Chapter 3

Operations Procedures

CONTENTS

Page

The Titan 34D and Titan IV 31
Launch Operations—Cape Canaveral 35
Launch Operations—Vandenberg Air Force Base ..,... 39
The Space Shuttle 39
Payload Processing 40
Pre-launch Processing, ... 41
Mission Operations 47
Post-launch Processing. 47

Boxes

Box *Page*

3-A. Titan 34D and Titan IV Launch Systems 33
3-B. The Space Shuttle Launch System 41

Figures

Figure *Page*

3-I. Overview of Vandenberg Titan Launch Facilities 31
3-2. Kennedy Space Center Payload Facilities 32
3-3. Titan 34D Launcher 34
3-4. Titan IV Launcher 34
3-5. Geosynchronous Orbit 34
3-6. High Inclination Orbit 35
3-7. Typical Titan Receipt-to-Launch Flow 36
3-8. Typical Titan Launch Schedule, Cape Canaveral. 37
3-9. Titan Integrate/Transfer/Launch 37
3-10. Titan 34D Checkout and Launch Control Equipment 38
3-11. Launch Complex 40 39
3-12. Orbiter Ground Turnaround Operations 40
3-13. The Orbiter Challenger Rests on the Mobile Launcher at Pad 39A With the Rotating Service Structure Containing the Payload Canister Moved Back From the ShuttIe (January 1983) 40
3-14. Space Shuttle Payloads Processing Classifications 42
3-l5. Payload Processing Flows at the Kennedy Space Center 43
3-16. Kennedy Space Center Space Shuttle System Ground Flow.... 44
3-17’. Orbiter Ground Turnaround Experience 45
3-18. Aerial Photograph—Important Facilities at Kennedy Space Center 46
3-19. The Orbiter Columbia, Undergoing Launch Processing for Its Second Voyage Into Space, Is Gently Lowered Toward the Solid Rocket Boosters and External Tank for Mating (August 1981) 47
3-20. The Space Shuttle Columbia Begins Its Roll Up the Ramp to Pad 39A After Completing the 3% Mile Journey From the Vehicle Assembly Building (September 1982). 48
3-21. The Space Shuttle Challenger Lifts Off in the First Nighttime Launch of the Shuttle Era (August 1983). 49

Table

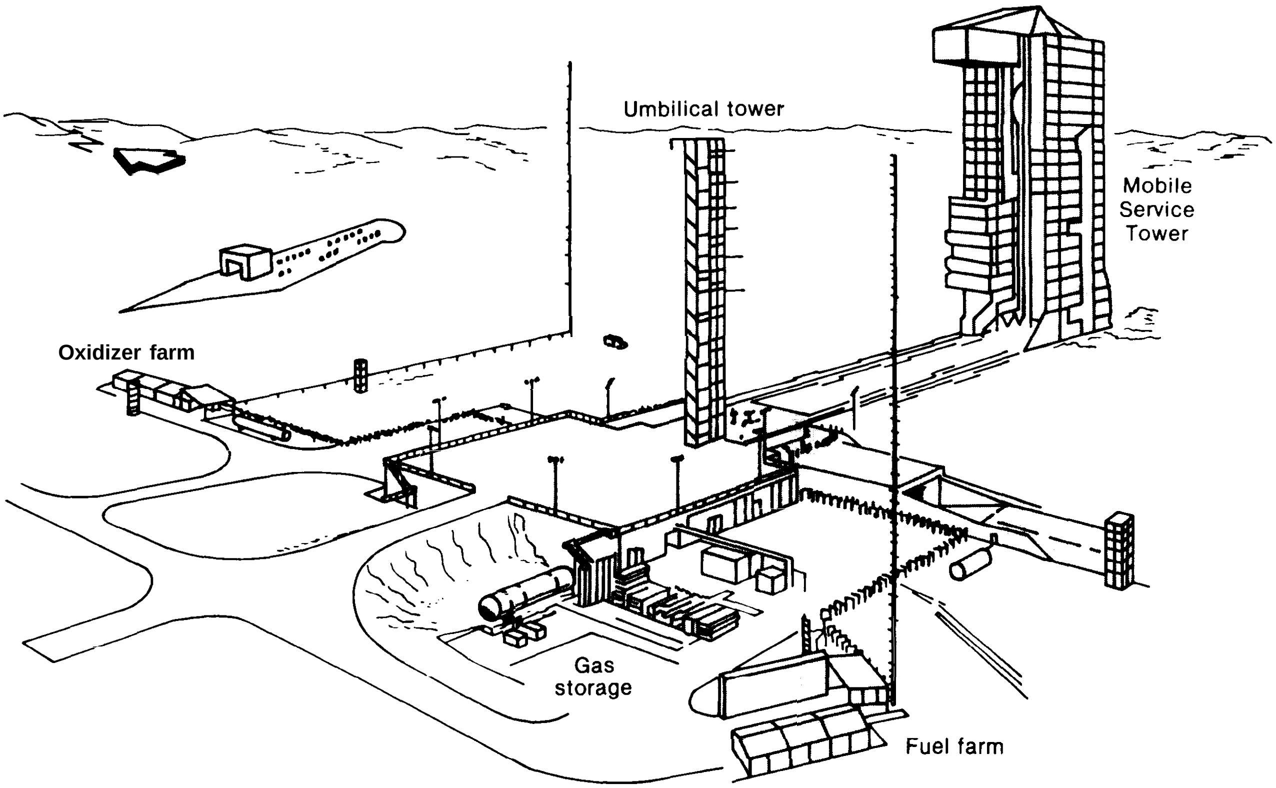
Table *Page*

3-1. Shuttle Mission Operations Functions. 49

Chapter 3
Operations Procedures

Existing operations, which are enormously varied and complex, offer important lessons for the design of future vehicles. Launch operations includes all the resources required to maintain and launch space vehicles, including unique facilities, specialized equipment, computer systems, scheduling, documentation, personnel, and management techniques (fig. 3-1; 3-2). Mission operations includes all activities associated with planning and executing a mission—flight planning, documentation, mission support, and training. This chapter summarizes operations procedures and schedules as they are currently followed for the Titan and the Shuttle.

Figure 3-1.—Overview of Vandenberg Titan Launch Facilities



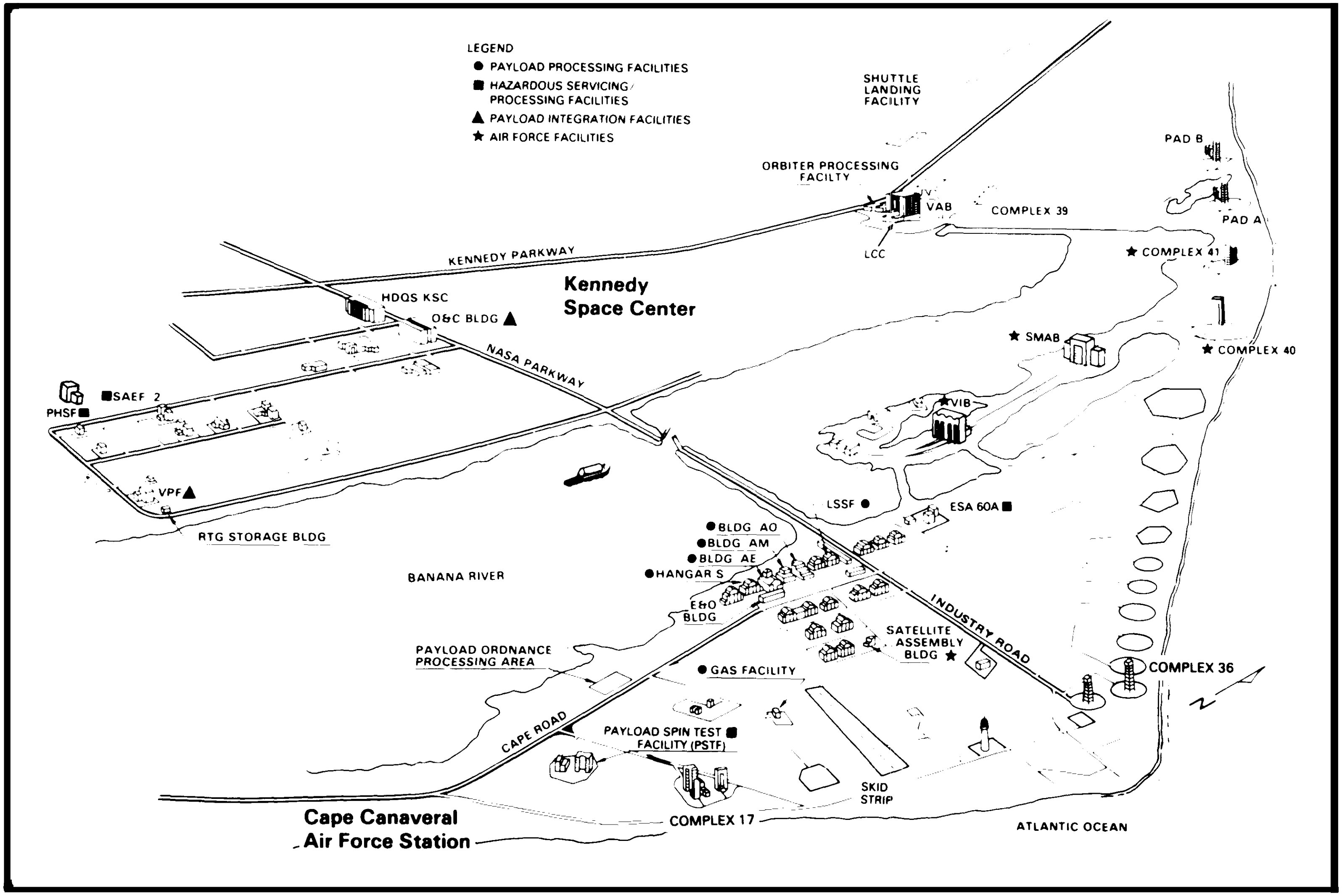
SOURCE: Aerospace Corp.

THE TITAN 340 AND TITAN IV

The Titan 34D (fig. 3-3; box 3-A), an expendable launch vehicle which evolved from the Titan II intercontinental ballistic missile,[1] is one of several models of the Titan III launcher the Air Force developed to launch a variety of military and civilian spacecraft. In January 1988, the Air Force took delivery of the first Titan IV launcher (fig. 3-4; box 3-A), which is larger and delivers a heavier payload to orbit than the Titan 34D.

