

AERODYNAMIC THRUST VECTORING AND TURNING CONTROL FOR DEEP SPACE VERTICAL ROCKET LAUNCH

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering degree in

Aeronautical Engineering

By

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DEPARTMENT OF AERONAUTICAL ENGINEERING
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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A++" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **SAI SASIKA M (40260020)** who carried the Project entitled "Aerodynamic Thrust Vectoring And Turning Control For Deep Space Vertical Rocket Launch" under our supervision from December 2023 to April 2024.

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ABSTRACT

New methods on Aerodynamic Thrusting Vector of Gimballing, Thrust Vector Nozzles, Fluid Injection, Aerospike Nozzles, Synthetic Jet Actuators for a successful rocket launch that requires precise control of rocket's trajectory into deep space. New methods on Turning Control on Control Surface, Reaction Control System, Roll Control, Gravity Pull, Stage Separation, Active Guidance for successful rocket launch into deep space. Vertical Takeoff and Landing (VTOL) deep space rocket designed for efficient planetary exploration and cargo transportation. This innovative spacecraft combines the capabilities of traditional rockets with VTOL technology, enabling precise landings on celestial bodies with varied terrain. The design integrates advanced propulsion systems, including ion engines and reusable stages, to enhance fuel efficiency and reduce mission costs. Furthermore, autonomous navigation and robust communication systems ensure reliable operation in remote environments. This abstract highlights the potential of VTOL deep space rockets to revolutionize space exploration by enabling agile and cost-effective missions to explore new frontiers beyond Earth. Rocket launches represent the culmination of extensive engineering, planning, and coordination, symbolizing humanity's quest to explore and expand beyond Earth's boundaries. From the initial stages of design and assembly to the final countdown and ignition, each launch embodies a combination of scientific innovation and technological prowess.

The payload carried by the rocket often includes satellites for communication, navigation, scientific research, or space exploration missions. Furthermore, rocket launches serve as critical milestones in space exploration, fostering international collaboration and advancing our understanding of the universe.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nearly above 70% of deep space vertical rocket launch are facing failure due to Thrust Vector Control Malfunction, Software or Control Surface Failure, System Errors, Inadequate Thrust Vector Control Authority, Aerodynamic Loads, Insufficient Testing, Integration Problems, Environmental Factors, Human Errors.

We can have a successful deep space VTOL by innovating new methods in testing scenarios by Integration testing ,Security testing, database test case, usability test case , performance test case, UAT testing Beta testing , acceptance testing CFD in turning control and aerodynamic thrust vectoring .

Understanding Existing TVC Technology, Analyzation Of Fluid Dynamics And Control Theory, Stimulation And Testing, Flight Control Software, Real-Time Operating Systems Modulation, Collabration And Feedback, Patent And Intellectual Property Safety. Artificial Intelligence And Control Algorithm modification all are curicial for successive launch.

A fundamental challenge in designing VTOL aircraft is achieving stable and controlled vertical take-off and landing, while also ensuring efficient forward flight. One of the critical technologies employed in VTOL aircraft to address this challenge is aerodynamic thrust vectoring. Aerodynamic thrust vectoring in VTOL refers to the method of manipulating the direction of the engine's thrust using aerodynamic surfaces during different flight phases in deep space4.

By adjusting the direction of the thrust by the new technologies, the aircraft can control its attitude and flight path, enabling smooth transitions between vertical take-off, hover, and forward flight modes. For vertical deep space rocket launches, turning control is a crucial aspect of the flight trajectory.

New turning control allows the rocket to change its orientation and direction during different phases of the launch to achieve the desired trajectory and reach its intended target in space. Successfully. Software simulators play a critical role in

the development and testing of aero thrust vectoring and turning control systems for aerospace applications.

These simulators provide a virtual environment where engineers and researchers can model, analyze, and optimize the performance of the thrust vectoring and turning control mechanisms. Here are some of the key reasons why software simulators are essential for this purpose:

Building and testing physical prototypes of aerospace systems, such as thrust vectoring mechanisms and control surfaces, can be expensive and timeconsuming. Software simulators offer a cost-effective alternative, allowing engineers to iterate through various design options virtually before physical implementation.

Testing thrust vectoring and turning control mechanisms on real aircraft or rocket prototypes can be risky. Using simulators eliminates the potential hazards associated with physical testing, ensuring the safety of both personnel and equipment.

Simulators enable rapid prototyping, allowing engineers to quickly evaluate different designs and control algorithms. This iterative approach helps optimize the performance of thrust vectoring and turning control systems more efficiently.

Simulators provide in-depth data and insights into the behavior of the aircraft or rocket during various maneuvers. Engineers can analyze factors like aerodynamic forces, control surface deflections, thrust vector angles, and stability characteristics to fine-tune the system.

Simulators allow for the reproduction of specific flight scenarios, including different weather conditions, altitude ranges, and mission profiles. Engineers can test the system's response in diverse conditions, preparing it for real-world challenges.

Using simulators, engineers can verify and validate the performance of the thrust vectoring and turning control systems against established design requirements and safety standards.

Software simulators facilitate the development and testing of control algorithms for thrust vectoring and turning maneuvers. Engineers can analyze the effectiveness of different control strategies without risking real assets.

Simulators enable the integration testing of the thrust vectoring and turning control systems with other aircraft or rocket subsystems. This helps identify and resolve potential integration issues before implementation.

Simulators provide a valuable training platform for pilots and operators to practice handling aircraft with thrust vectoring capabilities or complex turning maneuvers. It helps improve their skills without putting actual vehicles at risk.

Simulators can be used to assess the feasibility and benefits of incorporating new technologies and innovations into thrust vectoring and turning control systems.

CHAPTER 2

LITERATURE SURVEY

2.1 GENERAL

This article compared the production ease, continuity, simplicity of arm liftoff, mass, and ground clearance of the three classic kinds of UAV architectures. Furthermore, the authors go over the pluses and minuses of each UAV design. Also, the authors focused on the ease of production, the consistency of the task, the simplicity of the arm liftoff, the weight, and the height above the ground. The authors additionally go over the advantages and disadvantages of each design, starting with the former. According to the literature, UAVs with a high wing are the most reliable option for use in life-or-death situations. Medium-range long-endurance unmanned aerial vehicle (MALE UAV) concept design with blended wing-body architecture is the focus of this article. In this regard, the airfoils FX 76-MP-120, MH-18, and MH-108 were chosen for the design, and CAD (computer-aided draft) software was used to create three different versions of the concept. After doing a CFD (computational fluid dynamics) performance analysis and a stability analysis, the team concluded that the wingtip tailplane configuration was the most effective overall.

Researchers arrived at this verdict after performing both sorts of analysis. The primary focus of this article is the procedure for enhancing the efficiency of UAVs with fixed-wing configurations. It also details the results of a wind tunnel experiment with a blended wing body UAV. The main goal of the test was to assess the level of stability.

Results showed that, except from takeoff and landing, the UAV exhibited good stability throughout the flight. Within the scope of this research, three distinct configurations for a blended wing body passenger aeroplane are examined and analyzed. The research article evaluates and ranks the three designs based on criteria like flight and field performance, static stability, balance, weight, and passenger accommodation, but it does not decide which one is the best. Some examples of such characteristics are as follows: some of these features are the ability to fly and perform on the field, as well as static stability, balance, weight,

and passenger capacity. Also, consider static stability, balance, and weight [4]. This article takes a close look at the design and operation of a blended wing body aeroplane. The purpose of this research is to provide the findings of an aerodynamic analysis conducted on four potential blended wing body platform configurations. The primary focus of this study is on the effectiveness of the platforms for use in applications requiring unmanned aerial vehicles travelling at low subsonic speeds.

The blended wing body extended from the centerline of the fuselage to the wingtip, and it was made up of three different airfoils; the CFD programme is used to analyze these and other design features of all four models. These specific airfoils were given the model names MH-91, E374, and NLF1015. Integrating the Reynolds-averaged-Navier-Stoke equations with a low Reynolds turbulence model yielded accurate shear and normal stress acting on the wing surfaces. The purpose of this action was to improve precision. This was done to provide the highest degree of precision in the final results [5-10]. The study [5] used a variety of turbulence models, including -omega SST and Spalart-Allmaras, to analyze the external fluid's flow and identify its features.

To learn about the characteristics of the ambient fluid, this was done. This article explores the theoretical framework for, and the aerodynamic properties of, a VTOL-integrated blended wing body UAV. The essay is focused on the vertical takeoff and landing capabilities of the VTOL-integrated blended wing body UAV. This article focuses on the vertical takeoff and landing capabilities of the VTOL-integrated blended wing body UAV. This arrangement allows for vertical takeoff and landing by utilizing a propeller positioned in a duct along the plane's midline. Located smack dab in the middle of the plane is this duct. It can take off and land vertically due to the design of the plane. Experiments were conducted on two versions of the same model to determine the thrust of four propellers hidden within the fuselage at various angles of attack. The same model was used for all of these tests. The device's range and operational endurance are constrained by the capacity of the battery currently being used. [6]. According to the cited literature review and other online sources, one must conceptually construct three to four models by incorporating improvements from prior models, and one model must be optimized for surveillance application. This realization resulted from the realization

that having a single model that is optimized for surveillance application is essential. This suggests the importance of having access to at least one model designed for use in such a setting as surveillance.

This is the conclusion that may be derived from the need for a model optimized for surveillance applications. Inference reached from the data. When the first UAV plans were discovered, they were used to create the prototype for the BWB. With the use of relevant literature, researchers looked at the past connections between factors including payload weight, total weight, aspect ratio, and wingspan [2-5, 7, 11]. Roskam's work [12], detailed in [6, 8, 9], served as the basis for the theoretical calculations. Since the majority of the existing literature relied on CFD simulations, we started with them as part of our testing strategy. Because it would yield the most precise findings, it was thought that the trial-and-error approach would be the ideal place to start with the design. It is expected that the procedure would go through three or four iterations before an appropriate design is found for use in surveillance applications. Those methods were used in the studies that are described.

2.2 PROPOSED METHODOLOGY

The BWB-UAV is constructed with the assistance of a standardized formula as well as a sophisticated modeling tool. Sophisticated numerical modeling is utilized in order to simulate the actual working environment of the unmanned aerial vehicle in order to ascertain whether or not the BWB-modeled UAV is able to accomplish the desired missions while keeping expenses to a minimum.

2.2.1 Conceptual Design

The recommended methodology for this piece of research is fully dependent on the computational approach as a result, it is important that the essential component, the BWB UAV, be modeled. An industry-standard formula is applied in order to determine the design parameters, components, boundary conditions, and specifications for a variety of BWB UAVs. Because of the intricate nature of the BWB UAV's architecture, modelling plays a significant role in the process of developing the UAV's conceptual design.

2.2.2 Estimation of Overall Weight

The payload is a stabilized four-sensor UAV gimbal that can rotate a full 360 degrees, has a moving target indicator built in, and can record in 720p HD. The study assumes a payload weight of 5 kg, whereas the actual weight, including all accessories, is 4.5 kg. The total mass of the UAV can be roughly estimated by correlating past data with the weight of the payload. Thus, field work was done to refine payload weight estimates for the missions that made the cut. The new and distinctive link between payload weight and total weight of BWB UAV is derived from the established relationship provided. The typical comprehensive representations of link between payload mass and overall UAV mass are shown in Figure 1. According to the results the expected payload mass is 5 kg and the predicted overall UAV mass is 16.5 kg.

2.2.3 Design of Unique Propeller for Forward Speed

To design a high-performance propeller for forward motion, relevant researchers consider variables such overall weight, forward speed, propeller pitch, and propeller diameter. The fastest rate of progress that can be achieved in this endeavor is envisioned to be 75 m/s. The important relationships such as thrust and pitch of FWUAV's forward speed propeller are expressed and (respectively. Lift, forward speed, flow density, and cross-sectional area of the propeller are the primary variables which yields an estimated coefficient of lift of 0.997155556. Standard formulas, such are then used to determine the Reynolds number once an estimate has been made.

The determined lift coefficient and the Reynolds number are both utilized in the process of calculating and comparing the drag coefficient or a variety of different NACA aerofoils. For the conceptual design of the propeller, the NACA 25112 aerofoil profile is utilized. This shape functioned with a lower coefficient of drag than the majority of other aerofoil profiles.

The chord length, pitch, and its placements in the propeller were computed for the forward speed's propeller based on the afore mentioned. The values. The

forward speed executing propeller is illustrated in with constructions produced in accordance with the data that was determined.

2.2.4 Design of Unique Propeller for VTOL Maneuvering

The key design parameters are estimated with the use of mathematical equations. The diameter, pitch, chord lengths, and pitch angles of the propeller, which is aimed at carrying out VTOL operation, are the details that are discussed. The atmospheric velocity is measured to be 4 m/s, and it is assumed that the maximum rate of ascension is 50 m/s.

The aforementioned yields a lift coefficient of After establishing this estimate, the Reynolds number is obtained by applying the common formulas provided in The VTOL operation propeller lacks the NACA 25112 aerofoil, which increases the forward propeller's coefficient of drag over the VTOL operation propeller. The chord length, pitch, and locations in the propeller's chords for forward speed were determined using previously mentioned. The important relationships such as thrust and pitch of FWUAV's VTOL propeller are expressed in Equations respectively. Table contains the findings of this calculation. These authors are using a coaxial propeller technology, which enables them to design propellers that revolve both clockwise and anticlockwise using CAD design software. respectively, the CAD models of the VTOL propellers.

2.2.5 Design of Primary Data of BWB UAV

The main design criteria that went into making the BWB UAV were its wingspan, length, plan form area of the blended wing, and root chord. For these parameters to be found, a standard analytical method was used. Because of how important the wing loading is to the design process, we have decided that the wing loading for this BWB unmanned aerial vehicle should be 20 kg/m^2 . is used to calculate the plan form area of this blended wing, and then, using precedents, the aspect ratio (AR) is assumed to be 4. The assumed AR has been imposed in that contains the link between wingspan and plan form area of BWB UAV.

The typical relationship between length and wingspan of BWB-UAV is expressed. In most cases, the length-to-wingspan ratio of an unmanned aircraft falls around the range of 70-90%. The authors made the assumption that the design ratio () for this work is 70%; therefore, if that is the case, The relationship that exists between the chord length, wing area, and wing span is quite evident in Equation and it can be observed rather simply.

As a consequence of the analysis of the relevant literature, it was established that a taper ratio of 0.5 is the optimal number to employ in order to offer the lowest drag while maximizing lift at an angle of attack that is advantageous. As a direct consequence of this, the value of taper ratio that is chosen for this research is 0.5.

A high-wing design is envisioned for the purposes of this work. In order to compute chord at any span-wise position, the wingspan is always an essential aspect to take into consideration. With the assistance of these analytic approaches and a variety of additional supporting equations, the one-of-a-kind and highly advanced HBWB unmanned aerial vehicle can be constructed.

2.3 COMPUTATIONAL FLUID DYNAMICS (CFD)

The major objective of the cutting-edge and flexible CFD tool is to provide an accurate prediction of the aerodynamic pressures and forces (lift and drag) that the HBWB UAV will be subjected to in the foreseeable future. Within the domain of computational fluid dynamics, the discretization method is regarded as being of the utmost significance. In order to convert continuous functions into discrete functions, it is necessary to ensure that the distance between each point in the function remains unchanged during the transformation. If one makes the assumption that the flow's maximum speeds are 75 m/s in the forward direction and 50 m/s when it is operating in VTOL mode, then one might be able to reach the conclusion that the flow does not compress. This immediately leads to the implementation of a solution that is based on the application of pressure. It is possible to use ANSYS Fluent to model the unmanned aerial vehicle that has been proposed in order to calculate the amount of drag it would generate while

carrying out a range of maneuvers. Since the elaborate design leads to a rather high rate of turbulence formation, a traditional ϵ -epsilon turbulence model with quality of the second order is adopted.

The working pressure is determined to be 101325 Pa in light of the facts presented here. Due to the fact that the maximum velocities were determined to be 75 and 50 m/s, respectively, the identical sets of inputs were applied for both sets of calculations. On the surface of the vehicle, there is not a problem with sliding, but free slip is present on the unmanned aerial vehicle. The wall is what governs the volume, and it has a set of dimensions that are predetermined and dictated by the geometry of a cylinder. The wingspan is ten times greater than the length of the fuselage, while the length of the fuselage is fifteen times greater than the length of the wings. Figure 7 not only gives a concise example of the border conditional components but also indicates that the control volume has the shape of a cylinder.

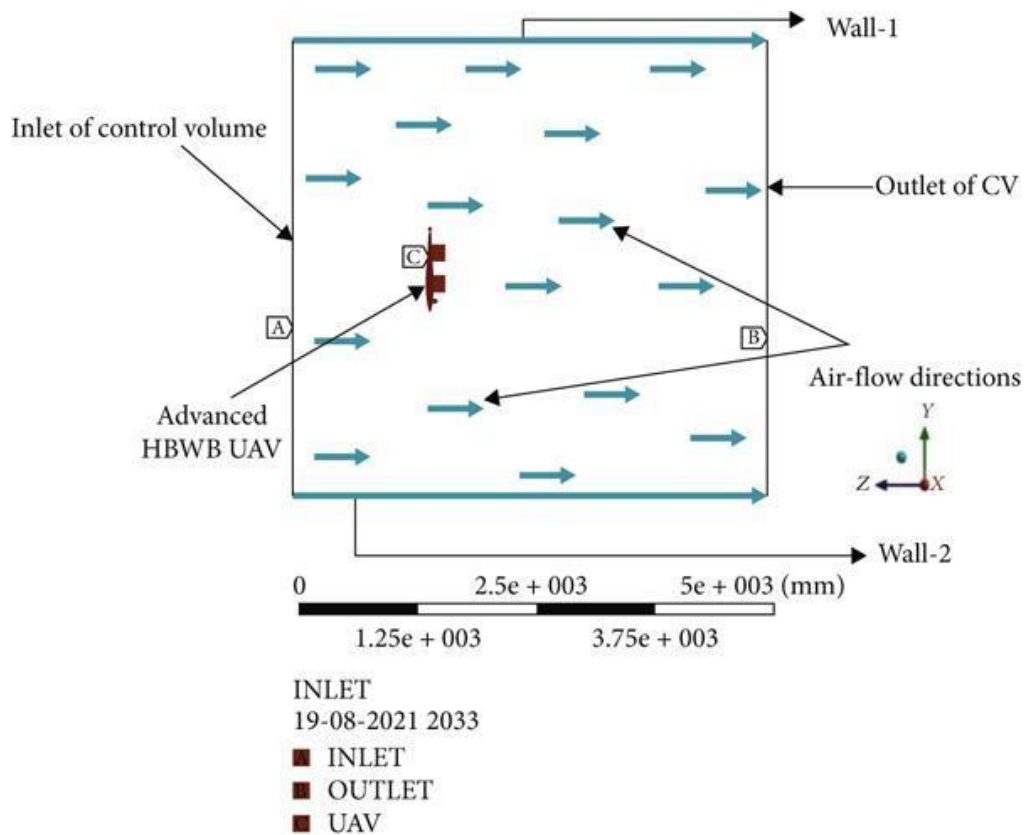


Fig:2.1 : Thrust Vectoring Air-Flow Directions

2.3.1 Fluid Parameters Study

The SIMPLE approach is applied in order to derive the velocity and pressure coupling, and it is needed that all significant equations have a quality level of second order or higher. The flow is incapable of being compressed and keeps its density constant throughout its entirety, ultimately reaching a maximum finalized velocity of 75 m/s. Because this control volume has been determined, the pressure-based solution can now be used to create a forecast regarding the properties of the fluid. This prediction can be made because this control volume has been established. The primary fluid parameters, such as pressure and volume, are measured at each node of a control volume, and then, the values of those parameters are determined. These parameters include pressure and volume. When an unmanned aerial vehicle is equipped with a propeller, the risk that it may experience turbulence is significantly increased. As a direct consequence of this, we are going to make use of the turbulence that is present. The large amount of labour that would be required to adequately display the turbulent flow led to the selection of the second order as the best option to pursue.

The development of a discretized unstructured grid on the HBWB UAV is depicted in an accurate manner. The process of precisely creating the grid is concluded when these facilities are utilized, and as a result, there is a large improvement in the possibility of achieving a trustworthy output.

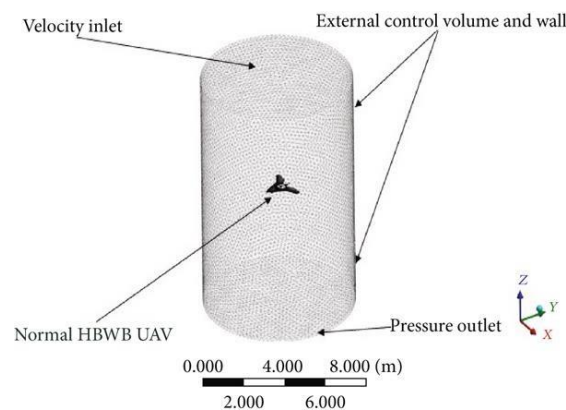


Fig:2.2 : HBWB UAV Volume Rate

2.3.2 Fluid-Structure Interaction (FSI)

This imposed FSI puts a variety of materials through tests for forward speed and VTOL operations so that it can select the material that is most likely to be able to withstand the working environmental conditions that have been described. In order to manufacture UAVs, manufacturers need to use components that are primarily made of lightweight materials that also have a high load resistance. The incorporation of a variety of lightweight materials into structural calculations that are constrained to aerodynamic force imposing conditions allows this to be achieved. To make an estimate of the structural results, computations with the help of finite computational element analyses (FEA) are carried out. In this simulation, an unstructured mesh is required to be used. The fine mesh facility is utilized for the production of difficult components such as vertical and horizontal propellers. The entirety of the structure is compelled to make use of the mesh facilities, which are dependent on the curvature and proximity of the base object, i.e., UAV. After much deliberation, the final rating for the mesh quality was 0.984 out of 1. The intricate mesh of the BWB UAV is displayed in its entire splendour.

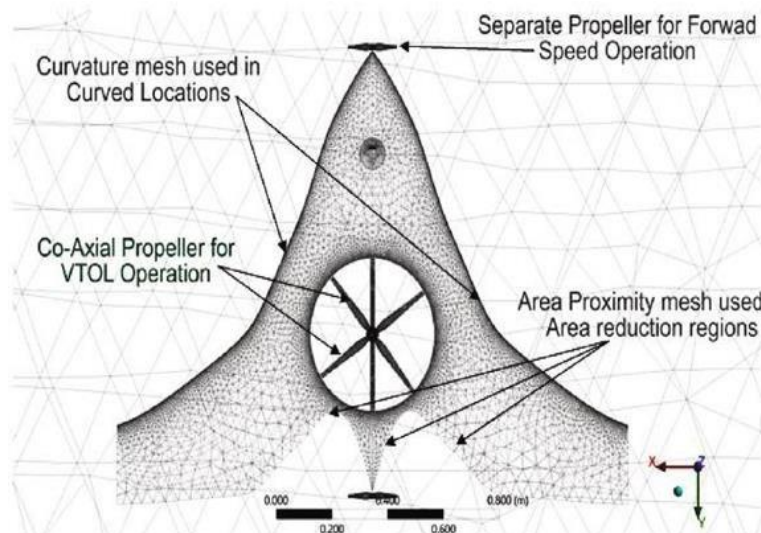


Fig:2.3 : VTOL Co-Axial Propeller Nose

2.3.3 VTOL Nozzle Analysis

The most essential boundary conditions for this FSI analysis are the impact on the aerodynamic load, the fixed support, and the remote displacements, while the most important initial conditions for this FSI analysis are the mechanical properties of lightweight materials. The aerodynamic load that is placed on the BWB UAV is completely taken into account and transferred using a one-way coupling FSI method.

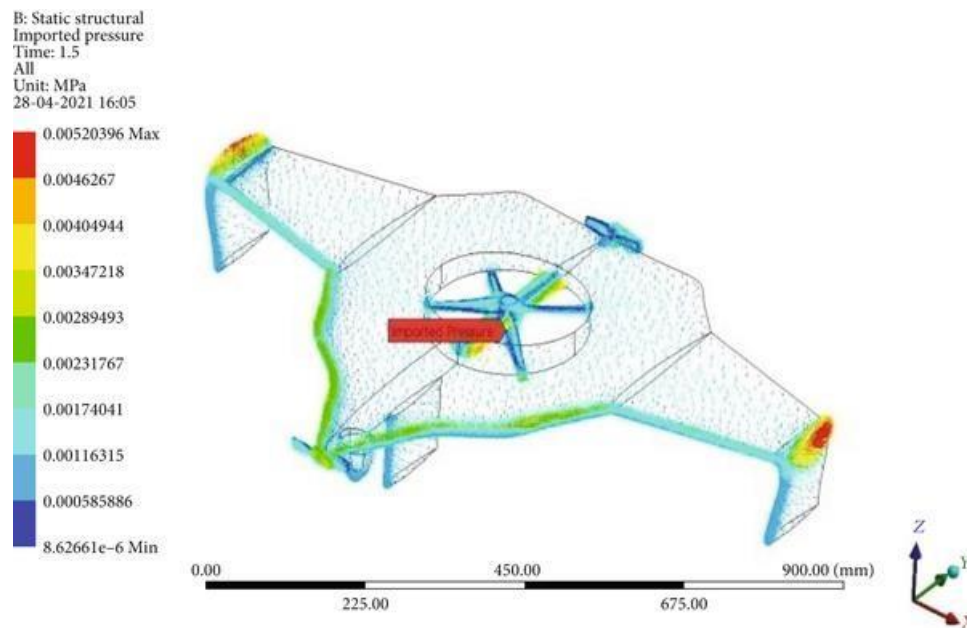


Fig:2.4 : VTOL Nozzle Analysis in Ansys

2.4 DESIGN CUSTOMIZATION OF VTOL ROCKET

The CFD method is utilized most frequently in the process of estimating and extracting the aerodynamic load that is placed on a BWB UAV. Aside from this UDL-based aerodynamic load, the remote displacement on the both the propellers is excellently used to present the representation of rotary action of these proposed propellers, and support deformations are clearly involved in the representation of hold constrictions at the landing gear of BWB UAV.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 AIM

To develop a new research on method of aerodynamic thrusting vector by and turning control for deep space vertical rocket launch to reduce failure rate of VTOL. A vertical take-off and landing (VTOL) aircraft is one that can take off and land vertically without relying on a runway. This classification can include a variety of types of aircraft including helicopters as well as thrust-vectoring fixed-wing aircraft.

