during the S-I stage portion of powered flight. MSFC built and tested the SA-9 S-I stage at Huntsville, Alabama, facilities; it was the last of eight built by the Center. The Chrysler Corporation Space Division (CCSD) built SA-8 and SA-10 S-I stages at contractor operated facilities located at MSFC's Michoud Assembly Facility, New Orleans, Louisiana. The contractor used the test facilities at MSFC's Huntsville test complex to static test the stages.

The S-IV stage, basically a 220-inch-diameter cylinder with ends closed by hemispherical bulkheads, measured 41 feet in length. A common bulkhead divided the cylinder into fuel (LH_2) and oxidizer (LOX) compartments. Fully loaded with propellant the stage weighed approximately 99,523 pounds. Six RL10A-3 rocket engines attached to a thrust structure on the aft hemispherical bulkhead propelled the stage with 90,000 pounds of thrust. A cylinder aft interstage joined the S-IV stage with the S-I stage, and a forward interstage (truncated cone) attached the S-IV stage to the IU. The Douglas Aircraft Company (DAC) built the S-IV stages at Santa Monica, California, and tested them at facilities at Sacramento, California.

The IU, a prototype of the production IU, was unpressurized on each of these vehicles. The cylindrical IU measured 154 inches in diameter and 34 inches in height. Assembled, it weighed 2650 pounds. The electronic components were mounted on panels attached to the cylinder wall

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allowed more development time for the SA-8 S-I stage, the first of two S-I flight stages (S-I-8 and S-I-10) built by the Chrysler Corporation Space Division.

instead of in pressurized tubes as on previous flight vehicles. The primary systems included guidance and control, tracking, telemetry, and emergency detection. MSFC completed structural assembly of the IU in Huntsville and also completed installation and checkout of the major IU systems furnished by several industries.

The dual payload was the most distinctive feature of the SA-9, SA-8, and SA-10 vehicles. Each of the vehicles carried an Apollo boilerplate spacecraft furnished by NASA's Manned Spacecraft Center, as had previous Block II Saturns. The Space and Information Systems Division (S&ID) of North American Aviation (NAA) built the spacecraft for MSC. The uninstrumented spacecraft consisted of a command module (CM), a service module (SM), an adapter, and a launch escape system (LES). The spacecraft simulated the characteristics of an Apollo spacecraft whose ultimate mission would be manned lunar landing and return to earth. It measured 63.4 feet in length from adapter field splice to the LES nose cone, had a maximum diameter of 12.1 feet, and weighed 18,600 pounds. The spacecraft's service module and adapter, modified into a shroud by MSFC, housed the second element of the payload, the Pegasus satellite. The shroud separated from the Pegasus in orbit, leaving the satellite free to deploy its wings.

The Pegasus satellite was permanently attached to the S-IV stage and the IU. In its stored position the satellite measured 17.4 feet by 7.11 feet; upon deployment, the wing panels extended to 96 feet and exposed 208 detector panels for penetration by meteoroids. The center section, an open framework of aluminum tubing, supported the wing frames, the solar cell array, and a thermally controlled canister containing the major electronic systems. The combined solar sensor/earth sensor system provided directional information. The electronic systems registered all penetrations, recorded the panel thickness, the panel number, and the time of penetration as well as temperature data. Upon ground command the memory system "read out" the information and transmitted it through telemetry to the ground. A digital command system provided on/off control of the

various system components, circuit replacement, certain in-flight tests, and other control functions. A solar cell (nickel-cadmium) battery power supply provided all power for the satellite during its one-year life expectancy. Thin sheets of aluminum coated with thin layers of mylar covered the wing panels. An extremely thin layer of vapor-deposited copper on gold foil coated the back of the mylar surface. An electric potential established between the outer aluminum skin and the inner metal coating charged the entire "sandwich" and made it a huge capacitor. Each time a meteoroid penetrated the panel, the material removed by the impact vaporized and formed a conducting gas plasma to discharge the capacitor. Double-sided capacitors (detector panels) with target sheets of three different thickness differentiated the levels of impact energy. The Fairchild Hiller Corporation (FHC), under direction of MSFC, designed and completed the Pegasus electronics work at the contractor's Space Systems Division at Bladensburg and Rockville, Maryland, and assembled and checked out the satellites at its Aircraft Missiles Division facility at Hagerstown, Maryland.

Unlike previous Saturn flights which had only to meet vehicle flight objectives to be termed successful, SA-9, SA-8, and SA-10 had to meet payload flight requirements as well.

Flight objectives for these vehicles were to: orbit spacecraft and satellite, guarantee a one-year orbital trajectory for the satellite, demonstrate S-I propulsion and vehicle control, demonstrate S-I/S-IV separation, demonstrate S-IV propulsion and vehicle control, demonstrate S-IV nonpropulsive venting system, demonstrate redesigned unpressurized IU and passive thermal control system, evaluate closed loop guidance accuracy and demonstrate the iterative guidance mode (IGM), demonstrate boilerplate CM and SM separation from S-IV/IU/SM adapter (SMA), and evaluate S-IV/IU/SMA exterior thermal control coating.

Payload objectives were to: evaluate launch environment, demonstrate LES jettison, demonstrate functional operation of the satellite's

mechanical, structural, and electronic subsystems, and evaluate meteoroid data sampling in near-earth orbit.[5]

SA-9 Flight

Vehicle Description

The vehicle for the first Saturn flight in 1965 closely resembled its immediate predecessor, SA-7. Its major differences were those resulting from improved vehicle technology and those dictated by the new mission requirements.

There was little change in the S-I stage (S-I-9), the last of eight produced at MSFC.

Changes in the S-IV stage (S-IV-9) included the addition of a blowdown vent (BDV) system in the forward interstage. The BDV augmented the nonpropulsive vent (NPV) system.[6] The NPV contained first on S-IV-7, opened at S-IV cutoff and remained open throughout the remaining flight to gradually vent the LH_2 residuals. Design engineers had hoped operation of the NPV would prevent pressure venting after S-IV cutoff and in turn, reduce the excessive vehicle moments (accelerations and angular rolls) caused by propulsive venting. But latent heat in the LH_2 tank insulation immediately after S-IV cutoff induced high boiloff pressure above that which could be vented by the NPV. The BDV system was added to supplement the NPV operation during the first 180 seconds following S-IV cutoff. It would relieve the excess pressure and prevent activation of the propulsive venting systems. The NPV and BDV had exit nozzles diametrically opposite each other and normally vented residuals at equal

5. P&VE Lab., SA-9 Saturn Vehicle Data Book, Oct. 15, 1963, pp. V-1-4; MSFC, MHM-10, p. 44; and MSFC, The Meteoroid Satellite Project Pegasus First Summary Report, NASA TN D-3505, Nov. 1966, pp. 4-6.

6. SA-7 contained the first NPV system as an auxiliary to the propulsive venting systems.

rates to avoid creating vehicle moments. Excessive roll movements of the vehicle at this point in flight could cause the Apollo shroud to damage the Pegasus wing structure as it separated from the satellite.[7]

Since S-IU-9 was the prototype of the production IU planned for the Saturn IB and Saturn V vehicles, it contained several changes. Its structure was 24 inches shorter and lighter than the one for S-IU-7. The systems were mounted on panels attached to the structure instead of in pressurized tubes as in S-IU-7. S-IU-9's guidance and control system incorporated new control commands for Pegasus deployment and a television transmitter to monitor the deployment. S-IU-9's guidance and control systems also employed the IGM for the first time. The IGM computed steering commands to correct misalignments during the pitch plane path guidance; this would steer the S-IV/IU and payload to the desired terminal conditions. S-IU-9 had S-IV cutoff programmed for a space-fixed velocity of 7678.50 miles per second (m/s) at a space-fixed angle of 90.033 degrees and at an altitude of 309 miles. This assured the correct trajectory at orbital insertion which was necessary to assure the payload a one-year orbital lifetime.

The vehicle mission required that the S-IV stage carry enough fuel to last until the guidance system commanded engine cutoff. But 250 pounds of LH_2 was the maximum residual possible using the NPV system. To satisfy both these restraints the Saturn I Program Manager ruled that the S-I stage would carry 28,000 pounds less propellant than on previous flights.[8]

The last major vehicle changes included reduction of camera coverage and use of a different paint on the S-IV and IU surfaces. SA-9 carried

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7. D. O. McNeil and W.H. Harmon, Aero-Astrodynamics Lab., MSFC, (MMC)-S-IV/Apollo Separation and Venting Study for SA-9 Vehicle, NASA TM X-53193, Jan. 18, 1965, pp. 3-4.

8. Gerald Wittenstein and Jerry Weiler, Aero-Astrodynamics Lab., MSFC, SA-9, 8, and 10 Dispersion Analysis, TM X-53263, May 17, 1965, pp. 1-5; and Teletype, Lee B. James, Manager, Saturn I/IB Program, MSFC, to Dr. Kurt Debus, Director, KSC, subj., "Propellant Weight on SA-9," Feb. 11, 1965.

For SA-8 and SA-10 the IGM terminal conditions would be altered to assure the correct residuals on board.

only one television camera used for Pegasus coverage whereas SA-7 had contained eight recoverable cameras and two television systems for stage separation and vehicle coverage. SA-9's television system was mounted to the inside of the payload adapter. The Illinois Institute of Technology developed the new paint used on surfaces of the S-IV-9 to provide thermal protection for the Pegasus payload, because surface heat could have jeopardized the satellite's mission.

Payload innovations included attachment of Pegasus A to the S-IV/IU stage and use of the uninstrumented and modified BP-16 as the protective shroud for Pegasus A.[9] MSFC modified the spacecraft's SM and adapter to serve as the shroud.

Prelaunch Operations

The SA-9 vehicle stood on Pad B of Launch Complex 37 (LC-37) at NASA's Kennedy Space Center (KSC) when this report period began in January 1965. Technicians were installing the ST-124 stablized platform in the S-IU-9 while co-workers completed premating checkouts of the BP-16 spacecraft and the Pegasus A satellite. The engineering crew completed installation of the ST-124 on January 5, attached Pegasus A to the S-IV stage on January 13, and erected the spacecraft on the vehicle on January 14.. Electrical mating of Pegasus A to the vehicle was completed January 15 and subsystems checkout and integrated launch vehicle tests resumed. On Febuary 1 ordnance installations in the S-I and S-IV stages ended. The all systems overall test ended February 1 and the countdown demonstration test on February 5.

9. Ibid; P&VE Lab., MSFC, Evaluation of Flight Test Propulsion Systems and Associated Systems, Saturn S-I-9 Stage, (IN-P&VE-P-65-5) Apr. 22, 1965, p. XI-1; J. E. Foley, et al., Aerospace Physics Branch, CCSD, Summary of Aerodynamic Data Obtained From the Saturn I, Block II Flight Test Program, TN-AE-66-140, p. 2; NASA, NASA TM X-53193, pp. 3-4; and NASA, New Release No. 65-38, Project: Pegasus - Saturn I, Feb. 15, 1965, p. 15.

NASA had accepted delivery of Pegasus A at KSC with some work still to be accomplished.[10] FHC and MSFC technicians completed most of the remaining effort in Hangar D at the launch site before the satellite was mated to the S-IV stage. In early February NASA directed that the satellite be modified to detect radiation induced meteoroids.[11] The modification, completed two days before the launch on February 14, electrically isolated one frame or logic group of the detector panels from its voltage source, making the frame a detector system for radiation induced pulses only. The threshold voltage at which the detector electronics responded was reduced to the lowest possible value to assure discrimination between the various penetrations. Test limited to those that could be accomplished with the satellite assembled on the vehicle verified that the system remained operational.[12]

Terminal countdown activities began February 15 at 9:44 p.m. EST, one day prior to launch. At T-515 minutes vehicle countdown operations began and continued until T-80 minutes at 6:40 a.m. EST, when monitoring indicated a possible malfunction in the B battery charging circuit of Pegasus A. Technicians discharged and recharged the battery to verify operation of the battery control circuit. The 30-minute hold planned for T-30 minutes was taken out of sequence to cover the operation. At T-26 minutes a power failure occurred in the Eastern Test Range (ETR) real-time flight

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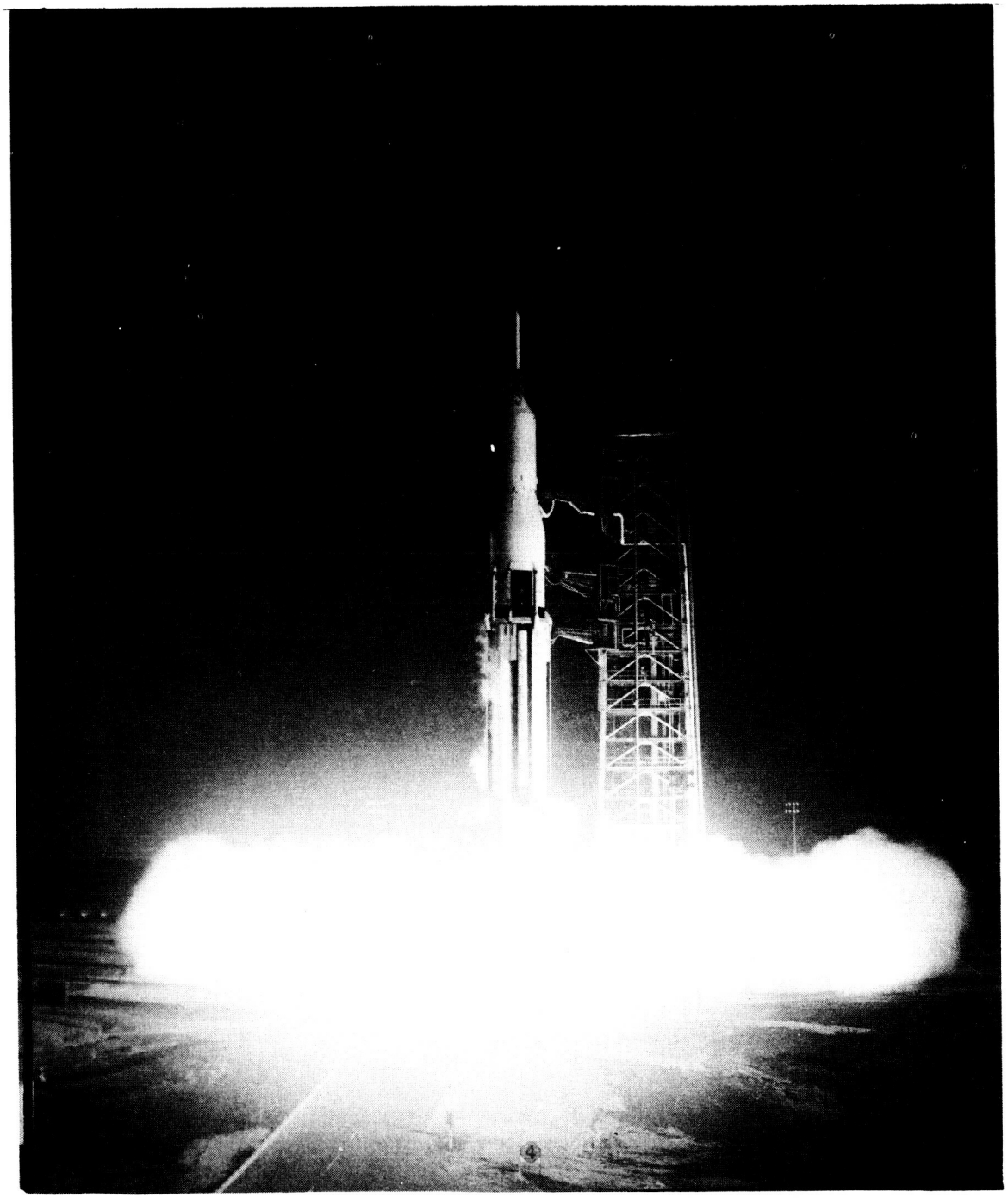
10. Due to development problems prior to 1965, Pegasus delivery had become the pacing item for the Saturn launch schedule. NASA had established new program guidelines, rescheduled launch of SA-9 and SA-8 two months later than planned and SA-10 one month later, established a Pegasus Project Office and appointed a Project Officer in MSFC's Industrial Operations to give concerted direction in monitoring and assisting FHC in its development and qualification program, and provided FHC with in-house help by MSFC's Astrionics Laboratory. To avoid undue delay of the SA-9 launch NASA had accepted Pegasus A with some work remaining.

11. NASA's Langley Research Center, subsequent to initiation of Pegasus development, had completed a series of tests which indicated that electrons stored in the capacitor dielectric when the detector was placed in a radiation environment were released in spontaneous short noise bursts. Since these were similar to the capacitor discharge pulses produced by meteoroid penetrations a method of discrimination needed to be developed. FHC at Ling-Temco-Vought, Inc., tested a discrimination circuit and found it discriminated against all of the radiation-induced pulses created. Although Pegasus A was at the launch site NASA approved modification of one frame of detector panels to make it receptive to radiation-induced pulses.

12. NASA TN D-3505, pp. 2-3 and 42-60.



SA-9 VEHICLE LAUNCHED

The SA-9, eighth Saturn I flight vehicle, carried a Pegasus meteoroid detection satellite into orbit after launch at LC-37B, Kennedy Space Center, on February 16, 1965.

safety computer. Electricians required one hour and seven minutes to reinsert and checkout the computer. Countdown then resumed and continued normally through liftoff.[13] SA-9's countdown procedure forced a recycle of the ST-124's digital computer back through guidance release 45 seconds before liftoff. This new approach eliminated all inertial velocity errors at liftoff.[14]

Liftoff and Vehicle Flight

Liftoff occurred at 9:37 a.m. EST on February 16, 1965.

Launch damage to LC-37B's ground support equipment (GSE) was lightest to date except for water damage. The water damage resulted when a torus ring in the launch water system separated at several joints and flooded the launcher.

The S-I stage flight performance was better than nominal. Ignition command occurred 3.39 seconds before the liftoff signal. Thrust buildup was satisfactory except for pressure disturbance in engine 3 similar to that experienced during the SA-7 launch. Later investigation disclosed that blockage of the igniter fuel system probably caused the disturbance.[15] Prior to future launches personnel will first inspect and test the igniter fuel passages leading from the hypergol container to the injector face. All other engines had satisfactory buildup of chamber pressure. The H-1 engines burned approximately 140 seconds before shutdown of the inboard engines. At LOX starvation 5.34 seconds later, the outboard engines cut off.

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13. KSC, Technical Progress Report, First Quarter CY 1965, (TR-168), Apr. 26, 1965, pp. 2-3.

14. On SA-7 the largest inertial errors had been caused by erroneous platform leveling signals issued during the holddown period and by azimuth alignment error. More exact alignment of the ST-124 cross-range accelerometer greatly reduced the latter error source. Saturn Flight Evaluation Working Group, MSFC, Results of the Eighth Saturn I Launch Vehicle Test Flight, SA-9, MPR-SAT-FE-66-4, Feb. 28, 1966, pp. 53-55.

15. The study revealed that the foreignmaterial could have lodged in the passage during shipment of the stage, as the position of the stage deviated from that used in previous transfer and shipping operations. MSFC, IN-P&VE-P-65, pp. II-23 and II-24.

Flight performance of the S-IV stage was satisfactory. The ullage rockets ignited after 146.32 seconds of flight, S-I/S-IV separation followed at 146.42 seconds, and S-IV ignition at 148.12 seconds of flight time. The S-IV propulsion system performed satisfactorily throughout powered flight. The RL-10 engines burned approximately 478.5 seconds, about 7.21 seconds short of the predicted burn time. High S-IV stage thrust and flowrate and a light S-IV ignition weight (due to less propellant residual in the S-I stage), together with the excess S-I cutoff velocity, accounted for the early cutoff. After S-IV cutoff the NPV system performed as planned.

The S-IU-9 guidance and control system performed satisfactorily. The ST-124 system, together with control rate gyros, provided attitude and rate control for both stages. Vehicle response to all signals was properly executed including roll maneuver, pitch program, and path guidance during S-IV stage flight.

At IGM initiation (163.9 seconds flight time) the vehicle's space-fixed velocity was almost one per cent higher than nominal. This caused the guidance system to issue a corrective nose-down pitch steering command. Since computer data showed the vehicle was to the left at guidance initiation, the guidance and control system also issued steering corrections in the yaw plane. Due to the higher than nominal performance of the S-I and S-IV stages, the vehicle reached the proper velocity for S-IV stage cutoff 8.35 seconds earlier than predicted. At this time the IGM correctly issued the cutoff command; the space-fixed velocity was 7678.98 m/s, slightly less than the 7679.0 m/s programmed for cutoff. The S-IV propellant utilization (PU) system indicated propellant residuals at cutoff included about 820 pounds of LOX and 250 pounds of LH_2.

Orbital insertion of the S-IV-9/Pegasus, IU, and the BP-16 spacecraft occurred 631.66 seconds after launch. The space-fixed velocity at insertion yielded a perigee altitude of 309 miles and an apogee altitude of 462.9 miles to provide an estimated orbital lifetime of 1188 days.

In the next 180 seconds of flight the payload experienced the high capacity blowdown of the S-IV LH_2 NPV (BDV) system as it vented residual LH_2. Although this resulted in a higher than expected roll rate, no appreciable tumble rates developed.

When high capacity venting ended, the Apollo shroud which housed the Pegasus jettisoned. Explosive nuts located at the forward end of Pegasus A, and another which attached the SM of BP-16 to the adapter, were triggered to eject the CM and SM and to expose Pegasus A. About 60 seconds following shroud separation, Pegasus wing deployment began.

The vehicle portion of flight ended with the S-IV/IU/SMA separation. At that time the vehicle had achieved all its flight objectives.

During the vehicle period of powered flight, vibrations observed were within design limits and compared well with SA-7. Because of the steeper trajectory, aerodynamic heating was generally less severe than on previous Block II flights. All electrical networks operated nominally during flight and the vehicle instrumentation system performed well. Telemetry coverage from the Cape area stations lasted longer than in past flights due to the higher altitude trajectory. Airborne tape recorders on the S-I, S-IV, and IU operated satisfactorily to produce data free of distortion from firing of retro and ullage rockets. The photo/optical instrumentation system consisted of 96 cameras that provided fair quality coverage from liftoff through Pegasus wing deployment. SA-9's measuring system transmitted 1228 measurements to ground tracking stations. Overall reliability of the system was 98.9 per cent.[16]

Pegasus Orbital Flight

NASA's Satellite Tracking and Data-Acquisition Network (STADAN) under control of Goddard Space Flight Center (GSFC) and certain elements

16. Teletypes, F. A. Speer, Chairman, Flight Evaluation Working Group, MSFC, to Dr. G. E. Mueller, Assoc. Adm., NASA, et al., subj., "SA-9 Flight Results," Feb. 19, 1965; Teletype, Speer to Mueller, subj. "SA-9 Flight Results," Feb. 26, 1965; and, NASA, NASA TN D-3505, pp. 60-62.

of the Department of Defense Gulf and Eastern Ranges monitored and tracked the SA-9 vehicle throughout flight and continued to monitor and track the satellite during the first five orbits. After that GSFC monitored and tracked the satellite. NASA established a Satellite Control facility (SATCON) at KSC to provide a single point for the collection and analysis of engineering data sufficient for the evaluation of the spacecraft's performance.

During orbital flight all measurements of the satellite were within predicted design limits. During the first few orbits, vented impulse, particularly the impingement of vented gaseous oxygen (GOX)[17] on the Pegasus wings, created most of the observed forces (accelerations) and moments imposed on the payload. From orbital insertion to depletion of propellant residuals,[18] the vehicle's roll motion increased from 2.5 degrees per second (deg./s) to 9.80 deg./s, while the pitch and yaw motion remained around 0.25 deg./s. By March 12, the motion of the satellite had converted to a flat spin. The spin rate was approximately 2 deg./s

At the beginning of orbital flight all systems of the satellite functioned properly.

Excellent TV coverage revealed that Pegasus wing deployment occurred as scheduled. The wings began unfolding in accordion fashion 60 seconds after jettison of the BP-16 shroud and continued unfolding for 40 seconds. Unfolded, the wings exposed the 208 detector panels.[19] Issuance of an

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17. On SA-9 the NPV system vented gaseous oxygen (GOX) upon the deployed wings. Since GOX imparted a greater impulse than gaseous nitrogen (GN_2) would have, design engineers decided to interchange the vent lines of the NPV system on SA-8 and SA-10 so that GN_2 instead of GOX would vent upon the wings.

18. The NPV system began operation at S-IV cutoff as did the BDV system; while the BDV system stopped operation after 180 seconds, the NPV system continued venting until all residuals were vented. This required three hours to clear the 250 pounds of LH_2 and 115 pounds of ullage gas residuals and 12 hours to clear 820 pounds of LOX, 100 pounds GOX, and 140 pounds helium residuals.

19. Each of the Pegasus wings contained 104 panels. Each panel consisted of two flat plate capacitors of aluminum, mylar, and copper bonded to each side of a one-inch-thick foam core. The capacitors had a target sheet thickness of 1.5 mil, 8 mil, and 16 mil and both capacitors in a given panel were of the same thickness.

improper command sequence by the receiving station impaired data transmission from the satellite's memory unit a short time after orbital insertion. On correction of the command sequence the receiving stations obtained transmissions of the memory register on schedule.

Throughout the entire orbital operation, the Pegasus detection subsystem registered meteoroid strikes in all three (1.5 mil, 8 mil, and 16 mil) thicknesses of the aluminum flat plate capacitors of the detector panels. However, the data received by ground stations neither identified the panels impacted nor verified the pulse of the impact. The loss of information prevented certain validity tests and also prevented a determination of whether the hit occurred on the front or backside of the wing. Insufficient electrical separation between the impacted detectors and the remaining detectors in the panel caused the data loss. Another contributing factor was the inability during the modification immediately prior to launch to change and to adequately test the sensitivity level of the panel identification circuity so it was completely compatible with that established for the hit detection electronics.

Program managers had anticipated a 10 per cent loss of detector panels due to shorting during orbital flight; however, within the first 20 days about 40 per cent had shorted and been deactivated. All of the 1.5-mil, 11 out of 34 of the 8-mil, and 285 out of the 358 of the 16-mil capacitors of the detector panels remained active, although some shorted intermittently. All other systems operated normally, with exception of the attitude sensing system. While the attitude sensing system did not perform within design specifications, its attitude data proved usable.

Pegasus A provided meteoroid penetration data from the 1.5-mil detectors that was quite usable; from the 8-mil detectors, usable; and from the 16-mil, questionable but usable with proper exercise of caution.[20]

20. MSFC, MPR-SAT-FE-66-4, pp. 89-93; and NASA, NASA TN D-3505, pp. 60-62.

SA-8 Flight

Vehicle Description

SA-8 was the first Saturn flight vehicle with both propulsive stages completely built and tested by private industry. This vehicle included the first S-I flight stage from CCSD and the fifth DAC-built S-IV stage. The S-I-8 also happened to be the first flight stage produced in the S-I plant at Michoud Operations.

The SA-8 vehicle, practically identical to the SA-9, had only two significant changes. The first involved alteration of the IGM terminal conditions to assure the correct residuals on boards;[21] the second was the interchange of LOX and LH_2 NPV vent lines to reduce the roll moment created when vented gases strike the Pegasus wings.[22]

NASA approved several changes in Pegasus B. The changes to the satellite corrected problems disclosed in the flight of Pegasus A and also improved the satellite's sensitivity to smaller meteoroids. To assure proper identification of detector groups penetrated by hits, FHC technicians provided additional isolation for the detectors and also increased the current recharge amplifier sensitivity. FHC made two changes to lower the shorting rate of detector panels which plagued Pegasus A. First, the contractor added a "burning-in" procedure on the panels to eliminate potential trouble spots in the dielectric. Then, FHC installed fuses between each individual capacitor and provided unlimited current supply to blow out the fuses upon ground command. This allowed removal of a single shorted panel instead of disconnection of an entire logic group.[23]

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21. See footnote 8 in this chapter; and NASA, NASA TM X-53263, pp. 1-5.

22. MSFC Saturn Flight Evaluation Working Group, Results of the Ninth Saturn I Launch Vehicle Test Flight, SA-8, MPR-SAT-FE-66-10, June 13, 1966, p. 94.

23. The 416 individual capacitors were grouped into 62 logic groups or information circuits, each of which could be switched on or off the data processing electronics by command from the ground. A shorted capacitor on Pegasus A disabled the entire logic group.

FHC also isolated certain target plates of each thickness from their voltage source to assess radiation effects in the flight environment.[24]

Vehicle Shipment and Pad Erection

In January 1965 the SA-8 stages were being readied for shipment to the launch site. During pre-shipping inspection at MAF the S-I-8 stage seemed accident-prone. On February 11 handling equipment dented the fuel tank; technicians later corrected this by pressing smooth. Then, workmen found various scratches, dents, and gouges on the GOX lines and the suction line bellows. Workmen replaced the 1½-inch GOX line and, since the other damges were not considered critical, completed shipping preparations. CCSD shipped the stage to KSC on February 22, where remaining adjustments would be made.[25]

DAC completed poststatic checkout and repair of S-IV-8 early in January and began preparing the stage for shipment. The contractor shipped the stage from its Sacramento Test Center (SACTO) to KSC on February 23.[26]

Stages of the SA-8 vehicle began arriving at KSC in February. The S-IV-8 arrived February 26 and the S-I-8 on February 28. MSFC shipped the IU from Huntsville to the launch site on March 2.

Prior to pad erection at the launch site, workmen corrected such S-I-8 discrepancies as: damaged fuel pressurization switch, removal of tension ties, contamination of the hydraulic fluid, moisture problems with the helicon connectors, and missing "O" rings. Contamination found

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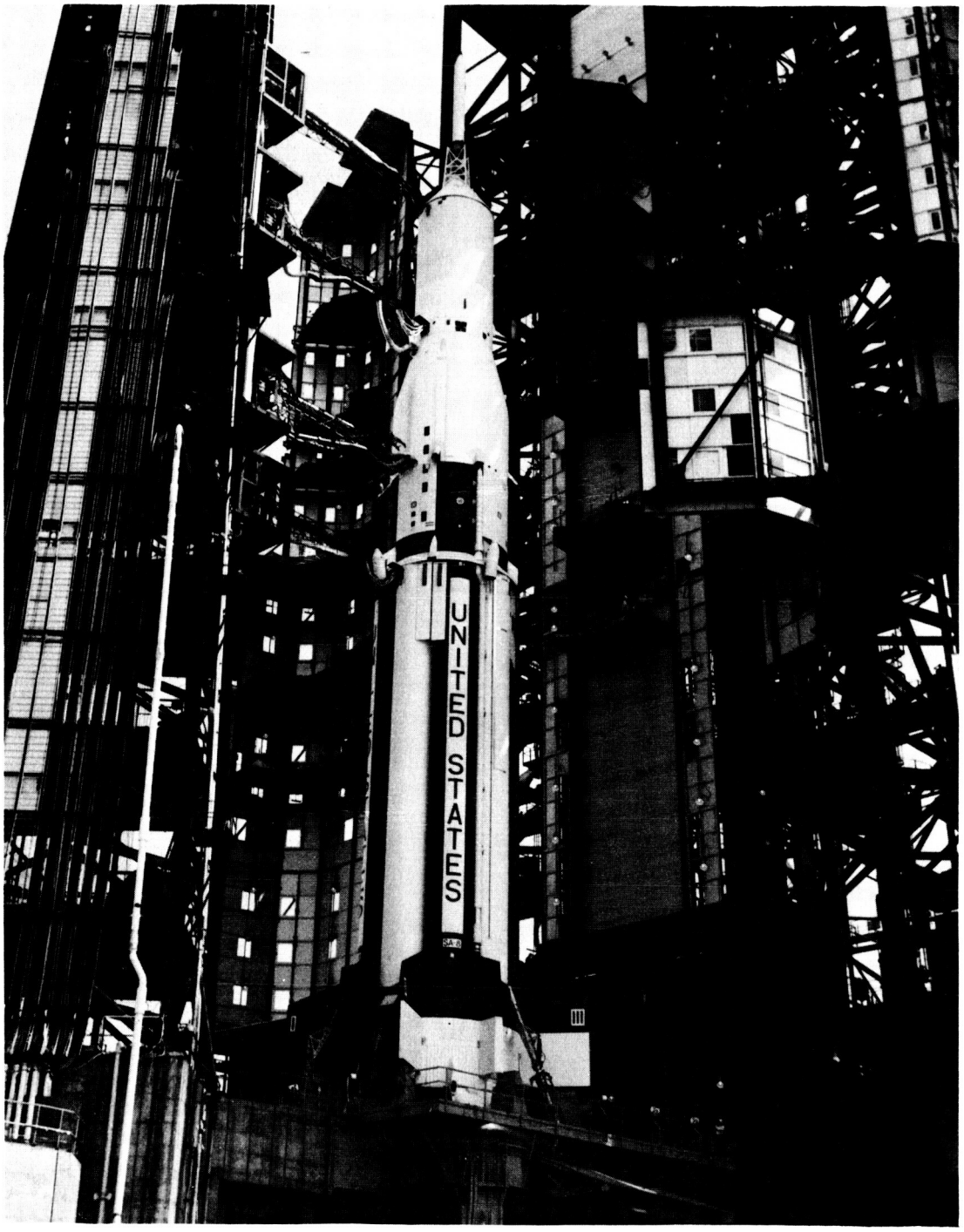
24. NASA, NASA TN D-3505, pp. 62-63, and 66-67, and Memo, Maj. Gen. Samuel Phillips, Dir., Apollo Program, NASA, to Dr. Raymond L. Bisplinghoff, et al., subj., "Minutes of Project Pegasus B Review Meeting, Feb. 25, 1965," March 8, 1965, and enclosure, subj., "Actions from the Project Pegasus Review Meeting held at Headquarters on February 25, 1965."

25. Michoud Assembly Facility (MAF), MSFC, Historical Report, January 1, 1965 - June 30, 1965, pp. 5 and 23.

26. Test Lab., MSFC, Test Laboratory Progress Report, February 12 - March 12, 1965, p. 42.



SA-8 IN PRELAUNCH TEST

The SA-8 vehicle in flight configuration is shown May 20, 1965, in LC-37B at KSC during the countdown demonstration test, with service structure pulled back.

in the S-I-8 engine gas generators compelled workmen to remove the generators and return them to Michoud for cleaning before reinstallation.[27]

S-I-8 pad erection occurred on March 2 followed by S-IV-8 and S-IU-8 erection on March 17. A series of systems tests of the vehicle followed, including radio frequency checks, tanking procedures, and simulated flights.

Meanwhile, in January, February, and March, the Pegasus contractor completed fabrication, modification, and checkout of Pegasus B. In early April FHC completed preparation for shipping the satellite to KSC.

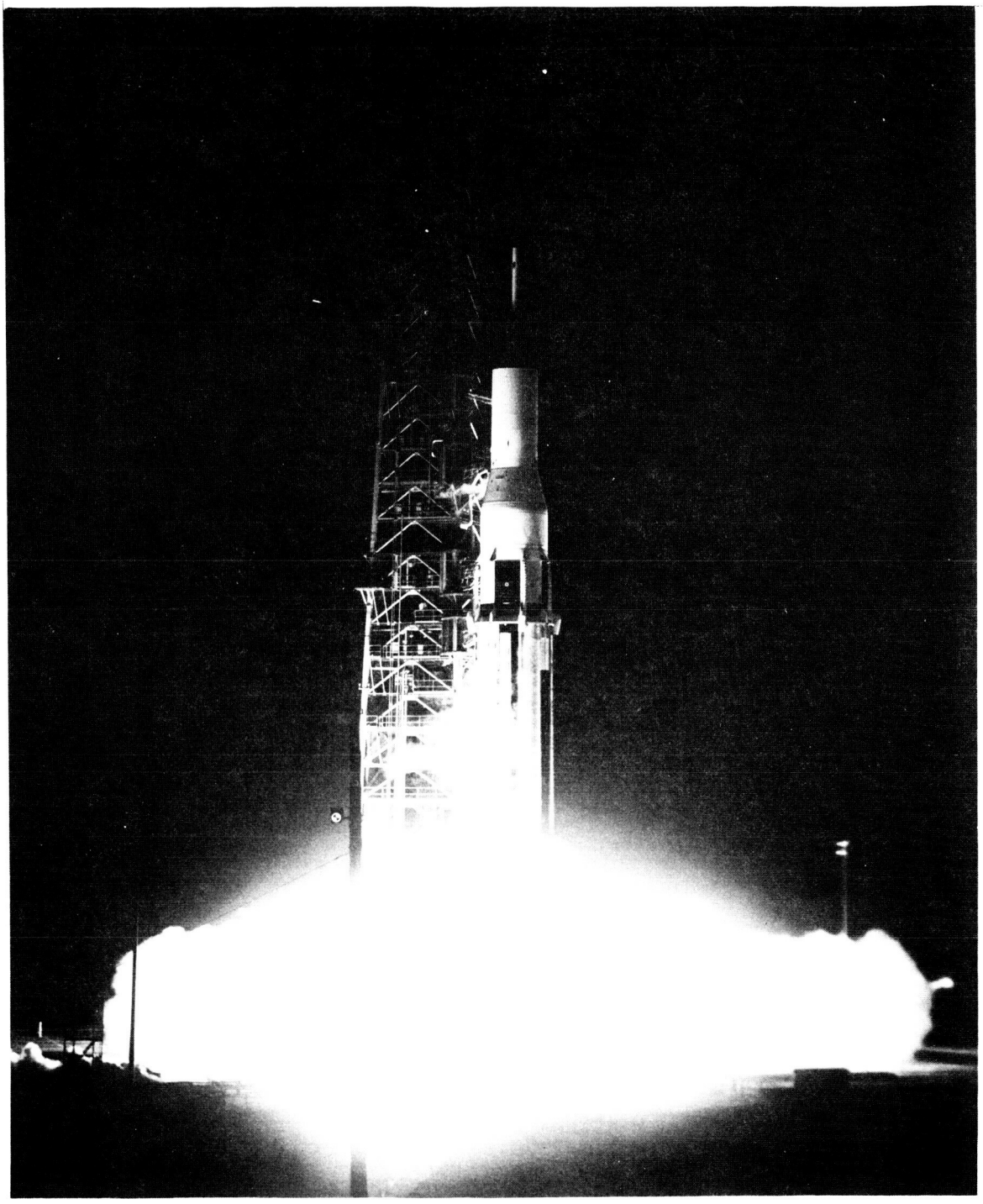
Sections of the payload arrived at KSC in April. The Apollo BP-26 CM, SM, and adapter which had been modified to serve as a shroud for Pegasus B, arrived at KSC on April 10. Pegasus B arrived at KSC on April 15. On completion of premating systems check and wing deployment checks, the KSC technicians attached Pegasus B to the S-IV/IU stage and enclosed it with the BP-26 SM and adapter. Emplacement of the CM and the LES on the vehicle followed. Electrical mating of the vehicle and payload ended on April 29.

Prelaunch Operations

The KSC launch crew started prelaunch checkout immediately after mating the vehicle. The checkout included the swing arm overall test, completed May 3; the launch vehicle cyrogenic tanking, completed May 11; the flight readiness test, completed May 14; the flight readiness review, completed May 17; and the countdown demonstration tests, which ended on May 20.

The first period of countdown began on May 23 at 8:00 a.m. EST and continued without interruption to the built-in hold which separated it from the final countdown. During this first phase of countdown a faulty

27. MAF, MAF Hist. Rpt., Jan. 1, 1965 - June 30, 1965, pp. 5 and 23, and KSC, TR-194, pp. 2-3.



SA-8 LEAVES PAD

The ninth Saturn I flight vehicle, SA-8, rises from an inferno of flame on May 25, 1965, at Cape Kennedy. This was the first nighttime Saturn launch.

exploding bridge-wire (EBW) firing unit was discovered. In the interval before final countdown, technicians traced the EBW trouble to a high-resistance connection in the plug on the high-voltage lead-in. Examination of other EBW units revealed a similar problem, and workmen repaired and tested all the faulty units before they were accepted as satisfactory.

The orbital position of Pegasus A dictated the liftoff time for SA-8. Plans called for Pegasus B to orbit in a path about 60 degrees away from Pegasus A. To meet the required liftoff time, final countdown started at 1:55 p.m. EST on May 24. The count continued uninterrupted to the scheduled 35-minute hold at T-30 minutes. The count stopped at 1:30 a.m. and resumed at 2:05 a.m. It proceeded normally to liftoff at the scheduled launch time.

The one anomaly during countdown occurred when LOX vapor periodically broke the theodolite line-of-sight to the ST-124 alignment window of the IU; this did not require a technical hold.[28]

Liftoff and Vehicle Flight

SA-8 was the first Saturn flight vehicle launched during nighttime and also the first to require no technical holds during countdown.

The vehicle lifted from the pad at 2:35 a.m. EST. Failure of the GH_2 vent disconnect on swing arm 3 to separate pneumatically at liftoff did not interfere with the launch since rotation of the swing arm actuated the mechanical release.[29] All other GSE performed satisfactorily and sustained very little damage during the launch.

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28. KSC, TR-194, pp. 3-4; and MSFC, MPR-SAT-FE-66-10, p. 5.

29. A similar malfunction occurred during the SA-7 launch. Both malfunctions resulted from increase weight of additional insulation placed on the hose connected to the disconnect ground half to preclude formation of liquid air between the vent hose and the insulation. The change, made prior to the SA-7 flight, added 50 pounds of weight which increased friction between the ground and disconnect valves and necessitated a larger force to achieve separation. The pneumatic actuator pressure would be increased to prevent recurrence during the SA-10 launch.

The S-I-8 H-1 engines began igniting in pairs 3.29 seconds prior to liftoff. Engine number 8 experienced an unexpected decrease in chamber pressure immediately following ignition; otherwise, thrust chamber pressure buildup for all the engines was normal. There was no indication of engine "pops" or pressure disturbance on any of the combustion stability monitors. The inboard engines burned 142 seconds to cutoff, approximately 1.61 seconds sooner than predicted. A short load (1037 pounds less) of LOX, lower than predicted fuel density, and increased power level all influenced the early cutoff. LOX starvation initiated cutoff of the outboard engines at 148.05 seconds of flight time. The sea level longitudinal thrust of the S-I stage averaged 1.3 per cent higher than predicted and the vehicle specific impulse averaged 0.1 per cent higher than predicted. All pressurization systems, purge systems, hydraulic systems, and other associated systems performed satisfactorily. The ullage rockets and LES jettisoned at 160.92 seconds of flight time.

The S-I/S-IV separation went smoothly. The S-IV propulsion and associated systems performed well within design limits. The S-IV-8 engines cut off 4.25 seconds sooner than predicted. The high S-IV stage thrust and flowrate, and the excess S-I cutoff velocity contributed to the early cutoff.

The guidance and control system performed very satisfactorily. The vehicle began responding properly to simultaneously executed roll and pitch programs shortly after liftoff. The system initiated pitch and yaw plane path guidance 17.77 seconds after S-I/S-IV separation. It employed the IGM at 166.69 seconds flight time for pitch plane path guidance. The IGM arrested vehicle steering commands about 2 seconds prior to S-IV cutoff. The system gave the S-IV cutoff signal at 624.151 seconds of flight time; the actual space-fixed velocity of the S-IV payload at orbital insertion (at 634.15 seconds flight time) yielded a perigee altitude of 314.6 miles and an apogee altitude of 465.1 miles. This resulted in an estimated orbital lifetime of 1220 days.

The NPV system, including the BDV, performed well within design limits and caused no appreciable roll deviation.

The Pegasus Apollo shroud separation occurred at 865.9 seconds. At this time the vehicle portion of flight ended with all mission objectives achieved.

The vibrations observed during vehicle powered flight compared favorably to those of SA-9 as did the aerothermodynamic environmental measurements. The SA-8 electrical system operated satisfactorily during vehicle and orbital phases of flight. The long-life battery in the IU provided power to telemetry links for 140 minutes, well exceeding the one-orbit requirement. Overall reliability of the SA-8 measuring system was 98.4 per cent. The system yielded 1150 measurements. The three airborne tape recorders (one each in the S-I, S-IV, and IU) operated satisfactorily and had no attenuation effects caused by retro and ullage rockets. The photo/optical instrumentation systems consisted of 79 cameras, 17 fewer than for SA-9, and provided fair quality coverage.[30]

Pegasus B Orbital Flight

The Pegasus wing deployment and all its systems worked properly and all measurements were initially within predicted limits.

Wing deployment started at 866 seconds of flight time and ended at 905.9 seconds flight time. The camera attached to the spacecraft adapter provided good coverage of the deployment.

The detection subsystem began receiving meteoroid hits within the first few orbits. All of the primary data systems functioned as expected. Although the shorting rate of detector panels caused by excessive current flow remained higher than desired on Pegasus B, the shorting did occur less often than on Pegasus A. All of the 1.5-mil detectors functioned normally, 11 of 34 of the 8-mil detectors remained active, and 285 of 358 of the 16-mil detectors remained active.

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30. MSFC, MPR-SAT-FE-66-10, pp. 1-6, 8-9, 14-15, 19-30, 39-57, and 91-97; and Teletype, William M. Bland, Jr., Chief, Checkout and Test Division, MSC, to NASA Headquarters, Attn: R. R. Gilruth, et al., subj., "Apollo Mission A-104 (SA-8) Flight Status Report," May 28, 1965.

The only major subsystem failure of Pegasus B occurred in the telemetry system. Eight days after launch intermittent failures of both the pulse amplitude modulated (PAM) channels and the pulse code modulated (PCM) channels began occurring. After system analysis and subsequent command switching, stable PCM communication was re-established. Although the PAM channel communication remained intermittent, data transmission occurred with sufficient frequency to permit adequate monitoring of the spacecraft.

NASA's STADAN provided orbital tracking of Pegasus B. Radar tracking coverage extended through the first five orbital revolutions. Minitrack observations of the satellite will continue throughout the lifetime of the satellite or until termination of the Pegasus experiment.

Telemetry data received by the tracking stations indicated the velocity impulse measurements of Pegasus B remained within predicted limits. S-IV NPV operation required six hours to clear LH_2 residuals and 25 hours to clear LOX residuals. The angular roll velocity imparted by venting the residuals increased to a maximum of 6.5 deg./s at 18 hours flight time compared to the 9.80 deg./s roll moment imparted by the S-IV-9 NPV system.

Ten days following orbital insertion the roll rate of Pegasus B decreased to 5.5 deg./s. At that time the vehicle had a tumble rate of 1.0 deg./s and was performing a gyroscopic precessional motion with a half-cone angle of approximately 30 degrees.[31] Eventually, the motion should convert to a flat spin.

SA-10 Flight

Vehicle Description

The final Saturn I flight vehicle resembled SA-8 in all major respects. Minor changes between the two vehicles consisted of deletion of the on-board camera attached to the spacecraft adapter section and addition of an

31. NASA, NASA TN D-3505, pp. 60-62, and MSFC, MPR-SAT-FE-66-10, pp. 93-98.

onboard camera to the outside of SA-10 to view engine exhausts, deletion of two telemetry systems form the S-I stage, and modification of the radar altimeter system.[32]

Pegasus C also differed from Pegasus B in several respects. Rework of the attitude subsystem provided better matching of sensitivity to the earth sensor heads. Assignment to Pegasus C beacons 1 and 2 of frequencies different from those used on Pegasus A and B avoided interference and confusion throughout the data acquisition network. Also, assignment to Pegasus C of code numbers different from those used on Pegasus B prevented the possibility of an encoder command to one satellite accidentally commanding another. Another change involved a new experiment NASA approved for the satellite, the attachment of removable coupons that could be retrieved from the space environment by Gemini astronauts for laboratory study. The new experiment involved replacement of some of the meteroid detection panels with dummy panels incorporating removable metal coupons cut from the detector material and coupons to which samples of thermal control surfaces had been affixed.[33]

NASA changed the projected orbit of Pegasus C to a nominal 332-mile circular orbit which, after a year of lifetime, would decay to a radius compatible with rendezvous of a Gemini spacecraft. This would make coupon recovery by astronauts possible.[34]

Vehicle Shipment and Pad Erection

In January 1965 both stage contractors were perfecting the final S-I and S-IV flight stages at the contractor sites, Michoud and Sacramento.

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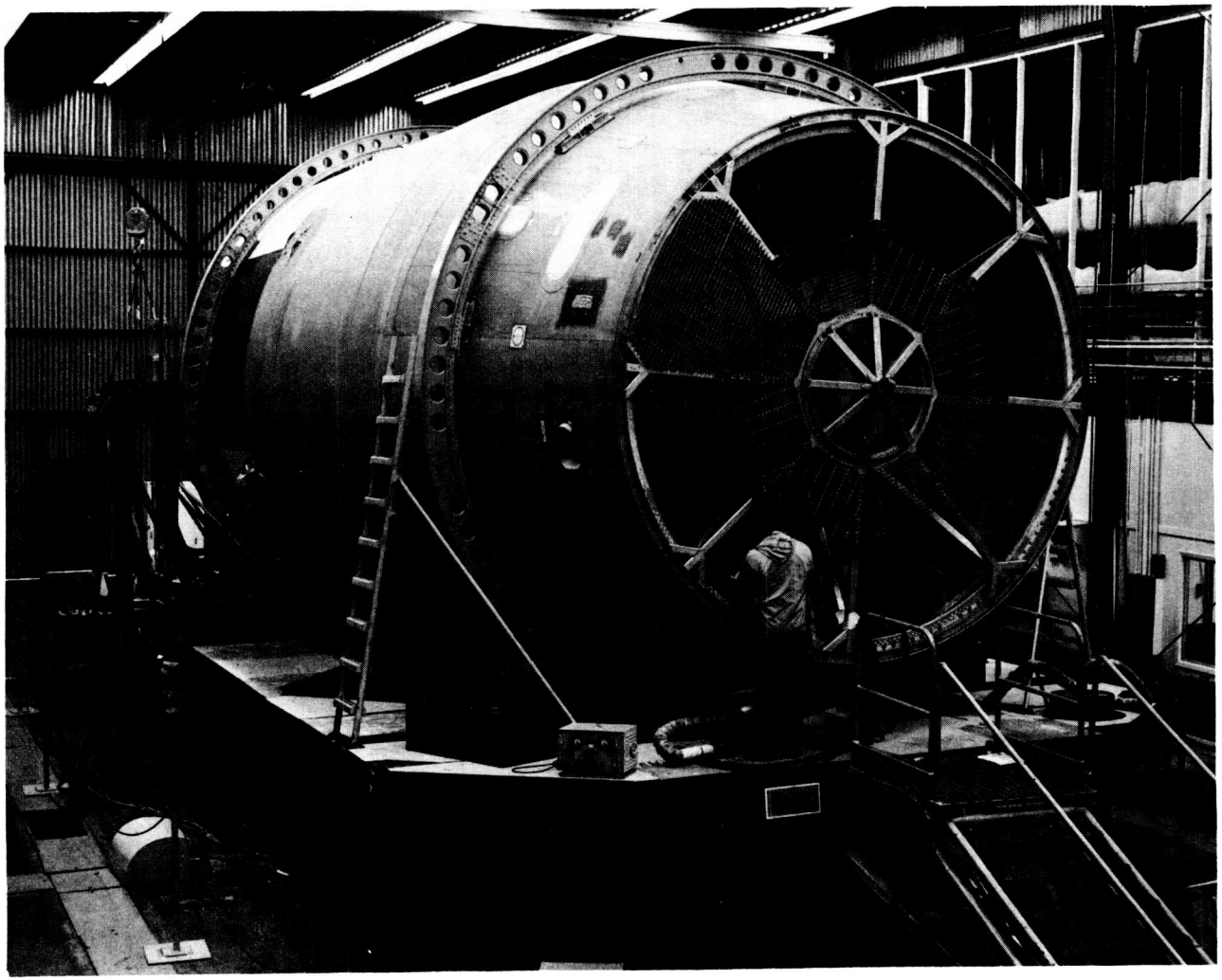
32. Aero-Astro Lab., Astr. Lab., and P&VE Lab., MSFC, SA-10 Technical Information Summary, July 16, 1965, (R-ASTR-S-104-65), p. 2.

33. NASA, NASA TN-D 3505, p. 64; and KSC, TR-250, pp. 1-3.

34. Teletype, Maj. Gen. Samuel C. Phillips, Dir., Apollo Program, NASA, to Dr. Wernher von Braun, Dir., MSFC, et al., subj., "Gemini Rendezvous with Pegasus," May 28, 1965; Teletype, Phillips to Col. Lee B. James, Dir., Saturn I/IB Project Office, MSFC, subj. "SA-10/Pegasus C Orbit Change," June 9, 1965; and NASA, NASA TN D-3505, p. 64.



S-IV STAGE AT SACTO

S-IV-10, the upper stage of the last Saturn I flight vehicle, is shown on its transporter at SACTO during checkout in January 1965.

CCSD moved the S-I-10 stage into Checkout Station No. 1 at the Michoud Assembly Facility on January 8 and began poststatic checkout and repair. Repairs included replacement and verification of a LOX pump cavity seal in engine 5 that had shown excessive leakage, and the smoothing of wrinkles caused by buckling of fuel tank 3. CCSD completed poststatic checkout and repair of S-I-10 on March 9 and stored the stage to await shipment to KSC.[35]

The S-IV-10 stage rested in Test Stand 2B at SACTO in early January while DAC technicians completed preparations for its acceptance firing. On January 21 the stage successfully performed a full-duration static firing of 480 seconds, incurring only minor anomalies. Afterwards, DAC completed poststatic checkout and stage repair. Workmen removed the stage from the stand on February 23 and began shipping preparations.[36]

FHC continued fabrication, checkout, and modification of Pegasus C through early June. The contractor added all of the same modifications applying to Pegasus B as well as the removable coupon experience..

At KSC LC-37B, pad preparations progressed for the SA-10 erection and the launch, scheduled to occur in August. The S-IV stage arrived at the launch site from DAC on May 10; the S-I stage from CCSD on May 31, and the IU from MSFC on June 1. KSC technicians erected S-I-10 on the pad on June 2. The S-IV-10 pad erection ended June 8, followed by erection of S-IU-10 and connection of all umbilicals on June 9.

The initial SA-10 launch date closely coincided with that of Gemini V. On June 21 NASA shifted the Saturn launch to July 30, the earliest date the vehicle could be readied for launch. This shift meant that problems with the GT-5 launch would not delay the SA-10 launch nor would they delay the subsequent modification of LC-37B to accommodate Saturn IB.[37]

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35. MSFC, MAF Hist. Rpt., July - Dec., 1965, pp. 1, 5-6, and 13.

36. MSFC, Test Lab. Progress Rpts., Jan. 12, 1965, to Feb. 12, 1965, p. 41; and Feb. 12, 1965, to Mar. 12, 1965, p. 42.

37. Teletypes, Rocco A. Petrone, Dir., Plans, Programs, and Resources, KSC, to Col. Lee B. James, Saturn I/IB Program Mgr., MSFC, subj., "Possible Interference of Scheduled Launch Date of SA-10 With That of GT-5," June 10, 1965; Kurt H. Debus, Dir., KSC, to Dr. George E. Mueller, Assoc. Adm., Office of Manned Space Flight, subj., "Possible Interface of Launch Schedules," June 11, 1965; and Maj. Gen. Samuel C. Phillips, Dir. Apollo Program Office, NASA, to Dr. Wernher von Braun, Dir., MSFC, subj., "Reschedule of SA-10 Launch," June 21, 1965.

At LC-37B, pad preparations for the SA-10 progressed toward the new launch date. The BP-9 SM and SM adapter arrived from MSFC on June 21, Pegasus C from FHC on June 22, and the BP-9 CM and LES from MCS on June 29. Each element of the payload received inspection on arrival. On July 6 technicians completed premating systems checks and panel deployment checks on Pegasus C. Then they attached Pegasus C to the S-IV stage and emplaced the SM, CM, and adapter. The workmen completed LES erection on July 8.

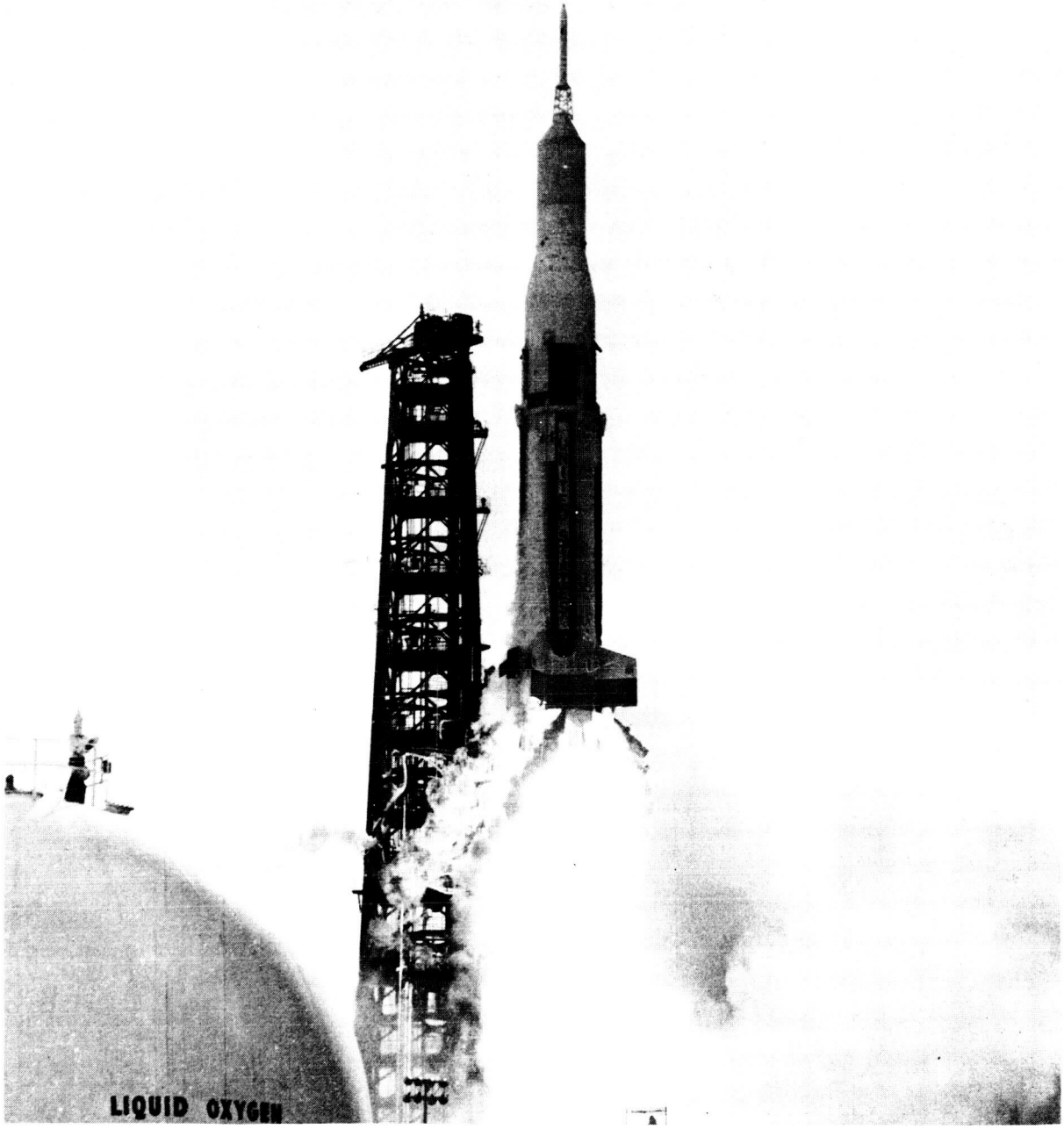
Prelaunch Operations

The customary series of ordnance installations, tanking, and prelaunch checkouts got underway on July 9. The launch crew completed the flight readiness test on July 20 and completed the countdown demonstration test without mishap on July 26 and 27.

The first part of the SA-10 launch countdown began at 11:20 a.m. on July 28 and continued without difficulty to the scheduled hold at 6:00 p.m. The terminal countdown resumed about 29½ hours later at 9:25 p.m., July 29. The launch crew managed to overcome several problems without interrupting this portion of the countdown operation. First, the S-I stage LOX fill line on the launcher developed a leak in the flex connection between the fixed LOX overland line from the storage facility and the S-I fill mast. Technicians replaced the flex connection. Second, the environmental control system duct from the umbilical tower to the Pegasus payload separated and required reconnection. The repairs did not require the 30-minute built-in hold scheduled 30 minutes prior to liftoff, but the hold was used to make launch time compatible with the launch window at 8:00 a.m. All mandatory range and field instrumentation was classified as "Go" at launch time with the exception of one S-I hydraulic temperature measurement. MSFC granted a waiver for deletion of this measurement.

Liftoff and Vehicle Flight

Liftoff occurred at 8:00 a.m. EST on July 30.



FINAL SATURN I

SA-10, the last of the Saturn I vehicles, rises on a tail of flame as it leaves LC-37B at Kennedy Space Center on July 30, 1965. The successful mission included orbiting of the third Pegasus meteoroid detection satellite.

All of the GSE and electrical support equipment at LC-37B operated normally during the countdown, automatic sequence, and liftoff. However, postlaunch evaluation revealed that GSE systems sustained considerably more damage than during any previous launch. An 18- to 20-knot wind blowing from the south/southwest caused the damage, mostly to equipment located north of the launcher center line. Damage included burned cables at the 35-foot level of the umbilical tower and flame damage to hoses, cables, and ducts of the swing arms. The need to refurbish the complex for Saturn IB launches minimized the impact of the damage.[38]

Flight performance of both the S-I-10 and S-IV-10 stage corresponded with that of the SA-9 and SA-8 stages.

The S-I-10 and S-IV-10 burns attained higher than nominal altitudes and ranges as had identical stages on the two previous Saturn flights. The S-I inboard engines burned 142.22 seconds and the outboard engines 148.32 seconds before cutoff. The total S-I engine burn, some 1.69 seconds shorter than nominal, produced a total space-fixed velocity 9.8 m/s higher than nominal. The S-IV engines received ignition command at 150.83 seconds of flight time and burned to guidance cutoff at 630.25 seconds of flight time, about 0.63 seconds short of normal burn. Slightly higher than nominal S-IV stage thrust and flowrate, along with the excess S-I cutoff velocity, contributed to the early S-IV cutoff. At S-IV cutoff the vehicle's total space-fixed velocity was 7591.50 m/s.

The S-IU-10 guidance and control system issued time commands to both stages, the IU, and the spacecraft for sequencing vehicle events throughout the entire period of flight. The system initiated pitch and yaw plane path guidance at 167.26 seconds of flight and arrested the steering commands about 2.0 seconds before S-IV cutoff.

At orbital insertion 10 seconds after S-IV cutoff the vehicle had attained a space-fixed velocity of 7595.0 m/s. This velocity provided

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38. MSFC, Saturn Flight Evaluation Working Group, Results of the Tenth Saturn I Launch Vehicle Test Flight SA-10, July 14, 1966, (MPR-SAT-FE-66-11), pp. 5-9; and KSC, TR-250, pp. 1-5.

a perigee of 327.9 miles and an apogee of 330.5 miles to yield an expected orbital lifetime of 720 days.

The NPV system performance shortly after S-IV cutoff compared favorably to that of the SA-8 system. The BDV vented the high boiloff rates immediately after engine cutoff without imparting any appreciable roll deviations.

With separation of the BP-9 shroud from Pegasus C at 811.95 seconds of flight time, the vehicle portion of flight ended.

Both the SA-10 stages, the IU, and all systems operated satisfactorily during the boost and orbital phases of vehicle flight; the vehicle successfully achieved all its assigned missions.

Overall reliability of SA-10's measuring system was 98.8 per cent. During flight, the airborne tape recorders operated as expected, as did the 11 telemetry links. The tracking systems, with exception of the MISTRAM and altimeter systems, provided excellent data. Prior to the flight, MSFC cancelled operation of the onboard television system because of insufficient mounting. However, the ground photo/optical instrumentation system produced good film coverage of the launch and flight. For the first time since beginning of the Saturn program, all the film from the tracking instruments were time-indexed.[39]

Pegasus C Orbital Flight

Pegasus C began deploying its wing panels 60 seconds after separation from the Apollo shroud. The wing deployment lasted about 41 seconds, ending at 912.0 seconds of flight time.

Initially, all of the Pegasus C spacecraft systems operated properly and all system temperatures remained within the permissible tolerance.

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39. MSFC, MPR-SAT-FE-66-11, pp. 1-9, 14-15, 18, 36, 38, 53, and 85; and Memo, George E. Mueller and Raymond L. Bisplinghoff, Assoc. Adms. for Manned Space Flight and Advanced Research and Technology, NASA, to Adm., NASA, Subj., "Pegasus III/SA-10 Saturn I Flight Mission Post Launch Report No. 1," Mission Operation Rpt. No. R-725-65-03, M-931-65-10, Aug. 16, 1965.

The detection subsystem immediately began recording hits on all three detector panel sizes and, in December 1965, were continuing to do so. The satellite experienced considerably less shorting of detector panels than had Pegasus A and Pegasus B.

NASA's STADAN started tracking Pegasus C at orbital insertion. Radar tracking coverage extended through the first five orbital revolutions and Minitrack observations continued to provide coverage through 1965. The Minitrack coverage will continue throughout the lifetime of the satellite or until termination of the Pegasus C experiment.

Telemetry data received by STADAN showed the velocity impulse measurements of Pegasus C compared favorably with those of Pegasus B. The S-IV NPV system required four to six hours to vent LH_2 residuals and 24 to 36 hours to vent LOX residuals.[40] The venting resulted in a maximum angular roll rate of 6.3 deg./s for Pegasus C, about 0.2 deg./s less than on Pegasus B. After 15 days of orbital flight the vehicle's roll rate decreased to about 5.6 deg./s. In its orbital flight Pegasus C continued to spin about its minimum moment of inertia axes as did Pegasus B. Its motion is expected to convert very slowly to that of a flat spin similar to Pegasus A.[41]

SATURN I ACCOMPLISHMENTS AND CONTRIBUTIONS TO AEROSPACE TECHNOLOGY[42]

The Saturn I program ended with the SA-10 flight on July 30, 1965. With this success the nation's first series of large launch vehicles had

40. This estimate of the required venting time is based on the amount of residual propellants and gases recorded at S-IV cutoff.

41. MSFC, MPR-SAT-FE-66-11, pp. 85-88; NASA NASA TN D-3505, pp. 64 and 104; and Memo, Mueller and Bisplinghoff to NASA Adm., Aug. 16, 1965, with R-725-65-03/M-65-10.

42. This section contains only a brief summary of Saturn I's accomplishments since the primary purpose of this report limits the coverage to the 1965 period. The NASA Saturn History, currently under contract, will provide the complete history of Saturn I.

achieved a perfect 10 out of 10 flights. And, however impressive its flight record, its contributions to aeronautical and astronautical research were even more far-reaching.

The Saturn I program served as a stepping stone to Apollo manned flights with the Saturn IB and Saturn V. Its accomplishments included expansion of development and launch facilities, development of new fabrication techniques and new transportation methods for large rockets, and improved methods for handling and storing large quantities of cryogenic fuel. The program also proved the validity of NASA's ground test philosophy and advanced automated checkout procedures. Industrial management techniques improved during the program as did reliability concepts.

Aside from the technological and managerial advances, the program supplemented NASA's scientific exploration of the earth's upper atmosphere and the earth orbital environment.

And, like most technological and scientific programs, Saturn I also generated numerous products for industrial and home use. Although this was not a specific mission of NASA, the nation's space agency through its technology utilization program kept private industry alerted to the new advances in equipment and materials.

Technology Foundations for Future Vehicles Established

Most important, Saturn I established the technological foundations for the more powerful Saturns to follow. As shown in the following flight summarization, each of the Saturn I flight vehicles had a mission that helped in the evolution of the future space rockets.

Saturn I's first flight demonstrated the clustered engine concept. Launched October 27, 1961, just three years after development began, SA-1's clustered-engine S-I stage produced a thrust of 1,300,000 pounds to attain a maximum altitude of 85 nautical miles and a maximum range of 214 nautical miles. With its dummy upper stages, this flight vehicle also demonstrated the structural rigidity of the airframe, the vehicle's control performance and reliability (coping with sloshing and non-rigid body dynamics), and the vehicle's compatibility to ground support equipment.

SA-2, launched April 25, 1962, attained a maximum altitude of 65 nautical miles and a maximum range of 50 nautical miles. This flight vehicle further verified the clustered engine concept, the structure, the first stage control system, and the compatibility of the vehicle and launch facility.

SA-3 and SA-4, in addition to the primary test objectives achieved by SA-1 and SA-2, had a balanced and systematic buildup of other missions in preparation for flight of the first vehicle with two "live" stages (Block II series). SA-3's S-I stage had provisions for full Block II propellant loading. During launch on November 16, 1962, SA-3 tested the new GSE umbilical swing arm connections, had engine cutoff initiated by LOX depletion rather than by timer, tested the Block II heat shield panel, tested (without actual S-I/S-IV stage separation) four solid fuel retrorockets identical to those employed in the Block II vehicle stage separation sequence, and tested in passenger form the stabilized guidance platform.

SA-4, launched March 28, 1963, continued the test missions of SA-3 and also tested the closed-loop accelerometer contol, verified the integrity of the structural airframe with use of some Block II aerodynamic protrusions (had antenna panels added to all four S-I fin positions and kits attached to the inert S-IV to simulate the Block II aerodynamic properties), provided thermal flight test of selected sensing devices, used an onboard playback recorder for data gathering, provided first engineering tests of the MISTRAM tracking device and the radar altimeter, and proved the feasibility of the engine-out concept with a programmed premature cutoff of one engine.

SA-5, launched January 29, 1964, proved the performance of the complete vehicle system and its capability of placing an inert payload of 37,700 pounds into an earth orbit. As the first Block II vehicle, SA-5, retained a Jupiter nosecone, had a payload compartment only slightly different from the dummy S-V third stage of the Block I configuration, had the first prototype of the IU flown on later vehicles, had the first

"live" S-IV stage which gave the vehicle its first orbital capability, had elongated S-I propellant tanks, and used the uprated H-1 engines (each producing 188,000 pounds thrust) in the S-I stage. During this flight, the vehicle also demonstrated the first S-I/S-IV separation sequence as well as flight control use of the S-I stage fins. SA-5 was the first Saturn vehicle to carry recoverable movie camera capsules to record specific flight events.

SA-6, the second Block II Saturn, reaffirmed the performance capability of the complete vehicle in its flight on May 28, 1964. SA-6, in addition to the developmental experiments performed by SA-5, demonstrated the physical compatibility of the launch vehicle and the first Apollo boilerplate spacecraft, successfully jettisoned the launch escape system, and employed active guidance (pitch, adaptive yaw, and delta minimum) during the S-IV stage portion of flight.

SA-7, on September 18, 1964, continued the developmental experimentations of SA-6. Considered as the prototype or the first of the operational Saturn vehicles, SA-7 did not contain the S-IV LOX backup pressurization system. The vehicle did, however, have the first complete flight test of the ST-124 system using closed loop during the S-IV stage powered flight. The vehicle also demonstrated an alternate LES tower jettison mode, verified the NPV system of the S-IV stage, and orbited the heaviest payload weight (39,000 pounds), which consisted of the expended S-IV stage, the IU, and the sand ballasted Apollo boilerplate spacecraft.

The SA-9 flight vehicle, described in more detail earlier in this chapter, had the first improved unpressurized IU, the prototype of the IU scheduled for use by the uprated Saturn I and Saturn V. SA-9 demonstrated the accuracy of the closed-loop guidance system using the IGM in attaining a predetermined orbital insertion at a given velocity and altitude. The vehicle also demonstrated an auxiliary NPV BDV system and provided the first demonstration of Apollo boilerplate/S-IV-IU separation. SA-9 inserted the first functional payload (Pegasus A) into orbit and provided the first live, high-resolution, fast-scan television broadcast originating on an orbiting satellite when it covered the Pegasus wing deployment.

SA-8 and SA-10, also described more fully earlier in this chapter, reaffirmed Saturn I's operational capability in orbiting Apollo boilerplate spacecraft and Pegasus satellites.[43]

Saturn I's Scientific Contributions

The first scientific experiment with a Saturn I occurred during the SA-2 flight. This also marked the first purely scientific large-scale experiment concerned with space environment. Appropriately designated "Project Highwater," the experiment released in the upper atmosphere nearly 30,000 gallons of water used to ballast SA-2's upper stage. The S-IV stage, deliberately exploded at an altitude of 65 miles, released the water which, within only five seconds, formed a massive ice cloud 4.6 miles in diameter. The cloud climbed to a height of 90 miles. SA-3 continued the scientific experiment, releasing S-IV's water ballast at an altitude of 104 nautical miles.

NASA's Office of Space Sciences authorized Project Highwater, and MSFC's Research Projects Laboratory planned and managed the experiment.

In November 1962 NASA's Office of Advanced Research and Technology authorized MSFC to proceed with the next Saturn supplementary scientific mission, Project Pegasus. The Pegasus satellite project was a part of NASA's expanding meteoroid detection study to define the hazard presented by meteoroids to space vehicles.[44] MSFC's Research Projects Laboratory

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43. MSFC, MHM-4, pp. 23-28; MHM-5, pp. 8-11; MHM-6, pp. 14-19; MHM-7, pp. 13-18; MHM-9, pp. 16-36; and MHM-10, pp. 23-40; NASA, Off. of Programs and Special Reports, Program Review, Apollo, Nov. 16, 1965, pp. 2-3; Exe. Off. of the Pres., National Aeronautics and Space Council, Report to the Congress from the President of the United States, 1965, pp. 12-13; NASA, Fourteenth Semiannual Report to Congress, July 1 - December 31, 1965, p. 32; and R. A. Chapman, Aero-Astrodynamics Lab., MSFC, Saturn I Block II Guidance Summary Report, NASA TM X-53398, Feb. 23, 1966, pp. 2-5; MSFC, Saturn I Summary, Feb. 15, 1966; and MSFC, Saturn Flight Evaluation Working Group, Results of the Saturn I Launch Vehicle Test Flights, MPR-SAT-FE-66-9, Dec. 9, 1966, pp. 1-6.

44. Earlier in 1962 MSFC had proposed to fly a Saturn I-boosted satellite having a meteoroid impact sensor then under development by NASA's Langley Research Center. This was the concept approved by NASA, and Langley Research Center provided MSFC substantial support throughout the duration of the project. NASA, NASA TN D-3505, p. 2.

again received project management.[45] On February 27, 1963, NASA contracted with Fairchild Stratos Corporation (now known as Fairchild Hiller Corporation) for three micrometeoroid satellites (two for flight, and one as backup). In March 1964 NASA approved a Pegasus mission for SA-10 and increased FHC's contract requirements to three flight capsules. At this time the meteoroid satellite was elevated from the status of passenger payload to that of prime objective payload for SA-9, SA-8, and SA-10.

As described in the first section of this chapter all three of the Pegasus launches were almost perfect. Initially the Pegasus satellites performed within expectations. The preliminary data gained from Pegasus indicated that the Apollo spacecraft structure as designed would be adequate to resist meteoroid penetration.[46] The satellites are continuing to provide meteoroid data and secondary measurements in regard to temperature and radiation effects. While all of the data from these satellites has yet to be received and analyzed, the information gained before the end of 1965 revealed that Project Pegasus accomplished its primary mission.[47]

PROGRAM FUNDING

The cost of the Saturn I program from its inception to end[48] amounted to $753,963,000. Of this amount $13,164,000 was obligated during the January 1 - December 31, 1965, period. The 1965 obligation was allotted

45. In 1964 NASA established a Pegasus Project Office within MSFC's Industrial Operations to monitor and assist FHC in Pegasus development and qualification. MSFC's Research Projects Laboratory continued to provide evaluation of Pegasus data.

46. Exe. Off. of the President, Report to the Congress from the President of the United States, 1965, p. 12.

47. MSFC, MHM-10, p. 44; and NASA TN D-3505, pp. 55-91 and p. 109.

48. The cost cited here is that expended through January 31, 1967; no further costs are anticipated.

MSFC, Financial Management Off. (FMO), Financial Status of Programs, January 31, 1967.

as follows: S-I stage, $2,807,000; S-IV stage, $752,000; Instrument Unit, $648,000; Ground Support Equipment, $294,000; and Vehicle Support, $8,663,000.[49]

Total Pegasus cost[50] amounted to $28,939,000. Pegasus contract costs totalled $27,798,000.[51] Direct cost of the Pegasus project in the 1965 report period totalled $8,249,000.[52]

SUMMARY

A record number of Saturn I launches from KSC occurred in the February - July 1965 period. SA-9, launched February 16, performed excellently and orbited an Apollo spacecraft shroud, BP-16, and the first Pegasus satellite, Pegasus A. SA-8, launched May 25, continued Saturn's flight success record. It too orbited an Apollo BP-26 shroud and Pegasus B. On July 30 the tenth and final Saturn I orbited the final Apollo boilerplate configuration, BP-9, and the final Pegasus satellite, Pegasus C.

The tenth Saturn I flight ended Phase I of the Apollo-Saturn launch

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49. Memo, Louis E. Snyder, Chief, Budget and Operations Branch, Financial Management Office, MSFC, to D. S. Akens, Chief, Historical Office, MSFC, subj., "MSFC's Obligations for Calendar Year 1965," Feb. 18, 1966.

Funds "obligated" included planned expenditures for which MSFC is obligated; it does not include the amount actually expended which is termed "direct cost." The direct cost cited for any period may cover current and prior obligations.

50. This amount covers cost through January 31, 1967; additional cost for tracking and miscellaneous data will continue throughout the lifetime of the satellites or until termination of the Pegasus experiments. MSFC FMO, Financial Status of Programs, January 31, 1967.