[1]A crew-rated version of the Titan 11 served as the launch vehicle for the Gemini program of the early 1960s.

Figure 3-2.—Kennedy Space Center Payload Facilities



SOURCE: National Aeronautics and Space Administration.

Box 3-A.—Titan 34D and Titan IV Launch Systems

The Titan 34D Vehicle

The Titan 34D is an expendable launch vehicle developed by Martin Marietta Corporation under contract with the Air Force. It is capable of launching up to 4,000 pounds of payload into geosynchronous orbit, or 30,000 pounds of payload into low earth orbit (LEO), and is now available commercially. * It consists of a two-stage liquid-fuel rocket core vehicle, which carries the payload, and two strap-on solid-fuel rocket motors.[2]

The solid-fuel rocket motors,[3] which are 122 inches in diameter and *90.4* feet long, develop about 1.4 million lb. thrust each. They are similar in construction to the solid-fuel rocket boosters for the Shuttle (though they rely on a different design for the seals between segments), and are built up of 5 individual segments.

The Titan IV Vehicle

The Titan IV expendable launch vehicle is the latest in the Titan family of launch vehicles. Developed by Martin Marietta Corporation under contract to the Air Force, the Titan IV uses the same fuels and subsystems as its sister vehicle, and provides the lift and cargo capability of the Space Shuttle. It is capable of launching 10,000 pounds of payload into geosynchronous orbit, or *39,000* pounds into low earth orbit, using the Centaur upper stage.

The overall design is similar to the Titan 34D but its core vehicle has been lengthened approximately *20* feet to carry more liquid propellant. The solid rocket motors have been increased to seven segments. Recently, Martin Marietta selected Hercules Aerospace Co. as an additional supplier of solid rocket boosters for the Titan IV.[4] These boosters will provide a **25** percent increase in payload capacity, The Air Force and Martin Marietta have developed three major versions of the Titan IV: a No Upper Stage (NUS), an Inertial Upper Stage (IUS), and a Centaur Upper Stage (Centaur).

Generic Titan Systems

The valves, ignition system, guidance system, and all the other systems aboard both launchers are controlled either by avionics located in the second stage of the core vehicle, or by telemetry from the ground. Guidance signals for the avionics complement are generated in the upper stages. The launch complexes and associated facilities are similar for both vehicles; they differ primarily in size.

Typically, a Titan 34D launch costs about $90 to $110 million including launch services. Launch services account for 12 to 20 percent of the total cost, depending on the extent and complexity of services required. A Titan IV launch costs $120 million, including launch services.

I In 1987, Martin Marietta formed a subsidiary corporation, Commercial Titan, Incorporated to market Titan launch services. Martin Marietta has negotiated with the Air Force to use launch complex 40 at Cape Canaveral (for a fee) for commercial launches. Andrew Wilson, "Titan Grows Stronger, " SPACE, vol. 3, pp. 8-11, 1987.

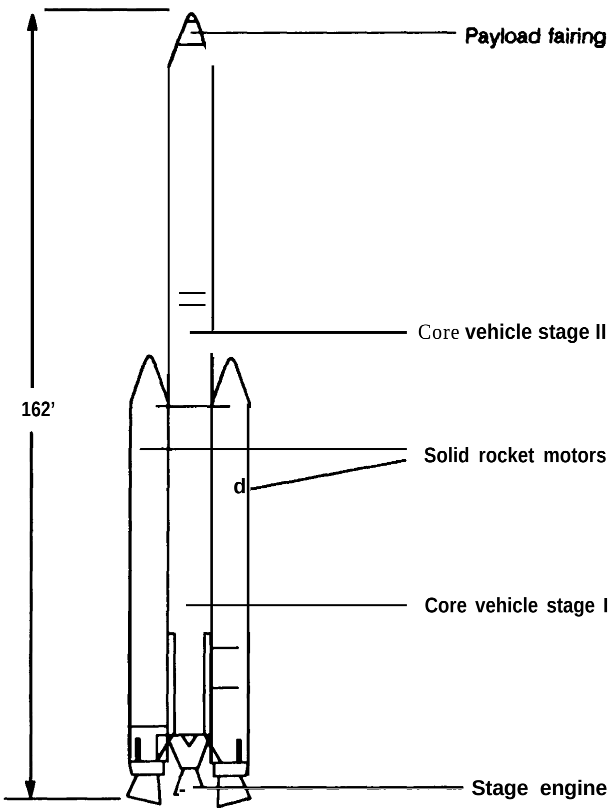
[2]Built by Chemical Systems Division, United Technologies Corp. It supplies similar, larger solid rocket boosters for the Titan 4.

The propellant in the core vehicle is hyperbolic, meaning that the fuel (Aerozine-50) and the oxidizer (nitrogen tetroxide) ignite on contact and therefore need no ignition system; at the right moment during the countdown, computers at the launch control center direct fuel valves to open, allowing the two fluids to mix. Turbopumps feed the liquid fuel engines, which are hydraulically gimbaled for steering.

[3]The propellant is a mixture of powdered aluminum, ammonium perchlorate, synthetic rubber, and various additives. The recent explosion at one of the Nation's two ammonium perchlorate plants has caused a severe shortage of the chemical for boosters.

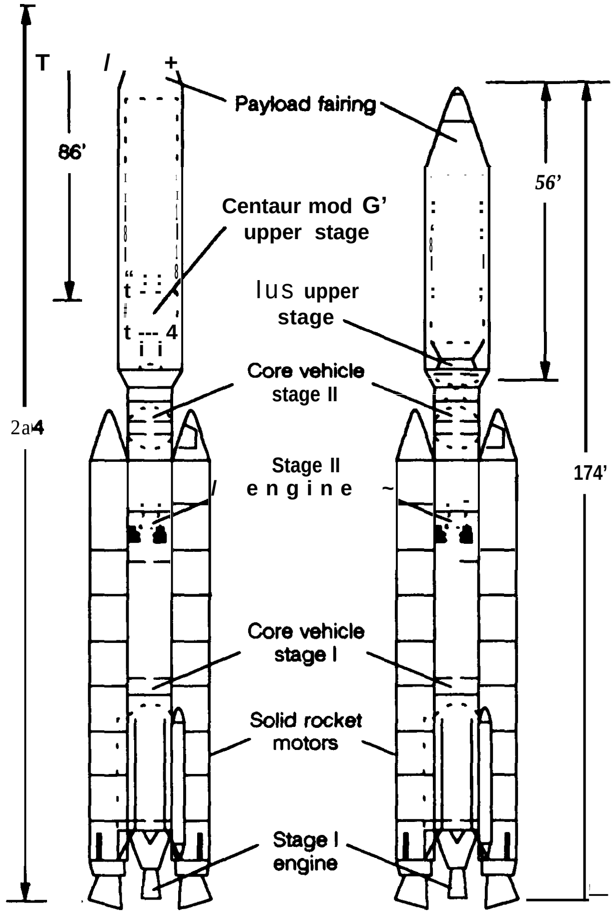
[4]See "Hercules Wins Contract for Titan 4 SRM Work, " *Aviation Week and Space Technology*, Oct. 26, 1987, p. 31.

Figure 3-3.-Titan 340 Lsuncher



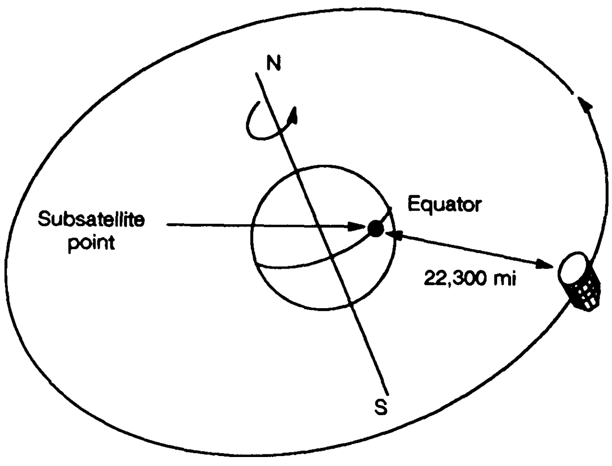
SOURCE: Martin Marietta

Figure 3-4. -Titsn IV Lsuncher



SOURCE: Martin Marietta.

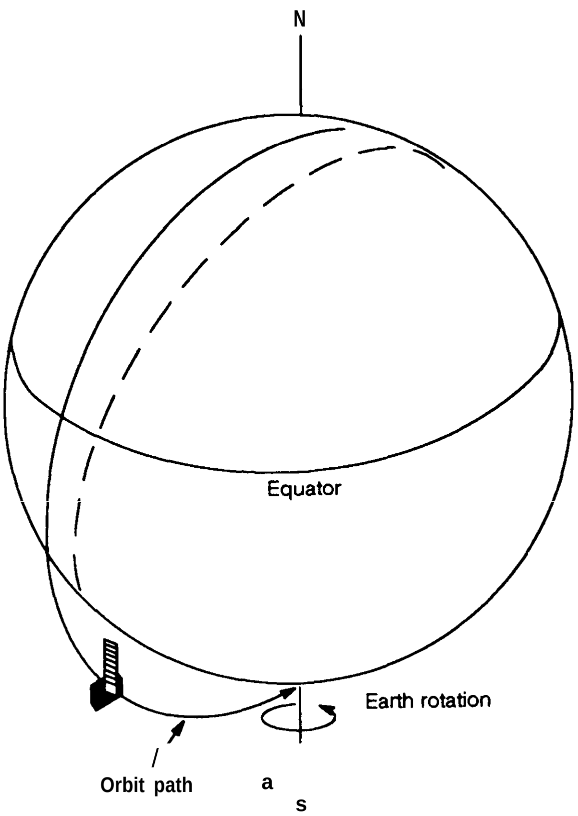
Figure 3-5.-Geosynchronous Orbit



SOURCE: Office of Technology Aaseaament, 19SS

The Air Force maintains two Titan launch complexes at Cape Canaveral Air Force Station, Florida, and two at Vandenberg Air Force Base, California. As the result of their geographical location at 28° north latitude, the East Coast launch complexes are used for launching payloads toward the East into low inclination and geosynchronous orbits (fig. 3-s). The West Coast launch complexes are used for launching payloads south into high inclination orbits, such as sun-synchronous, polar orbits (fig. 3-6).

