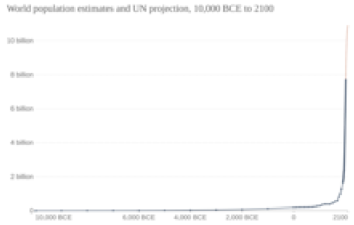
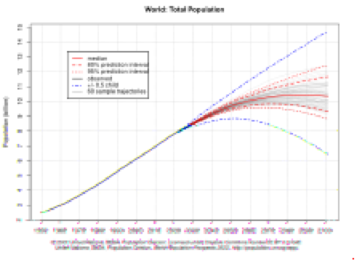


World population growth from 10,000 BCE to 2021[1]



High, medium, and low projections of the future human world population[2]

In demographics, the world population is the total number of humans currently living. It was estimated by the United Nations to have exceeded 8 billion in November 2022. It took over 200,000 years of human prehistory and history for the human population to reach one billion and only 219 years more to reach 8 billion.[3]

The human population experienced continuous growth following the Great Famine of 1315–1317 and the end of the Black Death in 1350, when it was nearly 370,000,000.[4] The highest global population growth rates, with increases of over 1.8% per year, occurred between 1955 and 1975, peaking at 2.1% between 1965 and 1970.[5] The growth rate declined to 1.1% between 2015 and 2020 and is projected to decline further in the 21st century.[6][7] The global population is still increasing, but there is significant uncertainty about its long-term trajectory due to changing fertility and mortality rates.[8] The UN Department of Economics and Social Affairs projects between 9 and 10 billion people by 2050 and gives an 80% confidence interval of 10–12 billion by the end of the 21st century,[2] with a growth rate by then of zero.[7] Other demographers predict that the human population will begin to decline in the second half of the 21st century.[9]

The total number of births globally is currently (2015–2020) 140 million/year, which is projected to peak during the period 2040–2045 at 141 million/year and then decline slowly to 126 million/year by 2100.[10] The total number of deaths is currently 57 million/year and is projected to grow steadily to 121 million/year by 2100.[11]

The median age of human beings as of 2020 is 31 years.[12]

Visual comparison of the world population in past and present

Estimates of world population by their nature are an aspect of modernity, possible only since the Age of Discovery. Early estimates for the population of the world[13] date to the 17th century: William Petty, in 1682, estimated the world population at 320 million (current estimates ranging close to twice this number); by the late 18th century, estimates ranged close to one billion (consistent with current estimates).[14] More refined estimates, broken down by continents, were published in the first half of the 19th century, at 600 million to 1 billion in the early 1800s and 800 million to 1 billion in the 1840s.[15]

It is difficult for estimates to be better than rough approximations, as even current population estimates are fraught with uncertainties from 3% to 5%.[16]

Estimates of the population of the world at the time agriculture emerged in around 10,000 BC have ranged between 1 million and 15 million.[17][18] Even earlier, genetic evidence suggests humans may have gone through a population bottleneck of between 1,000 and 10,000 people about 70,000 BC, according to the now largely discredited Toba catastrophe theory. By contrast, it is estimated that around 50–60 million people lived in the combined eastern and western Roman Empire in the 4th century AD.[19]

The Plague of Justinian caused Europe's population to drop by around 50% between the 6th and 8th centuries AD.[20] The population of Europe was more than 70 million in 1340.[21] From 1340 to 1400, the world's population fell from an estimated 443 million to 350–375 million,[22] with the Indian subcontinent suffering the most tremendous loss and Europe suffering the Black Death pandemic;[23] it took 200 years for European population figures to recover.[24] The population of China decreased from 123 million in 1200 to 65 million in 1393,[25] presumably from a combination of Mongol invasions, famine, and plague.[26]

Starting in AD 2, the Han dynasty of ancient China kept consistent family registers to properly assess the poll taxes and labor service duties of each household.[27] In that year, the population of Western Han was recorded as 57,671,400 individuals in 12,366,470 households, decreasing to 47,566,772 individuals in 9,348,227 households by AD 146, towards the end of the Han dynasty.[27] From 200 to 400, the world population fell from an estimated 257 million to 206 million, with China suffering the greatest loss.[23] At the founding of the Ming dynasty in 1368, China's population was reported to be close to 60 million; toward the end of the dynasty in 1644, it may have approached 150 million.[28] England's population reached an estimated 5.6 million in 1650, up from an estimated 2.6 million in 1500.[29] New crops that were brought to Asia and Europe from the Americas by Portuguese and Spanish colonists in the 16th century are believed to have contributed to population growth.[30][31][32] Since their introduction to Africa by Portuguese traders in the 16th century,[33] maize and cassava have similarly replaced traditional African crops as the most important staple food crops grown on the continent.[34]

The pre-Columbian population of the Americas is uncertain; historian David Henige called it "the most unanswerable question in the world."[35] By the end of the 20th century, scholarly consensus favored an estimate of roughly 55 million people, but numbers from various sources have ranged from 10 million to 100 million.[36] Encounters between European explorers and populations in the rest of the world often introduced local epidemics of extraordinary virulence.[37] According to the most extreme scholarly claims, as many as 90% of the Native American population of the New World died of Old World diseases such as smallpox, measles, and influenza.[38] Over the centuries, the Europeans had developed high degrees of immunity to these diseases, while the indigenous peoples had no such immunity.[39]

Map showing urban areas with at least one million inhabitants in 2006. Only 3% of the world's population lived in urban areas in 1800; this proportion had risen to 47% by 2000, and reached 50.5% by 2010.[40] By 2050, the proportion may reach 70%.[41]

During the European Agricultural and Industrial Revolutions, the life expectancy of children increased dramatically.[42] The percentage of the children born in London who died before the age of five decreased from 74.5% in 1730–1749 to 31.8% in 1810–1829.[43][44] Between 1700 and 1900, Europe's population increased from about 100 million to over 400 million.[45] Altogether, the areas populated by people of European descent comprised 36% of the world's population in 1900.[46]

Population growth in the Western world became more rapid after the introduction of vaccination and other improvements in medicine and sanitation.[47] Improved material conditions led to the population of Britain increasing from 10 million to 40 million in the 19th century.[48] The population of the United Kingdom reached 60 million in 2006.[49] The United States saw its population grow from around 5.3 million in 1800 to 106 million in 1920, exceeding 307 million in 2010.[50]

The first half of the 20th century in Imperial Russia and the Soviet Union was marked by a succession of major wars, famines and other disasters which caused large-scale population losses (approximately 60 million excess deaths).[51][52] After the collapse of the Soviet Union, Russia's population declined significantly – from 150 million in 1991 to 143 million in 2012[53] – but by 2013 this decline appeared to have halted.[54]

Many countries in the developing world have experienced extremely rapid population growth since the early 20th century, due to economic development and improvements in public health. China's population rose from approximately 430 million in 1850 to 580 million in 1953,[55] and now stands at over 1.3 billion. The population of the Indian subcontinent, which was about 125 million in 1750, increased to 389 million in 1941;

[56] today, India, Pakistan and Bangladesh are collectively home to about 1.63 billion people.[57] Java, an island in Indonesia, had about 5 million inhabitants in 1815; it had a population of over 139 million in 2020.[58] In just one hundred years, the population of Brazil decupled (x10), from about 17 million in 1900, or about 1% of the world population in that year, to about 176 million in 2000, or almost 3% of the global population in the very early 21st century. Mexico's population grew from 13.6 million in 1900 to about 112 million in 2010.[59][60] Between the 1920s and 2000s, Kenya's population grew from 2.9 million to 37 million.[61]

World population milestones in billions[62] (Worldometers estimates) Population 1 2 3 4 5 6 7 8 9 10 Year 1804 1930 1960 1974 1987 1999 2011 2022 2037 2057 Years elapsed 200,000+ 126 30 14 13 12 12 11 15 20

The UN estimated that the world population reached one billion for the first time in 1804. It was another 123 years before it reached two billion in 1927, but it took only 33 years to reach three billion in 1960.[63] Thereafter, it took 14 years for the global population to reach four billion in 1974, 13 years to reach five billion in 1987, 12 years to reach six billion in 1999 and, according to the United States Census Bureau, 13 years to reach seven billion in March 2012.[64] The United Nations, however, estimated that the world population reached seven billion in October 2011.[65][66][67]

According to the UN, the global population reached eight billion in November 2022,[68] but because the growth rate is slowing, it will take another 15 years to reach around 9 billion by 2037 and 20 years to reach 10 billion by 2057.[69] Alternative scenarios for 2050 range from a low of 7.4 billion to a high of more than 10.6 billion.[70] Projected figures vary depending on underlying statistical assumptions and the variables used in projection calculations, especially the fertility and mortality variables. Long-range predictions to 2150 range from a population decline to 3.2 billion in the "low scenario", to "high scenarios" of 24.8 billion.[70] One extreme scenario predicted a massive increase to 256 billion by 2150, assuming the global fertility rate remained at its 1995 level of 3.04 children per woman; however, by 2010 the global fertility rate had declined to 2.52.[71][72]

There is no estimation for the exact day or month the world's population surpassed one or two billion. The points at which it reached three and four billion were not officially noted, but the International Database of the United States Census Bureau placed them in July 1959 and April 1974 respectively. The United Nations did determine, and commemorate, the "Day of 5 Billion" on 11 July 1987, and the "Day of 6 Billion" on 12 October 1999. The Population Division of the United Nations declared the "Day of Seven Billion" to be 31 October 2011.[73] The United Nations marked the birth of the eight billionth person on 15 November 2022.[74][68]

- >80
- 77.5–80
- 75–77.5
- 72.5–75
- 70–72.5
- 67.5–70
- 65–67.5
- 60–65
- 55–60
- 50–55

2015 map showing average life expectancy by country in years. In 2015, the World Health Organization estimated the average global life expectancy as 71.4 years.[75]

As of 2012, the global sex ratio is approximately 1.01 males to 1 female.[76] Approximately 26.3% of the global population is aged under 15, while 65.9% is aged 15–64 and 7.9% is aged 65 or over.[76] The median age of the world's population is estimated to be 31 years in 2020,[12] and is expected to rise to 37.9 years by 2050.[77]

According to the World Health Organization, the global average life expectancy is 73.3 years as of 2020, with women living an average of 75.9 years and men approximately 70.8 years.[78] In 2010, the global fertility rate was estimated at 2.44 children per woman.[79] In June 2012, British researchers calculated the total weight of Earth's human population as approximately 287 million tonnes (630 billion pounds), with the average person weighing around 62 kilograms (137 lb).[80]

The IMF estimated nominal 2021 gross world product at US$94.94 trillion, giving an annual global per capita figure of around US$12,290.[81] Around 9.3% of the world population live in extreme poverty, subsisting on less than US$1.9 per day;[82] around 8.9% are malnourished.[83] 87% of the world's over-15s are considered literate.[84] As of April 2022, there were about 5 billion global Internet users, constituting 63% of the world population.[85]

The Han Chinese are the world's largest single ethnic group, constituting over 19% of the global population in 2011.[86] The world's most-spoken languages are English (1.132B), Mandarin Chinese (1.117B), Hindi (615M), Spanish (534M) and French (280M). More than three billion people speak an Indo-European language, which is the largest language family by number of speakers. Standard Arabic is a language with no native speakers, but the total number of speakers is estimated at 274 million people.[87]

The largest religious categories in the world as of 2020 are estimated as follows: Christianity (31%), Islam (25%), Unaffiliated (16%) and Hinduism (15%).[88]

World population (millions, UN estimates)[89] # Most populous countries 2000 2015 2030[A] 1 China[B] 1,270 1,376 1,416 2 India 1,053 1,311 1,528 3 United States 283 322 356 4 Indonesia 212 258 295 5 Pakistan 136 208 245 6 Brazil 176 206 228 7 Nigeria 123 182 263 8 Bangladesh 131 161 186 9 Russia 146 146 149 10 Mexico 103 127 148 World total 6,127 7,349 8,501 Notes:

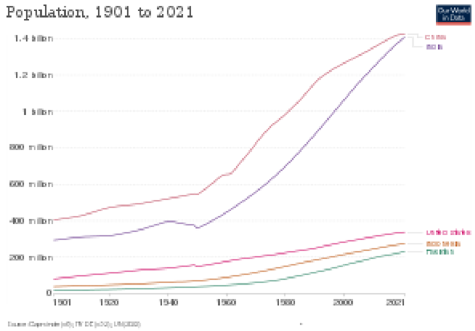
1. ^ 2030 = Medium variant.
2. ^ China excludes Hong Kong and Macau.

