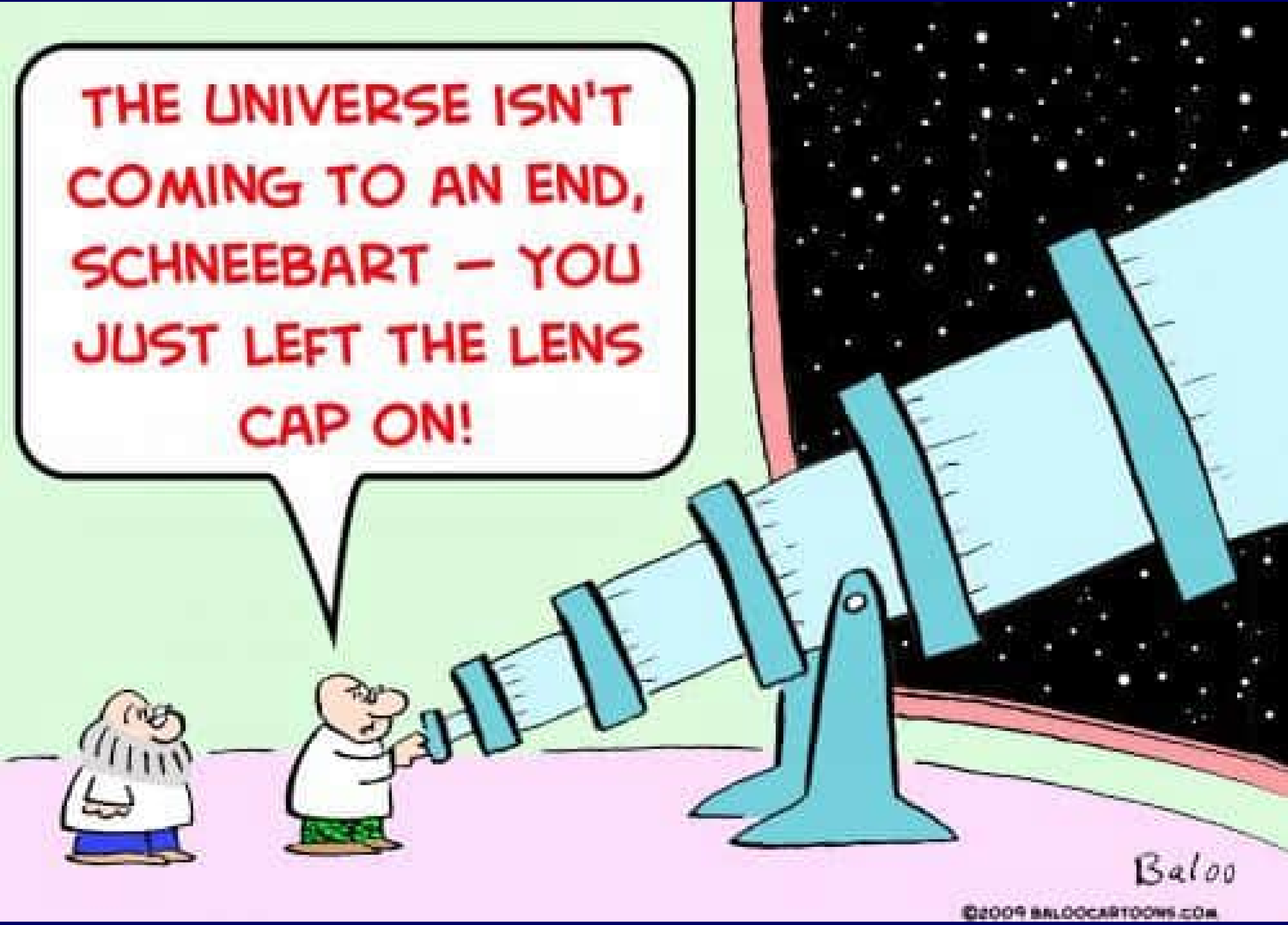
THE UNIVERSE ISN'T COMING TO AN END, SCHNEEBART – YOU JUST LEFT THE LENS CAP ON!
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Isoista raketeista

Cygnus 2023

Hannu Määttänen

Mikä on raketti

Rakettimoottori perustuu Newtonin kolmanteen lakiin, jonka mukaan voima aiheuttaa yhtä suuren vastavoiman. Tätä sanotaan voiman ja vastavoiman tai aktion ja reaktion laiksi.

Suurin
ja
mahtavin?

Miten suuruus määritellään?

- Korkein
- Painavin
- Tehokkain työntövoima
- Eniten massaa radalle
- Kallein

The **classical rocket equation**, or **ideal rocket equation** is a mathematical equation that describes the motion of vehicles that follow the basic principle of a rocket: a device that can apply acceleration to itself using thrust by expelling part of its mass with high velocity can thereby move due to the conservation of momentum. It is credited to the Russian scientist Konstantin Tsiolkovsky (Константи́н Эдуа́рдович Циолко́вский) who independently derived it and published it in 1903,[1][2] although it had been independently derived and published by the British mathematician William Moore in 1810,[3] and later published in a separate book in 1813.[4] American Robert Goddard also developed it independently in 1912, and German Hermann Oberth derived it independently about 1920.

The maximum change of velocity of the vehicle, Δv (with no external forces acting) is:

$$\Delta v = v_{\text{e}} \ln \frac{m_0}{m_f} = I_{\text{sp}} g_0 \ln \frac{m_0}{m_f},$$

where:

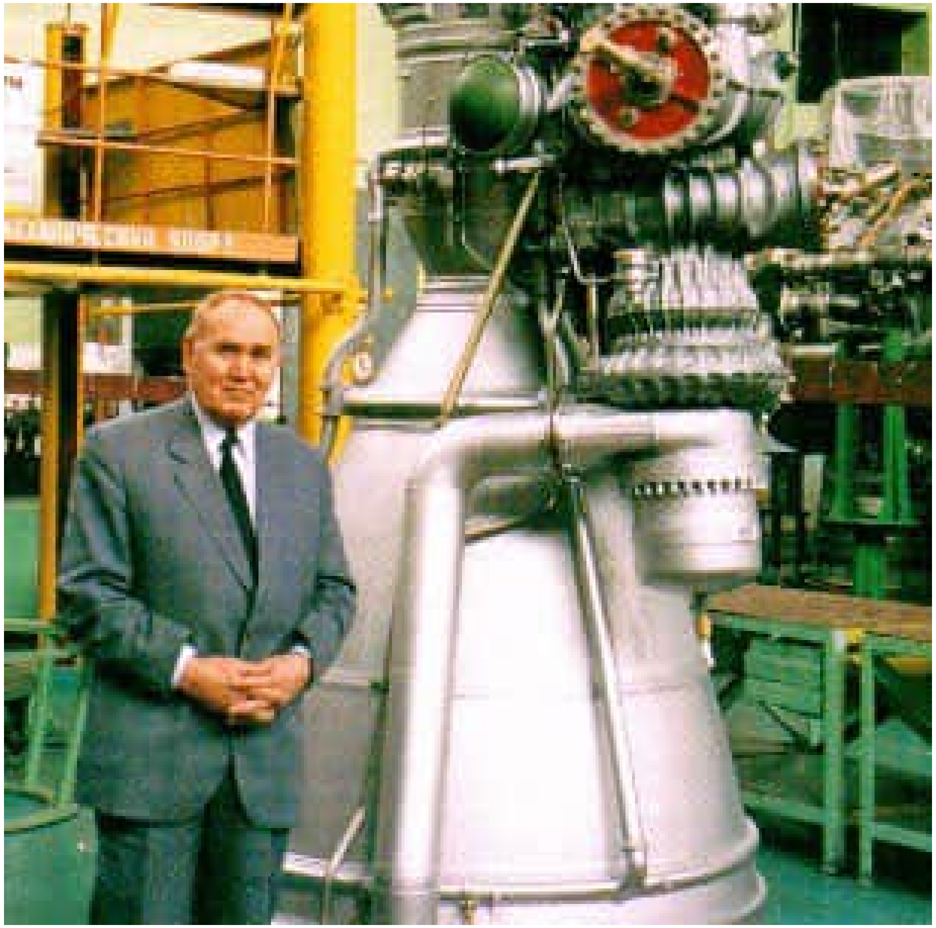
- $v_{\text{e}} = I_{\text{sp}} g_0$ is the effective exhaust velocity;
  - I_{sp} is the specific impulse in dimension of time;
  - g_0 is standard gravity;
- $\ln$ is the natural logarithm function;
- m_0 is the initial total mass, including propellant, a.k.a. wet mass;
- m_f is the final total mass without propellant, a.k.a. dry mass.

