

Operation: Outta Here!

Movie I: Taxiing and Takeoff

Movie II: En Route

Movie III: Landing

Instructional Curriculum

Mathematics: Grades 8-10

Dmitriy Voloshin

Table of Contents

Movie I: Taxiing and Takeoff

Introduction	pg. 5
Guiding Question	pg. 5
Main Concept	pg. 6
NASA Relevance	pg. 6
Prerequisite Skills	pg. 6
Case Study Objectives	pg. 6
NCTM Standards	pg. 7
Activity Preparation	pg. 8
Materials	pg. 8
Time for Activity	pg. 8
Engage	pg. 8
Explore	pg. 8
Explain	pg. 9
Extend	pg. 9
Evaluate	pg. 9
Pre-Algebra: Student Handout I.1	pg. 11
Pre-Algebra: Teacher Handout I.1	pg. 12
Pre-Algebra: Findings Sheet I.1	pg. 14
Algebra I: Student Handout I.2	pg. 15
Algebra I: Teacher Handout I.2	pg. 16
Algebra I: Findings Sheet I.2	pg. 18
Geometry: Student Handout I.3	pg. 19
Geometry: Teacher Handout I.3	pg. 21
Geometry: Findings Sheet I.3	pg. 23

Movie II: En Route

Introduction	pg. 24
Guiding Question	pg. 24
Main Concept	pg. 24
NASA Relevance	pg. 25
Prerequisite Skills	pg. 25
Case Study Objectives	pg. 25
NCTM Standards	pg. 26
Activity Preparation	pg. 27
Materials	pg. 27
Time for Activity	pg. 27
Engage	pg. 27
Explore	pg. 28
Explain	pg. 28
Extend	pg. 28
Evaluate	pg. 29
Case Study II.1: Student Handout	pg. 30
Case Study II.1: Teacher Handout	pg. 31
Case Study II.1: Findings Sheet	pg. 32
Case Study II.2: Student Handout	pg. 33
Case Study II.2: Teacher Handout	pg. 34
Case Study II.2: Findings Sheet	pg. 37
Case Study II.3: Student Handout	pg. 38
Case Study II.3: Teacher Handout	pg. 39
Case Study II.3: Findings Sheet	pg. 40

Movie III: Landing

Introduction	pg. 41
Guiding Question	pg. 41
Main Concept	pg. 41
NASA Relevance	pg. 42
Prerequisite Skills	pg. 42
Case Study Objectives	pg. 42
NCTM Standards	pg. 43
Activity Preparation	pg. 44
Materials	pg. 44
Time for Activity	pg. 44
Engage	pg. 44
Explore	pg. 44
Explain	pg. 45
Extend	pg. 45
Evaluate	pg. 46
Case Study III.1: Student Handout	pg. 47
Case Study III.1: Teacher Handout	pg. 48
Case Study III.1: Findings Sheet	pg. 49
Case Study III.2: Student Handout	pg. 50
Case Study III.2: Teacher Handout	pg. 51
Case Study III.2: Findings Sheet	pg. 52
Case Study III.3: Student Handout	pg. 53
Case Study III.3: Teacher Handout	pg. 54
Case Study III.3: Findings Sheet	pg. 55

Operation: Outta Here!

Case Study I (Movie 1): Taxiing and Takeoff

Instructional Curriculum
Mathematics, Grades 8-10

Introduction: Three case studies of various levels of difficulty are developed to accompany Movie 1. Each case study consists of the following scenario: there are multiple aircraft taxiing on the runway awaiting takeoff. Only one aircraft may take off at any given time. Each case study asks three questions about which aircraft will be first to take off, how much time it would take each aircraft to reach the takeoff point, etc.

The first case study (I.1) is designed for pre-Algebra students / Algebra I students. The students are asked questions about two aircraft taxiing on two parallel runways. Basic linear equation solving skills are needed to successfully complete the case study.

The second case study (I.2) is designed for advanced Algebra I students as it discusses a situation with three aircraft taxiing on perpendicular runways towards the final takeoff runway. Questions similar to those in the level I case study are being asked at the end of this case study.

The third case study (I.3) is designed for Geometry students familiar with the Pythagorean theorem as it discusses three aircraft taxiing on runways that form two 45-degree angles. The students are asked several critical thinking questions at the end of this case study.

Guiding Question: How can multiple aircraft move about the surface of an airport quickly and safely?

Main Concept: Paper-and-pencil calculations can be used to problem-solve simple cases but technology is required for speed and accuracy in more complicated cases.

NASA Relevance: The operational concept of Advanced Surface Automation seeks to automate some of the lower level tasks that humans now perform.

Prerequisite Skills: To successfully complete Case Study I Level 1, the students should be able to add positive integers and solve simple inequalities.

To successfully complete Case Study I Level 2, the students should be able to add positive integers, solve simple inequalities and linear equations.

To successfully complete Case Study I Level 3, the students should be able to add positive integers, solve simple inequalities and linear equations. The students should also be familiar with the Pythagorean theorem and 1-1- $\sqrt{2}$ triangles. The students should also be able to solve multiple step problems.

CS Objectives: By completing this case study the students will gain appreciation for some of the on-ground functions performed by the air-traffic controller while mastering their pre-algebra, algebra, and geometry skills.

The students will be able to:

Add positive integers;
Solve simple inequalities;
Solve linear equations;
Find the

hypotenuse in a right triangle;
Convert units of measure;
Simplify and add fractions;

NCTM Standards: *Fully Meets:*

NCTM: Numbers and Operations, Understand meanings of operations and how they relate to one another 9-12:

Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.

NCTM: Algebra, Understand patterns, relations, and functions 9-12:

Analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior.

Project 2061: Design and Systems, Designed Systems Grades 6-8 8E/3:

Computer control of mechanical systems can be much quicker than human control. In situations where events happen faster than people can react, there is little choice but to rely on computers. Most complex systems still require human oversight, however, to make certain kinds of judgments, to react to unexpected failures, and to evaluate how well the system is serving its intended purposes.

Partially Meets:

Project 2061: Grades 9-12 3B/3:

Complex systems have layers of controls. Some controls operate particular parts of the system and some control other controls. Even fully automatic systems require human control at some point.

Project 2061: Grades 9-12 2B/1:

Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave.

Activity Preparation: Before starting each module the students will watch the appropriate video clip on the website. The students will consult the appropriate *Operation: Outta Here!* website (<http://quest.arc.nasa.gov/test/ooh/design/>) where they will progress through the material at their own pace.

Materials: Each student is expected to have a pencil, ruler, sheet of paper, and an appropriate student handout. Calculators are optional.

Time for Activity: Each case study is expected to take between one and two academic hours depending on the skills of the students. A teacher may assign more than one case study per student.

Engage: Before each case study, the students should view the video clips on <http://quest.arc.nasa.gov/test/ooh/design/>. The students should also review the website at their own pace.

The teacher may start a discussion by asking the students if they've ever flown. The topics of delays and airport congestion should be addressed next after the students have established a connection between the subject matter and their lives.

Explore: After having the class discussion, divide the students into groups of two to four and ask them to brainstorm some of their own solutions to the problems presented in the movies. Give each group ten to fifteen minutes. Have each group put their ideas on post-its and to put them on the board.

Explain:

Once you collect most of the ideas from your class, read some of them to the students and discuss their merits.

Give the students several scenarios of multiple aircraft taxiing at the same time. Lead the discussion on how to calculate which aircraft will be first to take off. Explain that, generally, the aircraft that reaches the end of its taxiway first is the first aircraft cleared for takeoff. This is a good opportunity to demonstrate a few time and motion problems, problems using systems of equations, or problems dealing with Cartesian coordinates.

