READY, SET, LAUNCH!

INTRODUCING STUDENTS TO MICROELECTRONICS AND THE **PHYSICS OF ROCKETRY**

SOUTHERN ILLINOIS UNIVERSITY
EDWARDSVILLE

Department of Defense
DoDSTEM
Science · Technology · Engineering · Mathematics

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An SIUE student glues the fins for his team's rocket.

READY, SET LAUNCH! INTRODUCTION

The universe has always captured the wonder and curiosity of human beings, and recently it has become a source of much renewed scientific interest. The media is currently flooded with stories of people launching into space with a wide array of goals, ranging from exploration to colonization, to even entertainment! **The goal of this course is to use the preparation and launch of a "smart" rocket to introduce students to microelectronics and the physics of rocketry.**

In this PD course, you're going to

Watch preparation videos,

Build a rocket,

Use computer programs to model the flight of your rocket,

Launch your rocket with a specialized electronics payload, and

Analyze the experimental data you gather and compare it to the analytical model you made.

When you incorporate "Ready, Set, Launch!" into your curriculum, your students' mission will ultimately be to design and launch a model rocket with the appropriate payload to reach a predetermined apogee. Through a Massive Open Online Course (MOOC) format, students explore the physics and hardware associated with rocket flight. Concepts of systems engineering guide groups of students as they build their own model rockets and design for optimal payload. The project culminates with the launch of each group's chosen design, after which students engage in data analytics to understand their experimental results.

With concrete examples and engaging applications at hand, you will have the opportunity to :

- Introduce students to the concepts of physics most important to rocketry
- Explore sensors and microcontrollers with your students
- Engage in the engineering design process
- Create analytical models to reflect real-world phenomena
- Launch rockets and collect real data
- Use critical thinking to compare analytical models to observed experimental data

OPTIONAL VARIATIONS

Anchoring Phenomenon

To generate student interest in this project, provide context for their learning, and drive the design of their rocket, we have developed an anchoring phenomenon you may wish to introduce at the beginning of the course and expanded upon throughout. Appendix C has additional resources (links to articles and videos) you may wish to use for this phenomenon.

The selected resources will prompt students to consider the types of payloads (food, people, tools, etc.) necessary to keep the ISS running as well as how those heavy payloads make it off the ground and to their targeted stop on the ISS. Working in small groups, students will begin to consider the question:

"What exactly does it take to deliver payloads to the ISS?"

Variations for More In-Depth Student Data Analysis

A simple rocket launch in itself is very interesting to students. However, you may wish to go a step further and explore the relationship between the mass of the payload and the height of apogee. Two possible variations on such an investigation are presented in Appendix D.

UNIT PROGRESSION OVERVIEW

This MOOC is video driven and consists of 7 units of learning. All videos are available to you now (through June 16) as part of the workshop, and the starred videos are highly recommended as pre-work for the PD.

If you choose to incorporate Ready, Set, Launch! into your curriculum, please contact Dr. Jeffrey Sabby at jsabby@siue.edu. We will reopen all videos and provide rocket kits for your student teams.

The 7 units of learning as follows:

- Introduction to the Project
  - A brief video introduces students to the project and the path it will take.

- Rocket Hardware
  - Students gain an introduction to model rocket hardware and how it functions.

- Rocket Design
    - Students learn the physical principles of rocket flight that affect design choices.
    - Students derive simplified equations of motion to model rocket flight.
    - Students learn to use a more sophisticated modeling software to simulate rocket flight and optimize rocket design.

- Rocket Build and Avionics Hardware and Software
    - Students experience how to build a safe model rocket.
    - Students learn about the avionics hardware, component setup, and software use for monitoring and recording flight.

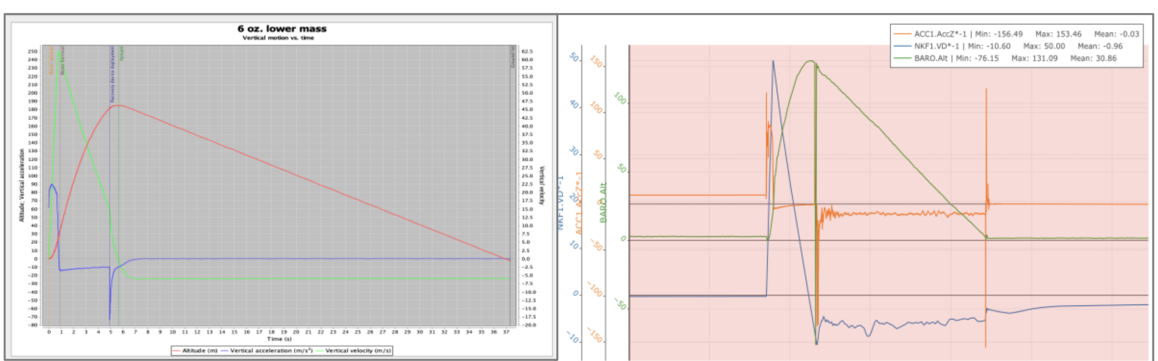
- Rocket Launch
    - Students learn how to safely prepare to launch a model rocket.
    - Students experience the thrill of watching their own rocket launched.

- Rocket Data Analysis and Handling
    - Students discover how to evaluate rocket launch data, connecting theoretical predictions to experimental observations.

In this guide, each unit is prefaced by

- a brief description
- applicable NGSS standards
- objectives for student learning, and
- next steps after that unit.

The MOOC's student-appropriate videos fully develop the concepts necessary for understanding rocket flight and analysis. Video content is paired with selected classroom activities to prepare for the launch of your students' rocket(s) and help them understand the data they've collected.



Modeled behavior (left) and experimental data (right) can be compared and examined to locate events like motor ignition, motor burnout, apogee, parachute ejection, and landing.

STANDARDS ALIGNMENT

This project meets 7 different NGSS standards. NGSS alignment information is provided before each instructional unit. More information can be found at https://www.nextgenscience.org/.

INSTRUCTIONAL UNITS

In this section you can find the breakdown of the 7 instructional units associated with Ready, Set, Launch!, including a brief unit description, SGSS standards alignment, unit objectives, next-steps. Descriptions, key words, and links for each video are also included.

1. INTRODUCTION

This video provides a course overview of theoretical, hands-on, and analysis components. Goals are presented for design/hardware (background concepts, terminology, and hardware, transferrable skills), build (introduction of and accounting for error), launch (picking a launch site, assembly of motor, using a launch system), and analysis (comparing observed and predicted data, suggesting improvements/iteration supported by data) components. Viewers are also introduced to critical rocket subsystems.

Objectives for this unit:

- Students will have a path for working through the theory of rocket flight and construction, launch, and analysis of a model rocket.

After this unit, you're ready to:

- Students will be ready to begin Unit 2, Rocket Hardware.

NGSS STANDARDS ALIGNMENT*

HS-ETS1: Engineering Design

- ***HS-ETS1-2****: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*

VIDEOS (7:38 total)

1.01 Intro to Single Stage Rocket (7:38)	**Key concepts:** Roadmap to project, learning goals
This short module introduces students to the project, what its goals are, and what students will be learning.	**Link:** https://siue.yuja.com/V/Video?v=5788518&node=25568921&a=1561679309&autoplay=1

2. ROCKET HARDWARE

Rocket Hardware videos highlight each component of the rocket body, exploring the function and relevance of each. The purpose of this unit is to familiarize students with the rocket body and to prepare students for the rocket build in the next unit.

Objectives for this unit:

- Students should understand what hardware is required for rocket flight.
- Students should understand the function of each piece of hardware and why it is necessary.

After this unit, you're ready to:

- Students will be ready to begin Unit 3, Rocket Design, where they will learn how the physics behind these hardware components enables rockets to fly.

NGSS STANDARDS ALIGNMENT*

HS-PS2 Motion and Stability: Forces and Interactions

- ***HS-PS2-3:*** *Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*

HS-PS3: Energy

- ***HS-PS3-3****: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*

VIDEOS (1 hr 7 min total)

2.01 Intro to Rocket Hardware (3:02)	**Key concepts:** materials, recovery systems, motors, avionics, launch instruments, air resistance, avionics, thrust, impulse
This video gives a brief history of model rocketry. There is also a hardware overview and concept terms important to rocketry are introduced.	**Link:** https://siue.yuja.com/V/Video?v=5788518&node=25568921&a=1561679309&autoplay=1

2.02 Rocket Bodies (5:03)

This video gives a brief description of rocket parts that will be significant for the build and design process.

Key concepts:
nosecone, body tubes, shock cord, parachute, wadding, fins, motor, shroud lines, lunch lugs, coupler, electronics bay, centering rings, payload

Link:
https://siue.yuja.com/V/Video?v=5936685&node=26411038&a=121843590&autoplay=1

2.03 Rocket Engines (4:18)

This video discusses motor function and components, understanding model rocket motor labels, and model rocket motor classifications.

Key concepts:
energy source, safety, ejection, nozzle, motor casing, delay charge, ejection charge, black powder, composite fuel, single use vs. reloadable

Link:
https://siue.yuja.com/V/Video?v=5788959&node=25572086&a=112363164&autoplay=1

2.04 Recovery Systems (3:12)

This video discusses how parachutes function, the equation for drag force, the equation for terminal velocity, and parachute size matters.

Key concepts:
parachutes, deployment, drag force, terminal velocity

Link:
https://siue.yuja.com/V/Video?v=5788789&node=25571023&a=1613637126&autoplay=1

2.05 Launch Controller (2:14)

This video covers how launch control systems function.

Key concepts:
launch controller setup and safety

Link:
https://siue.yuja.com/V/Video?v=5788790&node=25571030&a=383099464&autoplay=1

2.06 Launch Environment (3:19)

This video contains a detailed description of launch control system components and the requirements for a launch site.

Key concepts:
launch pad, launch rail, launch location

Link:
https://siue.yuja.com/V/Video?v=5788793&node=25571041&a=1591748067&autoplay=1

2.07 Electronics Bay (5:58)	
This video describes the electronics bay or avionics as the "brains of the rocket" and discusses common avionics components and their uses.	**Key concepts:** altimeter, IMU, microcontrollers, microcomputers, batteries, telemetry, GPS **Link:** https://siue.yuja.com/V/Video?v=5800597&node=25705145&a=763866019&autoplay=1

2.08 LiPo Batteries I (6:43)	
This video explains how batteries work and explains how rechargeable batteries are special.	**Key concepts:** cathode, anode, charge, current, reverse, electrolyte **Link:** https://siue.yuja.com/V/Video?v=5788802&node=25571116&a=2029685516&autoplay=1

2.09 LiPo Batteries II (6:49)	
This video differentiates between lithium ion and lithium polymer batteries. The rationale for using lithium polymer (LiPo) batteries for this project is discussed, and the video discusses power converters, capacity, and internal resistance.	**Key concepts:** cathode, anode, charge, current, reverse, electrolyte **Link:** https://siue.yuja.com/V/Video?v=5788816&node=25571167&a=1101833710&autoplay=1

2.10 Power Converters I (3:10)	
This video discusses current types and the need for power converters. It also sets up a basic boost converter circuit.	**Key concepts:** alternating current, direct current, power, voltage, current, inductor, capacitor, switch **Link:** https://siue.yuja.com/V/Video?v=5788819&node=25571176&a=227065156&autoplay=1

2.11 Power converters II (11:59)	
This video explains the physics and process of a converter boosting power.	**Key concepts:** inductor, diode, capacitor, switch, load, voltage, current, resistance, v=ir **Link:** https://siue.yuja.com/V/Video?v=5800643&node=25706189&a=2032108171&autoplay=1

2.12 Telemetry Radio (3:29)

This video discusses the need for communication to relay data mid-flight, both to the vehicle and from the vehicle.

Key concepts:
collect data, downlink, uplink, TELINT

Link:
https://siue.yuja.com/V/Video?v=5800648&node=25706262&a=452499057&autoplay=1

2.13 GPS (3:03)

This video explains how global positioning systems use 3-way communication between transmitters, satellites, and receivers to track location.

Key concepts:
GPS, transmitter, receiver, FCC license, latitude, and longitude coordinates

Link:
https://siue.yuja.com/V/Video?v=5800652&node=25706314&a=873982398&autoplay=1

2.14 Airflow & Cameras (2:55)

This video presents issues that should be considered when including a camera in the rocket payload

Key concepts:
video, durability, camera shroud

Link:
https://siue.yuja.com/V/Video?v=5800659&node=25706430&a=1773309503&autoplay=1

2.15 Phases of Flight (2:21)

This video discusses the phases of flight for a single stage model rocket, including: launch, motor burn, coasting, apogee and parachute deployment, descent, and search and recovery.

Key concepts:
launch, thrust, burn, acceleration, max velocity, coast, momentum, apogee, ejection, parachute, drift, recovery

Link:
https://siue.yuja.com/V/Video?v=5800666&node=25706554&a=193879399&autoplay=1

3. ROCKET DESIGN

The goal of this topic is to help students meet the engineering component of this course: to design the optimal payload for their rocket, allowing it to achieve the desired apogee. This goal is met as students explore the many factors that impact a rocket's flight, including forces acting on the rocket, aerodynamic features of the rocket, and the rocket's mass. Rocket Design is split into three sections: Stability and Performance, Analytical Model, and OpenRocket Computational Model.

Objectives for this unit:

- Students understand the physics of rocket flight.
- Students are able to set up equations of motion to model their own rocket flight.
- Students are able to use more sophisticated models to predict and analyze theoretical rocket performance and optimize design.

After this unit, you're ready to:

- Students can make an OpenRocket model of the rocket they will build.
- Using a simulation, students can model the effects of changing payload mass, motor thrust, and wind conditions on rocket behavior.
- Students are ready to begin Unit 4, Rocket build.

NGSS STANDARDS ALIGNMENT*

HS-PS2: Motion and Stability: Forces and Interactions

- ***HS-PS2-1:*** *Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration*
- ***HS-PS2-3:*** *Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*

HS-PS3: Energy

- ***HS-PS3-1****: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known*
- ***HS-PS3-2****: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).*
- ***HS-PS3-3****: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*

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HS-ETS1: Engineering Design

- ***HS-ETS1-2***: *Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering*
- ***HS-ETS1-4***: *Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.*

3.a STABILITY AND PERFORMANCE

The first unit, Stability and Performance, begins with the introduction of science concepts critical to rocketry, such as center of Gravity and Center of Pressure. Students continue to gain foundational understanding as they learn the significance of weight and area distribution as it relates to the rocket's stability.

