The Evolution of Rocket Engines and Their Role in Humanity's Quest for Interstellar Travel

Filip Rousek

Consultant: Morteza Kerachian

October 2025

0.1 Prohlášení

Prohlašuji, že jsem svoji seminární práci vypracovala samostatně a veškeré použité zdroje a další podkladové materiály uvádím v seznamu použitých zdrojů.

Datum: Podpis:

Contents

0.2 Introduction

0.2.1 Objectives and Structure of the Work

This Seminar work aims to explain and innovate on the rich history of rocket engines we as a civilization have as well as theorize on the possible directions we could improve this in the future.

The paper is structured as follows. Firstly, a brief introduction to the background and motivation of this work and humanity's strive for the stars. Secondly, a theoretical part explaining the basics and different types of engines (both air breathing and combustion) currently in use. Further on a relatively breath walk-down of the historical evolution of rocket engines and lastly some more theoretical projects and frameworks for better, faster and more effective propulsion. Thirdly, a practical part where I utilize NPSS and attempt to improve on current models and design a possible liquid fuel rocket engine, with the results of simulations ran on it. Last, but certainly not least is the conclusion in which I summarize this work and evaluate if it has succeeded in the goals I've set for myself and the results of the practical part.

0.2.2 Background and Motivation

Humanity has looked up at the starry night and wondered what is in it since its beginning. Many, both historically early (before the common era) and later (after the common era) give the sky and stars a significant position in their religions. The Ancient Egyptians believed that the stars were where souls ascended to the afterlife, Christianity believs in the concept of Heaven among the stars. *(Instert more examples here.)* And since our discovery of flight many have wondered. "Could we reach them?".

(talk about the era of space, the space race etc.) (Discuss why humanity strives for space and interstellar travel, and how propulsion technology is central to that goal.)

0.3 Theoretical Part

0.3.1 Classification of Propulsion Systems

Propulsion is defined as *"the action or process of propelling"* (*"to drive forward or onward by or as if by means of a force that imparts motion"*). By the Merriam-Webster Dictionary.

It can also be defined as "the act of changing the motion of a body with respect to an inertial reference frame."[15]

In engine propulsion, the most common way to achieve such thing is via *chemical combustion*. The energy can also be supplied by *solar radiation*, or a *nuclear reactor*. As such, the varios types of propulsion can be generally divided up into three categories:

- chemical propulsion
- nuclear propulsion
- solar propulsion

Propulsion Device	**Energy Source**[a]			**Propellant or Working Fluid**
	Chemical	Nuclear	Solar	
Turbojet	D/P			Fuel + air
Turbo-ramjet	TFD			Fuel + air
Ramjet (Hydrocarbon fuel)	D/P	TFD		Fuel + air
Ramjet (H_2 cooled)	TFD			Hydrogen + air
Rocket (chemical)	D/P	TFD		Stored propellant
Ducted rocket	TFD			Stored solid fuel + surrounding air
Electric rocket	D/P		D/P	Stored propellant
Nuclear fission rocket		TFD		Stored H_2
Solar heated rocket			TFD	Stored H_2
Photon rocket[b]		TFND		Photon ejection (no stored propellant)
Solar sail			TFD	Photon reflection (no stored propellant)

[a] **D/P** developed and/or considered practical; **TFD** technical feasibility has been demonstrated, but development is incomplete; **TFND** technical feasibility has not yet been demonstrated.
[b] Essentially a really big light bulb.

Table 1: Energy Sources and Propellants for Various Propulsion Concepts[15]

Input in rocket propulsion systems is either heat or electricity. Useful output thrust comes from the kinetic energy of the ejected matter and from the propellant pressure on inner chamber walls and at the nozzle exit; thus. rocket propulsion systems primarily convert input energies into the kinetic energy of the exhausted gas. The ejected mass can be in a solid, liquid or gaseous state. Often, combinations of two or more states are ejected. At high enough temperatures, the ejected mass can also be in a state of plasma.[15]

0.3.1.1 Duct Jet Propulsion

Duct jet engines, more commonly called ”air breathing” engines, are engines which utilize airflow that is then energized inside a duct. They use atmospheric oxygen to burn fuel stored onboard. This class includes the following:[15]

- turbojets
- turbofans
- ramjets
- pulse jets
- scramjets[14]

They are mentioned here mainly as to provide a background and comparison to rocket propulsion engines.