Six of the Earth's seven continents are permanently inhabited on a large scale. Asia is the most populous continent, with its 4.64 billion inhabitants accounting for 60% of the world population. The world's two most populated countries, China and India, together constitute about 36% of the world's population. Africa is the second most populated continent, with around 1.34 billion people, or 17% of the world's population. Europe's 747 million people make up 10% of the world's population as of 2020, while the Latin American and Caribbean regions are home to around 653 million (8%). Northern America, primarily consisting of the United States and Canada, has a population of around 368 million (5%), and Oceania, the least populated region, has about 42 million inhabitants (0.5%).[90] Antarctica only has a very small, fluctuating population of about 1200 people based mainly in polar science stations.[91]

Population by region (2020 estimates) Region Density(inhabitants/km2) Population(millions) Most populous country Most populous city (metropolitan area) Asia 104.1 4,641 1,411,778,000 – China[note 1] 13,515,000 – Tokyo Metropolis(37,400,000 – Greater Tokyo Area) Africa 44.4 1,340 0,211,401,000 – Nigeria 09,500,000 – Cairo(20,076,000 – Greater Cairo) Europe 73.4 747 0,146,171,000 – Russia, approx. 110 million in Europe 13,200,000 – Moscow(20,004,000 – Moscow metropolitan area) Latin America 24.1 653 0,214,103,000 – Brazil 12,252,000 – São Paulo City(21,650,000 – São Paulo Metro Area) Northern America[note 2] 14.9 368 0,332,909,000 – United States 08,804,000 – New York City(23,582,649 – New York metropolitan area[92]) Oceania 5 42 0,025,917,000 – Australia 05,367,000 – Sydney Antarctica ~0 0.004[91] N/A[note 3] 00,001,258 – McMurdo Station

Cartogram showing the distribution of the world population, each square represents half a million people.

A map of world population in 2019

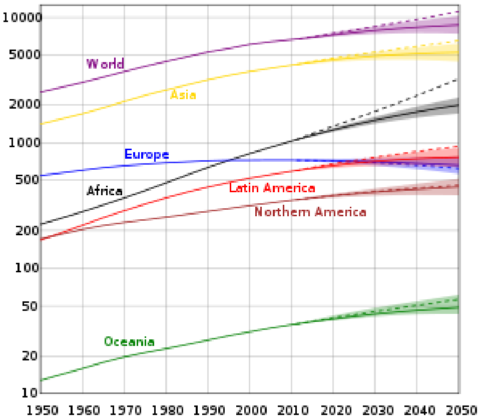


1901 to 2021 population graph of the five countries with the highest current populations

Rank Country / Dependency Population Percentage of the world Date Source (official or from the United Nations) 1 China 1,412,600,000 17.7% 31 Dec 2021 National annual estimate[93] 2 India 1,373,761,000 17.2% 1 Mar 2022 Annual national estimate[94] 3 United States 333,472,984 4.17% 23 Dec 2022 National population clock[95] 4 Indonesia 275,773,800 3.45% 1 Jul 2022 National annual estimate[96] 5 Pakistan 229,488,994 2.87% 1 Jul 2022 UN projection[97] 6 Nigeria 216,746,934 2.71% 1 Jul 2022 UN projection[97] 7 Brazil 215,552,699 2.69% 23 Dec 2022 National population clock[98] 8 Bangladesh 168,220,000 2.10% 1 Jul 2020 Annual Population Estimate[99] 9 Russia 147,190,000 1.84% 1 Oct 2021 2021 preliminary census results[100] 10 Mexico 128,271,248 1.60% 31 Mar 2022 National quarterly estimate[101]

Approximately 4.49 billion people live in these ten countries, representing around 56% of the world's population as of July 2022.

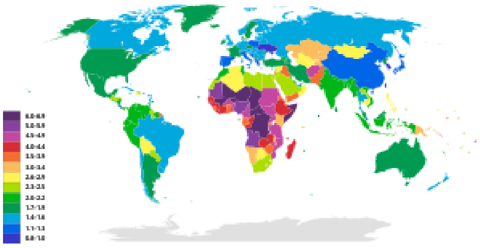
The tables below list the world's most densely populated countries, both in absolute terms and in comparison to their total populations, as of November 2022. All areas and populations are from The World Factbook, un□d rgpJ 2. A l are Woa–



Estimates of population evolution in different continents between 1950 and 2050, according to the United Nations. The vertical axis is logarithmic and is in millions of people.

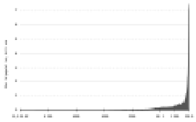
Population size fluctuates at differing rates in differing regions. Nonetheless, population growth has been the long-standing trend on all inhabited continents, as well as in most individual states. During the 20th century, the global population saw its greatest increase in known history, rising from about 1.6 billion in 1900 to over 6 billion in 2000[105] as the whole world entered the early phases of what has come to be called the "demographic transition". Some of the key factors contributing to this increase included the lessening of the mortality rate in many countries by improved sanitation and medical advances, and a massive increase in agricultural productivity attributed to the Green Revolution.[106][107] By 2000, there were approximately ten times as many people on Earth as there had been in 1700.

However, this rapid growth did not last. During the period 2000–2005, the United Nations estimates that the world's population was growing at an annual rate of 1.3% (equivalent to around 80 million people), down from a peak of 2.1% during the period 1965–1970.[6] Globally, although the population growth rate has been steadily declining from its peak in 1968,[108] growth still remains high in Sub-Saharan Africa.[109]



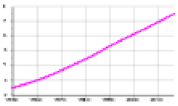
In fact, during the 2010s, Japan and some countries in Europe began to reduce in population, due to sub-replacement fertility rates.[104]

In 2019, the United Nations reported that the rate of population growth continues to decline due to the ongoing global demographic transition. If this trend continues, the rate of growth may diminish to zero by 2100, concurrent with a world population plateau of 10.9 billion.[6][69] However, this is only one of many estimates published by the UN; in 2009, UN population projections for 2050 ranged between around 8 billion and 10.5 billion.[110] An alternative scenario is given by the statistician Jorgen Randers, who argues that traditional projections insufficiently take into account the downward impact of global urbanization on fertility. Randers' "most likely scenario" reveals a peak in the world population in the early 2040s at about 8.1 billion people, followed by decline.[111] Adrian Raftery, a University of Washington professor of statistics and of sociology, states that "there's a 70 percent probability the world population will not stabilize this century. Population, which had sort of fallen off the world's agenda, remains a very important issue."[112]

- 

  Estimated world population figures, 10,000 BC–AD 2000

- Estimated world population figures, 10,000 BC–AD 2000 (in log y scale)

- 

  World population figures, 1950–2017

Global annual population growth[113]

Year	Population	Yearly growth		Density(pop/km2)	Urban population	
		%	Number		Number	%
1951	2,584,034,261	1.88%	47,603,112	17	775,067,697	30%
1952	2,630,861,562	1.81%	46,827,301	18	799,282,533	30%
1953	2,677,608,960	1.78%	46,747,398	18	824,289,989	31%
1954	2,724,846,741	1.76%	47,237,781	18	850,179,106	31%
1955	2,773,019,936	1.77%	48,173,195	19	877,008,842	32%
1956	2,822,443,282	1.78%	49,423,346	19	904,685,164	32%
1957	2,873,306,090	1.80%	50,862,808	19	933,113,168	32%
1958	2,925,686,705	1.82%	52,380,615	20	962,537,113	33%
1959	2,979,576,185	1.84%	53,889,480	20	992,820,546	33%
1960	3,034,949,748	1.86%	55,373,563	20	1,023,845,517	34%
1961	3,091,843,507	1.87%	56,893,759	21	1,055,435,648	34%
1962	3,150,420,795	1.89%	58,577,288	21	1,088,376,703	35%
1963	3,211,001,009	1.92%	60,580,214	22	1,122,561,940	35%
1964	3,273,978,338	1.96%	62,977,329	22	1,157,813,355	35%
1965	3,339,583,597	2.00%	65,605,259	22	1,188,469,224	36%
1966	3,407,922,630	2.05%	68,339,033	23	1,219,993,032	36%
1967	3,478,769,962	2.08%	70,847,332	23	1,252,566,565	36%
1968	3,551,599,127	2.09%	72,829,165	24	1,285,933,432	36%
1969	3,625,680,627	2.09%	74,081,500	24	1,319,833,474	36%
1970	3,700,437,046	2.06%	74,756,419	25	1,354,215,496	37%
1971	3,775,759,617	2.04%	75,322,571	25	1,388,834,099	37%
1972	3,851,650,245	2.01%	75,890,628	26	1,424,734,781	37%
1973	3,927,780,238	1.98%	76,129,993	26	1,462,178,370	37%
1974	4,003,794,172	1.94%	76,013,934	27	1,501,134,655	37%
1975	4,079,480,606	1.89%	75,686,434	27	1,538,624,994	38%
1976	4,154,666,864	1.84%	75,186,258	28	1,577,376,141	38%
1977	4,229,506,060	1.80%	74,839,196	28	1,616,419,308	38%
1978	4,304,533,501	1.77%	75,027,441	29	1,659,306,117	39%
1979	4,380,506,100	1.76%	75,972,599	29	1,706,021,638	39%
1980	4,458,003,514	1.77%	77,497,414	30	1,754,201,029	39%
1981	4,536,996,762	1.77%	78,993,248	30	1,804,215,203	40%
1982	4,617,386,542	1.77%	80,389,780	31	1,854,134,229	40%
1983	4,699,569,304	1.78%	82,182,762	32	1,903,822,436	41%
1984	4,784,011,621	1.80%	84,442,317	32	1,955,106,433	41%
1985	4,870,921,740	1.82%	86,910,119	33	2,007,939,063	41%
1986	4,960,567,912	1.84%	89,646,172	33	2,062,604,394	42%
1987	5,052,522,147	1.85%	91,954,235	34	2,118,882,551	42%
1988	5,145,426,008	1.84%	92,903,861	35	2,176,126,537	42%
1989	5,237,441,558	1.79%	92,015,550	35	2,233,140,502	43%
1990	5,327,231,061	1.71%	89,789,503	36	2,290,228,096	43%
1991	5,414,289,444	1.63%	87,058,383	36	2,347,462,336	43%
1992	5,498,919,809	1.56%	84,630,365	37	2,404,337,297	44%
1993	5,581,597,546	1.50%	82,677,737	37	2,461,223,528	44%
1994	5,663,150,427	1.46%	81,552,881	38	2,518,254,111	44%
1995	5,744,212,979	1.43%	81,062,552	39	2,575,505,235	45%
1996	5,824,891,951	1.40%	80,678,972	39	2,632,941,583	45%
1997	5,905,045,788	1.38%	80,153,837	40	2,690,813,541	46%
1998	5,984,793,942	1.35%	79,748,154	40	2,749,213,598	46%
1999	6,064,239,055	1.33%	79,445,113	41	2,808,231,655	46%
2000	6,143,494,000	1.31%	79,255,000	41	2,868,308,000	46%
2001	6,222,627,000	1.29%	79,133,000	42	2,933,079,000	47%
2002	6,301,773,000	1.27%	79,147,000	42	3,001,808,000	47%
2003	6,381,185,000	1.26%	79,412,000	43	3,071,744,000	48%
2004	6,461,159,000	1.25%	79,974,000	43	3,143,045,000	48%
2005	6,541,907,000	1.25%	80,748,000	44	3,215,906,000	49%
2006	6,623,518,000	1.25%	81,611,000	44	3,289,446,000	50%
2007	6,705,947,000	1.24%	82,429,000	45	3,363,610,000	50%
2008	6,789,089,000	1.24%	83,142,000	46	3,439,719,000	50%
2009	6,872,767,000	1.23%	83,678,000	47	3,516,830,000	51%
2010	6,956,824,000	1.22%	84,057,000	47	3,594,868,000	51%
2011	7,041,194,000	1.21%	84,371,000	47	3,671,424,000	52%
2012	7,125,828,000	1.20%	84,634,000	48	3,747,843,000	52%
2013	7,210,582,000	1.19%	84,754,000	48	3,824,990,000	53%
2014	7,295,291,000	1.17%	84,709,000	49	3,902,832,000	53%
2015	7,379,797,000	1.16%	84,506,000	50	3,981,498,000	54%
2016	7,464,022,000	1.14%	84,225,000	50	4,060,653,000	54%
2017	7,547,859,000	1.12%	83,837,000	51	4,140,189,000	55%
2018	7,631,091,000	1.10%	83,232,000	51	4,219,817,000	55%
2019	7,713,468,000	1.08%	82,377,000	52	4,299,439,000	56%
2020	7,795,000,000	1.05%	81,331,000	52	4,378,900,000	56%

The table below shows historical and predicted regional population figures in millions.[114][115][116] The availability of historical population figures varies by region.

