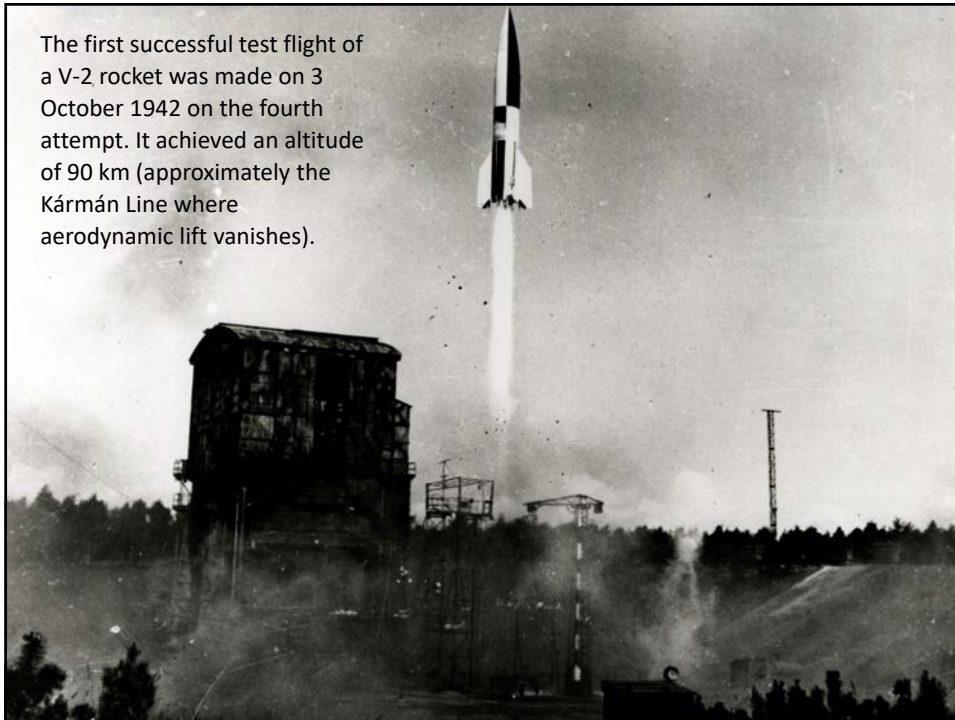




The first successful test flight of a V-2 rocket was made on 3 October 1942 on the fourth attempt. It achieved an altitude of 90 km (approximately the Kármán Line where aerodynamic lift vanishes).



Project Paperclip: Dark side of the Moon



- Sixty years ago the US hired Nazi scientists to lead pioneering projects, such as the race to conquer space. These men provided the US with cutting-edge technology which still leads the way today, but at a cost.
- The end of World War II saw an intense scramble for Nazi Germany's many technological secrets. The Allies vied to plunder as much equipment and expertise as possible from the rubble of the Thousand Year Reich for themselves, while preventing others from doing the same.

- The range of Germany's technical achievement astounded Allied scientific intelligence experts accompanying the invading forces in 1945.
- Even as Germany was losing the war, they were developing ground-breaking technologies developed in Nazi laboratories, workshops and factories.
 - supersonic rockets
 - nerve gas
 - jet aircraft
 - guided missiles
 - stealth technology
 - hardened armour
 - and much more



Underground production of German He-162 Volksjäger, Heinkel He162 "Salamander" jet fighters

A few of the many Nazi technologies



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In 1945, Soviet engineers discovered vast legacy of rocket weapons in the defeated Nazi Germany, including:

- V-2 (long-range guided ballistic missile), B&W checks on top
- V-1 (first cruise missile), grey over white on bottom left
- Anti-aircraft missiles, yellow over red on bottom right.
- Fritz-X (insert) and Henschel HS 293 guided anti-ship missiles



Messerschmitt Me 262A First Jet Fighter



Arado 234B Blitz ("Lightning") First Jet Bomber

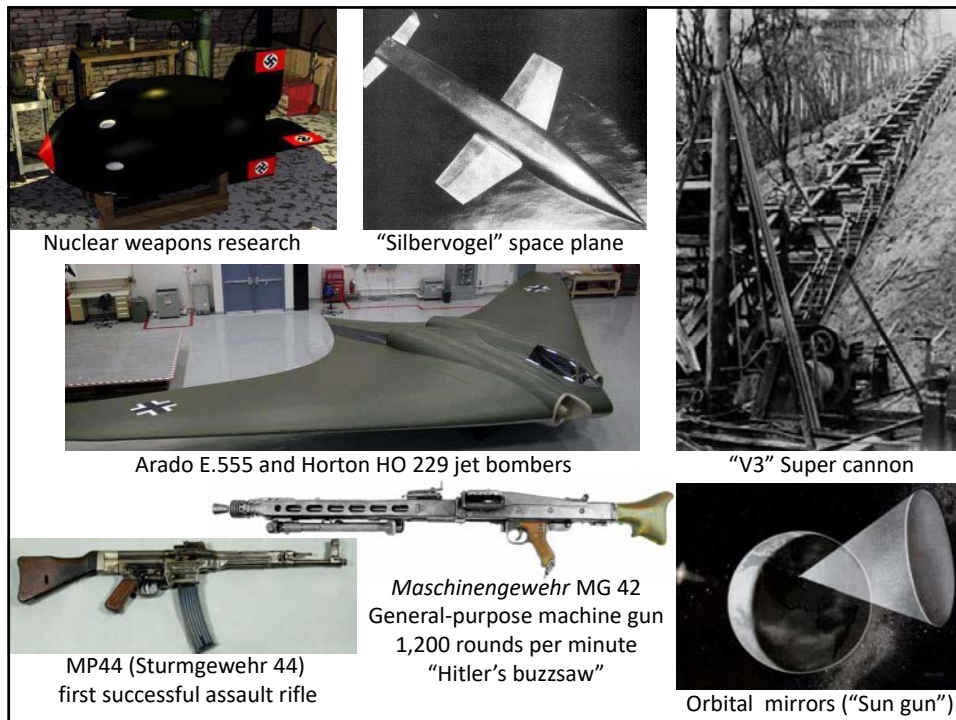


Me 163B Komet First rocket-propelled fighter



First production helicopter

Flettner Fl 282 Kolibri ("Hummingbird")



- The US and the Soviet Union in the first days of the Cold War, found themselves in a race against time to uncover Hitler's scientific secrets.
- In May 1945, Stalin's legions secured the atomic research labs at the prestigious Kaiser Wilhelm Institute in the suburbs of Berlin, giving their master the kernel of what would become the vast Soviet nuclear arsenal.
- US forces removed V-2 missiles from the vast Nordhausen complex, built under the Harz Mountains in central Germany, just before the Soviets took over the factory, in what would become their area of occupation. And the team which had built the V-2, led by Wernher von Braun, also fell into American hands.
- Shortly afterwards Major-General Hugh Knerr, deputy commander of the US Air Force in Europe, wrote:

"Occupation of German scientific and industrial establishments has revealed the fact that we have been alarmingly backward in many fields of research. If we do not take the opportunity to seize the apparatus and the brains that developed it and put the combination back to work promptly, we will remain several years behind while we attempt to cover a field already exploited."