Feature	Chemical Rocket Engine or Rocket Motor	Turbojet Engine	Ramjet Engine
thrust to weight ratio, typical	75:1	5:1, turbojet and afterburner	7:1 at Mach 3 at 9,144m (30,000ft)
Specific fuel consumption[a]	8 - 14	0.5 - 1.5	2.3 - 3.5
Specific thrust[b]	5,000 - 25,000	2500 (low Mach[c] numbers at sea level)	2700 (Mach 2 at sea level)
Specific impulse[d]	270 sec	1600 sec	1400 sec
Thrust change with altitude	Slight increase	Decrease	Decrease
Thrust vs. flight speed	Nearly constant	Increases with speed	Increases with speed
Thrust vs air temperature	Constant	Decreases with temperaure	Decreases with temperature
Flight speed vs. exhaust velocity	Unrelated, flight speed can be greater	Flight speed always less than exhaust velocity	Flight speed always less than exhaust velocity
Altitude limitation	None; suited for space travel	14,000 - 17,000 m	20,000 m at Mach 3, 30,000 m at Mach 5, 45,000 m at Mach 12

[a] Multiply by 0.102 to convert to $kg/(hr-N)$.
[b] Multiply by 47.9 to convert to N/m^2
[c] Mach number is the ratio of gas speed to local speed of sound (See Equation 1(Appendix .1.1)).
[d] *Specific impulse* is a performance parameter (See Equation 2(Appendix .1.1))

Table 2: Comparison of Several Characteristics of a Typical Chemical Propulsion Rocket Propulsion System and Two-Duct Propulsion Systems[15]

Out of all of the ducted engines, the *turbojet engine* is the most widely used.

0.3.1.1.1 Ramjet Engine

For supersonic flight in the speeds above Mach 2, the *ramjet engine* (which is a pure ducted engine) is the best suited within the earth's atmosphere. Its compression is purely gas dynamic and thrust is produced by increasing the momentum of the subsonic compressed air as it passes through the ramjet in a very similar manner to the functionality of *turbofan* and *turbojet* engines, just without any compressor or turbine hardware.[15]

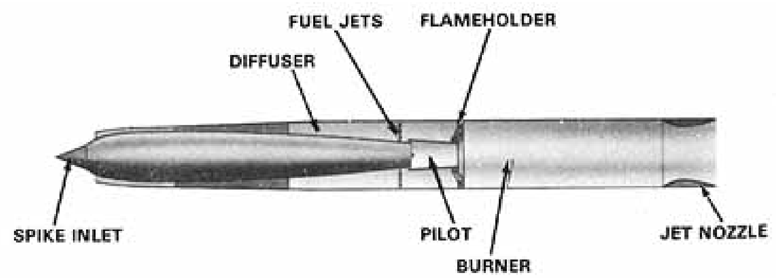

Figure 1: Simplified schematic of a ramjet engine with a supersonic inlet (a converging/diverging flow passage)[10]

Ramjets with subsonic combustion and hydrocarbon fuels have an upper speed limit of approx. 5 Mach; Hydrogen fuel with hydrogen cooling raises this maximum to at least 16 Mach.

0.3.1.1.2 Scramjet Engine

The Scramjet engine is a ramjet engine utilizing *super sonic combustion*. Which allows for much freeer and faster air flow than *turbojet* or *ramjet* engines.