The powered rotors such as cyclogyros /cyclocopters and gyrodynes. Some VTOL aircraft can operate in other modes as well, such as CTOL (conventional take-off & landing), STOL (short take-off & landing), or STOVL (short take-off & vertical landing). Others, such as some helicopters, can only operate as VTOL, due to the aircraft lacking landing gear that can handle taxiing. VTOL is a subset of V/STOL (vertical or short take-off & landing).

3.2 SCOPE OF THE PRESENT INVESTIGATION

Enabling rocket air rescue and medical aid via VTOL aircraft helps medical teams to effectively execute their missions even within densely populated regions. EASA has put forward a blueprint for vertiport designs, facilitating the landing of such aircrafts. These vertiports offer enhanced integration within city centres and are located in strategically designated areas where immediate assistance may be required. VTOLs offer several advantages for EMS. They enable faster response times as they can be swiftly dispatched from nearby hubs upon receiving a call for help. Studies suggest that VTOLs have the potential to produce less noise, contributing to a quieter operational environment. Additionally, electric VTOLs could significantly reduce emissions compared to conventional aircraft, promoting sustainability. With advanced flight control systems, VTOL handling becomes more manageable, even though they will not operate autonomously initially. Moreover, these aircraft are expected to be mechanically simpler than traditional EMS aircraft, potentially reducing both purchase and maintenance costs, making continuous safe operations more affordable.

3.2.1 Understanding Existing TVC Technology

Thrust vectoring, also known as thrust vector control (TVC), is the ability of an aircraft, rocket or other vehicle to manipulate the direction of the thrust from its engine(s) or motor(s) to control the attitude or angular velocity of the vehicle. In rocketry and ballistic missiles that fly outside the atmosphere, aerodynamic control surfaces are ineffective, so thrust vectoring is the primary means of attitude control. Exhaust vanes and gimbaled engines were used in the 1930s by Robert Goddard.

For aircraft, the method was originally envisaged to provide upward vertical thrust as a means to give aircraft vertical (VTOL) or short (STOL) take off and landing ability. Subsequently, it was realized that using vectored thrust in combat situations enabled aircraft to perform various maneuvers not available to conventional engined planes. To perform turns, aircraft that use no thrust vectoring must rely on aerodynamic control surfaces only, such as ailerons or elevator; aircraft with vectoring must still use control surfaces, but to a lesser extent.

3.2.2 Analyzation Of Fluid Dynamics And Control Theory

Fluid dynamics plays a crucial role in VTOL (Vertical Takeoff and Landing) aircraft design and operation. The aerodynamics of VTOL aircraft involve complex interactions between the aircraft, its propulsion system, and the surrounding air. Engineers must consider factors such as thrust distribution, airflow control, and stability to ensure safe and efficient flight. Many VTOL aircraft use thrust vectoring to control their direction of flight during takeoff, landing, and hovering. By directing engine exhaust, these aircraft can achieve the required lift and maneuverability. Effective flow control is essential for stable VTOL operation. Engineers use techniques such as boundary layer control, vortex generators, and control surfaces to manage airflow over the aircraft's surfaces and control its orientation. The downward flow of air generated by VTOL aircraft can have significant effects on nearby surfaces and structures, particularly during hover or low-speed flight. Engineers must account for these downwash effects when designing VTOL aircraft and assessing their impact on surrounding environments. Optimizing the aerodynamic efficiency of VTOL aircraft is essential for maximizing range and payload capacity. Engineers use computational fluid

dynamics (CFD) simulations and wind tunnel testing to refine designs and minimize drag.

3.2.3 Simulation And Testing

Simulation and testing are critical aspects of VTOL (Vertical Takeoff and Landing) aircraft development, enabling engineers to assess performance, safety, and reliability before deployment. Here's how simulation and testing are used in VTOL aircraft development. CFD simulations model the airflow around the aircraft, helping engineers understand aerodynamic behavior and optimize design parameters such as wing shape, thrust distribution, and control surfaces.

CFD simulations can predict lift, drag, and stability characteristics at various speeds and flight conditions. FEA is used to simulate structural stresses and deformations in VTOL aircraft components, ensuring they can withstand the forces experienced during takeoff, landing, and flight. FEA helps optimize the weight and strength of materials used in the aircraft's construction. FDS software simulates the aircraft's behavior in various flight scenarios, including takeoff, landing, hovering, and transition phases.

3.2.4 Flight Control Software

Flight control software plays a crucial role in VTOL (Vertical Takeoff and Landing) aircraft, enabling precise control of flight dynamics, stability, and maneuverability. Here's how flight control software is implemented in VTOL aircraft. Flight control software manages the aircraft's attitude (orientation) and stability by adjusting control surfaces, thrust vectoring systems, and propulsion outputs. It ensures the aircraft maintains desired pitch, roll, and yaw angles during all flight phases, including vertical takeoff, transition, and horizontal flight. VTOL aircraft rely on precise thrust management to achieve vertical lift and control altitude during takeoff, hovering, and landing. Flight control software regulates engine power, rotor speeds, or thrust vectoring angles to maintain stable vertical flight and respond to pilot inputs or external disturbances.

3.2.5 Real-Time Operating Systems Modulation

In VTOL (Vertical Takeoff and Landing) rocket, real-time operating systems (RTOS) are used to manage critical tasks, ensure timely execution of flight control algorithms, and maintain system reliability. Here's how RTOS is employed in VTOL. RTOS handles real-time execution of flight control algorithms, ensuring precise control of the aircraft's attitude, stability, and trajectory. It prioritizes critical control tasks, such as sensor data processing, control law computation, and actuator command generation, to minimize latency and maintain responsiveness. RTOS interfaces with various sensors, including accelerometers, gyroscopes, GPS receivers, air data probes, and vision systems, to gather real-time data on the aircraft's state and environmental conditions. It synchronizes sensor inputs, performs data fusion, and provides accurate estimates of the aircraft's position, velocity, and attitude for flight control.

3.2.6 Collaboration And Feedback

Collaboration and feedback are crucial aspects of developing VTOL (Vertical Takeoff and Landing) rocket technology. Collaboration involves interdisciplinary teams working together, including engineers, scientists, designers, and testers, to tackle various challenges such as propulsion, stability, and safety. Feedback loops are essential for iterative improvement. This involves collecting data from test flights, simulations, and real-world scenarios to identify areas for improvement. Engineers then analyze this feedback to make adjustments to the design, software algorithms, or operational procedures. Continuous collaboration and feedback help refine VTOL rocket systems, enhancing their reliability, efficiency, and safety for various applications.

3.2.7 Patent And Intellectual Property Safety

Patenting and protecting intellectual property related to VTOL rocket safety, it's essential to focus on innovative features, technologies, or methods that enhance safety during vertical takeoff, landing, and flight operations. Here's a general approach. Identify unique safety features or systems that improve VTOL rocket safety, such as advanced flight control algorithms, redundant propulsion systems, emergency landing protocols, or autonomous collision avoidance

mechanisms. Conduct a thorough patent search to ensure your idea is novel and hasn't been patented by others. This involves searching through existing patents related to VTOL rockets, propulsion systems, flight control, and safety mechanisms. Conduct a thorough patent search to ensure your idea is novel and hasn't been patented by others.

This involves searching through existing patents related to VTOL rockets, propulsion systems, flight control, and safety mechanisms. Draft claims that specifically define the novel aspects of your safety features. Claims should be broad enough to cover potential variations or improvements but specific enough to distinguish your invention from existing technologies. Consider other forms of intellectual property protection besides patents, such as trademarks for unique branding associated with safety features or trade secrets for proprietary algorithms or processes.

3.2.8 Artificial Intelligence And Control Algorithm

Artificial intelligence (AI) and control intelligence play significant roles in enhancing the performance, safety, and efficiency of VTOL rockets. AI algorithms are used to develop advanced flight control systems that manage the complex dynamics of VTOL rockets during takeoff, landing, and flight. These systems utilize sensor data to make real-time adjustments to stabilize the rocket, optimize trajectory, and prevent accidents. AI enables VTOL rockets to autonomously navigate through various environments, including urban areas or hazardous terrain, by processing sensor data (such as GPS, lidar, and cameras) to make decisions about trajectory planning, obstacle avoidance, and route optimization.

Fault Detection and Diagnosis: AI-based fault detection and diagnosis systems continuously monitor the health of critical components in VTOL rockets, such as engines, avionics, and control surfaces. By analyzing sensor data and system performance metrics, these systems can detect anomalies and predict potential failures before they occur, enhancing overall safety and reliability. AI algorithms are used to optimize mission planning for VTOL rockets, considering factors such as payload requirements, fuel efficiency, weather conditions, and airspace regulations. Machine learning techniques can analyze historical data to predict optimal flight paths and resource allocations for future missions. AI-based

adaptive control systems continuously learn from real-time feedback to adjust control parameters and optimize performance based on changing environmental conditions, vehicle dynamics, and mission objectives. This capability improves the responsiveness and agility of VTOL rockets in dynamic operating environments. AI technologies facilitate human-machine collaboration in VTOL rocket operations, enabling seamless interaction between human operators and autonomous systems. AI-powered decision support tools provide real-time insights and recommendations to operators, enhancing situational awareness and decision-making capabilities.

Overall, integrating AI and control intelligence into VTOL rocket systems enables safer, more efficient, and more capable operations in a variety of mission scenarios, ranging from space exploration to commercial transportation and beyond. AI algorithms are used to optimize mission planning for VTOL rockets, considering factors such as payload requirements, fuel efficiency, weather conditions, and airspace regulations. Machine learning techniques can analyze historical data to predict optimal flight paths and resource allocations for future missions.

CHAPTER 4

MATERIAL AND METHODOLOGY

4.1 EXPERIMENTAL

Materials And Methods. Network simulator software for developing new methods on Aerodynamic Thrusting Vector of Gimbaling, Thrust Vector Nozzles, Fluid Injection, Aerospike Nozzles, Synthetic Jet Actuators and new methods on Turning Control on Control Surface, Reaction Control System, Roll Control, Gravity Pull, Stage Separation, Active Guidance for successful vertical rocket launch into deep space.

Network simulators are software tools used for modeling, simulating, and analyzing computer networks. Some commonly used network simulators include in VTOL are:

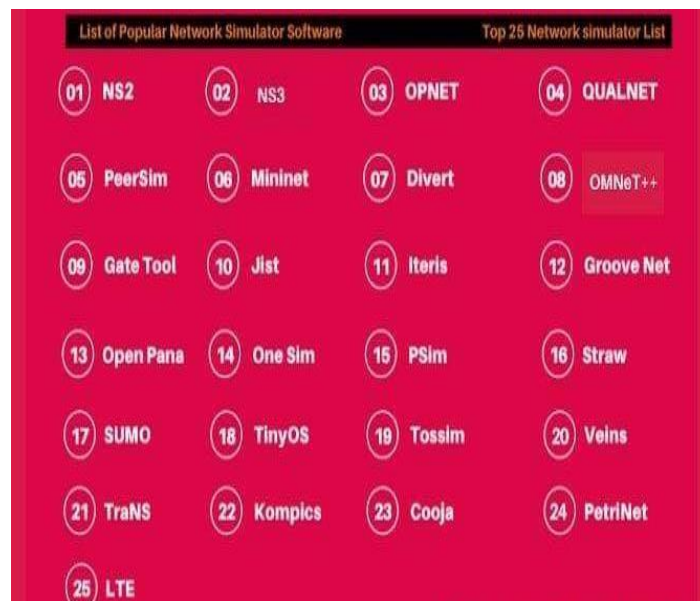


Fig:4.1 : Network Simulator Software List

4.1.1 NS2 Simulator

The "NS2" simulator, or simply "Network Simulator 2," is primarily focused on network simulation and is not specifically designed for rocket software simulation. Network Simulator 2 is a discrete-event simulator widely used in the field of

computer networking to simulate and analyze the performance of communication networks.

For rocket software and simulations, specialized software tools and platforms are used that are specifically designed for aerospace and rocket engineering applications. These tools often have advanced capabilities to model rocket propulsion systems, aerodynamics, structural dynamics, trajectory analysis, and more.

The purpose of establishing the mathematical model of the trans-medium aircraft by NS2 is to analyze the changes in the position and attitude of the trans-medium aircraft when it is subjected to external forces and moments. Among them, the input of the dynamic model is the pulling force and torque provided by the propeller, and the output is the speed and angular velocity of the aircraft; the input of the kinematic model is the output of the dynamic model that is, the speed and angular velocity of the aircraft, and the output is the position and attitude of the aircraft.

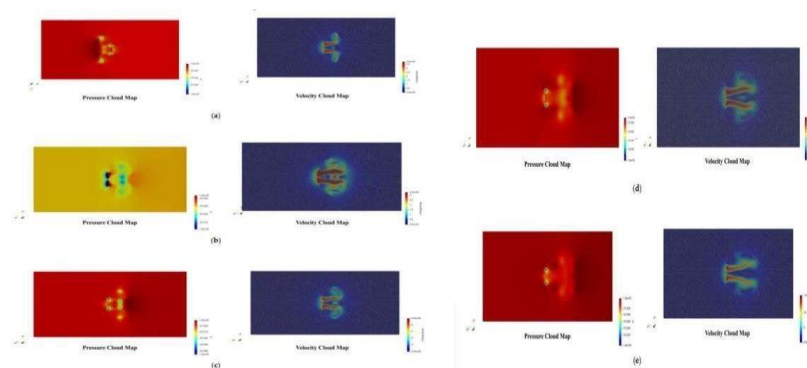


Fig:4.2 : NS2 Simulator Of VTOL

4.1.2 NS-3 Simulator

NS-3 is discrete-event network simulation software primarily used for networking research and development. It's widely used in academia and industry for studying network protocols, wireless networks, and related technologies. While NS-3 is not designed explicitly for rocket simulations, it can be adapted to model certain aspects of a rocket control system.

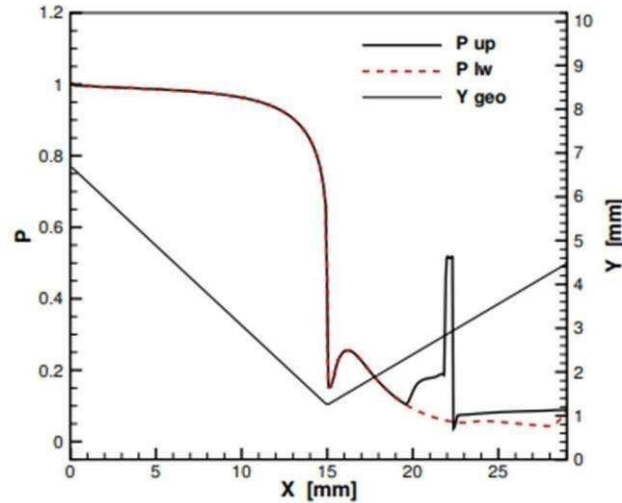


Fig:4.3 : NS3 Simulator VTOL Graph

4.1.3 Opnet

OPNET is a powerful network simulation tool used to model and analyze communication networks, including wired, wireless, and satellite networks. It is primarily utilized for research, design, and optimization of network protocols IN aerodynamic thrust vectoring, to control the direction of thrust generated by aircraft engines. It involves adjusting the orientation of exhaust nozzles to change the direction of the engine's thrust, enabling improved maneuverability and control.

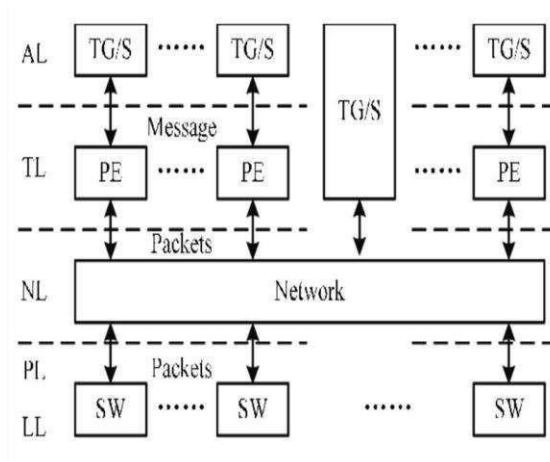


Fig:4.4 : Opnet Flow Chart of VTOL

4.1.4 Qualnet Simulator

QUALNET is a network simulation tool developed by Scalable Network Technologies, mainly used for modeling and simulating communication networks, wireless networks, and hoc networks (MANETs). There is no direct connection between QUALNET and rocket turning control simulations. QUALNET does not have built-in capabilities for simulating aerodynamics, rockets, or turning control in the aerospace context. For rocket turning control simulations, you would typically need to consider factors such as rocket propulsion, aerodynamic forces, control surfaces, stability, and guidance algorithms.

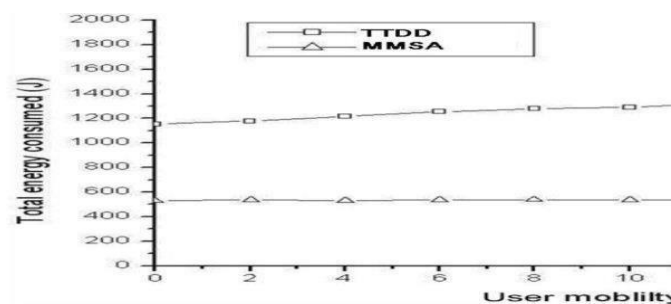


Fig:4.5 : Qualnet Simulator Graph of VTOL

4.1.5 PeerSim

PeerSim is new software or a specific tool for aerodynamic turning control simulations, it is highly recommend searching for the latest information on it through online research, official websites, or publications related to aerospace engineering and aerodynamics. Additionally, you can check with experts in the aerospace field or academic institutions to see if they have any knowledge or experience with this simulator.

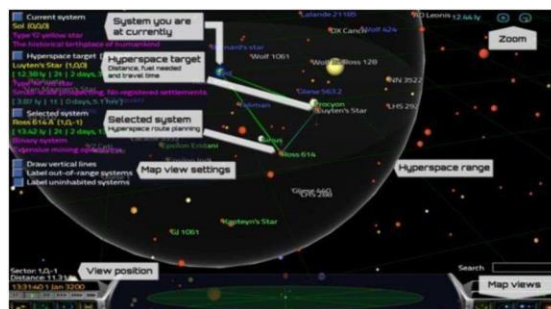


Fig:4.6 : Peersim Analysis

4.1.6 Mininet

Mininet allows users to create virtual networks with hosts, switches, controllers, and links, enabling network researchers and developers to experiment with different network topologies and configurations. However, Mininet itself does not have the capabilities to simulate rocket turning control. Aerodynamic simulations for rockets using Mininet involve complex modeling of fluid dynamics, rocket propulsion, control surfaces, stability, and guidance algorithms. These simulations require software designed specifically for aerodynamics and aerospace applications.

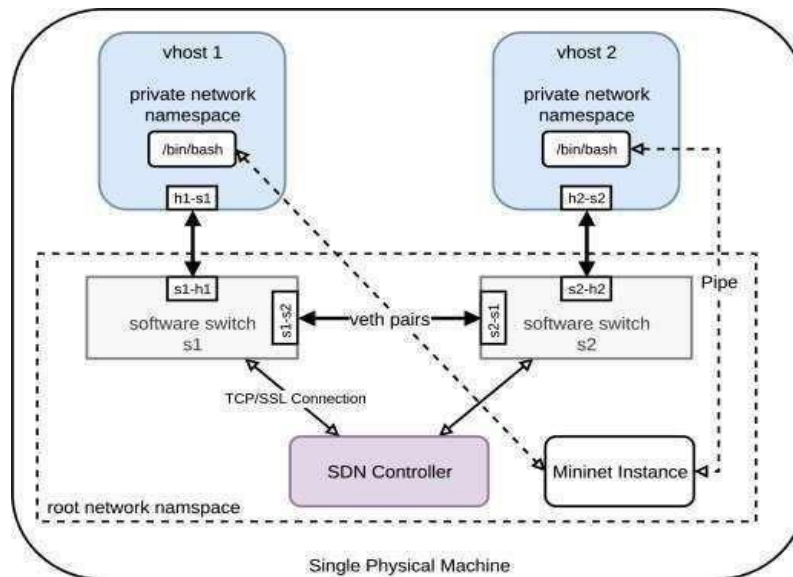


Fig:4.7 : Mininet Flow Chart of VTOL

4.1.7 Divert

"Divert simulator" specifically designed for rocket turning control simulations. It's possible that new software or tools may have emerged since then, or "divert simulator" could be a less-known or niche solution.

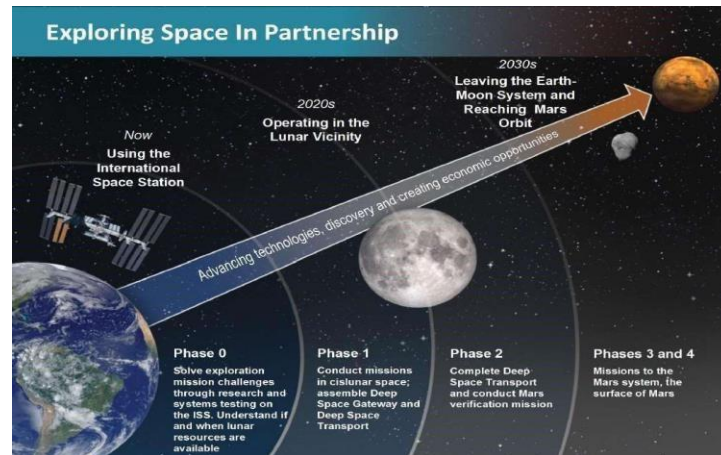


Fig:4.8 : Divert Analysis

4.1.8 Gate Tool

Gate Tool simulation used in aerodynamics or rocket simulations, including aerodynamic thrust vectoring indirectly. Instead, it is primarily used for simulating the passage of high-energy particles (such as gamma rays, electrons, and protons) through materials and is widely used in fields like particle physics experiments.

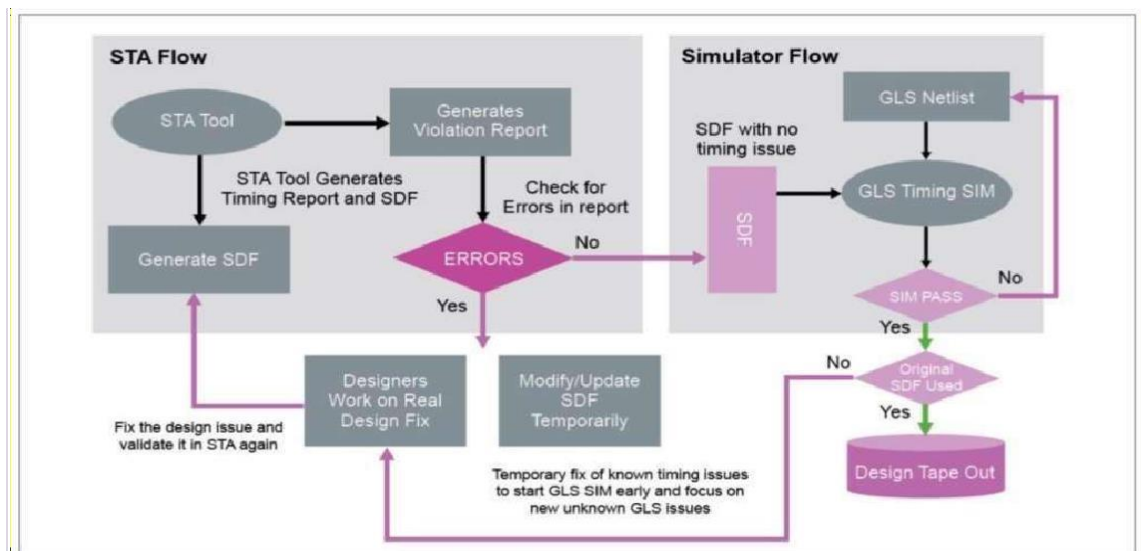


Fig:4.9 : Gate Tool Flow Chart of VTOL

4.1.9 OMNeT++

OMNeT++ is a discrete event simulation framework used primarily for modeling and simulating communication networks, protocols, and distributed systems. It allows users to create network models and evaluate their performance under various conditions and scenarios. OMNeT++ is widely used in academic and research settings for network-related simulations. It is used in simulation of thrust vectoring gimballing angles due to it's modularity, extensibility, visualization, scalability and multiple model of simulations.

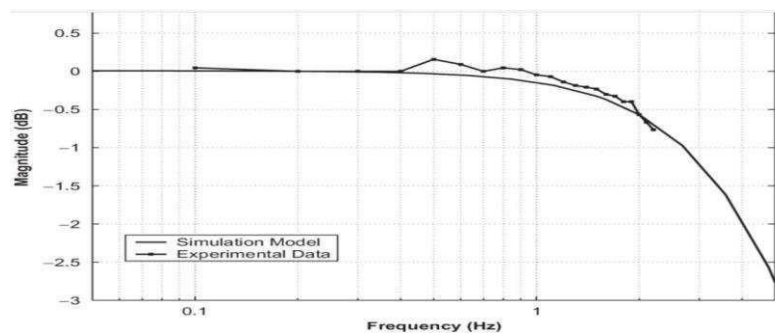


Fig:4.10 : OMNeT++ Flow Graph of Magnitude and Frequency

4.1.10 Jist

Jist (Java In Simulation Time) is a discrete-event network simulator, and it is part of the Jist/SWANS (Scalable Wireless Ad hoc Network Simulator) project. The Jist/SWANS project provides simulation capabilities for wireless ad hoc networks and sensor networks for Synthetic Jet Actuators.

