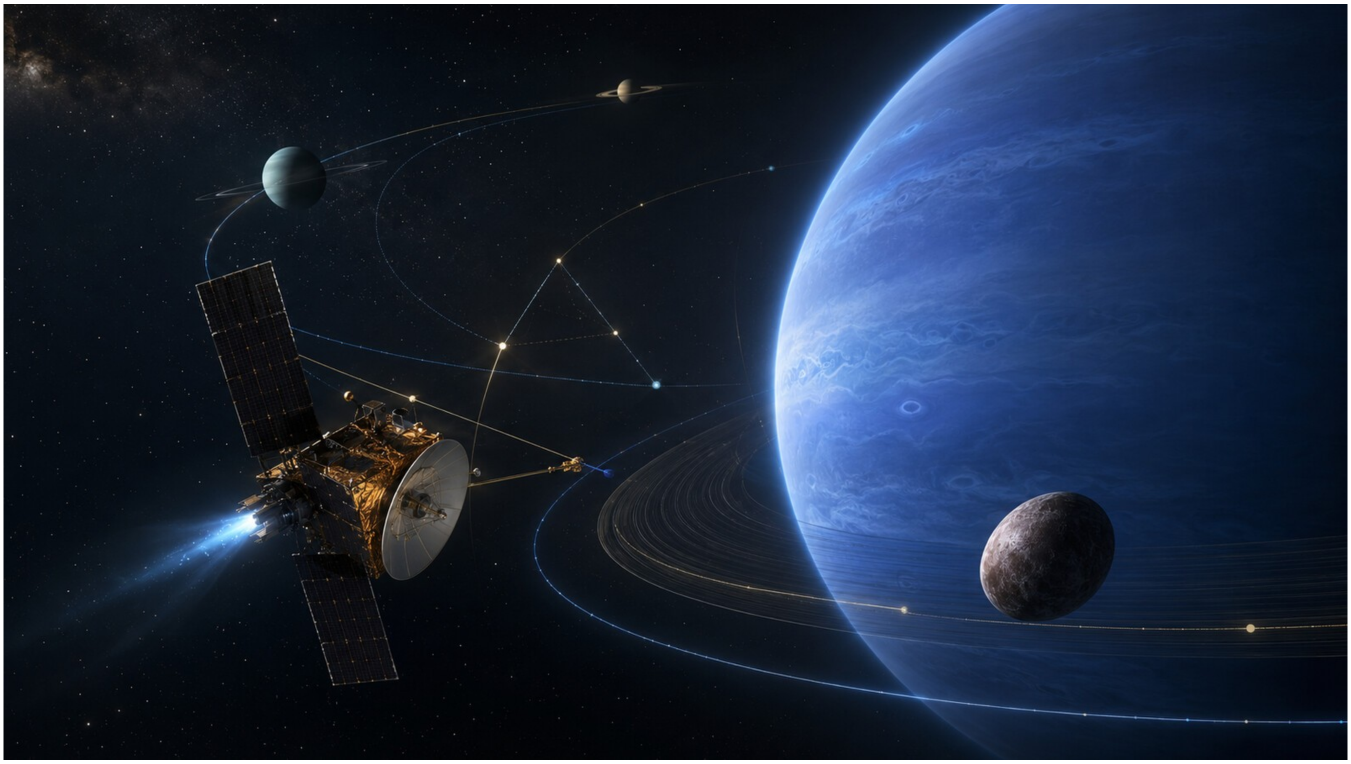
SPACE MATH EXPLORERS

Student Workbook

Ten Illustrated Missions in Algebra, Geometry, Trigonometry, and Data



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Grades 6-10 | Middle School Advanced / High School Foundations

Name: ____ Class: _____________________

A classroom-ready companion to the Space Math Explorers online course. Each mission uses an authentic space context while keeping the mathematics transparent, checkable, and adaptable.

Mission Handbook

This workbook follows ten missions. Each mission includes a visual briefing, action-based objectives, vocabulary, a data lab, estimation, graduated challenges, a hands-on engineering task, a career connection, guided and independent practice, a mission check, and reflection.

Suggested rhythm: Briefing -> Estimate -> Model -> Data lab -> Practice -> Engineer -> Explain -> Check

How to Use This Book

- Read the mission briefing and study the illustration.
- Write units at every step and show your reasoning.
- Use a calculator in degree mode when trigonometry is required.
- Complete the mission check without notes when your teacher directs.
- Use the reflection log to explain what your answer means.

Mission Map

No.	Mission	Core mathematics
1	Launch Calculations	Define variables and write expressions, Solve one- and two-step equations, Graph coordinates and interpret rates
2	Planetary Geometry	Calculate circumferences of circular orbits, Calculate surface areas of spheres, Calculate volumes and compare storage capacity
3	Outer Solar System Navigation	Solve multi-step and literal equations, Apply scale ratios to distance models, Navigate with right-triangle mathematics
4	Gravity and Orbital Paths	Solve systems of equations, Use similar triangles to find indirect measurements, Interpret quadratic flight paths
5	Orbital Motion and Gravity Lab	Calculate with scientific notation, Analyze inverse-square relationships, Model ellipses and periodic motion
6	Black Holes and Gravity Wells	Evaluate exponential models, Calculate gravity-well cone geometry, Determine coordinate distance and direction
7	Exoplanet Detectives	Calculate transit percent change, Evaluate probability and observation reliability, Estimate distance with parallax triangulation
8	Space Habitat Engineering	Solve resource inequalities, Calculate composite habitat geometry, Determine solar-panel angles
9	Space Station Structural Design	Apply scale drawings and unit conversions, Solve structural load systems, Use the Law of Cosines to analyze trusses
10	Outer Planets Capstone	Compare mission systems with mathematical models, Analyze giant-planet geometry, Solve a probe navigation challenge

Mission 1: Launch Calculations

Image credit: Mission 1, Launch Calculations - original AI-generated illustration created for Space Math Explorers using OpenAI image generation. NASA-inspired educational artwork; not an official NASA image.

MISSION BRIEFING

Prepare a launch by translating mission facts into variables, equations, and coordinate graphs.

Learning Targets

- I can define variables and write expressions.
- I can solve one- and two-step equations.
- I can graph coordinates and interpret rates.

Flight Vocabulary

variable, coefficient, constant, expression, equation, ordered pair, slope

Mission 1 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

Space-weather teams combine observations made in different time zones, evaluate signed-number expressions, and use rate equations to estimate when a disturbance may arrive.

Concept Flight Plan

- Convert local observations to a common 24-hour time before building a timeline.
- Treat positive and negative values as changes from a reference level.
- Use distance = rate x time and rearrange the formula for the missing quantity.
- Separate a computed answer from the evidence-based claim it supports.

Expanded Vocabulary

Term	Mission meaning
universal time	a shared time reference used to compare observations
24-hour clock	a time system numbered 00:00 through 23:59
signed number	a positive or negative value measured from a reference
elapsed time	the duration between two recorded times
rate	a comparison of two quantities with different units
substitution	replacing a variable with a known value
space weather	changing conditions in space influenced by solar activity
timeline	events arranged in chronological order

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 1 Special Topic: How Far Is Each Planet from the Sun?

A planet follows an elliptical orbit, so its actual distance from the Sun changes. This investigation uses average orbital distance, rounded for classroom calculations. Light-travel time is one-way: the time sunlight takes to reach the planet.