VIDEOS (46 min total)

3.01 Introduction to Rocket Design (3:52) This video provides an overview of the design process for the project's model rocket and the importance of performing simulation to determine the appropriateness of the rocket design.	**Key concepts:** parameters, engine systems, design software, constraints, apogee, stability, center of pressure, center of gravity **Link:** https://siue.yuja.com/V/Video?v=5801586&node=25724001&a=180588974&autoplay=1
3.02 Center of Gravity (7.50) This video discusses how the center of gravity is determined and provides an example problem. Kinematics equations map out the physics of the center of gravity.	**Key concepts:** center of gravity, balance, mass, kinematics equations **Link:** https://siue.yuja.com/V/Video?v=5801792&node=25727076&a=99917299&autoplay=1
3.03 Center of Pressure (7:25) This video discusses how the center of pressure is determined and provides an example problem. The importance of the center of pressure and its location behind the center of gravity are emphasized.	**Key concepts:** center of pressure, center of gravity, aerodynamic forces, lift, drag **Link:** https://siue.yuja.com/V/Video?v=5801777&node=25726909&a=203016971&autoplay=1

3.04 Equilibrium (2:31)

This video examines the three types of equilibrium: stable, unstable, and neutral and their impact on a rocket's flight.

Key concepts:
pitch, roll, yaw, stable equilibrium, unstable equilibrium, neutral equilibrium, stability

Link:
https://siue.yuja.com/V/Video?v=5801773&node=25726783&a=2837954&autoplay=1

3.05 Low-velocity Stability (3:46)

This video discusses rocket stability at launch and compares passive vs active guidance for a rocket launch.

Key concepts:
aerodynamic stability, launch rail, active guidance, passive guidance

Link:
https://siue.yuja.com/V/Video?v=5801762&node=25726643&a=33562543&autoplay=1

3.06 High-velocity Stability (5:14)

This video discusses the factors of stable vs. unstable and what it means if a rocket is too stable.

Key concepts:
center of pressure, center of gravity, angle of attack, aerodynamic stability, equilibrium, center of pressure, center of gravity, static margin

Link:
https://siue.yuja.com/V/Video?v=5801755&node=25726557&a=148569360&autoplay=1

3.07 Weight, Thrust, and Impulse (3:43)

This video provides meaning to common rocketry terms and their contribution to the rocket's performance.

Key concepts:
weight, thrust, impulse, specific impulse

Link:
https://siue.yuja.com/V/Video?v=5801807&node=25727397&a=54470056&autoplay=1

3.08 Thrust-to-weight ratio (3:59)

This video brings attention to the impact of various thrust to weight ratios and their impact on stability and performance.

Key concepts:
weight, thrust, acceleration

Link:
https://siue.yuja.com/V/Video?v=5801803&node=25727298&a=124258022&autoplay=1

3.09 Engine/motor discussion (4:16)

This video discusses the differences between liquid and solid motors and the optimal applications for each.

Key concepts:
liquid engines, complexity, efficiency, solid motors, cryogenic, non-cryogenic semi-cryogenic

Link:
https://siue.yuja.com/V/Video?v=5801797&node=25727204&a=213234437&autoplay=1

3.10 Motor and Ignitor (1:45)

This video breaks down the components of a solid model rocket motor and how the ignitor is inserted.

Key concepts:
nozzle, propellant, delay charge, ejection charge, starter (ignitor), leads

Link:
https://siue.yuja.com/V/Video?v=5801794&node=25727125&a=204293904&autoplay=1

3.11 Motor Selection (2:02)

This video considers the factors (i.e. classification, thrust) to consider in determining an appropriate motor for your specific rocket needs.

Key concepts:
motor class, impulse, diameter, thrust

Link:
https://siue.yuja.com/V/Video?v=5802053&node=25732626&a=168688844&autoplay=1

3.b ANALYTICAL MODEL

The second unit of Rocket Design, Analytical Model, transitions to using a theoretical, analytical model to solve for rocket flight parameters. The videos walk students using Newton's Second Law (F=ma) to write Kinematic Equations of Motion (EOMs) for the boost and coast phase of the rocket. The sum of the coast and boost heights are then used to determine the maximum height (apogee) the rocket will travel. Conversely, this process can be reversed to solve for the mass needed to reach a target altitude. Students will be shown an example problem and then be asked to apply the learning to create their own Google Sheets or Python analytical model.

VIDEOS (42 min total)

3.21 Derive and Describe Rocket Equations of Motion (9:47) This video describes the dynamics of a rocket and how the Equations of Motion and simplifying assumptions are used to predict apogee.	**Key concepts:** acceleration, velocity, position, thrust, equations, mass, phase, motor, assumptions, forces **Link:** https://siue.yuja.com/V/Video?v=5802187&node=25735144&a=55286960&autoplay=1
3.22 Solving Approximate Equations of Motion for Altitude (no drag) 11:34 This video provides walks through how to derive the apogee from the boost and coast phase, an example problem, and the reverse process for calculating the mass of a target altitude.	**Key concepts:** acceleration, velocity, position, thrust, equations, mass, phase, motor, assumptions, forces, coast **Link:** https://siue.yuja.com/V/Video?v=5802334&node=25737665&a=185160010&autoplay=1
3.23 Solving Equations of Motion using Google Sheets (11:54) This video provides an example for reference on how to create a Google Sheets spreadsheet for rocket dynamics analysis.	**Key concepts:** acceleration, velocity, equations, intervals, forces, timestep, altitude, apogee, graph **Link:** https://siue.yuja.com/V/Video?v=5802310&node=25737318&a=101303304&autoplay=1
3.24 Solving Equations of Motion in Python (9:01) This video provides an example for reference on how to create a Python scriptfor rocket dynamics analysis.	**Key concepts:** Python, matplotlib, numpy, parameters, acceleration, velocity, equations, intervals, forces, timestep, altitude, apogee, plot **Link:** https://siue.yuja.com/V/Video?v=5802343&node=25737822&a=128612411&autoplay=1

3.c OpenRocket COMPUTATIONAL MODEL

The third unit introduces students to the software OpenRocket. OpenRocket is used to perform simulations and generate data for a designed rocket's anticipated flight path. This data will be useful for optimizing rocket design, as well as for comparing it to the data generated in the analytical model. The videos in this unit provide instructions for downloading the software and becoming familiar with the critical variables. An OpenRocket file of the model rocket fabricated for this project is provided for exploration and for estimated flight parameters. This unit will be utilized by students who have the ability to download/access the software. Students without that capability will submit two chosen designs (based on their analytical models) to the teacher to be run through OpenRocket. This will allow for the determination of the payload mass that will be used for their rocket launch.

VIDEOS (1 hr 3 min total)

3.12 Install OpenRocket on Mac (3:12)	**Key concepts:** download, application, simulation, designs, java
This video provides a walkthrough of installing OpenRocket open-source software on a Mac computer.	**Link:** https://siue.yuja.com/V/Video?v=5802047&node=25732589&a=89006406&autoplay=1

3.13 Install OpenRocket on Windows (3:05)	**Key concepts:** download, application, simulation, designs, java
This video provides a walkthrough of installing OpenRocket open-source software on Windows.	**Link:** https://siue.yuja.com/V/Video?v=5802045&node=25732568&a=43503580&autoplay=1

Note: OpenRocket is not currently compatible with Chromebooks unless the Chromebook is run in developer mode.

3.14 Designing a Rocket in OpenRocket I (6:47)	**Key concepts:** Components, nosecone, diameter, length, appearance
This video demonstrates how to model the upper body of our rocket in OpenRocket.	**Link:** https://siue.yuja.com/V/Video?v=5802043&node=25732548&a=146420548&autoplay=1

3.15 Designing a Rocket in OpenRocket II (8:20)

This video demonstrates how to model the lower body of our rocket in OpenRocket.

Key concepts:
tube length, material, fin sweep, height,

Link:
https://siue.yuja.com/V/Video?v=5802042&node=25732516&a=53125167&autoplay=1

3.16 Adding a Motor and Parachute in OpenRocket (8:15)

This video covers critical factors for motor and parachute selection, along with how to import a specific motor into your rocket model.

Key concepts:
motor, parachute, dimensions, configuration, drag coefficient

Link:
https://siue.yuja.com/V/Video?v=5802039&node=25732498&a=49212485&autoplay=1

3.17 Rocket Weight (5:28)

This video demonstrates the effects of mass addition and its placement on stability and apogee.

Key concepts:
mass component, stability, payload, density, gravity

Link:
https://siue.yuja.com/V/Video?v=5802038&node=25732470&a=147533955&autoplay=1

3.18 OpenRocket Simulations I (7:49)

This video walks through how to set up appropriate parameters for an OpenRocket simulation and plotting a rocket flight.

Key concepts:
simulation, axis, plot, degrees, conditions, altitude, graph

Link:
https://siue.yuja.com/V/Video?v=5802037&node=25732458&a=119336350&autoplay=1

3.19 OpenRocket Simulations II (9:20)

This video shows how to use OpenRocket to plot different iterations for comparison in determining an optimal rocket configuration. Several examples provided examine critical factors like apogee.

KEY CONCEPTS
simulation, velocity, altitude, distance, motor class, conditions, apogee

Link:
https://siue.yuja.com/V/Video?v=5802055&node=25732691&a=24234833&autoplay=1

3.20 OpenRocket Optimization (8:04)

This video examines the balance between stable and safe vs effective and efficient. We also demonstrate the interactive process of designing a rocket for specific mission objectives.

Key concepts:
Performance, stability, weight, masses, fins, center of gravity, center of pressure, trade

Link:
https://siue.yuja.com/V/Video?v=5802054&node=25732646&a=107320&autoplay=1

3.25 Exporting OpenRocket Resources (3:05)

This video demonstrates how to export images of the rocket design for use in documents.

Key concepts:
export photos, appearance, change component colors

Link:
https://siue.yuja.com/V/Video?v=5802335&node=25737673&a=3756121&autoplay=1

4. ROCKET BUILD

This topic guides students and teachers through the actual construction of the rocket and the preparation of the avionics bay. Rocket build is divided into two units: Rocket Body Construction and Microelectronics Hardware and Software.

Objectives:

- Students understand the process of building a rocket.
- Students should understand the function of each component of the avionics hardware and why each piece is necessary.
- Students are able to set up and use the avionics hardware and software.

After this unit, you're ready to:

- With supervision, students can construct their rocket.
- Students can assemble the microelectronics into an avionics bay.
- Students are ready to begin Unit 5, Rocket Launch.

NGSS STANDARDS ALIGNMENT*

HS-PS2 Motion and Stability: Forces and Interactions

- ***HS-PS2-3:*** *Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*

HS-PS3: Energy

- ***HS-PS3-3****: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*

HS-ETS1: Engineering Design

- ***HS-ETS1-2****: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*

4.a ROCKET BODY CONSTRUCTION

These videos walk the viewer through building the rocket body and the many modifications that must be made to accommodate the avionics bay. The detailed rocket build instruction manual is provided in Appendix A.

VIDEOS (1 hr 2 min total)

4.1 Introduction to the Rocket Built (2:43)

This video presents a brief overview of the major components of the model rocket and the importance of material selection.

Key concepts:
rocket build, hardware, proper procedure

Link:
https://siue.yuja.com/V/Video?v=5804325&node=25769141&a=183995388&autoplay=1

4.2 Assemble Fins (8:30)

This video demonstrates how the fins are cut, glued, and prepared for installation.

Key concepts:
fin construction

Link:
https://siue.yuja.com/V/Video?v=5804313&node=25769026&a=18128352&autoplay=1

4.3 Assemble the motor mount (8:36)

This video walks through construction of the motor mount.

Key concepts:
motor mount construction

Link:
https://siue.yuja.com/V/Video?v=5973203&node=26510593&a=143693342&autoplay=1

4.4 Prepare the Fin Slots (4:35)

In this video, fins slots are cut into the lower body tube in preparation for fin installation.

Key concepts:
fin slot preparation

Link:
https://siue.yuja.com/V/Video?v=5804275&node=25768466&a=62634235&autoplay=1

4.5 Install the Motor Mount (7:07)

This video shows how to install the motor mount into the lower body tube.

Key concepts:
motor mount alignment and installation

Link:
https://siue.yuja.com/V/Video?v=5804266&node=25768286&a=84846112&autoplay=1

4.6 Install Fins (4:11)

In this video, fins are inserted into the lower body tube.

Key concepts:
fin alignment and installation

Link:
https://siue.yuja.com/V/Video?v=5804275&node=25768466&a=62634235&autoplay=1

4.7 Nose Cone Cut (2:09)

This video shows how to alter the nose cone to accommodate the avionics bay.

Key concepts:
nosecone fitting

Link:
https://siue.yuja.com/V/Video?v=5804266&node=25768286&a=84846112&autoplay=1

4.8 Securing the Nosecone (3:10)

In this video, installation of the nosecone is shown.

Key concepts:
nosecone installation

Link:
https://siue.yuja.com/V/Video?v=5804340&node=25769367&a=168831518&autoplay=1

4.9 Bulkhead generation (6:33)

In this video, the bulkhead is assembled and a hole for the antenna is drilled.

Key concepts:
bulkhead fabrication

Link:
https://siue.yuja.com/V/Video?v=5804335&node=25769266&a=93882091&autoplay=1

4.10 Assembly of the Upper Body Tube (8:17)

In this video, the upper body tube is fully assembled.

Key concepts:
coupler installation on lower body tube, bulkhead installation,

Link:
https://siue.yuja.com/V/Video?v=5814090&node=25904143&a=180914397&autoplay=1

4.11 Install Motor Retainer (3:51)	**Key concepts:** motor retention, motor retainer ring
In this video, the motor retainer ring is installed.	**Link:** https://siue.yuja.com/V/Video?v=5814063&node=25903969&a=4898518&autoplay=1

4.12 Shock Cord Length Considerations (2:09)	**Key concepts:** fitting the shock cord, tying knots
This video shows the critical step of how to measure and tie the shock cord to ensure the rocket stays connected during parachute deployment.	**Link:** https://siue.yuja.com/V/Video?v=5814039&node=25903811&a=158488320&autoplay=1

4.b MICROELECTRONICS: AVIONICS HARDWARE AND SOFTWARE

These videos introduce the microelectronics and telemetry. Once components are introduced, their integration and preparation for flight are demonstrated. The purpose of this topic is to prepare the avionics bay for use in flight. One component of preparation involves downloading the program Mission Planner, which allows the avionics bay to send information remotely to your ground control computer. Additionally, you will activate the GPS signal so that your rocket knows its location, and you will calibrate the IMU so that your avionics bay has accurate data about its orientation. These videos will walk you and your students through these vital steps. A more in-depth setup guide for the Navio2 and Mission Planner can be found at:
https://github.com/Brandonh291/Ready-Set-Launch-PD

VIDEOS (2 hrs 5 min total)

4.13 Introduction to Microelectronics Hardware (4:13)	**Key concepts:** Avionics hardware, processors, sensors, communications, making connections to industry tools
	Link: https://siue.yuja.com/V/Video?v=5974444&node=26516375&a=112989427&autoplay=1

4.14 Raspberry Pi (4:03)

Introduces the microcomputer used for this project and how it allows all data to be stored in a single location.
electronics and draw connections to industry.