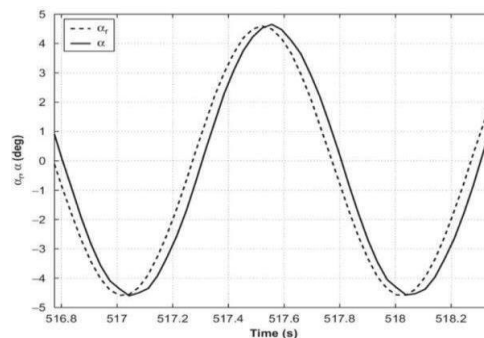


Fig:4.11 : Jist Graph of Angle of Attack

4.1.11 Iteris

"Simulation space" could potentially refer to a specific product, service, or a general concept related to simulations offered by Iteris. They offer services related to traffic management in deep space, intelligent transportation systems (ITS), weather analytics in trajectory.

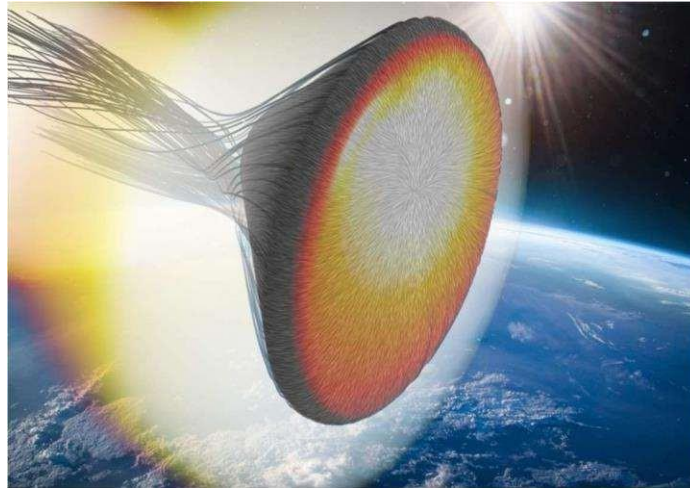


Fig:4.12 : Iteris of Analysis

4.1.12 Groove Net

"GrooveNet" simulation is indeed a specific simulation tool or project related to networking or any other domain, especially used for state transmission fluid injection.

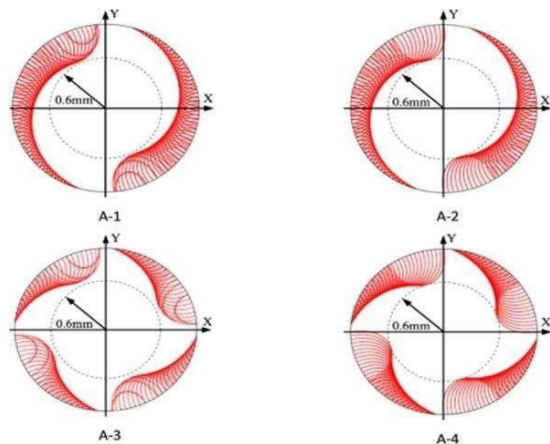


Fig:4.13 : Groove Net Analysis

4.1.13 Open Pana

"Open PANA" might refer to "Open Positioning Interface for Advanced Navigation," which is a project focusing on providing an open-source framework for positioning and navigation systems. However, this project is related to aerospace engineering thrust vector simulation for real time operating modulation.

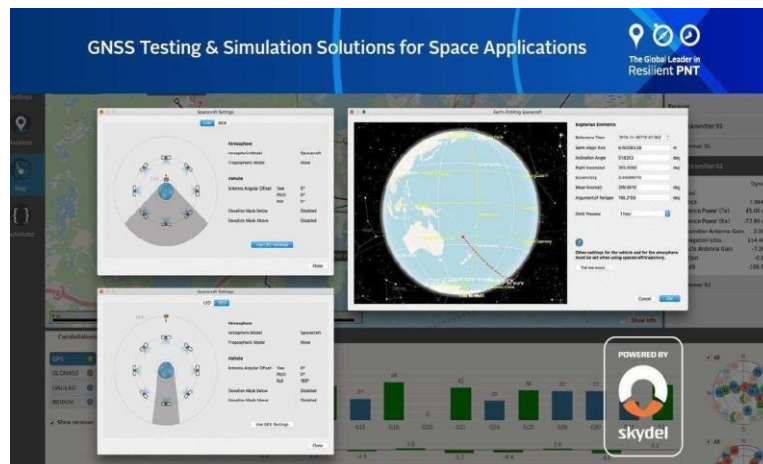


Fig:4.14 : Open Pana Analysis

4.1.14 One Sim

OneSim Simulator of the DTN simulator used in the world is defined as sim. The programming language used in One sim is Java. The most famous DTN routing protocol is offered by the researchers.



Fig:4.15 : One Sim Analysis

4.1.15 PSim

PSIM's power electronics simulator delivers unbeatable simulation speed while producing high-quality system-level results. Even with no prior experience, PSIM's friendly user interface means easy implementation and seamless adoption in any environment in trajectory path.

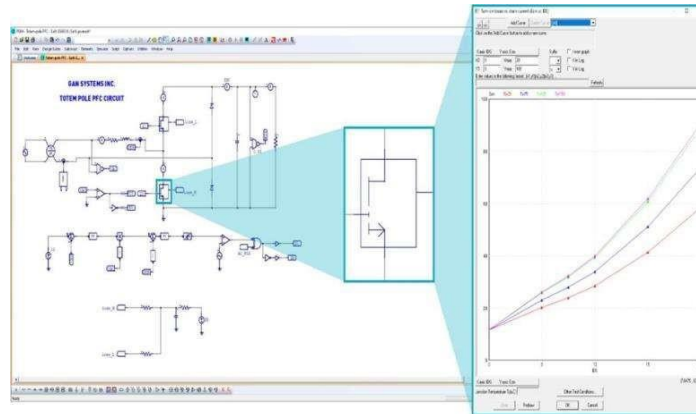


Fig:4.16 : PSim Analysis

4.1.16 Straw

STRAW Simulator is called a Street random Way Point mobility model. Random waypoint model simulation does not need to require origin-destination information. Straw simulator involves determining the vehicle's trajectory at each intersection.

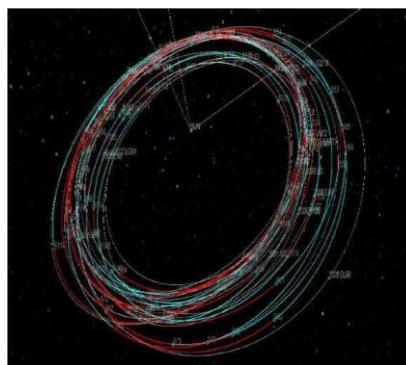


Fig:4.17 : Straw Analysis

4.1.17 Sumo

"Simulation of Urban MObility" (SUMO) is an open source, highly portable, microscopic traffic simulation package designed to handle large road networks and different modes of space path. It is mainly developed by employees of the Institute of Transportation Systems at the German Aerospace Center for gravity pull determination .

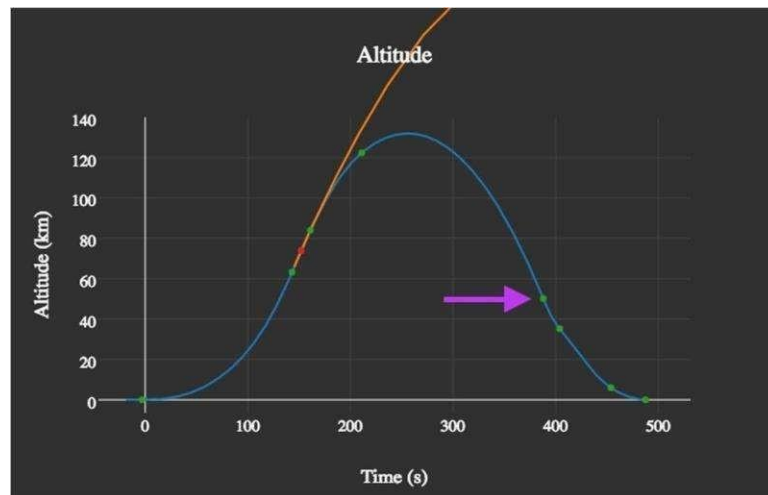


Fig:4.18 : Sumo Graph of Altitude

4.1.18 TinyOS

TinyOS Network simulator progress many event-driven applications structure aimed at embedded schemes and collection of mechanisms enable to build additional applications. We also assist the scholar in overcoming all their subject matter. And also, we provide wideranging support for the bewildering situation of scholars in turning angle in deep space. Tiny OS Network simulator is a open source framework, component based operating system which is particularly designed for low power wireless device.

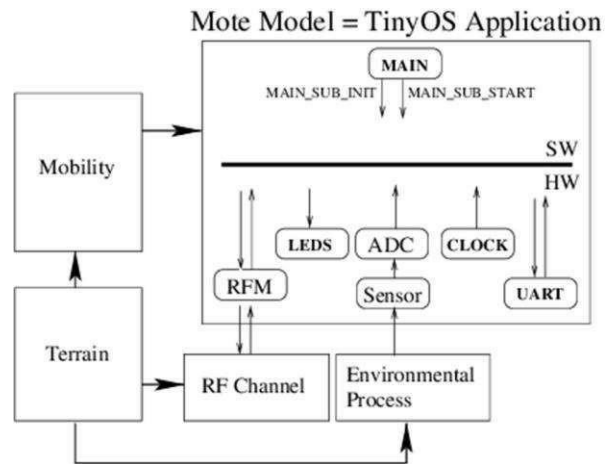


Fig:4.19 : TinyOS Flow Chart of VTOL

4.1.19 Tossim

TinyOS simulation for patent and intellectual property safety of rocket during launching process.

Tossim Simulator is a discrete event simulator framework for TinyOS wireless sensor network. Instead of NS2, we implement Tossim, which captures the network behavior and attraction based on bit granularity, not on the packet level for active guidance in space for rocket. We operate in a sensor network called motes. They are referred to as tiny sensing and computation device for limited communication, computation, and also energy resources.

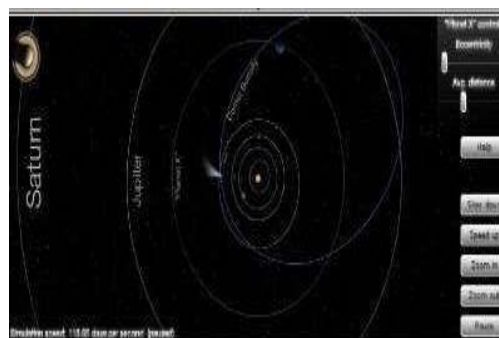


Fig:4.20 : Tossim Analysis

4.1.20 Veins

Veins is an open source framework for running vehicular network simulations. It is based on two well-established simulators: OMNeT++, an event-based network simulator, and SUMO, a road traffic simulator. It extends these to offer a comprehensive suite of models for IVC simulation for control algorithm of rocket into deep space. Space traffic simulation using veins.

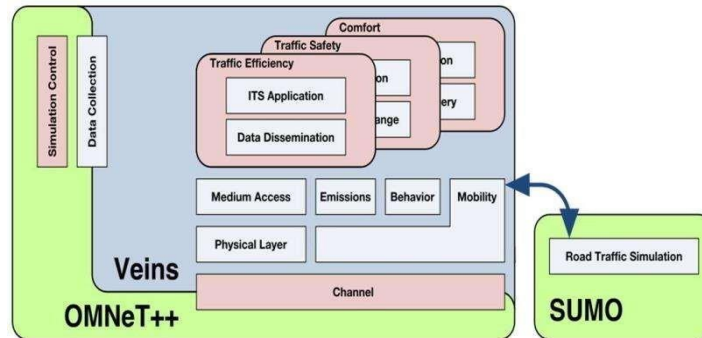


Fig:4.21 : Veins Flow Chart of VTOL

4.1.21 TRaNS

TraNS Simulator Projects refer to space traffic, and network simulation environment is simulation environments which integrate both traffic and network simulators. We also offer based on Springer papers to build a realistic simulation for vehicular ad-hoc networks. Trans referred to as the GUI tool, which incorporates deep space traffic and network simulators for active guidance.

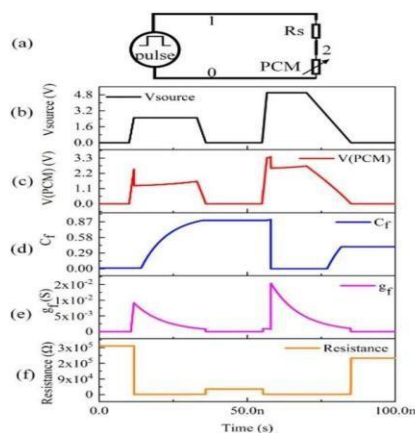


Fig:4.22 : TRaNS Graphical

4.1.22 Kompics

Kompics Simulator is a component model concentrated on building distributed systems by composing protocols 100.0n programmed as event-driven components. We ensure kompics components are reactive state machine which executes concurrently by a set of workers. In general, We support kompics projects with pluggable component schedulers at runtime for research scholars. Consequently, the process of We enables a simulation framework with deterministic debugging and reproducible performance evaluation of the unmodified kompics simulator system that helps in solving of integration problems in error time static analysis.

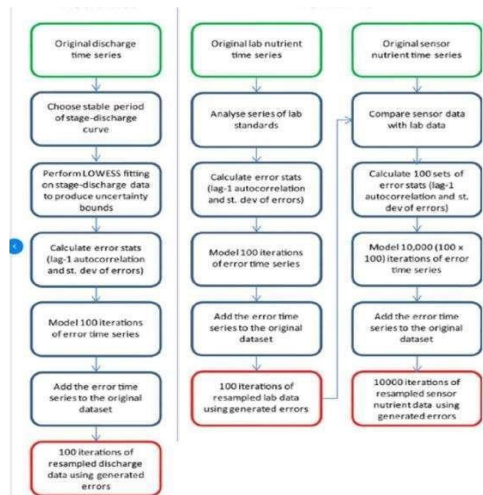


Fig:4.23 : Kompics Flow Chart

4.1.23 Cooja

The Cooja simulation platform as it enables not only the simulation of TBL, but the eventual implementation of this algorithm on real world notes. The Simulation results show that in a limited four rounds of communication, 76.67% of nodes would be localized with an average localization error of 0.5 meters in a 200m by 200m simulation area including 30 blind nodes and 50 anchors for Vernier rocket launch.

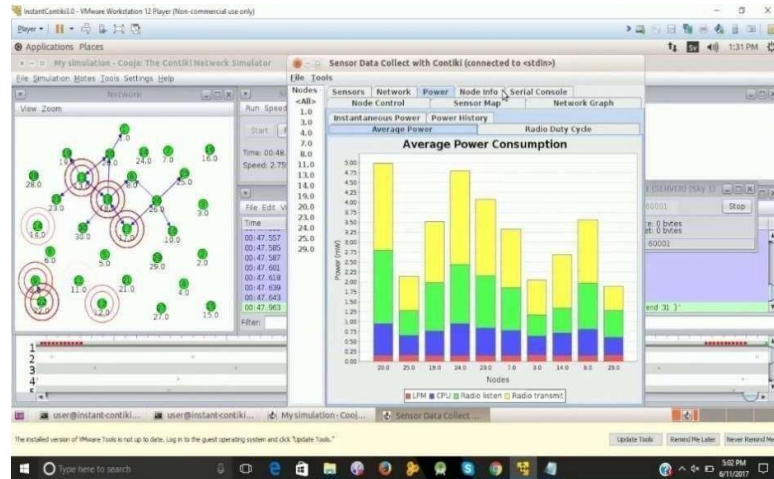


Fig:4.24 : Cooja Graphical Statistic

4.1.24 Petrinet

During the development stage of a space vehicle, instrumented tests are carried out on the ground to prove the operational capacity of each liquid-propellant rocket engine, which is installed in this type of vehicle. The task of elaborating a Test Bench project for a propulsion unit with this application is complex and involves several steps, one of these steps being related to the analysis of this bench capacity to meet the algorithms for the liquid-propellant rocket engine full run of tests, which is considered fundamental for this project's operational success. The method used in this work to carry out the simulation shows the operational response of each module of this architecture, in accordance with the steps contained in the purge algorithm, which allows for analyzing, for each event of the process, the Petri Nets properties, mainly those related to the conservativeness, liveness, deadlock-type, and confusion-type conflicts. The satisfactory results obtained in these simulations suggest that the modules provided for this architecture are sufficient and appropriate for carrying out all the steps contained in the purge algorithm, which will minimize or even eliminate the disorders that may be caused by the presence of foreign elements in the propellant supply lines during the tests with the rocket engine for successful deep space rocket launch.

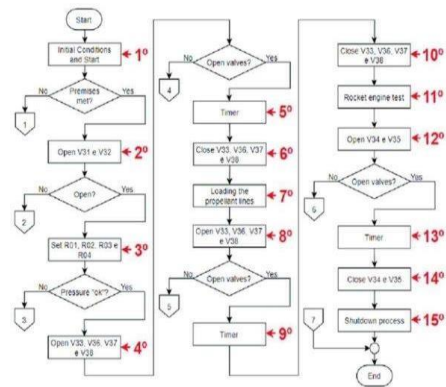


Fig:4.25 : PetriNet Flow Chart

4.1.25 OpenRocket

OpenRocket is a free, fully featured model rocket simulator that allows you to design and simulate your rockets before you build and flying them. Leverage state of the art Six-Degrees-of-Freedom flight simulation with over 50 variables. Analyse all aspects of your simulation with advanced plotting and exporting.

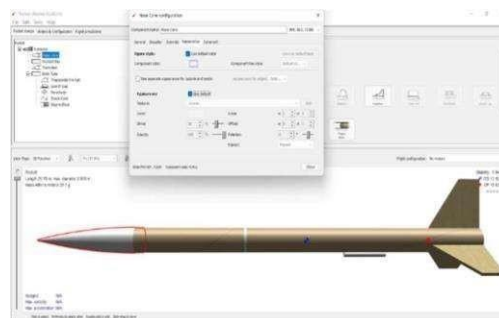


Fig:4.26 : OpenRocket Ansys

4.2 MATERIALS



Fig:4.27 Metallic Component Used in VTOL Rocket



Fig:4.28 : Chemical Component Used in VTOL Rocket

4.2.1 Structural Metallics

- 15 CDV6 : Low carbon steel used in solid rocket motor case.
- M250 : Maraging steel with high strength and high toughness used in booster solid rocket motor case.
- Titanium alloy: (Ti-6Al-4V) used in high pressure gas bottles .
- Aluminium Alloys: used in liquid propellant tanks, engine components, airframe in Reusable Launch Vehicles. Types: AA 2219, AA2014, AA6061.
- Magnesium/ Mg -Lithium alloys: used in upper stage structure like payload adopter, avionic decks, equipment bay structure. vi) Powder metallurgy products: used in nozzle throat for bi -propellant control thrusters.

4.2.2 Composites

- Carbon F / Kevlar F — Epoxy Resin: used in solid motor case, pressure vessel, interstages, payload adopter.
- Carbon C / Silica C — Phenolic Resin: used in ablative liners, nozzle throat inserts.

4.2.3 Thermo-Structurals

- Carbon Fibre/ Silicon Carbide Ceramic Matrix Used in nose-cap of heat-shield, leading edge and control surface of RLV.
- SiC F/SiC Ceramic Matrix Composite: used in high temperature / hot structures.

4.2.4 Thermal Protection System

- Carbon/Carbon Composite: used in nozzle throat, nosecone (SiC Coating).
- Silica tiles: (Silica Fibre in Si gel) used in space shuttle and SRE(capsule) mission.

- Polyurethane foam insulation for cryogenic propellant tanks and subsystems.
- Flexible Reusable Surface Insulation-FRSI Blanket / felt with Teflon coating used in leeward surface of RLV.

4.2.5 Special Materials Used

- Soft magnetic alloy: Fe-Co-V: used in torque motor in spacecraft.
- HED permanent magnet: Sm-Co: used in gyroscope, inertial navigation, guidance & control system, reaction momentum wheel in spacecraft.
- Bimetallics: (SS-Al and SS-Ti) used in Cryosystem for assembly of dissimilar items.
- Opto-electronics: used in photo sensors and photo diodes and photo voltaic devices for power generation in satellites.
- Electro-optics: used in High resolution imaging in Spacecrafts.

4.2.6 Chemicals

- Different coating materials are used for protection and imparting certain characteristics to surfaces, potting of connectors.
- Variety of adhesives/ bonding agents are used in processing, installation of sensors, assembly and integration operations.
- Most of these chemicals are polymers.

4.3 METHODOLOGY

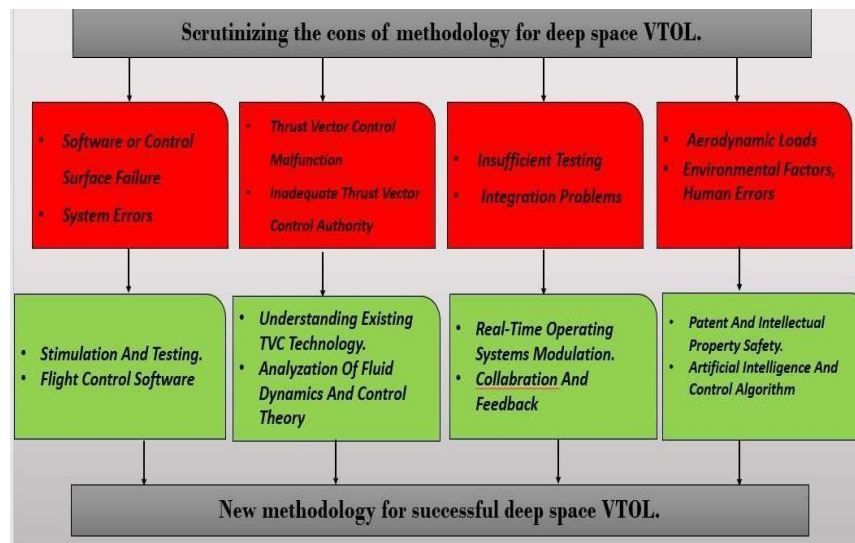


Fig:4.29 : Methodology Flow Chart of VTOL

4.3.1 Nozzle Cfd Validation

A Nozzle is a mechanical device that uses pressure energy and fluid enthalpy to increase the outflow velocity and control fluid flow direction. To obtain the nozzle duct's shock pattern, the flow inside the nozzle must be supersonic with a Mach number greater than one. The device that uses pressure energy and fluid enthalpy to increase the outflow velocity and control fluid flow direction. To obtain the nozzle duct's shock pattern, the flow inside the nozzle must be supersonic with a Mach number greater than one. Experimentally, the shock pattern is obtained for a nozzle with a Mach number 2 and nozzle pressure ratio (NPR) equivalent to 7 and below. For supersonic flow generation, a C–D nozzle is utilized. A nozzle without an expanding component will never produce supersonic air [3]. There are three-dimensional predicted fluid flows; the term one, two, or three-dimensional flow refers to the amount of organized space needed to demonstrate flow. Typically, physical motion appears to be three-dimensional. It is possible to reduce a three dimensional issue to a two-dimensional one and then simplify it to a one-dimensional one.

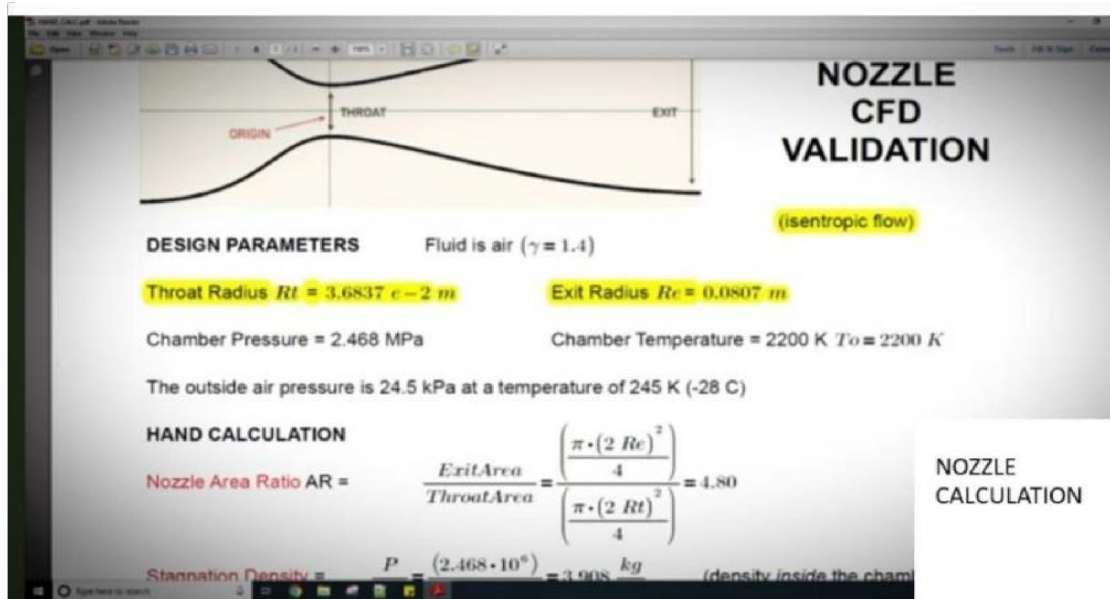


Fig.4.30 : Nozzle Calculation

4.3.2 Throat Radius Calculation

Throat radius calculation are the spontaneous condensation of wet steam often occurs in the steam ejector nozzle, this deteriorates the performance of the steam ejector. In this paper, we take changing the geometric parameters of the nozzle as the focus of our research and construct an internal connection between steam's condensation behaviour and the nozzle's throat radius, the nozzle's divergent section expansion angle, and the nozzle's divergent section length. Our numerical simulation results indicate that an increase in the throat diameter and reduction of the divergent section's expansion angle can inhibit steam condensation behaviour, to a certain extent. In particular, the steam condensation behaviour will disappear at a 0° expansion angle, but it is not affected by the change in the divergent section's length. In addition, the irreversibility that is seen under different changes to the nozzle's structure parameters was investigated and the results show that the entropy generation that is caused by a phase change accounts for a much higher proportion of the total entropy generation than heat transport and viscous dissipation do.