CONVERSION FLIGHT PLAN

- 1 astronomical unit (AU) = 149,597,870.7 kilometers.
- 1 mile = 1.609344 kilometers.
- Light travels 299,792.458 kilometers each second. One light-minute = 17.98754748 million kilometers.
- Use distance = speed x time and follow the final-answer precision shown in the table.

Complete the Planet Distance Table

Each planet supplies one measurement. Calculate and enter the other three. In the teacher edition, all fields are completed.

Rounding Rule: Keep all calculator digits during your calculations. Do not round intermediate results. Round only your final answer according to the precision requested in the table. Answers that differ by one unit in the final reported decimal place are acceptable.

Planet	Million km	Million miles	AU	Light time (min)
Mercury	57.909 (given)	________________	________________	________________
Venus	________________	________________	0.723336 (given)	________________
Earth	________________	92.956 (given)	________________	________________
Mars	________________	________________	________________	12.6723 (given)
Jupiter	778.341 (given)	________________	________________	________________
Saturn	________________	________________	9.536676 (given)	________________
Uranus	________________	1,783.744 (given)	________________	________________
Neptune	________________	________________	________________	250.0839 (given)

NASA data note: values are rounded mean orbital distances. Because planetary orbits are elliptical, instantaneous distances vary.

Planet Distance Calculations and Explanations

Convert kilometers to AU

AU = kilometers / 149,597,870.7. Example: Mercury = 57,909,227 / 149,597,870.7 = 0.3871 AU.

Convert kilometers to miles

Miles = kilometers / 1.609344.

Convert AU to kilometers

Kilometers = AU x 149,597,870.7.

Find one-way light time

Light-minutes = kilometers / 17,987,547.48.

Mission Analysis

1. Which planet is approximately ten times Earth's distance from the Sun? Support your answer with AU values.

2. How many additional light-minutes does sunlight need to reach Neptune compared with Earth?

3. Explain why a spacecraft message cannot travel instantly between Earth and an outer planet.

Mission 1 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Launch altitude telemetry. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Time (min)	Altitude (km)
0	2
1	6
2	10
3	14

Estimate Before You Calculate

Predict the altitude at 5 minutes before calculating.

COMMON MISSION ERROR

Do not confuse the starting value, 2 km, with the rate, 4 km/min.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 1 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Build and launch a paper straw rocket. Measure three flight distances, calculate the mean, and revise one design feature.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: signed numbers; ordered pairs; one-step equations.

Flight dynamics engineer uses equations, coordinates, rates, and uncertainty to predict vehicle motion.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 1 Practice A

Worked Launch Example

A launch vehicle carries 4 identical fuel cells and a 120-unit reserve for 920 total units. Write and solve $4f + 120 = 920$.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. A launch vehicle carries 4 identical fuel cells and a 120-unit reserve for 920 total units. Write and solve $4f + 120 = 920$.

2. A rover travels 18 km each hour. Write an expression for its distance after h hours and find the distance after 7 hours.

3. Mission control records points (0,40), (2,100), and (4,160) for time and altitude. Find the rate of change.

4. Solve $750 - 35t = 365$ for t and interpret the result as flight time in minutes.

Mission 1 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. A sensor reading is modeled by $y = 12x + 8$. Find y when $x = 6$ and identify the initial value.

6. An observatory records an event at 21:35 local time and is 5 hours behind Universal Time. Convert the event to Universal Time.

7. A magnetic index changes from +18 to -7. Find the signed change and its magnitude.

8. A plasma cloud travels 1.44×10^8 km at 800 km/s. Estimate travel time in hours.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 1 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. Solve 6x + 30 = 210.

2. Find the slope through (1,25) and (5,65).

3. Evaluate 15n - 4 when n = 8.

4. Convert 18:45 local time to UT for a location 4 hours behind UT.

5. A reading moves from -12 to +9. What is the change?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 2: Planetary Geometry

Image credit: Mission 2, Planetary Geometry - original AI-generated illustration created for Space Math Explorers using OpenAI image generation. NASA-inspired educational artwork; not an official NASA image.

MISSION BRIEFING

Model planets, moons, craters, and storage tanks with circles and three-dimensional solids.

Learning Targets

- I can calculate circumferences of circular orbits.
- I can calculate surface areas of spheres.
- I can calculate volumes and compare storage capacity.

Flight Vocabulary

radius, diameter, circumference, pi, surface area, volume, sphere, cylinder

Mission 2 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

NASA engineers estimate solar-array power from geometric area, use scale images to measure enormous regions, and distinguish linear, square, and cubic units.

Concept Flight Plan

- Decompose an irregular solar array into rectangles and triangles.
- Apply an image scale consistently to every measured length.
- Square a linear scale factor for area and cube it for volume.
- Use unit labels to test whether a formula matches the requested quantity.

Expanded Vocabulary

Term	Mission meaning
polygon	a closed two-dimensional figure made of line segments
composite area	area found by combining simpler shapes
solar cell	a device that converts light to electrical energy
power density	power produced per unit area
image scale	a ratio connecting image length to actual length
linear unit	a unit of distance such as meters
square unit	a unit used for area
cubic unit	a unit used for volume

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 2 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Crater diameter survey. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Crater	Diameter (km)
A	6
B	10
C	14
D	18

Estimate Before You Calculate

Rank the crater circumferences before calculating them.

COMMON MISSION ERROR

Do not substitute diameter for radius in $C=2\pi r$ unless you first divide by 2.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 2 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Create a scale solar-system distance strip or hallway model. Record the scale and check every placement with a proportion.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: decimals; radius and diameter; square and cubic units.

Planetary geologist measures craters, maps surfaces, and compares planetary features with scale and geometry.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 2 Practice A

Worked Launch Example

A circular crater has diameter 18 km. Find its circumference using pi = 3.1416.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. A circular crater has diameter 18 km. Find its circumference using pi = 3.1416.

2. A moon has radius 500 km. Find its surface area.

3. Find the volume of a cylindrical tank with radius 2 m and height 5 m.

4. A spherical probe has radius 3 m. Find its volume to the nearest tenth.

Mission 2 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. A mapping team covers 25,000 km^2 per day. How many whole days are needed to map 3,141,600 km^2?

6. A solar wing contains a 6 m by 2.5 m rectangle and a right triangle with base 2 m and height 2.5 m. Find total area.

7. Solar cells produce 210 W per square meter. Find the power from the 17.5 m^2 wing.

8. On an image, 1 cm represents 1,800 km. A plasma region measures 3.4 cm across. Find its actual width.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 2 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. Find the circumference of a circle with radius 7 km.

2. Find the volume of a 4 m by 3 m by 2 m prism.

3. If a sphere's radius doubles, by what factor does volume change?

4. A 12 m^2 array produces 190 W/m^2. Total power?

5. At 1 cm:2,500 km, what does 4.8 cm represent?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 3: Outer Solar System Navigation

Image credit: Mission 3, Outer Solar System Navigation - original AI-generated illustration created for Space Math Explorers using OpenAI image generation. NASA-inspired educational artwork; not an official NASA image.

MISSION BRIEFING

Navigate deep space with multi-step equations, scale ratios, the Pythagorean theorem, and tangent.

Learning Targets

- I can solve multi-step and literal equations.
- I can apply scale ratios to distance models.
- I can navigate with right-triangle mathematics.

Flight Vocabulary

literal equation, proportion, scale factor, hypotenuse, tangent, angle of elevation

Mission 3 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

Solar disturbances and spacecraft signals are tracked with speed-distance-time models, scale ratios, and indirect right-triangle measurements.