World historical and predicted populations (in millions)[117][118][119]

Region	1500	1600	1700	1750	1800	1850	1900	1950	1999	2008	2010	2012	2050	2150
World	585	660	710	791	978	1,262	1,650	2,521	6,008	6,707	6,896	7,052	9,725	9,746
Africa	86	114	106	106	107	111	133	221	783	973	1,022	1,052	2,478	2,308
Asia	282	350	411	502	635	809	947	1,402	3,700	4,054	4,164	4,250	5,267	5,561
Europe	168	170	178	190	203	276	408	547	675	732	738	740	734	517
Latin America[Note 1]	40	20	10	16	24	38	74	167	508	577	590	603	784	912
Northern America[Note 1]	6	3	2	2	7	26	82	172	312	337	345	351	433	398
Oceania	3	3	3	2	2	2	6	13	30	34	37	38	57	51

World historical and predicted populations by percentage distribution[117][118]

Region	1500	1600	1700	1750	1800	1850	1900	1950	1999	2008	2010	2012	2050	2150
Africa	14.7	17.3	14.9	13.4	10.9	8.8	8.1	8.8	13.0	14.5	14.8	15.2	25.5	23.7
Asia	48.2	53.0	57.9	63.5	64.9	64.1	57.4	55.6	61.6	60.4	60.4	60.3	54.2	57.1
Europe	28.7	25.8	25.1	20.6	20.8	21.9	24.7	21.7	11.2	10.9	10.7	10.5	7.6	5.3
Latin America[Note 1]	6.8	3.0	1.4	2.0	2.5	3.0	4.5	6.6						

8.5 8.6 8.6 8.6 8.1 9.4 Northern America[Note 1] 1.0 0.5 0.3 0.3 0.7 2.1 5.0 6.8 5.2 5.0 5.0 5.0 4.5 4.1 Oceania 0.5 0.5 0.4 0.3 0.2 0.2 0.4 0.5 0.5 0.5 0.5 0.5 0.6 0.5

The following table gives estimates, in millions, of population in the past. The data for 1750 to 1900 are from the UN report "The World at Six Billion"[120] whereas the data from 1950 to 2015 are from a UN data sheet.[89]

Year World Africa Asia Europe Latin America& Carib.[Note 1] North America[Note 1] Oceania Notes 70,000 BC < 0.015 0 0 [121] 10,000 BC 4 [122] 8000 BC 5 6500 BC 5 5000 BC 5 4000 BC 7 3000 BC 14 2000 BC 27 1000 BC 50 7 33 9 [citation needed] 500 BC 100 14 66 16 AD 1 200 23 141 28 1000 400 70 269 50 8 1 2 1500 458 86 243 84 39 3 3 1600 580 114 339 111 10 3 3 1700 682 106 436 125 10 2 3 1750 791 106 502 163 16 2 2 1800 1,000 107 656 203 24 7 3 1850 1,262 111 809 276 38 26 2 1900 1,650 133 947 408 74 82 6 1950 2,525 229 1,394 549 169 172 12.7 [123] 1955 2,758 254 1,534 577 193 187 14.2 1960 3,018 285 1,687 606 221 204 15.8 1965 3,322 322 1,875 635 254 219 17.5 1970 3,682 366 2,120 657 288 231 19.7 1975 4,061 416 2,378 677 326 242 21.5 1980 4,440 478 2,626 694 365 254 23.0 1985 4,853 550 2,897 708 406 267 24.9 1990 5,310 632 3,202 721 447 281 27.0 1995 5,735 720 3,475 728 487 296 29.1 2000 6,127 814 3,714 726 527 314 31.1 2005 6,520 920 3,945 729 564 329 33.4 2010 6,930 1,044 4,170 735 600 344 36.4 2015 7,349 1,186 4,393 738 634 358 39.3

Using the above figures, the change in population from 2010 to 2015 was:

- World: +420 million
- Africa: +142 million
- Asia: +223 million
- Europe: +3 million
- Latin America and Caribbean: +35 million
- Northern America: +14 million
- Oceania: +2.9 million

1. ^ a b c d e f North America is here defined to include the northernmost countries and territories of North America: Canada, the United States, Greenland, Bermuda, and Saint Pierre and Miquelon. Latin America & Carib. comprises Mexico, Central America, the Caribbean, and South America.

Long-term global population growth is difficult to predict. The United Nations and the US Census Bureau both give different estimates – according to the UN, the world population reached seven billion in late 2011,[114] while the USCB asserted that this occurred in March 2012.[124] Since 1951 the UN has issued multiple projections of future world population, based on different assumptions. From 2000 to 2005, the UN consistently revised these projections downward, until the 2006 revision, issued on 14 March 2007, revised the 2050 mid-range estimate upwards by 273 million.[citation needed]

Complicating the UN's and others' attempts to project future populations is the fact that average global birth rates, as well as mortality rates, are declining rapidly, as the nations of the world progress through the stages of the demographic transition, but both vary greatly between developed countries (where birth rates and mortality rates are often low) and developing countries (where birth and mortality rates typically remain high). Different ethnicities also display varying birth rates.[citation needed] Both of these can change rapidly due to disease epidemics, wars and other mass catastrophes, or advances in medicine and public health.

The UN's first report in 1951 showed that during the period 1950–55 the crude birth rate was 36.9/1,000 population and the crude death rate was 19.1/1,000. By the period 2015–20 both numbers had dropped significantly to 18.5/1,000 for the crude birth rate and 7.5/1,000 for the crude death rate. UN projections for 2100 show a further decline in the crude birth rate to 11.6/1,000 and an increase in the crude death rate to 11.2/1,000.[125],[126]

The total number of births globally is currently (2015–20) 140 million/year, is projected to peak during the period 2040–45 at 141 million/year and thereafter decline slowly to 126 million/year by 2100.[10] The total number of deaths is currently 57 million/year and is projected to grow steadily to 121 million/year by 2100.[11]

2012 United Nations projections show a continued increase in population in the near future with a steady decline in population growth rate; the global population is expected to reach between 8.3 and 10.9 billion by 2050.[127][128] 2003 UN Population Division population projections for the year 2150 range between 3.2 and 24.8 billion.[71] One of many independent mathematical models supports the lower estimate,[129] while a 2014 estimate forecasts between 9.3 and 12.6 billion in 2100, and continued growth thereafter.[130][131] The 2019 Revision of the UN estimates gives the "medium variant" population as; nearly 8.6 billion in 2030, about 9.7 billion in 2050 and about 10.9 billion in 2100.[132] In December 2019, the German Foundation for World Population projected that the global population will reach 8 billion by 2023 as it increases by 156 every minute.[133] In a modeled future projection by the Institute for Health Metrics and Evaluation the global population was projected to peak in 2064 at 9.73 billion people and decline to 8.79 billion in 2100.[134] Some analysts have questioned the sustainability of further world population growth, highlighting the growing pressures on the environment,[135][136] global food supplies, and energy resources.[137][138][139]

UN (medium variant – 2019 revision) and US Census Bureau (June 2015) estimates[140][141] Year UN est.(millions) Difference USCB est. (millions) Difference 2005 6,542 – 6,473 – 2010 6,957 415 6,866 393 2015 7,380 423 7,256 390 2020 7,795 415 7,643 380 2025 8,184 390

8,007 363 2030 8,549 364 8,341 334 2035 8,888 339 8,646 306 2040 9,199 311 8,926 280 2045 9,482 283 9,180 254 2050 9,735 253 9,408 228 UN 2019 estimates and medium variant projections (in millions)[140] Year World Asia Africa Europe Latin America/Caribbean Northern America Oceania 2000 6,144 3,741 (60.9%) 811 (13.2%) 726 (11.8%) 522 (8.5%) 312 (5.1%) 31 (0.5%) 2005 6,542 3,978 (60.8%) 916 (14.0%) 729 (11.2%) 558 (8.5%) 327 (5.0%) 34 (0.5%) 2010 6,957 4,210 (60.5%) 1,039 (14.9%) 736 (10.6%) 591 (8.5%) 343 (4.9%) 37 (0.5%) 2015 7,380 4,434 (60.1%) 1,182 (16.0%) 743 (10.1%) 624 (8.5%) 357 (4.8%) 40 (0.5%) 2020 7,795 4,641 (59.5%) 1,341 (17.2%) 748 (9.6%) 654 (8.4%) 369 (4.7%) 43 (0.6%) 2025 8,184 4,823 (58.9%) 1,509 (18.4%) 746 (9.1%) 682 (8.3%) 380 (4.6%) 45 (0.6%) 2030 8,549 4,974 (58.2%) 1,688 (19.8%) 741 (8.7%) 706 (8.3%) 391 (4.6%) 48 (0.6%) 2035 8,888 5,096 (57.3%) 1,878 (21.1%) 735 (8.3%) 726 (8.2%) 401 (4.5%) 50 (0.6%) 2040 9,199 5,189 (56.4%) 2,077 (22.6%) 728 (7.9%) 742 (8.1%) 410 (4.5%) 53 (0.6%) 2045 9,482 5,253 (55.4%) 2,282 (24.1%) 720 (7.6%) 754 (8.0%) 418 (4.4%) 55 (0.6%) 2050 9,735 5,290 (54.3%) 2,489 (25.6%) 711 (7.3%) 762 (7.8%) 425 (4.4%) 57 (0.6%) 2055 9,958 5,302 (53.2%) 2,698 (27.1%) 700 (7.0%) 767 (7.7%) 432 (4.3%) 60 (0.6%) 2060 10,152 5,289 (52.1%) 2,905 (28.6%) 689 (6.8%) 768 (7.6%) 439 (4.3%) 62 (0.6%) 2065 10,318 5,256 (51.0%) 3,109 (30.1%) 677 (6.6%) 765 (7.4%) 447 (4.3%) 64 (0.6%) 2070 10,459 5,207 (49.8%) 3,308 (31.6%) 667 (6.4%) 759 (7.3%) 454 (4.3%) 66 (0.6%) 2075 10,577 5,143 (48.6%) 3,499 (33.1%) 657 (6.2%) 750 (7.1%) 461 (4.4%) 67 (0.6%) 2080 10,674 5,068 (47.5%) 3,681 (34.5%) 650 (6.1%) 739 (6.9%) 468 (4.4%) 69 (0.7%) 2085 10,750 4,987 (46.4%) 3,851 (35.8%) 643 (6.0%) 726 (6.8%) 474 (4.4%) 71 (0.7%) 2090 10,810 4,901 (45.3%) 4,008 (37.1%) 638 (5.9%) 711 (6.6%) 479 (4.4%) 72 (0.7%) 2095 10,852 4,812 (44.3%) 4,152 (38.3%) 634 (5.8%) 696 (6.4%) 485 (4.5%) 74 (0.7%) 2100 10,875 4,719 (43.4%) 4,280 (39.4%) 630 (5.8%) 680 (6.3%) 491 (4.5%) 75 (0.7%)

In 1975, Sebastian von Hoerner proposed a formula for population growth which represented hyperbolic growth with an infinite population in 2025.[142] The hyperbolic growth of the world population observed until the 1970s was later correlated to a non-linear second-order positive feedback between demographic growth and technological development. This feedback can be described as follows: technological advance → increase in the carrying capacity of land for people → demographic growth → more people → more potential inventors → acceleration of technological advance → accelerating growth of the carrying capacity → faster population growth → accelerating growth of the number of potential inventors → faster technological advance → hence, the faster growth of the Earth's carrying capacity for people, and so on.[143] The transition from hyperbolic growth to slower rates of growth is related to the demographic transition.

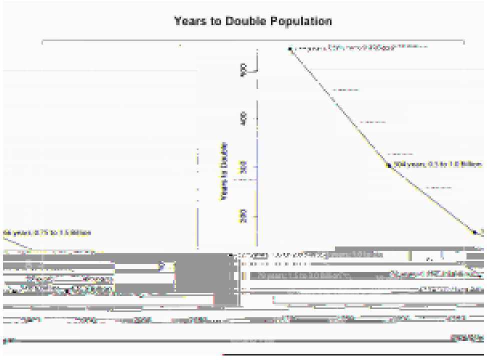
According to the Russian demographer Sergey Kapitsa,[144] the world population grew between 67,000 BC and 1965 according to the following formula:

$$N = \frac{C}{\tau} \operatorname{arccot} \frac{T_0 - T}{\tau},$$

where

N is current population, T is the current year, C = (1.86 ± 0.01)·1011, T0 = 2007 ± 1, . = 42 ± 1.

According to linear interpolation and extrapolation of UNDESA population estimates, the world population has doubled, or will double, in the years listed in the tables below (with two different starting points). During the 2nd millennium, each doubling took roughly half as long as the previous doubling, fitting the hyperbolic growth model mentioned above. However, after 2024, it is unlikely that there will be another doubling of the global population in the 21st century.[145]



Historic chart showing the periods of time the world population has taken to double, from 1700 to 2000

Starting at 500 million Population(in billions) 0.5 1 2 4 8 16 Year 1500 1804 1927 1974 2022 n/a Years elapsed — 304 123 47 48 — Starting at 375 million Population(in billions) 0.375 0.75 1.5 3 6 12 Year 1171 1715 1881 1960 1999 c. 2100[146] Years elapsed — 544 166 79 39 c. 100+

The total number of humans who have ever lived is estimated to be approximately 100 billion. Such estimates can only be rough approximations, as even modern population estimates are subject to uncertainty of around 3% to 5%.[16] Kapitsa (1996) cites estimates ranging between 80 and 150 billion.[147] The PRB puts the figure at 117 billion as of 2020, estimating that the current world population is 6.7% of all the humans who have ever lived.[148] Haub (1995) prepared another figure, updated in 2002 and 2011; the 2011 figure was approximately 107 billion.[149][150]

[151] Haub characterized this figure as an estimate that required "selecting population sizes for different points from antiquity to the present and applying assumed birth rates to each period".[150]

Robust population data only exist for the last two or three centuries. Until the late 18th century, few governments had ever performed an accurate census. In many early attempts, such as in Ancient Egypt and the Persian Empire, the focus was on counting merely a subset of the population for purposes of taxation or military service.[152] Thus, there is a significant margin of error when estimating ancient global populations.