51. FHC, Space Systems Division, Final Report, Pegasus Program, 1965, FR-MTS-01, p. 26.

52. Memo, Snyder to Akens, subj. "MSFC costs for period January 1, 1965, through December 31, 1965," Feb. 17, 1966.

vehicle flight program. Major General Samuel C. Phillips, Director of the Apollo Program for NASA, commented:

> "But I would observe that the Saturn I program to date in its series of....successful launches has clearly demonstrated the technical soundness of large launch vehicles employing multiple engines, and has clearly demonstrated the soundness of large high-energy stages employing LH_2 and LOX as propellants."[53]

Dr. Wernher von Braun, Director of MSFC, expressed his appreciation to MSFC employees on August 10, 1965. He said:

> "What you have done reflects the ability of our nation to move forward quickly. The Saturn I proved that we were correct in our heavy duty launch vehicle theories."
>
> "One of the most important products of our Saturn I program is the fact that we have built up confidence--both self-confidence and the trust of the American people who are depending upon us for American progress in space exploration."[54]

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53. 89th Congress, 1st sess., H. Rpt., Staff Study for Subcommittee on NASA Oversight of the Committee on Science and Astronautics, Pacing Systems of Apollo Program, Oct. 15, 1965.

54. Public Affairs Off., MSFC, Press Release No. 65-204, Aug. 10, 1965.

CHAPTER III: SATURN IB

Saturn IB is the second generation of the Saturn launch vehicle family. Incorporating existing designs from the Saturn I and Saturn V vehicles, the Saturn IB has since conception in 1962 evolved into a launch vehicle which is now ready to support orbital missions with the Apollo spacecraft.

At present, the first flight vehicle (SA-201) is at NASA's Kennedy Space Center (KSC) awaiting launch in early 1966. The primary effort in the Saturn IB program during the year 1965 has been directed toward proving the Saturn IB design through ground tests and preparing the first vehicles for flight.

The Saturn IB program calls for twelve vehicle launches during the 1966-68 period. The first and second flight vehicles have ballistic "lob shot" missions which will test the Apollo heat shield under conditions of high speed re-entry into the earth's atmosphere. The third vehicle, SA-203, is to test the Saturn V S-IVB's propulsion system under orbital conditions. SA-204 has the first assigned manned Apollo mission. The remaining IB flight missions are to orbit the complete Apollo spacecraft in both unmanned and manned missions.

No radical changes are required in the Saturn IB configuration to provide support to all the above missions. Each flight vehicle will consist of a redesigned Saturn I booster (designated the S-IB stage), together with an S-IVB upper stage (an upgraded version of the Saturn I S-IV stage) and an instrument unit originally designed for the Saturn V. Topped by the Apollo spacecraft, the basic vehicle will measure approximately 224 feet in height and about 21.7 feet in diameter, have a total weight empty of about 85 tons, and have a liftoff weight of nearly 650 tons.

PROGRAM MANAGEMENT HIGHLIGHTS

The IB development program managed for NASA by MSFC is to a great extent an industrial effort since most of the vehicle stages and support are procured from industry. Major contractors for each stage, the IU, and the engines are the same as those used in support of the Saturn I development program. This permits extensive exchange and use of the technology, trained personnel, equipment, and facilities employed in developing Saturn I. All contracts with industry for support of the Saturn IB program are solicited, negotiated, and managed by organizational elements within the MSFC organization.

Under MSFC's direction Chrysler Corporation Space Division (CCSD) builds the S-IB stage in former S-I manufacturing facilities at MSFC's Michoud Assembly Facility (MAF)[1] located near New Orleans, Louisiana, and tests the S-IB stages in modified S-I test facilities at MSFC's Huntsville test site. Douglas Aircraft Company (DAC) produces the S-IVB stages at Huntington Beach and Santa Monica, California, and tests the stages at Sacramento, California. Rocketdyne Division of North American Aviation (NAA) develops and produces the engines (H-1 and J-2) for both stages at Canoga Park, California, and Neosho, Missouri, plants. The prime instrument unit contractor is International Business Machines Corporation (IBM) with primary responsibility for full integration and checkout of the units. IBM accomplishes this in a newly activated facility in Huntsville, Alabama.

The MSFC Saturn I/IB Program Office has sole authority for directing the program. This office receives official program guidance and direction from the Apollo Program Office at NASA and from the Director of MSFC

1. MSFC redesignated Michoud Operations as the "Michoud Assembly Facility" (MAF) effective July 1, 1965. To avoid confusion in this chapter, all reference to the facility will be "MAF" and to the site itself "Michoud."

through the Director, Industrial Operations (IO). The Saturn I/IB Program Office directs the program within established technical, schedule, and resources limitations. It manages the entire MSFC/industry performance through phases of program planning, coordination, and contractor managerial and technical direction. The Center's staff offices and the Research and Development (R&D) Operations assist IO and the I/IB Program Office in accomplishing the IB development program. The R&D Operations provide in-depth technical competence in all launch vehicle disciplines and perform future project related studies and support research work.[2]

Major Program Actions

Major activity of the Saturn I/IB Program Office in 1965 has been directed toward finalizing configuration changes for SA-201, assisting contractors in pinpointing and overcoming production problems, developing detail flight mission objectives in support of mission changes, and providing management support for new mission assignments.

As stage contractors progressed with design qualification during 1965, many change orders originated for improving the flight hardware. By April, program officials recognized that excessive changes in SA-201 could cause unnecessary delay and undue costs. To avoid this, the MSFC Director on April 8 issued a memorandum freezing the baseline configuration for SA-201 and stipulating that only the "absolutely mandatory, make-fit changes be tolerated."[3] For the same reason program officials also froze the configuration for SA-202 and SA-203 effective August 24, 1965.[4]

During 1965 MSFC provided support to stage contractors in overcoming production problems. One of the important areas of concern involved

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2. Saturn I/IB Program Office, Saturn IB Launch Vehicle Program Development Plan, MA-001-003-2H, Jan. 1, 1967, pp. 1.3--1.35.

3. Memo, Dr. Wernher von Braun, Director, MSFC, to Dir., Industrial Operations and Dir., R&D Operations, subj., "Control of Engineering Changes," Apr. 8, 1965.

4. Memo, Lee B. James, Manager, Saturn I/IB Program, to Distribution, subj., "Control of Engineering Changes by SA-202 and SA-203 Launch Vehicles," Aug. 24, 1965.

quality control of materials at contractor sites and subcontractor facilities. CCSD and DAC also encountered late deliveries of components from vendors; this necessitated measures to reduce shortages and also caused use of nonflight components until flight components became available. Action taken to overcome these problems is described in the R&D section of this chapter.

MSFC also provided considerable management support in IU development, not only for the first flight IU, but in getting the contractor development program underway. On February 23 MSFC's R&D Director assigned a Technical Manager for the IU Program, who became responsible for assuring the full utilization and coordination of R&D launch vehicle engineering and management capability. On April 8 the chairman of the IU Configuration Control Board issued detail operating procedures for the board members. The members of this board would, insofar as possible, approve or disapprove changes affecting their individual areas. To further assure timely support and control, the Center's R&D Operations and Industrial Operations agreed, on April 27, to transfer to the IU office in IO the functions formerly carried out by the IU Project Office of R&D's Astrionics Laboratory.[5] IU development in 1965 presented materials and component problems similar to those experienced in stage development. It also required complete support in the transfer of documentation since basic IU design responsibility resided with MSFC instead of the lead contractor.

One area requiring additional management support near the end of 1965 concerned ground support and electrical support equipment deliveries to KSC. The concern and delay in this area stemmed from the problems usually

5. Memo., H. K. Weidner, Dir., R&D Operations, to Distribution, subj., "Assignment of Technical Manager for the I.U. Program," Mar. 15, 1965; Memo., Edmund F. O'Connor, Dir., IO, and H. K. Weidner, Dir., R&D Operations, to Distribution, subj., "Saturn Instrument Unit Programs," April 27, 1965; and Friedrich Duerr, Chairman, IU Configuration Control Board, and William K. Simmons, Jr., Co-Chairman, to Distribution, subj., "Detail Operating Procedures," April 8, 1965, w/encl., subj., "Instrument Unit Configuration Control Board Detail Operating Procedures."

associated with a new development area. To avoid delay in automatic checkout of SA-201 and to keep from pacing the launch program, officials agreed to give ESE of the Saturn IB IU Checkout Station, the IB Systems Development Facility (SDF), and LC-34 priority over Saturn V ESE. MSFC appointed a special task force to expedite delivery of all sets of equipment for the IB.[6]

Changes in missions for the various IB R&D flights received considerable attention throughout 1965. Payload commitments and mission profile changes resulted because of the increase in the payload capability of the IB due to uprated engines and hardware changes. Personnel at MSFC participated in developing the detail flight mission objectives in support of the mission changes and for inclusion in the Apollo Flight Missions Assignments document.[7]

MSFC received several of the mission assignments for the program near the beginning of or during 1965 and the Center's Director delegated management responsibility for the missions. The Center received approval for an LH_2 orbital experiment in late 1964. On March 5, 1965, the Director, MSFC, assigned responsibility for the project to the I/IB Program Office.[8] Later in March MSFC received the task of managing design and definition of a three-stage Saturn IB/Centaur launch vehicle system to support projected mission requirements beyond the Apollo program. The Center's Director established a Saturn IB/Centaur Program Office in Industrial Operations to provide management for this project.[9]

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7. Office of Manned Space Flight Directive, George E. Mueller, Assoc. Adm. for Manned Space Flight, to Distribution, subj., "Apollo Flight Mission Assignments," May 21, 1965; and Aero-Astrodynamics Lab., Monthly Progress Report, Sept. 1965, Sept. 14, 1965.

8. Memo, Lee B. James, Mgr., Saturn I/IB Program, to Distribution, subj., "LH_2 Experiment Assignment," Mar. 31, 1965.

9. Memo, Dr. Wernher von Braun, Dir., MSFC, to Distribution, subj., "Saturn IB/Centaur Project and Personnel Announcement," May 7, 1965; and Memo, Stanley R. Reinartz, Mgr., Saturn I/IB Centaur Program, to Distribution, subj., "Saturn IB/Centaur Planning and Scheduling (For Initial SA-210 Launch)," Aug. 9, 1965.

The directive for proceeding with the IB/Centaur SA-210 launch contained a restriction that no actual flight hardware or flight item connected GSE be procured until January 1966.

1965 Contract Actions

In 1965 MSFC's IO procured and NASA approved additional increases in the stage contracts and engine contracts, completed award of the prime IU contract, awarded IB improvement study contracts, procured initial design effort in support of Saturn IB/Centaur application, and also began converting all the major contracts from cost-plus-fixed-fee (CPFF) contracts to cost-plus-incentive-fee (CPIF).

S-IB Stage

S-IB stage contract action with CCSD began with a letter supplement in November 1962 to the S-I stage contract (NAS8-4016). Modification 34 to NAS8-4016 in October 1963 purchased 12 S-I stages for conversion to the S-IB configuration and one additional second stage adapter for use on a Saturn IB Dynamics/Facilities vehicle. Since then, NASA has increased CCSD's contract coverage to extend the reliability program, to increase direct engineering support to MSFC, to extend and revise the aeroballistics program, to provide additional design changes and qualification of certain S-I components, to procure new stage hardware, and to provide Saturn IB ground support equipment (GSE).[10]

In 1965 IO modified and increased the value of CCSD's contract (NAS8-4016) from $317,262,189 to $351,006,221. In addition to extending the services already under contract, the increase purchased new hardware, systems engineering, additional documentation, and support services. The purchases were acquired through separate modifications to Contract NAS8-4016.

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10. Historical Off., MSFC Historical Monograph No. 8 (MHM-8), History of the George C. Marshall Space Flight Center, July 1--Dec. 31, 1963, pp. 61-62; MHM-9, p. 69; and MHM-10, pp. 56-57.

NASA acquired S-IB Stage-KSC prelaunch checkout support from CCSD on February 1, 1965, for a total cost of $6,320,000. MSFC on June 18 completed negotiations with CCSD for the design, development, testing, and provisioning of the mechanical GSE. This purchase, implemented by Modification No. 206 on September 4, 1965, added approximately $4,152,717 to the cost of the contract. Design, modification, and maintenance of S-IB electrical support equipment (ESE) (not including ESE for vehicle launch support) amounted to $886,741 with an additional $687,324 for maintaining design and documentation work for ESE. Purchase of operation and maintenance support for the I/IB SDF accounted for $4,222,740 of the 1965 increase. The largest increase, $18,909,000, purchased systems engineering through contract action on December 30, 1965.[11]

Other major provisions covered by the 1965 increase included Saturn IB flight evaluation, dynamic test program support, I/IB thermodynamics and fluid mechanics program, support services to Rocketdyne, and system analysis of the IB vehicle with 205K H-1 engines. It also covered emergency detection system (EDS) qualification support and the IB EDS Breadboard Facility, Saturn IB systems integration, logistic spares support, computer support, and photo and TV support.[12]

Other activity involving CCSD's S-IB contract in 1965 concerned negotiations to close out the Saturn I effort and negotiations to incentivize the S-IB coverage. MSFC began negotiations with CCSD on April 22 for an equitable adjustment resulting from NASA's program redirection and termination of six S-I stages. The adjustment, when approved by NASA Headquarters in early 1966, will decrease the NAS8-4016 contract value by $27,859,834. MSFC requested a proposal from CCSD on June 8 for converting NAS8-4016 to a contract with an incentive arrangement. In the last

11. MAF, Historical Report, January 1, 1965--June 30, 1965, pp. 10-14; and July 1--December 31, 1965, pp. 13-15; and Saturn I/IB Program Off., MA-001-003-2H, p. 3.11.

12. MAF, Hist. Rpt., Jan. 1, 1965--June 30, 1965, pp. 10-14; and July 1--Dec. 31, 1965, pp. 13-15.

six months MSFC and CCSD completed cost negotiations and established share lines for incentivizing the contract. The MSFC/CCSD incentive position will be presented to NASA on January 11, 1966, for approval.

The CCSD S-IB stage facilities contract (NAS8-5602F) reflected no change in contract value in 1965. However, MSFC authorized CCSD to procure $20,198 of facilities equipment to support development of the SDF in lieu of other facilities equipment previously planned.[13]

In February 1965 NASA modified Rocketdyne's H-1 engine R&D contract to include uprating of the H-1 engine from 188,000 pounds thrust (188K) to 200K for Saturn IB application. This modification added $8,774,000 to the cost and brought the total value of the contract to $20,648,500.[14] On April 1, NASA gave approval for increasing the 200K H-1 engine to 205K to support Saturn IB application to even larger missions and modified Rocketdyne's contract accordingly. In June, MSFC began negotiations with Rocketdyne for a total of 22 H-1 engines, the final engines needed for the 12 Saturn IB vehicles.[15]

S-IVB Stage

Contract NAS7-101 provides for the engineering, research, development, fabrication, and test services for S-IVB stages as well as the design and manufacture of GSE in support of stage assembly and checkout operations. The 12 Saturn IB S-IVB flight stages have been purchased through separate modifications to the contract; the ground test stages purchased under the initial Saturn V contract are developed first in the IB configuration, tested, and then converted to the Saturn V configuration.

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13. Ibid.

14. Public Affairs Office (PAO), Press Release No. 65-43, Feb. 16, 1965.

15. PAO, Press Release No. 65-155, June 21, 1965; Engine Program Off., Quarterly Progress Report, F-1, H-1, J-2, and RL10 Engines, Jan., Feb., Mar., 1965, QPR-Eng-65-2, p. 16; and Teletype, Lee B. James, Mgr., Sat. I/IB Program to Maj. Gen. Samuel C. Phillips, USAF, Dir., Apollo Program, OMSF, NASA, Mar. 11, 1965.

Purchase of the first four S-IVB/IB flight stages was approved by NASA's Director of Procurement in December 1963 and negotiations for the remaining eight S-IVB/IB stages and a set of GSE commenced in September 1964 and ended January 27, 1965.[16] NASA completed purchase of the remaining S-IVB stages in March 1965, through a supplemental agreement with DAC. This supplemental agreement totalled $76,369,021 and brought DAC's S-IVB contract NAS7-101 value to $311,134,662.[17]

In the last quarter of 1965 MSFC began negotiations with DAC for converting Contract NAS7-101 from a CPFF contract to a CPIF contract. Negotiations were still in progress at the end of 1965.[18]

The J-2 engine contract provides engines for the Saturn IB and Saturn V S-IVB and for the Saturn V S-II stages. Negotiations to convert the J-2 engine CPFF production contract NAS8-5603 to a CPIF contract started in April and were completed in May with a CPIF effectivity date of July 1, 1965.[19] In December MSFC initiated negotiations with Rocketdyne on a combined R&D and production incentive contract. The development portion is expected to include sustaining engineering effort through December 1968, and the production portion is expected to include a procurement action for 52 additional J-2 engines.[20]

Instrument Unit

Contracts for all the major instrument unit (IU) components were awarded prior to 1965. The major contractors for the non-government furnished components include Electronic Communications, Inc., the flight control

16. MSFC, MHM-10, p. 64; and Saturn I/IB Program Off., Saturn I/IB Progress Report, Oct. 1, 1964--Mar. 31, 1965, I/IB-65-1, p. 8.

17. PAO, Press Release No. 65-83, April 11, 1965.

18. Saturn V Program Off., Saturn V Quarterly Progress Report, Oct., Nov., and Dec. 1965, MPR-SAT-V. 65-4, p. 20.

19. Ibid., MPR-SAT-V. 65-2, p. 28; and Engine Program Off., QPR-Eng-65-3, p. 19.

20. Engine Program Off., Semiannual Progress Rpt., F-1, H-1, J-2, C-1, and RL10 Engines, MPR-Eng-66-1, p. 24; and Saturn V Program Off., MPR-SAT-V. 65-4, p. 30.

computer; Bendix Corporation, the ST-124M inertial platform; IBM Federal Systems Division, the launch vehicle digital computer and the launch vehicle data adapter; General Dynamics Corporation, the structure for S-IU-201, 202, and 203; and NAA, the structure for the remaining Saturn IB and Saturn V IU's.[21]

On February 18, 1965, MSFC completed negotiations with IBM, the firm selected in 1964 as the lead IU contractor. NASA approved award of the lead contract (NAS8-14000), the first incentive contract to be negotiated in the Saturn IB Program, to IBM on March 31. Terms of the five-year contract required IBM to manufacture or procure components (except for government furnished equipment), conduct component checkout, structural assembly, installation of components, total IU checkout, and packaging of the IU for shipment from Huntsville to KSC. IBM would also conduct the post-flight analysis of the IU in support of the total MSFC mission post-flight analysis.[22] The contract called for IBM to assume full integration responsibilities as prime contractor beginning with SA-204. The contractor would work with MSFC in a "phase-in" period on S-IU-201 through 203.

MSFC negotiated a number of change orders against Contract NAS8-14000 in 1965 of which most were engineering. One change order, however, in April shortened IBM's phase-in period to end with S-IU-201 and required the contractor to assume full structural intergration responsibilities beginning with S-IU-202. Another change delineated IBM's support requirements at KSC.[23]

The only other major IU contract action occurred October 18, 1965, when NASA approved award of a subcontract by IBM to Electronic Communications Inc. The subcontract, a CPIF award estimated at $5,165,000, covered fabrication, test, and delivery of 13 Saturn IB and 17 Saturn V flight control computers.[24]

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21. MSFC, MHM-10, p. 81.
22. IBM Space Systems Center, Huntsville, Ala., Saturn IU Program Plan, April 5, 1966, (IBM-No. 66-966-0016), pp. 1.1-1.2.
23. Ibid.; and Saturn V Program Off., MPR-SAT-V. 65-3, p. 40
24. Teletype, George J. Vecchietti, Dir. of Procurement, NASA, to Contracts Off., Industrial Operations, MSFC, Oct. 18, 1965.

Funding

MSFC obligated a total of $268,908,000 for the Saturn IB effort during the year 1965. The obligation was allotted as follows:[25]

S-IB Stage	$54,547,000
S-IVB Stage	83,764,000
Instrument Unit	45,725,000
Ground Support Equipment	33,697,000
H-1 Engine (Procurement)	8,400,000
J-2 Engine (Procurement)	12,080,000
Vehicle Support	28,541,000
Saturn IB/Centaur design	2,154,000

RESEARCH AND DEVELOPMENT

There were three distinct phases of Saturn IB R&D in 1965. These were (1) basic stage R&D consisting of components and systems testing and qualification, design improvement, and problem solving; (2) test vehicle R&D consisting of the development and test of the dynamics vehicle and the facilities checkout vehicle in the two vehicle IB ground test programs preceding flight vehicle tests; and (3) the flight vehicle development, acceptance testing, and flight preparation.

Basic Stage Research and Development

S-IB Stage

The S-IB stage which boosts the second stage, instrument unit, and spacecraft in flight approximately 35 nautical miles is basically the

25. Memo, Louis E. Snyder, Chief, Budget and Operations Branch, Financial Management Off., MSFC, to D. S. Akens, Chief, Historical Off., MSFC, subj., "MSFC's Obligations for Calendar Year 1965," Feb. 18, 1966.

Funds obligated include planned expenditures for which MSFC is obligated; they do not include the amount actually expended which is termed "direct costs."

same as the Saturn I S-I stage. The S-IB stage is 80.3 feet in height and has a diameter of 21.4 feet. It is propelled by eight H-1 engines which burn liquid oxygen (LOX) and kerosene (RP-1) fuel, and it contains its own instrumentation and range safety systems which receive guidance and control commands from the IU.

CCSD completed the redesign required for converting the S-I design to the S-IB configuration in 1964. The redesign reduced the weight of the stage by about 20,000 pounds and included structural modifications, addition of partial aspirator turbine exhaust ducts, modifications to the propellant sensing system, and application of H-1 engines uprated from 188K to 200K.[26]

Qualification of the redesigned components and subsystems which commenced at MAF in 1964 continued to occupy the CCSD engineering team in 1965, as did product improvement.

Structural qualification of the second stage adapter, a major concern since 1964 tests revealed it did not fully qualify at design loads, resumed at MAF in January. Tests during the first half of 1965 led to structural reinforcement of the spiderbeam, a part of the adapter assembly. This modification proved successful on June 17[27] and structural qualification of the spiderbean ended on July 7.[28] On July 8 CCSD conducted a structural test of the seal plate subassemblies which are fastened to the spiderbeam to provide a firewall between the S-IB propellant containers and the S-IVB/IB engine compartment. The seal plate structures withstood the 140 per cent load test with no excessive stresses or deformations. The successful completion of this test ended the qualification test series for the second stage adapter.[29]

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26. MSFC, MHM-10, p. 53; and Saturn I/IB Program Off., MA-001-003-2H, pp. 9.21 and 9.31.

27. Saturn I/IB Program Off., I/IB-65-1, p. 5; P&VE Lab., Monthly Progress Report for Period December 1, 1964, through December 31, 1964, MPR-P&VE-65-1, pp. 46-47; and MPR-P&VE-65-2, p. 46.

28. P&VE Lab., MPR-P&VE-65-5, pp. 42 and 60; MPR-P&VE-65-6 (May), p. 44; MPR-P&VE-65-6 (June), p. 44; and MAF, Hist. Rpt., Jan. 1, 1965--June 30, 1965, p. 7.

29. P&VE Lab., MPR-P&VE-65-7, pp. 39-40.

On August 17 CCSD completed structural qualification of the S-IB fins, a part of the tail unit assembly. This was followed by structural tests of the fuel tank, a part of the propellant container assembly, in October. Three tests were involved: a free-standing, empty cylindrical section test on October 6; an aft bulkhead (liftoff) and a forward bulkhead (engine cutoff) test on October 15; and an aft skirt test (to loads simulating those up 64.6 seconds after liftoff) on October 20. The fuel tank qualified to 140 per cent of limit loads for all of the test conditions. On December 10 workmen qualified the heat shield backup structure, the last item for structural qualification in the tail unit assembly. Test procedures for structurally qualifying the LOX tank were completed near the end of December. Plans called for completion of this test series in January 1966.[30]

Results of systems and hardware tests at MAF and vehicle static tests at MSFC in 1965 led to several engineering changes to the S-IB design.

One of the more significant engineering changes involved removal of the four outboard engine skirts from S-IB-2 through S-IB-12 configurations. CCSD submitted this change to MSFC for approval in June. After evaluating the proposal MSFC gave its approval. Removal of the engine skirts represented a weight savings of approximately 1200 pounds per vehicle.[31]

A review of the discrete liquid level probes for S-IB-205 and subsequent IB stages, conducted in April, showed that only 15 of the usual 75 probes per stage would be needed to adequately predict and evaluate the stage behavior. MSFC approved the change in August and CCSD personnel began specifications for relocation of the probes.[32]

In November following qualification of the S-IB/S-II retro motor technicians discovered the protective phosphate coating on the exterior surfaces of the motor case to be non-conductive. Since conductive surfaces

30. Ibid., MPR-P&VE-65-8, p. 49; MPR-P&VE-65-10, p. 31; and MPR-P&VE-65-12, p. 25.
31. Ibid., MPR-P&VE-65-6, p. 43.
32. Ibid., MPR-P&VE-65-4, p. 32; and MPR-P&VE-65-7, p. 9.

were needed where the motor attached to the vehicle to prevent buildup of an electrostatic charge, a change order was issued to replace the phosphate coating on attachment surfaces with a rust-prohibitive grease coating.[33]

In 1965 MSFC, CCSD, and Rocketdyne continued separate and combined effort toward qualifying the H-1 engine and improving its performance capability and subsequently the performance of the S-IB stage.

Rocketdyne on April 23 completed qualification of the uprated 200K H-1 engine developed in 1964. The contractor tested two 200K engines, an inboard configuration and an outboard configuration. The two engines completed a total of 51 performance verification runs with an accumulated firing time of 4,582 seconds. In addition, the outboard engine completed environmental, safety limits, and malfunction test programs. No major problems were encountered during any of the tests.[34]

During the first quarter of 1965 Rocketdyne also completed development and qualification of an improved performance injector permitting even more engine capability. Production release, initially planned for S-IB-5 engines, was changed to occur with S-IB-3 engines; MSFC also authorized Rocketdyne to retrofit S-IB-1 and S-IB-2 engines with the improved injector.[35]

In the first quarter of 1965 MSFC, CCSD, and Rocketdyne participated in analysis to determine what effect uprating the H-1 engine to 205K or higher would have on the S-IB stage and on Saturn IB performance. On April 1 NASA authorized MSFC to approve a development program to increase performance of the 200K engine to support later Apollo vehicles and follow-on Saturn IB programs. MSFC amended Rocketdyne's contract.[36]

Although Rocketdyne encountered a few problems, development of the 205K engine progressed satisfactorily. Rocketdyne began acceptance tests of the engine in October and also delivered the first two 205K engines to

33. Ibid., MPR-P&VE-65-11, p. 26; and MPR-P&VE-65-12, p. 1.
34. Engine Program Off., QPR-Eng-65-2, p. 11; P&VE Lab., MPR-P&VE-65-5, p. 27; and PAO, Press Release No. 65-96, April 23, 1965.
35. Engine Program Off., QPR-Eng-65-2, p. 15.
36. Ibid., pp. 15-16.

CCSD in October.[37] By the end of the year Rocketdyne had either solved or neared solutions to problems encountered in development. One of these concerned the thrust OK pressure switch which showed a tendency to generate a cutoff command when experiencing pressure surges in the fuel pressure sensing lines. Rocketdyne solved this by installing a .004-inch orifice in the sensing line. The contractor released the .004 orifice to production in December and planned to retrofit the orifice on all flight and flight spare engines previously delivered. The thrust increase of the 205K engines also caused the tube thrust chambers to split and burn near the exit end. In progress were tests on two experimental stainless steel thrust chambers with tube wall thickness increased from .012 to .018 inch to preclude tube burning. These tests continued into 1966 as did tests of two new type LOX pump seals, one with a stronger carbon element and the other with an improved bellows. Rocketdyne hoped to use one of the new type seals as a replacement for the production LOX pump seal which failed several times during R&D testing.[38]

MSFC continued H-1 single engine tests at the Power Plant Test Stand at Huntsville to supplement Rocketdyne's acceptance tests of new components and also to support the Saturn IB Pogo (Oscillating Longitudinal Vehicle Acceleration) study. The first seven tests were of the 200K engine with the improved injector. Six others in support of the Pogo study were to establish the relationship between suction line resonant frequency and pump suction pressure for the S-IB oxidizer and fuel delivery systems.[39]

Analysis of the S-IB stage sequence revealed that the 6-second time differential between inboard engine cutoff and outboard engine cutoff used for Saturn I imposed a performance penalty on the S-IB stage. MSFC decided in December to change differential to three seconds. This change,

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37. P&VE Lab., MPR-P&VE-65- 9, p. 19; and PAO, Press Release No. 65-269, Oct. 28, 1965.

38. Engine Program Off., QPR-Eng-66-1, pp. 15-16.

39. Test Lab., Test Lab Historical Report, January 1 - December 31, 1965, pp. 3-4.

though not optimum from a maximum performance standpoint, would improve S-IB performance, permit a payload gain of 100 pounds, and meet vehicle requirements with minimum cost and change to the stage.[40]

S-IVB Stage

The S-IVB stage, propelled by a single 200K J-2 engine, burns about 64,000 gallons of LH_2 and 20,000 gallons of LOX in about 7.5 minutes of operation, to achieve orbital speed and altitude. Unlike Saturn V's S-IVB third stage, the S-IVB/IB does not re-ignite in space.

The S-IVB stage consists of five major structural assemblies; an aft interstage structure, an aft skirt assembly, the propellant tank assembly, the thrust structure, and the forward skirt assembly. The aft interstage structure connects the S-IB and S-IVB stages and is discarded during separation along with the S-IB stage. Mounted on the aft interstage are four retrorockets to provide the proper deceleration to the booster at stage separation so that adequate clearance is gained prior to J-2 engine ignition. The aft skirt assembly provides structural interface between the aft interstage and the propellant tank assembly. Two auxiliary propulsion system (APS) engines mounted to the aft skirt provide roll control during second stage powered flight and total attitude control during orbital coast. Also mounted on the aft skirt are three ullage rocket modules and the aft umbilical connector plate. The ullage rockets aid in settling propellant during stage separation which is necessary to insure proper engine inlet conditions prior to engine start. The propellant tank assembly consists of two propellant tanks which form an integral part of the stage structure and are separated by an insulated bulkhead. The LH_2 container is insulated with three dimensional polyurethane foam to aid maintenance of sub-zero temperatures necessary to minimize LH_2 boiloff. Bolted to the aft dome of

40. P&VE Lab., MPR-P&VE-65-11, pp. 25-26.
Maximum performance would be realized by going to an 8-engine cutoff; however, this type cutoff would not meet the requirement imposed for separation and guidance of the vehicle and would require redesign of the stage electrical system.

the propellant tank assembly is the thrust structure which provides an attach point for the J-2 engine, and which also distributes engine thrust over the entire tank circumference. Hydraulic system components, propellant feed lines, pneumatic components, and miscellaneous components supporting engine operation are mounted on the thrust structure. The forward skirt assembly connects the S-IVB stage to the IU assembly; it contains electronic equipment environmentally conditioned by cold plates using coolant provided by the IU thermal conditioning system. Range safety and telemetry antennas are mounted around the external periphery of the forward skirt assembly.

S-IVB stage development, the pacing item in Saturn IB development during 1964, reflected a more nearly current status in 1965 although in some areas it still ranged several weeks behind schedule.

DAC's emphasis in 1965 was on structural tests, component qualification, systems testing, and design improvement and problem solving.

Structural Tests: The S-IVB/IB series of structural tests proceeded satisfactorily at Huntington Beach during 1965. The contractor structurally tested the forward skirt assembly in February and March. In June DAC completed necessary redesign to correct deficiencies disclosed during tests of the thrust structure. Incorporation of the redesign was planned for all production vehicles except S-IVB-201 to which DAC added interim structural modifications to correct the deficiency. Vibration tests of the fuel vent system components, and of the LH_2 instrumentation probe structure were accomplished in July. In July and August test engineers structurally qualified the aft skirt assembly, and on October 26 completed qualification of the aft interstage structure. Completion of the aft interstage/aft skirt separation joint test on November 11 left only one structural test, the aft interstage retrorocket installation test, to be performed in 1966.

Structural qualification of the propellant tank assembly had occurred in 1964, but, in September 1965, tests of the S-IVB-203 propellant tank assembly revealed structural weakness around the manhole cover in the S-IVB LH_2 tanks. Closure of the cover, accomplished by seal and a bolting ring, imposed a load on the jamb weld. Engineers devised a temporary

fix using rings to support the welds and then applied a permanent fix by welding in a more flexible area to remove the stress and strain impinging on the weld itself. As a matter of caution, DAC repaired the jamb welds on S-IVB-201, S-IVB-202, and S-IVB-203.[41]

Component Qualification: Fabrication, qualification, and design improvement continued for S-IVB components. The S-IVB/IB ullage rocket passed qualification in 1965; problems with the S-IVB/IB retrorocket and with the battery prevented qualification of these two items.

Thiokol Chemical Corporation, supplier of the S-IVB/IB ullage rockets, completed four ullage rocket tests in September to complete cold aging and temperature gradient test requirements. The supplier conducted nine additional qualification tests in October to complete the qualification test requirements. The latter tests were hot aging tests and the sequential treatment vibration and shock tests. Preliminary evaluation of test results indicated that the ullage motor performed satisfactorily at all conditions tested. In October, pending formal verification and acceptance of the qualification program, MSFC authorized DAC to deliver five of the TX-280 ullage motors to KSC for use on S-IVB-201 and as spares.[42]

Results of initial qualification tests of the retrorocket led DAC to request Thiokol, the vendor, to make several changes involving the igniter assembly and the motor assembly installation. In November and December DAC performed retrorocket fit checks. In December MSFC approved the design concept for the retrorocket impingement curtain. In the latter months of 1965, DAC performed analysis of changes required to overcome a problem disclosed in the retrorocket plume impingement studies. The problem involved possible collision of the S-IB and S-IVB stages should one retrorocket fail to operate. MSFC waived the required changes for the first

41. DAC, Missile & Space Systems Division, S-IVB Saturn Monthly Technical Progress Report, SM-47276, Issue 35, p. 43; SM-47313, Issue 36, p. 60; SM-47384, Issue 38, p. 37; SM-47423, Issue 39, pp. 21, 42, and 44; SM-47486, Issue 40, pp. 40 and 45; and Saturn V Program Off., MPR-SAT-V. 65-4, p. 23.

42. P&VE Lab., MPR-P&VE-65-10, pp. 21-22; and DAC, SM-47423, Issue 39, p. 23.

two flight stages and asked DAC to complete changes effective with S-IVB-203 retrorockets. Delivery of three retrorockets to KSC in December brought the total number delivered to ten and completed requirements for S-IVB-201 and S-IVB-202 and spares.[43]

Problems experienced with the vendor-supplied battery in 1965 prompted DAC to work with the Eagle-Pitcher Company on solutions and deferred battery qualification. Strain gauge system problems required rework of the entire system. MSFC approved the necessary redesign in December, and the supplier started work immediately to eliminate the problems. Involved was redesign of the strain gauge module, the stage connections, and the stage harness and brackets. Battery casing problems caused DAC, in early December, to redesignate certain batteries already delivered for the stage electrical power system to use as ground test batteries. Also in December, during preparations for the S-IVB-202 static firing, a battery failed, destroying itself and causing isolated damage to the stage. Preliminary analysis revealed improper operation of the battery heater control unit and possible overload in the chilldown inverters causing LH_2 chilldown pump failures. Analysis of these latest problems continued into 1966.[44]

Systems Testing: Four major S-IVB systems were functionally qualified in 1965. These included the S-IB/S-IVB separation system, the propulsion system with S-IVB battleship stage tests, the J-2 engine, and the auxiliary propulsion system (APS).

In November DAC completed a separation shock test program to qualify the S-IB/S-IVB separation system and the mild detonation fuse installation. All tests were successfully performed with exception of the switch selector which failed to pass a post-test functional checkout; this was returned to MSFC for failure analysis.[45]

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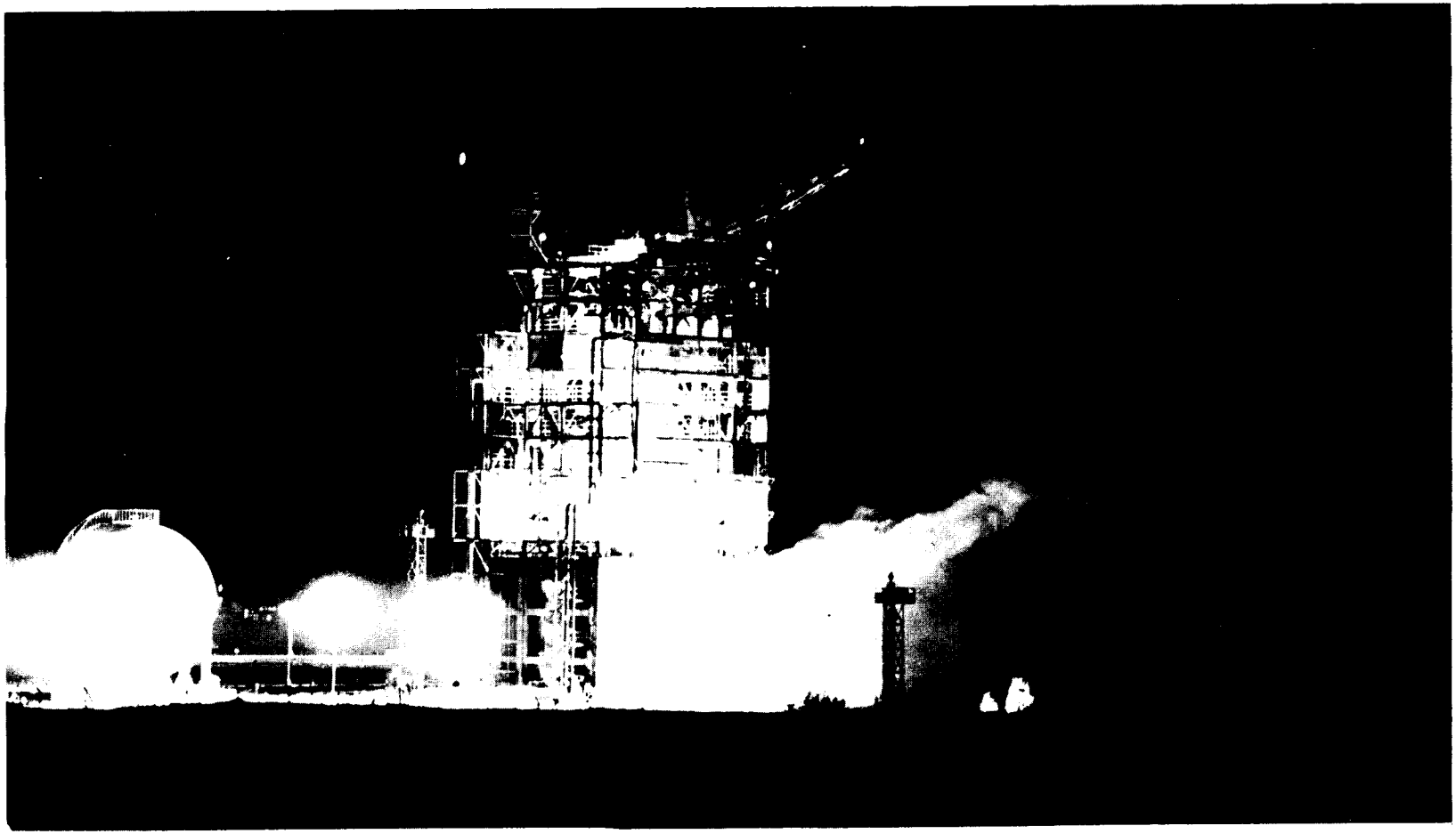
43. DAC, SM-47423, Issue 39, p. 23; SM-47486, Issue 40, p. 21; P&VE Lab., MPR-P&VE-65-8, p. 36; MPR-P&VE-65-9, pp. 17-18; and MPR-P&VE-65-12, p. 9.
44. DAC, SM-47522, Issue 41, p. 22.
45. DAC, SM-47486, Issue 40, p. 52.



S-IVB FIRES AT SACTO

The S-IVB Battleship at Sacramento Test Center (SACTO) is fired in a nighttime test. SACTO is operated by the S-IVB contractor, Douglas Aircraft Company.

The S-IVB/IB battleship[46] firings began in 1964 in the Beta I Complex at SACTO; the battleship stage endured its initial full-duration (414.7 second) static firing with engine No. J-2003 on December 23, 1964. On January 8, 1965, DAC began the first phase of a special thrust chamber and turbopump chilldown test program to provide engine start characteristics not obtainable in normal firings. After terminating three test attempts in January because of LOX chilldown pump failures, the contractor returned the pumps to the vendor for rework. Then on January 28, test personnel replaced engine No. J-2003 with J-2013 and completed extensive rework and modification prior to resumption of engine temperature conditioning tests on February 9. Discrepancies resulted in termination of six more tests before a successful run on February 25. The temperature conditioning test program ended March 6 with all objectives achieved. Special tests of the propellant utilization (PU) system began in March and continued into April. Two tests, a successful 11-second mainstage shakedown firing using J-2 engine J-0013 and a successful full-duration firing, demonstrated the excellent performance of the PU system. No adverse effects were apparent on the stage or facility because of high or low engine mixture ratios. Also in April the S-IVB battleship stage hydraulic system maintained the J-2 engine in a centered position during engine gimballing tests. A highly successful hot-gimbal, full-duration test on May 4 concluded the IB battleship hot-firing test phase. A series of aft environmental tests on May 13 and May 14 concluded the remainder of the battleship test program for the IB configuration. Conversion of the battleship stage to the Saturn V configuration commenced.[47]

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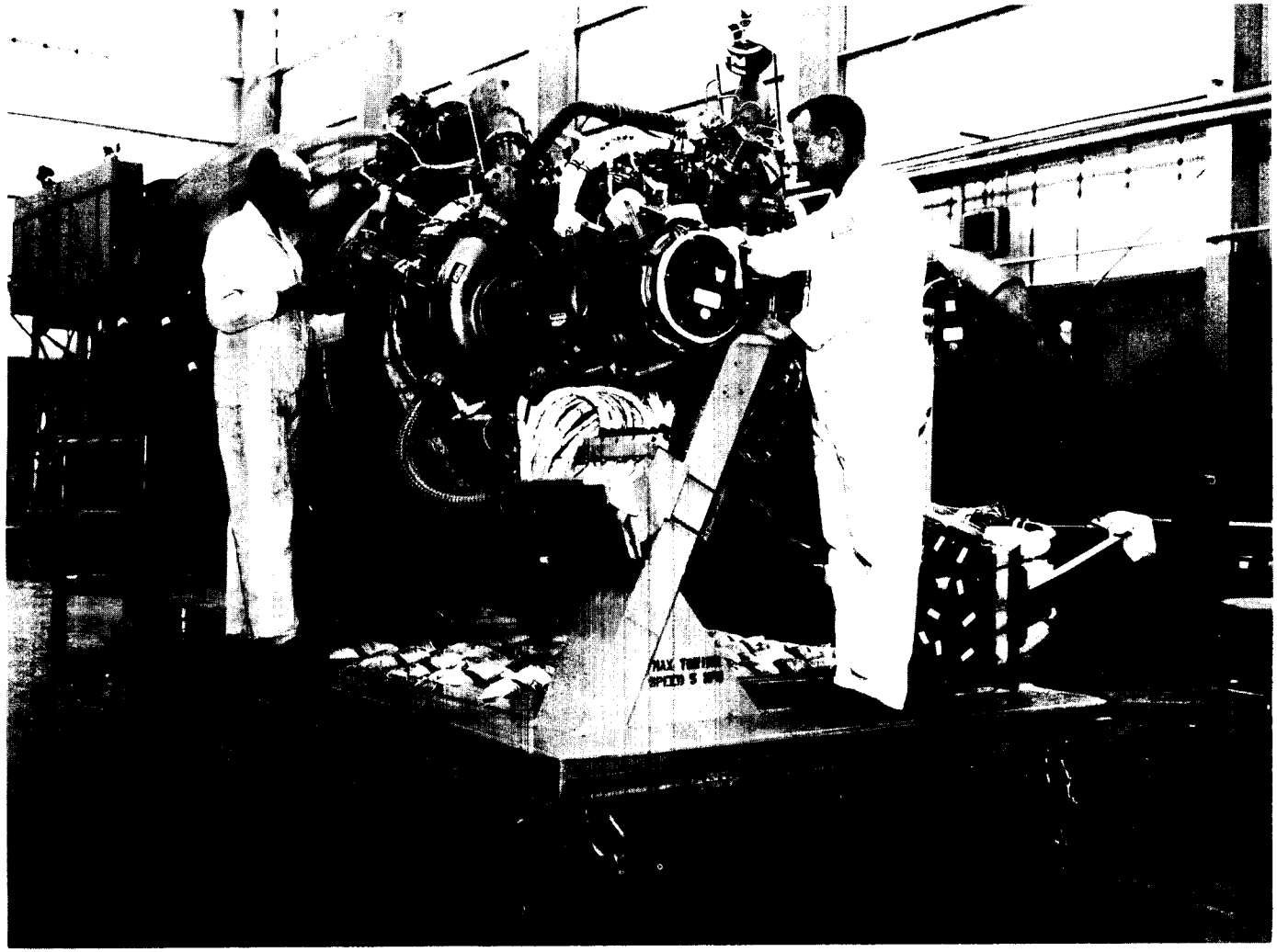
46. For details of the 1964 tests see MSFC, MHM-10, p. 73.

The battleship configuration duplicates the flight stage in all aspects with the exception that propellant containers are of heavier thickness. During battleship tests, engine firings are conducted to thoroughly evaluate the engine/stage performance, propellant feed system operation, and compatibility of all stage systems with engine systems.

47. DAC, SM-46960, Issue 30, p. 2; SM-47077, Issue 31, p. 1; SM-47145, Issue 32, p. 2; SM-47199, Issue 33, p. 2; and SM-47234, Issue 34, p. 1.



J-2 ENGINE INSPECTION

Test Laboratory technicians inspect the first J-2 engine received at MSFC. The engine arrived in March 1965 for use in cold-flow testing.

Construction of an S-IVB battleship test facility to provide flight support testing for the Saturn IB and Saturn V programs continued at MSFC. The MSFC tests would investigate and determine engine and stage operating limits, would investigate and determine possible simplification of engine and propellant conditioning systems, and would better define restart capabilities.[48] Configuration changes resulting from the DAC S-IVB/IB battleship firings and from qualification of other components caused some procurement delays for hardware to support the MSFC program. Delivery of hardware for the program was also constrained due to component shortages and priority of components for the S-IVB/IB flight stages.[49] Even so, MSFC Test personnel nearly readied the stand for activation in June and July with facility loading tests. On July 31 a successful thrust chamber chill down test was conducted with the facility, and in August the first S-IVB test occurred. From August 2 through December 17 the Test Laboratory conducted 11 firings in the facility for a total firing time of 2,316.37 seconds.[50] Hardware deliveries from DAC to support the program improved in December and were expected to continue in the future without further delay.[51]

Rocketdyne accomplished flight qualification of the 200K J-2 engine[52] in 1965. The engine contractor completed the flight rating tests (FRT) in July. In the FRT test series one engine (J-2023) successfully performed in 25 tests, accumulating a total firing time of 2,752 seconds. On completion of the FRT series Rocketdyne corrected problems associated with the start sequence. The correction involved the addition of a 50-millisecond delay in opening of the gas generator valve to prevent occurrence of a temperature spike in the gas generator, to eliminate the possibility of back flow of the gas generator combustion products into the gas generator LOX line, and to aid the ramping of the main LOX valve from its initial

48. P&VE Lab., MPR-P&VE-65-5, p. 34.

49. DAC, SM-47313, Issue 36, p. 3; SM-47384, Issue 38, p. 4; SM-47423, Issue 39, p. 3; and SM-47486, Issue 40, p. 3.

50. Test Lab., Addendum to Test Lab. Hist. Rpt., Jan. 1 - Dec. 31, 1965, pp. 1-3.

51. DAC, SM-47522, Issue 41, p. 3.

52. For details of the 1965 J-2 engine R&D history see the J-2 Engine section of Saturn V Chapter which follows this Saturn IB Chapter.

position to full open. Following correction of the start sequence, Rocketdyne on December 2 began the formal qualification test program for the 200K J-2 engine. In the period December 2 through December 17, technicians fired one engine in 30 consecutive tests to accumulate a total of 3,774 seconds firing time. Analysis of the tests revealed that all objectives were achieved; only one design deficiency, the start tank discharge valve bellows seal, became evident. By December 31 Rocketdyne completed redesign of the seal; it will be qualified in early 1966.[53]

Qualification of the auxiliary propulsion system involved four test phases. DAC completed Phase I qualification (engine cluster design evaluation) of the APS in October 1964 and began modifying the module for the second phase of tests.

Phase II tests to evaluate the APS module design at sea level conditions started at SACTO in March and ended on June 30. Technicians on April 16 conducted a four-hour 30-minute test simulating module firing during S-IVB orbit. This was followed by four successful Phase II APS mission profile tests, performed April 22, May 7, June 2, and June 4. A successful attitude effects test on June 30, during which technicians evaluated module performance while firing the module in a horizontal and an inverted position, ended the Phase II program. This phase of tests isolated several problems, the foremost being binding of a bellows in the fuel tank during purging operations. The binding was attributed to the inside diameter of the tank being out of tolerance. Corrective measures required a change in the tank manufacturing process to decrease the tolerance, and to allow for better control over the buildup of the tank bellows assembly. Other problems concerned improper operation of the quad check valves, helium line fill check valves, disconnects, and solenoid valves of the propellant control module and engines. Prevalent leakage was attributed to flow of the teflon valve seats. DAC discontinued use of hot gaseous nitrogen (GN_2) for purging of the module after deciding that it probably overheated the hardware

53. Engine Program Off., QPR-Eng-66-1, p. 21.

and caused a number of the failures. Contamination (metal particles) caused the solenoid valves to stick, and design engineers added a filter to avoid this.

Following the Phase II tests workmen removed the APS module from Complex Gamma Test Cell 2, disassembled and cleaned it, and then placed it in the Maintenance and Assembly Building for use in checking out the GSE.[54]

The Phase III APS tests with a new module occurred at the Huntington Beach Space Simulator. Phase III testing began in early April and ended successfully on April 30. The test objectives included thermodynamic design integrity at high and low temperature extremes and system leakage verification under vacuum conditions. After the tests, workmen converted the module for use in the S-IVB-201 acceptance firings in lieu of the flight APS modules. Conversion included replacement of the engine valves with complete engines and other minor modifications.[55]

Phase IV APS tests consisted of module preliminary flight rating tests to ensure that the design met all mission requirements. Vibrational tests of components preceded the first profile firing. Vibrational testing of the pneumatic control module in the radial, tangential, and thrust axes ended in July. Helium flow tests and operational performance tests occurred in August. APS ullage engine vibration qualification followed in September. After this test engineers discovered cracks in the engine trunion mounts and the nozzle exit flange. DAC returned one of the two fired engines to Rocketdyne, which welded a back-up ring to the trunnion mounts and the nozzle exit flange. Follow-up vibration and shock tests of the repaired engine were successful, as were tests of an unfired engine with the fix incorporated. On completion of the vibration tests, DAC redesigned the Phase IV APS module to incorporate fixes for the problems

54. DAC, SM-46960, Issue 30, pp. 36-37; SM-47077, Issue 31, pp. 45 and 48; SM-47199, Issue 33, p. 53; SM-47234, Issue 34, pp. 2 and 45; SM-47276, Issue 35, p. 52; and SM-47313, Issue 36, p. 49.

55. DAC, SM-47145, Issue 32, p. 51; SM-47199, Issue 33, p. 53; and SM-47234, Issue 34, p 46; and P&VE Lab., MPR-P&VE-65-6 (June), p. 32.

encountered. Test engineers conducted the first Phase IV flight rating test, a successful 4½-hour mission profile test, on September 30. On October 1 after loading the module with propellant and accomplishing an initial clearing burst of all engines, technicians initiated a planned six-day hold. The test objective--to demonstrate that the APS module could maintain operational capability during a minimum hold of six days --was successfully accomplished. DAC concluded Phase IV tests with a programmed 4½-hour mission profile test on October 9 which satisfied all Phase IV test objectives.[56]

DAC concluded the APS qualification test program with a Phase II(a) semi-automatically controlled performance firing on December 5. The Phase III APS module formerly converted for use in SA-201 acceptance firings was modified to incorporate redesigned components, vibration tested, and then employed in the Phase II(a) test.[57]

Materials Problems: DAC experienced two major problems in materials fabrication in 1965. One concerned weld defects and the other corrosion, both in the propellant tank assembly.

Welding problems first encountered with manufacture of the Saturn I S-IV stage showed up again as DAC began fabrication of the common bulkhead dome for the S-IVB stages. In 1964 MSFC authorized DAC to change to a TIG welding process which would produce stronger and more ductile welds. Application of the TIG method, effective in S-IVB-206, produced a number of unacceptable welds and resulted in suspension of the new process. When analysis revealed that the problem resulted from inadequately cleaned surfaces contaminating the welds, DAC changed cleaning procedures and on November 15, 1965, MSFC again approved the TIG method for S-IVB development.[58]

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56. DAC, SM-47313, Issue 36, p. 56; SM-47384, Issue 38, p. 1; SM-47423, Issue 39, pp. 1 and 40; and P&VE Lab., MPR-P&VE-65-7, p. 35; MPR-P&VE-65-8, p. 45; and MPR-P&VE-65-10, p. 21.

57. DAC, SM-47522, Issue 41, pp. 1 and 36; and P&VE Lab., MPR-P&VE-65-11, p. 27.

58. P&VE Lab., MPR-P&VE-65-6, pp. 79-81; MPR-P&VE-65-7, p. 65; MPR-P&VE-65-8, p. 105; MPR-P&VE-65-9, p. 62; MPR-P&VE-65-12, p. 53; and MPR-P&VE-66-1, p. 76.

Inspection of the propellant container of the facilities checkout stage (S-IVB-500F) and the S-IVB-201 stage, both of which were exposed to excessive amounts of moisture and water during manufacture, revealed that corrosion was the other major materials problem. Two factors contributed to the corrosion: electrolysis caused by dissimilar materials of the helium bottle connections in the LH_2 tank, and damage to the Alodine coating caused by excessive heating in the vicinity of LOX tank weldments. Both DAC and MSFC personnel worked to resolve this problem. DAC reported in December that changing the weld surface preparations and surface treatment procedures minimized the probability of corrosion.[59]

Instrument Unit

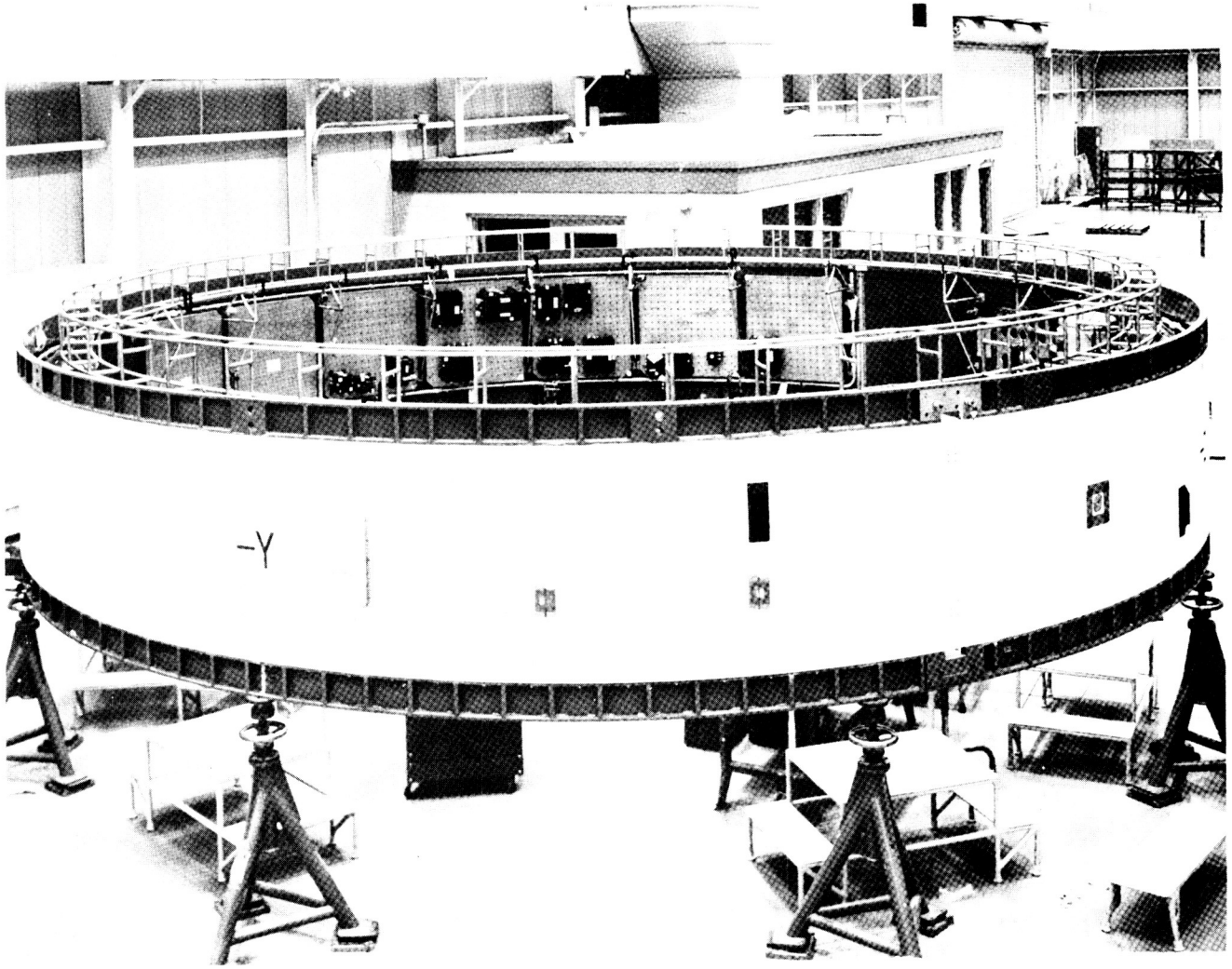
The instrument unit (IU) is a major structural and functional segment of the Saturn IB vehicle. The cylindrical structure is 21.7 feet in diameter and three feet high. It is divided into three segments to facilitate packaging, handling, and shipment. The 3990-pound unit is the nerve center of the vehicle, containing the navigation, guidance, control, and flight instrumentation systems for the vehicle. The IU is located forward of the S-IVB stage, and access to the inside of the S-IVB forward skirt area is provided through an IU door.

The basic Saturn IB/V IU design concept is derived from the flight-proved Saturn I IU. While the IB/V IU uses some of the same components as the operational Saturn I IU, the design criteria is improved upon and new technology is incorporated.

The Saturn IB and V IU's are identical except for adaptations in the IU network and control computer required by slightly extended operational periods and different vehicle dynamic characteristics.

The IB/V IU has electrical switch selectors which provide the communications link between the IU computer and each stage. The computer

59. Ibid., MPR-P&VE-65-4, p. 95; MPR-P&VE-65-5, p. 74; MPR-P&VE-65-6, pp. 76-77; and MPR-P&VE-65-12, pp. 53-54.



IU BEING ASSEMBLED

An Instrument Unit is shown in the Huntsville IBM plant's manufacturing area.

controls the mode and sequence of functions in all stages. The IU consists of six major systems: the structural system, the environmental control system, the guidance and control systems, measuring and telemetry system, and the electrical system.

MSFC is responsible for the IU design and development leading to production release of IU components. The Center has responsiblity for the overall mission and concept control throughout the development program.

MSFC made a number of IU design changes in 1965. One change concerning the onboard communications and tracking systems resulted from a continuing effort to reduce the complexity of the IU. Initial investigation revealed that it was not necessary to have both the Azusa C transponder and the Mistram transponder in the IU. Subsequent investigation showed the Azusa C to be more reliable. And, since improvement of the Mistram transponder required extended development time, MSFC recommended and NASA's Office of Manned Space Flight approved deletion of the Mistram and use of the Azusa in the Saturn/Apollo onboard systems.[60]

IBM personnel in the early months of 1965 participated in on-site training at MSFC in preparation for assuming the IU task. In March the contractor gradually began to assume the IU mission responsibility. IBM's procurement responsibility[61] became effective with the Saturn S-IU-204 for the majority of components not government furnished. Exceptions included the structural assemblies for S-IU-200/500S-II and S-IU-202 and subsequent vehicles, cable tray assembly beginning with S-IU-203, a few instrumentation components beginning with S-IU-203 and a few beginning with S-IU-205, and most of the electrical components beginning with either S-IU-201 or S-IU-202.[62] Because of the long leadtime for most of these

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60. Teletypes, Maj. Gen. Samuel C. Phillips, Dir., Apollo Program, NASA, to E. Betram, KSC, et al., "AFETR CW Radar Standardization," June 28, 1965; and "Azusa/Mistram," June 28, 1965.

61. See MHM-9, pp. 89-92, and MHM-10, pp. 81-84, for initial procurement action for major components.

62. IBM, IBM-66-966-0016, pp. 1.1/1.2; and 2.1 through 2.4.

components, their procurement received major emphasis in 1965. IBM's design definition began immediately with receipt of documentation from MSFC. Late release of some documentation and numerous engineering change orders hampered IBM's procurement actions. However, by the end of 1965 IBM had completed design definition, secured MSFC's approval of the designs for most of the components, selected subcontractors, and purchased the majority of components. The contractor had also purchased the component test equipment, inspected, tested, and installed it in the component test facility, and started manufacturing flight units.[63]

IBM personnel also participated in MSFC IU equipment initial development activities and in major development areas of non-flight programs retained at MSFC.

Buildup of the IU mockup neared completion at MSFC's Manufacturing Engineering (ME) Laboratory. With the mockup, Astrionics Laboratory personnel determined placement of navigation, telemetry equipment, and related systems such as the environmental control system (ECS), the electrical power system, measuring system, control accelerometers, control computer system, emergency detection system (EDS), C-band radar, azusa system, ST-124M platform, platform air supply, platform electronics, guidance command system, telemetry system, switch selector, guidance computer, and data adapter.

A January 7 decision called for installation of all the IU cables of the S-IU-201 configuration in the mockup, and this effort was started. MSFC transferred the mockup in an incomplete state to IBM for use as a fabrication pattern for cable forming jigs. Astrionics Laboratory furnished IBM the latest component outline drawings, and IBM proceeded to update the mockup to the latest configuration. Mockup cables for use on the stack mockup maintained at MSFC arrived from IBM in early March. Cables were found to be insufficient in length and some were of poor quality; correction of the cable length and routing discrepancies commenced. MSFC approved corrected cable length and routing discrepancies

63. Ibid., pp. 2.1 through 2.4.

for S-IU-201 and released the data to IBM for procurement and manufacturing activities in May. Procurement of the required tooling for IBM's in-house cable repair facility continued throughout 1965; 90 per cent of the required tooling was placed on order and about 60 per cent was received before the year ended. Minor cable repair commenced with the tooling received.[64]

In addition to completing the mockup as a development fixture, personnel completed checkout, assembly, test preparation, and testing of the IU ground test units. Units tested included the vibration test unit (S-IU-200V), the dynamic test unit (S-IU-200D/500D) described later in the vehicle ground test section, and the structural test unit (S-IU-200S/500S).

Vibration Tests: MSFC delivered the Saturn IB vibrational test unit to Wyle Laboratories, Huntsville, in November 1964. Preliminary test fixtures tests in December revealed excessive structure resonances. Facility modifications and preparation continued through January 27, 1965. In the first test of the S-IU-200V, on February 1, several mounting pads pulled loose from the structure during the first part of the test. Wyle personnel immediately completed repairs and on March 11 satisfactorily completed tests of the unit in the longitudinal (flight) direction. Problems involved debonding between component mounting brackets and the IU honeycomb structure, a result of poor quality control in the bonding technique; mounting bracket and LVDA/LVDC skip weld failures due to structural inadequacy; and rivet failures in the cable trays due to the test setup. Corrections required only minor redesign to overcome the skip weld failures. Evaluation of the test data indicated a structurally sound IU with only several areas of high transmissibility.

By the end of March Wyle completed reinstallation of the transverse fixtures and on April 1 and 2 completed fixture checkout in preparation

64. MSFC Saturn V Program Off., MPR-SAT-V.65-4, p. 23; MPR-SAT-V. 65-1, p. 30; P&VE Lab., MPR-P&VE-65-1, p. 23; and IBM, IBM-65-966-0007H, p. 18; IBM-65-966-0023H, p. 30; and IBM-65-966-0024H, p. 28/29.

for Phase II vibration tests of the IU. The vibration portion of the tests ended on May 30. Significant problems uncovered included bond failures, component mounting bracket failures, and excessive component mounting bracket responses. Design modifications involved having all the brackets on the IU bonded and bolted to the structure. The changes were incorporated and subjected to dynamic (shock) qualification on the IU in June and July. The shock tests ended July 31 and concluded the vibration test program.

After the tests MSFC released the S-IU-200V to IBM personnel for personnel training in disassembly and re-assembly procedures, transportation testing aboard the Pregnant Guppy and Super Guppy aircraft, and secondary road testing aboard a low-boy truck.[65]

Structural Tests: The IU structural test program consists of two units. The S-IU-200S/500S is used to verify structural segments provided by General Dynamics/Fort Worth (GD/FW), to be used in the first two flight units. The S-IU-200S/500S-II will verify structural segments furnished by NAA, Tulsa, for use in subsequent flight units.

General Dynamics delivered the structural segments for S-IU-200S/500S in December 1964, and MSFC personnel began structural fabrication of the unit. Component assembly was accomplished in the period February through March 1. On March 15 personnel moved the unit, complete except for installation of bracketry for the flight control computer, to the structural test facility. In April and early May technicians completed instrumentation of the unit, fabricated the remaining test fixtures, completed assembly of the test setup, and checked out the facility. CCSD personnel performed the tests under a modification to Contract NAS8-4016. In May, June, and July, tests involved removal and re-installation of an access door under maximum expected on-pad conditions. Optimum removal

65. Saturn I/IB Program Off., I/IB-65-1, p. 10; Saturn V Program Off., MPR-SAT-V. 65-1, p. 29; MPR-SAT-V. 65-2, p. 31; MPR-SAT-V. 65-3, pp. 3 and 40; P&VE Lab., MPR-P&VE-65-2, p. 31; MPR-P&VE-65-3, pp. 20-21 and 53; MPR-P&VE-65-4, pp. 15 and 45; MPR-P&VE-65-5, pp. 14 and 43; MPR-P&VE-65-6, pp. 13 and 45; and MPR-P&VE-65-6 (June), pp. 45-46.

and replacement time totalled 50 minutes. Test data indicated modification. Changes recommended regarded the number and size of fasteners, use of auxiliary door handles, and training techniques, and redesign of the door. MSFC's P&VE Structures Division initiated a study to determine the necessary redesign.

In August CCSD successfully qualified the S-IU-200S/500S unit at simulated flight cutoff load conditions for the Saturn IB. The maximum tension condition test, the last of the Saturn IB series on August 13, was also carried to 140 per cent limit loads to satisfy Saturn V test requirements. Afterwards, technicians removed the instrumentation cables from the structure and performed a combined loading/vibration test on the S-IVB forward skirt. The S-IU-200S/500S testing ended August 20, and MSFC modified the unit to replace the facilities checkout unit damaged in de-erection activities at Cape Kennedy, discussed later in this Chapter.[66]

NAA delivered the structural segments for S-IU-200S/500S-II (NAA Unit) on April 29. After completing receiving inspection MSFC released the segments to IBM for fabrication and assembly operations. MSFC directed engineering changes including the mechanical attachment of bonded bracket rework, and prepared engineering change procedures to correct minor document deficiencies noted during receiving inspection. In May IBM continued engineering liaison with NAA, placing emphasis on the rework items for the unit. Structural assembly of S-IU-200S/500S-II by the contractor was postponed until rework and modification of S-IU-201 and S-IU-202 ended; IBM began the structural assembly on June 10. On June 14 Porta-Shear test results on flight segments at NAA revealed the need for additional tests of the S-IU-200S/500S-II segments. Out of a total of 25 tests

66. Saturn I/IB Program Off., I/IB-65-1, p. 9; Saturn V Program Off., MPR-SAT-V 65-1, p. 29; MPR-SAT-V 65-2, p. 31; MPR-SAT-V 65-3, p. 40; MPR-SAT-V 65-4, pp. 1 and 34; and P&VE Lab., MPR-P&VE-65-2, pp. 31 and 47; MPR-P&VE-3, p. 53; MPR-P&VE-65-4, p. 43; MPR-P&VE-65-5, p. 23; MPR-P&VE-65-6 (May), p. 45; MPR-P&VE-65-6 (June), pp. 23 and 45; and MPR-P&VE-65-7, p. 40.

performed on the three segments, only the access door segment had Porta-Shear values below 2000 psi; stress analysis indicated two areas should be repaired. MSFC rejected IBM's proposed rivet repairs of these two areas and directed no repairs be made to the segments. In July IBM completed fabrication of the unit as was and completed all engineering changes and rework except rivet repair work. Two of the more important engineering changes stopped all antenna cutouts on S-IU-200S/500S-II and directed redesign of the umbilical door hinge. Still unsatisfied, MSFC near the end of July requested that a new S-IU-200S/500S-II structure be built using suitable segments from the existing S-IU-200S/500S-II structure and the structure originally scheduled for S-IU-203, on which work had also been stopped. IBM began fabrication of the new structure on September 3 and completed structural assembly on September 30. The contractor delivered the unit to MSFC on October 5. At MSFC technicians completed strain gauge installation on two of the segments and drilled mounting holes for the ST-124 on the third segment. In December the unit was installed in the test setup and preparations were completed for the access door removal and reinstallation tests scheduled for the first week in January 1966.[67]

Meanwhile, product improvement on the segments and on structural fabrication techniques proved to be a major concern throughout 1965 for MSFC, IBM, NAA, and GD/FW personnel.

X-ray evaluation of the GD/FW and NAA structural segments revealed many unfilled and partially filled cells in the adhesive-bonded core-to-core honeycomb splices. Corrective action by suppliers included different methods of Epocast application, beam shear testing of samples, and investigation of techniques to repair the core splices. Also, additional engineering liaison was maintained with the suppliers, and engineering change

67. Saturn V Program Off., MPR-SAT-V. 65-2, p. 31; MPR-SAT-V. 65-3, p. 42; MPR-SAT-V. 65-4, p. 34; P&VE Lab., MPR-P&VE-65-10, p. 32; MPR-P&VE-65-11, p. 40; MPR-P&VE-65-12, p. 25; and IBM, IBM-65-966-0007H, pp. 27 and 34; IBM-65-966-0008H, p. 9; IBM-65-966-0022H, pp. 2 and 30; IBM-65-966-0023H, p. 3.

orders incorporating MSFC directed changes were made to IBM supporting structural fabrication of S-IU-201 and subsequent units.

Another problem, revealed in September as technicians checked out the S-IU-201 on the Systems Checkout stand, proved to be an "out-of-round" condition preventing proper optical alignment. IBM personnel overcame the problem in October by developing a method of aligning the ST-124 mounting frame using a plastic filler material. IBM implemented the new method on S-IU-201 at KSC and followup tests verified accomplishment of all alignment requirements.[68]

Other IU activity at MSFC involved design qualification, product improvement, and preflight certification of major government furnished components[69] and of all components for flight units S-IU-201 through S-IU-203. IBM personnel phased into this activity under guidance from MSFC personnel in preparatory training prior to initiating component checkout in the IBM component test facility.

Among the major components undergoing qualification or preflight certification, in addition to the structural segments already described, were the environmental control system components, and guidance and control system components including the ST-124 inertial platform, the launch vehicle data adapter (LVDA), and the launch vehicle digital computer (LVDC). Personnel checked out these components in subsystem, system, and integrated system configurations.

Environmental Control System Qualification: The ECS maintains the instrument temperature for all components within operating limits. Major ECS components tested included the cold plates, sublimator, ST-124 stablized platform shrouds, ground support cooling unit (GSCU), gas bearing pump, water accumulator, methanol/water pump, and the temperature control valve assembly.

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68. IBM, IBM-65-966-0020H, pp. 7 and 41-42; IBM-65-966-0022H, p. 23; IBM-65-966-0023H, pp. 9 and 22-23; and IBM-65-966-0024H, p. 7.

69. Government-furnished components include those major IU components purchased from industry and furnished IBM as lead contractor. See MHM-10, p. 81, for additional information on these components.

Cold plates from several manufacturers were subjected to thermal, fluid flow, and vacuum tests for initial performance evaluation. Technical difficulties caused a slippage in delivery of cold plates by NAA's Atomics International Divison. The most serious problem was corrosion caused by interaction between the silver material used in the diffusion bonding process and the water/methanol solution used in the cooling operation. MSFC personnel began an in-house investigation of the problem. The Center also conducted a comparative investigation of the Atomics cold plates and of cold plates furnished by the Avco Corporation. This investigation revealed that the Avco plates were suprerior and, to avoid critical cold plate unavailability, MSFC authorized IBM to procure backup cold plate development from Avco. IBM placed a letter contract with Avco on April 1, 1965, for the S-IU-202 and S-IU-203 plates. MSFC completed qualification of the cold plate design in September. Investigation of two processes to overcome the corrosion problem continued through December. Results of the investigation indicated that treatment of plates with chromate had no pronounced effect on corrosion, but that plates treated with an epoxy coating remained free of corrosion after 80 days' exposure to the methanol/water solution.[70]

In extensive development tests of two sublimators, a 12-module type and a 7-module type, both displayed excellent operating stability and responded quickly and positively to changing heat loads. The initial 12-module sublimator had excess heat transfer, however, and was redesigned to the 7-module type. The sublimator was also redesigned in July to vent internally instead of externally, since venting of the water vapor exhaust directly into space would cause an unacceptable amount of disturbing torque to the vehicle. Qualification of the prototype sublimator occurred in August.

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70. P&VE Lab., MPR-P&VE-65-5, pp. 29 and 77; MPR-P&VE-65-6 (June), p. 33; MPR-P&VE-65-8, p. 45; MPR-P&VE-65-10, p. 63; MPR-P&VE-65-12, p. 55; Saturn V Program Off., MPR-SAT-V. 65-1, p. 31; and IBM, IBM-65-966-0007H, p. 5.

Qualification of the redesign unit required additional shock, vibration, and performance tests; preflight certification for this unit ended in October.[71]

Engineers designed three heat exchangers (the electronics box cold plate, the platform cooling shrouds, and the gas bearing gas supply heat exchanger) as the cooling system for the ST-124M system. These maintained thermal control during thermal, vacuum, and fluid flow tests performed with an operating ST-124 stabilized platform (production unit 3) and associated equipment. During the preflight certification tests the cooling system maintained the critical ST-124-3 electronic equipment within specified operating ranges.[72]

The GSCU is a self-contained chilling and pumping unit used initially to fill onboard IU and S-IVB methanol/water systems from the GSCU methanol/water reservoir and then for drain and purge operations should a launch delay occur. MSFC completed acceptance tests on the second GSCU on March 5 and transferred this unit to IBM's facility. Functional performance tests on the first or prototype GSCU ended at MSFC in September. Test results showed that the GSCU was capable of fulfilling the prelaunch support requirements. The results also indicated several problem areas inasmuch as defective components required replacement of the mixing valve twice, the temperature control box three times, and the temperature sensors once.[73]

Five gas bearing gas supply (GBGS) heat exchangers arrived at MSFC in May for qualification. One leaked from one of the GN_2 outlet tubes

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71. P&VE Lab., MPR-P&VE-65-3, p. 46; MPR-P&VE-65-4, p. 38; MPR-P&VE-65-6 (June), p. 33; MPR-P&VE-65-7, pp. 28 and 35; MPR-P&VE-65-8, p. 38; MPR-P&VE-65-10, p. 22; MPR-P&VE-65-12(S), pp. 4-5; W. T. Buckels, et. al., P&VE Lab., Development Testing of the Instrument Unit Environmental Control System, (TMX-53567), p. 12; and W. T. Buckels, Development Testing of the Sublimator, Saturn IB and Saturn V Instrument Unit Environmental Control System, IN-P&VE-P-66-3, pp. 1-3.

72. P&VE Lab., TMX-53567, p. 12; and Saturn V Program Off., MPR-SAT-V. 65-2, p. 33.

73. P&VE Lab., TMX-53567, pp. 4 and 14; and MPR-P&VE-65-4, p. 14; and MPR-P&VE-65-5, pp. 28-29.

after vibration and shock testing, and three failed during proof pressure testing by leaking at the GN_2 tube fittings. Fabrication of a new heat exchanger began. The redesigned heat exchangers in September successfully completed development qualification tests. Redesign of the gas bearing regulator assembly to meet vibration, shock, and pressure test requirements ended also in September. It was qualified in October.[74]

Preflight certification tests of the prototype water accumulator ended in October. The functional tests revealed a problem in the GN_2 pressurization system. Modification involved the addition of a bleeder assembly to provide an air flow path beneath the bladder to the ventport. This prevented a buildup of trapped air on the GN_2 side of the accumulator bladder and allowed adequate depressurization of the accumulator during simulator ascent tests. The redesigned accumulator underwent tests in December.[75]

Functional tests of the prototype methanol/water pump revealed several problems in the electrical system. An electrical short in the pump caused the failure of several transistors in the pump power supply circuit. Also a methanol/water leak into the pump motor caused the motor to demagnetize. The resulting electromagnetic radiation (noise to signal ratio) invalidated the water flow data provided by the sublimator water flow meter. MSFC began modification of the coolant pump and asked IBM to study use of a backup pump. Modifications were incorporated in the S-IU-201 flight pump. Even so, the S-IU-201 pump was found to be defective and was replaced at KSC by the S-IU-202 pump. The modified prototype pump completed preflight certification at MSFC in December. The IBM design of the requested backup pump and necessary ECS redesign awaited MSFC approval in December.[76]

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74. Ibid., MPR-P&VE-65-6 (May), p. 39; MPR-P&VE-65-8, pp. 38 and 45; MPR-P&VE-65-9, p. 20; and MPR-P&VE-65-10, p. 23.