Concept Flight Plan

- Rearrange d=rt before substituting values.
- Convert seconds to hours or days only after checking the units in the rate.
- Use a scale drawing to estimate a distance too large to measure directly.
- State the reference direction for every navigation angle.

Expanded Vocabulary

Term	Mission meaning
propagation	movement of a signal or disturbance through space
arrival time	the predicted time an object or disturbance reaches a location
baseline	a measured reference side used in triangulation
indirect measurement	finding a distance or height without measuring it directly
component	one directional part of a vector
resultant	the combined size and direction of components
bearing	a direction angle measured from a stated reference
unit conversion	multiplying by ratios equal to one to change units

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 3 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Deep-space signal route. Notice patterns, select a mathematical model, calculate, and communicate evidence.

East (km)	North (km)
3	4
6	8
9	12
12	16

Estimate Before You Calculate

Predict whether each direct distance is greater than either component but less than their sum.

COMMON MISSION ERROR

Do not add perpendicular components when a straight-line displacement is requested.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 3 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Map a classroom navigation route with east and north components. Compare walked distance with straight-line displacement.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: ratios; square roots; Pythagorean theorem; degree mode.

Spacecraft navigation engineer uses vectors, scale models, angles, and timing to guide probes.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 3 Practice A

Worked Launch Example

A probe starts with 1,200 energy units, uses 85 per day, and must keep 350. Solve 1200 - 85d = 350.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. A probe starts with 1,200 energy units, uses 85 per day, and must keep 350. Solve 1200 - 85d = 350.

2. Rearrange d = rt to solve for r, then find r for d = 900 km and t = 6 h.

3. At a scale of 1 cm : 100,000 km, represent 600,000 km on a model.

4. A rover is 6 km east and 8 km north of base. Find its direct distance.

Mission 3 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. A lander is 5 km above the surface and 12 km horizontally from a station. Find the angle of elevation.

6. A disturbance covers 150 million km in 42 hours. Find its average speed in km/s.

7. Two perpendicular magnetic-field components are 24 nT and 32 nT. Find their resultant magnitude.

8. A signal station sees an object at an elevation angle of 28 degrees from a 16 km horizontal baseline. Find height.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 3 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. At 1 cm : 50,000 km, how long represents 350,000 km?

2. Find the hypotenuse with legs 9 and 12.

3. Solve 950 - 50d = 300.

4. Travel time for 72,000 km at 400 km/s?

5. Components 9 and 12 have what resultant?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 4: Gravity and Orbital Paths

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MISSION BRIEFING

Use systems, similarity, and quadratics to analyze mission conditions and flight paths.

Learning Targets

- I can solve systems of equations.
- I can use similar triangles to find indirect measurements.
- I can interpret quadratic flight paths.

Flight Vocabulary

system, substitution, elimination, similar triangles, parabola, vertex, zero

Mission 4 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

Auroral height, magnetic-field strength, and spacecraft paths can all be modeled by combining equations, similar triangles, and geometric vectors.

Concept Flight Plan

- A mathematical model includes assumptions as well as equations.
- Similar triangles require corresponding angles and proportional sides.
- Perpendicular components combine with the Pythagorean theorem.
- Graph features must be interpreted in the physical context and valid time interval.

Expanded Vocabulary

Term	Mission meaning
aurora	light produced when energetic particles interact with the upper atmosphere
triangulation	using angles and a baseline to locate a distant point
corresponding sides	sides in the same relative positions in similar figures
magnetic field	a region in which magnetic forces can act
vector	a quantity with magnitude and direction
model assumption	a simplifying condition accepted for a calculation
domain	the allowed input values for a model
residual	the difference between an observed and predicted value

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 4 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Probe flight-height model. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Time (s)	Height (m)
0	2
1	27
2	42
3	47
4	42

Estimate Before You Calculate

Locate the likely maximum from the table before using the vertex formula.

COMMON MISSION ERROR

Do not treat every increasing pattern as linear; the changes here are not constant.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 4 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Drop a paper landing system from a fixed height. Time three trials, graph the results, and improve consistency.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: linear equations; proportions; coordinate graphs; functions.

Trajectory analyst uses systems, parabolas, simulations, and error analysis to evaluate flight paths.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 4 Practice A

Worked Launch Example

Two probes collect 26 samples; Probe A collects 4 more than B. Find each amount.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. Two probes collect 26 samples; Probe A collects 4 more than B. Find each amount.

2. Solve $x+y=14$ and $x-y=2$ by elimination.

3. A 2 m antenna casts a 3 m shadow while a tower casts a 45 m shadow. Find the tower height.

4. For $h(t) = -5t^2 + 30t + 2$, find the time and height of the vertex.

Mission 4 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. A 4 cm image represents 120 km. What distance does 7 cm represent?

6. Two observers 80 km apart measure an auroral feature. A simplified right triangle uses a 36 degree elevation angle. Estimate height using h=80tan36.

7. A magnetic field has perpendicular components 18 nT and 24 nT. Find magnitude.

8. Observed heights are 2 m below, 1 m above, and 3 m above a model. Find the mean signed residual.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 4 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. Solve a+b=40 and a-b=8.

2. A 5 m pole casts 8 m shadow; a tower casts 48 m. Height?

3. Find the vertex time of -4t^2+24t+1.

4. Find h=50tan40 degrees.

5. Components 7 and 24 give what magnitude?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 5: Orbital Motion and Gravity Lab

Image credit: Mission 5, Orbital Motion and Gravity Lab - original AI-generated illustration created for Space Math Explorers using OpenAI image generation. NASA-inspired educational artwork; not an official NASA image.

MISSION BRIEFING

Compute with scientific notation and explore inverse-square and periodic orbital models.

Learning Targets

- I can calculate with scientific notation.
- I can analyze inverse-square relationships.
- I can model ellipses and periodic motion.

Flight Vocabulary

scientific notation, exponent, inverse square, ellipse, focus, amplitude, period, midline

Mission 5 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

Space-weather forecasting depends on very large and small numbers, periodic solar cycles, graph interpretation, and comparisons between predicted and observed change.

Concept Flight Plan

- Write measurements in scientific notation before multiplying or dividing.
- Identify independent and dependent variables on every graph.
- Distinguish a periodic pattern from a constant linear trend.
- Use percent change to compare losses across systems of different sizes.

Expanded Vocabulary

Term	Mission meaning
mantissa	the coefficient in scientific notation, usually between 1 and 10
order of magnitude	the power of ten that describes a number's scale
solar cycle	a repeating pattern of solar activity of roughly eleven years
independent variable	the input placed on the horizontal axis
dependent variable	the response placed on the vertical axis
percent change	change divided by original value, expressed as a percent
correlation	a pattern in which variables change together
forecast	a prediction based on evidence and a model

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 5 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Solar-array force model. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Distance factor	Force (units)
1	72
2	18
3	8
4	4.5

Estimate Before You Calculate

Predict whether force at five times the distance will be above or below 4 units.

COMMON MISSION ERROR

Do not divide by the distance factor once; inverse-square models divide by its square.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 5 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Model an orbit with string, two focus points, and a pencil. Measure several center-to-path distances and describe variation.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: exponents; scientific notation; coordinate graphs; functions.

Orbital mechanics specialist uses scientific notation, periodic functions, and inverse-square laws to model orbits.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 5 Practice A

Worked Launch Example

Write 149,600,000 in scientific notation.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. Write 149,600,000 in scientific notation.