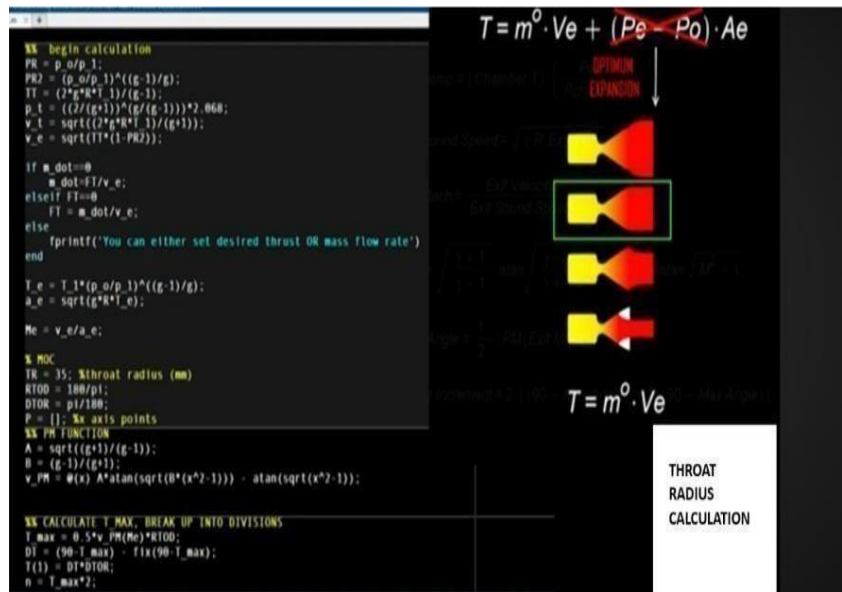


Fig:4.31 Throat Radius Calculation

4.3.3 Vehicle Model

The vehicle model is of length 15 meter , payload capacity is of 5000 kg, diameter is of 1.5 meter round which makes the vehicle more trust controlling In general, determining the weight is a complicated procedure requiring the use of calculus. We'll discuss the general answer at the bottom of this page. This figure shows a simplified version of this calculation which can be used by secondary students. For this figure, we assume that we already know the weight of each of the major parts of the rocket (the nose, recovery system, body tube, engine, and fins). The individual component weight is simply the mass of the component times the gravitational constant, g , which is 32.2 ft/square sec in English units and 9.8 meters/square sec in metric units. The total weight of the rocket is simply the sum of all the individual weights of the components.

We can generalize the addition of component weights and the result is the "discrete" version shown at the lower left of the figure. The zig-zag symbol is the greek letter sigma - which indicates summation. The "i" below the sigma is an index, and the index goes from 1 to some number "n", which is the total number of parts. So this equation says that the weight of the rocket is equal to the sum of the weight of "n" parts.



- Dry Mass: 1360.7 kg
- Fuel Mass: 21491.26 kg
- Payload Mass: 5000 kg
- Length: 15 m
- Diameter: 1.5 m
- C.G Location: 7 m from base

Fig:4.32 Vehicle Model

4.3.4 Landing Speed

The 'first cosmic velocity', known as the orbital velocity, will bring a rocket or other projectile into orbit around the Earth. A slower projectile will fall back to Earth.

The 'second cosmic velocity' is the so-called escape velocity from the Earth: 11.2 kilometers per second. This is the speed a rocket should attain in order to be able to escape from the Earth's gravitational field and fly to other planets. It follows from the laws of orbital mechanics that the escape velocity (11.2 km/s) is equal to the orbital speed (7.9 km/s) multiplied by 1.414 (i.e. by the square root of 2). If a spacecraft travels fast enough it is also possible to leave the Milky Way behind.

The 'third cosmic velocity' is the speed that a spacecraft needs to attain in order to be able to leave our solar system. This solar system escape velocity is about 42 kilometers per second (or 0.014 percent of the speed of light in a vacuum). Again, this is the product of the orbital velocity and the square root of 2. However, the orbital velocity now refers to the speed at which the Earth revolves around the Sun: about 30 kilometers per second multiplied by the square root of 2 equals about 42 kilometers per second. The 'fourth cosmic velocity' is the escape velocity from our galaxy - the Milky Way. It corresponds to about 320 kilometers per second. If you're trying to get to another planet, you'll need a fast-moving rocket to overcome Earth's gravity. To do that, you'd have to speed up to around 25,000 mph. But you'll also need to figure out the best time to leave Earth to get to

that planet. For example, Mars and Earth reach their closest distance to each other about every two years.

It's not that simple. Earth's gravity is still pulling down on the rocket. When a rocket burns propellants and pushes out exhaust, that creates an upward force called thrust. To launch, the rocket needs enough propellants so that the thrust pushing the rocket up is greater than the force of gravity pulling the rocket down. The propellants give the rocket enough energy to boost away from Earth's surface. Because of the pull of Earth's gravity, largest, heaviest spacecraft need the biggest rockets and the most propellant. The exhaust pushes out of a rocket's engine down toward the ground. That's the action force. In response, the rocket begins moving in the opposite direction, lifting off the ground. That's the reaction force. Then, the space plane, a miniature vehicle that is still being developed, demonstrated its ability to perform a series of approach and landing maneuvers that helped it touch down safely 30 minutes later, at 7:40 am local time in India.

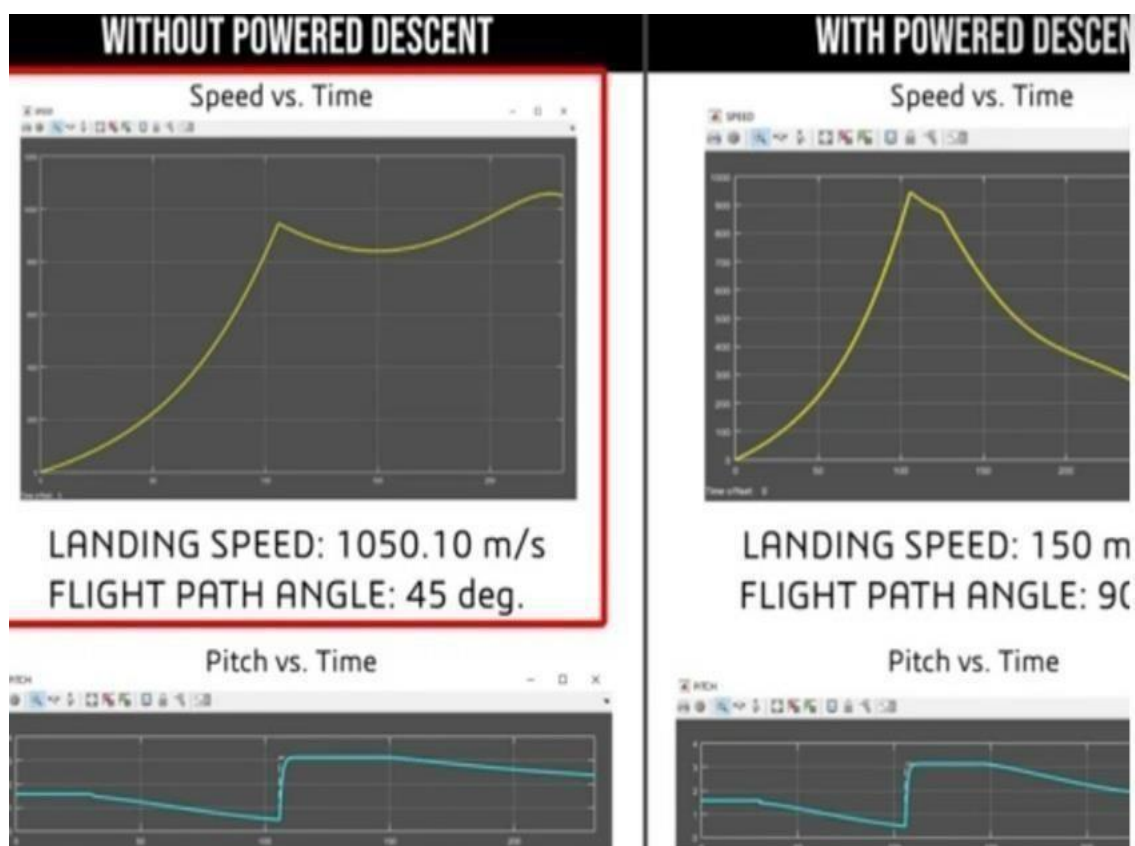


Fig:4.33 : Landing speed

4.3.4 Thrust From Nozzle

The optimal size of a rocket engine nozzle is achieved when the exit pressure equals ambient (atmospheric) pressure, which decreases with increasing altitude. The reason for this is as follows: using a quasi-one-dimensional approximation of the flow, if ambient pressure is higher than the exit pressure, it decreases the net thrust produced by the rocket, which can be seen through a force-balance analysis. If ambient pressure is lower, while the force balance indicates that the thrust will increase, the isentropic Mach relations show that the area ratio of the nozzle could have been greater, which would result in a higher exit velocity of the propellant, increasing thrust. For rockets traveling from the Earth to orbit, a simple nozzle design is only optimal at one altitude, losing efficiency and wasting fuel at other altitudes. Just past the throat, the pressure of the gas is higher than ambient pressure and needs to be lowered between the throat and the nozzle exit by expansion. If the pressure of the exhaust leaving the nozzle exit is still above ambient pressure, then a nozzle is said to be underexpanded; if the exhaust is below ambient pressure, then it is overexpanded. P1 Slight overexpansion causes a slight reduction in efficiency, but otherwise does little harm. However, if the exit pressure is less than approximately 40% that of ambient, then "flow separation" occurs. This can cause exhaust instabilities that can cause damage to the nozzle, control difficulties of the vehicle or the engine, and in more extreme cases, destruction of the engine.

In some cases, it is desirable for reliability and safety reasons to ignite a rocket engine on the ground that will be used all the way to orbit. For optimal liftoff performance, the pressure of the gases exiting nozzle should be at sea-level pressure when the rocket is near sea level (at takeoff). However, a nozzle designed for sea-level operation will quickly lose efficiency at higher altitudes. In a multi-stage design, the second stage rocket engine is primarily designed for use at high altitudes, only providing additional thrust after the first-stage engine performs the initial liftoff. In this case, designers will usually opt for an overexpanded nozzle (at sea level) design for the second stage, making it more efficient at higher altitudes, where the ambient pressure is lower. This was the technique employed

on the Space Shuttle's overexpanded (at sea level) main engines (SSMEs), which spent most of their powered trajectory in near-vacuum, while the shuttle's two sea-level efficient solid rocket boosters provided the majority of the initial liftoff thrust. In the vacuum of space virtually all nozzles are underexpanded because to fully expand the gas's the nozzle would have to be infinitely long, as a result engineers have to choose a design which will take advantage of the extra expansion (thrust and efficiency) whilst also not adding excessive weight and compromising the vehicle's performance. Additionally, as the temperature of the gas in the nozzle decreases, some components of the exhaust gases (such as water vapour from the combustion process) may condense or even freeze. This is highly undesirable and needs to be avoided. These can be advantageous, since a magnetic field itself cannot melt, and the plasma temperatures can reach millions of kelvins. However, there are often thermal design challenges presented by the coils themselves, particularly if superconducting coils are used to form the throat and expansion fields.

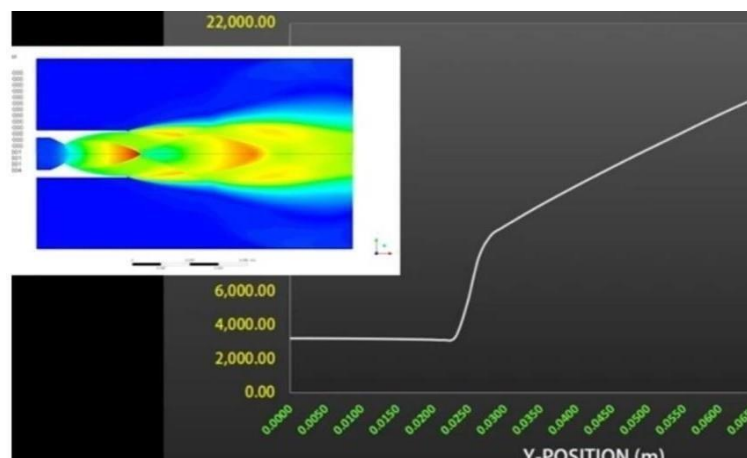


Fig:4.34 : CFD of Thrust From Nozzle

4.3.6 Nozzle Wall Analysis

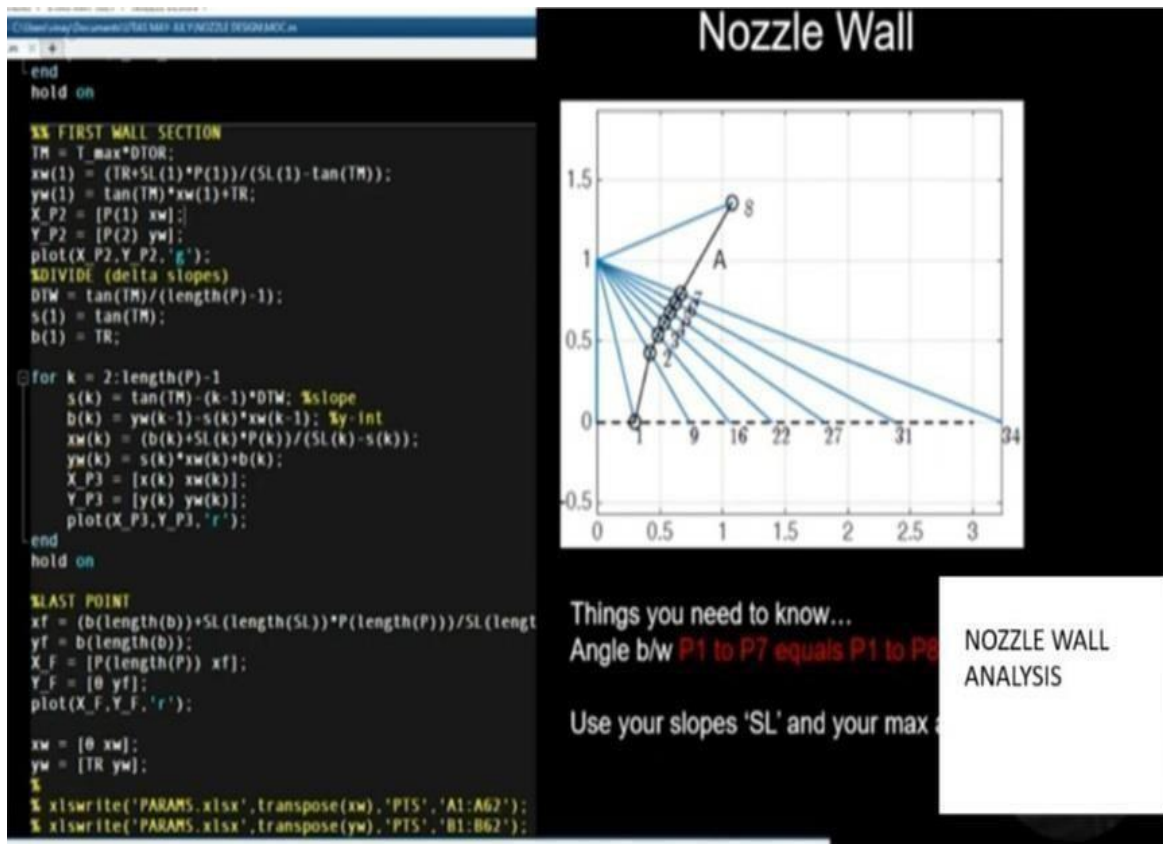


Fig. 4.35 : Nozzle Wall Analysis Coding

The nozzle accelerates the combustion products as the static pressure and temperature of the gases systematically drop in flowing to the exit. Modeling this as a onedimensional, isentropic flow process reveals that the flowrate per unit crosssectional area must reach a maximum (throat) where the gases reach the speed of sound in the flow; hence, the nozzle must be converging-diverging in shape. Both P_c acting against the injector face area axially exposed by the throat and static pressure acting against the divergent nozzle walls produce axial thrust.

The relationship between expansion ratio and the internal nozzle pressure ratio (or the ratio at any internal expansion ratio) for the one-dimensional, isentropic nozzle flow.

Since the gas velocity downstream of the throat is supersonic, overexpanded flows adjust to ambient pressure via oblique shock waves triggered

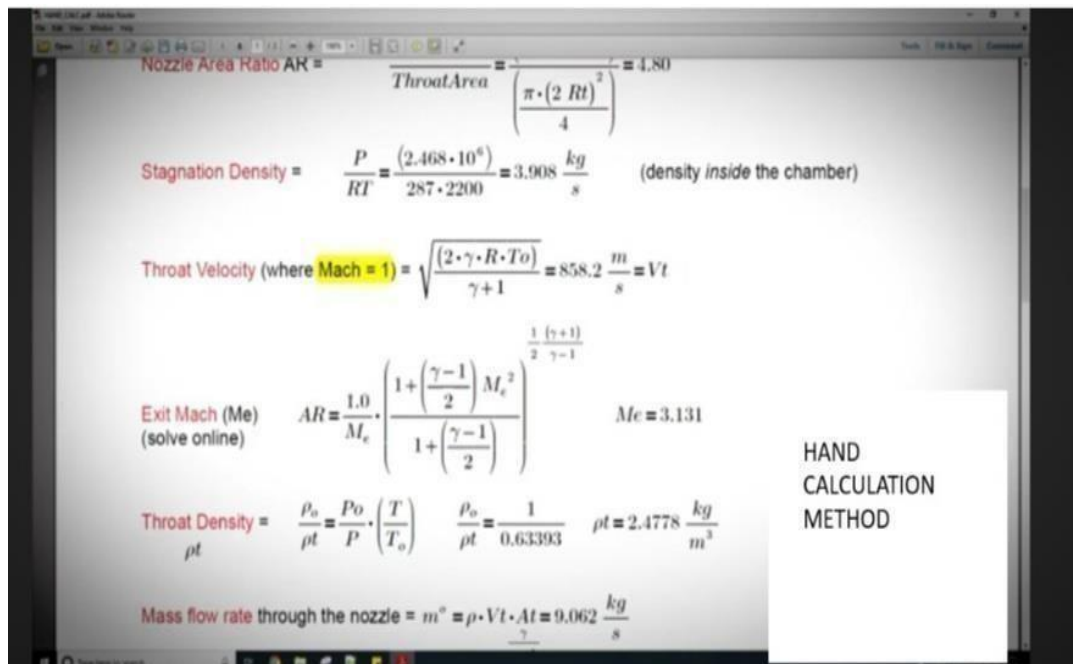
by the subsonic boundary layer thickening in response to the higher ambient back-pressure. Practical nozzles stabilize these shocks very near the exit, because shock oscillations can induce destructive side loads and locally high heating on the nozzle assembly. Both P_c acting against the injector face area axially exposed by the throat and static pressure acting against the divergent nozzle walls produce axial thrust.

The relationship between expansion ratio and the internal General industry guidelines exist for the subsonic nozzle entrance contour such that the shape of the sonic surface at the throat will approximate that commonly used in the Method of Characteristics (MOC) analysis applied downstream to the wall contour for the inviscid, supersonic expansion to a design exit pressure.

Although the above simplified flow model results are useful in predicting the overall effects of the major nozzle design variables, the real nozzle flow is two-dimensional, sub-to- supersonic in response to the local wall contour, and imbedded in a subsonic, usually turbulent boundary layer which determines the distribution of heat transfer to the wall, critical to the design of nozzle cooling. hence, the nozzle must be converging-diverging in shape.

These techniques produce an internal contour which rapidly turns the flow outward (expansion) immediately downstream of the throat and then inward with further expansion providing a shockfree turning to within 5-15 degrees of the axial direction. This results in a "bell" nozzle contour (Fig. 13) which is typically about 80% shorter than a 15 degree conical shape of the same expansion ratio and which only sacrifices 1-2% loss from the ideal .

4.3.7 Hand Calculation Method



The image shows a screenshot of a hand calculation method for rocket trajectories. It displays several equations and their results:

- Nozzle Area Ratio AR**:
$$AR = \frac{ThroatArea}{\left(\frac{\pi \cdot (2 \cdot Rt)^2}{4} \right)} = 4.80$$
- Stagnation Density**:
$$\frac{P}{Rt} = \frac{(2.468 \cdot 10^6)}{287 \cdot 2200} = 3.908 \frac{kg}{s} \quad (\text{density inside the chamber})$$
- Throat Velocity (where Mach = 1)**:
$$V_t = \sqrt{\frac{(2 \cdot \gamma \cdot R \cdot T_o)}{\gamma + 1}} = 858.2 \frac{m}{s} = V_t$$
- Exit Mach (Me) (solve online)**:
$$AR = \frac{1.0}{M_e} \cdot \left(\frac{1 + \left(\frac{\gamma - 1}{2} \right) M_e^2}{1 + \left(\frac{\gamma - 1}{2} \right)} \right)^{\frac{1}{2} \cdot \frac{(\gamma + 1)}{\gamma - 1}} \quad M_e = 3.131$$
- Throat Density**:
$$\frac{\rho_o}{\rho_t} = \frac{P_o}{P} \cdot \left(\frac{T}{T_o} \right) \quad \frac{\rho_o}{\rho_t} = \frac{1}{0.63393} \quad \rho_t = 2.4778 \frac{kg}{m^3}$$
- Mass flow rate through the nozzle**:
$$\dot{m} = \rho \cdot V_t \cdot A_t = 9.062 \frac{kg}{s}$$

A white box on the right side of the image contains the text: **HAND CALCULATION METHOD**

Fig:4.36 : Hand Calculation Method

Four new methods of analytical calculation of rocket trajectories are presented. The analytical methods have at least three advantages. First, the equations show explicitly the influence on the rocket trajectory of all parameters in the model. Second, the analytical solutions can be calculated with unlimited accuracy, within the domain of validity of the model. Thirdly, in the case of the present models, the numerical computation of analytical results can be performed in a few seconds on an ordinary PC, and thus computational cost is almost negligible. Analytical and numerical methods have common features; for example, they can be extended from a single stage to a multistage rocket by taking the final conditions of the preceding stage as the initial conditions for the next stage.

The numerical methods that dominate the research literature on rocket trajectories account for up to thirteen effects listed below in the next paragraph. The analytical methods that appear mostly in textbooks include three or four effects.

4.3.8 Beginning Rocket Modelling In Ansys Cfx

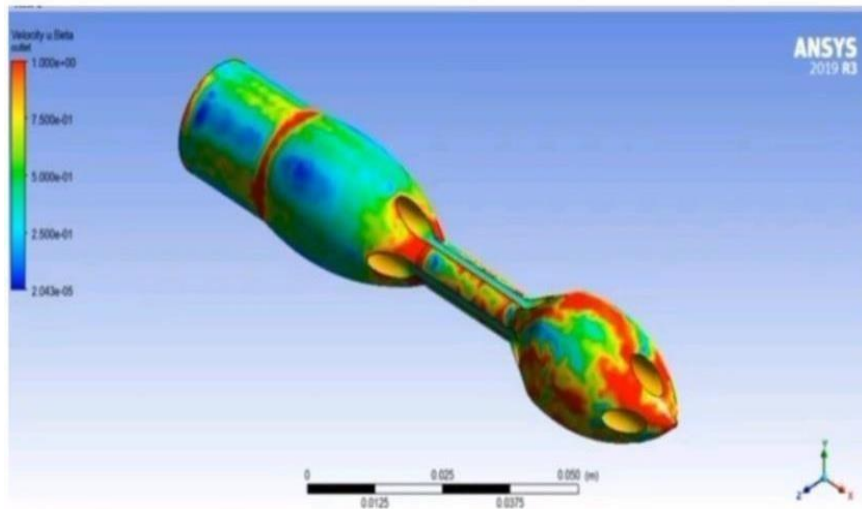


Fig:4.37 : Rocket VTOL In Ansys CFX

Rocket propulsion is a continuous process as long as there is propellant to be expelled. As the rocket's engines continue to burn propellant and expel it at high speed, the rocket experiences a continuous thrust, allowing it to overcome the force of gravity and achieve acceleration. • It's important to note that rocket propulsion doesn't rely on the atmosphere for thrust generation, unlike some other forms of propulsion like jet engines, which need air to operate. • This is why rockets can operate in the vacuum of space, making them the primary means of propulsion for spacecraft and vehicles designed for space exploration. • The efficiency and performance of rocket propulsion depend on various factors, including the design of the engine and nozzle, the type of propellant used, and the overall mass ratio of the rocket (the mass of the fully fueled rocket compared to the mass of the empty rocket). • Engineers continuously work on improving rocket propulsion systems to achieve higher thrust-to-weight ratios and increase the payload capacity and efficiency of space missions • The thrust acting on the rocket

is calculated using the mass flow rate of flue gas ($\dot{m}$), nozzle exit velocity (V_e) and pressure drop across the nozzle ($P_e - P_0$)

4.3.9 Nozzle Velocity Streamline

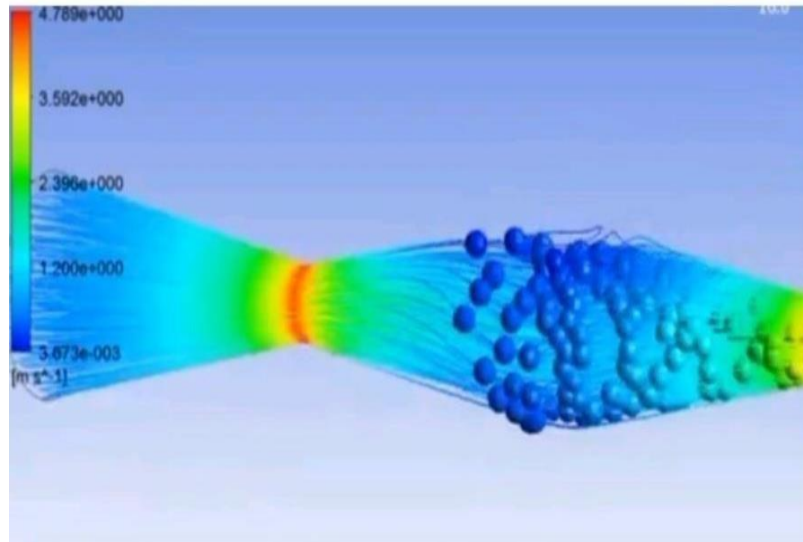


Fig:4.38 : Nozzle Velocity Streamline

The main function rocket nozzle is to maximize the speed of the combustion gases produced by the fuel in order to produce the highest thrust. The mass flow rate and engine output pressure both affect how much thrust the engine can generate. The significance of these three variable flows depends on how the rocket nozzle is designed. The following equations are intended for the nozzles' adiabatic, reversible, isentropic, and one dimensional flow. However, under real-world conditions, multidimensional currents and viscous effects, such as the wall boundary layer and the separation of flow, significantly alter the nozzle flow, as discussed by a number of researchers. The overall thrust and a specific impulse for a rocket propulsion system.

