Alternate Systems Review

RMTS Industries

Overview and Content

- Relevant Requirements
- ASR
  - Proposed subsystems
  - In depth options
- Applicable Building/Safety Code Summary
- Budget
- General Questions
- Acronyms

Relevant System Requirements

- 1.2 Building/Safety Codes
  - The Contractor will research building and safety codes involving the use of all system components. The Contractor will present a summary of the applicable requirements at the Alternative Systems Review (aka, Conceptual Design Review). The Contractor will ensure compliance with these codes and submit any necessary paperwork for approval.
- 1.3 Safety
  - Safety is of the highest concern in the design of this project. Proper safeguards must be implemented to prevent any reasonable chance of injury to those transporting, erecting, working on or operating the system.

Relevant System Requirements

- 1.4 Workmanship
  - The RMTS must have a professional and aesthetic appearance, including workmanship and consistency of parts, materials, assembly, and finishes. It will be constructed using best commercial practices (eg, will contain no openly exposed lubricants, sharp edges, loose components, dangling wires…).
- 2.1 RMTS Size
  - The RMTS design will accommodate National Association of Rocketry (NAR) motor sizes, ranging from Model Rocketry motors through High Power Level I motors (Classification 1/8A – I).

Relevant System Requirements

- 2.2 RMTS URD
    - The RMTS will be capable of surviving the unplanned rapid deconstruction (URD) of any motor up through HPR Level 1 with minimal damage to components.
- 2.2.1 RMTS Safety Factor
    - Contractor will verify structural integrity and safety of the RMTS design with a factor of safety (SF) of 5x all expected forces for normal operation of all motor sizes. The RMTS will safely contain the explosive force of all motor sizes, keeping operators safe and protecting nearby structures/infrastructure.
- 2.2.1.1 RMTS Structural Waiver
    - The safety factor requirement applies only to the structures and components that enure the safety of both personnel and equipment. Components may, on a case by case basis, have the safety factor requirement waived.

Relevant System Requirements

- 2.3 Performance Envelope
  - The RMTS will support the operation of up to a High Power Rocketry (HPR) Level I motor, including casing/nozzles and instrumentation with thrust according to a normal duration burn (+10%).
- 2.4 Weight and Balance
  - The RMTS will weigh a maximum of 500 lb, including rocket motor adapters, deflection plates (as appropriate) and instrumentation. Individual items or shipping containers must weigh less than 100 lb to allow safe transportation and assembly. Assembly and transportation will not require undue physical exertion or compromise safety in any way.

Relevant System Requirements

- 2.5 Subsystems
  - The RMTS will incorporate all subsystems and functions necessary to safely accommodate, fire, and test rocket motors throughout the specified motor range. Anticipated subsystems include: base structure, motor holding appliances, thrust measurement, thrust deflection plates (as appropriate), stand-off blast protection, remote ignition, status monitoring, warning lights/sirens, data recording/analysis, and common support tools.
- 2.7 Weather/Environment
  - The RMTS will be capable of surviving outdoors in the Alaskan environment year-round. This includes temperature, winds, and precipitation variations throughout the year.

Relevant System Requirements

- 2.7.1 Precipitation and Temperature Survival
  - The RMTS shall survive severe weather conditions such as rain up to 1 inch/hour or temperatures down to -40F.
- 2.7.2 RMTS Operating Environment
  - The RMTS shall be operated in an environment with minimal to no precipitation.
- 2.8 Reliability & Maintainability
  - The RMTS will require minimal maintenance. All components of the RMTS will remain operational for a minimum of 20 years. The Contractor will provide individual component and overall system reliability measures.

