Project Management and System Engineering Principles for Successful Student Rocketry: Lessons from ISPIDA

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Abstract

Each year several teams try to launch and land their rockets at the European Rocketry Challenge (EuRoC), where students build sounding rockets to carry a payload of at least one kg to an apogee of either 3000 m or 9000 m. In 2025, only 15 of 30 rockets launched and only 2 had a nominal recovery. After three successful launches, the Aerospace Team Graz (ASTG) reflected on the principles behind a successful flight. We found the key principles to be less technical, and more driven by team spirit, project management, and systems engineering. The identified principles after five years of student rocketry are:

Grow complexity with team capabilities: ISPIDA is the fifth rocket built by ASTG, and each new rocket was a step further, allowing the team to learn and tackle one challenge at a time.

Consistent teamwork: Building a rocket takes a lot of time. A monthly and weekly structure with clear, hard deadlines ensures the whole year is used productively.

Systems engineering: Using requirements, test lists, and FMECA early reduces the risk of late design changes and unexpected system behavior.

Iterative review: The first design is never the best. More eyes on a design means more mistakes caught while changes are still easy.

Test as you fly, fly as you test: A good testing campaign begins in the concept phase, establishing which tests can and must be performed. Early tests verify concept feasibility, subsystem tests confirm each subsystem works as intended, and system-level tests drill the team and surface unexpected errors.

Most of these principles are described in the NASA Systems Engineering Handbook and recommended by EuRoC, and also reflected in Akin's Laws of Spacecraft Design—but they apply equally to student teams.

Keywords

Student Rocketry, Project Management, System Engineering

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1. Introduction

Thanks to the European Rocketry Challenge and growing interest in space and rocketry, student rocketry is an expanding field that allows students to pursue interdisciplinary projects and learn by doing. In 2025, out of 30 teams, only 15 launched their rocket and only two achieved a nominal recovery.

Student rocketry projects face unique challenges: limited budgets, rotating team members, voluntary participation, and the pressure of a single launch opportunity. Despite these constraints, ASTG has achieved remarkable success over the last three years, launching three rockets that not only flew well but also landed intact and ready to fly again. This track record includes two EuRoC Overall Awards and one second place finish.

This paper presents the project management and systems engineering principles that enabled ASTG to consistently deliver successful rocket missions. Drawing from the ISPIDA project - our most ambitious vehicle to date - we share practical lessons learned in requirement management, team organization, testing strategies, and knowledge transfer within a student organization.

The following sections detail our approach: Section 2 provides a technical overview of ISPIDA, while Sections 3–10 explore specific management principles including reasonable planning, iterative development, team structure, system engineering practices, testing philosophy, and knowledge preservation. We conclude with key results and recommendations for other student rocketry teams.

Technical Description

Figure 1 shows the concept diagram of ISPIDA with all systems as blocks, the result of the concept phase. Figure 2. CAD of ISPIDA shows the finished CAD drawing at the end of the design phase. ISPIDA measures 4375 mm in length and 152.4 mm in diameter, with a lift-off mass of 47.0 kg. The single-stage hybrid rocket uses HTPB as solid fuel, N_2O as oxidizer, and N_2 as pressurizing gas. With a 9.5 s burn time and 32.1 kNs total impulse, it reaches the 9000 m target apogee. The hybrid engine features active e-reg via a servo-controlled ball valve for stable combustion pressure, with HTPB in a twisted finocyl geometry for enhanced efficiency. The aerostructure uses CFRP and GFRP composites optimized for strength-to-weight efficiency and radio-transparency. An air brake system enables active apogee targeting, while a Pitot-static probe provides real-time airspeed and altitude data. The custom flight computer integrates power management, avionics, and recovery electronics, collecting data from barometers, IMUs, and sun sensors via distributed CAN nodes. A self-developed telemetry system uses a custom protocol over LoRa with an external patch antenna. ISPIDA employs a fully redundant dual-deployment parachute system separating the main vehicle and guided nosecone. The nosecone integrates BUBO, a guided landing vehicle with a steerable parafoil below 450 m, autonomously navigating to a predefined landing zone using its own avionics and telemetry. The full technical report is available at https://astg.at/projects/ispida.

