# Michigan Aeronautical Science Association

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Organizational Document

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## What is MASA?

MASA is a group of engineering and science students at the University of Michigan. MASA stands for Michigan Aeronautical Science Association. MASA was founded in the fall of 2003, and participates in high power rocketry and rocketry-related research. It was accepted as a student organization by the Michigan Student Assembly.

### MASA Goals

To provide the University of Michigan community with an active club that allows members to explore engineering and science activities related to the design, construction, and launch of high power rockets. To grow membership to a sufficient size to allow members to build and launch interesting instrumented rocket projects and to sustain activities for a number of years.

### MASA Activities

MASA will be active in almost every facet of high power rocketry. MASA will build and launch its own rockets, experiment with hybrid rocket motor technology, and experiment with various payloads. MASA will do research to implement innovative techniques that could be applied to high power rocketry. Activities will engage students from a number of disciplines including aerospace engineering, mechanical engineering, electrical and computer engineering, physics, material science, and atmospheric and space sciences.

## Overview of High Power Rocketry

The following section presents an overview of high power rocketry for the reader who is unfamiliar with it. The section will describe how the high power rocketry organizations operate and the parts of a high power rocket.

### National Governing Bodies

Three governing bodies create the bylaws and certification levels for high power rocketry. The governing body in America for the high power rockets is Tripoli Rocketry Association (TRA). The governing body in Canada for the high power rockets is Canadian Association of Rocketry (CAR). The governing body in America for low power model rockets is the National Association of Rocketry (NAR). These three entities work together to keep high power rocketry running. They also certify all of the commercial motors that will be used in our rockets.

### High Power Rocket Components

#### Rocket Airframe

High power rocket airframes are subject to significant forces during liftoff and acceleration, and due to de-acceleration during recovery deployment. With forces over nine G’s and velocities at or beyond the speed of sound, airframes used in high power rocketry are significantly different from the paper or cardboard airframes used for hobby rocketry. In addition to withstanding flight forces, the airframes support and contain the rocket propulsion system, electronics, recovery system, as well as the payload, if present. Airframes are constructed from a variety of materials. The most basic are phenolic (a type of resin impregnated paper), various plastic tubing, and--for high performance designs--spun fiberglass. Over the past 10 years, people have begun to reinforce these tubes with composite materials such as fiberglass, Kevlar, and carbon fiber by applying thin sheets of these materials laminated with an epoxy filler. This makes the tubes much stronger, but adds a fair amount of weight to the rocket. Recently, some high power rocketeers have tried to make pure composite airframes from fiberglass or carbon fiber sheets, using mandrels to form the shapes. The use of pure carbon fiber airframes in particular will significantly reduce the weight of the rocket, and both are just as strong if not stronger than reinforced phenolic or plastic tubing. MASA would like to utilize this new technology of pure carbon airframes to participate in a fixed motor/altitude record project. Such a project involves flight and recovery of a rocket of any design to as high an altitude as possible using a fixed commercial motor with known thrust. The project might involve interactions with faculty and students in the material sciences department. For more information on this project, please see the "HyFlights" section in the Rocket Designs part of this paper.

## Propulsion

High power rockets are propelled by motors that vary from less than two inches in diameter to over four, and can output as much as 6,700 pounds/second of total thrust. Standard motor diameters are 29mm, 38mm, 54mm, 75mm, and 98mm. All commercial high power rocket motors are certified by the TRA, NAR, or the CAR. Exceptions to these certified motors are allowed and a subset of high power rocket enthusiasts make their own motors called "experimental motors," or EX motors. Due to standardization in motor casings, EX motors generally follow the commercial motor sizes, but can be mixed with a variety of materials, usually powdered metals to get performance unavailable in commercial propellants. Commercial motors come in "kits" where the parts must be assembled in the correct order, or else motor failure will occur. Commercial motors fall into two types. One is a solid motor, which contains ammonium perchlorate as an oxidizer, fuel, and a binder. They other type is a hybrid motor. The hybrid motor uses a liquid oxidizer (Nitrous Oxide) and a solid fuel. The advantages of the hybrid rocket motor is that it can be throttled, restarted (currently not available commercially), and is typically safer than solid rocket motors. Hybrids also have lower cost per flight. For those reasons, and an increased amount of research on hybrids in academia, we have chosen to use hybrid propulsion motors.

