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Atlas V

Atlas V[a] is an expendable launch system and the fifth major version in the Atlas launch vehicle family. It was originally designed by Lockheed Martin, now being operated by United Launch Alliance (ULA), a joint venture between Lockheed Martin and Boeing. Atlas V is also a major NASA launch vehicle. It is America's longest-serving active rocket. In August 2021, ULA announced that Atlas V would be retired, and all 29 remaining launches had been sold.[10] As of 10 November 2022, 19 launches remain.

Each Atlas V launch vehicle consists of two main stages. The first stage is powered by a Russian RD-180 engine manufactured by Energomash and burning kerosene and liquid oxygen. The Centaur upper stage is powered by one or two American RL10 engine(s) manufactured by Aerojet Rocketdyne and burns liquid hydrogen and liquid oxygen. The Star 48 upper stage was used on the *New Horizons* mission as a third stage. Strap-on solid rocket boosters (SRBs) are used in most configurations. AJ-60A SRBs were used originally, but they were replaced in November 2020 by Graphite-Epoxy Motor (GEM 63) SRBs. The standard payload fairings are 4.2 or 5.4 m (14 or 18 ft) in diameter with various lengths.[11]

Vehicle description

The Atlas V was developed by Lockheed Martin Commercial Launch Services (LMCLS) as part of the U.S. Air Force Evolved Expendable Launch Vehicle (EELV) program and made its inaugural flight on 21 August 2002. The vehicle operates from SLC-41 at Cape Canaveral Space Force Station (CCSFS) and SLC-3E at Vandenberg Space Force Base. LMCLS continued to market the Atlas V to commercial customers worldwide until January 2018, when United Launch Alliance (ULA) assumed control of commercial marketing and sales.[12][13]

Atlas V first stage

The Atlas V first stage, the Common Core Booster (not to be confused with the Delta IV's Common Booster Core), is 3.8 m (12 ft) in diameter and 32.5 m (107 ft) in length. It is powered by one NPO Energomash RD-180 main engine burning 284,450 kg (627,100 lb) of liquid oxygen and RP-1. The booster operates for about four minutes, providing about 4 MN (900,000 lb_f) of thrust.[14] Thrust can be augmented with up to five Aerojet AJ-60A or Northrop Grumman GEM 63 strap-on solid rocket boosters, each providing an additional 1.27 MN (290,000 lb_f) of thrust for 94 seconds.

The main differences between the Atlas V and earlier Atlas I and II family launch vehicles are:

- The first stage tanks no longer use stainless steel monocoque pressure stabilized "balloon" construction. The tanks are isogrid aluminum and are structurally stable when unpressurized.[14]
- Accommodation points for parallel stages, both smaller solids and identical liquids, are built into first-stage structures.[14]
- The *"1.5 staging"* technique is no longer used, having been discontinued on the Atlas III with the introduction of the Russian RD-180 engine.[14]
- The main-stage diameter increased from 3.0 to 3.7 m (9.8 to 12.1 ft).[15]

Centaur upper stage

The Centaur upper stage uses a pressure-stabilized propellant-tank design and cryogenic propellants. The Centaur stage for Atlas V is stretched 1.7 m (5 ft 7 in) relative to the Atlas IIAS Centaur and is powered by either one or two Aerojet Rocketdyne RL10A-4-2 engines, each engine developing a thrust of 99.2 kN (22,300 lb_f). The inertial navigation unit (INU) located on the Centaur provides guidance and navigation for both the Atlas and Centaur and controls both Atlas and Centaur tank pressures and propellant use. The Centaur engines are capable of multiple in-space starts, making possible insertion into low Earth parking orbit, followed by a coast period and then insertion into GTO.[16] A subsequent third burn following a multi-hour coast can permit direct injection of payloads into geostationary orbit.

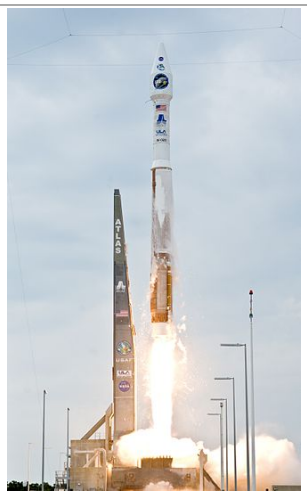
As of 2006, the Centaur vehicle had the highest proportion of burnable propellant relative to total mass of any modern hydrogen upper stage and hence can deliver substantial payloads to a high-energy state.[17]

Payload fairing

Atlas V payload fairings are available in two diameters, depending on satellite requirements. The 4.2 m (14 ft) diameter fairing,[18] originally designed for the Atlas II booster, comes in three different lengths: the original 9 m (30 ft) version and extended 10 and 11 m (33 and 36 ft) versions, first flown respectively on the AV-008/Astra 1KR and AV-004/Inmarsat-4 F1 missions. Fairings of up to 7.2 m (24 ft) diameter and 32.3 m (106 ft) length have been considered but were never implemented.[11]

A 5.4 m (18 ft) diameter fairing, with an internally usable diameter of 4.57 m (15.0 ft), was developed and built by RUAG Space[19] in Switzerland. The RUAG fairing uses carbon fiber composite construction and is based on a similar flight-proven fairing for the Ariane 5. Three configurations are manufactured to support the Atlas V:

Atlas V



Launch of an Atlas V 401 carrying the Lunar Reconnaissance Orbiter and LCROSS space probes on 18 June 2009.