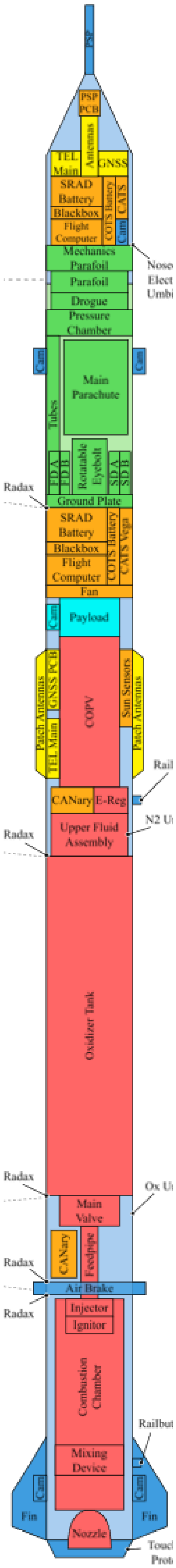

Figure 1. Concept diagram of ISPIDA

Managing over 60 students to integrate 100+ custom parts, 50+ PCBs, and thousands of lines of code into a single flight-ready vehicle demanded systematic approaches to planning, testing, and knowledge transfer - the core focus of this paper.

1.1. Reasonable Planning

Reaching the stars is important for growth, but when building a rocket that must actually fly, it is essential to ensure that team capabilities grow as fast as project complexity. As a student project, ISPIDA was not only driven by requirements but also by the pride of building the "best" system.

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This meant that significant complexity was added beyond the EuRoC bare minimum of "lift one kg to 9000 m." During the concept phase, the question "How much extra complexity can we afford?" was key to successful planning.

1.2. Go Step by Step

A rocket flight requires multiple subsystems to work together. Most of them are flight-critical, and even small problems can impair mission success. Add complexity to one subsystem after another and use as many proven systems as possible. ISPIDA was already designed with a future liquid rocket in mind. The filling station is built in a way that makes it easy to upgrade for a liquid engine. Before ISPIDA attempted to reach 9000 m, Halcyon proved that the hybrid engine works as intended, while ALCEDO demonstrated that the system can break the sound barrier.

1.3. Consistent Teamwork

To execute such a project, it is necessary to use all available time effectively. Weekly meetings of the leaders ensured that all subsystems stayed on track with the timeline, synergies could be identified, and resources were allocated according to demand. At least once a month, a major event with the entire project team took place—either a review or a test—to ensure all team members were aware of the current state of the project and could identify opportunities for improvement.
Each week at ASTG starts with the MOD-Meeting on Monday afternoon. There, all module leaders, board members, and system engineers come together to give an overview of what happened during the week, identify blockers, determine where sub-teams need more resources, and plan for the upcoming week. The protocol of this meeting serves as the starting point for all sub-team meetings. This structure keeps momentum high, keeps all members informed about ongoing activities, and ensures good coherence within the team. Over the course of the ISPIDA project, this regular cadence prevented critical issues from being discovered too late and enabled rapid reallocation of resources when bottlenecks emerged.

1.4. Monthly Deadlines

To ensure work progresses steadily rather than accumulating at project end, even though students tend to procrastinate, ASTG schedules a major event approximately once a month that serves as a firm deadline. This is either a review where recent progress must be presented on stage to the entire team, or a major test requiring functional hardware.
These monthly milestones serve multiple purposes: they force incremental progress, enable early detection of problems, provide natural checkpoints for timeline adjustments, and maintain team motivation through visible achievements. The public nature of reviews adds accountability, as no team wants to present incomplete work to their peers.

Figure 2. CAD of ISPIDA

1.5. System Engineering

The goal of system engineering is to ensure a technical system works as intended. The approach ASTG uses is loosely based on the NASA Systems Engineering Handbook [1]. However, since ASTG is a student team working on a voluntary basis, a more flexible approach is used.
At the beginning of the project, requirements were defined. Four types of requirements were established: EuRoC requirements, environmental requirements, interface requirements, and performance requirements.
EuRoC requirements*:* These requirements are given by EuRoC and are therefore very strict to follow. Only in special cases when it is technically impossible to meet them must a waiver be written for each unfulfilled requirement.
Environmental requirements*:* These specify in more detail the environment expected at the launch site as well as during the launch. They are stated by ASTG to increase the chances of a successful mission, e.g., expected wind speed at apogee.
Interface requirements*:* Since all people working on the project know each other and communicate while working on interfaces, changes to interface requirements can easily be made among the relevant people. These requirements serve more as an initial concept and working baseline rather than as strict, unchangeable specifications.
Performance requirements: These define when the mission can be called a success.