The present simulation is about the rocket engine nozzle via ANSYS Fluent. A rocket engine nozzle is a type of propellant nozzle. This means that the internal energy of the gas is converted into a driving force and forms a high-velocity fluid jet.

This nozzle is used in rocket engines to expand and accelerate the gases produced by burning fuels in propellants. The exhaust gases exit the nozzle at supersonic speed.

The operating mechanism of these missile nozzles is that the gases enter them at subsonic speeds. As the path becomes narrower, the gas is forced to accelerate until the throat section (with the lowest cross-sectional area), where the linear velocity of the flow to the speed of sound arrives.

The cross-sectional area increases again after passing through the throat area, and the gas expands. This linear velocity rises continuously to the point that its speed exceeds the sound velocity.

The present geometry is designed in a 2D model via Design Modeler. The computational zone is the interior of a rocket engine nozzle, the initial part of which is convergent-divergent and has a throat area.

In this project, we use the Density-based solver. The gas flow inside the rocket is compressible, and its density value is based on the ideal gas. The gas stream enters the rocket nozzle with a gauge pressure of 2268000 Pascal and exits at a gauge pressure of 39365 Pascal.

After calculation, 2D contours related to temperature, pressure, velocity, density, and enthalpy and 2D streamline are obtained.

The contours show that the gas flow accelerates significantly after passing through the throat area. This means that when the gas flow reaches the throat area, its speed increases and its pressure is broken due to the reduction of the crosssectional area

4.3.10 Stimulation Of Liquid Rocket Engine

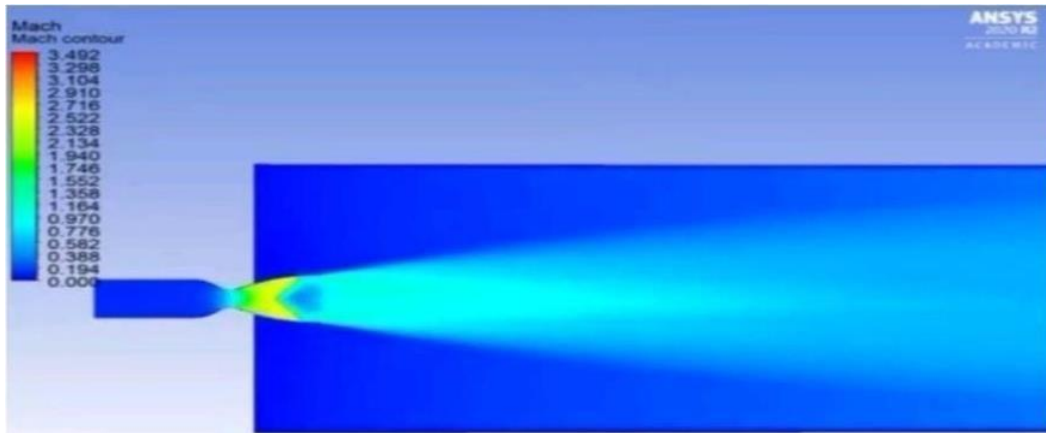


Fig:4.39 : Simulation of Liquid Rocket Engine

LRE uses hypergolic propellants (fuel and oxidizer) and combustion occurs when the fuel and oxidizer come in contact with the thrust chamber. The LRE considered is capable of delivering 630 kN thrust at a chamber pressure() of 6.4 Mpa. (LREs) need to be hot tested on the ground, in order to make them flight-worthy. Ground hot tests are critical, expensive, and involve considerable human efforts in acquiring the critical measurement parameters. Measurement sensors are prone to failure due to the hazardous propellant environment and are vulnerable to noise (internal and external) during the LRE ground hot tests. The usage of redundant sensors is not a viable solution for space applications due to cost, power, weight, and space constraints. Data-driven Soft Sensors (SS) are being used in different industrial processes. SS can provide an effective alternative and economical solution for space applications. The objective of the proposed work is to implement a suitable datadriven soft sensor for estimating three critical measurement parameters namely, turbine speed, chamber pressure , and propellant flow rate of LRE. Long Short-Term Memory (LSTM) networks are capable of learning order dependence in sequence prediction problems and are well-suited to make predictions based on time series data. As the selected LRE test data contain order dependence sequences, LSTM is well suited for the estimation of critical measurement parameters. LSTM-based soft sensor (LSTM-SS) was developed and trained using a large sample set of 59,80,000 data points

collected over a period of 12 years of LRE ground hot tests. The maximum root mean square error (RMSE) of 6.06% was obtained for propellant flowrate estimation, whereas the minimum RMSE of 0.22% for chamber pressure and RMSE of 0.87% for turbine speed were obtained. The obtained results show that the designed LSTM-SS has superior performance and better generalization for practical use. LSTM networks have the property of selectively remembering patterns for a long duration of time, just like the human brain. Given that the selected LRE test data contain start and end transients in addition to steady-state behavior, LSTM was preferred for the desired soft sensor design.

The Mutual Information (MI) technique was adopted to detect both linear and nonlinear relationships between the source and target parameters. The top ten measurement parameters with high MI scores for the three target variables were selected as input parameters for training the designed LSTM-SS model.

The Savitzky-Golay (SG) filter [9] was selected to de-noise the obtained parameters. It is a digital filter that increases the precision of the data by smoothing the data points without distorting the signal.

Careful tuning of the hyperparameters achieved a minimum RMSE of 0.22% for the critical chamber pressure estimation, which qualifies the LSTM-SS for practical applications.

4.3.11 Lox Ansys Fluent

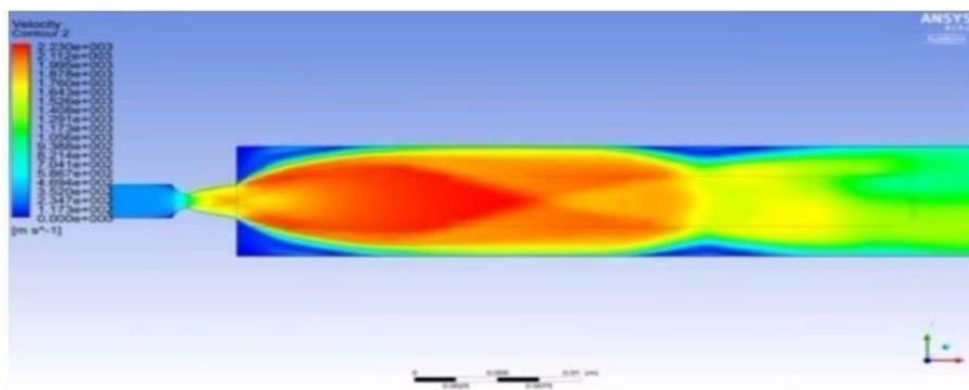


Fig:4.40 : Lox / Methane CFD

Future launchers will use rocket propulsion systems burning CH_4/LOx at supercritical conditions. Despite this new trend there is a lack of experimental data and numerical studies in literature using methane-oxygen combustion at these extreme conditions. Until now, only H_2/LOx injection and combustion has been investigated deeply. The aim of this investigation is the numerical study of the CH_4/LOx injection, mixing and combustion in liquid rocket engines with shear coaxial injectors, at supercritical conditions. Properties as isobaric specific heat and density have been calculated using different equations of state, and they have been compared with ideal gas and NIST data. The Soave Redlich-Kwong real gas model has been implemented to model the physical properties of the species in the single step methane/oxygen reacting mixture. An E.D.M. model describes the turbulence-chemical kinetics coupling. The use of real gas equation of state is computationally expensive so simulations have been also performed by the implementation of NIST data at 15MPa in the material database. The two approaches have been compared positively. The effect of activating LES model in cold flow simulations has been investigated.

4.3.12 Rocket Starting Simulation

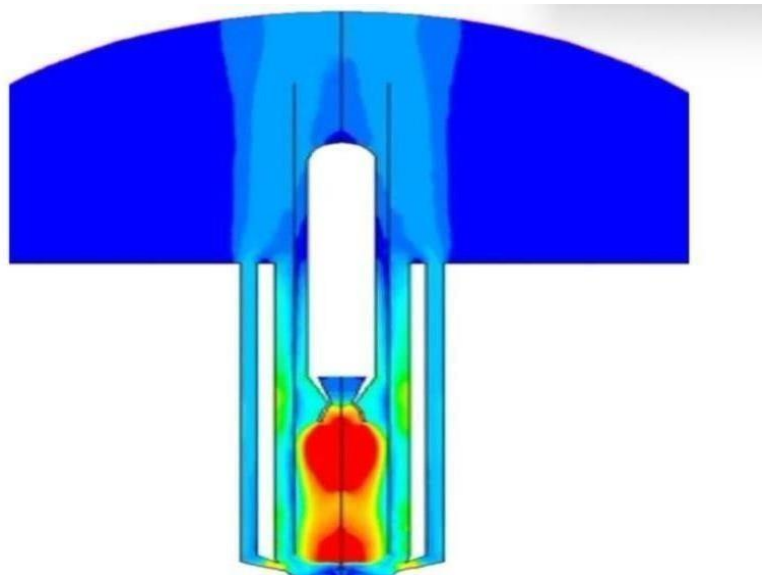


Fig:4.41 : CFD of Rocket Starting Simulation

The launch vehicle consists of three stages stacked on top of each other, plus 9 small solid-fuel rockets strapped to the outside of the first stage. Each of the four solid rocket motors is 1 meter (3.28 feet) in diameter and 13 meters (42.6 feet) long; each contains 11,765 kilograms (25,937 pounds) of hydroxyl-terminated polybutadiene (HTPB) propellant and provides an average thrust of 485,458 newtons (109,135 pounds) at sea level. The casings on the solid rocket motors are made of lightweight graphite epoxy. At the very top of this "stack" is the spacecraft, inside a protective metal shell. Mars Odyssey's main structure, or bus, is 1.7 meters (5.6 feet) tall, 2.6 meters (8.5 feet) wide and 2.2 meters (7.2 feet) deep. At launch it will weigh 725 kilograms (1,598 pounds), consisting of the 332-kilogram (731-pound) dry spacecraft plus 349 kilograms (769 pounds) of fuel.

4.3.13 LES Simulation of Turbulent Flames

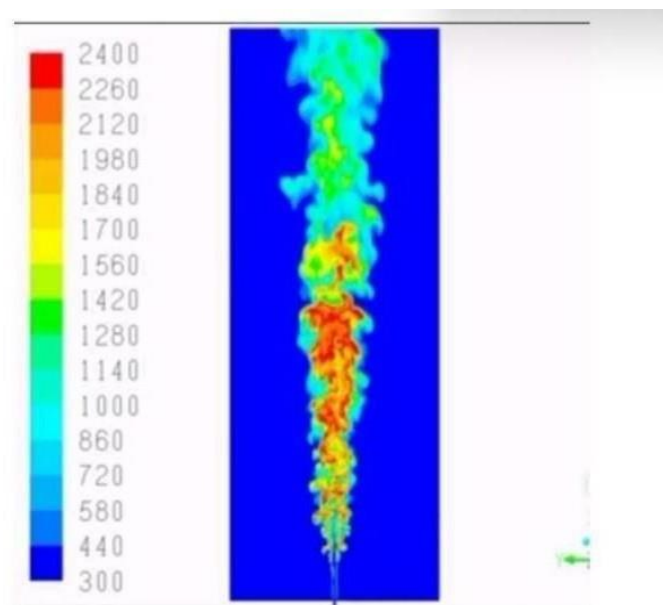


Fig:4.42 : LES Simulation of Turbulent Flames CFD

Turbulent flames, including jet flames (turbulent conical), bluff-body flames, and swirling premixed flames, are now reviewed with respect to static and dynamic stability. Turbulent conical jet flames in premixed cases have been significantly documented. Lyons [379] reviewed the understanding of turbulent, lifted

hydrocarbon jet flames and the conditions under which they stabilize. The authors reviewed the experiments which focused on the importance of several effects: partial premixing, edge flames, local extinction, streamline divergence, and large-scale structures. Mansour [380] investigated the stability characteristics of partially premixed turbulent lifted methane flames. Lifted, attached, blowout, and blowoff regimes were studied. The authors concluded from the experimental measurements that the mixture fraction field of the stabilization region was characterized by a certain level of mean and RMS fluctuations, suggesting that the stabilization mechanism was likely to be controlled by propagation. Turbulent flames produced by the combustion of hydrocarbon liquid or gas escaping from a source under pressure. These fires produce significant heat radiation and can cause structural failure on surfaces contacting the flame. This can give rise to other problems that can escalate the condition. Jet and spray fires vary according to the type of fuel, the conditions giving rise to the escaping fuel, including fuel pressure and leak size, duration of the leak, proximity to personnel, equipment, structures, and the external conditions of wind and degree of enclosure. Jet liquid fires can produce significant quantities of black smoke, which can lead to other problems relating to reduced visibility, toxic inhalation, or suffocation. The fully developed portion of the turbulent flame propagation process in an engine (i.e. 10-90% burned) has been observed to scale almost linearly with engine speed.³¹ This fact, combined with the observation that the turbulence intensity is also a linear function of engine speed, implies that the turbulent flame speed is approximately a linear function of the turbulent intensity. This linear relationship between turbulent flame speed and intensity has been verified in studies of turbulent combustion in bombs,^{28,32} and engines.^{7,9} The most extensive combustion bomb work is that of Sokolik et al.^{28,33-39} Figure 34 shows the approximately linear relationship which exists between the turbulent flame speed and the turbulent intensity. The sudden drop in turbulent flame speed for large values of the turbulent intensity is attributed to the extinction of the flame due to the high turbulence levels. Lancaster et al.⁹ present their results for a CFR engine in terms of a flame speed ratio defined as the ratio of the turbulent flame speed to the laminar flame speed, Fig. 35. These researchers measured the flame speed ratio as a function of compression ratio and showed no dependence existed. This implies that the turbulent scale is not important in determining the turbulent flame

velocity under normal operating conditions. Perhaps a better parameter for correlating data of this sort is the turbulent Reynolds number ($u'\lambda/\nu$) which Andrews et al.⁴ used in their review paper. The turbulent Reynolds number. In such applications, because of the confinement, there is strong recirculation and large-scale mixing, making the distributions of species concentrations and temperature quite complex, which, in turn also affects the distribution of radiative properties.

4.3.14 Rocket Speed Analysis

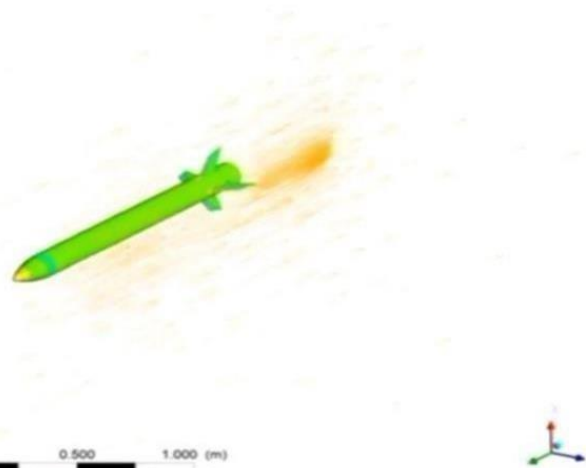
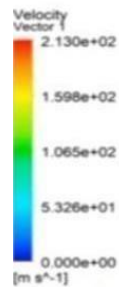


Fig:4.43 : Rocket Speed Analysis

This is the speed a rocket should attain in order to be able to escape from the Earth's gravitational field and fly to other planets. It follows from the laws of orbital mechanics that the escape velocity (11.2 km/s) is equal to the orbital speed (7.9 km/s) multiplied by 1.414 (i.e. by the square root of 2). Alternately a monopropellant fuel may be passed through a catalyst plate to produce the required chemical reaction. In this class of motor separate fuel and oxidiser tanks

are required along with turbine or similar pumps to generate required fuel flow rates. In many cases the fuel will need to be pressurised or stored in cryogenic tanks as it is not liquid at room temperature. The big advantage of liquid fueled engines is the ability to control thrust by being able to vary fuel flow rates and to be shut down and then restarted as required.

4.3.15 Barrel Shock

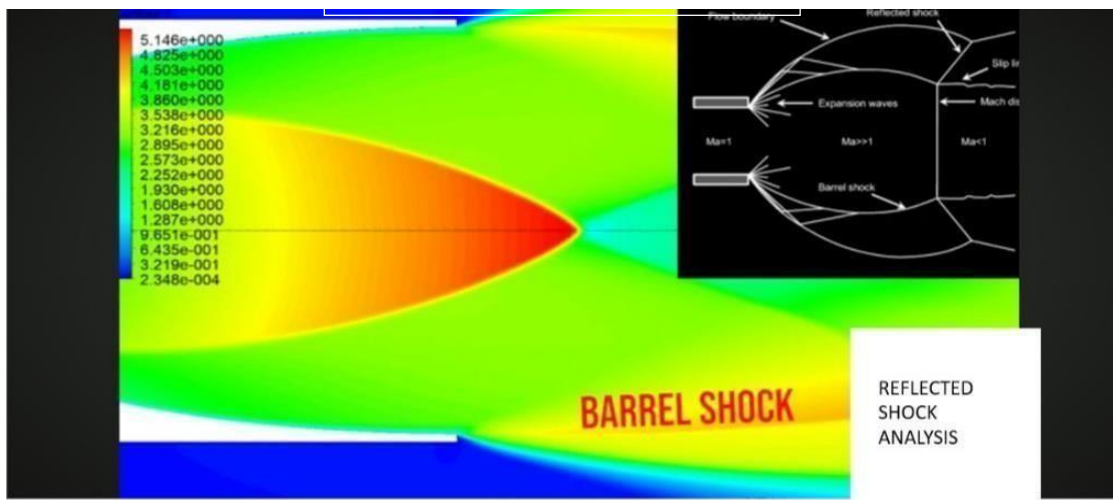


Fig:4.44 : Barrel Shock CFD

Two-dimensional supersonic flows out of rocket nozzles are one of three flow types: over-, perfectly-, or under-expanded. In under-expanded flows, an expansion fan is centered at the top and bottom tip of the rocket nozzle. When the waves from the expansion wave cross through the centerline and intersect the free boundary, the waves are reflected as compression waves. For higher exit-to-ambient pressure ratios, the compression waves coalesce and eventually form a barrel shock. The purpose of this study was to use the Method of Characteristics (MOC), a mathematical procedure for solving hyperbolic partial differential equations, to simulate the formation of the barrel shock. A MOC code was developed in the Python programming language to accomplish task. Results of the MOC code compared favorably with CFD results. The tests were carried out with the spark timing adjusted to the maximum brake torque timing in various equivalence ratios and engine speeds for gasoline and natural gas operations. In

this work, the lower heating value of gasoline is about 13.6% higher than that of natural gas. Based on the experimental results, the natural gas operation causes an increase of about 6.2% brake specific fuel consumption, 22% water temperature difference between outlet and inlet engine, 3% exhaust valve seat temperature, 2.3% brake thermal efficiency and a decrease of around 20.1% maximum brake torque, 6.8% exhaust gas temperature and 19% lubricating oil temperature when compared to gasoline operation. The results also revealed that, over the entire range of engine speed and equivalence ratio, the exhaust gas temperature and the lubricating oil temperature for gasoline operation higher than that of natural gas operation while the exhaust valve seat temperature for natural gas operation is higher. Jet injection has the potential to address many of the above mentioned challenges associated with hypersonic flight. Often, the requirements are conflicting. For example, the requirements for fuel injection include weak shocks for reduced drag and recirculation, enhanced vorticity for mixing and increased penetration for fuel dispersion. However, fluidic control of drag and or heat transfer requires reduced vorticity and penetration to maintain the cooling fluid near the surface. Reaction control jet application requires strong shocks and the associated highpressure recirculation regions to generate force amplification. The flowfield generated by transverse injection into a high-speed flow has been the subject of numerous investigations 17-21. The flow field generated by injection through a circular orifice is shown in Fig. 122. As indicated the flow is characterized by numerous shocks and secondary flow structures. The first flow feature encountered in the streamwise direction is the interaction or bow shock produced as a result of the freestream impacting on the injector streamtube. For injector configurations, where o/d is on the order of one or more, a separation region and lambda shock form upstream of the injector port. A horseshoe vortex forms between the jet and the interaction shock.

After entering the freestream, the underexpanded jet undergoes a rapid Prandtl-Meyer expansion surrounded by a barrel shock. A shock wave normal to the jet path known as the Mach disk, terminates the barrel shock, and compresses the flow to the effective back-pressure. Downstream of the Mach disk, a counter rotating vortex pair forms within the jet plume. Wake vortices are also formed. The plume vorticity and turbulent mechanisms induce the required large scale mixing

4.3.16 NOZZLE FLOW



60

The flow rate for a given nozzle can be calculated by the following formula

$$Q = K(P)^n$$

Q= Flow rate

K = K factor for nozzle

p = Pressure differential at the nozzle n = Is a constant that depends upon the spray pattern type.

The K factor is a unique constant for that particular nozzle which should be listed in the nozzle data table.

For many nozzles n = 0.5 which means the quotation simply becomes

$$Q = K\sqrt{P}$$

This is commonly used to apply to all nozzle but it is in fact erroneous to do so for some nozzles. In particular non spiral design full cone nozzles and wide angle full cone nozzles will have an n exponent of 0.46 or 0.44.

A further tip is to ensure that the K factor is in the correct units. Whilst it is technically a unit less constant it will depend upon whether metric or imperial units are being used for P and Q. There is a metric K factor and an imperial K factor for each nozzle.

So caution needs to be exercised when looking at K factors.

Specific gravity

If the fluid is heavier or lighter than water this too must be compensated for when calculating flow rates. Heavier fluids will experience a lower flow than water and

$$\frac{Q_2}{Q_1} = \sqrt{\frac{SG_1}{SG_2}}$$

Q1 = Flow rate for a fluid of Sg

Q1 = Flow rate for fluid of SG2

Q2= Flow rate for fluid of SG2

When using nozzle flow rate charts that list water flow rates one can obtain the flow rates for different fluids by rearranging the equation above and setting SG1 to be 1 (for water) and using the Q1 flow rate from the chart.

$$Q_2 = Q_1 \frac{1}{\sqrt{SG_2}}$$

What is interesting to note is that heavier than water fluids will spray less volume of fluid through a spray but the weight of the spray will still be heavier. This can be seen from the equation above as the flow rate (volume) is reduced by a 1/root SG factor where as the fluid weight of that spray will obviously be increase by a factor of SG2.

In most of the practical application cases the flow is turbulent and not laminar. Friction losses tend to strongly increase with liquid velocity.

Depending upon the type of nozzle, a different percentage of the available energy is used to break up the jet and give the desired spray pattern and spray angle.

For the above reason equation 5 gives reliable results if used in a limited pressure range around the pressure value where the flow rate is known, with this pressure range depending upon the type of nozzle.

Our experience has shown that one can expect the error in the calculated value to be lower than +/- 6% for pressure values ranging from 1/3 to 3 times the reference value.

As an example, a nozzle rated for 10 pm at 3 bars would have, according to equation 5 the following flow values:

- a 1 bar 5,77 lpm
- a 9 bar 17,3 lpm in real conditions it can be expected the flow rate values, to be:

- as high as 6,1 lpm a 1 bar
- as low as 16,2 lpm a 9 bar

Above considerations are to be used as a guideline only, because of the many factors influencing real operations which have not been considered here, for example **liquid, temperature, viscosity and density**.

4.3.17 Determined Calculation

CONSTANTS						
[Name]						
Series 1 at /LINE-OUTLET		AMBIENT PRESSURE	24500.000 Pa			
		EXIT AREA	0.020 m ²			
		AREA RATIO	4.801 m ²			
[Data]		THROAT AREA	0.0043 m ²			
Y [m]	Mach Number	Density [kg m ⁻³]	Pressure [Pa]	Velocity u [m s ⁻¹]	MASS FLOW	
0.00E+00	4.89E+00	4.82E-02	5.27E+03	1.91E+03	1.89E+0	
1.65E-03	4.89E+00	4.82E-02	5.27E+03	1.91E+03	1.89E+0	
3.29E-03	4.89E+00	4.82E-02	5.27E+03	1.91E+03	1.89E+0	
4.94E-03	4.89E+00	4.82E-02	5.27E+03	1.91E+03	1.89E+0	
6.59E-03	4.89E+00	4.82E-02	5.26E+03	1.91E+03	1.89E+0	
8.24E-03	4.90E+00	4.81E-02	5.26E+03	1.91E+03	1.88E+0	
9.88E-03	4.90E+00	4.81E-02	5.25E+03	1.91E+03	1.88E+0	
1.15E-02	4.90E+00	4.80E-02	5.24E+03	1.91E+03	1.88E+0	
1.32E-02	4.90E+00	4.80E-02	5.23E+03	1.		
1.48E-02	4.90E+00	4.79E-02	5.22E+03	1.		
1.65E-02	4.90E+00	4.78E-02	5.21E+03	1.		
1.81E-02	4.91E+00	4.77E-02	5.19E+03	1.		
1.98E-02	4.91E+00	4.76E-02	5.18E+03	1.		
2.14E-02	4.91E+00	4.74E-02	5.14E+03	1.		