Given the effective exhaust velocity determined by the rocket motor's design, the desired delta-v (e.g. orbital speed or escape velocity), and a given dry mass m_f, the equation can be solved for the required propellant mass $m_0 - m_f$:

$$m_0 = m_f e^{\Delta v / v_{\text{e}}}.$$

The necessary wet mass grows exponentially with the desired delta-v.

NK-33



Nikolai Kuznetsov ja NK33

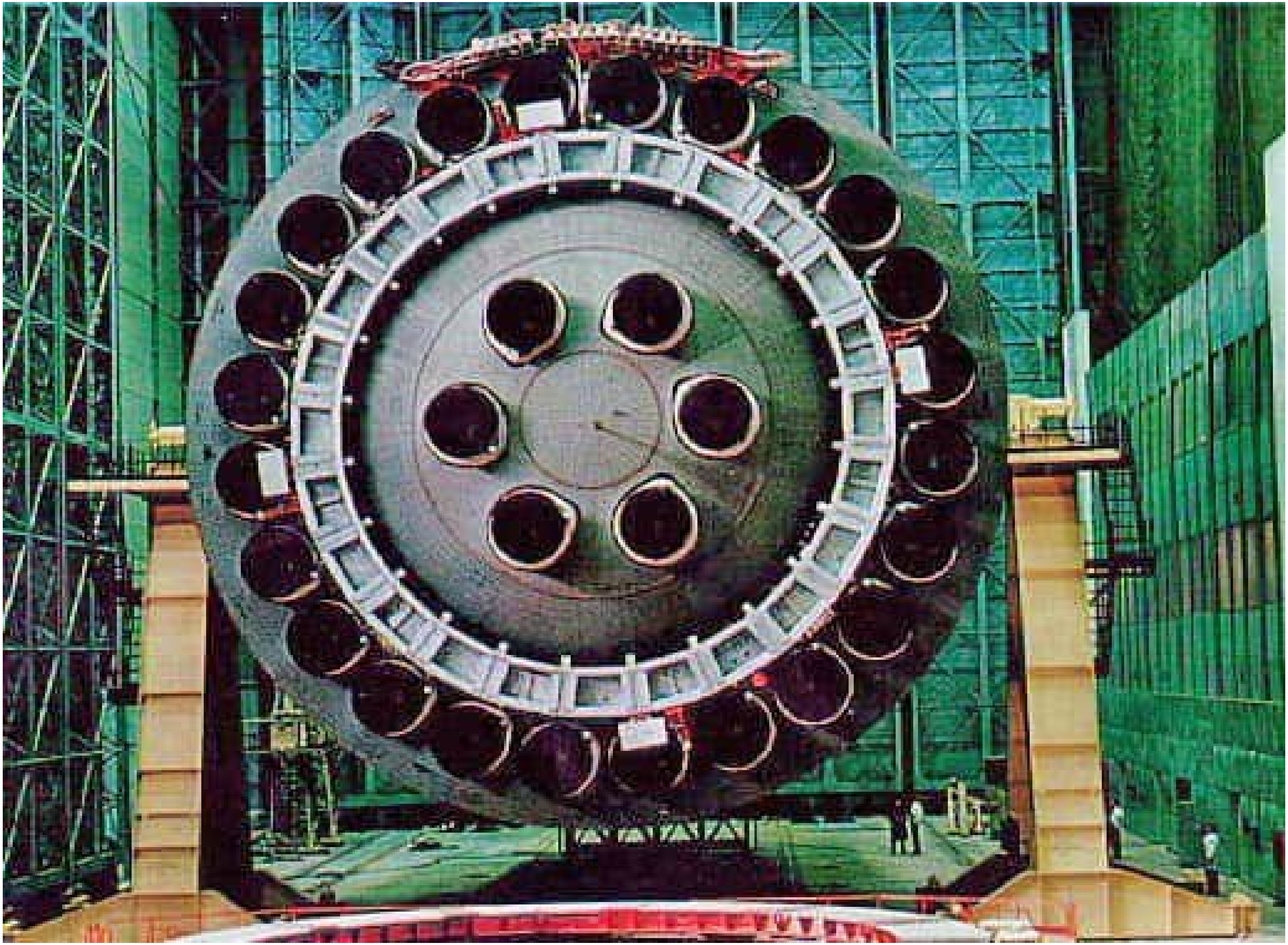
The NK-33 became the last upgrade of a similar engine developed during the Moon Race. Like its predecessor -- NK-15 -- the engine would power the first stage of the N1 launch vehicle. Comparing to its predecessor, NK-33 sported simplified pneumatic and hydraulic systems, more advanced controls, upgraded turbo-pumps and combustion chamber. The engine needed only seven interfaces employing explosive pyrotechnic devices, instead of 12 on NK-15.

N1

N1

The N1 was the Soviet counterpart to the US Saturn V and was intended to enable crewed travel to the Moon and beyond, with studies beginning as early as 1959. Its first stage, Block A, was the most powerful rocket stage ever flown for over 50 years, generating 45.4 MN of thrust.

N1



The NK-33 series engines are high-pressure, regeneratively cooled oxygen-rich staged combustion cycle bipropellant rocket engines. The turbopumps require subcooled liquid oxygen (LOX) to cool the bearings. These kinds of burners are highly unusual, since their hot, oxygen-rich exhaust tends to attack metal, causing burn-through failures. The United States had not investigated oxygen-rich combustion technologies until the Integrated Powerhead .Demonstrator project in the early 2000s. The Soviets, however, perfected the metallurgy behind this method. The nozzle was constructed from corrugated metal, brazed to an outer and inner lining, giving a simple, light, but strong structure.

