**Design Proposal for MIME Capstone Design**
**March 8th, 2026**
**Team C603**
**AIAA Student Competition Rocket Team (SCRT) - Roll Control**

# Roll Control System Development for the AIAA OSU SCRT Competition Rocket

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## 1.0 Introduction and Project scope

### 1.1 Background and Customer Context

The American Institute of Aeronautics and Astronautics (AIAA) Oregon State Student Competition Rocket Team (SCRT) designs, builds, and launches rockets for the AIAA competitions held for universities. This competition evaluates different categories including flight performance, payload capability, safety compliance, and data collection accuracy. A recurring challenge for SCRT is the ability to control roll for their rockets during ascent. This particular instability tends to stem from uneven and asymmetric aerodynamic loading and coupling effects [1].

The current rocket system and configuration does not feature a roll-control system. As documented in sponsor meetings [2], the roll-control effort is effectively starting from scratch. This means that there is no prototype or completed trade studies in place. Without the presence of a roll-control system, there is the possibility of excessive angular velocity about the longitudinal axis, further impacting flight stability and performance, potentially compromising onboard sensor performance, and payload survivability [1].

The customer has requested the development of an active roll-control system that integrates into an existing sub-scale solid-fuel rocket, while still complying with competition safety and geometric constraints. The system must be scalable to the full-scale rocket, be manufacturable by SCRT, fit within the structural constraints, and operate reliably under aerodynamic loading.

### 1.2 Problem Statement

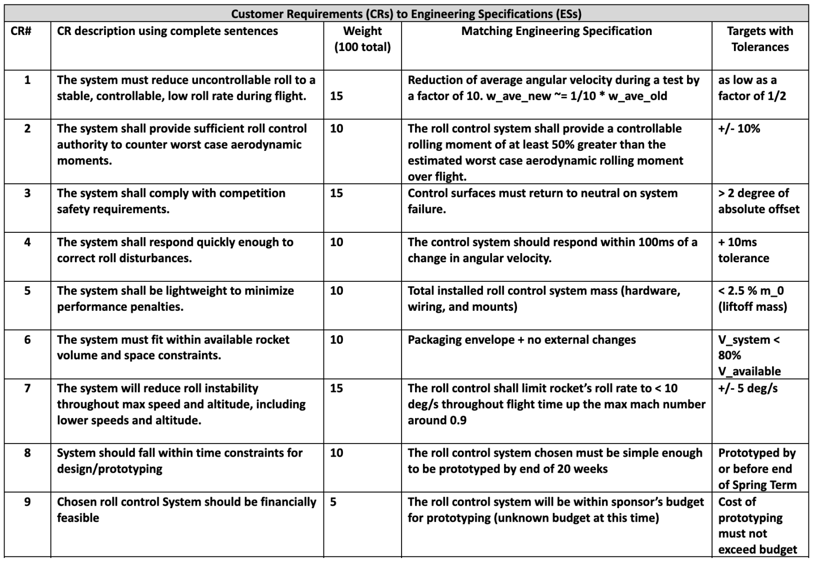
The objective of this project is to design, analyze, prototype, and construct a roll-control system capable of reducing uncontrolled roll in a sub-scale solid-fuel rocket to a stable and controllable rate during the ascent of the rocket, where stable is defined as reducing the average roll rate by at least one order of magnitude relative to baseline measurements.

Success for this project is defined as:

- Demonstrated reduction in average roll relative to baseline (control) flight data
- Sufficient authority to counter worst-case aerodynamic roll moments and rates
- Compliance with competition safety requirements
- Integration within existing fin geometry (0.125 in thickness)
- Design capable of scaling to full-scale rocket
- Manufacturability within SCRT’s capabilities