75. Ibid., MPR-P&VE-65-10, pp. 22-23; MPR-P&VE-65-11, p. 29; MPR-P&VE-65-12(S), p. 5; and TMX-53567, p. 14.

76. Ibid., TMX-53567, pp. 14-15; MPR-P&VE-65-12(S), p. 5; and IBM IBM-65-966-0023H, p. 10; and IBM-65-966-0024H, p. 9.

The ECS systems tests with an IU ECS mockup verified fill, drain, and purge operations of the GSCU and proper flow distribution of the cold plates for each individual component. Several full-duration tests simulating the heat loads imposed on the ECS during flight helped to determine the system stability and response characteristics. Generally, the ECS components performed satisfactorily in all the systems tests.[77]

Guidance and Control System Qualification: The guidance and control system determines the course of the vehicle through space and adapts that course to fulfill mission requirements. The system incorporates provisions for alignment and checkout during prelaunch tests of the vehicle at the launch facility; determines the instant at which the vehicle has attained the velocity and altitude required for injection into earth orbit; and issues the cutoff command signal to the S-IVB stage J-2 engine.

Receipt and qualification of the components for this system continued throughout 1965. Major components included the ST-124M platform, the LVDC and the LVDA, and an analog control computer. Qualification involved structural mounting tests, environmental tests, and simulation runs with test equipment.

Qualification of the mounting brackets for components of the system started at Brown Engineering Company (BECO) in February. BECO curtailed tests of the ST-124 mounting frame and the LVDC/LVDA support brackets in April because of failures due to high vibration levels. The brackets underwent modification and completed tests in June.[78]

Bendix Corporation delivered the first ST-124M to MSFC in March, and delivery of the platforms continued throughout 1965. In the second quarter of 1965 the supplier discovered corrosion on some of the silver plated wiring in a platform. The first and subsequent platforms were then rewired with nickel plated wire not subject to corrosion. Design

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77. Ibid., TMX-53567, pp. 11 and 23; MPR-P&VE-65-8, p. 39; MPR-P&VE-65-10, pp. 22-23; and MPR-P&VE-65-11, p. 30.

78. P&VE Lab., MPR-P&VE-65-2, p. 31; MPR-P&VE-65-3, p. 21; MPR-P&VE-65-4, p. 15; MPR-P&VE-65-5, p. 14; and MPR-P&VE-65-6 (May), pp. 12 and 13; MPR-P&VE-65-6 (June), pp. 12-13; and MPR-P&VE-65-7, pp. 11-12.

and fabrication of the ST-124M viewport boot enclosure and test fixture ended in June and leakage tests commenced. The tests ended when a clamp on the simulated window frame slipped because the enclosure failed to fit the frame properly. Technicians made the proper design changes and resumed the tests. The viewport leakrate tests, vibration tests, and vacuum tests ended successfully in July. Vibration tests of the ST-124M platform ended in October. The ST-124M filter test program commenced at Hayes International on November 2. Results indicated a filter life of 24 to 28 hours and methods of improving filter were recommended. One recommendation involved an increase of spare parts stock from three to 15 units at Launch Complex 34 because of the short life expectancy of some of the parts. The ST-124M cooling system provided adequate control of the platform and associated equipment during ECS tests; however, thermal tests simulating vehicle skin orbital temperatures revealed that critical component temperature limits would be exceeded in an operational flight mission. The direct conduction path from the hot vehicle skin to the ST-124M through the flight mounting bracket would cause the latter problem. Redesign began on an insulation structurally and thermally acceptable that would not impair alignment of the platform. IBM developed a method for overcoming the problem by aligning the mounting frame with plastic filler material.[79]

IBM/Owego experienced fabrication difficulties with the multi-layer printed circuit boards for the first launch vehicle data adapter (LVDA). This delayed delivery of the breadboard and its test equipment to MSFC approximately four months. It arrived from IBM's Owego facility on March 11. The Simplex Prototype 2 launch vehicle digital computer (LVDC) arrived on June 10. By the end of June IBM had delivered three computers and three checkout stations to MSFC and IBM in Huntsville. The LVDC/LVDA for the Saturn IB Breadboard became available for operation in October.

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79. Saturn V Program Off., MPR-SAT-V. 65-1, p. 31; MPR-SAT-V. 65-2, p. 33; and MPR-SAT-V. 65-3, p. 43; P&VE Lab., MPR-P&VE-65-6 (May), pp. 12-13; MPR-P&VE-65-6 (June), p. 45; MPR-P&VE-65-7, p. 22; MPR-P&VE-65-10, p. 32; MPR-P&VE-65-11, pp. 10-11; and MPR-P&VE-65-12(S), p. 6.

Structural qualification of the LVDA and the LVDC revealed that both failed to meet vibration specifications. MSFC designed an isolation system using Lord isolators to provide six degrees of freedom for the two components. Shock and vibration tests of the isolation bracketry ended in December.

Meanwhile, MSFC and IBM/Huntsville worked together on checkout of test equipment and on preparation of checkout tapes for simulation runs leading to the final flight program tapes. IBM delivered to MSFC on May 28 a preliminary flight program for SA-201. MSFC used the program in final checkout and integration of the LVDC/LVDA Simulator and the Advanced Vehicle Simulator. Problems were worked out and the simulators then used as the all-digital flight program verification tool.

On August 15 MSFC technicians accomplished a minimum LVDC simulation with a complete run on an early SA-201 flight tape through S-IVB stage cutoff. This helped to verify the vehicle and the LVDC simulators and communications between them. Specific items verified included prelaunch simulation, switch selector simulation and communication, LVDC memory printout, navigation accuracy verification, and discrete input and interrupt communication and processing.

On September 9 MSFC issued several waivers to accept the LVDC/LVDA flight system. With two exceptions the first flight program tape was also completed in September. After checkout of the preflight programs on production LVDC/LVDA 2, the components were readied for installation in S-IU-201.

In November, MSFC and IBM personnel completed processing all change requests necessary to generate the final S-IU-201 flight program. Flight program verification ended in November, and MSFC sent two early tapes to KSC: Update 01 on November 15 and Update 02 on November 24. On November 27 MSFC delivered Revision C of LVDC preflight program tape to KSC. This program, extensively checked out in the laboratory and exercised in MSFC's Saturn Development Breadboard Facility (SDBF), was loaded on the LVDC prior to its installation in the IU.

In addition to checking out prototype and S-IU-201 components in 1965, MSFC and IBM received and checked out most of the components for S-IU-202 and 203. Fabrication, assembly, and checkout of these units were underway as was mission engineering on flight program tapes for these units.[80]

Test Vehicle Status

In addition to structural, component, and system qualification tests for each stage at contractor development sites, two primary vehicle ground test programs are required to verify the Saturn IB vehicle configuration and facilities prior to flight vehicle acceptance testing and launch. They are the dynamic test program and the facilities checkout program.

Saturn IB Dynamic Tests

The dynamic test program verifies the vehicle's structural, guidance and flight control dynamic flight characteristics for each flight configuration.

The Saturn IB flight vehicle has four flight configurations that differ enough for each to require a separate series of dynamic tests. The configuration for SA-201, SA-202, SA-204, and SA-205 consists of the launch vehicle plus the Apollo spacecraft without the Lunar Excursion Module (LEM); the designation of this configuration in the dynamic test program is "SA-201/SA-202." The SA-203 configuration has no spacecraft and consists of the launch vehicle and a simple nose shroud. SA-206 is the first vehicle to fly a LEM and will use a boilerplate Command Service Module (CSM) rather than a standard CSM. SA-207 and subsequent Saturn IB vehicles

80. MSFC Saturn V Prog. Off., MPR-SAT-V. 65-1, p. 31; MPR-SAT-V. 65-2, p. 34; MPR-SAT-V. 65-3, p. 43; MPR-SAT-V. 65-4, p. 36; P&VE Lab., MPR-P&VE-65-6 (June), p. 13; MPR-P&VE-65-7, p. 11; MPR-P&VE-65-8, pp. 12-14; MPR-P&VE-65-9, p. 30; MPR-P&VE-65-12, pp. 11-12; and IBM, IBM-65-966-0008H, p. 17; IBM-65-966-0010H, p. 13; IBM-65-966-0020H, pp. 15-16; IBM-65-966-0022H, pp. 13-14; IBM-65-966-0023H, pp. 13-16; and IBM-65-966-0024H, pp. 13-17.

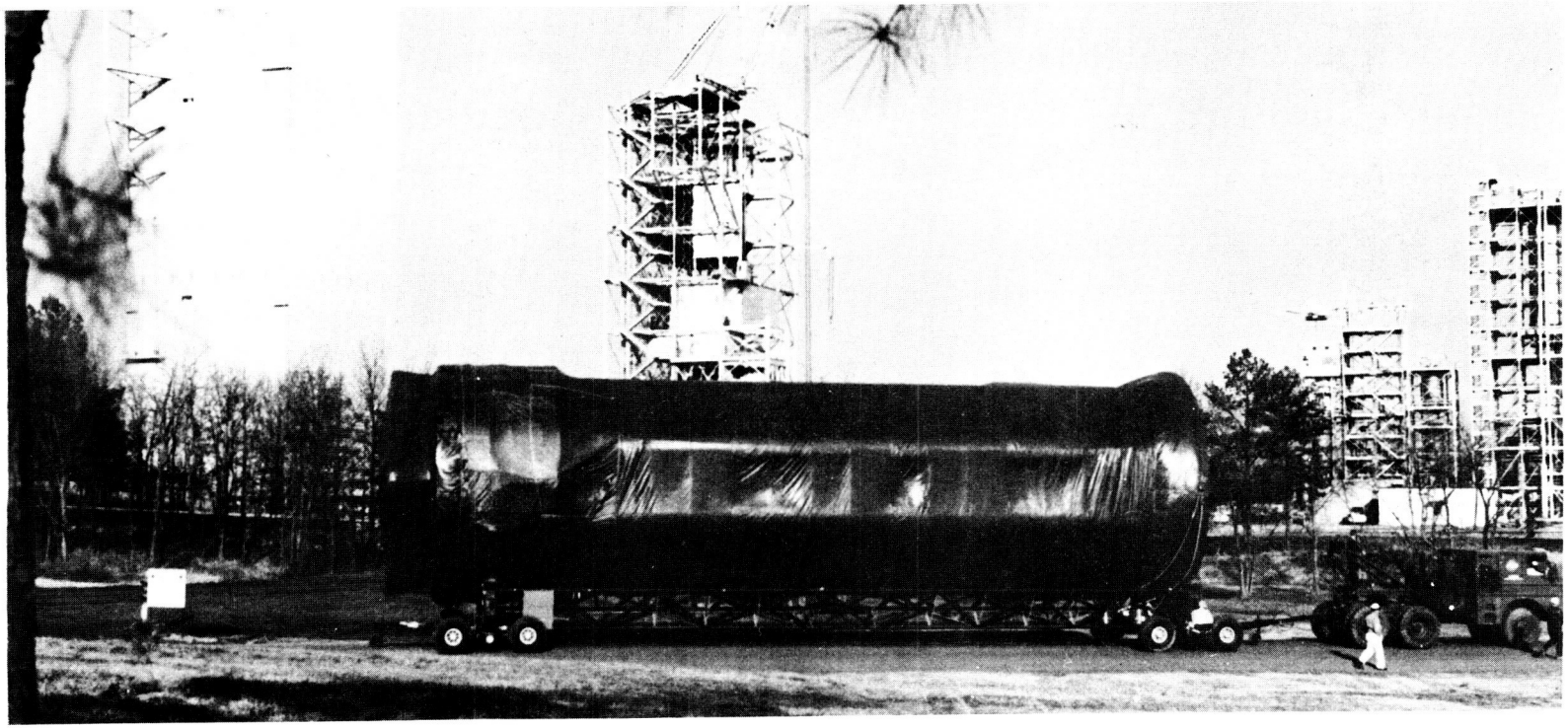
scheduled for the Manned Lunar Landing Program will consist of the launch vehicle and a complete Block II spacecraft; designation of this configuration in the dynamic test program is "SA-207."

MSFC completed modification of the former S-I Dynamic Test Stand for Saturn IB testing in early January. In January and February the primary contractors delivered all the stages and components required for the four IB series of dynamic tests.

CCSD modified the former Saturn I dynamic test stage (SA-D5) to the Saturn IB configuration (S-IB-D/F) for use first in dynamic tests and then in facilities checkout of Launch Complexes 34 and 37 at KSC. The contractor shipped the stage to MSFC in December 1964, and it arrived on January 4, 1965. The S-IVB dynamic test stage (S-IVB-D), which had been shipped by DAC aboard the States Marine Ship Aloha State to New Orleans and then transferred to the river barge Promise for the remainder of its trip to Huntsville, also arrived at the MSFC dock on Janaury 4. Test engineers installed both the S-IB-D/F and the S-IVB-D in the dynamic test tower in January and began installing instrumentation and checking out equipment in preparation for beginning the SA-203 series of tests.

Assembly of the dynamic test instrument unit (S-IU-200D/500D) ended at MSFC on February 1; it was moved on February 8 to the test tower and installed atop the S-IVB-D stage. NAA, contractor for the Apollo spacecraft, flew the Spacecraft LEM Adapter (SLA) from its Tulsa plant to MSFC as a bundle swinging from a giant helicopter because its size prohibited conventional air transport. The SLA, which would simulate the SA-203 nosecone shroud in the SA-203 dynamic configuration, arrived on January 19, but suffered damage on landing at MSFC and had to be repaired. Its repair delayed start of the SA-203 tests from February 15 to February 18.

The payload hardware, SM, CM, and the LEM Test Article (LTA-2) for changing the vehicle to the SA-202 configuration arrived separately by the Guppy aircraft. The Boilerplate 27 SM arrived from the Manned



S-IB DYNAMIC STAGE ARRIVES

The S-IB dynamic stage arrives at MSFC early in January 1965 from MAF for a series of tests as part of the Saturn IB dynamic vehicle.

Spacecraft Center (MSC) on February 13, the CM on February 14, and the LTA-2 on February 18. All of it was stored until mid-March.[81]

The first series of dynamic tests began on February 18 and lasted through March 2. Test personnel completed a dynamic analysis of the SA-203 S-IVB stage configuration to determine the maximum propellant velocity relative to the vehicle at cutoff. They also completed a lateral vibration analysis on the S-IB 203 stage configuration for liftoff, and a Saturn IB fin cantilevered vibration analysis for normal modes.[82]

Upon completion of the SA-203 configuration testing, technicians installed the Boilerplate 27 spacecraft (CM and SM) atop the SLA for the SA-201/SA-202 configuration. The second series of dynamic tests began on March 15. On March 27 the S-IB-D/F spiderbeam assembly crossbeam web cracked. This failure necessitated repair of the spiderbeam and rerun of some of the SA-201/SA-202 tests to investigate some unusual dynamic characteristics. By April 2 CCSD fabricated a fix for the spiderbeam and resumed testing. The SA-201/SA-202 tests continued through April 19 and included several reruns in pitch, yaw, and roll, a longitudinal (Pogo) series at six field conditions, and a Pogo test with fuel flow.[83]

Addition of the LTA-2 near the end of April converted the dynamic vehicle to the SA-207 and SA-206 configurations. All vehicle tests in the SA-207 configuration ended on May 12.

Original plans called for termination of the S-IB stage testing on May 15 so the stage could be sent to KSC for launch pad checkout. However, KSC decided and IB Program officials agreed to use the first S-IB flight stage for pad checkout. This permitted full vehicle dynamic testing in

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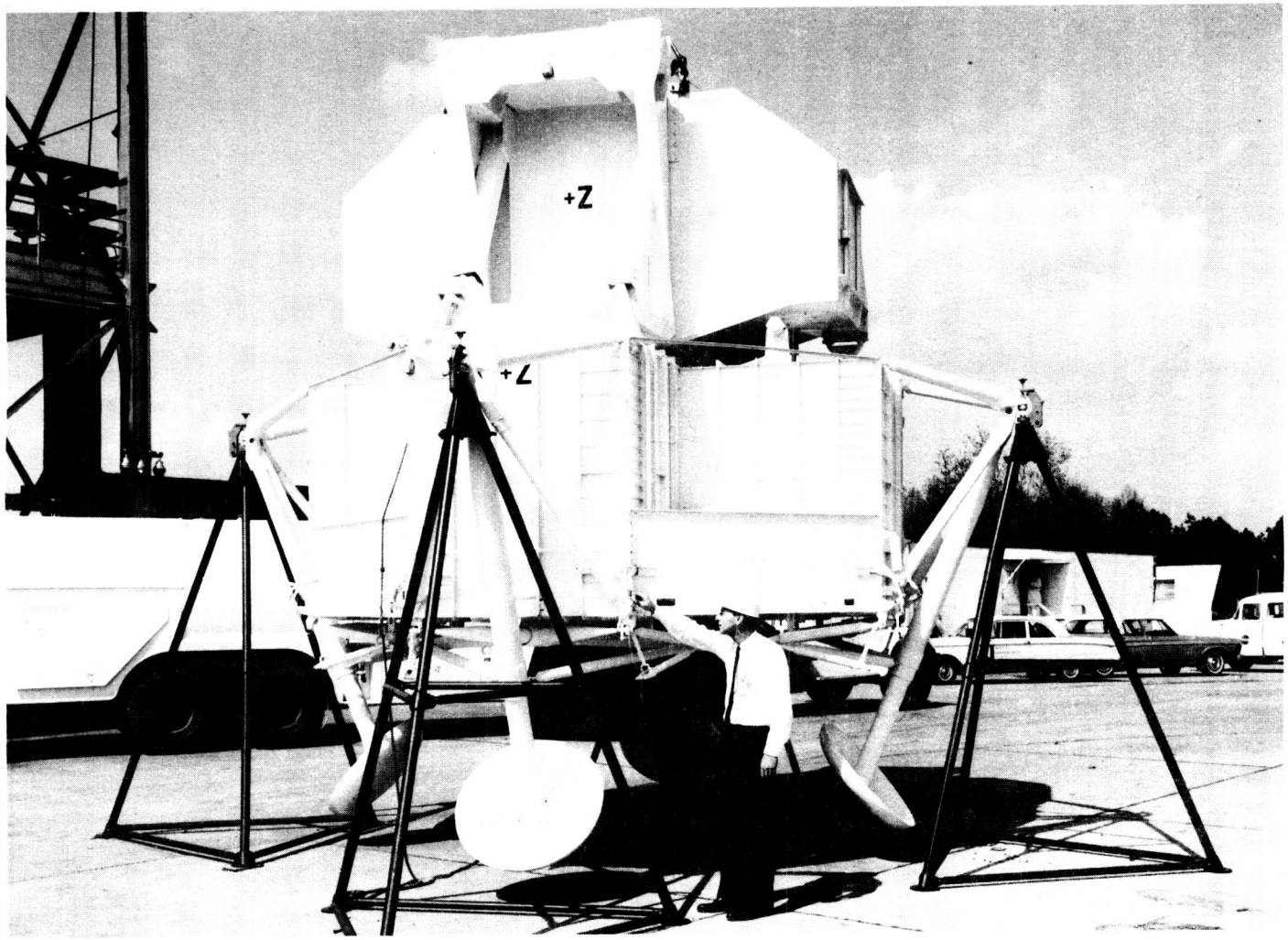
81. Saturn I/IB Program Off., I/IB-65-1, p. 7; Saturn V Program Off., MPR-SAT-V-65-1, p. 30; P&VE Lab., MPR-P&VE-65-2, p. 43; MPR-P&VE-65-3, p. 54; and PAO, Press Release 65-13, Jan. 19, 1965.

82. P&VE Lab., MPR-P&VE-65-3, p. 55; and Saturn I/IB Program Off., I/IB-65-1, p. 7.

83. Saturn I/IB Program Off., I/IB-65-1, p. 8; and P&VE Lab., MPR-P&VE-65-5, pp. 44 and 48.



LEM TEST MODEL AT MSFC

A P&VE Lab engineer inspects a test model of the Lunar Excursion Module provided by the builder for dynamic testing of the Saturn IB/Apollo space vehicle.

the SA-206 configuration to continue at MSFC. The series of tests on the SA-206 configuration ended May 27 and concluded the total vehicle dynamic test phase. Vehicle disassembly began immediately in preparation for upper stage tests.

The upper stage test (S-IVB, IU, Payload) phase began about August 1 and continued through September 11. This phase ended the entire Saturn IB dynamic test program as scheduled. Conversion of the hardware required in support of Saturn V dynamic tests began.[84]

Facilities Checkout Tests

The facilities checkout vehicle is used to check out stage and vehicle development, test, and launch facilities, GSE, and transportation equipment.

The first facility test article (S-IB-D/F) delivered to MSFC was never actually used in facility checkout except in the facility checkout of the dynamic test stand. The failure of its spiderbeam during the dynamic tests and the subsequent delay in completion of the dynamic test program prompted the decision in May to extend the vehicle dynamic tests using S-IB-D/F. Program officials authorized use of S-IB-1, then in temporary storage at Michoud, in the facility checkout of the launch complex. Following this decision CCSD began expediting poststatic checkout and modification of the S-IB-1 stage. With checkout completed on July 20, shipping preparations commenced. CCSD shipped the stage to KSC aboard the Promise barge on August 9. It arrived on August 14 and happened to be the first space cargo barged through the newly constructed Port Canaveral locks.[85]

Toward the end of January 1965 DAC began expediting redesign and delivery of certain vendor-supplied items for the S-IVB facilities

84. Saturn I/IB Program Off., I/IB-65-1, p. 8; P&VE Lab., MPR-P&VE-65-5, p. 44; MPR-P&VE-65-6, p. 46; and Saturn V Program Off., MPR-SAT-V-65-3, p. 27.

85. MAF, Hist Rpt., July - Dec. 31, 1965, p. 10; and Saturn Flight Evaluation Working Group, MSFC, Results of the First Saturn IB Launch Vehicle Test Flight, AS-201, MPR-SAT-FE-66-8, May 6, 1966, p. 13.

checkout stage (S-IVB-500F). The contractor also started expediting the manufacturing and final assembly process in hopes of completing the stage for delivery in early February. Turnover of the stage to NASA occurred at Seal Beach, California, on February 12. It was loaded aboard a special barge Orion to be towed up the Sacramento River to SACTO. Its successful arrival at SACTO on February 17 verified the water and road transportation methods and routes, thus assuring safe handling and transport of future flight stages.

At SACTO on February 18 workmen installed the S-IVB-500F stage in the recently completed Beta 3 Test Stand, the stand to be used in acceptance-firing the flight stages. Preparations for checking out the operational readiness of the stand and GSE with S-IVB-500F, which resembled a flight stage in every important detail except for an installed engine, continued through March and most of April. On April 21 test engineers conducted a highly successful cryogenic propellant loading test of the stage in a manual mode, and on May 1 completed Beta 3 Test Stand checkout with a successful automatically controlled cryogenic loading test of the S-IVB-500F. Workmen removed the stage from the stand on May 3 and after post-test inspection transported it on June 10 down the Sacramento River to Seal Beach.

At Seal Beach the S-IVB-500F was transferred on June 13 from the Orion to the S.S. Point Barrow freighter for transport to Cape Kennedy via the Panama Canal.[86] It passed through the Panama Canal on June 22, arrived at Michoud, Louisiana, on June 26, and entered Port Canaveral on June 29. Workmen unloaded the stage the next day and began preparations for using it in propellant loading tests on LC-34.

Mechanical assembly of the IU facilities checkout vehicle (S-IU-200F/500F) began at MSFC on February 8. Installation of the antenna mount insert started on March 8. In March the assembly operation suffered a

86. DAC, SM-46960, Issue 30, p. 2; SM-47077, Issue 31, p. 2; SM-47145, Issue 32, p. 2; SM-47199, Issue 33, p. 2; SM-47234, Issue 34, p. 1; and SM-47276, Issue 35, p. 1; and PAO, Press Release No. 65-145, June 10, 1965.

temporary delay caused by lack of documentation. By April 2, however, technicians completed all structural modification to the unit and by April 29 completed the assembly operations. After checkout of the unit MSFC transported the S-IU-200F/500F on June 19 to Michoud. There it was placed in storage to await reshipment aboard the Promise on August 9. It arrived at KSC on August 14 along with the S-IB-1 stage.[87]

In May, during the preliminary checkout of LC-34 which preceded vehicle checkout, technicians discovered a problem concerning access into the IU from LC-34 and LC-37. The problem, caused by elevation of the LEM servicing platform just above the IU, would exist only when the vehicle's payload included the LEM (the first being SA-206). MSFC representatives visited KSC on May 19 to help resolve the problem and to shorten the lead time for any new hardware delivery required.[88] Effort to resolve this problem continued throughout 1965.

Pad erection of the facilities checkout vehicle began in August. After completing preflight checkout of the S-IB-1 stage at KSC, technicians on August 18 erected it on LC-34. The S-IB-1 served as a spacer for the S-IVB-500F during propellant tankings to verify the LOX and LH_2 loading systems. The S-IU-200F/500F was erected atop the S-IVB-500F.

Vehicle checkout of LC-34 began on August 18 and, except for several days lost to Hurricane Betsy, progressed extremely well. During instrument compartment leak tests on September 10, overpressurization damaged the forward bulkhead on a fuel tank of S-IB-1, requiring replacement of the tank. The replacement was accomplished without any delay in checkout operations. Technicians completed the automatic, computer controlled propellant loading of S-IVB-500F on September 23.[89]

On completion of the tests on September 29, KSC technicians began dismantling the vehicle from the pad. The S-IU-200F/500F received

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87. Saturn V Program Off., MPR-SAT-V-65-1, p. 29; MPR-SAT-V-65-2, pp. 2 and 33; and MPR-SAT-V-65-3, p. 43.

88. P&VE Lab., MPR-P&VE-65-6 (May), p. 14.

89. P&VE Lab., MPR-P&VE-65-9, p. 29; Saturn Flight Evaluation Working Group, MPR-SAT-FE-66-8, p. 13; and DAC, SM-47384, Issue 38, p. 61.

extensive damage during the de-erection operations. Program officials decided then to return the unit to MSFC, transfer its internal components to the S-IU-200S/500S structure, and redesignate it the S-IU-500F for use at KSC to check out Saturn V launch facilities. Meanwhile, DAC technicians at KSC began converting the S-IVB-500F stage for use in Saturn V facilities checkout, and CCSD personnel began to complete prelaunch checkout of the S-IB-1 stage in preparation for the AS-201 flight.[90]

Flight Vehicle Development

Generally both stage contractors progressed on schedule in 1965 with development, testing, and delivery of stages for Saturn IB flight vehicles.

Both stages for flight vehicle SA-201 resided on the launch pad at KSC at the end of 1965; poststatic checkout and shipping preparations were in progress for S-IB-2 and S-IVB-202; S-IB-3 was undergoing poststatic modification and repair; preparation for acceptance testing of S-IVB-203 progressed; S-IB-4 awaited acceptance tests at MSFC, and S-IVB-204 was ready for shipment to the static test site at SACTO. Stages for SA-205 through SA-207 were in various phases of fabrication and assembly at the contractor sites.

In 1965 MSFC and IBM completed S-IU-201 and shipped it to KSC for mating with the S-IB-1 and S-IVB-201 stages. Development of the IU's required less lead time than for stages, and MSFC and IBM had S-IU-202 through S-IU-204 in various stages of fabrication and assembly at the year's end.

SA-201

The SA-201 vehicle is scheduled to boost the Apollo spacecraft 009 (without the LEM) on a ballistic lob shot from Cape Kennedy into the

90. Saturn V Program Off., MPR-SAT-V. 65-4, p. 34; and Saturn Flight Evaluation Working Group, MPR-SAT-FE-66-8, p. 13.

South Atlantic where the spacecraft will be recovered. On the ballistic lob the spacecraft is to reach an altitude of 650 miles which permits an almost circular re-entry having a speed of about 29,000 feet per second (fps). This re-entry speed will serve to validate the Apollo re-entry heat shield. The SA-201 flight is scheduled to occur in the first quarter of 1966.

The first Saturn IB launch vehicle consists of the S-IB-1 stage, the S-IVB-201 stage, and the S-IU-201. With attachment of the Apollo spacecraft 009 to the S-IU-201 at the launch site, the vehicle becomes the Apollo Saturn 201 (AS-201) vehicle.

S-IB-1 Assembly, Checkout, and Delivery: Assembly of the first flight booster ended at MAF on November 20, 1964, except for engine re-installation,[91] and CCSD moved the stage to Checkout Station No. 2 for prestatic checkout. Chrysler personnel completed checkout operations on February 2 and, while preparing the stage for shipment, reinstalled and performed electrical checks on the H-1 engines. The contractor on March 6 shipped the stage aboard the NASA barge Palaemon to MSFC in Huntsville. Upon its arrival at the Huntsville dock on March 14 it was immediately unloaded and installed in the former S-I static test tower which had been modified for S-IB use.[92]

Preparations for static tests included two propellant loading tests on March 24 and 29. These tests, performed by CCSD technicians assisted by MSFC test personnel, included leak checks of the stage and investigation of LOX boiloff rates. During the tests, technicians established tanking and LOX bubbling procedures for the required small LOX ullage of 1.7 per cent.[93]

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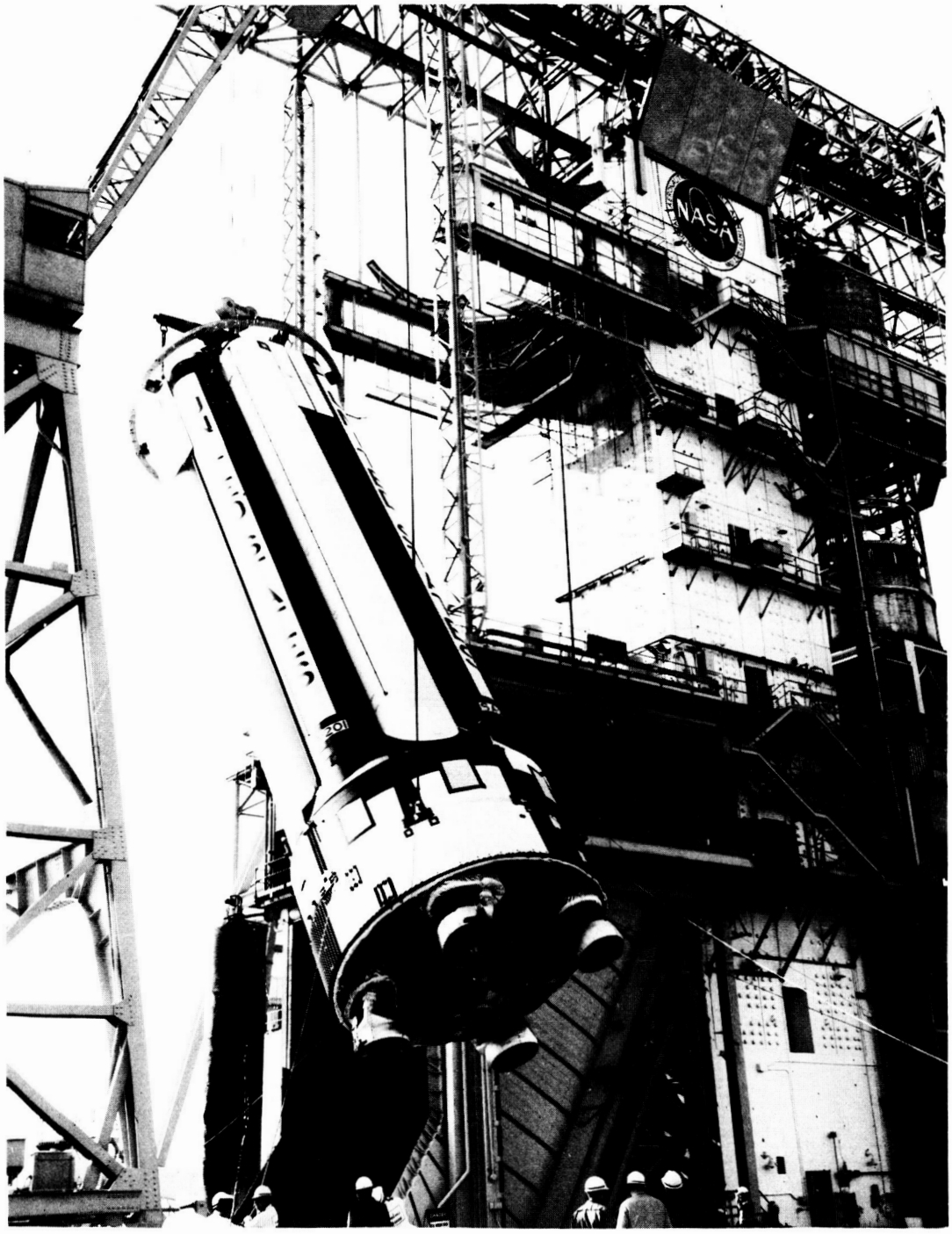
91. The engines had been returned to Rocketdyne in Neosho, Missouri, for LOX dome and injector retrofit in November 1964. See MSFC, MHM-10, p. 62.

92. MAF, Hist. Rpt., Jan. 1, 1965 - June 30, 1965, p. 6.

93. Test Lab., Hist. Rpt., Jan. 1, 1965 - Dec. 31, 1965, p. 1; and Systems Static Test Branch, CCSD, Saturn S-IB Stage Final Static Test Report, S-IB-1, June 4, 1965, pp. 1-2.



SATURN IB BOOSTER

S-IB-1, the first stage for the first Saturn IB flight vehicle, is placed in the static test stand at MSFC for tests on March 16, 1965.

The S-IB-1 performed successfully in two acceptance tests. The first on April 1 lasted 35 seconds with cutoff initiated by the control operator. In the second test, on April 13, the stage fired for 138.21 seconds to inboard engine cutoff and then 6.80 seconds longer to outboard engine cutoff. All systems operated satisfactorily during both tests.

Technicians removed the stage from the stand on April 19 and loaded it onboard Palaemon the next day for its return trip to Michoud. The stage arrived at Michoud on April 24.[94]

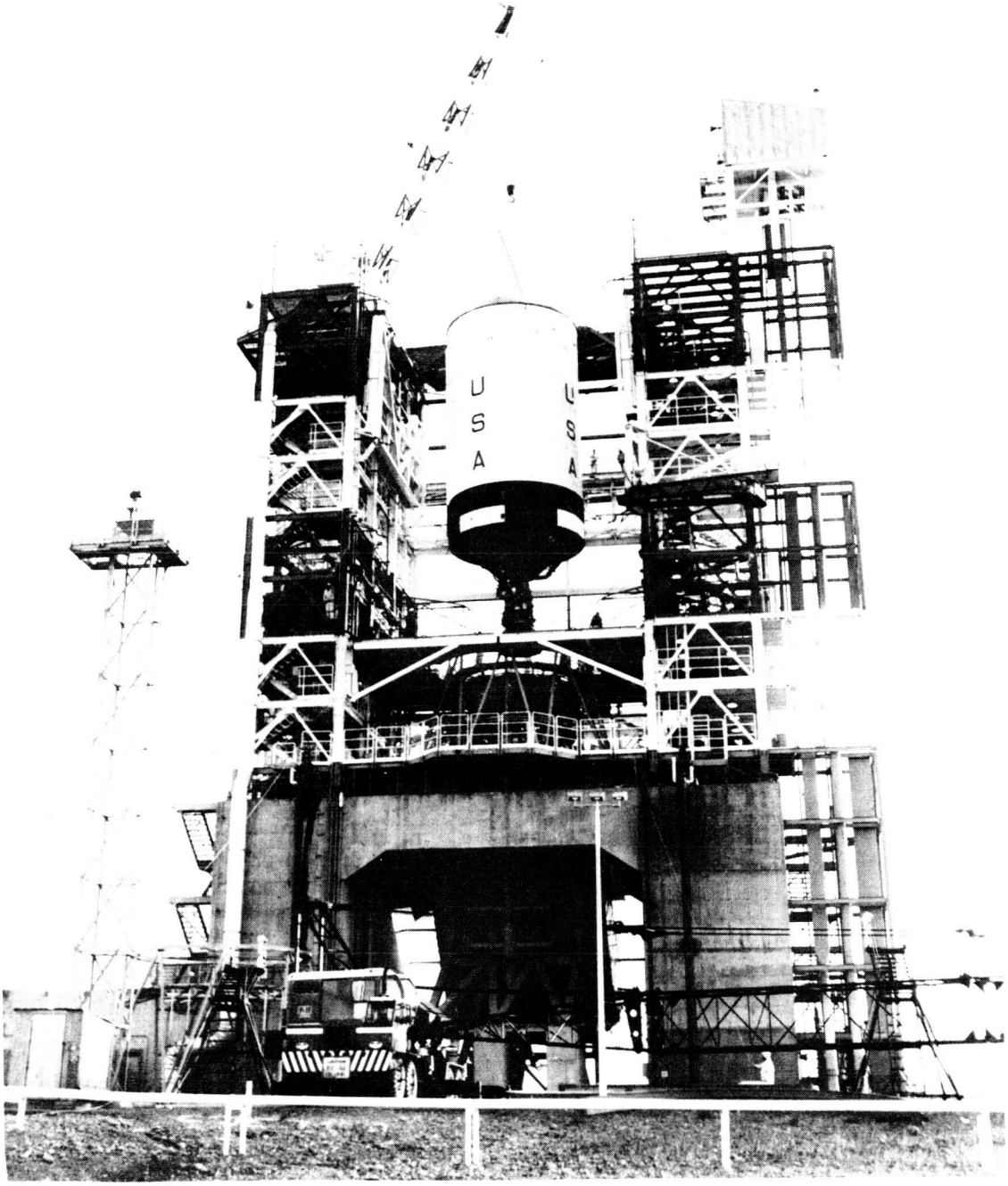
On June 11 CCSD placed S-IB-1 in the checkout area and began poststatic checkout and modification. The only major problem encountered during checkout was leakage of the turbopump LOX shaft seals on Engines H-7047 and H-7046 beyond specified limits. Rocketdyne personnel at CCSD replaced the seals and CCSD completed the poststatic checkout on July 19.[95]

Chrysler shipped S-IB-1 to KSC onboard the barge Promise on August 9. It arrived at the launch site on August 14.

S-IVB-201 Assembly, Checkout, and Delivery: Fabrication of forward and aft skirts and the thrust structure for S-IVB-201 ended in January and technicians joined them to the stage assembly in DAC's Space Systems Center. In late January DAC personnel moved the stage assembly to Tower No. 6, Position 11, for installation of J-2 engine J-2012, a non-flight engine which would allow checkout to proceed until a flight-type engine became available. After replacing the stage assembly in Tower 6, Position 9, technicians on February 24 began the checkout operations. Electrical continuity checks continued through March 30 when the contractor halted the checkout to allow modifications to the LH_2 tanks and installation of late parts, including the flight engine. Removal of the substitute checkout engine and installation of flight engine J-2015 occurred in the interval April 7 through April 14. Personnel completed final

94. Ibid.

95. MAF, Hist. Rpt. July 1 - Dec. 31, 1965, p. 10; and CCSD, Saturn S-IB Stage Assembly and Test Report, S-IB-1, RB-B1-EIR-5.1, Aug. 9, 1965, pp. 1-2 and 6-3.



FIRST FLIGHT S-IVB

The S-IVB-201, top stage for the first Saturn IB flight vehicle, is lowered into a test stand at SACTO for static firing, in October 1965.

inspection of the stage the following day and prepared it for shipment to SACTO for completion of the modifications, checkout, and stage acceptance tests.

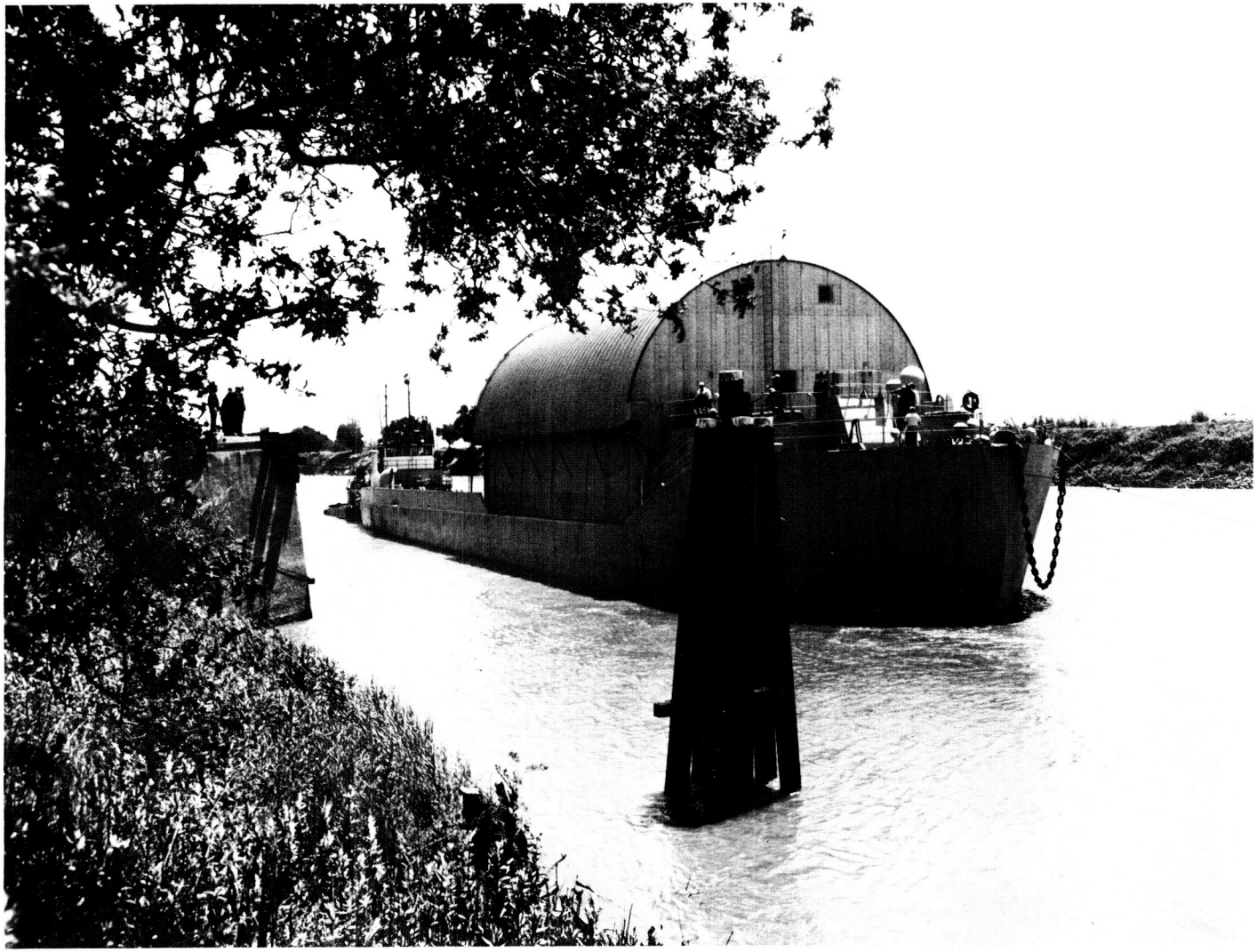
The stage arrived at the Courtland, California, dock onboard the Orion barge on May 5, was unloaded and transported overland to SACTO on May 6, and was installed in the Beta 3 Test Stand on May 7. Workmen then resumed the stage modifications which had been halted at Huntington Beach. Stage pre-checkout activities continued through July 14. On July 17 technicians completed an integrated systems checkout, on July 22 conducted a simulated static firing, and on July 27 completed the stage cryogenic loading test under control of the automatic GSE. Components in the Pneumatic Console "B" indicated inadequate performance during the loading test and DAC deleted a 10-second mainstage firing scheduled to follow.

The first attempt to static fire S-IVB-201 in a full-duration test ended prematurely on July 31 due to component malfunction in Pneumatic Console "A". Stage propellant loading and the automatic countdown sequence proceeded satisfactorily to the point of shutdown.[96] The stage performed the full-duration acceptance firing on August 8. The 200K J-2 engine fired for 452 seconds without mishap. The firing was controlled throughout, marking the first utilization of a fully automatic system to perform a complete checkout, propellant loading, and static firing of a flight stage.[97]

DAC completed postfiring checkout and formally presented the first S-IVB flight stage to NASA at the Beta 3 test site on August 31. The stage was then transported to the Courtland dock on September 3, loaded

96. Saturn I/IB Program Off., I/IB-65-1, p. 11; and DAC, SM-46960, Issue 30, p. 53; SM-47077, Issue 31, p. 67; SM-47145, Issue 32, p. 65; SM-47199, Issue 33, p. 63; SM-47234, Issue 34, pp. 43 and 45; SM-47276, Issue 35, pp. 50 and 52; and SM-47313, Issue 36, p. 48.

97. NASA, Astronautics and Aeronautics, 1965, Chronology on Science, Technology, and Policy, SP-4006, p. 373; and PAO, Marshall Star, Aug. 11, 1965.



SATURN TRANSPORTER

The barge Orion is shown transporting S-IVB-201 from Courtland, California, on the first leg of its voyage to Kennedy Space Center.

aboard Orion, and shipped to Richmond, California, where it was transloaded to the ocean-freighter Steel Executive for shipment to KSC.[98]

On September 14 DAC shipped the APS modules for S-IVB-201 to KSC. Then in October the contractor had the modules returned to Santa Monica for retrofitting to correct deficiencies discovered during APS qualification. Moisture contamination from an unknown source required that the assemblies be dried, reworked, and returned to SACTO for leak and functional tests. Return of the modules to KSC occurred in November.[99]

S-IU-201 Assembly, Checkout, and Delivery: Lack of complete IU assembly documentation in late 1964 continued in early 1965 to hamper IU assembly, particularly of the first unit, S-IU-201. During January 1965 IBM completed definition of the necessary non-government furnished S-IU-201 assembly hardware and started placing purchase orders. In late January IBM technicians assisted by MSFC personnel aligned and installed the structural assembly fixture in the high bay area of the IU facility.

Several factors contributed to delay in the S-IU-201 assembly operations. The late release of assembly documentation caused an impact on procurement leadtime for some of the hardware. Receiving inspection on government furnished (GFE) components for S-IU-201 revealed many discrepancies that required quite a number of engineering change orders and parts replacements. And, updating of the S-IU-201 design caused additional engineering changes in the IBM procured items.

On January 20 MSFC completed receiving inspection on the General Dynamics/Fort Worth S-IU-201 structural segments and delivered them to the IBM facility. These were mounted on the assembly fixture and fabrication started. IBM personnel completed 55 per cent of S-IU-201 fabrication in February. In May the contractor completed structural assembly modifications, installed the manifold bracket and the coolant

98. DAC, SM-47384, Issue 38, p. 38.
99. Ibid., SM-47423, Issue 39, p. 41; and SM-47486, Issue 40, p. 40.

manifolds, completed flowmeter assembly, and completed installation of 30 GFE components in the assembly. Cabling and tubing installation on S-IU-201 continued through July. Eight of the cables had to be reworked because of length problems and six were returned to the vendor because of poor workmanship. In the first week of August IBM completed installation of the remaining electrical system distributors, the 56-volt power supply, and the network cables. IBM completed S-IU-201 assembly in mid-August and moved the unit into the checkout station. However, a number of engineering changes and modifications continued to be accomplished under MSFC's direction in the checkout station.

On September 3 IBM delivered the S-IU-201 system test specification to MSFC for approval. During September technicians coded, checked out, and successfully ran the S-IU-201 checkout programs during the IU checkout. Also completed in September was the verification run of the SA-201 flight program on the LVDC simulator through S-IVB cutoff and through IU operation. Incorporation of the flight LVDC/LVDA program into the SA-201 flight program continued into October.

During IU checkout a number of mechanical problems became evident: mostly leaks in connections, seats, and welds. IBM halted the checkout to complete fixes for these problems and to incorporate a number of additional engineering change orders. MSFC personnel continued to assist in solving the problems.

S-IU-201 checkout ended the first week in October, and IBM officially turned over the unit to MSFC on October 6. Requirements for a number of parts replacements and necessary modifications still existed, and personnel accomplished some of these enroute to KSC aboard the Palaemon, and others at KSC after the unit's arrival on October 20. Installation of the final S-IU-201 flight program tape in the LVDC/LVDA occurred in late November.[100]

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100. Saturn I/IB Program Off., I/IB-65-1, p. 1; IBM-65-966-0004H, pp. 1-2, 23-24, and 30; IBM-65-966-0005H, pp. 1, 4, and 26; IBM-65-966-0007H, pp. 2, 27, and 32; IBM-65-966-0010H, p. 25; IBM-65-966-0011H, p. 1; IBM-65-966-0012H, p. 25; IBM-65-966-0020H, pp. 1, 6, and 32; IBM-65-966-0022H, pp. 1, 7, 22, and 30; and IBM-65-966-0023H, p. 2.

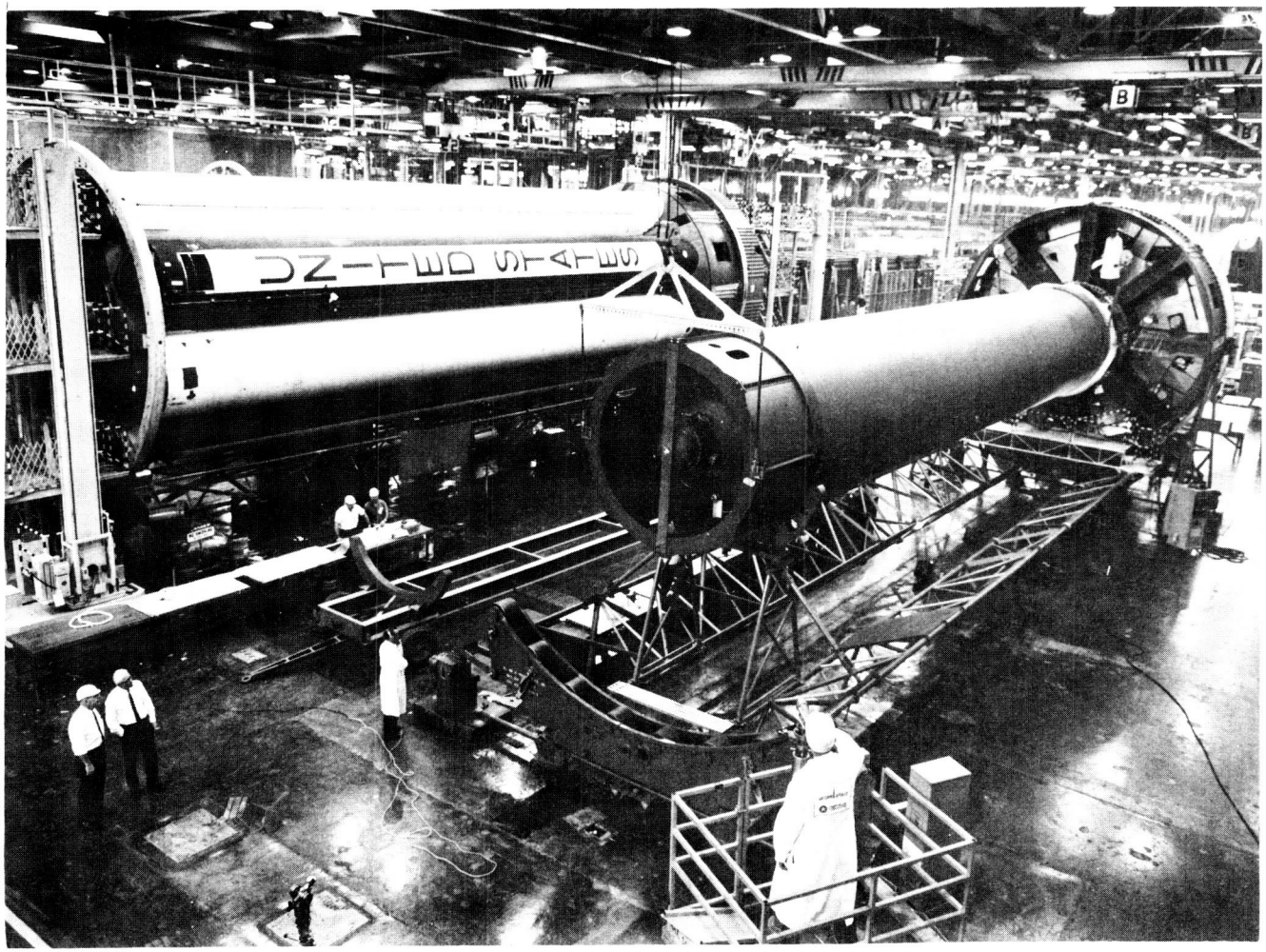
Prelaunch Checkout: The S-IB-1 stage arrived at KSC on August 14 aboard the barge Promise. At KSC the stage entered preflight checkout prior to being erected on Launch Complex (LC) 34 on August 18. In the interval from August 18 to September 29, S-IB-1 was used in the facility checkout of LC-34. During instrument compartment leak tests on September 10 overpressurization damaged the forward bulkhead on an S-IB fuel tank, necessitating replacement of the tank. This was accomplished without difficulty on September 29 without removal of the stage from the launch pad. Afterwards, technicians completed a thorough inspection of the stage in preparation for beginning of prelaunch tests.

The S-IVB-201 arrived at KSC on September 19, was unloaded from the barge, and moved to Hangar AF for receiving inspection and modification. Following de-erection of the facilities checkout vehicle, technicians on October 1 erected the S-IVB-201 atop the S-IB-1.

On October 20 crewmen unloaded the S-IU-201 from its transport barge, moved it to Hangar AF for receiving inspection and modification and, on October 25, erected it atop the S-IVB stage.

Test engineers applied power to the S-IB stage on October 21 with interim operating system programs for the RCA-110A computer used in vehicle checkout operations. Power application to the S-IVB stage occurred on October 26. Electrical mating of the entire vehicle ended on November 10. On November 27 the primary or final RCA-110A computer operating tape for automatic checkout operations arrived at KSC. Command guidance and control system checkout commenced on November 29.

During automatic LOX loading tests of the S-IB stage the fuel overfill sensor picked up approximately four inches above its specified setting. Investigation showed the sensor's setting as 9.92 in lieu of the required 13.915 inches. The setting was changed and, to prevent recurrence of this problem, CCSD was notified to renovate quality control and documentation to verify settings on future stages and to remove and change the fuel overfill sensors on S-IB-2 and subsequent stages to correct settings. The first successful automatic loading of the S-IB-1 during prelaunch checkout occurred on November 30.



SECOND AND THIRD BOOSTERS FORM

Taking shape in the Chrysler portion of the MAF manufacturing plant are S-IB-2 (left) and S-IB-3. This picture was made in January 1965.

S-IVB-201 testing revealed an oil leak in the engine gimbal system which required checkout and minor modification.[101]

SA-202

The SA-202 vehicle has much the same mission as SA-201, that of testing the Apollo command module heat shield. However, unlike the SA-201 which is to lob the spacecraft on a trajectory with a steep re-entry angle into the Atlantic, SA-202 will boost the spacecraft on a trajectory extending three-quarters of the way around the Earth with re-entry into the Pacific. This will provide a longer and shallower re-entry producing very high heat loads. Both types of trajectories are required to represent re-entry heating conditions which will be encountered in manned Earth orbital missions.

SA-202 consists of the S-IB-2 stage, the S-IVB-202 stage, and the S-IU-202. The vehicle becomes the Apollo Saturn 202 (AS-202) with attachment of its payload, the Apollo spacecraft 011. Spacecraft 011 consists of the LES, the CM, the SM, and a LEM/SLA.[102]

S-IB-2 Assembly, Checkout, and Delivery Preparations: CCSD completed assembly of the second flight booster on February 26 and moved it from the assembly area at Michoud to Checkout Station No. 2. There, technicians removed the eight H-1 engines and returned them to Rocketdyne for LOX dome and injector retrofit before beginning prestatic checkout of the stage. Reinstallation of the engines followed completion of the checkout on April 27, and preparations commenced for shipping the stage to Huntsville. Discovery on May 21 of a large dent on the aspirator of one engine resulted in return of the engine to Rocketdyne for repair. Following reinstallation of this engine CCSD on June 12 shipped S-IB-2 to MSFC.[103]

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101. Saturn Flight Evaluation Working Group, MPR-SAT-FE-66-8, p. 13; and P&VE Lab., MPR-P&VE-65-12(S), pp. 1-3.

102. Pamelia B. Pack, Aero-Astrodynamics Lab., AS-202 Launch Vehicle Operational Flight Trajectory, NASA TMX-53470, June 3, 1966, pp. 1-3; and NASA, Press Kit, Release No. 66-213, Project: Apollo/Saturn 202, Aug. 21, 1966.

103. MAF, Hist. Rpt., Jan. 1, 1965 - June 30, 1965, pp. 6-7.

It arrived in Huntsville on June 19, and MSFC and Chrysler test personnel installed it in the static test stand, prepared it for acceptance tests, and on June 30 completed a propellant loading test.

The first attempt at static firing S-IB-2, performed on July 8, ended prematurely after three seconds due to a malfunction of the thrust OK pressure switch No. 2 on Engine No. 4. The second firing on July 9 lasted 35 seconds with performance normal. Test personnel conducted the final static firing on July 20; the engines performed for 144.2 seconds duration and achieved all test objectives.

Workmen removed S-IB-2 from the static test stand on July 29 and shipped it to Michoud the following day.[104] On its arrival at Michoud on August 7 it underwent poststatic modification and repair. The stage was placed in Checkout Station No. 2 for poststatic checkout on October 1.

Poststatic checkout revealed that leakage of gear case oil through the LOX pump cavity "T" valve and check valve during the final static firing had contaminated an inboard engine. Technicians replaced the engine with a spare and during October and November completed removal, cleaning, and reinstallation of some 65 tube assemblies and fittings which had also been contaminated. Chrysler began preparations in December for shipping the stage to KSC.[105]

S-IVB-202 Assembly and Checkout: In late January DAC completed stage tank assembly operations for the S-IVB-202 and began internal insulation of the LH_2 tank. Hardware installations were completed in the LOX tank by early March and in the LH_2 tank by mid-March. In late March technicians joined the aft skirt and thrust structure to the stage tank cylinder and on April 5 joined the forward skirt. J-2 flight engine J-2016 arrived at Huntington Beach on April 13, underwent receiving inspection, and on April 28 was installed in the stage.

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104. Test Lab., Hist. Rpt., Jan. 1, 1965 - Dec. 31, 1965, pp. 1-2.
105. Ibid., and MAF Hist. Rpt., July 1 - Dec. 31, 1965, pp. 7 and 11.

The first phase of S-IVB-202 stage checkout began at Huntington Beach April 30. Insulation resistance checks, continuity checks, cold plate checks, and fore and aft umbilical checks ended in mid-May. On May 14 technicians applied electrical power to the stage for the first time. On June 7 DAC interrupted the checkout operations for completion of additional hardware changes and manufacturing originally scheduled to occur after checkout. The checkout resumed on June 16, and during July and early August the stage underwent propellant utilization system calibration, automatic checkout, range safety system checkout, exploding bridgewire system checkout, and engine alignment checkout. Phase I of the checkout ended at Huntington Beach in early August, and on August 20 DAC shipped the stage aboard Orion to Courtland, California. At Courtland it was unloaded from the barge and transported overland for the remainder of its journey to SACTO.

The S-IVB-202 stage arrived at SACTO on September 1, and workmen completed installing it in the Beta 3 Test Stand the following day. During September DAC completed additional electrical and propulsion systems modifications and installations and completed rework of the LOX and LH_2 access door jamb weld before resuming prefiring checkout. Phase 2 of the stage checkout and preparations for beginning acceptance firing tests ended with a simulated static firing test on October 25-26.

In the first attempt to static fire S-IVB-202 on October 29 the stage primary batteries proved incompatible with the GSE power supplies. Technicians replaced the batteries with secondary batteries on November 1 and initiated a new countdown for the second static firing attempt on the following day. It too ended after only 0.41 second because of a component malfunction in the J-2 engine combustion stability monitoring system. Corrective action included replacing accelerometers in the defective system, cable repair, and replacement of components which had exhibited abnormal or erratic operation. In the next test on November 9 the stage fired for 307 seconds mainstage; a malfunctioning LH_2 mass sensing unit in the PU subsystem prevented its firing to full duration. Correction of

this latest difficulty and a minor fire in the primary aft No. 2 battery during a countdown on November 19 delayed another full-duration attempt until the end of November. Countdown operations began November 30, and the full-duration acceptance firing successfully occurred on December 1. All test objectives were achieved during the 463.8-second mainstage firing with cutoff initiated automatically. Poststatic checkout and modification will end and a simulated flight test will be accomplished prior to stage shipment to KSC in mid-January.[106]

S-IU-202 Assembly and Checkout: GD/FW delivered the structural segments for S-IU-202 on April 1, 1965. MSFC completed receiving inspection on April 5 and personnel began "beefing up" or modifying the segments before beginning the assembly operations. Modification ended and structural assembly was completed in late April. Workmen moved the structure to the second assembly stand in early May. In June IBM received the assembly hardware for the cable tray but not the network cable documentation. Technicians installed five of the cold plates, and the manifold and hazardous gas detection system brackets in June. In July the thermal conditioning panels and available instrumentation was installed, and the ST-124 mounting frame was optically prealigned and then removed for further machining.

Late receipt of the network cable documentation caused IBM to reschedule completion of assembly from August 20 to September 30 and finally to October 15. Late GFE delivery and incorporation of engineering change orders also affected the schedule. By the end of October fabrication and assembly operations were 87 per cent complete. Five distributors were completed, accepted, and installed and all but three of the cables were installed in October. Checkout operations started in November while fabrication and assembly operations continued. Also, distributors and cables requiring updating to latest engineering change requests were removed, reworked and reinstalled. During November engineers

106. DAC, SM-46960, Issue 30, p. 53; SM-47077, Issue 31, p. 67; SM-47145, Issue 32, p. 65; SM-47199, Issue 33, p. 63; SM-47234, Issue 34, p. 55; SM-47276, Issue 35, p. 69; SM-47313, Issue 36, p. 63; SM-47384, Issue 38, p. 38; SM-47423, Issue 39, pp. 1 and 40; SM-47486, Issue 40, pp. 39-40; and SM-47522, Issue 41, pp. 35-36 and p. 41.

completed leak checks and cleanliness verification tests and began repairing leaks as required. Incorporation of several of the remaining GFE components and the S-IU-202 checkout continued through December. Checkout is scheduled for completion in early 1966 with shipment of the unit to KSC planned for February 1966.[107]

SA-203

The third Saturn IB flight vehicle has a mission entirely different from the SA-201 and SA-202 missions; it will support a liquid hydrogen (LH_2) orbital experiment to substantiate the S-IVB stage design and to assure success of the Saturn V lunar orbital rendezvous (LOR) mission. The experiment is required because previous cryogenic propellant tests have been limited to ground drop tests or short duration tests performed in an airplane flying a parabolic trajectory which could not simulate the orbital conditions of the S-IVB stage. SA-203 is to place S-IVB-203 into a 100 nautical mile earth orbit with a maximum of LH_2 onboard so that the adequacy of the Saturn V/S-IVB continuous orbital venting and ullaging system under a low gravity field can be demonstrated.

For this mission the flight vehicle will consist of a standard S-IB stage, the S-IVB stage with the experimental equipment, the IU, and a double-angle nose cone. The only separation occurring during flight is between the S-IB and the S-IVB stages; the S-IVB with residual LH_2 and experimental equipment, the IU, and the nose cone form the complete orbital payload.[108]

S-IB-3 Assembly and Checkout: No modifications are required to the S-IB stage to support the LH_2 experiment. Even so, S-IB-3 differs from the two previous S-IB flight stages in that it is the first S-IB stage to incorporate all the planned modifications completing the stage redesign

107. IBM, IBM-65-966-0007H, pp. 2, 27, and 33; IBM-65-966-0010H, pp. 18 and 25; IBM-65-966-0012H, pp. 2 and 25; IBM-65-966-0020H, pp. 30 and 32; IBM-65-966-0022H, p. 30; IBM-65-966-0023H, p. 30; and IBM-65-966-0024H, p. 27/28.

108. Advanced Studies Office, P&VE Lab., MSFC, Saturn IB Liquid Hydrogen Experiment Preliminary Launch Vehicle Design Definition, (NASA TM X-53159), Nov. 12, 1964, p. 7.

from the S-I configuration. The new changes incorporated in the S-IB-3 configuration include lightweight propellant tanks, titanium fuel pressurization spheres, low differential pressure LOX venting system, honeycomb heat shield panels, and reoriented inboard engine turbine exhausts.[109]

CCSD began clustering propellant tanks for S-IB-3 on January 21, 1965, and the contractor completed structural buildup of the stage in early June. The H-1 engines, the first produced with the 200K modifications, arrived at MAF ahead of schedule for installation, but parts shortages hampered other stage installations. On June 17 workmen at MAF moved the stage into Checkout Station No. 1 and began prestatic checkout. Checkout operations progressed as parts became available. Several problems showed up during the checkout. First, excessive LOX turbopump shaft seal leakage on Engine No. 2 resulted in replacement of the seal. Second, disconnection of a leaking tube assembly disclosed some metal chips and further analysis of the complete purge system revealed additional contamination by metal chips. This required purging the basket with missile grade air. Technicians completed checkout operations on August 14 and, after completing modifications and shipping preparations, transported the stage aboard Palaemon to MSFC on September 9.[110]

S-IB-3 arrived at MSFC on September 16. The next day workmen installed the stage in the static test tower and began preparations for checkout and acceptance firing tests. The stage completed simulated flight tests on September 29, October 8, October 11, and October 21; a propellant loading test on October 1; a 35.295-second static firing on October 12; and a full-duration (146.226-second) firing on October 26. All the tests were performed successfully and all test objectives achieved.

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109. The S-I stage redesign to the S-IB configuration was planned to occur in three development phases. While some of the changes have been retrofitted in the S-IB-1 and S-IB-2, the S-IB-3 is the first S-IB stage to have all the redesign built into the stage. See MSFC, MHM-8, pp. 61-67; MHM-9, pp. 70-77; NASA, TM X-53159, p. 30; and Systems Static Test Branch, CCSD, Saturn S-IB Stage Final Static Test Report, Stage S-IB-3, Nov. 30, 1965, p. 3.

110. MAF, Hist. Rpt. Jan. 1 - June 30, 1965, pp. 7 and 23; and July 1 - Dec. 31, 1965, pp. 10-11.

Workmen removed the stage from the static test stand on November 3 and loaded it on a barge the following day for its return shipment to Michoud.[111] It arrived at MAF on November 9 and entered poststatic modification and repair.[112]

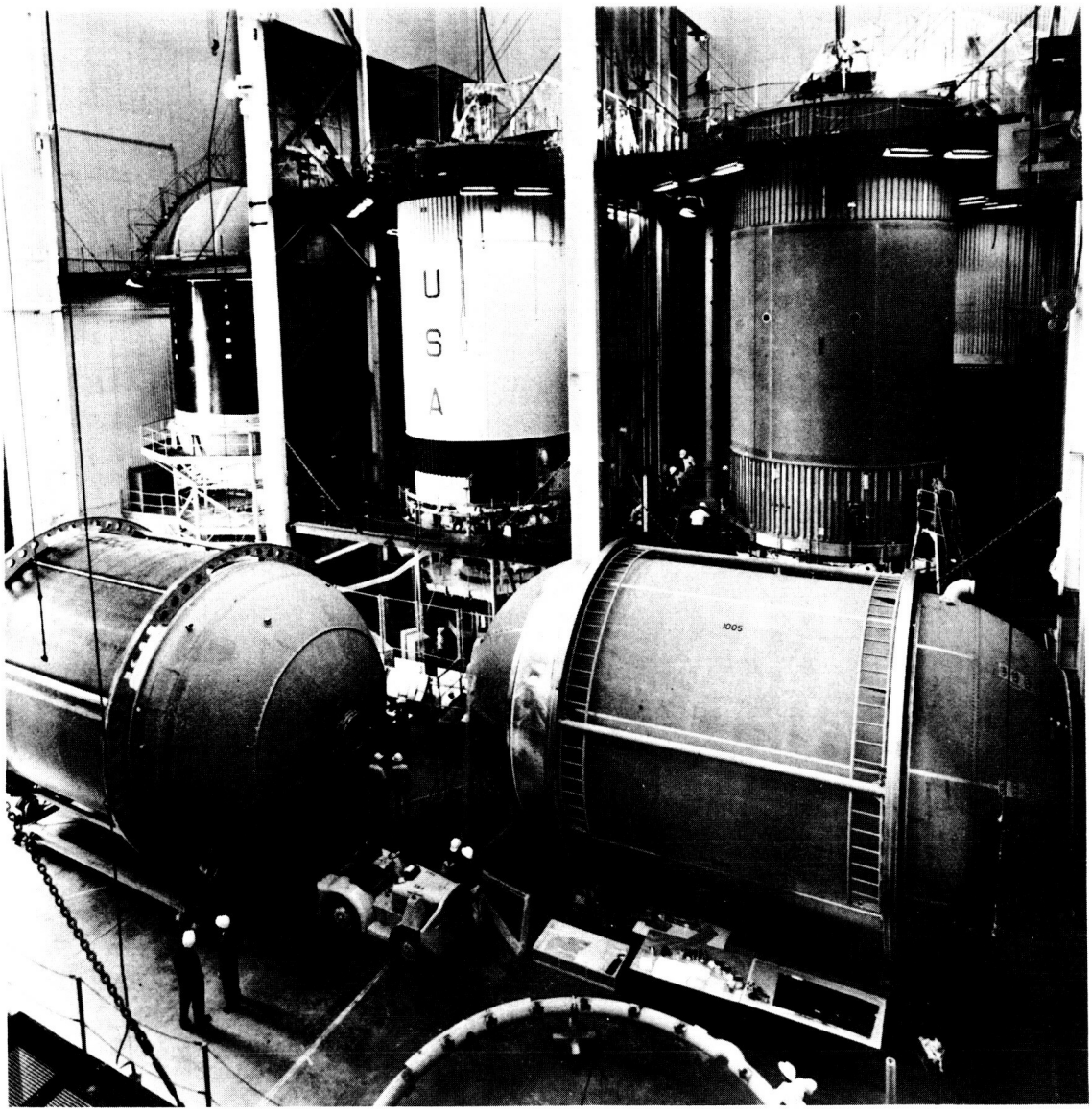
S-IVB-203 Assembly and Checkout: The S-IVB-203 has a number of changes incorporated in support of the LH_2 orbital experiment. The stage is configurated to simulate the Saturn V S-IVB stage functions which include: orbital insertion and control of propellants during transition to low-gravity operations; orbital coast and LH_2 tank venting during three earth orbits; LH_2 tank repressurization and partial simulation of orbital restart.

Externally, the S-IVB-203 forward skirt has new nozzles and fairings for the LH_2 tank continuous venting system. The forward skirt on the S-IVB-203, as it will be on all subsequent IB and V S-IVB stages, is made heavier than on S-IVB-201 and 202 due to revised loading conditions. Mounted on S-IVB-203's thrust structure is a second ambient helium sphere such as will be used on the Saturn V S-IVB to provide hydrogen tank repressurization for simulated restart up to and including J-2 engine chilldown. Jet nozzles are also mounted on the thrust structure to release pressurized LOX tank gas to simulate the Saturn V/S-IVB APS engine during simulation of the J-2 engine restart. Additional insulation consisting of aluminized mylar is added to the outside of the LH_2 tank forward dome to provide increased thermal protection and to minimize hydrogen boiloff during the orbital coast period.

The S-IVB-203 internal additions include another baffle ring in the LOX tank section necessary because of the off-loading of LOX for the 203 flight; a second instrumentation probe for temperature, pressure, and liquid vapor sensors for the LH_2 tank; more baffle rings to the LH_2 tank to prevent excessive propellant slosh at orbital injection and

111. Systems Static Test Branch, CCSD, Saturn S-IB Stage Final Static Test Report, Stage S-IB-3, pp. 3-5.

112. MAF, Hist. Rpt., July 1 - Dec. 31, 1965, p. 2.



S-IVB STAGES

Shown in various phases of assembly at the Douglas plant at Huntington Beach, Calfornia, are five S-IVB stages. This picture was made late in 1965.

during orbital maneuvers; and a special hydrogen tank manhole cover to provide mounting facilities for two television cameras and two lights which will be used to observe the behavior of the LH_2 under powered flight and orbital conditions. A grid pattern will be painted on the inside insulated wall of the LH_2 tank to be used for reference in the LH_2 experiment television pictures.

Along with the necessary modifications to the oxygen and fuel systems are the supporting changes necessary to the pneumatic control system which provides plumbing, pneumatically controlled valves, and switches to operate the oxygen and fuel systems. Also, a 28Vdc (volts of direct current) battery is added to the electrical system to supply power for the television cameras, camera heaters, and lights. And, associated signal conditioning and transmission capabilities are added to the telemetry and instrumentation system to support the new data collecting sensors.[113]

In the first quarter of 1965 DAC began subassembly of the S-IVB-203 thrust structure, aft skirt, and forward skirt. The contractor completed LH_2 tank insulation, clip bonding, and marking provisions for the LH_2 orbital experiment television cameras in April. Installations in the LH_2 and LOX tanks continued during May and June as did modifications for the LH_2 orbital experiment. Engine J-2019 arrived on May 1 and entered the engine checkout area. Technicians joined the thrust structure and the aft skirt to the tank assembly on June 26, completed forward skirt installations and joined the skirt to the stage on July 12, and installed the flight engine on July 22.

Toward the end of July technicians began the checkout operations. The vehicle contained substitute hardware in lieu of late hardware to permit the checkout operations to begin. The missing flight hardware would be installed "out of sequence" as it became available. DAC interrupted the

113. Management Services Off., Saturn-Apollo Space Vehicle Summary, AS-203/LH_2 Contributions to Saturn LOR, June 1966, pp. 22-24; P&VE Lab., Saturn IB Liquid Hydrogen Experiment Preliminary Launch Vehicle Design Definition, NASA TM X-53159, Nov. 12, 1964, pp. 1-2; and NASA, MSFC, KSC, CCSD, DAC, IBM, and Rocketdyne/NAA, Saturn IB News Reference, pp. 5A-1--5A-3/4.

factory checkout in early September to complete additional installations in the propellant tank and for rework of the LH_2 jamb weld after cracks were discovered on it, on the S-IVB-205, and on the common bulkhead test article. Factory checkout resumed on September 20 and ended on October 9 at DAC's Space Systems Center. Complete vehicle inspection ended on October 14, and personnel completed shipping preparations on October 27. The stage was transported to Seal Beach on October 29 and loaded on a barge for shipment to SACTO.[114]

Throughout 1965 MSFC and DAC personnel coordinated efforts in designing and working out the necessary S-IVB hardware, systems operations, and flight sequence changes necessary to make the S-IVB-203 simulate the S-IVB/V stage. Most of these changes were applied or installed on S-IVB-203 at SACTO prior to start of the acceptance test program.

MSFC personnel completed the detail and installation drawings for the LH_2 sphere and associated equipment required to support the LH_2 experiment in May. In August technicians completed analysis of the cryogenic storage bottle and then selected an isolator system to reduce to acceptable levels high frequency input to the electronics noticed during vibration tests. MSFC released the documentation for structural support of the sphere in August.[115]

MSFC Laboratories also developed and tested in-house the flight and test LH_2 manhole covers, the manhole window retaining rings, viewport seals, viewport, the television mounting brackets, and the television heating elements. Documentation for the LH_2 manhole cover was completed in February, and fabrication of test covers started. Wyle Laboratories began cryogenic tests of the viewport window seals in an LH_2 manhole cover for MSFC during June. Tests were completed with no seal leakage;

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114. DAC, SM-46960, Issue 30, pp. 55 and 78; SM-47077, Issue 31, pp. 67, 69, and 96; SM-47145, Issue 32, pp. 66 and 89; SM-47199, Issue 33, pp. 63 and 78; SM-47234, Issue 34, pp. 55 and 70; SM-47276, Issue 35, pp. 69 and 83; SM-47313, Issue 36, pp. 63 and 75; SM-47384, Issue 38, pp. 38, 55, and 67; SM-47423, Issue 39, pp. 57 and 68; SM-47486, Issue 40, pp. 40 and 67; and SM-47522, Issue 41, pp. 1 and 36.