## Electronics and Control

Electronics are used to trigger in-flight events, such as ignition of additional motors/stages and deployment of parachutes. These electronics are not used to guide the rocket because it is not feasible and more importantly, it is illegal as the rocket then becomes a "guided" missile. The electronics typically use an accelerometer, barometer, or a combination of the two to sense altitude, acceleration, and velocity of rocket. All of these parameters are continuously recorded to a static memory. Other electronics are simply timers, and will trigger an event after a set period of time. Electronics can be as complicated as several possible events with data recoding, or as simple as a single event with no data recording.

Rocket Flight Simulations

Before a rocket can be launched, the owner must be confident that his/her rocket is safe to launch. This means that the rocket is stable, not too heavy for the rocket motor launching it, and will attain a safe altitude. Under current high power rocketry rules, the TRA club organizing the launch is responsibly for determining range safety and for acquiring a launch waiver from the FAA for the duration of the launch. As a result, most sophisticated projects require the use of computer software that accurately simulates all aspects of the rocket's flight. Thus a virtual rocket can be built and launched with different virtual motors to get a very accurate outline of what the actual physical rocket's flight will be. The simulation also will help determining the optimal mass and shape to attain the highest altitude with a set rocket motor.

The MASA club currently has access to Rocksim 7, a state of the art simulation package that has a database of hundreds of commercial rocket motors, and performs basic calculations based on rocket mass and shape (body, nosecone, fins) to determine continuous acceleration, velocity, G forces, apogee height, and other flight parameters. Other commercial packages are available, and if necessary MASA can develop and validate its own specialized simulation software.

## Rocket Designs

This section documents the three initial projects that MASA will undertake. Two of these are rockets for commercial hybrid motors. The third project involves the construction of an experimental hybrid motor.

Project **Hybrid I**

While most current members have good fundamental engineering techniques, an introduction is necessary to high powered rocketry design utilizing hybrid rocket