Extend:

After demonstrating several problems and giving students background information on the issues of taxiing and takeoff congestion, distribute the case studies to the students.

There are three levels of case study I: I.1, I.2, and I.3. The levels of difficulty increase with the level numbers. Case study I.1 is written for pre-Algebra end not-yet-proficient Algebra I students. Case study I.2 is written for Algebra I students. Finally, case study I.3 is written for Geometry students.

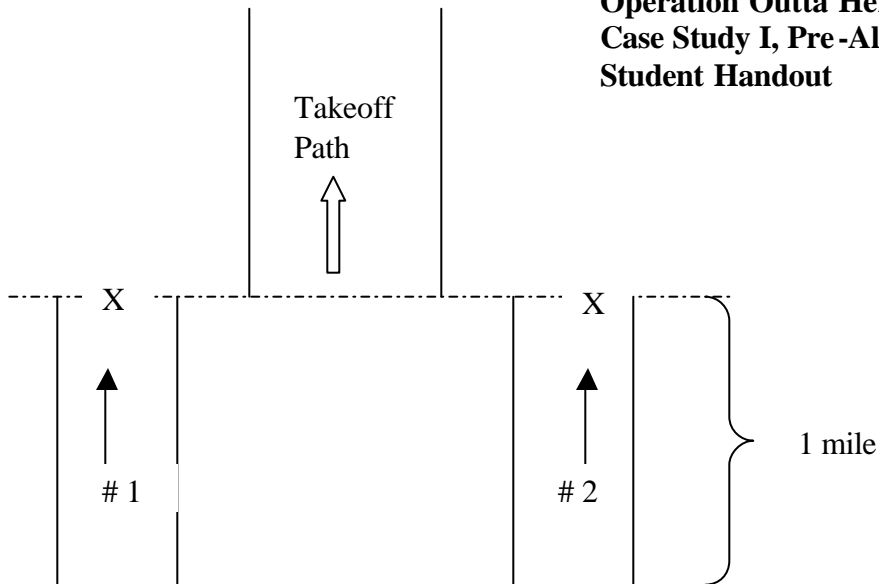
Should you decide to devote more classroom time to Operation: Outta Here, you may wish to give more than one case study per student. For example, students in your pre-Algebra class may begin by analyzing case study I.1 and then attempt to analyze case study I.2, perhaps, with some additional help from their instructor. Geometry students may work on case study I.2 after completing case study I.3.

Depending on the skills of your students and your teaching style, the students may work on their case studies individually or in groups. Case studies may be completed in class or at home.

Evaluate:

As students complete the case studies, their findings shall be presented to the class. Have each student or group, if appropriate, fill out the Findings Sheet where the students will indicate their findings and show their reasoning. After analyzing students' responses, proceed with re-teaching or enrichment as needed.

Operation Outta Here!
Case Study I, Pre-Algebra (I.1)
Student Handout



Problem Statement:

You are an air traffic controller overlooking two parallel one mile-long taxiways. Generally, the aircraft that reaches the end of the taxiway first (marked with “X”) will be the first aircraft cleared for takeoff.

Aircraft # 1 starts at the beginning of taxiway # 1 by traveling 3 minutes at 12 miles per hour. Then the aircraft stops for 2 minutes and finally travels 4 additional minutes at 6 miles per hour.

Aircraft # 2 starts at the beginning of taxiway # 2 by traveling 5 minutes at 6 miles per hour. Then the aircraft stops for 2 minutes and finally travels 6 additional minutes at 5 miles per hour.

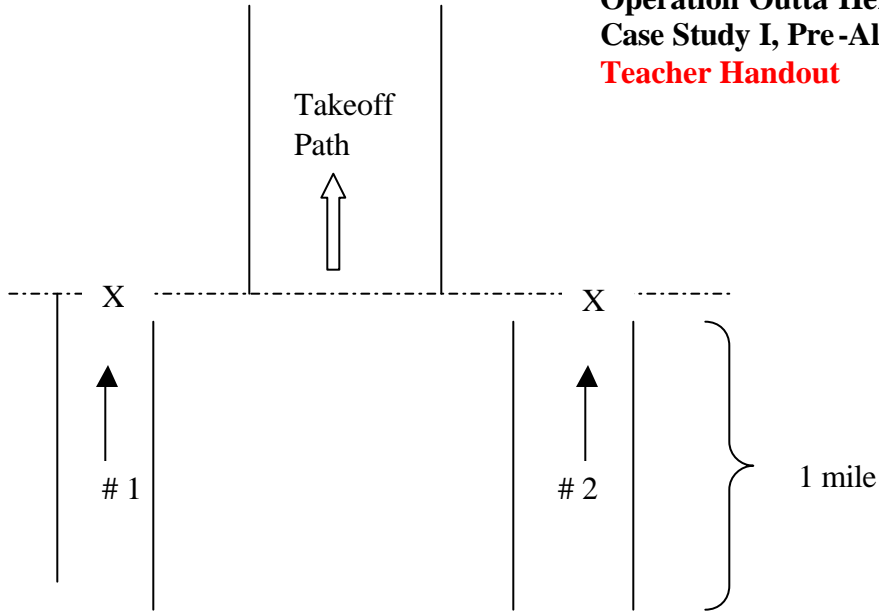
Analysis Questions:

Question 1: How long will it take for aircraft # 1 to reach the takeoff path?

Question 2: How long will it take for aircraft # 2 to reach the takeoff path?

Question 3: Which aircraft will take off first and why?

Operation Outta Here!
Case Study I, Pre-Algebra (I.1)
Teacher Handout



Problem Statement:

You are an air traffic controller overlooking two parallel one mile-long taxiways. Generally, the aircraft that reaches the end of the taxiway first (marked with “X”) will be first cleared for takeoff.

Aircraft # 1 starts at the beginning of taxiway # 1 by traveling **3 minutes** at 12 miles per hour. Then the aircraft stops for **2 minutes** and finally travels **4 additional minutes** at 6 miles per hour.

Aircraft # 2 starts at the beginning of taxiway # 2 by traveling **5 minutes** at 6 miles per hour. Then the aircraft stops for **2 minutes** and finally travels **6 additional minutes** at 5 miles per hour.

Analysis Questions:

Question 1: How long will it take for aircraft # 1 to reach the takeoff path?

[3 min + 2 min + 4 min = 9 min]

Do you want to explain the math a little more here??

Question 2: How long will it take for aircraft # 2 to reach the takeoff path?

[5 min + 2 min + 6 min = **13 min**]

Question 3: Which aircraft will take off first and why?

[**Aircraft # 1** will take off first because it will be first to reach the takeoff path.]

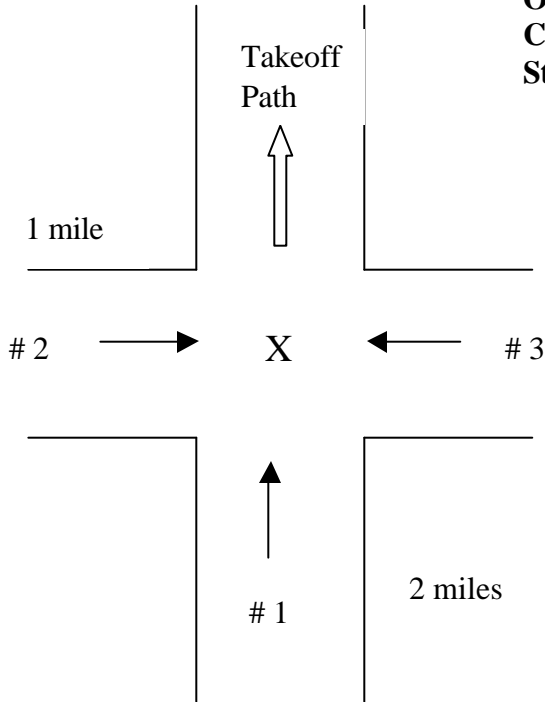
Operation Outta Here!
Case Study I, Pre-Algebra (I.1)
Findings Sheet

Name(s): _____
Period: _____
Date: _____

Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<i>Question 1:</i> How long will it take for aircraft # 1 to reach the takeoff path?		
<i>Question 2:</i> How long will it take for aircraft # 2 to reach the takeoff path?		
<i>Question 3:</i> Which aircraft will take off first and why?		