Function	Medium-lift launch vehicle
Manufacturer	United Launch Alliance
Country of origin	United States
Cost per launch	US$110–153 million in 2016[1]
Size	
Height	58.3 m (191 ft) with payload fairing, 52.4 m (172 ft) with Starliner
Diameter	3.81 m (12.5 ft)
Mass	590,000 kg (1,300,000 lb)
Stages	2 (3 with Star 48 upper stage)
Capacity	
Payload to low Earth orbit	
Orbital inclination	28.70°
Mass	8,210–18,850 kg (18,100–41,560 lb)[2]
Payload to geostationary transfer orbit	
Mass	4,750–8,900 kg (10,470–19,620 lb)
Associated rockets	
Family	Atlas
Based on	Atlas III
Comparable	Delta IV · Falcon 9 · Long March 3B · Proton-M · Saturn IB
Launch history	

20.7 m (68 ft), 23.4 m (77 ft), and 26.5 m (87 ft) long.[19] While the classic 4.2 m (14 ft) fairing covers only the payload, the RUAG fairing is much longer and fully encloses both the Centaur upper stage and the payload.[20]

Upgrades

Many systems on the Atlas V have been the subject of upgrade and enhancement both prior to the first Atlas V flight and since that time. Work on a new Fault Tolerant Inertial Navigation Unit (FTINU) started in 2001 to enhance mission reliability for Atlas vehicles by replacing the existing non-redundant navigation and computing equipment with a fault-tolerant unit.[21] The upgraded FTINU first flew in 2006,[22] and in 2010 a follow-on order for more FTINU units was awarded.[23]

In 2015, ULA announced that the Aerojet Rocketdyne-produced AJ-60A solid rocket boosters (SRBs) then in use on Atlas V would be superseded by new GEM 63 boosters produced by Northrop Grumman Innovation Systems. The extended GEM 63XL boosters will also be used on the Vulcan Centaur launch vehicle that will replace the Atlas V.[24] The first Atlas V launch with GEM 63 boosters happened on 13 November 2020.[25]

Human-rating certification

Proposals and design work to human-rate the Atlas V began as early as 2006, with ULA's parent company Lockheed Martin reporting an agreement with Bigelow Aerospace that was intended to lead to commercial private trips to low Earth orbit (LEO).[26]

Human-rating design and simulation work began in earnest in 2010, with the award of US$6.7 million in the first phase of the NASA Commercial Crew Program (CCP) to develop an Emergency Detection System (EDS).[27]

As of February 2011, ULA had received an extension to April 2011 from NASA and was finishing up work on the EDS.[28]

NASA solicited proposals for CCP phase 2 in October 2010, and ULA proposed to complete design work on the EDS. At the time, NASA's goal was to get astronauts to orbit by 2015. Then-ULA President and CEO Michael Gass stated that a schedule acceleration to 2014 was possible if funded.[29] Other than the addition of the Emergency Detection System, no major changes were expected to the Atlas V rocket, but ground infrastructure modifications were planned. The most likely candidate for the human-rating was the N02 configuration, with no fairing, no solid rocket boosters, and dual RL10 engines on the Centaur upper stage.[29]

On 18 July 2011, NASA and ULA announced an agreement on the possibility of certifying the Atlas V to NASA's standards for human spaceflight.[30] ULA agreed to provide NASA with data on the Atlas V, while NASA would provide ULA with draft human certification requirements.[30] In 2011, the human-rated Atlas V was also still under consideration to carry spaceflight participants to the proposed Bigelow Commercial Space Station.[31]

In 2011, Sierra Nevada Corporation (SNC) picked the Atlas V to be the booster for its still-under-development Dream Chaser crewed spaceplane.[32] The Dream Chaser was intended to launch on an Atlas V, fly a crew to the ISS, and landing horizontally following a lifting-body reentry.[32] However, in late 2014 NASA did not select the Dream Chaser to be one of the two vehicles selected under the Commercial Crew competition.

On 4 August 2011, Boeing announced that it would use the Atlas V as the initial launch vehicle for its CST-100 crew capsule. CST-100 will take NASA astronauts to the International Space Station (ISS) and was also intended to service the proposed Bigelow Commercial Space Station.[33][34] A three-flight test program was projected to be completed by 2015, certifying the Atlas V/CST-100 combination for human spaceflight operations.[34] The first flight was expected to include an Atlas V rocket integrated with an uncrewed CST-100 capsule,[33] the second flight an in-flight launch abort system demonstration in the middle of that year,[34] and the third flight a crewed mission carrying two Boeing test-pilot astronauts into LEO and returning them safely at the end of 2015.[34] These plans did not materialize.

In 2014, NASA selected the Boeing CST-100 space capsule as part of the CCD program after extensive delays. Atlas V is the launch vehicle of the CST-100. The first launch of an uncrewed CST-100 capsule, Boeing OFT, occurred atop a human-rated Atlas V on the morning of 20 December 2019; the mission failed to meet goals due to a spacecraft failure, though the Atlas V launcher performed well.[35][36] In 2022, an Atlas V launched a Starliner capsule for the second time, ending with mission success.[37][38]

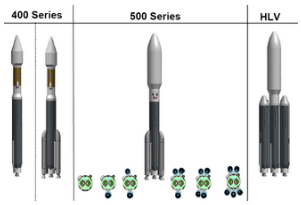
Project Kuiper

Amazon has selected the Atlas V to launch satellites for Project Kuiper. Project Kuiper will offer a high-speed satellite internet constellation service. The contract signed with Amazon is for nine launches. Project Kuiper aims to put thousands of satellites into orbit. ULA is Amazon's first launch provider.[39]

Versions

Each Atlas V booster configuration has a three-digit designation. The first digit shows the diameter (in meters) of the payload fairing and has a value of "4" or "5" for fairing launches and "N" for crew capsule launches (as no payload fairing is used when a crew capsule is launched). The second digit indicates the number of solid rocket

Status	Active
Launch sites	Cape Canaveral, SLC-41 VAFB, SLC-3E
Total launches	**97**[3][4][5] [show] **401:** 41 **411:** 6 **421:** 9 **431:** 3 **501:** 7 **511:** 1 **521:** 2 **531:** 5 **541:** 9 **551:** 12 **N22:** 2
Success(es)	**97** [show] **401:** 41 **411:** 6 **421:** 9 **431:** 3 **501:** 7 **511:** 1 **521:** 2 **531:** 5 **541:** 9 **551:** 12 **N22:** 2
First flight	21 August 2002 Hot Bird 6
Last flight	10 November 2022 JPSS-2
Type of passengers/cargo	Space probes Perseverance Curiosity InSight Juno LRO / LCROSS MMS MRO MAVEN New Horizons OSIRIS-REx Solar Dynamics Observatory Van Allen Probes Boeing X-37B Cygnus SolO Starliner GOES TDRS NRO classified payloads Intruder Quasar SBIRS



Atlas V family with asymmetric SRBs. The HLV was not developed.

boosters (SRBs) attached to the base of the launch vehicle and can range from "0" through "3" with the 4 m (13 ft) fairing, and "0" through "5" with the 5 m (16 ft) fairing. As seen in the first image, all SRB layouts are asymmetrical. The third digit represents the number of engines on the Centaur stage, either "1" or "2".