Figure 3-6. - High Inclination Orbit



SOURCE: Office of Technology Assessment, 1988

Launch Operations—Cape Canaveral[2]

Contractors’ assemble and prepare the launch vehicle and payloads, monitored by Air Force personnel (figs. 3-7 and 3-8). At Cape Canaveral, the launcher is prepared and launched following a modified integrate-transfer-launch procedure (ITL),[4] in which the launch vehicle is assembled in the Vertical Integration Building and Solid Motor Assembly Building, and wheeled out to the launch complex on a transporter (fig. 3-9). Other procedures, such as stacking of the solid rocket motors, can be carried out in parallel while the core vehicle is assembled and tested. This technique minimizes the amount of time the vehicle must remain on the launch pad.

At Cape Canaveral, the ITL concept makes it possible to sustain about four Titan launches per year from each of two pads (pad 40 and 41). The addition of some new facilities and upgrades of existing facilities would enable six to eight launches from each pad. Currently, the Air Force plans to launch approximately six vehicles per year from the East Coast. Martin Marietta expects to launch an additional three commercial vehicles per year from pad 40 at Cape Canaveral.

The average time from receipt of launcher components and payload at Cape Canaveral to launch is 5 to 9 months, depending on the complexity of the vehicle desired.[5] The Air Force expects each Titan IV to spend 8 to 9 1/2 weeks on the launch pad, and each commercial Titan 34D about 6 weeks.

Launch operations begin with the arrival of the parts of a launch vehicle, by rail, truck, and aircraft.

Solid Rocket Motors

Solid-fuel rocket motor segments and other solid rocket booster parts arrive at the launch center by rail. After inspecting the parts visually, technicians inspect the propellant-filled motor segments for internal manufacturing flaws in the Non-destructive Test Facility.’ These items are

---

[2] Much of the data for this section was supplied by the “Spacecraft Users Guide, ” Martin Marietta, April 1982.

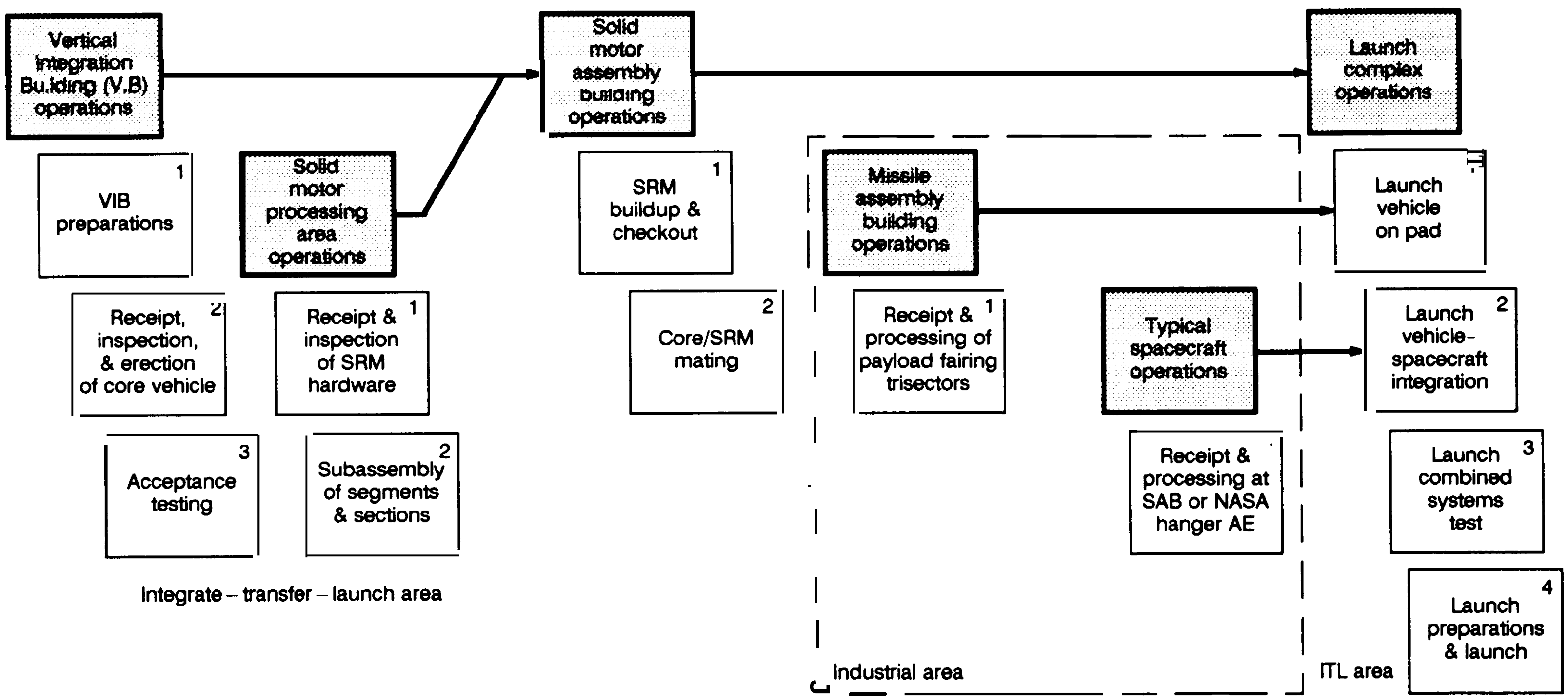
[3] Martin Marietta, which builds the Titan launch vehicle, is the principal contractor. Other major contractors involved in the launch process include the Chemical Systems Division of United Technologies (solid rocket motors), McDonnell Douglas (payload fairing), Boeing (Inertial Upper Stage), and General Dynamics (Centaur Upper Stage).

[4] The Cape Canaveral launch complex was originally designed to support up to 60 launches per year. However, it has never reached that productivity goal, in part because launch procedures have grown more complicated and require a greater number of facilities than are available. In addition, high demand for launches never materialized. See chs. 4 and 5 for additional details.

[5] Assembly and checkout of the Titan IV is likely to take several weeks longer than the Titan 111 because Martin Marietta is doing most of the initial assembly at Cape Canaveral rather than the factory in Denver.

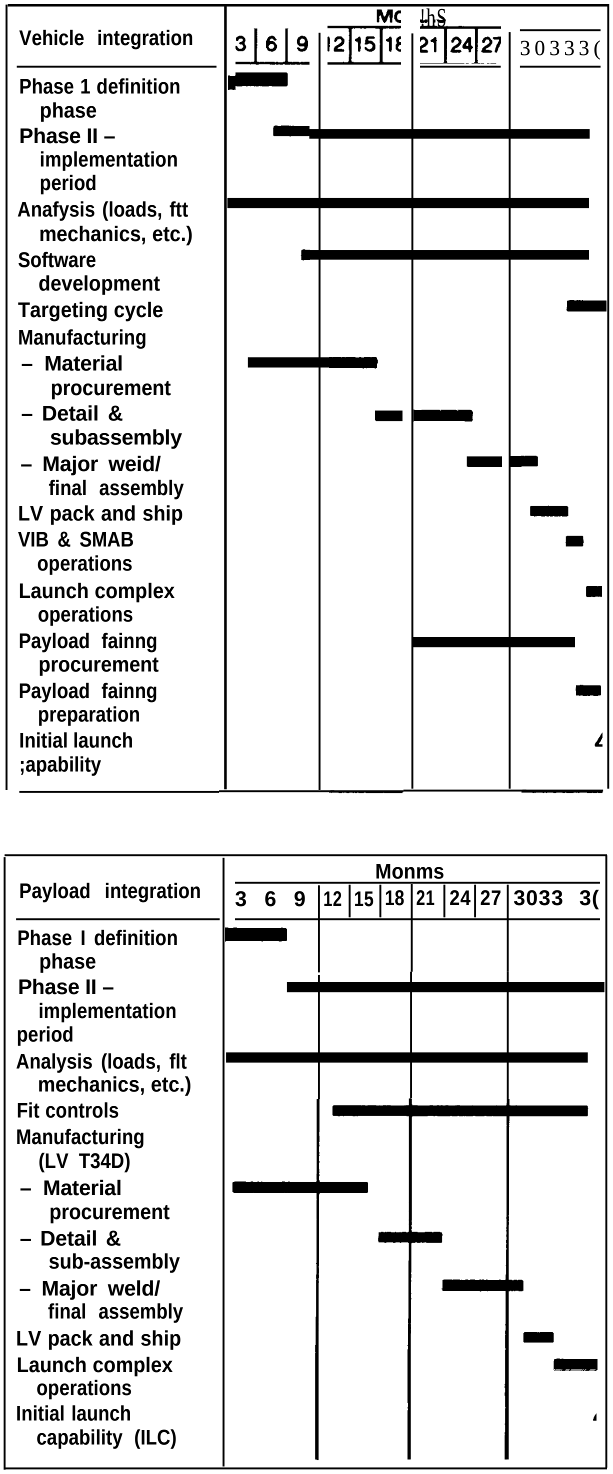
[6] After a Titan 34D exploded 8.5 seconds into flight on April 18, 1986, the Air Force launched a detailed investigation into the cause of the failure. After discovering that the failure was likely the result of debonding of the insulation within the Titan solid rocket motor (see “Titan Solid Booster Failure Caused Vandenberg Accident, ” ***Aviation Week and Space Technology,*** May *5, 1986,* pp. 24-5), the Air Force developed an extensive non-destructive inspection program to qualify the booster segments. It also included additional sensors to monitor launcher systems. See “Titan Mission Success Based on Tighter Heavy Booster Standards, ” ***Aviation Week and Space Technology, Nov. 2, 1987,*** pp. 25-6.

Figure 3-7.—Typical Titan Receipt-to-Launch Flow



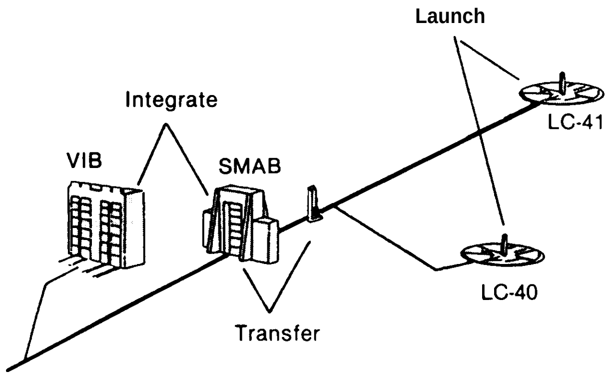
SO Martin Marietta.