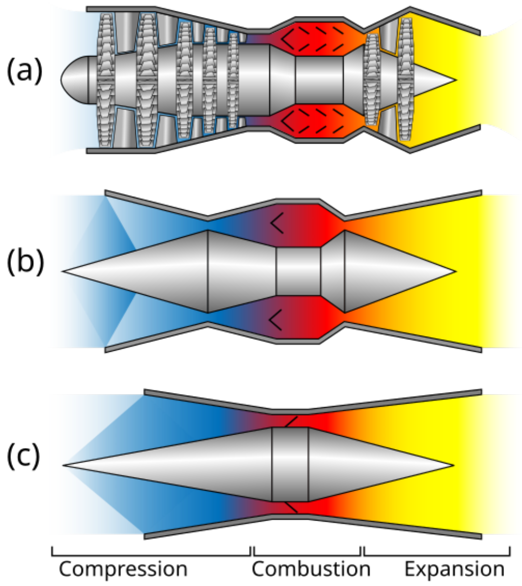

Figure 2: The compression, combustion, and expansion regions of: **(a)** turbojet, **(b)** ramjet, and **(c)** scramjet engines.[5]

So far, Scramjet engines have only been used in a few prototype vehicles and military experiments. A Scramjet relies on high vehicle speed to compress the incoming air forcefully before combustion (hence sc (*supersonic combustion*) **ramjet**), but whereas a ramjet decelerates the air to subsonic velocities before combustion using shock cones, a Scramjet has no shock cone and slows the airflow using shockwaves produced by its ignition source in place of a shock cone.[14;19]

0.3.1.2 Rocket Propulsion

Rocket propulsion is based fundamentally on *Newton's Third Law of Motion* — for every action, there is an equal and opposite reaction. In a rocket engine, the "action" is the high-velocity expulsion of exhaust gases, while the "reaction" propels the vehicle forward. Unlike air-breathing engines, rockets carry both fuel and oxidizer, allowing them to function in the vacuum of space.[15]

0.3.1.2.1 Chemical Rocket Engines

Chemical propulsion remains the most widely used method of achieving thrust in spaceflight. It relies on the combustion of chemical propellants that release large amounts of thermal energy, which is converted into kinetic energy of the exhaust gases. Two major types exist: *solid* and *liquid* rocket engines.[15]

Solid Rocket Engines

Solid rocket motors use propellants in a single solid mixture, often consisting of a powdered oxidizer (such as ammonium perchlorate) combined with a binder that also acts as fuel. They are mechanically simple, capable of long storage, and deliver high thrust rapidly after ignition. However, they cannot be throttled or shut down once ignited, limiting flexibility.[15]

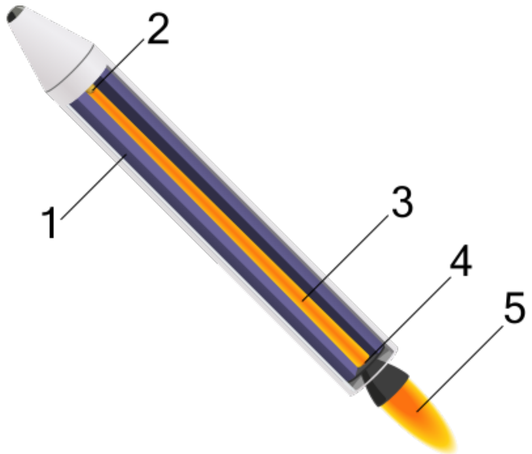

Figure 3: A simplified diagram of a solid-fuel rocket. **(1)** A solid fuel-oxidizer mixture (propellant) is packed into the rocket, with a cylindrical hole in the middle. **(2)** An igniter combusts the surface of the propellant. **(3)** The cylindrical hole in the propellant acts as a combustion chamber. **(4)** The hot exhaust is choked at the throat, which, among other things, dictates the amount of thrust produced. **(5)** Exhaust exits the rocket.[13]

Liquid Rocket Engines

Liquid-propellant engines store the oxidizer and fuel in separate tanks and feed them into a combustion chamber using pumps or pressurization. The most common combinations are RP-1 (refined kerosene) with liquid oxygen (LOX), or liquid hydrogen (LH_2) with LOX. They can be throttled, restarted, and provide high efficiency but require complex plumbing and cryogenic storage.[15]