In addition, since the NK-33 uses LOX and RP-1 as propellants, which have similar densities, a single rotating shaft could be used for both turbopumps. NK-33 engine has among the highest thrust-to-weight ratio of any Earth-launchable rocket engine; only the NPO Energomash RD-253 and SpaceX Merlin 1D engines achieve a higher ratio. The specific impulse of the NK-33 is significantly higher than both of these engines. The NK-43 is similar to the NK-33, but is designed for an upper stage, not a first stage. It has a longer nozzle, optimized for operation at altitude, where there is little to no ambient air pressure. This gives it a higher thrust and specific impulse, but makes it longer and heavier. It has a thrust-to-weight ratio of about 120:1.

N1

21. 2.1969 Heti lähdön jälkeen murtui putki moottorissa 2. T+25 sek tulipalo. Tuhoutui T + 69 sek 12,2 km:n korkeudessa.

3. 7.1969 Yölaukaisu. Happipumppuun joutunut osa sai aikaan moottoreiden pysäytyksen. Tuhoutui heti nousun jälkeen tuhoten lähtöalustan, jona korjaus kesti 18 kuukautta.

N1

26. 6.1971 Lähti kiertymään heti laukaisun jälkeen. Hajosi T + 51 sek.

23. 11.1972 Tuhoutui T + 107 sek. Värähtelyt ja paineiskut hajoittivat happipumpun.

RD-170

The RD-170 is the world's most powerful and heaviest liquid-fuel rocket engine. .

4 combustion chambers, 4 nozzles
1 set of turbines and pumps; turbine produces approximately 257,000 hp (192 MW); equivalent to the power output of 3 nuclear-powered icebreakers

Vacuum thrust: 7,887 kN
Vacuum Isp: 338 s (3.31 km/s)
Sea-level Isp: 309 s (3.03 km/s)
Weight: 9,750 kilograms
Thrust-to-weight ratio: 82

Saturn V - F1 moottori

Propellant	LOX / RP-1
Mixture ratio	2,27 69% O2, 31% RP-1
Thrust, vacuum	7 770 kN
Thrust, sea-level	6,770 kN
Thrust-to-weight ratio	94,1
Specific impulse, vacuum	304 s (2,98 km/s)
Specific impulse, sea-level	263 s (2,58 km/s)
Mass flow	1 789 kg/s) (LOX) 788 kg/s) (RP-1)
Kuivapaino	8 400 kg

Apollo

The Apollo lunar payload included a command module, service module, and Lunar Module, with a total mass of 45 t .

Lähtöpaino 2,8 miljoonaa kg. Kuuhun n. 1,6 % lähtömassasta.

When the third stage and Earth-orbit departure fuel was included, Saturn V placed approximately 140 t into low Earth orbit.

Moottoreista - nestepolttoaineet

Current cryogenic types

Liquid oxygen (LOX) and highly refined kerosene (RP-1). This combination is widely regarded as the most practical for boosters that lift off at ground level and therefore must operate at full atmospheric pressure.
LOX and liquid hydrogen. Used on the Centaur upper stage, the Delta IV rocket, the H-IIA rocket, most stages of the European Ariane 5, and the Space Launch System core and upper stages.
LOX and liquid methane (from Liquefied natural gas) are planned for use on several rockets in development, including Vulcan, New Glenn, SpaceX Starship, and Rocket Lab Neutron.

Moottoreista - nestepolttoaineet

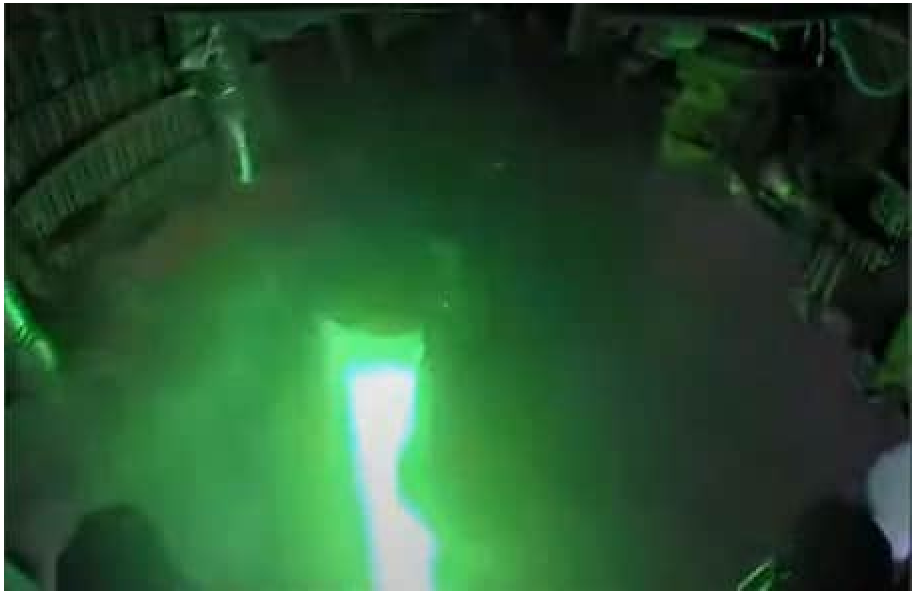
Current storable types
Dinitrogen tetroxide (N_2O_4) and hydrazine (N_2H_4), MMH, or UDMH. Used in military, orbital, and deep space rockets because both liquids are storable for long periods at reasonable temperatures and pressures. N_2O_4/UDMH combination is hypergolic, making for attractively simple ignition sequences.
Monopropellants such as hydrogen peroxide, hydrazine, and nitrous oxide are primarily used for attitude control and spacecraft station-keeping where their long-term storability, simplicity of use, and ability to provide the tiny impulses needed outweighs their lower specific impulse as compared to bipropellants. Hydrogen peroxide is also used to drive the turbopumps on the first stage of the Soyuz launch vehicle.

Moottoreista - nestepolttoaineet

Most liquid chemical rockets use two separate propellants: a fuel and an oxidizer. Typical fuels include kerosene, alcohol, hydrazine and its derivatives, and liquid hydrogen. Many others have been tested and used. Oxidizers include nitric acid, nitrogen tetroxide, liquid oxygen, and liquid fluorine.

Sytysneste

If the ignition fluid of the rocket engine is TEA-TEB (Triethylaluminum + Triethylboron). During the ignition phase, we may see green flames in the rocket engines. For example, SpaceX's Merlin 1D Engine uses TEA-TEB as its Ignition Fluid.



Rakettitekniikkaa

Practical H2–O2 rocket engines run fuel-rich so that the exhaust contains some unburned hydrogen. This reduces combustion chamber and nozzle erosion.

Delta Heavy

Tietoisku:
US gallona on 3.785411784 litraa

Rakettitekniikan käsitteitä

Newton: Newton on SI-järjestelmän mukainen voiman yksikkö. Yksikkö on nimetty Isaac Newtonin mukaan.

Yksi newton on voima, joka antaa yhden kilogramman massalle kiihtyvyyden 1 m/s^2. Newton on siis johdannaisyksikkö, jonka määritelmä perustuu perusyksikköjen kilogramma, metri ja sekunti määritelmiin. Käytännössä newton on se voima, jolla maapallo vetää pinnallaan olevaa noin 102-grammaista kappaletta puoleensa – voima on kappaleen paino.