Operation Outta Here!
Case Study I, Algebra I (I.2)
Student Handout



Problem Statement :

You are an air traffic controller overlooking three taxiways leading to a takeoff runway. Taxiways # 2 and # 3 are one mile-long and form a right angle with taxiway # 1, which is two miles-long, and with the takeoff runway. Generally, the aircraft that reaches the end of its taxiway first is the first aircraft cleared for takeoff.

Aircraft # 1 starts at the beginning of taxiway # 1 by traveling 3 minutes at 30 miles per hour. Then the aircraft stops for 1 minute and finally travels 2 additional minutes at 15 miles per hour.

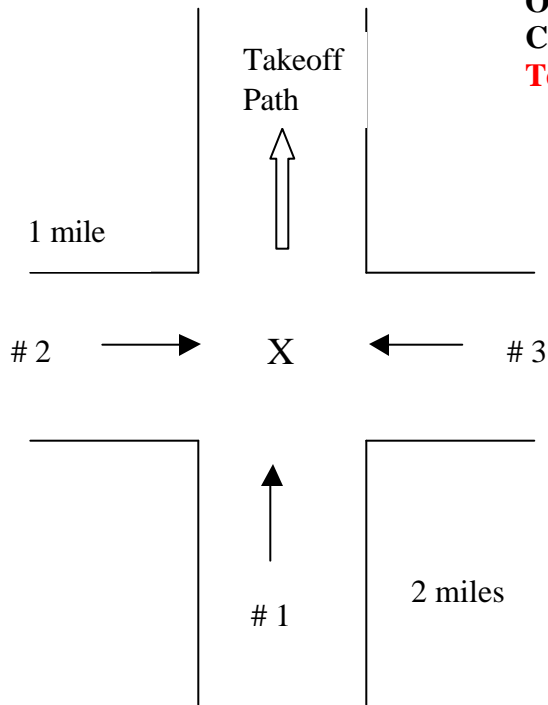
Aircraft # 2 starts at the beginning of taxiway # 1 by traveling 3 minutes at 15 miles per hour. Then the aircraft stops for 1 minute and finally travels 1 additional minute at 15 miles per hour.

Aircraft # 3 starts at the beginning of taxiway # 3 by traveling 2 minutes at 20 miles per hour. Then the aircraft stops for 1 minute and finally travels 1 additional minute at 20 miles per hour.

Analysis Questions :

- Question 1: Which aircraft will take off first and why?
- Question 2: What would happen if aircraft # 1 does not stop for 1 minute?
- Question 3: Which aircraft would be the closest to the end of its taxiway after 1 minute, 2 minutes, and 3 minutes?

Operation Outta Here!
Case Study I, Algebra I (I.2)
Teacher Handout



Problem Statement :

You are an air traffic controller overlooking three taxiways leading to a takeoff runway. Taxiways # 2 and # 3 are one mile-long and form a right angle with taxiway # 1, which is two miles-long, and with the takeoff runway. Generally, the aircraft that reaches the end of its taxiway first is the first aircraft cleared for takeoff.

Aircraft # 1 starts at the beginning of taxiway # 1 by traveling 3 minutes at 30 miles per hour. Then the aircraft stops for 1 minute and finally travels 2 additional minutes at 15 miles per hour.

Aircraft # 2 starts at the beginning of taxiway # 1 by traveling 3 minutes at 15 miles per hour. Then the aircraft stops for 1 minute and finally travels 1 additional minute at 15 miles per hour.

Aircraft # 3 starts at the beginning of taxiway # 3 by traveling 2 minutes at 20 miles per hour. Then the aircraft stops for 1 minute and finally travels 1 additional minute at 20 miles per hour.

Based on highlighted information above, the teacher will construct the following chart with the students. Please be sure to check your units of measure.

Aircraft # 1	Aircraft # 2	Aircraft # 3
3 min @ 30 m/h = 1.5 m	3 min @ 15 m/h = .75 m	2 min @ 20 m/h = 2/3 m
1 min stop	1 min stop	1 min stop
2 min @ 15 m/h = 0.5 m	1 min @ 15 m/h = .25 m	1 min @ 20 m/h = 1/3 m
Σ t, d = 6 min, 2 m	Σ t, d = 5 min, 1 m	Σ t, d = 4 min, 1 m

Analysis Questions:

Question 1: Which aircraft will take off first and why?

[Aircraft # 3 will take off first because it would take the least amount of time to reach the end of its taxiway.]

Question 2: What would happen if aircraft # 1 does not stop for 1 minute?

[If aircraft # 1 does not stop for 1 minute, it would arrive to the end of its taxiway at the same time as aircraft # 2.]

Question 3: Which aircraft would be the closest to the end of its taxiway after 1 minute, 2 minutes, and 3 minutes?

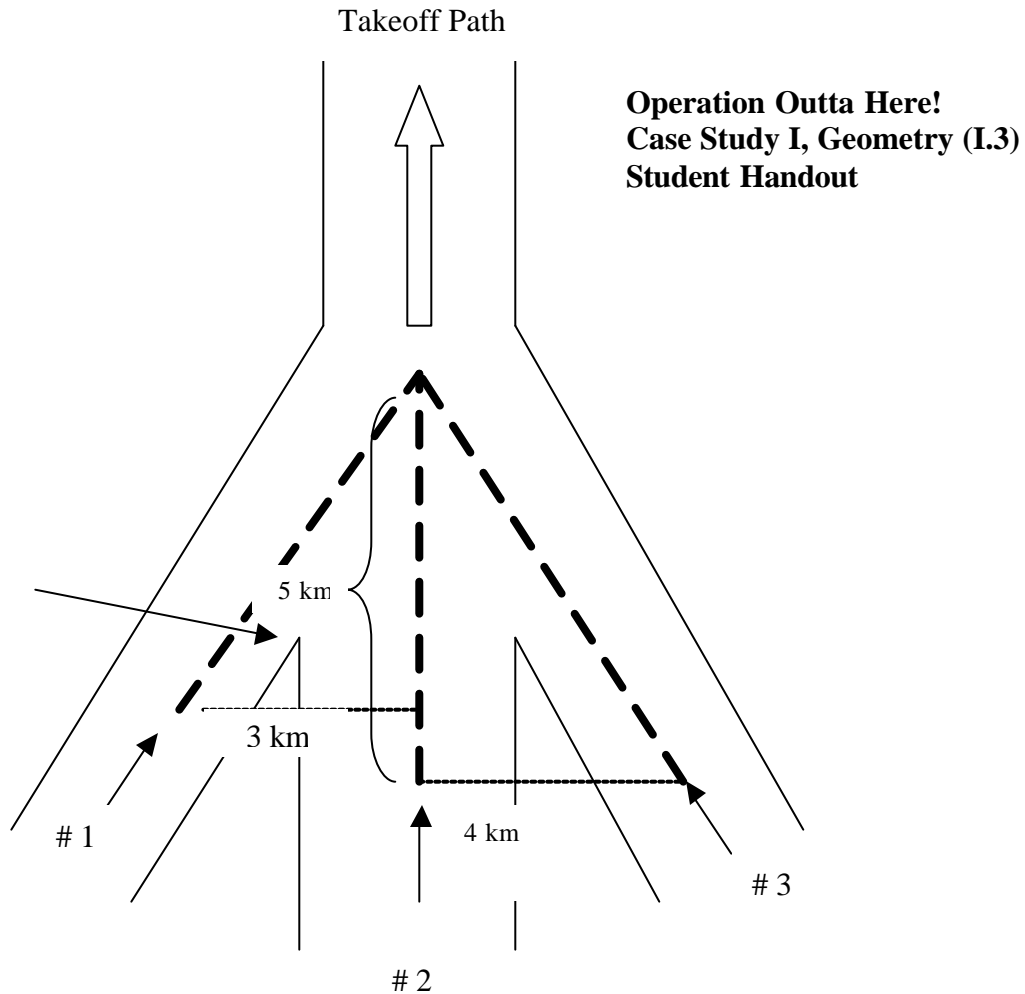
[After 1 minute, aircraft # 3 would be closest to the end of its taxiway.
After 2 minutes, aircraft # 3 would be closest to the end of its taxiway.
After 3 minutes, aircraft # 1 would be closest to the end of its taxiway.]