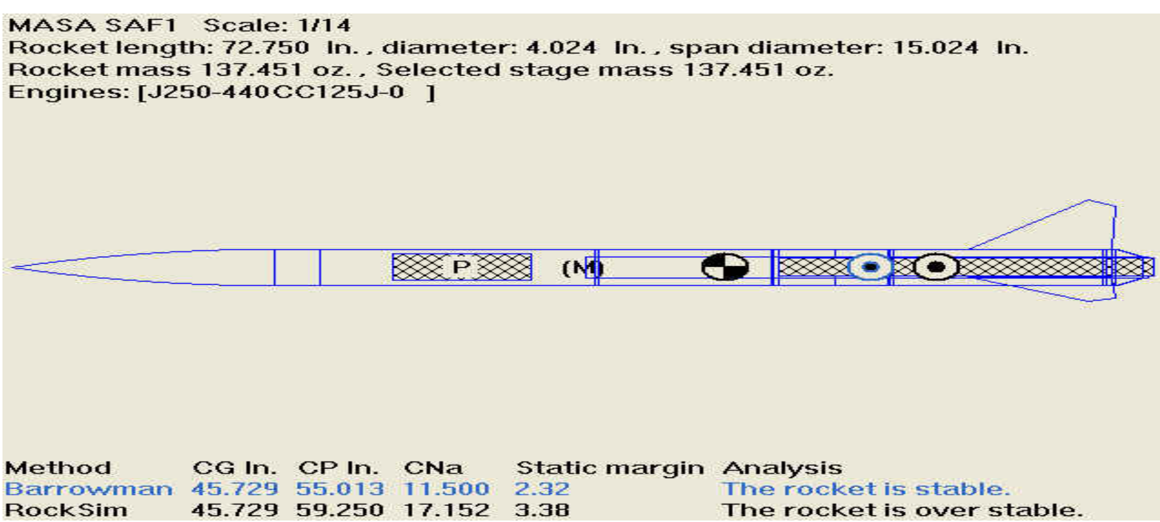


Figure 1

propulsion. The first rocket will be a straightforward design with a large stability margin. The rocket will be 4 inches in diameter, and about six feet tall. A Hypertek hybrid J class motor will be used for propulsion and the rocket will electronically deploy its recovery system at apogee for simplicity. The above figure (fig 1.) is a Rocksim 2-dimensional image of our initial rocket. Current simulations project an apogee of about 1500' which is a good height for a launch which purpose is to prove our rocket building skills and hybrid rocket motor technology.

Project **Hy-Flights**

Our second project will build on what the MASA team learned during the Hybrid-I flight(s). The project's main goal is to set Tripoli's official altitude record for a J impulse class hybrid rocket motor. The current record is approximately 10,000'. We chose this goal because it is recognized by the Tripoli Rocketry Association, will present many interesting engineering challenges, while being realistic and achievable. We hope this project will raise significant excitement within the Michigan community for high power rocketry and engineering.

The key to successfully reaching our goal will be in the use of lightweight composite materials. Materials such as carbon fiber and fiberglass will improve the strength to weight ratio of the rocket. This ratio is important when designing a rocket for maximum altitude. Rocksim and technical articles will also be used to determine optimal design and rocket mass. With enough research, we are confident that we could fly our rocket higher than the current Tripoli national hybrid J class altitude record. The rocket will utilize a 54mm Hypertek hybrid J-330. The rocket will have a minimum diameter, meaning that the rocket body will be nearly the same diameter as the motor diameter, and will be approximately 5 feet long.

We will use the data from the Rocksim simulations to determine the most efficient fin possible. Figure 2 shows our initial fin design, which is based on a 30-60-90 right triangle. This fin platform initially seems to have the best properties for supersonic flight, however we are still evaluating other fin shapes. The fin shape itself is important because it is what keeps the rocket stable during flight. It is also the part on the rocket that will most affect its drag coefficient.

Current plans are for a tasteful blue and maize metallic paint job with a silver nose cone. We will consult with members of the Automotive Engineering Department on suitable paint application techniques.