Rakettitekniikkaa

RP-1 was developed in the 1950's to solve a high heat problem, where raw kerosene would break down into wax that clogged valves and caused uneven burn etc.

RP-1 is a more refined version of kerosene in the following ways: very low sulfur, very low olefins and aromatics, more branched-chain alkanes, very low impurities and a narrow range of molecular weights.

Regardless of chemical constraints, there is a supply issue due to the lack of a market. Alternative fuels like RP-2, while being superior, are far too expensive to consider currently, though research continues.

Rakettitekniikkaa

Practical H2–O2 rocket engines run fuel-rich so that the exhaust contains some unburned hydrogen. This reduces combustion chamber and nozzle erosion.

Hydrogen requires a theoretical minimum of 3.3 kWh/kg to liquefy, and 3.9 kWh/kg including converting the hydrogen to the para isomer, but practically generally takes 10-13 kWh/kg compared to a 33 kWh/kg heating value of hydrogen.

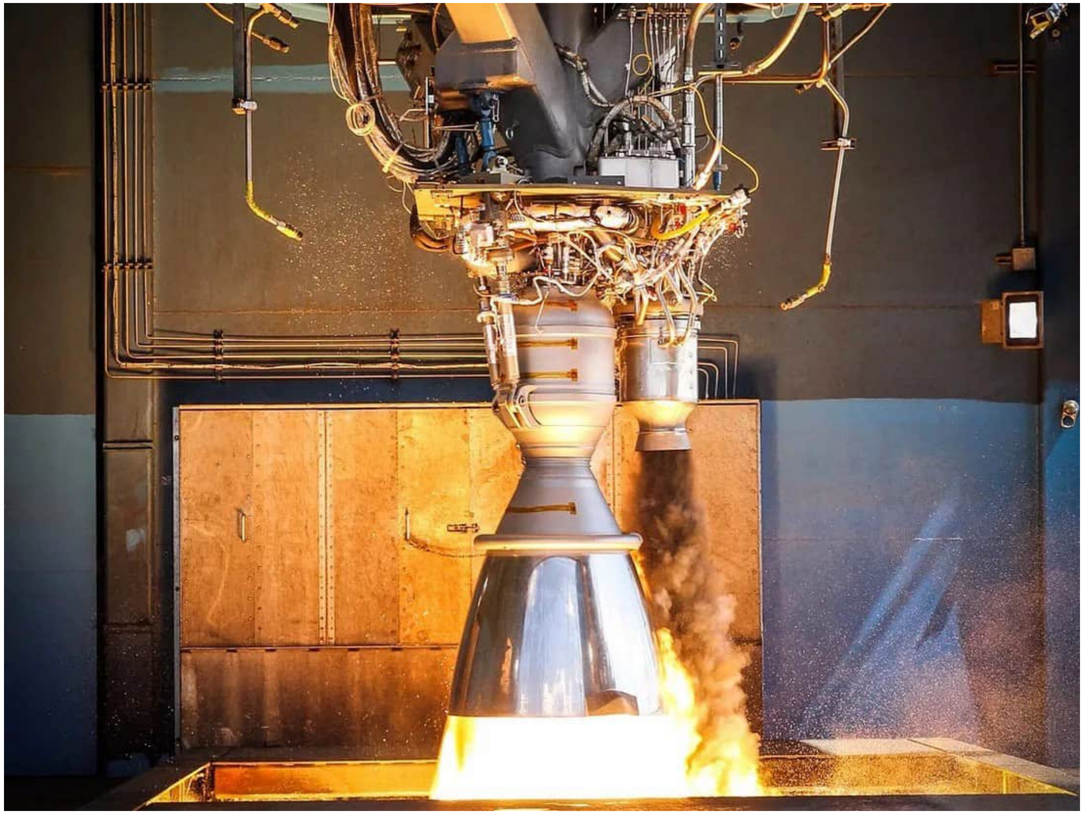
Rakettitekniikkaa

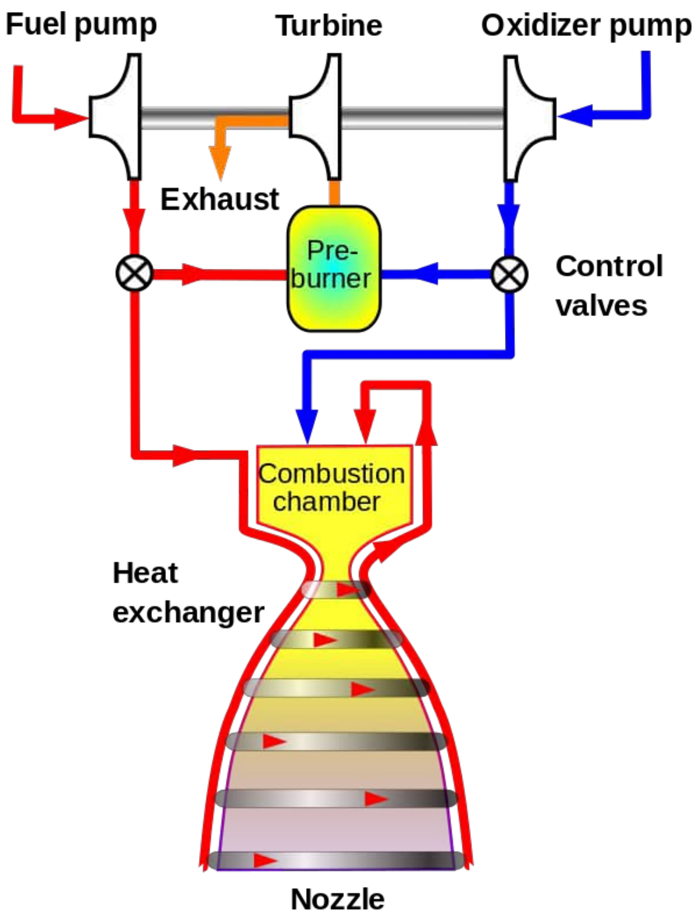
Spesifinen impulssi (Specific impulse, SI).

Spesifinen impulssi on rakettimoottorin tehokuutta kuvaava luku, jonka yksikkö on sekunti. Tämä luku kertoo kuinka monta sekuntia moottori voi tuottaa työntöä käyttäessään työntövoimansa verran polttoainetta. Kemiallisilla rakettimoottoreilla SI on tyypillisesti luokkaa 200 - 400 sekuntia.

Eräs keskeinen luku on työntövoiman suhde rakettimoottorin painoon. Tyypillisesti luokkaa 100.