Key concepts:
Raspberry Pi capabilities, sensors, Linux

Link:
https://siue.yuja.com/V/Video?v=5974421&node=26516255&a=136405360&autoplay=1

4.15 Navio2 (2:31)

This video describes the heart of our avionics system, the Navio2. This shield (add-on board) attached to the Raspberry Pi introduces new hardware and software functionality.

Key concepts:
Robot Operating System (ROS), ArduPilot, GNSS, MS5611 barometer, dual IMU

Link:
https://siue.yuja.com/V/Video?v=5974407&node=26516171&a=56577360&autoplay=1

4.16 UART (3:38)

This video explains how the Universal Asynchronous Receiver Transmitter (UART) is used to transmit data packets from the rocket to the ground control station (laptop).

Key concepts:
asynchronous data transmission, data packets

Link:
https://siue.yuja.com/V/Video?v=5974435&node=26516321&a=151484371&autoplay=1

4.17 GNSS Receiver & GPS Antenna (2:57)

This video describes how the two-part system of Global Position System (GPS), detecting satellite signals, and the Global Navigation Satellite System (GNSS), receiving signals and translating them into measurements, work together to determine position. This is a passive system only for receiving signals, not tracking the user.

Key concepts:
GPS antenna, GNSS receiver

Link:
https://siue.yuja.com/V/Video?v=5974428&node=26516291&a=61763330&autoplay=1

4.18 Microelectronics Power Module (4:02)

This video discusses how the component regulates the power (voltage) from the battery to the Raspberry Pi/Navio2 to ensure it has the right amount.

Key concepts:
power regulation, battery life estimation

Link:
https://siue.yuja.com/V/Video?v=5974424&node=26516278&a=35155250&autoplay=1

4.19 Dual IMU (2:58)

This video shows how Inertial Measurement Units (IMUs) combine accelerometer, gyroscope, and magnetometer to determine the 3-D position and orientation of an object.

Key concepts:
IMU, spatial frame of reference, degrees of freedom, accelerometer, gyroscope, magnetometer

Link:
https://siue.yuja.com/V/Video?v=5974414&node=26516208&a=146645224&autoplay=1

4.20 Barometer (3:00)

This video explains how the measure of atmospheric pressure can be used to determine altitude.

Key concepts:
atmospheric pressure, relation of atmospheric pressure to altitude

Link:
https://siue.yuja.com/V/Video?v=5974482&node=26516585&a=33842246&autoplay=1

4.21 Radio Transmitter & Receiver (3:55)

This video defines telemetry as data collected at a distance and explains how we the rocket is able to communicate its health and stability by sending sensor information to ground control.

Key concepts:
transmitters, receivers, frequency, controller channels

Link:
https://siue.yuja.com/V/Video?v=5974411&node=26516202&a=37479840&autoplay=1

4.22 PWM (5:27)

This video discusses how the Pulse Width Modulation (PWM) component regulates the power (voltage) from the battery to the Raspberry Pi/Navio2 to ensure the electronics have the right amount of power.

Key concepts:
pulse width/duration modulation, voltage reduction, duty cycles,

Link:
https://siue.yuja.com/V/Video?v=5974404&node=26516140&a=136115138&autoplay=1

4.23 ADC (2:57)

This video explains the difference between continuous analog signals and discrete digital signals. It also discusses how this conversion is made and the importance of bit levels.

Key concepts:
analog to digital conversion, continuous and discrete signals, bit levels

Link:
https://siue.yuja.com/V/Video?v=5974485&node=26516595&a=54736358&autoplay=1

4.24 I2C (4:27)

This video discusses serial communication using the inter-integrated circuit (I2C) protocol on the Navio2, allowing multiple devices to pass data simultaneously. Advantages and disadvantages of I2C are also discussed.

Key concepts:
inter-integrated circuit (I2C), serial communication, controller and agent devices,

Link:
https://siue.yuja.com/V/Video?v=5974394&node=26516099&a=40072185&autoplay=1

4.25 Introduction to Microcontroller Setup (3:16)

This video is an introduction to the software setup that will be required to set up the Navio2 for rocket avionics.

Key concepts:
flashing operating system, secure shell (SSH) communication, configuring/starting ArduPilot

Link:
https://siue.yuja.com/V/Video?v=5974498&node=26516622&a=214670976&autoplay=1

4.26 Download and Flash the Raspberry Pi OS (2:34)

This video walks through how to install the operating system onto the Raspberry Pi using an SD card.

Key concepts:
flashing an operating system, Raspberry Pi OS, balenaEtcher

Link:
https://siue.yuja.com/V/Video?v=5974496&node=26516611&a=136024180&autoplay=1

4.27 Configuring the Raspberry Pi and Navio2 (3:01)

This video introduces the microcomputer used for this project and how it allows all data to be stored in a single location.

Key concepts:
connecting Raspberry Pi to internet

Link:
https://siue.yuja.com/V/Video?v=5974442&node=26516350&a=192992296&autoplay=1

4.28 Microcontroller Summary (1:56)

This video contains a summary of the Microcontrollers videos thus far, covering the hardware and setup of the Raspberry Pi, Navio2, ArduPilot WiFi, telemetry radio, flashing an OS onto a SD card, and SSH.

Key concepts:
microcontroller review

Link:
https://siue.yuja.com/V/Video?v=5974486&node=26516597&a=75514598&autoplay=1

4.29 Introduction to Mission Planner (2:09)

This video provides a walkthrough for the Ground Control Station (GCS) software, Mission Planner.

Key concepts:
ground control station, Mission Planner, ArduPilot, telemetry

Link:
https://siue.yuja.com/V/Video?v=5989167&node=26574037&a=100151028&autoplay=1

4.30 Installing Mission Planner (2:52)

This video gives an overview of the setup of Mission Planner (PC only) with the Navio2/Raspberry Pi to allow mission planning and data collection for the rocket.

Key concepts:
Mission Planner installation

Link:
https://siue.yuja.com/V/Video?v=5989165&node=26574034&a=70045618&autoplay=1

4.31 Telemetry Radio Setup (3:33)

This video walks through how to set up a connection between the avionics telemetry radio and the Navio2.

Key concepts:
Navio2 connection to telemetry radio

Link:
https://siue.yuja.com/V/Video?v=5974489&node=26516601&a=53475430&autoplay=1

4.32 Connect System to Mission Planner Using Telemetry (4:49)

This video shows how to set up the telemetry antenna for Ground Control (laptop) and the rocket (Navio2/Raspberry Pi) using Mission Planner.

Key concepts:
Telemetry connection to field laptop

Link:
https://siue.yuja.com/V/Video?v=5989155&node=26574014&a=130087720&autoplay=1

4.33 Arming and Disarming the Single Stage Rocket avionics (7:11)

This video shows how to change the settings in the Navio2 to allow the microcontroller to function as rocket avionics, and allow for easier data analysis after launch.

Key concepts:
Navio2 settings, arming/disarming, BitMask parameters, log files

Link:
https://siue.yuja.com/V/Video?v=5989343&node=26575007&a=64352386&autoplay=1

4.34 Calibrate Mission Planner IMU (2:43)

This video shows how to calibrate the accelerometer onboard the Navio2 using Mission Planner.

Key concepts:
accelerometer calibration, Mission Planner

Link:
https://siue.yuja.com/V/Video?v=5989346&node=26575029&a=153991730&autoplay=1

4.35 Calibrate Compass (2:14)

This video demonstrates how to “orient” the avionics by calibrating the Navio2 compass and magnetometer.

Key concepts:
compass and magnetometer calibration

Link:
https://siue.yuja.com/V/Video?v=5989347&node=26575032&a=88617457&autoplay=1

4.36 Calibrate GPS (1:32)

This video provides instruction on how to achieve a GPS Fix using the Navio2 and Mission Planner.

Key concepts:
GPS calibration

Link:
https://siue.yuja.com/V/Video?v=5989345&node=26575019&a=196714624&autoplay=1

4.37 Mission Planner Mapping without WiFi (3:07)

Provides instruction on downloading a saved map of the launch site for use on the Ground Control Station.

Key concepts:
setting position to map vehicle location

Link:
https://siue.yuja.com/V/Video?v=5989344&node=26575017&a=102861024&autoplay=1

4.38 Conclusion

This video is a brief recap of preparing the ground station and how it applies to real-life applications.

Key concepts:
summary of avionics content, connections to industry

Link:
https://siue.yuja.com/V/Video?v=5989334&node=26574963&a=140037969&autoplay=1

5.ROCKET LAUNCH

This topic helps students prepare for the big day: LAUNCH day! In the first section, Prepare for Launch Day, students consider the different aspects of preparing for a rocket launch. The second section, Launch Day, will walk you through the process of actually launching the rocket.

Additionally, your local chapter of the National Association of Rocketry is an invaluable resource for assistance with locating an appropriate launch site as well as launch day support. **Please visit https://www.nar.org/safety-information/model-rocket-safety-code/ to view the NAR Model Rocketry Safety Code and https://www.nar.org/contest-flying/u-s-model-rocket-new-sporting-code/introduction/launching-requirements/ for launch site specifications.**

Objectives:

- Students are able to prepare their rocket for launch.
- Students understand where and how to safely launch a rocket.
- Students are able to troubleshoot common problems with rocket launches.

After this unit, you're ready to:

- You are able to set up your launch site and date.
- Students can pack the parachute and prepare the rocket for launch.
- With supervision, students can set up the launch site and launch their rocket.
- You are ready to proceed to Unit 6, Rocket Data Analysis and Handling.

NGSS STANDARDS ALIGNMENT*

HS-PS2 Motion and Stability: Forces and Interactions

- ***HS-PS2-3:*** *Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*

HS-PS3: Energy

- ***HS-PS3-3****: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
-

HS-ETS1: Engineering Design

- ***HS-ETS1-2****: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*

5.a PREPARE FOR LAUNCH DAY

This first section, Prepare for Launch Day, should be completed WELL ahead of the actual launch day, as it provides valuable information related to detailed launch requirements, including how to pick a launch site and launch regulations. Because of the inherent risks to people, property, and equipment, it is critical that launch site regulations are strictly followed.

VIDEOS (21 min total)

5.1 Launch Introduction (2:42)

This video reviews what the actual launch will look like and discusses the important concepts and procedures that will be covered to prepare for the big launch day.

Key concepts:
launch day preparation overview

Link:
https://siue.yuja.com/V/Video?v=5814103&node=25904257&a=182462326&autoplay=1

5.2 Launch Environment (3:19)

This video covers the critical factors influencing the launch and the surrounding area with an emphasis on adherence to the NAR guidelines for launch lugs, minimum site dimensions, and wind speeds.

Key concepts:
launch location, launch control system, state/local/NAR guidelines, weather conditions, fire hazards

Link:
https://siue.yuja.com/V/Video?v=5814105&node=25904266&a=196302421&autoplay=1

5.3 Picking an Appropriate Launch Site (4:08)

This video delves deeper into the impact of wind on the launch and landing of the rocket. Wind gradient and weather cocking are introduced, and the video discusses how to compensate for these in order to land in a desirable area.

Key concepts:
selecting launch site for safety and rocket recovery, weathervaning/wind cocking, drift

Link:
https://siue.yuja.com/V/Video?v=5814109&node=25904313&a=136993494&autoplay=1

5.4 Launch Pad Setup (4:08)

This video reviews what the actual launch will look like and discusses the important concepts and procedures that will be covered to prepare for the big launch day.

Key concepts:
launchpad assembly, height of blast plate

Link:
https://siue.yuja.com/V/Video?v=5814115&node=25904373&a=93728124&autoplay=1

5.5 Install Recovery Wadding (1:57)

This video discusses the importance of recovery wadding and demonstrates how to install it.

Key concepts:
recovery wadding insertion

Link:
https://siue.yuja.com/V/Video?v=5814116&node=25904389&a=102145501&autoplay=1

5.6 Prepare Recovery System (4:10)

This video walks users through the steps of properly folding the parachute to safeguard deployment.

Key concepts:
parachute folding

Link:
https://siue.yuja.com/V/Video?v=5815473&node=25916571&a=52412459&autoplay=1

5.b LAUNCH DAY

It's LAUNCH Day! This is where your hard work pays off. You will finally take your carefully-built rocket outside and launch it in the air to the target altitude.

Before getting too excited about the launch, you must know a couple of things in advance to ensure a successful and safe flight. This Launch Day section teaches the detailed steps of how to proceed with a rocket launch by providing how to set up a proper launch site and launch rails, how to install and ignite motors, and how to launch your rocket with a launch controller.

You may want to perform two test launches before launching with your avionics package. We will test the first launch with no payload. This ensures that your rocket was appropriately built and that you are following the correct launch steps. We will be using the F15 motor, so please refer to the F15 motor installation video for the first launch. A second test launch may be performed using an F67 motor and a "dummy payload." This launch confirms that the motor can handle the mass of the avionics bay without putting the avionics in danger.

The final launch uses an F67 motor and the full avionics bay, communicating with your ground station. The data to be analyzed later in the course is done with this avionics launch so keep this in mind when you want to start collecting data by properly arming and disarming. Most importantly, have FUN!

Appendix B has launch checklists for before, during, and post-launch, as well as sample launch logs.

VIDEOS (32 min total)

5.7 Prepare Engine (0:43)

This video explains how to safely connect launch controller clamps to the ignitor wires.

Key concepts:
ignitor insertion, connection to launch control system

Link:
https://siue.yuja.com/V/Video?v=5815465&n

5.7a Install F15 Motor (3:10)

This video walks through how to prepare the F15 motor and place the ignitor for the structural integrity launch.

Key concepts:
F15 motor insertion, nozzle, create thrust ring, ignitor insertion, securing ignitor

Link:
https://siue.yuja.com/V/Video?v=7199011&node=30640816&a=164836106&autoplay=1

5.7b Install F67 Motor (2:47)

This video instructs users on how to prepare the F67 motor and place the ignitor for the dummy payload and avionics launches.

