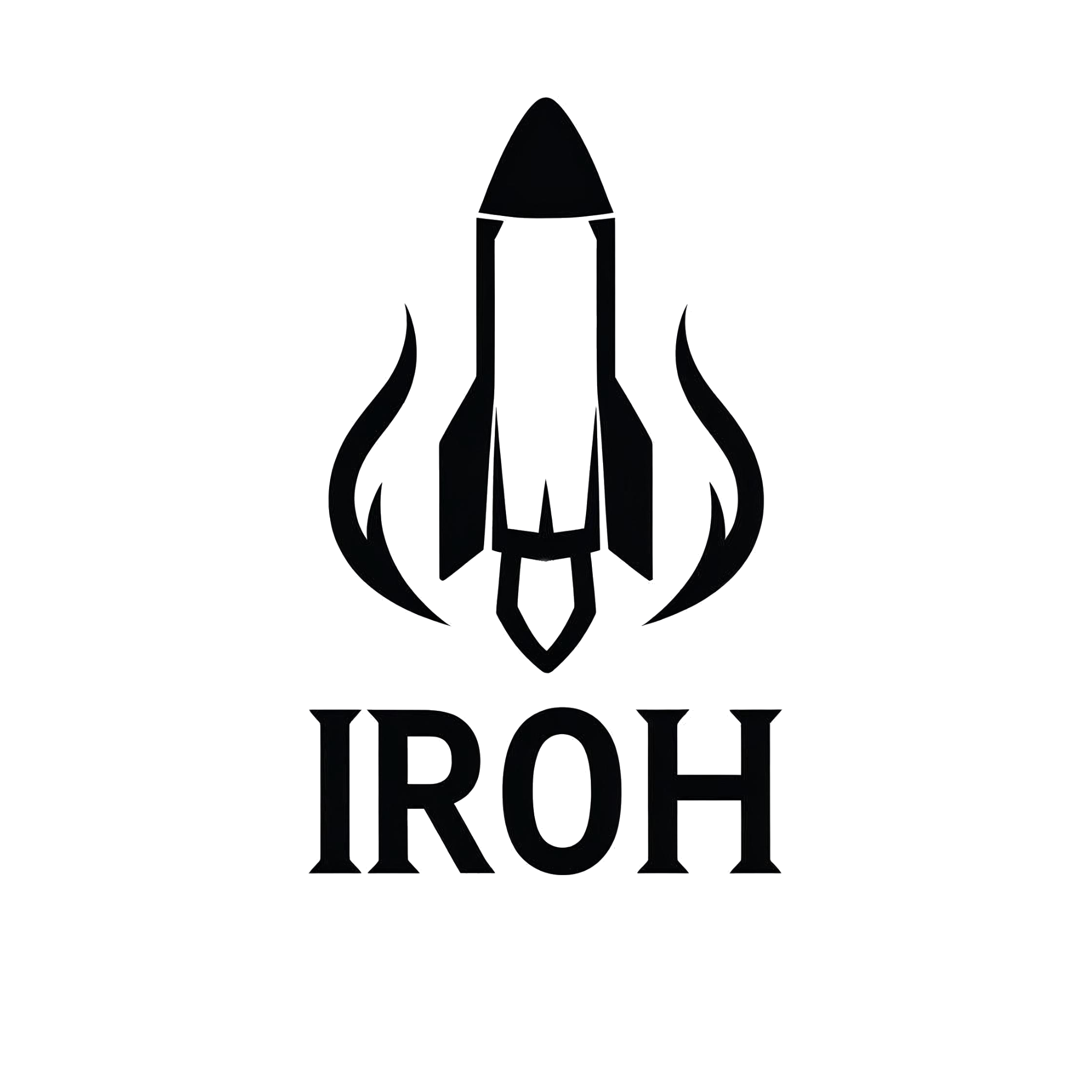
**Software Requirements Specification**

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**Iroh TVC Model Rocket**

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# 1.0 Introduction

## ***1.1 Purpose***

The purpose of this document is to define the functional and non-functional requirements for the successful development of a Thrust Vector Controlled (TVC) Model Rocket. The TVC system aims to provide real-time flight stabilization and dynamic trajectory adjustments through thrust deflection using a dual-axis servo mechanism.