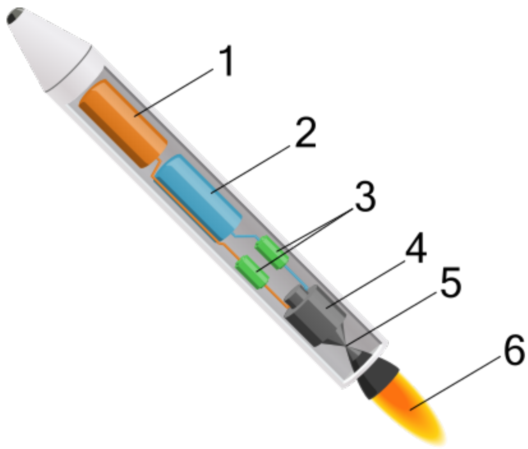

Figure 4: A simplified diagram of a liquid-propellant rocket. **(1)** Liquid rocket fuel. **(2)** Oxidizer. **(3)** Pumps carry the fuel and oxidizer. **(4)** combustion chamber mixes and burns the two liquids. **(5)** Combustion product gasses enter the nozzle through a throat. **(6)** Exhaust exits the rocket.[12]

Hybrid Rocket Engines

A hybrid rocket uses a combination of a liquid oxidizer and a solid fuel. This design offers a compromise between the safety of solid motors and the controllability of liquid systems. Notable examples include SpaceShipOne's nitrous oxide (N_2O) and hydroxyl-terminated polybutadiene (HTPB) hybrid engine.[15]

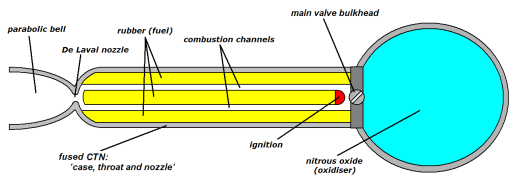

Figure 5: Hybrid rocket motor detail of SpaceShipOne[7]

0.3.1.2.2 Non-Chemical Rocket Engines

Beyond chemical propulsion, various non-chemical systems have been developed to improve efficiency and endurance for deep-space missions.

Electric Propulsion

Electric propulsion systems, such as ion and Hall-effect thrusters, use electrical energy (from solar arrays or nuclear sources) to accelerate charged particles. They produce low thrust but extremely high specific impulse, making them ideal for long-duration missions where gradual acceleration is acceptable.[15]

Nuclear Thermal Propulsion (NTP)

In nuclear thermal systems, a nuclear reactor heats a propellant—typically hydrogen—to extremely high temperatures before expansion through a nozzle. This method can theoretically double the specific impulse compared to chemical rockets, offering a promising balance between power and efficiency for interplanetary travel.[15]

0.3.2 A brief history of rocket engines

0.3.2.1 Early Concepts and the First Rocket Engine

(Briefly cover early gunpowder rockets and pioneers like Tsiolkovsky, Goddard, Oberth.)

0.3.2.2 The First Rocket to Reach Space

The German *Aggregat-4*, better known as the *V-2 rocket*, was the first human-made object to reach the edge of space. Developed under the direction of Wernher von Braun during World War II, the V-2 achieved suborbital altitudes exceeding 80 km in 1944 and was capable of carrying a 1-ton warhead to a range of about 320 km.[11]

Figure 6: Rocket engine used by V-2[2]