115. P&VE Lab., MPR-P&VE-65-5, p. 43; MPR-P&VE-65-6 (May), p. 46; MPR-P&VE-65-6 (June), p. 47; and MPR-P&VE-65-7, pp. 6 and 50.

however, considerable problems were encountered with breakage of the quartz viewports. MSFC initiated a backup program on an alternate cover and completed analysis of the breakage problem which revealed that tensile stress induced on the outside surface of the window caused the breakage. Additional study revealed that the ribs in the gasket material were responsible for inducing the stress. A change from the nylon ribbed gasket to a Narmco flat gasket proved successful during subsequent tests. In October vibration and shock proof tests were completed. And in November a manhole cover with the quartz viewport window sealed by Narmco gaskets was sent to SACTO for further qualification on S-IVB-203 during the stage acceptance tests. Development and tests of an alternate cover having Plexiglass viewport sealed with the Narmco flange gasket also progressed to delivery of a fixture to SACTO to undergo qualification on S-IVB-203. Effort continued at MSFC into 1966 on still another alternate, that of a Pyrex viewport. Another effort continuing into 1966 concerned evaluation of various materials for use as floats on LH_2 in order to render the surface visible to television during the S-IVB-203 experiment.[116]

DAC personnel completed design of the SA-203 continuous vent system to simulate that of Saturn V, analyzed and revised the propulsion sequence of events peculiar to the LH_2 experiment, and resized the pressurization system orifices to comply with conditions unique to the SA-203 mission. Definition of the special acceptance test requirements imposed by the LH_2 experiment received prime consideration in October, November, and December. Test sequence and goals were established in November and work initiated on computer programs to be used for evaluating the data. Because of the impossibility of duplicating orbital events, complete simulation will not occur during tests; however, all commands for events will be given and all systems will be exercised.

116. Ibid., MPR-P&VE-65-2, p. 17; MPR-P&VE-65-3, pp. 84-85; MPR-P&VE-65-4, p. 13; MPR-P&VE-65-5, pp. 12 and 73-74; MPR-P&VE-65-6 (May), p. 76; MPR-P&VE-65-6 (June), p. 80; MPR-P&VE-65-7, pp. 10 and 65-66; MPR-P&VE-65-8, pp. 11-12 and 103-105; MPR-P&VE-65-9, pp. 1-2 and 61-62; MPR-P&VE-65-11, p. 96; and MPR-P&VE-65-12, pp. 51-52.

Installations, modifications, and limited checkout of S-IVB-203 progressed at the Beta 1 Test Stand through December. Delay in completing the LH_2 tank closing caused by engineering changes, rework, and repair, plus other problems and parts shortages, delayed completion of the checkout. A revised schedule calls for completion of the subsystems and integrated systems tests in January 1966 and stage acceptance firing in early February.[117]

S-IU-3 Assembly: Extensive low Porta-Shear test values were obtained on S-IU-203 and S-IU-204 structural segments at NAA's Tulsa facility in June. On June 14 IBM directed NAA to stop further work on these segments. After completing corrective tooling action NAA proceeded to bond new segments for S-IU-203. These were delivered to IBM on July 23. However, MSFC directed IBM to use the better of these segments to build a new S-IU-200S/500S-II and to use GFE segments for structural assembly of the S-IU-203. Structural assembly of S-IU-203 ended on September 4 and personnel painted the unit with low-emissivity paint and moved it to an assembly stand. Assembly operations started on October 1. By the end of December most of the structural rework required to accomplish shock mounting of the LVDA/LVDC and other components was complete, 65 tube assemblies were in various stages of checkout, cleaning, and installation, and 85 of the 139 cables required for the unit were on hand. Completion of assembly will occur in the first quarter of 1966.[118]

SA-203 Nosecone Assembly: Program officials selected a nosecone for the SA-203 payload in leiu of an Apollo shell because it permitted 1500 to 2000 more pounds of LH_2 to be carried onboard for the experiment.

MSFC has responsibility for fabricating the SA-203 nosecone. It is a double-angle or bi-conic skin- and-stringer-type construction fabricated

117. DAC, SM-47384, Issue 38, pp. 14-15; SM-47423, Issue 39, pp. 16-17; SM-47486, Issue 40, pp. 14-15; and SM-47522, Issue 41, pp. 1, 10, 13, and 36.

118. IBM, IBM-65-966-0010H, p. 8; IBM-65-966-0012H, p. 25; IBM-65-966-0020H, p. 32; IBM-65-966-0022H, p. 30; IBM-65-966-0023H, p. 30; and IBM-65-966-0024H, p. 27/28.

to duplicate the present LEM adapter ring used for the standard Saturn IB/ Apollo configuration. Its exterior is coated with an ablative material. The nosecone, weighing about 3500 pounds, will be bolted to the IU and will not separate in orbit.

MSFC released the documentation for the long leadtime items for the nosecone in February and released a complete package of assembly and detail drawings for the nosecone in April. Workmen completed the fixture for the upper frustrum cone assembly on July 21 and completed the lower frustrum cone assembly on July 29. Final assembly and ring installation were completed on August 4. Stringer and clip installations commenced in August.

In August MSFC decided to place the cryogenic storage bottle and inflight vents on the aft frustrum on the nosecone instead of on the S-IVB stage. By the end of December personnel had completed the necessary modifications for adapting the cryogenic storage bottle and the inflight vents to the nosecone and had completed modifications for mounting to the aft frustrum the accelerometers needed to gain longitudinal, pitch, and yaw measurements. Toward the end of December Wyle Laboratories began a series of vibration tests on a test specimen of the aft frustrum having the component mounting plates but dummy components. Schedules called for completion of the tests in February 1966.[119]

SA-204

A possible manned mission is scheduled for the fourth flight vehicle if the SA-201, SA-202, and SA-203 flights are successful. SA-204 will consist of S-IB-4, S-IVB-204, S-IU-204, and will have attached as the payload the Apollo spacecraft 012.

119. NASA, TM X-53158, p. 19; P&VE Lab., MPR-P&VE-65-3, p. 54; MPR-P&VE-65-4, p. 47; MPR-P&VE-65-6 (May), p. 14; MPR-P&VE-65-6 (June), pp. 16 and 47; MPR-P&VE-65-7, p. 50; MPR-P&VE-65-8, p. 18; MPR-P&VE-65-9, p. 6; MPR-P&VE-65-11, pp. 12 and 53; MPR-P&VE-65-12, p. 27; N. C. Milwee, Manufacturing Engineering Lab., MSFC, "Quarterly Rpt., July - Sept. 1965," (draft), no date; and Wyle Laboratories, Vibration Test Program on Saturn IB/SA-203, Cryogenic Storage Bottle and Component Mounting Plate, p. 5.

S-IB-4 Assembly: On April 6, 1965, CCSD positioned the S-IB-4 tail unit assembly into the main assembly cluster fixture in the Michoud Assembly Facility. Workmen attached the 105-inch LOX container to the tail unit on April 8; attached the spiderbeam assembly on April 13 and, during the period May 14 through August 9, completed clustering the remaining propellant containers. The inboard engines were installed without incident in mid-July; installation of the outboard engines ended August 3. Chrysler completed buildup of S-IB-4 on October 6, completed prestatic checkout operations November 9, and began preparations for shipping the stage to MSFC.

S-IB-4 left Michoud aboard the NASA barge Palaemon on December 7 and arrived at the Huntsville Dock on December 13. The following day workmen unloaded the stage and installed it in the static test stand where preparations for static tests in early 1966 commenced.[120]

S-IVB-204 Assembly: DAC technicians joined the S-IVB-204 LOX tank to the cylindrical section in mid-January, completed leak and dye checks of the stage propellant tank February 19; and began LH_2 tank insulation installation February 25. Subassembly of the stage aft skirt, forward skirt, and thrust structure began in March. LH_2 tank installations ended in July and LOX tank installations started. Personnel also completed receiving inspection of the J-2025 engine for S-IVB-203 in July. Workmen completed joining of the thrust structure and aft skirt to the stage assembly in early September, joined the forward skirt on September 10, and began factory checkout of the stage on September 25. Installation of the engine occurred on September 30. Stage checkout at the Huntington Beach Space Systems Center ended with a simulated flight test on December 15 and vertical inspection ended on December 20. During the remainder of

120. Earl M. Wilson and Walter T. Liebrecht, Inspection Services Section, Product Inspection and Test Branch, Quality Control Dept., CCSD, Saturn S-IB Stage Assembly and Test Report, S-IB-4, RB-B4-EIR-5.1, pp. 1.3 and 3.1-3.11; and Test Lab., Hist. Rpt., Jan. - Dec. 1965, pp. 2-3.

December preparations progressed for shipment of the stage aboard Orion to SACTO on January 10.[121]

S-IU-204 Assembly: IBM began structural fabrication of S-IU-204 in October and completed approximately 75 per cent of the fabrication process before the end of 1965.[122]

SA-205

The SA-205 vehicle will be almost identical to SA-204. It will consist of the S-IB-5, S-IVB-205, and S-IU-205. It will carry Apollo 014 spacecraft as the payload.

S-IB-5 Assembly: Fabrication of S-IB-5 subassemblies began January 8, 1965. CCSD personnel positioned the S-IB-5 tail unit assembly in the main assembly cluster fixture at MAF on July 15, 1965. On August 5, assembly men attached the 105-inch LOX container to the tail unit, attached the spiderbeam to the 105-inch LOX container on August 10, and on August 18 began clustering the remaining propellant tanks. Clustering operations ended on August 30. Personnel installed the inboard engines on October 15 and the outboard engines on October 27. Stage buildup ended on November 30 and workmen moved S-IB-5 to the checkout station for prestatic checkout and shipping preparations. Checkout operations were still in progress when the year ended.[123]

S-IVB-205 Assembly: DAC welders began forming segments for the S-IVB-205 tank cylinder in March 1965. They completed the segments in April and shaved and X-rayed the cylinder welds. Joining of the LOX tank and LH_2 tank shells ended in early May, and welding of the forward dome to the LH_2 tank, which began on May 20, ended in early June. Later in June technicians detected a crack in the jamb weld of the LOX tank

121. DAC, SM-47077, Issue 31, pp. 55 and 59; SM-47145, Issue 32, p. 66; SM-47199, Issue 33, p. 63; SM-47234, Issue 34, p. 56; SM-47276, Issue 35, p. 70; SM-47313, Issue 36, p. 63; SM-47384, Issue 38, p. 55; SM-47423, Issue 39, p. 57; SM-47486, Issue 40, p. 59; and SM-47522, Issue 41, p. 51.

122. IBM, IBM-65-966-0022H, p. 3; and IBM-65-966-0024H, p. 27/28.

123. Earl M. Wilson and Walter T. Liebrecht, CCSD, Saturn S-IB Stage, Assembly and Test Report, S-IB-5, (RB-B5-EIR-5.1), Aug. 10, 1966, pp. 1.3 and 2.1--2.7.

during leak and dye checks. Subsequent repair operations did not end until late September.

Insulation installation in the LOX and LH_2 tanks which began in July ended in November. On December 9 technicians joined the aft skirt and the thrust structure to the tank assembly and the following day joined the forward skirt. At the end of December preparations for completing final stage installations were in progress as was rework of engine J-2033 for replacement of a faulty augmented spark igniter plug. Engine installation and factory checkout of the stage are scheduled for January 1966.[124]

Subsequent Flight Vehicles: Fabrication and assembly of stages for SA-206, SA-207, and SA-208 progressed as follows at contractor sites in 1965:

CCSD personnel began clustering propellant containers for S-IB-6 on October 25 and continued stage buildup through the remainder of 1965. CCSD also began structural subassembly of S-IB-7 and S-IB-8 during 1965.

At DAC fabrication and assembly of components for S-IVB-206 and S-IVB-207 commenced. In September DAC reassigned the S-IVB-207 common bulkhead to S-IVB-206 because of TIG weld difficulties in forming the bulkhead for S-IVB-206. Welders joined the bulkhead to the S-IVB-206 LOX aft dome and LOX tank in early September, joined the LOX tank to the LH_2 tank cylinder in late September, completed welding the forward dome to the tank assembly on October 7, and ended the joining operations in late October. Jamb weld repairs and hydrostatic tests on the tanks ended in November and insulation installations were started. Engine J-2049 arrived for S-IVB-206 on December 30. Meanwhile, welders also completed jamb weld rework for the S-IVB-207 forward and aft domes. Additional tests following

124. DAC, SM-46960, Issue 30, p. 55; SM-47077, Issue 31, p. 69; SM-47145, Issue 32, p. 66; SM-47199, Issue 33, p. 64; SM-47234, Issue 34, p. 46; SM-47276, Issue 35, p. 70; SM-47313, Issue 36, p. 64; SM-47384, Issue 38, p. 55; SM-47423, Issue 39, p. 58; SM-47486, Issue 40, p. 59; and SM-47522, Issue 41, p. 52.

125. Walter T. Liebrecht and Leroy E. Butts, Uprated I S-IB Stage Assembly and Test Report, S-IB-6, (RB-B6-EIR-5.1), Nov. 4, 1966, p. 13; and MAF, Hist. Rpt., July - Dec. 1965, p. 8.

repair operations, however, revealed further defects which subsequent tests indicated would not degrade stage integrity. By the end of December technicians completed joining the LOX tank to the LH_2 tank and began welding the forward dome to the tank assembly.[126]

SATURN IB/CENTAUR

While NASA chose in 1962 to develop the two-stage Saturn IB vehicle to meet the more immediate Apollo requirements, development plans stipulated that the capability of adding a third stage should be maintained. Third stage configurations under consideration at that time included the application of various Centaur configurations with the S-IB and S-IVB stages, application of the Agena vehicle, and adaptation of a multi-mission module. To support NASA's projected mission requirements beyond the Apollo program each of these, as well as additional third stage possibilities, were analyzed by MSFC during subsequent years.[127]

In 1962 and 1963 possible payloads for a three-stage Saturn IB included the Voyager, various combinations of the Surveyor, and a variety of orbital missions. In September 1964 NASA directed MSFC to consider also a Cislunar Pegasus mission.[128] Of the third stage Saturn IB concepts analyzed by MSFC to support these missions, the Centaur having a 260-inch-diameter shroud evolved as the more promising.

On September 23, 1964, NASA's Director of Advanced Missions Program directed MSFC to review the Saturn IB/Centaur combination and to establish

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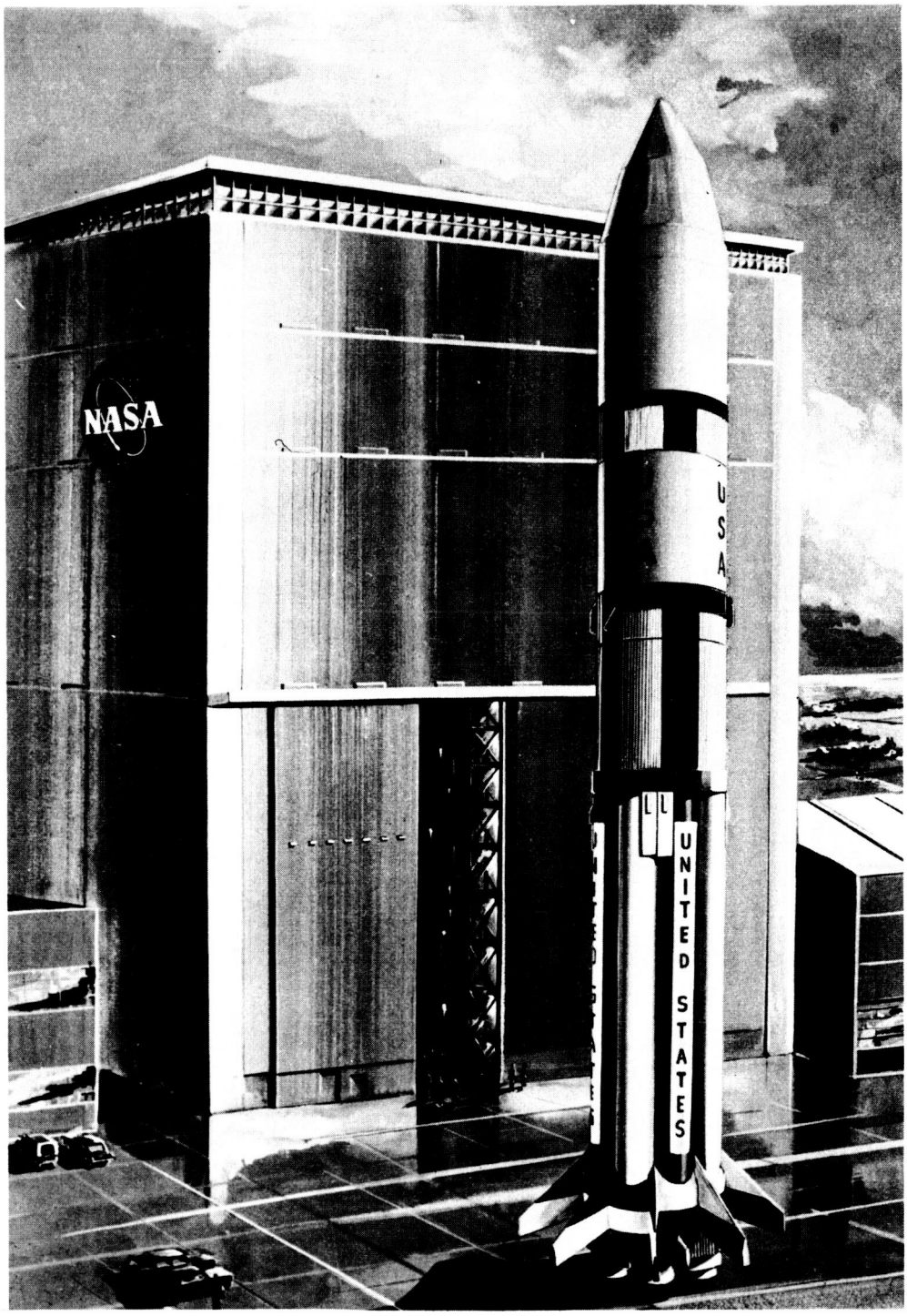
126. DAC, SM-47486, Issue 40, pp. 59-60; and SM-47522, Issue 41, p. 52.

127. MSFC, MHM-8, pp. 79-85; MHM-9, pp. 99-103; and MHM-10, pp. 100-105, contain summaries of studies conducted by MSFC of Saturn IB third stage concepts in 1962, 1963, and 1964.

128. Teletypes, William B. Taylor, NASA, to MSFC, Attn. P. J. DeFries, Aeroballistics Lab., Sept. 14, 1964; and John H. Disher for Samuel C. Phillips, Maj. Gen., Dir., Apollo Program Off., NASA, to MSFC, Attn. Col. Lee B. James, Manager, Saturn I/IB Program Off., Jan. 7, 1965.



SATURN IB/CENTAUR

This drawing shows the proposed Saturn IB/Centaur launch vehicle.

what long lead development should be initiated to meet future project schedules.[129]

In December 1964 Dr. Robert Seamans, NASA's Associate Administrator, approved plans for initiation of a definition and design program for the Saturn IB/Centaur three-stage launch vehicle system and assigned the task to the Office of Manned Space Flight and to MSFC. NASA delineated specific management roles in March 1965 by naming MSFC as project manager for the Saturn IB/Centaur System and Lewis Research Center as Centaur Systems manager. On April 7, 1965, Major General Samuel C. Phillips, Director, Apollo Program, NASA, forwarded an amendment to the FY 1965 Research and Development Appropriation which authorized $5 million to the Saturn IB program for Saturn IB/Centaur design. The authorization specified that only the hardware essential to design effort be procured.[130]

Preliminary effort initiated to identify the necessary changes to adapt the Centaur to the Saturn IB continued, and design studies commenced for effecting the necessary changes. By April MSFC completed identifying most of the changes required to adapt the Centaur, purchased off-the-shelf from Lewis Research Center, to the Saturn IB.

The preliminary design completed in April served as a basis for detail design and vehicle definition. It called for no significant structural modifications to the S-IB stage, the S-IVB stage, or the IU. However, it required that the S-IB stage be pressurized on the launch pad for on-pad protection during maximum wind conditions and also reduced the safety factors to those of unmanned vehicles. This was suggested in lieu of minor strengthening of the lower stages because the ground and flight loads under maximum wind conditions exceeded those of the Apollo vehicle design.[131]

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129. Teletype, Edward Z. Gray, Dir., Advanced Missions Program Off., NASA, to MSFC, Attn. Dr. Ernst Stuhlinger, Research Projects Lab., Sept. 23, 1964.

130. Teletype, Maj. Gen. Samuel C. Phillips, Dir., Apollo Program Off., NASA, to MSFC, Attn. Stan Reinartz, Saturn IB/Centaur Program Mgr., Apr. 7, 1965.

131. Advanced Studies Off., P&VE Lab., Saturn IB/Centaur, IN-P&VE-A-65-6, Apr. 5, 1965, pp. 1-2.

In accordance with the preliminary design, the Centaur as the third stage would be enclosed in a 260-inch-diameter cylindrical shroud. The payload would be enclosed in a fairing consisting of a conical frustrum and a nosecone resembling that used for the SA-203 LH_2 experiment. Within the shroud and payload fairing would be the payload, payload adapter, the Centaur tankage structure, and the Centaur/Saturn conical interstage. The shroud would support the payload weight since the Centaur would collapse should its internal pressure be lost. It and the Centaur/Saturn conical interstage would be mated with the IU and the S-IVB stage. The payload fairing and shroud would be separated during the S-IVB stage burn to expose the payload, Centaur tankage, and the interstage. The S-IVB/Centaur would separate after S-IVB cutoff and then Centaur/payload separation would occur following the Centaur burn.

Preliminary development plans called for internal modifications to the Centaur stage to be performed by the stage contractor, General Dynamics/Convair. These would involve deletion of the fill and vent lines, installation of lightweight insulation on tank walls, installation of temporary valves and blanks required to maintain tank pressure during transportation to MSFC, installation of attachments to propellant tanks if required for piping or wiring installed at MSFC, deletion of jettisonable insulation panels, and deletion of astrionics equipment.

MSFC would fabricate the nose fairing, shrouds, payload adapter, aft interstage, shroud jettison system, Centaur tank support brackets, and snubbers in the shroud. Center personnel would install measuring devices and a destruct system for the shroud, install the GN_2 shroud and interstage purge system, relocate the reaction control system, increase the H_2O_2 capacity depending on control requirements, and would reinstall 50-pound H_2O_2 motors (deleted after the Atlas/Centaur-3). MSFC would also install fill, drain, and vent lines and valves from tank to shroud, install umbilical connections and supports in the shroud, install retro-motor brackets on the interstage, fabricate a mockup, install astrionics equipment, and provide GSE.

KSC would install the GSE and would modify the LC-34 and LC-37 complexes for the Saturn IB/Centaur.[132]

Detail design and documentation for the IB/Centaur vehicle continued at MSFC through mid-November when the Center received word from NASA to terminate the effort in favor of a Saturn V/Centaur program.[133]

At the time of program termination MSFC laboratories had completed all the interface control documentation (ICD) for the IU to the interstage adapter, for the interstage adapter to the Centaur, and most of the ICD for the Centaur to the payload. A study identifying the IU/Centaur mating problems was in progress. Work was initiated on the stage assembly drawings. All major system modifications and layouts necessary to adapt the Centaur stage to the IB vehicle were completed. Studies on specific problems encountered in making the design changes were in progress as was effort to revise the layouts to the latest MSFC/Lewis Research Center discussions and agreements. NASA requested MSFC to complete documentation of the IB/Centaur efforts accomplished in order to preserve the effort for potential future requirements.[134]

Cancellation of the Saturn IB/Centaur program did not preclude use of the standard Saturn IB or an improved Saturn IB in support of the Apollo Applications program. Studies for improving the IB and on adaptation of the IB vehicle for Apollo Applications payloads are covered in a later Chapter of this monograph entitled "Advanced Studies Program."

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132. P&VE Lab., IN-P&VE-A-65-6 (May), p. 46.

133. Teletype, John H. Disher, Dep. Dir., Saturn/Apollo Applications Program, NASA, to Gen. E. F. O'Connor, Dir., Industrial Operations, MSFC, et. al., Nov. 18, 1965.

134. P&VE Lab., MPR-P&VE-65-9, pp. 4-5; and Teletype, Disher to O'Connor, Nov. 18, 1965.

FACILITIES, SUPPORT EQUIPMENT, AND TRANSPORTATION

Facilities

Many of the facilities supporting the Saturn IB program are used in common with the Saturn I and Saturn V programs. Those used in common with the Saturn V program mostly include the S-IVB and IU facilities. These are funded with Saturn V program funds and are described more fully in the Saturn V chapter of this monograph. The Saturn I facilities used for the Saturn IB program include production, ground test, and launch facilities; these underwent final conversion for IB application during 1965.

Major Saturn IB facilities are located at Huntsville, Alabama; at MAF near New Orleans; at the NASA Computer Center, Slidell, Louisiana; at Huntington Beach, Santa Monica, and Sacramento, California; and at KSC, Cape Kennedy, Florida.

Huntsville Facilities

Located at Huntsville are the Saturn IB facilities at MSFC and the IBM IU facilities near MSFC. Primary MSFC and IBM facilities for the IB became operational in 1965.

Modification of the Saturn I dynamic test stand for Saturn IB testing ended at MSFC in January 1965. Activation of the stand in its new capacity occurred on February 18 with the first series of Saturn IB dynamic tests. Use of the stand for IB testing ended with the final series of dynamic tests on September 11.[135]

Conversion of the former S-I static test tower at MSFC for S-IB static testing ended in February 1965. Technicians installed the first

135. Saturn I/IB Program Off., I/IB-65-1, p. 8; and Saturn V Program Off., MPR-SAT-V. 65-3, p. 27.

S-IB flight stage in the stand on March 14 and conducted the first static firing in the stand on April 1.[136]

The Saturn IB Systems Development Facility (SDF) at MSFC also became operational in 1965. Activity to ready the facility involved acquisition and emplacement of GSE used in vehicle automated checkout. This activity is described in the section dealing with "Support Equipment".

In Huntsville's Industrial Research Park near MSFC the IU contractor completed and dedicated its Space Guidance Center. The facility, dedicated in October, included four buildings housing administrative offices, assembly, and checkout facilities for the IU.[137]

Installation of structural assembly fixtures occurred in Stations No. 1 and No. 2 of the highbay assembly area during January and February. In January MSFC delivered the structural segments for the first flight IU to IBM and assisted IBM personnel in activating the assembly facility by beginning fabrication and assembly of S-IU-201.

MSFC personnel also assisted IBM in activating the Systems Test Complex. Installation of the Telemetry Ground Station was approximately 95 per cent complete at the beginning of 1965. Power was applied to the station on January 9. In January technicians installed the Digital Events Evaluator in Control Room A and completed installation of most of the racks for the electrical support equipment in January and February. Installation of the first RCA-110A computer occurred in the facility in February. In June IBM received the IU checkout stand and mounted it on the supporting jacks and attached the umbilical cable holding bracket. Also in June the mechanical system test set checkout was started and the power transfer switch for the Ground Control Computer System installed. Remaining equipment was received, checked out, and installed in July.

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136. Test Lab., Hist Rpt., Jan. 1 - Dec. 31, 1965, p. 1; and Systems Static Test Branch, CCSD, Saturn S-IB Stage Final Static Test Report, S-IB-1, June 4, 1965, pp. 1-2.

137. Guy L. Jackson, "260,000-Square-Foot Unit Is Dedicated Here By IBM" in The Huntsville News, Oct. 7, 1965.

In August IBM activated the facility with installation of S-IU-201. S-IU-201 checkout continued through the first week in October. On removal of the S-IU-201 IBM effected design changes in some of the equipment to prevent recurrence of problems associated with the S-IU-201 checkout. The contractor then began incorporating the S-IU-500FS test program changes not required for S-IU-201 into the checkout operating system.

Although IBM assumed responsibility for system and component testing on a gradual scale, the contractor began procurement of the long leadtime systems checkout and component test equipment for the Component Acceptance Test Complex immediately upon completion of negotiations for the lead contract. By May IBM had procured, checked out, and installed a goodly portion of the equipment required in the receiving inspection facility and had managed to process approximately 1,228 parts through the facility. By the end of the year most of the component test equipment was on hand, installed, and in operation; the backlog of parts awaiting inspection averaged less than 100 daily and a quick processing of critical flight parts was possible.[138]

Louisiana Facilities

The Saturn facilities at Michoud house government management personnel, the S-I/IB stage contractor operations, the Saturn V S-IC stage contractor operations, and support service contractor operations. Most of the S-I/S-IB facilities at MAF have been operational for several years.

Major construction completed at Michoud in 1965 included a South Mezzanine Cafeteria with a seating capacity of approximately 800 located in the manufacturing plant; a High Pressure Test Facility providing high and low test capabilities; a Hazardous Test Facility; and conversion of Saturn I Checkout Station No. 1 to support S-IB stage checkout. Other

138. IBM, IBM-65-966-0004H, pp. 23 and 30; IBM-65-966-0005H, pp. 26-27; IBM-65-966-0007H, p. 40; IBM-65-966-0010H, p. 32; IBM-65-966-0020H, p. 46; IBM-65-966-0022H, pp. 37-38, and p. 40; IBM-65-966-0023H, p. 39; and IBM-65-966-0024H, pp. 1-2.

effort completed included additions to the existing dock embarkment to preclude erosion resulting from tidal action; landscaping involving the addition of an entrance drive for visitor parking for the Engineering and Office Building; pavement of four parking lots covering 11 acres; construction of access roads; lighting and rehabilitation of airstrip; and modification of the steam plant.

Construction underway at the end of 1965 involved construction of an L-shaped contractor services building to house medical, reproduction, fire, communication, plant protection, transportation, and photographic services; extension to the Saturn marine dock; modification of the Chemical Waste Deep Well system; and modification of the storm drainage system. Also in progress at the year's end were emergency roof repairs and other emergency repairs to restore facilities to their original state following a visit by Hurricane Betsy on September 9 and 10.[139]

Nearby at the Slidell Computer Operations Office which supports MSFC's management group and the industrial contractors at Michoud, modifications completed in 1965 included the addition of a mechanical room to house additional air handling, an additional chiller, and extended ductwork providing more air conditioning for additional computer loads. At the end of 1965 Quinn Construction Company, under a contract awarded February 27, was continuing construction of a two-story addition and basement to the computer building. Completion of the additions in early 1966 will add approximately 40,000 square feet of floor area to the building. Cafeteria additions to the facility were also in progress at the end of 1965.[140]

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139. MAF, Hist. Rpt., Jan. 1, 1965 - June 30, 1965, pp. 2, 6, and 37-39; July 1 - Dec. 31, 1965, pp. 40-45; Saturn I/IB Program Off., I/IB-65-1, p. 13; PAO, Press Release No. 65-125; and Teletype, W. E. Lilly, Dir., Manned Space Flight Program Control Off., NASA, to H. H. Gorman, Dep. Dir., Admin., MSFC, subj., "Funding of Hurricane Damage Repairs at Michoud Assembly Facility," Sept. 16, 1965.

140. MAF, Hist. Rpt., Jan. 1 - June 30, 1965, pp. 37 and 48; PAO, Press Release 65-48, Mar. 2, 1965; and Saturn V Program Off., MPR-SAT-V. 65-2, p. 41.

California Facilities

Located at Huntington Beach, Santa Monica, and Sacramento, California, are the industrial S-IVB development and test facilities. Most of these facilities were designed and built to support S-IVB/V development prior to initiation of the Saturn IB S-IVB development program. They required only slight modification to support S-IVB/IB effort and will be reconverted later for the S-IVB/V effort.

In 1965 following completion of the S-IV stage development DAC received NASA approval for relocating the Saturn I S-IV dual assembly towers from Santa Monica to Huntington Beach Space Systems Center. At Huntington Beach one tower would provide an additional capability for installations on a vertical S-IVB stage as well as J-2 engine installations, and the other tower a facility for high pressure leak checks. On July 2 DAC awarded the architectural and engineering contract for relocation of the towers to Holmes and Narver, Inc. The design criteria for conversion of the towers and tooling installations was completed in September, and in October Holmes and Narver poured the foundations for the towers and started erection of the steel framework. Fabrication of the tooling and production test equipment for the towers commenced in October and continued throughout the remainder of 1965.

Other 1965 effort on S-IVB production facilities involved modification of special tooling in Tower No. 1 at Huntington Beach in June to convert the tower for S-IVB common bulkhead tests, and conversion of the LH_2 cylinder welder and the cylinder-to-ring trim and welding fixture for both MIG- and TIG-type welding in July.[141]

At DAC's test site in Sacramento both the acceptance firing stands at the Beta Complex became operational.

Buildup of Beta 3 Test Stand continued into mid-February when grounding and bonding of the automatic GSE and mechanical equipment on the test

141. DAC, SM-47276, Issue 35, p. 69; SM-47313, Issue 36, p. 63; SM-47384, Issue 38, p. 55; SM-47423, Issue 39, p. 57; and SM-47486, Issue 40, p. 59.

stand and in the Test Control Center ended. Workmen on February 18 installed the S-IVB Facilities Checkout stage in the stand and continued preparations for checking out the operational readiness of the stand. Checkout of the stand began with a successful cryogenic propellant loading test, conducted manually, on April 21; a successful automatically controlled cryogenic loading test of the vehicle completed the stand checkout on May 1. Installation of the first flight S-IVB (S-IVB-201) in the stand occurred on May 7. Its successful checkout as well as that of S-IVB-202 occurred in the stand during 1965.

Use of the Beta 1 stand for S-IVB/IB Battleship firings continued through May 1965. The stand was then converted and used for S-IVB/V Battleship firings through September 8. Afterwards, Beta I stand conversion for S-IVB flight stage acceptance firings, including automatic GSE installation and checkout, proceeded through October. On November 3 workmen installed S-IVB-203 in the stand and during the remainder of 1965 performed prefiring activities in preparation for the first static firing scheduled for early 1966.

Basic construction of two other SACTO facilities also ended in 1965. Joint occupancy of the Vertical Checkout Laboratory, used for post-firing checkout, occurred in July 1965. The Alpha 1 test stand, used as a common bulkhead test facility, was completed in October 1965.[142]

Florida Facilities

Since KSC is responsible for launch facility construction, this report contains only a summary of the major activity in support of the Saturn IB launch program. The Saturn IB program requires modification of two launch complexes originally used in support of the Saturn I launches.

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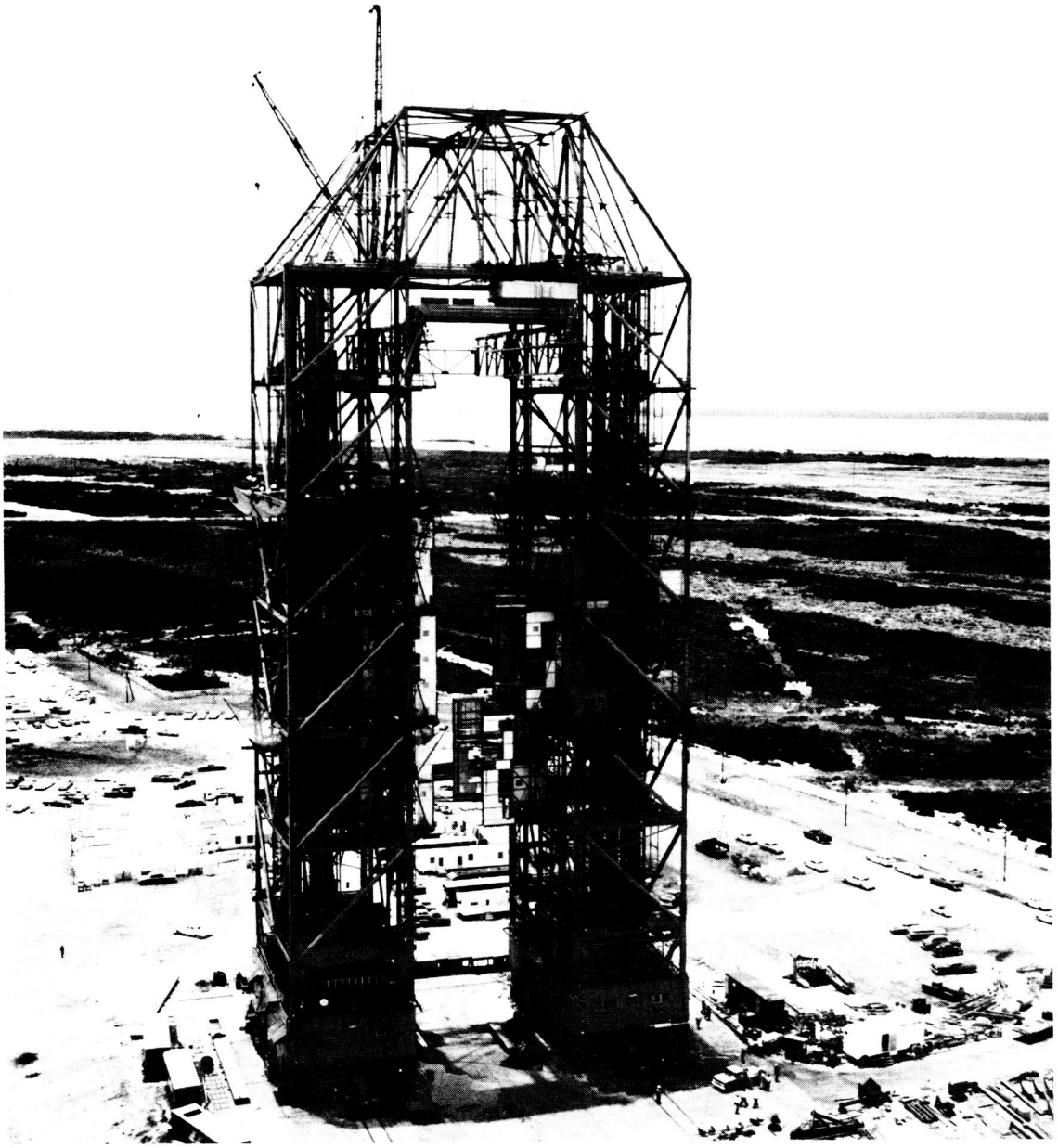
142. Saturn I/IB Program Off., I/IB-65-1, p. 14; DAC, SM-46960, Issue 30, p. 53; SM-47077, Issue 31, p. 67; SM-47145, Issue 32, p. 65; SM-47199, Issue 33, p. 63; SM-47234, Issue 34, pp. 43 and 45; SM-47384, Issue 38, p. 38; SM-47486, Issue 40, p. 40; and SM-47522, Issue 41, pp. 1 and 36; and Saturn V Program Off., MPR-SAT-V. 65-1, p. 46; MPR-SAT-V. 65-2, p. 50; MPR-SAT-V. 65-3, p. 60; and MPR-SAT-V. 65-4, pp. 51-52.



LC-34 GANTRY

This is the service structure at Kennedy Space Center's Launch Complex 34, pictured in June 1965 during modification to support Saturn IB launches.

Launch Complex 34 (LC-34), scheduled to support the AS-201 launch, was last used in support of the Saturn I SA-4 launch in March 1963. Modification of the complex to support the Saturn I, Block II series began immediately and continued until the last quarter of 1963 following the decision to launch all remaining Saturn I vehicles from LC-37. A program to modify the facility to support the Saturn IB was immediately initiated. Actual modification got underway in October 1964 with emphasis directed toward the service structure, propellant storage and transfer system, pneumatics, instrumentation and communications, and vehicle servicing.

McDowell-Wellman Engineering Company completed Phase I modifications to the service structure in August 1965. Final inspection of the work occurred on August 17 and subsequent corrective adjustments to the launch escape system hut and hoist machinery ended on August 25, completing all of the Phase I modification.

R. E. Clarson, Inc., received the contract for Phase II service structure modifications on January 27, 1965, and completed the work on August 25.

By the end of 1965 most of the remaining LC-34 modification was completed including all the support service systems. Acquisition of the support equipment is described in the next section of the chapter entitled "Support Equipment."

Vehicle checkout of the LC-34 facility and most of the GSE ended in October and at the end of 1965 only minor modifications remained to be finished prior to the AS-201 launch.

Modification of LC-37 to support Saturn IB launches began also in 1964; however, only effort not affecting the Saturn I launch program could be started. The preparatory design work and award of modification contracts continued in early 1965 although the last Saturn I launch did not occur until July 30, 1965.

Awarded in February were contracts to J. C. Abbott, February 10, for modification of the monorail in the spare parts building; to James A. Oberlin, February 15, for pressurization of the service structure

machinery room; and to F. A. Kennedy, February 25, for construction of the service structure fire-water system. A contract for construction of modifications to Hangar AE of the mission control center was awarded to Magna Building Corporation on March 29 and work began on April 7. Also on April 7, KSC awarded the Construction Services Company a contract to fabricate, construct, and install the modifications to the GH_2 facility. Two days later the Pittsburgh-Des Moines Steel Company received the contract covering design, fabrication, and erection of the 125,000-gallon LN_2 storage tank at the LC-37B converter-compressor facility. The contract for construction of modifications to Hangar S of the mission control center went to Smith and Sapp Construction Company on April 29. M. Connell and Associates completed the design for modifications to the service structure on June 1, and on July 2 the Blount Brothers Corporation received the contract to adapt LC-37 for Saturn IB.

Work completed toward modification of LC-37 in 1965 included the emergency egress-ingress system by Julian Evans and Associates on June 1; Phase B and C alteration of the LC-37 stiff leg jib hoist by Fincor, Inc., on June 24 and August 24; construction of the fire-water system for the service structure in June; modification of Hangar AE on August 13; modification of the GN_2 facility in September; and erection and hydrostatic test of the LN_2 storage tank in December.[143]

Support Equipment

Support equipment includes all electrical and mechanical equipment and services needed to accommodate the Saturn IB stages and the entire vehicle from assembly through liftoff.

143. KSC, Technical Progress Report, First Quarter, CY-1965, TR-168, pp. 9-13; Second Quarter, CY-1965, TR-194, pp. 7 and 10; and Third Quarter, CY-1965, TR-250, pp. 2.2--2.6.

Factory Checkout GSE

Most of the ground support equipment (GSE) supporting stage assembly and development checkout at contractor sites became operational in 1964, the remainder in 1965. Initial prime contracts either purchased or required the contractors to furnish all of this GSE not furnished as government equipment.

In 1965 CCSD completed conversion of checkout equipment in the Saturn S-I Checkout Station No. 1 at MAF to make it compatible with Checkout Station No. 2 and the S-IB stages.[144]

DAC continued in 1965 the installation of ESE in the Engineering Developmental Systems Integration Laboratories (EDSIL) at Huntington Beach. DAC also continued equipment checkout and performed equipment modification to make it correspond with the latest stage configurations undergoing factory checkout. Rerun of the GSE self test to the S-IVB-201 configuration ended in January. In February and March DAC completed vehicle simulator configuration 201 testing on the electrical telemetry and propulsion subsystems. DAC modified the vehicle simulator to the 202 configuration in April and completed S-IVB-202 development checkout. Modification of the simulator to the S-IVB-203 configuration began near the end of May and continued through early July. In July DAC initiated tests at the facility with the automatic ground equipment test set (GETS) using the ATOLL computer language (acceptance, test, or launch language) especially developed for automatic checkout operations. The contractor also continued in 1965 to install and modify GSE at SACTO. The contractor used the equipment at SACTO in advanced phases of APS and battleship testing and in automatic checkout of the stages before, during, and following static firings.[145]

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144. MAF, Hist. Rpt., Jan. 1 - June 30, 1965, p. 6.

145. DAC, SM-46960, Issue 30, p. 58; SM-47145, Issue 32, p. 68; SM-47199, Issue 33, p. 66; SM-47234, Issue 34, p. 59; and SM-47313, Issue 36, p. 66.

Installation and checkout of equipment in IBM's checkout station continued into the second quarter of 1965. The RCA-110A computer for the facility arrived in February and was installed in March. IBM activated the facility on July 20 and began station verification on July 29. Checkout of the first flight unit, S-IU-201, ended in October.[146]

Launch Support and Launch GSE

NASA and program participants identified and purchased the additional GSE and launch support in 1965 required for the Saturn IB launch program at KSC.

MSFC completed contract negotiations with the General Electric Company (GE) for the Saturn IB and V ESE mission support on March 22; NASA signed the contract on April 1. Negotiations on the fabrication and checkout phase of the contract continued through April.[147]

In September CCSD received a contract supplement to the S-I/IB stage contract in the amount of $41,200,128 to cover support services for launches from LC-34 and LC-37. Of this, $36,617,410 was for the IB launch support. The contract covered installation/modification, checkout, and maintenance of GSE, including propellant storage and transfer systems, pneumatic systems, electrical systems, launch site radio frequency and telemetry checkout equipment, and launch support stations; completion of environmental control systems begun under previous contracts, launch site documentation and refurbishment of pads after launch; and engineering assistance to KSC Launch Support Equipment Engineering Division in design modifications.[148]

Definition of DAC's requirements to provide adequate GSE and manpower for Saturn IB and Saturn V S-IVB KSC operations continued throughout

146. IBM, IBM-66-966-0016, p. 8.3.

147. Saturn V Program Off., MPR-SAT-V. 65-1, p. 35; and PAO, Press Release No. 65-100, Apr. 27, 1965.

148. KSC, TR-250, p. 2.2; Saturn I/IB Program Off., MA-001-003-2H, p. 3.4; and PAO, Press Release No. 65-231, Sept. 21, 1965.

1965. Early in November a joint NASA/DAC program alignment task group was formed and given a charter to define DAC's activities at KSC, to estimate the task to be performed in Fiscal Year 1966, to establish a reasonable working schedule, and to list priority tasks to be performed.[149]

IBM's IU contract signed on March 31 called for IBM to furnish GSE launch support involving IU checkout, pad erection, and servicing. NASA later modified the contract to authorize IBM to provision spares for the IU GSE.

Development, installation, and checkout of the GSE required to support launch readiness of the Saturn IB vehicle and of the LC-34 and LC-37B facilities at KSC received the largest concentrated activity in 1965.

This also involved preparation and activation of the SDF at MSFC used to develop and debug the computer and checkout programs for automatic checkout of the vehicle at KSC. The SDF also supported GSE and vehicle system debugging, and was used for certification of systems integration.

MSFC received and accepted both RCA-110A computers for the facility before the end of March. Installation of mechanical support equipment (MSE) in the facility progressed as scheduled; however, receipt and installation of ESE lagged behind schedule. This resulted from late ESE engineering releases and procurement. Program officials established a special MSFC task force to expedite delivery of the ESE and also agreed to give the Saturn IB IU Checkout Station, the SDF, and LC-34 ESE priority over Saturn V ESE.

MSFC used the partially operational SDF in March in a test designed to verify the compatibility of the GSE and associated vehicle systems with the ST-124M stabilized platform. Other minor tests were accomplished before the facility became fully operational by using substitute methods and by initiating manual instead of automatic checkout of some equipment.[150]

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149. DAC, SM-46960, Issue 30, p. 8; SM-47384, Issue 38, p. 3; SM-47423, Issue 29, p. 3; SM-47486, Issue 40, p. 3; and SM-47522, Issue 41, p. 3.

150. Saturn I/IB Program Off., I/IB-65-1, p. 12; and Saturn V Program Off., MPR-SAT-V. 65-1, p. 34.

In May the projected operational date for the SDF slipped from July 7 to July 27 and available operational time for the SDF was programmed on a priority basis. Coding and debugging of some programs continued to be accomplished partially by a desk operation. In September technicians successfully tested the GETS by using the Saturn IB Launch Computer Complex Operating System program at the SDF and at KSC. The Operating System tape was also used to apply power to the SA-201 at KSC in October. The LVDC/LVDA for the SDF became available in October, and MSFC and IBM personnel worked together on checkout of test equipment and on final preparation of the S-IU-201 flight program tape. The final SA-201 flight program (Revision C) verification on the SDF ended in mid-November and was forwarded to KSC for computer loading prior to installation of the LVDC in S-IU-201.

Checkout of program tapes for some of the SA-202 and SA-203 IU systems on the SDF also progressed during 1965.[151]

Commensurate with SDF activity at MSFC was the acquisition, checkout, and installation of GSE for LC-34 and LC-37. Two sets of ESE and MSE are required at Saturn IB facilities at KSC: one set for LC-34, and one set for LC-37B. During the first quarter of 1965, MSE activities progressed satisfactorily; however, ESE for LC-34 reflected the delay experienced due to late ESE engineering releases and procurements.

Although constrained by component qualification and vendor manufacturing problems in development of S-IVB GSE, DAC managed to deliver the S-IVB umbilicals for LC-34 to MSFC in February for swing arm tests. DAC delivered the forward umbilical kits for LC-34 in May. Under technical direction of MSFC's Test Laboratory, CCSD personnel performed tests of the umbilical swing arms for both LC-34 and LC-37. Arms No. 1, No. 2, No. 3, and No. 4 for LC-34 arrived in the period February 17 through March 23. Workmen incorporated numerous modifications into the arms and their associated equipment, ranging from installations of vehicle fluid service lines to

151. IBM, IBM-65-966-0008H, pp. 17 and 26-28; IBM-65-966-0010H, pp. 13 and 22-23; IBM-65-966-0020H, pp. 15-16; IBM-65-966-0022H, pp. 13-14 and 23-24; IBM-65-966-0023H, pp. 13-16, 23, and 26-27; and IBM-65-966-0024, pp. 13-17 and 23/24.

modification of the S-IVB/IU umbilical carriers. Chrysler satisfactorily completed testing of the arms during the period April 13 through June 21. All modification of the arms and S-IVB/IU umbilical carrier assembly were then completed, and they were shipped to KSC on June 25 for installation at LC-34.

Special tests in July at MSFC were satisfactorily performed on the backup ground umbilical housing for the service module, on the electrical eject plate of the S-IVB forward umbilical carrier assembly, and on a new pneumatic lockpin installed in swing arm No. 4. Results of the latter test indicated the new design would be acceptable for use on all Saturn IB swing arms.

Testing of the LC-34 Apollo access arm began on September 13 when the arm truss structure was mated to the arm actuating assembly. A fixture simulating the environmental chamber (EC) was fabricated and installed on the arm in lieu of the EC which had not been received. Strain gauge data was recorded and analyzed with normal results. However, rotation tests (manual and automatic) to determine proper rotation rates and operating pressure failed to produce desired results due to improper design of the hydraulic return line shutoff valve cam plate. MSFC's Test Laboratory and KSC began investigating redesign.

The EC arrived on October 1, and the EC simulating fixture was removed and the EC installed on the access arm and made ready for tests. Prior to performing the EC tests, test engineers also tested with good results a redesigned cam plate in the hydraulic return shutoff system. Mating of the EC with the command module proved unsatisfactory and required additional modification. Because of the urgent need for the access arm at LC-34, technicians incorporated many temporary "fixes" to make the system operational and then shipped it to KSC.[152]

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152. DAC, SM-47145, Issue 32, p. 32; SM-47276, Issue 35, p. 81; SM-47522, Issue 41, p. 62; Test Lab., Hist Rpt., Jan. - Dec. 1965, pp. 4-7; and P&VE Lab., MPR-P&VE-65-2, pp. 18-19; MPR-P&VE-65-3, p. 19; MPR-P&VE-65-4, p. 13; MPR-P&VE-65-5, p. 20; MPR-P&VE-65-6, p. 18; and MPR-P&VE-65-6 (June), p. 11.

Also completed in 1965 was the design, development, checkout, and integration of IU component handling equipment (CHE) required for staging the IU on the launch pad. CHE developed by IBM included an IU hoist and hoist track to transport components weighing over 35 pounds through the IU access door to an IU cart; the cart to travel within the IU on the S-IVB stage work platform to the designated mounting location; and body-fitted component handling harness to assist personnel in transporting and installing IU components weighing between 10 and 25 pounds to prevent accidental puncture of the S-IVB stage bulkhead.

The body-fitted handling harness was tested during February in the IU interstage mockup area at MSFC. Test engineers using the body-fitted harness climbed in and out of the IU access opening and installed and removed components from the cold plate wall with relative ease.

During February analysis indicated interference problems would exist between the IU component handling cart, the S-IVB access kit, and the IU and S-IVB components. Steps were taken by MSFC, DAC, and IBM to effect the necessary redesign or modification required to resolve the problem. A similar problem became evident in May with regard to access into the IU from LC-34 and LC-37B when the structure platform above the IU would be used for servicing the Lunar Excursion Module (LEM). This problem of interference was eliminated on Pad 34 by raising platform No. 5 by 18 inches. Platform No. 5 on LC-37 would be raised 24 inches to eliminate the problem while servicing SA-203 and would be modified as necessary prior to the launching of SA-206, the first vehicle with a LEM to be launched from LC-37.

In June IBM completed with good results a functional test of the hoist, track, door frame assembly, the IU cart, and the LVDA fixture. The contractor encountered problems on the functional test of the battery fixture and discontinued further testing until modification of the prototype CHE to the production level. By July all design and documentation for the production CHE was complete except for an additional fixture required to handle the power distributor and a fixture for the S-IVB

stage batteries. On August 11 IBM personnel demonstrated the prototype CHE in the MSFC S-IVB/IU mockup for KSC and MSFC personnel. Following the demonstration KSC personnel made some suggestions for minor changes on the hoist. MSFC approved the final design of the equipment pending the requested changes. On August 2 IBM personnel participated in a CHE test at KSC. The use of the internal cart and door hoist was demonstrated in the S-IU-200F using an actual ST-124M component. Further testing of the CHE fixtures continued to ensure CHE/S-IU-201 compatibility. A few changes resulted due to changes in the cabling and plumbing runs on S-IU-201. On September 17 MSFC informed IBM that a required stair-climbing capability had been omitted from the transporter cart. IBM agreed to modify the cart for this capability and to retrofit the LC-34 and LC-37 carts. This modification satisfied the basic requirement that the cart be interchangeable between LC-34, LC-37, and LC-39. IBM informed MSFC that it could not meet delivery of production CHE on some hardware by the target date of October. This was due to incorporation of the requested demonstration changes, because actual unit installation in the S-IU-201 presented problems not anticipated during design, and because of vendor problems with the cart columns and hoist.[153] Shipment of production CHE to KSC continued throughout the remainder of 1965.

Receipt and installation of pneumatic GSE for servicing the vehicle at LC-34 suffered delay in 1965 due to vendor failure to maintain supply schedules to the prime contractors. The IU LC-34 pneumatic GSE underwent final acceptance tests at the Hayes International Corporation on April 26. By the end of July DAC completed factory checkout on most of the S-IVB pneumatic GSE for LC-34 and continued an all-out effort to complete final assembly of the pneumatic consoles to meet an August 21 deadline. Hamilton Standard Division of United Aircraft Corporation delivered the S-IVB APS

153. IBM, IBM-64-966-0004H, p. 9; IBM-65-966-0005H, pp. 18-19; IBM-65-966-0006H, p. 5; IBM-65-966-0007H, p. 9; IBM-65-966-0008H, pp. 10-11; IBM-65-966-0010H, pp. 11 and 20; IBM-65-966-0020H, pp. 11 and 26; and P&VE Lab., MPR-P&VE-65-3, pp. 19 and 30; MPR-P&VE-65-4, p. 20; MPR-P&VE-65-6 (May), pp. 14 and 22-23; MPR-P&VE-65-6 (June) p. 13; MPR-P&VE-65-7, p. 21; MPR-P&VE-65-8, pp. 12, 26, and 49-50; and MPR-P&VE-65-9, pp. 3 and 30.

fuel unit servicer on September 10 and shipped the Unit 2 oxidizer servicer to KSC on November 19. CCSD completed necessary modifications to the LC-34 pneumatic system in the early fall and completed documentation on new service equipment and modification to existing service equipment at KSC. Use of alternate means or interim equipment at KSC prevented any significant delays or constraints during facility and facility vehicle tanking tests in September.[154]

The pneumatic consoles formed a part of the equipment located in the launch control center (LCC) used to check out flight vehicles prior to launch. In addition to the propellant tanking checkout equipment the LCC contained the S-IB checkout equipment and the S-IVB checkout equipment. Portions of the facility received functional checkout in September during the propellant loading of the facilities checkout vehicle. The total simulation of the propellant tanking system allowed correction of discrepancies noted in the DAC S-IVB and in the IU pneumatic consoles prior to checkout of the flight vehicle hardware. Inadequate flowrate had to be corrected in the S-IVB consoles. Hayes International Corporation replaced a failed inlet supply valve in the IU pneumatic console. In December program officials approved removal of all differential pressure gauges from the IU pneumatic consoles and plugging of the gauges in the S-IVB and APS consoles.[155]

By the end of September most of the equipment for the automatic ground control station at LC-34 had been received, installed, and checked out. This included the digital computers and checkout equipment used during vehicle prelaunch tests and the vehicle test power equipment. Already checked out was the digital data acquisition system (DDAS) computer and the DDAS computer interface. On September 22 technicians completed checkout of the GETS. An integrated GETS test started on September 28 and

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154. KSC, TR-250, p. 22; P&VE Lab., MPR-P&VE-65-5, p. 14; MPR-P&VE-65-6 (June), pp. 10-13; MPR-P&VE-65-9, p. 2; MPR-P&VE-65-11, pp. 7-8; and DAC, SM-47423, Issue 39, p. 67; SM-47486, Issue 40, p. 78; and SM-47522, Issue 41, p. 62.

155. P&VE Lab., MPR-P&VE-65-11, pp. 7 and 11; and MPR-P&VE-65-12, p. 10.

ended October 2. MSFC on September 30 shipped a temporary cabling system for the final checkout console racks already installed in the facility. Other equipment received and made operational in the facility included all of the telemetry checkout boxes and panels, an air-cooled LVDC for use in completing functional check of the Aerospace Computer Manual Exerciser (ACME), the launch control computer, the flexible automatic circuit tester (FACT), and all of the IU ESE and cables.

Receipt of an interim operating system program for the RCA-110A computer allowed test engineers on October 26 to apply power to the S-IB-201 flight stage. Power application to the first S-IVB flight stage occurred on October 26, and electrical mating of the entire vehicle ended November 10. Arrival of the final RCA-110A computer operating tape on November 27 permitted command guidance and control system checkout to commence November 29. By the end of the year, most of the required GSE including the ESE was installed and operational for LC-34.[156]

Receipt and installation of GSE and ESE continued throughout 1965 for LC-37B. CCSD completed testing and shipment of the LC-37B umbilical swing arms and the access arms. Installation of other GSE progressed as scheduled; however, late ESE deliveries did pose problems and threatened to affect the scheduled activation of the complex.

Transportation

Most of the transportation methods and equipment used in moving Saturn IB stages are the same or similar to those used to transport Saturn I stages. Special transporters carry the stages on short hauls over land routes; for long hauls, barges ferry the stages over water routes, and supersize aircraft fly the stages via air.

156. Saturn Flight Evaluation Working Group, MPR-SAT-FE-66-8, p. 13; P&VE Lab., MPR-P&VE-65-12, p. 1; and IBM, IBM-65-966-0022H, pp. 26-27.

SATURN BARGE FLOTILLA

Three NASA barges used in transporting Saturn stages are seen on the Tennessee River near MSFC early in 1965. The barges are tied together and pushed by a single tugboat. The two covered barges contain Saturn IB stages bound for MSFC.

S-IB Stage Transportation

The S-IB stage land transporter, operational for several years, is the same fixture used in assembling the stage. The fixture is set on two dolly assemblies and is towed by a prime mover such as an M-26 military tractor. The transporter is also employed as a shipping cradle for stage shipment by barge.

Two barges, Promise and Palaemon, transport S-IB stages to and from CCSD's manufacturing site at Michoud, Louisiana, and the stage test site, MSFC in Huntsville. These vessels also transport the stages to KSC for launch.

CCSD personnel completed training for shipping the stages aboard the barges in 1964. In 1965 MSFC's Test Laboratory furnished to CCSD as GFE the shipping covers necessary to protect the stages during river shipment.[157] The contractor completed nine S-IB stage shipments in 1965; the first, S-IB-1 from Michoud to MSFC, occurred on March 6.

Two contract actions in 1965 concerned S-IB stage transportation. On May 19, 1965, MSFC extended for one year a contract to Mechling Barge Line Inc., of Joliet, Illinois, for towing three Saturn vehicle barges, the two S-IB stage barges and a third barge being readied to transport the large Saturn V booster. In September NASA requested Navy assistance in salvaging the Promise barge, beached on the Michoud levee as a result of Hurricane Betsy. Avondale Shipyards of Harvey, Louisiana, received the contract for repairing the $89,139 damages inflicted to the barge by the hurricane.[158]

S-IVB Stage Transportation

The S-IVB ground transporter consists of a built-up base frame mounted on a four-wheeled undercarriage at the rear end, and two sets of drop legs at the forward end. It is towed by a tractor. The S-IVB transporter

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157. Test Lab., MPR, May 12 - June 12, 1965, p. 45; and Sept. 12 - Oct. 12, 1965, p. 26.

158. PAO, Press Release No. 65-128, May 19, 1965; Teletype, W. F. Boone, Dep. Assoc. Adm. for Defense Affairs, NASA, to RUECD/Chief, Bureau of Ships, Dept. of Navy, Wash., et al., subj., "Request for U. S. Navy Salvage Assistance," Sept. 17, 1965; and MAF, Hist. Rpt., July - Dec. 1965, p. 43.

STORM BEACHES PROMISE

The Saturn barge Promise was left grounded on a levee at MAF in the path of Hurricane Betsy September 9-10, 1965.

provides support and shock isolation for the stage during all normal land, sea, and air transportation.

The S-IVB dynamic test stage, first S-IVB stage cradled in a transporter during shipment, arrived at MSFC on January 4, 1965. Additional transportation employed in shipment of the stage included instrumentation kits to monitor vibration measurements of the stage, stage protective covers, the dolly transporters, and stage handling kits. The Aloha State, a States Marine Ship, transported the stage from the West Coast via the Panama Canal to New Orleans. There it was transloaded onboard the Promise barge for the remainder of its journey to MSFC.[159]

Early in January 1965 the Harbor Boat Building Company completed modification of the West Coast Barge (YFNB-20) Orion for use in shipping S-IVB and other Saturn stages along the California Coast. MSFC personnel coordinated the loading and tiedown of the S-IVB-F, first S-IVB stage to use the barge for transport from Seal Beach to Sacramento. The Orion left Seal Beach on February 12 on its maiden trip. At Courtland dock the stage was unloaded from the barge and transported overland on the transporter to its test site at SACTO.[160]

Modification of Point Barrow, a former Navy LSD scheduled for ocean transport of the S-IVB, ended in May 1965. Design and fabrication of the marine tiedown equipment necessary for S-IVB shipments aboard Point Barrow was accomplished by MSFC Test Laboratory personnel. Center personnel delivered the tiedown equipment and also completed inspection and approval of the modified Point Barrow in May. The vessel officially became available to NASA on June 1. On June 13 it departed Seal Beach en route to Michoud and then to KSC. MSFC personnel traveled aboard the vessel during its trip to observe the initial use of the tiedown equipment and transport

159. Saturn I/IB Program Off., I/IB-65-1, p. 7.
160. Ibid., and Saturn V Program Off., MPR-SAT-V. 65-1, p. 30.

of the S-IVB-F and a Saturn V S-II Fitup Fixture. The Point Barrow delivered the S-II fixture at Michoud on June 26 and arrived at KSC with the S-IVB-F stage on June 30.[161]

During 1965 MSFC and NASA continued investigations begun in 1964 on the possibility of air transport of the S-IVB stage. Aero Spacelines, Inc., owner of the Pregnant Guppy used in S-IV stage transport, proposed in late 1964 that a "Super" or "Very Pregnant Guppy" be used for S-IVB transport. Pending a reply from MSFC in January 1965 Aero Spacelines informed the Center that the firm would continue on its own to modify the aircraft for S-IVB transport. MSFC then, with assistance from the U. S. Air Force, Boeing, and DAC, began investigation to determine the feasibility and operational characteristics of an aircraft of the proposed configuration. The Center's Test Laboratory monitored wind tunnel tests of the aircraft at the United Aircraft Research Laboratory, Hartford, Connecticut, during the period May 3-7. On June 3 MSFC met with Federal Aviation Agency (FAA) representatives and arranged for FAA to flight test and evaluate the large aircraft and to serve also as NASA's consultant on this project.

On completion of the aircraft modification, FAA required a ground vibration survey be conducted on the craft. MSFC's Test Laboratory monitored the survey conducted for FAA by DAC. Following the survey FAA requested additional modification to the aircraft. Flight test of the craft, dubbed "Super Guppy" began August 31, 1965, and the aircraft logged 13 hours' flight time within the next seven days. An MSFC representative began monitoring the flight tests at Mojave, California, in September.

On September 16 NASA announced selection of Aero Spacelines, Inc., for negotiation of a contract to provide air transport service for large government cargoes with the Super Guppy on completion of flight tests. On September 25 during a cross country flight test the nose section failed resulting in some damage. Aero Spacelines repaired the plane and then

161. Test Lab., MPR, May 12 - June 12, 1965, p. 46; and June 12 - July 12, 1965, p. 31.

in November completed the initial flight test requirements. MSFC awarded a one-year contract to Aero Spacelines on December 22 for flying large rocket cargoes in the Super Guppy. Scheduled flight tests of the craft with an S-IVB dummy stage onboard began December 29.[162]

Investigation of requirements for S-IVB flight aboard the Super Guppy also commenced early in 1965. On May 25 MSFC, DAC, and Aero Spacelines representatives met to discuss flight of the stage aboard the large plane. MSFC held other meetings with DAC in June relative to instrumentation and GSE design requirements necessary for S-IVB air shipment. The S-IVB stage contractor designed and fabricated all the support handling and tiedown equipment, environmental and preservation equipment, and the instrumentation necessary to support air shipment of the stage. DAC also modified and added rollers to the S-IVB cargo lift trailer and designed and fabricated a rail system compatible with the S-IVB transporter to support Guppy transport. Five of the cargo lift trailers were modified to allow mating of the rail systems with the Super Guppy, and three of the S-IVB transporters were made compatible with the aircraft.[163]

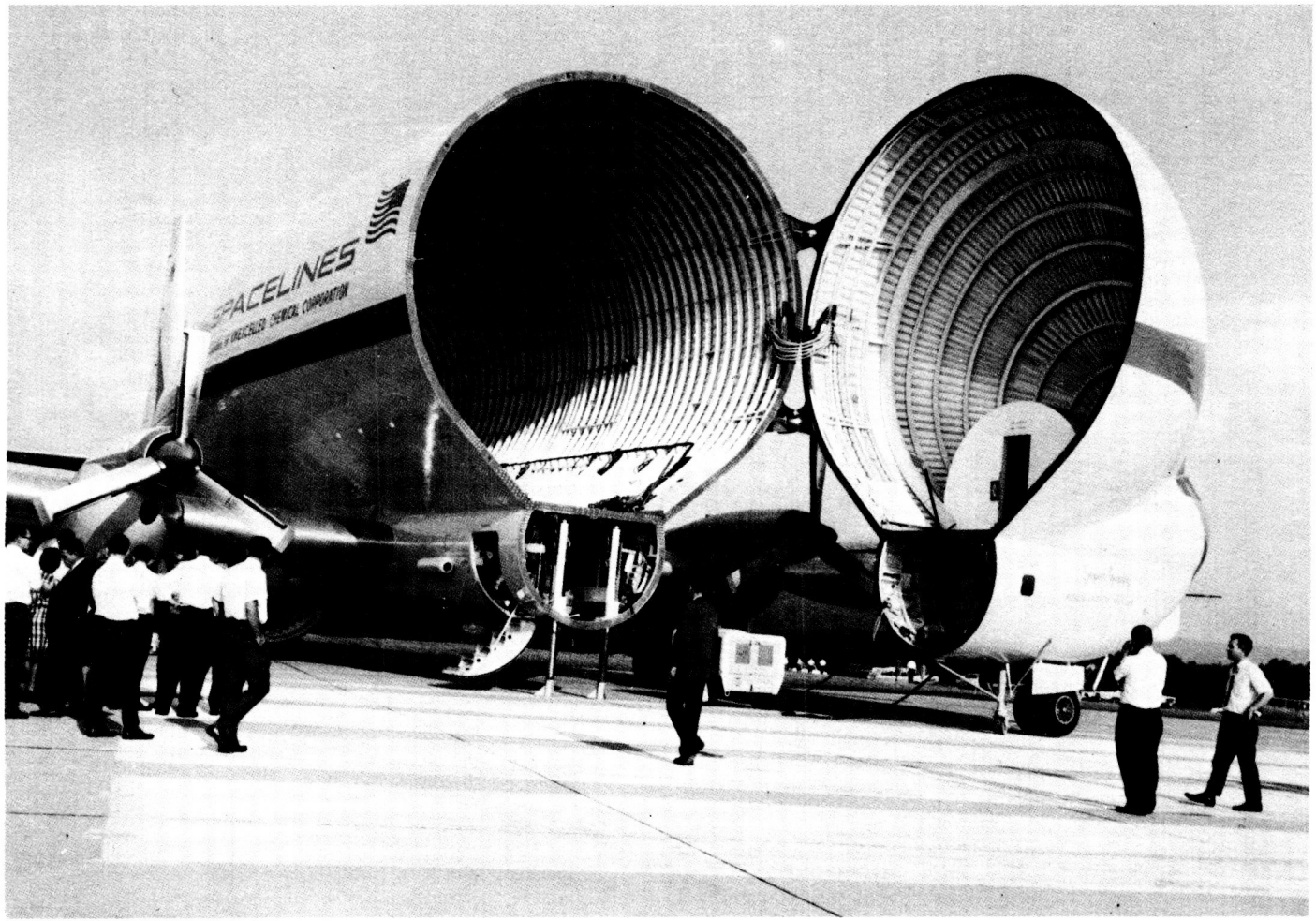
Instrument Unit Transportation

The IU is built so that it can be disassembled and transported in three sections. It is shipped in a container built by Hayes International and is moved about via a transporter cart.

Hayes International Corporation completed fabrication of the first IU shipping container for MSFC in February 1965. Results of acceptance tests revealed minor structural failure and container leakage. Hayes

162. Test Lab., MPR, Feb. 12 - Mar. 12, 1965, p. 41; May 12 - June 12, 1965, pp. 46-47; Aug. 12 - Sept. 12, 1965, p. 29; Sept. 12 - Oct. 12, 1965, pp. 26-27; Oct. 12 - Nov. 12, 1965, pp. 25-26; and Hist. Rpt., Jan. - Dec. 1965, pp. 29-30; Teletype, W. J. Odonnell, NASA, to Joe Jones, PAO, MSFC, subj., "NASA to Contract With Aero Spacelines for Use of Super Guppy," Sept. 16, 1965; and PAO, Press Release No. 65-229, Sept. 16, 1965, and Press Release No. 65-311, Dec. 22, 1965.

163. Test Lab., MPR, May 12 - June 12, 1965, pp. 46-47; June 12 - July 12, 1965, pp. 30-31; and July 12 - Aug. 12, 1965, p. 28; DAC, SM-47276, Issue 35, p. 2; and SM-47313, Issue 36, p. 2; and P&VE Lab., MPR-P&VE-65-6 (June), pp. 21-22; and MPR-P&VE-65-7, p. 19.



NEW AIR CARRIER

The Super Guppy, an aircraft large enough to transport the S-IVB stage and Saturn V instrument unit, is displayed in September 1965 during its flight test program.

strengthened the frame by adding a stiffener along the longitudinal axis, and caulked all water leakage points to prevent further leakage. The contractor then delivered the container to MSFC on February 26. MSFC's Test Laboratory made additional minor revisions to the container in early March and began procurement action for a second container.[164]

Road tests of the IU transporter occurred at MSFC on April 6 to determine the stability of the transporter at all towing speeds. In August MSFC and IBM personnel disassembled and packaged a dummy IU (S-IU-200V) in the transportation container and performed environmental transportation tests. Personnel successfully conducted a flight test aboard the Pregnant Guppy aircraft on August 6 and road tests using an MSFC truck on August 10.[165]

Meanwhile, possible shipment of fully assembled IU's aboard the Super Guppy aircraft or by marine transportation received study and trial. Based on results of preliminary investigation the following recommendations were made in June: 1) Ship the assembled S-IU-201 on a transporter fabricated by the Manufacturing Engineering Laboratory aboard a covered barge from MSFC to KSC. 2) Perform an instrumented flight test program with the S-IU-200V on the larger aircraft. 3) Modify equipment for IU shipment by the Super Guppy if test data proves favorable. 4) Ship subsequent IU's by the Super Guppy.[166]

MSFC began preparations for shipping S-IU-201 by barge to KSC. The Test Laboratory designed, fabricated, and furnished the IU shipping cover to IBM and also provided tiedown arrangement design to support shipment. MSFC and IBM personnel shipped the S-IU-201 to KSC aboard the Palaemon barge on October 9. The instrumented IU flight test program aboard the Super Guppy also began in late October. Vibration data obtained on both the transporter and the fully assembled S-IU-200V during the first flight

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164. Test Lab., MPR, Jan. 12 - Feb. 12, 1965, p. 39; Feb. 12 - Mar. 12, 1965, p. 40; and Mar. 12 - Apr. 12, 1965, p. 37.

165. Ibid., Mar. 12 - Apr. 12, 1965, p. 38; and P&VE Lab., MPR-P&VE-65-8, p. 50.

166. Test Lab., MPR, May 12 - June 12, 1965, pp. 47-48.

test indicated that shipment by the Super Guppy would provide less vibration than had shipment in segments aboard the Pregnant Guppy.[167]

SATURN IB SUMMARY

Primary effort in the Saturn IB program during the year 1965 has been directed toward proving the Saturn IB design through ground tests and toward preparing the first vehicles for flight. Completion of the Saturn IB/S-IVB Battleship testing at the Sacramento Test Center (SACTO) on May 4 established the validity of the S-IVB design concepts and the functional operation of flight-type hardware. Successful static firing of the first S-IB flight stage (S-IB-1) at MSFC on April 1 verified its performance. Acceptance firing of the first S-IVB flight stage (S-IVB-201) ended on August 8, and on September 11 dynamic testing of the Saturn IB configuration concluded at MSFC. Checkout of the S-IU-201 ended in early October, and functional checkout of the instrument unit systems and checkout of the flight program tapes for S-IU-201 on the Systems Development Facility was completed in November.

At Kennedy Space Center preparations for the first Saturn IB launch gained impetus. Vehicle checkout of the launch facility (LC-34) and ground support equipment ended on September 29. The S-IB-1 stage used in launch facility checkout underwent repair and inspection on the same day; the S-IVB-201 was mated to S-IB-1 in October, and on October 25 workmen erected the S-IU-201 atop the S-IVB stage. Pad erection of the Apollo 009 payload occurred on December 26. Prelaunch checkout operations with the automatic checkout equipment commenced in October and continued through December.

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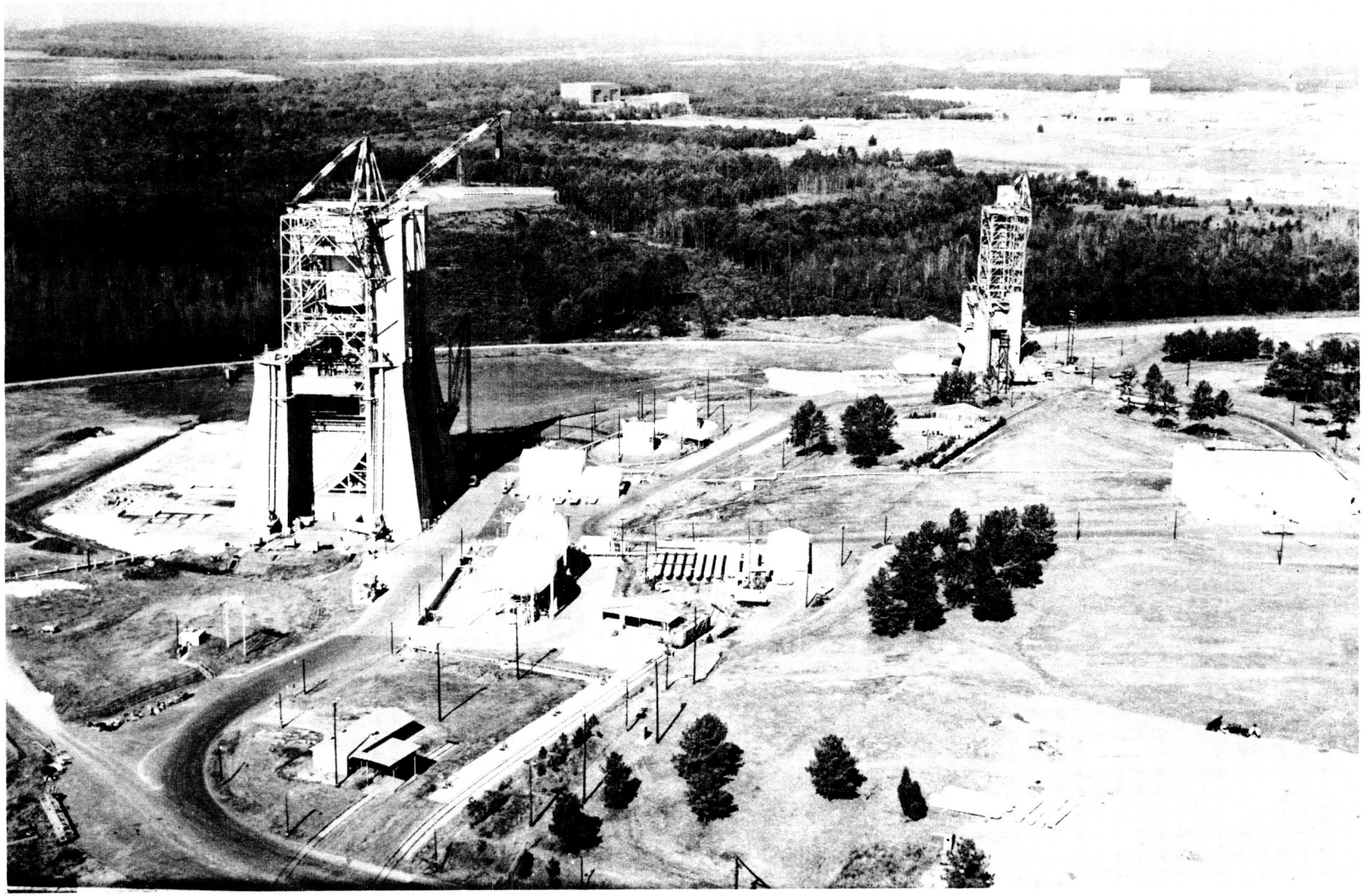
167. P&VE Lab., MPR-P&VE-65-9, p. 30; Test Lab., MPR, Aug. 12 - Sept. 12, 1965, p. 29; Sept. 12 - Oct. 12, 1965, pp. 26-27; and Oct. 12-Nov. 12, 1965, p. 25.