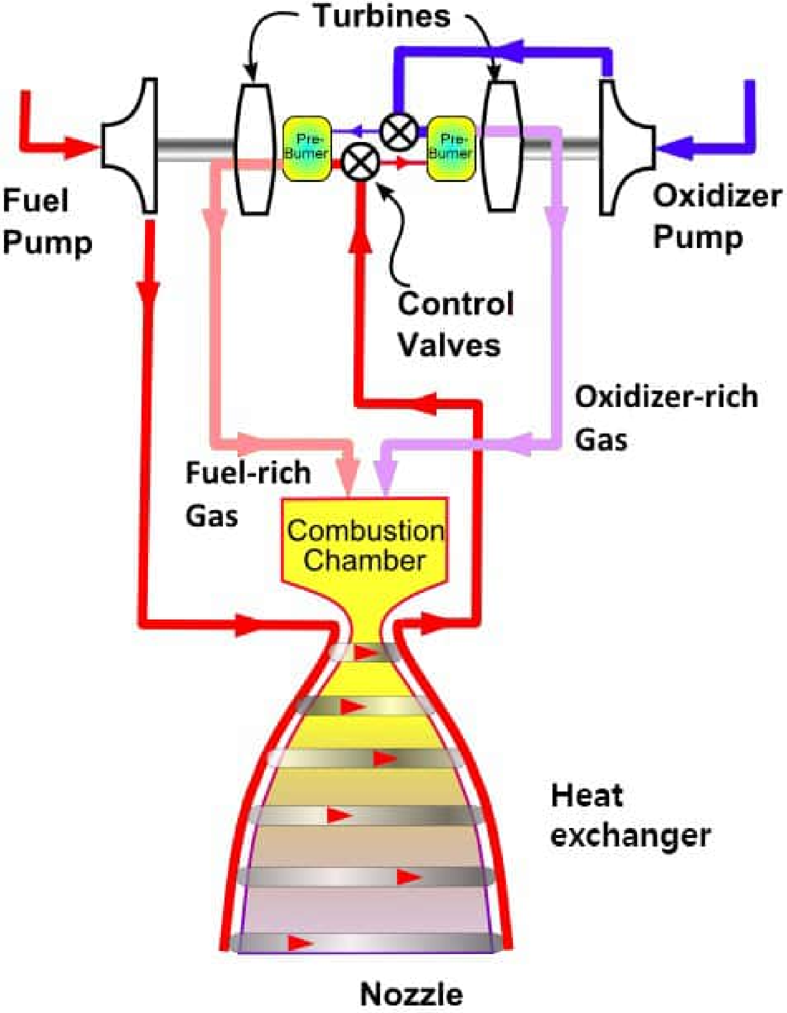
Open cycle





The Gas Generator Cycle taps off a small amount of fuel and oxidizer from the main flow (typically 2 to 7 percent) to feed a burner called a gas generator.

Closed cycle



Space Shuttle Solid Rocket Booster

The SRBs were the largest solid-propellant motors were the largest solid-propellant motors ever flown and the first of such large rockets designed for reuse. Each is 45,46 m long and 3,71 m in diameter. Each SRB weighed approximately 590 t at launch. The two SRBs constituted about 69% of the total lift-off mass.

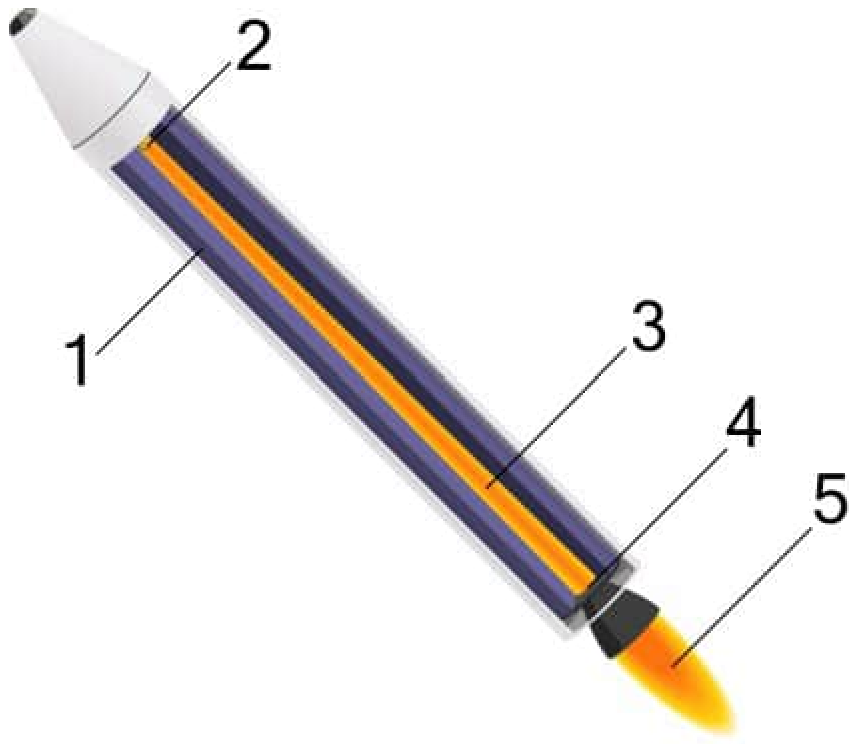
Space Shuttle Solid Rocket Booster

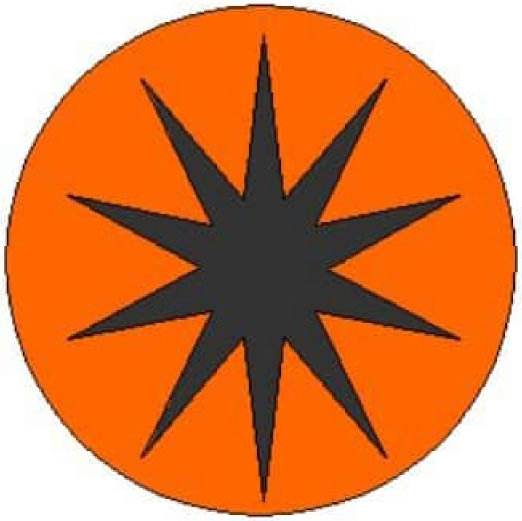
Ammoniuperkloraatti (NH4ClO4) toimi hapettimena ja polttoaineena hienojakoinen alumiinijauhe. Palavan aineen määrä 500 t. Boosterin tyhjäpaino noin 91 t

Poltto 127 sekuntia, jolloin 45 km:n korkeudessa ja nopeus n. 5000 km/h.

The propellant had an 11-pointed star-shaped perforation in the forward motor segment and a double-truncated-cone perforation in each of the aft segments and aft closure.

Solid Rocket Booster





2 on sytytin. Massa palaa koko pituudella.

Palavan massan poikkipintaa muotoilemalla voidaan säätää palamisen edistymisen nopeutta.

Artemis

Artemis on Nasan Kuuhun suuntaava avaruusohjelma Artemis-ohjelmassa on tarkoituksena yksittäisten lentojen sijaan synnyttää lopulta pysyvä pinnalle yltävä ja miehitetty Kuu-toiminta.