- Thus began Project Paperclip, the US operation which saw von Braun and more than 700 others spirited out of Germany from under the noses of the US's allies. Its aim was simple: "To exploit German scientists for American research and to deny these intellectual resources to the Soviet Union."
- Events moved rapidly. President Truman authorised Paperclip in August 1945 and, on 18 November, the first Germans reached America.
- There was, though, one major problem. Truman had expressly ordered that anyone found "to have been a member of the Nazi party and more than a nominal participant in its activities, or an active supporter of Nazism

Originally named Operation Overcast, the renaming to Project Paperclip was ironic. The paperclip that pinned program requirements to files of "recruited" scientists didn't seem to retain the "no Nazi" provision.

- Under this criterion even von Braun himself, the man who masterminded the Moon shots, would have been ineligible to serve the US. A member of numerous Nazi organisations, he also held rank in the SS. His initial intelligence file described him as "a security risk".

SS *Sturmabführer* (Major) Wernher von Braun (behind Himmler)



- Herr von Braun's associates included (among others):

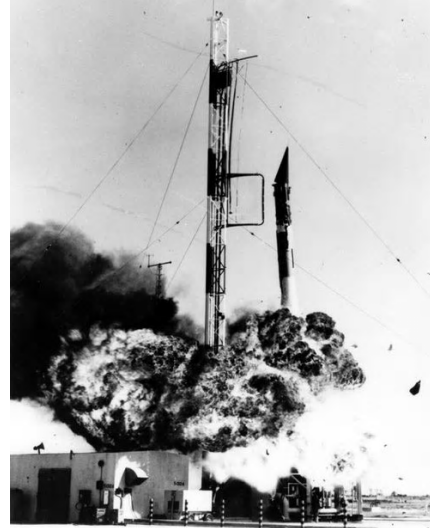
- Arthur Rudolph**, former chief operations director at Nordhausen, where 20,000 slave labourers died producing V-2 missiles. Led the team which built the Saturn V rocket. A loyal member of the NSDAP, he was called "100 per cent Nazi, dangerous type".
- Kurt Debus**, rocket launch specialist, another Nazi Party member and SS officer. His report stated: "He should be interned as a menace to the security of the Allied Forces." He became the first Kennedy Space Center Director (1962-1974).
- Hubertus Strughold**, Luftwaffe Oberst (Colonel), called "the father of space medicine", designed Nasa's on-board life-support systems. Subordinates conducted human "experiments" at Dachau and Auschwitz, where inmates were frozen and put into low-pressure chambers, often dying in the process.

- All of these men were cleared to work for the US, their alleged crimes covered up and their backgrounds bleached by a military which saw winning the Cold War, and not upholding justice, as its first priority.



The inter-service rivalry that delayed America's first satellite launch

- The International Geophysical Year (IGY, July 1957 to December 1958) opened the door for American scientists to launch Earth-orbiting satellites with the goal of exploring solar and geophysical phenomenon.
- But the Soviet Union got there first with Sputnik's launch on October 4, 1957.
- America's response on Dec. 6 failed spectacularly. Luckily, Wernher von Braun and the US Army had kept a satellite-ready rocket in storage, one they pulled out to help America recover from the sting of Vanguard's failure.



Vanguard's spectacular failure

Background

- The United States announced its intention to launch a satellite as part of the IGY with an announcement from the White House on July 29, 1955.
- But Wernher von Braun, the former Nazi rocket scientists now working for the US Army, had already proposed a satellite program to the Assistant Secretary of Defense six months earlier. Called **Project Orbiter**, it wasn't the long-term program of von Braun's dreams. It would be a quick way to put a small satellite into orbit, as much a scientific endeavour as a psychological one. He knew the first nation into space would have an advantage in the space age he saw just over the horizon.
- The Orbiter satellite would launch on a four-stage rocket, the first stage would be one of von Braun's Redstone missiles and the upper three stages would be clusters of solid Loki II-A rockets developed by Caltech's Jet Propulsion Laboratory. With each stage firing as the one below it cut out, the satellite would enough momentum to leave the Earth's atmosphere.

- But the Army wasn't the only military service keen on bringing America into the space age.
- Another strong contender was the US Navy whose Project Vanguard proposed using a two-stage launch vehicle based on the Viking sounding rocket to put a modest satellite into orbit.
- The US Air Force submitted two proposals similar proposals using intercontinental ballistic missile topped with sounding rockets as upper stages to launch small payloads.
- A secret committee led by Homer J. Stewart, Jet Propulsion Lab., would decide.



A Viking sounding rocket launch

- The Air Force proposals were in a poor position.
 - Proposed launch systems were based on offensive missiles.
 - USAF missiles only existed on paper for the moment. It seemed somewhat unlikely that these rockets would be ready to launch a satellite within the timeframe of the IGY.
 - Ongoing USAF reconnaissance programs would suffer without the resources and personnel reassigned to yet another project.
- Navy's Vanguard was different, plus its scientists were mainly Jewish.
 - Though it also existed mostly on paper, the Viking first stage was an American-made sounding rocket that had no use as an offensive weapon.
 - The Navy's proposal alone promoted the idealistic notion that science was a peaceful undertaking with relatively few military connections.
- The committee chose Vanguard over Orbital, 3-2 (2 abstain; 1 absent) on political rather than technical grounds (Vanguard was seen as non-military; Army's Nazi connections a possible PR risk).

- When von Braun heard the decision, he was shocked and furious. His ire increased when he learned that the absent member, Professor Francis Charles McMath from the University of Michigan Observatory, was partial to Project Orbiter. Would McMath's attendance have swayed the undecided voters to favour the Army's proposal? Was his inability to attend part of a conspiracy?
- Von Braun set about revising the Orbiter proposal in the hopes of changing the Stewart Committee's collective mind, but they remained steadfast in their decision.
- But von Braun did find a sympathetic ear in Stewart himself. The two men shared a conviction that the unproven Navy system would ultimately fail and that the burden of a satellite launch would eventually fall to the Army.



- Army Ordnance agreed. And so von Braun and Stewart conspired to retain Project Orbiter's capabilities though under a different name, putting faith in a convoluted bureaucratic labelling system to camouflage their secret.
- Orbiter was revised to use a scaled-down Sergeant rocket rather than Loki for the three upper stages with an elongated Redstone as the first stage. It was a configuration that could put a satellite in orbit, or with a dummy fourth stage it would be a perfect system to test different re-entry materials. Five missiles were diverted to a "re-entry test program," including Redstone missiles RS-27 and RS-29.
- If the Navy failed and the Army was called on to launch a satellite, these rockets could be reconfigured for the job in less than three months.



- In September of 1956, RS-27 was redesignated Jupiter C. "Jupiter" imbue it with the priority of the Army-Navy rocket program of the same name and "C" denoting it as a composite re-entry test flight. Early in the morning of the 20th, the rocket rose from the launch pad, reached a top speed of 13,000 miles per hour, and covered a distance of 3,350 miles on its short flight. The dummy fourth stage was lofted to a peak altitude of 682 miles. It was clear that had the fourth stage been active it could have put a satellite into orbit. Von Braun's system worked.
- RS-29 stayed in storage for more than a year.
- On October 4, 1957, the Soviet Union successfully launched R-7 Russian Sputnik 1, the first successful orbital satellite. About the size of a basketball, it weighed only 183 pounds and took about 98 minutes to orbit the Earth on its elliptical path.



