Scaled Model of a Small Diameter Bomb (SDB) for Educational and Research Application

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***Abstract*—This paper describes the design and development of a prototype of a small diameter bomb (SDB). It is an educational model developed for research and learning purposes only.**
The model has been scaled to a maximum length of 1.0 meter. It replicates the geometry and the functional aspect of a real-time SDB. It is an inert and non-propulsive model. It is powered by low-voltage electronics. The project includes additive manufacturing (AM), an embedded system and IoT (Internet of Things). The prototype includes four internal modules. They are guidance, avionics, payload (dummy), and tail control. All of these parts are printed using 3d printers.

***Index Terms*—3d printing, additive manufacturing, guidance simulation, safe demonstrator, small diameter bomb**

I. INTRODUCTION

In recent years, the defense industry has undergone significant development due to advancements in robotics. However, several innovations have also come with certain drawbacks. One of these drawbacks is collateral damage. Collateral damage is damage caused to undesired targets by such munitions during attacks and wars. To bridge this gap, this paper presents an inert, educational prototype of a Small Diameter Bomb (SDB) that captures the structural and control characteristics of a real-time precision-guided munition, without any propulsive or explosive functionality.

This prototype is developed for educational applications and serves as a modular research demonstrator, combining 3D printing, control electronics, IoT (Internet of Things), and embedded systems.

This model is inspired by the GBU-39, which is manufactured by the Boeing Company in Missouri, USA. Unlike static aerospace models, this system includes movable control fins, internal segmentation, and sensor-based feedback, allowing a realistic demonstration of guidance and stabilization principles.

This work contributes to the growing field of additive manufacturing in the defense industry, focusing on safe, hands-on learning for first-year and second-year undergraduate students in defense, additive manufacturing, and robotics disciplines.

II. DESIGN OBJECTIVES

The major design goals of the educational SDB model are:

1. To design a scaled, safe, and inert aerodynamic model of a modern SDB system.
2. To fabricate the structure entirely using 3d printing, with modular internal segmentation.
3. To implement sensor-based attitude measurement and servo-controlled tail fins for flight path simulation.
4. To provide a low-voltage (≤6 V) platform suitable for classroom use.
5. To facilitate project-based learning in guidance, control, and system integration.

III. SYSTEM OVERVIEW

A. Physical Parameters

Parameter	Specification
Total Length	1.0 m
Maximum Diameter	0.14 m
Body Segments	4 (Nose, Avionics, Payload, Tail)
Total Weight	2kg
Material	PETG (3D printed)

Fins	4 movable tail fins (servo-controlled)
Surface Finish	PETG

The fuselage consists of four detachable segments for easy printing, transport, and maintenance. Each section is joined via M3 and M4 screws, maintaining alignment and modularity.

B. Internal Segmentation

Segment	Function	Key Components
Nose Section (Guidance)	Simulates seeker head	2x LiDAR Sensors (VL53L0X)
Avionics Section	Houses electronics	ESP32 microcontroller, battery, telemetry
Payload Section (Inert)	Demonstrates mass distribution	ESP32 And BMP280 (Pressure and Temperature Sensor)
Tail Section	Fins + control actuation	4× high torque servos, stabilizer frame, hinge pins

Each section includes internal 3D-printed ribs and trays to support electronics and wiring channels. The functional block diagram of the overall project is shown in Figure 1.

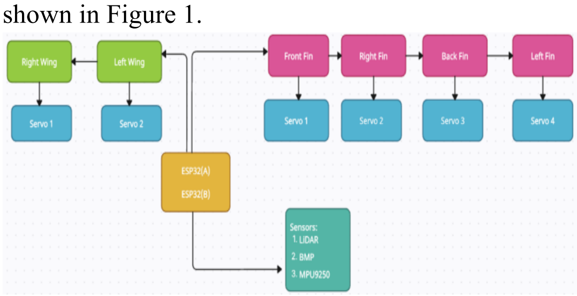

Figure 1: Block Diagram of the SDB

IV. DESIGN AND FABRICATION

A. CAD Design

The model was designed in Autodesk Fusion 360 for static stress and aerodynamic flow distribution.

Design Feature	Specification
Wall Thickness	5.0 mm
Fin Sweep Angle	180°
Fin Material	PETG
Joint System	M3 + M4 Hex (Allen) Screws

The finalised CAD model of the SDB is shown in Figure 2.

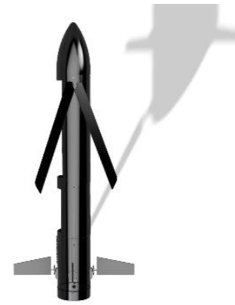

Figure 2: CAD Model of the SDB.