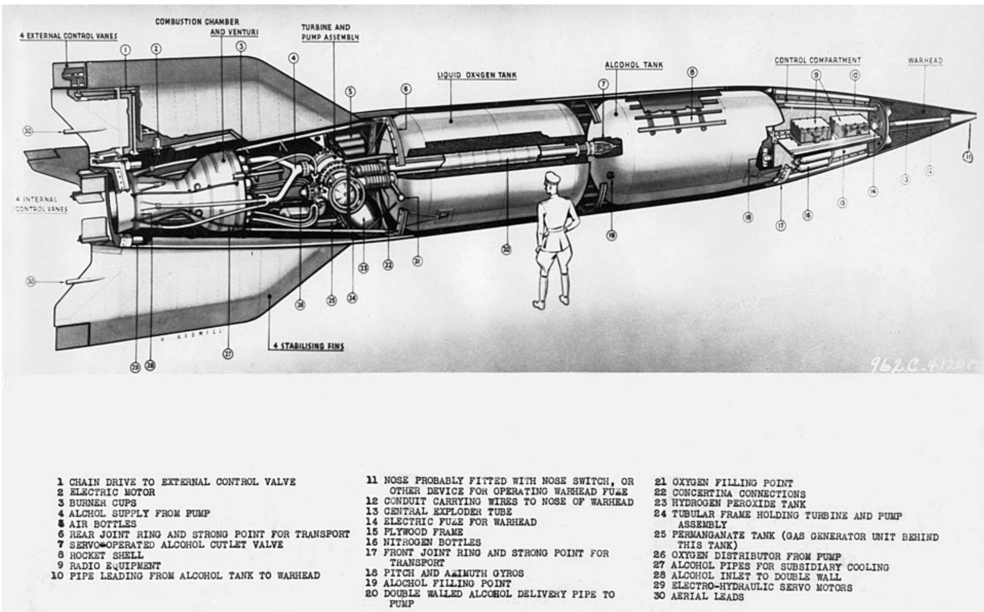

Figure 7: A U.S. Army cut-away diagram of the V-2[4]

The V-2 used a liquid-propellant engine burning ethanol and liquid oxygen in a gas-generator cycle, producing roughly 25 metric tons of thrust. Its innovations—including turbopumps, gyroscopic guidance, and regenerative cooling—formed the foundation of post-war rocket programs in both the United States and the Soviet Union. The American Redstone and Jupiter missiles, as well as the Soviet R-7 that launched *Sputnik*, directly descended from V-2 technology.[11]

Figure 8: A sectioned V-2 engine on display at the Deutsches Museum, Munich (2006)[6]

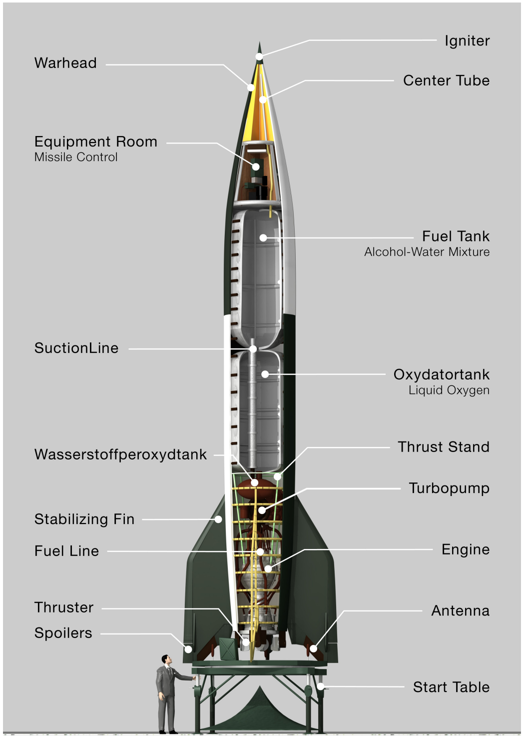

Figure 9: Layout of a V2 rocket[8]

0.3.2.3 The Saturn V F-1 Engine

The engine who got man to the moon upon the widely known Saturn V rocket was the Rocketdyne F-1 gas-generator cycle single combustion chamber liquid-propellant rocket engine.[20]

It is the most powerful single-nozzle liquid-fueled engine ever used and was placed upon the first stage of Saturn V.[20]

TYPE	SPECIFICATION
Length	19ft
Width	12ft 4in
Thrust (sea level)	1,500,000 lbs
Specific Impulse (minimun)	260 sec
Rated run duration	150 sec
Flowrate	*Oxidizer:* 3,945 lbs/sec (24,811 gpm)
	Fuel: 1,738 lbs/sec (15,471 gpm)
Mixture ratio	2.27:1 (oxidizer to fuel)
Chamber pressure	965 psia
Weight flight configuration	18,500 lbs maximum
Expansion area ratio	16:1 (with nozzle extension)
	10:1 (without nozzle extension)
Combustion temperature	*Thrust Chamber* 5,970°F
	Gas Generator 1,465°F
Maximum exit nozzle diameter	11ft 7in

Table 3: Technical specifications of the F-1 Engine.[20]

0.3.2.4 Post-Saturn Developments

Following the success of the Saturn V, rocket propulsion entered a new era marked by reusability, efficiency, and high-performance engines.