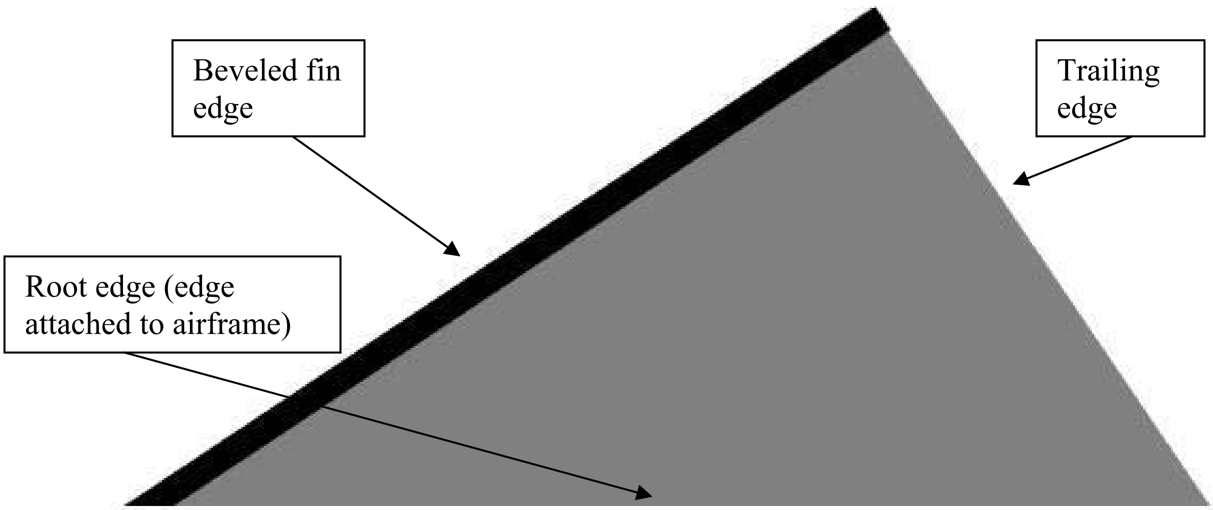


Figure 2

Figure 3 shows an initial design of the entire rocket. The rocket will utilize dual deployment recovery because of the high altitude the rocket will attain. This means that a drogue parachute will be deployed close to apogee to slow and control the decent of Hy-Flights, and the onboard altimeter (with possible backup) will deploy a full parachute at an altitude of 500 feet AGL is reached. We are also considering the use of a tracking beacon on the rocket to aid in recovery.

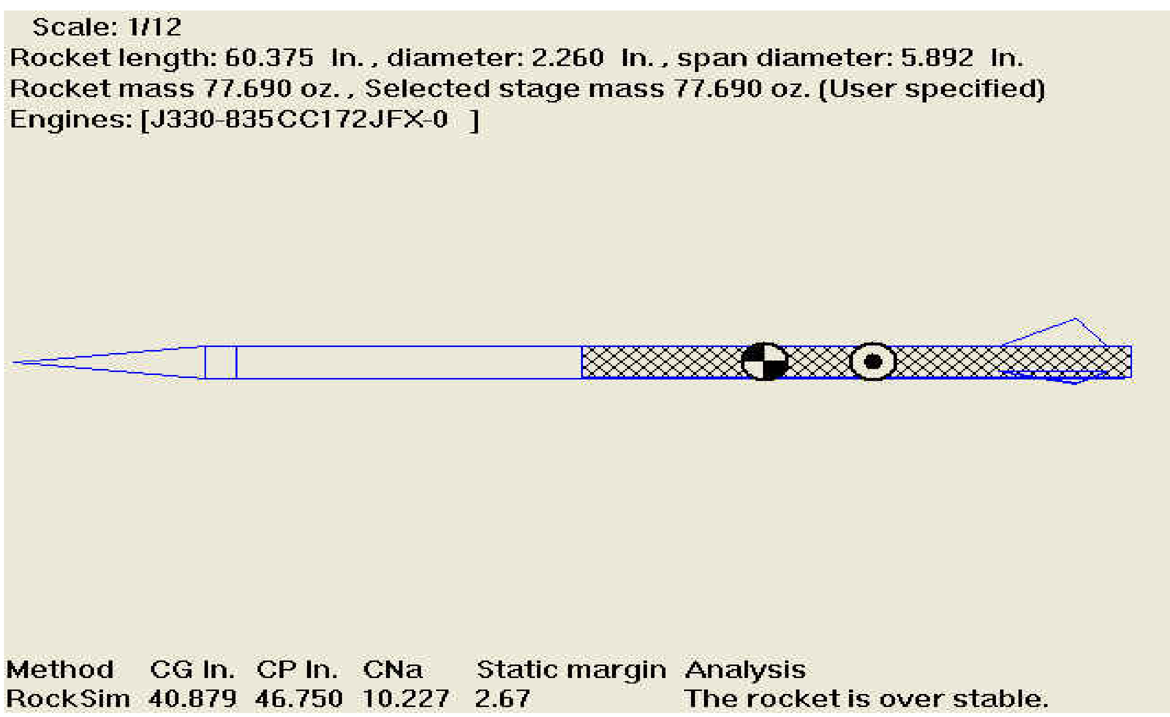


Figure 3

Current simulation data reports the maximum altitude with a J-330 of 10,300'with a maximum velocity of 809 mph. Simulations with a slight variation to the design will attain an altitude of 13900 and a maximum velocity of 890mph with a K-240 engine.