Other stages readied for launch by the contractors included the S-IB-2, acceptance-fired on July 9 for 35 seconds and on July 20 for 144 seconds; and the S-IVB-2, acceptance-fired on November 2 for 41 seconds, on November 9 for 307 seconds, and on December 1 for 463.8 seconds. These stages awaited shipment to the launch site.

Chrysler Corporation Space Division also completed acceptance firing of the S-IB-3 stage, placed S-IB-4 in the static test tower for tests, assembled and started prestatic checkout of S-IB-5, started assembly of S-IB-6, and started subassembly of S-IB-7 and S-IB-8. Douglas Aircraft Company completed installation of S-IVB-203 on the Beta 1 stand at SACTO and started prefiring activities, completed prestatic checkout of S-IVB-204, ended structural assembly of S-IVB-205 and started final stage installations, and initiated subassembly of S-IVB-206 and S-IVB-207. International Business Machines Corporation had S-IU-202, S-IU-203, and S-IU-204 in various stages of assembly.

During 1965 MSFC participated in developing detailed flight mission assignment data to support mission changes and also directed hardware changes and new development to support an LH_2 Orbital Experiment for SA-203. Center personnel completed preliminary effort to identify changes involved in adapting the Centaur flight stage to the Saturn IB in support of NASA's projected mission requirements beyond the Apollo program.



SATURN V FACILITIES

Featured in this low aerial view are the S-IC Test Stand (left) holding a booster, and the F-1 Engine Test Stand.

CHAPTER IV: SATURN V

The primary objective of the Saturn V program is to provide a vehicle that can perform the boost phase of the Manned Lunar Landing Mission. To do this, the vehicle must be capable of carrying a 98,000-pound Apollo spacecraft through an earth parking orbit and into a translunar trajectory.

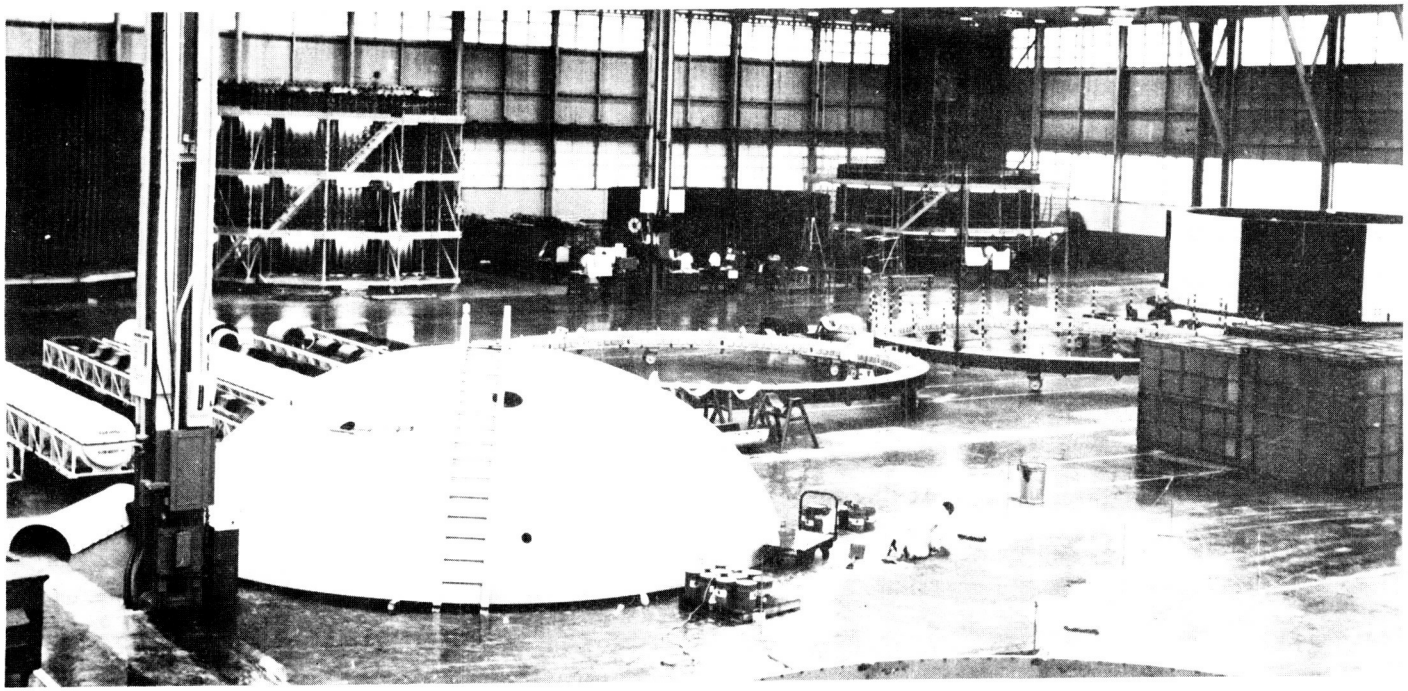
A secondary but highly important objective is the development of a powerful and flexible launch vehicle capable of a wide range and variety of missions. The missions made feasible by Saturn V include extended exploration of the moon, orbiting research laboratories, long-duration space operations including satellite inspection and repair, and planetary probes. Consideration has been given in the design of Saturn V to meeting the requirements of future missions without compromising crew safety, mission success, or Apollo program schedules.

The overall length of the vehicle in the moon mission configuration is approximately 363 feet; this length includes the spacecraft and launch escape system, for which NASA's Manned Spacecraft Center at Houston, Texas, has management responsibility. The vehicle weighs over 6 million pounds at liftoff and consists of the S-IC first stage, S-II second stage, S-IVB third stage, Instrument Unit (IU), and the three-module spacecraft composed of the Command Module, Service Module, and Lunar Excursion Module. Each propulsive stage contains its own instrumentation, safety, measuring, and power systems, but receives guidance and control commands from the IU; the engine servoactuators of each stage execute guidance commands from the IU.

VEHICLE RESEARCH AND DEVELOPMENT

S-IC Stage

The S-IC stage, 138 feet long and 33 feet in diameter, is the booster stage for the Saturn V launch vehicle. The stage weighs about 306,886



S-IC ASSEMBLY AT MICHOUD

Components of an S-IC stage are shown in May 1965 at Michoud Assembly Facility (Boeing manufacturing area).

pounds empty and 4.68 million pounds fully fueled for launch. Five F-1 engines burn RP-1 fuel and liquid oxygen (LOX); each engine generates thrust of approximately 1.5 million pounds, for a total stage thrust of 7.5 million pounds. The S-IC stage powers the Apollo/Saturn V vehicle for the first 152 seconds of flight.

MSFC and the Boeing Company are jointly responsible for the design, development, manufacture, and test of the S-IC. MSFC, with Boeing's support, builds two prototype ground test stages--the all-systems (S-IC-T) and structural test (S-IC-S) stages--and the first two flight stages--S-IC-1 and S-IC-2. Boeing, working principally in MSFC's Michoud Assembly Facility (MAF) at New Orleans, Louisiana, provides two ground test stages and eight of the first ten flight stages. These stages for which Boeing is responsible are: the dynamic test stage (S-IC-D), the facilities checkout stage (S-IC-F), and flight stages S-IC-3 through S-IC-10. Additional flight stages S-IC-11 through S-IC-15 were included in the current Saturn V production schedule but were not under contract during this report period, pending development of funding requirements by NASA for these stages.

The prime S-IC stage contract, NAS8-5608, dates from January 1963. At the beginning of 1965 this contract's value was approximately $608.2 million.

Under the contract Boeing's Space Division actually has three major assignments in the Saturn V/Apollo program, all provided under separate schedules of Contract NAS8-5608 as follows:[1]

Schedule I--Design, development, assembly, and test of the S-IC stage and related ground support equipment (GSE); this work is accomplished primarily at MAF.

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1. MSFC Historical Office, History of the George C. Marshall Space Flight Center, July 1--December 31, 1964, (MHM-10), Vol. II, p. 39; and 89th Congress, 2nd Session, House report, 1967 NASA Authorization, Hearings Before the Subcommittee on Manned Space Flight of the Committee on Science and Astronautics on HR 12718 (Superseded by HR 14324) Feb. 18, 24; Mar. 1, 2, 3, and 31, 1966, (No. 4) Part 2, p. 973. (Note: Some figures describing the launch vehicle are approximations. All apply only to the first three flight vehicles; subsequent vehicles will be lighter.)

Schedule II--Saturn V vehicle systems engineering and integration, GSE requirement identification, and management services for the vehicle program; these services, formerly identified as "Saturn V Mission Support," are provided mainly at Huntsville.

Schedule III--Launch operations support, provided at Kennedy Space Center (KSC).

Contract NAS8-5608 was modified 184 times during Calendar Year 1965, and its value increased to $715.4 million. On March 19 NASA directed MSFC to convert Schedule I of the cost-plus-fixed-fee (CPFF) contract to a cost-plus-incentive-fee (CPIF) contract by the end of the year. On March 26 NASA and Boeing signed a supplemental agreement incorporating a new delivery schedule called Plan VIII (NASA designation MA-2) and extending the Schedule I period of performance through April 8, 1969. MSFC forwarded to NASA Headquarters for approval on December 29, 1965, a supplemental agreement (SA) providing for conversion of the contract to CPIF; the cost-effective date of this SA was July 2, 1965. NASA Headquarters approval was pending at the end of the year. Meanwhile, on December 3, 1965, MSFC and Boeing negotiated the SA establishing Schedule III (Saturn V launch operations support), permitting transfer of that work previously performed under Schedule I. This conversion was effective December 31, 1965.[2]

During 1965 design and engineering of the S-IC stage was nearly completed. This design was confirmed through a broad-based test program consisting of qualification, structural, reliability, and captive-firing tests. At the end of the year six stages were structurally complete, four of these stages had completed post-manufacturing checkout, and the first ground test stage (S-IC-T) had completed its full captive-firing program of 15 tests at MSFC/Huntsville.

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2. Michoud Assembly Facility (MAF), MSFC, Historical Report, January 1--June 30, 1965, pp. 19-21; July--December 1965, pp. 23-25; 89th Cong., 2nd sess, House Rpt., 1967 NASA Authorization, p. 1024; and review comments by Program Control Section, Contracts Office, Industrial Operations, MSFC, Sept. 15, 1967.

Boeing manpower in the Southeast for fulfillment of Contract NAS8-5608 totalled more than 11,000 at the end of this report period. Approximately 6,000 were at MAF and MTF, 4,400 at Huntsville, and 850 at KSC.[3]

The Plan VIII schedule approved in March 1965 changed the location for static-firing of S-IC-3. This third flight stage would be tested on the MSFC stand at Huntsville instead of the new Mississippi Test Facility S-IC Stand (B-2 position), which would not be activated in time. B-2 Position at MTF would be utilized for S-IC-4 and subsequent captive-firings.[4]

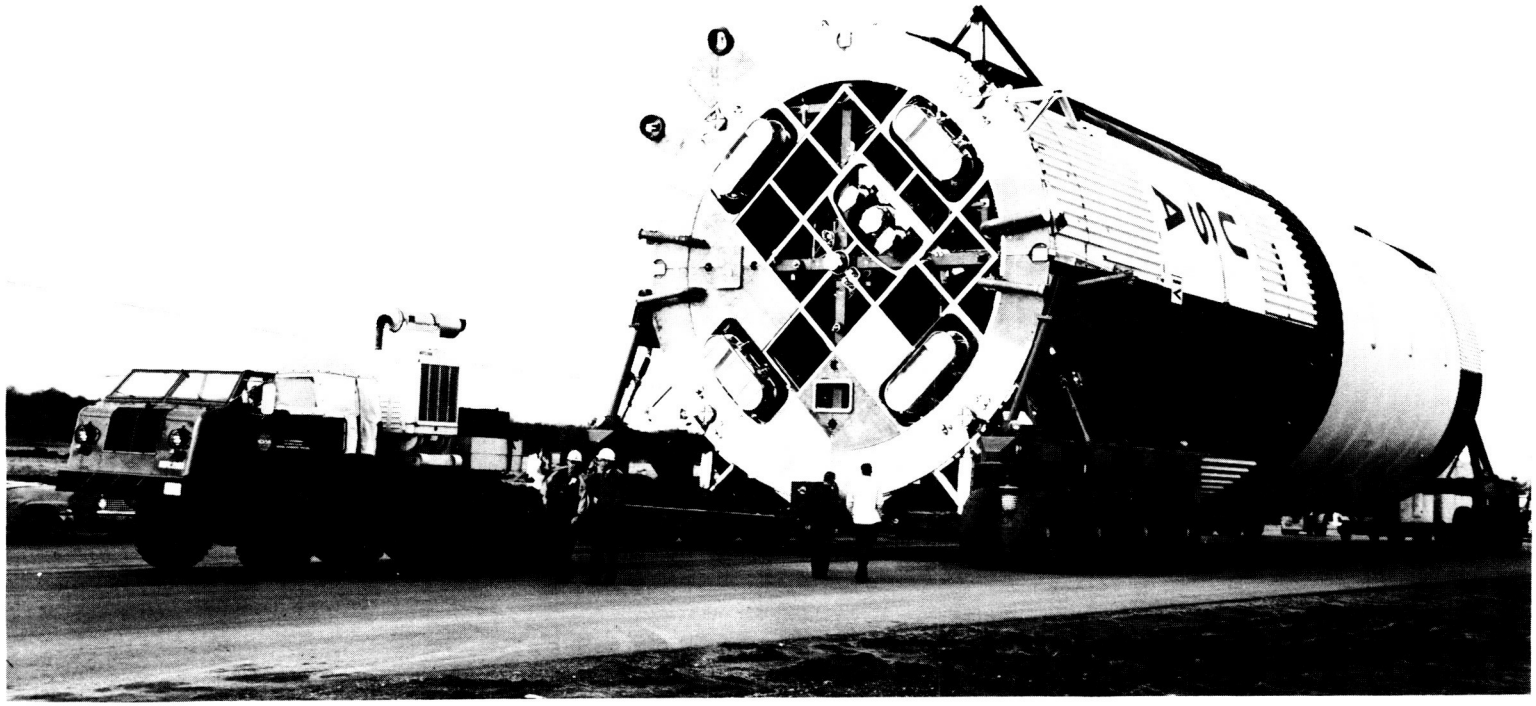
S-IC-T Stage

S-IC-T, the all-systems test stage, was the first Saturn V booster built as a complete stage at MSFC and one of two ground test stages assembled at the Center. When the current report period began on January 1, 1965, technicians in the Manufacturing Engineering (ME) Laboratory were preparing to join the two major assemblies--the aft and forward sections of the stage--in horizontal assembly operations. Workmen rapidly mated the assemblies to form the 138-foot booster stage. On February 27-28 ME Lab personnel prepared the stage for transfer to the S-IC static test stand in the Center's West Test Area.

On March 1, 1965, ahead of schedule, S-IC-T rolled out of ME Lab and moved to the static test stand, where workmen placed the stage in the test tower. On March 8 personnel completed installation and checkout of manual GSE, nearly 11 weeks ahead of schedule. Load tests began on the thrust structure the same day. Structural testing ended on March 10, eight days ahead of schedule. Technicians installed the five F-1 engines

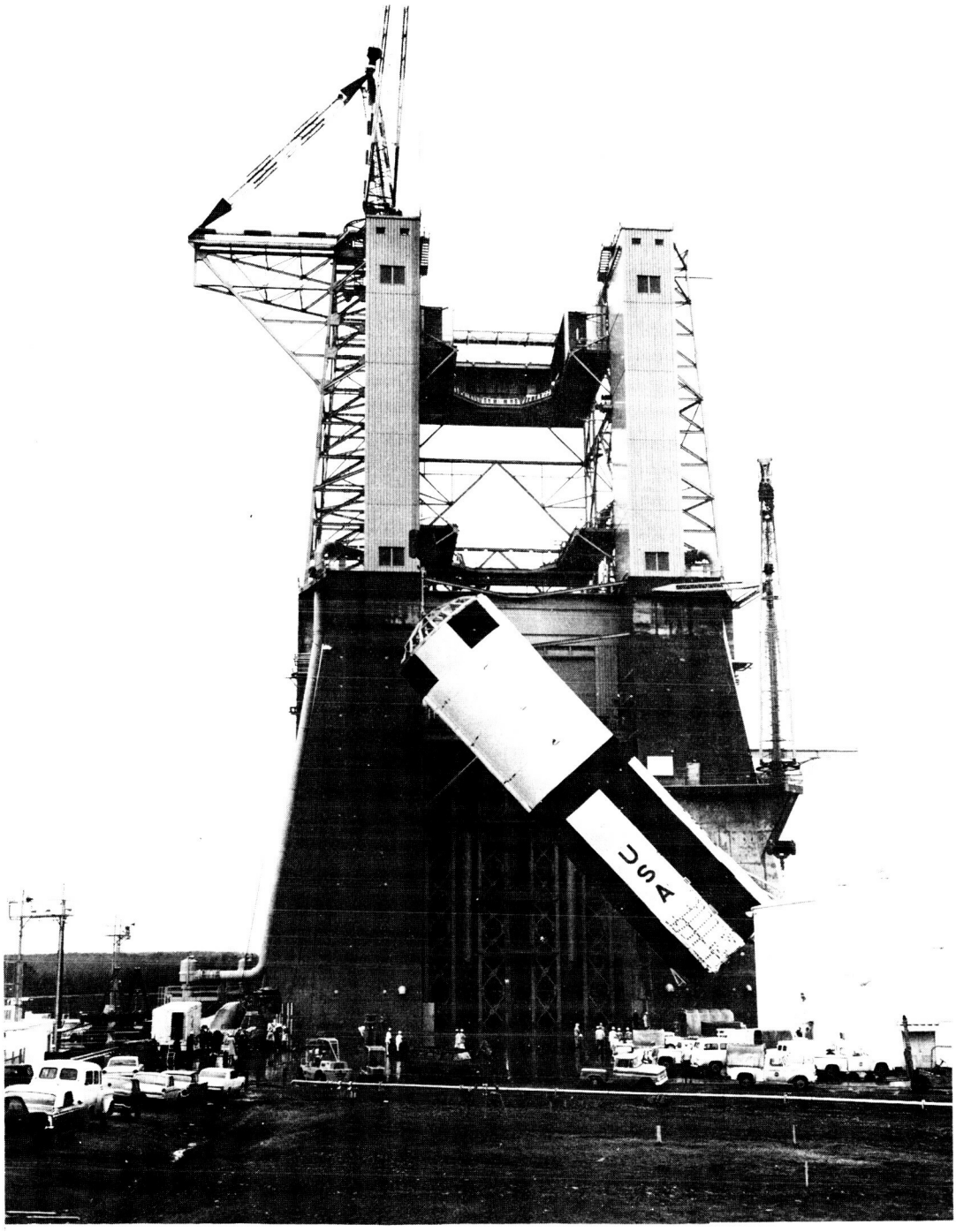
3. 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, pp. 977-982.

4. The Boeing Company, Quarterly Progress Report, January 1 Through April 1, 1965, Contract No. NAS8-5608, Document No. D5-11994-8, Apr. 21, 1965, p. 134.



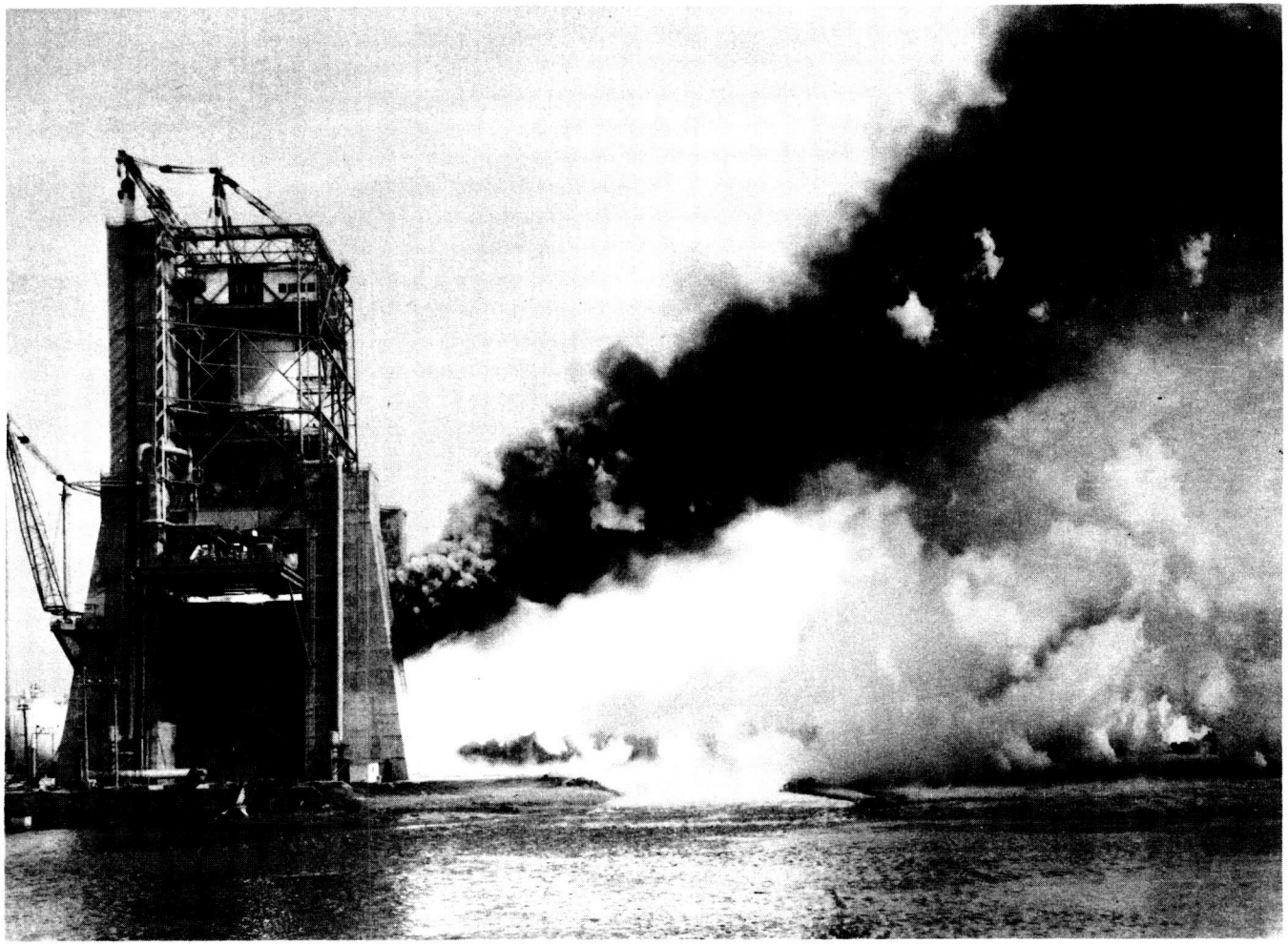
ON WAY TO STAND

At MSFC on March 1, 1965, the S-IC-T all systems stage, without engines, is rolled from its assembly site to the static test stand. Engines would be added after erection in the stand.



S-IC-T INSTALLED FOR TEST

The all systems S-IC stage is erected in the captive firing stand at MSFC on March 1, 1965.



SATURN V BOOSTER FIRED

All five F-1 engines on the S-IC all systems stage fire at the MSFC static test facility. Activated in April 1965, this stand was the scene of 15 captive firings during the rest of the year.

in the period from March 27 to March 30. The first S-IC-T single-engine firing occurred on April 9 and was unintentionally terminated during start transition at approximately 40 per cent of rated thrust. The second test, S-IC-02, occurred later the same day and lasted 2.5 seconds. Test S-IC-03 on April 10 ran the scheduled duration of 16 seconds. The first five-engine test, S-IC-04, occurred on April 16 for a scheduled duration of 6.5 seconds. This test occurred two months ahead of schedule. Other five-engine tests conducted manually were as follows:

S-IC-05	May 6	15.6 seconds
S-IC-06	May 20	40.8 seconds
S-IC-07	June 8	41.1 seconds
S-IC-08	June 11	90.9 seconds

At this point technicians removed four engines and replaced cracked injectors that had been revealed by inspection. Following reinstallation of engines, Test S-IC-09 was conducted on July 29, for a duration of 17.6 seconds. The first full-duration run, No. S-IC-10, 143.6 seconds, occurred on August 5 and ended with LOX depletion. This final manual configuration firing was termed "highly successful" and achieved all test objectives. Accumulated static firing time through S-IC-10 was 379.3 seconds.[5]

Modification of the S-IC-T to the configuration for automatic firings began in ME Lab on August 12. Technicians completed electrical modification on September 7 and mechanical modifications early in October.

The first S-IC-T firing in automatic configuration, No. S-IC-11, occurred October 8, for a scheduled LOX-depletion duration of 45 seconds. Other "automatic" tests were as follows:

S-IC-12	November 3	90.5 seconds
S-IC-13	November 24	148.4 seconds

5. Saturn V Program Office, Saturn V Quarterly Progress Report, January--March 1965, pp. 9-10; Test Laboratory, Historical Report, January--December 1965, pp. 7-8; and E. F. O'Connor, Dir., Ind. Ops., MSFC, paper, "Saturn Launch Vehicles," at second annual meeting, American Institute of Aeronautics & Astronautics, San Francisco, California, July 26-29, 1965, paper 65-302. (Note: Some firing figures are approximations and do not distinquish between inboard and outboard engines.)

READY FOR LOAD TESTS

The fuel tank and thrust structure of the S-IC-S structural test stage is installed in the MSFC Load Test Annex for structural testing.

S-IC-14	December 9	146.07 seconds
S-IC-15	December 16	40.98 seconds

(The last two firings ended separately for inboard and outboard engines; the single inboard engine was deliberately planned to burn a few seconds less than the four outboard engines in each case.)

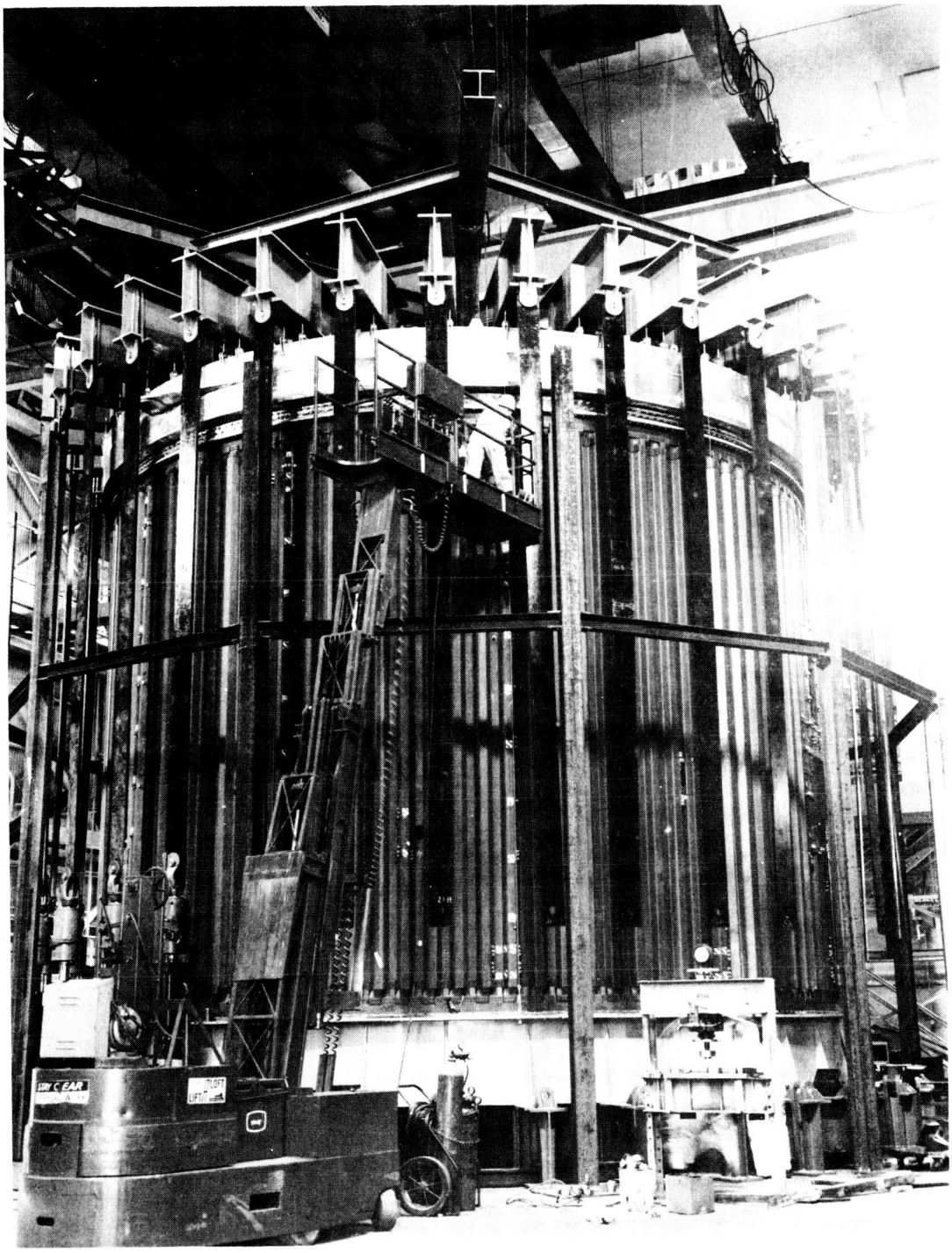
Upon completion of S-IC-T captive firings that totalled 842 seconds, technicians began late in December 1965 to prepare for removal of the stage from the test stand and for installation in its place of S-IC-1, the first Saturn V flight booster.[6]

S-IC-S Stage

The S-IC-S structural test stage was constructed at Huntsville in sections for use in various structural tests. The aft section, consisting of the thrust structure and fuel tank, went from the ME Lab to the Propulsion and Vehicle Engineering (P&VE) Lab's Load Test Annex on February 19 and was turned over to Boeing for test preparations. Workmen installed the stage on the simulated hold-down arms. Boeing personnel performed load tests simulating various static firing conditions during April, May, and June; these tests simulated maximum thrust and gimbal loads. The last captive-firing condition test occurred on June 21; the structure withstood 140 per cent of the design load. Personnel then added the intertank to the aft section in preparation for flight simulation tests. Meanwhile, workmen prepared fixtures for tests of fin and fairing assemblies and apex gore specimens.

During October 1965 Boeing personnel successfully performed the launch pad standby load test on the aft section, achieving the required 140 per cent limit load. On October 28 personnel conducted to 140 per cent limit the ground wind/launch pad condition tests, with fuel tank empty and unpressurized. On November 19 a launch rebound test demonstrated the

6. Test Lab., Hist. Rpt., Jan.--Dec. 1965, pp. 8-9; and N. C. Milwee, Manufacturing Engineering Lab., "Quarterly Report, July--September 1965," (draft). (Note: Some firing times are approximations.)



STRUCTURAL TEST

Workmen install a Saturn V booster intertank into the structural test fixture at the MSFC Load Test Annex.

section's integrity 135 per cent of design limit load, with the fuel tank water-filled. At the end of this period preparations were underway for January 1966 tests of the flight cutoff conditions.

The S-IC-S forward assembly (LOX tank, intertank, and forward skirt), which was delivered to P&VE in March 1965, was stored upright in an outside holding area to await future tests, expected to occur in 1966.[7]

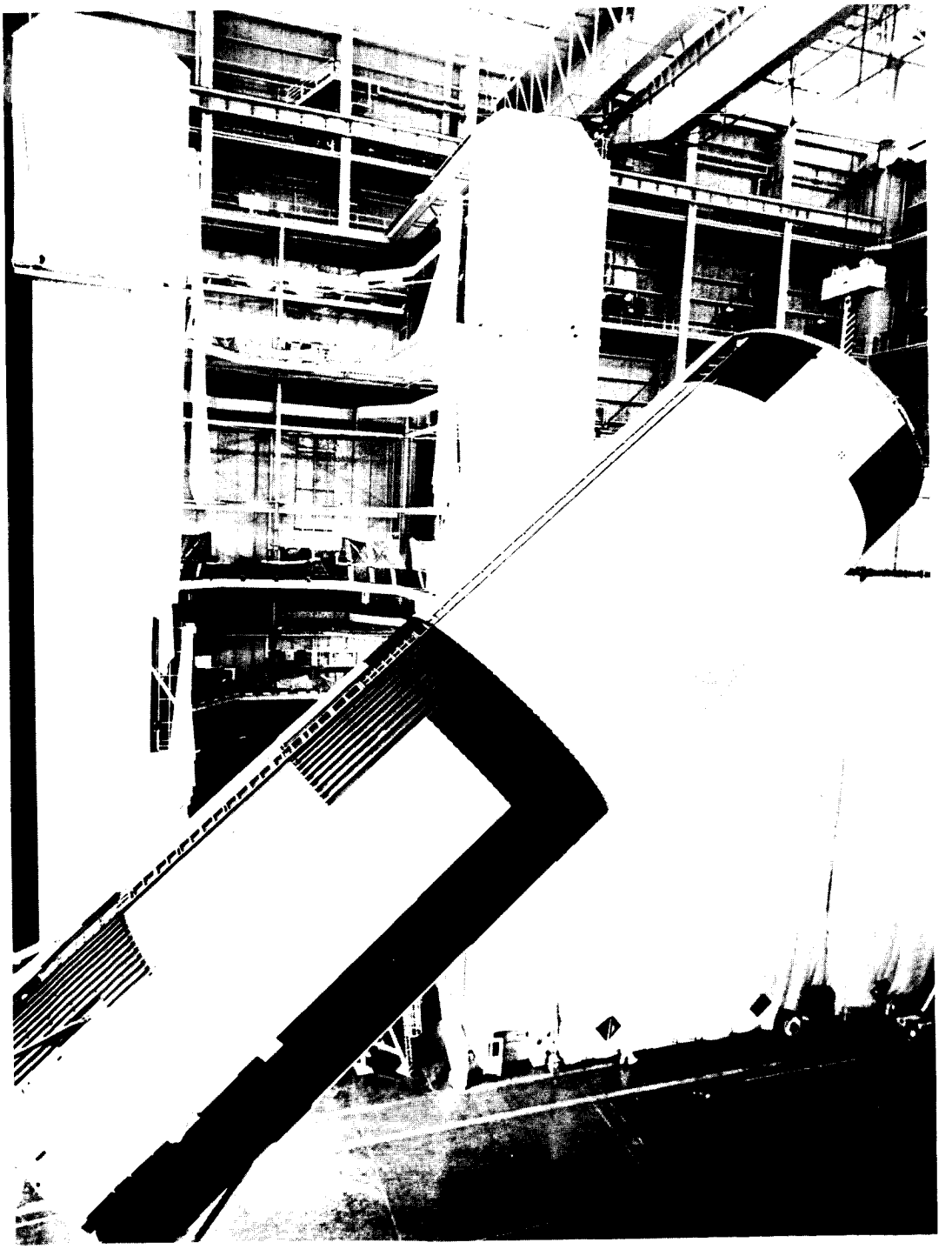
S-IC-D Stage

S-IC-D, the dynamic test stage, was the first stage assembled by Boeing at MAF. Early in 1965 Boeing completed the thrust structure and on March 24 installed it in the Vertical Assembly Building (VAB) there. The completed fuel tank went into the hydrostatic test tower during the first quarter of 1965 for preparation and hydrostatic testing. Also during the first quarter, Boeing workmen began welding together the upper and lower subassemblies of the LOX tank.

During the second quarter of the period Boeing finished welding of the LOX tank and installed ring baffles. The fuel tank underwent hydrostatic testing on May 6, and the LOX tank on May 26. Final assembly of the aft and forward sections of the stage occurred in the VAB from May 28 to June 16, and the S-IC-D emerged from the assembly tower on June 27 after a delay for rework of GSE fittings.

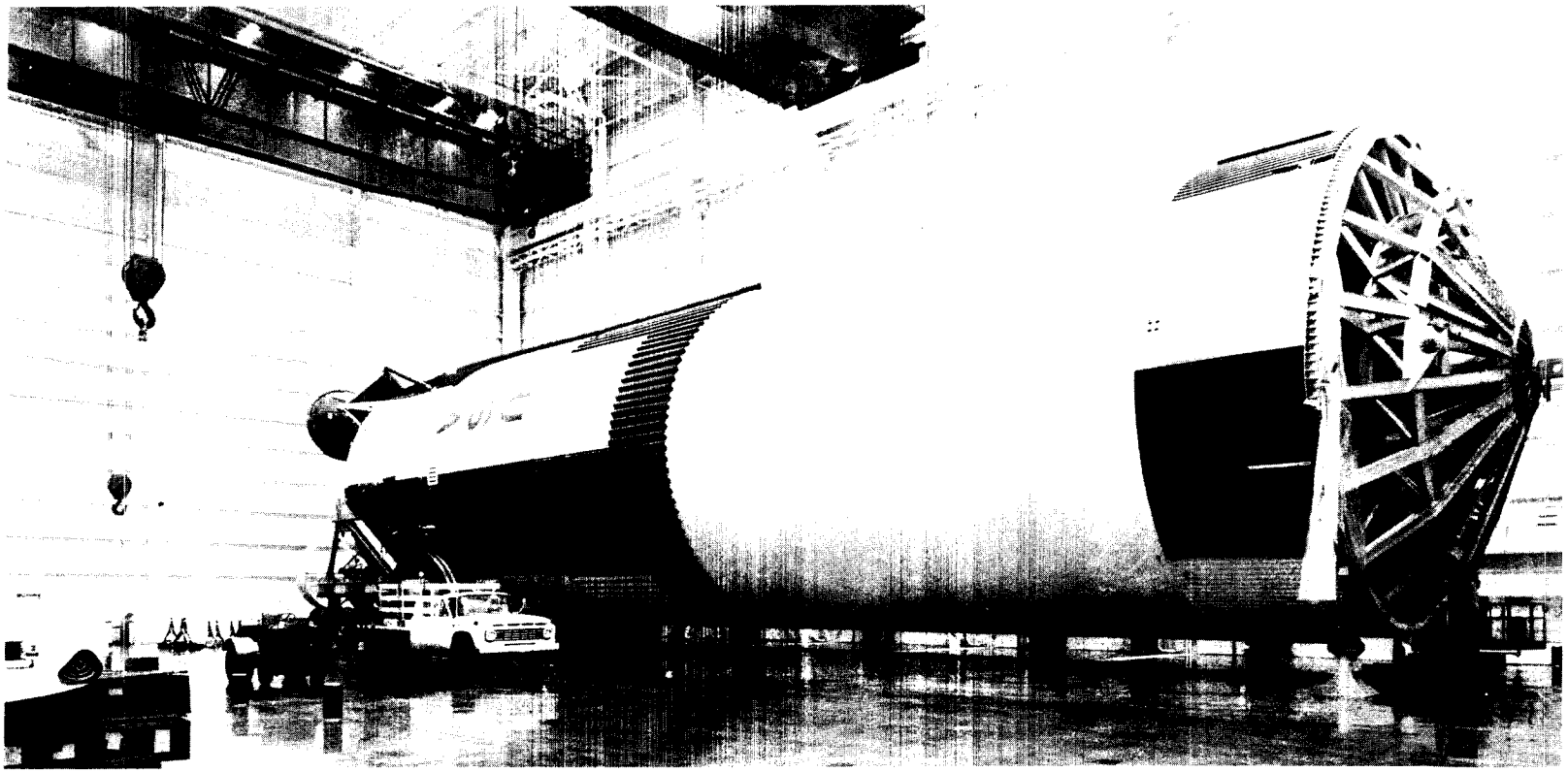
Horizontal assembly operations on the stage ended at MAF on August 25. Post-manufacturing tests followed. Stage checkout was about 20 per cent complete when Hurricane Betsy struck with 100 mph winds on September 9-10. S-IC-D escaped damage in the storm, but some MAF facilities, including the stage test facility, sustained severe damage. On September 13 workmen moved the stage to permit repairs to the checkout building. The dynamic booster returned to the stage checkout building on September 20 for completion of tests, weighing, and preparation for shipment to Huntsville where it will undergo dynamic tests.

7. Propulsion and Vehicle Engineering (P&VE) Lab., Monthly Progress Report, Feb. 1-28, 1965, p. 56; Mar. 1-30, 1965, pp. 48-49; April 1-30, 1965, p. 45; May 1-31, 1965, p. 48; June 1-30, 1965, p. 49; Oct. 1-31, 1965, p. 34; and Nov. 1-30, 1965, p. 42.



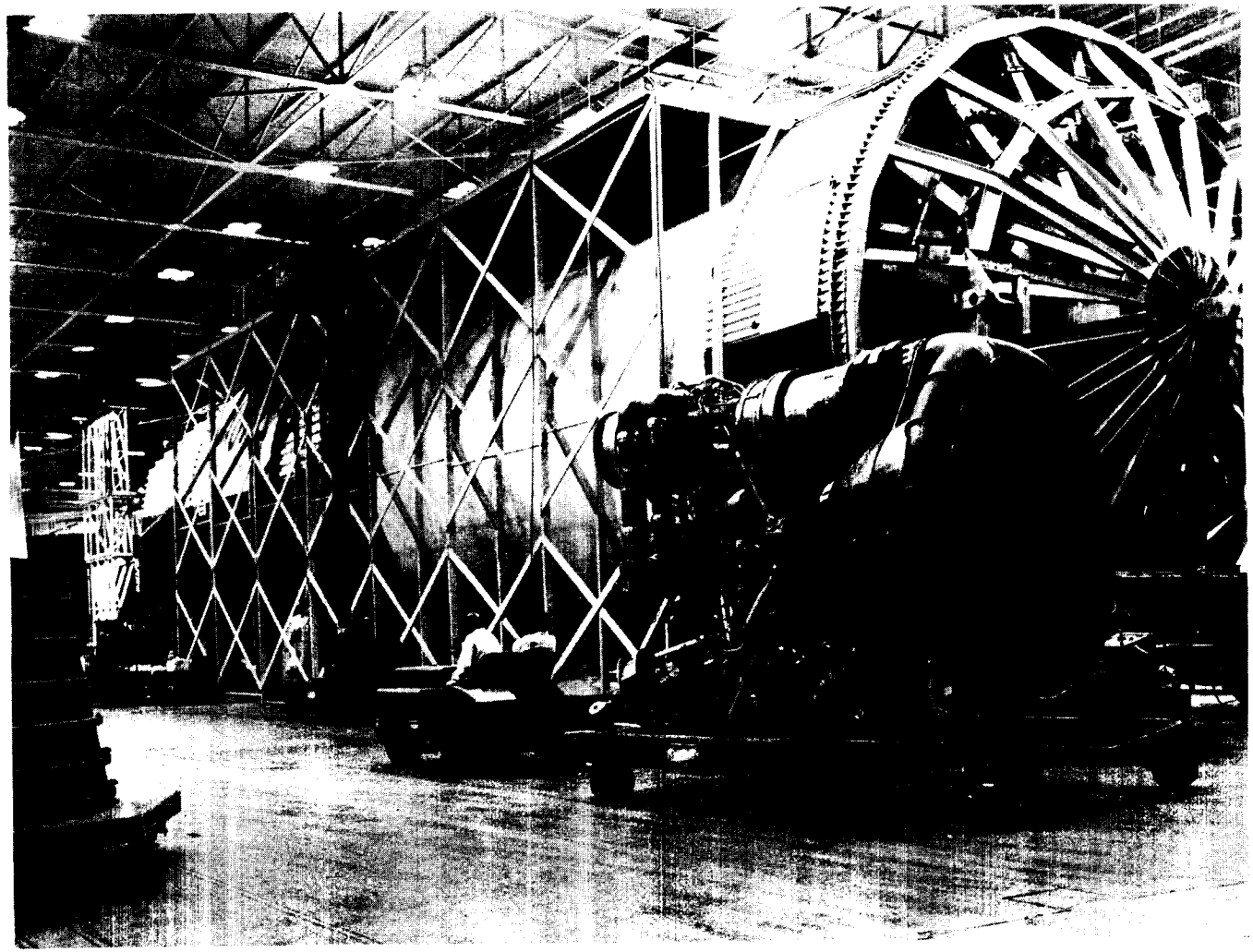
ASSEMBLY COMPLETED

S-IC-D is removed from vertical assembly tower at MAF by Boeing workmen in June 1965. It was later prepared for shipment to Huntsville for dynamic tests.



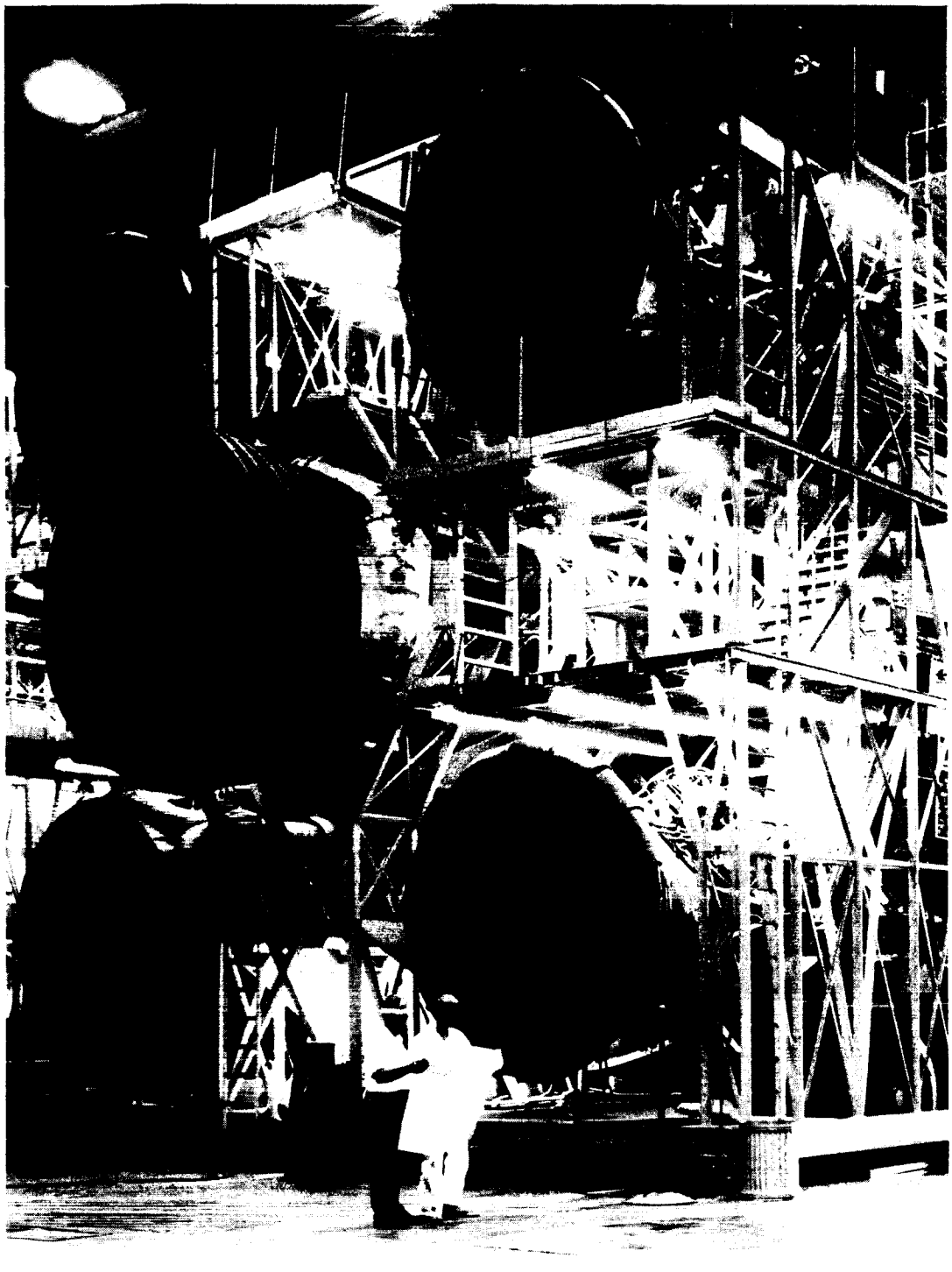
DYNAMIC BOOSTER AT MSFC

S-IC-D, the first stage of the Saturn V dynamic vehicle, rests in Building 4755 after arriving here from MAF in October 1965.



ENGINE AND VEHICLE

An F-1 engine without its flight skirt extension is towed past the forward end of the S-IC-1 while assembly of the booster was nearing completion in ME Lab's Building 4705, August 1965.



POWER END OF S-IC STAGE

In this September 1965 photo made at an MSFC assembly building, nozzles of F-1 engines attached to the S-IC-1 are framed by supports and work platforms.

S-IC-D left the MAF dock aboard the barge Poseidon on October 6, 1965. The stage arrived at MSFC's Saturn V dock October 13. On October 14 personnel moved the stage aboard its transporter to the ME Lab for storage until needed. Simulated engines were installed on December 7. At the end of the year S-IC-D was waiting for completion of modifications to the Saturn V Dynamic Test Facility. Facility readiness was expected in January 1966.[8]

S-IC-F Stage

The facilities checkout stage, S-IC-F, entered this report period ready for the start of major assembly at MAF. Boeing welded bulkhead and skin assemblies for the fuel and LOX tanks during the first quarter of the year.

On June 14 technicians completed the fuel tank and positioned it for hydrostatic testing. Work on the forward skirt ended June 30. By the end of June the thrust structure was 97 per cent complete, and the LOX tank assembly was almost complete.

Following hydrostatic testing the S-IC-F fuel tank moved to the final assembly station on July 16, and the LOX tank followed on August 11. Vertical assembly operations started on July 15 and ended on August 25. Upon its arrival at the horizontal assembly station, workmen transferred the stage to stationary support fixtures in order to free the transporter it had occupied; MSFC needed the transporter for S-IC-2 horizontal assembly. Very minor hurricane damage (rain spots on the LOX tank) occurred in September while S-IC-F was undergoing systems installation; Boeing lost three days of work when the storm caused plant shutdown for that period of time. A labor strike in mid-September caused slowdown of work on the stage, but apparently did not affect the delivery schedule.

Following horizontal assembly and systems installation, S-IC-F moved to a systems test cell for post-manufacturing checkout on November 19.

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8. Saturn V Program Office, Saturn V QPR, Jan.--Mar. 1965, p. 7; April--June 1965, p. 7; and July--Sept. 1965, p. 8.

At the period's end on December 31, post-manufacturing checkout was proceeding on schedule in spite of parts shortages, with completion expected early in January 1966 and delivery to KSC the same month.[9]

S-IC-1 Stage

ME Lab personnel moved the fuel tank bulkhead subassemblies for the first flight stage into the MSFC Vertical Assembly Facility on February 3, 1965. After joining of the two assemblies to form the tank, workmen installed baffles on March 5. Welding of LOX tunnels into the tank followed. Assembly of the LOX tank proceeded. Meanwhile, the stage's thrust structure, which had arrived from Boeing at MAF on January 27, underwent several major engineering changes.

Joining of the fuel tank and thrust structure started April 27. The completed assembly moved to the horizontal assembly area of ME Lab May 10. LOX tank assembly ended April 26 and hydrostatic testing and cleaning of this tank was completed June 1. The forward skirt was mated June 1-9 and the intertank June 9-25. The LOX tank then moved to Building 4705 for mating with the fuel tank thrust structure assembly.

Horizontal assembly proceeded through July, August, and most of September. Workmen installed the five F-1 engines during August. MSFC personnel completed horizontal assembly and transferred the stage to Quality Laboratory on September 27, on schedule. Late-delivered parts and systems, and modification kits were installed out-of-sequence during quality checkout of the stage, which continued satisfactorily to the end of this report period.[10]

S-IC-2 Stage

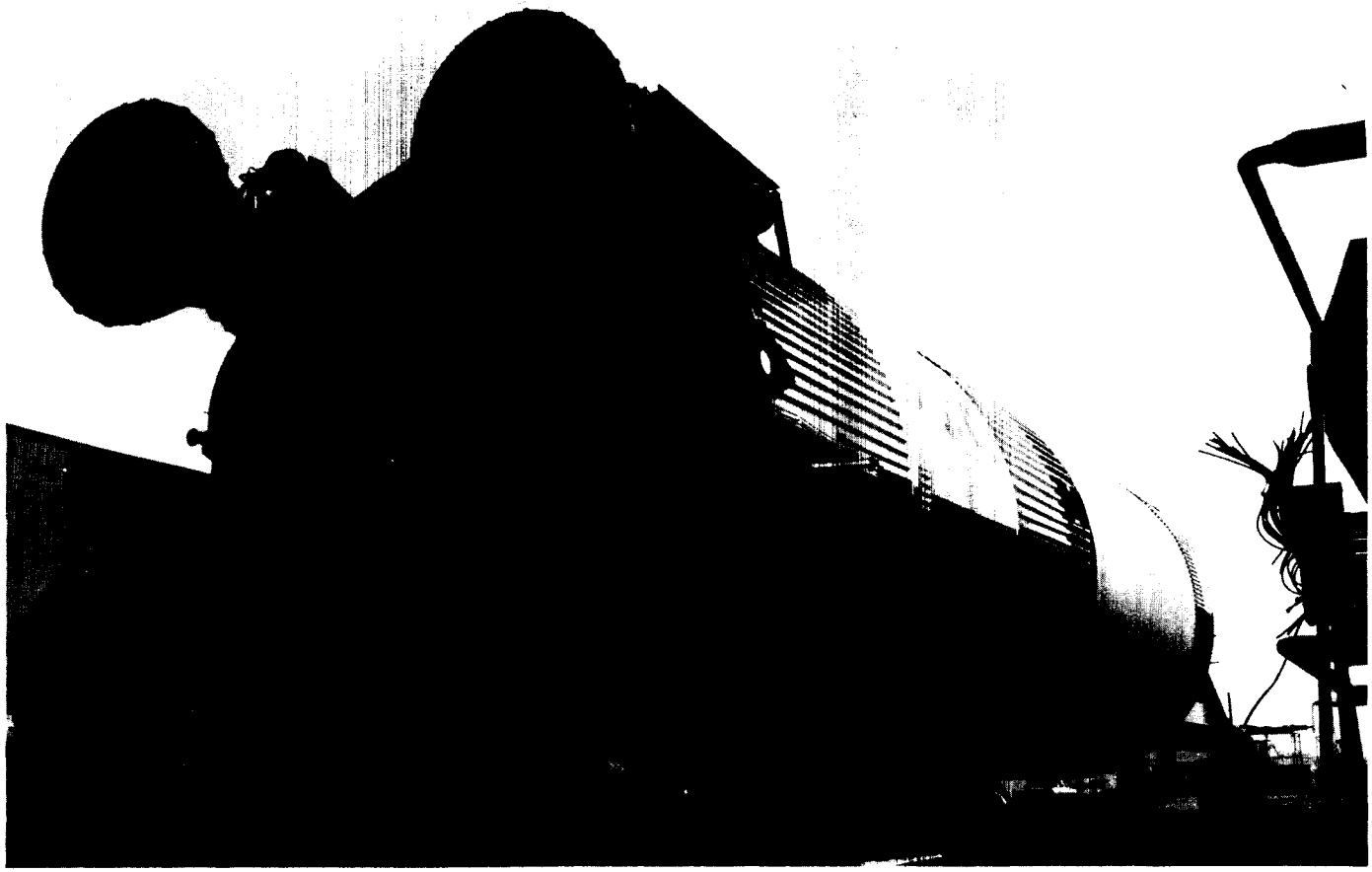
Welding of fuel and LOX tank gore segments for S-IC-2, the second flight booster, began early in this report period. Fuel tank closeout

9. Ibid., Jan.--Mar. 1965, pp. 7-8; April--June 1965, p. 9; July--Sept. 1965, p. 9; and Oct.--Dec. 1965, p. 8.

10. Ibid., Jan.--Mar. 1965, p. 10; April--June 1965, p. 11; July--Sept. 1965, p. 13; and Oct.--Dec. 1965, p. 11; ME Lab., "Pert Analysis on S-IC-1," dated Sept. 17, 1965, and interview with V. B. Hamrick, ME Lab, Oct. 12, 1967.

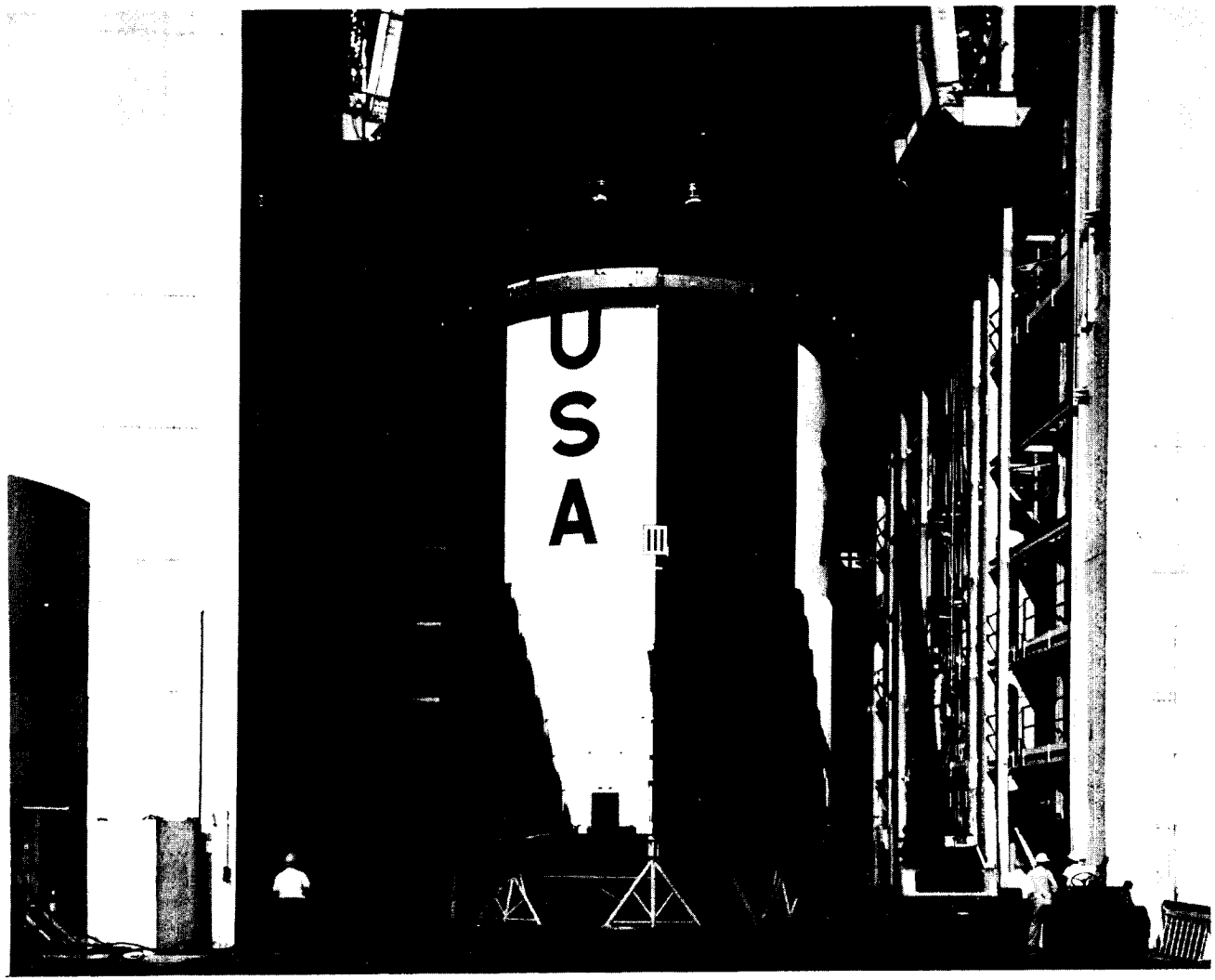
FOR FIRST FLIGHT

The bottom half of S-IC-1, consisting of thrust structure and fuel tank, moves on a transporter from hydrostatic test to assembly area. This is part of Saturn V scheduled to fly in 1967.



SATURN V FLIGHT BOOSTER

S-IC-1, the first Saturn V flight booster, moves from Building 4705 where it was assembled to Building 4708 for quality checkout.



FUEL TANK ASSEMBLY IN VAB

The fuel tank assembly of S-IC-2 is shown in the MSFC Vertical Assembly Building.

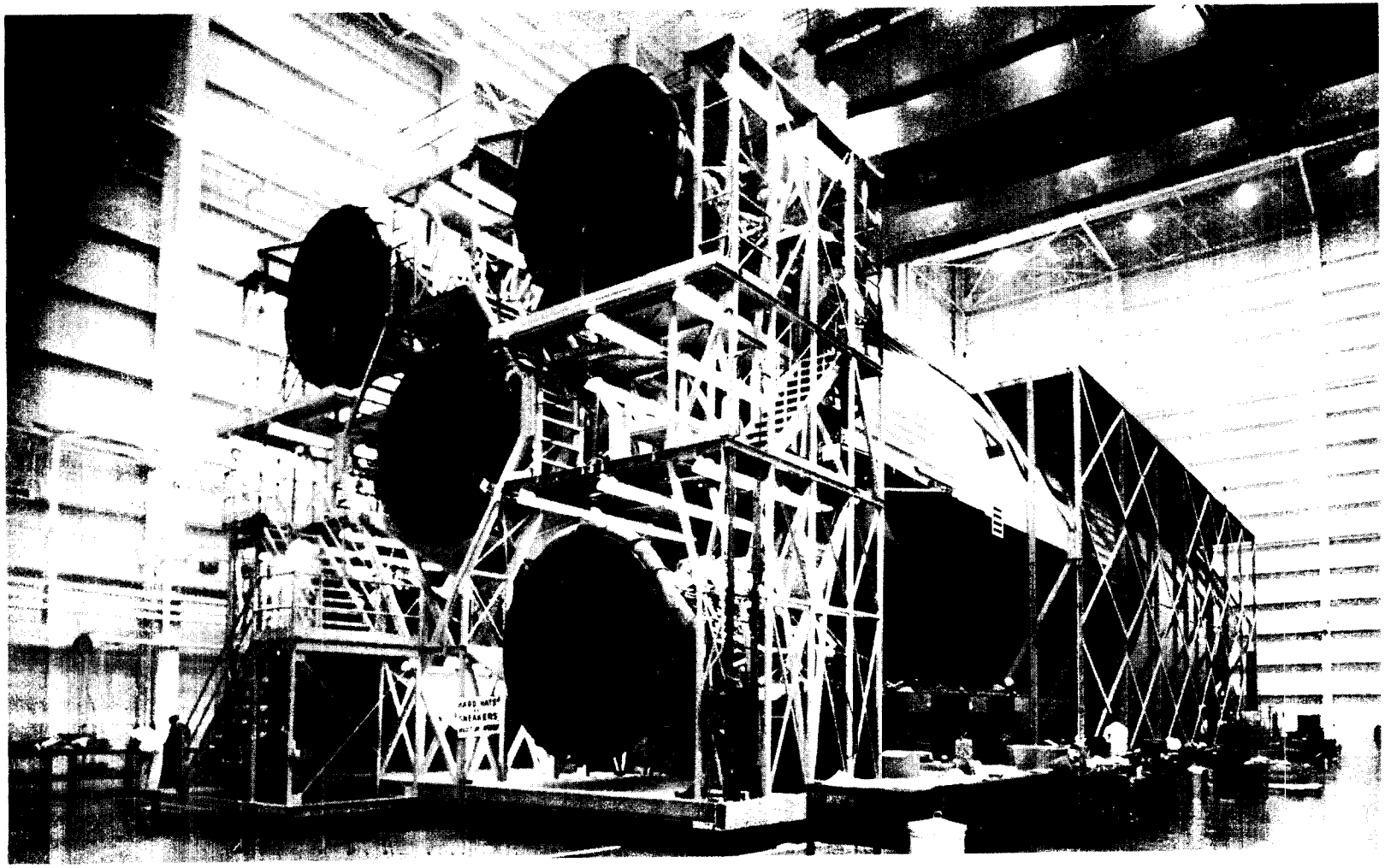
welding ended on May 28. LOX tank assembly was completed and baffle installation started in June. In the ME Lab's VAB, mating of the fuel tank to the thrust structure was completed on September 18; horizontal assembly started in Building 4755 (the Multi-Purpose Vehicle Assembly Building) on September 19. Thrust structure/fuel tank assembly ended November 8; it was the first flight hardware to occupy Building 4755.

LOX tank hydrostatic testing and cleaning occurred from September 28 to October 18. The forward skirt and LOX tank assemblies were joined together on October 25. The intertank, which had been completed on October 18, was attached to the LOX tank/forward skirt October 25-November 8. This forward section moved from the vertical assembly tower to the horizontal assembly area on December 4, where workmen spliced the section to the aft section of the stage. Five F-1 engines were installed on the stage December 6-11. Horizontal assembly operations were continuing when the period ended, with completion due in January 1966.[11]

S-IC-3 Stage

Assembly of the third S-IC flight stage progressed at MAF early in 1965. Welding of the LOX tank and fuel tank subassemblies ended in June. Boeing workmen completed the thrust structure on August 30 and the intertank on September 10. Hurricane Betsy on September 9-10 and a labor strike delayed completion of the forward skirt final assembly until October 9. Both the fuel tank and the LOX tank sustained some corrosion and pitting damage from water and falling gravel when the VAB roof was severely damaged by the hurricane. Hydrostatic test of the fuel tank ended on October 4; the LOX tank emerged from hydrostatic test on October 11. Personnel completed vertical assembly on December 8 and moved the stage to the horizontal assembly area, where horizontal installations were in progress at the end of the report period. F-1 engines for S-IC-3,

11. Ibid., Jan.--Mar. 1965, p. 11; April--June 1965, pp. 11-12; July--Sept. 1965, p. 13; and Oct.--Dec. 1965, pp. 11-12; Milwee, ME Lab., "Quarterly Rpt., July--Sept. 1965," (draft); ME Lab.,"Pert Analysis on S-IC-2", dated Jan. 7, 1966; and interview with V. B. Hamrick, ME Lab., Oct. 12, 1967.



SATURN V BOOSTER COMPLETED

MSFC workmen completed installation of engines on S-IC-2 in December 1965.

which officials had feared would be delivered late, arrived at MAF in October and November. The engines were undergoing buildup and functional test checkout when the current period ended.[12]

S-IC-4 Stage

Welding operations on the S-IC-4 stage began in the second quarter of 1965. Thrust structure final assembly began on schedule August 13; a labor strike delayed completion. Prior to the hurricane, assembly of the fuel tank was near completion. Corrosion and pitting damage occurred to the fuel tank's upper bulkhead. By the end of September the LOX tank was nearly complete. Stage assembly operations were in progress and on schedule at the end of this report period, December 31, 1965. The fuel tank was being installed in the hydrostatic test tower and the LOX tank subassemblies were being joined and welded.[13]

S-IC-5 Stage

Fabrication and assembly of the fifth flight stage began late in 1965. Machinists completed three of the four Y-rings; work was in progress on both bulkheads for the fuel tank; final assembly of the thrust structure began on December 8; work was in progress and on schedule on all major structural subassemblies when the year ended.[14]

General Development Problems

S-IC stage development problems in the first quarter of this period included delivery by vendors of unsatisfactory components, parts shortages created by late deliveries prior to this period, and out-of-sequence assembly operations caused by engineering changes. MSFC and Boeing instituted

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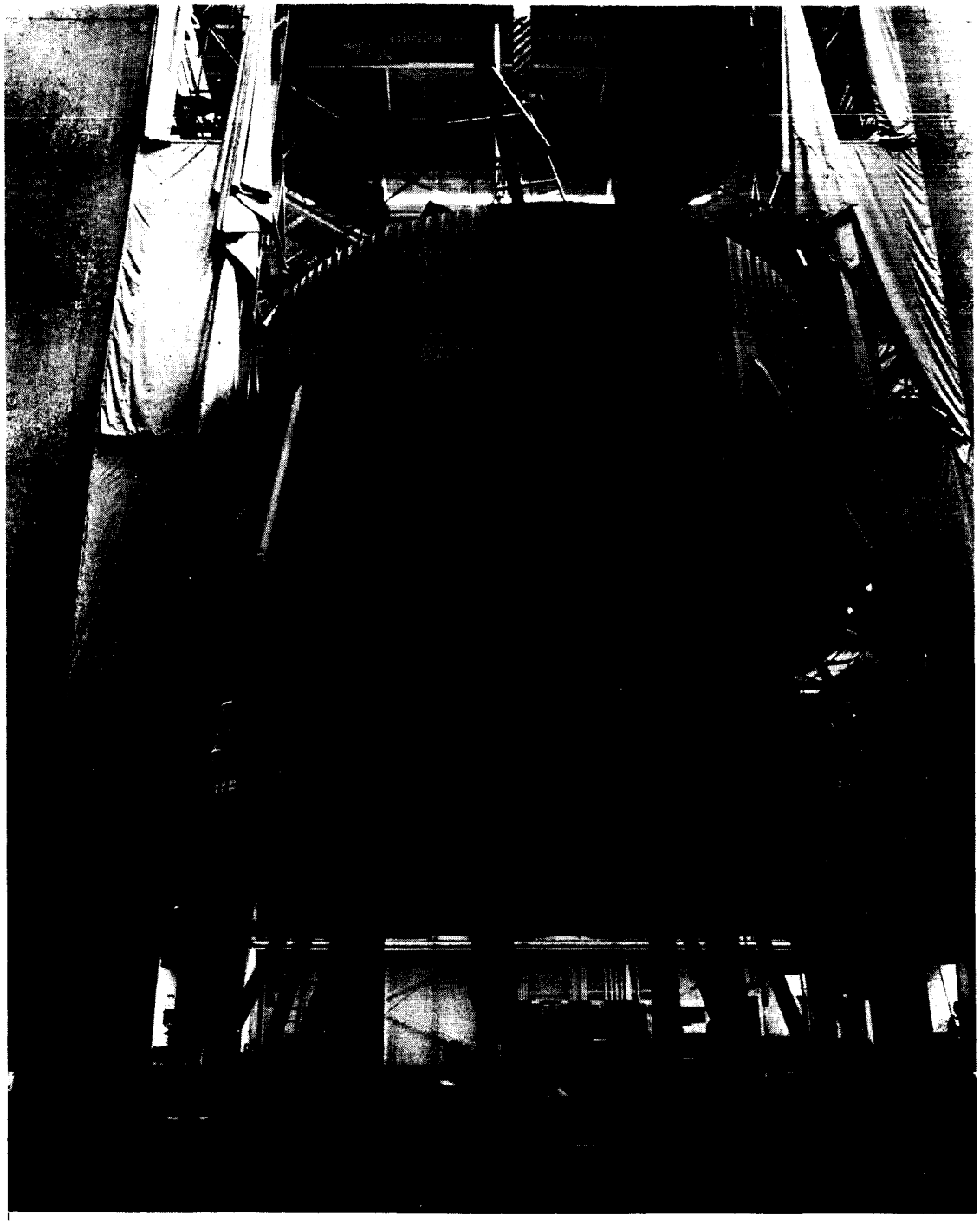
12. Saturn V Prog. Off., Saturn V QPR, April--June 1965, p. 12; July--Sept. 1965, pp. 13-14; and Oct.--Dec. 1965, p. 12.
13. Ibid., April--June 1965, p. 12; July--Sept. 1965, p. 14; and Oct.--Dec. 1965, p. 12.
14. Ibid., Oct.--Dec. 1965, p. 12.



S-IC ASSEMBLY AT MAF

The thrust structure for an S-IC stage is lowered into position to start assembly of this stage at Michoud Assembly Facility. This 90,000-pound section supports the stage's five engines.

stricter quality controls to insure delivery of acceptable components. On-time deliveries improved. MSFC remedied the schedule impact caused by out-of-sequence assembly operations by allocating additional time for implementation of engineering changes and by strengthening change control procedures.

Bulkhead welding problems at MAF that had delayed assembly of S-IC-D and S-IC-F were solved early in the current period by improvement of manufacturing methods. A new welding problem appearing this period involved difficulty in welding LOX tunnels in the fuel tank. Technicians developed a new welding process that resulted in higher quality welds and greater speed.

During the second quarter of 1965 MSFC rejected all electrical cables fabricated by Boeing in Huntsville for the S-IC-1 thrust structure area because of improper length. New cables fabricated at MAF by Boeing were checked out on the S-IC mockup at Huntsville before use. The shortage of acceptable cables still existed late in the current period. MSFC hoped to prevent major schedule impact by "work-arounds."

Failure of the destruct ordnance cowling on S-IC-T during static firing dictated the redesign of the cowling. Engineers reworked the S-IC-1 cowling by installing additional bonded brackets to the propellant tank skin. Late in the period engineers were studying means to mechanically attach the cowling to the pressurization and electrical tunnels for use on S-IC-2 and subsequent flight stages; this expedient would eliminate the bonding process that had previously been necessary.

Also late in 1965, upper LOX lines failed qualification tests and required extensive redesign. Engineers undertook a parallel program of redesign, manufacture, and testing.[15]

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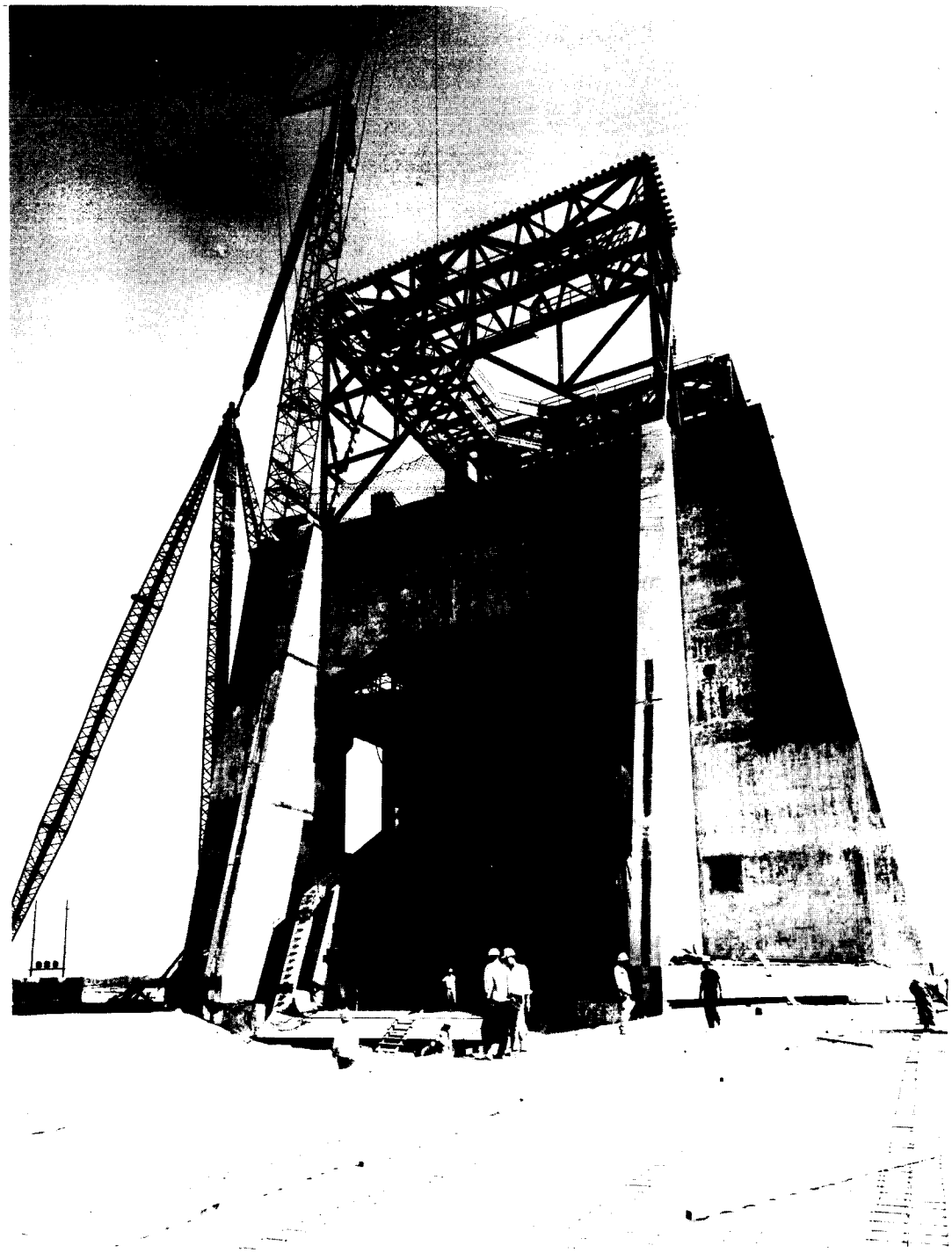
15. Ibid., Jan.--March 1965, p. 11; April--June 1965, p. 13; and July--Sept. 1965, p. 15.



MTF S-II TEST STAND

This May 1965 picture at MTF shows the first of two S-II static test stands. Known as A-2, this stand was placed in operation late in 1965.

S-II Stage

The S-II, second stage of the Saturn V launch vehicle, is 81.5 feet long and 33 feet in diameter. Its empty weight is approximately 88,200 pounds. Fully fueled for launch the stage weighs about 1,040,803 pounds. A cluster of five Rocketdyne J-2 liquid hydrogen (LH_2) engines provides propulsive power totalling about one million pounds of thrust. Designed to perform at high altitude, the S-II stage in a typical Apollo-Saturn V mission begins firing after the first stage of the vehicle drops away; it propels the space vehicle for a period of more than 6 minutes, from an altitude of approximately 50 miles to a height of 118 miles, until the engines cut off and the stage separates and falls back to earth.

