March 9, 2011. In twenty-seven years of service, beginning with its maiden launch on August 30, 1984, *Discovery* orbited the Earth 5,830 times, flew a total of 148,221,675 miles, carried 252 crewmembers to space, made thirteen missions to the ISS, and logged a total of 365 mission days – a year in space.[316]

NASA named *Discovery* after four British vessels: Henry Hudson's ship used in the 1610-11 voyage to find a Northwest passage between the Atlantic and Pacific oceans; *HMS Discovery* led by Captain James Cook, which was used to explore the South Pacific in the 1770s; a second *HMS Discovery* that was part of Captain George Nares' 1875-76 expedition to the North Pole; and the *RRS Discovery*, which carried Captain Robert Falcon Scott's crew during the 1901-04 *Discover Expedition* to Antarctica.

The following sections provide a description of *Discovery's* original assembly (Part IIA), and subsequent modifications (Part IIB), within the broader context of SSP-wide developments. Following the physical description of *Discovery's* systems (Part IIC), her missions and milestones are examined (Part IID). Part IIE concludes this section with a description of ground and ferry operations, which generally pertain to the entire orbiter fleet.

IIA. Manufacture and Assembly

Orbiter Manufacturers

The "production orbiter" OV-103 was built under Production Contract NAS9-14000, Schedule B, awarded to Rockwell International Corporation (now, The Boeing Company) on January 29, 1979.[317] The $1.9 billion contract also included the construction of OV-104 (*Atlantis*), the conversion of *Challenger* from a test vehicle (STA-099) into a flight orbiter, and major orbiter modifications. About 250 major subcontractors provided the approximately two million individual components, parts, and systems to Rockwell's Downey and Palmdale assembly facilities (see Figure Nos. B-1 through B-18 for representative photographs of individual components being manufactured).[318] Major structural components, including the upper and lower forward fuselage, the aft fuselage, the crew module, and the FRCS, were built and tested at Rockwell's Downey, California, facility. Other major structural modules were manufactured under subcontract to Rockwell's Space Transportation Systems Division. Rockwell selected McDonnell Douglas, St. Louis, Missouri, for the $50 million subcontract to build the OMS pods; Grumman Aerospace Corporation in Bethpage, New York, for $40 million, to build the orbiter wings (including the elevons); General Dynamics/ Convair Aerospace in San Diego, California,

[316] NASA KSC, *Space Shuttle Era Facts*.
[317] Chris Gebhardt, "After 26 Years, Workhorse Discovery Stands Ready for Final Mission," February 22, 2011, http://www.nasaspaceflight.com/2011/02/workhorse-discovery-stands-ready-for-final-mission/.
[318] NASA, "Space Transportation System Contractors." In *NSTS Shuttle Reference Manual*, 1988, 971-990; NASA, "Orbiter Manufacturing and Assembly," April 7, 2002, http://spaceflight.nasa.gov/shuttle/reference/shutref/manu/.

to build the midfuselage for $40 million, and Fairchild Industries/Fairchild Republic in Farmingdale, New York, to build the vertical tail, including the rudder/speed brake, for $13 million. North American Rockwell divisions in Tulsa, Oklahoma, and Columbus, Ohio, provided the orbiter payload doors and body flap, respectively.

General Orbiter Flow and Build Sequence

> *The thing I think was most interesting is people at Palmdale had an unwritten agreement with the astronauts. That agreement was to do the best job they could, to give 100 percent, to make sure that it was the best orbiter vehicle that we could ever deliver because of their safety.*[319]

The shuttle parts manufactured by contractors across the US (see table on the following page) were transported to Building 150 at the US AFP 42, Site 1 North, in Palmdale, California, for assembly into the orbiter *Discovery*. The 5,800-acre government-owned, contractor-operated plant is located approximately 50 miles north of Los Angeles. NASA signed a memorandum of agreement with the USAF in 1973 to use Building 150 for the assembly, integration, testing, and checkout of the orbiters. The final assembly of all flight-ready orbiters, as well as the orbiter prototype *Enterprise*, occurred in the building's two high bays.[320]

The general orbiter build sequence, as outlined by Boeing, began with the delivery of the mid-fuselage from the General Dynamics facility in San Diego.[321] After being offloaded, this major component was checked out, then placed in a work station for the installation of systems. Following delivery from Downey, the lower forward fuselage was assembled, checked out, and mated with the midfuselage. The aft compartment was fabricated and assembled at Downey; the auxiliary power unit (APU) system also was installed and checked out here. This subassembly was transported to Palmdale, where it was mated to the midfuselage. The crew module followed a similar path. The structure was manufactured and assembled at Downey, where the systems, including the airlock, were installed. Following checkout, the crew module was transported to Palmdale for installation of the avionics crew system, followed by mating. The upper forward fuselage followed from Downey. The orbiter wings, fabricated, assembled, and checked out at Grumman's facility in Bethpage, New York, were transported by ship from New York, to Long Beach, California, via the Panama Canal, then transported overland to Palmdale and installed in

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[319] Robert H. Kahl, interview by Rebecca Wright, *NASA STS Recordation Oral History Project*, August 25, 2010, 3, http://www.jsc.nasa.gov/history/oral_histories/STS-R/KahlRH/KahlRH_8-25-10.htm.
[320] Archaeological Consultants Inc., "Shuttle Orbiter Final Assembly Building/Building 150," (documentation package, NASA JSC, 2007), 7, 11-12.
[321] Boeing, *Orbiter Vehicle Data Pack Document: Orbiter Vehicle Discovery (OV-103), Volume I,* (Huntington Beach, California: The Boeing Company, 2011), 269-272.