MASA Hybrid Rocket Motor Project

Hybrid rocket motors is a new type of propulsion that currently has promising characteristics over solid propellants such as the ability to throttle and restart in flight. These enhanced characteristics make the rocket safer while also allowing for a more diverse flight plan. MASA would like to become more familiar with Hybrid motor technology and will do so by incorporating it into rocket designs as well as direct experimentation. MASA will build and test its own hybrid rocket motor. The motor will be approximately 1 inch in diameter and 10 inches long. The oxidizer will be Nitrous Oxide and the fuel has yet to be determined, but most probably an inert plastic (PVC) or wax. After constructing the motor, MASA will conduct static tests to more fully understand the workings of a hybrid motor. This project will serve as a base for additional hybrid propelled rocket designs which may incorporate the ability to throttle the motor in flight. Figure 4 shows a simple outline of our hybrid motor design.

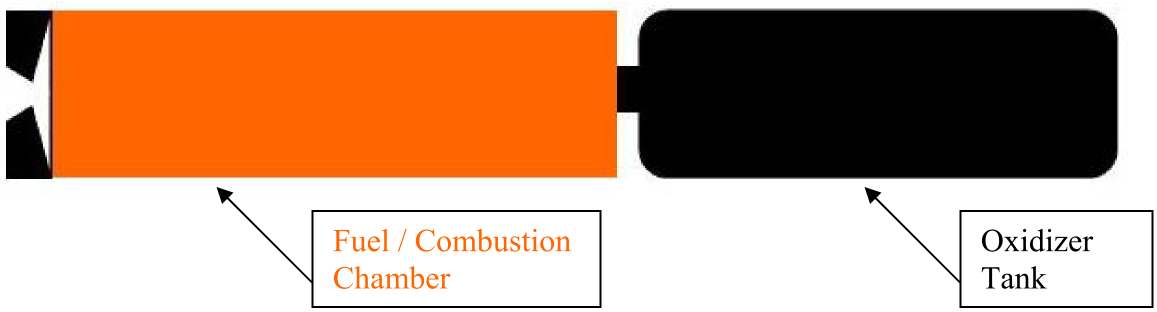


Figure 4

The design of hybrid motors by MASA is a significant extension to the design and construction of high powered rocketry. It will provide MASA with complete control over all aspects of rocket design, and in the area of propulsion technology, allow MASA to work in an area of current academic interest (such as Stanford) and one where there are minimal regulation and safety concerns.

**Long Term MASA Goals: Future Projects**

The first two projects outlined in this organizational document focused on rocket design and high altitude flights. MASA's future projects will not only focus on attaining a high altitude, but also slot in significant payloads. Some payloads that are currently being investigated are GPS units for rocket tracking, TV camera transmitter for onboard video, and other scientific projects to be determined later. Another idea is to use onboard sensors to monitor stresses on various components of the airframe. Our reasoning for integrating payloads into our rockets is that by collecting data in flight we may more fully understand various attributes of our rocket designs as well as making the flights more interesting. Payloads provide us with an opportunity to work with Michigan students who are interested in using the rocket flight as an experimental environment to conduct their own research. This will allow MASA to attract members from a broader base of the Michigan community. We envision students in biology, physics, and computer science fabricating experiments to fly in our rockets. Committing to the launch and recovery of payloads--which will increase the weight and size of the rocket--adds to the complexity and challenge for the design team. Incorporating a payload into the confined space of a rocket will be an engineering challenge that is pertinent to current aerospace engineering.

## MASA Resource Requirements

### University of Michigan Project Space

MASA will need storage, bench space, and access to machine tools in order to design and fabricate its projects. Possible locations would include the engineering projects building, lab space in the FXB building, or project space in the space sciences building. The propellants that we will use to launch our rocket motors are completely inert and therefore will neither require any special containment, nor pose a fire hazard. We estimate that we would require a bench space of 10 ft. X 14. to simultaneously work on various aspects of our projects. Storage lockers or storage shelves should be long enough to contain the rocket motors and body components so that they can be secure.