2. Multiply (3 x 10^5)(2 x 10^3).

3. A force is 72 units at distance r. Find the force at 2r and 3r.

4. For y = 3 sin(t) + 5, state amplitude, midline, maximum, minimum, and period.

Mission 5 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. An ellipse has closest distance 120 and farthest distance 180 units. Find their mean as a center-distance estimate.

6. A sensor count rises from 2.4 x 10^5 to 3.0 x 10^5. Find the percent increase.

7. Solar-array power falls from 8.0 kW to 6.6 kW. Find percent decrease.

8. Activity peaks occur in years 3, 14, and 25. Estimate period and predict the next peak.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 5 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. Write 0.0000042 in scientific notation.

2. A force is 90 at r. What is it at 3r?

3. For y=4sin(t)+7, find maximum and minimum.

4. Percent decrease from 500 to 425?

5. Peaks at years 6,17,28. Next peak?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 6: Black Holes and Gravity Wells

Image credit: Mission 6, Black Holes and Gravity Wells - original AI-generated illustration created for Space Math Explorers using OpenAI image generation. NASA-inspired educational artwork; not an official NASA image.

MISSION BRIEFING

Investigate black-hole models with exponential change, cone geometry, and coordinate navigation.

Learning Targets

- I can evaluate exponential models.
- I can calculate gravity-well cone geometry.
- I can determine coordinate distance and direction.

Flight Vocabulary

exponential, growth factor, decay factor, cone, coordinate distance, direction angle, quadrant

Mission 6 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

Energetic particles are described with exponential change, kinetic-energy models, voltage comparisons, and vector components of magnetic forces.

Concept Flight Plan

- Exponential models multiply by a constant factor each interval.
- A formula's squared variable can dominate the size of the result.
- Normalize values when comparing particles with different masses or charges.
- Explain the limits of a visual gravity-well model.

Expanded Vocabulary

Term	Mission meaning
charged particle	a particle with positive or negative electric charge
kinetic energy	energy associated with motion
voltage	electric potential difference per unit charge
magnetic force	force on moving charge in a magnetic field
decay factor	the multiplier between 0 and 1 in exponential decay
half-life	time required for a quantity to fall to half its value
normalization	rescaling values for fair comparison
model limitation	a way a model differs from the real system

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 6 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Detector signal decay. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Interval	Signal
0	800
1	400
2	200
3	100

Estimate Before You Calculate

Predict the signal at interval 5 without calculating every intermediate value.

COMMON MISSION ERROR

Do not subtract a constant amount from an exponential sequence; multiply by the decay factor.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 6 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Build a flexible-fabric gravity-well model, roll objects through it, and record how path and speed change. State the model's limitations.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: powers; coordinate distance; volume formulas; trigonometry.

Astrophysicist uses exponential models, geometry, coordinates, and simulations to study extreme objects.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 6 Practice A

Worked Launch Example

A signal follows S = 800(0.5)^x. Find S after 3 intervals.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. A signal follows S = 800(0.5)^x. Find S after 3 intervals.

2. A particle model is P = 12(2)^x. Find P after 4 intervals.

3. Find the volume of a cone with radius 6 cm and height 10 cm.

4. Find the distance between (2,3) and (10,9).

Mission 6 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. Find the direction angle from (2,3) to (10,9), measured above the positive x-axis.

6. A particle speed doubles. In a model where kinetic energy is proportional to v^2, by what factor does energy change?

7. A detector count begins at 6,400 and halves every 3 hours. Find the count after 9 hours.

8. Magnetic-force components are -15 units horizontally and +20 vertically. Find magnitude and describe the quadrant.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 6 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. Evaluate 500(0.2)^2.

2. Cone volume: r=3, h=8.

3. Distance from (0,0) to (5,12).

4. If speed triples in an E proportional to v^2 model, energy factor?

5. 3,200 halves every 2 h. Amount after 6 h?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 7: Exoplanet Detectives

Image credit: Mission 7, Exoplanet Detectives - original AI-generated illustration created for Space Math Explorers using OpenAI image generation. NASA-inspired educational artwork; not an official NASA image.

MISSION BRIEFING

Analyze distant-world evidence using percent change, probability, and triangulation.

Learning Targets

- I can calculate transit percent change.
- I can evaluate probability and observation reliability.
- I can estimate distance with parallax triangulation.

Flight Vocabulary

transit, percent decrease, experimental probability, independent events, parallax, baseline

Mission 7 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

Scientists compare solar flares, plasma eruptions, sunspots, and detector events with tables, Venn diagrams, percentages, probability, and evidence-based claims.

Concept Flight Plan

- A Venn diagram displays overlap between two categories.
- Correlation alone does not prove that one variable causes the other.
- Use relative frequency to compare groups with different totals.
- A scientific claim should cite data and acknowledge uncertainty.

Expanded Vocabulary

Term	Mission meaning
solar flare	a rapid release of energy from the Sun
coronal mass ejection	a large eruption of magnetized plasma from the Sun
sunspot	a darker region associated with strong magnetic fields
Venn diagram	overlapping sets showing shared and distinct members
relative frequency	category count divided by total count
sample size	the number of observations analyzed
outlier	a value far from the general pattern
causation	a relationship in which one event directly produces another

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 7 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Exoplanet transit brightness. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Time (h)	Brightness
0	10000
2	9998
4	9900
6	9997
8	10001

Estimate Before You Calculate

Identify the likely transit and estimate its percent depth.

COMMON MISSION ERROR

Do not calculate percent decrease using the new value as the denominator.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 7 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Use a lamp, ball, and light sensor or phone app to model a transit. Graph brightness over time and compare trials.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: percent change; probability; tables and graphs; tangent.

Exoplanet data scientist uses statistics, probability, graphs, and geometry to evaluate evidence of distant worlds.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 7 Practice A

Worked Launch Example

Star brightness drops from 10,000 to 9,900 units. Find the percent decrease.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. Star brightness drops from 10,000 to 9,900 units. Find the percent decrease.

2. 45 of 50 observations are usable. Find experimental reliability.

3. Two independent instruments each work with probability 0.90. Find the probability both work.

4. Use d=b/tan(theta) with b=2 units and theta=10 degrees.

Mission 7 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. Brightness readings dip every 6 days at days 6, 12, 18, and 24. Predict the next dip and state the period.

6. Of 60 solar events, 38 are flares, 27 are plasma eruptions, and 15 are both. How many are in at least one group?

7. In a sample of 80 large sunspots, 52 produce major flares. Find relative frequency.

8. A small sample shows 6 of 8 events with a pattern; a large sample shows 63 of 90. Compare rates and identify the more reliable estimate.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 7 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. Brightness 8,000 drops to 7,920. Percent decrease?

2. 27 successes in 30 trials?

3. If parallax angle decreases with fixed baseline, does distance rise or fall?

4. Sets have 25 and 18 members with overlap 7. Union size?

5. 42 successes in 60 trials?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 8: Space Habitat Engineering

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MISSION BRIEFING

Design a habitat using inequalities, composite solids, and solar-panel trigonometry.

Learning Targets

- I can solve resource inequalities.
- I can calculate composite habitat geometry.
- I can determine solar-panel angles.

Flight Vocabulary

inequality, solution set, composite solid, hemisphere, sine, cosine, tangent

Mission 8 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

A safe habitat must balance solar power, radiation exposure, shielding area, resource reserves, and geometric design constraints.

Concept Flight Plan

- Translate safety limits into inequalities.
- Compute exposed surface area rather than hidden interior boundaries.
- Compare power demand with production under degraded conditions.
- Evaluate risk using both numerical evidence and stated assumptions.

