

National Aeronautics and Space Administration

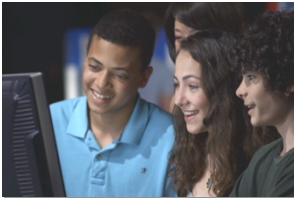
Smart Skies™

**Distance-Rate-Time Mathematics
In Air Traffic Control**

Grades 5-9

Standards-Based

Free!



Rebecca Green and Greg Condon
NCTM Regional Meeting – Louisville, KY

7-Nov-2013

Presentation Overview

Welcome
Introduction to Air Traffic Control (ATC)
Predicting ATC Conflicts
Multiple Representation Simulator
Solving Problems on ATC Simulator & App
The Mathematics of Speed Change
How to Access the Classroom Materials
Dissemination

Smart Skies™

Challenges of Air Traffic Control

During the busiest travel times, about how many commercial planes are flying in the US?



About 5,000 planes!

Smart Skies™

World's Largest D-R-T Problem


Smart Skies™



24 Hours Of Flight
A 60-Second Animation


Two Classroom Activity Sets

FlyBy Math



Pre-algebra or Algebra

LineUp With Math



Pre-algebra

Free!

- Real-world applications
- Multiple representations
- Aligned to state math standards

Free!

Smart Skies™

Smart Skies FlyBy Math



www.smartskies.nasa.gov/flyby

FlyBy Math Overview

FlyBy Math video

FlyBy Math™

Analyze Two-Plane Problems

Planes at same altitude

$D = R \cdot T$

- Which plane arrives first at the intersection?
- How far apart are the planes at that time?

FlyBy Math™

Standards-based & Classroom-tested

- Rates
- Data collection
- Modeling
- Measurement
- Graphing
- Problem solving

Alignment to the Common Core Standards in process.

FlyBy Math™

Multiple Representations

Physical experiment

Print-based worksheets with 6 math methods

Distance traveled vs. Time

Pre-algebra & Algebra

Multiple Representation Simulator

FlyBy Math™

Five Air Traffic Control Problems

1	2	3	4	5
Same Speed	Same Speed	Different Speeds	Different Speeds	Different Speeds

Grade 5

Grade 6

Grade 7

Grade 8

Grade 9

FlyBy Math™

Understand Problem 2


- Speed of each plane = **1/2 foot per second**
- Will the planes meet at the intersection?
- If not, how far apart will they be when the first plane arrives?

16 ft 20 ft

WAL27 NAL63

FlyBy Math™


Physical Experiment



- Students act as Pilots, Controllers, and NASA Scientists.
- Students measure & lay out two jet routes.
- Pilots step down the routes.
- Students measure and record time and separation distance.

FlyBy Math™

Six Math Methods



- Non-traditional**
 - Count feet and seconds
 - Draw and stack blocks
 - Plot points on two vertical lines
- Traditional**
 - Plot points on a grid
 - Derive & use the distance-rate-time formula
 - Graph two linear equations

FlyBy Math™

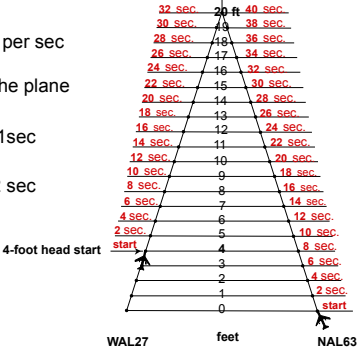
Count Feet and Seconds

Speed = $\frac{1}{2}$ ft per sec

This means the plane travels:

$\frac{1}{2}$ ft in 1 sec
or
1 ft in 2 sec

4-foot head start



WAL27 feet NAL63

FlyBy Math™

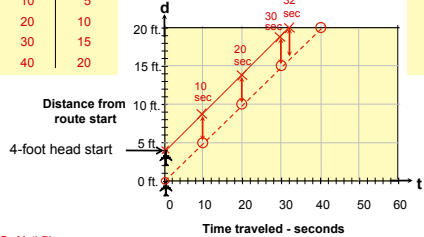
Graph Two Linear Equations

NAL63 $d = 0.5t$

WAL27 $d = 0.5t + 4$

t seconds	d feet
0	0
10	5
20	10
30	15
40	20

t seconds	d feet
0	4
10	9
20	14
30	19
40	24



Distance from route start

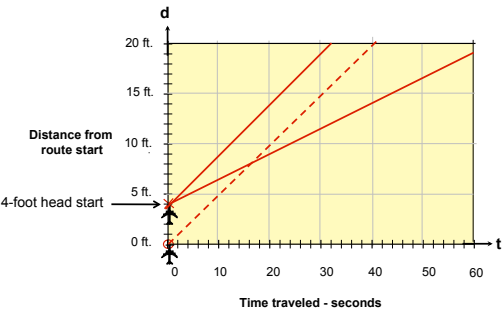
4-foot head start

Time traveled - seconds

FlyBy Math™

Let's Slow One Plane

What happens to the planes where the lines intersect?



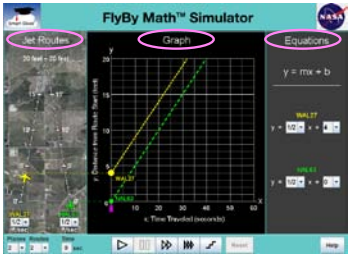
Distance from route start

4-foot head start

Time traveled - seconds

FlyBy Math™

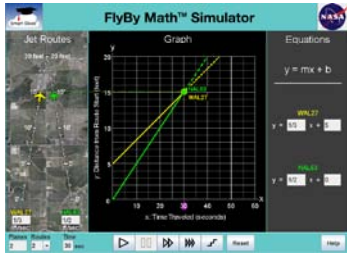
Multiple Representation Simulator



- In each panel, we can change speed & starting position.
- A change in one panel changes the other two panels.
- Helps students link the math to the real world.

FlyBy Math™

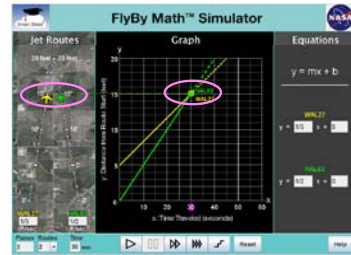
Crash or No Crash?



- When the lines cross on the graph, do the planes collide?
- We can use the simulator to answer the question.

FlyBy Math™

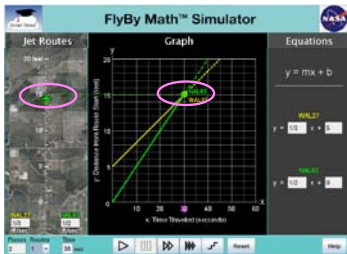
No Crash!



- On the graph, the lines intersect at (30, 15).
- At 30 sec, each plane is 15 ft from its jet route start.
- Note: the planes are on 2 routes that intersect at 20 ft.

FlyBy Math™

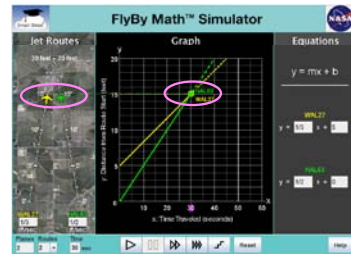
Crash!



- On the graph, the lines again intersect at (30, 15).
- At 30 sec, each plane is again 15 ft from the jet route start.
- Note: the planes are flying on the **same** route.

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Challenge!



- For 2 planes on **2 routes**, configure the graph to represent a collision.
- Hint: Where is the only place on the routes a collision can occur?

FlyBy Math™



[www.smartskies.nasa.gov/lineup](http://www.smarts skies.nasa.gov/lineup)

LineUp with Math™

Math-Based Decisions in Air Traffic Control (ATC)

Distance = Rate · Time
Proportional Reasoning



Web-based ATC simulator

- Act as an Air Traffic Controller
- Use a simulator and **math**
 - to change plane routes and speeds
 - to keep planes safely separated and on time

LineUp With Math™

Standards Based & Classroom Tested

- Aligned with State Standards:
 - Distance = rate • time
 - Proportional reasoning
 - Problem solving
 - Decision making
- Tested with 4,500 students nationwide

Alignment to the Common Core Standards in process.

LineUp With Math™

Intro to ATC and the Simulator

Welcome to Sector 33 video

ATC Simulator Problem 3-8

Line up 3 planes over MOD, 3 Nmi apart.

To do this:	Challenge:
<ul style="list-style-type: none"> Change route Change speed 	<ul style="list-style-type: none"> Match the target time. Requires math.