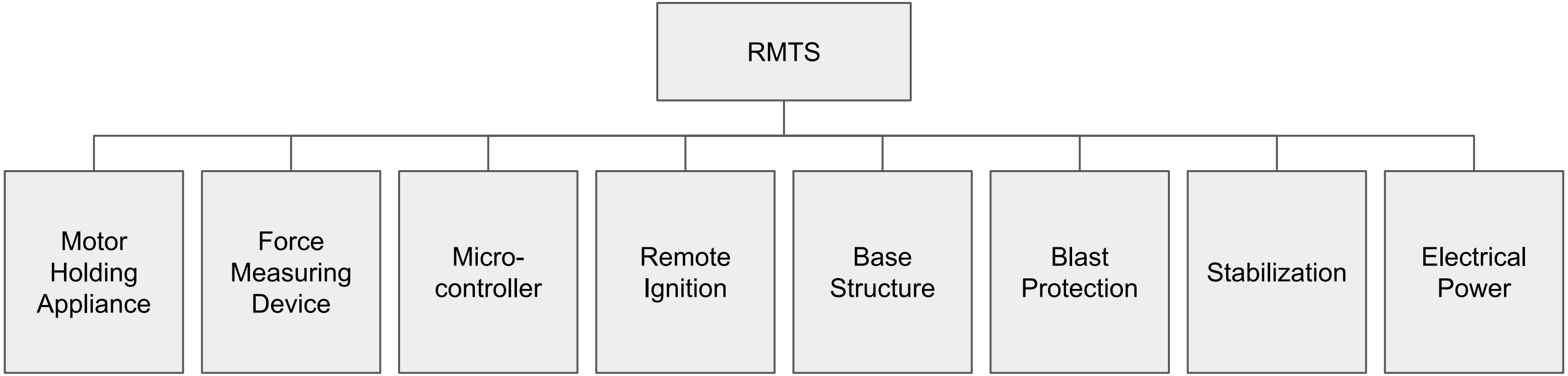
Relevant System Requirements

- 2.9 Compatibility
  - The RMTS will make maximum use of existing like components used at UAF’s (1) College of Engineering & Mines (CEM); and (2) Geophysical Institute (GI) for similar assets, balancing the need for compatibility with that of proven performance of newer components. Rationale for component choices will be explained in appropriate discussions, briefings, and written documentation.
- 2.10.1 Form Factor
  - The RMTS will be designed such that all individual components may be transported using either a 6.5-foot pickup bed with cab-height bed topper, or a 6 x 14 x 6 ft mobile ground control station trailer. The design of the components and securing devices will preclude damage to either the RMTS or the trailer and will not require undue physical exertion. The RMTS will be capable of being transported in a maximum of 7 major items or hardened cases, each weighing no more than 100 lb.

System/Subsystem Description

Proposed Subsystems

- Motor Holding Appliance
- Force Measuring Device
- Microcontroller
- Remote Ignition
- Base Structure
- Blast Protection
- Stabilization
- Electrical Power

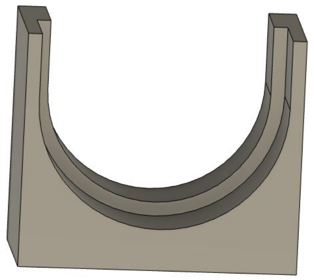


Motor Holding Appliance

Mechanical system that will cradle the rocket motor and hold it in place during firing. Front and back must be clear for thrust and ejection charge

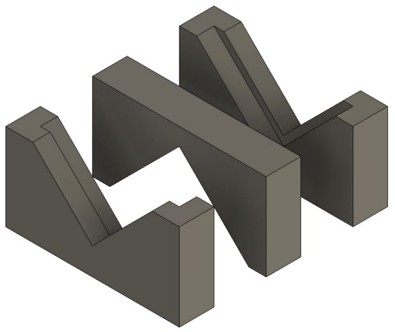
Alternatives:

- Multiple dies
  - Pros: Simple, very secure
  - Cons: Have to swap dies, more parts
- All-in-one
  - Pros: Don't have to swap dies
  - Cons: More complex, might hold motors worse



Recommendation

All-in-one



Estimated Cost: $100

Force Measuring Device

Transducer that will convert the rocket motor thrust into an electrical signal that can be sampled.