For example, an Atlas V 551 has a 5-meter fairing, 5 SRBs, and 1 Centaur engine, whereas an Atlas V 431 has a 4-meter fairing, 3 SRBs, and 1 Centaur engine.[40] The Atlas V N22 with no fairing, two SRBs, and 2 Centaur engines was first launched in 2019. The flight carried the Starliner vehicle for its first orbital test flight.

As of June 2015, all versions of the Atlas V, its design and production rights, and intellectual property rights are owned by ULA and Lockheed Martin.[41]

Capabilities

List date: 8 August 2019 [42] Mass to LEO numbers are at an inclination of 28.5°.

Upper stages

- SEC – Single Engine Centaur
- DEC – Dual Engine Centaur

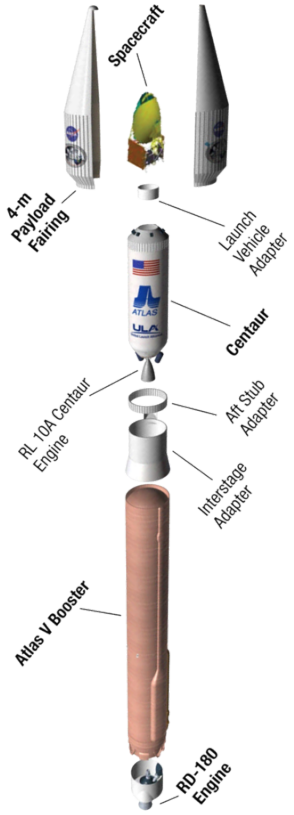
Launch system status

- ☐ Active
- ☐ Retired
- ☐ Never launched; not planned

	Topaz
Boosters – AJ-60A[6]	
No. boosters	0 to 5
Height	17 m (56 ft)[6]
Diameter	1.6 m (5 ft 3 in)
Gross mass	46,697 kg (102,949 lb)
Propellant mass	42,630 kg (93,980 lb)[7]
Maximum thrust	1,688.4 kN ($379,600\ lb_f$)
Specific impulse	279.3 s (2.739 km/s)
Burn time	94 seconds
Propellant	HTPB
Boosters – GEM 63[8][9]	
No. boosters	0 to 5
Height	20.1 m (66 ft)[8]
Diameter	1.6 m (5 ft 3 in)
Gross mass	49,300 kg (108,700 lb)
Propellant mass	44,200 kg (97,400 lb)
Maximum thrust	1,663 kN ($374,000\ lb_f$)
Burn time	94 seconds
Propellant	HTPB
First stage – Atlas CCB	
Height	32.46 m (106.5 ft)
Diameter	3.81 m (12.5 ft)
Empty mass	21,054 kg (46,416 lb)
Propellant mass	284,089 kg (626,309 lb)
Powered by	1 RD-180
Maximum thrust	3,827 kN ($860,000\ lb_f$) (sea level) 4,152 kN ($933,000\ lb_f$) (vacuum)
Specific impulse	311.3 s (3.053 km/s) (sea level) 337.8 s (3.313 km/s) (vacuum)
Burn time	253 seconds
Propellant	RP-1 / LOX
Second stage – Centaur	
Height	12.68 m (41.6 ft)
Diameter	3.05 m (10.0 ft)
Empty mass	2,316 kg (5,106 lb)
Propellant mass	20,830 kg (45,920 lb)
Powered by	1 RL10A or 1 RL10C (SEC), or 2 RL10A (DEC)

Version	Fairing	CCBs	SRBs	Upper stage	Payload to LEO, kg	Payload to GTO, kg	Launches to date	Base price
401	4 m	1	–	SEC	9,797	4,750 [43]	41	US$109 million [1]
402	4 m	1	–	DEC	12,500 [44]	–	0	–
411	4 m	1	1	SEC	12,150 [43]	5,950	6	US$115 million [1]
412	4 m	1	1	DEC	–	–	0	–
421	4 m	1	2	SEC	14,067 [43]	6,890	9	US$123 million [1]
422	4 m	1	2	DEC	–	–	0	–
431	4 m	1	3	SEC	15,718 [43]	7,700	3	US$130 million [1]
501	5.4 m	1	–	SEC	8,123 [43]	3,775	7	US$120 million [1]
502	5.4 m	1	–	DEC	–	–	0	–
511	5.4 m	1	1	SEC	10,986[43]	5,250	1	US$130 million [1]
512	5.4 m	1	1	DEC	–	–	0	–
521	5.4 m	1	2	SEC	13,490 [43]	6,475	2	US$135 million [1]
522	5.4 m	1	2	DEC	–	–	0	–
531	5.4 m	1	3	SEC	15,575 [43]	7,475	5	US$140 million [1]
532	5.4 m	1	3	DEC	–	–	0	–
541	5.4 m	1	4	SEC	17,443 [43]	8,290	9	US$145 million [1]
542	5.4 m	1	4	DEC	–	–	0	–
551	5.4 m	1	5	SEC	18,814 [43]	8,900	12	US$153 million [1]
552	5.4 m	1	5	DEC	20,520 [44]	–	0	–
Heavy (HLV / 5H1)	5.4 m	3	–	SEC	–	–	0	–
Heavy (HLV DEC / 5H2)	5.4 m	3	–	DEC	29,400	–	0	–

Maximum thrust	99.2 kN (22,300 lb_f) (RL10A)
Specific impulse	450.5 s (4.418 km/s) (RL10A-4-2)
Burn time	842 seconds (RL10A-4-2)
Propellant	LH_2 / LOX



Atlas V 401

Version	Fairing	CCBs	SRBs	Upper stage	Payload to LEO, kg	Payload to GTO, kg	Launches to date	Base price		
N22 (for CST-100 Starliner) [45]		None	1	2	DEC	~13,000 [46] (to ISS)	–	2	–	

Launch cost

Before 2016, pricing information for Atlas V launches was limited. In 2010, NASA contracted with ULA to launch the MAVEN mission on an Atlas V 401 for approximately US$187 million.[47] The 2013 cost of this configuration for the U.S. Air Force under their block buy of 36 launch vehicles was US$164 million.[48] In 2015, the TDRS-M launch on an Atlas 401 cost NASA US$132.4 million.[49]