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These requirements are more like design goals. **Self-made requirements do not slow a project down; they ensure all efforts focus on the project goals. They are not meant to be strict rules but written results of a thinking process that can be adapted when necessary. They remind the team of what they initially planned.**
For ISPIDA, this flexible approach proved crucial when initial airbrake designs failed ground tests. The performance requirement specified apogee accuracy, not a specific solution. This allowed the team to iterate the design three times without requiring formal requirement changes, ultimately delivering a working system that met the original goals.

1.6. Strong Review

Reviews serve multiple purposes in the development process. They provide a structured moment to verify that designs meet requirements, ensure interfaces are properly defined across subsystems, maintain project momentum through strict deadlines, and enable multiple design iterations before hardware commitment.
ASTG's review process includes several key elements. Presentations are professional but include occasional humor to maintain student team spirit. Food and drinks during breaks are not luxuries but valuable investments in team cohesion and engagement. Inviting alumni and external experts adds perspectives that challenge assumptions and identify blind spots the core team might miss.
The most critical element is documentation and follow-through: a protocol is written after each review and read before the next one to verify that feedback was incorporated. For ISPIDA, this practice caught several cases where initial feedback was acknowledged but not implemented, preventing issues from propagating to later design stages.

1.7. Test as you fly, fly as you test

There is only one launch opportunity. The only way to ensure it goes as planned is to thoroughly test the system on the ground. To maximize the effectiveness of testing, each subsystem is first tested independently and then integrated. For example, two days before each hot-fire test, a dry run is conducted. This ensures that "easier to find" mistakes, such as software bugs, hardware miswiring, etc., can be identified and fixed in the controlled environment of the workshop, so during the hot-fire tests the team can focus on combustion-related challenges. To ensure all systems are tested, ASTG begins planning in the concept phase. While writing requirements, all testable requirements are separated and collected into a testing list. Tests that are desirable but not critical are also added to this list. In the testing list, each test is categorized as vital, required, or additional.
Vital tests: These tests are required by EuRoC and therefore absolutely must be completed. They have the highest priority.
Additional tests*:* These tests are desirable but not essential. They demonstrate that the system can perform as expected.
Required tests*:* These tests are required by the team and are necessary to show that the system works as intended.
This structured approach to testing paid dividends for ISPIDA. The dry runs before hot-fire tests caught 23 configuration errors across four test campaigns, preventing costly and potentially dangerous failures during actual engine burns. Similarly, independent subsystem testing identified incompatibility between the flight computer and telemetry system that would have been far more difficult to diagnose during integrated tests.

1.8. Passing on knowledge

A student team by its nature has members only for a limited period. Therefore, it is crucial to ensure the team is not dominated by a few experienced members who graduate, leaving the rest of the team lost. Teaching new members is often more work than doing tasks yourself, but it pays off quickly. When older members delegate work to younger ones, they must review the work to ensure that as few mistakes as possible are repeated.
ASTG implements several practices to support effective knowledge transfer. Alumni are invited to reviews whenever possible, providing continuity and institutional memory that helps prevent the team from repeating past mistakes. Before any part is sent to manufacturing, a second "senior" team member must sign the drawing. This ensures consistent high standards and creates a formal teaching moment where experienced members share design considerations with newer ones.
For ISPIDA, the 957-page technical report serves as another knowledge transfer mechanism, documenting not only what was

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built but why decisions were made. This allows future teams to understand the reasoning behind design choices, not just the results. Not only must the technical knowledge be passed on, also the project management knowledge must be considered and updated. For example, timeline templates, testing list templates. It helps a lot when the project leaders of the last years are available for questions and advice.

1.9. Learn to iterate

Your best design efforts will inevitably be modified or even discarded in the final design—this is not failure but progress. This principle, captured in the aerospace saying, "your first design is never your best design," holds especially true for student teams. The work invested in an initial design is never wasted; it builds understanding and reveals what doesn't work, both of which are valuable. The main goal of reviews is to determine whether a solution is optimal, not to validate existing work. Be willing to iterate when better ideas emerge, even if it means abandoning weeks of effort. For ISPIDA, the airbrake mechanism went through three complete redesigns, the recovery electronics were restructured twice, and the filling station layout changed four times before construction. Each iteration brought the team closer to a robust solution. Embracing iteration as a design tool, rather than viewing it as setbacks, accelerates learning and ultimately delivers better results. [2]

2. Results

ISPIDA successfully demonstrated that structured project management and system engineering enable student teams to execute complex rocketry missions. The vehicle achieved all primary objectives: 9368 m apogee (target: 9000 m), nominal dual-deployment recovery with zero damage, and first place at EuRoC 2025 with the Overall Award. The guided landing vehicle BUBO landed safely though off-target, demonstrating the feasibility of autonomous guidance while revealing areas for improvement. In Figure 3. ISPIDA during Launch one can see ISPIDA at during the flawless takeoff.