0.3.2.4.1 Space Shuttle Main Engine (SSME)

NASA's Space Shuttle Main Engine (RS-25) represented a leap in reusable liquid propulsion. It was a staged-combustion hydrogen–oxygen engine capable of being throttled between 65% and 109% thrust. Each RS-25 generated about 1.8 MN of thrust and could be reused up to 55 times.[20]

0.3.2.4.2 Soviet and Russian Advances

In the Soviet Union, engineers developed the RD-170 and its derivatives, the world's most powerful liquid rocket engines by total thrust (7.9 MN). These engines used a closed-cycle staged combustion process with kerosene and LOX, achieving exceptional efficiency and reliability, later adapted for Zenit and Atlas launch vehicles.[3]

0.3.2.4.3 Modern Developments: Merlin and Raptor

SpaceX's *Merlin* engines, used on the Falcon 9, utilize RP-1 and LOX in a gas-generator cycle optimized for reusability. The newer *Raptor* engine, employing methane and LOX in a full-flow staged combustion cycle, represents one of the most advanced chemical rocket engines ever built. Its design emphasizes reusability, efficiency, and adaptability for interplanetary missions, particularly SpaceX's Starship program aimed at Mars colonization.[spacex2020]

0.3.3 Emerging Propulsion Technologies

As mentioned at the beginning of this work, there still are ideas and possible engines that have yet to depart the zone of science fiction as either our technology isn't advanced enough to produce and test such engines or they have been demonstrated to not be technically effective for their complexity/price or we have no use for them yet. I shall talk about a select few of these in the following parts. Mainly the following:

- Nuclear Propulsion (both Fusion and Fission)
- Ion Engines
- Solar Sails
- Antimatter Engines
- Field Propulsion

0.3.3.1 Field Propulsion

Field propulsion, as defined by Yoshinari Minami is the act of propulsion not by usual means of momentum thrust, but instead by pressure thrust derived from an interaction of a spaceship with the physical structure of space-time. (Assuming that space as a vacuum possesses a substantial physical structure.)[9]

As the theory stands, field propulsion remains speculative and has not yet been experimentally demonstrated. It arises from the idea that spacetime itself may be manipulated to create a net force on a spacecraft without the expulsion of reaction mass. Concepts such as the *Alcubierre warp drive*, derived from solutions to Einstein's field equations, suggest that spacetime could theoretically be contracted in front of and expanded behind a spacecraft, allowing apparent faster-than-light travel.[9]

However, the energy requirements are currently astronomical, exceeding the mass–energy of entire planets, and the feasibility of generating negative energy densities remains purely theoretical. Despite these limitations, research into quantum vacuum interactions and general relativistic field manipulation continues at a conceptual level, keeping the idea alive in advanced propulsion discussions.[9]

0.3.4 Theoretical Framework for Interstellar Propulsion

Interstellar travel demands propulsion technologies far beyond current chemical or even nuclear capabilities. Several theoretical and conceptual projects have proposed methods to achieve fractions of the speed of light.

0.3.4.1 Project Daedalus

Conceived in the 1970s by the British Interplanetary Society, *Project Daedalus* proposed a two-stage fusion-powered spacecraft capable of reaching 12% the speed of light. It would use pellets of deuterium and helium-3 ignited by electron beams to produce thrust. Though technologically beyond current reach, Daedalus provided a credible engineering framework for interstellar flight.[16]

0.3.4.2 Breakthrough Starshot

A modern descendant of the Daedalus concept, *Breakthrough Starshot* envisions launching gram-scale probes accelerated by ground-based laser arrays to 20% the speed of light. The probes would use lightweight sails reflecting focused laser beams, allowing rapid travel to nearby stars like Proxima Centauri within a human lifetime.[17]

0.3.4.3 The Alcubierre Drive

Proposed by Miguel Alcubierre in 1994, the *warp drive* concept relies on the manipulation of spacetime geometry, compressing space ahead of the craft and expanding it behind. This would allow effective faster-than-light travel without violating local relativistic constraints. Nonetheless, it requires exotic matter with negative energy density, which has not been observed in usable quantities.[1]

These speculative frameworks demonstrate the profound link between physics and engineering in the pursuit of interstellar travel, emphasizing that humanity's ultimate propulsion systems may rely as much on breakthroughs in fundamental science as on technological advancement.