Pre-modern infant mortality rates are another critical factor for such an estimate; these rates are very difficult to estimate for ancient times due to a lack of accurate records. Haub (1995) estimates that around 40% of those who have ever lived did not survive beyond their first birthday. Haub also stated that "life expectancy at birth probably averaged only about ten years for most of human history",[150] which is not to be mistaken for the life expectancy after reaching adulthood. The latter equally depended on period, location and social standing, but calculations identify averages from roughly 30 years upward.

- Demographics of the world
- Anthropocene
- Birth control
- Coastal population growth
- Demographic transition
- Population decline
- Doomsday argument
- Family planning
- Food security
- Human overpopulation
- Megacity
- Natalism
- One-child policy
- Population growth
- Population dynamics
- Two-child policy

Lists:

- List of population concern organizations
- List of countries and dependencies by population
- List of sovereign states and dependencies by total fertility rate
- List of countries by population growth rate
- List of countries by past and projected future population
- List of countries by population in 1900
- List of countries and dependencies by population density
- List of largest cities
- List of religious populations
- Lists of organisms by population – for non-human global populations

Historical:

- Historical censuses
- Historical demography

1. ^ Excluding its Special Administrative Regions (SARs) of Hong Kong and Macau.
2. ^ Excludes Mexico, Central America and the Caribbean, which are included here under Latin America.
3. ^ The Antarctic Treaty System limits the nature of national claims in Antarctica. Of the territorial claims in Antarctica, the Ross Dependency has the largest population.

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CFM56 Rear view of a CFM56-5 Type Turbofan National origin France/United States Manufacturer CFM International First run June 1974 Major applications Airbus A320 family Airbus A340-200/-300 Boeing 737 Classic / Next Gen Boeing KC-135R Stratotanker McDonnell Douglas DC-8-70 Number built 32,645 (June 2018)[1] Developed from General Electric F101 Developed into CFM International LEAP General Electric Affinity General Electric GE90

The CFM International CFM56 (U.S. military designation F108) series is a Franco-American family of high-bypass turbofan aircraft engines made by CFM International (CFMI), with a thrust range of 18,500 to 34,000 lbf (82 to 150 kN). CFMI is a 50–50 joint-owned company of Safran Aircraft Engines (formerly known as Snecma) of France, and GE Aviation (GE) of the United States. Both companies are responsible for producing components and each has its own final assembly line. GE produces the high-pressure compressor, combustor, and high-pressure turbine, Safran manufactures the fan, gearbox, exhaust and the low-pressure turbine, and some components are made by Avio of Italy and Honeywell from the US. The engines are assembled by GE in Evendale, Ohio, and by Safran in Villaroche, France. The completed engines are marketed by CFMI. Despite initial export restrictions, it is the most used turbofan aircraft engine in the world, in four major variants.

The CFM56 first ran in 1974.[2] By April 1979, the joint venture had not received a single order in five years and was two weeks away from being dissolved.[3] The program was saved when Delta Air Lines, United Airlines, and Flying Tigers chose the CFM56 to re-engine their DC-8s and shortly thereafter it was chosen to re-engine the Boeing KC-135 Stratotanker fleet of the U.S. Air Force.[3] The first engines entered service in 1982.[4] Several fan blade failure incidents were experienced during the CFM56's early service, including one failure that was a cause of the Kegworth air disaster, and some engine variants experienced problems caused by flight through rain and hail. Both of these issues were resolved with engine modifications.

Research into the next generation of commercial jet engines, high-bypass ratio turbofans in the "10-ton" (20,000 lbf; 89 kN) thrust class, began in the late 1960s. Snecma (now Safran), who had mostly built military engines previously, was the first company to seek entrance into the market by searching for a partner with commercial experience to design and build an engine in this class. They considered Pratt & Whitney, Rolls-Royce, and GE Aviation as potential partners, and after two company executives, Gerhard Neumann from GE and René Ravaud from Snecma, introduced themselves at the 1971 Paris Air Show a decision was made. The two companies saw mutual benefit in the collaboration and met several more times, fleshing out the basics of the joint project.[5]

At the time, Pratt & Whitney dominated the commercial market. GE needed an engine in this market class, and Snecma had previous experience of working with them, collaborating on the production of the CF6-50 turbofan for the Airbus A300.[2] Pratt & Whitney was considering upgrading their JT8D to compete in the same class as the CFM56 as a sole venture, while Rolls-Royce dealt with financial issues that precluded them from starting new projects; this situation caused GE to gain the title of best partner for the program.[5]

A major reason for GE's interest in the collaboration, rather than building a 10-ton engine on their own, was that the Snecma project was the only source of development funds for an engine in this class at this particular time. GE was initially considering only contributing technology from its CF6 engine rather than its much more advanced F101 engine, developed for the B-1 Lancer supersonic bomber. The company was faced with a dilemma when the United States Air Force (USAF) announced its Advanced Medium STOL Transport (AMST) project in 1972 which included funding for the development of a 10-ton engine – either to build a "limited" technology 10-ton engine with Snecma, or a similar engine with "advanced" technology on their own. Concerned that the company would be left with only the "limited" engine in its portfolio if it did not win the Air Force contract (for which it was competing with Pratt & Whitney and a General Motors division with its "advanced" engine), GE decided to apply for an export license for the F101 core technology.[6]

GE applied for the export license in 1972 as their primary contribution to the 10-ton engine project. The United States Department of State's Office of Munitions Control recommended the rejection of the application on national security grounds; specifically because the core technology was an aspect of a strategic national defense system (B-1 bomber), it was built with Department of Defense funding, and that exporting the technology to France would limit the number of American workers on the project.[7] The official decision was made in a National Security Decision Memorandum signed by the National Security Advisor Henry Kissinger on 19 September 1972.[8]

While national security concerns were cited as the grounds for rejection, politics played an important role as well. The project, and the export issue associated with it, was considered so important that French President Georges Pompidou appealed directly to U.S. President Richard Nixon in 1971 to approve the deal, and Henry Kissinger brought the issue up with President Pompidou in a 1972 meeting. GE reportedly argued at the highest levels that having half of the market was better than having none of it, which they believed would happen if Snecma pursued the engine on their own without GE's contribution. Nixon administration officials feared that this project could be the beginning of the end of American aerospace leadership.[9]

There was also speculation that the rejection may have been, in part, retaliation for French involvement in convincing the Swiss not to purchase American-made LTV A-7 Corsair II aircraft that had been competing against a French design,[9] the Dassault Milan. In the end, the Swiss did not purchase either aircraft, opting for the Northrop F-5E Tiger II instead.[10]

Despite the export license being rejected, both the French and GE continued to push the Nixon Administration for permission to export the F101 technology. Efforts continued throughout the months following the rejection, culminating in the engine becoming an agenda topic during the 1973 meeting of Presidents Nixon and Pompidou in Reykjavik. Discussions at this meeting resulted in an agreement that allowed the development of the CFM56 to proceed. Contemporary reports state that the agreement was based on assurances that the core of the engine, the part that GE was developing from the military F101, would be built in the U.S. and then transported to France in order to protect the sensitive technologies.[11] The joint venture also agreed to pay the U.S. an $80 million royalty fee (calculated at $20,000 per engine predicted to be built) as repayment for the development money provided by the government for the F101 engine core.[5] Documents declassified in 2007 revealed that a key aspect of the CFM56 export agreement was that the French government agreed not to seek tariffs against American aircraft being imported into Europe.[12]

With the export issue settled, GE and Snecma finalized the agreement that formed CFM International (CFMI), a 50–50 joint company that would be responsible for producing and marketing the 10-ton engine, the CFM56. The venture was officially founded in 1974.[13] The "CF" in the engine name stands for GE's designation for commercial turbofan engines, while the "M56" is the name of Snecma's original engine proposal.[14] The two primary roles for CFMI were to manage the program between GE and Snecma, and to market, sell and service the engine at a single point of contact for the customer. CFMI was made responsible for the day-to-day decision making for the project, while major decisions (developing a new variant, for example) required the go-ahead from GE and Snecma management.[2]

The CFMI board of directors is currently split evenly between Snecma and GE (five members each). There are two vice presidents, one from each company, who support the President of CFMI. The president tends to be drawn from Snecma and sits at CFMI's headquarters near GE in Cincinnati, Ohio.[2]

The work split between the two companies gave GE responsibility for the high-pressure compressor (HPC), the combustor, and the high-pressure turbine (HPT); Snecma was responsible for the fan, the low-pressure compressor (LPC), and the low-pressure turbine (LPT).[15] Snecma was also responsible for the initial airframe integration engineering, mostly involving the nacelle design, and was initially responsible for the gearbox, but shifted that work to GE when it became apparent that it would be more efficient for GE to assemble that component along with their other parts.[16]

Development work on the CFM56 began before CFMI was formally created. While work proceeded smoothly, the international arrangement led to unique working conditions. For example, both companies had assembly lines, some engines were assembled and tested in the U.S. and others in France. Engines assembled in France were subject to the initially strict export agreement, which meant that GE's core was built in the U.S., then shipped to the Snecma plant in France where it was placed in a locked room into which even the President of Snecma was not allowed. The Snecma components (the fore and aft sections of the engine) were brought into the room, GE employees mounted them to the core, and then the assembled engine was taken out to be finished.[17]

The first completed CFM56 engine first ran at GE in June 1974 with the second running in October 1974. The second engine was then shipped to France and first ran there on 13 December 1974. These first engines were considered "production hardware" as opposed to test examples and were designated as the CFM56-2, the first variant of the CFM56.[16]

The engine flew for the first time in February 1977 when it replaced one of the four Pratt & Whitney JT8D engines on the McDonnell Douglas YC-15, an entrant in the Air Force's Advanced Medium STOL Transport (AMST) competition.[18] Soon after, the second CFM56 was mounted on a Sud Aviation Caravelle at the Snecma flight test center in France. This engine had a slightly different configuration with a long bypass duct and mixed exhaust flow,[nb 1] rather than a short bypass duct with unmixed exhaust flow.[nb 2] It was the first to include a "Thrust Management System".[19]

After testing the engine for several years, both in the air and on the ground, CFMI searched for customers outside of a possible AMST contract. The main targets were re-engine contracts for the Douglas DC-8 and the Boeing 707 airliners, including the related military tanker, the KC-135 Stratotanker. There was little initial interest in the engine, but Boeing realized that the CFM56 might be a solution to upcoming noise regulations.[5] After announcing that a 707 would be configured with the CFM56 engine for flight tests in 1977, Boeing officially offered the 707-320 with the CFM56 engine as an option in 1978. The new variant was listed as the 707-700.[20] Due to limited interest from the airlines in a re-engined 707, Boeing ended the 707-700 program in 1980 without selling any aircraft.[21] Despite the lack of sales, having the commercial 707 available with the CFM56 helped the engine's competitiveness for the KC-135 re-engine contract.[22]

A nose-on view of several re-engined KC-135R aircraft taxiing prior to takeoff. The new engines are CFM56-2 high-bypass turbofans.

Winning the contract to re-engine the KC-135 tanker fleet for the USAF would be a huge boon to the CFM56 project (with more than 600 aircraft available to re-engine), and CFMI aggressively pursued that goal as soon as the Request For Proposals (RFP) was announced in 1977. Like other aspects of the program, international politics played their part in this contract. In efforts to boost the CFM56's chances versus its competitors, the Pratt & Whitney TF33 and an updated Pratt & Whitney JT8D, the French government announced in 1978 that they would upgrade their 11 KC-135s with the CFM56, providing one of the first orders for the engine.[23]

The USAF announced the CFM56 as the winner of the re-engine contract in January 1980. Officials indicated that they were excited at the prospect of replacing the Pratt & Whitney J57 engines currently flying on the KC-135A aircraft, calling them "...the noisiest, dirtiest, [and] most fuel inefficient powerplant still flying" at the time.[24] The re-engined aircraft was designated the KC-135R. The CFM56 brought many benefits to the KC-135, decreasing takeoff distance by as much as 3,500 ft (1,100 m), decreasing overall fuel usage by 25%, greatly reducing noise (24 dB lower) and lowering total life cycle cost. With those benefits in mind, the United States Navy selected the CFM56-2 to power their variant of the Boeing 707, the E-6 Mercury, in 1982.[22] In 1984 the Royal Saudi Air Force selected the CFM56-2 to power their E-3 Sentry aircraft (also related to the 707 airframe). The CFM56-2-powered E-3 also became the standard configuration for aircraft purchased by the British and French.[2]

The CFM-56 installed on the DC-8.