Fig:4.46 : Determined Calculation

The formula for calculating rocket range is a complex one that takes into account several factors. While I can provide you with a simplified version, please note that the actual range calculation for rockets involves various additional considerations and factors. Here's a basic formula for estimating rocket range.

4.5 WORKING

The Vertical Takeoff and Landing (VTOL) capability of rockets relies on thrust vectoring, where the rocket's engines can be angled to provide the necessary lift to take off vertically and land safely. This is achieved by adjusting the direction of the exhaust gases expelled from the rocket's engines. Additionally, sophisticated guidance and control systems help stabilize and maneuver the rocket during the vertical ascent and descent phases. Deep space rockets operate

similarly to other rockets but with some adaptations for the challenges of long-duration space travel. Deep space missions require power for various systems onboard the spacecraft. Solar panels, radioisotope thermoelectric generators (RTGs), or nuclear reactors are commonly used to generate electricity for propulsion, communication, and scientific instruments.

4.6 ALGORITHM

ardupilotmega.xml

```
<param index="5" label="Autoreboot" minValue="0" maxValue="1"
increment="1">Autoreboot (0=user reboot, 1=autoreboot).</param>
```

```
<param index="6">Empty.</param>
```

```
<param index="7">Empty.</param>
```

```
</entry>
```

```
<entry value="42425" name="MAV_CMD_DO_ACCEPT_MAG_CAL"
hasLocation="false" isDestination="false">
```

```
<description>Accept a magnetometer calibration.</description>
```

```
<param index="1" label="Magnetometers Bitmask" minValue="0" maxValue="255"
increment="1">Bitmask of magnetometers that calibration is accepted (0 means
all).</param>
```

```
<param index="2">Empty.</param>
```

```
<param index="3">Empty.</param>
```

```
<param index="4">Empty.</param>
```

```
<param index="5">Empty.</param>
```

```
<param index="6">Empty.</param>
```

```
<param index="7">Empty.</param>
```

```
</entry>
```

```

<entry value="42426" name="MAV_CMD_DO_CANCEL_MAG_CAL"
hasLocation="false" isDestination="false">

<description>Cancel a running magnetometer calibration.</description>

<param index="1" label="Magnetometers Bitmask" minValue="0" maxValue="255"
increment="1">Bitmask of magnetometers to cancel a running calibration (0
means all).</param>

<param index="2">Empty.</param>

<param index="3">Empty.</param>

<param index="4">Empty.</param>

<param index="5">Empty.</param>

<param index="6">Empty.</param>

<param index="7">Empty.</param>

</entry>

<entry value="42429" name="MAV_CMD_ACCELCAL_VEHICLE_POS"
hasLocation="false" isDestination="false">

<description>Used when doing accelerometer calibration. When sent to the GCS
tells it what position to put the vehicle in. When sent to the vehicle says what
position the vehicle is in.</description>

<param index="1" label="Position"
enum="ACCELCAL_VEHICLE_POS">Position.</param>

<param index="2">Empty.</param>

<param index="3">Empty.</param>

<param index="4">Empty.</param>

<param index="5">Empty.</param>

<param index="6">Empty.</param>

```

<param index="7">Empty.</param>

</entry>

<entry value="42428" name="MAV_CMD_DO_SEND_BANNER"
hasLocation="false" isDestination="false">

<description>Reply with the version banner.</description>

<param index="1">Empty.</param>

<param index="2">Empty.</param>

<param index="3">Empty.</param>

<param index="4">Empty.</param>

<param index="5">Empty.</param>

<param index="6">Empty.</param>

<param index="7">Empty.</param>

</entry>

<entry value="42427" name="MAV_CMD_SET_FACTORY_TEST_MODE"
hasLocation="false" isDestination="false">

<description>Command autopilot to get into factory test/diagnostic
mode.</description>

<param index="1" label="Test Mode" minValue="0" maxValue="1"
increment="1">0: activate test mode, 1: exit test mode.</param>

<param index="2">Empty.</param>

<param index="3">Empty.</param>

<param index="4">Empty.</param>

<param index="5">Empty.</param>

<param index="6">Empty.</param>

<param index="7">Empty.</param>

</entry>

<entry value="42501" name="MAV_CMD_GIMBAL_RESET" hasLocation="false" isDestination="false">

<description>Causes the gimbal to reset and boot as if it was just powered on.</description>

<param index="1">Empty.</param>

<param index="2">Empty.</param>

<param index="3">Empty.</param>

<param index="4">Empty.</param>

<param index="5">Empty.</param>

<param index="6">Empty.</param>

<param index="7">Empty.</param>

</entry>

<entry value="42502" name="MAV_CMD_GIMBAL_AXIS_CALIBRATION_STATUS" hasLocation="false" isDestination="false">

<description>Reports progress and success or failure of gimbal axis calibration procedure.</description>

<param index="1" label="Axis" enum="GIMBAL_AXIS">Gimbal axis we're reporting calibration progress for.</param>

<param index="2" label="Progress" units="%" minValue="0" maxValue="100">Current calibration progress for this axis.</param>

<param index="3" label="Status" enum="GIMBAL_AXIS_CALIBRATION_STATUS">Status of the calibration.</param>

<param index="4">Empty.</param>

<param index="5">Empty.</param>

<param index="6">Empty.</param>

<param index="7">Empty.</param>

</entry>

<entry value="42503"

name="MAV_CMD_GIMBAL_REQUEST_AXIS_CALIBRATION"

hasLocation="false" isDestination="false">

<description>Starts commutation calibration on the gimbal.</description>

<param index="1">Empty.</param>

<param index="2">Empty.</param>

<param index="3">Empty.</param>

<param index="4">Empty.</param>

<param index="5">Empty.</param>

<param index="6">Empty.</param>

<param index="7">Empty.</param>

</entry>

<entry value="42505" name="MAV_CMD_GIMBAL_FULL_RESET"

hasLocation="false" isDestination="false">

<description>Erases gimbal application and parameters.</description>

<param index="1">Magic number.</param>

<param index="2">Magic number.</param>

<param index="3">Magic number.</param>

<param index="4">Magic number.</param>

```

<param index="5">Magic number.</param>

<param index="6">Magic number.</param>

<param index="7">Magic number.</param>

</entry>

<!-- 42600 used by common.xml -->

<entry value="42650" name="MAV_CMD_FLASH_BOOTLOADER"
hasLocation="false" isDestination="false">

<description>Update the bootloader</description>

<param index="1">Empty</param>

<param index="2">Empty</param>

<param index="3">Empty</param>

<param index="4">Empty</param>

<param index="5" label="Magic Number" increment="1">Magic number - set to
290876 to actually flash</param>

<param index="6">Empty</param>

<param index="7">Empty</param>

</entry>

<entry value="42651" name="MAV_CMD_BATTERY_RESET"
hasLocation="false" isDestination="false">

<description>Reset battery capacity for batteries that accumulate consumed
battery via integration.</description>

<param index="1" label="battery mask">Bitmask of batteries to reset. Least
significant bit is for the first battery.</param>

<param index="2" label="percentage" minValue="0" maxValue="100"
increment="1">Battery percentage remaining to set.</param>

```

</entry>

<entry value="42700" name="MAV_CMD_DEBUG_TRAP" hasLocation="false" isDestination="false">

<description>Issue a trap signal to the autopilot process, presumably to enter the debugger.</description>

<param index="1">Magic number - set to 32451 to actually trap.</param>

<param index="2">Empty.</param>

<param index="3">Empty.</param>

<param index="4">Empty.</param>

<param index="5">Empty.</param>

<param index="6">Empty.</param>

<param index="7">Empty.</param>

</entry>

<entry value="42701" name="MAV_CMD_SCRIPTING" hasLocation="false" isDestination="false">

<description>Control onboard scripting.</description>

<param index="1" enum="SCRIPTING_CMD">Scripting command to execute</param>

</entry>

<entry value="42702" name="MAV_CMD_NAV_SCRIPT_TIME" hasLocation="false" isDestination="false">

<description>Scripting command as NAV command with wait for completion.</description>

<param index="1" label="command">integer command number (0 to 255)</param>

<param index="2" label="timeout" units="s">timeout for operation in seconds. Zero means no timeout (0 to 255)</param>

<param index="3" label="arg1">argument1.</param>

<param index="4" label="arg2">argument2.</param>

<param index="5">Empty</param>

<param index="6">Empty</param>

<param index="7">Empty</param>

</entry>

<entry value="42703" name="MAV_CMD_NAV_ATTITUDE_TIME"
hasLocation="false" isDestination="false">

<description>Maintain an attitude for a specified time.</description>

<param index="1" label="time" units="s">Time to maintain specified attitude and
climb rate</param>

<param index="2" label="roll" units="deg">Roll angle in degrees (positive is lean
right, negative is lean left)</param>

<param index="3" label="pitch" units="deg">Pitch angle in degrees (positive is
lean back, negative is lean forward)</param>

<param index="4" label="yaw" units="deg">Yaw angle</param>

<param index="5" label="climb_rate" units="m/s">Climb rate</param>

<param index="6">Empty</param>

<param index=

<field type="uint8_t" name="bank">Bank number.</field>

</message>

<message id="11003" name="DEVICE_OP_WRITE_REPLY">

```

<description>Write registers reply.</description>

<field type="uint32_t" name="request_id">Request ID - copied from
request.</field>

<field type="uint8_t" name="result">0 for success, anything else is failure
code.</field>

</message>

<!-- realtime Adaptive Controller tuning message -->

<message id="11010" name="ADAP_TUNING">

<description>Adaptive Controller tuning information.</description>

<field type="uint8_t" name="axis" enum="PID_TUNING_AXIS"
instance="true">Axis.</field>

<field type="float" name="desired" units="deg/s">Desired rate.</field>

<field type="float" name="achieved" units="deg/s">Achieved rate.</field>

<field type="float" name="error">Error between model and vehicle.</field>

<field type="float" name="theta">Theta estimated state predictor.</field>

<field type="float" name="omega">Omega estimated state predictor.</field>

<field type="float" name="sigma">Sigma estimated state predictor.</field>

<field type="float" name="theta_dot">Theta derivative.</field>

<field type="float" name="omega_dot">Omega derivative.</field>

<field type="float" name="sigma_dot">Sigma derivative.</field>

<field type="float" name="f">Projection operator value.</field>

<field type="float" name="f_dot">Projection operator derivative.</field>

<field type="float" name="u">u adaptive controlled output command.</field>

</message>

```

```

<!-- camera vision based attitude and position delta message -->

<message id="11011" name="VISION_POSITION_DELTA">

<description>Camera vision based attitude and position deltas.</description>

<field name="time_usec" type="uint64_t" units="us">Timestamp (syncd to UNIX
time or since system boot).</field>

<field name="time_delta_usec" type="uint64_t" units="us">Time since the last
reported camera frame.</field>

<field type="float[3]" name="angle_delta" units="rad">Defines a rotation vector
[roll, pitch, yaw] to the current MAV_FRAME_BODY_FRD from the previous
MAV_FRAME_BODY_FRD.</field>

<field type="float[3]" name="position_delta" units="m">Change in position to the
current MAV_FRAME_BODY_FRD from the previous FRAME_BODY_FRD
rotated to the current MAV_FRAME_BODY_FRD.</field>

<field type="float" name="confidence" units="%">Normalised confidence value
from 0 to 100.</field>

</message>

<!-- Angle of Attack and Side Slip Angle message -->

<message id="11020" name="AOA_SSA">

<description>Angle of Attack and Side Slip Angle.</description>

<field type="uint64_t" name="time_usec" units="us">Timestamp (since boot or
Unix epoch).</field>

<field name="AOA" type="float" units="deg">Angle of Attack.</field>

<field name="SSA" type="float" units="deg">Side Slip Angle.</field>

</message>

<message id="11030" name="ESC_TELEMETRY_1_TO_4">

```

<description>ESC Telemetry Data for ESCs 1 to 4, matching data sent by BLHeli ESCs.</description>

<field type="uint8_t[4]" name="temperature" units="degC">Temperature.</field>

<field type="uint16_t[4]" name="voltage" units="cV">Voltage.</field>

<field type="uint16_t[4]" name="current" units="cA">Current.</field>

<field type="uint16_t[4]" name="totalcurrent" units="mAh">Total current.</field>

<field type="uint16_t[4]" name="rpm" units="rpm">RPM (eRPM).</field>

<field type="uint16_t[4]" name="count">count of telemetry packets received (wraps at 65535).</field>

</message>

<message id="11031" name="ESC_TELEMETRY_5_TO_8">

<description>ESC Telemetry Data for ESCs 5 to 8, matching data sent by BLHeli ESCs.</description>

<field type="uint8_t[4]" name="temperature" units="degC">Temperature.</field>

<field type="uint16_t[4]" name="voltage" units="cV">Voltage.</field>

<field type="uint16_t[4]" name="current" units="cA">Current.</field>

<field type="uint16_t[4]" name="totalcurrent" units="mAh">Total current.</field>

<field type="uint16_t[4]" name="rpm" units="rpm">RPM (eRPM).</field>

<field type="uint16_t[4]" name="count">count of telemetry packets received (wraps at 65535).</field>

</message>

<message id="11032" name="ESC_TELEMETRY_9_TO_12">

<description>ESC Telemetry Data for ESCs 9 to 12, matching data sent by BLHeli ESCs.</description>

```

<field type="uint8_t[4]" name="temperature" units="degC">Temperature.</field>

<field type="uint16_t[4]" name="voltage" units="cV">Voltage.</field>

<field type="uint16_t[4]" name="current" units="cA">Current.</field>

<field type="uint16_t[4]" name="totalcurrent" units="mAh">Total current.</field>

<field type="uint16_t[4]" name="rpm" units="rpm">RPM (eRPM).</field>

<field type="uint16_t[4]" name="count">count of telemetry packets received
(wraps at 65535).</field>

</message>

<message id="11033" name="OSD_PARAM_CONFIG">

<description>Configure an OSD parameter slot.</description>

<field type="uint8_t" name="target_system">System ID.</field>

<field type="uint8_t" name="target_component">Component ID.</field>

<field type="uint32_t" name="request_id">Request ID - copied to reply.</field>

<field type="uint8_t" name="osd_screen">OSD parameter screen index.</field>

<field type="uint8_t" name="osd_index">OSD parameter display index.</field>

<field type="char[16]" name="param_id">Onboard parameter id, terminated by
NULL if the length is less than 16 human-readable chars and WITHOUT null
termination (NULL) byte if the length is exactly 16 chars - applications have to
provide 16+1 bytes storage if the ID is stored as string</field>

<field type="uint8_t" name="config_type"
enum="OSD_PARAM_CONFIG_TYPE">Config type.</field>

<field type="float" name="min_value">OSD parameter minimum value.</field>

<field type="float" name="max_value">OSD parameter maximum value.</field>

<field type="float" name="increment">OSD parameter increment.</field>

```

</message>

<message id="11034" name="OSD_PARAM_CONFIG_REPLY">

<description>Configure OSD parameter reply.</description>

<field type="uint32_t" name="request_id">Request ID - copied from request.</field>

<field type="uint8_t" name="result"
enum="OSD_PARAM_CONFIG_ERROR">Config error type.</field>

</message>

<message id="11035" name="OSD_PARAM_SHOW_CONFIG">

<description>Read a configured an OSD parameter slot.</description>

<field type="uint8_t" name="target_system">System ID.</field>

<field type="uint8_t" name="target_component">Component ID.</field>

<field type="uint32_t" name="request_id">Request ID - copied to reply.</field>

<field type="uint8_t" name="osd_screen">OSD parameter screen index.</field>

<field type="uint8_t" name="osd_index">OSD parameter display index.</field>

</message>

<message id="11036" name="OSD_PARAM_SHOW_CONFIG_REPLY">

<description>Read configured OSD parameter reply.</description>

<field type="uint32_t" name="request_id">Request ID - copied from request.</field>

<field type="uint8_t" name="result"
enum="OSD_PARAM_CONFIG_ERROR">Config error type.</field>

<field type="char[16]" name="param_id">Onboard parameter id, terminated by NULL if the length is less than 16 human-readable chars and WITHOUT null

termination (NULL) byte if the length is exactly 16 chars - applications have to provide 16+1 bytes storage if the ID is stored as string</field>

<field type="uint8_t" name="config_type"
enum="OSD_PARAM_CONFIG_TYPE">Config type.</field>

<field type="float" name="min_value">OSD parameter minimum value.</field>

<field type="float" name="max_value">OSD parameter maximum value.</field>

<field type="float" name="increment">OSD parameter increment.</field>

</message>

<message id="11037" name="OBSTACLE_DISTANCE_3D">

<wip/>

<!-- This message is work-in-progress and it can therefore change, and should NOT be used in stable production environments -->

<description>Obstacle located as a 3D vector.</description>

<field type="uint32_t" name="time_boot_ms" units="ms">Timestamp (time since system boot).</field>

<field type="uint8_t" name="sensor_type"
enum="MAV_DISTANCE_SENSOR">Class id of the distance sensor type.</field>

<field type="uint8_t" name="frame" enum="MAV_FRAME">Coordinate frame of reference.</field>

<field type="uint16_t" name="obstacle_id" instance="true"> Unique ID given to each obstacle so that its movement can be tracked. Use UINT16_MAX if object ID is unknown or cannot be determined.</field>

<field type="float" name="x" units="m"> X position of the obstacle.</field>

<field type="float" name="y" units="m"> Y position of the obstacle.</field>

<field type="float" name="z" units="m"> Z position of the obstacle.</field>

```

<field type="float" name="min_distance" units="m">Minimum distance the sensor
can measure.</field>

<field type="float" name="max_distance" units="m">Maximum distance the sensor
can measure.</field>

</message>

<message id="11038" name="WATER_DEPTH">

<description>Water depth</description>

<field type="uint32_t" name="time_boot_ms" units="ms">Timestamp (time since
system boot)</field>

<field type="uint8_t" name="id" instance="true">Onboard ID of the sensor</field>

<field type="uint8_t" name="healthy">Sensor data healthy (0=unhealthy,
1=healthy)</field>

<field type="int32_t" name="lat" units="degE7">Latitude</field>

<field type="int32_t" name="lng" units="degE7">Longitude</field>

<field type="float" name="alt" units="m">Altitude (MSL) of vehicle</field>

<field type="float" name="roll" units="rad">Roll angle</field>

<field type="float" name="pitch" units="rad">Pitch angle</field>

<field type="float" name="yaw" units="rad">Yaw angle</field>

<field type="float" name="distance" units="m">Distance (uncorrected)</field>

<field type="float" name="temperature" units="degC">Water temperature</field>

</message>

<message id="11039" name="MCU_STATUS">

<description>The MCU status, giving MCU temperature and voltage. The min and
max voltages are to allow for detecting power supply instability.</description>

```

```
<field type="uint8_t" name="id" instance="true">MCU instance</field>

<field type="int16_t" name="MCU_temperature" units="cdegC">MCU Internal
temperature</field>

<field type="uint16_t" name="MCU_voltage" units="mV">MCU voltage</field>

<field type="uint16_t" name="MCU_voltage_min" units="mV">MCU voltage
minimum</field>

<field type="uint16_t" name="MCU_voltage_max" units="mV">MCU voltage
maximum</field>

</message>

</messages>

</mavlink>
```

CHAPTER 5

RESULT AND DISCUSSION

5.1 RESULT

As a result the successful VTOL has been modelled and designed.

It has been developed with new analysis and software uses with the vigorous change in the simulation in turning control and thrust vectoring. It lacks all the drawbacks and has potential to reach high

This Vertical Takeoff and Landing (VTOL) rocket have revolutionized aviation by enabling aircraft to operate in confined spaces, navigate complex environments, and provide versatile transportation solutions.

5.1.1 The Role of Vectored Thrust in Vertical Landing

Vectored thrust plays a crucial role in enabling vertical landing for VTOL aircraft. Here are the key aspects of how vectored thrust makes vertical landing possible.

5.1.2 Nozzle Tilt

By tilting the engine nozzles, the direction of the Engine exhaust can be redirected,. Tilting the nozzles downward allows the aircraft to generate vertical lift forces necessary for takeoff and landing.

This adjustment of the nozzles provides the required vertical thrust component.

5.1.3 Throttle Control

Throttle levels can be adjusted to control the direction and magnitude of thrust. Precise control over thrust is essential for maintaining stability during vertical landing maneuvers.

5.1.4 Differential Thrust Vectoring

To control the vehicle's rotation and attitude during landing, differential thrust vectoring is employed. By independently adjusting the thrust of each engine or nozzle, the aircraft can achieve the desired orientation and achieve smooth and controlled vertical landings.



Fig:5.1 : Newly Designed Deep Space VTOL Rocket

5.2 DISCUSSION AND FUTURISTIC SCOPE

The future scope of rockets is vast and includes exploration beyond Earth's orbit, such as manned missions to Mars and beyond, asteroid mining, space tourism, and satellite deployment for communication, observation, and scientific research. Advancements in propulsion technologies, reusable rocket systems, and international collaborations are likely to drive innovation and expand the possibilities for rocket applications in the future.

Additionally, developments in materials science, artificial intelligence, and propulsion systems may lead to faster, more efficient, and more sustainable rocket designs, opening up even more opportunities for space exploration and utilization.

VTOL drones and aircraft can be deployed for search and rescue missions, disaster relief, and medical evacuation in remote or inaccessible areas. VTOL aircraft are used for reconnaissance, surveillance, and tactical operations, offering enhanced maneuverability and accessibility in diverse environments. VTOL drones have the potential to streamline logistics operations by delivering packages quickly and efficiently to remote or congested areas. VTOL technology could enable the development of personal air vehicles, offering individuals the ability to travel short to medium distances autonomously. VTOL drones can be utilized for crop monitoring, spraying pesticides, and precision agriculture, improving efficiency and yields in farming practices. Overall, the scope of VTOL technology is vast, with ongoing advancements in propulsion, autonomy, and infrastructure paving the way for new and innovative applications across various industries.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

A successful vertical deep space rocket launch marks a momentous achievement in the field of space exploration and signifies several key aspects. A deep space rocket launch requires cutting-edge Technology and engineering expertise. The success of such a mission demonstrates the capability of humanity to overcome significant technical challenges and push the boundaries of what is possible. Scientific Exploration Deep space missions often carry scientific instruments and payloads that aim to study celestial bodies, collect data on cosmic phenomena, or explore the far reaches of our solar system and beyond.

6.2 CONCLUSION

In conclusion, VTOL (Vertical Takeoff and Landing) rockets represent a promising advancement in rocket technology, offering increased flexibility, efficiency, and versatility in accessing space and beyond. By combining the capabilities of traditional rockets with the ability to take off and land vertically, VTOL rockets have the potential to revolutionize various applications, including satellite deployment, cargo delivery, military operations, and space tourism. With ongoing advancements in propulsion, autonomy, and infrastructure, VTOL rockets are poised to play a significant role in the future of space exploration and transportation.

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AERODYNAMIC THRUST VECTORING AND TURNING CONTROL FOR DEEP SPACE VERTICAL ROCKET LAUNCH

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Abstract:

- New methods on Aerodynamic Thrusting Vector of Gimbaling, Thrust Vector Nozzles, Fluid Injection, Aerospoke Nozzles, Synthetic Jet Actuators for a successful rocket launch that requires precise control of rocket's trajectory into deep space.
- New methods on Turning Control on Control Surface, Reaction Control System, Roll Control, Gravity Pull, Stage Separation, Active Guidance for successful rocket launch into deep space.

Introduction:

Nearly above 70% of deep space vertical rocket launch are facing failure due to Thrust Vector Control Malfunction, Software or Control Surface Failure, System Errors, Inadequate Thrust Vector Control Authority, Aerodynamic Loads, Insufficient Testing, Integration Problems, Environmental Factors, Human Errors.

We can have a successful deep space VTOL by innovating new methods in testing scenarios by Integration testing ,Security testing, database test case , usability test case , performance test case, UAT testing Beta testing , acceptance testing CFD in turning control and aerodynamic thrust vectoring .

Understanding Existing TVC Technology, Analyzation Of Fluid Dynamics And Control Theory, Stimulation And Testing, Flight Control Software, Real-Time Operating Systems Modulation, Collabration And Feedback, Patent And Intellectual Property Safety.

AERODYNAMIC THRUST VECTORING AND TURNING CONTROL FOR DEEP SPACE VERTICAL ROCKET LAUNCH
Artificial Intelligence And Control Algorithm modification all are curicial for successive launch.

A fundamental challenge in designing VTOL aircraft is achieving stable and controlled vertical take-off and landing, while also ensuring efficient forward flight. One of the critical technologies employed in VTOL aircraft to address this challenge is aerodynamic thrust vectoring. Aerodynamic thrust vectoring in VTOL refers to the method of manipulating the direction of the engine's thrust using aerodynamic surfaces during different flight phases in deep space⁴. By adjusting the direction of the thrust by the new technologies, the aircraft can control its attitude and flight path, enabling smooth transitions between vertical take-off, hover, and forward flight modes. For vertical deep space rocket launches, turning control is a crucial aspect of the flight trajectory. New turning control allows the rocket to change its orientation and direction during different phases of the launch to achieve the desired trajectory and reach its intended target in space. Successfully. Software simulators play a critical role in the development and testing of aero thrust vectoring and turning control systems for aerospace applications. These simulators provide a virtual environment where engineers and researchers can model, analyze, and optimize the performance of the thrust vectoring and turning control mechanisms. Here are some of the key reasons why software simulators are essential for this purpose:

- 1. Cost-Effectiveness:** Building and testing physical prototypes of aerospace systems, such as thrust vectoring mechanisms and control surfaces, can be expensive and timeconsuming. Software simulators offer a cost-effective alternative, allowing engineers to iterate through various design options virtually before physical implementation.
- 2. Safety:** Testing thrust vectoring and turning control mechanisms on real aircraft or rocket prototypes can be risky. Using simulators eliminates the potential hazards associated with physical testing, ensuring the safety of both personnel and equipment.
- 3. Rapid Prototyping and Optimization:** Simulators enable rapid prototyping, allowing engineers to quickly evaluate different designs and control algorithms. This iterative approach helps optimize the performance of thrust vectoring and turning control systems more efficiently.
- 4. Detailed Analysis:** Simulators provide in-depth data and insights into the behavior of the aircraft or rocket during various maneuvers. Engineers can analyze factors like aerodynamic

AERODYNAMIC THRUST VECTORING AND TURNING CONTROL FOR DEEP SPACE VERTICAL ROCKET LAUNCH
forces, control surface deflections, thrust vector angles, and stability characteristics to fine-tune the system.

