

# LineUp with Math

Math-Based Decisions in Air Traffic Control

# A FACILITATOR GUIDE TO LINEUP WITH MATH

Interactive Simulator Student Workbooks

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# Becoming Acquainted with LineUp with Math

#### A Smart Skies™ Educational Product

### What is LineUp with Math™?

LineUp with Math™ enables learners to explore and apply decision-making and proportional reasoning skills to resolve distance-rate-time problems in realistic air traffic control situations. To solve the problems, learners use a web-based interactive Air Traffic Control (ATC) simulator that represents an air traffic controller's screen. The accompanying workbooks provide the underlying mathematics and strategies to enable learners to optimize their solutions.

LineUp with MathTM consists of six problem sets containing the following:

- > Supporting facilitator materials
- → A learner workbook (fillable PDFs or print)
- → Interactive ATC simulator problems (web-based or download)

#### **Access to Materials**

All materials, including the interactive ATC Simulator, are free and accessible from the LineUp with Math™ website:

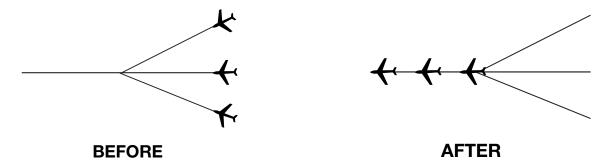
https://www.nasa.gov/stem-content/smart-skies-lineup-with-math2/

Access to the ATC simulator is available at the following address:

https://atcsim.nasa.gov/simulator/sim2/sector33.html

### **Overview**

In LineUp with Math™ learners apply proportional reasoning to make decisions and resolve conflicts in realistic air traffic control problems involving two or more planes. The challenge is each problem is to line up the planes safely, with the proper spacing, at a given intersection of routes.



Learners explore the problems using an interactive Air Traffic Control (ATC) simulator. To increase and refine their decision-making skills, learners use the learner workbooks that provide instruction and practice in mathematics and strategies to enable them to optimize their solutions. After completing the learner workbooks, learners return to the simulator and apply newly learned skills to properly line up the planes while also optimizing the time for the last plane to reach the final intersection.

LineUp with Math™ addresses the following types of ATC problems:

- → Two-plane and three-plane conflicts resolved with route changes
- → Two-plane and three-plane conflicts resolved with speed changes
- → Three-plane, four-plane, and five-plane conflicts resolved with speed changes or with speed and route changes.

LineUp with MathTM uses an airspace based upon a real sector in the National Airspace System. The sector, formally designated as ZOA33 and referred to as Sector 33, is located in norhtern California. The sector distances have been modified to simplify learner calculations.

#### 6 Problem Sets

The instructional materials have been packaged in the form of six Problem Sets.

- Problem Set A: An introduction to the environment of real air traffic control.
- → Problem Sets B and C: Analysis of conflicts between two or three planes and resolution of the conflicts by rerouting.
- → Problem Set D: An introduction to the basic effects of differences in speed.
- → Problem Sets E and F: Analysis of conflicts between two or three planes and resolution of the conflicts by changing plane speed.

Each Problem Set contains:

- → A facilitator guide with analysis of simulator problems and answer key to student workbooks
- → Interactive or multimedia component (e.g. simulator or videos)
- → A student workbook

### **ATC Simulator**

The interactive ATC simulator can be accessed from the LineUp with Math™ website or download it from the LineUp with Math website to give learners easy access to the ATC Simulator only.

The simulator provides a user-friendly realistic simulation of Sector 33 as viewed by a controller on a sector display screen. At the beginning of each simulator problem, two or more planes travel along

merging routes. Learners use proportional reasoning and distance-rate-time relationships to identify potential conflicts at the intersections of the routes. Depending on the problem, learners can resolve the conflict by changing routes or plane speeds.

The goal is to line up the planes safely, with proper spacing, at a given intersection, not only safely but also as quickly as possible. The target time shown on the simulator screen for each problem is the optimal time for that problem.

The simulator features problems with 2, 3,4, and 5 planes. The key two- and three-plane problems are supported by the learner workbooks. The remaining two- and three-plane problems provide additional practice. The four- and five-plane problems enable learners to explore more challenging scenarios.

The simulator website includes the following support materials:

- → Introduction (to the simulator)
- → Help guide
- → 4 supplemental videos

### **Background and Instructional Videos**

Four videos are available to view online or download on the LineUp with Math™ website and on the simulator website.

The first video, "Welcome to Sector 33," presents the vocabulary, units, and graphical representations used in air traffic control. It prepares learners for their first session with the interactive ATC Simulator and the activities in the first learner workbook (Problem Set A).

The second and third videos, "24 Hours of Air Traffic across the World" and "24 Hours of Air Traffic in the US," compress 24-hours of flight paths to one minute. The videos illustrate the world's biggest distance-rate-time problem and motivates the study of air traffic control.