Expanded Vocabulary

Term	Mission meaning
radiation dose	energy deposited by radiation in matter
exposure rate	dose received per unit time
shielding	material used to reduce radiation exposure
safety margin	extra capacity beyond the expected requirement
power budget	comparison of electrical production and demand
degradation	loss of performance over time
constraint	a condition a valid design must satisfy
trade-off	a choice that improves one goal while limiting another

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 8 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Habitat daily water budget. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Day	Water left (L)
0	960
3	780
6	600
9	420
12	240

Estimate Before You Calculate

Predict the latest safe whole day if 240 L must remain in reserve.

COMMON MISSION ERROR

When dividing an inequality by a negative number, reverse the inequality sign.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 8 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Build two paper habitat models with equal material area. Compare their volumes and recommend a design.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: inequalities; circle area; cylinder volume; trigonometry.

Space habitat systems engineer uses inequalities, geometry, power budgets, and safety margins to protect crews.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 8 Practice A

Worked Launch Example

A crew has 960 L of water, must reserve 240 L, and uses 60 L/day. Solve 960-60d >= 240.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. A crew has 960 L of water, must reserve 240 L, and uses 60 L/day. Solve 960-60d >= 240.

2. Find the volume of a cylinder with r=4 m and h=6 m.

3. Find the volume of a hemispherical roof with radius 4 m.

4. A 5 m solar panel tilts 30 degrees. Find vertical rise and horizontal span.

Mission 8 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. A support rises 3 m over a 4 m run. Find its angle.

6. A crew dose limit is 500 units. Background is 260 and a storm adds 18 units per hour. Solve 260+18h <= 500.

7. A 24 m^2 array produces 180 W/m^2 but storm damage reduces output by 12%. Find new power.

8. A habitat needs 3.6 kW and a 15% safety margin. Does 3,801.6 W meet the target?

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 8 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. Solve 700-40d >= 220.

2. Circle floor area with r=5.

3. A 10 m panel at 30 degrees has what rise?

4. Solve 150+25h<=400.

5. 2,000 W loses 8%. New power?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 9: Space Station Structural Design

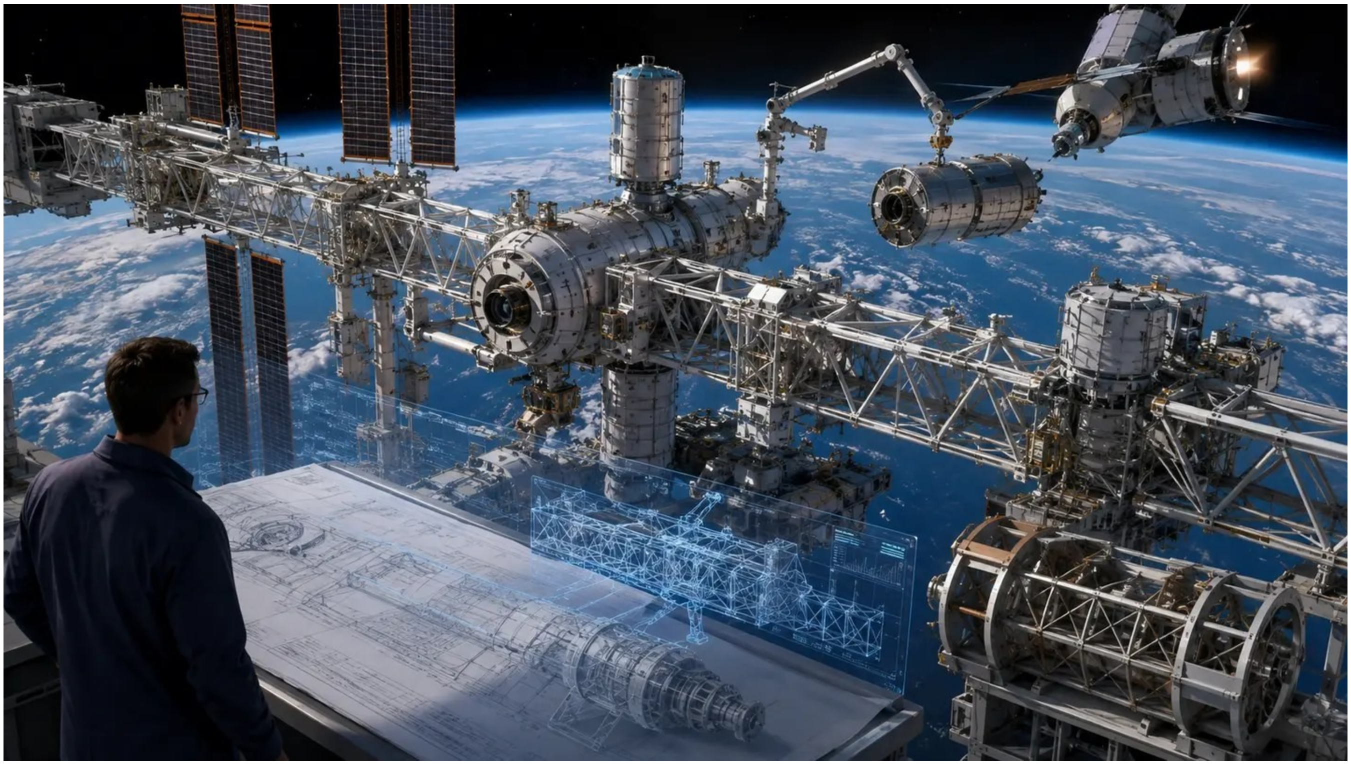

Image credit: Mission 9, Space Station Structural Design - original AI-generated illustration created for Space Math Explorers using OpenAI image generation. NASA-inspired educational artwork; not an official NASA image.

MISSION BRIEFING

Plan a modular station with scale drawings, systems of equations, and truss geometry.

Learning Targets

- I can apply scale drawings and unit conversions.
- I can solve structural load systems.
- I can use the law of cosines to analyze trusses.

Flight Vocabulary

scale drawing, dimensional analysis, system, load, truss, included angle, Law of Cosines

Mission 9 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

Satellite designers use scale drawings, component vectors, solar-array output, and space-weather trends to predict structural and orbital performance.

Concept Flight Plan

- Use dimensional analysis for every blueprint conversion.
- Resolve loads or fields into perpendicular components.
- Interpret a correlation between solar activity and orbital decay cautiously.
- Include safety factors when a design uses an estimated maximum load.

Expanded Vocabulary

Term	Mission meaning
orbital decay	gradual lowering of an orbit due to drag and other effects
atmospheric drag	resistance from particles in the upper atmosphere
re-entry	return of an object from orbit into denser atmosphere
load component	part of a force acting along an axis
safety factor	design strength divided by expected load
trend line	a line summarizing the direction of data
interpolation	estimating within known data
extrapolation	estimating beyond known data

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 9 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Station support loads. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Support	Load (N)
A	700
B	500
Total	1200
Difference	200

Estimate Before You Calculate

Predict which support carries more and verify both system conditions.

COMMON MISSION ERROR

Do not check only the total; a system solution must satisfy both equations.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 9 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Construct a spaghetti or paper truss. Test its maximum load, identify failure points, and improve the design.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: unit conversions; systems; triangles; cosine.

Aerospace structural engineer uses systems, vectors, scale drawings, and trigonometry to analyze loads and structures.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 9 Practice A

Worked Launch Example

At 1 cm : 2.5 m, what real length does a 12 cm corridor represent?