## ***1.2 System Scope***

This project details the design, development, and deployment of a Thrust Vector Control (TVC) system integrated into the model rocket named “Iroh.” The overall system includes hardware components such as servos, an altimeter, a gyroscope, and other sensors, along with embedded software. However, this document will primarily focus on the embedded software implementation that controls the dual-axis servo mechanism essential for TVC. The main objective is to achieve stable flight and a controlled descent with a safe landing by actively deflecting the rocket’s thrust vector.

***1.3 Nomenclature***

| **Term** | **Definition** |
| --- | --- |
| AGL | Above Ground Level – altitude measurement relative to the ground surface directly beneath. |
| Altimeter | A sensor that measures altitude |
| Apogee | The highest point reached by the rocket during its flight trajectory. |
| Dual-axis | Refers to control or movement in two perpendicular planes or axes. |
| Embedded Software | Software programmed into hardware to perform dedicated functions. |
| Gyroscope | A sensor used to measure orientation and angular velocity. |
| Iroh | The name of the model rocket being developed in this project. |
| Servo | An actuator device that precisely controls angular position. |
| TVC | Thrust Vector Control – a method of controlling the rocket’s flight by deflecting its thrust. |

## ***1.4 References***

Arduino. *Arduino Official Website.* [Online]. Available:<https://www.arduino.cc>

## ***1.5 Document Overview***

This Software Requirements Specification (SRS) document provides a detailed description of the Thrust Vector Control (TVC) embedded software for the model rocket “Iroh.” The document’s structure is as follows:

* **Section 1: Introduction** – Presents the project purpose, scope, nomenclature, and references.
* **Section 2: Overall Description** – Describes the system architecture and context.
* **Section 3: Functional Requirements** – Specifies the detailed functional behaviors of the TVC system.
* **Section 4: Non-Functional Requirements** – Outlines constraints such as performance, reliability, and safety.
* **Appendices** – Include supporting materials such as glossary, diagrams, and related documents.

# 2.0 Overall Description

## 2.1 System Environment

The TVC system operates within the embedded environment of the model rocket during flight. The system environment includes the following:

* Hardware:
  + Microcontroller (e.g., Arduino or Teensy) for processing sensor data and controlling servos
  + Dual-axis servo motors for thrust vector deflection
  + Sensors including gyroscope, accelerometer, and altimeter for real-time flight data
  + Power supply from onboard batteries
* Software:
  + Embedded firmware running real-time TVC control algorithms to stabilize and adjust rocket’s trajectory
  + Communication interfaces for sensor input and servo output
  + Safety and fault detection to handle anomalies during flight
* Physical Environment:
  + The rocket operates under unpredictable flight conditions, including variable acceleration, vibration, temperature changes, atmospheric pressure variations, and varying terrain
  + The system must reliably function throughout launch, ascent, apogee, and descent

## ***2.2 Functional Requirements Specification***

This section defines the functional requirements of the embedded software that controls the TVC system in the “Iroh” model rocket. Each requirement specifies a function the system must perform to ensure correct operation throughout the rocket’s flight.

### 2.2.1 Sensor Input

The system shall interface with a gyroscope, accelerometer, and altimeter to acquire real-time flight data for control and estimation.

### 2.2.2 Flight State Estimation

The software shall estimate the rocket's orientation and flight phase (e.g., launch, ascent, apogee, descent) using sensor data..

### 2.2.3 Control Algorithm

The control algorithm shall execute in real-time, processing flight data to generate appropriate control signals for thrust vector adjustment.

### 2.2.4 Servo Actuation

The system shall drive two servo motors to control thrust direction along two perpendicular axes based on the output of the control algorithm.

### 2.2.5 Apogee Detection

The system shall detect apogee by identifying a peak in altitude followed by a sustained drop and trigger transition to descent mode.

### 2.2.6 System Initialization

On startup, the system shall initialize all components and perform sensor calibration procedures to ensure accurate readings.