Key concepts:
F67 motor insertion, nozzle, built-in thrust ring, ignitor insertion, securing ignitor

Link:
https://siue.yuja.com/V/Video?v=7199019&node=30640841&a=127584072&autoplay=1

5.8 Launch Procedure (1:19)

This video guides users on how to properly operate the launch controller for a safe launch.

Key concepts:
launch procedure, safety protocol

Link:
https://siue.yuja.com/V/Video?v=5815464&node=25916455&a=54883592&autoplay=1

5.9 1st Launch: Rocket Test Launch (1:41)

This video explains the reasoning for the integrity test of the structure and the immediate steps if a misfire should occur.

Key concepts:
stability and structural integrity testing, launch procedures

Link:
https://siue.yuja.com/V/Video?v=5815462&node=25916441&a=107563438&autoplay=1

5.10 1st Launch: Trouble-shooting (3:00)

This video reminds learners that the best part of mistakes is what we can learn from them. Advice is offered on what might have happened and why and how to correct it for the next time.

Key concepts:
structural integrity, recovery separation, recovery system deployment, launch control system connections and battery

Link:
https://siue.yuja.com/V/Video?v=5815461&node=25916423&a=204410788&autoplay=1

5.11 2nd Launch: Dummy Payload (2:43)

In this final test, the rocket is launched with a dummy payload simulating the mass of the avionics bay. This will test the structural integrity of the rocket before using avionics.

Key concepts:
payload simulation, practice, stability

Link:
https://siue.yuja.com/V/Video?v=5815458&node=25916397&a=145568312&autoplay=1

5.12 2nd Launch: Troubleshooting (1:13)

This video discusses troubleshooting rocket hardware problems that may present during the payload simulation.

Key concepts:
payload simulation, troubleshooting structural issues

Link:
https://siue.yuja.com/V/Video?v=5815456&node=25916382&a=3971064&autoplay=1

5.13 Calibrating Mission Planner (3:37)

This video shows how to correctly calibrate and orient Mission Planner, so that it recognizes how the rocket is oriented in real space.

Key concepts:
sensor calibration, orientation, setting parameters, Mission Planner

LINK
https://siue.yuja.com/V/Video?v=5815498&node=25916781&a=56190008&autoplay=1

5.14 Preflight Avionics Check (3:02)

This video reviews all aspects of the avionics in preparation for flight including the Navio2 connection and parameters, telemetry antenna set-up, and GPS acquisition.

Key concepts:
Mission Planner, COM port, baud rate, GPS signals, logging parameters

Link:
https://siue.yuja.com/V/Video?v=5815494&node=25916726&a=140885970&autoplay=1

5.15 3rd Launch: with Avionics (2:20)

This video goes over all the critical components of the rocket to make sure everything runs smoothly and safely for the data collection launch.

Key concepts:
Mission Planner, ArduPilot, pre-launch assembly and preparation

Link:
https://siue.yuja.com/V/Video?v=5815481&node=25916658&a=145700960&autoplay=1

5.16 3rd Launch: Trouble-shooting (0:55)

This video focuses on determining whether a launch didn't go according to plan because of problems with the avionics or the rocket body itself and discusses how to address the issue.

Key concepts:
troubleshooting avionics

Link:
https://siue.yuja.com/V/Video?v=5815478&node=25916618&a=70283344&autoplay=1

5.17 Selecting Desired Flight Log Data (7:32)

This video shows how to sift through the massive amounts of data that can be collected by the Navio2 to find the desired flight log data.

Key concepts:
data flash log, parameters, acceleration, velocity, altitude, arming, disarming, Mission Planner

Link:
https://siue.yuja.com/V/Video?v=5816047&node=25922272&a=82441209&autoplay=1

6. ROCKET DATA ANALYSIS AND HANDLING

It's time to see how well your rocket performed! You probably have some idea from the qualitative data you collected while watching your rocket launch, but this next topic will help you derive quantitative data to provide more specific information about your rocket's flight.

This topic, Rocket Analysis and Data Handling, shows you how to manipulate and analyze the data collected during the flight. Data collected onboard your avionics bay is written as binary log files (.BIN). This file is handy for a small flight computer like the Raspberry Pi/Navio2 because it does not take up much storage. These files need to be converted into a different format to be usable on a PC for creating data plots in Google Sheets or Python. (Instructions for Mission Planner on Mac are still under development.) The videos walk through the steps of converting the Bin files into log files and, ultimately, into a CSV (comma-separated values) file for your spreadsheet. You'll then have access to all the data and tools needed to get a clear picture of your rocket's performance and how closely your predicted flight pattern matched the actual flight

In the unfortunate event that your launch does not occur, we have made available actual launch data so that students can still perform the data analysis of the expected vs the actual.
You can find the backup launch data inside the IE 106 Single Stage Rocket Example Data at https://github.com/Brandonh291/Ready-Set-Launch-PD

Objectives:

- Students are able to locate and export data files from their launch.
- Students use multiple computational tools to examine experimental data for launch events.
- Students can compare predicted vs. actual data from their launches.

After this unit, you're ready to:

- Start planning how to implement this course into your curriculum!

NGSS STANDARDS ALIGNMENT*

HS-PS2: Motion and Stability: Forces and Interactions

- ***HS-PS2-1:*** *Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.*

HS-PS3: Energy

- ***HS-PS3-1****: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.*

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HS-PS3: Energy

HS-PS3-2:

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).

HS-ETS1: Engineering Design

- ***HS-ETS1-4****: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.*

VIDEOS (63 min total)

6.1 Post Processing Flight Data (3:20)

This video demonstrates how to download and convert the .bin flight log from the Navio2 and its conversion to a .log file in preparation for further data processing.

Key concepts:
downloading flight bin files, conversion to log files

Link:
https://siue.yuja.com/V/Video?v=5816125&node=25923021&a=38437273&autoplay=1

6.2 Analysis of Flight Data (7:36)

This video shows how to use Mission Planner to view plots for acceleration, altitude, and velocity data from the launch. It also shows how to understand the graphs in relation to launch events.

Key concepts:
launch data graphing, launch events, mission planner

Link:
https://siue.yuja.com/V/Video?v=5816122&node=25922990&a=19692159&autoplay=1

6.3 Install Spyder on Mac (2:33)

This video walks through how to install the Spyder integrated development environment (IDE) in a Mac OS if you wish to use Python to graph data.

Key concepts:
Spyder IDE installation on Mac, Python

Link:
https://siue.yuja.com/V/Video?v=5816121&node=25922974&a=155331161&autoplay=1

6.4 Install Spyder on Windows (2:04)

In order to use Python to graph data, this video walks through how to install the Spyder integrated development environment (IDE) in Windows OS.

Key concepts:
Spyder IDE installation on Windows, Python

Link:
https://siue.yuja.com/V/Video?v=5816120&node=25922970&a=205694528&autoplay=1

6.5 Export OpenRocket Simulation File (1:48)

This video is a recap of how to export OpenRocket simulations in order to compare predicted data (OpenRocket) to the experimental data of launch.

Key concepts:
export OpenRocket flight simulation data

Link:
https://siue.yuja.com/V/Video?v=5816118&node=25922953&a=144432276&autoplay=1

6.6 Comparison of Predicted vs. Actual Performance (9:27)

This video explains how to use Python to parse and plot the predicted data from OpenRocket with experimental data from the actual rocket launch.

Key concepts:
Python, CSV and .log files, graphing data, launch events

Link:
https://siue.yuja.com/V/Video?v=5816116&node=25922944&a=91933150&autoplay=1

6.7 Kalman Filter

This video discusses the Kalman filter, a crucial component in data handling for many real-life aerospace systems that rely on the optimal balance of sensors and model predictions.

Key concepts:
state estimation algorithm, model behavior vs. sensor measurements, disturbances to the model

Link:
https://siue.yuja.com/V/Video?v=5816115&node=25922932&a=156254766&autoplay=1

6.8 Pulling Data off the Raspberry Pi (6:33)

This video guides users on how to access the flight data from the Navio2/Raspberry Pi using a USB drive.

Key concepts:
Raspberry Pi, mounting a USB flash drive in Raspberry Pi,

Link:
https://siue.yuja.com/V/Video?v=5816182&node=25923398&a=136590664&autoplay=1

6.9 Analyzing Flight Data Using UAV Log Viewer (5:36)

This video shows how users can use UAV Log Viewer to view the rocket trajectory and get a preliminary look at the altitude, velocity, and acceleration.

Key concepts:
Ardupilot UAV log viewer, graphing data, launch events, understanding graphed data

Link:
https://siue.yuja.com/V/Video?v=5816178&node=25923372&a=107027858&autoplay=1

6.10 Parsing Data (6:32)

Provides step-by-step directions on how to convert a BIN file to a LOG file and then from a LOG file to a CSV file using Mission Planner on a Chromebook.

Key concepts:
downloading flight bin files, conversion to log files

Links:
https://siue.yuja.com/V/Video?v=5816177&node=25923370&a=3422592&autoplay=1

LOG parser:
http://spacelab.web.illinois.edu/python-testing/upload-file

6.11 Analyzing Flight Data in Google Sheets (6:36)

This video walks users through importing CSV files into Google Sheets and demonstrates how to plot altitude for predicted vs experimental.

Key concepts:
Google sheets, graphing launch data, comparing theoretical/experimental results, launch events

Link:
https://siue.yuja.com/V/Video?v=5816172&node=25923345&a=122675781&autoplay=1

6.12 Analyzing Experimental Data in Python (3:25)

This video guides user through importing CSV files into Python and shows how to do an initial plot of altitude for the predicted vs experimental.

Key concepts:
Python, graphing launch data, comparing theoretical/experimental results, launch events

Link:
https://siue.yuja.com/V/Video?v=5816167&node=25923302&a=140306476&autoplay=1

APPENDIX A

SINGLE STAGE ROCKET BUILD INSTRUCTIONS

The following instructions have been developed to guide you step-by-step through the rocket building process. In places where the written instructions may diverge from the video walkthrough, we encourage you to ***follow the written instructions***, as they have continued to be updated according to testing and experience. You will also find tips not presented in the videos.

Single-Stage Rocket (SSR)

Build Instructions

Hardware Parts needed

(1) Estes Super Big Bertha Rocket Kit

A. Motor mount tube
B. (2) Centering rings
C. (1) Notched centering ring
D. (2) Body tubes
E/F. (8) Laser-cut wood sheets
G. (4) Laser-cut wood sheet
H. (2) Launch lugs
I. Tube coupler
J. Nose Cone
K/L. Engine retainer set
M. Shock cord
N. Parachute
O. Shock cord mount

2

Hardware Additional parts needed

P. (1) Wooden centering ring, (Apogee, #13416)

Q. (1) #8-32 x 1-58" Eyebolts

R. (1) #8-32 Stainless steel nylon lock nuts

S. (2) #8 Zinc flat washers

T. 300-lb. Kevlar shock cord, length = 3 times the length of the rocket body + 6", (Apogee, #30326)

U. (1) 1/8" quick link

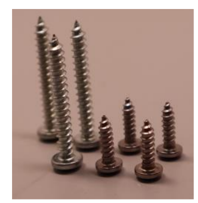
V. (1) 275-lb. ball bearing swivel

W. (3) 2.561 outer-diameter wooden bulkhead disks, (1) of the included eyebolts will be used

X. Avionics/electronics bay (3-D print files provided in Microcontroller Electronics kit.)

Y. (4) #8 Screws, shorter (½" long)

Z. (3) #8 Screws, longer (3/4" to 1" long)



AA. (1) Ripstop nylon parachute. Any chute between 30" and 48" is acceptable.

BB. Rail buttons

3

Hardware Additional materials needed

Consumables

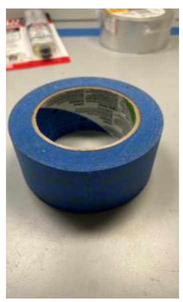
Wood glue

2-part epoxy

Sandpaper

Super glue

Painter's tape



Recovery wadding

Tools needed

- Drill with 1/8" and 1/2" bits
- Screwdriver
- X-acto or other craft knife
- Scissors
- Clamps
- Ruler
- Pencil
- Long needle-nose pliers
- Adjustable wrench
- Socket wrench with socket that fits the lock nuts (***R***)

Optional:

- Hacksaw
- Mitre box

4

Step 1: Prepare rocket fins

Materials needed:

- Estes Super Big Bertha Kit parts E, F, G
- Craft or X-acto knife
- Sandpaper
- Wood glue
- Super glue
- *Clamps

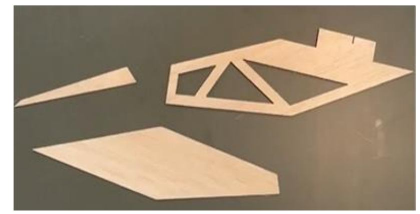
*Optional

6

Step 1: Prepare rocket fins (cont'd)

1.1 Break all components (parts ***E, F, G***) out of the balsa wood sheets, using a craft knife if necessary. Lightly sand both sides of all components.

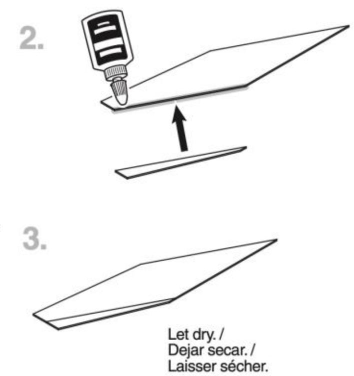
Save the waste balsa as you may wish to use it as a tool in later steps (such as using it to apply/scrape off glue).



1.2 Step 1 goes fastest if you treat it like an assembly line, completing each sub-step for all fins at one time.

Glue together parts E and F so that your outer fin looks like the one in picture 3. Repeat until you have 8 total fin covers. You may find clamps useful to position the fins as they dry.

Allow about 5 minutes for the glue to begin drying on a fin before you manipulate it for the next step.



Estes Super Big Bertha Model Rocket Instructions, Estes Industries, LLC, Penrose, CO, 2019, p. 3

7

Step 1: Prepare rocket fins (cont'd)

CAUTION

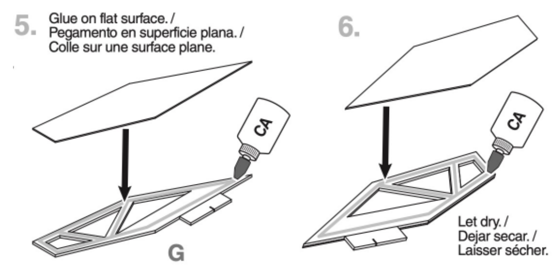
*Super glue sets and dries in seconds. Make sure to apply the glue and position the fins quickly. Once the fins are in place, you will **not** be able to move/slide them, so be sure to prepare and position your pieces before you start gluing.*

1.3 Dry fit the inner fin ribbing (***G***) with a fin cover assembly from step 1.2. Place them next to each other in exactly the orientation they will have once glued.