Sputnik 1

- **Sputnik 1** (/ˈspʌtnɪk/; Russian: Спутник-1 [ˈspʊtnʲɪk] "Satellite-1", or ПС-1 ["PS-1", i.e., Russian: Простейший Спутник-1 "Elementary Satellite 1"]) was the first artificial Earth satellite. The Soviet Union launched it into an elliptical low Earth orbit on 4 October 1957. It was a 58 cm (23 in) diameter polished metal sphere, with four external radio antennae to broadcast radio pulses. It was visible all around the Earth and its radio pulses were detectable.
- This surprise success precipitated the American Sputnik crisis and triggered the Space Race, a part of the larger Cold War. The launch ushered in new political, military, technological, and scientific developments.



This metal arming key prevented contact between the batteries and the transmitter prior to launch.

- Tracking and studying *Sputnik* from Earth provided scientists with valuable information, even though the satellite itself wasn't equipped with sensors. The density of the upper atmosphere could be deduced from its drag on the orbit, and the propagation of its radio signals gave information about the ionosphere.
- Sputnik 1* was launched during the International Geophysical Year from Site No.1/5, at the 5th Tyuratam range, in Kazakh SSR (now known as the Baikonur Cosmodrome). The satellite travelled at about 29,000 kilometres per hour (18,000 mph; 8,100 m/s), taking 96.2 minutes to complete each orbit.
- It transmitted on 20.005 and 40.002 MHz, which were monitored by amateur radio operators throughout the world. Signals continued for 21 days until transmitter batteries ran out on 26 October 1957.
- Sputnik 1* burned up on 4 January 1958, as it fell from orbit upon re-entering Earth's atmosphere, after travelling about 70 million km (43.5 million miles) and spending three months in orbit.

Sergei Pavlovich Korolev

- Sergei Pavlovich Korolev** was a lead Soviet rocket engineer and spacecraft designer during the Space Race in the 1950s and 1960s. He is regarded by many as the father of practical astronautics. He was involved in the development of the R-7 Rocket, *Sputnik 1*, and launching *Laika* and the first human being, Yuri Gagarin, into space.
- Although Korolev trained as an aircraft designer, with strengths proved to be in design integration, organization and strategic planning. Arrested on a false official charge as a "member of an anti-Soviet counter-revolutionary organization" (later be reduced to "saboteur of military technology"), he was imprisoned in 1938 for almost six years, including some months in a Kolyma labour camp.



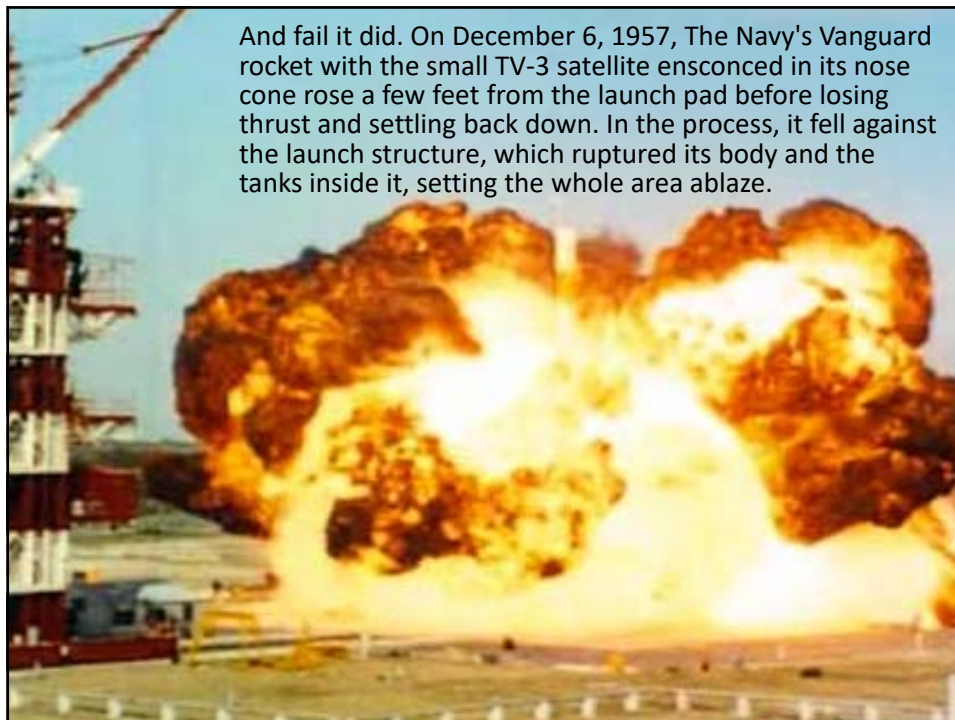
Born	12 January 1907
Died	14 January 1966 (aged 59)
Buried	The Kremlin
Citizen	Ukrainian
Occupation	Rocket engineer, Chief Designer of the Soviet space program
Spouse(s)	Ksenia Vincentini Nina Ivanovna Kotenkova
Children	1
Military career	
Allegiance	Soviet Union
Service	Red Army 45-52
Rank	Polkovnik (colonel)

- Following his release Korolev became a recognized rocket designer and a key figure in the development of the Soviet ICBM missile program. He later directed the Soviet space program and was made a Member of Soviet Academy of Sciences, overseeing the early successes of the Sputnik and Vostok projects including the first human Earth orbit mission by Yuri Alexeyvich Gagarin on 12 April 1961. Korolev's unexpected death in 1966 interrupted implementation of his plans for a Soviet manned Moon landing before the United States 1969 mission.



- Before his death he was officially identified only as *Glavny Konstruktor* (Главный Конструктор), or the *Chief Designer*, to protect him from possible cold war assassination attempts by the United States. Even some of the cosmonauts who worked with him were unaware of his last name; he only went by *Chief Designer*. Only following his death in 1966 was his identity revealed and he received the appropriate public recognition as the driving force behind Soviet accomplishments in space exploration during and following the International Geophysical Year.





- The failure gave the Army a tiny launch window, just three days beginning on January 29, 1958; in the meantime the Navy retained control over the Cape Canaveral launch site.
- The Army moved RS-29 to Florida and started preparing for its mission, and when the launch window opened the rocket was erected on the launch pad.
- Late on the evening of January 31, the rocket, renamed Jupiter C like its mate, rose off the launch pad and sent the diminutive Explorer 1 satellite into orbit.

This could have been achieved in 1956!!!!



Explorer 1's 1958 launch

JPL's William Pickering, James van Allen, and von Braun hold a model Explorer 1



Reasons for Russia's initial success in space



- A definite plan for developing large rockets for ICBMs that were suitable for space launches even though America could have launched the first satellite.
- Only one agency was involved.
- Chief Designer Korolev had the support of Khrushchev.
- Good luck – Because Soviet atomic weapons were large and required large launch vehicles, large rockets were available.

Reasons for America's initial trailing in space



- Started later than Soviets in developing rockets for ICBMs.
- Initially three agencies involved in developing rockets (Army, Navy and Air Force). First launch awarded to Navy rather than more advanced Army.
- Eisenhower administration had little interest in space research.
- Americans did not anticipate the impact space research would have.
- Bad luck/good design – American atomic weapons were smaller.