Operation Outta Here!
Case Study I, Algebra I (I.2)
Findings Sheet

Name(s): _____
Period: _____
Date: _____

Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<i>Question 1:</i> Which aircraft will take off first and why?		
<i>Question 2:</i> What would happen if aircraft # 1 does not stop for 1 minute?		
<i>Question 3:</i> Which aircraft would be the closest to the end of its taxiway after 1 minute, 2 minutes, and 3 minutes?		



Problem Statement :

You are an air traffic controller overseeing three taxiways leading to a takeoff runway. Taxiway # 1 forms a 45° angle with taxiway #2.

Generally, the aircraft that reaches the end of its taxiway first is the first aircraft cleared for takeoff.

Aircraft # 1 will begin taxiing at the point 3 kilometers west of aircraft # 2 taxiing path.
 Aircraft # 3 will begin taxiing at the point 4 kilometers east of aircraft # 2 taxiing path.
 What about aircraft #2? – Relying completely on the graph??

Analysis Questions:

Question 1: How far is aircraft # 1 from the end of its taxiway? Aircraft # 2? Aircraft # 3?

Question 2: Which aircraft is the closest to the end of its taxiway?

Question 3: If aircraft # 1 starts taxiing at the constant speed of 15 km/h and aircraft # 2 starts taxiing at the constant speed of 20 km/h, what would be the minimum speed required for aircraft # 3 in order to arrive to the end of its taxiway at least one minute before aircraft # 1 or aircraft # 3?

Analysis Questions:

- Question 1: How far is aircraft # 1 from the end of its taxiway? [$3\sqrt{2}$ km b/c there is a 1-1- $\sqrt{2}$ triangle formed with one right and two 45° angles.]
 Aircraft # 2? [5 km as evident from the graph.]
 Aircraft # 3? [$\sqrt{41}$ km b/c we're looking for a hypotenuse in a triangle with sides of 4 km and 5 km.]
- Question 2: Which aircraft is the closest to the end of its taxiway? [Aircraft # 1 is the closest aircraft to the end of its taxiway at $\sqrt{41}$ km.]
- Question 3: If aircraft # 1 starts taxiing at the constant speed of 15 km/h and aircraft # 2 starts taxiing at the constant speed of 20 km/h, what would be the minimum speed required for aircraft # 3 in order to arrive to the end of its taxiway at least one minute before aircraft # 1 or aircraft # 3?

[Suggest to students to populate the following table:

	Aircraft # 1	Aircraft # 2	Aircraft # 3
Taxiway Length [km]	$3\sqrt{2}$	5	$\sqrt{41}$
Taxiing Speed [km/h]	15	20	x
Taxiing Time [hr]	$3\sqrt{2} / 15$	$5 / 20$	$\sqrt{41} / x$
Taxiing Time, Simplified [hr]	$.2\sqrt{2}$.25	$\sqrt{41} / x$

Upon examining the data the students should notice that aircraft # 2 has a shorter taxiing time than aircraft # 1 [$.25 < .2\sqrt{2}$]. Therefore, in order to take off first, aircraft # 3 would need to taxi $\sqrt{41}$ km in 14 min [$.25 \text{ hr} - 1 \text{ min} = 15 \text{ min} - 1 \text{ min} = 14 \text{ min}$]. Then its speed would have to be $30\sqrt{41} / 7$ km/h [$\sqrt{41} / 14 \text{ km/min} = 60\sqrt{41} / 14 \text{ km/hr} = 30\sqrt{41} / 7 \text{ km/h}$].]

Operation Outta Here!
Case Study I, Geometry (I.3)
Findings Sheet

Name(s): _____
 Period: _____
 Date: _____

Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<i>Question 1:</i> How far is aircraft # 1 from the end of its taxiway? Aircraft # 2? Aircraft # 3?		
<i>Question 2:</i> Which aircraft is the closest to the end of its taxiway?		
<i>Question 3:</i> If aircraft # 1 starts taxiing at the constant speed of 15 km/h and aircraft # 2 starts taxiing at the constant speed of 20 km/h, what would be the minimum speed required for aircraft # 3 in order to arrive to the end of its taxiway at least one minute before aircraft # 1 or aircraft # 3?		

Operation: Outta Here!

Case Study II (Movie I): En Route

Instructional Curriculum
Mathematics, Grades 8-10

Introduction: Three case studies of various levels of difficulty are developed to accompany Movie 2. Each case study consists of the following scenario: a student is assigned a role of a pilot who has encountered some bad weather; a student is asked to analyze the ways to avoid the bad weather.

The first case study (II.1) is designed for pre-Algebra students / Algebra I students. The students are asked to calculate the slopes and equations followed by the aircraft when avoiding bad weather.

The second case study (II.2) is designed for advanced Algebra I students as it continues from the information discovered in case study II.1 and asks the students to represent their findings graphically.

The third case study (II.3) is designed for advanced Algebra I as it involves the creating and solving of the systems of equations.

Guiding Question: How can the current air transportation system safely handle a substantial increase in the number and frequency of aircraft in the system?

Main Concept: The decisions that must be made during a flight: avoiding weather, flight paths, landing, changing airspace, proximity to other aircraft, etc. are currently done via pilot-ground communication.

Automation of many of these tasks will allow these decisions to be made through advanced airspace concepts, reducing the number of pilot-ground communications and hand-offs needed for a simple flight, thereby relieving ground controllers of an unrealistic and dangerous workload.

NASA Relevance: Advanced Airspace Concepts address this capacity problem and can maintain the system even when there is bad weather. By giving pilots more control, these concepts will take the burden off ground controllers and automate in-flight decisions. This is a paradigm shift from the current air transportation system. Also, oceanic separation is a way for these concepts to be safely flight-tested without air traffic controllers.

Prerequisite Skills: To successfully complete Case Study II Level 1, the students should be able to create and solve basic motion (time-distance) equations and to be able to calculate the slope

To successfully complete Case Study II Level 2, which builds on the previous case, the students should be able to plot points and graph linear equations.

To successfully complete Case Study II Level 3, the students should be able to create and solve the systems of equations.

CS Objectives: By completing this case study the students will gain appreciation for some of the situations encountered by the pilots en route while mastering their pre-algebra, algebra, and geometry skills.

The students will be able to:

Calculate slope;
Solve linear
equations;
Solve systems of
equations;

Plot points;
Graph linear
functions;
Convert units of
measure;

NCTM Standards: *Fully Meets:*

NCTM: Numbers and Operations, Understand meanings of operations and how they relate to one another 9-12:

Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.

NCTM: Algebra, Understand patterns, relations, and functions 9-12:

Analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior.