Figure 3-8.–Typlcai Titan Launch Scheduie, Cape Canaverai



SOURCE: Martin Marietta

Figure 3-9.—Titan integrate/Transfer/Launch



SOURCE. Martin Marietta.

transported to the Solid Motor Assembly Building (SMAB), where they are stored. In the SMAB, the contractor erects the solid rocket boosters, beginning with the the aft subassembly. Electrical cabling and other supports are installed, as well as emergency-destruct explosive charges.

Core **Vehicle**

Concurrently, the two stages of the core vehicle are inspected and assembled atop the launch vehicle transporter in the Vertical Integration Building (VIB). The VIB contains two cells for assembly and checkout and two cells capable of storing Titan core vehicles. Technicians connect and test the electrical umbilicals and staging connectors, check out the inertial guidance system, and install connections for the payload.

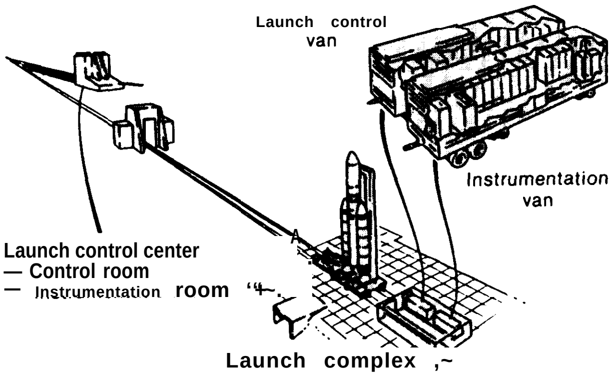
Launch Vehicle Assembly

The core vehicle, mounted on its transporter, is towed to the Solid Motor Assembly Building, where the solid rocket motors and other launcher components are positioned and attached. In the SMAB, technicians thoroughly check all subsystems of the core vehicle and the solid rocket boosters—electrical, propulsion, flight control, hydraulic, guidance, airborne instrumentation, tracking, and flight safety subsystems (fig. 3-10).

Payload Integration and Processing

Payload integration begins months before the payload or launch vehicle arrives at the launch facility, often while the payload is in production.

Figure 3-10.—Titan 34D Checkout and Launch Control Equipment



SOURCE: Martin Marietta.

Payload managers discuss flight plan and payload requirements for vehicle services with the launch vehicle managers and determine the appropriate launch vehicle configuration. Several different payload fairings and upper stages are available, depending on the size, weight, and configuration of the payload.

When the payload arrives at the launch facility, it is assembled, checked out, and tested in facilities off the pad; it is installed on the vehicle at the launch complex several weeks before launch. Payload technicians make all electrical and other connections and test for mechanical and electrical integrity with the launch vehicle.

Launch Complex

The launch complexes 40 or 41,[7] several thousand feet from the VIB, comprise many subsystems (fig. 3-11). Before the vehicle reaches the launch complex, contractor technicians also inspect, test, and repair each subsystem in the appropriate launch complex—the concrete deck of the pad and its exhaust duct, water deluge system (to cool the exhaust and lower the pressure from hot exhaust gases), and vehicle air-conditioning system. They fill the fuel and oxidizer storage tanks and erect support stands for the flexible hoses necessary for filling, venting, and draining the rocket.

After the launcher is completely assembled in the Solid Motor Assembly Building, the transporter tows it to one of the two launch complexes. The Mobile Service Tower rolls into position around the vehicle, and access platforms are lowered into place. Payload specialists then install and test the payload, which has been processed in parallel with the vehicle. Launch vehicle specialists also carry out tests of the vehicle.

The actual time the vehicle must spend on the launch pad depends directly on the type and complexity of the upper stages and payload. With a standard payload, such as a geosynchronous communications satellite, which is encapsulated off-pad, average total pad time is about 6 weeks. If significant checkout and servicing must occur just before launch, as in the case of a payload requiring extensive fueling or the Interim Upper Stage, the payload may remain on the pad for as long as 11 weeks.

In preparation for the final countdown, all the ordnance is installed, and the liquid oxidizer and fuel are loaded into the core vehicle. After batteries of tests, simulations, and verifications, the rocket is declared ready for launch. The range contractor monitors and evaluates all pre-launch environmental conditions at the launch site, including ground winds, gusts, high-altitude winds, ceiling, cloud cover, and visibility.

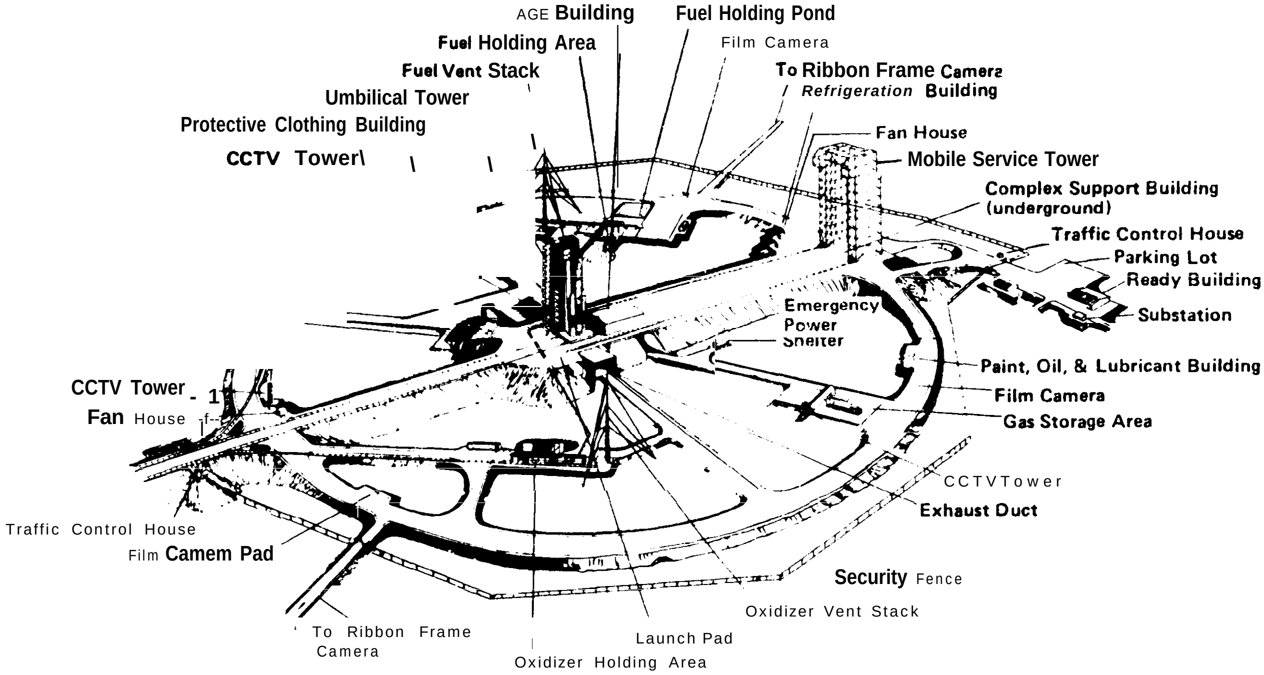
A typical terminal launch countdown lasts less than one shift, and includes preparations and rollback of the mobile service tower. Command-destruct loops are checked with range safety; the telemetry system is checked. The mobile service tower is rolled back. The core vehicle propellant tanks are pressurized to flight pressure, the pressures inside the solid-fuel rocket motor casings are verified as stable, and the guidance system checked. Final checkout, countdown, and launch are monitored and controlled from the control center, located in the VIB.

Post Launch Activities

Launch processing is not complete with the launch. After liftoff, the launch control center is shut down and reset. The launch area is tested

[7] Launch Complex 40 will be used for Titan 34D commercial and government launches. Launch Complex 41 has been modified to accommodate the Titan IV.

Figure 3.11.— Launch Complex 40



SOURCE: Martin Marietta

for toxic vapors and inspected to determine how much damage was sustained from the high-temperature rocket exhaust and vibration, and how much refurbishment the transporter and pad will need before the next launch.

Whether the launch is successful or not, launch data, both from the ground facilities and from the launcher[8] are recorded and analyzed for anomalies or other indications of future problems. If the launch is unsuccessful for some reason, these data may be the only means of determining the cause of failure.

[8]The launch vehicle carries hundreds of sensors to record various environmental factors during launch, including temperature, vehicle acceleration, and vibration. This information is telemetered to the launch complex for later analysis.

Launch Operations—Vandenberg Air Force Base

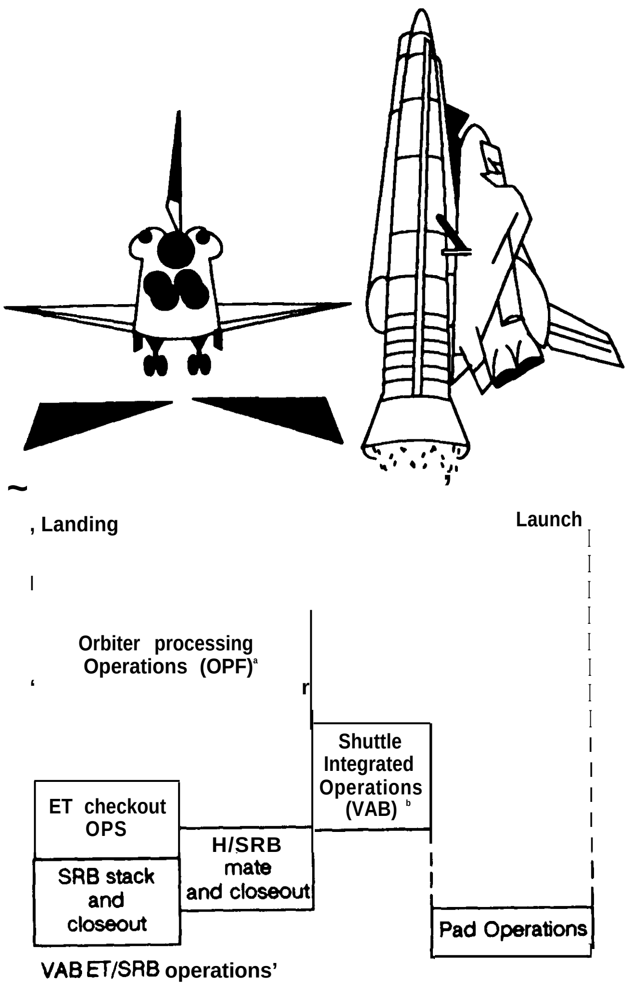
As noted, vehicle assembly and processing differ significantly at Vandenberg Air Force Base, primarily because the vehicle is fully assembled on the pad. The launch complex is therefore considerably simpler, as there is no Vehicle Integration Building, Launcher Transporter, or Solid Motor Assembly Building. Consequently the launch rate is lower, as an average of 163 days are required for assembly and launch of each Titan 34D with its payload. This allows only about two and one-quarter launches per pad per year from Vandenberg.