The Impact of Sputnik 1 on the USA

- The launch of Sputnik 1 surprised the American public, and shattered the perception created by American propaganda of the United States as the technological superpower, and the Soviet Union as a backward country.
- Meanwhile, the televised failure of *Vanguard TV3* on 6 December 1957 deepened American dismay over the country's position in the Space Race.
- The **Sputnik crisis** was a period of public fear and anxiety in Western nations. There were fears that the Soviets would create ballistic missiles capable of carrying nuclear weapons from Eastern Europe to the U.S. The same rocket (R7) that launched Sputnik could send a nuclear warhead anywhere in the world. The Soviets had demonstrated this capability on 21 August 1957 with a 6,000 km test flight of the R-7 booster. TASS announced it five days later and the event was widely reported in *Aviation Week* and other media.

- Initially President Eisenhower played down the success of Sputnik 1. Five days after the launch of *Sputnik 1*, Eisenhower told a reporter,

"Now, so far as the satellite itself is concerned, that does not raise my apprehensions, not one iota".



- A public backlash quickly changed his mind.
- In 1958 Eisenhower declared three "stark facts" the United States needed to confront:
 1. The USSR had surpassed the United States and "the rest of the free world" in scientific and technological advancements in outer space.
 2. If the USSR maintained this superiority, it might use it as a means to undermine the United States' prestige and leadership.
 3. If the USSR became the first to achieve significantly superior military capability in outer space and create an imbalance of power, it could pose a direct military threat to the United States.

- In February 1958, Eisenhower authorized formation of the Advanced Research Projects Agency, later renamed the Defense Advanced Research Projects Agency (DARPA), within the Department of Defense (DoD) to develop emerging technologies for the U.S. military.
- Eisenhower signed the the *National Aeronautics and Space Act* on 29 July 1958, creating NASA as a single organisation for peaceful space exploration rather than having the three services competing against each other.
- The Americans took a more aggressive stance in the emerging space race resulting in an emphasis on science and technical research and reforms in many areas to the education system.
 - The federal government began investing in science, engineering and mathematics at all levels of education.
 - The *National Defense Education Act* (NDEA). The act was a four-year program that poured billions of dollars into the U.S. education system.
- **The Space Race had begun in earnest!**



Sputnik 1 Propaganda

- Sputnik 1 was not immediately used for Soviet propaganda. The Soviets had kept quiet about their earlier accomplishments in rocketry, fearing that it would lead to secrets being revealed and failures being exploited by the West.
- When the Soviets began using Sputnik in their propaganda, they emphasized pride in the achievement of Soviet technology, arguing that it demonstrated the Soviets' superiority over the West. People were encouraged to listen to Sputnik's signals on the radio and to look out for Sputnik in the night sky. While Sputnik itself had been highly polished, its small size made it barely visible to the naked eye. What most watchers actually saw was the much more visible 26-metre core stage of the R-7.
- Shortly after the launch of PS-1, Khrushchev pressed Korolev to launch another satellite to coincide with the 40th anniversary of the October Revolution, on 7 November 1957.



- After newspapers and TV stations all over the world applauded the launch of Sputnik 1, Khrushchev realised that he had a propaganda gift and used it effectively for the next several years.
- The USSR was very clever in never advertising upcoming launches. Only successful launches were announced after the event to give the impression that they had no failures. Nothing could be further from the truth.
- Western World
 - Led to believe that all Soviet rocket launches were successful.
 - Gained the impression that the USSR was superior to the USA in military as well as space technology. This also was untrue.
 - Some developing nations moved into the Soviet sphere of influence.
- United States. The Democrats campaigned on Soviet themes:
 - Missile Gap. The USSR has more ICBMs than the USA. Untrue.
 - Republicans were derelict in letting the USSR get ahead in space.
 - Democrats would restore the USA to technology leadership.

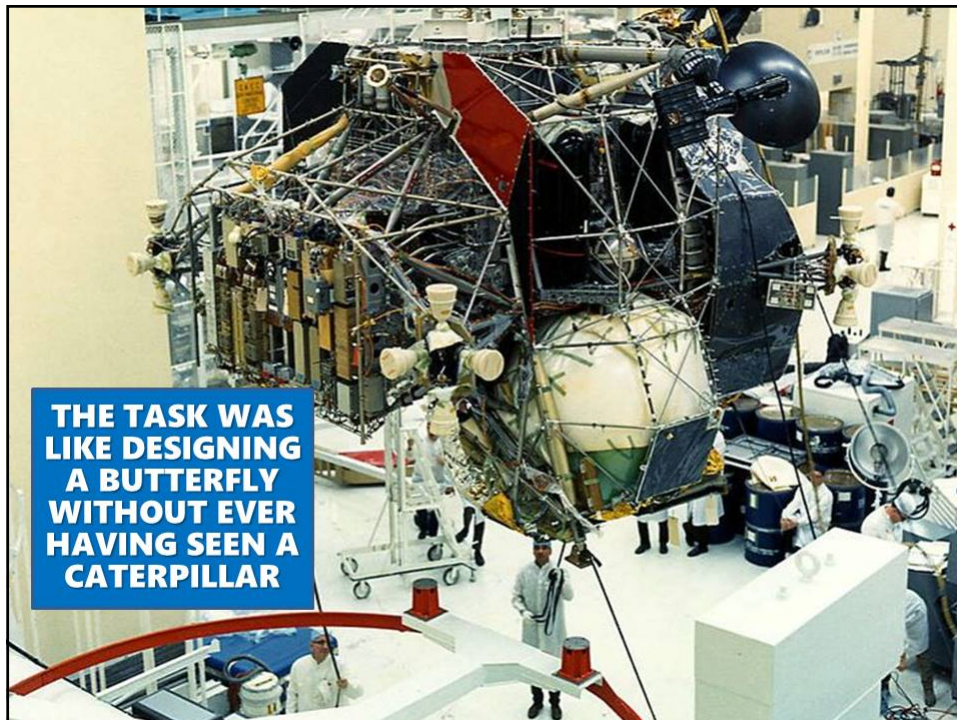
“We choose to go to the moon.” (JFK)

- When John F. Kennedy became President of the United States in January 1961, many Americans perceived that the United States was losing the Space Race with the Soviet Union, which had successfully launched the first artificial satellite, Sputnik 1, almost four years earlier. The perception increased when Russian cosmonaut Yuri Gagarin became the first man in space on April 12, 1961 before the U.S. could launch its first Project Mercury astronaut.
- Convinced of the political need for an achievement which would decisively demonstrate America's space superiority, and after consulting with NASA to identify such an achievement, Kennedy stood before Congress on May 25, 1961, and proposed that:

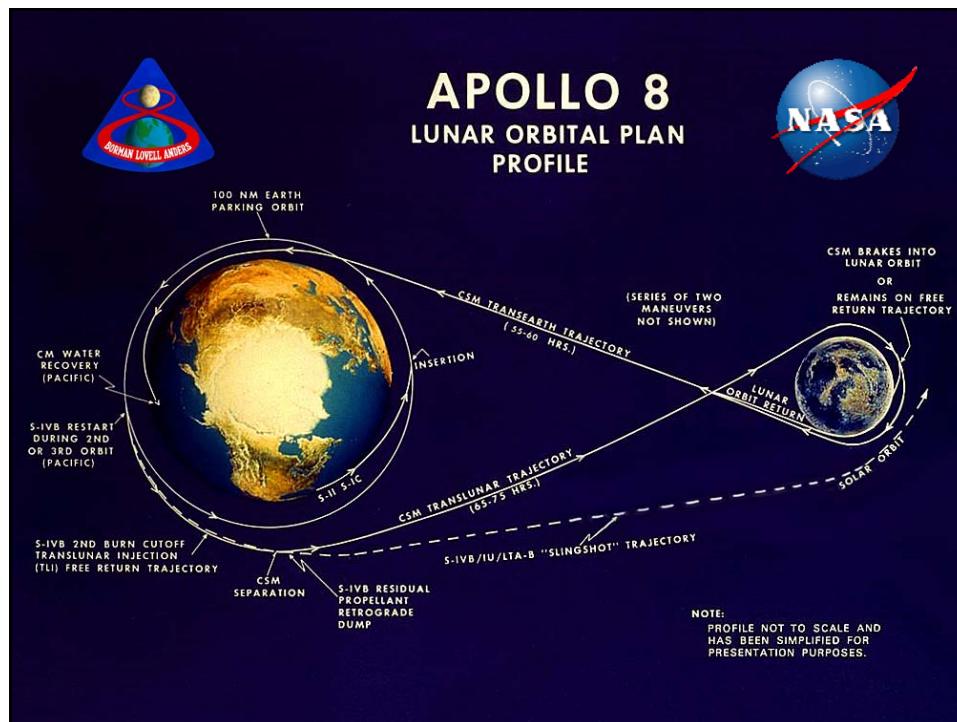


“This nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth.... Recognising the head start obtained by the Soviets with their large rocket engines, which gives them many months of lead-time, and recognising that they will exploit this lead for some time to come in still more impressive successes, we nevertheless are required to make new efforts on our own.”

- NASA management with experts like Wernher von Braun advised Kennedy that the USSR could not match the industrial might of the US aerospace industry for a huge new project starting from scratch, estimated to cost in 1961 dollars 20 to 40 billion. It actually cost \$24 billion in 1961 dollars.
- **JFK's political masterstroke: the USA had the advantage of a well-funded program with a definite goal.**
- Eisenhower wasn't so bullish, "Anyone who spends \$40 billion to put a man on the moon just for prestige is nuts."
- The moon program was an enormous challenge for engineers as it was like being asked to design a butterfly without ever having seen a caterpillar.

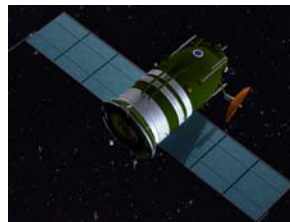


THE TASK WAS
LIKE DESIGNING
A BUTTERFLY
WITHOUT EVER
HAVING SEEN A
CATERPILLAR



Soviet crewed lunar programs

- The **Soviet crewed lunar programs** were a series of programs to land a man on the Moon, in competition with the United States Apollo program to achieve the same goal set publicly by President John F. Kennedy on May 25, 1961.
- The Soviet government publicly denied participating in such a competition, but secretly pursued two programs in the 1960s:
 - crewed lunar flyby missions using Soyuz 7K-L1 (Zond) spacecraft launched with the Proton-K rocket, and



Zond

- a crewed lunar landing using Soyuz 7K-LOK and LK Lander spacecraft launched with the N1 rocket.

Moon landing using N1 rocket

- As early as 1961, the Soviet leadership made public pronouncements about landing a man on the moon and establishing a lunar base; however serious plans were not made until several years later.
- Sergei Korolev, the senior Soviet rocket engineer, was more interested in launching a heavy orbital station and in crewed flights to Mars and Venus. With this in mind, Korolev began the development of the super-heavy N-1 rocket with a 75-ton payload.



All four attempted launches of the N1 (1969-1972) failed.



Zond moon orbit and flyby using Proton rocket

- Another main space design bureau headed by Vladimir Chelomei proposed a competing cislunar orbiting mission using a heavy UR-500K rocket (later renamed the Proton rocket) and a two-crew LK-1 spacecraft (below).



LK-1

Proton

- Later, Chelomei also proposed a Moon landing program with a super-heavy UR-700 rocket and an LK-700(LK-3) spacecraft.



Official approval for Soviet crewed moon missions

- The Soviet government issued a response to the American Apollo challenge after three years. According to the first government decree about the Soviet crewed Moon programs (Decree 655-268), adopted in August 1964:
 - Chelomei was instructed to develop a Moon flyby program with a projected first flight by the end of 1966, and
 - Korolev was instructed to develop the Moon landing program with a first flight by the end of 1967.
- Following the change from Nikita Khrushchev to Leonid Brezhnev in 1964, the Soviet government in September 1965 assigned the flyby program to Korolev, who redesigned the cislunar mission to use his own Soyuz 7K-L1 spacecraft and Chelomei's Proton rocket.
- Korolev organized full scale development of both programs, but died after surgery in January 1966. According to a government decree of February 1967, the first crewed flyby was scheduled for mid-1967, and the first crewed landing for the end of 1968.



Korolev's tomb in the Kremlin wall

Discord within Soviet moon project teams

- Korolev and Chelomei fought constantly and both Soviet moon projects were starved for funds. The USSR could not really afford one manned moon program and certainly not two.

The Americans outspent the Russians 4:1 in funding Apollo.
- Chelomei made a major breakthrough in the rivalry between the two men when he hired Khrushchev's son, Sergei, in 1958. With Khrushchev's support, Chelomei's bureau grew quickly through consolidation of other bureaus and factories being dissolved in Khrushchev's defense downsizing. In 1959 Chelomei gained the elite title of General Designer of OKB-52. A secret joke of the day was:

"Have you heard, they're closing the Bolshoi Theatre?"
"How's that?"
"It'll become a whorehouse for OKB Chelomei."
- Acquisition of heavy bomber and cruise missile factories gave Chelomei the technology to enter ballistic missiles and spacecraft. He effectively utilised his political clout in his struggle with Korolev.