Alternatives:

- Load Cell
- Spring Scale
- Pressure Gauge

Recommendation

Dual design of load cell and pressure gauge system with design review for implementation decision

Force Measuring Device

Load Cell	
Description: Bought or made load cell(s) used to measure linear rocket force	
Estimated Cost: $500 - $1000	
Pros:	Cons:
● Little to no motion ● Can cover whole range of needed thrusts ● Sampling rate can be determined by other components ● General high accuracy 0.5% of max ● Different load cells could be switched with relative ease	● Expensive for higher accuracy ● Expensive for larger rating ● Requires amp and ADC for reading ● Load cell can become unusable if max load is exceeded

Force Measuring Device

Spring Scale	
Description: Purely mechanical, large linear spring that would move and have distance moved recorded then converted to force.	
Estimated Cost: $200 - $300	
Pros:	Cons:
• Springs would not fail if max load is exceeded • Very simple • Cheaper • No digital interface needed	• Very long spring system would be needed to support full range of motors • Spring scales are known to be inaccurate • Movement of the motor/mounting surface would subtract total force

Force Measuring Device

Pressure Gauge	
Description: Rocket motor pushing against hydraulic cylinder with hydraulic pressure measured by the sensor and converted to force	
Estimated Cost: $300 - $700	
Pros:	Cons:
• Generally cheaper than set of load cells • Only one sensor so no changing needed • Easy to design a fail point to protect sensor • Little to no motion	• Hydraulics, need a fluid suitable for large temperature range • Sensor would need to be high precision • Does a sensor with high enough precision exist and is it economical

Microcontroller

Simple computer capable of sampling the output of the force measuring device and recording it in the user's desired format

Alternatives:

- ESP32
  - Pros: Includes built-in WiFi and analog to digital converters, many models with different features
  - Cons: Fewer tutorials and documentation and what's available tends to be lower quality
- Raspberry Pi
  - Pros: Includes a full operating system and a GUI, multiple programming languages can be used, can use software libraries for more advanced analysis of data
  - Cons: GPIO pins are digital, so the force measuring device will have to be digital or a separate analog to digital converter will be needed
- Arduino
  - Many online tutorials and good documentation, built in analog to digital converters, newest models have built-in WiFi
  - Cons: Uses higher voltage

Recommendation: Arduino

Microcontroller

SparkFun Thing Plus - ESP32 WROOM (USB-C)