THE SPACE SHUTTLE

Unlike the Titan, the Shuttle orbiter was designed to be reused, which means that launch processing includes recovering and refurbishing the orbiter and the solid rocket boosters (fig. 3-12). The current Shuttle (fig. 3-13; box 3-B) can lift up to 48,000 pounds into low-Earth orbit (about 160 nautical miles above Earth's surface).

Shuttle launch operations requires the use of a wide variety of both advanced and routine tech-

Figure 3-12. -Orbiter Ground Turnaround Operations

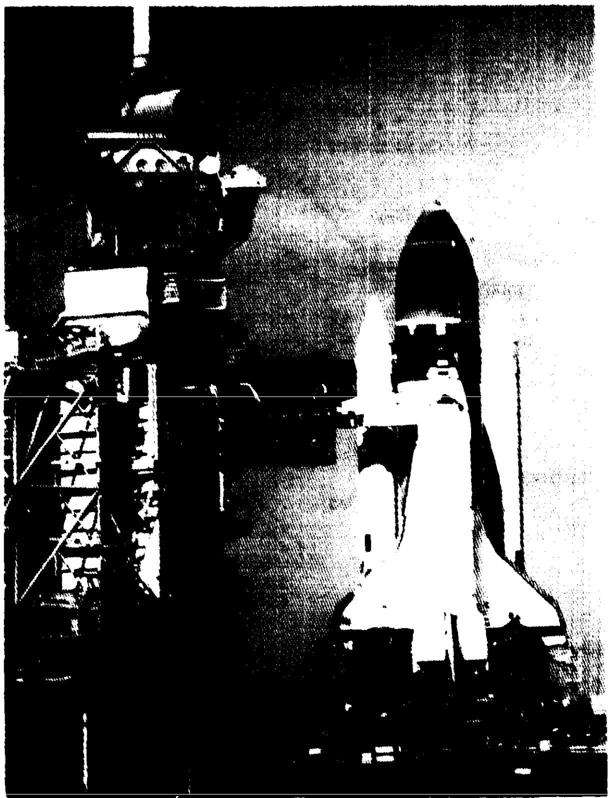


[a] Orbiter Processing Facility
[b] Vehicle Assembly Building
c Vehicle Assembly Building External Tank/Solid Rocket Booster Operations

SOURCE: National Aeronautics and Space Administration

nologies and interrelated subsystems. At Kennedy Space Center (KSC), Shuttle processing is carried out by contractors monitored by NASA employees. Lockheed Space Operations Company currently holds the prime contract for this work. Lockheed subcontracts with a variety of other companies, including Rockwell International, the prime contractor for the Shuttle orbiter. Approximately 6,550 contractors and 640 NASA employees directly support Shuttle launch operations at KSC. Johnson Space Center has responsibility for on-orbit mission operations and some launch operations, which involve about 5,675 contrac-

Figure 3-13.—The Orbiter Challenger Rests on the Mobile Launcher at Pad 39A With the Rotating Service Structure Containing the Payload Canister Moved Back From the Shuttle (January 1983)



SOURCE: National Aeronautics and Space Administration.

tors and 1,065 NASA employees. Marshall Space Flight Center contributes engineering expertise for Shuttle modifications and supports the Shuttle with approximately 1,000 NASA employees and 11,000 prime contractor employees.

Payload Processing

Payloads for the Space Shuttle can be installed either horizontally or vertically (figs. 3-14 and 3-15). Horizontal payloads, such as Spacelab, are installed in the orbiter when it is still in the Orbiter Processing Facility, prior to being mated with the external tank and solid-fuel rocket boosters. Vertical payloads are installed in the orbiter's payload bay after the fully assembled Shuttle arrives at the launch pad.

The payload owner assembles the payload to its final launch configuration by, for example, in-

Box 3-B.—The Space Shuttle Launch System

The shuttle launch vehicle consists of three major subsystems:

- the *orbiter,* with the crew compartment and payload bay, which also contains the three Space Shuttle main engines (SSMES). About the size of a DC-9, the orbiter weighs about 215,000 Ibs., without its payload, and has a 15 by 60 foot cylindrical payload bay. I
- the *extermd tank,* which holds liquid hydrogen and oxygen to fuel the SSMES.
- *two segmented solid-fuel rocket boosters* (SRBS). These are each made up of 5 motor segments.

At launch, the main engines are ignited, followed seven seconds later by the SRBS. Two and one-half minutes into the flight, explosive bolts separate the orbiter from the SRBS, which parachute into the Atlantic Ocean and are recovered. After about eight minutes of flight, the Shuttle main engines shut down and the external tank separates from the orbiter, breaks up as it reenters the atmosphere and falls into the Indian Ocean. In space, the orbiter maneuvering system, fueled by hyperbolic propellants, propells the craft into the orbit desired for the mission.

After the Shuttle crew completes its mission, the orbiter returns to earth where it can land on any of several runways,[2] and is carried back to Kennedy Space Center, to be refurbished for the next launch. Although the Air Force built a Shuttle processing center and launch pad at Vandenberg Air Force Base, CA, it is now in the process of being mothballed.

'Following the loss of Challenger, the fleet now consists of three orbiters—Columbia, Discovery, and Atlantis. NASA has contracted with Rockwell International to build a fourth orbiter, which will replace Challenger by 1992.

'For safety reasons, especially after the loss of Challenger, the Shuttle will normally land at Edwards Air Force Base, However, in an emergency, the Shuttle can touch down at Cape Kennedy, or one of the alternative emergency landing sites.

stalling solar panels, antennas or other items, and performing minor repairs. Payload owners have five options for processing payloads, ranging from minimum KSC involvement—essentially "ship and shoot, " where the payload is ready for launch and can be installed in the orbiter 2 to 50 days before launch with no servicing, to maximum KSC involvement—where all flight experiments and component hardware must be delivered up to a year before launch for technicians to assemble, integrate and test.[9]

Pre-launch Processing

The basic processing flow is organized according to the integrate—transfer—launch (ITL) concept, which separates the major processing elements and allows certain functions to proceed in parallel until the vehicle is assembled in the Vehicle Assembly Building and carried to the launch pad (fig. 3-16).

Orbiter Processing

Orbiter processing constitutes the critical limit to the achievable flight rate. Refurbishing the orbiter Columbia for the second Shuttle flight consumed nearly 200 work days (three shifts per day). By the ill-fated flight of the Challenger in January 1986, this turnaround time had been reduced to 55 days (fig. 3-17).[10] However, the numerous modifications to the process of orbiter refurbishment, made as a result of the Challenger accident, have led to an estimated future orbiter turnaround of about 160 days, to decrease over four years t. 75 days.[11] FOr a four orbiter fleet, a 75 day Orbiter turnaround time would allow 12 to 14 flights per year.

In the Orbiter Processing Facility, NASA contractors check and refurbish every major system in the orbiter after each flight, including the avionics, brakes, electrical systems, and windows. They inspect the Shuttle main engines, and completely replace the bearings and turbines. Any of the 31,000 ceramic tiles of the thermal protection system that are missing or damaged during the flight are also replaced; all tiles are re-waterproofed. Modifications to the orbiters are made during refurbishment.[12] Finally, any horizontal

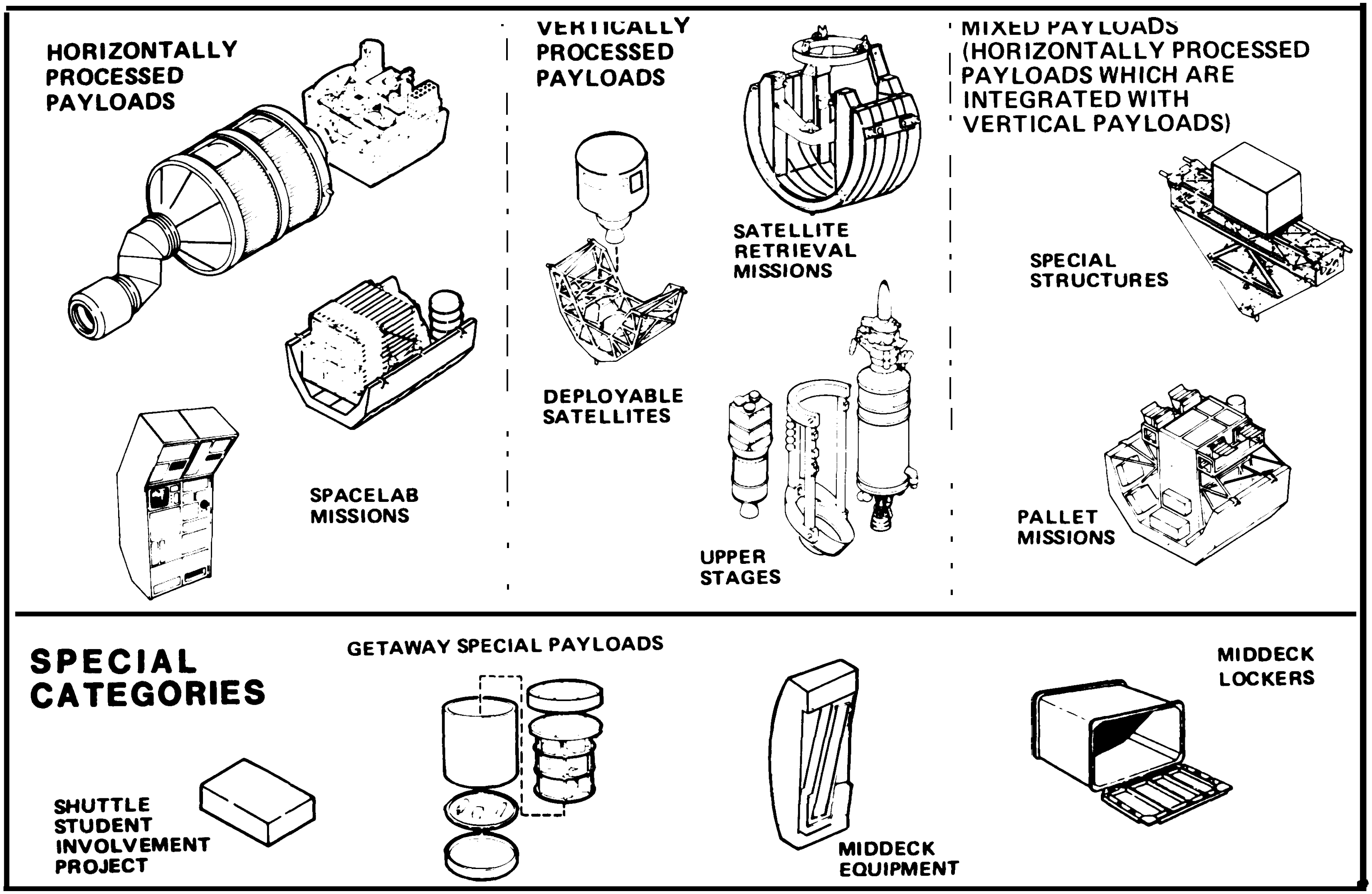
[9]For a detailed breakdown of these options, see James M. Ragusa, "Historical Data and Analysis for the First Five Years of KSC STS Payload Processing," NASA, September 1986, ch. 4.