Apply a bead of super glue (also known as CA) across the surface of the inner fin ribbing. Quickly place the outer fin cover on the inner fin ribbing.

Turn the assembly upside down and repeat for the other side of the fin.

At the end of this process you will have four fins.



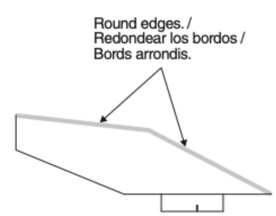
Estes Super Big Bertha Model Rocket Instructions, Estes Industries, LLC, Penrose, CO, 2019, p. 3

Step 1: Prepare rocket fins (cont'd)

1.4 Once the fins are dry, use sandpaper to round the fins along the what will be the leading edges when the rocket is launched.

The profile should be semicircular.

7.



9

Step 2: Assemble motor mount

Materials needed:

- Motor mount tube (***A***)
- Cardboard centering ring (***B***)
- Notched cardboard centering ring (***C***)
- Wooden centering ring (***P***)
- Eyebolt (***Q***)
- Locknut (***R***)
- Washers (***S***)

- Pencil
- Ruler
- Drill with 1/8” bit
- Pliers
- Wood glue
- Super glue (CA)
- *Socket wrench (11/32)

*Optional

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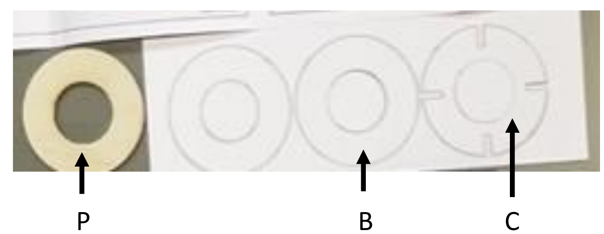
Step 2: Assemble motor mount (cont'd)

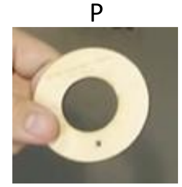
2.1 Make a mark 1" from the end of the motor mount tube (**A**) and cut off the end. The resulting tube should be 7" long. (The 1" piece may be discarded.)

2.2 Using a pencil, mark the motor mount tube (***A***) at ½", 3", and 6 ½".

2.3 Remove the notched centering ring (***C)*** and one of the plain centering rings (***B***) from the cardboard sheet in the rocket kit. For stress purposes, we will use a wooden component (***P***) as our third centering ring.



Choose a location in the middle of the wooden ring width (P.) Drill a 1/8" hole through the ring.



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Step 2: Assemble motor mount (cont'd)

2.4 Fit the wooden ring (***P***) on the 6 ½" mark of the motor mount tube (***A***) and fit the notched centering ring (**C**) at the 3" mark, and the plain cardboard centering ring (**B**) at the ½" mark.

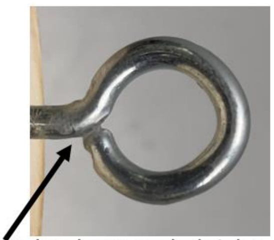
If the wooden centering ring seems too small, you may need to sand the inner circumference until it fits the motor mount tube.

2.5 Once all centering rings are in their respective positions, place a bead of wood glue on the top of each circle where it meets the motor mount tube. Wait 15 to 30 minutes, flip the tube, and glue the bottom of each centering ring in same fashion. Allow the glue to dry another 15 to 30 minutes.

Step 2: Assemble motor mount (cont'd)

2.6 Look closely at your eyebolt (***Q***). Use pliers to close any gap as much as possible and follow up with one or two drops of super glue to seal the connection. Before permanently installing the hardware, ensure that any gap in the eyebolt is closed.

Massive gap ***must*** be closed.



Closed gap has been sealed tight with superglue.

WARNING

Failure to close this gap may cause the rocket's recovery system to fail.

2.7 Place one washer (***R***) on the top and one on the bottom of the 1/8" hole in the wooden ring and thread the eyebolt (***Q***) through the top, as shown.

Attach the locknut (***S***) from the bottom of the ring; you may need to use a deep socket to ensure the nut is fully tight to the ring.

When you are finished, the opening in the eyebolt should be perpendicular to the ring of the motor mount tube.

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Step 3: Prepare fin slots and install first rail button

Materials needed:

- Fin slot guide from Super Big Bertha instruction manual, p. 2
- Body tube (***D***)
- Ruler
- Pencil
- Painter’s or masking tape
- Scissors
- Craft or X-acto knife

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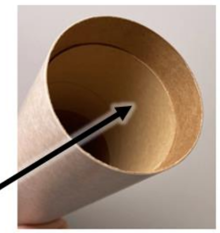
Step 3: Prepare fin slots and install first rail button (cont'd)

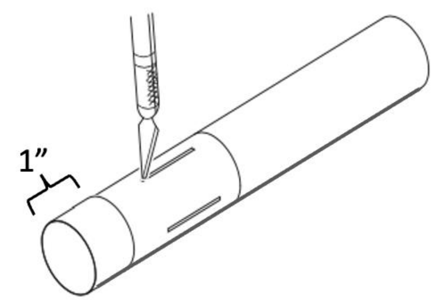
3.1 Check the body tube (***D***). If the coupler (***J***) was stored inside the body tube for shipping, remove it now and set aside for Step 7.



This coupler must be removed before cutting the body tube.

3.2 Cut out the fin-slot guide sheet inside the instruction manual. Using masking or painter's tape, Secure the bottom of the paper guide (marked "bottom") 1" from the bottom of the second stage body tube (***D***) using masking or painter's tape. There should be a 1" gap between the edge of the body tube and start of the paper.

Carefully cut the fin slots.



Adapted from Estes Super Big Bertha Model Rocket Instructions, Estes Industries, LLC, Penrose, CO, 2019, p. 2.

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Step 3: Prepare fin slots and install first rail button (cont'd)

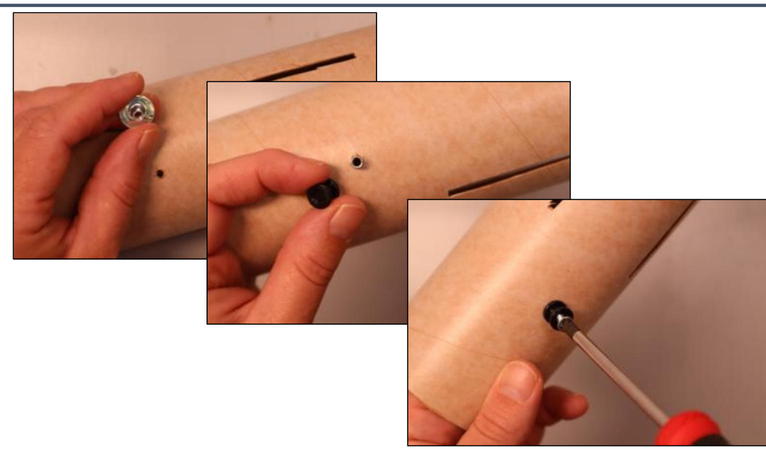
3.3 Mid-way between two fin slots, measure 2 ¼" up from the bottom of the lower body tube and mark the location with pencil.

Drill a 5/32" hole at this location.

3.4 Separate the pieces of the rail button (***BB***). Insert the flanged weld-nut backing into the hole from the inside of the rocket body tube.

Place the nylon spacer around the weld nut on the outside, with the routed side facing outward.

Insert the screw and tighten.



Step 4: Install motor mount

Materials needed:

- Motor mount tube from step 2
- Lower body tube from step 3
- Fins from step 1
- Pencil
- Wood glue
- Dowel rod (or waste balsa strip left over from step 1)

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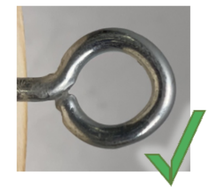
Step 4: Install motor mount (cont'd)

4.1 Before installation, double check that the eyebolt gap has been closed and has been sealed tight with superglue.



CAUTION

If at this point you choose to attach the Kevlar shock cord to the eyebolt, you must ensure that:

1) The shock cord is sufficiently long. If it is too short, you will need to remove it and install a longer cord.

2) The shock cord is kept knot-free and protected from the glue used in the remainder of the build.

3) The knot used to secure the cord to the eyebolt is made far enough away from the eyebolt that it will be accessible outside the body tube once the motor mount is installed

Regardless of whether you install the shock cord now or after motor mount installation, you will need a system post-build to access the bolt for service.

Otherwise, shock cord installation is addressed in steps 12 and 13.

Step 4: Install motor mount (cont’d)

4.2

First dry mount the motor mount. Insert the motor mount, wooden circle first, into the fin-slot end of the body tube from step 3, as shown in the image.

Double-check that the the eyebolt is visible from the top of the lower body tube.

Rotate the motor mount as needed to ensure that the slots in the middle cardboard centering ring are aligned with the fin slots in the body tube.

Rotate motor mount until notches in center ring align with fin notches in body tube.

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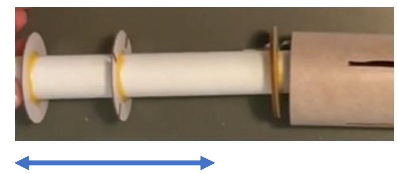
Step 4: Install motor mount (cont'd)

4.3 Dry mount the fins in the fin slots to ensure proper alignment of the motor mount. If the fins do not insert fully/snugly, **adjust** the motor mount depth in the body tube until they do.

Carefully remove the fins only.

Using a pencil, mark the position on the body tube where the interior slotted cardboard centering ring crosses the fin slot. Make a mark where both the top and bottom of the cardboard centering ring cross the opening.



Adjust motor mount depth until fins fit snugly into the notches in the middle centering ring.

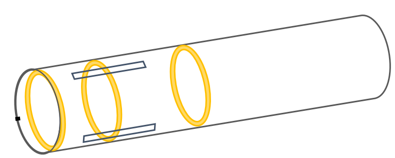
Mark on the body tube next to each fin slot where the center ring intersects with the fins.

Step 4: Install motor mount (cont’d)

4.4 Remove the motor mount and place next to the lower body tube at the depth you will eventually install it, using the marks you made as a guide. Use the dowel to measure the distance of the rings from the bottom of the lower body tube. Mark the distance of each ring on the dowel.

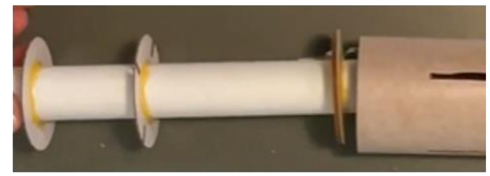
4.5 Apply wood glue to the end of the balsa stick and insert it up to the deepest guide mark from step 4.4. At this depth apply a ring of wood glue inside the lower body tube.

Repeat the process of applying the glue ring with the next deepest mark on the guide stick until you have completed 3 glue rings inside the body tube.



Step 4: Install motor mount (cont'd)

4.6 Insert the motor mount into the lower body tube, ensuring that the the eyebolt gap has been closed, the wooden ring goes in first, and that the eyebolt is facing the open upper end of the body tube.



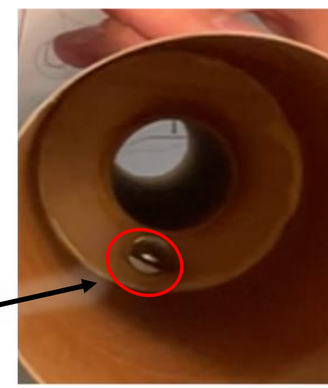
Use the marks in made in step 4.3 as a guide for the necessary depth and ensure that the center ring's notches align well with the fin slots in the body tube.

22

Step 4: Install motor mount (cont’d)

4.7 Turn the body tube upside down and run another bead of wood glue around the outside circumference of the visible motor mount cardboard centering ring, filling any gaps between the centering ring and body tube. Allow a dry time of 15 to 30 minutes.

4.8 Set the body tube upright. Apply a dab of wood glue to one end of a dowel or long thin piece of waste balsa from step 1. Use this “glue stick” to reapply glue to the outside edge of the wooden centering ring, along the corner where it meets the outer cardboard tube. Make sure to fill in all gaps. Allow a dry time of 15 to 30 minutes.



Note: Avoid getting glue on eyebolt as it is very difficult to clean glue off this piece.

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Step 5: Attach fins

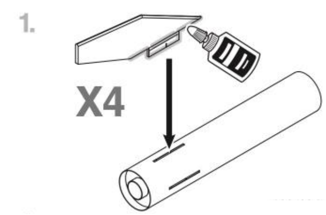
Materials needed:

- Lower body tube from step 4
- Fins from step 1
- Ruler
- Pencil
- Wood glue

Step 5: Attach fins

5.1 Attach fins and launch lugs as directed in the Estes kit instructions below.

Apply wood glue along the fin tab and the side edge where it will touch the body tube.

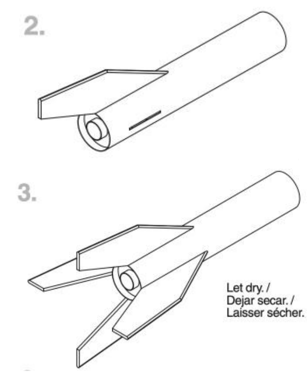


5.2 Laying the rocket body horizontal, place a fin into a fin slot, being careful to insert the fin tab into the slotted centering ring inside the rocket body.

Apply glue to any gap between the fin and the body, but ensure that excess glue does not drip down the rocket body.

Keeping the body tube horizontal, allow the glue to dry 10-15 min before rotating the tube and inserting the next fin.

Repeal for all fins and keep the body tube horizontal until the glue has dried.



Estes Super Big Bertha Model Rocket Instructions, Estes Industries, LLC, Penrose, CO, 2019, p. 4.