Project 2061: Design and Systems, Designed Systems Grades 6-8
8E/3:

Computer control of mechanical systems can be much quicker than human control. In situations where events happen faster than people can react, there is little choice but to rely on computers. Most complex systems still require human oversight, however, to make certain kinds of judgments, to react to unexpected failures, and to evaluate how well the system is serving its intended purposes.

Partially Meets:

Project 2061: Grades 9-12 3B/3:

Complex systems have layers of controls. Some controls operate particular parts of the system and some control other controls. Even fully automatic systems require human control at some point.

Project 2061: Grades 9-12 2B/1:

Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave.

Activity Preparation: Before starting each module the students will watch the appropriate video clip on the website. The students will consult the appropriate *Operation: Outta Here!* website (<http://quest.arc.nasa.gov/test/ooh/design/>) where they will progress through the material at their own pace.

Materials: Each student is expected to have a pencil, ruler, calculator, sheet of paper, and an appropriate student handout.

Time for Activity: Each case study is expected to take between one and two academic hours depending on the skills of the students. A teacher may assign more than one case study per student. Note: case study II.2 is based on case study II.1.

Engage: Before each case study, the students should view the video clips on <http://quest.arc.nasa.gov/test/ooh/design/>. The students should also review the website at their own pace.

The teacher may start a discussion by asking the students if they've ever flown. The teacher may continue by discussing different obstacles that a pilot could encounter en route.

Explore: After having the class discussion, divide the students into groups of two to four and ask them to brainstorm some of their own solutions to the problems presented in the movies. Give each group ten to fifteen minutes. Have each group put their ideas on post-its and ask them to put their ideas on the board.

Explain: Once you collect most of the ideas from your class, read some of them to the students and discuss their merits.

Give the students several scenarios of pilots encountering bad weather. Lead the discussion on how to calculate the best route to avoid it. This is a good opportunity to demonstrate a few time and motion problems, problems using systems of equations, or problems requiring plotting points and graphing.

Extend: After demonstrating several problems and giving students background information on the issues the pilots face en route, such as bad weather, distribute the case studies to the students.

There are three levels of case study II: II.1, II.2, and II.3. The levels of difficulty increase with the level numbers. Case study II.2 requires familiarity with the case study II.1.

Should you decide to devote more classroom time to Operation: Outta Here, you may wish to give more than one case study per student. For example, students who successfully complete case study II.1 may be assigned case study II.2.

Depending on the skills of your students and your teaching style, the students may work on their case studies individually or in groups. Case studies may be completed in class or at home.

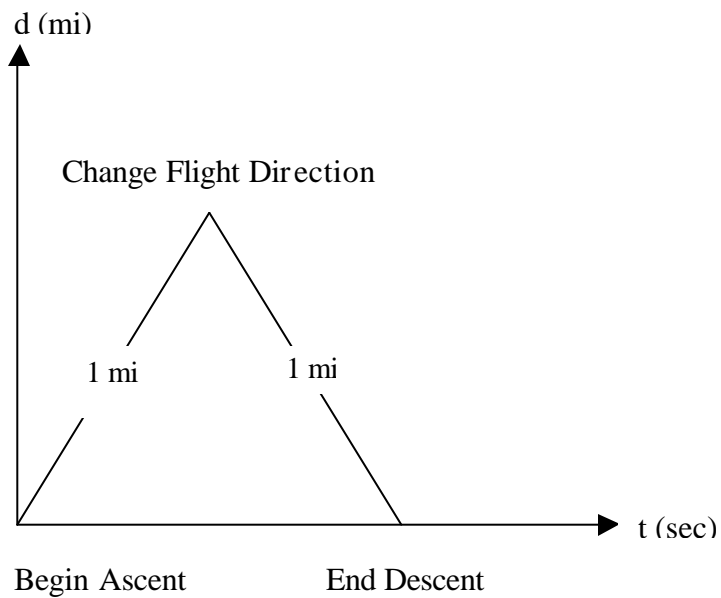
Evaluate:

As students complete the case studies, their findings shall be presented to the class. Have each student or group, if appropriate, fill out the Findings Sheet where the students will indicate their findings and show their reasoning. After analyzing students' responses, proceed with re-teaching or enrichment as needed.

Operation: Outta Here!
Case Study II, Level 1 (II.1)
Student Handout

You are an airline pilot who just received directions to change your flight course in order to avoid a storm system in front you. You are ordered to climb 1 mile flying northeast at 750 m/h. After passing the storm, to return to the original course, you will descend 1 mile flying southeast at 750 m/h.

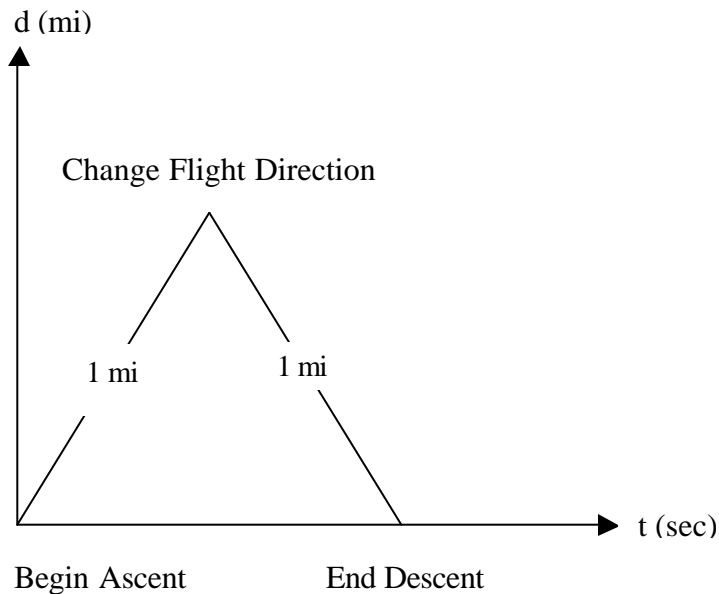
Determine the slopes and linear equations necessary to avoid the storm.



Operation: Outta Here!
Case Study II, Level 1 (II.1)
Teacher Handout

You are an airline pilot who just received directions to change your flight course in order to avoid a storm system in front you. You are ordered to climb 1 mile flying northeast at 750 m/h. After passing the storm, to return to the original course, you will descend 1 mile flying southeast at 750 m/h.

Determine the slopes and linear equations necessary to avoid the storm.



Begin by instructing the students to convert 750 mi/hr to 0.21 mi/sec. Since the aircraft speed is constant, in the first flight segment, while ascending, the equation would be $d=0.21t$, $m=0.21$ ($m = \text{slope}$). In the second segment, while descending, the equation would be $d=2-0.21t^*$, $m=-0.21$.

* To descend 1 mile, aircraft's motion could be described by $d=1-0.21t$ equation. To offset the fact that flight path began after ascending 1 mile, the equation would be $d=1+(1-0.21t)$ or $d=2-0.21t$.

Operation Outta Here!
Case Study II.1
Findings Sheet

Name(s): _____
Period: _____
Date: _____

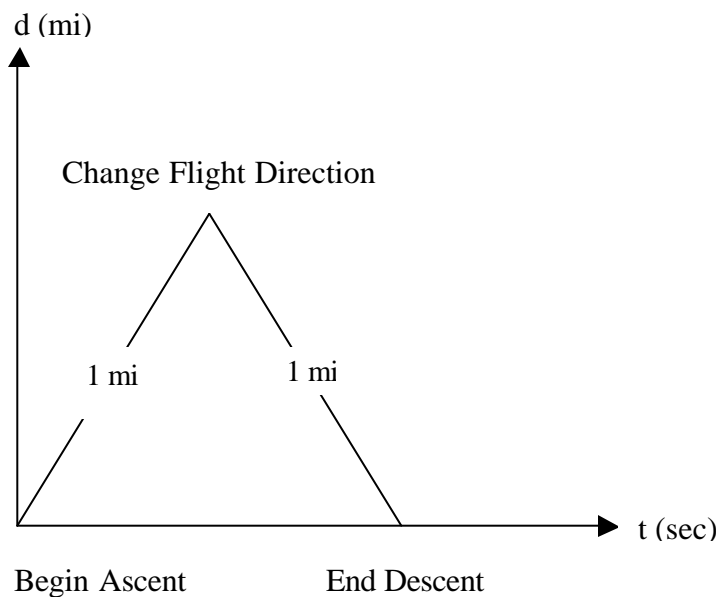
Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<i>Question 1:</i> Determine the slopes of the linear equations necessary to avoid the storm.		
<i>Question 2:</i> Derive the linear equations necessary to avoid the storm.		