Beyond technical achievements, the management approach delivered measurable project success. Over 60 students collaborated across 12 months to integrate 100+ custom parts, 50+ PCBs, and thousands of lines of code into a flight-ready system. The structured review process caught critical design flaws in three subsystems before hardware commitment. The test campaign identified 23 configuration errors during dry runs that would have caused failures during expensive hot-fire tests or launch.
The 957-page technical report documents not only the final design but the decision-making process, enabling effective knowledge transfer. Most significantly, the vehicle required only minimal maintenance after landing and is ready for reuse—validating the "test as you fly" philosophy and demonstrating sustainable student rocketry.

3. Discussion

Some of those key principles are already described in the NASA SYSTEMS ENGINEERING HANDBOOK [1] and some are also recommended by the EuRoC Requirements [3]. Nevertheless, student teams tend to cut the corner and do only the fun part. While documentation and system engineering is often boring and feels inefficient for projects at student level, a lot of the rockets at EuRoC are at a level of complexity that can significantly benefit from some system engineering.
The ISPIDA project demonstrates that structured project management and system engineering principles can be effectively adapted for student rocketry, despite the unique constraints of voluntary participation, rotating membership, and limited budgets.
The voluntary nature of student projects increases the importance of the social environment. Free food and from time-to-time free beer can significantly boost engagement.
The discussed principles are not a matter of money or resources but rather mindset based. The main challenge for a student team is to build a social structure that enables this process.
Several elements proved particularly critical to success. Early alignment of requirements with team capabilities prevented overcommitment while still pushing technical boundaries. The weekly MOD-Meeting structure, maintained momentum and enabled rapid resource reallocation, addressing a common failure mode where student projects lose energy mid-cycle. Monthly firm deadlines through reviews and tests forced incremental progress and

prevented the accumulation of work near launch.

The flexible approach to requirements proved essential. Unlike professional aerospace projects, student teams benefit from treating internal requirements as guidelines rather than contracts. This allowed ISPIDA to iterate airbrake designs three times without formal requirement changes, ultimately delivering a working system. However, EuRoC requirements remained non-negotiable, providing necessary external discipline.

The "test as you fly" philosophy required significant upfront investment—dry runs before each hot-fire test consumed considerable time—but paid dividends by catching countless errors in controlled conditions. This approach is particularly valuable for student teams with single launch opportunities and limited budgets.

Knowledge transfer through the technical report, drawing sign-off process, and alumni involvement addresses student team sustainability. However, ISPIDA also revealed that not all knowledge transfers equally well through documentation; hands-on mentorship during subsystem integration proved irreplaceable for teaching troubleshooting skills and engineering judgment.

These principles are broadly applicable to student rocketry teams, though implementation details must adapt to team size, experience level, and institutional support.

4. Conclusions

This paper demonstrates that student rocketry teams can consistently deliver successful missions through structured project management and system engineering principles. ISPIDA's achievement—9368 m apogee with nominal recovery, zero damage, and the EuRoC Overall Award—validates this approach.

The key principles identified are: match project complexity to team capabilities, progress incrementally through proven technologies, maintain momentum via weekly coordination and monthly deadlines, use flexible requirements as guides rather than constraints, implement comprehensive ground testing before flight, and invest heavily in knowledge transfer mechanisms.

Figure 3. ISPIDA during Launch

These practices enabled over 60 students to collaborate effectively, integrate complex subsystems, and execute a single-launch mission successfully. The test campaign's prevention of 23 potential failures and the vehicle's ready-for-reuse condition after landing demonstrate the value of systematic approaches even in resource-constrained student environments.

Student rocketry teams facing similar challenges—voluntary participation, rotating membership, limited budgets, and single launch opportunities—can adapt these principles to their contexts. While implementation details vary, the core philosophy remains structure enables creativity, planning enables execution, and systematic approaches enable student teams to achieve professional-grade results.

ASTG's track record of two EuRoC Overall Awards and one second place over three years proves that excellence in student rocketry is achievable and repeatable through disciplined project management.

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