### 2.2.7 Fault Handling

The system shall monitor sensors and actuators for faults. Upon detecting anomalies, it shall enter a safe state or revert to default behavior to maintain stability.

### 2.2.8 Optional Data Logging

If onboard storage is present, the system shall record time-stamped sensor and control data throughout the flight for post-analysis.

### 2.2.9 Optional Camera Integration

If a camera module is installed, the system shall initiate video recording at launch and stop upon landing. Camera control should operate independently of core flight control systems to avoid interference.

## 2.3 Intended Users

The intended users of this system are university-level students or hobbyists with a basic to intermediate experience in embedded systems, microcontrollers (e.g., Arduino), and rocketry. Users are expected to:

* Understand electronic circuit assembly and sensor integration.
* Be able to upload and debug embedded software.
* Follow basic safety procedures for handling explosive material used in model rocketry.
* Interpret sensor data and analyze flight performance.

## 2.4 Non-Functional Requirements

This section outlines attributes that do not directly specify system behaviors but are essential for the performance and usability of the embedded TVC system. These non-functional requirements ensure the system operates reliably, efficiently, and safely within the constraints of a model rocket environment. Key aspects include reliability, timing performance, power consumption, physical constraints, maintainability, and safety.

### 2.4.1 Reliability

The system shall operate reliably throughout the entire flight phase, including launch, ascent, apogee, and descent, without failure under typical model rocket conditions.

### 2.4.2 Real-Time Performance

The embedded system shall process sensor inputs and compute control outputs with a maximum latency of 100 milliseconds (0.1 seconds) to ensure timely thrust vector adjustments for stable flight.

### 2.4.3 Power Efficiency

The system shall operate on a limited battery capacity and must not exceed a total average power draw of 2.5W during flight.

### 2.4.4 Size and Weight Constraints

All components, including the microcontroller, sensors, and servos, must fit within the payload space of an E-class model rocket and contribute minimally to total launch weight.

### 2.4.5 Maintainability

The firmware should be modular and well-documented to facilitate updates, debugging, and reuse across multiple flight tests.

### 2.4.6 Safety

The system must include basic fault handling such as servo lockout on loss of signal or sensor failure to prevent erratic control behavior.

# 3.0. Requirements Specification

This section details the specific functional and non-functional requirements that the Thrust Vector Control (TVC) system must fulfill. These requirements define the expected behaviors, inputs, outputs, and constraints to ensure the system meets its intended purpose of providing stable and controlled flight for the model rocket “Iroh.”

## 3.1 Functional Requirements

### 3.1.1 Sensor Data Acquisition

The system shall continuously acquire real-time flight data from onboard sensors, including the gyroscope, accelerometer, and altimeter, with a minimum update rate of 50 Hz.

### 3.1.2 Flight Stabilization Control

The system shall process sensor data and compute appropriate thrust vector deflections to maintain rocket stability and orientation during all flight phases.

### 3.1.3 Servo Actuation

The system shall output precise PWM signals to the dual-axis servos to adjust thrust direction with an angular resolution of at least 0.1 degrees.

### 3.1.4 Launch Detection

The system shall detect launch initiation using sensor thresholds and activate the TVC control algorithms within 0.5 seconds after liftoff.

### 3.1.5 Apogee Detection

The system shall identify apogee (highest flight point) using sensor data and initiate controlled descent procedures immediately upon detection.

### 3.1.6 Fault Detection and Safety

The system shall monitor sensor and actuator health, triggering safe mode or system shutdown in the event of detected faults or anomalies.

### 3.1.7 Data Logging

The system shall log flight data including sensor readings and servo positions at a minimum rate of 10 Hz for post-flight analysis.

### 3.1.8 Communication Interface

The system shall support wired or wireless communication for telemetry data transmission during flight.

### 3.1.9 Optional Camera Control

If equipped, the system shall interface with an onboard camera module to control video recording start/stop synchronized with flight phases.

## ***3.2 Non-Functional Requirements***

(Refer to Section 2.4 for detailed non-functional requirements including reliability, timing, power, physical constraints, maintainability, and safety.)