The fourth video, "I'm an Air Traffic Controller," introduces learners to the career of an air traffic controller. It gives insight into the workings of air traffic control towers and the people who work in them.

#### **Student Workbooks**

Each problem set includes a student workbook that can be used as a fillable PDF or printed worksheet. They introduce learners to pertinent air traffic control concepts as well as problem analysis and solution methods.

- → Problem Set A: An introduction to the environment of real air traffic control.
- → Problem Sets B and C: Analysis of conflicts between two or three planes and resolution of the conflicts by rerouting.
- → Problem Set D: An introduction to the basic effects of differences in speed.
- → Problem Sets E and F: Analysis of conflicts between two or three planes and resolution of the conflicts by changing plane speed.

Workbooks B, C, E, and F include worksheets that support selected simulator problems. These worksheet titles match the problem number in the simulator.

#### **Facilitator Guide**

Each problem set is accompanied by a facilitator guide that includes:

- → An overview
- → A list of objectives, prerequisites, and materials
- → An analysis of the relevant ATC simulator problems
- → Key points for each problem
- → The solutions for each simulator problem
- → An answer key for each workbook problem

#### **Instructional Goals**

LineUp with Math<sup>™</sup> has two overarching goals:

- → Enable learners to use mathematical reasoning and problem-solving skills to investigate and sole realistic distance-rate-time problems in air traffic control.
- → Offer learners a variety of problem solving approaches, tools, skills, and experiences in the context of challenging, yet accessible, real-world problems.

The following table lists the materials and specific learning objectives for each problem set.

Problem Set	Materials	Objectives
A Introduction to air traffic control sectors	<ul> <li>→ Four Videos         <ul> <li>Welcome to Sector 33</li> <li>24 Hours of Air Traffic across the World (optional)</li> <li>24 Hours of Air Traffic in the US</li> <li>I'm an Air Traffic Controller</li> <li>→ Student Workbook A</li> <li>→ Teacher Guide A</li> </ul> </li> </ul>	<ul> <li>Learn the vocabulary of air traffic control.</li> <li>Learn the units (nautical miles and knots) of air traffic control.</li> <li>Learn to read and interpret an airspace sector diagram.</li> <li>Learn the air traffic control spacing requirements for safety and efficiency</li> </ul>
<b>B</b> 2-plane conflicts: change routes	<ul> <li>→ Facilitator Guide B</li> <li>→ Student Workbook B</li> <li>→ Simulator problems 2-1*, 2-2*, 2-3*</li> </ul>	<ul> <li>Analyze a sector diagram to identify a spacing conflict between two planes, each traveling at the same speed.</li> <li>Resolve the conflict by changing the route for one plane.</li> </ul>
C 3-plane conflicts: change routes	<ul> <li>→ Facilitator Guide C</li> <li>→ Student Workbook C</li> <li>→ Simulator problems 3-1*, 3-2*, 3-7</li> </ul>	<ul> <li>→ Analyze a sector diagram to identify a spacing conflict among three planes, each traveling at the same speed.</li> <li>→ Resolve the conflict by changing the route for one or more planes.</li> </ul>

Problem Set	Materials	Objectives
<b>D</b> Effects of speed differences	<ul><li>→ Facilitator Guide D</li><li>→ Student Workbook D</li></ul>	<ul> <li>→ Learn that when a plane's speed is reduced, the difference in the plane's distance traveled can be calculated by multiplying the difference in speed by the amount of time traveled.</li> <li>→ Learn how to associate a decrease in plane speed in knots with a decrease in distance traveled each minute.</li> <li>→ Learn the correspondence between a 60-knot reduction in plane speed and the resulting decrease in distance traveled (in 1 minute) over a 10 nautical mile interval on a jet route.</li> </ul>
<b>E</b> 2-plane conflicts: change speeds	<ul> <li>→ Facilitator Guide E</li> <li>→ Student Workbook E</li> <li>→ Simulator problems 2-4*, 2-5*, 2-6*, 2-7*</li> </ul>	<ul> <li>→ Analyze a sector diagram to identify spacing conflicts between two planes, each traveling at the same speed.</li> <li>→ Resolve the conflicts by changing the speed of one plane.</li> </ul>
<b>F</b> 3-plane conflicts: change speeds	<ul> <li>→ Facilitator Guide F</li> <li>→ Student Workbook F</li> <li>→ Simulator problems 3-3*, 3-4*, 3-5*, 3-6*, 3-8, 3-9, 3-11, 3-12</li> </ul>	<ul> <li>Analyze a sector diagram to identify spacing conflicts among three planes, each traveling at the same speed.</li> <li>Resolve conflicts by changing the speed of one or more planes.</li> <li>Resolve conflicts by changing the speed or the speed and route of one or more planes.</li> </ul>

<sup>\*</sup> The simulator problems marked with an asterisk (\*) are supported by worksheets in the student workbooks.

## Preparing to Teach LineUp with Math

### **Instructional Activities**

The following sequence of instructional activities is recommended for implementing each LineUp with Math™ problem set.