[10]Charles R. Gunn, "Space Shuttle Operations Experience, " Paper IAF-87-216, delivered at the 38th Congress of the International Astronautical Federation, Oct. 10-17, 1987.

[11]However, some Shuttle operations experts have raised concerns that new safety related requirements for orbiter processing may make it extremely difficult to reach the goal of 75 days turnaround within 4 years.

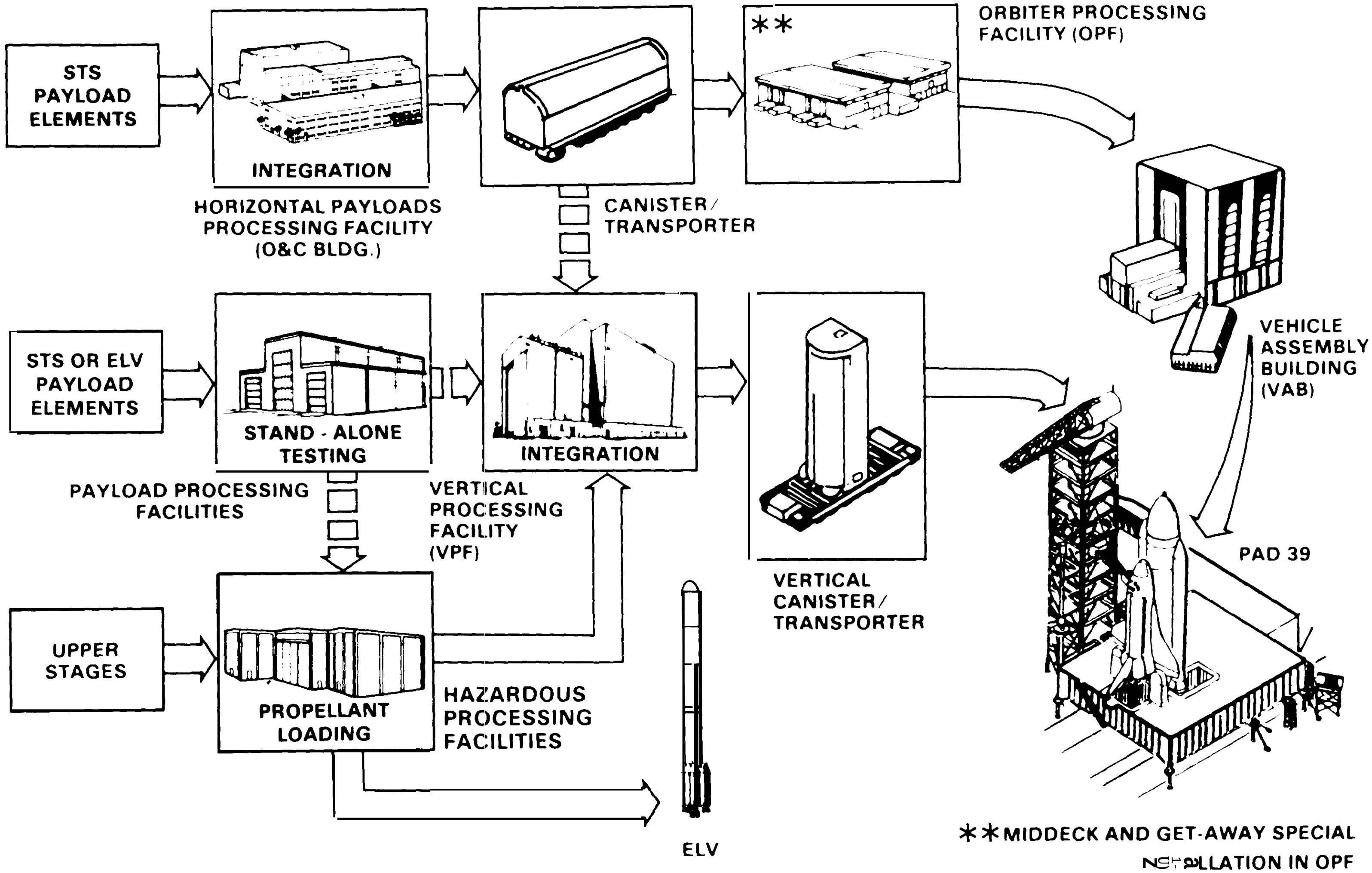
[12]These modifications can significantly lengthen the time necessary to process the orbiter.

Figure 3-14.—Space Shuttle Payloads Processing Classifications



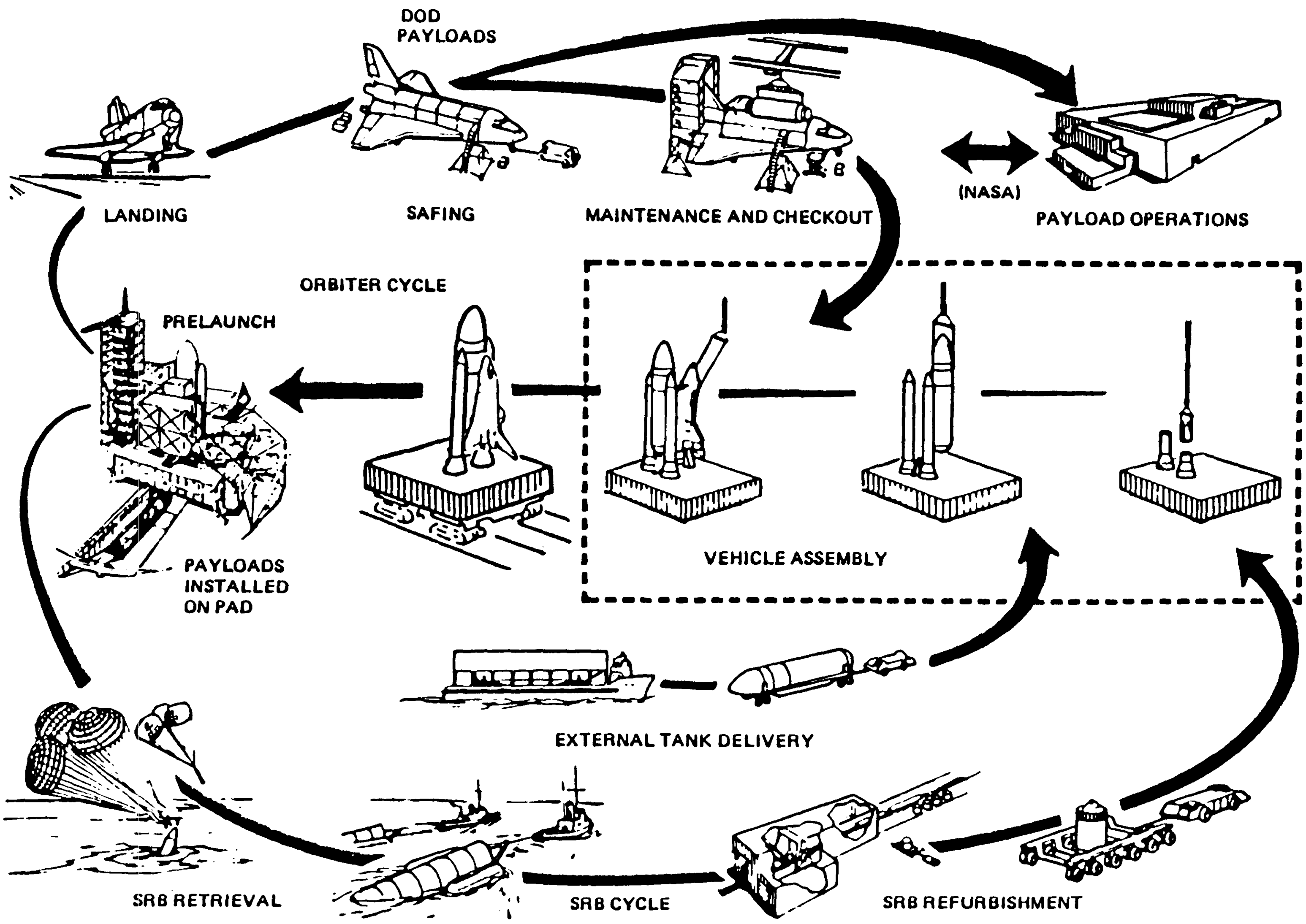
SOURCE: National Aeronautics and Space Administration.