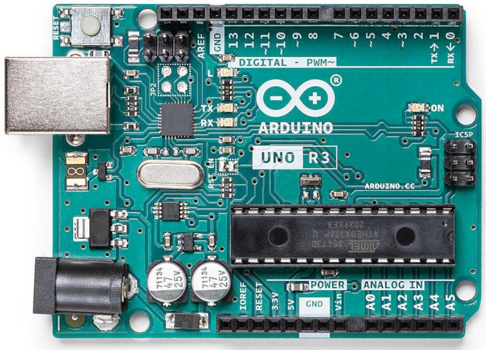
$33.73

https://www.sparkfun.com/sparkfun-thing-plus-esp32-wroom-usb-c.html

Raspberry Pi 5

$120.00

https://www.raspberrypi.com/products/raspberry-pi-5/



Arduino Uno Rev3

$27.60

https://store.arduino.cc/products/arduino-uno-rev3

Remote Ignition

Mechanism to start the rocket motor

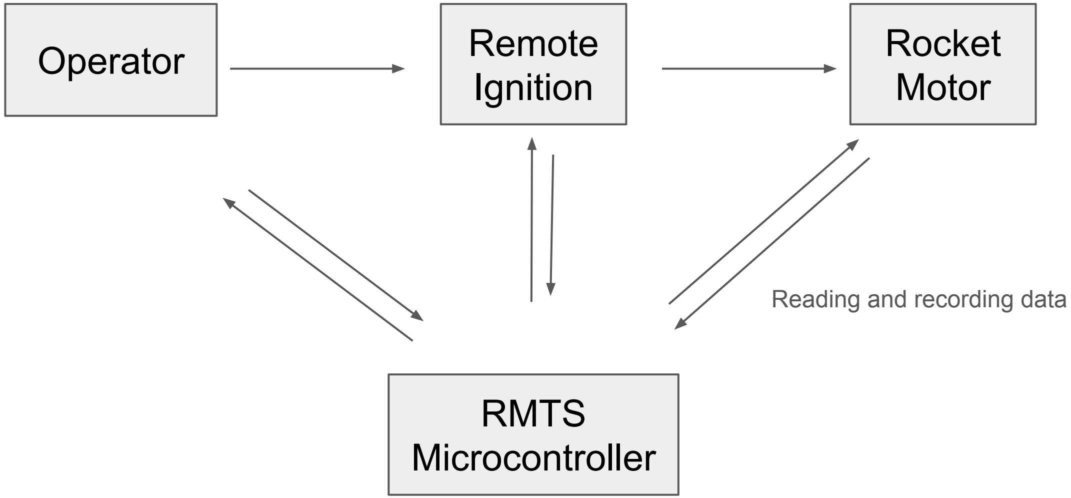
Alternatives:

- Mechanism with microcontroller or simpler components like buttons or toggles
  - Pros: Simple and reliable
  - Cons: Easy to be accidentally touched, need safety design
- Mechanism using the force sampling microcontroller or a separate microcontroller
  - Pros: The trigger stroke can be set to prevent accidental triggering
  - Cons: More complicated and may not work in extreme weather
- Wired or wireless user control
  - Wired: Simple and reliable, but the operating distance depends on the length of the line.
  - Wireless: It can be operated from a distance, which is safer for the operator. However, it is not as reliable as wired.

Recommendation

Wireless user control with safety buttons design.

Remote Ignition



Base Structure

Structure that holds the rocket mount and other components, withstands the force of the motor, and provides environmental protection

Alternatives:

Orientation

- Motor firing up
  - Pros: smaller, more stable, all forces in one direction(no need to worry about weight moments)
  - Cons: can’t fire indoors
- Motor firing sideways
  - Pros: can fire indoors
  - Cons: larger, less stable, momentary forces

Recommendation

Motor firing up

Base Structure

Structure that holds the rocket mount and other components, withstands the force of the motor, and provides environmental protection

Alternatives:

Construction

- Metal frame that can be unbolted for transportation
  - Pros: more stable, less complex, easier to repair and work on
  - Cons: longer set up, larger
- Frame permanently installed in plastic cases can be used without much assembly
  - Pros: short set up, small, light
  - Cons: less naturally stable, more complex, harder to service

Recommendation

Permanently installed if motor is fired straight up

Base Structure

Structure that holds the rocket mount and other components, withstands the force of the motor, and provides environmental protection

Alternatives:

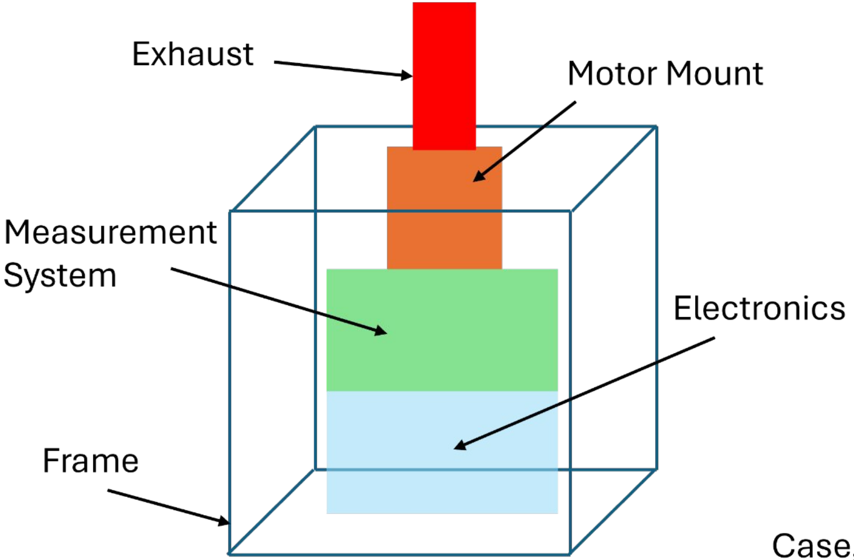
Material

- Steel/stainless
  - Pros: strong, cheaper
  - Cons: can corrode, more difficult to assemble
- Aluminum Extrusion
  - Pros: corrosion resistant, easy to assemble.
  - Cons: expensive, weaker

Recommendation

None - more research/ decisions need to be made to make this decision

Base Structure



Case,
Fame to be
Permanently
Mounted in

Cost: very rough estimate - $300-$500 (excluding case)

Pelican Case Image:
https://www.pelican.com/us/en/product/cases/cube-case/protector/0370?_gl=1*wbj57x*_up*MQ..*_gs*MQ..&gclid=CjwKCAjwiY_GBhBEEiwAFaghvskS0tSfLWWvYgLFkMrJ_03PFh99hWY8lAMUzdTV4z8SdHkjsBUMbRoC3IMQAvD_BwE&gclsrc=aw.ds&gbraid=0AAAAAC2Sjwhy75eqHHYtfwn4932o9qWki

Blast Protection

Structures to route rocket motor gases away from users during normal operation and catastrophic failure

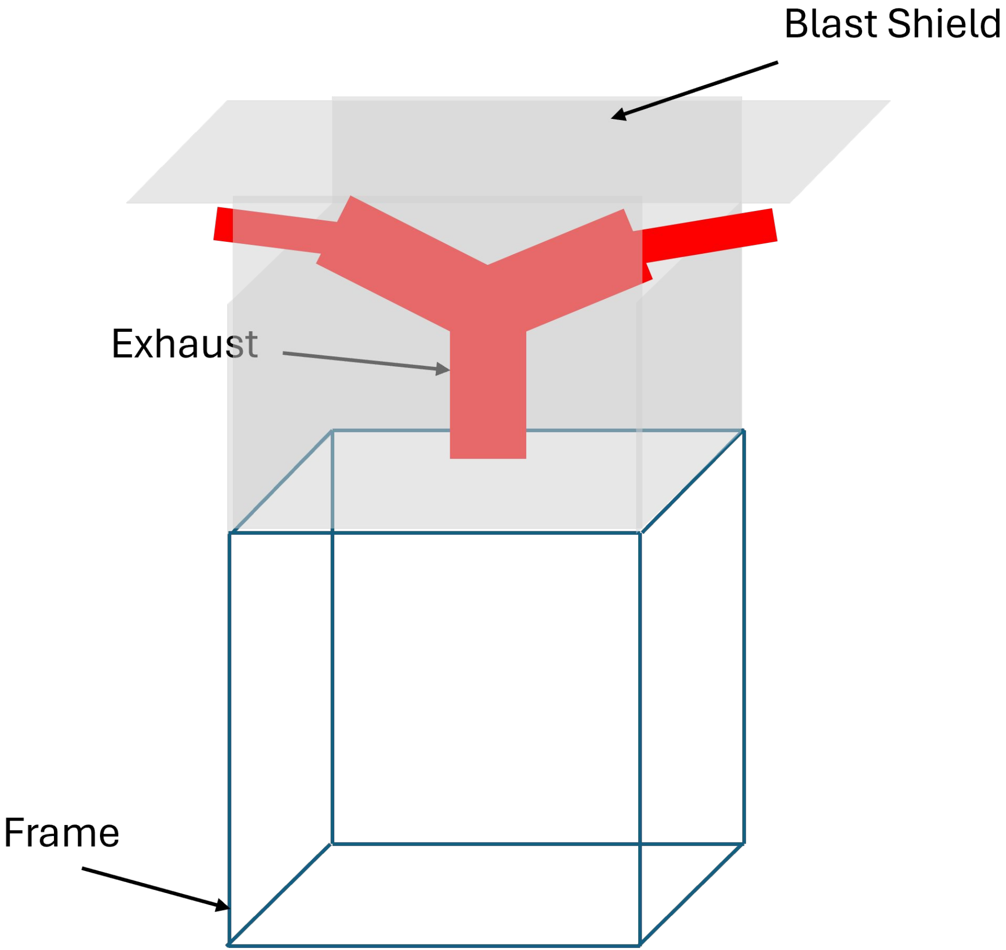
Alternatives:

- Metal plates bolted to housing/skeleton
  - Pros: durable, stronger
  - Cons: heavy, more expensive, blocks view, rigid
- Plastic cases surrounding the frame inside
  - Pros: lightweight, see-through, can flex more, cheap
  - Cons: weaker, less durable

Recommendation

Plastic/plexiglass if it can withstand the forces 5x

Blast Protection



Cost: $100 - $150

Stabilization

Mechanism to prevent the RMTS from tipping over, sliding, and vibrating excessively during testing

Alternatives:

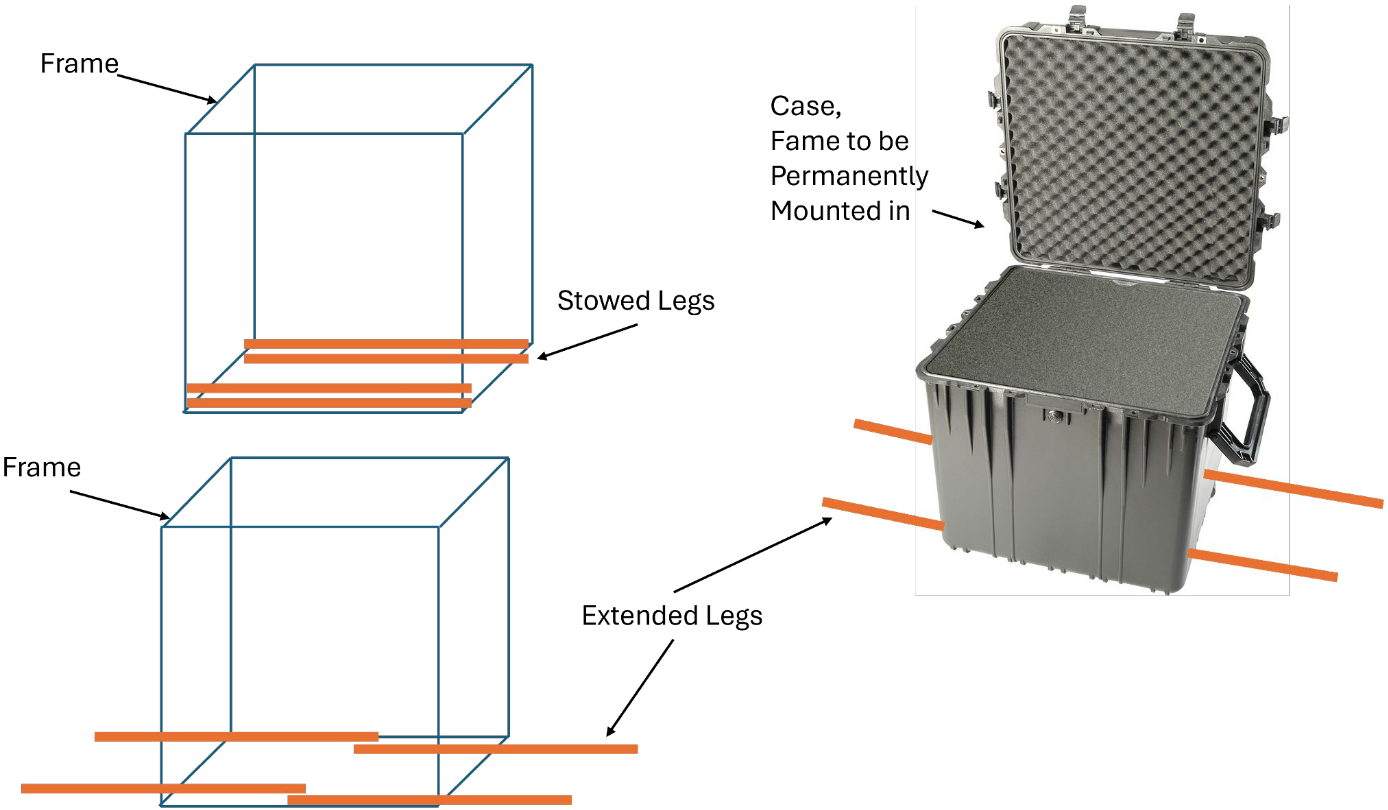
- Bolt to surface
  - Pros: most secure
  - Cons: highest demand of testing location
- Sand bags
  - Pros: low demand on testing location
  - Cons: tester need to have sandbags or sandbags need to be included
- Stabilization legs
  - Pros: low demand on testing location, no extra materials required
  - Cons: complex, add weight directly to RMTS
- Strap to anchor points
  - Pros: Stable, less intrusive than bolting to surface
  - Cons: Requires existing anchor points or ground anchors, requires straps