Operation: Outta Here!
Case Study II, Level 2 (II.2)
Student Handout

You are an airline pilot who just received directions to change your flight course in order to avoid a storm system in front you. You are ordered to climb 1 mile flying northeast at 750 m/h. After passing the storm, to return to the original course, you will descend 1 mile flying southeast at 750 m/h.

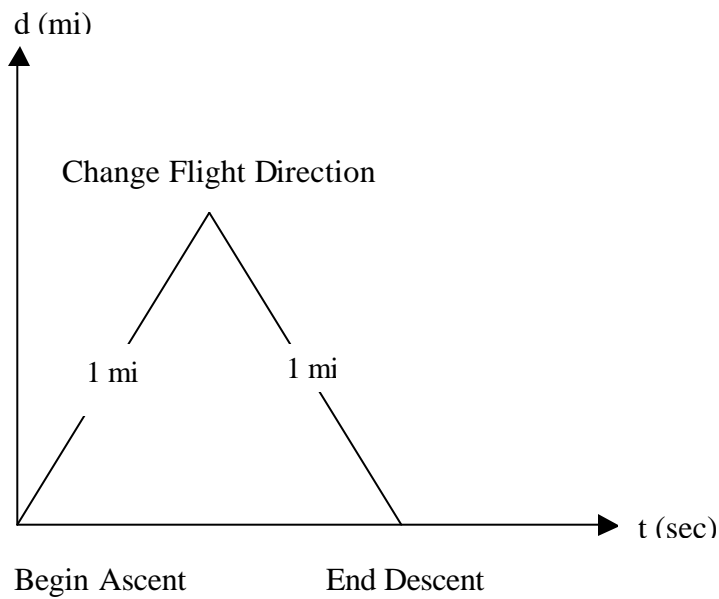
Graph both flight segments on the same graph. In other words, map out the path for the plane that will enable it to follow the course outlined in case study II.1.



Operation: Outta Here!
Case Study II, Level 2 (II.2)
Teacher Handout

You are an airline pilot who just received directions to change your flight course in order to avoid a storm system in front you. You are ordered to climb 1 mile flying northeast at 750 m/h. After passing the storm, to return to the original course, you will descend 1 mile flying southeast at 750 m/h.

Graph both flight segments on the same graph. In other words, map out the path for the plane that will enable it to follow the course outlined in case study II.1.



As discussed in case study II.1, in the first scenario, while climbing, the equation would be $d=0.21t$, $m=0.21$ ($m = \text{slope}$). In the second scenario, while descending, the equation would be $d=2-0.21t$, $m=-0.21$.

Before proceeding further, convert 750 mi/hr to 0.21 mi/sec by dividing 750 by 3600. Also note that it will take the plane 4.8 seconds to ascend/descend 1 mile at a constant speed of 750 m/h.

Begin by calculating how long it will take the plane to ascend 1 mile at 0.21 mi/sec. Since the ascent will take 4.8 seconds, the mathematical equation describing this part of the flight would be: $d(t) = 0.21t$, $0 \leq t \leq 4.8$. Then construct the following table:

*Table 1: Ascent Time Schedule
(Total Flight Time)*

Ascent Time	
$0 \leq t \leq 4.8$	$d = 0.21t$
0	0
1	0.21
2	0.42
3	0.63
4	0.84
4.8	1.0

Instruct the students to use 1-second intervals on the time axis (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10). On the distance axis the students should use 0.1-mile intervals (0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0).

Direct the students to plot the five points above (as little as two points may be required for more advanced students) and to connect them with a straight line. Thus, a $d=0.21t$ graph will be completed.

Since the aircraft has a constant speed, it will also take 4.8 seconds to descend 1 mile. Because the aircraft begins its descend after 1 mile and it takes 4.8 seconds to do so, the equation describing its descend would be $d(t) = 1 - 0.21t$, $0 \leq t \leq 4.8$.

Please clarify to the students that in order to place both graphs on the same axis, the beginning time of the descent would be 4.8 seconds after the ascent began. Consequently, the descent would end 9.6 (4.8×2) seconds after the beginning of ascent.

Therefore, we must adjust the equation from $d=1-0.21t$ to $d=2-0.21t$ in order to account for a fact that the descent would begin at 1 mile after 4.8 seconds of total flight time and would end after 9.6 seconds of total flight time. In other words, the descent could be described mathematically as: $d(t) = 1 - 0.21t$, $4.8 \leq t \leq 9.6$.

Refer to the two tables below:

Table 2: Descent Time Schedule

Descent Time	
$0 \leq t \leq 4.8$	$d = 1 - 0.21t$
0	1
1	0.79
2	0.58
3	0.37
4	0.16
4.8	0

OR

Table 3: Total Flight Descent Time Schedule

Total Flight Time	
$4.8 \leq t \leq 9.6$	$d = 2 - 0.21t$
4.8	1
5	0.95
6	0.74
7	0.53
8	0.32
9.6	0

If the students were to graph the descent separately from the ascent, Table 2 data should have been used. Since the students are asked to graph both flight segments on the same graph, Table 3 data should be used.

Finally, instruct the students to graph the second flight segment using Table 3 on the same graph where they graphed the first flight segment (Table 1).

Operation Outta Here!
Case Study II.2
Findings Sheet

Name(s): _____
Period: _____
Date: _____

Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<p><i>Question 1:</i> Map out the path the plane will follow to avoid the storm introduced in case study II.1</p>		

Operation: Outta Here!
Case Study II, Level 3 (II.3)
Student Handout

You are an airline pilot flying east at a constant speed of 750 mi/hr. You will be flying over the storm front moving in the same directions. The area affected by the storm has a longitudinal shape and it is 600 miles long. The storm is moving at a speed of 100 mi/hr.

Using a system of equations answer the following question. How long will your aircraft be flying over the area affected by the storm? Illustrate your answer graphically.

Operation: Outta Here!
Case Study II, Level 3 (II.3)
Teacher Handout

You are an airline pilot flying east at a constant speed of 750 mi/hr. You will be flying over the storm front moving in the same directions. The area affected by the storm has a longitudinal shape and it is 600 miles long. The storm is moving at a speed of 100 mi/hr.

Using a system of equations answer the following question. How long will your aircraft be flying over the area affected by the storm? Illustrate your answer graphically.

Using time as the independent variable and distance as the dependent variable, we can describe the motion of the aircraft as: $d_a(t) = 750t$. Similarly, the distance traveled by the storm and the area it affects would be: $d_s(t) = 100t + 600$.

In order to calculate how long it will take the aircraft to fly over the area affected by the storm, we must set the distances traveled by the aircraft and the storm equal to each other: $d_a(t) = d_s(t)$. Therefore, $750t = 100t + 600$; $650t = 600$; $t = 0.92$ [hr]. It will take the aircraft 0.92 hours or 55 minutes to fly over the storm and the area it affects.