Manufacturers of Major Orbiter Components and Subcomponents[322]

Major component	Subcomponent	Manufacturer	Location
Midfuselage		Convair Aerospace Division of General Dynamics Corporation	San Diego, CA
Aft fuselage		Columbus Aircraft Division of Rockwell International (tooling)	Columbus, OH
		Los Angeles Aircraft Division (upper truss thrust structure)	Los Angeles, CA
Forward fuselage		Space Transportation Systems Division of Rockwell International	Downey, CA
	Crew module	Los Angeles Aircraft Division (panels)	Los Angeles, CA
		Avco (bulkheads)	Nashville, TN
		Vought Corporation (skins and bulkheads)	Dallas, TX
		Marvin Engineering (skins and ejection panels)	Inglewood, CA
		Merco Manufacturing Co. (star tracker panels)	Anaheim, CA
	Airlock	Space Transportation Systems Division of Rockwell International	Downey, CA
Wings		Grumman Corporation	Bethpage, NY
	Elevons	Grumman Corporation	Bethpage, NY
	Landing gear doors	Grumman Corporation	Bethpage, NY
Payload bay doors		Tulsa Division of Rockwell	Tulsa, OK
	Actuation system	Curtiss Wright	Caldwell, NJ
	Latches	Ball Brothers Research Corp.	Boulder, CO
	Signal processor	TRW Systems, Electronic Systems Division	Redondo Beach, CA
	Data interleaver	Harris Corp., Electronics Systems Division	Melbourne, FL
Forward reaction control system		Space Transportation Systems Division of Rockwell International	Downey, CA
	Fuel and oxidizer tanks	Martin Marietta	Denver, CO
	Thrusters	Marquardt Co., CCI Corp.	Van Nuys, CA
Vertical stabilizer		Fairchild Republic	Farmingdale, NY
	Rudder/speed brake	Fairchild Republic	Farmingdale, NY
OMS/ RCS pods		McDonnell Douglass	St. Louis, MO
	OMS engines	Aerojet General	Sacramento, CA
	RCS thrusters	Marquardt Co., CCI Corp.	Van Nuys, CA
Body Flap		Columbus Aircraft Division of Rockwell International	Columbus, OH

the vehicle. The vertical tail, made by Fairchild Republic in Farmingdale, New York, was conveyed to Palmdale via truck. At Palmdale, it was checked out and prepared for installation.

[322] NASA, "Space Transportation System Contractors," 971-990; Boeing, *OV-104, Volume I,* 282-304.

The payload bay doors followed from their manufacture site in Tulsa, Oklahoma. Following mating of the payload bay doors, the FRCS, manufactured, assembled, and checked out at Downey, was shipped to Palmdale, where it was prepped and mated. The nose and main landing gear, followed by the body flap, arrived from their manufacturing sites, and were offloaded, checked out, prepared for placement, and installed at Palmdale. The aft orbiter maneuvering system/reaction control system (OMS/RCS) pods, manufactured by McDonnell Douglas in St. Louis, Missouri, were transported by aircraft to the Palmdale assembly facility for installation of the TPS materials. They were not installed on *Discovery* at Palmdale, but were transported separately by aircraft to KSC.[323] After final assembly was completed, the orbiter underwent acceptance testing and final checkout, before being prepared for delivery to KSC.

Historically, according to Gerald Blackburn, the actual build cycle for the orbiter fleet was from about 1972, when long lead items were purchased for *Enterprise* (OV-101), to about 1992. *Columbia* (OV-102) took the longest to build, about seven years, from first lead item on through. Most of the other vehicles had a three to four year build cycle. "A lot of the lessons learned were on *Columbia*, which later translated into the rest of the fleet." [324] The most intense period of orbiter construction at Palmdale was from 1979 to 1986. In 1986, there were four orbiters at KSC.[325]

OV-103 Assembly

Construction of OV-103 began in August 1979, with the long lead fabrication of the crew module. During the latter half of 1980, fabrication of the wings, lower fuselage, and midfuselage was started, and structural assembly of the wings, crew module, midfusleage and aft fuselage were begun. Fabrication and assembly of the payload bay doors and body flap were initiated in March and October 1982, respectively.