0.4 Practical Part

0.4.1 Methodics

In this practical part I will use the software *Numerical Propulsion System Simulation* (NPSS) to design a liquid-propellant rocket engine. The aim is to follow a clear, ordered method so that the engine model is built, simulated, and analysed step by step.

1. **Define the design requirements**

    - Choose the engine's purpose (for example: first stage of a launch vehicle, sea-level take-off).
    - Select the propellants (for example RP-1 + LOX, or LH_2 + LOX).
    - Set the main targets: thrust (in Newtons or kN), burn time (seconds), maximum allowable engine mass, and operating environment (sea level vs vacuum).

2. **Select the engine cycle & make initial assumptions**

    - Decide on the engine cycle type (gas-generator, staged-combustion, etc.).
    - Make initial assumptions: chamber pressure, mixture ratio (oxidiser : fuel), expansion ratio of the nozzle.
    - Note constraints: engine size, material limits, cooling, manufacturability.

3. **Build the NPSS model**

    - Set up NPSS with the main components: feed system, pumps/turbines, combustion chamber, nozzle.
    - Input the assumed parameters: mass flows, pressures, temperatures, geometry (for example throat area, exit area).
    - Run the simulation for the "design-point" (the normal operating condition).

4. **Analyse the design-point results**

    - Extract performance data: thrust, specific impulse (I_{sp}), propellant mass flow, chamber and nozzle pressures and temperatures.

- Compare the results with your design targets from Step 1. If the targets are not met, return to Step 2 (adjust assumptions) or Step 3 (modify model) and iterate.

5. **Perform parametric / sensitivity studies**

   - Vary one parameter at a time (for example mixture ratio, chamber pressure, expansion ratio) and see how performance changes.
   - Record which parameters have the largest effect (sensitivity) and find trade-offs (for example higher chamber pressure improves I_{sp} but may increase mass or cost).
   - Use these findings to refine your design toward a better balance.

6. **Check off-design / operating range conditions**

   - Use NPSS to simulate the engine under different conditions: for example different ambient pressures (sea level vs high altitude), partial throttle or start-up conditions.
   - Determine how performance changes under these conditions: does thrust drop? does I_{sp} fall? Are there stability problems?

7. **Document and reflect on the results**

   - Prepare tables and graphs presenting your results (design point outputs, parametric study results).
   - Discuss your assumptions (for example: ignoring cooling losses, assuming ideal pumps) and their impact.
   - Reflect on what I would do differently if you had more time or resources, and what the limits of my design are.

0.5 Conclusion

.1 Appendix A: Definitions

.1.1 Equations

.1.1.1 Mach Number

The Mach number (M or Ma), often only Mach, is a dimensionless quantity in fluid dynamics representing the ratio of flow velocity past a boundary to the local speed of sound.[18]

$$M = \frac{u}{c} \tag{1}$$

where:

- M is the local Mach number,[18]
- u is the local flow velocity with respect to the boundaries (either internal, such as an object immersed in the flow, or external, like a channel), and[18]
- c is the speed of sound in the medium, which in air varies with the square root of the thermodynamic temperature.[18]

.1.1.2 Specific Impulse

The *specific impulse* I_s represents the thrust per unit propellant ”weight” flow rate. It is an important figure of merit of the performance of any rocket propulsion system, a concept similar to kilometers per liter or miles per hour as applied to an automobile. A higher number often indicates a better performance. If the total propellant mass flow rate is $\dot{m}$ and the standard acceleration of gravity is g_0 (with an *average* value at the Earth's sea level of 9.8066 m/sec^2 or 32.174 ft/sec^2), then

$$I_s = \frac{\int_0^t F\,dt}{g_0 \int_0^t \dot{m}\,dt} \tag{2}$$

.1.1.3 General Theory of Relativity

Book Sources

[3] Boris Chertok. *Rockets and People Volume IV: The Moon Race*. Vol. 4. Rockets and People. NASA, 2012.