LineUp With Math™

The Goal Over MOD

The planes must be spaced 3 Nmi apart over MOD. The last plane must arrive in 3 min and 48 sec.

LineUp With Math™

A Closer Look at the Goal

LineUp With Math™

The Simulator

LineUp With Math™ Simulator
Solving NASA Problem 2-1

LineUp With Math™

Select Problem 3-8

LineUp With Math™

1. Select Problem

2. Run Problem

Operating the Simulator

LineUp With Math™

Toggle the call sign arrow to change route

Toggle the speed arrow to change speed

Control buttons

Access the Simulator

- Go to www.atcsim.nasa.gov
- Click on "Link to the simulator."
- Select and run Problem 3-8 without changes.
- Try solving Problem 3-8 with route changes and/or speed changes.

LineUp With Math™

Can We Predict the Outcome?

	DAL88	UAL74	AAL12
Speed:	600 kts	600 kts	600 kts
Distance to MOD:	35 Nmi	35 Nmi	35 Nmi

LineUp With Math™

What's the Spacing Over MOD?

LineUp With Math™

All 3 planes: Are the same distance, 35 Nmi, from MOD.
 Are flying at the same speed, 600 kts.
 Arrive over MOD at the same time!!!

Ways to Achieve 3 Nmi Spacing

- ✓ Route Change(s)
- ✓ Speed Change(s)
- ⊗ Altitude Change(s)

Smart Skies™

Try Using a Route Change

Can you change the route for:
UAL74? DAL88? AAL12?

LineUp With Math™ **No** **No** **Yes**

Analyze the Route Change

Let's change the route for AAL12.
What's its new flight distance to MOD? **32 Nmi**

LineUp With Math™

Try Using a Speed Change

Let's reduce the speed of UAL74.
Try 540 knots (smallest reduction).

LineUp With Math™

Our Strategy

- "AAL12 cleared direct MINAH to MOD."
- "UAL74 reduce speed to 540 knots."

LineUp With Math™

Reset Problem 3-8

LineUp With Math™ Simulator
Solving NASA Problem 3-8

LineUp With Math™

Try the Route & Speed Changes

Send AAL12 direct MINAH to MOD.

Click on AAL12 Call Sign to Change Route

Slow UAL74 to 540 kts.

Click on UAL74 Speed to Change Speed

Run (Fast Forward) the Problem

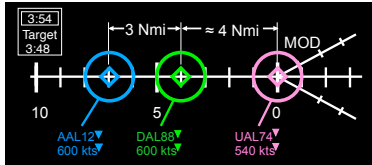
LineUp With Math™

Result of Route & Speed Changes



At MOD, note the spacing and time:

- 3 Nmi between AAL12 & DAL88
- ≈ 4 Nmi between DAL88 & UAL74
- 3 minutes, 54 seconds (target is 3:48)



How can you keep UAL74 from falling so far behind?

LineUp With Math™

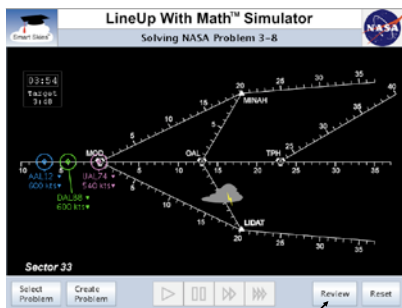
Review & Fine Tune the Solution



- Investigate the problem in Review mode.
- Pause at 1, 2, & 3 minutes.
- Note the plane spacing each minute.