Starting in 2016, ULA provided pricing for the Atlas V through its RocketBuilder website, advertising a base price for each launch vehicle configuration, which ranges from US$109 million for the 401 up to US$153 million for the 551.[1] Each additional SRB adds an average of US$6.8 million to the cost of the launch vehicle. Customers can also choose to purchase larger payload fairings or additional launch service options. NASA and Air Force launch costs are often higher than equivalent commercial missions due to additional government accounting, analysis, processing, and mission assurance requirements, which can add US$30–80 million to the cost of a launch.[50]

In 2013, launch costs for commercial satellites to GTO averaged about US$100 million, significantly lower than historic Atlas V pricing.[51] However, in recent years the price of an Atlas V [401] has dropped from approximately US$180 million to US$109 million, in large part due to competitive pressure that emerged in the launch services marketplace during the early 2010s. ULA CEO Tory Bruno stated in 2016 that ULA needs at least two commercial missions each year in order to stay profitable going forward.[52] ULA is not attempting to win these missions on purely lowest purchase price, stating that it "would rather be the best *value* provider".[53] In 2016, ULA suggested that customers would have much lower insurance and delay costs because of the high Atlas V reliability and schedule certainty, making overall customer costs close to that of using competitors like the SpaceX Falcon 9.[54]

Historically proposed versions

In 2006, ULA offered an Atlas V Heavy option that would use three Common Core Booster (CCB) stages strapped together to lift a 29,400 kg (64,800 lb) payload to low Earth orbit.[55] ULA stated at the time that 95% of the hardware required for the Atlas V Heavy has already been flown on the Atlas V single-core vehicles.[11] The lifting capability of the proposed launch vehicle was to be roughly equivalent to the Delta IV Heavy,[11] which uses RS-68 engines developed and produced domestically by Aerojet Rocketdyne.

A 2006 report, prepared by the RAND Corporation for the Office of the Secretary of Defense, stated that Lockheed Martin had decided not to develop an Atlas V heavy-lift vehicle (HLV).[56] The report recommended for the U.S. Air Force and the National Reconnaissance Office (NRO) to "determine the necessity of an EELV heavy-lift variant, including development of an Atlas V Heavy", and to "resolve the RD-180 issue, including coproduction, stockpile, or United States development of an RD-180 replacement".[57]

In 2010, ULA stated that the Atlas V Heavy variant could be available to customers 30 months from the date of order.[11]

Atlas V PH2

In late 2006, the Atlas V program gained access to the tooling and processes for 5-meter-diameter stages used on Delta IV when Boeing and Lockheed Martin space operations were merged into the United Launch Alliance. This led to a proposal to combine the 5-meter-diameter Delta IV tankage production processes with dual RD-180 engines, resulting in the **Atlas Phase 2**.

An **Atlas V PH2-Heavy** consisting of three 5-meter stages in parallel with six RD-180s was considered in the Augustine Report as a possible heavy lifter for use in future space missions, as well as the Shuttle-derived Ares V and Ares V Lite.[58] If built, the Atlas PH2-Heavy was projected to be able to launch a payload mass of approximately 70 t (69 long tons; 77 short tons) into an orbit of 28.5° inclination.[58]

Booster for GX rocket

The Atlas V Common Core Booster was to have been used as the first stage of the joint US-Japanese **GX rocket**, which was scheduled to make its first flight in 2012.[59] GX launches would have been from the Atlas V launch complex at Vandenberg Air Force Base, SLC-3E. However, the Japanese government decided to cancel the GX project in December 2009.[60]

Out-licensing rejected by ULA

In May 2015, a consortium of companies, including Aerojet and Dynetics, sought to license the production or manufacturing rights to the Atlas V using the AR1 engine in place of the RD-180. The proposal was rejected by ULA.[61]

Atlas V launches

Flight No.	Date and time (UTC)	Type	Serial no.	Launch site	Payload	Type of payload	Orbit	Outcome	Remarks
1	21 August 2002 22:05	401	AV-001	CCAFS, SLC-41	Hot Bird 6	Commercial communications satellite (comsat)	GTO	Success [62]	First Atlas V launch
2	13 May 2003 22:10	401	AV-002	CCAFS, SLC-41	Hellas Sat 2	Commercial comsat	GTO	Success [63]	First satellite for Greece and Cyprus
3	17 July 2003 23:45	521	AV-003	CCAFS, SLC-41	Rainbow-1	Commercial comsat	GTO	Success [64]	First Atlas V 500 launch First Atlas V launch with SRBs
4	17 December 2004 12:07	521	AV-005	CCAFS, SLC-41	AMC-16	Commercial comsat	GTO	Success [65]	Last flight of the 521 configuration
5	11 March 2005 21:42	431	AV-004	CCAFS, SLC-41	Inmarsat-4 F1	Commercial comsat	GTO	Success [66]	First Atlas V 400 launch with SRBs
6	12 August 2005 11:43	401	AV-007	CCAFS, SLC-41	Mars Reconnaissance Orbiter (MRO)	Mars orbiter	Heliocentric to Areocentric	Success [67]	First Atlas V launch for NASA
7	19 January 2006 19:00	551	AV-010	CCAFS, SLC-41	New Horizons	Pluto and Kuiper Belt probe	Hyperbolic	Success [68]	Boeing Star 48B thir stage used, first Atla V launch with a third stage.
8	20 April 2006 20:27	411	AV-008	CCAFS, SLC-41	Astra 1KR	Commercial comsat	GTO	Success [69]	
9	9 March 2007 03:10	401	AV-013	CCAFS, SLC-41	Space Test Program-1	6 military research satellites	LEO	Success [70]	▪ First ULA Atlas launch ▪ First Atlas V nigh launch ▪ First three-burn Atlas V mission ▪ Orbital Express ▪ FalconSAT-3
10	15 June 2007 15:12	401	AV-009	CCAFS, SLC-41	USA-194 (NROL-30/NOSS-4-3A and -4-3B)	Two NRO Reconnaissance satellites	LEO	Success [71]	First Atlas V flight fo the National Reconnaissance Office [72] Atlas did r achieve the intende orbit, but payload compensated for shortfall. NRO declared the missior a success.[71][73][74]
11	11 October 2007 00:22	421	AV-011	CCAFS, SLC-41	USA-195 (WGS-1)	Military comsat	GTO	Success [75]	Valve replacement delayed launch.[76]