5. Scenario Reproduction: Simulators allow for the reproduction of specific flight scenarios, including different weather conditions, altitude ranges, and mission profiles. Engineers can test the system's response in diverse conditions, preparing it for real-world challenges.

6. Verification and Validation: Using simulators, engineers can verify and validate the performance of the thrust vectoring and turning control systems against established design requirements and safety standards.

7. Control Algorithm Development: Software simulators facilitate the development and testing of control algorithms for thrust vectoring and turning maneuvers. Engineers can analyze the effectiveness of different control strategies without risking real assets.

8. Integration Testing: Simulators enable the integration testing of the thrust vectoring and turning control systems with other aircraft or rocket subsystems. This helps identify and resolve potential integration issues before implementation.

9. Training and Skill Enhancement: Simulators provide a valuable training platform for pilots and operators to practice handling aircraft with thrust vectoring capabilities or complex turning maneuvers. It helps improve their skills without putting actual vehicles at risk.

10. Future Technology Assessment: Simulators can be used to assess the feasibility and benefits of incorporating new technologies and innovations into thrust vectoring and turning control systems.

Materials And Methods.

□ Network simulator software for developing new methods on Aerodynamic Thrusting Vector of Gimbaling, Thrust Vector Nozzles, Fluid Injection, Aerospike Nozzles, Synthetic Jet Actuators and new methods on Turning Control on Control Surface, Reaction Control System, Roll Control, Gravity Pull, Stage Separation, Active Guidance for successful vertical rocket launch into deep space are :

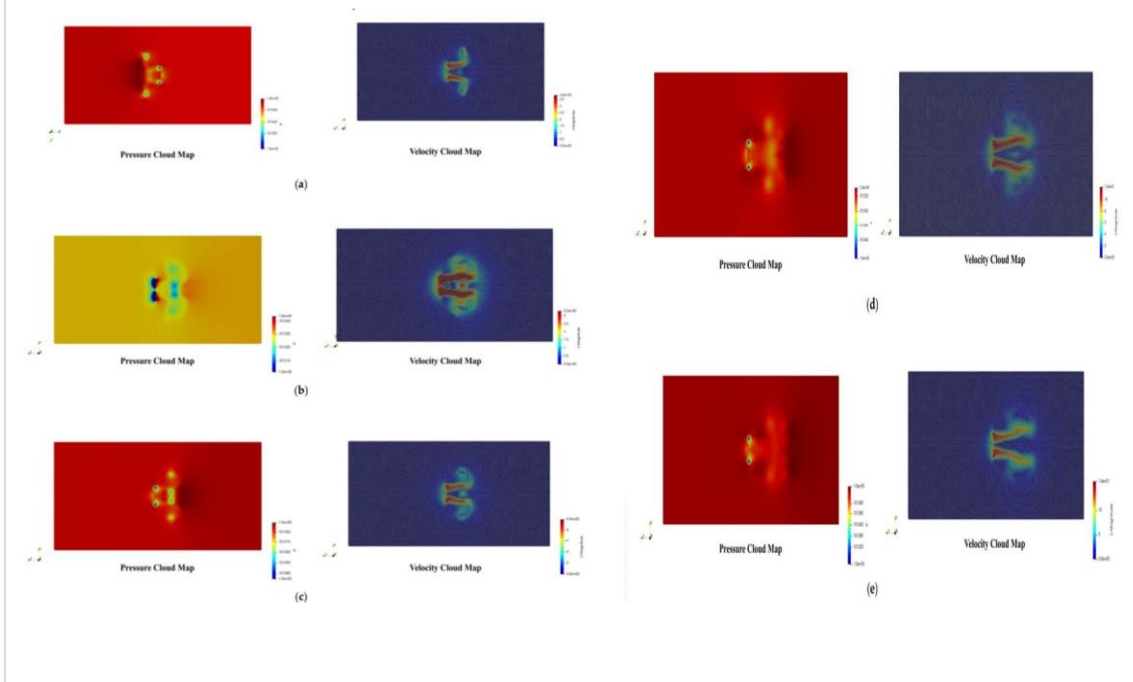
1) **NS2 Simulator.**

The "NS2" simulator, or simply "Network Simulator 2," is primarily focused on network simulation and is not specifically designed for rocket software simulation. Network Simulator 2 is a discrete-event simulator widely used in the field of computer networking to simulate and analyze the performance of communication networks.

For rocket software and simulations, specialized software tools and platforms are used that are specifically designed for aerospace and rocket engineering applications. These tools often have advanced capabilities to model rocket propulsion systems, aerodynamics, structural dynamics, trajectory analysis, and more.

The purpose of establishing the mathematical model of the trans-medium aircraft by NS2 is to analyze the changes in the position and attitude of the trans-medium aircraft when it is subjected to external forces and moments. Among them, the input of the dynamic model is the pulling force and torque provided by the propeller, and the output is the speed and angular velocity of the aircraft; the input of the kinematic model is the output of the dynamic model, that is, the speed and angular velocity of the aircraft, and the output is the position and attitude of the aircraft.

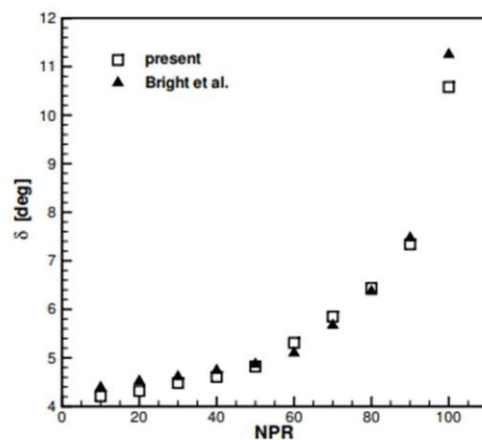
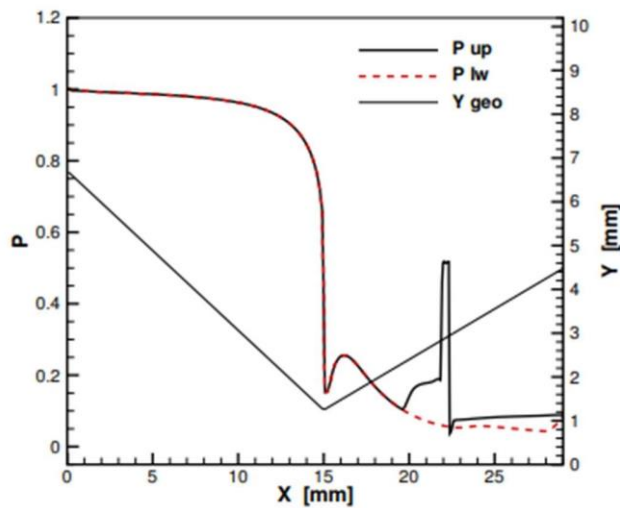
Ns2 cloud mapping simulations.



2) NS-3 Simulator.

NS-3 is discrete-event network simulation software primarily used for networking research and development. It's widely used in academia and industry for studying network protocols, wireless networks, and related technologies. While NS-3 is not designed explicitly for rocket

AERODYNAMIC THRUST VECTORING AND TURNING CONTROL FOR DEEP SPACE VERTICAL ROCKET LAUNCH simulations, it can be adapted to model certain aspects of a rocket control system.

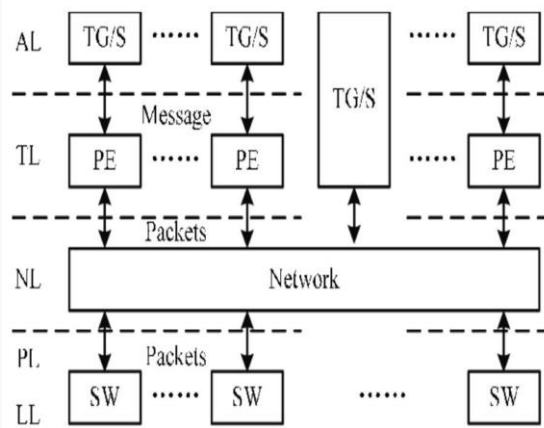


NS-3 simulator of Fluid thrust vectoring of great producing torque overall view

NS-3 Simulator of turning control comparison with other error methods.

3)OPNET:

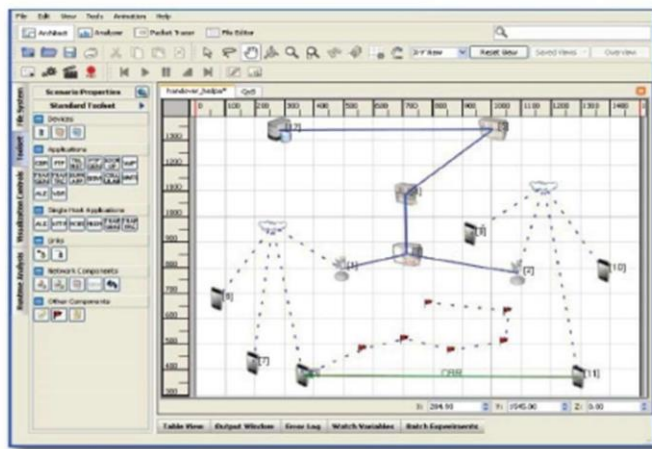
OPNET is a powerful network simulation tool used to model and analyze communication networks, including wired, wireless, and satellite networks. It is primarily utilized for research, design, and optimization of network protocols IN aerodynamic thrust vectoring, to control the direction of thrust generated by aircraft engines. It involves adjusting the orientation of exhaust nozzles to change the direction of the engine's thrust, enabling improved maneuverability and control.



OPNET simulator for thrust vectoring enhanced communication.

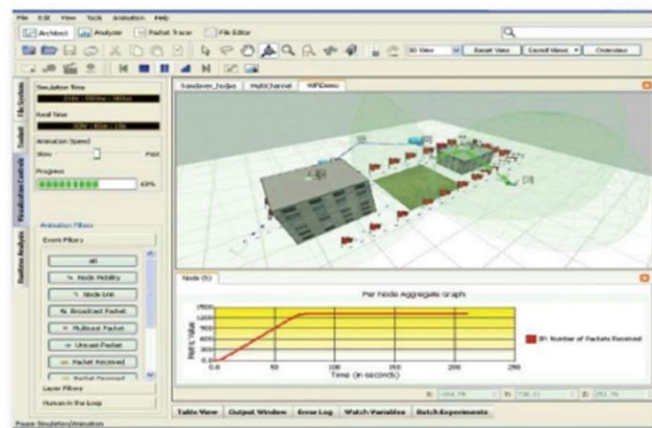
4)QUALNET Simulator:

QUALNET is a network simulation tool developed by Scalable Network Technologies, mainly used for modeling and simulating communication networks, wireless networks, and hoc networks (MANETs). There is no direct connection between QUALNET and rocket turning control simulations. QUALNET does not have built-in capabilities for simulating aerodynamics, rockets, or turning control in the aerospace context. For rocket turning control simulations, you would typically need to consider factors such as rocket propulsion, aerodynamic forces, control surfaces, stability, and guidance algorithms. This requires complex modeling and simulation tools tailored for aerospace applications.



Design Modee

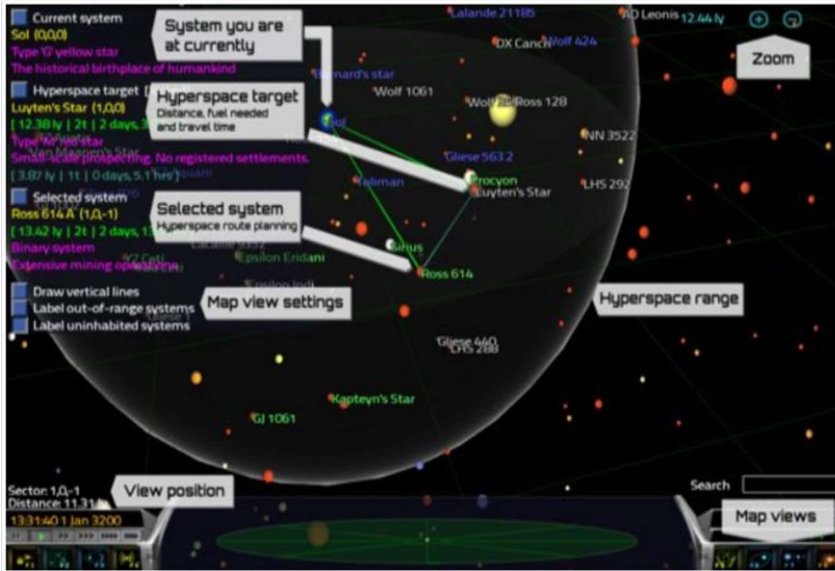
QUALNET Design mode and Visualize mode in turning control.



Visualize Modee

5)PimSeer:

PimSEER" is new software or a specific tool for aerodynamic turning control simulations, it is highly recommend searching for the latest information on it through online research, official websites, or publications related to aerospace engineering and aerodynamics. Additionally, you can check with experts in the aerospace field or academic institutions to see if they have any knowledge or experience with this simulator.

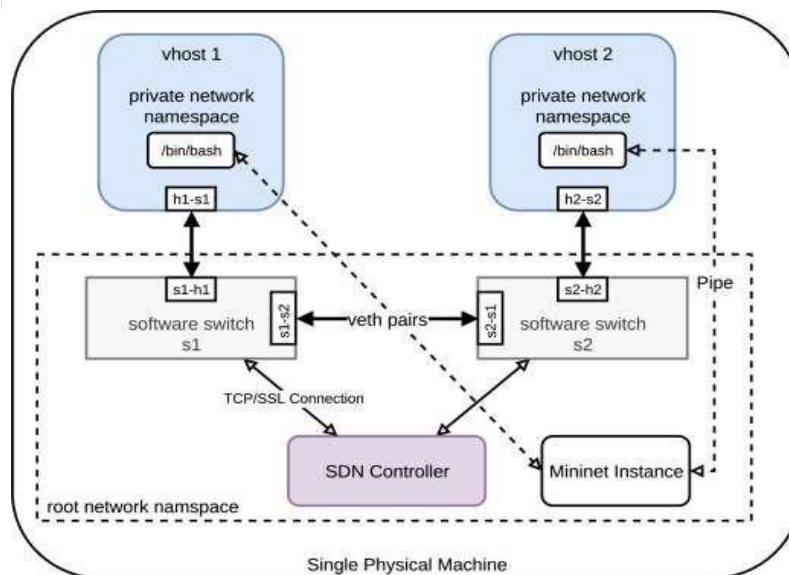


Deep space clear view trajectory pathway planning for rocket usin PimSeer simulator.

6)Mininet:

Mininet allows users to create virtual networks with hosts, switches, controllers, and links, enabling network researchers and developers to experiment with different network topologies and configurations. However, Mininet itself does not have the capabilities to simulate rocket turning control. Aerodynamic simulations for rockets using Mininet involve complex modeling of fluid dynamics, rocket propulsion, control surfaces, stability, and guidance algorithms. These simulations require software designed specifically for aerodynamics and aerospace applications.

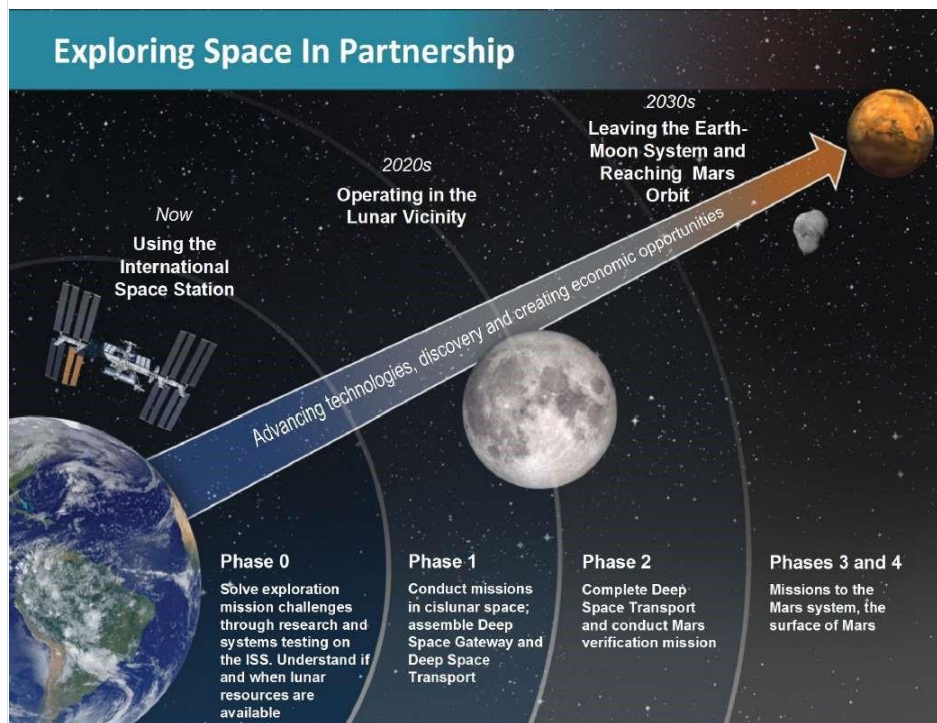
Mininet simulator pathroot for network namespace in deep space.



7)Divert :

Divert simulator" specifically designed for rocket turning control simulations. It's possible that new software or tools may have emerged since then, or "divert simulator" could be a less-known or niche solution.

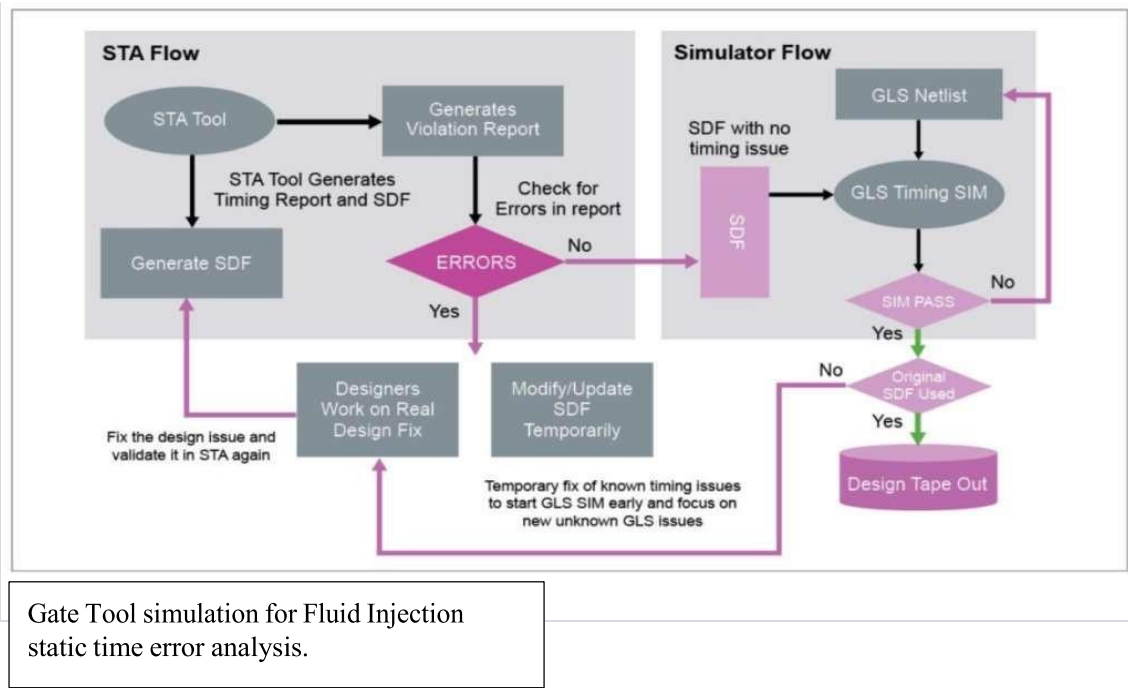
Divert simulator pathway



Divert simulator turning angles.

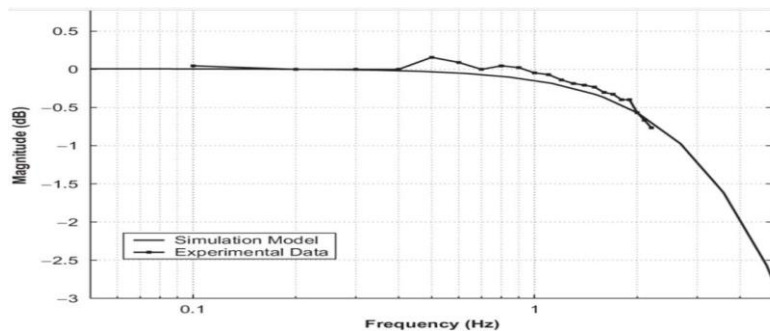
8)Gate Tool:

Gate Tool simulation used in aerodynamics or rocket simulations, including aerodynamic thrust vectoring indirectly. Instead, it is primarily used for simulating the passage of high-energy particles (such as gamma rays, electrons, and protons) through materials and is widely used in fields like particle physics experiments.



9) OMNeT++ :

OMNeT++ is a discrete event simulation framework used primarily for modeling and simulating communication networks, protocols, and distributed systems. It allows users to create network models and evaluate their performance under various conditions and scenarios. OMNeT++ is widely used in academic and research settings for network-related simulations. It is used in simulation of thrust vectoring gimbaling angles due to its



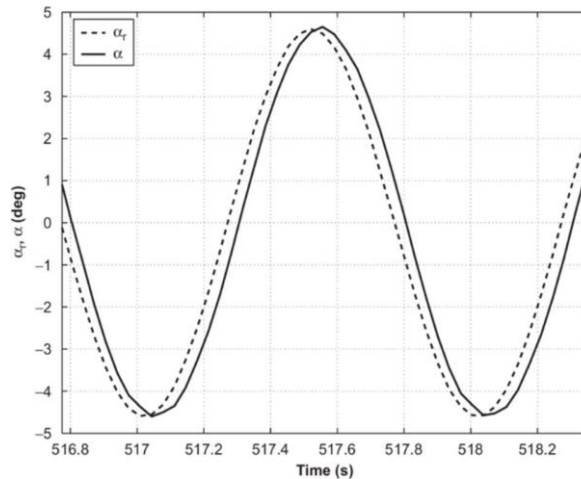
modularity, extensibility, visualization, scalability and multiple model of simulations.

OMNeT++ Gimballing thrust for deep space rocket launch simulation.

10) Jist:

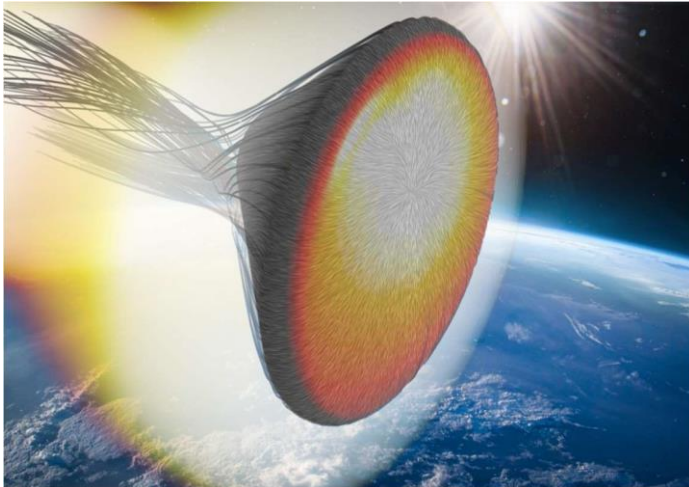
Jist" (Java In Simulation Time) is a discrete-event network simulator, and it is part of the Jist/SWANS (Scalable Wireless Ad hoc Network Simulator) project. The Jist/SWANS project provides simulation capabilities for wireless ad hoc networks and sensor networks for Synthetic Jet Actuators.

Jist simulation for roll control
static time analysis.



11) Iteris:

"Simulation space" could potentially refer to a specific product, service, or a general concept related to simulations offered by Iteris. They offer services related to traffic management in deep space, intelligent transportation systems (ITS), weather analytics in trajectory.

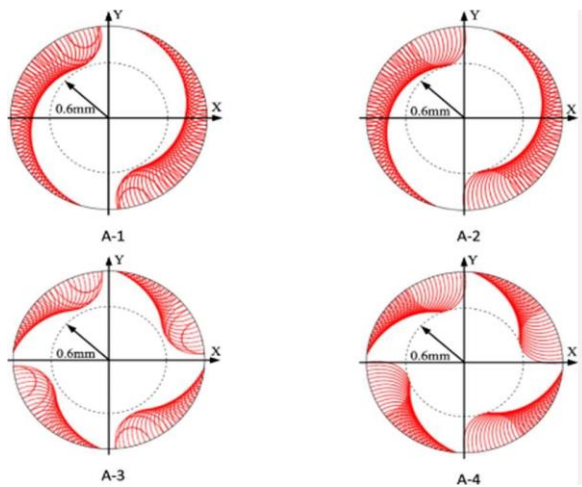


Hypersonic Aerospike Nozzle for deep
space rocket travel Iteris simulation.