B. 3D Printing Parameters

Parameter	Value
Nozzle	0.4 mm
Layer Height	0.2 mm
Infill	15% (Gyroid)
Filament	PETG
Total Filament Used	2kg
Print Time	~90 hours
Assembly Method	Adhesive + threaded fasteners

V. ELECTRONIC SUBSYSTEM

A. Hardware Components

Component	Function
ESP32 (×2)	Central control and data handling
MPU9250	IMU for pitch and roll sensing
BMP280	Barometric pressure (altitude simulation)
Servos (×4)	Tail fin deflection
LiDAR VL53L0X	2D maps and models of the sensed environment
12V AC Adapter	Higher Voltage Input
Buck Converter	Voltage Regulation to Lower output

B. Control Architecture

The system is powered by a 12V AC Adapter. A buck converter is used to decrease the output voltage to 6V. This output voltage is supplied to the 4 servos in the actuator bay.

It is also supplied to the microcontrollers housed in the payload and avionics bay.

The signal flow from the ESP32 in the payload bay to the IMU, LiDARs and BMP280 sensors is done via the I^2C protocol. The ESP32 in the avionics bay shares signals with the servos in the actuator bay via Pulse Width Modulation (PWM). It allows to move the fins with varying angular velocities. The ESP32 of the avionics bay communicates with the IoT devices through Wi-Fi. It allows various devices connected to the same Wi-Fi to rotate the fins using a website.

C. Communication System

A Wi-Fi-based dashboard displays the Pitch, Roll, and Yaw angles from MPU9250. It also displays the Gyroscope Values from MPU9250. Additionally, it displays the Magnetometer Values from MPU9250. Finally, it shows the Sensor Data from VL53L0X and BMP280.

VI. FUNCTIONAL SIMULATION

A. Power System

The average power of the system is between 10-12W. It has a runtime of maximum 90 minutes.

B. Safety Validation

There are no moving propellers, pressure vessels, or propellant systems. The mechanical forces are restricted to lightweight servo actuation only. All edges rounded and fin tips blunted for safe classroom handling.

The fabricated inert model of the SDB is shown in Figure 3.

Figure 3: Fabricated inert model of the SDB

VII. DISCUSSION

A. Educational and Research Relevance

The Safe SDB Model integrates aerodynamic concepts, control systems, and materials — into a tangible, interactive prototype. Students gain hands-on experience in the concepts of:

1. System integration and embedded control.
2. Additive manufacturing and assembly.
3. Guidance and control algorithms (PID, proportional navigation).
4. Data acquisition and telemetry.

The model also demonstrates Design Thinking principles — ideation, prototyping, testing, and iteration — making it ideal for multidisciplinary teams in mechanical, electrical, and aerospace programs.

B. Advantages

The model of the SDB has the following advantages:

1. It is fully 3D printed and has a modular design. It is also built with a low-cost budget (20000INR ~ USD250).
2. Safety: It operates on 6V and has no propulsion or combustion.
3. Compactness: It can be easily handled in labs or exhibitions.
4. Educationally rich: It links theoretical defense concepts to physical systems.

C. Limitations

The SDB also has the following limitations:

1. It lacks actual aerodynamic forces and can only demonstrate static simulation only.
2. The servo torque limits fin actuation speed.
3. It is built with lightweight materials (PETG) and limits outdoor testing.

D. Sustainability

All materials (PETG) are recyclable, aligning with sustainable engineering goals.

VIII. FUTURE WORK

The current model of the SDB is only a static model built with hobby electronics. We wish to upgrade and develop the same with:

1. Integration of a low-speed airflow test chamber for aerodynamic visualization.
2. Incorporation of augmented reality (AR) for virtual trajectory overlay.
3. AI-based trajectory correction via onboard neural PID (TinyML).
4. Coupling with drone-carried release simulation for teaching drop dynamics.
5. Upgrading internal structure with carbon-fiber PETG hybrid for high rigidity.

IX. CONCLUSION

The 3D-Printed Safe Educational SDB Model demonstrates that complex aerospace systems can be safely and effectively represented through additive manufacturing and low-voltage embedded electronics. The model provides a hands-on tool for teaching aerodynamics, control theory, and systems engineering to first-year and interdisciplinary engineering students. By combining safety, scalability, and educational depth, this project serves as a blueprint for developing intelligent aerospace demonstrators in academic environments, encouraging innovation and real-world learning in the next generation of aerospace engineers.

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