Flight No.	Date and time (UTC)	Type	Serial no.	Launch site	Payload	Type of payload	Orbit	Outcome	Remarks
12	10 December 2007 22:05	401	AV-015	CCAFS, SLC-41	USA-198 (NROL-24)	NRO reconnaissance satellite	Molniya	Success [77]	
13	13 March 2008 10:02	411	AV-006	VAFB, SLC-3E	USA-200 (NROL-28)	NRO reconnaissance satellite	Molniya	Success [78]	First Atlas V launch from Vandenberg.[78]
14	14 April 2008 20:12	421	AV-014	CCAFS, SLC-41	ICO G1	Commercial comsat	GTO	Success [79]	▪ Lockheed Martin Commercial Launch Services launch ▪ Heaviest payload launched by an Atlas until the launch of MUOS in 2012. ▪ Largest comsat in the world at time of launch until the launch of TerreStar-1 in 2009 by Ariane 5 and then Telstar 19V on 21 July 2018 by Falcon 9
15	4 April 2009 00:31	421	AV-016	CCAFS, SLC-41	USA-204 (WGS-2)	Military comsat	GTO	Success [80]	
16	18 June 2009 21:32	401	AV-020	CCAFS, SLC-41	LRO/LCROSS	Lunar exploration	HEO to Lunar	Success [81]	First Centaur stage t impact on the Moon.
17	8 September 2009 21:35	401	AV-018	CCAFS, SLC-41	USA-207 (Palladium At Night - PAN)	Military comsat [82]	GTO[82]	Success [83]	The Centaur upper stage fragmented in orbit about 24 March 2019.[84]
18	18 October 2009 16:12	401	AV-017	VAFB, SLC-3E	USA-210 (DMSP 5D3-F18)	Military weather satellite	LEO	Success [85]	
19	23 November 2009 06:55	431	AV-024	CCAFS, SLC-41	Intelsat 14	Commercial comsat	GTO	Success [86]	LMCLS launch
20	11 February 2010 15:23	401	AV-021	CCAFS, SLC-41	SDO	Solar telescope	GTO	Success [87]	
21	22 April 2010 23:52	501	AV-012	CCAFS, SLC-41	USA-212 (X-37B OTV-1)	Military orbital test vehicle	LEO	Success [88]	A piece of the extern fairing did not break up on impact, but

Flight No.	Date and time (UTC)	Type	Serial no.	Launch site	Payload	Type of payload	Orbit	Outcome	Remarks
									washed up on Hilton Head Island.[89]
22	14 August 2010 11:07	531	AV-019	CCAFS, SLC-41	USA-214 (AEHF-1)	Military comsat	GTO	Success [90]	
23	September 21, 2010 04:03	501	AV-025	VAFB, SLC-3E	USA-215 (NROL-41)	NRO reconnaissance satellite	LEO	Success [91]	
24	5 March 2011 22:46	501	AV-026	CCAFS, SLC-41	USA-226 (X-37B OTV-2)	Military orbital test vehicle	LEO	Success [92]	
25	15 April 2011 04:24	411	AV-027	VAFB, SLC-3E	USA-229 (NROL-34)	NRO reconnaissance satellite	LEO	Success [93]	
26	7 May 2011 18:10	401	AV-022	CCAFS, SLC-41	USA-230 (SBIRS GEO-1)	Missile Warning satellite	GTO	Success [94]	
27	5 August 2011 16:25	551	AV-029	CCAFS, SLC-41	Juno	Jupiter orbiter	Hyperbolic to Jovicentric	Success [95]	
28	26 November 2011 15:02	541	AV-028	CCAFS, SLC-41	Mars Science Laboratory (MSL)	Mars rover	Hyperbolic (Mars landing)	Success [96]	First launch of the 5 configuation [97] Centaur entered orb around the Sun.[98]
29	24 February 2012 22:15	551	AV-030	CCAFS, SLC-41	MUOS-1	Military comsat	GTO	Success [99]	▪ 200th Centaur launch [100] ▪ Heaviest payloa launched by an Atlas until launch of MUOS-2
30	4 May 2012 18:42	531	AV-031	CCAFS, SLC-41	USA-235 (AEHF-2)	Military comsat	GTO	Success[101]	
31	20 June 2012 12:28	401	AV-023	CCAFS, SLC-41	USA-236 (NROL-38)	NRO reconnaissance satellite	GTO	Success [102]	50th EELV launch
32	30 August 2012 08:05	401	AV-032	CCAFS, SLC-41	Van Allen Probes (RBSP)	Van Allen Belts exploration	HEO	Success [103]	
33	13 September 2012 21:39	401	AV-033	VAFB, SLC-3E	USA-238 (NROL-36)	NRO reconnaissance satellites	LEO	Success [104]	
34	11 December 2012 18:03	501	AV-034	CCAFS, SLC-41	USA-240 (X-37B OTV-3)	Military orbital test vehicle	LEO	Success [105]	