To illustrate the findings graphically, we must graph both $d_a(t)$ and $d_s(t)$. I suggest using the one-hour intervals on t-axis (0, 1, 2) and using 100-mile intervals on the d-axis (0, 100, ..., 1500). Next, construct the following table:

t [hr]	$d_a(t)$ [mi]	$d_s(t)$ [mi]
0	0	600
1	750	700
2	1500	800

Finally, plot the points and graph both $d_a(t)$ and $d_s(t)$. Last, shade the triangular area formed between the d-axis and the graphs. Any time that corresponds with the shaded region means that the aircraft will be flying over the storm and the area it affects.

Operation Outta Here!
Case Study II.3
Findings Sheet

Name(s): _____
Period: _____
Date: _____

Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<i>Question 1:</i> Using a system of equations answer the following question. How long will your aircraft be flying over the area affected by the storm?		
<i>Question 2:</i> Illustrate your answer graphically.		

Operation: Outta Here!

Case Study III (Movie III): Landing

Instructional Curriculum
Mathematics, Grades 8-10

Introduction: Three case studies of various levels of difficulty are developed to accompany Movie 3. Each case study consists of the following scenario: a student is assigned a role of an air traffic controller who is asked to analyze different landing patterns.

The first case study (III.1) is designed for pre-Algebra students / Algebra I students. The students are asked to calculate the number of landings per hour, among other things, given one landing strip at the airport.

The second case study (III.2) is designed for Algebra I students as it asks questions about landing on two landing strips.

The third case study (III.3) is designed for advanced Algebra I as it combines scenarios presented in the first two case studies and asks students to choose the best alternative.

Guiding Question: How can the air transportation system increase the number of aircraft that can land safely on airport runways?

Main Concept: Modeling different configurations of aircraft for approach and descent allows for the exploration of relationships between the aircraft flight paths, to make and test conjectures about them, and to increase the traffic flow of the system.

NASA Relevance: The operational concept of formation flight and landing seeks to increase the number of aircraft that can land safely within a given timeframe and airspace, thus increasing traffic flow and efficiency within the system.

Prerequisite Skills: To successfully complete Case Study III Level 1, the students should be able to convert units of measure, multiply and divide fractions and decimals.

To successfully complete Case Study III Level 2, the students should be able to convert units of measure, multiply and divide fractions and decimals.

To successfully complete Case Study III Level 3, the students should be able to perform all the tasks named above and to compare the findings.

CS Objectives: By completing this case study the students will gain appreciation for some of the situations encountered by the air-traffic controllers while mastering their pre-algebra and algebra skills.

The students will be able to:

Analyze word
problems;
Solve linear
equations;
Exercise critical

thinking skills;
Compare findings;
Convert units of
measure;

NCTM Standards: *Fully Meets:*

NCTM: Numbers and Operations, Understand meanings of operations and how they relate to one another 9-12:

Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.

NCTM: Algebra, Understand patterns, relations, and functions 9-12:

Analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior.

Project 2061: Design and Systems, Designed Systems Grades 6-8 8E/3:

Computer control of mechanical systems can be much quicker than human control. In situations where events happen faster than people can react, there is little choice but to rely on computers. Most complex systems still require human oversight, however, to make certain kinds of judgments, to react to unexpected failures, and to evaluate how well the system is serving its intended purposes.

Partially Meets:

Project 2061: Grades 9-12 3B/3:

Complex systems have layers of controls. Some controls operate particular parts of the system and some control other controls. Even fully automatic systems require human control at some point.

Project 2061: Grades 9-12 2B/1:

Mathematical modeling aids in technological design by simulating

how a proposed system would theoretically behave.

Activity Preparation: Before starting each module the students will watch the appropriate video clip on the website. The students will consult the appropriate *Operation: Outta Here!* website (<http://quest.arc.nasa.gov/test/ooh/design/>) where they will progress through the material at their own pace.

Materials: Each student is expected to have a pencil, ruler, calculator, sheet of paper, and an appropriate student handout.

Time for Activity: Each case study is expected to take between one and two academic hours depending on the skills of the students. A teacher may assign more than one case study per student. Note: case study III.3 includes materials from the case study III.1 and the case study III.2.

Engage: Before each case study, the students should view the video clips on <http://quest.arc.nasa.gov/test/ooh/design/>. The students should also review the website at their own pace.

The teacher may start a discussion by asking the students about the role the air traffic controllers play. A concept of different landing patterns and airport designs should be introduced (see NASA's *Friendly Skies* website).

Explore: After having the class discussion, divide the students into groups of two to four and ask them to brainstorm some of their own solutions to the problems presented in the movies. Give each group ten to fifteen minutes. Have each group put their ideas on post-its and put these ideas up on the board.

Explain:

Once you collect most of the ideas from your class, read some of them to the students and discuss their merits.

Guide the students to research different airport design models. Discuss the advantages and disadvantages of different designs (better capacity but higher cost, for example).

Discuss the noise reduction guidelines currently in use. Mention various local legislations designed to reduce the noise pollution around the airports. Explain that in order to curb the noise pollution, most airports do not operation around the clock.

Extend:

After demonstrating several problems dealing with calculating the number of landings at an airport of a certain design, distribute the case studies to the students.

There are three levels of case study III: III.1, III.2, and III.3. The levels of difficulty increase with the level numbers. Case study III.3 includes information from case studies III.1 and III.2.

Should you decide to devote more classroom time to Operation: Outta Here, you may wish to give more than one case study per student. For example, students who successfully complete case study III.1 may be assigned case study III.2.

Depending on the skills of your students and your teaching style, the students may work on their case studies individually or in groups. Case studies may be completed in class or at home.

Evaluate:

As students complete the case studies, their findings shall be presented to the class. Have each student or group, if appropriate, fill out the Findings Sheet where the students will indicate their findings and show their reasoning. After analyzing students' responses, proceed with re-teaching or enrichment as needed.

Operation: Outta Here!
Case Study III, Level 1 (III.1)
Student Handout

You are an air traffic controller asked to calculate the number of aircraft that can land in your airport using different landing scenarios.

Under this scenario, your airport has one landing strip that is 5 km long. Assume the landing speed of each aircraft to be 250 km/h. For safety reasons, all aircraft must maintain a safety distance of 1 km when approaching the airport and when landing. Because of noise restrictions there are no take-offs and landings at your airport between midnight and 6 o'clock in the morning.

- Question 1: During the hours of operation, how many landings does your airport accept per hour?
- Question 2: How many landings does your airport accept on a daily basis?
- Question 3: On average, how many landings per hour does your airport accept?
- Question 4: What extraneous variables could affect the number of landings your airport could accept per hour?

Operation: Outta Here!
Case Study III, Level 1 (III.1)
Teacher Handout

You are an air traffic controller asked to calculate the number of aircraft that can land in your airport using different landing scenarios.

Under this scenario, your airport has one landing strip that is 5 km long. Assume the landing speed of each aircraft to be 250 km/h. For safety reasons, all aircraft must maintain a safety distance of 1 km when approaching the airport and when landing. Because of noise restrictions there are no take-offs and landings at your airport between midnight and 6 o'clock in the morning.

Question 1: During the hours of operation, how many landings does your airport accept per hour?

To answer the first question, begin by converting 250 km/h into 250,000 m / 3,600 s or into 69.4 m/s. Since all landing aircraft are required to maintain a safety distance of 1,000 m, the airport will be able to accept one landing every 14.4 seconds (1,000 m / 69.4 m/s). Therefore, the airport will be able to accept 250 landings per hour (3600 s / 14.4 s).

Question 2: How many landings does your airport accept on daily basis?

Since the takeoffs and landings are not allowed at the airport between 00:00 and 06:00, the airport is in operation mode for 18 hours a day (24 hr – 6 hr). Therefore, the airport could accept as many as 4,500 landings a day (18 hrs * 250 landings/hr).