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. At 1 cm : 2.5 m, what real length does a 12 cm corridor represent?

2. At the same scale, how long is an 18 m laboratory on the drawing?

3. Supports A and B carry 1,200 N total, and A carries 200 N more. Find both loads.

4. Two truss beams are 8 m and 11 m with included angle 60 degrees. Find the third side.

Mission 9 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. A model is enlarged by scale factor 3. State the area and volume scale factors.

6. A 1,500 N load acts at 40 degrees above horizontal. Find horizontal and vertical components.

7. A support's expected load is 1,200 N and required safety factor is 1.5. Find minimum rated strength.

8. Re-entries rise from 8 to 14 as an activity index rises from 40 to 70. Find the slope and explain it as association, not causation.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 9 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. Convert 7.5 m to cm.

2. Solve A+B=900, A-B=100.

3. Law of Cosines with a=5,b=7,C=60 degrees.

4. 800 N at 60 degrees: vertical component?

5. 900 N load with factor 1.8 needs what rating?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Mission 10: Outer Planets Capstone

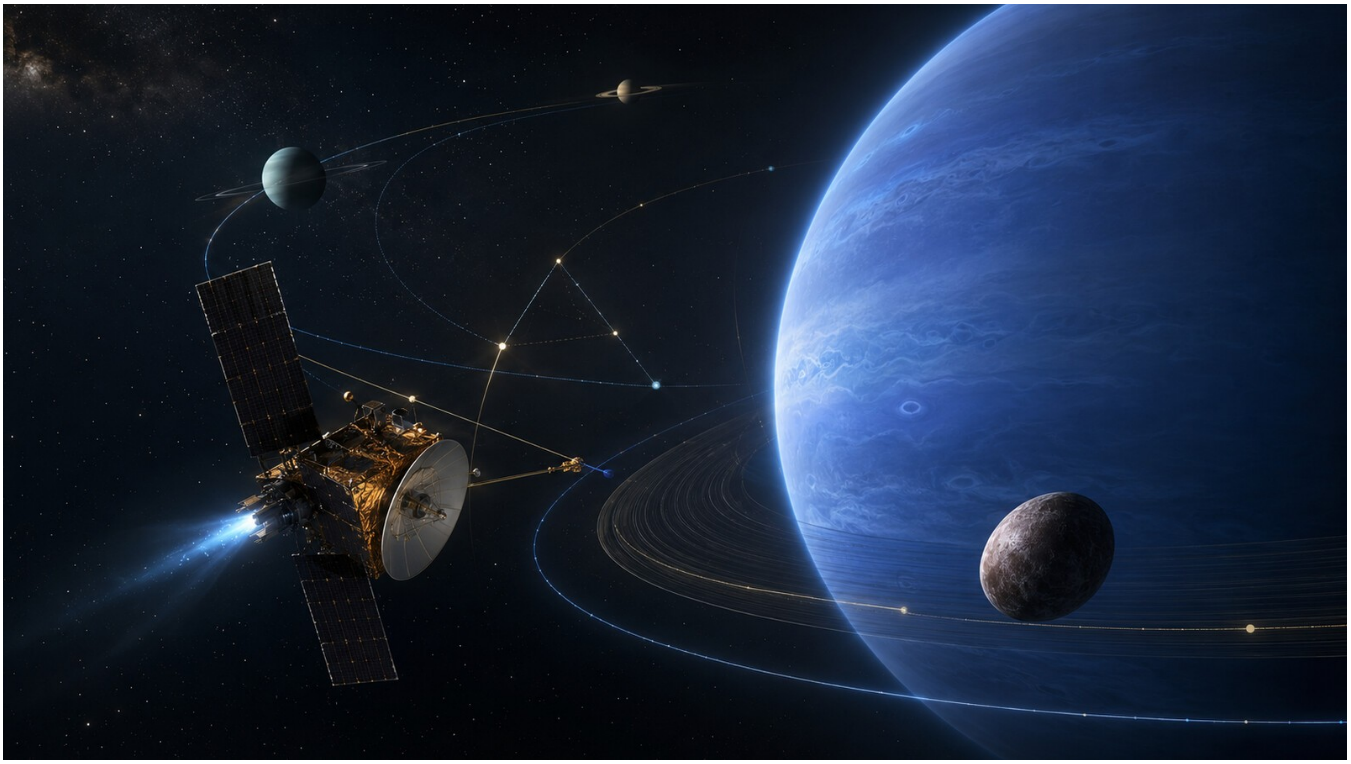

Image credit: Mission 10, Outer Planets Capstone - original AI-generated illustration created for Space Math Explorers using OpenAI image generation. NASA-inspired educational artwork; not an official NASA image.

MISSION BRIEFING

Integrate algebra, geometry, trigonometry, and data interpretation into a giant-planet mission plan.

Learning Targets

- I can compare mission systems with mathematical models.
- I can analyze giant-planet geometry.
- I can solve a probe navigation challenge.

Flight Vocabulary

linear model, quadratic model, vertex, scale factor, displacement, bearing, reasonableness

Mission 10 Concepts and Vocabulary

NASA SPACE-MATH CONNECTION

The capstone adds a space-weather forecast: teams integrate timelines, graphs, scientific notation, geometry, probability, power constraints, and evidence-based recommendations.

Concept Flight Plan

- Define each variable, unit, assumption, and data source.
- Choose a representation suited to the evidence: table, graph, diagram, equation, or Venn diagram.
- Test a plan under a normal case and a storm case.
- Communicate uncertainty and recommend a decision supported by calculations.

Expanded Vocabulary

Term	Mission meaning
scenario analysis	comparing results under different assumed conditions
sensitivity analysis	testing how a result changes when an input changes
uncertainty	a quantified or described limit on knowledge
evidence-based claim	a conclusion directly supported by analyzed data
validation	checking a model against known or observed values
contingency	a backup action for an unfavorable condition
threshold	a value that triggers a decision or response
mission recommendation	a justified action based on objectives, constraints, and evidence

Before You Calculate

Identify the known values, unknown quantity, units, model or diagram, and one assumption.

Mission 10 Data Lab and Challenge Levels

MISSION DATA FILE — CLASSROOM SIMULATION

Outer-planet mission options. Notice patterns, select a mathematical model, calculate, and communicate evidence.

Plan	Cost / risk
A	1800 / 2.4%
B	2100 / 1.2%
C	2400 / 0.8%
Budget	2200 max

Estimate Before You Calculate

Choose a feasible plan before calculating cost per percentage point of risk reduction.

COMMON MISSION ERROR

Do not recommend a plan from one number alone; apply every constraint and state uncertainty.

Graduated Mission Practice

Flight Training: Identify the known quantities, unknown quantity, and units. Describe the pattern or relationship.

Mission Ready: Choose a formula, calculate one additional value, and check the result against your estimate.

Mission Specialist: Change one condition, compare the result, and defend a recommendation with evidence.

Mission 10 Engineering, Communication, and Career

Select and Defend a Formula

Select a formula or model for the Mission Data File. Explain why it fits the known values, unknown value, units, and pattern.

Hands-On Engineering Challenge

Teams design an outer-planet mission under cost, power, travel-time, and risk constraints, then defend a recommendation.

Engineering cycle: Ask → Imagine → Plan → Create → Test → Improve → Communicate

Explain It to Mission Control

Communicate a claim, numerical evidence, units, reasoning, and one assumption or limitation. Use a paragraph, labeled diagram, graph, or brief presentation.