By the end of the 1970s, airlines were considering upgrading their aging Douglas DC-8 aircraft as an alternative to buying new quieter and more efficient aircraft. Following the French KC-135 order in 1978, the April 1979 decision by United Airlines to upgrade 30 of their DC-8-61 aircraft with the CFM56-2 was important for securing the development of the CFM56;[25] GE and Snecma were two weeks away from freezing development had that order not materialized.[5] This decision marked the first commercial purchase (rather than government/military) of the engine, and Delta Air Lines and Flying Tiger Line soon followed suit, giving the CFM56 a firm footing in both the military and commercial market.[2]

Engine inlet of a CFM56-3 engine on a Boeing 737-400 series showing the non-circular design

In the early 1980s Boeing selected the CFM56-3 to exclusively power the Boeing 737-300 variant. The 737 wings were closer to the ground than previous applications for the CFM56, necessitating several modifications to the engine. The fan diameter was reduced, which reduced the bypass ratio, and the engine accessory gearbox was moved from the bottom of the engine (the 6 o'clock position) to the 9 o'clock position, giving the engine nacelle its distinctive flat-bottomed shape. The overall thrust was also reduced, from 24,000 to 20,000 lbf (107 to 89 kN), mostly due to the reduction in bypass ratio.[26]

Since the small initial launch order for twenty 737-300s split between two airlines,[2] over 5,000 Boeing 737 aircraft had been delivered with CFM56 turbofans by April 2010.[27]

The CFM56 Being tested on GE's 747 in 2002

In 1998, CFMI launched the "Tech56" development and demonstration program to create an engine for the new single-aisle aircraft that were expected to be built by Airbus and Boeing. The program focused on developing a large number of new technologies for the theoretical future engine, not necessarily creating an all-new design.[28][29] When it became clear that Boeing and Airbus were not going to build all-new aircraft to replace the 737 and A320, CFMI decided to apply some of those Tech56 technologies to the CFM56 in the form of the "Tech Insertion" program which focused on three areas: fuel efficiency, maintenance costs and emissions. Launched in 2004, the package included redesigned high-pressure compressor blades, an improved combustor, and improved high- and low-pressure turbine components[30][31] which resulted in better fuel efficiency and lower nitrogen oxides (NOx) emissions. The new components also reduced engine wear, lowering maintenance costs by about 5%. The engines entered service in 2007, and all new CFM56-5B and CFM56-7B engines are being built with the Tech Insertion components. CFMI also offers the components as an upgrade kit for existing engines.[30]

In 2009, CFMI announced the latest upgrade to the CFM56 engine, the "CFM56-7B Evolution" or CFM56-7BE. This upgrade, announced with improvements to Boeing's 737 Next Generation, further enhances the high- and low-pressure turbines with better aerodynamics, as well as improving engine cooling, and aims to reduce overall part count.[32] CFMI expected the changes to result in a 4% reduction in maintenance costs and a 1% improvement in fuel consumption (2% improvement including the airframe changes for the new 737); flight and ground tests completed in May 2010 revealed that the fuel burn improvement was better than expected at 1.6%.[33] Following 450 hours of testing, the CFM56-7BE engine was certified by FAA and EASA on 30 July 2010[34] and delivered from mid-2011.

The CFM56-5B/3 PIP (Performance Improvement Package) engine includes these new technologies and hardware changes to lower fuel burn and lower maintenance cost. Airbus A320s were to use this engine version starting in late 2011.[35]

The LEAP is a new engine design based on and designed to replace the CFM56 series, with 16% efficiency savings by using more composite materials and achieving higher bypass ratios of over 10:1. LEAP entered service in 2016.[36]

As of June 2016, the CFM56 is the most-used high-bypass turbofan. It has achieved more than 800 million engine flight hours, and at a rate of one million flight hours every eight days it is expected to have achieved one billion flight hours by 2020. It has more than 550 operators and more than 2,400 CFM56-powered jet aircraft are in the air at any given moment. It is known for its dependability: its average time on wing is 30,000 hours before a first shop visit, with the current fleet record at 50,000 hours.[4]

As of July 2016, 30,000 engines have been built: 9,860 CFM56-5 engines for the Airbus A320ceo and A340-200/300 and more than 17,300 CFM56-3/-7B engines for the Boeing 737 Classic and 737NG. In July 2016, CFM had 3,000 engines in backlog.[3] Lufthansa, launch customer for the CFM56-5C-powered A340, have an engine with more than 100,000 flight hours, having entered commercial service on 16 November 1993, overhauled four times since.[37] In 2016 CFM delivered 1,665 CFM56 and booked 876 orders, it plans to produce CFM56 spare parts until 2045.[38]

By October 2017, CFM had delivered more than 31,000 engines and 24,000 were in service with 560 operators, it attained 500 million flight cycles and 900 million flight hours, including over 170 million cycles and 300 million hours since 1998 for the B737NG's -7B and over 100 million cycles and 180 million hours for the A320ceo's -5B since 1996.[39] By June 2018, 32,645 were delivered.[1] Strong demand will extend production to 2020, up from 2019.[40]

Exhaust gas temperature margin erodes with usage. One or two performance restoration shop visits, costing $0.3-$0.6m for a -5 series, can be performed before taking the engine off wing, which can restore 60% to 80% of the original margin. Once restored, the life limited parts must be replaced after: 20,000 cycles for the hot section ($0.5m), 25,000 for the axial compressor, and 30,000 for the fan and booster ($0.5m-$0.7m) for a recent CFM56. The whole engine parts cost more than $3m, $3.5 to $4m with the shop work-hours, around $150 per cycle.[41]

By June 2019, the CFM56 fleet had surpassed one billion engine flight hours (nearly 115,000 years), having carried more than 35 billion people, over eight million times around the world.[42]

The CFM56 production will wind down as the final 737NG engine was delivered in 2019 and the last A320ceo engine will be delivered in May 2020. Production will continue at low levels for military 737s and spare engines and will conclude around 2024.[43]

Unit cost: US$10 million (list price)[44]

The CFM56 is a high-bypass turbofan engine (most of the air accelerated by the fan bypasses the core of the engine and is exhausted out of the fan case) with several variants having bypass ratios ranging from 5:1 to 6:1, generating 18,500 to 34,000 lbf (80 kN to 150 kN) of thrust. The variants share a common design, but the details differ. The CFM56 is a two-shaft (or two-spool) engine, meaning that there are two rotating shafts, one high-pressure and one low-pressure. Each is powered by its own turbine section (the high-pressure and low-pressure turbines, respectively). The fan and booster (low-pressure compressor) evolved over the different iterations of the engine, as did the compressor, combustor and turbine sections.[2]

Swirl fuel nozzles of a CFM56 annular combustor

Most variants of the CFM56 feature a single-annular combustor. An annular combustor is a continuous ring where fuel is injected into the airflow and ignited, raising the pressure and temperature of the flow. This contrasts with a can combustor, where each combustion chamber is separate, and a canannular combustor which is a hybrid of the two. Fuel injection is regulated by a Hydromechanical Unit (HMU), built by Honeywell. The HMU regulates the amount of fuel delivered to the engine by means of an electrohydraulic servo valve that, in turn, drives a fuel metering valve, that provides information to the full authority digital engine controller (FADEC).[45]

In 1989, CFMI began work on a new, double-annular combustor. Instead of having just one combustion zone, the double-annular combustor has a second combustion zone that is used at high thrust levels. This design lowers the emissions of both nitrogen oxides (NOx) and carbon dioxide (CO2). The first CFM56 engine with the double-annular combustor entered service in 1995, and the combustor is used on CFM56-5B and CFM56-7B variants with the suffix "/2" on their nameplates.[46]

GE started developing and testing a new type of combustor called the Twin Annular Premixing Swirler combustor, or "TAPS", during the Tech 56 program.[29] This design is similar to the double-annular combustor in that it has two combustion zones; this combustor "swirls" the flow, creating an ideal fuel–air mixture. This difference allows the combustor to generate much less NOx than other combustors. Tests on a CFM56-7B engine demonstrated an improvement of 46% over single-annular combustors and 22% over double-annular combustors.[47] The analytical tools developed for TAPS have also been used to improve other combustors, notably the single-annular combustors in some CFM56-5B and -7B engines.[48]

CFM56-3 showing 3 stages of LP compressor at left (section of bypass duct removed) and 9 stages of HP compressor.

The high-pressure compressor (HPC), that was at the center of the original export controversy, features nine stages in all variants of the CFM56. The compressor stages have been developed from GE's "GE1/9 core" (namely a single-turbine, nine-compressor stage design) which was designed in a compact core rotor. The small span of the compressor radius meant that the entire engine could be lighter and smaller, as the accessory units in the system (bearings, oiling systems) could be merged to the main fueling system running on aviation fuel.[5] As design evolved HPC design improved through better airfoil design. As part of the Tech-56 improvement program CFMI has tested the new CFM-56 model with six-stage high-pressure compressor stages (discs that make up the compressor system) that was designed to deliver same pressure ratios (pressure gain 30) similar to the old nine-stages compressor design. The new one was not fully replacing the old one, but it offered an upgrade in HPC, thanks to improved blade dynamics, as a part of their "Tech Insertion" management plan from 2007.[29][49][50]

CFMI tested both a mixed and unmixed exhaust design at the beginning of development;[2] most variants of the engine have an unmixed exhaust nozzle.[nb 2] Only the high-power CFM56-5C, designed for the Airbus A340, has a mixed-flow exhaust nozzle.[nb 1][51]

GE and Snecma also tested the effectiveness of chevrons on reducing jet noise.[nb 3][52] After examining configurations in the wind tunnel, CFMI chose to flight-test chevrons built into the core exhaust nozzle. The chevrons reduced jet noise by 1.3 perceived loudness decibels during takeoff conditions, and are now offered as an option with the CFM56 for the Airbus A321.[53]

Fan and fan case of a CFM56-5

The CFM56 features a single-stage fan, and most variants have a three-stage booster on the low-pressure shaft,[nb 4] with four stages in the -5B and -5C variants.[54] The booster is also commonly called the "low-pressure compressor" (LPC) as it is part of the low-pressure spool and continues the air compression done by the inner part of the fan before it reaches the high-pressure compressor. The original CFM56-2 variant featured 44 tip-shrouded fan blades,[55][nb 5] although the number of fan blades was reduced in later variants as wide-chord blade technology developed, down to 22 blades in the CFM56-7 variant.[56]

The CFM56 fan features dovetailed fan blades which allows them to be replaced without removing the entire engine, and GE/Snecma claim that the CFM56 was the first engine to have that capability. This attachment method is useful for circumstances where only a few fan blades need to be repaired or replaced, such as following bird strikes.[57]

The fan diameter varies with the different models of the CFM56, and that change has a direct impact on the engine performance. For example, the low-pressure shaft rotates at the same speed for both the CFM56-2 and the CFM56-3 models; the fan diameter is smaller on the -3, which lowers the tip speed of the fan blades. The lower speed allows the fan blades to operate more efficiently (5.5% more in this case), which increases the overall fuel efficiency of the engine (improving specific fuel consumption nearly 3%).[26]

Pivoting-door thrust reversers are installed on the CFM56-5. Noise-reducing chevrons can also be seen at the engine's rear.

The CFM56 is designed to support several thrust reverser systems which help slow and stop the aircraft after landing. The variants built for the Boeing 737, the CFM56-3 and the CFM56-7, use a cascade type of thrust reverser. This type of thrust reverse consists of sleeves that slide back to expose mesh-like cascades and blocker doors that block the bypass air flow. The blocked bypass air is forced through the cascades, reducing the thrust of the engine and slowing the aircraft down.[58]

The CFM56 also supports pivoting-door type thrust reversers. This type is used on the CFM56-5 engines that power many Airbus aircraft such as the Airbus A320. They work by actuating a door that pivots down into the bypass duct, both blocking the bypass air and deflecting the flow outward, creating the reverse thrust.[59]

Cooling air tubes (for turbine blade tip to shroud clearance control) circle the iridescent turbine casing on a CFM56-7B26

All variants of the CFM56 feature a single-stage high-pressure turbine (HPT). In some variants, the HPT blades are "grown" from a single crystal superalloy, giving them high strength and creep resistance. The low-pressure turbine (LPT) features four stages in most variants of the engine, but the CFM56-5C has a five-stage LPT. This change was implemented to drive the larger fan on this variant.[51] Improvements to the turbine section were examined during the Tech56 program, and one development was an aerodynamically optimized low-pressure turbine blade design, which would have used 20% fewer blades for the whole low-pressure turbine, saving weight. Some of those Tech56 improvements made their way into the Tech Insertion package, where the turbine section was updated.[29] The turbine section was updated again in the "Evolution" upgrade.[30][33]

The high-pressure turbine stages in the CFM56 are internally cooled by air from the high-pressure compressor. The air passes through internal channels in each blade and ejects at the leading and trailing edges.[57]

An original CFM56-2 at the Safran museum

The CFM56-2 series is the original variant of the CFM56. It is most widely used in military applications where it is known as the F108; specifically in the KC-135, the E-6 Mercury and some E-3 Sentry aircraft. The CFM56-2 comprises a single-stage fan with 44 blades, with a three-stage LP compressor driven by a four-stage LP turbine, and a nine-stage HP compressor driven by a single-stage HP turbine. The combustor is annular.[55]

Model Thrust BPR OPR Dry weight[nb 6] Applications CFM56-2A2 (A3) 24,000 lbf (110 kN) 5.9 31.8 4,820 lb (2,190 kg) E-3 Sentry, E-6 Mercury CFM56-2B1 22,000 lbf (98 kN) 6.0 30.5 4,671 lb (2,120 kg) KC-135R Stratotanker, RC-135 CFM56-2C1 22,000 lbf (98 kN) 6.0 31.3 4,635 lb (2,100 kg) Douglas DC-8-70

A CFM56-3 series engine mounted on a Boeing 737-500 airliner showing flattening of the nacelle at the bottom of the inlet lip.

