© April 2025 | IJIRT | Volume 11 Issue 11 | ISSN: 2349-6002

Autonomous Landing Gear Deployment Model

M.A. Kelkar[1], S. Deore[2], R, George[3], P. Jadhav[4], R. Gunjal[5], S. Sapkal[6]
[1,2,3,4,5,6] *2nd year student of the Aerospace department from Sandip University Nashik, Maharashtra, India*

***Abstract*—With the growing demand for reusable spaceflight technologies, the safe and efficient landing of rocket boosters has become a critical area of focus in aerospace engineering. This project presents the design and development of a scaled-down autonomous landing gear deployment model inspired by real-world systems used by organizations such as SpaceX and Blue Origin [1],[5]. The system employs an Arduino Uno microcontroller interfaced with an ultrasonic sensor to detect descent height and trigger servo motor-driven leg deployment at a specified altitude. The landing gear comprises a combination of main and supporting legs, integrated with mechanical springs to absorb impact forces and enhance stability during landing. The model was validated through a series of component-level and system-level tests. This prototype provides foundational insights into the dynamics of small-scale autonomous landing systems and can be further enhanced with features such as hydraulic dampers and thrust vectoring.**

***Index Terms*—Autonomous Landing System, Reusable Rockets, Landing Gear Deployment, Aerospace Model Prototyping, Vertical Takeoff and Landing (VTOL)**

I. INTRODUCTION

The increasing emphasis on cost-effective and sustainable space exploration has led to rapid advancements in reusable launch vehicle (RLV) technology. Organizations such as SpaceX and Blue Origin have demonstrated the viability of reusing the first stage of rockets [1],[5], significantly reducing mission costs and increasing launch frequency. A critical component in such reusable systems is the autonomous landing mechanism, particularly the deployment of landing gear systems that ensure a safe and stable touchdown.[7]

Motivated by these advancements, this project focuses on developing a scaled-down, autonomous landing gear deployment model. The primary objective is to simulate a self-activating mechanical system that mimics the landing functionality of reusable rockets. Unlike large-scale implementations that incorporate complex thrusters and hydraulics, this model emphasizes simplicity, functionality, and affordability using readily available electronic and mechanical components.

The model is designed to deploy landing legs automatically using an Arduino Uno microcontroller interfaced with ultrasonic sensors and servo motors. The system is triggered during descent when a pre-defined altitude is reached, allowing the landing legs to extend and stabilize the structure upon impact. Although thrusters are not included in this miniature version, the project serves as a foundational step toward understanding and prototyping autonomous landing mechanisms.

II. RESEARCH METHODOLOGY

A. Conceptual Framework

The project began with a comprehensive review of current reusable rocket technologies [4],[5], with a particular focus on the landing leg mechanisms of SpaceX's Falcon 9 and Blue Origin’s New Shepard. Due to limited access to proprietary design details, the team developed a custom approach based on simplified principles of mechanical linkages and electronic actuation.

B. Design and Prototyping

The primary design objective was to create a reliable mechanical linkage system for landing legs that could be deployed autonomously. The rocket body and leg configurations were developed using iterative CAD modelling [8]. A prototype was built using lightweight acrylic sheets, which were chosen for their availability, ease of machining, and sufficient strength for a scaled model.

C. Component Selection

Electronic components were selected based on compatibility, responsiveness, and ease of programming. An Arduino Uno microcontroller served as the central control unit[3]. A servo motor was selected for its precise angular control and quick response. An ultrasonic sensor was used to determine the rocket's proximity to the ground during descent. Springs were incorporated into the landing legs to act as shock absorbers.

D. Circuit Integration and Coding

A control circuit was assembled to integrate all electronic components. Custom code was written and uploaded to the Arduino to interpret altitude data from the ultrasonic sensor [9]. Upon detecting a descent to 30 cm, the Arduino sends a signal to the servo motor to initiate the deployment of the landing gear.

E. Testing and Evaluation

The project included a multi-phase testing strategy. Initially, individual components were tested for reliability and compatibility. Once validated, subsystem testing followed, focusing on the coordination between sensor data and motor response. Finally, full system integration was tested in a controlled environment to evaluate performance during simulated landing scenarios [10]. Observations were recorded for response time, deployment accuracy, and structural integrity of the landing mechanism.

III. MECHANISM

A. Structural Components

The landing gear comprises two main types of legs: main legs and supporting legs. The main legs are directly responsible for absorbing the impact during landing and are structurally reinforced with mechanical springs that function as shock absorbers. Supporting legs are mounted between the main legs and the rocket body and are designed to stabilize the structure during deployment.

The precise tension in the supporting legs plays a crucial role in the success of the landing. Excessive tension can cause mechanical failure or rebound effects upon contact with the surface, while insufficient tension can result in collapse or instability.