Mission Readiness and Career Connection

Prerequisites: models; scale factors; displacement; probability; claims.

Mission systems engineer integrates algebra, geometry, data, uncertainty, and constraints into mission decisions.

Mathematical practices: model with mathematics; use tools strategically; attend to precision; construct an evidence-based argument.

Mission 10 Practice A

Worked Launch Example

Fuel is F=2400-75t. Find fuel after 20 days.

Use the formula or equation from the mission lessons. Label each quantity, substitute values, solve, and interpret the result.

Guided Challenges

1. Fuel is F=2400-75t. Find fuel after 20 days.

2. Plan A costs 50t+800 and Plan B costs 30t+1200. Find the break-even time and cost.

3. Planet B has twice Planet A's radius. Compare surface areas and volumes.

4. Find circumference of an orbit with radius 80,000 km.

Mission 10 Practice B: NASA-Style Investigation

Use tables, diagrams, graphs, formulas, and written evidence as appropriate. Show conversions and label every unit.

5. A probe travels 15,000 km east and 20,000 km north. Find displacement and direction north of east.

6. Normal solar-array output is 6.4 kW. A storm may reduce it by 18% while critical demand is 5.5 kW. Is output sufficient?

7. A storm has probability 0.30 and a shield succeeds with probability 0.92 if a storm occurs. Find probability of a storm and shield failure.

8. Plan A has 2.4% failure risk and costs 1,800 units. Plan B has 1.2% risk and costs 2,100. Compute extra cost per percentage point of risk reduction.

Data-to-Claim Prompt

Write one claim supported by your calculations. State one limitation or uncertainty.

Mission 10 Check

Complete without notes if directed. Show enough work to make your reasoning visible.

1. If radius triples, surface area factor?

2. Solve 70t+500=40t+1100.

3. Legs 21 and 28: hypotenuse?

4. 7.5 kW loses 16%. New output?

5. P(storm)=0.25 and P(failure|storm)=0.10. Joint probability?

Mission Extension

Change one numerical condition in a practice problem. Solve the revised problem, then explain how and why the answer changed.

Reflection Log

Which model or strategy was most useful in this mission? Describe one check that increased your confidence.

Final Mission Reflection

Choose one algebra model, one geometry model, and one trigonometry model from the course. Explain what each helped you discover about a space mission.

Completion Record

[ ] Mission 1: Launch Calculations

[ ] Mission 2: Planetary Geometry

[ ] Mission 3: Outer Solar System Navigation

[ ] Mission 4: Gravity and Orbital Paths

[ ] Mission 5: Orbital Motion and Gravity Lab

[ ] Mission 6: Black Holes and Gravity Wells

[ ] Mission 7: Exoplanet Detectives

[ ] Mission 8: Space Habitat Engineering

[ ] Mission 9: Space Station Structural Design

[ ] Mission 10: Outer Planets Capstone

Student Glossary of Mathematical and Space Terms

Use the course meaning shown here. Terms marked as space vocabulary support the mission context; mathematical notation and units retain their defined meanings.

Term	Student-friendly definition	Mission example
amplitude	The distance from a periodic model's midline to a maximum or minimum.	In y=3sin(t)+5, the amplitude is 3.
angle of elevation	An upward angle measured from a horizontal reference line.	A station measures a lander above the horizon.
astronomical unit (AU) [space]	A distance unit equal to about 149.6 million kilometers.	Earth's average distance from the Sun is 1 AU.
average	A representative value; in this course it usually means the arithmetic mean.	Add the flight distances and divide by the number of trials.
baseline	A measured reference length used in scale or triangulation.	Two observation points form a baseline.
bearing	A direction angle measured from a stated reference direction.	The probe travels 53.1° north of east.
coefficient	A numerical factor multiplying a variable.	In 12x+8, the coefficient of x is 12.
composite solid	A three-dimensional figure made from two or more familiar solids.	A habitat combines a cylinder and hemisphere.
constant	A value that does not change in a particular model.	The 8 in y=12x+8 is constant.
constraint	A condition that every acceptable solution or design must satisfy.	A mission plan must remain under budget.
coordinate	A number that identifies a point's position along an axis.	The point (6,8) has two coordinates.
correlation	A pattern in which two variables change together; it does not prove cause.	Activity and orbital decay may be correlated.

Student Glossary of Mathematical and Space Terms

Use the course meaning shown here. Terms marked as space vocabulary support the mission context; mathematical notation and units retain their defined meanings.

Term	Student-friendly definition	Mission example
cubic unit	A unit used to measure volume.	A tank's capacity is measured in cubic meters.
data	Recorded observations or measurements used as evidence.	Brightness readings form a transit dataset.
diameter	A segment through a circle's center with endpoints on the circle.	Diameter is twice the radius.
displacement	Straight-line change in position with a stated direction.	A probe moves east and north from its start.
domain	The input values for which a model is defined or meaningful.	Negative mission time is outside the domain.
ellipse	A closed curve with two focus points.	A planetary orbit can be modeled as an ellipse.
equation	A statement that two mathematical expressions are equal.	$4f+120=920$ models the fuel total.
estimate	A reasonable approximate value found before or instead of an exact result.	Predict whether the answer is near 10 or 100.
evidence-based claim	A conclusion supported directly by analyzed information.	The table supports the recommended mission plan.
exponent	A number showing how many times a base is used as a factor.	In 10^8, the exponent is 8.
expression	Numbers, variables, and operations without an equality sign.	$18h+40$ is an expression.
factor	A number or expression multiplied by another.	The scale factor is 3.

Student Glossary of Mathematical and Space Terms

Use the course meaning shown here. Terms marked as space vocabulary support the mission context; mathematical notation and units retain their defined meanings.

Term	Student-friendly definition	Mission example
focus	One of two fixed points used to define an ellipse.	The Sun lies near one focus of an orbit.
function	A rule assigning exactly one output to each permitted input.	Height is modeled as a function of time.
gravity well [space]	A visual model representing how gravity affects paths near a massive body.	A fabric model suggests curved paths but has limitations.
hypotenuse	The side opposite the right angle in a right triangle.	It represents direct distance in a navigation triangle.
inequality	A comparison showing that quantities are greater than, less than, or possibly equal.	$960-60d \geq 240$ protects the water reserve.
inverse-square relationship	A relationship in which an output varies with one divided by distance squared.	Doubling distance makes force one-fourth as large.
light-minute [space]	The distance light travels in one minute, about 17.99 million kilometers.	Sunlight reaches Earth in about 8.3 minutes.
linear model	A model with a constant rate of change and a straight-line graph.	Altitude $y=4x+2$ rises 4 km each minute.
mean	The sum of values divided by the number of values.	The mean of three launch distances summarizes the trials.
midline	The horizontal center line of a periodic model.	For $y=3\sin(t)+5$, the midline is $y=5$.
mission control [space]	The team and facilities that monitor and direct a mission.	Students explain calculations to Mission Control.
model	A mathematical representation of a situation, including assumptions and limits.	An equation models remaining fuel.

Student Glossary of Mathematical and Space Terms

Use the course meaning shown here. Terms marked as space vocabulary support the mission context; mathematical notation and units retain their defined meanings.