The first derivative of the CFM56 series, the CFM56-3 was designed for Boeing 737 Classic series (737-300/-400/-500), with static thrust ratings from 18,500 to 23,500 lbf (82.3 to 105 kN). A "cropped fan" derivative of the -2, the -3 engine has a smaller fan diameter at 60 in (1.5 m) but retains the original basic engine layout. The new fan was primarily derived from GE's CF6-80 turbofan rather than the CFM56-2, and the booster was redesigned to match the new fan.[26]

A significant challenge for this series was achieving ground clearance for the wing-mounted engine. This was overcome by reducing the intake fan diameter and relocating the gearbox and other accessories from beneath the engine to the sides. The resulting flattened nacelle bottom and intake lip yielded the distinctive appearance of the Boeing 737 with CFM56 engines.[60]

Model Thrust BPR OPR Dry weight Applications CFM56-3B1 20,000 lbf (89 kN) 6.0 27.5 4,276 lb (1,940 kg) Boeing 737-300, Boeing 737-500 CFM56-3B2 22,000 lbf (98 kN) 5.9 28.8 4,301 lb (1,950 kg) Boeing 737-300, Boeing 737-400 CFM56-3C1 23,500 lbf (100 kN) 6.0 30.6 4,301 lb (1,950 kg) Boeing 737-300, Boeing 737-400, Boeing 737-500

The CFM56-4 series was a proposed improved version of the CFM56-2 designed for the Airbus A320 family of aircraft. Competing with the RJ500 engine being developed by Rolls-Royce, the -4 series was designed to produce 25,000 lbf (110 kN) and was to feature a new 68 in (1.73 m) fan, a new low-pressure compressor and a full authority digital engine controller (FADEC). Soon after the upgrade project was launched in 1984, International Aero Engines offered their new V2500 engine for the A320. CFMI realized that the CFM56-4 did not compare favorably with the new engine and scrapped the project to begin working on the CFM56-5 series.[5]

The CFM56-5 series is designed for the Airbus aircraft and has a very wide thrust rating of between 22,000 and 34,000 lbf (97.9 and 151 kN). It has three distinct sub-variants; the CFM56-5A, CFM56-5B and CFM56-5C,[5] and differs from its Boeing 737 Classic-fitted cousins by featuring a FADEC and incorporating further aerodynamic design improvements.

The CFM56-5A series is the initial CFM56-5 series, designed to power the short-to-medium range Airbus A320 family. Derived from the CFM56-2 and CFM56-3 families, the -5A series produces thrusts between 22,000 and 26,500 lbf (98 kN and 118 kN). Aerodynamic improvements such as an updated fan, low-pressure compressor, high-pressure compressor and combustor make this variant 10–11% more fuel efficient than its predecessors.[61][62]

Model	Thrust	BPR	OPR	Dry weight	Applications
CFM56-5A1	25,000 lbf (111 kN)	6.0	31.3	4,995 lb (2,270 kg)	Airbus A320
CFM56-5A3	26,500 lbf (118 kN)	6.0	31.3	4,995 lb (2,270 kg)	Airbus A320
CFM56-5A4	22,000 lbf (97.9 kN)	6.2	31.3	4,995 lb (2,270 kg)	Airbus A319
CFM56-5A5	23,500 lbf (105 kN)	6.2	31.3	4,995 lb (2,270 kg)	Airbus A319

Front view of an A319-112 CFM56-5B6 with its fan removed

An improvement of the CFM56-5A series, it was originally designed to power the A321. With a thrust range between 22,000 and 33,000 lbf (98 kN and 147 kN) it can power every model in the A320 family (A318/A319/A320/A321) and has superseded the CFM56-5A series. Among the changes from the CFM56-5A is the option of a double-annular combustor that reduces emissions (particularly NOx), a new fan in a longer fan case, and a new low-pressure compressor with a fourth stage (up from three in earlier variants). It is the most numerous engine supplied to Airbus.[54][63]

Model	Thrust	BPR	OPR	Dry weight	Applications
CFM56-5B1	30,000 lbf (130 kN)	5.5	35.4	5,250 lb (2,380 kg)	Airbus A321
CFM56-5B2	31,000 lbf (140 kN)	5.5	35.4	5,250 lb (2,380 kg)	Airbus A321
CFM56-5B3	33,000 lbf (150 kN)	5.4	35.5	5,250 lb (2,380 kg)	Airbus A321
CFM56-5B4	27,000 lbf (120 kN)	5.7	32.6	5,250 lb (2,380 kg)	Airbus A320
CFM56-5B5	22,000 lbf (98 kN)	6.0	32.6	5,250 lb (2,380 kg)	Airbus A319
CFM56-5B6	23,500 lbf (100 kN)	5.9	32.6	5,250 lb (2,380 kg)	Airbus A319, A320
CFM56-5B7	27,000 lbf (120 kN)	5.7	35.5	5,250 lb (2,380 kg)	Airbus A319, A319CJ
CFM56-5B8	21,600 lbf (96 kN)	6.0	32.6	5,250 lb (2,380 kg)	Airbus A318, A318CJ
CFM56-5B9	23,300 lbf (100 kN)	5.9	32.6	5,250 lb (2,380 kg)	Airbus A318, A318CJ

With a thrust rating of between 31,200 and 34,000 lbf (139 kN and 151 kN), the CFM56-5C series is the most powerful of the CFM56 family. It powers Airbus' long-range A340-200 and -300 airliners, and entered service in 1993. The major changes are a larger fan, a fifth low-pressure turbine stage, and the same four-stage low-pressure compressor found in the -5B variant.[64]

Unlike every other variant of the CFM56, the -5C features a mixed-exhaust nozzle,[nb 1] which offers slightly higher efficiency.[51]

Model Thrust BPR OPR Dry weight Applications CFM56-5C2 31,200 lbf (139 kN) 6.6 37.4 8,796 lb (3,990 kg) Airbus A340-211/-311 CFM56-5C3 32,500 lbf (145 kN) 6.5 37.4 8,796 lb (3,990 kg) Airbus A340-212/-312 CFM56-5C4 34,000 lbf (151 kN) 6.4 38.3 8,796 lb (3,990 kg) Airbus A340-213/-313

The CFM56-7 first ran on 21 April 1995.[65] Rated with a takeoff thrust range of 19,500–27,300 lbf (87–121 kN), it powers the -600/-700/-800/-900 Boeing 737 Next Generation; compared to the CFM56-3, it has greater durability, 8% fuel burn improvement and a 15% reduction in maintenance costs.[66]

Improvements are due to its 61-inch titanium wide chord fan, 3D aerodynamics designed new core and low-pressure turbine with single crystal high-pressure turbine and Full Authority Digital Engine Control (FADEC).[66] Fan blades are reduced from 36 (CFM56-5) to 24 and it incorporates features from the CFM56-5B such as a double-annular combustor as an option.

Less than two years after entry into service, the Next-Generation 737 received 180 minutes Extended range twin engine Operations (ETOPS) certification from the US Federal Aviation Administration (FAA). It also powers the Boeing 737 military versions : Airborne Early Warning & Control, C-40 Clipper transport and P-8 Poseidon Maritime Aircraft.[66]

CFM56-7B specifications[66] Model Thrust BPR OPR Dry weight Applications CFM56-7B18 19,500 lbf (86.7 kN) 5.5 32.7 5,216 lb (2,370 kg) Boeing 737-600 CFM56-7B20 20,600 lbf (91.6 kN) 5.4 32.7 5,216 lb (2,370 kg) Boeing 737-600, Boeing 737-700 CFM56-7B22 22,700 lbf (101 kN) 5.3 32.7 5,216 lb (2,370 kg) Boeing 737-600, Boeing 737-700 CFM56-7B24 24,200 lbf (108 kN) 5.3 32.7 5,216 lb (2,370 kg) Boeing 737-700, Boeing 737-800, Boeing 737-900 CFM56-7B26 26,300 lbf (117 kN) 5.1 32.7 5,216 lb (2,370 kg) Boeing 737-700, Boeing 737-800, Boeing 737-900, BBJ CFM56-7B27 27,300 lbf (121 kN) 5.1 32.7 5,216 lb (2,370 kg) Boeing 737-800, Boeing 737-900, BBJ/BBJ2, AEW&C, MMA

The CFM56 has an in-flight shutdown rate of 1 incident per 333,333 hours.[67] Record time on wing before the first shop visit was 30,000 hours in 1996,[67] to 40,729 hours in 2003[68] and 50,000 hours in 2016.[4]

There have been several engine failures in the early service of the CFM56 family which were serious enough to either ground the fleet or require aspects of the engine to be redesigned. The engines have also suffered, periodically, from thrust instability events tentatively traced to Honeywell's hydromechanical unit.

There are several recorded incidents of CFM56 engines flaming out in heavy rain and/or hail conditions, beginning early in the CFM56's career. In 1987, a double flameout occurred in hail conditions (the pilots managed to relight the engines), followed by the TACA Flight 110 incident in 1988. Both CFM56 engines on the TACA 737 flamed out while passing through hail and heavy rain, and the crew was forced to land without engines on a grassy levee near New Orleans, Louisiana. CFMI modified the engines by adding a sensor to force the combustor to continuously ignite under these conditions.[5]

In 2002, Garuda Indonesia Flight 421 had to ditch in a river because of hail-induced engine flameouts, killing a flight attendant and injuring dozens of passengers. Prior to this accident, there were several other incidents of single or dual flameouts due to these weather conditions. After three incidents through 1998, CFMI made modifications to the engine to improve the way in which the engine handled hail ingestion. The major changes included a modification to the fan/booster splitter (making it more difficult for hail to be ingested by the core of the engine) and the use of an elliptical, rather than conical, spinner at the intake. These changes did not prevent the 2002 accident, and the investigation board found that the pilots did not follow the proper procedures for attempting to restart the engine, which contributed to the final result. Recommendations were made to better educate pilots on how to handle these conditions, as well as to revisit FAA rain and hail testing procedures. No further engine modifications were recommended.[69]

One issue that led to accidents with the CFM56-3C engine was the failure of fan blades. This mode of failure led to the Kegworth air disaster in 1989, which killed 47 people and injured 74 more. After the fan blade failed, the pilots mistakenly shut down the wrong engine, resulting in the damaged engine failing completely when powered up for the final approach. Following the Kegworth accident, CFM56 engines fitted to a Dan-Air

737-400 and a British Midland 737-400 suffered fan blade failures under similar conditions; neither incident resulted in a crash or injuries.[70] After the second incident, the 737-400 fleet was grounded.

At the time it was not mandatory to flight test new variants of existing engines, and certification testing failed to reveal vibration modes that the fan experienced during the regularly performed power climbs at high altitude. Analysis revealed that the fan was being subjected to high-cycle fatigue stresses worse than expected and also more severe than tested for certification; these higher stresses caused the blade to fracture. Less than a month after grounding, the fleet was allowed to resume operations once the fan blades and fan disc were replaced and the electronic engine controls were modified to reduce maximum engine thrust to 22,000 lbf (98 kN) from 23,500 lbf (105 kN).[71] The redesigned fan blades were installed on all CFM56-3C1 and CFM56-3B2 engines, including over 1,800 engines that had already been delivered to customers.[5]

In August 2016 Southwest Airlines Flight 3472 suffered a fan blade failure, but landed later without further incident. While the aircraft sustained substantial damage, there were no injuries.[72]

On 17 April 2018, Southwest Airlines Flight 1380 suffered from what appears to be a fan blade failure, debris from which punctured a window. The Boeing 737-700 landed safely, but one passenger was killed and several were injured.[73][74]

Airlines have reported 32 events involving sudden instability of thrust, at various points during flight, including high thrust settings during climb to altitude. The problem has been long-standing. In 1998, two 737 pilots reported that their engine throttles suddenly increased to full thrust during flight. A very recent investigation has led to the tentative conclusion that the problem originates in the Hydromechanical unit, and may involve an unacceptable level of fuel contamination (with water, or particulate matter, including biodegradable material that create solids in the fuel), or overuse of biocides to reduce bacterial growth. Boeing told Aviation Week and Space Technology that CFM International had revised its FADEC software. The new software "...'reduces the duration and degree of thrust-instability events' by cycling the fuel monitoring valve (FMV) and the EHSV (electrohydraulic servo valve) to clean the EHSV spool." This software fix is not intended to be a definitive solution to the problem; CFM claimed that no further reports have reached it after this change was made.[75]

- Airbus A320 family
    - Airbus A318
- Airbus A340
- Boeing 707-700 (prototype only)
- Boeing 737 Classic
- Boeing 737 Next Generation
    - Boeing 737 AEW&C
    - Boeing C-40 Clipper
    - Boeing P-8 Poseidon
- Boeing Business Jet
- Boeing E-3D Sentry
- Boeing E-6 Mercury
- Boeing KC-135R Stratotanker
    - Boeing RC-135
    - Boeing WC-135
- McDonnell Douglas DC-8 Super 70