Flight No.	Date and time (UTC)	Type	Serial no.	Launch site	Payload	Type of payload	Orbit	Outcome	Remarks
35	31 January 2013 01:48	401	AV-036	CCAFS, SLC-41	TDRS-K (TDRS-11)	Data relay satellite	GTO	Success [106]	
36	11 February 2013 18:02	401	AV-035	VAFB, SLC-3E	Landsat 8	Earth Observation satellite	LEO	Success[107]	First West Coast Atla V Launch for NASA
37	March 19, 2013 21:21	401	AV-037	CCAFS, SLC-41	USA-241 (SBIRS GEO 2)	Missile Warning satellite	GTO	Success [108]	
38	May 15, 2013 21:38	401	AV-039	CCAFS, SLC-41	USA-242 (GPS IIF-4)	Navigation satellite	MEO	Success [109]	First GPS satellite launched by an Atlas V
39	19 July 2013 13:00	551	AV-040	CCAFS, SLC-41	MUOS-2	Military comsat	GTO	Success [110]	
40	September 18, 2013 08:10	531	AV-041	CCAFS, SLC-41	USA-246 (AEHF-3)	Military comsat	GTO	Success [111]	
41	November 18, 2013 18:28	401	AV-038	CCAFS, SLC-41	MAVEN	Mars orbiter	Hyperbolic to Areocentric	Success [112]	
42	6 December 2013 07:14:30	501	AV-042	VAFB, SLC-3E	USA-247 (NROL-39)	NRO reconnaissance satellite	Low Earth orbit	Success [113]	
43	January 24, 2014 02:33	401	AV-043	CCAFS, SLC-41	TDRS-L (TDRS-12)	Data relay satellite	GTO	Success[114]	
44	April 3, 2014 14:46	401	AV-044	VAFB, SLC-3E	USA-249 (DMSP-5D3 F19)	Military weather satellite	Low Earth orbit	Success [115]	50th RD-180 launch
45	April 10, 2014 17:45	541	AV-045	CCAFS, SLC-41	USA-250 (NROL-67)	NRO reconnaissance satellite	GTO	Success[116]	
46	May 22, 2014 13:09	401	AV-046	CCAFS, SLC-41	USA-252 (NROL-33)	NRO reconnaissance satellite	GTO	Success[117]	
47	August 2, 2014 03:23	401	AV-048	CCAFS, SLC-41	USA-256 (GPS IIF-7)	Navigation satellite	MEO	Success[118]	
48	August 13, 2014 18:30	401	AV-047	VAFB, SLC-3E	WorldView-3	Earth imaging satellite	Low Earth orbit	Success [119]	
49	September 17, 2014 00:10	401	AV-049	CCAFS, SLC-41	USA-257 (CLIO)	Military comsat[120]	GTO[120]	Success[121]	The Centaur upper stage fragmented or 31 August 2018[122]

Flight No.	Date and time (UTC)	Type	Serial no.	Launch site	Payload	Type of payload	Orbit	Outcome	Remarks
50	October 29, 2014 17:21	401	AV-050	CCAFS, SLC-41	USA-258 (GPS IIF-8)	Navigation satellite	MEO	Success[123]	50th Atlas V launch
51	December 13, 2014 03:19	541	AV-051	VAFB, SLC-3E	USA-259 (NROL-35)	NRO reconnaissance satellite	Molniya	Success [124]	First use of the RL-10C engine on the Centaur stage
52	January 21, 2015 01:04	551	AV-052	CCAFS, SLC-41	MUOS-3	Military comsat	GTO	Success[125]	
53	March 13, 2015 02:44	421	AV-053	CCAFS, SLC-41	MMS	Magnetosphere research satellites	HEO	Success[126]	
54	May 20, 2015 15:05	501	AV-054	CCAFS, SLC-41	USA-261 (X-37B OTV-4/AFSPC-5)	Military orbital test vehicle	LEO	Success[127]	
55	July 15, 2015 15:36	401	AV-055	CCAFS, SLC-41	USA-262 (GPS IIF-10)	Navigation satellite	MEO	Success[128]	
56	September 2, 2015 10:18	551	AV-056	CCAFS, SLC-41	MUOS-4	Military comsat	GTO	Success[129]	
57	October 2, 2015 10:28	421	AV-059	CCAFS, SLC-41	Morelos-3	Comsat	GTO	Success[130]	
58	October 8, 2015 12:49	401	AV-058	VAFB SLC-3E	USA-264 (NROL-55)	NRO reconnaissance satellites	LEO	Success[131]	
59	October 31, 2015 16:13	401	AV-060	CCAFS SLC-41	USA-265 (GPS IIF-11)	Navigation satellite	MEO	Success[132]	
60	December 6, 2015 21:44	401	AV-061	CCAFS SLC-41	Cygnus CRS OA-4	ISS logistics spacecraft	LEO	Success[133]	First Atlas rocket use to directly support th ISS program
61	February 5, 2016 13:38	401	AV-057	CCAFS SLC-41	USA-266 (GPS IIF-12)	Navigation satellite	MEO	Success[134]	
62	March 23, 2016 03:05	401	AV-064	CCAFS SLC-41	Cygnus CRS OA-6	ISS logistics spacecraft	LEO	Success[135]	First stage shut dow early but did not affe mission outcome
63	June 24, 2016 14:30	551	AV-063	CCAFS SLC-41	MUOS-5	Military comsat	GTO	Success[136]	
64	July 28, 2016 12:37	421	AV-065	CCAFS SLC-41	USA-267 (NROL-61)	NRO reconnaissance satellite	GTO	Success[137]	
65	September 8, 2016 23:05	411	AV-067	CCAFS SLC-41	OSIRIS-REx	Asteroid sample return	Heliocentric	Success[138]	

Flight No.	Date and time (UTC)	Type	Serial no.	Launch site	Payload	Type of payload	Orbit	Outcome	Remarks
66	November 11, 2016 18:30	401	AV-062	VAFB SLC-3E	WorldView-4 (GeoEye-2) + 7 NRO cubesats	Earth Imaging, cubesats	SSO	Success[139]	LMCLS launch
67	November 19, 2016 23:42	541	AV-069	CCAFS SLC-41	GOES-R (GOES-16)	Meteorology	GTO	Success[140]	100th EELV launch
68	December 18, 2016 19:13	431	AV-071	CCAFS SLC-41	EchoStar 19 (Jupiter 2)	Commercial comsat	GTO	Success[141]	LMCLS launch Last flight of the 4 configuration
69	January 21, 2017 00:42	401	AV-066	CCAFS SLC-41	USA-273 (SBIRS GEO-3)	Missile Warning satellite	GTO	Success[142]	
70	March 1, 2017 17:49	401	AV-068	VAFB SLC-3E	USA-274 (NROL-79)	NRO Reconnaissance Satellite	LEO	Success[143]	
71	April 18, 2017 15:11	401	AV-070	CCAFS SLC-41	Cygnus CRS OA-7	ISS logistics spacecraft	LEO	Success[144]	
72	August 18, 2017 12:29	401	AV-074	CCAFS SLC-41	TDRS-M (TDRS-13)	Data relay satellite	GTO	Success[145]	
73	September 24, 2017 05:49	541	AV-072	VAFB SLC-3E	USA-278 (NROL-42)	NRO Reconnaissance Satellite	Molniya	Success[146]	
74	October 15, 2017 07:28	421	AV-075	CCAFS SLC-41	USA-279 (NROL-52)	NRO Reconnaissance satellite	GTO	Success[147]	
75	January 20, 2018 00:48	411	AV-076	CCAFS SLC-41	USA-282 (SBIRS GEO-4)	Missile Warning satellite	GTO	Success[148]	
76	March 1, 2018 22:02	541	AV-077	CCAFS SLC-41	GOES-S (GOES-17)	Meteorology	GTO	Success[149]	Expended the 100th AJ-60 SRB
77	April 14, 2018 23:13	551	AV-079	CCAFS SLC-41	AFSPC-11	Military comsat	GEO	Success[150]	
78	May 5, 2018 11:05	401	AV-078	VAFB SLC-3E	InSight MarCO	Mars lander; 2 CubeSats	Hyperbolic (Mars landing)	Success[151]	First interplanetary mission from VAFB; first interplanetary CubeSats.
79	October 17, 2018, 04:15	551	AV-073	CCAFS SLC-41	USA-288 (AEHF-4)	Military comsat	GTO	Success[152][153]	250th Centaur. The Centaur upper stage fragmented in orbit c 6 Apr 2019.[154][155]
80	August 8, 2019, 10:13	551	AV-083	CCAFS SLC-41	USA-292 (AEHF-5)	Military comsat	GTO	Success[156]	