Term	Student-friendly definition	Mission example
orbit [space]	The curved path of an object around another object because of gravity.	A planet follows an orbit around the Sun.
ordered pair	Two coordinates written in a fixed order, usually (x,y).	The point (2,10) records time and altitude.
parabola	The U-shaped graph of a quadratic function.	A flight-height model can form a downward-opening parabola.
parallax [space]	An apparent position shift caused by viewing an object from different locations.	Astronomers use parallax to estimate distance.
percent change	Change divided by the original value, expressed as a percent.	A brightness drop can be measured as a percentage.
period	The input interval after which a pattern repeats.	A sine model repeats after one period.
probability	A number from 0 to 1 describing how likely an event is.	A probability of 0.90 is 90%.
quadratic model	A model containing a squared variable whose graph is a parabola.	Height may be modeled by $h(t)=-5t^2+30t+2$.
radius	The distance from a circle or sphere's center to its edge.	A diameter equals two radii.
rate	A comparison of quantities with different units.	Kilometers per hour is a rate.
reasonableness	The quality of fitting known facts, estimates, units, and context.	A negative travel time is not reasonable.
residual	The difference between an observed value and a model's predicted value.	A positive residual lies above the prediction.

Student Glossary of Mathematical and Space Terms

Use the course meaning shown here. Terms marked as space vocabulary support the mission context; mathematical notation and units retain their defined meanings.

Term	Student-friendly definition	Mission example
scale factor	A multiplier relating corresponding measurements in similar figures or models.	A 3 cm drawing may represent 300,000 km.
scientific notation	A way to write a number as a coefficient times a power of ten.	149,600,000 is 1.496×10^{8}.
simulation	A controlled representation used to investigate how a system may behave.	Classroom mission data are labeled simulations.
slope	The rate of vertical change compared with horizontal change.	Slope 4 means altitude rises 4 km per minute.
square unit	A unit used to measure area.	Planetary surface area uses square kilometers.
system of equations	Two or more equations solved together for shared unknowns.	Two support-load equations determine A and B.
telemetry [space]	Measurements transmitted from a spacecraft or instrument.	Altitude and temperature readings are telemetry.
transit [space]	The passage of one object in front of another from an observer's viewpoint.	An exoplanet transit may reduce measured starlight.
triangulation	Finding a location or distance using a measured baseline and angles.	Observers estimate auroral height indirectly.
unit conversion	Changing a measurement to an equivalent value in another unit.	Convert kilometers to miles using a ratio equal to one.
variable	A symbol representing an unknown or changing quantity.	The variable t can represent time.
vector	A quantity having both magnitude and direction.	A magnetic field can be represented by components.

Student Glossary of Mathematical and Space Terms

Use the course meaning shown here. Terms marked as space vocabulary support the mission context; mathematical notation and units retain their defined meanings.

Term	Student-friendly definition	Mission example
vertex	The turning point of a parabola.	The vertex gives maximum height in a downward-opening model.
volume	The amount of three-dimensional space an object occupies.	A tank's volume describes capacity.

Formula, Symbol, and Unit Reference

Select a formula by matching the requested quantity, known values, units, and geometric or algebraic relationship. Define every variable when you use a formula.

Name	Formula or equivalence	Use
Rate model	$d=rt$	distance = rate × time
Slope	$m=(y_2-y_1)/(x_2-x_1)$	rate of change
Circle circumference	$C=2\pi r=\pi d$	distance around a circle
Circle area	$A=\pi r^2$	area inside a circle
Sphere surface area	$A=4\pi r^2$	exterior area of a sphere
Sphere volume	$V=(4/3)\pi r^3$	space inside a sphere
Cylinder volume	$V=\pi r^2 h$	base area × height
Cone volume	$V=(1/3)\pi r^2 h$	one-third of a matching cylinder
Pythagorean theorem	$a^2+b^2=c^2$	right-triangle side relationship
Tangent	$\tan\theta=\text{opposite}/\text{adjacent}$	right-triangle angle or side

Notation and Units

Keep variable names, operation signs, coordinate order, exponents, π, inequality signs, and formula structure unchanged. Always attach the correct linear, square, or cubic unit to a result.

Formula, Symbol, and Unit Reference

Select a formula by matching the requested quantity, known values, units, and geometric or algebraic relationship. Define every variable when you use a formula.

Name	Formula or equivalence	Use
Quadratic vertex time	$t=-b/(2a)$	input coordinate of a parabola's vertex
Percent change	(new-original)/original ×100%	signed relative change
Experimental probability	successes/trials	observed relative frequency
Independent events	P(A and B)=P(A)P(B)	joint probability when independent
Inverse square	$F=k/r^2$	output decreases with squared distance
Arithmetic mean	sum of values/number of values	average used in this course
Distance formula	$d=\sqrt{[(x_2-x_1)^2+(y_2-y_1)^2]}$	coordinate-plane distance
Law of Cosines	$c^2=a^2+b^2-2ab\cos C$	side in a non-right triangle
Astronomical unit	1 AU≈149.6 million km	average Earth-Sun distance
Light time	time=distance/speed of light	one-way signal or sunlight time

Notation and Units

Keep variable names, operation signs, coordinate order, exponents, π, inequality signs, and formula structure unchanged. Always attach the correct linear, square, or cubic unit to a result.

Mathematical Action-Verb Reference

The first verb in an objective or direction tells you what evidence to produce.

Action verb	What the student should do
analyze	Examine parts, patterns, and relationships to reach a conclusion.
calculate	Use arithmetic or a formula to obtain a numerical result.
compare	Identify meaningful similarities and differences.
convert	Express an equivalent measurement in another unit or form.
define	State the precise meaning of a term.
describe	Communicate relevant characteristics or steps.
determine	Find an answer using evidence and reasoning.
estimate	Find a reasonable approximate value.
evaluate	Judge a value, expression, model, or claim using criteria.
explain	Communicate how or why, supported by reasoning.
graph	Represent a relationship on coordinate axes.
identify	Recognize and name the requested feature or value.
interpret	Explain what a mathematical result means in context.
justify	Support a choice or claim with mathematical evidence.
model	Represent a situation with mathematics.
predict	State an expected result before observing or calculating it.
solve	Find values that satisfy a mathematical condition.
verify	Check that a result satisfies the model, units, and context.

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This V8 edition is the controlled English source for multilingual adaptation. Translation work must reference the V8 wording, glossary, formulas, numerical values, answer keys, image credits, and page content. Later English revisions require a new version number and a documented translation-impact review.

Locked Content

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- All action-based objectives and student directions
- All glossary definitions and approved source terms
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Localization Decisions Requiring Approval

- Decimal point or decimal comma
- Digit-grouping convention
- Unit spacing and abbreviations
- Right-to-left mathematical layout
- Regional word choice and grade-level register

Curriculum Reference and Attribution

The expanded mathematical practices in this independent educational adaptation were informed by NASA IMAGE/POETRY, Exploring Space Mathematics: Space Math I. The reference emphasizes compact investigations, authentic space-weather contexts, formula substitution, scale drawings, triangle properties, graphs, tables, percentages, probability, and evidence-based reasoning for Grades 7-9.

All new Space Math Explorers wording, numerical values, questions, worked solutions, module organization, and illustrations are original to this course. No NASA endorsement is implied.

Reference

Odenwald, S., and contributing educators. Exploring Space Mathematics: Space Math I. NASA IMAGE satellite Education and Public Outreach Project (POETRY).

https://faculty.tamuc.edu/cdavis/resources/AESP/InstructionalMaterials/Space%20Math%20I.pdf

Planet-distance reference: NASA/JPL-Caltech, Solar System Sizes and Distances Reference Guide. https://d2pn8kiwq2w21t.cloudfront.net/documents/scaless_reference_xJvjKH2.pdf

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