Variant -2[76] -3[76] -5[77] -5B[78] -5C[78] -7B[79] Type Dual rotor, axial flow, high bypass ratio turbofan Compressor 1 fan, 3 LP, 9 HP 1 fan, 4 LP, 9 HP 1 fan, 3 LP, 9 HP Combustor Annular (double annular for -5B/2 and -7B/2 "DAC") Turbine 1 HP, 4 LP 1 HP, 5 LP 1 HP, 4 LP Control Hydro-mechanical + limited electronic Dual FADEC Length 243 cm (96 in) 236.4 cm (93.1 in) 242.2 cm (95.4 in) 259.97 cm (102.35 in) 262.2 cm (103.2 in) 250.8 cm (98.7 in) Width 183–200 cm (72–79 in) 201.8 cm (79.4 in) 190.8 cm (75.1 in) 190.8 cm (75.1 in) 194.6 cm (76.6 in) 211.8 cm (83.4 in) Height 214–216 cm (84–85 in) 181.7 cm (71.5 in) 210.1 cm (82.7 in) 210.5 cm (82.9 in) 225 cm (89 in) 182.9 cm (72.0 in) Dry weight 2,139–2,200 kg4,716–4,850 lb 1,954–1,966 kg4,308–4,334 lb 2,331 kg5,139 lb 2,454.8–2,500.6 kg5,412–5,513 lb 2,644.4 kg5,830 lb 2,386–2,431 kg5,260–5,359 lb Takeoff thrust 106.76–95.99 kN24,000–21,580 lbf 89.41–104.6 kN20,100–23,520 lbf 97.86–117.87 kN22,000–26,500 lbf 133.45–142.34 kN30,000–32,000 lbf 138.78–151.24 kN31,200–34,000 lbf 91.63–121.43 kN20,600–27,300 lbf Thrust/weight 4.49-4.9 4.49-5.22 4.2-5.06 5.44-5.69 5.25-5.72 3.84-5 100% RPM LP 5176, HP 14460 LP 5179, HP 14460 LP 5000, HP 14460 LP 5000, 14460 LP 4784, HP 14460 LP 5175, HP 14460 Variant -2[55] -3[26] -5[62] -5B[54] -5C[64] -7B[66] Air flow/sec 784–817 lb356–371 kg 638–710 lb289–322 kg 816–876 lb370–397 kg 811–968 lb368–439 kg 1,027–1,065 lb466–483 kg 677–782 lb307–355 kg Bypass ratio 5.9-6.0 6.0-6.2 5.4-6.0 6.4-6.5 5.1-5.5 Max OPR 30.5-31.8 27.5-30.6 31.3 32.6-35.5 37.4-38.3 32.8 Fan diameter 68.3 in (173 cm) 60 in (152 cm) 68.3 in (173 cm) 72.3 in (184 cm) 61 in (155 cm) Application Boeing KC-135Boeing 707Douglas DC-8-70 Boeing 737 Classic Airbus A319Airbus A320 Airbus A320 family Airbus A340-200/300 Boeing 737 Next Generation Takeoff TSFC[80] 0.366–0.376 lb/(lbf⋅h)10.4–10.7 g/(kN⋅s) 0.386–0.396 lb/(lbf⋅h)10.9–11.2 g/(kN⋅s) 0.3316 lb/(lbf⋅h)9.39 g/(kN⋅s) 0.3266–0.3536 lb/(lbf⋅h)9.25–10.02 g/(kN⋅s) 0.326–0.336 lb/(lbf⋅h)9.2–9.5 g/(kN⋅s) 0.356–0.386 lb/(lbf⋅h)10.1–10.9 g/(kN⋅s) Cruise TSFC[81][82][83] 0.65 lb/(lbf⋅h)18 g/(kN⋅s) (-2B1) 0.667 lb/(lbf⋅h)18.9 g/(kN⋅s) (-3C1)

0.596 lb/(lbf·h)16.9 g/(kN·s) (-5A1) 0.545 lb/(lbf·h)15.4 g/(kN·s) (-5B4) 0.545 lb/(lbf·h)15.4 g/(kN·s) (-5C2)

- Shenyang WS-10
- Shenyang WS-20

Related development

- CFM International LEAP
- General Electric F101
- General Electric Affinity
- PowerJet SaM146

Comparable engines

- IAE V2500
- Pratt & Whitney PW6000

Related lists

- List of aircraft engines

1. ^ a b c Mixed Exhaust Flow refers to turbofan engines (both low and high bypass) that exhaust both the hot core flow and the cool bypass flow through a single exit nozzle. The core and bypass flows are "mixed".
2. ^ a b Unmixed Exhaust Flow refers to turbofan engines (usually, but not exclusively high-bypass) that exhaust cool bypass air separately from their hot core flow. This arrangement is visually distinctive as the outer, wider, bypass section usually ends mid-way along the nacelle and the core protrudes to the rear. With two separate exhaust points, the flow is "unmixed".
3. ^ Chevron is the name for sawtooth cutouts that are sometimes applied to the exhaust nozzles of jet engines to reduce the jet noise. An example can be seen here [1] Archived 5 September 2018 at the Wayback Machine. (The pictured engine is not a CFM56.)
4. ^ The Low-Pressure Shaft, in a two-shaft engine, is the shaft that is turned by the low-pressure turbine (LPT). Generally the fan section(s) and the booster section(s) (also known as the "low-pressure compressor") are located on the low-pressure shaft.
5. ^ Shrouds are plates that are a part of a fan (or compressor, or turbine) blade. Generally, the shroud of one blade rests on the shroud of the adjacent blade, forming a continuous ring. Shrouds in the middle of blades are often used to damp vibrations. Shrouds at the tips of fan blades are often used to minimize air leakage around the tips. A midspan shroud is visible on the fan blades here [2]. (Note that these fan blades are not from a CFM56.) (Gunston, Bill (2004). Cambridge Aerospace Dictionary. Cambridge University Press. 2004. p.558-9.)
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A regularly updated listing of planned orbital missions from spaceports around the globe. Dates and times are given in Greenwich Mean Time. “NET” stands for no earlier than. “TBD” means to be determined. Recent updates appear in red type. Please send any corrections, additions or updates by e-mail to: sclark@spaceflightnow.com.

See our Launch Log for a listing of completed space missions since 2004.

Dec. 19: Electron/"Virginia is for Launch Lovers" delayed Dec. 18: Electron/"Virginia is for Launch Lovers" scrubbed Dec. 15: Falcon 9/Starlink 4-37 delayed; Electron/"Virginia is for Launch Lovers" delayed Dec. 14: Falcon 9/SWOT delayed; Electron/"Virginia is for Launch Lovers" delayed; Adding date for Falcon 9/O3b mPOWER 1 & 2; Adding date for Falcon 9/Starlink 4-37; Falcon 9/Starlink 2-2 delayed; Adding Falcon 9/Starlink 5-1; Adding Falcon 9/EROS C3; Falcon 9/Transporter 6 delayed; Adding Falcon 9/OneWeb 16; Adding Falcon 9/Starlink 2-4; Adding date for Falcon 9/GPS 3 SV06; Falcon 9/SDA Tranche 0 delayed; Adding date for Falcon 9/Crew 6 Dec. 7: RS-1/Flight 1 delayed; Electron/"Virginia is for Launch Lovers" delayed; Adding date for Falcon 9/ispace Hakuto-R Mission 1; Falcon 9/O3b mPOWER 1 & 2 delayed Dec. 6: Falcon 9/ispace Hakuto-R Mission 1 delayed; Falcon 9/OneWeb 15 delayed Dec. 5: Falcon 9/OneWeb 15 delayed; Adding date and time for Falcon 9/ispace Hakuto-R Mission 1; Falcon 9/Starlink 4-37 delayed; Adding RS-1/Flight 1; Adding Electron/"Virginia is for Launch Lovers"; Falcon 9/O3b mPOWER 1 & 2 moved forward; Falcon 9/SDA Tranche 0 delayed Nov. 30: Falcon 9/ispace Hakuto-R Mission 1 delayed; Falcon 9/Starlink 4-37 delayed; Adding date and time for Falcon 9/OneWeb 15; Falcon 9/SWOT delayed; Adding time for Ariane 5/Galaxy 35, Galaxy 36, and MTG-I1

TBDElectron • "Virginia is for Launch Lovers"

Launch window: TBD Launch site: LC-2, Mid-Atlantic Regional Spaceport, Wallops Island, Virginia

A Rocket Lab Electron launch vehicle will lift off with three satellites for HawkEye 360, radio frequency geospatial analytics provider. This will be the first Rocket Lab mission from a new launch pad in Virginia. Delayed from Dec. 7, Dec. 9, Dec. 13, Dec. 15, Dec. 16 and Dec. 18. [Dec. 19]

Dec. 20/21Vega-C • Pléiades Neo 5 & 6

Launch time: 0147 GMT on 21st (8:47 p.m. EST on

20th

) Launch site: ZLV, Kourou, French Guiana

An Arianespace Vega-C rocket, designated VV22, will launch the Pléiades Neo 5 and 6 Earth observation satellites for Airbus. Pléiades Neo 5 and 6 are the third and fourth members of the four-satellite Pléiades Neo constellation built, owned, and operated by Airbus. Delayed from Nov. 21, Nov. 23, and Nov. 24. [Nov. 29]

Dec. 28Falcon 9 • Starlink 5-1

Launch time: Approx. 0819 GMT (3:19 a.m. EST) Launch site: SLC-40, Cape Canaveral Space Force Station, Florida

A SpaceX Falcon 9 rocket will launch another batch of Starlink internet satellites. This mission will be the first into Shell 5 of the Starlink constellation, targeting a polar orbit after liftoff from Cape Canaveral. The Falcon 9's first stage booster will land on a drone ship in the Atlantic Ocean. [Dec. 14]

Dec. 28/29Falcon 9 • EROS C3

Launch time: 0658 GMT on 29th (1:58 a.m. EST on 29th; 10:58 p.m. PST on

28th

) Launch site: SLC-4E, Vandenberg Space Force Base, California

A SpaceX Falcon 9 rocket will launch the EROS C3 high-resolution Earth-imaging satellite for ImageSat International, an Israeli remote sensing company. EROS C3 was built by Israel Aerospace Industries and will collect optical multispectral imagery. The Falcon 9's first stage booster will return to Landing Zone 4 at Vandenberg Space Force Base. [Dec. 14]

TBDRS-1 • Flight 1

Launch window: TBD Launch site: LP-3C, Pacific Spaceport Complex, Kodiak Island, Alaska

An ABL RS-1 rocket will launch on its first orbital test flight, carrying two CubeSats for OmniTeq, a company with plans to deploy a constellation of small satellites to provide maritime communications services. Delayed from November and Dec. 7. [Dec. 7]

NET Jan. 2Falcon 9 • Transporter 6

Launch time: 1455 GMT (9:55 a.m. EST) Launch site: SLC-40, Cape Canaveral Space Force Station, Florida

A SpaceX Falcon 9 rocket will launch the Transporter 6 mission, a rideshare flight to a sun-synchronous orbit with numerous small microsatellites and nanosatellites for commercial and government customers. The Falcon 9's first stage booster will return to Landing Zone 1 at Cape Canaveral

Space Force Station. Delayed from October, November, and December. [Dec. 14]

JanuaryFalcon 9 • OneWeb 16

Launch time: TBD Launch site: SLC-40, Cape Canaveral Space Force Station, Florida

A SpaceX Falcon 9 rocket will launch 40 satellites into orbit for OneWeb, which is developing and deploying a constellation of hundreds of satellites in low Earth orbit for low-latency broadband communications. This will be the second launch of OneWeb satellites with SpaceX, and OneWeb's 16th launch overall. The Falcon 9's first stage booster will return to Landing Zone 1 at Cape Canaveral Space Force Station. [Dec. 14]

JanuaryFalcon 9 • Starlink 2-4

Launch time: TBD Launch site: SLC-4E, Vandenberg Space Force Base, California

A SpaceX Falcon 9 rocket will launch another batch of Starlink internet satellites. This mission will deploy the Starlink satellites into a high-inclination orbit inclined 70 degrees to the equator. The Falcon 9's first stage booster will land on a drone ship in the Atlantic Ocean. [Dec. 14]

JanuaryFalcon Heavy • USSF 67

Launch time: TBD Launch site: LC-39A, Kennedy Space Center, Florida

A SpaceX Falcon Heavy rocket will launch the USSF 67 mission for the U.S. Space Force. The mission will launch the Space Force's second Continuous Broadcast Augmenting SATCOM, or CBAS 2, military communications satellite and the Long Duration Propulsive ESPA 3A, or LDPE 3A, rideshare satellite hosting multiple experimental payloads. Delayed from 4th Quarter 2022. [Oct. 26]

TBDFalcon 9 • Starlink 2-2

Launch time: TBD Launch site: SLC-40, Cape Canaveral Space Force Station, Florida

A SpaceX Falcon 9 rocket will launch another batch of Starlink internet satellites. This mission will deploy the Starlink satellites into a high-inclination orbit inclined 70 degrees to the equator after flying southeast from Cape Canaveral. Delayed from Nov. 16 and Nov. 18. Delayed from December. [Dec. 14]