12) Groove Net:

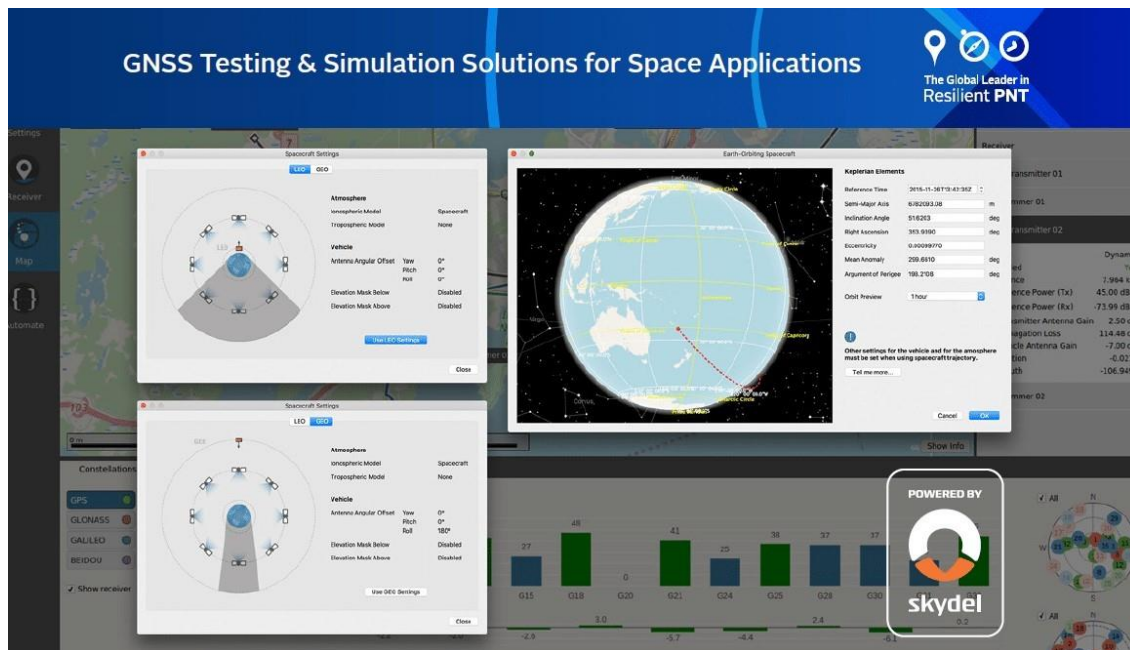
"GrooveNet" simulation is indeed a specific simulation tool or project related to networking or any other domain, especially used for state transmission fluid injection.

Groove Net simulation of helical
fluid injection in gravity pull.



13)Open Pana:

"OpenPANA" might refer to "Open Positioning Interface for Advanced Navigation," which is a project focusing on providing an open-source framework for positioning and navigation systems. However, this project is related to aerospace engineering or thrust vector simulation



for real time operating modulation.

Open Pana simulation for navigation of space real time modulation.

Navigation
mode in
deep space for
all orbit
angles

14) One Sim:

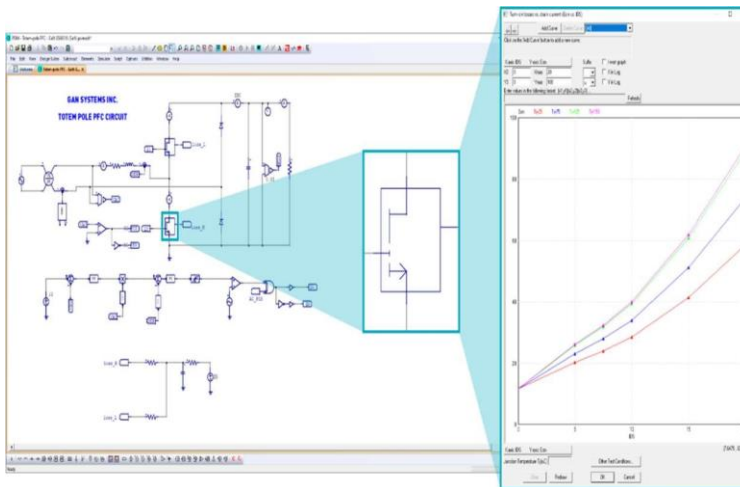
OneSim Simulator of the DTN simulator used in the world is defined as sim. The programming language used in One sim is Java. The most famous DTN routing protocol is offered by the researchers.¹ The main logic of some DTN routing algorithms is understood by the researchers based on the implementation of these routing protocols for stage separations.



One Sim simulator for stage separation angle control in deep space.

15) PSim:

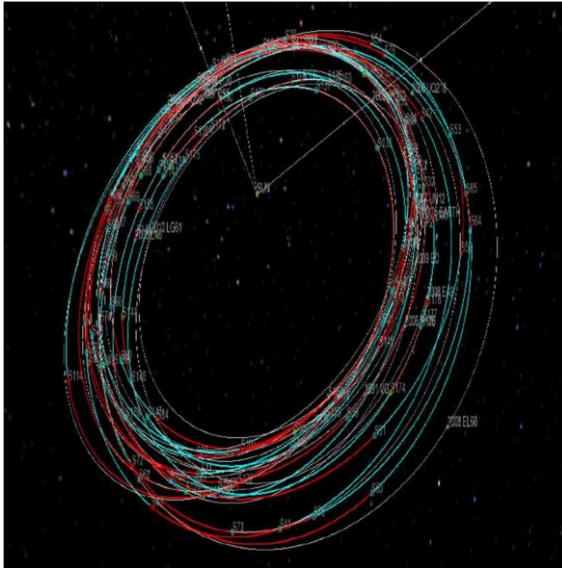
PSIM's power electronics simulator delivers unbeatable simulation speed while producing high-quality system-level results. Even with no prior experience, PSIM's friendly user interface means easy implementation and seamless adoption in any environment in trajectory path. PSIM and its add-on modules provide robust system-level design and simulation across multiple areas especially for velocity reaction control.



PSim simulation for velocity reaction control in various orbit.

16) Straw:

STRAW Simulator is called a Street random Way Point mobility model. Random waypoint model simulation does not need to require origin-destination information. [Straw simulator](#) involves determining the vehicle's trajectory at each intersection.

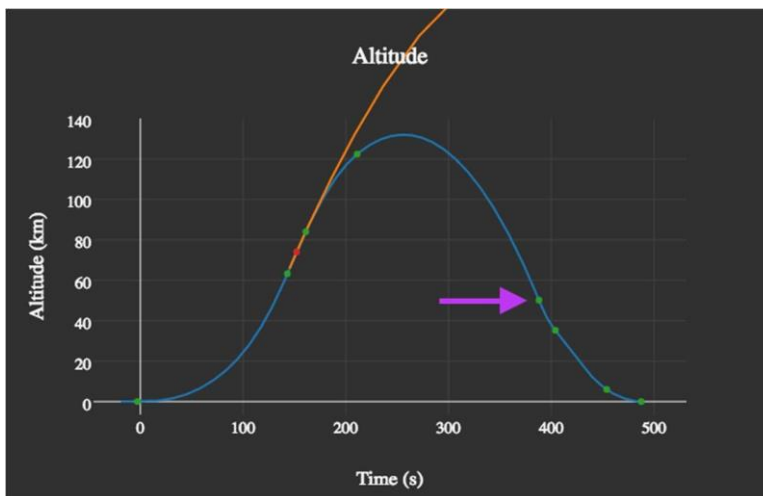


Straw simulation for each trajectory of rocket state distribution testing scenario.

17) SUMO:

["Simulation of Urban MObility" \(SUMO\)](#) is an open source, highly portable, microscopic traffic simulation package designed to handle large road networks and different modes of space path.

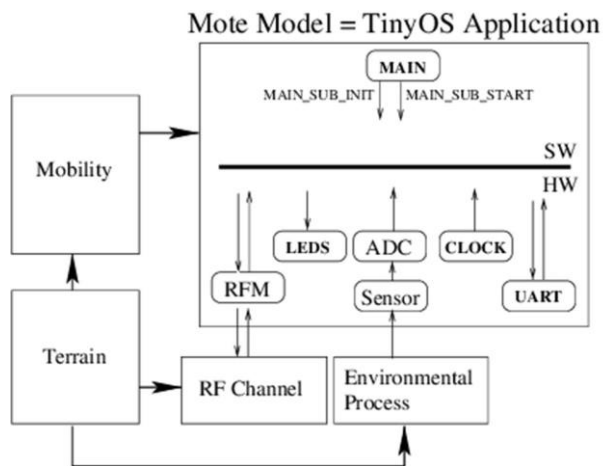
It is mainly developed by employees of the [Institute of Transportation Systems at the German Aerospace Center](#) for gravity pull determination .



SUMO simulator gravity pull .

18) TinyOS:

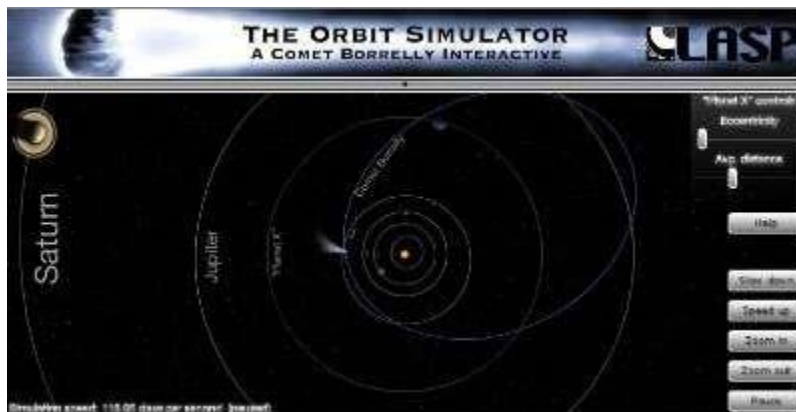
TinyOS Network simulator progress many event-driven applications structure aimed at embedded schemes and collection of mechanisms enable to build additional applications. We also assist the scholar in overcoming all their subject matter. And also, we provide wideranging support for the bewildering situation of scholars in turning angle in deep space. Tiny OS Network simulator is a open source framework, component based operating system which is particularly designed for low power wireless device.



TinyOS simulztion for patent and intellectual property safety of rocket during launching process.

19) Tossim:

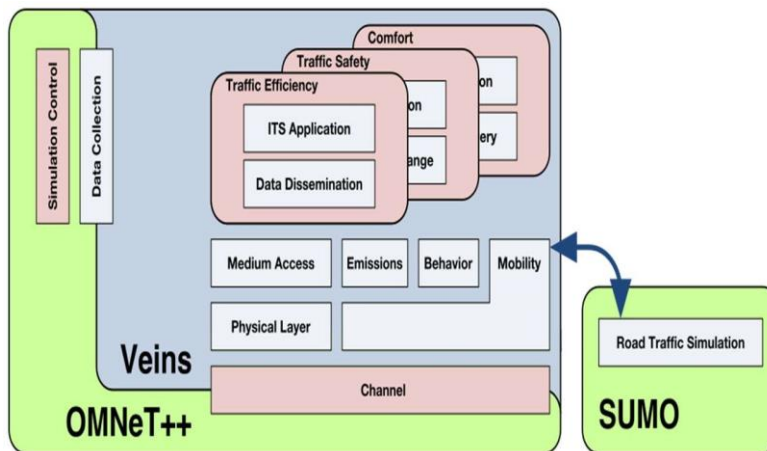
Tossim Simulator is a discrete event simulator framework for TinyOS wireless sensor network. Instead of NS2, we implement Tossim, which captures the network behavior and attraction based on bit granularity, not on the packet level for active guidance in space for rocket. We operate in a sensor network called motes. They are referred to as tiny sensing and computation device for limited communication, computation, and also energy resources.



Rocket active guidance of Tossim simulator during turning angles.

20) Veins:

Veins is an open source framework for running vehicular network simulations. It is based on two well-established simulators: OMNeT++, an event-based network simulator, and SUMO, a road traffic simulator. It extends these to offer a comprehensive suite of models for IVC simulation for control algorithm of rocket into deep space.



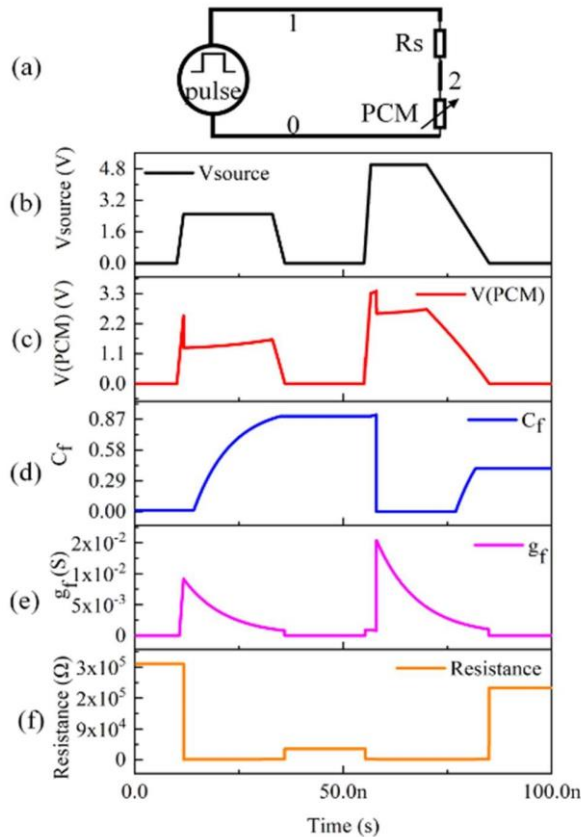
It extends these to offer a comprehensive suite of models for IVC simulation for control algorithm of rocket into deep space.

Space traffic simulation using veins.

Space traffic simulation

21) TraNs:

TraNS Simulator Projects refer to space traffic, and network simulation environment is simulation environments which integrate both traffic and network simulators. We also offer based on Springer papers to build a realistic simulation for vehicular ad-hoc networks. Trans referred to as the GUI tool, which incorporates deep space traffic and network simulators for active guidance.



TraNs simulator for active guidance of rocket into deepspace,

22)Kompics:

Kompics Simulator is a component model concentrated on building distributed systems by composing protocols programmed as event-driven components. We ensure kompics components are reactive state machine which executes

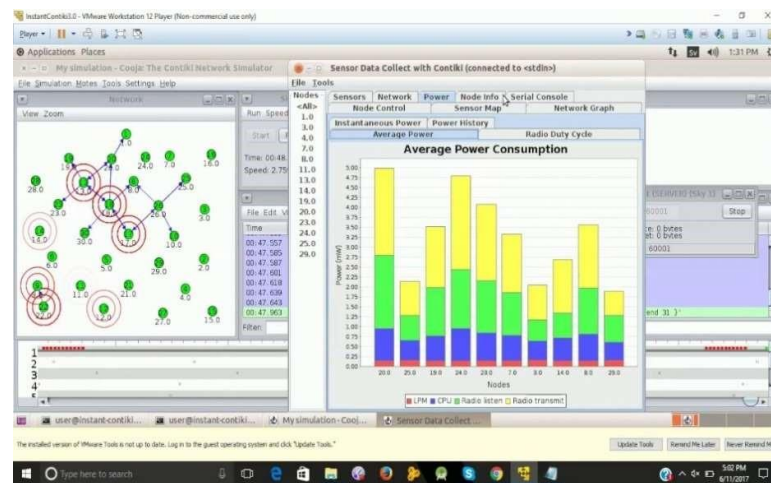
concurrently by a set of workers. In general, We support kompics projects with pluggable component schedulers at runtime for research scholars. Consequently, the process of We enables a simulation framework with deterministic debugging and reproducible performance evaluation of the unmodified kompics simulator system that helps in solving of integration problems in error time static analysis.



Kompics simulator outcome for error time state transmission for analysis of flow analysis.

23) Cooja:

The Cooja simulation platform as it enables not only the simulation of TBL, but the eventual



implementation of this algorithm on real world motes. The Simulation results show that in a limited four rounds of communication, 76.67% of nodes would be localized with an average localization error of 0.5 meters in a 200m by 200m simulation area including 30 blind nodes and 50 anchors for Vernier rocket

launch.

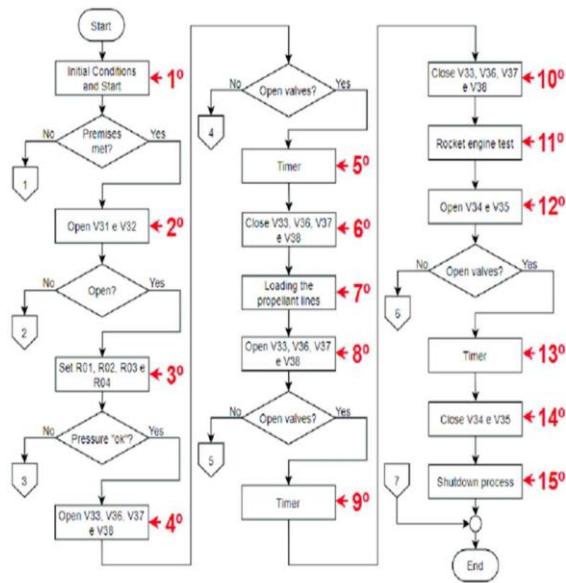
Average power consumption for Vernier rocket for torque producing comparison rate with Cooja simulator.

24) PetriNet:

During the development stage of a space vehicle, instrumented tests are carried out on the ground to prove the operational capacity of each liquid-propellant rocket engine, which is installed in this type of vehicle. The task of elaborating a Test Bench project for a propulsion unit with this application is complex and involves several steps, one of these steps being related to the analysis of this bench capacity to meet the algorithms for the liquid-propellant rocket engine full run of tests, which is considered fundamental for this project's operational success. Due to the high costs involved in this project's elaboration and execution, it is strategic to use computational resources to evaluate, by simulation, the main operational functionalities that are previously established for this bench to perform. In this context, this work presents a model proposal through Petri Nets to evaluate, by computer simulation, an architecture capacity that was designed for the Test Bench to meet an algorithm dedicated to the liquid-propellant pipelines purge during the run of hot tests with the liquid-propellant rocket engine. The method used in this work to carry out the simulation shows the operational response of each module of this architecture, in accordance with the steps contained in the purge algorithm, which allows for analyzing, for each event of the process, the Petri Nets properties, mainly those related to the conservativeness, liveness, deadlock-type, and confusion-type conflicts. The simulation carried out with the proposed model allows for the portrayal of the physical architecture and the operational states of the purge system according

AERODYNAMIC THRUST VECTORING AND TURNING CONTROL FOR DEEP SPACE VERTICAL ROCKET LAUNCH to the steps foreseen in the algorithm, showing that the conservation property is met because the number of marks remains constant, the vivacity property is also met since all positions have been reached, and there is no mortaltype conflict, as the simulation is not stopped; only confusion-type conflict is identified, which was solved with the strategic insertion of

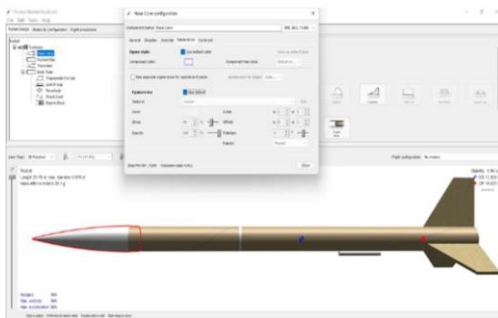
resources in the model in order to fix crashes related to the competition for tokens in the transition-enabled entries. The satisfactory results obtained in these simulations suggest that the modules provided for this architecture are sufficient and appropriate for carrying out all the steps contained in the purge algorithm, which will minimize or even eliminate the disorders that may be caused by the presence of foreign elements in the propellant supply lines during the tests with the rocket engine for successful deep space rocket launch.



PetriNets simulator applied in pure algorithm for a rocket engine test with liquid propellant.

25)OpenRocket:

OpenRocket is a free, fully featured model rocket simulator that allows you to design and simulate your rockets before you build and flying them.Leverage state of the art Six-Degreesof-Freedom flight simulation with over 50 variables. Analyse all aspects of your simulation with advanced plotting and exporting.



OpenRocket simulation of rocket for VTOL with successive methods of test scenarios, analyzation, turning control , thrust vectoring.

EXTERNAL COATING OF ROCKET:

Selection of materials:

- High Specific Strength.
- High Specific Modulus.
- Fabrication Easiness.
- Easy availability.
- Critical requirements.
- Service Conditions.

SPECIAL REQUIREMENTS UNDER ADVERSE CONDITIONS:

- High Pressure.
- High Temperature.
- Thermo-Structural needs.
- Soft Magnets.
- HED Permanent Magnets.
- Bi-metallics.
- Opto-Electronics.
- Electro-Optics.

TYPES OF MATERIALS:

1. Structural Metallic Materials.
2. Composite Materials.
3. Thermo-Structural Materials 4. Thermal Protection Materials.
5. Special Materials.
6. Chemicals.

STRUCTURAL METALLICS:

- i) 15 CDV6 : Low carbon steel used in solid rocket motor case.
- ii) ii) M250 : Maraging steel with high strength and high toughness used in booster solid rocket motor case.
- iii) Titanium alloy: (Ti-6Al-4V) used in high pressure gas bottles .
- iv) Aluminium Alloys: used in liquid propellant tanks, engine components, airframe in Reusable Launch Vehicles. Types: AA 2219, AA2014, AA6061.
- v) Magnesium/ Mg -Lithium alloys: used in upper stage structure like payload adopter, avionic decks, equipment bay structure.
- vi) Powder metallurgy products: used in nozzle throat for bi -propellant control thrusters.

COMPOSITES:

- i) Carbon F / Kevlar F – Epoxy Resin: used in solid motor case, pressure vessel, interstages, payload adopter.
- ii) Carbon C / Silica C – Phenolic Resin: used in ablative liners, nozzle throat inserts.

THERMO-STRUCTURALS:

- i) Carbon Fibre/ Silicon Carbide Ceramic Matrix Used in nose-cap of heat-shield, leading edge and control surface of RLV.
- ii) SiC F/SiC Ceramic Matrix Composite: used in high temperature / hot structures.

THERMAL PROTECTION SYSTEM:

- i) Carbon/Carbon Composite: used in nozzle throat, nosecone (SiC Coating). ii) ii) Silica tiles: (Silica Fibre in Si gel) used in space shuttle and SRE (capsule)mission.
- iii) Polyurethane foam insulation for cryogenic propellant tanks and subsystems.
- iv) Flexible Reusable Surface Insulation-FRSI Blanket / felt with Teflon coating used in leeward surface of RLV.

SPECIAL MATERIALS USED

- i) Soft magnetic alloy: Fe-Co-V: used in torque motor in spacecraft.
- ii) HED permanent magnet: Sm-Co: used in gyroscope, inertial navigation, guidance & control system, reaction momentum wheel in spacecraft.

- iii) Bimetallics: (SS-Al and SS-Ti) used in Cryosystem for assembly of dissimilar items.
- iv) Opto-electronics: used in photo sensors and photo diodes and photo voltaic devices for power generation in satellites.
- v) Electro-optics: used in High resolution imaging in Spacecrafts.

CHEMICALS:

- i) Different coating materials are used for protection and imparting certain characteristics to surfaces, potting of connectors.
- ii) Variety of adhesives/ bonding agents are used in processing, installation of sensors, assembly and integration operations.
- iii) Most of these chemicals are polymers.

MATERIALS USED:



15 CDV6-Low
Carbon Steel



M250- Maraging
Steel



Titanium Alloy



Aluminium Alloy



Magnesium Alloy



Powder Metallurgy



Carbon Fiber.



Silica C



SiC Ceramic Matrix
Composite.



Liquid Hydrogen



Liquid Oxygen

RESULTS AND DISCUSSION.



New developed vertical rocket launch named “Satee 1” into deep space.



New rocket of Satee 1 with new methods of simulations and testing software of developed aerodynamic thrust vectoring and turning control for successful vertical rocket launch approved by many collaborators of many aerospace field and “Journal Of Aeronautics” term.

□ A successful deep space VTOL (Vertical Take-Off and Landing) rocket launch is a significant milestone in space exploration. It demonstrates advancements in

aerospace technology and the capability to access and navigate deep space environments by simulation and testing of flight control software in field of New methods on Aerodynamic Thrusting Vector of Gimballing, Thrust Vector Nozzles, Fluid Injection, Aerospike Nozzles, Synthetic Jet Actuators for a successful rocket launch that requires precise control of rocket's trajectory into deep space . New methods on Turning Control on Control Surface, Reaction Control System, Roll Control, Gravity Pull, Stage Separation, Active Guidance for successful rocket launch into deep space .

Conclusion:

A successful vertical deep space rocket launch marks a momentous achievement in the field of space exploration and signifies several key aspects:

1. Technological Advancements: A deep space rocket launch requires cutting-edge technology and engineering expertise. The success of such a mission demonstrates the capability of humanity to overcome significant technical challenges and push the boundaries of what is possible.
2. Scientific Exploration: Deep space missions often carry scientific instruments and payloads that aim to study celestial bodies, collect data on cosmic phenomena, or explore the far reaches of our solar system and beyond. The successful launch enables these valuable scientific endeavors, contributing to our understanding of the universe.
3. Space Travel Prowess: Deep space missions involve navigating through vast distances, harsh environments, and complex celestial trajectories. A successful launch reflects the proficiency of space agencies and organizations in orchestrating such intricate missions.
4. Inspirational Impact: Deep space missions capture the public's imagination and inspire future generations of scientists, engineers, and space enthusiasts. They showcase humanity's drive to explore the cosmos and encourage the pursuit of ambitious space exploration goals.
5. Potential for Future Exploration: Accomplishing a deep space rocket launch opens up opportunities for further exploration and potential future missions to explore new destinations in space, such as distant planets, asteroids, or even interstellar space.

In conclusion, a successful deep space rocket launch is a testament to human ingenuity, our thirst for knowledge, and the potential for exploring the vast cosmos that surrounds us. It is a collective achievement that pushes the boundaries of science and technology while inspiring the world to dream big and reach for the stars.

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Aerodynamic Trust Vectoring And Turning Control For Deep Space Vertical Rocket Launch

Sai Sasika M, Dr. S Prakash , Dr. Anand T.

2023 Innovations in Power and Advanced Computing Technologies (i-PACT)

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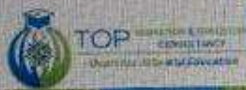
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PAPER-TITLE: AERODYNAMIC THRUST VECTORING AND TURNING CONTROL FOR DEEP SPACE
VERTICAL ROCKET LAUNCH

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