[9] Yoshinari Minami and Herman David Froning. *Field Propulsion Physics and Intergalactic Exploration*. Nova Science Publishers, 2018.

[11] Michael J. Neufield. *The rocket and the reich : Peenemünde and the coming of the ballistic missile era*. "Accessed via the Internet Archive on October 29th, 2025". New York: The Free Press, 1995. URL: https://archive.org/details/isbn_9780029228951.

[14] Corin Segal. *The scramjet engine: processes and characteristics*. Cambridge : Cambridge University Press, 2009.

[15] George Paul Sutton and Oscar Biblarz. *Rocket propulsion elements*. 9th. Wiley, 2017.

[20] Anthony Young. *The Saturn V F-1 Engine : Powering Apollo into History*. Springer New York, 2008.

Online Sources

[17] Wikipedia contributors. *Breakthrough Starshot — Wikipedia, The Free Encyclopedia*. Accessed October 30, 2025. 2025.

[18] Wikipedia contributors. *Mach Number*. Accessed: 2025-10-09. 2025. URL: https://en.wikipedia.org/wiki/Mach_number.

[19] Wikipedia contributors. *Scramjet*. Accessed: 2025-10-12. 2025. URL: https://en.wikipedia.org/wiki/Scramjet.

Miscellaneous Sources

[16] Unknown Author. *Project Daedalus: The Propulsion System Part 1; Theoretical considerations and calculations. 2. Review of Advanced Propulsion Systems*. `https://web.archive.org/web/20130628001133/http://daedalus-zvezdolet.narod.ru/doceng/07eng.doc`. Microsoft Word Document (.doc). Originally avalible at `https://daedalus-zvezdolet.narod.ru/` (site defunct). Retrieved on October 29th, 2025 via the Internet Archive Wayback Machine. n.d.

Images

[2] Bairuilong. *Rocket engine used by V-2*. Schematic. License: CC BY-SA 4.0. 2014. URL: https://en.wikipedia.org/wiki/File:V-2_f%C3%B6rbr%C3%A4nningskammare.JPG.

[4] U.S. Air Force. *A U.S. Army cut-away diagram of the V-2*. Schematic. Released into the Public domain. 1945. URL: https://en.wikipedia.org/wiki/File:Esquema_de_la_V-2.jpg.

[5] GreyTrafalgar. *The compression, combustion, and expansion regions of: (a) turbojet, (b) ramjet, and (c) scramjet engines.* Schematic. 2011. URL: https://en.wikipedia.org/wiki/Scramjet#/media/File:Turbo_ram_scramjet_comparative_diagram.svg.

[6] Jaypee. *A sectioned V-2 engine on display at the Deutsches Museum, Munich (2006)*. Schematic. License: GNU Free Documentation License, Version 1.2. 2006. URL: https://commons.wikimedia.org/wiki/File:Rocket_engine_A4_V2.jpg.

[7] jrockley. *Hybrid rocket motor detail of SpaceShipOne*. Schematic. Released into the Public Domain. 2007. URL: https://commons.wikimedia.org/wiki/File:SpaceShipOne_schematic.png.

[8] Eberhard Marx. *Aggregat4-Schnitt-engl*. Schematic. License: CC BY-SA 4.0. 2014. URL: https://en.wikipedia.org/wiki/File:Aggregat4-Schnitt-engl.jpg.

[10] NASA. *LIQUID HYDROGEN AS A PROPULSION FUEL,1945-1959*. Schematic. Originally published on the NASA website. Archived version accessed on 12.10.2025. Public domain. 2011. URL: https://web.archive.org/web/20110222032757/https://history.nasa.gov/SP-4404/app-b7.htm.

[12] Pbroks13. *Liquid-Fuel Rocket Diagram*. Schematic. License: CC BY-SA 4.0. 2018. URL: https://commons.wikimedia.org/wiki/File:Liquid-Fuel_Rocket_Diagram.svg.

[13] Pbroks13. *Solid-Fuel Rocket Diagram*. Schematic. License: CC BY-SA 4.0. 2018. URL: https://en.wikipedia.org/wiki/File:Solid-Fuel_Rocket_Diagram.svg.