Figure 3-15.—Payload Processing Flows at the Kennedy Space Center



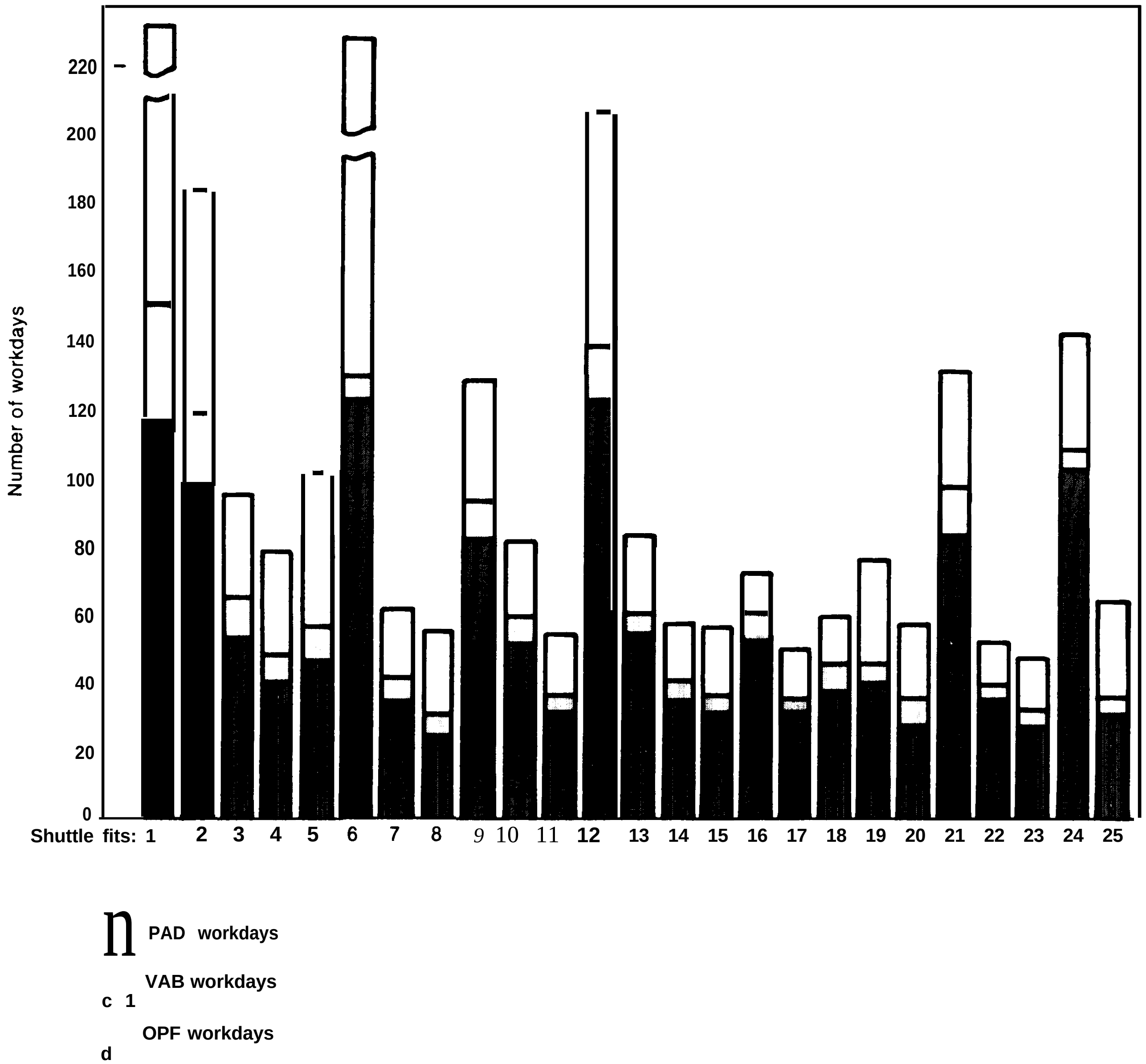
SOURCE:

Figure 3-16.—Kennedy Space Center Space Shuttle System Ground Flow



SOURCE: National Aeronautics and Space Administration.

Figure 3-17.—Orbiter Ground Turnaround Experience



SOURCE: National Aeronautics and Space Administration.

payloads, such as Spacelab, are installed in the payload bay.

Solid Rocket Boosters (SRBS)

The contractor (Morton Thiokol) ships new solid-fuel rocket motor segments and associated hardware, including the forward and aft closures, nozzle assemblies, and nozzle extensions by rail. When the segments arrive at KSC, they are moved into the Rotational Processing and Surge Facility where they are inspected and stored until needed.

Assembling and testing the SRBS requires about 33 days (three shifts). After the aft booster assemblies are attached to support posts on the mobile launcher platform, the rocket motor segments—all filled with live propellant—are added, inspected and tested. During the stacking process, which lasts several hours per segment, everyone but the stacking crew must evacuate the Vehicle Assembly Building (fig. 3-18).

External Tank

Meanwhile, the external tank, which is manufactured by Martin Marietta, is transported to KSC by sea barge from the Michoud Assembly Facility at New Orleans, Louisiana. In the Vehicle Assembly Building (VAB), contractors inspect the external insulation and comections for ground support equipment, as well as the cryogenic tanks for holding liquid oxygen and liquid hydrogen.

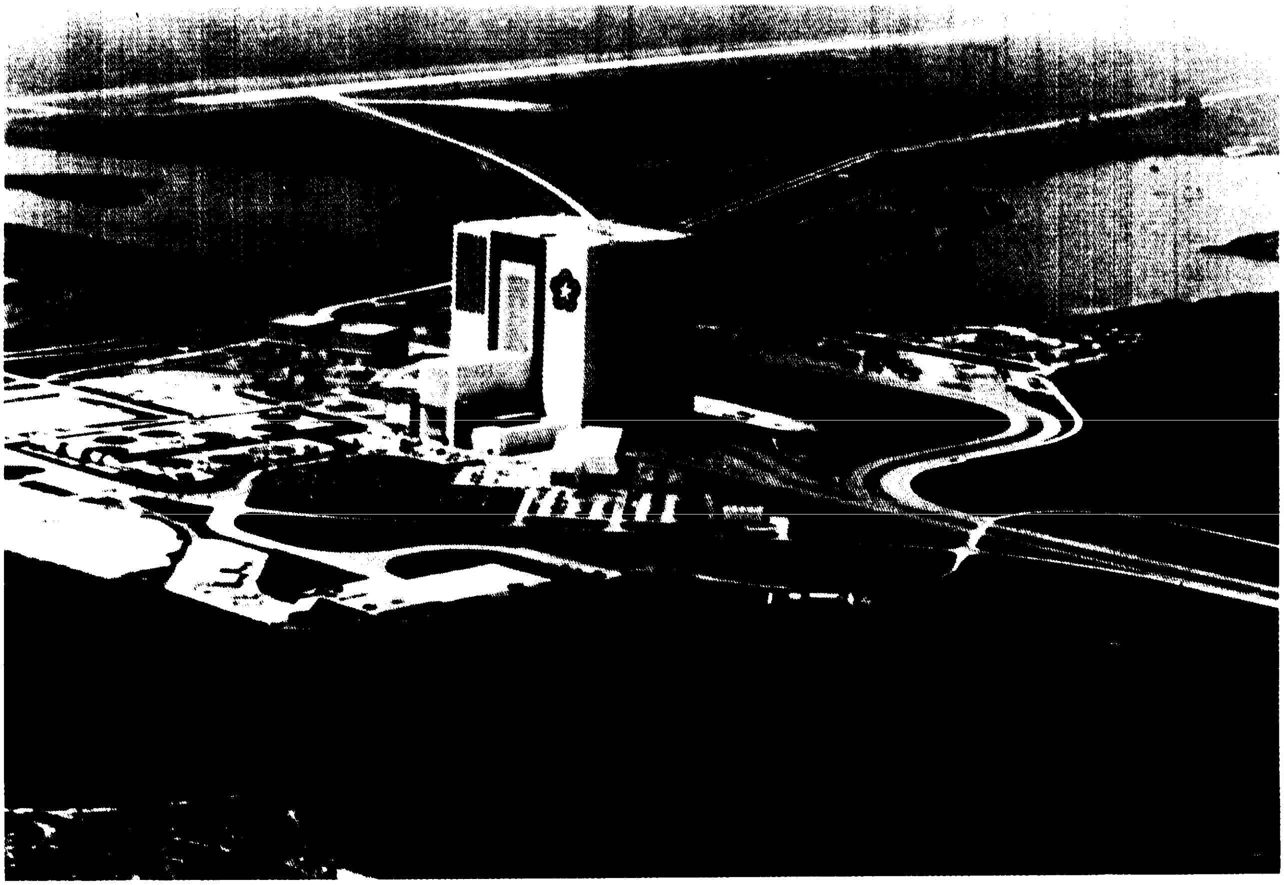
A crane hoists the tank to a vertical position and transfers it to the mobile launcher platform, where it is mated with the twin SRBS. The electrical systems are checked and the many fluid valves tested.

Vehicle Assembly and Integration

After orbiter processing is complete, it is towed to the VAB High Bay, lifted to the vertical, and mated to the external tank and SRBS (fig. 3-19). After mating all the sections of the Shuttle and connecting all umbilicals, technicians test each connection electrically and mechanically.

The computer-controlled launch processing system, which is operated from the firing rooms of

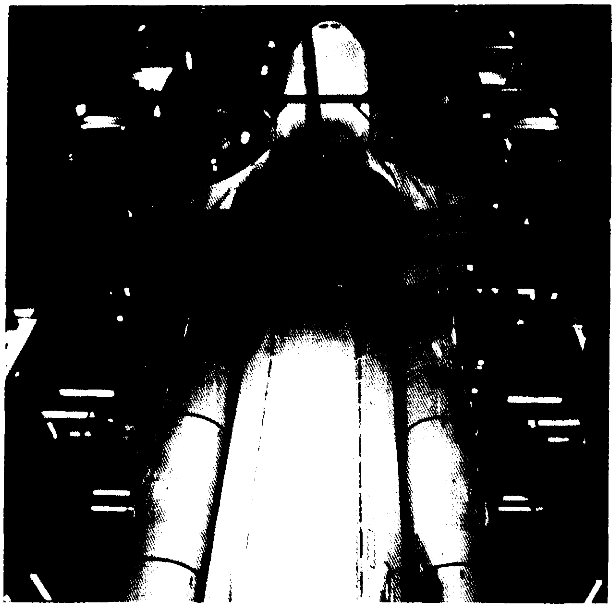
Figure 3-18.—Aerial Photograph—Important Facilities at Kennedy Space Center



Dominating the view is the Vehicle Assembly Building, which is 525 ft. high. The low structure in the foreground is the Launch Control Center.