Recommendation

Stabilization legs

Cost: $60

Stabilization



Electrical Power

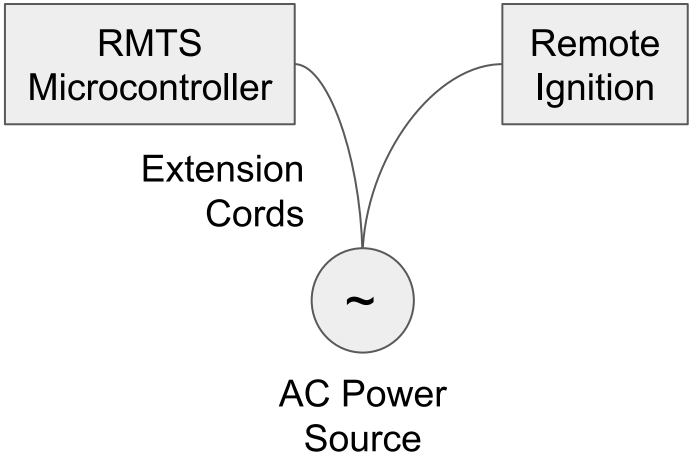
Subsystem to power microcontroller, remote firing mechanism, and other electrical components

Alternatives:

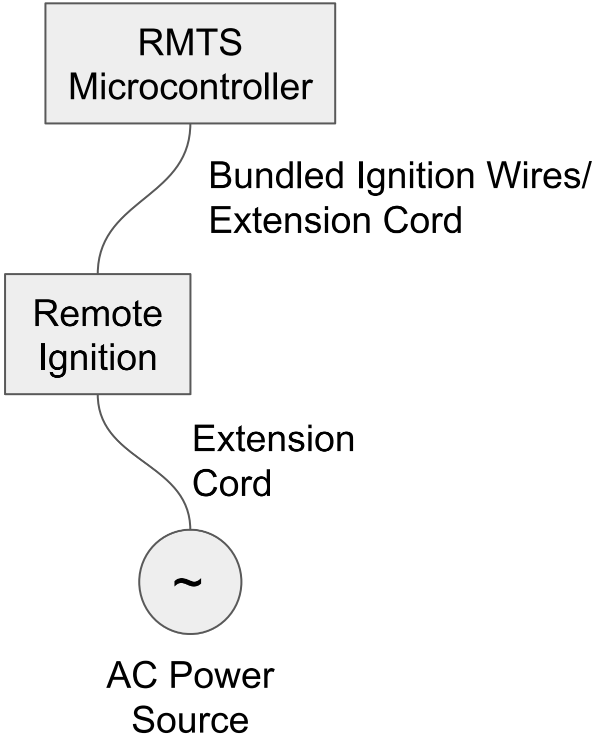
- AC power from test location
  - Pros: AC power will be available at most test locations, power can be transferred long distances using extension cords, extension cord could be bundled with any cables from remote ignition subsystem
  - Cons: AC/DC converters will be needed, not all locations will have AC power and a generator could be needed
- Batteries
  - Pros: No AC power source is needed
  - Cons: Spare batteries will always be needed, individual electronic devices may need their own batteries depending on power consumption, the rocket motor igniter may require a battery with high voltage or current capacity