At the beginning of 1965 the S-II stage prime contract, NAS7-200, was valued at $475.8 million. Major contract increases occurred in May, June, July, and October 1965. The value of Contract NAS7-200 at the end of this one-year report period was $526.1 million, which reflected a net increase of $50.3 million during the year. The S-II prime contract covers R&D, production, and test of the ground test stages and 10 flight stages. A planning estimate for five additional flight stages was submitted to NASA before the end of the year. The contract is a cost-plus-fixed-fee type; S&ID planned to submit its proposal for converting the contract to cost-plus-incentive-fee by April 1966.[16]

The S-II has been described by NASA officials as the pacing item in the development of the Saturn V. It has the largest LH_2 tank ever built and is probably the most difficult of the stages to build, because of the many new design ideas and manufacturing features. Early in 1965, because of delays, NASA realigned the ground test program in an effort to reduce cost and maintain schedules.

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16. North American Aviation (NAA), Inc., Space and Information Systems Division (S&ID), Saturn S-II Stage Monthly Progress Report, January 1965, SID 63-266-30, p. 3; May 1965, p. 9; June 1965, p. 9; July 1965, p. 45; and October 1965, p. 47; 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, pp. 919 and 923; and review comments Sept. 15, 1967, by Program Control Section, Contracts Office, Ind. Operations, MSFC. (Note: Some stage descriptive figures are approximations. All apply only to the first three flight vehicles.)

This S-II project rephasing, disclosed in Saturn S-II Master Program Schedule No. 17 dated February 1, 1965, made these major revisions:

1. Cancelled the dynamic test stage (S-II-D).
2. Substituted the structural static test stage (S-II-S) as a dynamic stage.
3. Transferred the all-systems test stage (S-II-T) with its GSE from Santa Susana to MTF for dual uses of Stand A-2 checkout and all-systems testing.
4. Assigned the facilities checkout stage (S-II-F) directly to KSC, bypassing MTF.
5. Scheduled an end to the Electro-Mechanical Mockup (EMM) test program at Downey and transfer of its GSE to MTF, for use in the second S-II test stand, A-1.

These program changes eliminated two sets of GSE, alleviated overloading of assembly facilities at Seal Beach, increased confidence in meeting flight stage delivery schedules to KSC, saved money, and freed a test stand (Coca IV) at Santa Susana for possible other use.

Upon destruction of S-II-S/D during a test at Seal Beach in September 1965, there was a further program realignment: S-II-T would have to be used for dynamic testing at MSFC following all-systems test and MTF stand A-2 checkout.[17]

The S-II stage completed a substantial portion of its ground testing in 1965. Among accomplishments were successful cluster battleship firings and completion of the EMM, common bulkhead test tank (CBTT), and structural test programs.

Among the R&D problems that plagued the S-II during this report period, probably the two most serious had to do with establishment of welding techniques and methods of effectively bonding insulation materials to the sidewalls and bulkheads of the stage. Progress toward solution

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17. 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, pp. 131-132; S&ID "Saturn S-II Master Program Schedule, Issue No. 17," Feb. 1, 1965; and Ltr., Dr. W. von Braun, Dir., MSFC, to Maj. Gen. Samuel Phillips, Apollo Program Director, NASA, Feb. 26, 1965.

was significant in both areas during the year. Because of the great demands on the S-II stage, welds have to be almost perfect; S&ID technicians achieved an improved weld. A new type of insulation material strong enough to withstand pressurization and temperature extremes was developed. This glass cloth honeycomb material, which also had the added advantage of reducing the weight of the stage, was applied 1.6 inches thick on the outside of the LH_2 tank. A remaining problem was to find a way to test the installed insulation without destroying it; pressurizing with helium proved its strength and integrity.

Solutions to other serious S-II problems during this period included development of the common bulkhead; a successful battleship firing program, which included engine gimballing and propellant utilization (PU) system operation; 82 per cent completion of component qualification for the stage; and redesign and successful proof test of the aft LOX bulkhead.[18]

S&ID manpower employed in the S-II program at the end of this report period totalled about 8,640. This was at about the peak of the program.[19]

S-II Battleship *

When this period began S&ID personnel at Santa Susana were preparing the S-II battleship for its first cluster firing. Installation of GSE special development devices (SDD) for firing was completed on March 26, about one week behind schedule. Personnel performed the first cluster ignition test on April 24. On May 7 a third attempt at a 10-second firing was successful. Various problems delayed the next scheduled firing until July 13 (ten attempts were made before success). Following this 27-second firing on July 13, technicians performed a static test of 150 seconds duration on July 20. On August 9 S&ID accomplished a full-duration cluster firing which was terminated manually after 385.6 seconds

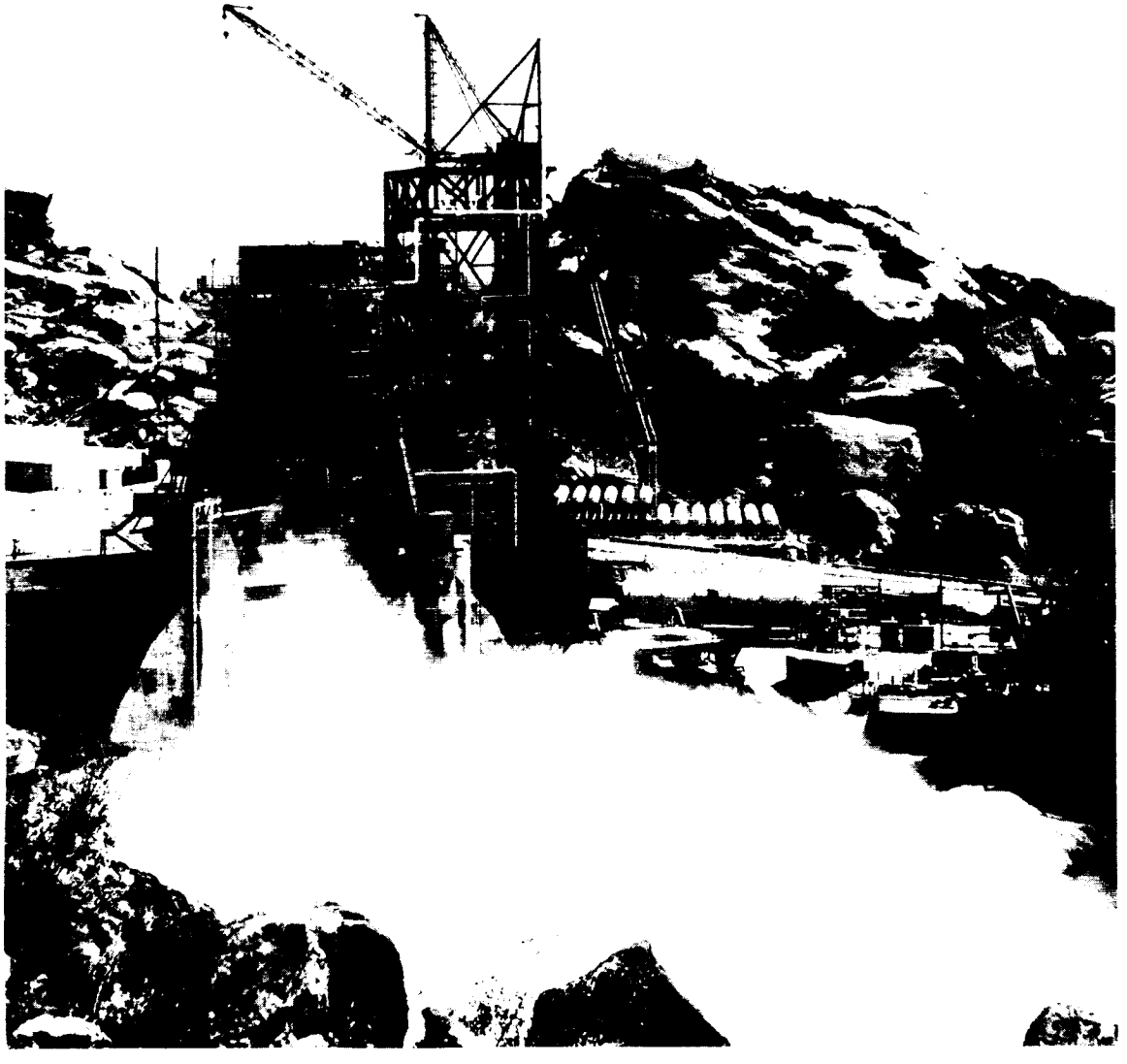
18. 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, pp. 898-906.

19. Ibid., p. 918.

* A battleship is a ground test stage with thick, heavy tanks and plumbing which enable the stage to withstand above-normal pressurization during full-duration static firings and repeated cycling.

BEFORE THE TEST

This is a close-up photograph of the S-II battleship's J-2 engine area. Made in August 1965, the picture shows preparations for static firing at Santa Susana Field Laboratory.



S-II STAGE TEST

The S-II battleship at Santa Susana Field Laboratory is fired in August 1965. The stage has five J-2 liquid hydrogen engines.

of mainstage operation. Workmen then converted the battleship and the facility for flight configuration firings. A labor strike, heavy rains and checkout problems delayed completion of this conversion until December 18. Personnel failed in eight attempts at a 15-second firing, finally achieving an 18-second firing of flight engines on December 29. A full-duration test was scheduled for January 1966.[20]

S-II-F Stage

Fabrication of major assemblies for the S-II-F, facilities checkout stage, proceeded on schedule early in this report period. By the end of June workmen had completed structural assembly of the thrust structure, forward skirt, aft LOX bulkhead, and common bulkhead. Work started on the interstage. Vertical buildup of the stage ended at Seal Beach on August 16. Following this operation S&ID personnel conducted pneumatic proof tests of both propellant tanks, then cleaned, sealed, and pressurized the tanks before installing insulation and stage systems. Problems in insulation closeout delayed systems installation during the last quarter of this period and slipped the manufacturing shop completion into January 1966. At the close of the period the delivery date of S-II-F to KSC was expected to slip about two months--from January 3 to March 7, 1966.[21]

S-II-S/D Stage

During January NASA and S&ID finalized plans to cancel the S-II dynamic test stage, S-II-D, and to reassign S-II-S, the structural static test stage, to the dual role of structural and dynamic testing. The revised master program schedule (No. 17) dated February 1, 1965, designated

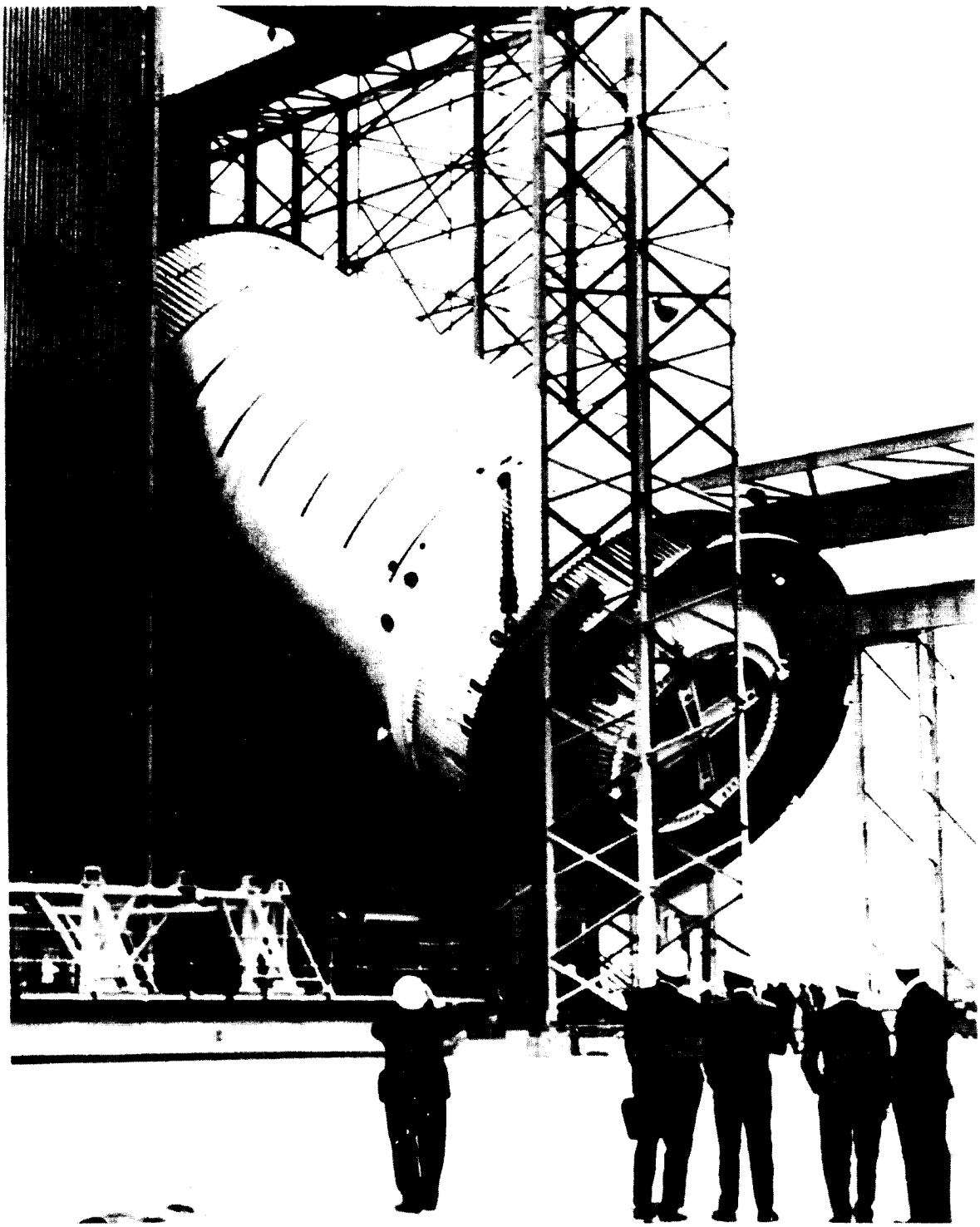
20. Saturn V Prog. Off., Saturn V QPR, Jan.--March 1965, p. 13; April--June 1965, p. 15; July--Sept. 1965, p. 18; and Oct.--Dec. 1965, p. 14.

21. Ibid., Jan.--March 1965, p. 14; April--June 1965, p. 16, July--Sept. 1965, p. 19; and Oct.--Dec. 1965, p. 15.

the dual-purpose stage S-II-S/D. The S-II-S stage, following completion of structural tests at Seal Beach, would be modified to the S-II-D configuration and delivered to MSFC for dynamic testing as part of the Saturn V vehicle. Accordingly, fabrication of S-II-D terminated during January 1965.

Workmen completed assembly of S-II-S five days ahead of schedule on January 31. The stage was moved from the vertical assembly facility and installed in the structural static test tower on February 23 and preparation started for testing. Pretest operations began on March 22. Hydrostatic tests followed. During April workmen conducted four thrust structure tests. On April 30, during the final test simulating a flight condition, a failure occurred in which the No. 3 engine mount was torn from the structure, the skin of the structure was torn, and thrust longerons broken. An investigation of the failure revealed that the structure was understrength in the region of the damage. Modifications to the stage preceded the next test sequence which began on May 4 and ended in June. Meanwhile, repairs were started, continuing until July 16. Center engine thrust load testing in July resulted in structural failure of rivets and attach bolts, which required repair and delayed completion of the S-II-S test program. Further static tests on August 14 caused more structural damage--buckling of the forward skirt. Load testing continued in August and September, with local damage occurring in several areas of the stage. On September 29, during ultimate load testing with hydrostatic pressurization at Seal Beach, the stage ruptured and was destroyed; the failure occurred at approximately 138 per cent limit load, thus demonstrating optimum design and verifying the structural integrity of the stage. In spite of the failure, this concluded structural testing.

A failure evaluation team concluded that the trouble probably started in the interstage, caused rupture of the aft LOX and common bulkheads, and released water from the LH_2 tank. The sudden loss of 3.2 million pounds of water from the tanks caused the stage to collapse.



S-II STRUCTURAL TEST STAGE

The S-II-S stage in the Saturn V program is erected into test position at North American's Seal Beach Facility in February 1965. The stage was destroyed in a structural test accident September 29, 1965.

MSFC designated S-II-T, the all-systems stage, as the replacement for S-II-S/D. It will be shipped to MSFC for dynamic testing after completion of static firings at MTF.[22]

S-II-T Stage

Master program schedule change No. 17 dated February 1, 1965, called for S-II-T to be delivered to MTF for hot-firing in Stand A-2. S&ID completed the stage's common bulkhead in February and the aft LOX bulkhead in March. Vertical assembly started late in February and ended on May 25. After rollout from the VAB at Seal Beach, the stage underwent pneumatic proof testing, then returned to the VAB for systems installation and completion of insulation closeout. Systems installation ended on September 17, and all manufacturing was completed by September 30. The stage left Seal Beach on October 1 aboard the AKD Point Barrow and arrived at MTF on October 17. Workmen installed it in Test Stand A-2 on October 19. Buildup and checkout of the stage, facility, and GSE continued to the end of the period.[23]

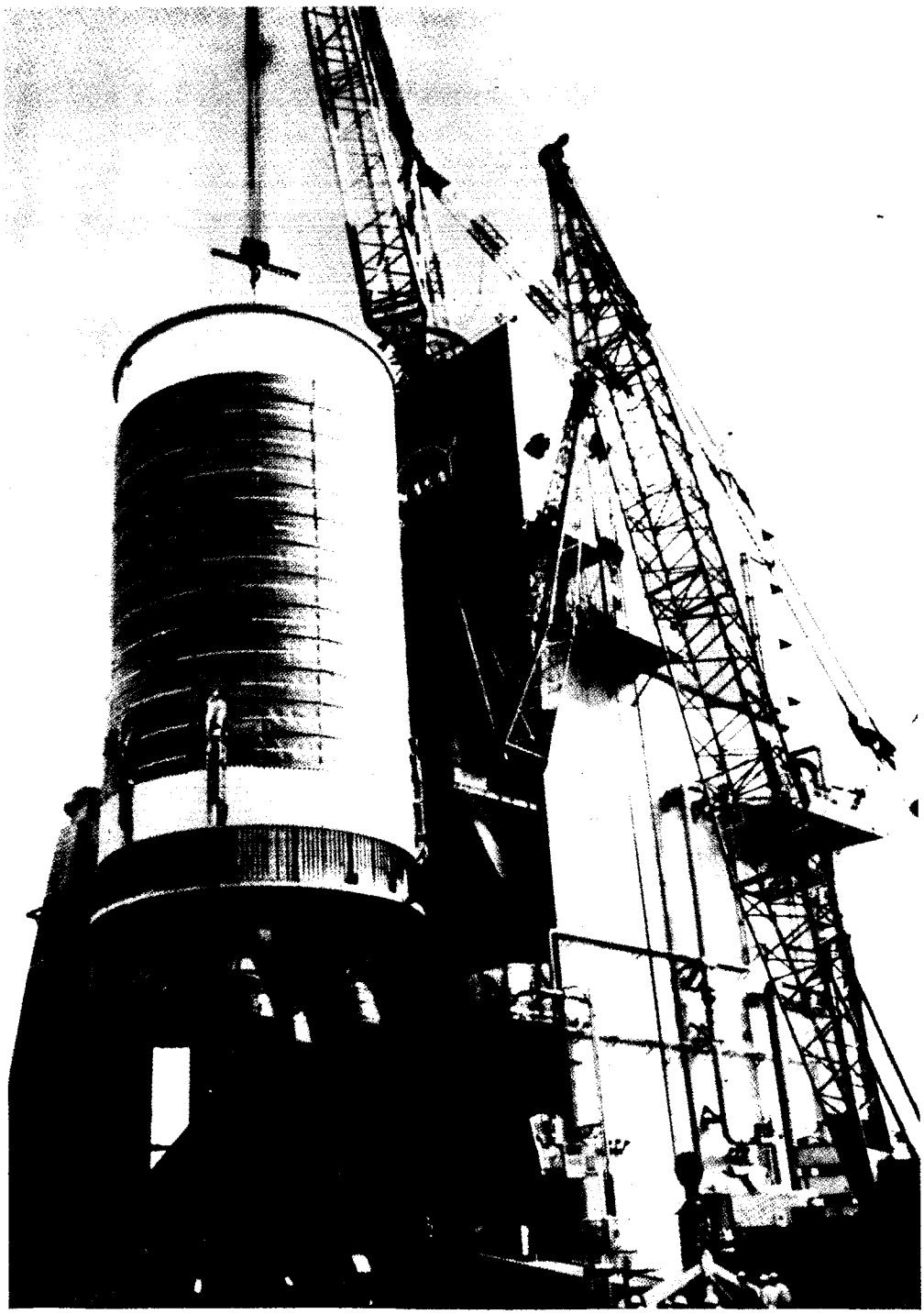
Special Test Articles

Among the special test articles in the S-II stage development and ground test program are the common bulkhead test tank (CBTT), the Electro-Mechanical Mockup (EMM), the High-Force Test Article, and the S-II Fit-up Fixture (also called the S-II simulator).

The CBTT is a shortened version of the S-II stage, designed to help solve the special insulation and structural problems of the common bulkhead. Workmen at Seal Beach completed on May 24, 1965, the assembly of

22. NAA, S&ID, S-II Stage MPR, Jan. 1965, pp. 29 and 33; and Feb. 1965, p. 39; and Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, p. 14; and Oct.--Dec. 1965, pp. 15 and 17; and NAA, S&ID, S-II Stage MPR, March 1965, p. 37; April 1965, p. 36; May 1965, p. 41; July 1965, p. 23; and Sept. 1965, p. 41

23. Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, pp. 15-16; April--June 1965, p. 17; July--Sept. 1965, p. 21; and Oct.--Dec. 1965 p. 17.



S-II-T GOES INTO STAND

Workmen at MTF install the S-II static test stage into A-2 Stand on October 19, 1965, in preparation for captive firings.

the CBTT and loaded it on a Type I transporter on May 27. On June 1 this special test article began its journey to the Santa Susana test facility via the barge Orion and land transport, arriving at Santa Susana June 3. S&ID personnel there finished installing insulation and completed on July 8 the preparation for the first CBTT test; they accomplished structural verification of the tanks with pneumatic pressurization on July 11. Numerous insulation leaks were discovered, but attempts at repair were unsuccessful. Liquid nitrogen (LN_2) fill and drain tests were run successfully on August 21 and September 12, using a mylar helium bag to prevent insulation leaks. The final scheduled test of the CBTT test program ended on November 6, when the skirt-to-tank joint was tested to 1.3 times the design limit pressure; the common bulkhead was tested to 1.4 times the limit burst pressure--all without apparent damage.[24]

The EMM is a simulated stage located at S&ID's Downey, California, plant where the stage contractor interfaces the automatic checkout equipment (ACE) with as much of the stage as can be simulated. The EMM developed automatic checkout tapes for actual stages and served as a baseline for all of the checkout tapes. When this report period began, S&ID was near completion of stage systems installation and acceptance testing of ACE racks in the EMM. ACE fabrication for EMM activation ended in February 1965. All ACE racks became operational during March. Completion of the functional integration of all ACE stations occurred April 10; this was a major EMM milestone. Modification kits to permit changing the EMM to the S-II-1 configuration began arriving in April. Activation of the EMM was completed during May. In July project officials decided because of schedule delays not to modify the EMM to the S-II-1 configuration; all efforts at modification stopped. A test and deactivation schedule was established in August. "Debugging" and verification of the stage system automatic checkout tapes already produced by the EMM proceeded to completion late in September. EMM control power was turned off on October 4;

24. Saturn V Prog. Off., Saturn V QPR, April--June 1965, p. 15; July--Sept. 1965, pp. 18-19; and Oct.--Dec. 1965, p. 14.

personnel then began to deactivate and disassemble the EMM. By the end of November the equipment in this stage simulator had been transferred to other sites and all personnel reassigned.[25]

The High-Force Test Program consists of subjecting certain key components of the S-II stage to structural vibration loads simulating the launch condition. Stage components assembled by S&ID for this program included the forward skirt, aft interstage, and thrust structure. In July S&ID selected Wyle Laboratories at Huntsville as the test agency for this program; NASA approved this selection in September. Assembly of the High-Force Test Articles began in October. MSFC stopped all work on the program in November except design and fabrication of test hardware. Late in November MSFC rescinded the stop order and permitted test plans to proceed. S&ID released all drawings for the test specimens in December, and fabrication and assembly work continued at the year's end.[26]

The Fit-up Fixture, or S-II stage simulator, was built at Seal Beach. Its purpose is to train technicians in the transport and handling of the stage and to serve as a facility checkout item for S-II static test positions and other facilities. Its first scheduled use was to be checkout of Test Stand A-2 at MTF. On May 11, 1965, S&ID workmen moved the simulator aboard the AKD Point Barrow, which departed Seal Beach June 13. Also aboard the Point Barrow as cargo was an S-IVB stage en route to Cape Kennedy. After passing through the Panama Canal, the vessel arrived at MAF on June 26. At the MAF dock the S-II simulator was unloaded. The next day workmen loaded it on the NASA shuttle barge Pearl River for the 7-hour trip to MTF. The newly completed canal lock there lifted the barge and its cargo into the canal system. Unloading of the simulator and accompanying equipment occurred June 28. Workmen stored them to await availability of Test Stand A-2, where instrumentation and equipment were

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25. NAA, S&ID, S-II Stage MPR, Jan. 1965, pp. 21-23; Feb. 1965, pp. 26-28; Mar. 1965, pp. 23-24; April 1965, pp. 20-21; May 1965, p. 24; July 1965, p. 33; Aug. 1965, pp. 34-36; Sept. 1965, p.

26. Ibid., Mar. 1965, p. 1; June 1965, p. 54; July 1965, pp. 34-35; Sept. 1965, p. 55; Oct. 1965, p. 19; Nov. 1965, p. 43; and Dec. 1965, p. 46.

being installed. On August 29 workmen lifted the simulator from a barge and positioned it in the test stand to check clearance and alignment. Additional installation and removal tests during September trained operating crews and revealed some facility inadequacies that would require correction before installation of S-II-T into the stand. Its mission at MTF complete, the S-II simulator returned to Seal Beach in October aboard the Point Barrow. It arrived at Seal Beach November 2 and was unloaded and stored.[27]

S-II-1 Stage

S&ID began in February 1965 the fabrication of major structural subassemblies for the first flight stage, S-II-1. The first hardware assembled was the aft facing sheet for the common bulkhead. Assembly also started during the first quarter of the year on tank cylinders. Hydrostatic testing of the aft facing sheet revealed a slight leak in the weld, which technicians repaired. By the middle of the year the thrust cone assembly and the aft skirt assembly were complete at Seal Beach. Common bulkhead work was progressing satisfactorily, and installation of brackets on the forward skirt was well underway at Tulsa. Vertical buildup of S-II-1 began on July 6. On July 9 S&ID completed the aft skirt and thrust structure. Completion of the forward skirt came on August 10 and the common bulkhead on September 13. All engine deliveries were completed in November. By November 25 all major subassemblies of the stage were completed with final assembly of the aft LOX bulkhead. Vertical buildup was achieved on December 28. Hydrostatic test and cleaning of both propellant tanks was scheduled to start early in 1966.[28]

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27. Ibid., June 1965, pp. 59-62; Aug. 1965, p. 17; Oct. 1965, p. 32; and Nov. 1965, p. 38.

28. Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, p. 16; April--June 1965, p. 18; July--Sept. 1965, p. 23; and Oct.--Dec. 1965, p. 17.

S-II-2 Stage

During May 1965 S&ID began structural assembly of the second flight stage at Seal Beach by commencing the meridian welding of the common bulkhead aft facing sheet. The final weld of the bulkhead was made on May 29, followed by X-ray and dye-penetrant inspection. By the end of the year's second quarter all meridian welds were complete on the forward facing sheet. During the third quarter workmen fabricated and installed honeycomb insulation and prepared to fit together the aft and forward facing sheets of the common bulkhead. Assembly of the forward bulkhead was completed and the aft bulkhead was ready for the "dollar" plate weld closure. Aft skirt panels were installed on the thrust structure before October 1. Technicians completed the thrust structure assembly on October 15 and common bulkhead assembly on December 17. All J-2 engine deliveries for the stage were completed during November. Assembly completion of the forward skirt and the aft bulkhead were expected in January 1966.[29]

S-II-3 Stage

Assembly of S-II-3, the third flight stage, started in June 1965. By the end of September technicians had completed the dollar welds of both facing sheets of the common bulkhead. X-ray and dye-penetrant inspections as well as hydrostatic and leak tests were made on the forward facing sheet. Six meridian welds on the stage's forward bulkhead were made. During the last quarter of the year completion of the forward bulkhead was achieved, both common bulkhead facing sheets were being held for minor meridian weld repairs, and preparation was underway for layup and bonding of common bulkhead insulation. Thrust structure components arrived before the end of the year from S&ID's plant at Tulsa.[30]

29. Ibid., April--June 1965, p. 18; July--Sept. 1965, p. 23; and Oct.--Dec. 1965, p. 17.
30. Ibid., July--Sept. 1965, p. 23; and Oct.--Dec. 1965, p. 18.

S-II-4 Stage

Assembly of the fourth flight stage, S-II-4, began in September 1965 with fabrication of the common bulkhead. In the fourth quarter of the year most of the meridian welds were completed on the common bulkhead facing sheets. At the end of the period certification was in progress on the forward bulkhead meridian welder for the S-II-4 configuration.[31]

S-IVB Stage

Saturn V's third stage, the S-IVB, is 58.6 feet long and 21.7 feet in diameter. The aft interstage flares to a diameter of 33 feet at the base to match the S-II stage. The stage's empty weight is about 26,536 pounds; propellants increase the launch weight to 255,000 pounds. (The S-IVB in a slightly different configuration also serves as the second stage of the Saturn IB launch vehicle, scheduled to fly well over a year before the Saturn V. The Saturn IB S-IVB development project is reported in the Saturn IB chapter of this monograph.)

The Saturn V S-IVB's function in the Lunar Orbital Rendezvous (LOR) mission is to power the space vehicle following burnout and separation of the S-II stage at an altitude of approximately 113 miles. The S-IVB's single J-2 engine burns for about 141 seconds, accelerates the vehicle to orbital velocity, and inserts it into a parking orbit some 115 miles above the earth. After the vehicle coasts in orbit for two or three revolutions, the S-IVB restarts and burns for another 318 seconds to achieve the required transfer velocity to place it on a trajectory toward the moon. The S-IVB and Instrument Unit remain attached to the Lunar Excursion Module to provide added inertia to the LEM while the Command/Service Module unit separates, turns around, and redocks with the LEM. After this redocking, the S-IVB/IU separates from the spacecraft, the launch vehicle's mission completed.[32]

31. Ibid., July--Sept. 1965, p. 23; and Oct.--Dec. 1965, p. 18.

32. Saturn V Prog. Off., Saturn V Project Development Plan, Sept. 1965, p. 3-6. (Note: Some figures here are approximations. All apply only to the first three flight vehicles.)

Douglas Aircraft Company (DAC) holds the prime contract for the design, development, manufacture, and test of the S-IVB stage. J-2 engines for the stage, which generate thrust of approximately 200,000 pounds in the early vehicles, are procured from Rocketdyne by MSFC's Engine Program Office. The S-IVB stage contract, NAS7-101, which was awarded to DAC by NASA in August 1962, originally covered only Saturn V requirements. NASA amended this contract in December 1963 to provide S-IVB stages for the newly approved Saturn IB vehicle, an intermediate vehicle between the Saturn I and the Saturn V. Early in the current report period Contract NAS7-101 covered the ground test stages for both vehicle programs, all 12 Saturn IB flight stages, and six of the 15 flight stages currently approved for the Saturn V vehicle. At that point the contract's value was approximately $319 million. On May 17, 1965, MSFC submitted to the NASA Office of Manned Space Flight (OMSF) for approval the procurement plan for nine additional Saturn V S-IVB stages (for vehicles SA-507 through SA-515). Following plan modification and approval by OMSF, the Center on July 9 forwarded the request for quotation (RFQ) to DAC. NASA estimated the nine new stages plus related equipment and services would increase the S-IVB prime contract's value by more than $150 million. At the end of 1965 MSFC and DAC were still negotiating on the contract supplement.[33]

Meanwhile, in mid-1965 DAC and MSFC began the task of converting from cost-plus-fixed-fee (CPFF) to cost-plus-incentive-fee (CPIF) the basic S-IVB contract. During August and September MSFC evaluated DAC's proposed conversion plan and established the Center's pre-negotiation position. NASA Headquarters reviewed this pre-negotiation position from September to December. On December 1 OMSF approved the MSFC pre-negotiation position covering cost, fee, and incentive criteria. Cost negotiations which had

33. MHM-10, Vol. I, pp. 64 and 121; Saturn V Prog. Off., "Saturn V Weekly Rpt. No. 20," May 24, 1965; "No. 28," July 20, 1965; and telephone interview with Edgar King, Jr Saturn V Prog. Off., MSFC, Apr. 26, 1967.

started on September 21 continued underway at the end of 1965, with completion anticipated in January 1966.[34]

The S-IVB development and production project was generally on schedule at the end of 1965. The same ground test stages used in Saturn IB development are later modified and used for the Saturn V program. The ground test program was in the process of being converted from Saturn IB to Saturn V vehicle configuration throughout this period: The Sacramento Test Center (SACTO) battleship firing series was complete; MSFC's battleship program was well underway; the dynamic test stage ended Saturn IB tests and was ready for Saturn V testing; the facilities checkout stage was in the final phase of conversion to Saturn V; the IB structural test program was almost complete; and the stage simulator for MSFC use was in post-manufacturing checkout. The first four flight stages for Saturn V were in manufacture and checkout: S-IVB-501 was undergoing systems checkout at Huntington Beach; S-IVB-502 was nearly complete structurally; and manufacture of S-IVB-503 and S-IVB-504 was well underway.

DAC had a number of development problems but solved many of them with technology gained from the Saturn I's S-IV project. Among these were solutions to welding problems, cryogenic insulation development, and common bulkhead fabrication. Many problems plagued and prolonged the battleship program. Among them were engine interface, engine restart, stage component, and stage and facility systems problems. DAC solved these and completed the battleship program at SACTO with full success.[35]

S-IVB Structural Test Stage

S-IVB-S, the structural test stage, was under test at Huntington Beach in the Saturn IB configuration prior to 1965. Saturn IB structural

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34. Saturn V Prog. Off., "Saturn V Weekly Rpt. No. 32," Aug. 16, 1965; "No. 36," Sept. 13, 1965; "No. 38," Sept. 27, 1965; "No. 43," Nov. 1, 1965; and "No. 48," Dec. 6, 1965.

35. 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, pp. 798, 802, and 835.

tests continued throughout 1965. Air-frame qualification of this configuration came on October 26, but one structural test remained to be performed at the end of the year before the stage could be converted for Saturn V configuration tests.[36]

S-IVB Battleship Stages

There are two S-IVB battleship stages. The principal battleship for the stage development is at SACTO in California. A second battleship is installed in a test position at MSFC where it is operated by Test Laboratory.

The SACTO battleship in the Saturn IB configuration began operating in 1964. Its first firing occurred in December 1964, and the first full-duration test came before the end of that month. The IB firing program with a flight-type engine continued early in 1965 with satisfactory full-duration firings on March 31, April 15, and May 4. The Saturn IB series of battleship tests at SACTO ended on May 14, 1965, with an aft interstage environmental temperature conditioning test.

Conversion of the stage to the Saturn V configuration began in May and was largely completed on June 4. Test personnel attempted the first Saturn V development firing on June 19; the test ended with an automatic cutoff after seven seconds. The second firing on June 26 consisted of a 170-second "first-burn" firing followed by a 4-second restart firing which indicated good performance of all systems. During the third firing on July 1 an explosion occurred in the thrust cone area after 3 to 4 seconds of firing; this caused a fire that damaged wiring and instrumentation. On August 13 fire interrupted another firing after 10 seconds, but damage was minor. The first two-burn full-duration firing of the battleship occurred on August 17: firings were for 170 and 320 seconds, respectively. The final two-burn test came on August 20, for 170 and 360 seconds. These tests concluded the Saturn V S-IVB battleship test program at SACTO and

36. Sat. V Prog. Off., Sat. V QPR, Oct.--Dec. 1965, p. 23.

established the validity of the S-IVB design concepts and functional operations of flight-type hardware. Workmen removed the stage from Beta I stand on September 8 and shipped it to Tullahoma, Tennessee, for J-2 engine environmental testing at Arnold Engineering Development Center.[37]

At MSFC, Test Laboratory proceeded during June and July 1965 to activate the S-IVB test stand for the MSFC battleship. Personnel conducted the first successful ignition test for 2.1 seconds on August 2. Other short-duration firings occurred on August 10, August 18, September 8, and September 10. A full-duration test lasting 400 seconds came on September 15, and a 250-second firing followed on September 29. The J-2 engine used in this first series of firings was removed from the stage on October 4 and replaced on October 11 with an engine of a later configuration. Also installed at this time was engine gimballing equipment. Four battleship firings using this new engine occurred for long durations ranging from 300 to 432.4 seconds during November and December 1965. All four firing tests yielded normal results. During the five-month period 11 tests were conducted for a total of 2,316.3 seconds.[38]

S-IVB Dynamic Stage

S-IVB-D, the dynamic test stage, underwent Saturn IB vehicle tests at MSFC during the first five months of this report period. On May 27, 1965, personnel completed the Saturn IB total vehicle test program. Upper stage testing in the Saturn IB configuration then proceeded until September 11. The aft skirt for conversion of the stage to the Saturn V configuration (S-IVB-500D) left Seal Beach on the Point Barrow September 24, 1965. The skirt arrived at MSFC on November 2 as scheduled. Meanwhile, testing of the S-IVB/IU/Payload portion of the Saturn V vehicle configuration occurred in the period from October 15 through November 6.

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37. Ibid., Jan.--Mar. 1965, p. 19; April--June 1965, p. 21; and July--Sept. 1965, p. 26; and Saturn V Prog. Off., "Saturn V Weekly Rpt. No. 16," Apr. 26, 1965; "No. 18," May 10, 1965; "No. 20," May 24, 1965; "No. 24," June 21, 1965; "No. 25," June 29, 1965; "No. 26," July 7, 1965; "No. 32," Aug. 23, 1965.

38. Sat. V Prog. Off., Saturn V QPR, July--Sept. 1965, pp. 26-27; and Oct.--Dec. 1965, pp. 20-21; and Test Lab, Hist. Rpt., Jan. 1--Dec. 31, 1965, Addendum pp. 1-3.

Near the end of this period program officials decided, since the S-II-D stage was still unavailable for test, to use the S-IVB-D for Super Guppy aircraft flight tests during the first quarter of 1966.[39]

S-IVB Facilities Checkout Stage

S-IVB-500F, the facilities checkout stage, was in the final phase of manufacture at DAC's Huntington Beach plant at the beginning of this report period. The stage left the Seal Beach dock February 12 and arrived at SACTO February 17, where workmen installed it in Beta 3 Test Stand for use in qualifying the stand for S-IVB-201 acceptance testing. Personnel at SACTO accomplished propellant loading without major problems on April 21. The stage/facility checkout there ended on May 1 with a successful automatic propellant loading test. The stage was removed from the stand on May 3 and underwent post-test inspection of tanks, insulation, and welds; the inspection revealed no discrepancies. The stage departed SACTO on June 10 for Kennedy Space Center. It was transloaded at Seal Beach from the Orion to the Point Barrow. The S-IVB-500F arrived at KSC on June 30 for use in facilities checkout of Launch Complexes 34, 37, and 39. The Saturn V aft interstage for the stage left Seal Beach by ship October 19 and arrived at KSC November 2. The stage was undergoing final conversion to Saturn V configuration when this report period ended December 31, 1965.[40]

S-IVB Stage Simulator

S-IVB-500ST, the stage simulator, was in assembly at Huntington Beach when this period opened. The simulator is a stage mockup for use in the Systems Development Facility (breadboard) at MSFC in developing integrated computer tapes for launching the Saturn V vehicle. Assembly continued until

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39. Sat. V Prog. Off., Sat. V QPR, April--June 1965, p. 21; July--Sept. 1965, p. 27; and Oct.--Dec. 1965, p. 21.

40. Ibid., Jan.--Mar. 1965, p. 20; April--June 1965, p. 22; and Oct.--Dec. 1965, p. 21; and "Saturn V Weekly Rpt. No. 16," Apr. 26, 1965; "No. 17," May 4, 1965; "No. 20," May 24, 1965; and "No. 26," July 7, 1965.

near the end of 1965. DAC shipped the simulator to SACTO by barge on December 15. Arriving at the test center December 21, it went into the Vertical Checkout Laboratory December 22. Systems checkout in this tower is scheduled for the first quarter of 1966, with shipment to MSFC expected in April 1966.[41]

S-IVB-501 Stage

The first flight stage in the Saturn V configuration was in fabrication and assembly at Santa Monica and Huntington Beach when 1965 began. Structural assembly proceeded on schedule. Joining of the propellant tanks, plus tank testing, occurred the second quarter of the period. During the third quarter workmen completed insulation installation, assembly of the thrust structure and forward skirt assembly, tank installations and cleaning, J-2 engine buildup, and painting operations. Joining of stage structural components ended November 15 and engine joining on November 29. Post-manufacturing checkout began on November 22 and proceeded slowly due to parts shortages; checkout was scheduled for completion in February 1966.[42]

S-IVB-502 Stage

DAC began fabrication of the second Saturn V flight stage early in 1965. Assembly of propellant tanks progressed satisfactorily at Santa Monica throughout the second quarter of the year. By July 1 the LOX tank was complete and undergoing leak and proof testing at Huntington Beach. The stage was in the hydrostatic test tower by the end of September. At the end of 1965 leak and dye checks, tank insulation installation, and tank cleaning were complete.[43]

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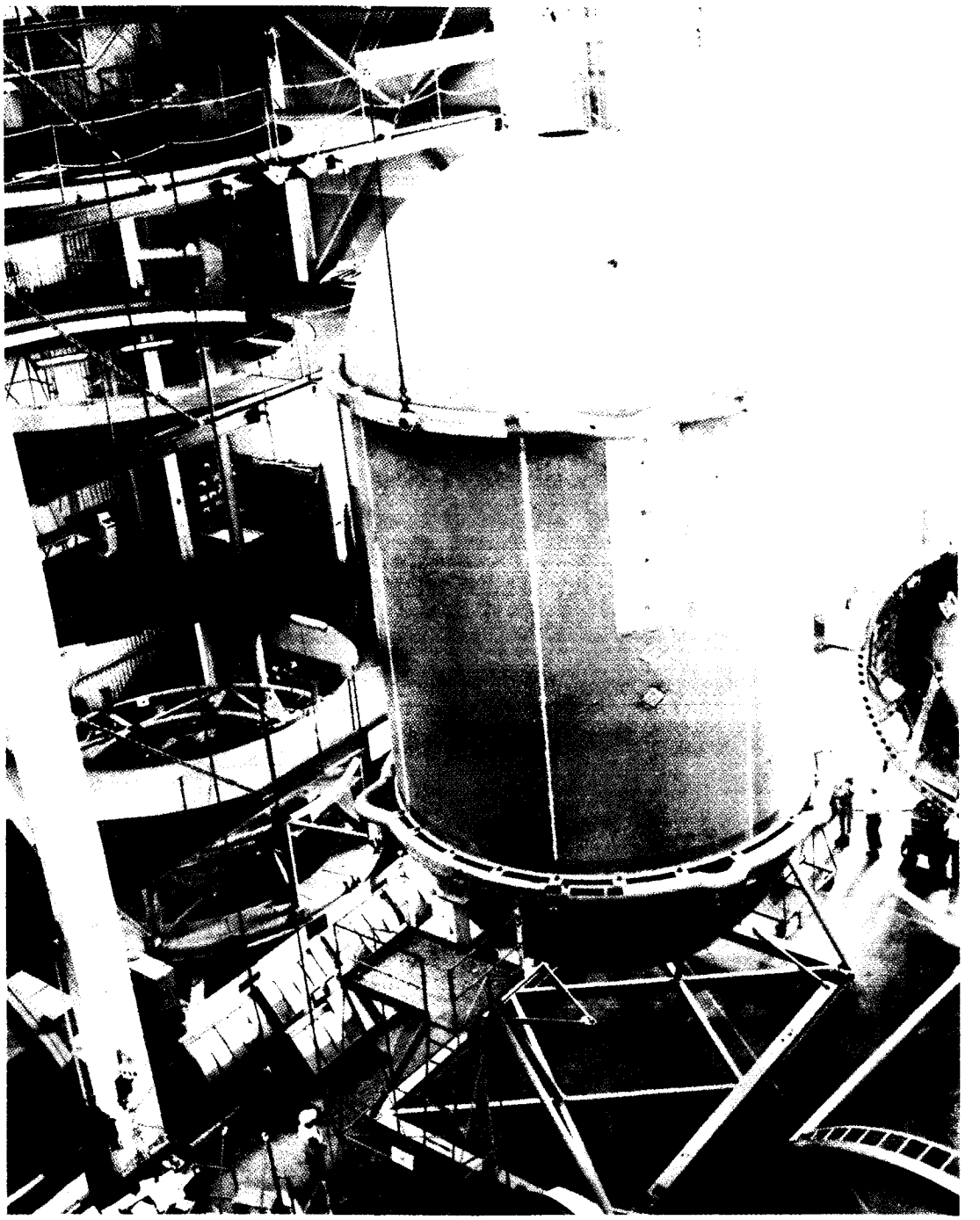
41. Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, p. 21; and Oct.--Dec. 1965, p. 23.
42. Ibid., April--June 1965, p. 23; July--Sept. 1965, p. 28; and Oct.--Dec. 1965, p. 23.
43. Ibid., Jan.--Mar. 1965, p. 21; April--June 1965, p. 23; and July--Sept. 1965, p. 28.



TOPMOST STAGE OF SA-501

S-IVB-501 stage is shown on a support stand at Douglas Aircraft Company's plant at Huntington Beach, California, during assembly.

S-IVB-503 Stage

Fabrication and assembly of the third flight stage began at Santa Monica in the third quarter of this year. Fabrication of propellant tanks was nearing completion by December 31, 1965.[44]

S-IVB-504 Stage

The fourth Saturn V flight stage encered fabrication and assembly operations near the end of the 1965 report period. When the year ended the aft common bulkhead was awaiting fit-up of honeycomb insulation and the forward common bulkhead was being prepared for the "dollar" weld.[45]

Instrument Unit

The instrument unit (IU) for the Saturn V and the Saturn IB is almost identical. The IU is a non-propulsive cylindrical structure three feet high and about 21.7 feet in diameter, which houses the guidance systems for the entire vehicle during powered flight. The Saturn V IU weighs 4,750 pounds in the first three flight vehicles (4,230 for later vehicles) and contains instrumentation for guidance, control, telemetry and tracking, and associate power and electronics systems, as well as an enviromental control system. Commands for engine gimballing, in-flight sequencing of engine propulsion systems, staging operations, and all primary timing signals originate in the IU.

MSFC has NASA responsiblity for IU development. During 1964 the Center selected International Business Machines Corporation (IBM) to be the lead contractor and to integrate all IU systems and assemble and check out all flight IU's; IBM assumes mission responsiblity with the

44. Ibid., July--Sept. 1965, p. 28; and Oct.--Dec. 1965, p. 24.
45. Ibid., Oct.--Dec. 1965, p. 24.

fourth Saturn IB flight vehicle and the first Saturn V vehicle. Negotiations with IBM on Contract NAS8-14000 ended on February 18, 1965. MSFC approved the contract March 10 and forwarded it to NASA Headquarters March 11. NASA gave final approval to the contract on March 31, 1965. Major electronic components for the IU are provided by IBM and Bendix Corporation under contracts separate from the lead contract (which after finalization is called the IU prime contract).

A number of ground test IU's for the Saturn IB/V program were assembled in-house by MSFC, others by IBM at Huntsville, with MSFC initially supplying the components and equipment. A few ground test units were complete when this report period began, and others were under construction. The test program began on completed units early in 1965 and expanded throughout the period.[46]

MSFC was responsible for the design and development leading to the production release of the IU and its components. Although the Center retains overall mission and concept control throughout the life of the program, there was a gradual transition of mission responsibilities from MSFC to IBM as soon as the prime contract took effect on March 31. In general, IBM assumed responsibility for procurement, acceptance checkout, and testing with the fourth Saturn IB and the first Saturn V flight vehicles. IBM personnel participated with MSFC on specific major development areas of the ground test IU programs retained at MSFC.[47]

The current report period was a time of design finalization, structural assembly, and environmental testing. Redesign of the IU structure to permit more stringent tension occurred during the last half of 1964; documentation for this "beefed-up" design was released before the end of 1965. IBM and structural segment vendors had largely incorporated the structural changes by the start of 1965. Some IU project delays occurred

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46. Gen. O'Connor, AIAA Paper 65-302, July 1965; MHM-10, pp. 80-81 and 122-123; and Saturn V Prog. Off., Sat. V QPR, Jan.--Mar. 1965, p. 29.

47. IBM, Saturn Instrument Unit Mission Program Plan, MSFC Document No. I-1-102-5, Apr. 5, 1966, pp. 1, 2-1, and 3-1.

during 1965 because of late component deliveries. In spite of this problem, test programs moved forward nearly on schedule and some aspects of the ground test program were completed. Structural fabrication of the first Saturn V flight IU began toward the end of this report period.[48]

S-IU-500V

Structural fabrication of the vibration test IU for the Saturn V program began on March 29, 1965. Structural assembly began in April and ended June 14, seven weeks late because of late component deliveries and other problems. Component assembly ended August 19. Wyle Laboratories at Huntsville received the unit for test on August 20. Vibration testing began on September 15. Wyle conducted acoustics tests on the unit November 10-13. The X-axis vibration test began December 3 and was completed December 14. The first lateral-axis test was in progress at the end of 1965, and the second and final lateral-axis test was scheduled for Janaury 1966.[49]

S-IU-200S/500S

The Saturn IB/V structural test unit assembled of materials fabricated by General Dynamics Corporation, S-IU-200S/500S, arrived at the MSFC structural test facility March 15, about six weeks late. P&VE Laboratory personnel subsequently completed all Saturn V load condition tests required in the test plan; on August 13 the structure successfully withstood 140 per cent limit loads and thus structurally qualified those units fabricated by General Dynamics. After completion of testing in August, this unit was modified to replace S-IU-200F/500F at KSC and was redesignated S-IU-500F (see details later in this section).[50]

48. 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, p. 239; and Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, pp. 29-31; July-Sept. 1965, pp. 40-43; and Oct.--Dec. 1965, p. 34.

49. Saturn V Prog. Off., Sat. V QPR, Jan.--Mar. 1965, p. 30; July--Sept. 1965, p. 42; and Oct.--Dec. 1965, p. 34.

50. Ibid., Jan.--Mar. 1965, p. 29; July--Sept. 1965, p. 40; and Oct.--Dec. 1965, p. 34.

S-IU-200S/500S-II

This unit is the structural test unit procured from North American Aviation. Assembly of structural segments began at IBM on June 10, 1965. Fabrication ended on September 30; IBM delivered the unit to P&VE Lab for test preparation on October 6. The first series of tests began on December 30, 1965.[51] These tests will qualify IU's fabricated by North American.

S-IU-200D/500D

Assembly of the dynamic test unit for both vehicle programs was completed February 8, 1965. The unit moved on schedule to the Dynamic Test Facility at MSFC on February 8. The Saturn IB total vehicle test ended on May 27. Conversion to the Saturn V configuration followed. Successful Saturn V dynamic testing in Configuration III (a vehicle segment consisting of S-IVB stage, IU, and Payload) occurred between October 15 and November 6, 1965.[52]

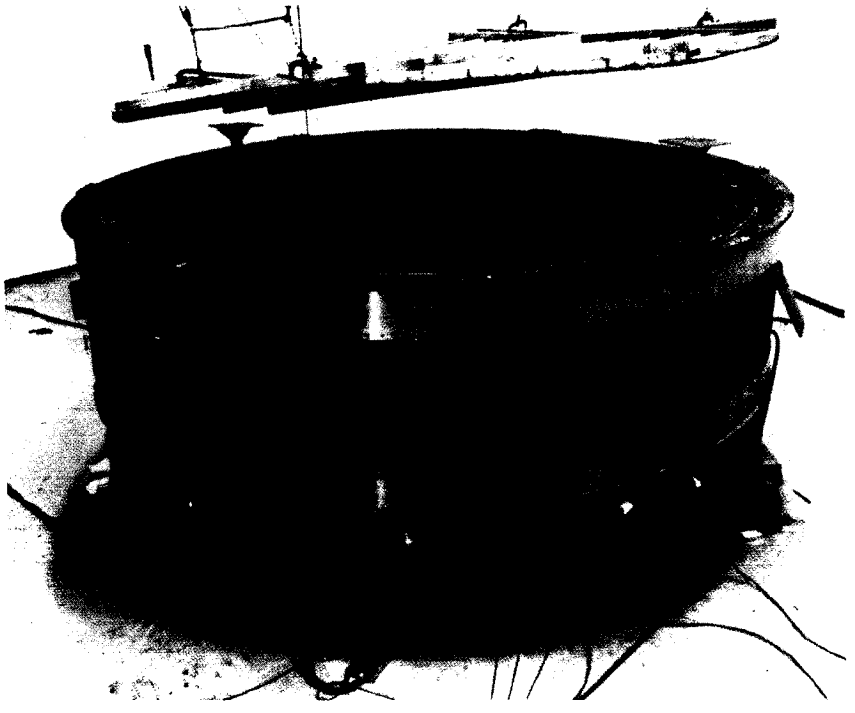
S-IU-500ST

The systems test unit, which will be used in the Systems Development Facility (breadboard) at MSFC, was being modified structurally early in this report period. This modification ended as scheduled on July 2. Component assembly started one week late as scheduled, on July 12. ME Laboratory personnel completed assembly of the S-IU-500ST in the last quarter of the year after delay due to component unavailability and delivered the completed IU to the breadboard facility on December 14, without impact on the program schedule.[53]

S-IU-500FS

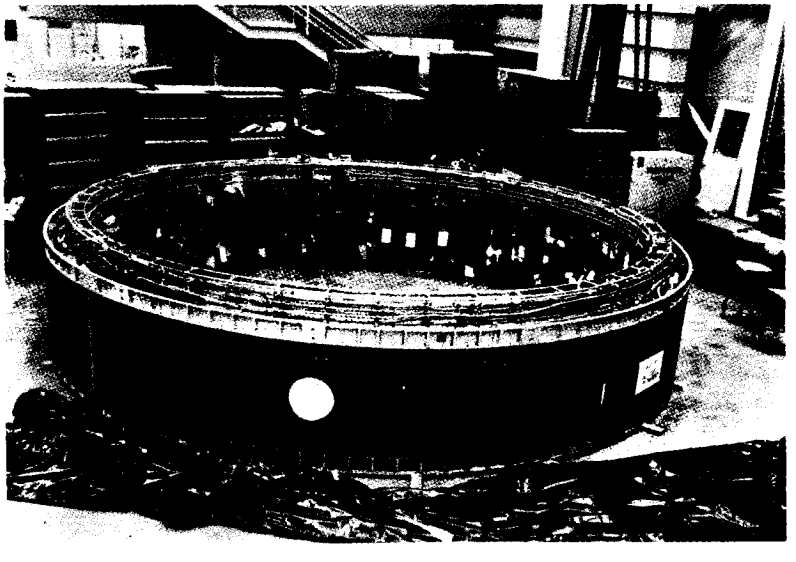
Structural fabrication of the flight systems test unit, S-IU-500FS, ended on March 30, 1965, and mechanical assembly began. Workmen at MSFC

51. Ibid., April--June 1965, p. 31; and Oct.--Dec. 1965, p. 34.
52. Ibid., Jan.--Mar. 1965, p. 30; and April--June 1965, p. 32.
53. Ibid., April--June 1965, p. 33; and Oct.--Dec. 1965, p. 36; and ME Lab. Working Schedule, "Saturn IB and V 260-Inch Instrument Unit Program," Aug. 30, 1965.



INSTRUMENT UNIT TESTED

S-IU-500V is shown in acoustics test setup at Wyle Laboratories, Huntsville.



UNIT DELIVERED

S-IU-500ST, a Saturn V ground Test instrument unit, is delivered to the Saturn V System Development Facility at MSFC.

completed component assembly on June 15. On August 6 application of heat-reflecting paint (necessary for thrust-effect testing of structure and components) was completed, and components were reinstalled. Checkout of the ground equipment test set started September 1 and was completed by September 30. S-IU-500FS moved on December 6, 1965, from ME Laboratory to Quality and Reliability Assurance (Quality) Laboratory. Several tests were completed on the unit by the end of the report period.[54]

S-IU-200F/500F

The facilities checkout IU mechanical assembly began at MSFC on February 8, 1965. Lack of documentation caused a temporary delay in fabrication and assembly during March. Structural modification of the unit ended April 2 and component assembly on April 29. MSFC shipped the completed unit by barge to MAF on June 19. From MAF the unit was reshipped on the barge Promise on August 9. It arrived at KSC August 13 and was unloaded the following day to checkout Saturn IB Launch Complex 34. Late in this period workmen extensively damaged the S-IU-200F/500F during de-erection operations after completion of LC-34 checkout. Program officials decided to ship the damaged unit to MSFC, transfer its internal components to S-IU-200S/500S, and redesignate the latter S-IU-500F.[55]

S-IU-501

The first Saturn V flight IU, S-IU-501, was undergoing fabrication at IBM/Huntsville at the end of 1965, following receipt of structural segments from the vendor, NAA, on November 8. Structural fabrication was scheduled for completion in January 1966.[56]

54. Ibid., April--June 1965, p. 33; and Oct.--Dec. 1965, p. 36.
55. Ibid., Jan.--Mar. 1965, p. 30; April--June 1965, p. 33; July--Sept. 1965, p. 43; and Oct.--Dec. 1965, p. 34.
56. Ibid., Oct.--Dec. 1965, p. 36.

Major Electronic Components

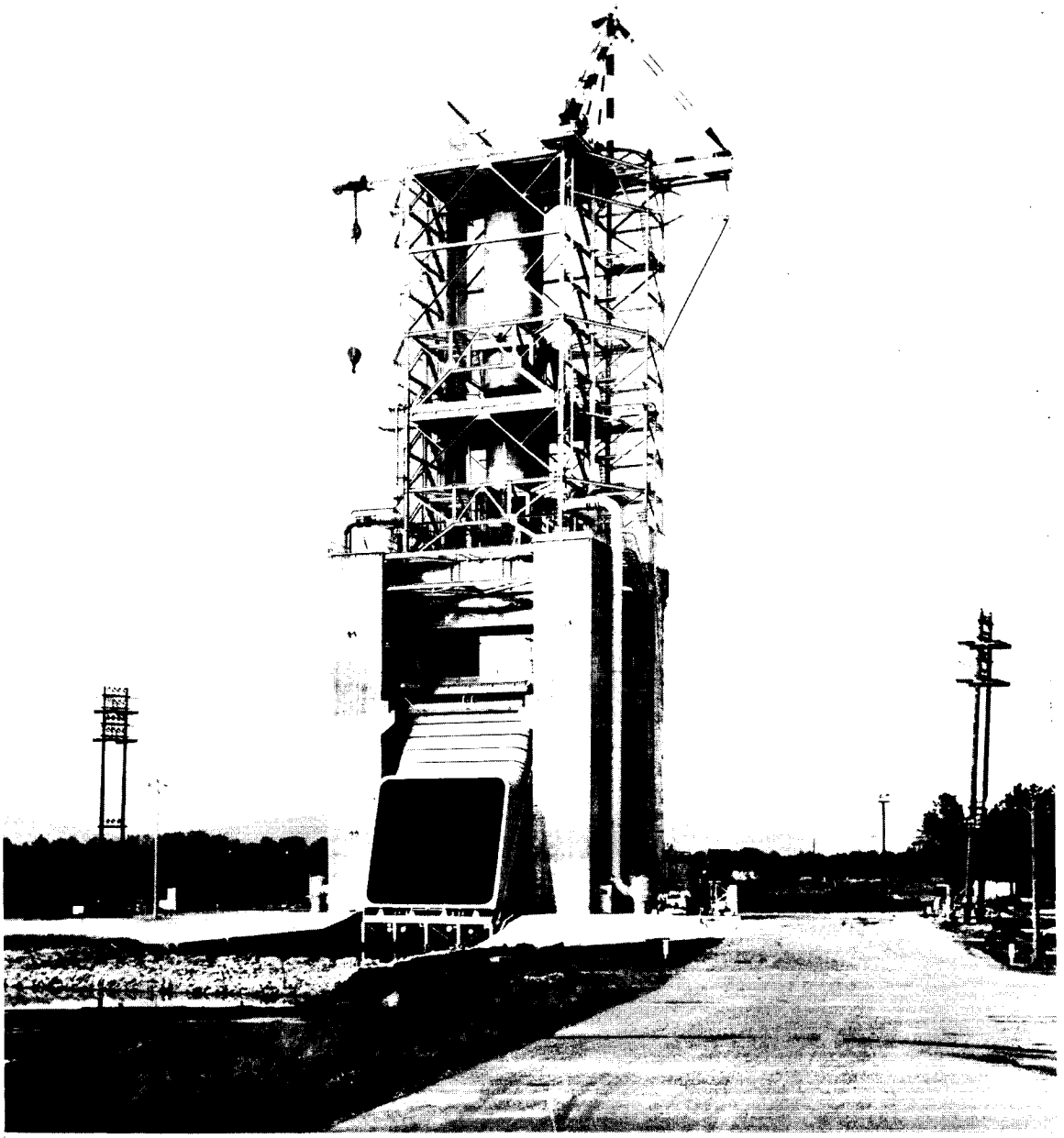
Among the major electronic components for the IU are the ST-124M inertial platform system, provided under contract by Bendix, and the launch vehicle digital computer and launch vehicle data adapter (LVDC/LVDA), supplied by IBM under separate contract.

Bendix delivered to MSFC on March 15, 1965, the first ST-124M platform. During the second quarter of the period Bendix discovered corrosion on silver-plated wiring of the platform; platforms were then rewired with nickel-plated wire not subject to corrosion. Platform unit No. 3, for use in S-IU-500FS, arrived at MSFC on June 30, where it underwent environmental testing. Bendix delivered Unit No. 6 to the Center on August 9. Deliveries continued through the remainder of 1965.[57]

IBM delivered to MSFC on March 11, 1965, the LVDA Breadboard No. 1 and its test equipment; the delivery was four months behind the contract delivery date because of fabrication difficulties. LVDC Prototype No. 2 was received on April 6 and LVDA No. 2 on June 10. By mid-year MSFC had received three LVDC's and three LVDA's plus their checkout stations, and had placed this equipment in operation at MSFC and IBM/Huntsville. During the third quarter of 1965 MSFC and IBM completed the IU designs on the LVDC/LVDA bracket installations. The flight system for the first flight Saturn IB was delivered September 9, 1965, in an incomplete condition. Production of other LVDC/LVDA systems continued to slip behind schedule late in this report period.[58]

57. Ibid., Jan.--Mar. 1965, p. 31; April--June 1965, p. 33; and July--Sept. 1965, p. 43.

58. Ibid., Jan.--Mar. 1965, p. 31; April--June 1965, p. 34; July--Sept. 1965, p. 43; and Oct.--Dec. 1965, p. 36.



ENGINE STAND IS READY

The MSFC F-1 Engine Test Stand is shown in May 1965 almost ready for use in single-engine firings.

ENGINE RESEARCH AND DEVELOPMENT

F-1 Engine

The F-1 engine system provides primary propulsive power for the first (S-IC) stage of the Saturn V launch vehicle. This engine, the largest liquid rocket engine system in the free world, is capable of more than 1.5 million pounds of thrust. The F-1 burns kerosene and liquid oxygen. A cluster of five engines is used on the S-IC stage, producing a total thrust in excess of 7.5 million pounds.

Rocketdyne Division of North American Aviation, Inc., holds the contract for development, test, and production of the F-1. The engine has been under development since 1959. Rocketdyne operates under two major contracts in the F-1 project: Contract NASw-16 covers R&D; contract NAS8-5604 is the production contract, which during this report period called for delivery of 76 engines. Preparation began in the third quarter of 1965 for negotiations leading to conversion of Contract 8-5604 from a cost-plus-fixed-fee to a cost-plus-incentive-fee contract. Actual conversion negotiations between MSFC and Rocketdyne got underway in the last quarter of the year. At the end of 1965 negotiations were in the final stages, with completion expected early in 1966. F-1 engine development and production were on schedule at the end of the report period, and deliveries met all Saturn V requirements.[59]

Development and Testing

Pump and combustion instability problems encountered during the early phase of F-1 engine development had largely been solved by the start

59. L. F. Belew, Mgr., Engine Prog. Off., MSFC, paper, "Apollo Vehicle Propulsion Systems," AIAA Annual Meeting, July 26-29, 1966, Paper 65-303; MHM-10, Vol. I, p. 129; Saturn V Prog. Off., Saturn V QPR, July--Sept. 1965, p. 36; and Oct.--Dec. 1965, p. 29.

of the current report period. The engine had performed satisfactorily through completion of flight rating tests (FRT) in December 1964. Testing was generally routine during 1965, with efforts directed toward meeting qualification requirements; extensive test time accumulated during the year. A limited study was made into uprating the engine, which would require considerable modification; but since there was no requirement at the time for an uprated F-1, no uprating work was planned immediately.[60]

Rocketdyne and NASA personnel conducted more than 500 F-1 engine system tests during 1965. These firings included both developmental and acceptance tests; they occurred at the Rocket Engine Test Site (RETS), Edwards, California, and at MSFC. Engine test time for the year exceeded 56,300 seconds. Development tests and acceptance firings of production engines occurred at RETS; engine evaluation and verification testing at two MSFC stands demonstrated relatively trouble-free operation of the engine system. A large proportion of firings during the year represented full-duration tests.[61]

Engine system testing during 1965 largely involved demonstration of combustion stability and performance of a qualification configuration thrust chamber injector. The selected injector underwent repeated tests satisfactorily. Although many minor problems appeared during the course of intensive testing, no major new troubles were evident. By November 12, 1965, Rocketdyne had completed three of the four phases of test accumulation called for in the contract; the fourth phase of this program was scheduled for completion in February 1966. One R&D engine was retired during the last half of 1965 after accumulating a record 5,322 seconds of operation; qualification life demonstration for the F-1 engine was 2,250 seconds.[62]

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60. Belew, AIAA Paper 65-303.

61. Ibid., and Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, p. 24; April--June 1965, p. 26; July--Sept. 1965, pp. 32 and 34; and Oct.--Dec. 1965, p. 26.

62. Engine Prog. Off., Quarterly Progress Rpt., F-1, H-1, J-2, and RL10 Engines, April, May and June 1965, p. 26; and Semi-Annual Prog. Rpt., July--Dec. 1965, pp. 1 and 2.

Several component development problems occupied engineers. Principal problems included thrust chamber jacket cracking; injector braze separations and hot-gas leaks between tubes; gas generator injector braze cracks and combustion instability; heat exchanger turbine seal leakage; and turbopump manifold failures. Rocketdyne solved most of these component problems prior to the end of the period. Two turbopump explosions occurred during December tests, one apparently because of turbine defects and the other because of metal fatigue in a LOX pump that had run more than twice its ordinary life. By the end of 1965 Rocketdyne had completed qualification testing of 20 of the 48 components to be tested; qualification testing had started on 20 other components.[63]

Production and Delivery

Rocketdyne delivered 23 production F-1 engines during 1965, including six engines the first quarter, four the second quarter, five the third quarter and eight engines the fourth quarter of the year. These deliveries completed engine requirements for all Saturn V flight boosters through the third (S-IC-3).[64]

J-2 Engine

The J-2 is a high-performance rocket engine with multiple restart capability. It uses LH_2 and LOX propellants to develop normal thrust of 200,000 pounds in the vacuum of space. The J-2 is designed to be used singly or in clusters. One J-2 propels the S-IVB stage and payload of the Saturn V; five J-2's provide power for the S-II stage.

Rocketdyne, the contractor for this engine, began its development in 1960. The principal contracts with NASA for the J-2 are NAS8-19, which

63. Engine QPR, April--June 1965, pp. 1-6; and Semi-Annual Prog. Rpt., July--Dec. 1965, pp. 1-11.

64. Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, p. 23; July--Sept. 1965, p. 23; and Oct.--Dec. 1965, p. 30.

covers R&D, and NAS8-5603, the production contract. Prior to the current report period NAS8-5603 called for delivery of 55 engines. NASA announced in November 1965 that the contract would be amended to add 48 production J-2 engines. This contract amendment, when completed in 1966, would convert the fixed-fee contract to an incentive-fee contract, effective July 1, 1965. Also in November NASA asked Rocketdyne to make a proposal to provide 52 additional J-2 engines, for delivery in 1967 and 1968. MSFC and Rocketdyne had completed negotiations for the conversion in May 1965; Rocketdyne signed the amendment and MSFC approved it, but the contract awaited NASA Headquarters approval at the end of 1965. Negotiations also were underway for consolidation of the development and production program into one incentive contract.[65]

Development and Testing

Major development problems of the J-2 program solved prior to this report period included fuel pump stall and gas generator LOX valve regulation. Rocketdyne engineers during 1965 continued intensive testing of complete engine systems as well as individual components in order to improve performance of the engine. They also worked with DAC to solve engine chilldown problems in the S-IVB battleship program.

R&D and production engines underwent more than 700 static firing tests at Rocketdyne's Santa Susana Field Laboratory (SSFL) during 1965. These testsat SSFL's five positions accumulated firing time in excess of 73,000 seconds. Many of these tests were for full duration of 500 seconds or longer. By the end of 1965 the J-2 had operated in 1,764 tests totalling 131,825 seconds. A number of successful engine restart tests were among these firings, signifying the solution of one major engine problem. In July Rocketdyne completed the FRT series for the J-2 engine; this formal test program included 25 tests of the same engine for a total of 2,752 seconds, including performance and safety limit

65. Belew, AIAA Paper 65-303; Engine Prog. Off., Semi-Annual Prog. Rpt., July--Dec. 1965, p. 30; Saturn V Prog. Off., Saturn V QPR, July--Sept. 1965, p. 36; and 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, p. 133.

extremes. Qualification testing of the J-2 engine at the 200,000-pound-thrust (200K) level began on December 2, 1965, and ended successfully on December 17, 1965; this program included 30 tests of the same engine for 3,774 seconds. The qualification test program confirmed the reliability required for manned flight. Post-test assessment revealed only one design deficiency--a bellows seal in the start tank discharge valve. A redesigned seal was scheduled to be evaluated early in 1966.[66]

J-2 component testing during the period concentrated principally on eliminating problems in the fuel and LOX turbopumps and in the gas generator. The new fuel turbine curvic coupling developed in 1964 was successfully tested on 28 sets of turbine wheels for more than 43,000 seconds without failures. A stud-drive coupling developed as a backup operated well in tests and was adopted for the 230K engine that was later to be developed. LOX turbopump turbine wheel analysis following redesign and tests at high speed and temperature revealed significant improvement and greatly reduced the occurrence of "fir tree" cracks previously observed; thicker wheels proved the solution to this problem. A new gas generator configuration incorporating a modified choke ring appeared to eliminate the combustor body burn-through problem experienced in 1964. Component qualification program planning progressed well; by December 31 there were 21 components undergoing test, and five tests had been completed.[67]

As part of the various studies on ways to increase the payload capability of Saturn vehicles, MSFC and Rocketdyne investigated J-2 engine uprating. These studies, completed early in 1965, showed that the engine could be uprated sufficiently to obtain appreciable payload gains. Accordingly, in July 1965 Rocketdyne initiated a 230K engine development program. Two new engines of the 230K configuration and two rebuilt engines underwent testing during the last six months of 1965. Comparison tests were

66. Engine Prog. Off., Engine QPR, Jan.--Mar. 1965, p. 17; April--June 1965, p. 15; and Semi-Annual Prog. Rpt., July--Dec. 1965, p. 21.

67. Engine Prog. Off., Engine QPR, Jan.--Mar. 1965, pp. 18-19; Apr.--June 1965, pp. 19-20; and Semi-Annual Prog. Rpt., July-Dec. 1965 p. 24.

made at sea level and simulated altitude. The first 230K engine accumulated 5,104 seconds of operation in 55 sea level and simulated altitude tests.[68]

In an experimental (J-2X) program during the latter part of this report period, the objectives were to design, fabricate, and test a tapoff engine system using as many standard J-2 components as possible. The J-2X program aimed at increasing the engine's reliability and flexibility through design improvements. Rocketdyne demonstrated satisfactory starting characteristics and mainstage engine performance in 51 tests during this period. Innovations included starts without precooling the thrust chamber, operation at low thrust levels on tank head pressure only, and starting with a solid propellant gas generator rather than a start tank.[69]

Production and Delivery

Rocketdyne delivered 41 production J-2 engines during 1965 in support of the Saturn ground and flight test programs. These deliveries included seven engines in the first quarter of the year, 11 each in the second and third quarters, and 12 in the last quarter. A total of 49 engines had been delivered at the end of the period. The engine contractor maintained deliveries two to three weeks ahead of schedule during the last half of 1965.[70]

C-1 Engine

NASA initiated the C-1 engine project on August 8, 1964. The mission objective of this project is to provide a 100-pound-thrust engine

68. Belew, AIAA Paper 65-303, pp. 12-13; and Engine Prog. Off., Semi-Annual Prog. Rpt., July--Dec. 1965, pp. 21-23.

69. Engine Prog. Off., Semi-Annual Prog. Rpt., July--Dec. 1965, pp. 24 and 28.

70. Engine Prog. Off., Engine QPR Jan.--Mar. 1965, p. 19; April--June 1965, p. 22; and July--Dec. 1965, p. 28.

capable of meeting the collective requirements of the following applications: reentry control for the Apollo command module; ullage settling for the Saturn V/S-IVB stage; reaction control for the Saturn V and Saturn IB S-IVB stage, the Apollo service module, and the Apollo lunar excursion module; and extended mission requirements of reaction control systems on Apollo Applications Program flights. The C-1 project consists of three phases: Phase I is definition; Phase II, development; and Phase III, production.[71]

MSFC began Phase I on March 5, 1965, by placing competitive six-month definition and design demonstration contracts with two firms, TRW Systems Group and Reaction Motors Division of Thiokol Chemical Corporation. Both contractors completed design studies ending Phase I by September 5, 1965, and demonstrated firings supporting their concepts. Negotiations for Phase II (development) began September 6 and ended September 17, 1965. An evaluation board then convened; the board presented its findings to the NASA Administrator on October 12, 1965. On October 18 the Administrator announced selection of RMD and authorized the firm to proceed with development of the C-1 engine. In the two-and-a-half months remaining in this report period after contract award, RMD concentrated on basic design, selection of vendors, initiation of procurement actions, and setup of manufacturing and test facilities. RMD's principal plant is at Denville, New Jersey. The company released designs on the prototype engine and components. Prior to the end of 1965 RMD initiated testing on the engine injector and two types of valves. The major test effort was on the injector in an effort to select the optimum design.[72]

VEHICLE GROUND SUPPORT EQUIPMENT

Launch vehicle ground support equipment (GSE) includes the hardware used to check out assembled vehicles, to handle, transport, and service

71. MSFC, Launch Vehicle Project Engines Development Plan, July 1, 1965, pp. 1-3 and 2-27.
72. Engine Prog. Off., Semi-Annual Prog. Rpt., July--Dec. 1965, p. 34.

the stages and instrument unit, and to launch the vehicle. Only the most significant items of GSE are covered in this report.

Under supplements to the S-IC prime contract NASA selected Boeing to operate the Saturn V systems development facility (breadboard), integrate the mechanical support equipment (MSE), and supply certain major portions of the hardware. General Electric Company (GE) was selected to design and provide electrical support equipment (ESE) under a supplement to the Apollo support contract (NASw-410). Negotiations with Boeing and GE on these contract supplements were nearing completion when the current report period began.[73]

MSFC established, effective February 1, 1965, an interim Configuration Control Board. This board's purpose was to process engineering changes to Saturn V GSE contracts managed by the Center's Industrial Operations.

Negotiations between Boeing and MSFC on the GSE mission contract ended early in 1965. This mission contract included management of the vehicle GSE program and the provision of MSE. MSFC forwarded the vehicle GSE support (management) amendment to NASA Headquarters on February 4, where it received approval on March 11. The MSE amendment went to Washington on March 11 and received Headquarters approval on March 30, 1965.

The design phase of the GE contract supplement received GE approval on March 22. This $40 million modification covered only the design of ESE for Saturn V and Saturn IB launches. The contract supplement providing for fabrication, assembly, and checkout of this ESE at MSFC continued under negotiation.[74]

In April 1965 NASA modified the Boeing contract to provide engineering services and instrumentation for the Saturn V dynamic test program. This contract change was valued at $3.1 million.[75]

Early in July Brown Engineering Company received a $3.6 million contract covering nine discrete control equipment systems to be used between

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73. MHM-10, pp. 123-124.

74. Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, p. 35; and NASA, Astronautics and Aeronautics, 1965 (SP-4006), p. 235.

75. NASA, SP-4006, p. 191.

the launch vehicle and the GSE of the launch complex. Two of these discrete control equipment systems were for use in the Saturn V breadboard, located at MSFC; six systems were for use at KSC's Launch Complex 39 (LC-39).[76] The ninth system was allocated to Astrionics Laboratory for computer facility research.