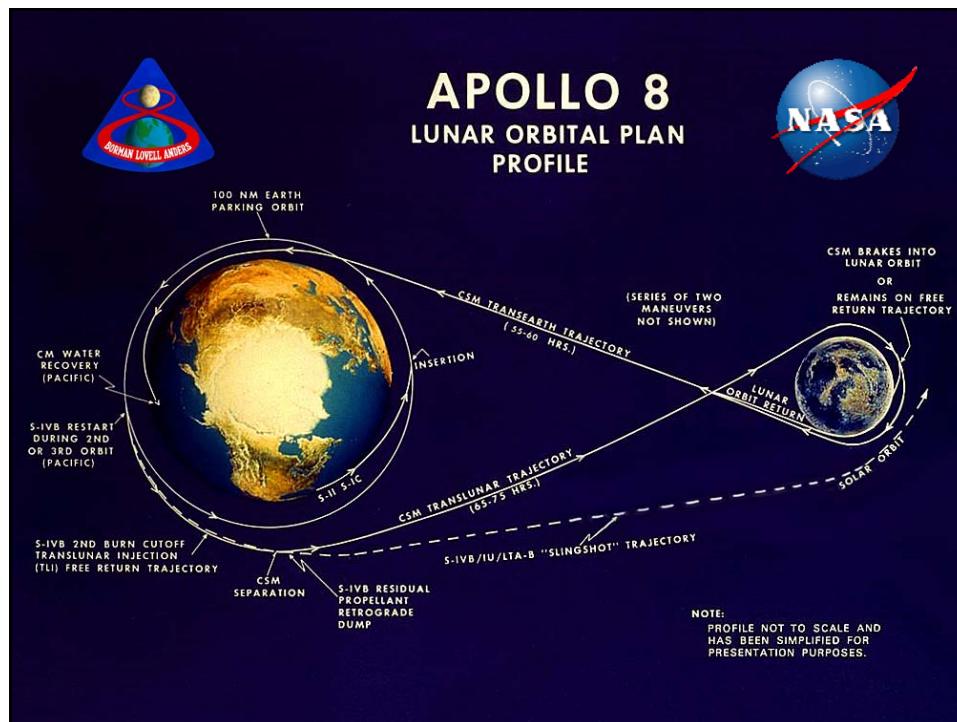
Zond versus Apollo 8

- Zond (Зонд) is Russian for “probe”. It was the name of a series of Soviet unmanned test spacecraft using a stripped-down Soyuz.
- Apollo (right below) had one significant advantage over Zond (left):
 - The design of the Saturn V rocket for Apollo and procedures for reaching the moon were decided early and adhered to.
 - Korolev made numerous changes in the design of the N1 rocket and procedures for reaching the moon, which in the end were basically adopted from publicised Apollo procedures.



Zond – Circumlunar missions, 1967-1970

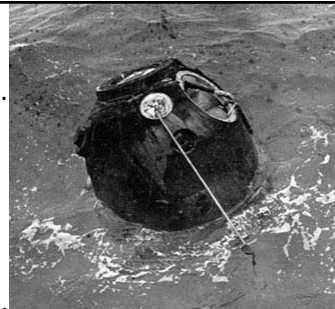
- Missions 4 through 8 were test flights under for the Soviet Moonshot during the Moon race. The Soyuz spacecraft was used for the Moon-aimed missions, stripped down to make it possible to launch around the Moon from the Earth. They were launched on the Proton rocket which was just powerful enough to send the Zond on a free return trajectory around the Moon without going into lunar orbit (the type path that Apollo 13 flew in its emergency abort). With minor modification, Zond was capable of carrying two cosmonauts.
- In the beginning there were serious reliability problems with both the new Proton rocket and the similarly new Soyuz spacecraft, but the test flights pressed ahead with some glitches. The majority of test flights from 1967–1970 (Zond 4 to Zond 8) showed problems during re-entry.
- The Zond spacecraft made only unmanned automatic flights. Four of these suffered malfunctions that would have injured or killed any crew.
- The USS *McMorris* was shadowing the Soviet recovery ships, collecting intelligence.



- The USS *McMorris* was shadowing the Soviet recovery ships, collecting intelligence. Photographs taken by the *McMorris* of the descent module bobbing in the ocean raised concern at NASA that the Soviets were planning a manned circumlunar flight soon.

Recovery of the Zond 5 capsule.

- The United States had been tracking Zond 5 for its entire flight, and this was a catalyst for the decision to launch Apollo 8 to the moon in December instead of the originally planned mission of testing the lunar module in high Earth orbit.



USSR Recovery Vessel Nevel



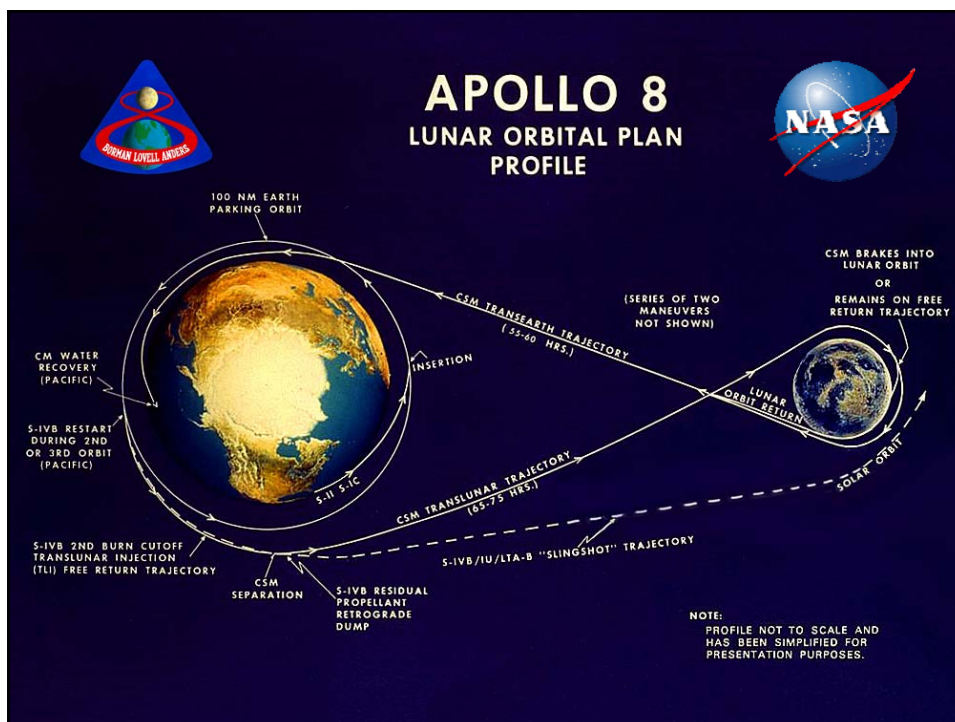
Destroyer Escort USS *McMorris*

Apollo 8 – Circumlunar mission

- **Apollo 8**, the second manned spaceflight mission in the Apollo space program, was launched on December 21, 1968.
- It was the first manned spacecraft to leave low Earth orbit, reach the Moon, orbit it, and return.
- The three-astronaut crew—Frank Borman, James Lovell, and William Anders—were the first humans to fly to the Moon, to witness and photograph an Earthrise, and to escape the gravity of a celestial body.



- Apollo 8 was the third flight and the first crewed launch of the Saturn V rocket and was the first human spaceflight from the Kennedy Space Center, adjacent to Florida's Cape Canaveral.



- Originally planned as the second crewed Apollo Lunar Module/ command module test in an elliptical medium Earth orbit in early 1969, the mission profile was changed in August 1968 to a more ambitious command-module-only lunar orbital flight to be flown in December, because the lunar module was not yet ready to make its first flight.



CAUTION

The launch of Apollo 8 was probably **the biggest risk** ever taken by America in its space program. Special permission was obtained from President Johnson as NASA was desperate to avoid being beaten by the Soviets in orbiting a man around the moon. The ghost of the Sputnik 1 first satellite launch still haunted the Americans 11 years on.