### 1.3 Customer Requirements and Engineering Specifications

Customer requirements (CRs) were translated into measurable engineering specifications through a House of Quality process, as seen in Table 1. The key customer requirements included reduction of uncontrollable roll, provide sufficient roll control authority, and compliance with competition safety requirements [2]. These were mapped to measurable engineering specifications such as, reduction of average angular velocity (by a factor of 10), increased controllable rolling moment (50% greater than worst case aerodynamic rolling moment), and control surfaces returning to neutral on system failure (within 2 degrees of offset). These direct translations ensured that all proposed design concepts were evaluated using objective and customer driven metrics.



| Customer Requirements (CRs) to Engineering Specifications (ESs) | | | | |
|---|---|---|---|---|
| **CR#** | **CR description using complete sentences** | **Weight (100 total)** | **Matching Engineering Specification** | **Targets with Tolerances** |
| 1 | The system must reduce uncontrollable roll to a stable, controllable, low roll rate during flight. | 15 | Reduction of average angular velocity during a test by a factor of 10. w_ave_new ~= 1/10 * w_ave_old | as low as a factor of 1/2 |
| 2 | The system shall provide sufficient roll control authority to counter worst case aerodynamic moments. | 10 | The roll control system shall provide a controllable rolling moment of at least 50% greater than the estimated worst case aerodynamic rolling moment over flight. | +/- 10% |
| 3 | The system shall comply with competition safety requirements. | 15 | Control surfaces must return to neutral on system failure. | > 2 degree of absolute offset |
| 4 | The system shall respond quickly enough to correct roll disturbances. | 10 | The control system should respond within 100ms of a change in angular velocity. | + 10ms tolerance |
| 5 | The system shall be lightweight to minimize performance penalties. | 10 | Total installed roll control system mass (hardware, wiring, and mounts) | < 2.5 % m_0 (liftoff mass) |
| 6 | The system must fit within available rocket volume and space constraints. | 10 | Packaging envelope + no external changes | V_system < 80% V_available |
| 7 | The system will reduce roll instability throughout max speed and altitude, including lower speeds and altitude. | 15 | The roll control shall limit rocket's roll rate to < 10 deg/s throughout flight time up the max mach number around 0.9 | +/- 5 deg/s |
| 8 | System should fall within time constraints for design/prototyping | 10 | The roll control system chosen must be simple enough to be prototyped by end of 20 weeks | Prototyped by or before end of Spring Term |
| 9 | Chosen roll control System should be financially feasible | 5 | The roll control system will be within sponsor's budget for prototyping (unknown budget at this time) | Cost of prototyping must not exceed budget |

**Table 1.** House of Quality translating SCRT roll-control customer requirements into engineering specifications. Developed by team.

## 2.0 Design Process and Development of Alternatives

## 2.1 Design Methodology

The team followed a structured concept development and evaluation process to ensure the constraints and requirements of the SCRT competition rocket were met. The initial efforts of the team focused on defining the system level constraints via multiple meetings with SCRT team leads. These meetings and discussions clarified the geometric limitations, safety requirements, available internal space, and the performance expectations of the system.

Following the constraint definition, broad concept generation was performed across multiple differing roll-control approaches. Each team member evaluated different control concepts and strategies to ensure that a comprehensive exploration of potential solutions occurred.

Concepts were screened through preliminary assessments based on control authority, added mass, structural impacts, system complexity, and manufacturability. To ensure feasibility, concepts requiring significant structural redesign or excessive mass addition were eliminated early.

The team then developed a weighted decision matrix to objectively evaluate and compare the remaining concepts using customer driven evaluation criteria. This process helped ensure that the final concept selection aligned with both the performance requirements and implementation constraints.

## 2.2 Concept Generation

Multiple differing roll-control concepts were evaluated, including, canards, trim tabs, spinnerons, fin-can rotation, cold-gas thrusters, thrust vector control, and differential fin control. Each of these concepts was evaluated for control authority, mass impact, design complexity, applicability, system reliability, and system cost.