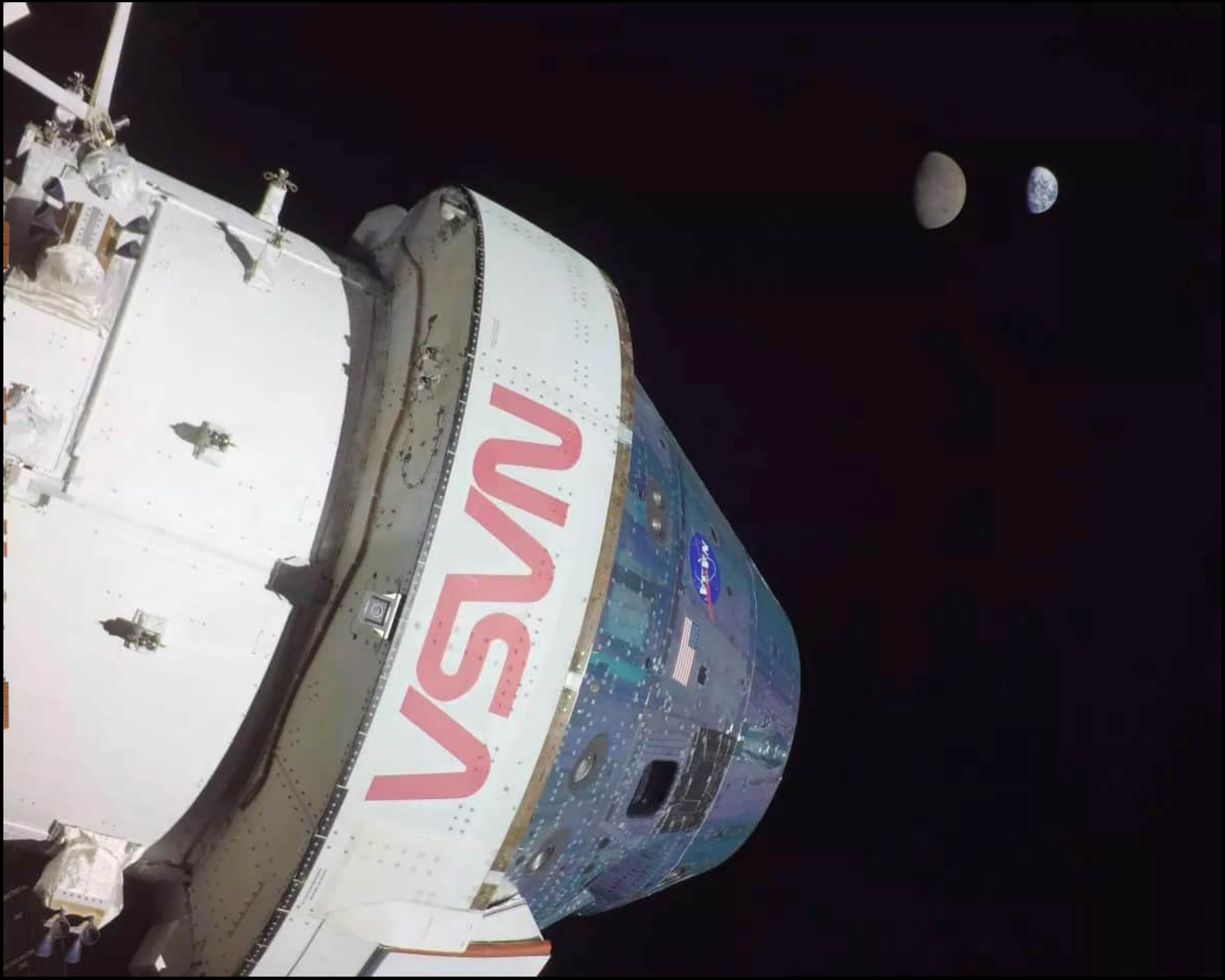
Ensimmäinen miehitetty lento kohdistuu mahdollisesti Shackleton-kraatteriin. Tavoitteena on ihmisten pysyvä oleskelu Kuussa vuoteen 2028 mennessä.

Artemis-ohjelmaan liittyvät Kuun pinnalla sijaitseva tukikohta ("Artemis Base Camp"), kulkuneuvo Kuun pinnalla liikkumiseen (Lunar Terrain Vehicle, LTV) ja liikuteltava asumus, jolla tutkijat voivat tehdä pitkäkestoisia matkoja Kuun pinnalla. Lisäksi ohjelmaan liittyy Lunar Gateway-asema Kuun kiertoradalla, jossa voi tehdä pitkäkestoisia kokeita Marsin tutkimusmatkaa varten.

Artemis

On 16 November 2022, Artemis 1 launched from Kennedy Space Center Launch Complex 39B, the first time the RS-25 engine had flown since the Space Shuttle's final flight, STS-135, on 21 July 2011.

Artemis



Artemis

He lentävät ensi vuonna Kuun ympäri

3.4. Nasa ja Kanadan avaruusjärjestö CSA julkistivat Artemis II -lennon miehistön. Orion-aluksen kyydissä Kuun ympärilennolle lähtevät yhdysvaltalaiset **Christina Hammock Koch, Reid Wiseman** ja **Victor Glover** sekä kanadalainen **Jeremy Hansen.** Kullakin astronautilla Hansenia lukuun ottamatta on takanaan yksi lento Kansainväliselle avaruusasemalle.

"Ensimmäistä kertaa yli 50 vuoteen nämä yksilöt ihmiskunnasta – Artemis II:n miehistö – lentävät Kuun läheisyyteen. Miehistöön kuuluvat ensimmäinen nainen, ensimmäinen ei-valkoihoinen ja ensimmäinen kanadalainen kuulennolla", **Vanessa Wyche** Nasasta totesi.

Noin kymmenpäiväinen Artemis II -lento toteutuu marraskuussa 2024, ellei viivästyksiä ilmene. Seuraavalle vuodelle suunnitelmissa on Artemis III, joka sisältää miehitetyn laskeutumisen Kuun etelänapa-alueelle.

Artemis II -lennolle lähtevät Christina Hammock Koch, Reid Wiseman (edessä), Victor Glover ja Jeremy Hansen.

SPACEX

TESLA

SpaceX – Falcon 9 - 1. vaihe

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Korkeus	42 m
Halkaisija	3,7 m
Kuivapaino	25 600 kg
Polttoaine	395 700 kg

Kilometrin korkeuteen Falcon 9 kohoaa n. 25 sekuntia moottorien käynnistymisestä.

Ensimmäisen kilometrin CO_2-päästö n. 75 000 000 g

SpaceX – Falcon

Copernicus Sentinel-6 lifts off on a SpaceX Falcon 9 rocket.

With global mean sea level rising because of climate change, Copernicus Sentinel-6 Michael Freilich is the next radar altimetry reference mission to extend the legacy of sea-surface height measurements, until at least 2030.

SpaceX – Falcon Heavy

LEO:lle	64 800 kg
GTO:lle	26 700 kg
Marsin kiertoradalle	16 800 kg

SpaceX – Falcon Heavy

Falcon Heavyn 6. helmikuuta 2018, kyydissään Elon Muskin käytetty Tesla Roadster..

Falcon 9 ja110 000 gallonaa nestemäistä happea

SpaceX Raptor Merlin

	Raptor	Merlin
Työntövoima	2,3 MN	847 kN
Tehoalue	20 – 100 %	20 – 100 %
Työntö-/painosuhde	143,8	184
Kammion paine	300 bar	9,7 MPa
Impulssi, pinta	363 s	311 s
Impulssi tyhjö	327 s	282 s
Kulutus happi	510 kg/s	
Kulutus metaani/ RP-1	140 kg/s	140 kg/s
Korkeus	3,1 m	
Leveys	1,3 m	92 cm
Kuivapaino	1600 kg	470 kg

SpaceX - Starship

But at least six of the 33 methane-fueled Raptor engines on the Super Heavy booster, or the rocket's first stage, shut down as it climbed into the sky. The Starship lost control around two minutes into the mission, veering from its planned flight corridor until an autonomous fight termination system blew up the rocket four minutes after liftoff. There were no people or operational payloads on-board the rocket.