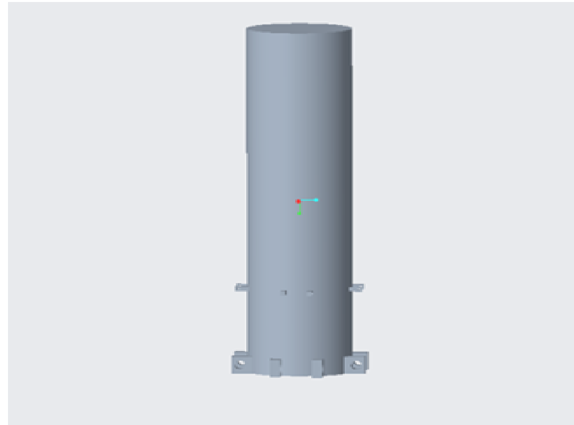

Fig. 1: Main Rocket Body
Illustrates the central structure where all internal components are housed, including the Arduino Uno, power supply, and anchoring points for the legs.

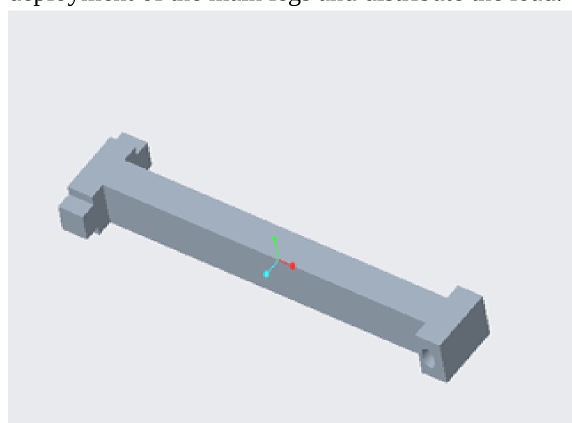

Fig. 2: Supporting Leg Design
Depicts the angled support legs that guide the deployment of the main legs and distribute the load.

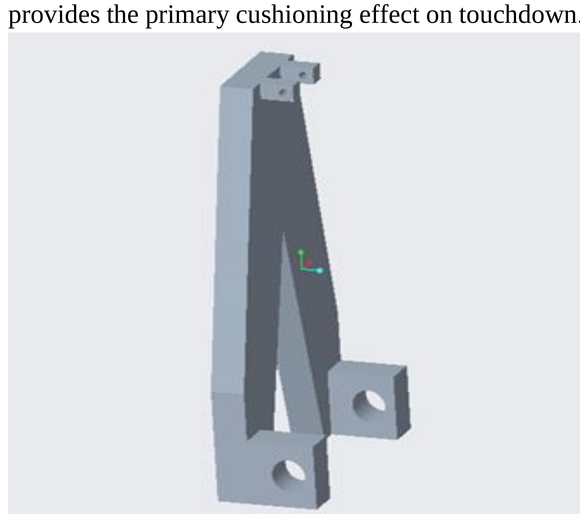

Fig. 3: Main Leg Design
Shows the robust, spring-loaded landing leg that provides the primary cushioning effect on touchdown.

B. Working Principle

The Arduino Uno receives continuous input from the ultrasonic sensor about the altitude of the descending rocket. When the measured distance from the ground reaches 30 cm, the microcontroller sends a signal to the servo motor, which activates a mechanical linkage system that deploys the supporting and main legs outward.

As the legs deploy, the supporting legs spread to create lateral stability while the main legs extend vertically downward. Springs integrated into the main legs compress upon impact, absorbing kinetic energy and reducing vibrational stress.

The system mimics real-world landing gear functionality on a reduced scale and offers insight into automated deployment timing, impact absorption, and structural balance during vertical landings.

IV. PARAMETERS

The system parameters of the autonomous landing gear deployment model are presented in the table below. These parameters were determined through iterative design and physical testing to ensure optimal performance and mechanical reliability for a scaled-down model.

Parameter	Value	Unit
Rocket height	60	cm
Outer diameter	7.6	cm
Inner diameter	7.4	cm
Wall thickness	0.2	cm
Landing leg length	16	cm
Landing leg width (top)	2.5	cm
Landing leg width (bottom)	5.0	cm
Deployment angle	60	degrees
Material used	Acrylic sheet	—
Deployment time	1.5	seconds
Motor type	Servo motor	—
Power supply	5V DC	—
Sensor used	Ultrasonic	—
Trigger altitude	30	cm
Total model weight	0.85	kg

Table (1) System parameters

V. CONCLUSION

The development of the autonomous landing gear deployment model successfully demonstrates the feasibility of creating a self-actuating system capable of stabilizing a rocket during landing. The integration of mechanical components with programmable electronics such as Arduino, ultrasonic sensors, and servo motors enabled the simulation of real-world re-landing mechanisms used in modern aerospace applications. The deployment logic, triggered at a pre-set altitude, was performed reliably during tests, and the structural design effectively absorbed landing forces through spring-based damping.

This project serves as a foundational prototype for further research in autonomous landing systems, particularly for reusable launch vehicles. It offers insights into component synchronization, deployment timing, and impact mitigation using basic and affordable hardware. The use of acrylic as a structural material proved suitable for the prototype but could be replaced with advanced composites or lightweight alloys in future iterations.

Future work may focus on incorporating terrain-sensing capabilities, improving aerodynamic efficiency, and scaling the system for higher loads and complex environments. Additionally, the integration of thrust vectoring and hydraulic or pneumatic damping systems could enhance the landing precision and robustness of the design [4].

Overall, this project lays the groundwork for more advanced and scalable autonomous landing technologies suitable for both educational and experimental aerospace platforms

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