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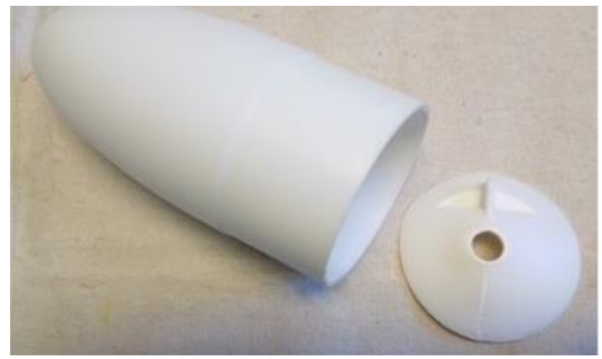
Step 6: Cut the nose cone

Materials needed:

- Nosecone (***J***)
- Craft or X-acto knife

  -or-

- Sandpaper
- *Hacksaw and mitre box
- *Clamps



*Optional

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Step 6: Cut the nose cone (cont'd)

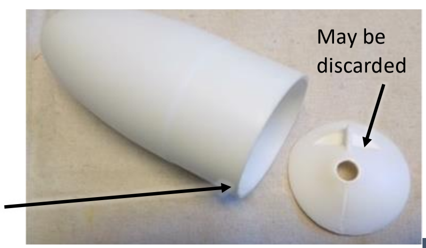
6.1 The inside of the nose cone (***J***) is used to store our GPS antenna and, if desired, a mass-holder. The nose cone comes with a hard covering at the bottom which needs to be removed for this rocket build.

Using a craft knife, (or placing the nosecone in a mitre box secured with clamps using a hacksaw,) cut at the shoulder of the cylindrical section of the tube as shown. Be careful using sharp instruments on the unsteady nose cone. Discard the separated disk.

Cut across the tube at this shoulder.

6.2 Sand the trimmed edge of the nosecone so that the cut surface is flat.

Sand this edge down after cutting.



28

Step 7: Assemble body tubes

Materials needed:

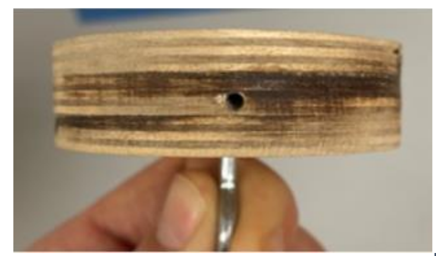
- 3 wooden bulkhead disks (with the eyebolt from one of the packages) (***W***)
- Avionics bay (***X***)
- Upper body tube (***D***)
- Coupler (***J***)
- Rail button (***BB***)
- Sandpaper
- Drill with 1/8” bit
- Pliers
- Pencil
- Wood glue

Step 7: Assemble body tubes (cont'd)

7.1 To secure the two body tubes to one another, we need to add the coupler inside. However, we are NOT securing the coupler per kit instructions, instead positioning our payload in the upper body so that it will have very little freedom to move around during flight.

To begin we need to create a wooden bulkhead. Take three of the "Tube Bulkhead Disks" (***W***) shown to the right. Place the three plates together and glue them, taking care to ensure that they are perfectly aligned.

Put the body tube around the disks while they dry with a weight, such as your bottle of wood glue, on top of them to ensure the disks dry aligned correctly. Allow 15 to 30 minutes to dry.



If the bulkhead disks are not aligned correctly now, it is very tedious to sand them down to fit inside of the body tube later.

30

Step 7: Assemble body tubes (cont'd)

7.1 To secure the two body tubes to one another, we need to add the coupler inside. However, we are NOT securing the coupler per kit instructions, instead positioning our payload in the upper body so that it will have very little freedom to move around during flight.

To begin we need to create a wooden bulkhead. Take three of the "Tube Bulkhead Disks" (***W***) shown to the right. Place the three plates together and glue them, taking care to ensure that they are perfectly aligned.

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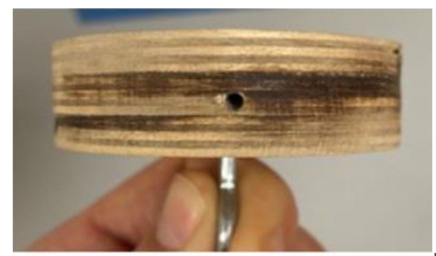
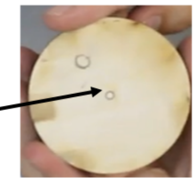


If the bulkhead disks are not aligned correctly now, it is very tedious to sand them down to fit inside of the body tube later.

Step 7: Assemble body tubes (cont'd)

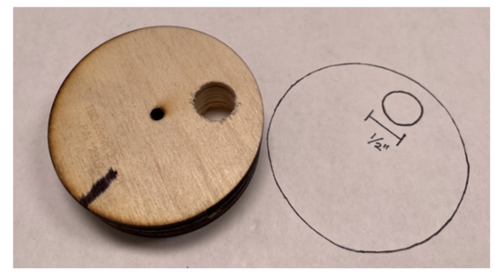
7.2 Once the bulkhead is glued and dried, drill a 1/8" hole through the center of the disks using a 1/8" drill bit; this will accommodate the top eye bolt.

Use a 1/8" drill bit to drill the eye bolt hole here.



7.3 Use the bulkhead template provided at the end of these instructions to mark on the bulkhead where to make the GPS antenna hole.

With the hole marked, use a ½" drill bit to drill a hole all the way through the bulkhead.



7.4 Take one eyebolt from one of the bulkhead packages (***W***). Use pliers to close any gap in the eyebolt as much as possible and follow up with one or two drops of super glue to seal the connection. Before permanently installing the hardware, ensure that any gap in the eyebolt is closed.

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Step 7: Assemble body tubes (cont'd)

7.5 Install an eyebolt inside of the 1/8" center hole. Use pliers to tighten the eyebolt.

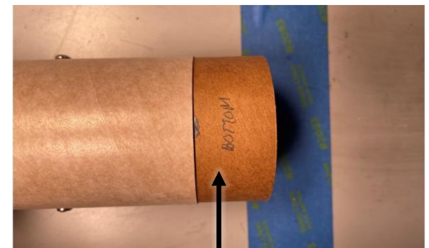
7.6 Gather the following items, which will be placed in this order from left to right:

- Cut Nosecone
- Electronics bay
- Wooden Bulkhead
- Coupler (***I***)

Place the nosecone into the upper body tube first. Next, insert the electronics bay. Finally, insert the wooden bulkhead with the eyebolt facing AWAY from the nosecone.

Step 7: Assemble body tubes (cont'd)

7.7 Ensuring everything is fully seated towards the nosecone, place the coupler inside the upper body tube. Take a pencil and trace the edge of the coupler where it meets the bottom of the tube. Mark the exposed end of the coupler "bottom."



Mark this edge

7.8 Remove the coupler. Apply wood glue to the coupler around the side marked "bottom."

Insert the glued coupler into the *lower* body tube, as deep as the pencil mark you made on the coupler. Allow 15 to 30 minutes to dry.

Note: the coupler is not glued to the top body tube.

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Step 7: Assemble the body tubes (cont'd)

7.9 Insert the flanged weld-nut backing into the hole from the inside of the rocket body tube.

Place the button around the weld nut on the outside, with the routed side facing outward.

Apply a dab of epoxy inside the weld nut threads, then insert the screw and tighten.

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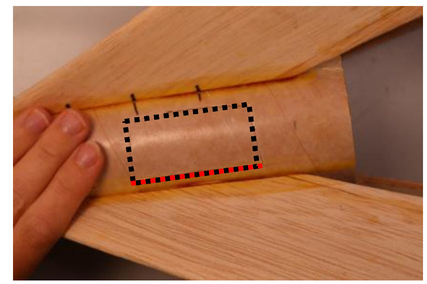
Step 7: Assemble body tubes (cont'd)

7.10 Between two of the fins, measure 4" up from the bottom edge of the tube and make a mark. Measure 2 ¼" up from the bottom edge of the tube and make a mark.

Using these marks as the bounds, draw a 1" high rectangle between the fins.



To be cut through
To be scored only

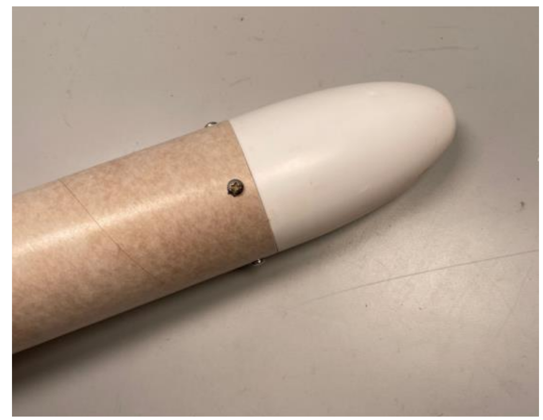
7.11 Use a craft knife to carefully cut through the body tube on three sides of this rectangle. Carefully score (but don't cut through) the fourth side. This is the hatch through which you can add or adjust any masses for testing. The hatch can be closed for flight with painter's tape.

Make a second hatch between the bays on the opposite side of the rocket (180° from this one).

Step 8: Secure the nosecone

Materials needed:

- Nosecone from step 6
- Upper body tube from step 7
- Drill with 1/8” bit
- Ruler
- Pencil/Marker
- (4) small screws (**Y**)
- screwdriver

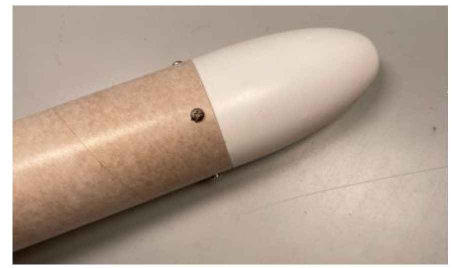


36

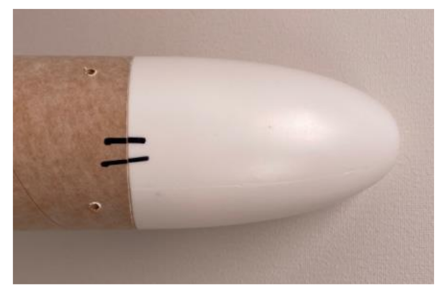
Step 8: Secure the nosecone (cont'd)

8.1 Ensure the nose cone is fully seated in the upper body tube. While the nose cone is still seated, mark the tube ¾" back from where it meets the nose cone. Use a 1/8" drill bit to drill a hole through the tube and nose cone. Insert small screw (***Y***) to secure.

Repeat this process three more times at 90° intervals around the tube.



8.2 Make a mark on both the nosecone and upper body tube to show you how to realign the screw holes when the nosecone is removed to insert the avionics bay.



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Step 9: Secure wooden bulkhead to the upper body tube

Materials needed:

- Nose cone from step 8
- Avionics bay (***X***)
- Wooden bulkhead from step 7
- 3 long screws (***Z***)
- Ruler
- Pencil
- Screwdriver

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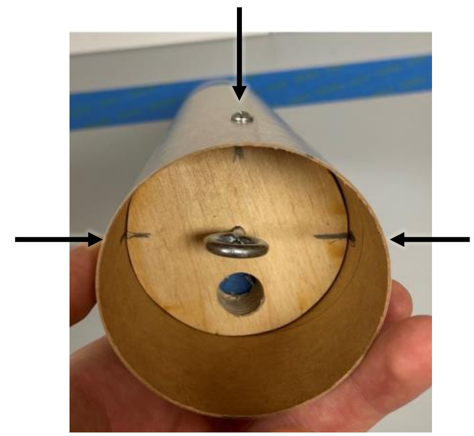
Step 9: Secure wooden bulkhead to the upper body tube (cont'd)

9.1 Ensure all components in the upper body tube are still fully seated towards the nosecone. Measure the distance of the bulkhead to the end of the tube and add half the width of the bulkhead. Use this distance to mark the depth on the outside of the upper body tube.

Starting at the location immediately adjacent to the antenna hole in the bulkhead, mark an "X" on the depth line. *Do not drill at this location!*

From the "X" mark three additional places around the circumference of the tube, approximately 90° apart. Using a 1/8" drill bit, drill a hole about ¼" shorter than the length of your long screws (**Z**), through the body tube and into the side of the bulkhead. Insert long screws (***Z***) to secure.



Drill holes where the arrows indicate.

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Step 10: Install the motor retainer

Materials needed:

- Motor retainer set (***K, L***)
- Avionics bay (***X***)
- Sandpaper
- Two-part epoxy
- Lower body tube from step 7

Step 10: Install the motor retainer (cont'd)

10.1 To install the motor retainer, use sandpaper to abrade the inside of the inner motor retainer ring.

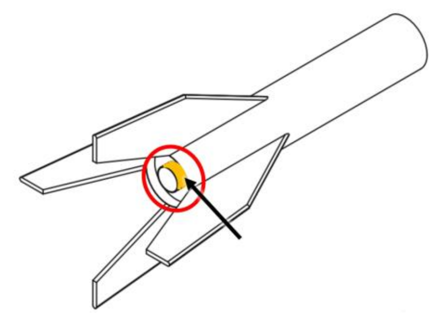
Estes Super Big Bertha Model Rocket Instructions, Estes Industries, LLC, Penrose, CO, 2019, p. 4.

CAUTION

Two-part epoxy sets and dries very quickly, but the fumes are strong and should not be inhaled. Make sure to apply the epoxy and position the inner motor retainer ring quickly. Place the lower rocket body in a warm, well-ventilated location to cure.

10.2 Every epoxy brand will have its own directions and procedures. Working in a well-ventilated area, closely follow the directions for mixing your specific brand of epoxy.

Once the epoxy is ready to use, apply to the outside of the exposed end of the motor mount tube. Quickly place the inner motor retainer ring on the epoxied surface and allow to cure.



41

Step 11: Rocket finishing

Materials needed:

- Spray paint
- Masking or painter’s tape
- Stencils
- Stickers

*Optional

42

Step 11: Rocket finishing (cont'd)

11.1 Have fun with designs on the rocket body! Use tape and stencils when spray painting to make your rocket colorful or even to add your school's logo. SIUE sure looks nice on there, doesn't it. ☺

Make sure to tape off all interfaces (like the coupler and bottom of the nosecone (if exposed when painting).

Note: When using spray paint, work in a well-ventilated space. Be sure to put down protective covers on the surfaces where you are painting and be careful to avoid getting paint on yourself.