Flight No.	Date and time (UTC)	Type	Serial no.	Launch site	Payload	Type of payload	Orbit	Outcome	Remarks
81	December 20, 2019, 11:36	N22	AV-080	CCAFS SLC-41	Starliner Boeing OFT	Uncrewed orbital test flight	LEO (ISS)	Success	First flight of a Dual-Engine Centaur on Atlas V. First orbital test flight of Starliner Planned to visit ISS, but an anomaly with the Starliner vehicle left the spacecraft in too low an orbit to d so. The Atlas V rock performed as expected and thus t mission is listed as successful here.[157]
82	February 10, 2020, 04:03	411	AV-087	CCAFS SLC-41	Solar Orbiter	Solar heliophysics orbiter	Heliocentric	Success[158]	Last Flight of the 41 configuration
83	March 26, 2020, 20:18	551	AV-086	CCAFS SLC-41	USA-298 (AEHF-6)	Military comsat	GTO	Success[159]	First ever flight for t U.S. Space Force. 500th flight of the RL10 engine
84	May 17, 2020, 13:14	501	AV-081	CCAFS SLC-41	USA-299 (USSF-7 (X-37B OTV-6, Falcon-Sat-8))	X-37 military spaceplane; USAFA sat.	LEO	Success[160]	Sixth flight of X-37B FalconSat-8
85	July 30, 2020, 11:50	541	AV-088	CCAFS SLC-41	Mars 2020	Mars rover	Heliocentric	Success[161]	Launch of the Perseverance rover
86	November 13, 2020, 22:32	531	AV-090	CCAFS SLC-41	USA 310 (NROL-101)	NRO Reconnaissance Satellite	LEO	Success[162]	First usage of new GEM 63 solid rocket boosters.
87	18 May 2021, 17:37	421	AV-091	CCAFS, SLC-41	USA 315 (SBIRS-GEO 5)	Missile warning satellite	GTO	Success [163]	First usage of RL-10C-1-1 upper stage engine. Mission was successful, but unexpected vibration was observed in the new engine. Further use of this engine variant is on hold pending better understanding.[164]
88	27 September 2021 18:12	401	AV-092	VSFB, SLC-3E	Landsat 9	Earth Observation satellite	LEO	Success [165]	
89	16 October 2021 09:34	401	AV-096	CCAFS, SLC-41	Lucy	Space probe	Heliocentric	Success [166]	
90	7 December	551	AV-093	CCAFS, SLC-41	STP-3	Technology demonstration	GEO	Success [167]	Longest flight ever b an Atlas V Rocket

Flight No.	Date and time (UTC)	Type	Serial no.	Launch site	Payload	Type of payload	Orbit	Outcome	Remarks
91	January 2022 19:00	511	AV-084	CCSFS, SLC-41	USSF-8 (GSSAP 5 & 6)	Space Surveillance	GEO	Success[168]	First and only planne flight of the 511 configuration
92	1 March 2022 21:38	541	AV-095	CCSFS, SLC-41	GOES-T	Meteorology	GEO	Success[169]	
93	19 May 2022 22:54	N22	AV-082	CCSFS, SLC-41	Boe OFT-2	Uncrewed orbital test flight	LEO (ISS)	Success[170]	
94	1 July 2022 23:15	541	AV-094	CCSFS, SLC-41	USSF-12 (WFOV)	Early warning	GEO	Success[171]	Last flight of the 541 configuration 100th flight of an R 180 engine
95	4 August 2022 10:29	421	AV-097	CCSFS, SLC-41	USA-336 (SBIRS GEO-6)	Missile warning satellite	GEO	Success[172]	Last flight of the 421 configuration
96	4 October 2022 21:36	531	AV-098	CCSFS, SLC-41	SES-20 & SES-21	Communication Satellites	GEO	Success[173]	Last flight of the 531 configuration
97	10 November 2022 09:49	401	AV-099	VSFB, SLC-3E	JPSS-2 / LOFTID	Environmental Satellites	SSO	Success[174]	Last flight of the 401 configuration and las Atlas V launch from VSFB. Final flight of an Atlas V with a 4-meter fairing. 100th use of Single Engine Centaur.

ULA has stopped selling the Atlas V. It will fly 19 more launches.[175]

For planned launches, see List of Atlas launches (2020–2029).