Question 3: On average, how many landings per hour does your airport accept?

On average, the airport accepts 187 landings per hour (4,500 landing/day / 24 hrs/day = 187.5 landings. Please note that we must round down 187.5 to 187).

Question 4: What extraneous variables could affect the number of landings your airport could accept per hour?

Students' answers may vary, but could include some of the following: change in weather patterns, equipment issues, absence of available gates, etc.

Operation Outta Here!
Case Study III.1
Findings Sheet

Name(s): _____
 Period: _____
 Date: _____

Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<i>Question 1:</i> During the hours of operation, how many landings does your airport accept per hour?		
<i>Question 2:</i> How many landings does your airport accept on daily basis?		
<i>Question 3:</i> On average, how many landings per hour does your airport accept?		
<i>Question 4:</i> What extraneous variables could affect the number of landings your airport could accept per hour?		

Operation: Outta Here!
Case Study III, Level 2 (III.2)
Student Handout

You are an air traffic controller asked to calculate the number of aircraft that can land in your airport using different landing scenarios.

Under this scenario, your airport has two landing strips, each is 5 km long. Assume the landing speed of each aircraft to be 200 km/h. For safety reasons, all aircraft must maintain a safety distance of 1,500 meters when approaching the airport and when landing. Because of noise restrictions there are no take-offs and landings at your airport between 11 p.m. and 6 a.m.

- Question 1: During the hours of operation, how many landings does your airport accept per hour?
- Question 2: How many landings does your airport accept on daily basis?
- Question 3: On average, how many landings per hour does your airport accept?
- Question 4: What extraneous variables could affect the number of landings your airport could accept per hour?

Operation: Outta Here!
Case Study III, Level 2 (III.2)
Teacher Handout

You are an air traffic controller asked to calculate the number of aircraft that can land in your airport using different landing scenarios.

Under this scenario, your airport has two landing strips, each is 5 km long. Assume the landing speed of each aircraft to be 200 km/h. For safety reasons, all aircraft must maintain a safety distance of 1,500 meters when approaching the airport and when landing. Because of noise restrictions there are no take-offs and landings at your airport between 11 p.m. and 6 a.m.

Question 1: During the hours of operation, how many landings does your airport accept per hour?

To answer the first question, begin by converting 200 km/h into $200,000 \text{ m} / 3,600 \text{ s}$ or into 55.6 m/s. Since all landing aircraft are required to maintain a safety distance of 1,500 m, the airport will be able to accept two (because there are two landing strips) landings every 27 seconds ($1,500 \text{ m} / 55.6 \text{ m/s}$). Therefore, the airport will be able to accept 133 pairs of landings per hour ($3600 \text{ s} / 27 \text{ s}$) or 266 landings per hour.

Question 2: How many landings does your airport accept on daily basis?

Since the takeoffs and landings are not allowed at the airport between 23:00 and 06:00, the airport is in operation mode for 17 hours a day ($24 \text{ hr} - 7 \text{ hr}$). Therefore, the airport could accept as many as 4,522 individual landings a day ($17 \text{ hrs} * 266 \text{ landings/hr}$).

Question 3: On average, how many landings per hour does your airport accept?

On average, the airport accepts 188 landings per hour ($4,522 \text{ landing/day} / 24 \text{ hrs/day} = 188.4 \text{ landings}$). Please note that we must round down 188.4 to 188).

Question 4: What extraneous variables could affect the number of landings your airport could accept per hour?

Students' answers may vary, but could include some of the following: change in weather patterns, equipment issues, absence of available gates, etc.

Operation Outta Here!
Case Study III.2
Findings Sheet

Name(s): _____
 Period: _____
 Date: _____

Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<i>Question 1:</i> During the hours of operation, how many landings does your airport accept per hour?		
<i>Question 2:</i> How many landings does your airport accept on daily basis?		
<i>Question 3:</i> On average, how many landings per hour does your airport accept?		
<i>Question 4:</i> What extraneous variables could affect the number of landings your airport could accept per hour?		

Operation: Outta Here!
Case Study III, Level 3 (III.3)
Student Handout

You are an air traffic controller asked to calculate the number of aircraft that can land in your airport using different landing scenarios.

Under the first scenario, your airport has one landing strip that is 5 km long. Assume the landing speed of each aircraft to be 250 km/h. For safety reasons, all aircraft must maintain a safety distance of 1 km when approaching the airport and when landing. Because of noise restrictions there are no take-offs and landings at your airport between midnight and 6 o'clock in the morning.

Under the second scenario, your airport has two landing strips, each is 5 km long. Assume the landing speed of each aircraft to be 200 km/h. For safety reasons, all aircraft must maintain a safety distance of 1,500 meters when approaching the airport and when landing. Because of noise restrictions there are no take-offs and landings at your airport between 11 p.m. and 6 a.m.

Under which scenario, on average, will the airport allow more landings per hour?

Operation: Outta Here!
Case Study III, Level 3 (III.3)
Teacher Handout

You are an air traffic controller asked to calculate the number of aircraft that can land in your airport using different landing scenarios.

Under the first scenario, your airport has one landing strip that is 5 km long. Assume the landing speed of each aircraft to be 250 km/h. For safety reasons, all aircraft must maintain a safety distance of 1 km when approaching the airport and when landing. Because of noise restrictions there are no take-offs and landings at your airport between midnight and 6 o'clock in the morning.

Under the second scenario, your airport has two landing strips, each is 5 km long. Assume the landing speed of each aircraft to be 200 km/h. For safety reasons, all aircraft must maintain a safety distance of 1,500 meters when approaching the airport and when landing. Because of noise restrictions there are no take-offs and landings at your airport between 11 p.m. and 6 a.m.

Under which scenario, on average, will the airport allow more landings per hour?

Under the first scenario, the airport would allow an hourly average of 187 landings (per day). [Begin by converting 250 km/h into $250,000 \text{ m} / 3,600 \text{ s}$ or into 69.4 m/s . Since all landing aircraft are required to maintain a safety distance of 1,000 m, the airport will be able to accept one landing every 14.4 seconds ($1,000 \text{ m} / 69.4 \text{ m/s}$). Therefore, the airport will be able to accept 250 landings per hour ($3600 \text{ s} / 14.4 \text{ s}$). Therefore, under the first scenario, on average, the airport accepts 187 landings per hour ($4,500 \text{ landing/day} / 24 \text{ hrs/day} = 187.5 \text{ landings}$. Please note that we must round down 187.5 to 187).]

Under the second scenario, the airport would allow an hourly average of 188 landings (per day). [Begin by converting 200 km/h into $200,000 \text{ m} / 3,600 \text{ s}$ or into 55.6 m/s . Since all landing aircraft are required to maintain a safety distance of 1,500 m, the airport will be able to accept two (because there are two landing strips) landings every 27 seconds ($1,500 \text{ m} / 55.6 \text{ m/s}$). Therefore, the airport will be able to accept 133 pairs of landings per hour ($3600 \text{ s} / 27 \text{ s}$) or 266 landings per hour. Thus, under the second scenario, the airport accepts 188 landings per hour ($4,522 \text{ landing/day} / 24 \text{ hrs/day} = 188.4 \text{ landings}$. Please note that we must round down 188.4 to 188).]

By comparing both scenarios, it becomes obvious that the second scenario is more beneficial as it allows one extra landing per hour when averaged during the twenty-four hours.

Operation Outta Here!
Case Study III.3
Findings Sheet

Name(s): _____
Period: _____
Date: _____

Directions: Fill out this sheet completely and turn it in with all work to your teacher.

Question	Answer	Reasoning
<i>Question 1:</i> Under which scenario (of the two presented in the case study), on average, will the airport allow more landings per hour?		