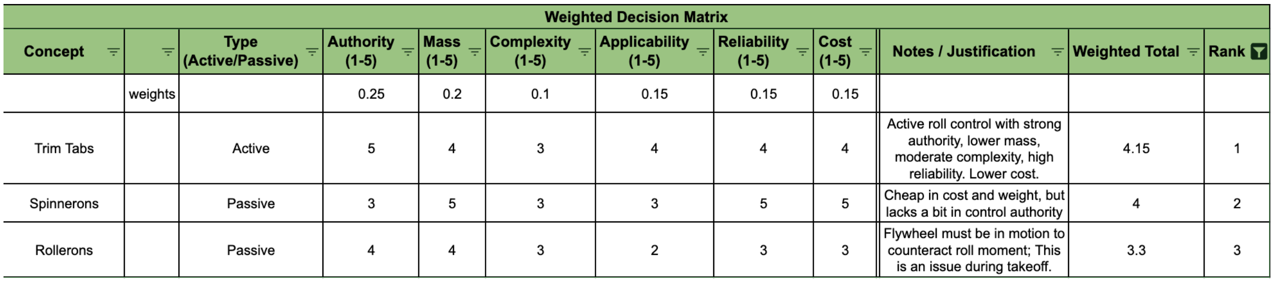
## 2.3 Trade Study and Concept Downselection

A weighted decision matrix was used to evaluate the remaining roll-control concepts using customer-driven criteria. The evaluation weights were determined based on priorities identified during sponsor meetings and engineering judgment. Control authority was assigned the highest weight because this represents the fundamental project scope. Mass was also heavily weighted due to both strict competition and customer mass constraints, while reliability and applicability ensured the system could operate consistently and integrate within the existing rocket geometry. Complexity and cost were given lower weights since increased system complexity were acceptable if they also improved roll-control performance.

The evaluation criteria and weights used in the decision matrix are:

- Control Authority (25%)
- Mass (20%)
- Complexity (10%)
- Applicability (15%)
- Reliability (15%)
- Cost (15%)

Each concept was scored from 1–5 for each criterion, and weighted scores were used to determine the final ranking. A summary of the highest-ranking concepts is shown in Table 2.



**Weighted Decision Matrix**

| Concept | | Type (Active/Passive) | Authority (1-5) | Mass (1-5) | Complexity (1-5) | Applicability (1-5) | Reliability (1-5) | Cost (1-5) | Notes / Justification | Weighted Total | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | weights | | 0.25 | 0.2 | 0.1 | 0.15 | 0.15 | 0.15 | | | |
| Trim Tabs | | Active | 5 | 4 | 3 | 4 | 4 | 4 | Active roll control with strong authority, lower mass, moderate complexity, high reliability. Lower cost. | 4.15 | 1 |
| Spinnerons | | Passive | 3 | 5 | 3 | 3 | 5 | 5 | Cheap in cost and weight, but lacks a bit in control authority | 4 | 2 |
| Rollerons | | Passive | 4 | 4 | 3 | 2 | 3 | 3 | Flywheel must be in motion to counteract roll moment; This is an issue during takeoff. | 3.3 | 3 |

**Table 2.** Top concepts from the weighted decision matrix used for roll-control system downselection. Developed by team.

After applying the weighted scoring system, concepts such as thrust vector control and cold-gas systems offered high authority but were eliminated due to mass, complexity, and integration risk. Spin-can concepts were eliminated due to mechanical complexity and structural redesign requirements. Trim tabs ranked first with a total weighted score of 4.15. This was primarily due to the trim tabs' beneficial balance of authority, low mass addition, manageable complexity, and compatibility with existing rocket architecture. The trim-tab concept provided sufficient roll moment generation with minimal structural disruption. Therefore, the team selected the trim tab concept based on these findings.

## 3.0 Individual Design Concept

### 3.1 Individual Architecture

The proposed individual design consists of an internally mounted servo driving a supported hinge shaft integrated within the trim tab and fin structure. The trim tab spans the root section of the fin trailing edge and remains flush with the fin in its neutral position. The system's deflection range and geometry can be seen in Figure 2.