In March 1982, major components for the assembly of OV-103 began to arrive at the Palmdale assembly facility, starting with the midfuselage, and followed by the elevons later that month. The wings and lower forward fuselage were delivered to Palmdale at the end of April 1982; both were attached to the mid-fuselage in May. The upper forward fuselage arrived in July, the vertical stabilizer in August, the body flap in October, and the crew module in December. Also, installation of the TPS tiles was under way by October 1982. A pictorial representation of the final assembly of *Discovery* is provided in Figure Nos. B-19 through B-58.

The aft fuselage was delivered in January 1983 and installed that month. Also in January, the crew module and upper forward fuselage were installed. The OMS pods also arrived in January, and in February, the FRCS arrived. A fit-check was completed, and then the FRCS was set up

[323] Boeing, *OV-103, Volume I*, 261. The OMS/RCS pods could be interchanged between vehicles as required to accommodate maintenance and schedule requirements.
[324] Blackburn, interview, 11.
[325] Blackburn, interview, 14.

under a temporary clean room for inspections. In March 1983, the four sections of the payload bay doors were installed. First was the forward port door, then the forward starboard door, followed by the aft port and starboard doors, respectively. The FRCS and the body flap were installed in June.[326] Throughout this time, a number of smaller shuttle components were installed. Final assembly of *Discovery* concluded on August 12, 1983. Post-checkout was completed on September 9, 1983, and testing and other work continued on OV-103 over the next month.

Discovery was rolled out of Building 150 on October 16, 1983 (Figure No. B-59). It weighed 151,419 pounds without the SSMEs, about 6,870 pounds less than *Columbia.* From Palmdale, *Discovery* was transported overland to DFRC, mated to the SCA (Figure No. B-60), and flown to KSC, where it arrived on November 9, 1983.

Over the next six months, *Discovery* spent time in both the OPF for processing, and the VAB for storage. Beginning on May 12, 1984, the ET and SRBs were attached to *Discovery*, and all were moved to LC 39A one week later. On June 2, the SSMEs were tested for twenty seconds as part of a flight readiness firing of the main propulsion system. Deemed a success, *Discovery*'s first launch was scheduled for June 25.[327] The key events and dates for *Discovery's* build sequence are summarized in the following table.

[326] Archaeological Consultants Inc., "Shuttle Orbiter Final Assembly Building/Building 150," 16-17.
[327] Chris Gebhardt, "After 26 Years."

Key Events and Dates in the Construction of OV-103[328]

Date	Event
August 27, 1979	Long lead fabrication of the crew module starts
June 1, 1980	Fabrication and assembly of wings starts
June 20, 1980	Lower fuselage fabrication starts
September 29, 1980	Assembly of crew module starts
October 1, 1980	Assembly and fabrication of mid-fuselage starts
November 10, 1980	Structural assembly of aft fuselage starts
December 8, 1980	Initial installation of the aft fuselage starts
March 2, 1981	Fabrication and assembly of payload bay doors starts
October 19, 1981	Body flap detailed assembly and fabrication starts
October 26, 1981	Initial system installation into the crew module starts in Downey, Calif.
January 4, 1982	Initial system installation of the upper forward fuselage starts
March 16, 1982	Midfuselage delivered to Rockwell International's facility in Palmdale
March 30, 1982	Elevons delivered to Palmdale
April 30, 1982	Wings arrive at AFP 42 from the Grumman Corporation
April 30, 1982	Lower forward fuselage on dock in Palmdale
July 16, 1982	Upper forward fuselage on dock in Palmdale
August 5, 1982	Vertical stabilizer on dock in Palmdale
September 3, 1982	Final assembly starts
October 15, 1982	Body flap on dock in Palmdale
December 28, 1982	Crew module on dock in Palmdale
January 11, 1983	Aft fuselage on dock in Palmdale
February 25, 1983	Final assembly completed and closeout installation in Palmdale
February 28, 1983	Initial subsystems test starts and power-on in Palmdale
May 13, 1983	Initial subsystems testing completed
July 26, 1983	Subsystems testing completed
August 12, 1983	Final acceptance completed
September 9, 1983	Post-checkout completed in Palmdale
October 16, 1983	Rollout from Palmdale
October 28, 1983	First SSME on dock at KSC
November 5, 1983	Overland transport from Palmdale to DFRC
November 6, 1983	Flight from Edwards Air Force Base to Vandenberg Air Force Base
November 8, 1983	Flight from Vandenberg Air Force Base to Carswell Air Force Base in Texas
November 9, 1983	Flight from Carswell Air Force Base in Texas to KSC
November 15, 1983	Modification starts at the Orbiter Processing Facility
December 22, 1983	Second SSME on dock at KSC
January 5, 1984	Third SSME on dock at KSC
June 2, 1984	Flight Readiness Firing
August 30, 1984	First Flight (STS-41D)

[328] NASA KSC, "Space Shuttle Overview: *Discovery* (OV-103)," December 8, 2008, http://www-pao.ksc.nasa.gov/shuttle/resources/orbiters/discovery.html.