Flight data displayed on SpaceX's live webcast indicated the rocket reached a maximum altitude 39 kilometers and a top speed of 2 157 kilometers per hour. The test flight reached supersonic speed and continued beyond the point of maximum aerodynamic pressure, when the vehicle had to endure the harshest structural loads of its ascent.

SpaceX - Raptor

The engine structure itself is mostly aluminum, copper, and steel; oxidizer-side turbopumps and manifolds subject to corrosive oxygen-rich flames are made of an Inconel-like SX500 superalloy. Raptor's main combustion chamber can contain 300 bar of pressure, the highest of all rocket engines. Certain components are 3D printed. The Raptor's gimbaling range is 15°, higher than the RS-25's 12.5° and the Merlin's 5°. In mass production, SpaceX aims to produce each engine at a unit cost of US$250,000.

SpaceX - Raptor

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Spacex Starhopper

SpaceX Super Heavy Booster

The manufacturing process starts with rolls of steel, which are unrolled, cut, and welded along the cut edge to create a cylinder of 9 m in diameter, 1.82 m in height, and 4 mm thick, and around 1,600 kg in mass. These cylinders, are stacked and welded along their edges to form the outer layer of the rocket. Inside, the methane and oxygen tanks are separated by robot-made domes. Before final assembly, grid fins are added to the interstage, and the chines are added after stacking of the propellant tanks.

The first-stage Super Heavy booster is 69 m tall, 9 m wide, and is composed of four general sections: the engine section, the fuel tank, the oxygen tank, and the interstage. Elon Musk has stated that the final design will have a dry mass between 160 t and 200 t, with the tanks weighing 80 t and the interstage 20 t.

StarShip – metaanista

Metaanipäästöjä syntyy lehmän pötsissä tapahtuvasta hajoamisreaktiosta, jonka seurauksena lehmät röyhtäilevät metaanin ulos elimistöstään. Yksi lehmä päästää vuosittain noin 100 kiloa metaania, joka vastaa haitaltaan henkilöautoa, jolla ajetaan vuodessa 10 000 kilometriä.

Vuonna 2022 Suomessa lypsylehmiä oli tiloilla 247 900 yksilöä.

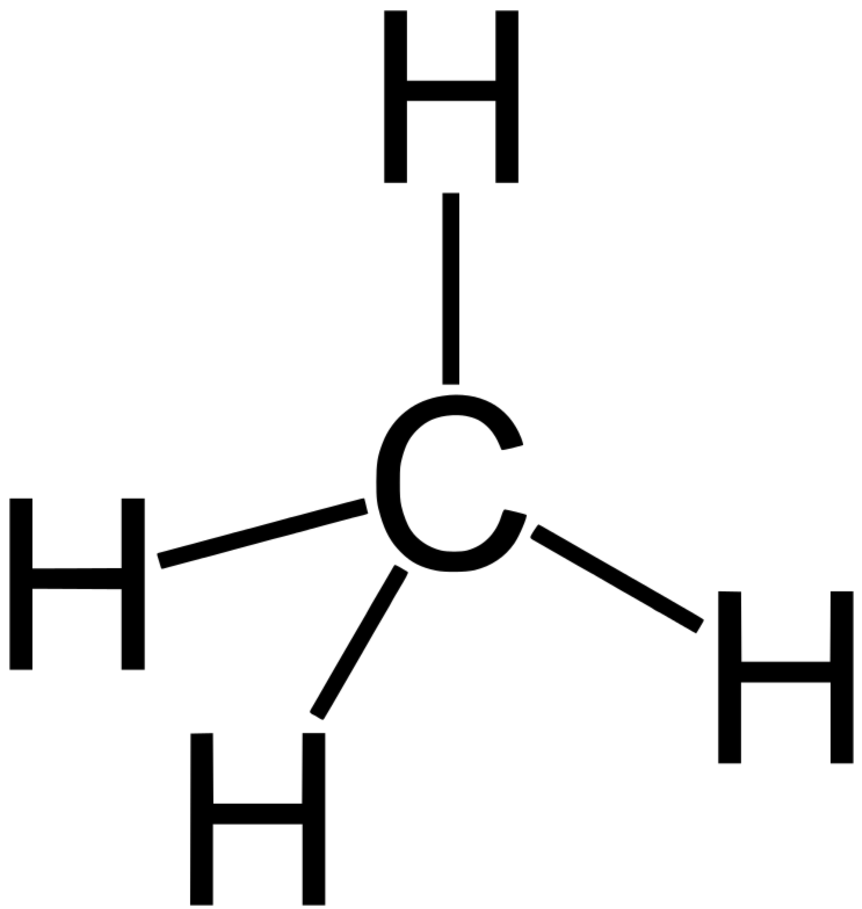
Super Heavyn tankissa 800 tonnia metaania.

SpaceX Raptor

Metaani on yksinkertaisin hiilivety ja alkaani. Se on hajuton, ilmaa kevyempi kaasu.

Alkaani on hiilivety, jossa hiiliatomien välillä on vain yksinkertaisia kovalenttisia sidoksia.

Kovalenttinen sidos (co- 'yhteinen', valenssi) on kemiallinen sidos, jossa atomit jakavat elektroneja keskenään tasaisesti.



SpaceX

Raptor operates with an oxygen-to-methane mixture ratio of about 3.6:1, lower than the stoichiometric mixture ratio of 4:1 necessary to burn all propellants completely. Operation at the stoichiometric ratio provides better performance in theory but usually results in overheating and destruction of the engine. The propellants leave the pre-burners. They are injected into the main combustion chamber as hot gases instead of liquid droplets, enabling much higher power density as propellants mix rapidly via diffusion.

SpaceX – Starship ensi lento

After a canceled launch attempt on 17 April 2023, due to a frozen valve, Booster 7 and Ship 24 lifted off on 20 April at 13:33 UTC in the first orbital flight test. Because three engines were disabled prior to liftoff and several more shut down during the flight, the vehicle reached only a maximum altitude of 39 km. The spacecraft also lost hydraulic control of the Raptor engines later in the flight, which led to multiple unplanned cartwheels. At around 3 minutes following liftoff, the rocket received a command to activate the automated flight termination system. However, the flight termination system failed to destroy the vehicle, the vehicle tumbled for another 40 seconds, and finally exploded. Had everything proceeded as planned, the spacecraft would have continued to fly with its ground track passing through the Straits of Florida and eastward around the globe, with a hard splashdown in the Pacific Ocean around 100 km northwest of Kauai in the Hawaiian Islands, having made nearly one full revolution around the Earth.

On this first flight, Starship broke the record for the most powerful rocket-stage ever launched, which had been held by the N1 rocket for the previous 50 years up to that point.

SpaceX – Starship ensi lento

But at least six of the 33 methane-fueled Raptor engines on the Super Heavy booster, or the rocket's first stage, shut down as it climbed into the sky. The Starship lost control around two minutes into the mission, veering from its planned flight corridor until an autonomous fight termination system blew up the rocket four minutes after liftoff. There were no people or operational payloads on-board the rocket.