Recommendation: AC power

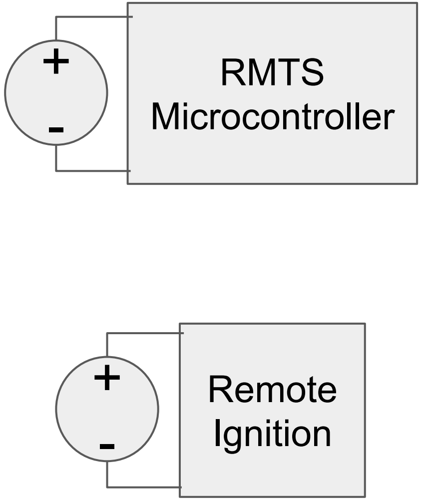
Electrical Power



AC Power for Both RMTS and Remote Ignition Subsystem



AC Power Passed to RMTS Through User's Remote Ignition Subsystem



Battery Power for Both RMTS and Remote Ignition Subsystem

Recommended Subsystems

- Motor Holding Appliance: All-in-one
- Force Measuring Device: Load cells or pressure gauge
- Microcontroller: Arduino
- Remote Ignition: Wireless user control with safety buttons design
- Base Structure: upright built into case
- Blast Protection: Plexiglass
- Stabilization: Fold out legs
- Electrical Power: AC Power

Studies and Analyses

Magnitude of tasks (magnitude order)

- Design of force measurement system
- Design of microcontroller/electrical system for proper force measurement
- Design of housing for stability/strength
- Design of blast protection for 5x i class explosion
- Remote ignition system

Task Interrelationships

- Design of frame depends on design of all other subsystems
- Design of microcontroller system and electrical system depend of force measurement
- Blast protection system depends on motor mounting direction/ frame design
- Remote ignition system depends on electrical system

Proposed Improvements

- Weatherproof covering to protect RMTS from the elements when it is set up

Applicable Building/Safety Codes Summary

Environmental, Health, Safety and Risk Management Office

- MSDS for rocket motor must be uploaded
- Hearing conservation and indoor air quality rules could apply
- Occupational safety Standard Operating Procedure (SOP) may be required by Campus Safety Officer

UAF Fire Department

- RMTS could be affected by rules about fire extinguishers and storage of combustible materials
- Fire inspection could be required

Budget

Parts Budget

	Item	Cost($)
Prototype	Structure and Mechanical	41.61
	Electronics and Controls	159.85
Product	Structure and Mechanical	1243.29
	Electronics and Controls	420.75
Total		1665.5

Labor Budget

Number of Personnel	7
Hours Per Week	9
Number of Weeks	15
Hourly Rate	$100.00
Total Labor Budget	$94,500.00

Questions

Acronyms

AC - Alternating Current

GUI - Graphical User Interface

MSDS- Material Safety Data Sheet

RMTS - Rocket Motor Test Stand

SOP - Standard Operating Procedure

UAF - University of Alaska Fairbanks

USB-C - Universal Serial Bus-C

Amp - Amplifier

ADC - Analog Digital Converter