Notable missions

The first payload, the Hot Bird 6 communications satellite, was launched to geostationary transfer orbit (GTO) on 21 August 2002 by an Atlas V 401.[176]

On 12 August 2005, the Mars Reconnaissance Orbiter was launched aboard an Atlas V 401 launch vehicle from Space Launch Complex 41 at Cape Canaveral Air Force Station (CCAFS). The Centaur upper stage of the launch vehicle completed its burns over a 56-minute period and placed MRO into an interplanetary transfer orbit towards Mars.[67]

On 19 January 2006, New Horizons was launched by a Lockheed Martin Atlas V 551 rocket. A third stage was added to increase the heliocentric (escape) speed. This was the first launch of the Atlas V 551 configuration with five solid rocket boosters, and the first Atlas V with a third stage.[177]

On 6 December 2015, Atlas V lifted its heaviest payload to date into orbit – a 16,517 lb (7,492 kg) Cygnus resupply craft.[178]

On 8 September 2016, the OSIRIS-REx Asteroid Sample Return Mission was launched on an Atlas V 411 launch vehicle. It arrived at the asteroid Bennu in December 2018 and departed back to Earth in May 2021 to arrive September 2022 at with a sample ranging from 60 grams to 2 kilograms in 2023.[179]

The first four Boeing X-37B spaceplane missions were successfully launched with the Atlas V. The X-37B, also known as the Orbital Test Vehicle (OTV), is a reusable robotic spacecraft operated by USAF that can autonomously conduct landings from orbit to a runway.[180] X-37B flights are launched on Atlas V's from Cape Canaveral Space Force Station in Florida. The first Vandenberg Air Force Base landing at the Space Shuttle 15,000 ft (4,600 m) runway occurred in December 2010.[181] Landings occur at both Vandenberg and Cape Canaveral depending on mission requirements.[180]

On 20 December 2019, the first Starliner crew capsule was launched in Boe-OFT un-crewed test flight. The Atlas V launch vehicle performed flawlessly but an anomaly with the spacecraft left it in a wrong orbit. The orbit was too low to reach the flight's destination of ISS, and the mission was subsequently cut short.

Mission success record

In its 94 launches (as of July 2022), starting with its first launch in August 2002, Atlas V has achieved a 100% mission success rate and a 98.93% vehicle success rate.[182] This is in contrast to the industry success rate of 90%–95%.[183]

The first anomalous event in the use of the Atlas V launch system occurred on 15 June 2007, when the engine in the Centaur upper stage of an Atlas V shut down early, leaving its payload – a pair of NROL-30 ocean surveillance satellites – in a lower than intended orbit. The cause of the anomaly was traced to a leaky valve, which allowed fuel to leak during the coast between the first and second burns. The resulting lack of fuel caused the second burn to terminate 4 seconds early.[184] Replacing the valve led to a delay in the next Atlas V launch.[76] However, the customer (the National Reconnaissance Office) categorized the mission as a success.[185][186]

A flight on 23 March 2016, suffered an underperformance anomaly on the first-stage burn and shut down 5 seconds early. The Centaur proceeded to boost the Orbital Cygnus payload, the heaviest on an Atlas to date, into the intended orbit by using its fuel reserves to make up for the shortfall from the first stage. This longer burn cut short a later Centaur disposal burn.[187] An investigation of the incident revealed that this anomaly was due to a fault in the main engine mixture-ratio supply valve, which restricted the flow of fuel to the engine. The investigation and subsequent examination of the valves on upcoming missions led to a delay of the next several launches.[188]

Notable payloads

- Boeing Starliner
- Boeing X-37
- ELaNa
- Geostationary Operational Environmental Satellite
- GPS
- Inmarsat
- InSight
- Juno
- Lucy
- Lunar Reconnaissance Orbiter
- Lunar Crater Observation and Sensing Satellite
- Mars Reconnaissance Orbiter
- Curiosity
- Perseverance and Ingenuity
- MAVEN
- MUOS-1 (200th Centaur upper stage launch)
- New Horizons
- NROL launches
- OSIRIS-REx
- Solar Dynamics Observatory
- Solar Orbiter
- Space Test Program
- USA-212

Replacement with Vulcan

In 2014, geopolitical and U.S. political considerations because of the Russian war with Crimea led to an effort to replace the Russian-supplied RD-180 engine used on the first-stage booster of the Atlas V. Formal study contracts were issued in June 2014 to a number of U.S. rocket-engine suppliers.[189] The results of those studies led to a decision by ULA to develop the new Vulcan Centaur launch vehicle to replace the existing Atlas V and Delta IV.[190]

In September 2014, ULA announced a partnership with Blue Origin to develop the BE-4 LOX/methane engine to replace the RD-180 on a new first-stage booster. As the Atlas V core is designed around RP-1 fuel and cannot be retrofitted to use a methane-fueled engine, a new first stage is being developed. This booster will have the same first-stage tankage diameter as the Delta IV and will be powered by two 2,400 kN (540,000 lb_f) thrust BE-4 engines.[189][191][192] The engine was already in its third year of development by Blue Origin, and ULA expected the new stage and engine to start flying no earlier than 2019.

Vulcan was initially planned to use the same Centaur upper stage as on Atlas V, and later to upgrade to ACES, however ACES is no longer being pursued, and Centaur V will be used instead.[193] It will also use a variable number of optional solid rocket boosters, called the GEM 63XL, derived from the new solid boosters planned for Atlas V.[24]

As of 2017, the Aerojet AR1 rocket engine was under development as a backup plan for Vulcan.[194]

As of August 2023, the first Vulcan flight is planned late 2023.[195]

Retirement

In August 2021, ULA announced that they are no longer selling launches on the Atlas V and they would fulfill their 29 existing launch contracts.[10] They made a final purchase of the RD-180 motors they needed and the last of those motors were delivered in April 2021. The last launch will occur "some time in the mid-2020s".[10] As of October 2022, 20 launches remain.

Photo gallery

Core stage of an Atlas V being raised to a vertical position.

X-37B OTV-1 (Orbital Test Vehicle) being encased in its payload fairing for its 22 April 2010, launch.

An Atlas V 541 is moved to the launch pad.

Atlas V 401 on launch pad

Atlas V ignition

An Atlas V 551 with the New Horizons probe launches from Launch Pad 41 in Cape Canaveral.

See also

Comparable rockets:

- Angara
- Ariane 5
- Delta IV
- Falcon 9
- Falcon Heavy
- GSLV Mk III
- H-IIA
- H-IIB
- Long March 5
- Proton
- Vulcan Centaur
- Zenit
- Medium-lift launch vehicle
- Comparison of orbital launchers families
- Comparison of orbital launch systems

Notes

a. Pronounced "Atlas five". "V" is the roman numeral 5.

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External links

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  - Atlas 500 series cutaway (https://web.archive.org/web/20160409203927/http://www.ulalaunch.com/uploads/docs/Atlas500_Cutaway.pdf)
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