Advantages of Saturn V – Apollo

• Saturn V:

- Rocket design settled early and adhered to
- Project objectives were set and budget virtually unlimited
- Project had government and Presidential support
- Boeing, North American Aviation, Douglas Aircraft Company and IBM were lead contractors.
- Design for large Stage 1 rocket engines started early
- Although there were major problems during development, engines could be statically tested

• Apollo:

- The method for astronauts travelling to and from the moon - lunar orbit rendezvous (LOR) - was decided early and adhered to.
- The mission used state-of-the-art computer systems



Saturn-V rocket

- The **Saturn V** (pronounced "Saturn five") was an American human-rated expendable rocket used by NASA between 1967 and 1973. The three-stage liquid-propellant super heavy-lift launch vehicle was developed to support the Apollo program for human exploration of the Moon. It was later used to launch Skylab, the first American space station.
- The Saturn V was launched 13 times from the Kennedy Space Center in Florida with no loss of crew or payload.
- As of 2019, the Saturn V remains the tallest, heaviest, and most powerful (highest total impulse) rocket ever brought to operational status. It holds records for the heaviest payload launched and largest payload capacity to low Earth orbit (LEO) of 140,000 kg (310,000 lbs.), which included the third stage and unburned propellant needed to send the Apollo Command/Service Module and Lunar Module to the Moon.



- The largest production model of the Saturn family of rockets, the Saturn V was designed under the direction of Wernher von Braun and Arthur Rudolph at the Marshall Space Flight Center in Huntsville, Alabama. Boeing, North American Aviation, Douglas Aircraft Company, and IBM were the lead contractors.
- To date, the Saturn V remains the only launch vehicle to carry humans beyond low Earth orbit.
- A total of 15 flight-capable vehicles were built, but only 13 were flown. An additional three vehicles were built for ground testing purposes.
- A total of 24 astronauts were launched to the Moon, three of them twice, in the four years spanning December 1968 through December 1972.



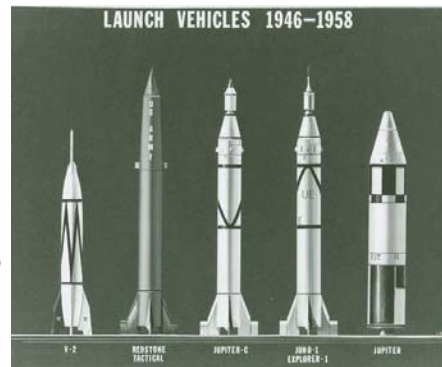
The Astronauts of Apollo



- The origins of the Saturn V rocket begin with the US government bringing Wernher von Braun along with about 700 German rocket engineers and technicians to the USA in Operation Paperclip. President Truman authorised the 1946 program with the purpose of harvesting Germany's rocket expertise, to give the US an edge in the Cold War through development of intermediate-range (IRBM) and intercontinental ballistic missiles (ICBM).
- America's geo-political rival, the Soviet Union, was also trying to secure some of the Germans. They got the "second team".
- Von Braun was put into the rocket design division of the Army due to his prior direct involvement in the creation of the V-2 rocket. Between 1945 and 1958, his work was restricted to conveying the ideas and methods behind the V-2 to the American engineers.
- Despite Von Braun's many articles on the future of space rocketry, the US Government continued funding Air Force and Navy rocket programs to test their Vanguard missiles in spite of numerous costly failures.



- It took the 1957 Soviet launch of Sputnik 1 atop an R-7 ICBM, capable of carrying a thermonuclear warhead against the US, for the U.S. military and government to start taking serious steps towards putting Americans in space.
- Finally, they turned to von Braun and his team, who during these years created and experimented with the Jupiter series of rockets. The Juno I was the rocket that launched the first American satellite in January 1958, and part of the last-ditch plan for NACA (the predecessor of NASA) to get its foot in the Space Race.
- The Jupiter series was one more step in von Braun's journey to the Saturn V, later calling that first series "an infant Saturn". The Saturn program was named Saturn because the planet is the next planet after Jupiter.
- The Saturn V rocket and the Apollo Program were outstanding successes for the USA.



The moon landing received world-wide publicity, more than Sputnik 1.

Advantages of Saturn V – Apollo

• Saturn V:

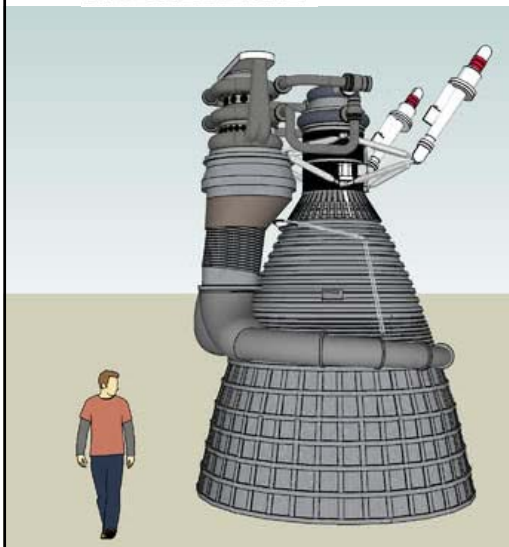
- Rocket design settled early and adhered to
- Project objectives were set and budget virtually unlimited
- Project had government and Presidential support
- Boeing, North American Aviation, Douglas Aircraft Company and IBM were lead contractors.
- Design for large Stage 1 rocket engines started early
- Although there were major problems during development, engines could be statically tested

• Apollo:

- The method for astronauts travelling to and from the moon - lunar orbit rendezvous (LOR) - was decided early and adhered to.
- The mission used state-of-the-art computer systems



Rocketdyne F-1 rocket engine

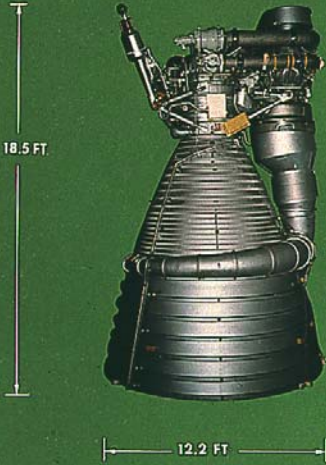


Size of a Rocketdyne F-1 rocket engine



Dr. von Braun standing by five F-1 engines of the Saturn V First Stage


F-1 ENGINE



	VEHICLE EFFECTIVITY	
	SA-501 THRU SA-503	SA-504 & SUBSEQUENT
THRUST (SEA LEVEL)	1,500,000 LB	1,522,000 LB
THRUST DURATION	150 SEC	165 SEC
SPECIFIC IMPULSE (LB-SEC/LB)	260 SEC MIN	263 MIN
ENGINE WEIGHT DRY	18,416 LB	18,500 LB
ENGINE WEIGHT BURNOUT	20,096 LB	20,180 LB
EXIT-TO-THROAT AREA RATIO	16 TO 1	16 TO 1
PROPELLANTS	LOX & RP 1	LOX & RP 1
MIXTURE RATIO	2.27±2%	2.27±2%

CONTRACTOR: NAA/ROCKETDYNE
VEHICLE APPLICATION:
SATURN V/S-IC STAGE (FIVE ENGINES)

IND B1413D



Proton (Протон) rocket, UR500 - USSR

- Proton is an expendable launch system used for both commercial and Russian government space launches.
- The first Proton rocket was launched in 1965. Modern versions of the launch system are still in use as of 2019, making it one of the most successful heavy boosters in the history of spaceflight, having had over 395 successful launches.
- The rocket is intended to be retired before 2030.