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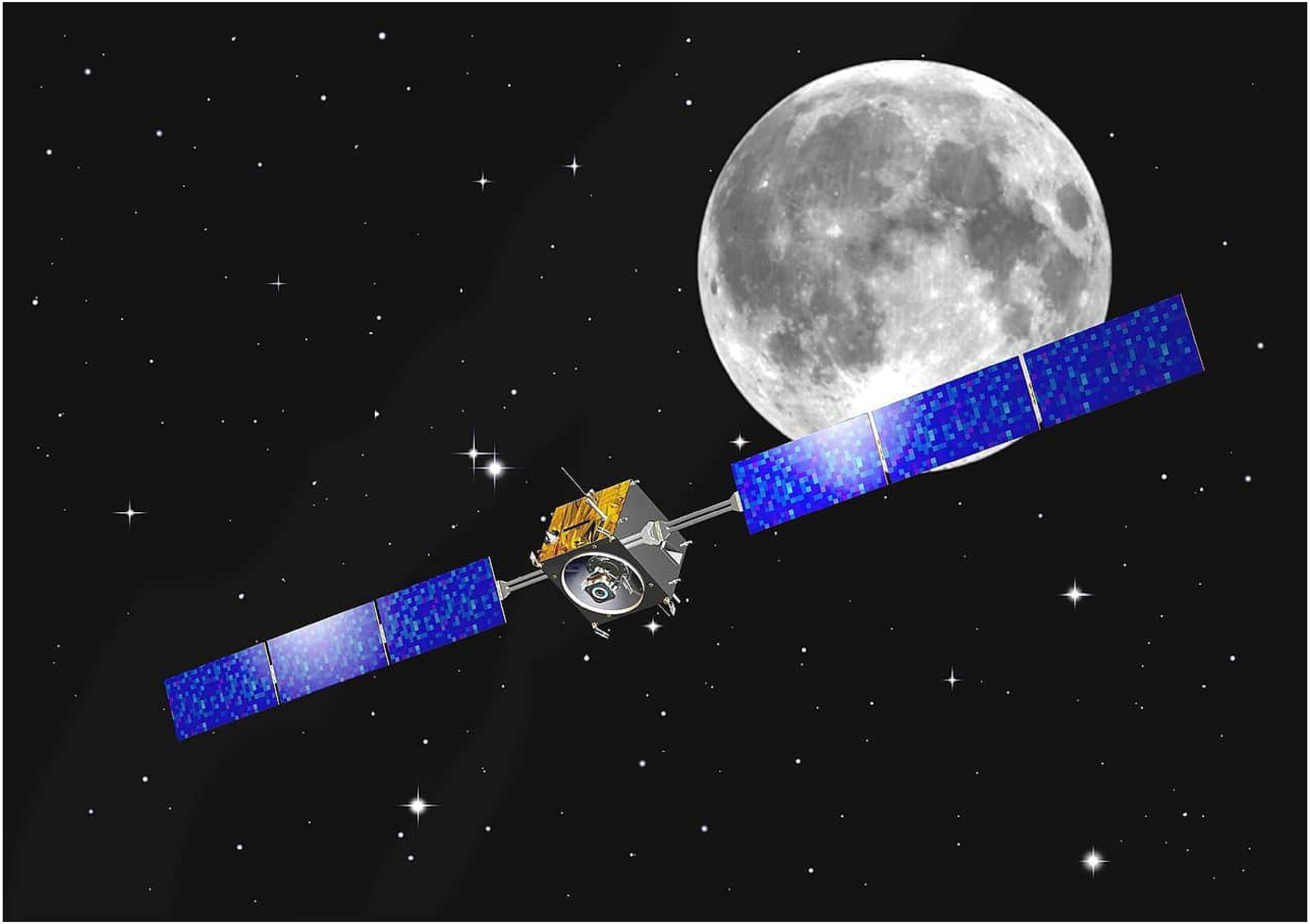
Ionimoottoreista / SMART-1



SMART-1

SMART-1 was a Swedish-designed European Space Agency satellite that orbited around the Moon. It was launched on 27 September 2003 at 23:14 UTC from the Guiana Space Centre in Kourou, French Guiana. "SMART-1" stands for Small Missions for Advanced Research in Technology-1. On 3 September 2006 (05:42 UTC), SMART-1 was deliberately crashed into the Moon's surface, ending its mission.

SMART-1 was about one meter across, and lightweight in comparison to other probes. Its launch mass was 367 kg or 809 pounds, of which 287 kg was non-propellant.

The solar arrays made capable of 1850 W at the beginning of the mission, were able to provide the maximum set of 1,190 W to the thruster, giving a nominal thrust of 68 mN, hence an acceleration of 0.2 mm/s2 or 0.7 m/s per hour (i.e., just under 0.00002 g of acceleration).

Thruster operating time: 5000 h
Xenon throughput: 82 kg
Total Impulse: 1.2 MN-s
Total ΔV: 3.9 km/s

Ionimoottorien käyttökohteita

Tiangong space station

China's Tiangong space station is fitted with ion thrusters. Four Hall-effect thrusters, which are used to adjust and maintain the station's orbit. According to the Chinese Academy of Sciences, the ion drive used on Tiangong has burned continuously for 8,240 hours without a glitch, indicating their suitability for Chinese space station's designated 15-year lifespan.

Dawn

Dawn launched on 27 September 2007, to explore the asteroid Vesta and the dwarf planet Ceres. It used three Deep Space 1 heritage xenon ion thrusters (firing one at a time). Dawn's ion drive is capable of accelerating from 0 to 97 km/h in 4 days of continuous firing.

Starlink

SpaceX's Starlink satellite constellation uses Hall-effect thrusters powered by krypton or argon to raise orbit, perform maneuvers, and de-orbit at the end of their use.

Delta IV Heavy: tehokkain LH2 / LOX -moottori, työntövoima 3 140 kN

Kiinalaisen LandSpacen metaanikäyttöinen kantoraketti laukaistiin onnistuneesti 12. heinäkuuta. Kiinalainen startup LandSpace Technology laukaisi ensimmäisenä maailmassa metaanikäyttöisen raketin kiertoradalle,
LandSpace pä ihitti näyttävästi Elon Muskin luotsaaman SpaceX:n, joka epäonnistui metaaniraketin laukaisussa aikaisemmin tänä vuonna. Myös toinen yhdysvaltalainen yhtiö Relativity Space kehittää samankaltaista moottoritekniikkaa. Kantoraketti Zhuque-2 laukaistiin Jiuquanin avaruuskeskuksesta Gobin aavikolta. Sen päämääränä oli aurinkosynkroninen kiertorata (SSO) 600–800 kilometrin korkeudessa.

Long March 9

Long March 9 is a Chinese super-heavy carrier rocket concept that is currently under development. It is the ninth iteration of the Long March rocket family, named for the Chinese Red Army's 1934–35 Long March campaign during the Chinese Civil War.

Current plans call for the Long March 9 to have a maximum payload capacity of 150,000 kg to low Earth orbit (LEO) and 54,000 kg to trans-lunar injection. Its first flight is expected to occur around 2033, in advance of possible Chinese crewed lunar missions sometime during the 2030s.

Teknofokus

Astrotarvikkeita kuudella vuosikymmenellä

Isoista raketeista

Cygnus 2023

Hannu Määttänen