#### **Estimated time: 30 minutes**

Begin with the three introductory videos and one optional video.

- → Welcome to Sector 33
- → 24 Hours of Air Traffic in the US
- → I'm an Air Traffic Controller
- → 24 Hours of Air Traffic across the World (optional)

#### **Estimated time: 30 minutes**

Introduce the ATC simulator with the animated introduction. It is recommended to project the simulator and animated Introduction for the whole class, in pairs, or on individual devices.

#### **Estimated time: 30 minutes**

Assign the simulator problems featured in the student workbook. Provide time for students to explore the simulator and the assigned interactive ATC problems.

#### **Estimated time: 30 minutes**

Assign the worksheets in the accompanying student workbook.

#### **Estimated time: 30 minutes**

After students have completed the workbook revisit the assigned problems on the simulator to see if they can optimize their solution and match the target time on the simulator screen. Supplementary simulator problems could be assigned for additional practice.

### **Materials**

Classroom Materials:

- → Facilitator Guide (this document)
- → Video clips
- → ATC simulator
- > Facilitator Guide for each problem set
- > Student Workbook for each problem set
- → Complete set of solutions to all ATC simulator problems

# Implementing LineUp with Math

#### **NASA Resources**

NASA has a rich supply of resources and delivery methods ranging from print-based, multimedia, and television.

These resources can all be accessed from the NASA web portal at:

https://www.nasa.gov

They may also be accessed from the Smart SkiesTM website at:

https://www.nasa.gov/stem-content/smart-skies-lineup-with-math2/

### **Providing NASA with your Assessment**

To ensure these materials are the best they can be NASA needs your feedback and suggestions.

Please take a few minutes to contact us at: aeroSTEM@nasa.onmicrosoft.com

Thank you!

# Apppendix—Glossary

**Aircraft:** Device(s) that are used or intended to be used for flight in the air, and when used in the air traffic control terminology, may include the flight crew.

Air Traffic: Aircraft operating in the air or on an airport surface, exclusive of loading ramps and parking areas.

**Airspace:** The space lying above the earth or above a certain area of land or water, especially the space lying above a nation and coming under its jurisdiction.

**Air Traffic Control:** A service operated by appropriate authority to promote the safe, orderly and expeditious flow of air traffic.

**Call Sign:** The unique designator for each flight. Is composed of a 3-letter abbreviation for the airline name and a unique flight number.

Conflict: When 2 aircraft do not meet the minimum separation standards.

**Flight Plan:** Specified information relating to the intended flight of an aircraft that is filed orally or in writing with an FSS or an ATC facility.

Flight Path: A line, course, or track along which an aircraft is flying or intended to be flown.

Ideal Spacing: In air traffic control, the distance between aircraft to assure their orderly movement.

Knot: Units of speed for air and sea travel. One knot equals one nautical mile per hour.

**Minimum Separation:** In air traffic control, the minimum allowed distance between aircraft to achieve their safe movement in flight and while landing and taking off.

**Nautical Miles:** Unit of measure for distance in air and sea travel. A nautical mile is 1.15 times a statute mile used in land travel.

**Route:** A defined path, consisting of one or more courses in a horizontal plane, which aircraft traverse over the surface of the earth.

Sector: A geographic area of the airspace for which a controller is responsible.

# Acknowledgements

SmartSkies™ LineUp with Math™ was developed and produced at NASA Ames Research Center with sponsorship by the Airspace Systems Program and with contributions and support from the following individuals:

#### **Sponsor**

Robert Jacobsen Program Manager NASA Airspace Systems

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#### **Simulator Concept**

William Preston Nancy Smith Lynne Martin Tom Prevot **Bruce Heath** Crystal Harris ShaRhonda Kersey **Software Development** 

Lydia Mackovitch Khanh Trinh

**ATC Technical Support** 

William Preston Forrest West

**Education Evaluation** 

Rebecca Sims Christina O'Guinn

Strategies and Solutions

Mark Cavolowsky Christopher Cho

Web and Graphic Support

Linda Conrad Jeffrey Simmons Geoffrey Bruce Christopher Cho

Video Support

Jesse Carpenter and the NASA Ames Video Group Lee Hall and the FAA Oakland ARTCC staff Jake Burkart

**Technical Review** 

Dr. Dallas Denery

**Teachers and Students** 

The authors thank the facilitators and learners who tested LineUp with Math™ including the following teachers who participated in the local classroom tests:

JoAnne Asato Larry Cohbra Martha Hanisch Agnes Kaiser Arthur Michelson Elizabeth Mogin **Dolores Procaccio** Bernadette Salgarino

All materials are free and available to download from the LineUp With Math™ websites:

https://www.nasa.gov/stem-content/smart-skies-lineup-with-math2/

ATC Simulator: <a href="https://atcsim.nasa.gov">https://atcsim.nasa.gov</a>

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