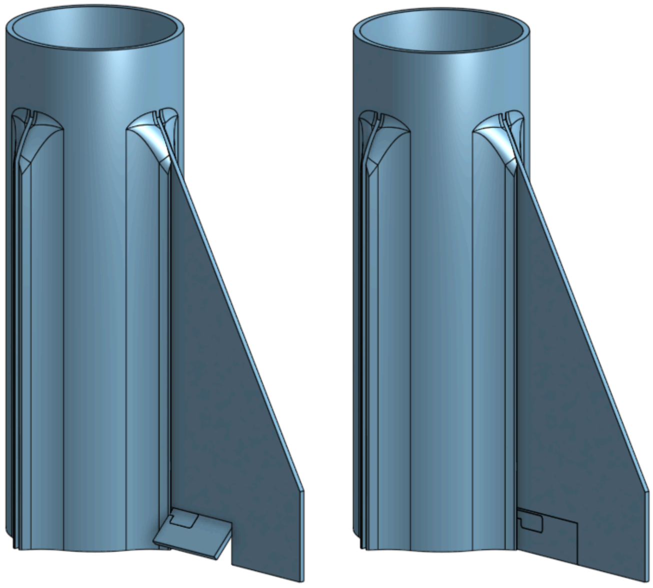


**Figure 2.** CAD model of the servo-controlled trim tab integrated within the rocket fin. The left view shows the trim tab at a 45 degree deflection, while the right view shows the trim tab in its neutral (0 degree deflection) position aligned with the fin surface. Developed by team.

The system architecture is as follows:

- A high torque servo is mounted within the rocket airframe and outer fairings.

- A rigid coupler connects the servo output shaft to a hinge shaft about the trim tabs rotational axis.
- The hinge shaft passes through the rocket fairing and fin root and is supported by internal bearings.
- A clamp hub secures the trim tab to the hinge shaft.
- The shaft continues toward the fin tip as is supported by a secondary support.

When actuated, the servo rotates the hinge shaft, deflecting the trim tab relative to the fixed fin. This deflection generates an aerodynamic moment opposing the rocket's roll rate and also a drag force opposing the rocket's thrust. To ensure the negative impacts of this system are minimal, the trim tab is designed to remain aligned with the fin surface at the neutral position to minimize drag during the ascent of the rocket.

## 3.2 Aerodynamic and Performance Considerations

The trim tab produces a roll moment by altering the aerodynamic loading of a surface, leading to a change in the moment about a rotation axis [3]. The magnitude of both the aerodynamic force and generated roll moment is proportional to the dynamic pressure, trim tab surface area, deflection angle, and the radial distance from the rocket axis [4]. Dynamic pressure increases with velocity, which also increases the available control authority in the flight stages where roll disturbances are most significant. The team's preliminary analysis also indicated that modest trim tab deflection angles are sufficient in generating rolling moments exceeding estimated worst-case aerodynamic disturbances.

The system's servo selection is primarily driven by required output torque under maximum aerodynamic hinge moments. The servo must overcome aerodynamic loading while maintaining an appropriate factor of safety. The selected servo torque rating was verified against the manufacturer's specifications to ensure the system would have adequate margin [5]. Additional servo selection criteria include response time, resolution, power consumption, and thermal tolerance.

The control system is designed to provide consistent and rapid corrective input to damp roll motion without creating overcorrections and oscillatory motions. Proper damping of the system is crucial to ensure oscillatory instability is avoided [6]. Maintaining neutral alignment during steady ascent minimizes drag and reduces overall performance penalty.

## 3.3 Advantages and Disadvantages Relative to Requirements

Advantages:

- High control authority with small deflection angles
- Low additional mass compared to thrust-based systems
- Compact integration within existing fin geometry

- Fail-safe capability by returning to neutral position
- Manufacturable using available resources

Disadvantages:

- Increased mechanical complexity compared to passive stabilization
- Potential structural reinforcement required near hinge region
- Added electrical integration requirements

Despite these disadvantages, the concept satisfies customer requirements more effectively than alternative concepts evaluated

## 4.0 Team Go-Forward Design and Rationale

### 4.1 Final Selected Concept

The team has selected the internally actuated servo-driven trim tab system as the go-forward design. The selected configuration of the trim tab system incorporates an internal servo mounted within the airframe fairings that drives a hinge shaft passing through the frame. The trim tab is attached at root-span using a clamp that couples the tab to the hinge shaft. To reduce the bending stress, the hinge shaft is supported by bushings within the fin structure.