It is used to launch:

- telecommunications satellites
- navigation satellites (GLONASS)
- modules for orbital stations (Mir and ISS)
- interplanetary spacecraft (Mars-96)
- early warning satellites

UR-500*

Total number of launches: 377
Successful: 337 (89%)
Developer and producer: Mikhail Khronichev State Space Research and Production Center

* military legend

The rocket is designed to place spacecraft into low Earth or geostationary orbit. Proton is practically unrivalled in the world in terms of the cost of delivering 1 kg of payload to orbit. As of April 2011, the total cost of Proton-M with DM booster or Breeze-M booster was about 2.4 billion rubles (about \$80 mn).

Technical specifications, Proton-M

Length, meters	55
Diameter, meters	7.4
Take-off mass, tons	702
Number of stages	3
Fuel / oxidant:	C2H8N2 / N2O4**
Gross weight capability * payload, tons	~22

**unsymmetrical dimethylhydrazine (UDMH)/nitrogen tetroxide

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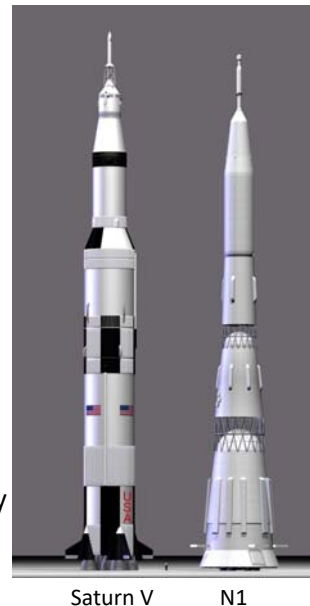
Main historical stages

- First launch of Proton-M model with Breeze-M booster
- First launch of three-stage Proton-K model with D booster
- First launch of two-stage UR-500 model: placing Proton-3 satellite in orbit. Later the rocket labelled this name
- Starting R&D on a super-heavy intercontinental ballistic missile. It was later decided to develop a carrier rocket on the basis of the IZH

- Rushed development led to dozens of failures between 1965 and 1972. Proton did not compete its State Trials until 1977, at which point it was judged to have a higher than 90% reliability. Its design was kept secret until 1986.
- Proton initially started its life as a "super heavy ICBM". It was designed to launch a 100-megaton (or larger) thermonuclear weapon over a distance of 13,000 km. It was hugely oversized for an ICBM and was never deployed in such a capacity.
- Proton was eventually used as a space launch vehicle. It was the brainchild of Vladimir Chelomei's design bureau as a foil to Sergei Korolev's N1 rocket, whose purpose was to send a two-man Zond spacecraft around the Moon. Korolev openly opposed Proton and Chelomei's other designs for their use of toxic propellants.
- With the retirement of the USA's space shuttle, the Proton rocket has been used to send astronauts to the international space station.

N1 (*Ракета-носитель, Raketa-nositel*) rocket, USSR

- The **N1** (Russian: **H1**) was a super heavy-lift launch vehicle intended to deliver payloads beyond low Earth orbit, acting as the Soviet counterpart to the US Saturn V. It was designed with crewed extra-orbital travel in mind. Development work started on the N1 in 1959. Its first stage is the most powerful rocket stage ever built.
- The **N1-L3** version was designed to compete with the United States Apollo program to land a man on the Moon, using the same lunar orbit rendezvous method.
- N1-L3 was underfunded and rushed, starting development in October 1965, almost four years after the Saturn V. The project was badly derailed by the death of its chief designer Sergei Korolev in 1966.



Saturn V

N1

N1 (Ракета-носитель, *Raketa-nositel*) rocket, USSR

- There were four attempts to launch an N1 rocket (1969, 1971 x 2, 1973). Each failed.
- During the second launch attempt the N1 rocket crashed back onto its launch pad shortly after liftoff and exploded, resulting in one of the largest artificial non-nuclear explosions in human history. All 30 motors of the N1 first stage had prematurely shut down. The launch complex was destroyed, taking over two years to rebuild. More than 100 scientists and technicians were killed. The USSR was out of the moon race.
- The N1 program was suspended in 1974, and in 1976 was officially canceled. Along with the rest of the Soviet crewed lunar programs, the N1 was kept secret almost until the collapse of the Soviet Union in December 1991; information about the N1 was first published in 1989.



The second test fails at lift-off.



Proton rocket

- Hiring Krushchev's son gave Chelomei significant political clout until Krushchev's fall from power in October 1964.
- Post 1964, the project was underfunded and rushed with the rocket not reliable until well after 1970.
- Unlike Khrushchev, Brezhnev was cautious and would not risk a manned circumlunar flight just to beat the USA.



Proton RD-232 engines



N1 engine cluster



N1 rocket

- The underfunded and rushed project was not configured until 4 years after Saturn V.
- Clashes with Chelomei. E.g., N1 unable to use large engines and had to cluster 30 small ones for 1st Stage.
- The 30 motors could not be fired together in static tests leading to major problems coordinating their firing.
- All four N1 disasters resulted from premature 1st stage motor shutdown.
- 1960s USSR computers not capable of supporting project.



Summary

- Not only did Chelomai and Korolev compete for scarce resources, there were other rocket designs also (e.g., Glushko), each with competing Kremlin sponsors. All were short-changed in the end.
- Politics doomed the USSR moon shot, so they started looking ahead to Mars.

Comments

1. **Would man have gone to the moon if Sputnik 1 had not been the first spacecraft to orbit the earth?**
 - Both countries had a high rate of unsuccessful unmanned moon sorts before July 1969 (USSR, 25 of 44 failures; USA, 11 of 23).
 - However, USA Surveyor had 5 of 6 soft landings from 1966-1968, so technological problems were being solved.
 - Politics, critical for the USSR, almost was for the USA too, but wasn't quite.
 - Apollo took unimaginable risks for their success. For example, Neil Armstrong had 16 seconds of fuel left when the Eagle landed. Those risks would be impossible to take today.

2. Were the Soviets close to a successful moon landing?

- No. While the United States centralized their space exploration program in one agency (NASA) and it had one focused lunar program (Apollo), the Soviet program was decentralized and fragmented.
- Decentralization of effort in the Soviet Union not only meant competition of design teams, but competition within the Kremlin of the supporters of those teams. There was little if any room for sharing resources: e.g., if Korolev had access to Chelomei's larger engines, N1's engine problems *might* have been solved.
- Socialism (i.e., communism) tends to work best if there is unity of direction and ample available resources on hand, but it is not a productive system in itself. The USSR had to rob rubles from Peter to pay Paul, and those rubles had to first be taken from others. It was an inherently non-viable corrupt zero-sum game with mostly losers and no long-term organisational winners.
- Ultimately, the Soviet Union collapsed (1991) from over-extension.

3. What human costs were paid for a successful moon landing?

- The program was always a political priority (beat the USSR). In early 1961, President Kennedy said he wasn't much interested in space *per se*.
- Everyone from top to bottom worked under extreme pressure, often leading to burn-out. This pressure even included the families of astronauts, who had to always appear perfect!
- Eight of 30 Apollo astronauts died in accidents on earth (three in the Apollo 1 fire, four in T38 plane crashes and on auto accident). None were lost in space flight.
- 22 of 29 married astronauts divorced. All marriages were severely tested by lengthy separations, intrusive public relations, groupies and the like.
- Astronauts were superbly trained for space flight but not for life when they returned to earth. Many had trouble adapting to life on earth (today we call it PTSD).