11.2 If you paint over the nosecone and body, make sure to re-mark the alignment of the nosecone as in step 8.2

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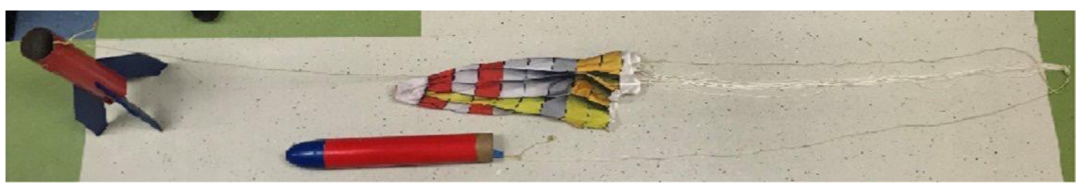
Step 12: Prepare flight system

Materials needed:

- Rocket body from step 10
- Parachute (***AA***)
- Shock cord (***T***)
- Quick link (***U***)
- Quick link (***V***)
- Scissors



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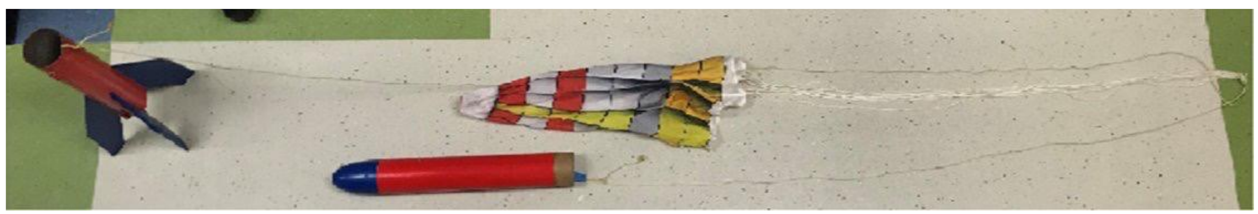
Step 12: Prepare flight system (cont'd)

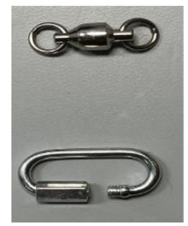
12.1 The length of the shock cord should be 3 times the length of the rocket body plus 6" to accommodate attaching the cord to the engine mount in the lower body. (The picture below shows the relative lengths needed.)

Cut the shock cord to the appropriate length.



Step 12: Prepare flight system (cont'd)

12.2 Interlock the swivel and quick link as shown.



12.3 Attach the swivel to the shock cord approximately 1/3 of the way down one side of the shock cord.

Start by pulling one loop through the swivel ring.

Step 12: Prepare flight system (cont'd)

12.4 Loop the back of the cord around the swivel head and pull the cord taut.

12.5 Pull the cord tight down around the ring.

Step 12: Prepare flight system (cont'd)

12.6 Gather the shroud lines of the parachute. Most parachutes have 4 or more lines so be sure to include all of them. Extend the lines away from the parachute and tie a knotted loop in the bundle of lines, approximately 3" from the end of the cords.

12.7 Place the loop of parachute lines into the open quick link. Close the quick link and ensure it is tight.

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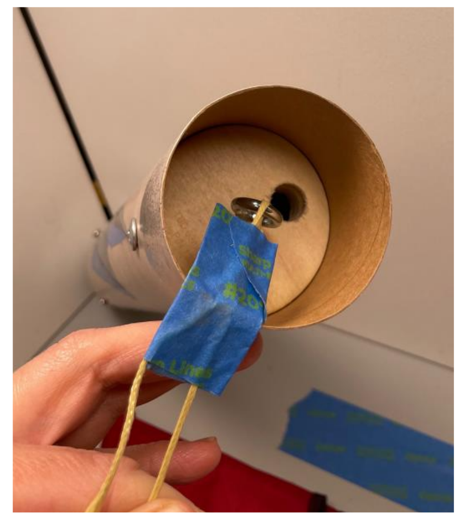
Step 13: Attach shock cord

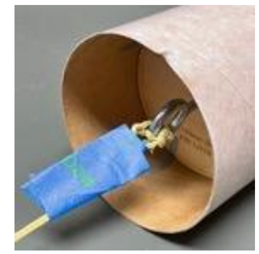
Materials needed:

- Shock cord from step 12
- Upper rocket body from step 9
- Lower rocket body from step 10
- Painter's tape



Step 13: Attach shock cord (cont'd)

13.1 Find the end of the Kevlar shock cord closer to the quick link. Attach this end of the cord to the eye bolt on the wooden bulkhead inside the upper body tube. Make a secure knot (we use square knots but any non-slip knot is fine), then cover the knot and the section of cord that comes into contact with the body tube with masking or painter's tape.



13.2 Attach the other end of the shock cord to the eye bolt on the top of the motor mount. Working deep in the lower body tube can be tricky; long needle nose pliers can help you guide the cord and thread it through the eye bolt.

Once the cord is securely through the bolt, you can make the knot outside the body tube. Make a secure knot (a square knot or any other non-slip knot) and cover the knot and the section of cord that comes into contact with the body tube with masking or painter's tape.

Step 14: Prepare flight recovery

Materials needed:

- Parachute, swivel, and quick link assembly from step 12.
- Recovery wadding

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Step 14: Prepare flight recovery (cont’d)

14.1 Take three sheets of recovery wadding to prepare the rocket for launch.

14.2 Place the first two pieces of recovery wadding inside the lower body tube up against the motor mount. Pull the Kevlar cord to the opposite side of the tube and place the last piece of recovery wadding inside the tube.

Be sure to space the sheets out well, leaving no gaps inside of the tube. Ensure that you cannot see the motor mount tube to protect your parachute from taking damage during flight.

14.3 Neatly coil (but do not tie) the lower 2/3 of the Kevlar shock cord on top of the recovery wading as shown.

Do not make the coil too tight or it will not properly deploy.

Step 14: Prepare flight recovery

14.4 Detach the parachute from the shock cord using the quick link.

Lay the parachute on a flat surface and gather it such that the shroud lines are all lined up at the bottom of the parachute and can be bundled together neatly.

14.5 Make a ‘U’ shape with the shroud lines as shown, ensuring that the quick link stays at the edge of the parachute.

14.6 Fold the bottom edge of the parachute 2/3 of the way up towards the top edge (Picture A). Fold the top edge of the parachute down to meet with the bottom folded edge. (Picture B) Ensure that the quick link is still accessible from the end of the parachute.

A

B

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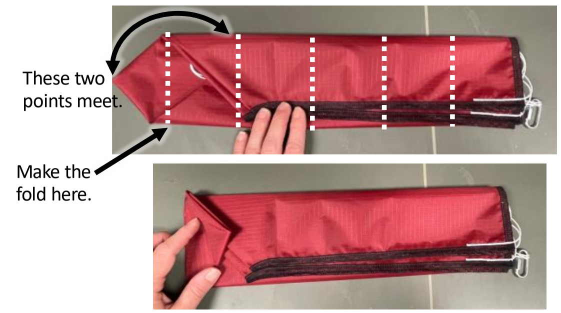
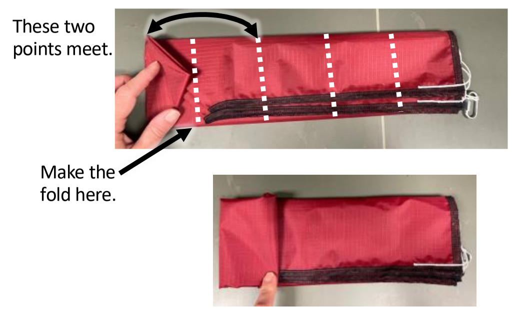
Step 14: Prepare flight recovery (cont'd)

14.7 From the left (closed) end of the parachute, make a fold to the right at about 1/6 of the length of the parachute.



14.8 From the left side again, make another fold to the right at about 1/5 of the remaining length of the parachute.



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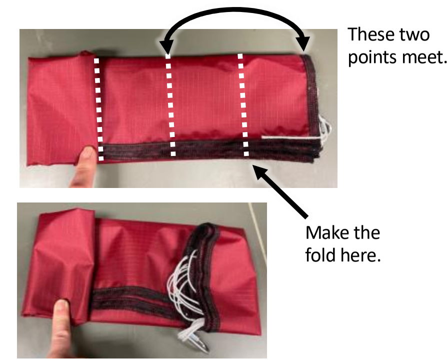
Step 14: Prepare flight recovery (cont'd)

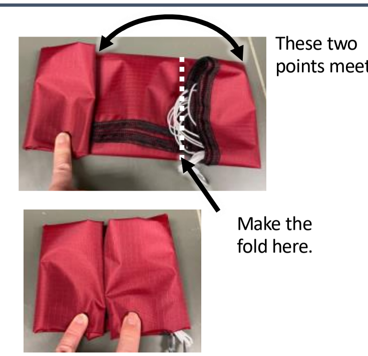
14.9 From the right side, make a fold towards the left at about 1/4 the length the parachute.

Be sure that the quick link remains accessible outside the folded parachute.



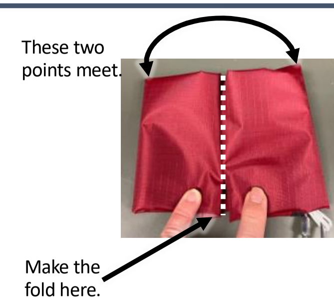
14.10 From the right side, make a fold underneath the open edge of the fold from step 14.6.

The folded sides should now be touching.



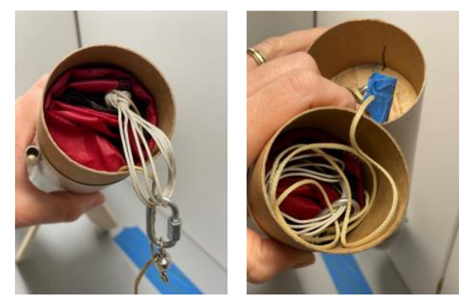
Step 14: Prepare flight recovery (cont'd)

14.11 Fold in half one final time, ensuring that the quick link is still accessible from outside the folded parachute.



14.12 Carefully insert the folded parachute into the lower body tube.

Loosely coil the remaining Kevlar cord on top of the parachute.



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Step 14: Prepare flight recovery (cont’d)

14.13 Take the two rocket halves and connect them as shown. The gap between the body tubes should be minimal.

If it is a tight fit, ensure the shock cord is not in the way of the tube. If no cords are in the way and there is still a tight fit, the packed parachute is too long; unravel the parachute and fold it again tighter.

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Step 15: Install motor and prepare for launch (cont'd)

If using an Estes F15-4, proceed with step 15.1

If using an Aerotech F67-4 motor, skip to step 15.5.

CAUTION

If you are using any other previously modeled rocket motor, follow the motor manufacturer's instructions.

WARNING

Steps 15.1 to 15.2 and 15.5 should only be completed once you are out **in the field**, preparing to launch.

Steps 15.3 to 15.4 and 15.6 to 15.8 should only be completed once your rocket is **on the launchstand**, ready to launch.

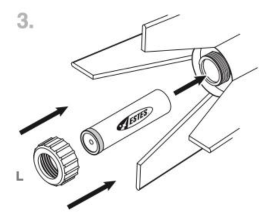
Failure to follow these instructions or insertion of the motor and/or ignitors before indicated may result in serious harm.

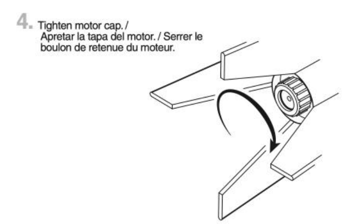
Step 15: Install motor and prepare for launch (cont'd)

15.1 In the field: For the Estes F-15, wrap a 1/4”-3/8” wide strip of masking or duct tape around the nozzle-end of the motor. Wrap around the cardboard 4-6 times until you have created a raised lip.

If there is any excess tape extending beyond the end of the motor, trim it off with a craft or X-acto knife.

15.2 In the field: Insert the motor into the motor mount tube and screw on the outer retainer ring to secure.





Estes Super Big Bertha Model Rocket Instructions, Estes Industries, LLC, Penrose, CO, 2019, p. 5.

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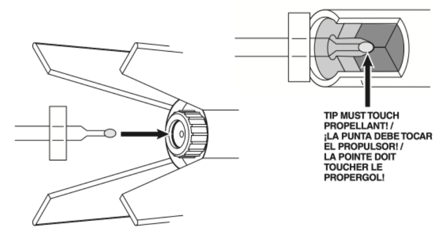
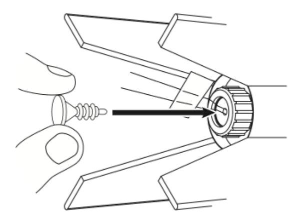
Step 15: Install motor and prepare for launch (cont'd)

15.3 **On the launchstand:** Do not remove the paper from the F15-4 ignitor. Carefully insert the treated end of the ignitor fully into the nozzle of the motor. The tip must be touching the propellant for ignition.



15.4 **On the launchstand:** With the ignitor in place, fully insert a plastic plug into the nozzle. The cap should be flat against the nozzle.



Estes Super Big Bertha Model Rocket Instructions, Estes Industries, LLC, Penrose, CO, 2019, p. 5.

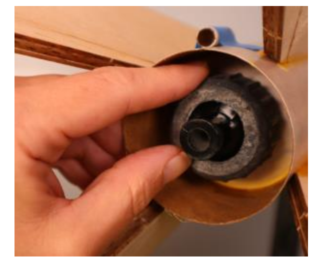
Step 15: Install motor and prepare for launch (cont'd)

15.5 **If using the F67-4:**

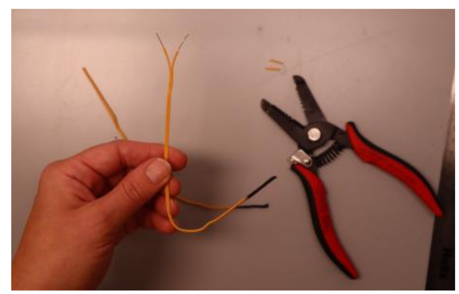
The F67 is fabricated with a built-in thrust ring, so you don't need to make one using tape.

In the field: Carefully insert the motor into the motor mount tube and screw on the outer retainer ring to secure.

This lip serves as a thrust ring.

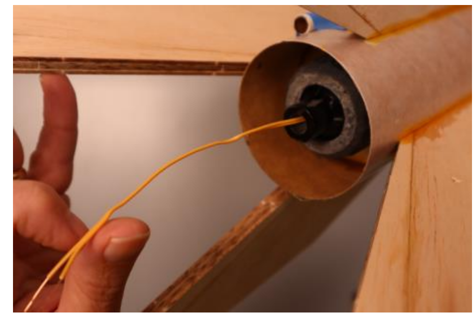


15.6 On the launchstand: If the wires of the ignitor supplied with the motor are not stripped at the ends, strip about ½" length of insulation off the ends of the wires.