### Advisor

MASA will need a faculty advisor to encourage interest in the club. It is almost requisite to have a faculty advisor to get Michigan project space and funding. An advisor will also be able to provide links to other groups at Michigan. In addition the advisor may have contacts with local alums or emeritus faculty who would be interested in our projects. MASA has established contact with Michigan Team 1 (Tripoli) Prefecture (http://www.team1.org) and we will use their launch facilities in Three Oaks or Manchester Michigan for our projects.

### Tools

To design and create our rockets, the rocket simulation program “Rocksim 7.0” will be used (by the owner of the software, Matthew McKeown) to produce and model the parts of the rocket. Rocksim will also be used on our second project to predict the optimal mass and drag of the rocket so that we can have the rocket attain the highest altitude. Rocksim will also be used to conduct simulated launches, so that we can prove our rocket design is correct. In addition to Rocksim, we will use the University of Michigan Technical Journal Resources to create optimal designs for our more advanced rockets.

### Funding

MASA recognizes that it needs to generate a significant portion of the funding required to design, build, and successfully launch our projects. We will accomplish this by using several types of fundraising. These will include creating opportunities for individuals and companies to sponsor parts of the rocket. MASA will also apply to the AIAA for funding for projects. Fundraising within the university will include t-shirt sales and participation in campus events.

Possible Corporate Contributions

There are a large number of companies that share interest in the projects and research that we will be conducting. We expect that this interest will translate into donations of materials, rocket motors, and components that we cannot directly manufacture ourselves. In the area of composite components, companies include Performance Rocketry and Shadow Composites. In the area of hybrid propulsion systems some of the most reliable hybrid motors are manufactured by Hypertek of Cesaroni Technologies, Aerotech, and Ratt Works hybrids. Electronics are a critical component for launch telemetry and deployment of recovery systems. We will need recording altimeters and or accelerometers and, possibly in the future, staging electronics. Some of the highest quality flight tested electronics are manufactured by G-Wiz, Black Sky, Missileworks, and Perfect Flite.

## MASA Founders and Past Work

MASA was founded in the fall of 2003 by Matthew McKeown and Jeffrey Lydecker. Currently there are ten active members of MASA, most of whom are students in the College of Engineering, or some other scientific major. Several members have hands on experience with basic machining and construction techniques.

The Co-Founders of MASA have a significant amount of rocketry related experience. Co-Founder Matthew McKeown has over seven years of experience in the design, fabrication, and flight of high powered model rockets and has over 50 mid and high power launches. He is a member in good standing of the National Association of Rocketry (NAR) and is a certified Level 2 member of Tripoli Rocketry Association (TRA). Level two certification requires a written test, and a successful flight (launch and recovery) of a rocket with a thrust no less than 1200 Newtons. During the summer of 2003 McKeown launched a 25 pound 2-stage rocket that flew to 7100' feet with successful recovery at the annual TRA national LDRS launch (See Fig 5 for picture). This rocket used three altimeters to control the ignition of the second stage and deployment of the parachutes. Co-Founder Jeff Lydecker is currently exploring the use of inertial fusion for interstellar space propulsion under Professor Terry Kammash of the Nuclear Engineering department of the University of Michigan. Jeff Lydecker also has researched general helicopter design, from which some aeronautical techniques can be applied to rockets.


Figure 5

**Current MASA Membership**

The MASA membership to date in alphabetical order, along with the member's anticipated major can be found in the following table.

| Name | Major |
|---|---|
| Ryan Anderson | Biological Science |
| Greg Dunkelberger | Aerospace Engineering |
| Josh Frens-String | Political Science |
| Peter Gullekson | Mechanical Engineering |
| Jeffery Lydecker | Aerospace Engineering |
| Matthew McKeown | Aerospace Engineering |
| Rohin Moza | Computer Science |