NASA modified the Boeing contract again in September 1965 to provide services in connection with systems engineering and integration of mechanical GSE. By terms of this $4.5 million modification Boeing would assist the P&VE Laboratory in such tasks as GSE analysis, qualification and acceptance testing, and design verification.[77]

RCA 110A Computer

The RCA 110A computer system is used to check out, test, and launch the Saturn V. NASA signed a contract with Radio Corporation of America (RCA) in August 1964 covering 19 of these ground computer systems plus related services and support for both Saturn V and Saturn IB. Later, because of a change in program requirements, NASA cancelled orders for two of these systems.

The 110A system for the S-IU-500FS checkout was installed early in 1965 at MSFC's Quality Laboratory. Officials accepted the installation on April 6.

Installation of the 110A acoustical test unit occurred at Wyle Laboratories, Huntsville, in February following its delivery on February 5. Acoustical testing began March 4 and was complete by the end of March. Vibration and other acoustical tests continued at Wyle's facility until completion on June 14, 1965. The computer moved to Astrionics Laboratory the week of June 21 for installation there.[78]

RCA 110A units No. 1 and No. 2 were designated to support the breadboard facility at MSFC. Unit No. 1, designated SDBF/LCC (Launch Control

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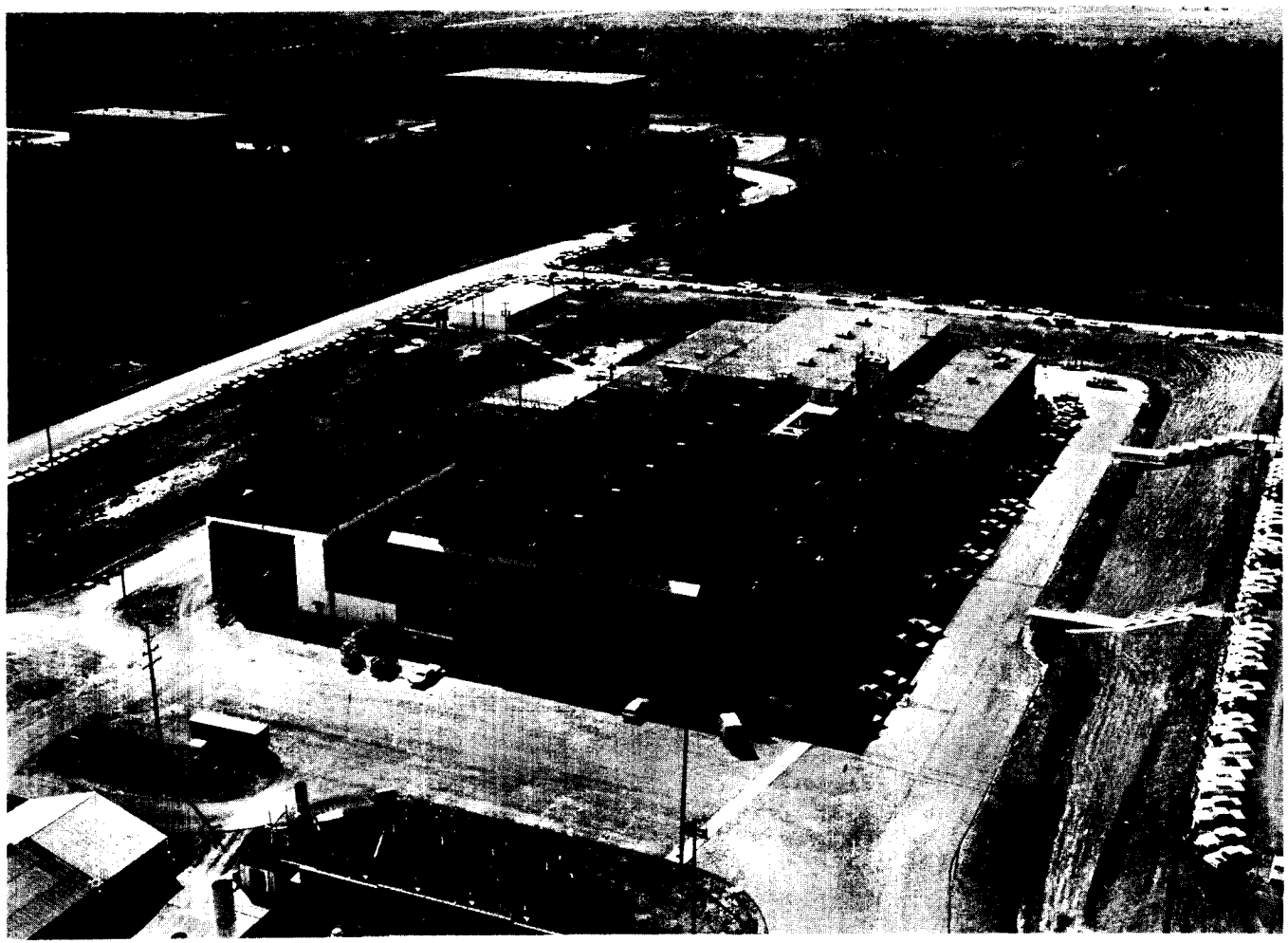
76. Ibid., p. 319.
77. Ibid., p. 447.
78. Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, p. 34; and April--June 1965, p. 37; Saturn V Prog. Off., "Saturn V Weekly Rpt. No. 6," Feb. 15, 1965; and interview Sept. 29, 1967, with L. H. Summer, Saturn V Program Office, MSFC.



QUALITY LABORATORY

The structure in foreground is Building 4708 where Saturn boosters are checked out following assembly. At upper left is another Quality Lab building, used for receipt and inspection of components and subassemblies from contractors. At upper right is a Manufacturing Engineering Laboratory building.

Center) arrived at MSFC in June for installation in the breadboard facility by RCA personnel. It was operational by July 23. Unit No. 2, designated SDBF/ML (Mobile Launcher) arrived at the Center on July 21. Installation was complete by July 29 and finally approved on August 17.

The RCA 110A for use in the Saturn V IU checkout station in Huntsville was delivered to IBM on August 24 and accepted on September 10, 1965.[79]

RCA delivered to KSC in November and December 1965 two 110A units. The unit for LCC Firing Room 1 arrived at KSC on November 7. Delivered on December 15 was the unit for Mobile Launcher 1.

Late in 1965 NASA authorized a second RCA 110A computer system for installation in Astrionics Laboratory. Delivery of this unit was forecast for February 1966.

Meanwhile, on September 2 MSFC and RCA completed the negotiations for the RCA 110A logistics and maintenance effort (Contract NAS8-15496). At the end of the year MSFC had submitted the contract to NASA Headquarters for approval. Its final approval was expected in January 1966.[80]

Breadboard Facility

The Saturn V SDBF is a prototype set of checkout equipment for the first facility checkout of LC-39 at KSC. It is located at MSFC and scheduled to be operated by Boeing.

Installation and checkout of equipment and instrumentation in the breadboard facility, located in Building 4708, proceeded throughout 1965 following initiation in 1964. Late deliveries of ESE hindered completion of the breadboard. By late 1965 activation of the facility was progressing on an expedited basis. The start of the ground support test set subsystem checks of ESE is required by February 1, 1966. SBDF activities

79. Ibid., April--June 1965, pp. 37-38; and July--Sept. 1965, p. 48.
80. Ibid., July--Sept. 1965, p. 48; and Oct.--Dec. 1965, p. 39.

completed late in 1965 included delivery of the S-IU-500ST, installation of the LCC discrete control system, delivery of all telemetry checkout station equipment, and partial delivery of two display system consoles and associated electronics. Operation of the breadboard facility was scheduled to begin in March 1966.[81]

Operational Display Systems

Sanders Associates, Inc., was the winner in December 1964 of a $7.2 million contract to provide MSFC with seven Saturn V operational display systems. These systems will be used with computers for vehicle checkout and launch.

MSFC held the first display system design review at the Sanders plant in February 1965. By the middle of 1965 Sanders estimated that delivery of the first system would slip three months, but no program impact was anticipated. Additional delivery delays occurred in the third quarter, forcing MSFC to substitute a Saturn I display system for use in the S-IU-500FS program. The contractor delivered a two-display console system in December 1965, but MSFC diverted the system from the breadboard to Astrionics in order to expedite programming effort there. Another two-console system was installed in the Saturn V breadboard facility in February 1966.[82]

Service Arm/Umbilical Test Program

Nine service arms are required on the Mobile Launcher to provide ground services for the Saturn V vehicle prior to launch. These arms

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81. Ibid., July--Sept. 1965, p. 48; and Oct.--Dec. 1965, pp. 39-41.

82. Ibid., Jan.--Mar. 1965, p. 35; April--June 1965, p. 47; July--Sept. 1965, p. 47; and Oct.--Dec. 1965, p. 41; and interview Sept. 29, 1967, with L. H. Summer, Saturn V Program Office, MSFC.

bridge the space between the Mobile Launcher tower and the Apollo-Saturn vehicle. They provide access for personnel and for propellant servicing, and also convey the electrical, pneumatic, air-conditioning, and hydraulic umbilicals to the vehicle stages, instrument unit, and spacecraft. MSFC's Test Laboratory receives delivery of the service arms and umbilical equipment from the manufacturers and subjects these devices to a program of testing before accepting them for use at KSC.

Failure of the service arm contractor to deliver these items on schedule delayed the test program during this report period. Consequently, several service arms for upper portions of SA-500F (facilities checkout vehicle) were shipped directly and unqualified from the manufacturer to the launch site at KSC. Other service arms, principally those for the first two stages of SA-500F, plus all umbilicals for the vehicle, were under test at MSFC when this period ended; they were scheduled to be shipped to KSC by March 1, 1966.[83]

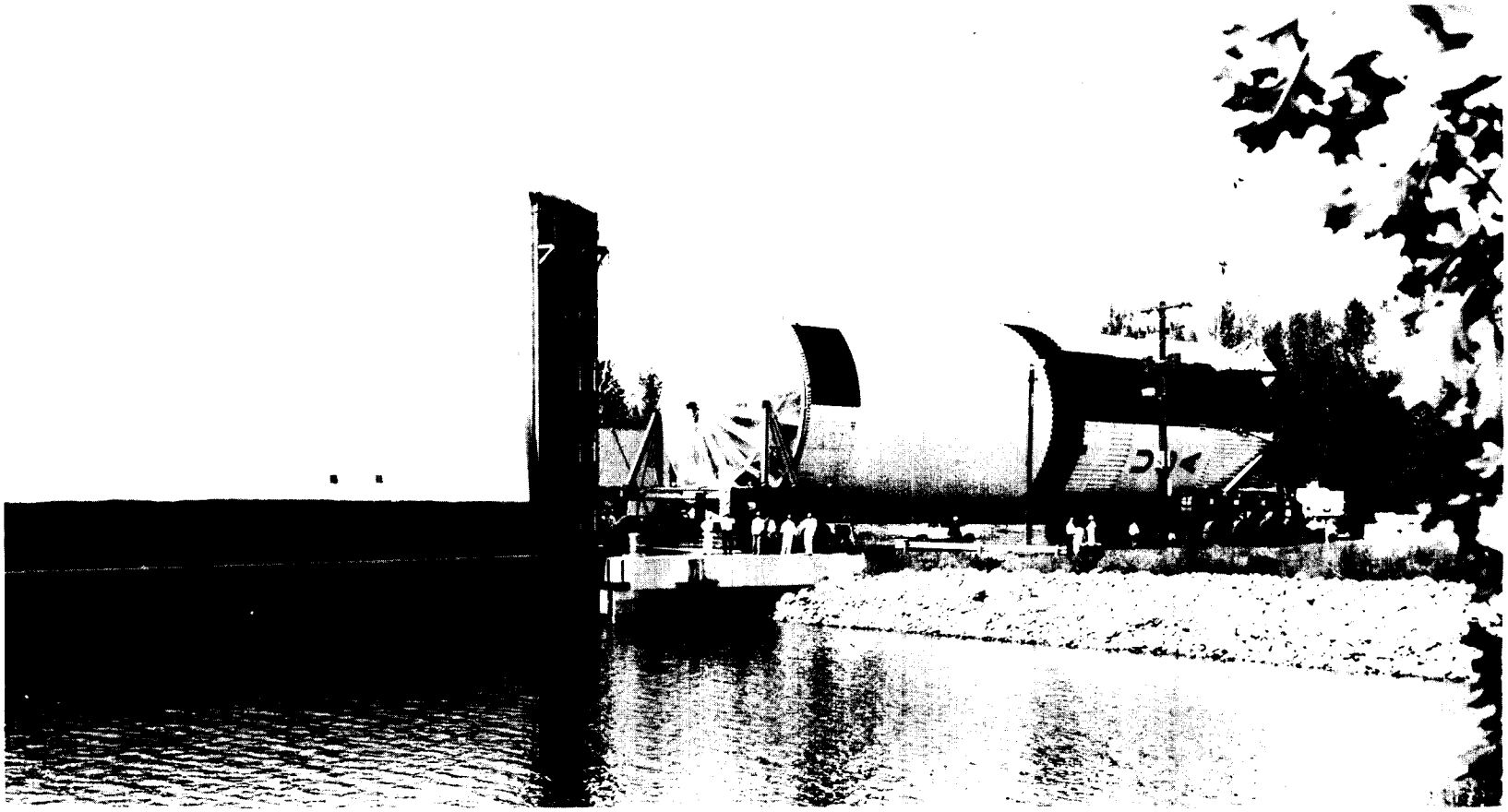
The Test Laboratory also conducted tests at MSFC on a variety of additional vehicle GSE in support of KSC and MTF. GSE items tested during 1965 included the S-IC ground supply hydraulic and checkout units, holddown arms, S-IVB forward lanyard prototype service arm tip assembly, LOX and LH_2 system disconnects, and various valves, regulators, and couplers.[84]

Transportation GSE

Equipment and devices for land, water, and air movement of Saturn V hardware are included in the transportation GSE category.

On January 29, 1965, MSFC awarded to Dortech, Inc., a $1.3 million contract to build three of the seven S-IC stage transporters required in

83. Ibid., July--Sept. 1965, p. 48; and Oct.--Dec. 1965, p. 41.
84. Test Lab., MPR, Aug. 12--Sept. 12, 1965, pp. 14-18.



DYNAMIC BOOSTER DELIVERED

The Saturn V dynamic booster, first stage built by Boeing at MAF, rolls out of the cargo hangar of the new NASA barge Poseidon at the MSFC Saturn dock. The delivery occurred October 14, 1965.

the program. Three transporters had previously been assembled or contracted. The Dortech contract covered Transporters 104, 105, and 106, the fourth through sixth to be built. Transporter 103, fabricated by Fruehauf Trailer Company, Inc., was completely assembled at MSFC on March 23, 1965; checking and alignment ended April 7, and MSFC shipped this transporter to MAF for road tests and checkout, with the S-IC simulator aboard. Early in April MSFC issued the request for quotation for the seventh and final S-IC transporter. On April 21 MSFC amended Dortech's contract to include a fourth transporter, No. 107, completing purchase requirements. Dortech delivered Transporter 104 to MAF on October 14; MAF accepted the transporter October 17 and put it into service to support S-IC-F. Transporter 105 arrived at MAF November 1 and completed test on November 4. Transporter 106 was delivered to MAF November 22 and accepted December 2, 1965. Transporter 107 was due for delivery early in January 1966.[85]

Hayes International Corporation completed in February 1965 the fabrication of the Instrument Unit shipping container. After tests, MSFC revised the container. Road tests on April 6 confirmed the container's stability.[86]

MSFC began in May to revise the Saturn Stage Transportation Plan. This formal plan was completed and disseminated on September 1, 1965.[87]

The Center continued during 1965 to expand and modify its fleet of Saturn water transport vessels. The major vessel in the fleet was the Navy surplus YFNB 40, designated for transporting the S-IC stage from assembly to test and launch sites. On February 1, 1965, MSFC awarded to Avondale Shipyard Corporation a $770,000 contract for conversion of the 260-foot barge. Avondale completed work on the craft early in the fall of 1965. NASA named the vessel Poseidon. Poseidon

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85. Ibid., Jan. 12--Feb. 12, 1965, p. 38; Mar. 12--Apr. 12, 1965, p. 37; Apr. 12--May 12, 1965, p. 39; Oct. 12--Nov. 12, 1965, p. 24; and Nov. 12--Dec. 12, 1965, p. 24.

86. Ibid., Jan 12--Feb. 12, 1965, p. 39; and Mar. 12--Apr. 12, 1965, pp. 37-38.

87. Ibid., Apr. 12--May 12, 1965, p. 40; and Aug. 12--Sept. 12, 1965, p. 28.

made its first trip from MAF to MSFC October 6-13, 1965, carrying the S-IC-D stage, the first Saturn V booster manufactured at MAF by Boeing.[88]

MSFC received bids on February 5 covering modification of three Navy YFNB barges into open-deck shuttle barges (two for use at MTF/MAF and one for KSC). Avondale Shipyard Corporation received this contract. YFNB 45, renamed Pearl River, was completed on May 1 and delivered to MAF May 3. YFNB 44, the shuttle barge for KSC, was completed May 8 and delivered May 15. YFNB 38, renamed Little Lake, was delivered by Avondale July 31 and assigned to MTF/MAF.[89]

The newly converted Navy AKD Point Barrow, a self-propelled sea-going ship operated by the Military Sea Transport Service, was officially made available to NASA June 1, 1965, after inspection and approval by MSFC Test Laboratory personnel. Point Barrow was placed into service June 13, when it departed Seal Beach carrying the S-II simulator and the S-IVB-F to MAF and KSC.[90]

NASA's West Coast barge Orion underwent sea trials and practice loading operations in January 1965 following its conversion from a Navy YFNB. The Orion was scheduled to transport S-II and S-IVB stages between points along the California coast. Test Laboratory coordinated loading and tiedown of the first S-IVB stage to use Orion. The barge departed Seal Beach for Sacramento on February 12, 1965, on its first mission as a member of the Saturn fleet.[91]

The Clermont, first gas turbine-powered tugboat ever built, was delivered to MTF in October 1965 upon completion of construction by a

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88. Ibid., Jan. 12--Feb. 12, 1965, p. 39; Public Affairs Office, Press Release 65-23, Feb. 2, 1965; and The Huntsville Times, Oct. 14, 1965.

89. Test Lab, Test MPR, Jan. 12--Feb. 12, 1965, p. 40; Feb. 12--Mar. 12, 1965, p. 40; and Apr. 12--May 12, 1965, p. 40; and Test Lab, Hist. Rpt. Jan.--Dec. 1965, p. 28.

90. Test Lab, Test MPR, May 12--June 12, 1965, p. 46; and June 12--July 12, 1965, p. 31.

91. Ibid., Jan. 12--Feb. 12, 1965, p. 39; and Feb. 12--Mar. 12, 1965, p. 41.

shipbuilding firm at Slidell, Louisiana. The 69-foot boat was designed by MSFC for use in the MTF canal system and as an auxiliary fireboat.[92]

Two barge-mounted cyrogenic tanks, the first of nine to be modified from surplus Army barges, arrived at MTF early in July 1965 for acceptance tests. The 135-foot vessels will be used to transport LH_2 in support of Saturn V test firings and launches. Each tank has a capacity of 250,000 gallons.[93]

MSFC began in 1963 to transport certain items of Saturn hardware by means of a modified Boeing Stratocruiser aircraft known as Pregnant Guppy, owned by Aero Spacelines, Inc. The S-IV stage, F-1 engine, Pegasus satellites, and Apollo spacecraft modules were among major items transportable by Pregnant Guppy. MSFC renewed the Pregnant Guppy contract annually. In May 1965 the Center extended this contract, valued at $1.6 million for the year, to June 30, 1966.[94]

At the start of this report period MSFC was evaluating a proposal by Aero Spacelines to provide a "Very Pregnant Guppy" aircraft, an enlarged version of the Pregnant Guppy capable of transporting hardware as large as the S-IVB stage. In January 1965--failing a reply from MSFC on whether to proceed with development of such an aircraft--Aero Spacelines informed the Center that it would continue the project on its own. Test Laboratory sought through contacts with the Air Force and Boeing to determine the feasibility and operational characteristics of an enlarged Guppy. In March 1965 Test Laboratory personnel were assigned to monitor the Very Pregnant Guppy development program. In May these personnel observed a wind tunnel model test of the proposed plane; this test showed that such a plane was feasible and would fly. Meetings in May and June 1965 led to agreements for flight-testing and evaluation of the big aircraft. Upon completion of modifications to the basic plane, the

92. PAO, Press Release 65-264, Oct. 20, 1965.
93. MTF, Hist. Rpt. Jan. 1--Dec. 31, 1965, p. 56.
94. NASA, SP-4006, p. 234.

WEST TEST AREA

This aerial photograph made in October 1965 shows a wide view of the West Test Area. Principal structures include the S-IC Test Stand, F-1 Engine Test Stand, Dynamic Test Stand, Blockhouse, and High-Pressure Water Facility.

Federal Aviation Agency (FAA) required a ground vibration survey of the craft; this survey was conducted by DAC, the S-IVB stage contractor, and coordinated technically by Test Laboratory. Concurrently, an MSFC study established the feasibility of shipping IU flight units on the new plane. On August 31, 1965, the new aircraft--now named "Super Guppy"--performed its maiden flight test. In September Test Laboratory sent a representative to Mojave, California, to observe and coordinate the Super Guppy's flight test program. A test accident on September 25, 1965, damaged the nose section. With repairs completed, test personnel resumed flight tests in November 1965. Late in December MSFC awarded to Aero Spacelines a one-year $1.6 million contract covering services of this aircraft, defined by its owners as the world's largest. The contract also provided for an extension of Pregnant Guppy services.[95]

Other air transportation activities in 1965 included a survey by Test Laboratory of large helicopters to determine the feasibility of moving IU's by this method; the modification by DAC of three S-IVB stage transporters to make them compatible with the Super Guppy aircraft; and modification of five cargo-lift trailers to allow mating of rail facilities with the Super Guppy.[96]

FACILITIES

Primary facilities for Saturn V development, production, checkout, and test were largely in operation or under construction prior to 1965.

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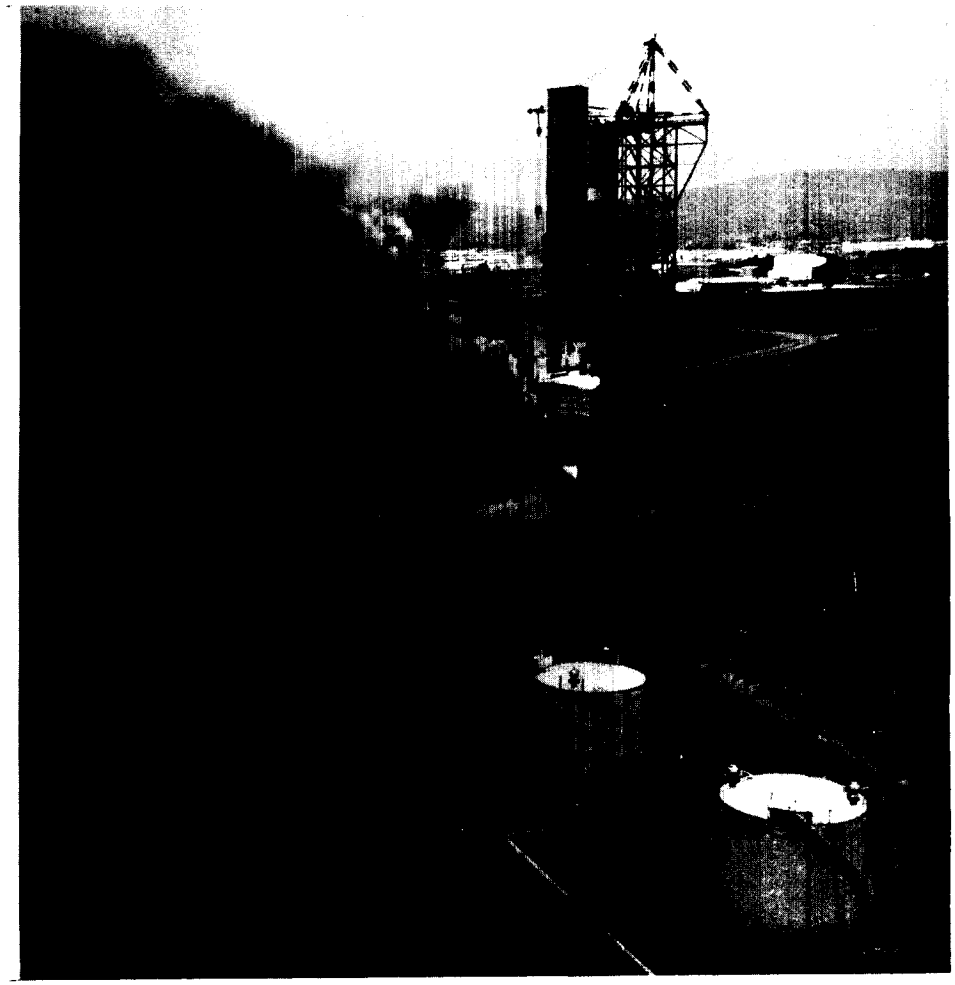
95. Test Lab., Test MPR, Apr. 12--May 12, 1965, p. 41; May 12--June 12, 1965, pp. 46-47; Aug. 12--Sept. 12, 1965, p. 29; Sept. 12--Oct. 12, 1965, p. 27; NASA, SP-4006, p. 562; and Test Lab., Hist. Rpt., Jan.--Dec. 1965, pp. 29-30.

96. Test Lab., Test MPR, May 12--June 12, 1965, p. 46; and July 12--Aug. 12, 1965, p. 28.



MSFC FACILITY ACTIVATED

An F-1 engine fires for 84 seconds in July 1965 at MSFC's new single engine test stand.

Some major brick-and-mortar work was still in progress during this report period, and a great deal of equipment installation and activation work occurred.

Facilities involved included government installations as well as government-furnished resources at the industrial plants of prime contractors across the United States. Most of the production and considerable testing occurred at contractor plants, but some manufacturing and most of the testing was accomplished by contractors at government-owned facilities. The most significant NASA Saturn V facilities under cognizance of MSFC during 1965 were at the Center at Huntsville and at Mississippi Test Facility (MTF) and Michoud Assembly Facility (MAF). Major facilities at contractor plants were at the Boeing Company, North American Aviation (Space and Information Systems and Rocketdyne Divisions), Douglas Aircraft Company, and International Business Machines Corporation. Launch facilities, which are the responsibility of Kennedy Space Center, are only briefly covered in this report.

MSFC

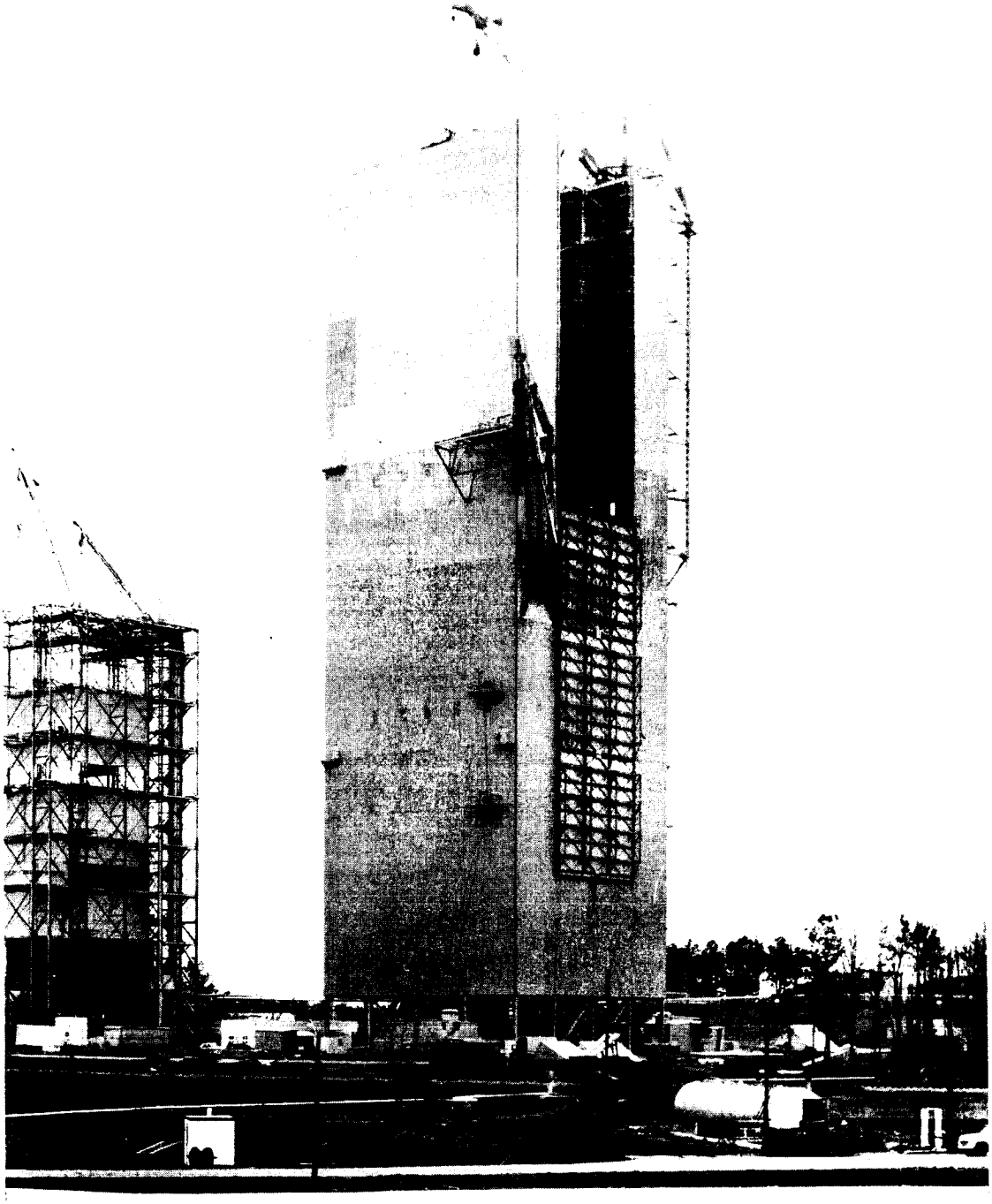
Most MSFC Saturn V facilities are located in the Test Area.

Workmen on the S-IC Static Test Stand were winding up construction and performing activation tasks when this period began. With work substantially complete, the S-IC-T all-systems test stage went into the stand on March 1, 1965, to be readied for firing tests. The stand became operational on April 9 with the first firing of S-IC-T.

Technical systems installation on the F-1 Engine Test Stand proceeded early in this period. By the end of June 1965 the stand was ready to receive its first engine for test. The stand became operational with its first engine test on July 8, 1965.[97]

The Saturn V Dynamic Test Stand, largest structure at MSFC, was structurally complete at the beginning of 1965 except for minor tasks and

97. Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, p. 39; and April--June 1965, p. 42.



DYNAMIC STAND WAITS

The tallest structure at MSFC, the Saturn V Dynamic Test Facility, is shown late in 1965 as it awaits erection within its walls of the Saturn V dynamic test vehicle. The facility is over 400 feet high.

INSIDE DYNAMIC STAND

Work platforms in the Saturn V Dynamic Test Stand, completed in 1965 at MSFC, indicate the size of the vehicle that will occupy the facility early in 1966.

rework of the 150-ton and 200-ton derricks. Derrick acceptance was completed May 24. On June 3 a contract was awarded for modifications and additions required for the dynamic test program. Additional modifications and equipment hoists started during November were scheduled for completion in April 1966. An inspection on November 23, 1965, cleared the way for the start of preparations for installation of the dynamic test stage, S-IC-D, scheduled for January 1966. Technical systems installation which began June 18, 1965, was still in progress at the end of 1965.

J-2/S-IVB Test Facility--The brick-and-mortar portion of this construction project ended in mid-February 1965. Technical systems installation, which was two-thirds complete at the beginning of this report period, ended in June. This facility included LOX storage and expansion of the blockhouse. Activation of the test stand was complete on August 2, 1965, when operations began with the first firing of the MSFC S-IVB battleship.[98]

Components Test Facility--MSFC took beneficial occupancy of this facility in June 1965 after the contractor finished major construction work. Technical systems installation proceeded to completion and checkout on August 25. Construction of an addition to the Components Test Facility, scheduled for completion July 25, 1965, slipped because some material was diverted to MTF; the basic construction was 98 per cent complete by the end of 1965. Technical systems installation for this addition started in July 1965 and was 95 per cent complete at the end of this period.[99]

Saturn V GSE Test Facility--Almost complete structurally at the start of 1965, this facility was finished in May 1965. Technical systems also were complete. Installation of the vehicle motion simulator slipped because of late delivery; completion of this portion of the project came in December 1965. Construction of an addition to the GSE Test Facility proceeded throughout the period; work was nearly enough complete in November 1965 to permit the start of additional technical systems installation.[100]

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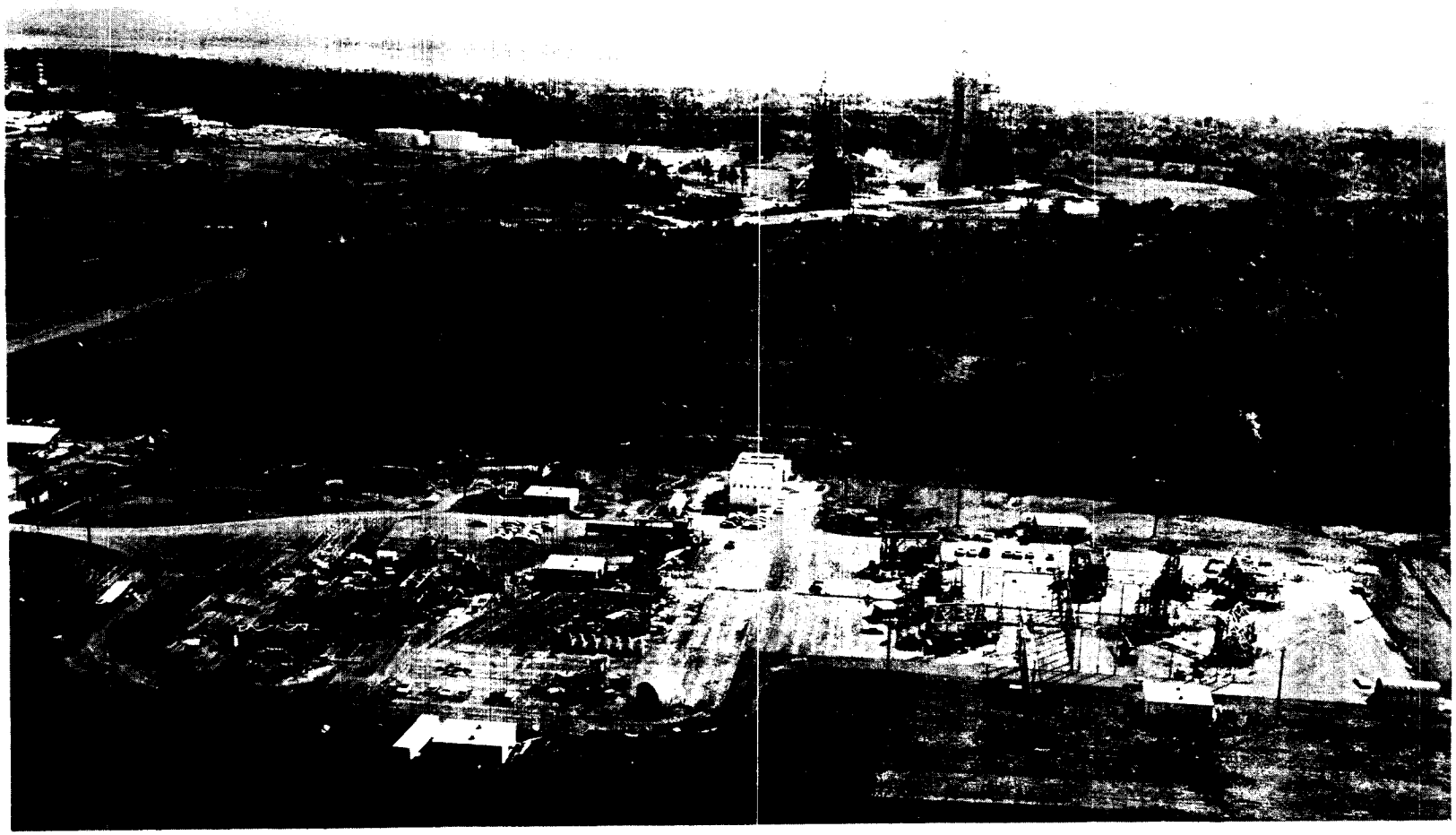
98. Test Lab., Hist. Rpt., Jan.--Dec. 1965, pp. 32-33; and Addendum, pp. 1-2.

99. Saturn V Prog. Off., Saturn V QPR, April--June 1965, p. 43; and Test Lab., Hist. Rpt., Jan.--Dec. 1965, pp. 33-34.

100. Test Lab., Hist. Rpt., Jan.--Dec. 1965, pp. 31-34.



SATURN V GSE TEST FACILITY

The Ground Support Equipment test facility for Saturn V is shown in this aerial photo (foreground). Swing arms and other GSE are tested here.

PAYLOAD ADAPTER DELIVERED

A helicopter dangling the Apollo spacecraft adapter arrives at the MSFC Saturn V Dynamic Test Stand. Brought from Tulsa, Oklahoma, in January 1965, the adapter will be part of the Saturn V dynamic test vehicle.

Acoustic Model Test Facility--The contractor completed basic construction in July 1965. Technical systems installation was complete in December.[101]

Saturn V Road--The portion of this super road connecting MSFC shop areas with the Dynamic Test Facility was completed March 15, 1965. The entire road from manufacturing and checkout areas to the Barge Dock and Loading Facility on the Tennessee River was operational by June 30, 1965.[102]

Expansion and Modernization of High-Pressure Gas Systems--This project, which began in October 1964, was 83 per cent complete at the end of 1965.

Addition to Test Support Shop--Construction on this project ended in December 1965.[103]

Saturn Support Test Area--This area includes several facilities. The Transportation Hangar and Addition to Building S-4653 was scheduled for completion early in 1966. The Acoustic Control Communication Center was substantially complete at the end of the period. The High-Pressure Gas and Propellants System was 28 per cent complete. Replacement of the deflector pit at the Power Plant Test Stand ended on November 1, 1965. And fabrication of the helium cryogenic type purifier was in progress with delivery expected in April 1966.[104]

Several major facilities projects in areas other than Test Laboratory underwent changes in the report period.

ME Laboratory's Building 4755, designed as the Hangar for Vehicle Components, became available for beneficial occupancy late in October 1965. ME Lab moved into the big building and utilized it as a multi-purpose technology facility and assembly area. Also during the last quarter of 1965 ME personnel moved the machine shop from Building 4711 to Building 4705 and planned to relocate the sheet metal and welding shops to 4705

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101. Ibid., p. 34.
102. Sat. V Prog. Off., Sat. V QPR, April--July 1965, p. 43.
103. Test Lab., Hist. Rpt., Jan.--Dec. 1965, p. 34.
104. Saturn V Prog. Off., Sat. V QPR, Dec.--Oct. 1965, pp. 46-47.

(formerly a Saturn assembly building). Design was underway for conversion of Building 4711 into space for developing manufacturing techniques.[105]

P&VE Laboratory began using the new Load Test Annex in March 1965. A $2 million extension to the Load Test Annex was 78 per cent complete at the end of 1965. The Center awarded a $726,000 contract in October for new P&VE facilities. These included three additions to the Materials Laboratory: a two-story engineering physics laboratory addition, a one-story welding and chemical metallurgy laboratory, and a one-story chemistry laboratory. Awarded late in the year was a $358,808 contract for a Non-Destructive Testing Facility for use by the Materials Laboratory. An extension to Building 4610, the P&VE office building, was 77 per cent complete when this period ended.[106]

Michoud Assembly Facility

Major Saturn V facilities under construction at MAF during 1965 included the High-Pressure Test Facility, Hydrostatic Test and Cleaning Facility in the Vertical Assembly Building, Vehicle Components and Hazardous Materials Storage Buildings, S-IC Stage Test and Checkout Facility, and the Engine Test Buildup Facility.

The High-Pressure Test Facility, which had been in partial use since 1963, underwent a number of additions and changes during this period. Workmen had completed construction and activation of this facility by the end of the period.

Early in 1965 workmen built a steel containment wall around the Hydrostatic Test and Cleaning Facility to prevent damage to surrounding areas of the Vertical Assembly Building in case of test accidents. Other jobs in this period included completion of the tank repair position,

105. ME Lab., "Qtly. Hist. Rpt., Oct.--Dec. 1965," (draft), no date.
106. 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, p. 603.

installation of additional ladders and catwalks, erection of a personnel elevator, and installation of a small bridge crane, motorized curtains, and a floodlight system. The facility was complete at the end of the period.[107]

Construction of the Stage Test and Checkout Facility progressed throughout the period. Brick-and-mortar work on all four test cells of this facility ended in June 1965. Completion of the cells was delayed by Hurricane Betsy in September. The final quarter of 1965 saw completion of the facility's gaseous nitrogen system.[108]

The Vehicle Components and Hazardous Materials Storage Buildings were scheduled for completion in the fall of 1965. The Vehicle Components Building suffered severe damage in August when the roof collapsedin a heavy rainstorm. The contractor's insurance covered the loss of about $100,000. Roof repair was substantially complete by December 31, 1965.[109]

Construction of the Engine Build-up Facility began in July 1965. Completion and activation came late in the report period in time to support buildup of the first six F-1 engines that arrived by air during the last quarter of the year for use on S-IC-3.[110]

In February a $1.2 million contract was awarded covering expansion of the Central Computer Facility at Slidell, Louisiana. Work on this new wing of the main operations building started in March 1965 and was scheduled for completion in one year. Work progressed throughout the rest of 1965 and was 44 per cent complete at the end of the year.[111]

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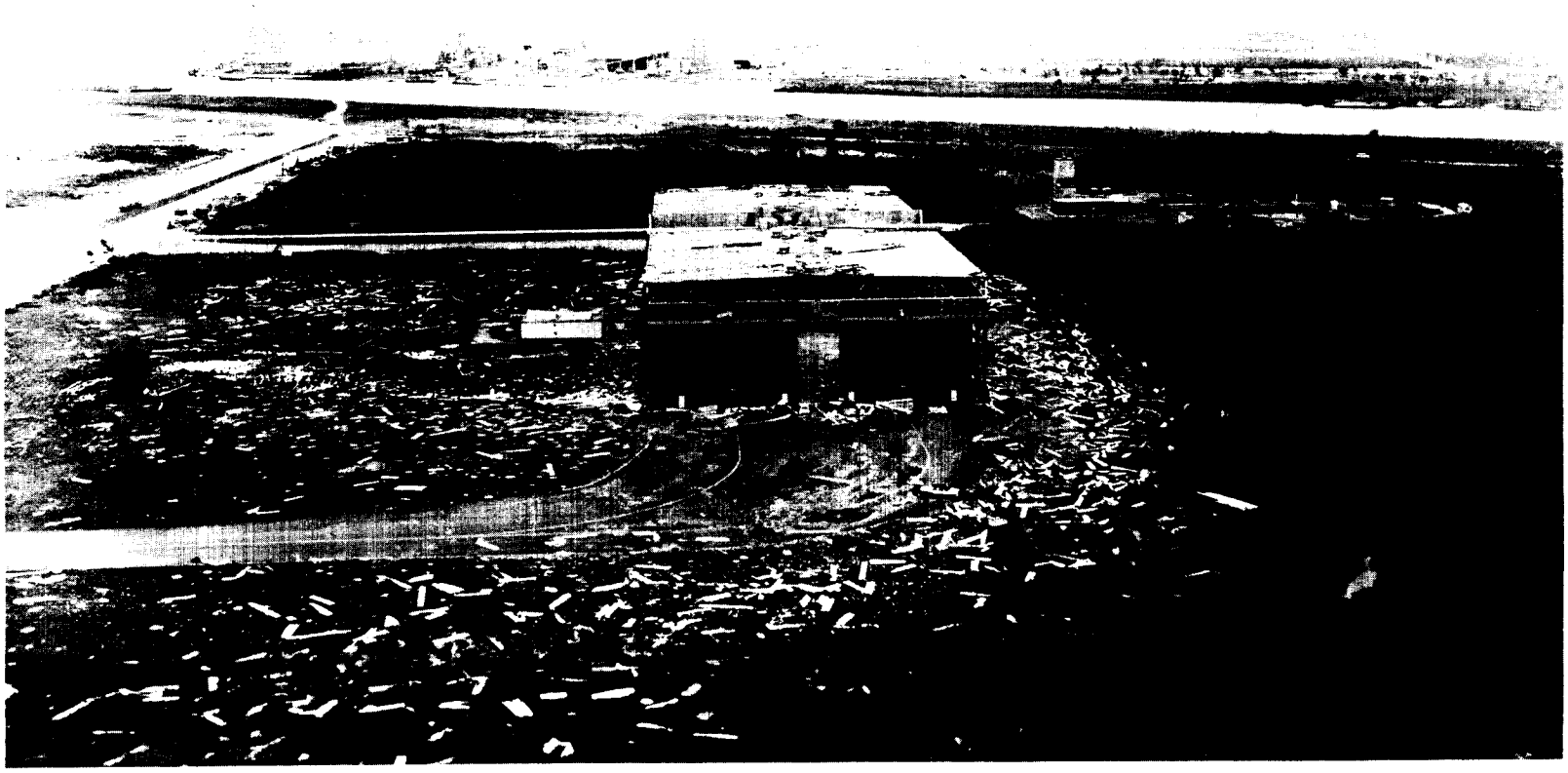
107. Saturn V Prog. Off., Saturn V QPR, Jan.--Mar. 1965, pp. 42-43; April--June 1965, p. 47; July--Sept. 1965, pp. 57-58; and Oct.--Dec. 1965, p. 49.

108. Ibid., April--June 1965, p. 47; July--Sept. 1965, p. 58; and Oct.--Dec. 1965, p. 49.

109. MAF, Hist. Rpt., July--Dec. 1965, pp. 42-43.

110. Saturn V Prog. Off., Sat. V QPR, July--Sept. 1965, p. 58; and Oct.--Dec. 1965, p. 50.

111. Michoud Operations, Hist. Rpt., Jan.--June 1965, p. 48; and 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, p. 604.



HURRICANE HITS MICHOUD

Building 420 at MAF, the Stage Test Position Facility, is shown after Hurricane Betsy in September 1965.

Other construction work during the year included air-conditioning additions at Slidell, an 800-seat cafeteria, dock and road additions, additions to production facilities, and modifications to the deep well used for chemical waste disposal. Marine dock and storm drainage system improvements were underway.

An unscheduled event at MAF that adversely affected facilities was Hurricane Betsy, which struck September 9-10 and caused heavy damage to buildings and equipment. Structural damage was estimated at over $2 million. Repair work began immediately after the storm and was scheduled for completion early in 1966.[112]

Mississippi Test Facility

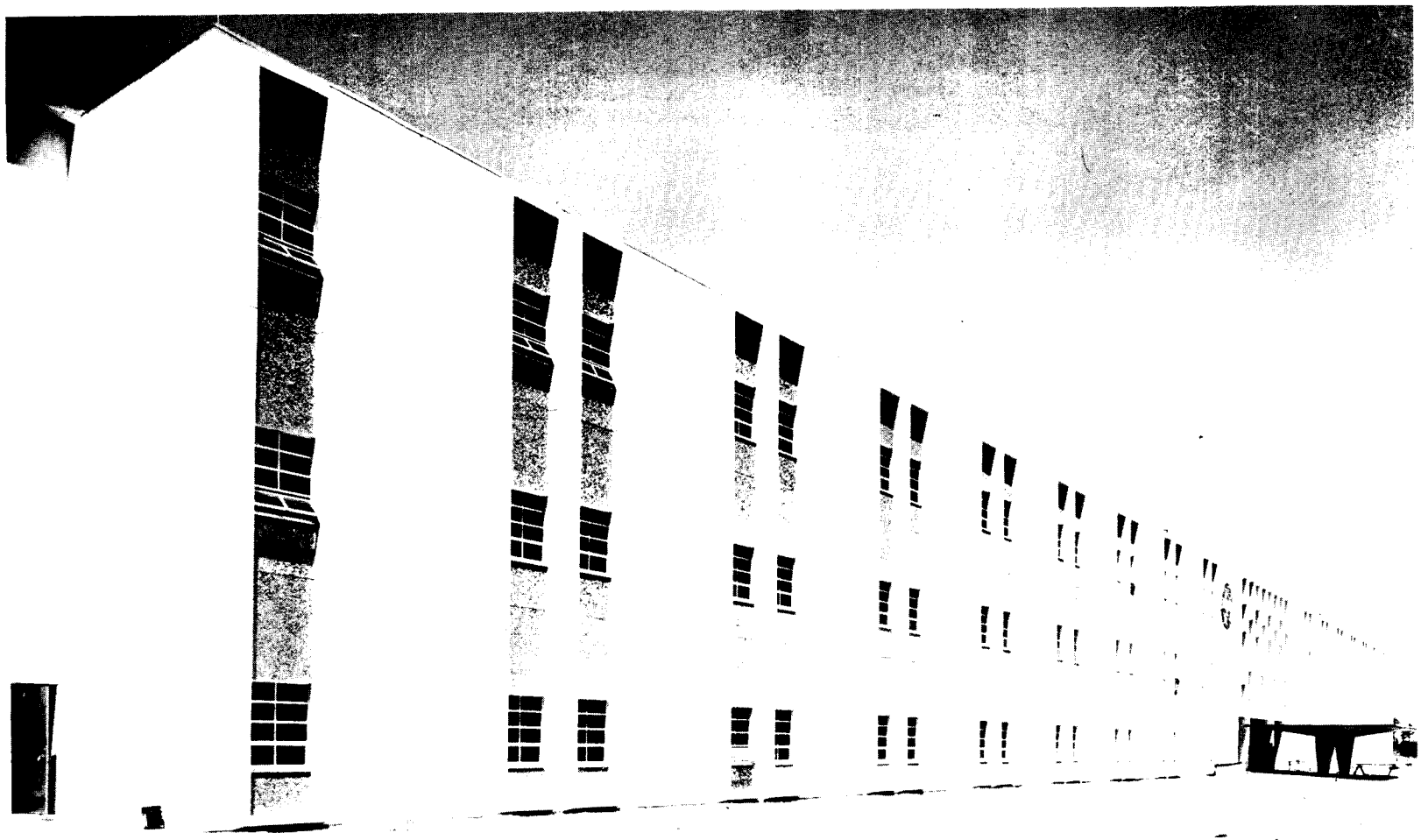
The year 1965 was a busy construction year at MTF. Completion and activation tasks reached major proportions on numerous test, support, and waterway facilities.

Major facilities completed at MTF during 1965 included: the High-Pressure Gas Facility, S-II Test Stand A-2, the Data Acquisition Facility, the Central Control Building and Data Handling Center, the Office and Administration Building, S-IC Booster Storage Building, the Electronic, Instrumentation, and Materials Laboratory, Test Maintenance Building, Sonic Measuring Facilities, mooring devices and piers for the Cryogenics Docks, Bascule Bridge, the Main Canal system, and Navigation Lock.

New facility contracts awarded at MTF during this report period included: S-IC Test Position B-1, March 2, for $4.7 million; S-II Stage Service and Checkout Building and Cryogenic Barge Service Building, February 8, for $4.3 million; and Components Service Facility, March 12, for $3.2 milion.

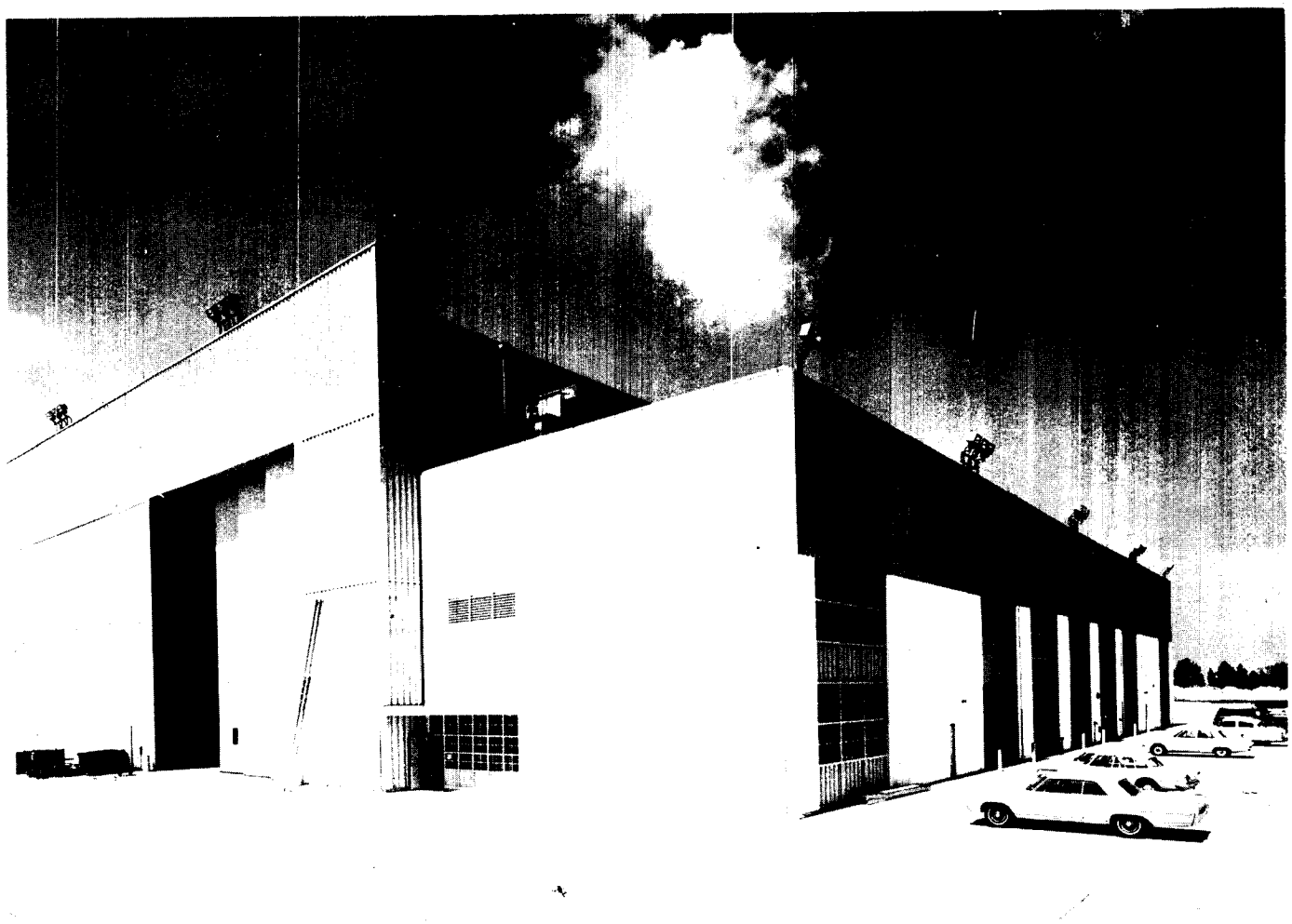
Other major uncompleted projects at the end of 1965 included: the High-Pressure Water Pump Station, the S-IC and S-II test control

112. MAF, Historical Rpt., July--Dec. 1965, pp. 42-43.



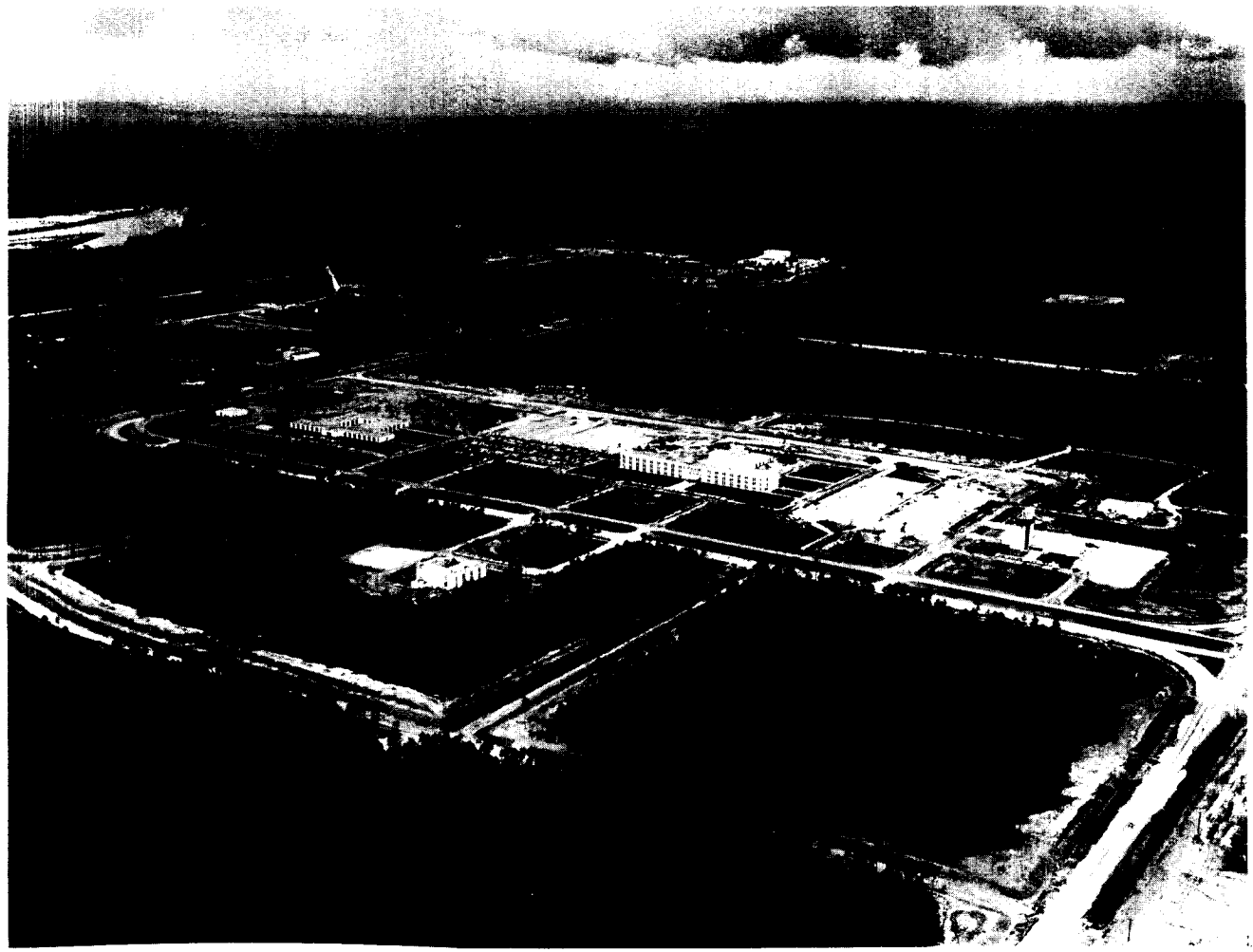
MTF ADMINISTRATIVE BUILDING

This structure at Mississippi Test Facility, completed during 1965, accommodates about 875 government and contractor personnel.



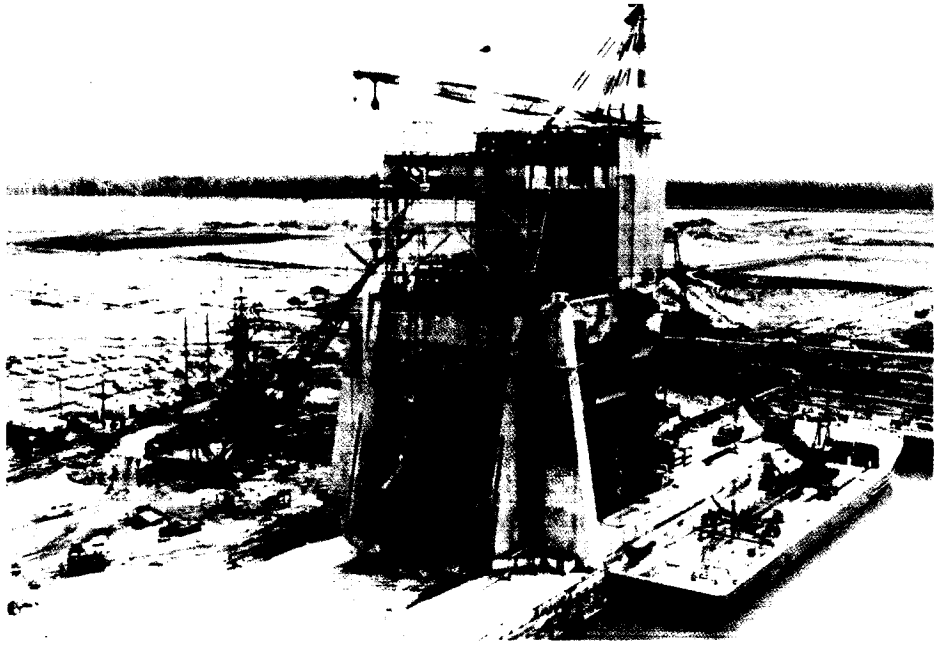
BOOSTER STORAGE BUILDING

This building, 71 feet high, is large enough to house two horizontal S-IC stages. The storage building is at MTF.



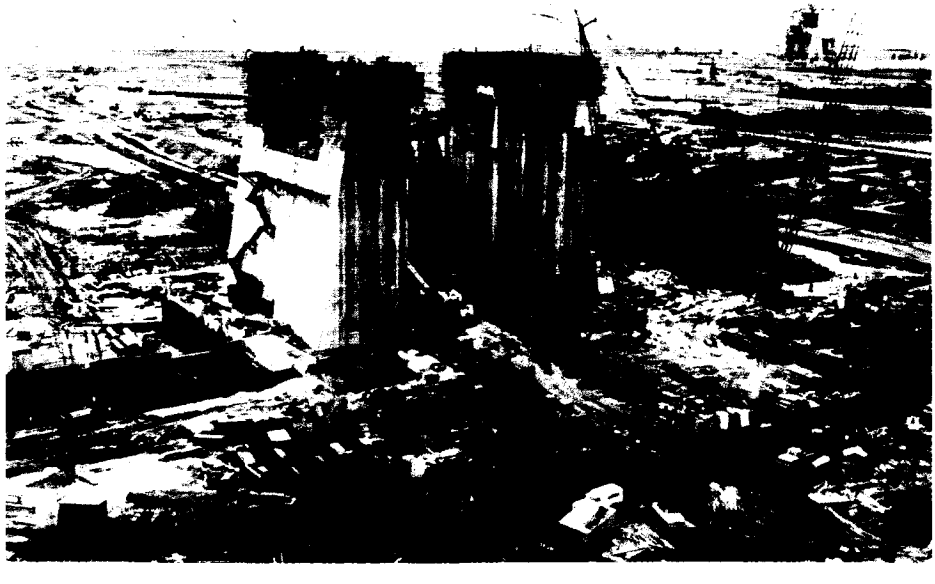
GENERAL VIEW OF MTF

This aerial photograph made in July 1965 shows administrative portions of Mississippi Test Facility. The canal and test facilities are not shown.



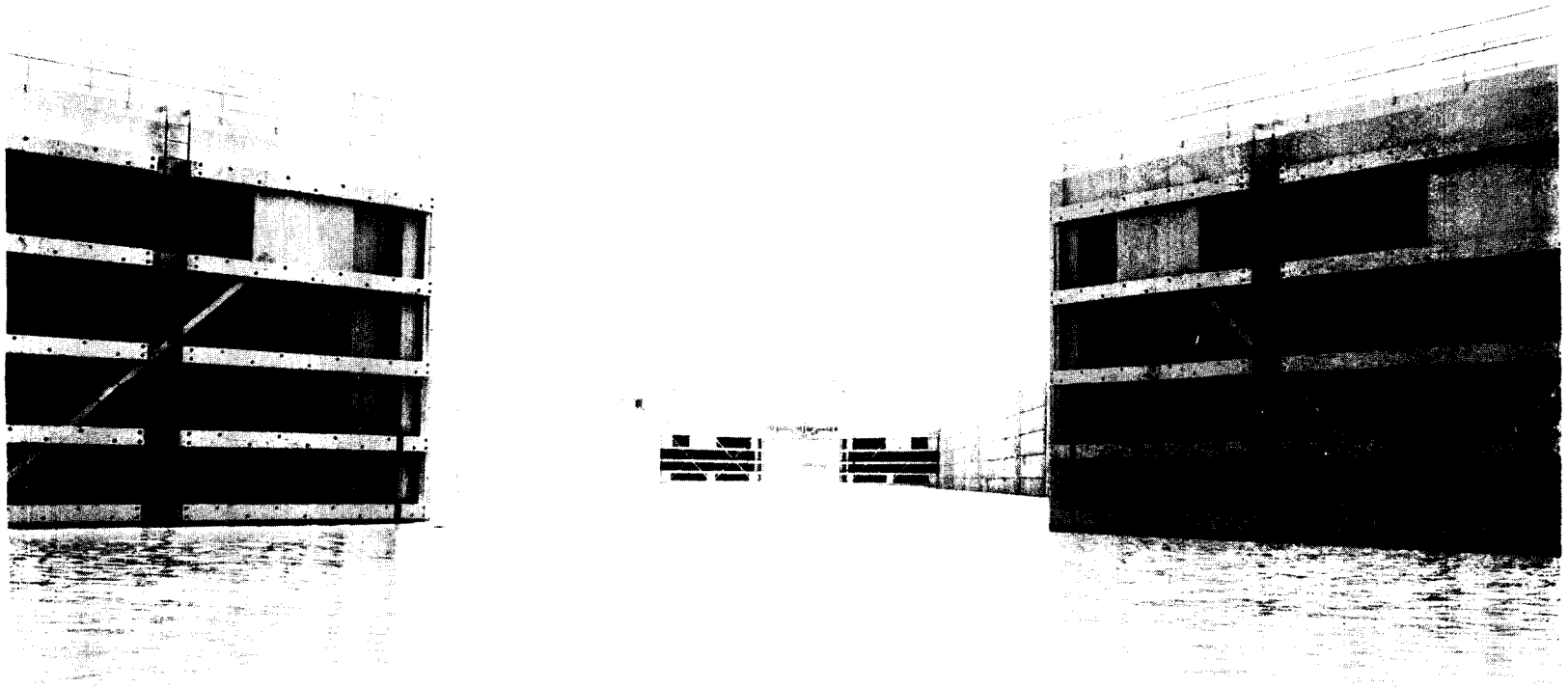
S-II STAND NEARS COMPLETION

The A-2 Test Stand at Mississippi Test Facility is shown in mid-1965 as construction neared an end.



S-IC STAND PROGRESSES

The S-IC static test stand at MTF is shown under construction.



MTF LOCK OPENS

The big doors of the Mississippi Test Facility lock system open in May 1965 signifying completion of the MTF canal system.

centers, S-II Test Stand A-1, and Mobile Equipment Maintenance Building. The installation and checkout of technical systems for a large number of these major facilities progressed well throughout the year. Of the three phases of technical systems installation, Phase I was 99 per cent complete, Phase II was 60 per cent complete, and three of the six steps of Phase III were complete.[113]

Contractor Facilities

S-IC stage facilities other than those at MSFC, MTF, and MAF are located at contractor and other government plants. The principal Boeing manufacturing facilities are at Seattle, Washington, and Wichita, Kansas, and are owned by Boeing. Facilities construction at these sites was relatively minor during 1965.

Major S-II stage facilities are at Downey, Seal Beach, and Santa Susana Field Laboratory (SSFL), all in California. NASA owns the Downey plant and S&ID operates its development facilities. Seal Beach facilities for fabrication, assembly, and test are on land leased from the Navy and are operated for NASA by S&ID. NASA provides the test facilities at SSFL.

Work at Downey in 1965 concerned mostly the S-II Electro-Mechanical Mockup. Activation of this facility occurred early in the current period. Installation of a high-pressure helium system in July completed all scheduled construction of this facility.[114]

Facilities construction at Seal Beach involved the Vertical Checkout and Pneumatic Test Building, Bulkhead Fabrication Building, Vertical Assembly and Hydrotest Building, and Pneumatic Test, Paint, and Packaging Building. Substantial progress on these buildings during 1965 saw completion of several portions of the facilities and beneficial occupancy of others. The plant was partly operational when the period ended.[115]

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113. MTF, Hist. Rpt. Jan.--Dec. 1965, pp. 1 and 9-13.

114. Sat. V Prog. Off., Sat. V QPR, Jan.--Mar. 1965, p. 45; and July--Sept. 1965, p. 59.

115. Ibid., April--July 1965, pp. 59-60; and Oct.--Dec. 1965, pp. 50-51; and NASA, 14th Semi-annual Report to Congress, July 1 - Dec. 31, 1965, p. 45.

At Santa Susana early in this period workmen completed activation of a component test cell and modified one vertical test stand. Construction of the Common Bulkhead Test Site ended in February. The CBTT was installed and checkout completed December 18 with a battleship firing attempt.[116]

S-IVB stage engineering, development, final assembly, and checkout are performed at DAC's Huntington Beach Space Systems Center. DAC owns facilities at Santa Monica, where fabrication is accomplished of structural, mechanical, and electrical assemblies for the stage. Testing activities are centered at Sacramento Test Center (SACTO) which is owned by DAC; NASA, however, provides many of the SACTO facilities.

Since the S-IVB development and production facilities were largely completed and in use at Huntington Beach and Santa Monica, facilities construction during 1965 was mostly at SACTO. Conversion of the Beta I Test Stand for acceptance testing of the Saturn V/S-IVB was in progress when the period began. Construction also was underway on the Vertical Checkout Laboratory and the Alpha I Common Bulkhead Test Facility. Joint occupancy of the VCL, used for post-firing checkout, began in July 1965, but construction delays occurred because of labor walkouts. Conversion of Beta I ended on October 4 and activation occurred November 3 with installation of S-IVB-203. The contractor finished construction of the Alpha I stand October 12 and the CBTT was undergoing tests at the end of the period. Basic construction on the VCL and all other facilities projects at SACTO was complete by the end of 1965.[117]

F-1 engines are developed, manufactured, and tested in California by Rocketdyne at facilties owned by North American Aviation and the government. Engineering, fabrication, and assembly operations are performed at Rocketdyne's Canoga Park facilities, provided in part by NASA

116. Ibid., Jan.--Mar. 1965, p. 45; July--Sept. 1965, p. 59; and Oct.--Dec. 1965, p. 50.

117. Ibid., Jan.--Mar. 1965, p. 46; April--June 1965, p. 50; July--Sept. 1965, p. 60; and Oct.--Dec. 1965, pp. 51-52.

funds. Component development occurs at SSFL, owned partly by NAA and partly by the government; and engine developmental and acceptance testing are at Edwards Air Force Base's Rocket Engine Test Site (RETS), which was built with NASA funds. All these F-1 facilities were operational during 1965, and only minor modifications, repair, and maintenance work occurred during the period.[118]

J-2 engine manufacture occurs primarily at Canoga Park. Most J-2 testing of components and engines occurs at SSFL, where considerable facilities construction was done during the current report period. Some J-2 environmental testing is scheduled at the Air Force's Arnold Engineering Development Center at Tullahoma, Tennessee, where a test cell was being modified during 1965. At SSFL's Vertical Test Stand 3 in the Bowl Area, the two engine test positions were completely modernized and activated by March 1965. A 45,000-gallon LH_2 tank was repaired and placed into service the second quarter of the year. The Delta Test Area--used for FRT and acceptance testing--was in operation throughout this period, and only repairs and modifications were done. In the components test area one new test cell was activated in May and another in July 1965. A third test cell underwent modifications.[119]

Kennedy Space Center

Launch facilities construction at KSC is the responsibility of that Center. Only brief coverage of Saturn V launch facilities is provided in this report.

Major elements of Launch Complex 39 (LC-39) were complete or nearing completion at the end of 1965. They include the Vehicle Assembly Building

118. 89th Cong., 2nd sess, House Rpt., 1967 NASA Authorization, pp. 149-150 and 255; and Engine Prog. Off., Launch Vehicle Engines Project Development Plan, July 1, 1965, pp. 9-1 and 9-4.

119. Engine Prog. Off., Engine PDP, July 1, 1965, pp. 9-8 and 9-11; and Engine OPR., Jan--Mar., 1965, p. 20; Apr.--June, 1965, p. 25; and Semi-Annual Prog. Rpt., July--Dec. 1965, pp. 30-31.

(VAB), Launch Control Center (LCC), three Mobile Launchers (ML), two transporters, two launch pads, and one Mobile Service Structure (MSS). Only three of the four high bays in the VAB and three of the four firing rooms in the LCC are to be outfitted for the Apollo/Saturn V program.

VAB low bay beneficial occupancy occurred July 5, 1965; equipment installation was scheduled by mid-1966. The first high bay was occupied beneficially in November 1965, and equipment was being installed at the year's end in Firing Room 1; this facility should be ready for facility checkout in the spring of 1966. Construction of Pad A, the first of the two launch positions, ended in October 1965, and Pad B construction proceeded toward expected completion late in 1966. Steel erection on the MSS was completed in November 1965. Erection and equipment installation of the three mobile launchers was complete at the end of 1965. Transporter No. 1 was ready for service, and the second transporter was expected to be acceptance tested in the spring of 1966. More than 25 facility projects at LC-39 were completed during the year. Among these were the Crawlerway, Ordnance Storage Building, Launch Equipment Shop, and an Instrumentation Building.[120]

FUNDING

MSFC obligated a total of $1,035,758,000 in the Saturn V vehicle program during Calendar Year 1965. This total was divided into program segments as follows:

S-IC Stage, $197,481,000; S-II Stage, $230,645,000; S-IVB Stage, $130,199,000; Instrument Unit, $76,206,000; Ground Support Equipment,

120. 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, pp. 620-625.

$99,500,000; F-1 Engine procurement, $54,100,000; J-2 Engine procurement, $68,954,000; Vehicle Support, $178,673,000.[121]

SUMMARY

All three stages of the Saturn V launch vehicle underwent full-duration ground test firings during 1965.

The first complete S-IC stage (S-IC-T, the all-systems test stage) completed manufacturing at MSFC early in the year. Static testing began in April, about three months ahead of schedule, and ended successfully in December, one month earlier than expected.

Five flight S-IC stages and four ground test stages were in various phases of manufacture. Delivery of the first flight stage (S-IC-1) to checkout was accomplished at Huntsville. Boeing at Michoud delivered to Huntsville the dynamic test stage (S-IC-D), the first complete stage manufactured by Boeing. Boeing also completed the facilities checkout stage (S-IC-F), which would be delivered to KSC in 1966 to begin the checkout of LC-39.

In the S-II stage project, a substantial portion of the ground test program was completed in spite of major problems in manufacturing and test. Successful battleship cluster firings occurred, as well as completion of Electro-Mechanical Mockup, Common Bulkhead Test Tank, and structural test programs. A test accident at Seal Beach destroyed the structural test stage (S-II-S), but only after its structural integrity had been demonstrated. A realignment of the S-II ground test program early in 1965 eliminated one stage (S-II-D) and substituted another stage (S-II-S/D) for two test functions--structural and dynamic tests. With destruction

121. Memo, Louis E. Snyder, Chf., Budget and Operations Branch, Financial Management Office, MSFC, to D. S. Akens, Chief, Historical Office, MSFC, subj., "MSFC's Obligations for Calendar Year 1965," Feb. 18, 1966.

of this stage as noted, a further switch was made, utilizing the S-II-T all-systems stage for later dynamic testing. Generally, the S-II stage was the pacing item in the Saturn V program, causing the program to slip somewhat behind schedule. The first four flight stages, however, were in production at the end of the year.

S-IVB stage progress was significant. Upon completion of the Saturn IB/S-IVB dynamic test program at MSFC, personnel began conversion of the stage to the Saturn V configuration. The Saturn V/S-IVB battleship program went to successful completion at SACTO, including a restart demonstration. The S-IVB-F facilities checkout stage was delivered to KSC and modified to the Saturn V configuration. By the year's end the first four flight stages were in manufacturing.

The Instrument Unit ground development and qualification test programs neared compeletion during the year. MSFC and IBM established and qualified the IU design by extensive structural, dynamic, and vibration testing.

F-1 engine progress in 1965 included the first single-engine and first cluster firing on the all-systems test stage (S-IC-T), both ahead of schedule. More than 46,000 seconds of R&D testing was accomplished. Engine reliability was confirmed and confidence increased with the greatly accelerated rate of testing and demonstration of combustion stability. The qualification program moved steadily toward expected completion in 1966. Rocketdyne delivered three sets of flight engines in 1965. Conversion of the R&D and production contracts from fixed-fee to incentive type neared official completion at the year's end.

The J-2 engine FRT program ended in July 1965. The qualification testing program of the 200K engine ended in December, confirming the reliability required for manned flight. Five-engine cluster firings also occurred, as noted above. Rocketdyne delivered 42 production engines. The production contract was converted to an incentive contract, and negotiation started for consolidation of the total J-2 project into one incentive contract.

Facilities construction at MSFC saw many major items completed and placed in operation. Only a few additions to major facilities and a handful of new construction projects remained incomplete at the end of 1965.

At MAF during the year workmen completed the facilities necessary for a fully operational manufacturing plant. A few facilities were in the final stages of activation.

The first S-II test stand at MTF and its supporting facilities neared operational readiness. Significant progress was made in construction and activation of remaining test, support, and waterway facilities.