Step 15: Install motor and prepare for launch (cont'd)

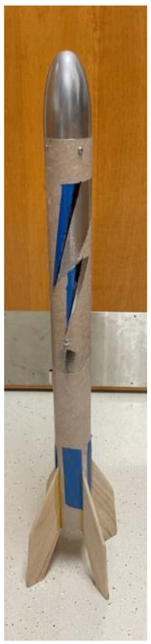
15.7 **On the launchstand:** Insert the chemically treated end of the ignitor into the nozzle, all the way up until it cannot go any further (about 3 ½”). Do not force the wires up further as it could damage the ignitor.



15.8 **On the launchstand:** Fold the wire outside to conform to the shape of the nozzle.

Wrap a ½” strip of masking, painter’s or duct tape over the ignitor and around the outside of the nozzle as shown

Congratulations!



Your rocket build is finished and you are ready for launch!

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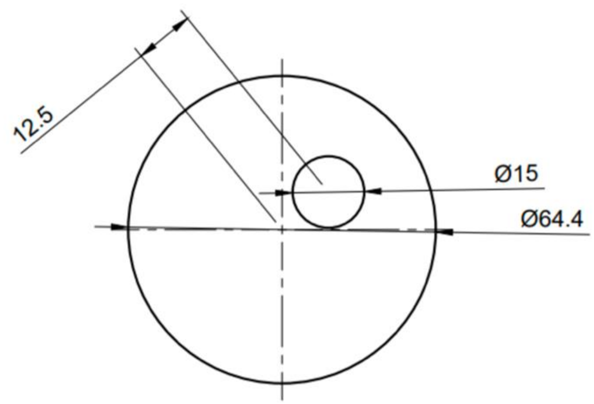


Measurements are in mm

LAUNCH CHECKLISTS, PROCEDURES, AND LOG

Congratulations! You made it to launch day! In this section you will find

- Day Before Launch Checklist
- Launch Procedure
- Post-Launch Checklist
- Launch Log

These procedures have been developed to minimize the risk of accidentally forgetting a critical step (like packing the parachute!) on a busy launch day. Also included is a sample flight log you may wish to use to make field notes about your rocket launch.

You must follow all federal, state, and local guidelines in addition to the launch procedures listed here.

Your local chapter of the National Association of Rocketry is an invaluable resource for assistance with identifying local ordinances, locating an appropriate launch site, and even launch day support. **Please visit https://www.nar.org/safety-information/model-rocket-safety-code/ to view the NAR Model Rocketry Safety Code and https://www.nar.org/contest-flying/u-s-model-rocket-new-sporting-code/introduction/launching-requirements/ for launch site specifications.**

Day Before Launch Checklist

- ☐ Batteries charged/charging
- ☐ Gather equipment
- ☐ Launch location permission received
- ☐ Launch count/line-up settled
- ☐ Verify objective for each launch
- ☐ Identify motors needed
- ☐ Weather check
- ☐ Avionics bay functions check
- ☐ Pack and prepare launch bags holding tools and hardware.

Day of Launch Checklist

- ☐ Motor allocation
- ☐ Charged batteries
- ☐ Transport equipment to launch site
- ☐ Equipment List
    - o Launch system, including launch rod
    - o Rockets
    - o Tool kit (screwdrivers, pliers, craft knife, scissors, etc.)
    - o Hardware Kit (screws, eyebolts, masking and duct tape, super glue, epoxy, etc.)
    - o Motors
    - o Fire Extinguisher
- ☐ Weather check
- ☐ Avionics bay packing

Post Launch Procedure

- ☐ Disconnect battery from launch system
- ☐ Extinguish any fire
- ☐ Recover rocket(s)
- ☐ Complete launch log
- ☐ Disarm electronics
- ☐ Launch site disassembly
- ☐ Store all launch equipment in appropriate area
- ☐ Store un-used motors in fireproof cabinet
- ☐ Ensure all batteries are disconnected
- ☐ Collect all flight data and videos/pictures
- ☐ Dunk used motors in water and dispose
- ☐ Ensure electronics are stored properly
- ☐ Conduct after action report

SINGLE STAGE ROCKET LAUNCH PROCEDURE

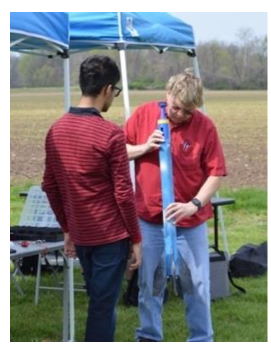
1. Equipment inventory:

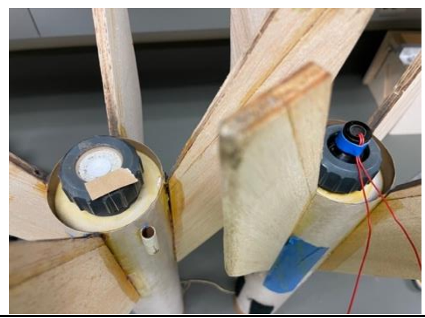
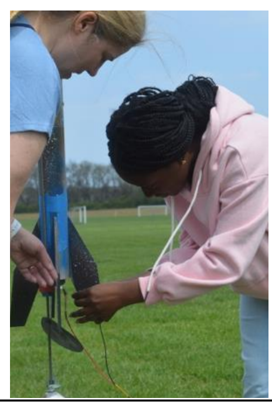
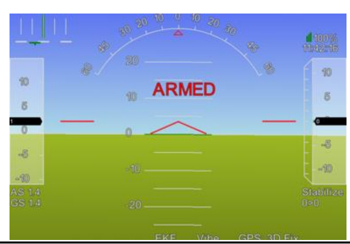
- ☐ Motors:
  - **1..1.** Estes D12-3, E12-4, E16-6 or F15-4 (S2)
  - **1..2.** Aerotech F67-4 (B)
- ☐ Igniters
- ☐ Parachutes
  - **1..1.** Nylon (36,48,58)”
  - **1..2.** 30” Dino Chutes
- ☐ Recovery Wadding
- ☐ Kevlar Shock Chord
- ☐ Tools:
  - **1..1.** Long Needle Nose Pliers
  - **1..2.** Screwdriver
  - **1..3.** Sandpaper
  - **1..4.** Scissors
- ☐ Launch Stand
- ☐ Launch Controller
- ☐ Batteries for launch controller
- ☐ Electronics Bay
- ☐ Dummy Payload (Equivalent Weight of Electronics Bay)
- ☐ Duct Tape
- ☐ Masking Tape

	2. Launch site and weather conditions meet all local and NAR launch safety requirements	**https://www.nar.org/safety-information/model-rocket-safety-code/**
	3. Permission has been obtained to launch at the selected site.	
	4. Wooden bulkhead in Supper body tube is secured with screws.	

	5. Shock cord is tied securely to bulkhead eyebolt and motor mount eyebolt.  
	6. Cord is taped to prevent zippering.  
	7. Both upper and lower eyebolts are closed and sealed with superglue. 
	8. Recovery wadding has been placed in lower body tube. **NOTE:** Be sure to position wadding all around shock cord. 
	9. Parachute swivel is securely attached 1/3 of the way down the shock cord from the upper body tube.  

	10. Lower shock cord is rolled up and placed into lower body tube.	
	11. Parachute is folded, and lower shroud line loops are all captured by the quick link.	
	12. Quick link is attached to the swivel and closed tightly.	
	13. Parachute is packed into lower body tube.	
	14. Upper body tube is placed on lower body tube. The connection moves (does not stick) but is not too loose.	

	15. The motor has a thrust ring. **NOTE:** If using an F15-4 motor, be sure to wrap duct tape around the nozzle end at least 6 times to properly secure motor.  
	16. The motor is installed in the motor mount and the retainer ring is securely closed. 
	17a. If this is an integrity launch (motor Estes F15-4), skip to step 20.
	17b. For launching with Aerotech F67-4, electronics payload is prepared. (See Electronics Payload instructions.) 
	18. Electronics payload or dummy payload is placed securely into rocket. **NOTE:** Be sure antenna goes into hole in bulkhead. 

	19. Nosecone is installed on rocket and secured with screws.	
	20. Rocket is placed on launch stand and lugs slide freely.	
	21. Ignitor is installed and has been secured.	
	22. Motor ignitor leads are separated from each other and launch system ignition leads are safely attached.	
	23. Electronics payload is armed in Mission Planner, and satellites are acquired.	

	24. All personnel are evacuated to a safe distance.	
	25. Count down (loudly enough that everyone can hear.)	**5, 4, 3, …**
	26. Launch Rocket.	

Date: Location: #

Rocket:	
Mass:	

Motor	Ignitors
B:	B:
S2:	S2:
Chute:	
Av. Config/Payload:	

Objective:

Time:	Weather:

Observations:

OR model:

APPENDIX C

HELPFUL RESOURCES RELATING TO THE ANCHORING PHENOMENON

Anchoring Phenomenon—

What does it take to deliver payloads to the International Space Station?

There are three overarching categories/phases of student interactions, each with their own driving questions, that move students towards answering what it takes to deliver payloads to the ISS. The categories are as follows:

Phase 1: Physics in Rocketry

How and why do we launch rockets? What forces and rocketry hardware allow a rocket to take flight? How does math (programmed into electronics) make this happen?

NASA Blog: What does it take to keep the station stocked with supplies?

A brief intro to an article on keeping ISS supplied – showing the need for re-supply missions.
https://blogs.nasa.gov/spacestation/2018/04/30/what-does-it-take-to-keep-the-station-stocked-with-supplies/

NASA Launchpad: Liftoff with Solid Rocket Boosters

This video explains how solid rocket boosters work and how they propel vehicles into space.
https://youtu.be/AhDfo5u1Tys

Rocket Science in 60 Seconds: What are the SLS Avionics

This is a brief introduction to how avionics "steer, fly, track and guide" the SLS rocket on its flight to the moon.
https://youtu.be/hCiSBnbHy0c

Phase 2:
Designing the Ideal Payload for a Rocket

What decisions are made about the types of payloads sent to the ISS? How does the mass of these payloads affect stability and accuracy of rocket flight? How can we manipulate the variable of payload mass to help ensure a successful flight?

Tools of the Astronaut Trade

This short Smithsonian article describes some of the common tools needed in assembling/maintaining the ISS.
https://www.smithsonianmag.com/air-space-magazine/tools-of-the-astronaut-trade-15273242/

Space X Delivers Avocados and Ice Cream to Space Station

One page article detailing a recent Space-X flight to the ISS, listing the variety of items represented in the payload.
https://in.mashable.com/science/24404/elon-musks-spacex-supplies-nasa-space-station-with-ice-cream-ants-robotic-arm-avocados

Minimizing Mass

In this video from the New Zealand Science and Learning Hub, Peter Beck from Rocket Lab discusses the importance of minimizing payload mass to escape the increasing-mass "spiral of doom."
https://www.sciencelearn.org.nz/resources/391-rockets-and-mass

Space Force: $10,000 orange

Two-minute clip from the fictional series Space Force in which the value of sending fresh fruit to astronauts to explained.
https://www.youtube.com/watch?v=CcHUBrR7hOg

Living and Working in Space: Advanced Food Tech

Food in space needs to be shelf-stable for up to five years. This video explores the means by which technology makes this happen.
https://youtu.be/zQEPKKmQGG0

Phase 3:
Evaluating Rocket Designs

How do we determine a successful/the most successful rocket design to send to the ISS? Each of the attached videos contains post-launch footage in which telemetry readings begin and there are views of the astronauts within…NOT "doing anything" as the rocket navigates itself. What data is being sent via telemetry? Why does this data matter? How could you use it to determine if the flight path is successful?

SpaceX Sends First All Commercial Crew to the ISS.

This brief article about the SpaceX's first all-commercial crew includes video of the launch. Observe the telemetry readings after the rocket has launched. This is very similar to the data we will be analyzing in the final phase of this project.
https://www.cbsnews.com/news/spacex-launch-space-station-how-to-watch-time-channel-stream-2022-04-08/

Boeing Starliner fails key NASA mission as autonomous flight system malfunctions

This article and the attendant video discuss how a small error in the timing of thrust motors disrupted the flight of Boeing's Starliner spacecraft, changing the trajectory and preventing the vehicle from reaching the ISS.
https://www.cnbc.com/2019/12/20/boeings-starliner-flies-into-wrong-orbit-jeopardizing-trip-to-the-international-space-station.html

Crew-3 Mission| Coast and Rendezvous

REALLY long video of the Crew-3 Dragon liftoff, sending fresh astronauts and cargo to the ISS. At 6:25:45 there is only 1 minute to lift off. Then, at 6:26:25, the screen begins to display the velocity, altitude and time. This leads right into what we're going to do with the computational model. By the time you get to 6:31, the rocket has gone through multiple stages and you get an inside look at the crew just "chilling" in their seats…math allows the rocket to be self-driving!
https://www.youtube.com/watch?v=fk5PWZIATvU

APPENDIX D

POSSIBLE VARIATIONS FOR MORE IN-DEPT STUDENT DATA ANALYSIS

Teacher Preparation:

For the following masses, use OpenRocket to add the specified mass component to the bottom of the rocket and run the simulation to find apogee. Make note of the apogee for the conditions you simulated.

Mass	Apogee
0 g	
20 g	
40 g	
60 g	
80 g	
100 g	
120 g	

These mass increments have been tested.
*****DO NOT EXCEED 130 g OR YOUR ROCKET MAY BECOME UNSTABLE*****

Student Projects:

I. "Given apogee, find payload mass."

Provide all student teams the same OpenRocket file, but give each team a ***different target apogee*** based on the apogees you found above. Do not share the masses associated with each apogee.

Students are required to use their team's target apogee to find the payload mass required. Students use OpenRocket to add a first-guess mass payload to their rocket. They run the simulation and note apogee. Based on the results, students change the payload according to whether the simulated apogee was too high (so the payload needs to be heavier) or too low (the payload needs to be lighter). This can be repeated as many times as necessary until students reach the desired apogee. Students report the required payload mass before launch day.

When the student launch occurs, each team launches with the payload mass they believe they will need to reach their target apogee.

II. "Given payload mass, find apogee."

Provide all student teams the same OpenRocket file, but give each team a ***different payload mass*** to add as a component to the bottom of their rocket. Do not share the associated expected apogees.

Students are required to use their team's payload mass to find the expected apogee. Students use OpenRocket to add the mass payload to their rocket. They run the simulation and note apogee. Students report the expected apogee before launch day.

When the student launch occurs, each team launches with their specified payload mass and make note of the apogee attained.

Post launch questions for all student teams:

Did your rocket reach your target apogee? Why/why not?

What kind of (weather) conditions may have prevented you from reaching apogee?

Compare (graph) the payload mass/apogee data from all student launches. What are the patterns you notice?