Jan. 18Falcon 9 • GPS 3 SV06

Launch window: TBD Launch site: SLC-40, Cape Canaveral Space Force Station, Florida

A SpaceX Falcon 9 rocket will launch the U.S. Space Force's sixth third-generation navigation satellite for the Global Positioning System. The Falcon 9's first stage booster will land on a drone ship in the Atlantic Ocean. The satellite was built by Lockheed Martin. Delayed from late 2022. [Dec. 14]

JanuaryFalcon 9 • WorldView Legion 1 & 2

Launch time: TBD Launch site: SLC-40, Cape Canaveral Space Force Station, Florida

A SpaceX Falcon 9 rocket will launch the first two WorldView Legion Earth observation satellites for Maxar Technologies. Maxar plans to deploy six commercial WorldView Legion high-resolution remote sensing satellites into a mix of sun-synchronous and mid-inclination orbits on three SpaceX Falcon 9 rockets. Delayed from January and September 2021. Delayed from March, May, June, July, and September 2022. Delayed again from 4th Quarter 2022. [Nov. 22]

NET JanuaryFalcon Heavy • ViaSat 3 Americas

Launch time: TBD Launch site: LC-39A, Kennedy Space Center, Florida

A SpaceX Falcon Heavy rocket will launch the ViaSat 3 Americas broadband communications satellite. ViaSat 3 Americas is the first of at least three new-generation Boeing-built geostationary satellites for ViaSat. A small communications satellite named Arcturus will launch as a secondary payload for Astranis. Delayed from 3rd Quarter and December. [Nov. 22]

Early 2023Falcon 9 • SES 18 & SES 19

Launch time: TBD Launch site: Cape Canaveral, Florida

A SpaceX Falcon 9 rocket will launch SES 18 and SES 19 communications satellites for SES of Luxembourg. SES 18 and 19, built by Northrop Grumman, will provide C-band television and data services over the United States. [May 24]

TBDSSLV • BlackSky Global

Launch time: TBD Launch site: Satish Dhawan Space Center, Sriharikota, India

India's Small Satellite Launch Vehicle (SSLV) will launch on its first commercial mission with four Earth observation satellites for BlackSky Global, a Seattle-based company. The rideshare mission for BlackSky is being arranged by Spaceflight. Delayed from November, late 2019 and early 2020. Delayed from early 2021 and July. [March 31]

TBDStarship • Orbital Test Flight

Launch time: TBD Launch site: Starbase, Boca Chica Beach, Texas

A SpaceX Super Heavy and Starship launch vehicle will launch on its first orbital test flight. The mission will attempt to travel around the world for nearly one full orbit, resulting in a re-entry and splashdown of the Starship near Hawaii. Delayed from early 2022. [March 9]

1st QuarterFalcon 9 • O3b mPOWER 3 & 4

Launch time: TBD Launch site: SLC-40, Cape Canaveral, Florida

A SpaceX Falcon 9 rocket will launch the second pair of O3b mPOWER broadband internet satellites into Medium Earth Orbit for SES of Luxembourg. The satellites, built by Boeing, will provide internet services over most of the populated world, building on SES's O3b network. The Falcon 9's first stage booster will land on a drone ship in the Atlantic Ocean. [Nov. 22]

Feb. 16Soyuz • Progress 83P

Launch time: TBD Launch site: Baikonur Cosmodrome, Kazakhstan

A Russian government Soyuz rocket will launch the 83rd Progress cargo delivery ship to the International Space Station. The rocket will fly in the Soyuz-2.1a configuration. [Oct. 26]

Feb. 19Falcon 9 • Crew 6

Launch time: TBD Launch site: LC-39A, Kennedy Space Center, Florida

A SpaceX Falcon 9 rocket will launch a Crew Dragon spacecraft on the program's ninth flight with astronauts. The Falcon 9's first stage booster will land on a drone ship in the Atlantic Ocean. NASA astronauts Stephen Bowen, Warren "Woody" Hoburg, UAE astronaut Sultan Al Neyadi, and Russian cosmonaut Andrey Fedyaev will launch on the Crew Dragon spacecraft to begin a six-month expedition on the International Space Station. The Crew Dragon will return to a splashdown at sea. [Dec. 14]

FebruaryFalcon 9 • Inmarsat 6 F2

Launch window: TBD Launch site: Cape Canaveral, Florida

A SpaceX Falcon 9 rocket will launch the Inmarsat 6 F2 communications satellite for London-based Inmarsat. Built by Airbus Defense and Space, the satellite carries L-band and Ka-band payloads to provide mobile communications services to airplanes and ships. [Nov. 22]

1st QuarterVulcan Centaur • Peregrine

Launch window: TBD Launch site: SLC-41, Cape Canaveral Space Force Station, Florida

A United Launch Alliance Vulcan Centaur rocket will launch on its inaugural flight with the Peregrine commercial lunar lander for Astrobotic. The Peregrine robotic lander will carry multiple experiments, scientific instruments, and tech demo payloads for NASA and other customers. The Vulcan Centaur rocket will fly in the VC2S configuration with two GEM-63XL solid rocket boosters, a short-length payload fairing, and two RL10 engines on the Centaur upper stage. Delayed from mid-2022 and late 2022. [Oct. 26]

FebruaryAriane 5 • Syracuse 4B & Heinrich Hertz

Launch window: TBD Launch site: ELA-3, Kourou, French Guiana

Arianespace will use an Ariane 5 ECA rocket, designated VA259, to launch the Syracuse 4B and Heinrich Hertz communications satellites. Syracuse 4B, built by Airbus, will relay secure communications between French military aircraft, ground vehicles, and naval vessels, including submarines. The Heinrich Hertz satellite, built by OHB, will test new communications technologies on a mission funded by the German government. The small Ovzon 3 geostationary communications satellite for the Swedish company Ovzon will also be on this launch. [Nov. 22]

MarchFalcon 9 • Polaris Dawn

Launch time: TBD Launch site: LC-39A, Kennedy Space Center, Florida

A SpaceX Falcon 9 rocket will launch a Crew Dragon spacecraft on the program's 10th flight with astronauts. The Falcon 9's first stage booster will land on a drone ship in the Atlantic Ocean. The Polaris Dawn mission will be commanded by billionaire Jared Isaacman, making his second trip to space. He will be joined on the all-private mission by pilot Scott "Kidd" Poteet, and SpaceX employees Sarah Gillis and Anna Menon. The Crew Dragon will return to a splashdown at sea. Delayed from November and December. [Sept. 22]

MarchFalcon 9 • SDA Tranche 0

Launch time: TBD Launch site: SLC-4E, Vandenberg Space Force Base, California

A SpaceX Falcon 9 rocket will launch around 10 Tranche 0 demonstration satellites for the U.S. military's Space Development Agency. The launch is the first of two Falcon 9 missions to carry SDA demonstration spacecraft for a future constellation of military missile tracking and data relay satellites. The Falcon 9's first stage booster will return to Landing Zone 4 at Vandenberg. Delayed from Sept. 24. Delayed from Sept. 29 by payload supply chain issues. Delayed from January due to satellite issue. [Dec. 14]

MarchAntares • NG-19

Launch time: TBD Launch site: Pad 0A, Wallops Island, Virginia

A Northrop Grumman Antares rocket will launch the 20th Cygnus cargo freighter on the 19th operational cargo delivery flight to the International Space Station. The mission is known as NG-19. The rocket will fly in the Antares 230+ configuration, with two RD-181 first stage engines and a Castor 30XL second stage. This will be the final flight of an Antares 230+ rocket before a redesign with new U.S.-made engines. [Oct. 26]

MarchFalcon 9 • IM-1

Launch time: TBD Launch site: LC-39A, Kennedy Space Center, Florida

A SpaceX Falcon 9 rocket will launch the IM-1 mission with the Nova-C lander built and owned by Intuitive Machines. The IM-1 mission will attempt to deliver a suite of science payloads to the surface of the moon for NASA's Commercial Lunar Payload Services program. Delayed from 3rd Quarter of 2022, December 2022, and January 2023. [Oct. 26]

MarchSoyuz • ISS 69S

Launch time: TBD Launch site: Baikonur Cosmodrome, Kazakhstan

A Russian government Soyuz rocket will launch the crewed Soyuz MS-23 spacecraft to the International Space Station with the next team of three cosmonauts and astronauts to live and work on the complex. The crew is led by commander Oleg Kononenko, who will be joined by Russian flight engineer Nikolai Chub and NASA astronaut Loral O'Hara. The rocket will fly in the Soyuz-2.1a configuration. [Sept. 22]

MarchDelta 4-Heavy • NROL-68

Launch time: TBD Launch site: SLC-37B, Cape Canaveral Space Force Station, Florida

A United Launch Alliance Delta 4-Heavy rocket will launch a classified spy satellite cargo for the U.S. National Reconnaissance Office. The largest of the Delta 4 family, the Heavy version features three Common Booster Cores mounted together to form a triple-body rocket. This is the penultimate flight of a Delta 4 rocket. [Oct. 26]

Early 2023Falcon 9 • WorldView Legion 3 & 4

Launch time: TBD Launch site: SLC-40, Cape Canaveral Space Force Station, Florida

A SpaceX Falcon 9 rocket will launch the second pair of WorldView Legion Earth observation satellites for Maxar Technologies. Maxar plans to deploy six commercial WorldView Legion high-resolution remote sensing satellites into a mix of sun-synchronous and mid-inclination orbits on three SpaceX Falcon 9 rockets. [Nov. 22]

1st QuarterFalcon 9 • O3b mPOWER 5 & 6

Launch time: TBD Launch site: SLC-40, Cape Canaveral Space Force Station, Florida

A SpaceX Falcon 9 rocket will launch the third pair of O3b mPOWER broadband internet satellites into Medium Earth Orbit for SES of Luxembourg. The satellites, built by Boeing, will provide internet services over most of the populated world, building on SES's O3b network. The Falcon 9's first stage booster will land on a drone ship in the Atlantic Ocean. [Nov. 22]

2nd QuarterFalcon Heavy • USSF 52

Launch time: TBD Launch site: LC-39A, Kennedy Space Center, Florida

A SpaceX Falcon Heavy rocket will launch the USSF 52 mission for the U.S. Space Force. The Falcon Heavy will launch an unspecified military payload on this mission. Delayed from October 2021 and 2nd Quarter 2022. Delayed from October. [Oct. 26]

NET April 5Ariane 5 • JUICE

Launch window: TBD Launch site: ELA-3, Kourou, French Guiana

Arianespace will use an Ariane 5 ECA rocket, designated VA261, to launch the European Space Agency's Jupiter Icy Moons Explorer mission, or JUICE. The JUICE spacecraft, built by Airbus, will make detailed observations of the giant gas planet and its three large ocean-bearing moons — Ganymede, Callisto and Europa — with a suite of remote sensing, geophysical and in situ instruments. JUICE will enter orbit around Jupiter in July 2031. This will mark the final launch of Europe's Ariane 5 rocket. [Nov. 22]

AprilAtlas 5 • CST-100 Starliner Crew Flight Test

Launch window: TBD Launch site: SLC-41, Cape Canaveral Space Force Station, Florida

A United Launch Alliance Atlas 5 rocket, designated AV-085, will launch Boeing's CST-100 Starliner spacecraft on its first mission with astronauts, known as the Crew Test Flight, to the International Space Station. The capsule will dock with the space station, then return to Earth to landing in the Western United States. NASA astronauts Butch Wilmore and Suni Williams will fly on the mission. The rocket will fly in a vehicle configuration with two solid rocket boosters and a dual-engine Centaur upper stage. Delayed from August and 1st Quarter of 2020. Delayed from mid-2020 after Boeing decision to refly the Orbital Flight Test. Delayed from early 2021, June 2021, and late 2021. Delayed from late 2022 to implement fixes on the Starliner spacecraft after OFT-2. [Nov. 22]

2nd QuarterAtlas 5 • USSF 51

Launch time: TBD Launch site: SLC-41, Cape Canaveral Space Force Station, Florida

A United Launch Alliance Atlas 5 rocket, designated AV-101, will launch the USSF 51 mission for the U.S. Space Force. This mission will launch an undisclosed payload for the military. [Oct. 26]

MayFalcon 9 • Axiom Mission 2

Launch time: TBD Launch site: LC-39A, Kennedy Space Center, Florida

A SpaceX Falcon 9 rocket launched a Crew Dragon spacecraft on the program's 11th flight with astronauts. The commercial mission, managed by Axiom Space, is commanded by former NASA astronaut Peggy Whitson. Paying passengers John Shoffner will serve as pilot of the mission. Two commercial space fliers from Saudi Arabia will also be on the approximately two-week mission to the space station. The Crew Dragon will return to a splashdown at sea off the coast of Florida. [Oct. 26]

SummerAtlas 5 • ViaSat 3 EMEA

Launch time: TBD Launch site: SLC-41, Cape Canaveral Space Force Station, Florida

A United Launch Alliance Atlas 5 rocket, designated AV-100, will launch launch the ViaSat 3 EMEA broadband communications satellite. ViaSat 3 Americas is the second of at least three new-generation Boeing-built geostationary satellites for Viasat. ViaSat EMEA will cover the Europe, Middle East, and Africa regions. [Nov. 22]