SOURCE: National Aeronautics and Space Administration

Figure 3-19.—The Orbiter Columbia, Undergoing Launch Processing for Its Second Voyage Into Space, Is Gently Lowered Toward the Solid Rocket Boosters and External Tank for Mating (August 1981)



SOURCE: National Aeronautics and Space Administration.

the launch control center, semi-automatically controls and checks out much of the Shuttle vehicle, both in the VAB and at Launch Complex 39. If any subsystem is found unsatisfactory, the computer will provide data that help isolate the fault.

Transfer and Launch

When the Shuttle is fully assembled on the Mobile Launch Platform, a crawler-transporter slips under and slowly (1 mph) moves the Shuttle to Launch Complex 39A or B (fig. 3-20). Once at the pad, workers gain access to the Shuttle through the fixed service structure, which also provides liquid hydrogen and oxygen to the external tank. The rotating service structure gives access to service fuel cells and the life-support system, to load and remove payloads, and to load hyperbolic fuels for the orbital maneuvering system and the reaction control system. Those payloads to be installed vertically are transported to the rotating service structure in a protective payload canister.

After the Shuttle arrives at the pad, most checkout operations are controlled from the launch control center. After these operations, power is applied to the orbiter and supporting ground support equipment, launch-readiness tests are performed, and the tanks are prepared to receive their fuels. The Shuttle is now ready for the cryogenic propellants to be loaded and the flight crew to board.

During the final six or seven hours of the countdown, the mission software is updated and the liquid hydrogen and liquid oxygen loaded into the external tank. Finally, the flight crew and operations personnel complete all preparations and the Shuttle lifts into space (fig. 3-21).

Mission Operations

Mission operations (table 3-1) comprise all activities associated with planning and executing a mission and the payloads to be carried. The primary focus is on gathering data, performing analyses, and developing the software required to meet the mission's objectives. Mission operations begin the first day a payload is conceived, continue through the day of the launch, and end only after the mission is satisfactorily completed and the data analyzed. From early mission planning to completion, mission operations for a Shuttle flight may take two years or more.

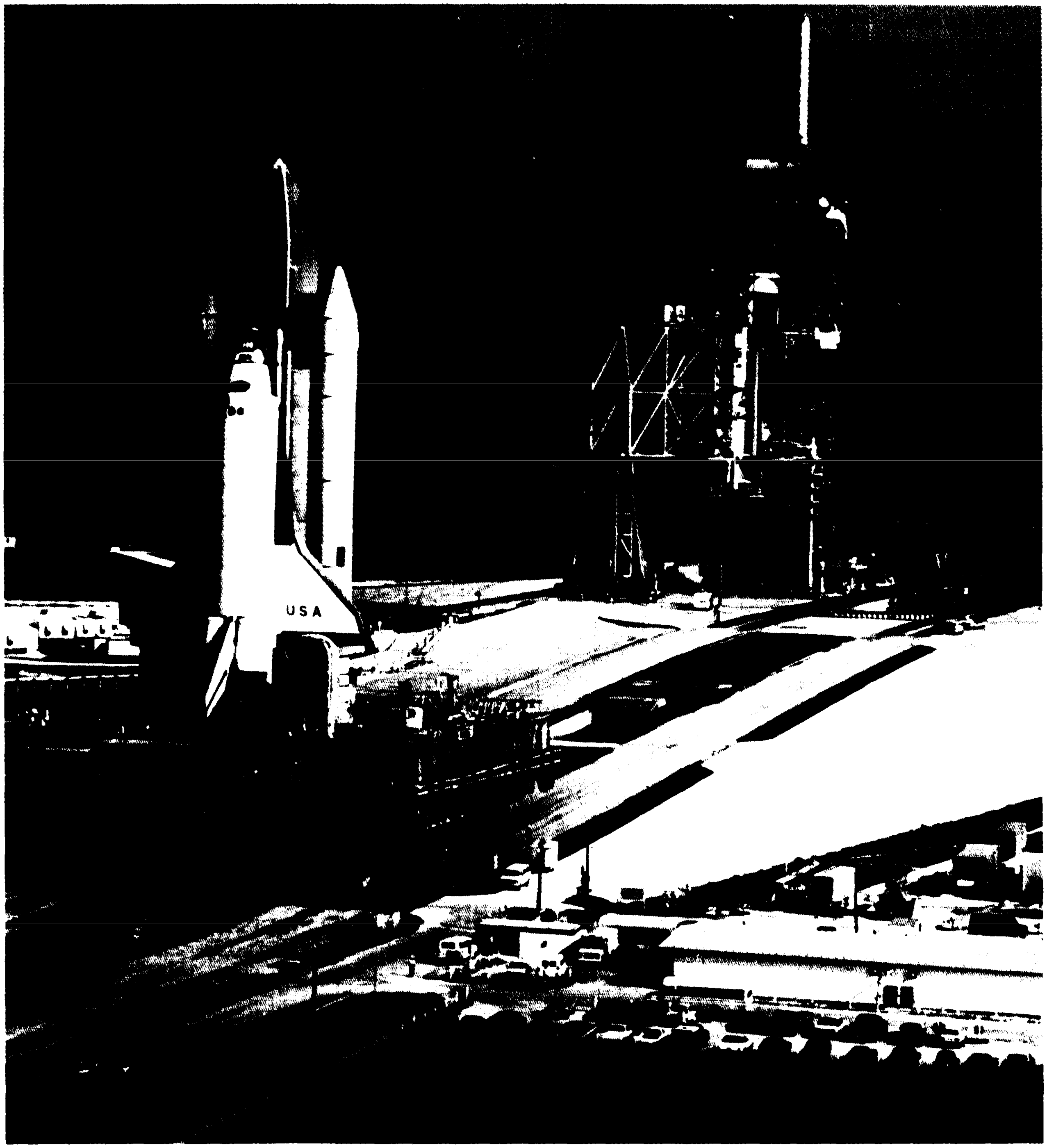
Tracking stations scattered around the world and the Tracking, Data, and Relay Satellite System (TDRSS) give orbiter crews access to Mission Control for most of the orbit.[13] The Johnson Space Center (JSC) at Houston, TX is the central control point for Shuttle missions; payloads and related systems are controlled from the Jet Propulsion Laboratory (Pasadena, CA), the Goddard Space Flight Center (Greenbelt, MD), or JSC.

Post= launch Processing

Two minutes into the Shuttle's flight, the two solid-fuel rocket boosters are jettisoned and parachute into the Atlantic Ocean downrange from KSC. Two specially designed retrieval vessels recover the boosters and their various components. The smaller components are hauled on board the ships, whereas the boosters are towed back to the

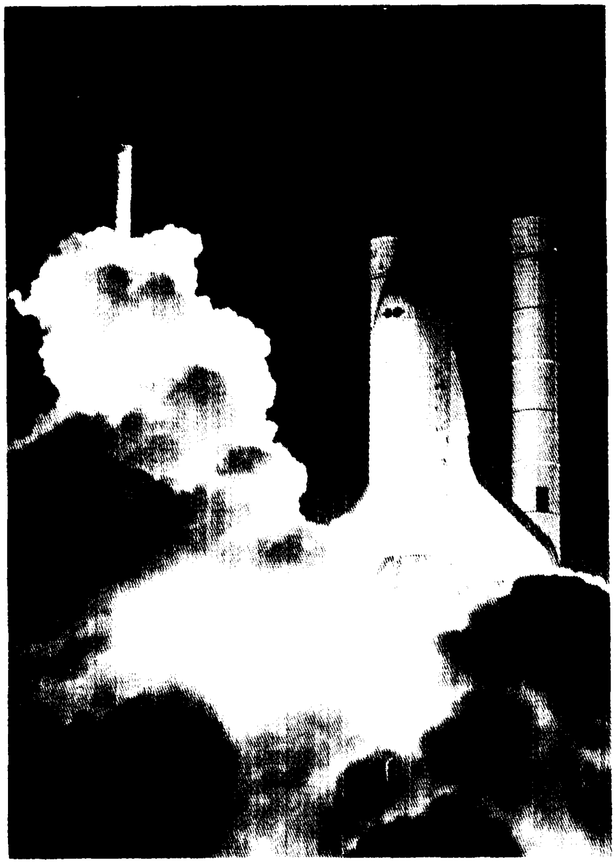
[13] When TDRSS deployment is complete (three spacecraft), it will allow the crew to contact Mission Control nearly 100 percent of the time in orbit. The second of two TDRSS satellites is scheduled for deployment on the first Shuttle flight after standdown.

Figure 3-20.—The Space Shuttle Columbia Begins Its Roll Up the Ramp to Pad 39A After Completing the 3.5 Mile Journey From the Vehicle Assembly Building (September 1982)



SOURCE: National Aeronautics and Space Administration.

Figure 3-21.–The Space Shuttle Challenger Lifts Off in the First Nighttime Launch of the Shuttle Era (August 1983)



SOURCE: National Aeronautics and Space Administration

Table 3-1.—Shuttle Mission Operations Functions

- Design Shuttle trajectory and flight plan
- Develop flight and ground documentation to support operations
- Provide mission support with flight planning, flight systems, payload support, and trajectory teams
- Provide maintenance, operations, mission reconfiguration, and sustaining engineering for support facilities (mission control center and simulation and training facilities)
- Develop plans and provide training to crews, customers, and flight controllers
- Develop operating concepts and requirements

SOURCE: Johnson Space Center

KSC Solid Rocket Booster Disassembly Facility. At this facility, the boosters and other components are washed, disassembled, cleaned, and stripped before they are shipped by rail to the prime contractor (Morton Thiokol) for refurbishing and reloading.

When the Shuttle orbiter returns from its mission in space, it normally lands at Edwards Air Force Base in California. In emergencies, it can also land at KSC; White Sands, NM; Zarogosa, Spain; Casablanca, Morocco; Rota, Spain; or Guam. After landing, it must be drained of hazardous fuels and inspected for any exterior damage. Payload technicians remove any payloads brought back to Earth. If it lands anywhere but KSC, the orbiter must be lifted onto the back of a specially equipped Boeing 747 and flown back to the Shuttle Landing Facility at KSC.