### 4.2 Rationale for Selection

The selected trim-tab configuration received the highest score in the team's decision matrix while also demonstrating a balanced combination of the evaluation criteria. The concept provides sufficient rolling moment to counter disturbances while also remaining compatible with the existing fin geometry and constraints. The system also complies with the competition safety requirements and can be manufactured using SCRT's available resources. Additionally, the presence of an electrical engineer on our team supports control system implementation by specializing in the integration of sensors, on-flight computers, servo electronics, and software. Overall, this trim-tab solution offers the most balanced approach between performance and implementation risk.

## 5.0 Risk Assessment and Mitigation

Several technical risks were identified during the concept development phases. Structural failure at hinge interface is a significant concern due to stress under aerodynamic loading. Another risk identified was servo malfunction or insufficient torque under high loads. Additional risks identified include potential flutter in the trim tab, and integration conflicts with the constrained airframe volume.

To mitigate these risks, the team will implement finite element analysis (FEA) to evaluate the stress distribution and factor of safety under predicted aerodynamic loads. The servo and hinge shaft assembly will also undergo bench testing under simulated loads to verify the accuracy of the torque capacity. To further mitigate these risks, the team will implement testing incrementally, beginning with structural validation before full flight integration. Finally, fail safe features will ensure that the trim tab will return to a neutral position in case of power loss or a system malfunction.

### 5.1 Validation and Performance Verification

The verification of system performance is essential to demonstrating compliance with our customer requirements. The roll-control system will be validated through different stages of testing designed to reduce risk while also working to increase the fidelity of our system.

Initial validation will involve bench testing of the servo and hinge shaft assembly under different simulated aerodynamic loading conditions. Torque output, angular response rate, and repeatability will all be measured to confirm that the actuator meets the design requirements with additional safety margin.

Following bench validation, a prototype fin assembly will be fabricated and subjected to structural evaluation. The hinge region will be inspected for deflection, stress, and potential fatigue concerns. If feasible, airflow testing will be performed to provide a qualitative assessment of trim tab deflection effects.

The final stages of validation will involve integration into the subscale rocket configuration. Roll rate data will be collected during flight and also compared to baseline uncontrolled roll measurements. Success will be defined as a measurable reduction in average roll rate, stable corrective behavior without causing oscillatory compensation, and the additional requirements defined in the problem statement section 1.2.

## 6.0 Project Execution Plan

The project will proceed through:

1. Detailed mechanical design and CAD modeling
2. Prototype fabrication of fin and hinge assembly
3. Bench testing of servo torque response
4. Aerodynamic estimation and validation
5. Subscale rocket integration and testing

This approach reduces the integration risk while still validating performance progressively over each step.

## 7.0 Conclusion

This proposal presents a structured and research backed solution to solving the SCRT Rocket's problem of uncontrolled roll. Through requirement decomposition, concept generation, quantitative trade studies, and downselects, trim tabs were selected as the best and most viable solution. The internally actuated trim tab design satisfies all of the customer requirements for roll reduction, safety compliance, mass efficiency, and manufacturability.

Trim tabs offer strong control authority while remaining compatible with team resources and competition constraints. With proper testing and validation this system provides a feasible path toward improving rocket control, stability, and performance.

## References

[1] Etkin, B., and Reid, L. D., *Dynamics of Flight: Stability and Control*, 3rd ed., John Wiley & Sons, New York, NY, 1996.

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[5] MKS Servos Co., Ltd., "HV747 Digital Servo Specifications," n.d., from https://mksservo.com

[6] Stevens, B. L., and Lewis, F. L., *Aircraft Control and Simulation*, 3rd ed., John Wiley & Sons, Hoboken, NJ, 2003.