Facilities at contractor and other sites were generally complete and in operation for the manufacture, assembly, and checkout of S-II and S-IVB stages, the Instrument Unit, and F-1 and J-2 engines.[122]

122. 89th Cong., 2nd sess., House Rpt., 1967 NASA Authorization, pp. 127-133 and 251-255; and Executive Office of the President, Report to the Congress from the President of the United States, U. S. Aeronautics and Space Activities, 1965, Jan. 31, 1966, pp. 14-15.

CHAPTER V: ADVANCED STUDIES PROGRAM

MSFC performed and monitored a wide variety of advanced study programs during 1965. Studies contracted to Saturn stage prime contractors and other aerospace firms supplemented in-house investigations by Center laboratories and offices. Many MSFC organizational elements participated in the execution and management of these studies. The Future Projects Office, which became the Advanced Systems Office about the middle of the report year, integrated and coordinated study projects originating at this Center.

While the study emphasis at MSFC was on improving current launch vehicles and projecting more advanced vehicle systems, there was increasing activity in related areas. These included post-Apollo missions, earth-orbital and lunar operations, and systems for exploration of the near-earth planets.

LAUNCH VEHICLE STUDIES

MSFC conducted many vehicle studies in-house during this year, and contracted additional study programs to private industry. A major portion of these studies aimed at improving the two Saturn vehicles, IB and V.

Saturn IB

In June 1964 MSFC awarded to Chrysler Corporation and Douglas Aircraft Company concurrent contracts for studies of improved Saturn IB vehicles for post-Apollo missions. Chrysler's contract, valued at $170,000, called for investigation of improving vehicle capability by uprating the S-IB stage, by using solid motor strap-ons, and by uprating the S-IVB stage. The Douglas $99,000 contract was for evaluating the use of a 260-inch-

diameter solid motor to replace the S-IB stage and to assist Chrysler in investigating modifications to the S-IVB stage. Both contractors also investigated the use of a cryogenic third stage. Upon completion of these supervised studies in the spring of 1965, MSFC's Advanced Systems Office summarized the results and made recommendations for further study effort. The studies provided a matrix of possible vehicles from which to choose.[1]

As an outgrowth of these studies, MSFC in June 1965 awarded a $191,000 contract to Douglas covering the study of a Saturn IB having a solid first stage. Douglas was due to complete this project in March 1966. In December 1965 two further study contracts went to Saturn IB prime contractors, one to Chrysler and the other to Douglas. The $450,000 Chrysler "prime" study contract and the Douglas $116,346 supporting contract were designed to investigate in detail six vehicle concepts suggested by the earlier studies. All of these concepts involved strapping on solid motors of various sizes and numbers for "boost-assist" to the modified S-IB first stage of the vehicle. They are briefly described as follows:

1. A "zero" stage for launch, consisting of four 120-inch-diameter solid rocket motors strapped to the S-IB stage.

2. An S-IB stage with only four H-1 engines, with four 120-inch solid motors attached.

3. An S-IB stage with all eight H-1 engines and with two 120-inch solid motors attached.

4. A Saturn IB vehicle with four Minuteman solid rockets attached to the S-IB stage.

5. A Saturn IB with eight Minuteman motors strapped on.

6. A cluster of five 120-inch solid rocket motors strapped to the booster.

Completion of these studies was scheduled by October 1966.[2]

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1. Advanced Systems Office, Saturn IB Improvement Studies (Phase I) Executive Summary Report, NASA TM X-53323, Aug. 26, 1965, pp. 1-2; and Digest of FY-64 Funded Advanced Studies, Aug. 1966, p. 9.

2. Adv. Sys. Off., Digest of FY-65 Funded Advanced Studies, July 1966, pp. 3-4; and Public Affairs Office, Marshall Star, Jan. 5, 1966, pp. 1 and 10.

A Saturn IB/Centaur study during this period, not under management of MSFC, was awarded by NASA's Lewis Research Center, which managed the Centaur launch vehicle program. Lewis awarded this $100,000 study contract to General Dynamics/Convair. The six-month study would determine the specific vehicle design changes and ground support equipment required for use of the Centaur as an upper stage of the Saturn IB vehicle. The three-stage vehicle was proposed at that time for launchings of Voyager spacecraft to the planet Mars. The study was in progress when this report period ended.[3]

Saturn V

Improvement of the Saturn V vehicle for post-Apollo missions in the 1970's was the objective of a series of study contracts that MSFC awarded to vehicle prime contractors in June and October 1964. Six contracts were awarded--four to Boeing Company, one to North American Aviation, Inc., (NAA), and one to Douglas. To Boeing went a $215,000 contract covering S-IC stage improvements, a $246,000 contract for vehicle fluid and flight mechanics, a $227,000 study of liquid/solid integration, and an $80,000 contract for a resources study of liquid/solid integration. NAA won a $217,000 contract to study S-II stage uprating methods. And Douglas received a $209,000 contract for study of S-IVB stage improvements.[4]

Study contractors, supervised by MSFC representatives, completed these Saturn V improvement studies in April 1965. MSFC summarized the entire study program in an executive summary report. The summary report was based on the six Saturn V Modified Launch Vehicle study contracts plus two engine studies: Rocketdyne investigated uprating F-1 and J-2

3. PAO, Marshall Star, Sept. 8, 1965, pp. 1 and 10.
4. Future Projects Office, Bulletin No. 10, May 1965, p. 24; and Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, Aug. 1966, pp. 10-11.

engines in a $146,000 contract; Pratt & Whitney Aircraft Company performed a $500,000 study of advanced upper stage engines. The studies considered, among others, the following methods of uprating the Saturn V: uprate the thrust of the F-1 engine and increase the stage's propellant capacity; add a sixth F-1 in the S-IC stage plus increased propellant capability; use a large solid motor for boost-assist; add J-2 engines in the S-II stage plus increased propellant capacity; and use improved or advanced upper stage engines plus increased propellant capacity.

The several configurations under study included all-liquid propellant systems and liquid/solid integrated systems. The resulting modified launch vehicles would have payload capabilities ranging from 15 to 25 per cent above the standard Saturn V. MSFC concluded in its summary of the studies in July 1965 that: the proposed modified vehicles would be a practical means of uprating Saturn V; that designs and manufacturing would be within present technology and tooling capability; and that no insurmountable engineering problems would be involved. The studies also suggested alternate approaches to Saturn V growth. As a result, MSFC and the prime contractors obtained a detailed knowledge of the contractor manufacturing capabilities and facility limitations existing if an uprated Saturn V were approved for production.

Concurrently, MSFC was conducting a large number of in-house studies for uprating Saturn V, using the same ground rules and assumptions employed by the contractors in their studies. This in-house work resulted in a multitude of uprating method suggestions and numerous vehicle configurations.[5]

A second round of Saturn V improvement study contracts came in December 1965, when the Center awarded one study to each of the three Saturn V prime contractors. This new series of studies, further defining new vehicle concepts, was to examine eight variations of the modified Saturn V, covering a payload range between the Saturn IB and Saturn V and a payload range beyond the existing Saturn V capabilities. Boeing received a $370,000

5. Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, Aug. 1966, p. 10; and Modified Launch Vehicle (MLV) Saturn V Improvement Study Composite Summary Report, NASA TM X-53252, July 2, 1965, pp. 1, 2, 16-17, 43-44, and 53-54.

contract, NAA a $329,624 contract, and Douglas a $96,730 contract. Configurations to be studied were as follows:

1. An intermediate size vehicle consisting of modified S-II and S-IVB stages with new type hydrogen engines.

2. A two-stage intermediate vehicle with two, three, or four 120-inch-diameter solid motors strapped to the S-II stage.

3. A third two-stage vehicle consisting of S-II and S-IVB stages with six to 12 Minuteman motors strapped to the S-II stage.

4. A two-stage vehicle with an S-IC stage having uprated F-1 engines and increased propellant tank capacity; the vehicle's second stage would be a modified S-IVB stage.

5. A fifth concept consisting of an uprated S-IC stage topped by a standard S-II stage.

6. A sixth concept with a three-stage vehicle consisting of S-IC stage with five F-1 engines uprated to 1.8 million pounds thrust, and modified S-II and S-IVB stages with new type hydrogen engines.

7. A three-stage vehicle consisting of the basic Saturn V with four 120-inch solid motors strapped to the S-IC stage for boost-assist.

8. A basic Saturn V with an unspecified number of liquid rocket pods attached, each pod using two F-1 engines.

Boeing was to serve as the study systems integration contractor in all configurations having the S-IC stage. NAA was to be the systems integrator for all concepts not having an S-IC stage. The studies were just beginning when the current report period ended and were due for completion in October 1966.[6]

Post-Saturn Vehicles

Continued during 1965 was the long-range general study of the next large launch vehicle after Saturn V. The original study contracts in

6. PAO, Marshall Star, Jan. 5, 1966, pp. 1 and 10; and Boeing, Final Report -- Studies of Improved Saturn V Vehicles and Intermediate Payload Vehicles (P-115) Summary, Report D5-13183, Oct. 7, 1966.

this program were awarded in August 1962 and completed late in 1963. Fiscal Year 1964 post-Saturn study activity concerned primarily a $1.5 million study with the Martin Company. Martin completed this study in November 1964. Its three major objectives were design analysis, mission analysis, and technology. Martin also performed a parallel study of launch facilities and operations (managed by NASA Kennedy Space Center) and test facilities and operations (managed by MSFC Test Laboratory). Based on these studies, MSFC early in 1965 selected a "baseline" vehicle to serve as a reference point for future studies. The selected baseline vehicle was a two-stage, all-reusuable vehicle using liquid hydrogen/liquid oxygen in both stages. The first stage was 74 feet in diameter, 207 feet long, with 18 M-1 engines mounted around a plug nozzle. The second stage, also 74 feet in diameter, was 73 feet long with 16 HG-3 engines (300,000 pounds thrust each engine) arranged around a plug nozzle. Liftoff weight of this proposed vehicle was 18.3 million pounds. Minimum payload capability was 1.07 million pounds. Recovery was planned by a series of parachutes and retrorockets.[7] No significant follow-up effort on the post-Saturn launch vehicle study was undertaken in 1965 following completion of this study.

Reusable Vehicles

Studies of a reusable orbital transport, performed both in-house by MSFC personnel and by industrial contractors, continued during 1965 after considerable earlier effort. Lockheed Aircraft Corporation and General Dynamics/Astronautics undertook parallel Reusable Orbital Transport (ROT) studies in June 1964 and completed them during the current period. In a $776,000 study of a reusable first stage, Lockheed concluded in August 1965 with a proposed stage design plus integration of ground complex and overall systems. The GD/A study, under a $492,000 contract, considered the design of a second stage for the ROT. This study ended in June 1965

7. Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, Aug. 1966, pp. 7-8; and FPO, Post-Saturn Launch Vehicle Study (Part III) Executive Summary Report, NASA TM X-53260, May 14, 1965, pp. 1-2 and 13-15.

with definition of an attractive ROT second stage and planning data for additional studies leading to program definition of the system.[8]

In December 1965 Martin/Denver started a seven-month, $51,000 contract for a comparison of launch modes for a Reusable Aerospace Passenger Transport. This study aimed at comparing the relative merits of horizontal takeoff and vertical takeoff launch modes in a reusable passenger vehicle system. This project was in progress when the period ended, with completion scheduled in July 1966.[9]

Also in December 1965, Lockheed received a $237,100 contract calling for investigation of methods for development of an incremental ROT, as an extension of presently approved launch vehicles. This study was due for completion in October 1966. Its results would be compared with the data on the ROT system defined in other studies as a two-stage all-reusable system.[10]

Other Vehicle Studies

A large number of other launch vehicle studies ended during 1965. Among the major contracted studies were the following, briefly summarized:

Launch Vehicle Component Cost Study, by Lockheed, June 1964 to June 1965, $139,000. Objectives: to develop a cost estimating and evaluation model to provide guidelines for evaluation of future vehicle concepts in comparison with existing systems.

Launch Vehicle Cost Parameters Study, under two contracts by General Dynamics and Martin, June 1964 to May 1965, $97,000 and $98,000. Objectives: to provide a general methodology for consideration of cost dynamics and

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8. Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, Aug. 1966, pp. 6-7.

9. MSFC, Comparison Study of Reusable Passenger Transport Launch Modes, Executive Summary Report, NASA TM X-53652, Sept. 27, 1967, pp. 1, 2, and 9.

10. Adv. Sys. Off., Digest of FY-65 Funded Advanced Studies, July 1966, p. 2.

cost implications involved in satisfying requirements of a selected group of general contingencies.

Human Engineering Data and Concepts for Handling Advanced Nuclear Systems in Space, Martin, June 1964 to June 1965, $98,000. Objectives: to determine how, where, and when man can handle and operate nuclear systems in space, and alternatives open to him.

Human Engineering Requirements: Ground Support of Nuclear Systems, by Douglas, June 1964 to May 1965, $74,000. Objective: to develop human engineering criteria in the design of advanced nuclear space systems and associated ground facilities and GSE.

Launch Vehicle Cost Model, by General Dynamics, June 1964 to June 1965, $138,000. Objective: to develop a cost methodology directed toward the evolution of a conceptual framework which could be applied to different technologies and mission concepts.

Launch Vehicle System Criteria Study, by two contractors, Boeing and North American Aviation, $247,000 and $300,000. Objectives: to develop basic evolution criteria, desirable key design features, and promising advanced concepts for future launch vehicle systems.[11]

APOLLO APPLICATIONS STUDIES

A major group of studies started in 1964 to extend the Apollo lunar landing program following its completion in the 1970s. This broad program would adapt the Saturn launch vehicles and Apollo spacecraft to support extended lunar exploration and a variety of manned earth-orbital missions. All the proposed missions were primarily for science and applications experiments. Kinds of earth-orbital uses envisioned for the modified Apollo system included astronomy, bioscience and physical science, remote

11. Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, August 1966, pp. 2-5 and 11-12.

sensing of features on and above the earth and under the ocean, and space operations and technology. Lunar-orbital applications included surveys of the moon to determine composition, mineralogy, geology, etc. Proposed lunar surface missions consisted principally of extending the basic Apollo mission, by observing and testing near landing sites, returning lunar material to earth for analysis, increasing lunar stay-time, increasing the use of instrumentation on the surface, and increasing astronaut mobility.[12]

This program of study was officially known throughout more than half of 1965 as Apollo Extension System studies. Before the end of the report period the designation of the program had been changed to Apollo Applications Program (AAP). Much of the study effort for AAP was performed in-house at MSFC, but an increasing amount was placed in the hands of contractors. This Center's study participants concentrated on selection and description of candidate experiments. MSFC and other NASA centers monitored the contracted studies. Only the highlights are reported here.

Orbital Operations

In May 1965 North American Aviation concluded a $100,000, nine-month study, Utilization of Spent Launch Vehicle Stages in Support of Earth Orbital Missions. Results of the study, submitted to MSFC, indicated that the S-IVB stage could be readily available and inexpensive as an experiment module in the Apollo Applications Program. The study also indicated the feasibility of separating the Apollo from the S-IVB stage, turning it around, and docking to the forward end of the spent stage, to provide crew access to the tanks of the stage. MSFC asked the Office of Manned Space Flight (OMSF) for funds to continue the study in more detail. The Center began to identify and document experiments applicable to AAP. With the

12. George E. Mueller, Associate Administrator for Manned Space Flight, NASA, speech prepared for presentation at XVI International Astronautical Congress, Athens, Greece, Sept. 14, 1965.

help of a support contractor (Brown Engineering Company), MSFC evaluated 84 AAP experiments that could be housed in the propellant tanks of an S-IVB. Late in 1965 an S-IVB Workshop Working Group was organized at the Center. Members of this group developed several concepts for use with both Saturn IB and Saturn V launch vehicles. Preliminary drawings of these configurations were presented to MSFC management and to NASA OMSF late in December. Selection of the most promising configurations was pending at the end of the period.[13]

S-IVB Workshop planning responsibility at MSFC was divided as follows among the organizational units involved: The Advanced Systems Office had responsibility for direction and management of the total effort. The Advanced Studies Office of P&VE Laboratory had R&D technical coordination and direction, as well as management of the S-IVB Workshop Working Group. P&VE Lab was responsible for design and for the airlock and environmental control systems. P&VE also would develop the engineering and biomedical experiments. Research Projects Lab would develop scientific experiments. Astrionics Lab would develop the workshop's artificial gravity experiment. Manufacturing Engineering Lab would fabricate the workshop mock-up.[14]

In September 1965 NASA awarded to Ball Brothers Research Corporation a $117,175 contract calling for definition and engineering requirements for an earth-orbiting solar telescope mount. Management of this study project was assigned to NASA Manned Spacecraft Center. This six-month study, in progress when the current report period ended, considered a

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13. P&VE Lab. Monthly Progress Report for Period May 1 Through May 31, 1965, MPR-P&VE-65-6, p. 5; MPR-P&VE-65-7, p. 4; and MPR-P&VE-65-12, p. 4; Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, pp. 14-15; and letter, H. H. Koelle, Dir. FPO, MSFC, to E. Z. Gray, OMSF, NASA, Apr. 7, 1965 (with enclosure).

14. Memo, Adv. Sys. Off., MSFC, to Addressees, subject, "Revised Objectives and Guidelines for the S-IVB Workshop Effort," Dec. 3, 1965 (with enclosure).

telescope system capable of being housed in the service module of the Apollo spacecraft and operated by astronauts. This study was later to be named the Apollo Telescope Mount.

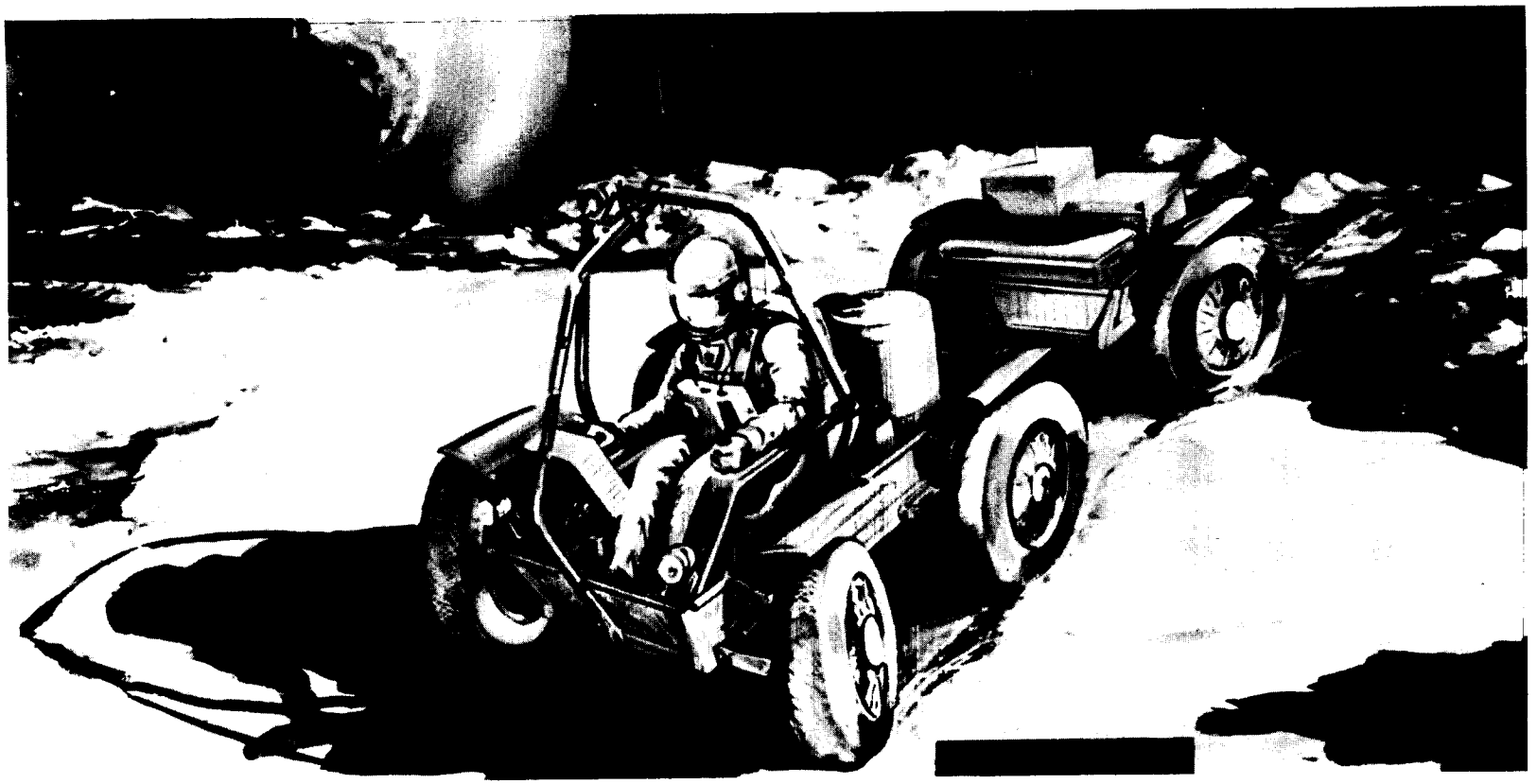
Another significant AAP study project assigned to MSC late in 1965 was the Apollo Experiments Pallet project. NASA awarded four separate contracts valued at $375,000 each to Lockheed, McDonnell, Martin, and Northrop. These four-month studies would produce design and development specifications and a mockup of the experiments pallet. This pallet would house scientific, technological, and engineering experiments designed to be carried on Apollo missions. The study program was due for completion early in 1966.[15]

Lunar Surface Applications

March and April 1965 saw completion of three LESA (Lunar Exploration Systems for Apollo) studies by General Dynamics, Westinghouse, and Garrett Corporation. In these early AAP studies, General Dynamics investigated operations and logistics under a $139,000 contract; Westinghouse studied communications and control ($82,000 contract); and Garrett considered human factors and environmental control ($99,000 contract).

In June 1965 contractors completed two Apollo Logistics Support Systems (ALSS) studies. NASA had awarded these parallel $800,000 studies in June 1964 to Boeing and Bendix. The objective was to prepare preliminary design and specifications for a mobile lunar laboratory (Molab) to support the initial Apollo landings for a two-man, 14-day scientific mission on the lunar surface. Upon completion of these preliminary studies, MSFC in June 1965 extended the Boeing and Bendix contracts in the amount of $565,000 and $570,000 respectively. The extended contracts were for the purpose of investigating a modified Apollo lunar excursion module (LEM) as a shelter for use in conjunction with a local scientific survey

15. MSFC PAO, Marshall Star, Sept. 29, 1965, p. 2; Manned Spacecraft Center PAO, Space News Roundup, Nov. 26, 1965, p. 8; and Ball Brothers Research Corp., ATM Study Program, Final Report, Apr. 1, 1966, pp. 1-1 and 1-2.



MOON VEHICLE CONCEPT

This is the Boeing concept of Local Scientific Survey Module (LSSM), the product of a 1965 study contract.

module (LSSM). The LSSM would be much smaller than the Molab considered in the original Boeing and Bendix studies. It would provide astronauts with local mobility for transportation from the LEM shelter-laboratory.

In support of the LSSM studies MSFC awarded, also in June 1965, two study contracts covering design, development, and fabrication of a Mobility Test Article (MTA). The MTA models would be small lunar surface vehicles designed to operate at one-sixth earth gravity, as it exists on the moon. The contractors for this study were General Motors and Bendix. The individual contracts were funded at about $400,000 each and scheduled to be completed in 11 months. General Motors would have one type of wheel and the Bendix model another type.[16]

In June 1965 Bell Aerosystems Company completed a 12-month study of lunar flying vehicles, conducted under a $199,000 contract. This rocket-powered "lunar hopper" would transport astronauts on 50-mile lunar surface exploration missions. Following completion of this study, MSFC awarded Bell a follow-on contract valued at $489,000 for a study to produce design of a lunar manned flying system (MFS) for trips up to 15 miles from a LEM shelter. This study was due for completion in April 1966.

The Center awarded two contracts for study of low-thrust engines for the MFS. These two studies supported the Bell MFS study. Receiving a $58,570 contract for this purpose was Bell Aerosystems; a $106,413 parallel contract went to TRW Systems Group. Another MFS supporting study was awarded to Westinghouse. This $145,000 contract modification to an existing contract had as its purpose the development of a radar altimeter for the MFS.[17]

Other major lunar surface AAP studies awarded during 1965 and in progress at the end of this report period included:

In Situ Lunar Sample Analysis, to NASA Goddard Space Flight Center, in April, $200,000 contract;

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16. Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, August 1966, pp. 17-19; and Digest of FY-65 Funded Advanced Studies, July 1966, pp. 12 and 16.

17. Adv. Sys. Off., Digest of FY-65 Funded Advanced Studies, July 1966, pp. 14-15.

Lunar Surface Instrument Complex Definition (Lunar Drill), two contracts--Northrop Space Laboratories, $510,000; and Westinghouse, $571,000 --both awarded in July;

Human Factors, Visual Simulation, North American, in December, $42,000;

Surface Vehicle Navigation, Bendix, in September, $58,000.

Manned System Criteria for Extraterrestrial Surface Roving Vehicle, Honeywell, in February, $168,000;

Optical Astronomy Package Feasibility Study for AAP, Kollsman Instrument Corporation, in June, $144,000;

Radio Astronomy and Plasma Study for AAP Lunar Surface Missions, North American, in June, $98,000;

Scientific Mission/Instrument Studies, Bendix, in May, $299,000;

Study for Optical Technology--Apollo Extension Systems, two contracts --Perkin-Elmer Corporation, $143,000; and Chrysler, $402,000--both awarded in November with completion scheduled in November 1967.[18]

EARTH-ORBITAL STUDIES

In addition to orbital studies covered in the AAP section of this chapter, MSFC engaged in a variety of other earth-orbital studies, both in-house and through contracts.

Part of a continuing study of orbital launch operations to support manned planetary and lunar missions ended in October 1965. This was the Advanced Orbital Launch Operations (AOLO) study performed by Ling-Temco-Vought. This phase of the AOLO study began in May 1964 and was valued at $228,000. Its general purpose was to develop an operational concept for orbital launch operations.

An Orbital Tanker Design study undertaken in June 1964 by Lockheed was completed in April 1965. The objective of this $221,000 study was

18. Adv. Sys. Off., Advanced Studies Program, October 1966, pp. 45-46; Digest of FY-66 Funded Advanced Studies, August 1967 (Revision), p. 18.

to develop firm conceptual designs of the orbital tanker and prepare a research, development, testing, and evaluation plan.

The Orbital Launch Facility study, by Boeing, began under a $150,000 contract in June 1964 and ended in September 1965. This study was part of an overall orbital launch operations investigation. Purpose of the study was to provide estimates of the design, development, testing, and operating requirements for an orbiting facility which would give needed support in the orbital launch of a manned interplanetary vehicle.[19]

LUNAR STUDIES

Lunar studies, in addition to those covered in this chapter's AAP section, include Scientific Mission Support for Extended Lunar Exploration. North American Aviation received this study contract for $195,000 in December 1965 and was just beginning work on it when the period ended. The study was due for completion in August 1966. The primary objective was to provide an estimate of experimental systems and operational requirements for typical lunar scientific programs.

Awarded to Grumman Aircraft Engineering Corporation in April 1965 was a $77,554 study of Man-System Locomotion and Display Criteria for Extraterrestrial Vehicles. This study was due for completion in February 1966. Its basic objectives were to determine the feasibility of a man-operated maneuverable lunar roving vehicle in both a shirtsleeve and a spacesuited environment.

A Lunar Surface Exploration Equipment study undertaken in August 1965 was an experimental investigation to develop man-system design criteria for lunar scientific equipment. This $58,586 contract by United Aircraft was to define a prototype mission. Completion of the study was planned for August 1966.

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19. Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, August 1966, pp. 13-15.

Development of Tables for Celestial Navigation of the Lunar Surface was the name of a study begun in December 1965 by the University of Virginia. To be completed in January 1967, this study aimed at developing tables for all lunar surface operations including surface vehicle operation, exploration using a lunar flying vehicle, exploration on foot, and for preparation of LEM liftoff for return to the orbiting Apollo spacecraft.[20]

PLANETARY/NUCLEAR STUDIES

A continuing study started in June 1963 and renewed in May 1964 was the Planetary Transportation Systems Model study. In parallel contracts, Martin/Denver and GD/A developed an automated matrix model of planetary transportation systems. An objective of this study was the evaluation of advanced propulsion systems in connection with potential mission requirements. The follow-on contracts completed in February and March 1965 were valued at $49,000 each.[21]

Mission-Oriented Study of Advanced Nuclear System Parámeters, a study project started in June 1963 by TRW Space Technology Laboratories, continued throughout 1965 by contract extensions. Objectives were to identify and define the design requirements for a manned operational nuclear space propulsion system available in the 1970-1980 period. TRW completed one phase of this long-term study in March 1965 and received another extension expanding the scope of work and incorporating additional mission concepts and parameters. Upon completion in March 1966, the study will cost a total of $552,000.

Manned Mars and Venus Exploration was the title of a study contract which MSFC awarded in June 1964 to General Dynamics/Convair. The contractor completed this $200,000 study and published the final report

20. Adv. Sys. Off., Digest of FY-65 Funded Advanced Studies, July 1966, pp. 7-8.

21. Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, August 1966, p. 20.

June 8, 1965. The study examined planetary missions using several modifications of launch vehicles and different types of chemical and nuclear rocket propulsion systems.

A study on Manned Mars Surface Operations, awarded by MSFC to Avco Corporation for $132,000 in July 1964, ended in September 1965 when Avco published results in the final report. The study was concerned with scientific objectives of Mars exploration, including a description of activities, assessment of alternative experiments, determination of engineering support for the exploration, and designation of a brief and an extended Mars mission.

General Dynamics/Fort Worth completed in May 1965 a study of Mission Requirements: Manned Mars and Venus Exploration. This $192,000 study undertaken in June 1964 had as its objective the development of methods of analyzing and evaluating proposed payloads, vehicles, mission modes, and missions.

Another planetary/nuclear study was one concerning Low Acceleration Space Transportation Systems. Under separate contracts awarded in June 1964, United Aircraft Corporation ($85,000) and General Electric Company ($77,000) completed this project in June 1965 and published the final reports. The dual effort was for the purpose of assessing the feasibility of accomplishing manned Mars missions in the 1975-1985 period using a combination of chemical, nuclear rocket, and nuclear-electric propulsion. MSFC extended both these studies during 1965, funding the United Aircraft contract in the amount of $47,000 and the General Electric contract by $142,000. The extended efforts were scheduled to end in April 1966 and July 1966, respectively.[22]

In January 1965 MSFC awarded to Lockheed a $396,920 contract covering a study on Modular Nuclear Vehicles, Technology Problems, and Safety Systems. This study, to be completed in January 1966, was to establish

22. Adv. Sys. Off., Digest of FY-64 Funded Advanced Studies, August 1966, pp. 8-9 and 21-23; and Digest of FY-65 Funded Advanced Studies, July 1966, pp. 9-10.

the overall test program requirements for developmental ground testing of the most probable nuclear rocket stages envisioned for a variety of advanced space missions.[23]

23. Adv. Sys. Off., Digest of FY-65 Funded Advanced Studies, July 1966, pp. 10-11; and Advanced Studies Program, October 1966, p. 34.

APPENDICES

APPENDIX A: SATURN I CHRONOLOGY

JANUARY - DECEMBER 1965

January 5 - An engineering crew at Kennedy Space Center (KSC) completed installation of the ST-124 guidance platform in the SA-9 instrument unit (S-IU-9). The SA-9 launch vehicle, with the exception of the ST-124, had been installed on Pad B of Launch Complex 37 (LC-37B) in November 1964.

January 8 - Chrysler Corporation Space Division (CCSD) moved the S-I-10 stage into Checkout Station No. 1 at the Michoud Assembly Facility (MAF) and began post-static checkout and repair.

January 12 - The launch support crew completed receiving inspection of Pegasus A at the launch site.

January 13 - Technicians at KSC attached Pegasus A, encased in its Apollo service module shroud and adapter, to the S-IV-9 stage in preparation for the scheduled launch.

January 14 - The Apollo BP-16 command module was erected on the SA-9 launch vehicle at LC-37B.

January 21 - The S-IV-10 successfully performed a full-duration static firing of 480 seconds at Douglas Aircraft Company's (DAC's) Sacramento Test Center (SACTO).

February 1 - The S-I/S-IV ordnance installations on SA-9 were completed.

February 12 - Technicians at KSC completed the countdown demonstration test for SA-9.

February 14 - With launch only two days off, MSFC and Fairchild Hiller Corporation (FHC) technicians at KSC modified Pegasus A so that one frame or logic group of the wing panels could serve as a detector for radiation-induced meteoroids.

February 16 - The Saturn I SA-9 vehicle, launched by NASA from KSC, performed excellently during flight and placed Apollo boilerplate spacecraft (BP-16) and the first Pegasus satellite into separate orbits. On an

orbital trajectory having an apogee of 462 miles and a perigee of 308 miles, the functioning Pegasus A satellite exposed 2,300 square feet of instrumented surface to gather meteoroid data, store the information, and transmit it to earth receiving stations.

February 22 - CCSD completed poststatic checkout and repair of the S-I-8 stage and shipped it to KSC aboard the barge Promise.

February 23 - DAC shipped S-IV-8 to KSC from SACTO.

- DAC personnel completed poststatic checkout and repair of the S-IV-10 stage and removed the stage from Test Stand 2B at SACTO.

February 26 - The S-IV-8 stage arrived at KSC.

February 28 - The first industry-produced Saturn I first stage (S-I-8) arrived at KSC from MAF.

March 2 - MSFC shipped the instrument unit for SA-8 (S-IU-8) to KSC.

- Technicians at KSC erected the S-I-8 stage on LC-37B.

March 9 - CCSD completed poststatic checkout and repair of S-I-10 at MAF and stored the stage to await shipment to KSC.

March 17 - KSC technicians at LC-37B erected the S-IV-8 stage and the S-IU-8 atop the S-I-8 stage and began a series of systems tests including radio frequency checks, tanking procedures, and simulated flights.

April 10 - Apollo spacecraft BP-26 arrived at KSC and entered receiving inspection.

April 21 - Pegasus B, second of the micrometeoroid detection satellites, arrived at KSC to be readied for launch.

April 29 - KSC technicians completed the electrical mating of the SA-8 vehicle and payload and started prelaunch checkout.

May 10 - DAC delivered the tenth and last Saturn I S-IV stage (S-IV-10) to KSC aboard the Pregnant Guppy aircraft.

May 24 - The final period of countdown for the SA-8 launch started at 1:55 p.m. EST and, except for a scheduled 35-minute hold, continued uninterrupted to liftoff.

May 25	-	SA-8 performed the ninth successful Saturn I flight test. The vehicle lifted from the launch pad at 2:35 a.m. EST, performed as planned, and accomplished all assigned missions. SA-8 placed in orbit Pegasus B, an improved version of the Pegasus A satellite. Pegasus B operated properly and gathered information on the frequency of meteoroids in the near-earth environment.
May 26	-	The first stage (S-I-10) for the tenth and last Saturn I launch vehicle left MAF aboard the barge Promise to arrive at KSC May 31.
June 1	-	S-IU-10, the final instrument unit for the Saturn I vehicles, arrived at KSC from MSFC.
June 2	-	KSC technicians erected S-I-10 on LC-37B.
June 8	-	The launch support crew at KSC erected the S-IV-10 atop the S-I stage on LC-37B.
June 9	-	KSC technicians erected the S-IU-10 on the SA-10 vehicle and began connecting umbilicals of the launch support equipment.
June 21	-	The Apollo BP-9 service module and service module adapter, modified by MSFC to serve as a shroud for the Pegasus C experiment, arrived at KSC.
	-	To avoid delay of the SA-10 launch and also delay of the planned LC-37B modification, NASA shifted the launch to July 30 ahead of the Gemini V launch.
June 22	-	Fairchild Hiller Corporation shipped the third meteoroid detection satellite, Pegasus C, to KSC aboard Pregnant Guppy aircraft.
June 29	-	The last boilerplate version of the Apollo spacecraft command module arrived at KSC from NASA's Manned Spacecraft Center along with the launch escape system.
July 6	-	Following completion of pre-mating systems checks and panel deployment checks, technicians at KSC attached Pegasus C to the S-IV-10 stage. They then positioned BP-9 as the shroud for the satellite.
July 27	-	The KSC launch crew successfully completed the countdown demonstration test for SA-10.

July 29	-	The final phase of countdown for the SA-10 launch got underway at 9:25 p.m. EST and continued to liftoff without any technical holds.
July 30	-	SA-10, in the final flight test of the Saturn I program, performed excellently. Ten minutes and 40 seconds after the 8 a.m. launch the vehicle inserted its dual payload of Pegasus C and BP-9 into an orbital trajectory. The spacecraft separated from the satellite during the third minute of orbital flight, leaving the satellite free to deploy its panels and begin its mission of gathering meteoroid data.
	-	The SA-10 flight concluded NASA's seven-year Saturn I program, which contributed significant developments to aerospace technology.
In December	-	Preliminary data from the three Pegasus flights indicated that the Apollo spacecraft structure as designed would be adequate to resist meteoroid penetration.

APPENDIX B: SATURN IB CHRONOLOGY

JANUARY - DECEMBER 1965

January 4	-	Two Saturn IB stages slated for use in the dynamic test program arrived at MSFC: the S-IB dynamic test/facilities checkout stage (S-IB-D/F) from Chrysler Corporation Space Division (CCSD), Michoud, Louisiana, and the S-IVB dynamic test stage (S-IVB-D) from Douglas Aircraft Company (DAC), Huntington Beach, California.
January 21	-	The S-IB stage contractor (CCSD) began clustering propellant tanks for S-IB-3 at the Michoud Assembly Facility (MAF).
January 27	-	MSFC completed negotiations with DAC for the remaining eight S-IVB/IB stages and a set of ground support equipment (GSE).
	-	NASA Kennedy Space Center (KSC) awarded R. E. Clarson, Inc., a $2,179,000 contract for Phase II modification of the Launch Complex 34 (LC-34) service structure to support Saturn IB launches.
February 1	-	NASA amended CCSD's S-I/IB contract (NAS8-4016) to include prelaunch checkout support at KSC. This amendment added about $6,320,000 to the cost of the contract.
February 2	-	CCSD at Michoud completed prestatic checkout of the first flight S-IB stage (S-IB-1) and began preparations for shipping it to MSFC for static tests.
February 8	-	MSFC completed assembly of the instrument unit (S-IU-200D/500D) for use in the Saturn IB and V dynamic tests and moved it to the Saturn IB dynamic test tower for installation atop the S-IVB-D stage.
	-	MSFC began the mechanical assembly of the instrument unit (IU) for use in facilities checkout (S-IU-200F/500F).

February 12	-	DAC completed final assembly of the S-IVB facilities checkout stage (S-IVB-500F) and turned the stage over to NASA at Seal Beach, California.
	-	DAC shipped the first flight-weight S-IVB stage (S-IVB-500F) from its Huntington Beach development facility to the Sacramento Test Center (SACTO) aboard the NASA barge Orion. The S-IVB-500F will be used in facilities checkout at SACTO and later at KSC.
February 17	-	Successful arrival of the S-IVB-500F at SACTO verified the water and road transportation methods and routes for the future S-IVB flight stages.
February 18	-	MSFC completed negotiations with International Business Machines Corporation (IBM) on Contract NAS8-14000 covering total component integration, checkout, and shipment of Saturn IB and Saturn V instrument units.
	-	Technicians at SACTO installed the S-IVB-500F in the recently completed Beta test stand 3 and began checkout of the facility with propellant loading tests.
February 24	-	DAC initiated prestatic checkout of the first flight S-IVB stage (S-IVB-201) in Tower 6, Position 9, at the Space Systems Center at Huntington Beach.
February 26	-	CCSD completed assembly of S-IB-2 at MAF and moved it from the assembly area to Checkout Station 2 for prestatic checkout.
In February	-	NASA modified the Rocketdyne Division of North American Aviation (NAA) H-1 engine R&D contract to include uprating the H-1 from 188,000 pounds thrust (188K) to 200K for Saturn IB application.
	-	NASA approved Modification No. 27 to Rocketdyne H-1 engine production contract NAS7-162 converting it from cost-plus-fixed-fee (CPFF) to cost-plus-incentive-fee (CPIF).
March 2	-	MSFC awarded Quinn Construction Company of New Orleans a contract to build an addition to the Central Computer Facility at Slidell, Louisiana. The addition will provide 40,000 square feet to the floor area

of the facility which supports MSFC management operations and S-I/IB and S-IC contractors in the Michoud area.

March 6	-	The S-IB-1 stage left MAF aboard the barge Palaemon for MSFC.
March 14	-	S-IB-1 arrived at MSFC from the contractor's assembly plant at Michoud.
March 15	-	Chrysler technicians placed the S-IB-1 into a static test stand at the MSFC test complex in Huntsville and began readying the stage for static firings.
March 29	-	CCSD test personnel completed the second of two propellant loading tests of S-IB-1 at the MSFC Static Test Tower.
March 31	-	NASA approved award of the Saturn IB/V IU contract to IBM. This contract (NAS8-14000), the first incentive contract to be negotiated in the Saturn IB program, called for IBM to manufacture or procure components (except GFE), conduct component checkout, structural assembly, installation of components, total IU checkout, and packaging of the IU for shipment from Huntsville. IBM will also conduct the post-flight analysis of the IU in support of the total MSFC mission post-flight analysis.
In March	-	Both RCA 110A computers for the Saturn IB Systems Development Facility (SDF) arrived at MSFC.
	-	NASA delineated specific management roles for the Saturn IB/Centaur System to MSFC and Lewis Research Center. MSFC received project management for the Saturn IB/Centaur system and Lewis management of the Centaur systems.
April 1	-	The S-IB-1 performed successfully its first static firing of 35 seconds, with engine cutoff initiated by the control operator.
	-	NASA authorized Rocketdyne to increase the 200K H-1 engine to 205K to support Saturn IB application to even larger missions and also modified the engine contract to include this work.

April 6 - CCSD positioned the S-IB-4 tail unit assembly into the main assembly cluster fixure at MAF and began clustering the propellant tanks.

April 7 - Major General Samuel C. Phillips, Director, Apollo Program, NASA, forwarded to MSFC an amendment to the FY 1965 Research and Development Appropriation authorizing transfer of $5 million to the Saturn IB program for Saturn IB/Centaur design.

April 11 - MSFC awarded the firm of Mason-Rust a new ten-month contract for support services to both government and contractor elements at Michoud during the remainder of 1965. The new contract, a cost-plus-award-fee type, differs from the previous cost-plus-fixed-fee (CPFF) support contract with Mason-Rust in that the contractor's fee is based on an evaluation of his performance rather than a fixed negotiated sum.

April 13 - CCSD test personnel successfully static-fired the S-IB-1 stage a second time at MSFC. The firing lasted 138.21 seconds from ignition command to inboard engine cutoff and 6.8 seconds longer to outboard engine cutoff.

April 15 - DAC completed final inspection of S-IVB-201 at the assembly site prior to readying the stage for shipment to SACTO.

April 20 - Workmen loaded the S-IB-1 stage onboard Palaemon for its return trip to MAF to undergo poststatic modification and checkout.

April 21 - Test engineers conducted a highly successful manual mode cryogenic propellant loading test of the S-IVB-500F in Beta Test Stand 3.

April 22 - MSFC began negotiating with CCSD on an equitable adjustment to Contract NAS8-4016 resulting from NASA's program redirection and termination of six S-I stages. Negotiations would continue throughout 1965.

April 24 - The S-IB-1 stage arrived at MAF from MSFC where it had undergone static tests.

April 29	-	MSFC completed assembly of the S-IU-200F/500F.
April 30	-	DAC technicians initiated prestatic checkout of the S-IVB-202 stage in Tower 6 at the contractor's Huntington Beach Space Systems Center.
	-	The S-IVB contractor loaded the first flight S-IVB stage aboard the NASA barge Orion for shipment to SACTO.
May 1	-	DAC test engineers completed checkout of the Beta 3 Test Stand at SACTO with a successful automatically-controlled cryogenic loading test of the S-IVB-500F.
May 4	-	The S-IVB Battleship stage successfully performed a hot-gimbal, full-duration firing to conclude the Saturn IB Battleship hot-firing test phase.
May 5	-	S-IVB-201 arrived at Courtland, California, aboard the barge Orion. Here it was unloaded and placed on the S-IVB transporter for the remainder of its journey to SACTO.
May 6	-	S-IVB-201 arrived at SACTO and preparations immediately began for positioning it in the Beta 3 Test Stand on the following day.
May 14	-	The S-IVB Battleship stage ended a series of aft environmental temperature conditioning tests to conclude the test program for the Saturn IB configuration. Conversion of the stage to the Saturn V configuration will follow.
May 18	-	MSFC awarded a contract to the Pittman Construction Company of New Orleans, Louisiana, to build a service building at Michoud for use by the support services contractor.
May 19	-	MSFC awarded a one-year contract to Mechling Barge Lines, Inc., Joliet, Illinois, for towing three Saturn barges used to transport Saturn I/IB boosters and the Saturn V booster.
May 27	-	The Saturn IB dynamic test vehicle completed the last of four vehicle configuration tests simulating the four major flight configurations of the IB. This ended the total vehicle test program; upper stage testing of the S-IVB, S-IU, and payload would continue.

In May	-	MSFC authorized DAC to initiate design of support equipment for transporting the S-IVB stage via "Super Guppy" aircraft.
June 12	-	CCSD shipped the S-IB-2 stage from MAF to MSFC.
June 13	-	After arriving at Seal Beach from SACTO aboard the barge Orion the S-IVB-500F stage was transferred to the USNS Point Barrow for its trip to KSC via the Panama Canal.
June 18	-	MSFC completed negotiations with CCSD for the design, development, testing, and provisioning of the mechanical GSE.
June 19	-	S-IB-2 stage arrived at MSFC's Huntsville dock where CCSD and MSFC personnel unloaded it, moved it to the static test tower, and began preparations for its series of acceptance firings.
	-	MSFC shipped the S-IU-200F/500F to Michoud to await reshipment to KSC where it will be used in facilities checkout of LC-34.
June 25	-	NASA announced the appointment of Col. C. H. Bolender (USAF) as Mission Director for the first and second Apollo/Saturn IB flights. Assigned to the Mission Operations Organization in the Office of Manned Space Flight, NASA, Col. Bolender was given overall responsibility for directing the assigned missions.
June 28	-	After investigating ways to reduce the complexity of the Saturn/Apollo on-board communications and tracking systems, MSFC recommended and NASA approved deletion of the MISTRAM transponder and use of the more reliable Azusa "C" as both were not required for program success. Initial plans had called for use of both transponders to satisfy CW radar tracking during the launch powered phase.
June 29	-	The Point Barrow, which left Seal Beach on June 13 with the S-IVB-500F stage and stopped at Michoud on June 26 to unload other cargo, arrived at KSC, the destination for the S-IVB-500F.

In June	-	MSFC began contract negotiations with Rocketdyne for the 22 remaining engines needed for the 12 Saturn IB vehicles.
July 1	-	Conversion of the J-2 engine production contract (NAS8-5603) from CPFF to CPIF became effective on this date.
July 2	-	NASA KSC awarded Blount Brothers Corporation a $6,745,000 contract to adapt LC-37 for Saturn IB.
July 8	-	A faulty signal from an engine pressure switch automatically ended the first attempt to static fire S-IB-2. The test, conducted by CCSD personnel at MSFC's Huntsville Test Facility, lasted only three seconds.
July 9	-	The S-IB-2 stage successfully performed a short-duration (35-second) captive firing in the S-IB stage test stand at MSFC.
July 14	-	S-IVB-201 stage pre-firing checkout, in progress since May 7, ended at the Beta 3 test stand at SACTO.
July 15	-	CCSD assemblymen began clustering propellant tanks for the S-IB-5 stage at MAF.
July 19	-	CCSD completed poststatic modification and checkout of the S-IB-1 stage at Michoud and began preparation for shipping the stage to KSC.
July 20	-	The CCSD-built S-IB-2 stage successfully completed its series of static tests with a 2½-minute full-duration test.
July 27	-	DAC technicians accomplished the first cryogenic loading test of a flight S-IVB stage with S-IVB-201 at SACTO.
July 30	-	The second Saturn IB booster (S-IB-2) left MSFC's Huntsville port aboard the Palaemon barge on its return trip to Michoud. There it would undergo poststatic firing checkout and modification before being transported to KSC for flight.

July 31	-	Component malfunction in Pneumatic Console A at SACTO prematurely ended the first attempt to static fire S-IVB-201. Stage propellant loading and the automatic countdown sequence proceeded satisfactorily to the point of cutoff.
In July	-	Rocketdyne completed the flight rating test of the 200K J-2 engine at the Santa Susana Field Laboratory (SSFL).
	-	DAC completed manual checkout of the Ground Equipment Test Set (GETS) and then initiated automatic tests of the set.
	-	Rocketdyne initiated a development program to uprate the J-2 engine thrust capability from 200K to 230K.
August 7	-	Upon its arrival at MAF technicians began poststatic modification and repair of the S-IB-2 stage.
August 8	-	The S-IVB-201 stage successfully performed a full-duration firing of 452 seconds. The test was computer-controlled throughout, marking the first use of a fully automatic system to perform a complete checkout, propellant loading and static-firing of a vehicle stage.
August 9	-	CCSD shipped the first flight booster, S-IB-1, to KSC. The stage will be used in launch facilities checkout and then readied for flight.
August 14	-	S-IB-1 and the S-IU-200F/500F arrived at KSC aboard the barge Promise from Michoud, Louisiana. The S-IB-1 was the first cargo barged through the new Port Canaveral locks.
	-	CCSD personnel at MAF completed prestatic checkout of S-IB-3.
August 18	-	Workmen at KSC erected the S-IB-1 stage, the S-IVB-500F stage, and the S-IU-200F/500F on LC-34 and began vehicle checkout of the Saturn IB launch facilities.
August 20	-	DAC completed the first phase of S-IVB-202 prestatic checkout at the Huntington Beach Space Systems Center and prepared the stage for shipment to SACTO.

August 25	-	McDowell Wellman Engineering Company completed Phase I modifications to the LC-34 service structure and R. E. Clarson, Inc., completed Phase II modifications to the structure, making it compatible with the Saturn IB configuration.
August 31	-	DAC officially turned S-IVB-201 over to NASA during a ceremony at the SACTO Beta 3 test stand.
September 1	-	The S-IVB-202 stage arrived at SACTO from Huntington Beach.
September 2	-	DAC technicians installed the S-IVB-202 stage on the SACTO Beta 3 test stand and continued stage modification not accomplished at Huntington Beach because of parts shortages and design changes.
September 3	-	DAC transported the S-IVB-201 to the Courtland dock, loaded it on board the Orion and shipped it to Richmond, California, where it was transloaded to the ocean freighter Steel Executive for the rest of its journey to KSC.
September 4	-	NASA modified CCSD's S-I/IB contract in the amount of $4,152,717 to cover design development, testing, and provisioning of the mechanical GSE.
September 9	-	Hurricane Betsy entered the Michoud area about 8 pm, CST, and left severe roof and building damage to MAF. It also washed the NASA barge Promise upon the levee, inflicting barge damage in the amount of $89,138.
	-	NASA barge Palaemon with the Chrysler-built S-IB-3 stage as cargo, weathered Hurricane Betsy near Baton Rouge, Louisiana, without damage during the first day of its journey from Michoud to MSFC in Huntsville.
	-	IBM delivered the flight launch vehicle digital computer and launch vehicle data adapter (LVDC/LVDA) for the SA-201 vehicle.
September 11	-	The upper stage testing in the Saturn IB dynamic test program ended at MSFC.

September 14 - DAC shipped the S-IVB-201 auxiliary propulsion system (APS) modules by truck to KSC following successful module firing tests and poststatic checkout.

September 16 - The S-IB-3 arrived at MSFC's Huntsville port. Chrysler test engineers would static-fire the stage in MSFC's S-IB test stand before returning it to MAF.

- NASA announced selection of Aero Spacelines, Inc., of California, for negotiation of a contract to provide air transportation service for large government cargoes. Under the sole source contract Aero Spacelines will operate the "Super Guppy", the only aircraft in existence which can accommodate such outsized cargoes as S-IVB stages and instrument units and the Apollo Lunar Excursion Module adapter.

September 19 - The S-IVB-201 arrived at KSC aboard the S.S. Steel Executive; it was off-loaded and moved to the Special Assembly Building for receiving inspection.

September 25 - On completion of S-IVB-204 assembly at the Space Systems Center, DAC personnel began the Phase I prestatic checkout of the stage in Tower 6.

September 29 - Vehicle checkout of the Saturn IB LC-34 at KSC ended successfully.

October 1 - The S-IVB flight stage for AS-201 (S-IVB-201) was mated to the S-IB-1 stage on LC-34 at KSC.

- NASA approved a two-year incentive contract with Pratt and Whitney for follow-on RL10 engine research and development, effective this date. The contract covers qualification of the RL10A-3-3 (uprated version) for Centaur application and continued flight support.

October 6 - IBM, during the dedication of its new Huntsville plant, performed a symbolic "turn-over" of the first Saturn IB instrument unit to NASA.

- Workmen at MAF completed buildup of the S-IB-4 stage and the stage entered prestatic checkout.

October 9	-	DAC completed prestatic checkout of S-IVB-203 at the Huntington Beach Space Systems Center.
October 15	-	MSFC awarded two contracts for repair of buildings at MAF damaged by Hurricane Betsy. Tri-State Roofing Company of Knoxville, Tennessee, received a contract to repair roofing damage, and J. A. Jones Construction Company, Charlotte, North Carolina, received a contract to make all other repairs including structural, electrical, and glass damage.
October 20	-	The S-IU-201 arrived at KSC aboard Palaemon and was unloaded and taken to Hangar AF for prelaunch checkout.
October 25	-	Chrylser technicians began clustering propellant containers for the S-IB-6 stage.
	-	Technicians at KSC erected S-IU-201 atop the S-IVB-201 stage on LC-34.
	-	Apollo Command Module 009, part of the payload for the AS-201 vehicle, arrived at KSC and entered checkout.
October 26	-	DAC technicians completed the S-IVB-202 prestatic firing checkout at SACTO.
	-	The S-IB-3 successfully performed a 2½-minute static firing in the S-IB stage static test stand at MSFC in Huntsville.
October 27	-	Apollo Service Module 009 arrived at KSC and entered prelaunch checkout prior to being mated with the AS-201 vehicle.
October 28	-	Rocketdyne delivered to CCSD at Michoud the first two H-1 engines uprated from 200K to 205K. Eight of the uprated engines will add about 40,000 pounds thrust to the S-IB stage and increase the total thrust of the stage to 1,640,000 pounds.
October 29	-	Difficulties experienced with the stage electric power system terminated the first S-IVB-202 acceptance firing attempt.
	-	The S-IVB stage contractor shipped S-IVB-203 to SACTO.

November 2	-	The second S-IVB-202 acceptance firing attempt ended after .41 second of mainstage because of a component malfunction in the J-2 engine combustion stability monitoring system.
November 8	-	S-IB-3 arrived at Michoud from Huntsville to undergo poststatic modification and checkout.
November 9	-	The S-IVB-202 stage performed a long-duration (307 seconds mainstage) acceptance firing; a malfunctioning LH_2 mass sensing unit in the propellant utilization (PU) subsystem prevented completion of the test to full duration.
	-	Prestatic checkout of S-IB-4, completed at MAF on this date, revealed no significant problems.
November 29	-	CCSD technicians completed poststatic functional checkout of S-IB-2 at MAF.
November 30	-	The S-IB-1 underwent an automatic LOX loading test at KSC to verify the automatic LOX loading and replenish systems and the LOX drain systems. The stage received a LOX load of 100 per cent; during the loading all stage systems functioned normally.
	-	CCSD technicians completed assembly of S-IB-5 and moved it into the Checkout Station for prestatic checkout.
December 1	-	The S-IVB-202 stage successfully achieved all test objectives during its full-duration (463.8 seconds mainstage) acceptance firing. Cutoff was inititated automatically when the PU system indicated less than one per cent LOX.
December 7	-	The S-IB-4 stage departed Michoud aboard the NASA barge Palaemon for the MSFC test site at Huntsville.
December 14	-	Workmen unloaded S-IB-4 from the Palaemon barge, moved it to the MSFC static test tower, and completed its installation in the tower.
	-	NASA announced it had renewed a contract with the firm of Mason-Rust for continued provision of support services at MAF during 1966. The renewal increased the cost of the basic contract to $13,121,252.

December 15	-	DAC completed Phase I of the S-IVB-204 prestatic checkout and successfully performed a simulated flight test prior to beginning preparations for shipping the stage to SACTO.
December 17	-	Rocketdyne completed qualification of the J-2 engine at the 200K level.
December 21	-	NASA Headquarters selected The Range Systems Division of Ling-Temco-Vought, Inc., Dallas, Texas, for final negotiations to provide computer support services for MAF. When awarded, the contract will provide operation and maintenance of some 20 digital and analog computers, a data transmission system, a data reduction system, and related electronic equipment.
December 22	-	MSFC awarded a one-year contract to Aero Spacelines, Inc., Santa Barbara, California, for air transportation of large rocket cargoes in its Super Guppy aircraft. The contract, estimated at $1.6 million, provides for three one-year renewal options and also provides for a previous NASA-Aero Spacelines contract for use of the firm's smaller Pregnant Guppy craft.
December 26	-	Technicians at KSC erected Apollo Spacecraft 009 atop the SA-201 launch vehicle at LC-34. With the addition of the spacecraft the vehicle became the Apollo Saturn 201 (AS-201).
December 30	-	NASA increased CCSD's S-I/IB contract some $18,909,000 to cover additional systems engineering.
In December	-	MSFC initiated negotiations with Rocketdyne on a combined J-2 R&D and production incentive contract.
	-	MSFC and Rocketdyne entered negotiations to convert the H-1 R&D contract NAS7-190 from a CPFF to a CPIF contract.
	-	CCSD began preparations for shipping the S-IB-2 stage to the KSC launch site.
	-	CCSD completed clustering the propellant tanks for the S-IB-6 stage.

APPENDIX C: SATURN V CHRONOLOGY

JANUARY - DECEMBER 1965

January 29 - MSFC awarded to Dortech, Inc., a $1.3 million contract to build three of the seven S-IC stage transporters.

January 31 - Workmen at Seal Beach, California, completed assembly of S-II-S five days ahead of schedule.

In January - Aero Spacelines informed MSFC that it would continue the "Very Pregnant Guppy" project on its own pending formal NASA approval.

- NASA's West Coast barge, Orion, underwent sea trials and practice loading operations following its conversion from a Navy YFNB.

February 1 - MSFC announced these major revisions in the S-II stage program: cancellation of the dynamic test stage (S-II-D); substitution of the structural static test stage (S-II-S) as a dynamic stage; transfer of the all-systems test stage (S-II-T) from Santa Susana to Mississippi Test Facility (MTF); assignment of the facilities checkout stage (S-II-F) directly to Kennedy Space Center (KSC); and scheduling of an end to the Electro-Mechanical Mockup (EMM) test program.

- MSFC established an interim Configuration Control Board to process engineering changes to Saturn V contracts.

- MSFC awarded to Avondale Shipyard Corporation at New Orleans, Louisiana, a $770,000 contract for conversion of the 260-foot barge YFNB 40, later named Poseidon.

February 3 - Manufacturing Engineering (ME) Laboratory personnel at MSFC moved the fuel tank bulkhead subassemblies for the first flight stage (S-IC-1) into the Vertical Assembly Building (VAB).

February 8 - S-IU-200F/500F mechanical assembly began at MSFC.

- The Corps of Engineers, NASA's construction agent, awarded a $4.3 million contract for S-II Stage Service and Checkout Building and Cryogenic Barge Service Building at MTF.

- MSFC workmen complected assembly of the S-IU-200D/500D,

February 12	-	The barge Orion departed Seal Beach for Sacramento on its first mission as a member of the Saturn fleet.
February 17	-	The S-IVB-500F arrived at Sacramento Test Center (SACTO) and installation began in Beta 3 Test Stand.
February 18	-	NASA completed negotiations with International Business Machines Corporation (IBM) on Contract NAS8-14000 for the Saturn V Instrument Unit (IU).
February 19	-	The aft section of S-IC-S was moved from the ME Lab to Load Test Annex and turned over to the Boeing Company for test preparations.
In February	-	A $1.2 million contract was awarded to Quinn Construction Company, Inc., for expansion of the Central Computer Facility at Slidell, Louisiana.
	-	Workmen completed the brick-and-mortar portion of the J-2/S-IVB Test Facility at MSFC.
	-	Hayes International Corporation completed fabrication of the Instrument Unit shipping container at its Birmingham facilities.
	-	Installation of the RCA 110A ground computer acoustical test unit occurred at Wyle Laboratories, Huntsville.
	-	North American Aviation's Space and Information Systems Division (S&ID) began the fabrication of major structural subassemblies for the first flight stage, S-II-1.
	-	Automatic checkout equipment fabrication for EMM activation ended at Downey, California.
March 1	-	S-IC-T, ahead of schedule, rolled out of ME Lab., moved to the static test stand, and was erected in the stand.
March 2	-	MTF awarded to Blount Brothers Corporation a $4.7 million contract for construction of S-IC Test Position B-1.
March 10	-	MSFC approved IBM contract NAS8-14000 and sent it to NASA Headquarters for approval.
March 11	-	IBM delivered to MSFC the Launch Vehicle Data Adapter (LVDA) Breadboard No. 1.
	-	NASA approved the Boeing Saturn V ground support equipment (GSE) mission contract.

March 12	- A $3.2 million contract for the Components Service Facility was awarded at MTF to Mike Bradford and Company, Inc.
March 15	- S-IU-200S/500S arrived at the MSFC structural test facility.
	- Bendix Corporation delivered the first ST-124M platform to MSFC.
March 23	- Assembly of S-IC Transporter 103 was completed at MSFC.
March 24	- S-IC-D thrust structure was installed in the VAB at Michoud Assembly Facility (MAF).
March 26	- NASA and Boeing signed a supplemental agreement incorporating a new Saturn V delivery schedule called Plan VIII.
March 29	- Workmen at MSFC began structural fabrication of the vibration test IU for the Saturn V.
March 30	- The mechanical support equipment (MSE) amendment to the Boeing/MSFC contract for GSE was approved by NASA Headquarters.
	- MSFC workmen completed structural fabrication of the S-IU-500FS and began mechanical assembly.
March 31	- NASA gave final approval of the IBM instrument unit prime contract, and IBM assumed its contract responsibilities.
In March	- Propulsion and Vehicle Engineering (P&VE) Laboratory began using the new Load Test Annex.
	- S-IC-S forward assembly was delivered to P&VE Lab. and stored to await future tests.
	- Modernization of the two engine test positions was completed at Santa Susana Field Laboratory's (SSFL's) Vertical Test Stand 3 in the Bowl Area.
	- MSFC Test Laboratory personnel were assigned to monitor the Very Pregnant Guppy development program.
	- Work started on the main wing of the Central Computer Facility at Slidell, Louisiana.

April 6	- MSFC's Quality and Reliability Assurance Laboratory accepted the installation of the RCA 110A system for the S-IU-500FS checkout.
April 9	- The MSFC S-IC Test Stand became operational with the first firing of S-IC-T.
	- The first single-engine S-IC-T firing ocurred at MSFC.
April 10	- The functional integration of all automatic checkout stations, a major Electro-Mechanical Mockup milestone, was completed at Downey.
April 16	- The first S-IC-T five-engine test occurred two months ahead of schedule, lasting 6.5 seconds.
April 21	- MSFC amended Dortech's contract to include a fourth S-IC transporter, No. 107.
April 24	- S&ID personnel performed the first S-II Battleship cluster ignition test at SSFL.
April 29	- S-IU-200F/500F component assembly ended at MSFC.
April 30	- During the final test of S-II-S at Seal Beach, a failure occurred which seriously damaged the stage.
In April	- NASA modified the Boeing contract to provide engineering services and instrumentation for the Saturn V dynamic test program.
May 1	- S-IVB-500F stage and facility checkout ended at SACTO.
	- Avondale Shipyard Corporation completed modification of the YFNB 45, renamed Pearl River.
May 8	- Avondale Shipyard Corporation completed conversion of the shuttle barge for KSC.
May 10	- The S-IC-1 moved to horizontal assembly area of ME Lab.
May 17	- MSFC submitted to the NASA Office of Manned Space Flight (OMSF) for approval the procurement plan for nine additional Saturn V S-IVB stages.

May 24	- S&ID workmen at Seal Beach completed assembly of the Common Bulkhead Test Tank (CBTT).
	- Derrick acceptance was completed on the Saturn V Dynamic Test Stand.
May 25	- Vertical assembly of the S-II-T, in progress at Seal Beach since February, was completed.
In May	- The Saturn V GSE Test Facility was finished at MSFC.
	- MSFC and Rocketdyne Division of North American Aviation, Inc., completed negotiations for conversion of the J-2 contract to an incentive type.
	- MSFC extended the Pregnant Guppy contract, valued at $1.6 million for the year, to June 30, 1966.
	- Technicians at SACTO began conversion of the S-IVB Battleship Stage from the Saturn IB to the Saturn V configuration.
	- S&ID began structural assembly of the S-II-2 at Seal Beach.
	- Activation of the electro-mechanical mockup was completed at Downey.
June 1	- The Navy AKD Point Barrow was officially made available to NASA.
June 3	- The Common Bulkhead Test Tank arrived at Santa Susana for testing.
	- A contract was awarded for modifications and additions to the Saturn V Dynamic Test Stand at MSFC.
June 10	- Assembly of the S-IU-200S/500S-II structural segments began at IBM in Huntsville.
	- The S-IVB-500F departed SACTO for KSC.
June 13	- Point Barrow was placed into service when it departed Seal Beach carrying the S-II simulator and the S-IVB-F to MAF and KSC.
June 14	- MSFC workmen completed structural assembly of S-IU-500V.

June 14	- Vibration and other acoustical testson the RCA 110A system continued at Wyle Laboratories.
June 15	- Workmen at MSFC completed component assembly of the S-IU-500FS.
June 16	- Final assembly of the S-IC-D aft and forward sections ended at MAF.
June 18	- Technical systems installation began on the MSFC Saturn V Dynamic Test Stand.
June 19	- MSFC shipped the completed S-IU-200F/500F by barge to MAF.
	- Test personnel at SACTO attempted the first Saturn V development firing of the S-IVB battleship; the test ended after seven seconds because of an automatic cutoff.
June 21	- In its last captive-firing condition test at MSFC S-IC-S withstood 140 per cent of the design load.
June 27	- The S-IC-D emerged from the assembly tower at MAF.
June 28	- The S-II simulator and accompanying equipment was unloaded and stored at MTF.
June 30	- S-IVB-500F arrived at KSC for use in facilities checkout of Launch Complexes 34, 37, and 39.
	- The entire Saturn V Road, from MSFC manufacturing and checkout areas to the Barge Dock and Loading Facility on the Tennessee River, opened for travel.
In June	- Welding of the S-IC-3 LOX tank and fuel tank subassemblies was completed at MAF.
	- The RCA 110A completed vibration and acoustical testing at Wyle Laboratories and moved to Astrionics Laboratory for installation.
	- Brick-and-mortar work on all four test cells of the MAF Stage Test and Checkout Facility was complete.
	- MSFC took beneficial occupancy of the Components Test Facility at Huntsville.

In June	- Technical systems installation was completed on the MSFC J-2/S-IVB Test Facility.
	- S&ID technicians at Seal Beach began assembly of S-II-3, the third flight stage.
July 1	- During the third firing of the S-IVB Battleship stage (Saturn V configuration) at SACTO an explosion occurred and caused a fire that damaged wiring and instrumentation.
	- The completed LOX tank for the S-IVB-502 stage was undergoing leak and proof testing at Huntington Beach.
July 5	- VAB low bay beneficial occupancy occurred at KSC's Launch Complex 39.
July 6	- Workmen began vertical buildup of the S-II-1 at Seal Beach.
July 8	- The CBTT was installed and checkout completed at SSFL.
	- The F-1 Engine Test Stand at MSFC became operational with its first engine test.
July 13	- A 27-second S-II Battleship firing took place at SSFL.
July 16	- The S-IC-F fuel tank moved to final assembly at MAF.
July 20	- Technicians performed a static test of the S-II Battleship at SSFL for 150 seconds duration.
July 23	- RCA 110A Unit No. 1, designated SDBF/LCC (Launch Control Center), became operational at MSFC.
July 29	- RCA 110A Unit No. 2 was installed at MSFC.
July 31	- Avondale completed rework of the YFNB 38, renamed Little Lake, for MTF/MAF.
In July	- Installation of a high-pressure helium system completed all scheduled construction of the Electro-Mechanical Mockup at Downey.
	- The contractor completed basic contruction of the Acoustic Model Test Facility at MSFC.

In July	- Rocketdyne initiated a J-2 230K engine development program.
	- Rocketdyne completed the flight rating test (FRT) series for the J-2 engine at SSFL.
	- Two barge-mounted cryogenic tanks, the first of nine to be modified from surplus Army barges, arrived at MTF.
	- S&ID selected Wyle Laboratories at Huntsville as the test agency for the S-II High-Force Test Program.
	- Brown Engineering Company received a $3.6 million contract covering nine digital control equipment systems.
August 2	- MSFC personnel conducted the first successful ignition test of the MSFC S-IVB Battleship for 2.1 seconds.
	- Activation of the J-2/S-IVB Test stand was completed with the first firing of the MSFC S-IVB Battleship.
August 5	- The first full-duration run of S-IC-T (for 143.6 seconds) occurred at MSFC.
August 9	- S&ID at SSFL accomplished a full-duration S-II Battleship cluster firing which was terminated manually after 385.6 seconds.
August 13	- Boeing workmen at MAF began final assembly of the S-IC-4 thrust structure.
	- The structure of the S-IU-200S/500S withstood 140 per cent limit loads at MSFC, proving its structural integrity.
	- The S-IU-200F/500F arrived at KSC.
August 14	- Further static test on S-II-S stage at Seal Beach caused buckling of the forward skirt.
August 16	- Vertical buildup of the S-II-F stage ended at Seal Beach.
August 17	- The first two-burn full-duration firing of the S-IVB battleship lasted 170 and 320 seconds, respectively, at SACTO.
August 19	- Workmen completed component assembly of the S-IU-500V at Huntsville.

August 20	-	The Saturn V S-IVB battleship test was concluded with a two-burn test for 170 and 360 seconds at SACTO.
August 25	-	Horizontal assembly operation of S-IC-D stage ended at MAF.
	-	Technical systems installation and checkout of the J-2/S-IVB Test Facility at MSFC was completed.
August 31	-	The new aircraft Super Guppy performed its maiden flight test at Mojave, California.
In August	-	The Vehicle Components Building at MAF suffered severe damage when the roof collapsed in a heavy rainstorm.
September 1	-	MSFC completed and disseminated the revised Saturn Stage Transportation Plan.
September 2	-	MSFC and Radio Corporation of America (RCA) completed the negotiations for the RCA 110A logistics and maintenance effort (Contract NAS8-15496).
September 8	-	The S-IVB Battleship was removed from Beta I stand at SACTO and shipped to Tullahoma, Tennessee, for engine environmental testing.
September 9	-	Hurricane Betsy caused heavy damage to MAF buildings and equipment.
September 10	-	IBM at Huntsville accepted the RCA 110A that was delivered August 24.
September 15	-	The S-IVB battleship at MSFC fired for 400 seconds, a full-duration test.
	-	Wyle Laboratories, Huntsville, began vibration testing of the S-IU-500V.
September 19	-	S-IC-2 stage horizontal assembly started at MSFC.
September 21	-	MSFC and DAC began negotiations to convert the S-IVB contract from cost-plus-fixed-fee (CPFF) to cost-plus-incentive-fee (CPIF).
September 24	-	The aft skirt needed for conversion of the S-IVB-D stage to the Saturn V configuration left Seal Beach on the Point Barrow.

September 25	-	A flight test accident at Mojave damaged the nose section of the Super Guppy aircraft.
September 27	-	MSFC personnel completed S-IC-1 horizontal assembly and transferred the stage to Quality Laboratory.
September 29	-	During ultimate load testing at Seal Beach the S-II-S stage ruptured and disintegrated at approximately 138 per cent limit load, thus demonstrating optimum design and verifying the structural integrity of the stage.
September 30	-	MSFC technicians completed checkout of the S-IU-500FS ground equipment test set.
	-	IBM completed fabrication of the S-IU-200S/500S-II at Huntsville.
	-	All manufacturing was completed at Seal Beach on the S-II-T stage.
In September	-	NASA modified the Boeing contract by $4.5 million to provide services in connection with systems engineering and integration of mechanical GSE.
	-	Workmen at Seal Beach began assembly of the fourth flight stage, S-II-4.
October 1	-	The S-II-T stage left Seal Beach aboard the AKD Point Barrow.
October 8	-	The first S-IC-T firing in automatic configuration occurred at MSFC for a scheduled duration of 45 seconds.
October 11	-	A J-2 engine replaced an earlier model on the MSFC Battleship stage.
October 12	-	The contractor finished construction of the Alpha I stand at SACTO.
October 13	-	The S-IC-D arrived at MSFC's Saturn V dock after leaving the MAF dock aboard the barge Poseidon October 6; this was the Poseidon's first trip.
October 14	-	Dortech delivered the S-IC Transporter 104 to MAF.

October 15	-	S&ID technicians at Seal Beach completed the thrust structure of S-II-2 stage.
	-	Technicians at MSFC began Saturn V dynamic testing of the S-IU-200D/500D.
October 17	-	The S-II-T arrived at MTF.
October 19	-	Workmen installed the S-II-T in Test Stand A-2 at MTF.
In October	-	MSFC awarded a $726,000 contract for three additions to the P&VE Lab's Materials Division Laboratory.
	-	Construction of LC-39 Pad A ended at KSC.
	-	ME Laboratory's Building 4755 became available for beneficial occupancy.
	-	The Clermont, first gas turbine-powered tugboat ever built, was delivered to MTF.
	-	The S-II simulator, after completing its mission at MTF, returned to Seal Beach aboard the Point Barrow.
November 1	-	S-IC Transporter 105 arrived at MAF.
November 2	-	The aft skirt of the S-IVB-500D arrived at MSFC.
November 3	-	Beta I Test Stand at SACTO was activated with installation of S-IVB-203.
November 6	-	The final scheduled test of the CBTT program ended successfully at SSFL.
November 7	-	The RCA 110A for Launch Control Center Firing Room 1 arrived at KSC.
November 8	-	North American Aviation shipped S-IU-501 structural segments to IBM/Huntsville.
November 12	-	Rocketdyne completed three of the four phases of F-1 engine testing called for in the engine development contract.
November 15	-	DAC workmen at Huntington Beach completed joining of S-IVB-501 stage structural components.

November 19	-	S-IC-F moved to a system test cell at MAF for post-manufacturing checkout.
November 22	-	S-IC Transporter 106 was delivered to MAF.
	-	Post-manufacturing checkout began on the S-IVB-501 Stage at Huntington Beach.
November 23	-	A facility inspection cleared the way for the start of preparation for installation of S-IC-D into the Dynamic Test Stand at MSFC.
November 29	-	Technicians at Huntington Beach completed installing engines of the S-IVB-501 stage.
In November	-	All engine deliveries for the S-II-1 and S-II-2 were completed at Seal Beach.
	-	The Super Guppy resumed flight tests in California following repairs.
	-	NASA announced that the J-2 production contract would be amended to add 48 engines. NASA also asked Rocketdyne to provide 52 additional J-2 engines for delivery in 1967 and 1968.
	-	An addition to the GSE Test Facility at MSFC was nearly enough complete to start technical systems installation.
	-	Steel erection on the LC-39 Mobile Service Structure was completed at KSC.
	-	The first VAB high bay was occupied at KSC.
December 3	-	MSFC and Boeing negotiated the supplemental agreement establishing Schedule III (Saturn V launch operations support) effective December 31, 1965.
December 6	-	S-IU-500FS moved from ME Laboratory to Quality Laboratory.
December 8	-	Personnel at MAF completed vertical assembly of the S-IC-3 stage and moved the stage to the horizontal assembly area.
	-	Final assembly began on the S-IC-5 thrust structure at MAF.

December 11	-	MSFC technicians completed installation of five F-1 engines on the S-IC-2 stage.
December 14	-	ME Laboratory delivered the completed S-IU-500FS to Quality Laboratory at MSFC.
December 15	-	The RCA 110A unit for Mobile Launcher 1 was delivered to KSC.
December 17	-	Qualification testing of the J-2 engine at the 200,000-pound-thrust (200K) level, which began on December 2, ended successfully at SSFL.
	-	Technicians at Seal Beach completed assembly of the common bulkhead of the S-II-2 stage.
December 18	-	Workmen at SSFL completed conversion of the S-II Battleship and facility for flight configuration firings.
December 28	-	S-II-1 Stage vertical buildup was achieved at Seal Beach.
December 29	-	MSFC forwarded to NASA Headquarters for approval a supplemental agreement providing for conversion of the Boeing S-IC stage contract to to CPIF; the cost-effective date of this change was July 2.
December 30	-	P&VE Lab. started the first series of S-IU-200S/500S-II tests.
In December	-	The MSFC Test Support Shop addition was completed.
	-	Two F-1 turbopump explosions occurred--one at SSFL and one at Edwards.
	-	Technicians began to prepare for removal of S-IC-T from the test stand at MSFC.
	-	MSFC awarded to Aero Spacelines a one-year $1.6 million contract covering services of the Super Guppy and providing for an extension of Pregnant Guppy services.
	-	Sanders Associates, Inc., delivered a two-display operational console system to MSFC.

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