LineUp With Math™

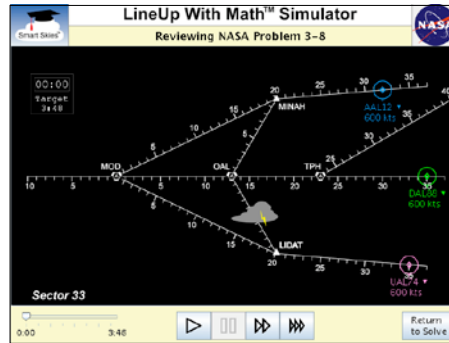
Review the Problem 3-8 Solution



Review

LineUp With Math™

Using Review Mode

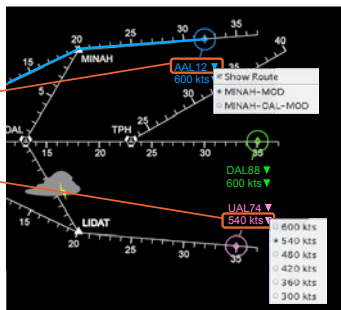


LineUp With Math™

The Solution

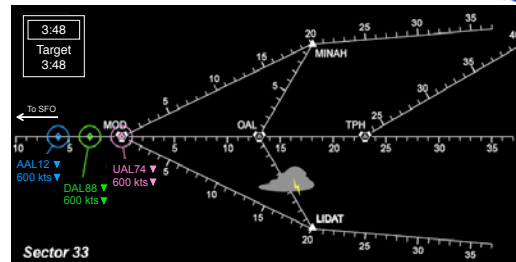


1. Return to Solve Mode & reset the problem.
2. Change the route of AAL12 direct from MINAH to MOD.
3. Slow UAL74 to 540 kts.
4. After 3 minutes, speed up UAL74 to 600 kts.



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Goal Achieved!



The planes are spaced 3 Nmi apart over MOD.
The last plane arrived in 3 min and 48 sec.

LineUp With Math™

Create Your Own ATC Problems

LineUp With Math™ Simulator
Creating New Problem

Smart Board

UAL74
DAL88
NW456
USAS1

MOD
OAL
TPH
MANAH
LIGHT

Sector 33

Select Problem Clear Note: The Save Feature is not available in this version. More Info Return to Solve

LineUp With Math™

Understanding Speed Change

UAL 74
540 kts

- 600 kts
- 540 kts
- 480 kts
- 420 kts
- 360 kts
- 300 kts

- We changed a plane's speed to achieve Ideal Spacing and meet the Target Time.
 - How did we know which speed to select?
 - Why is the speed menu in 60-knot increments (600 kts, 540 kts, 480 kts ...)?
- To explain, we begin with 2 walkers.

LineUp With Math™

The Math Behind Speed Changes

$D = R \cdot T$

3 minutes 2 minutes 1 minute

Gaby 10 steps/minute

Tonisha 9 steps/minute

Distance - steps

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Connect Knots & Steps Per Minute

- How do walker speeds (steps per minute) relate to plane speeds (nautical miles per hour)?
- Controllers make decisions in **minutes**, not hours. So controllers use speed in **miles per minute**.

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Minute by Minute

1 hr = 60 minutes

A plane's speed is **600** knots:
In 1 hour, it flies 600 Nmiles.
In 60 minutes, it flies 600 Nmiles.
In 1 minute, it flies **10** Nmiles.

A plane's speed is **540** knots:
In 1 hour, it flies 540 Nmiles.
In 60 minutes, it flies 540 Nmiles.
In 1 minute, it flies **9** Nmiles.

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Plane Spacing Each Minute

$D = R \cdot T$

3 minutes 2 minutes 1 minute

Gaby 10 steps/minute

Tonisha 9 steps/minute

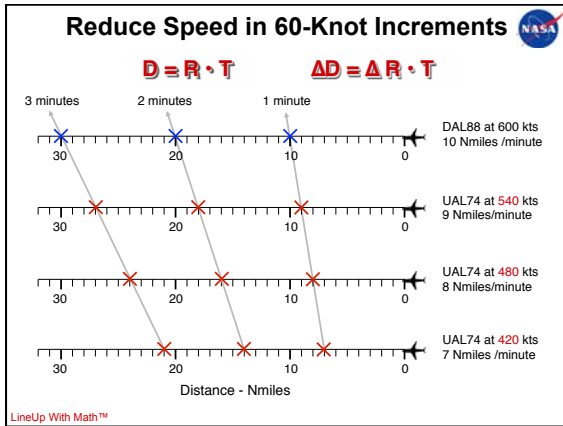
Distance - steps

DAL88 at 600 kts
10 Nmiles /minute

UAL74 at 540 kts
9 Nmiles/minute

Distance - Nmiles

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- ### Solution Strategy
- Determine:**
1. The order of plane arrival and spacing at MOD
 2. How much each plane must fall back
 3. If you can, use a route change
 4. If not, then use speed change and duration
- LineUp With Math™

Classroom Implementation

Explore with the Simulator.

Do the math in a Workbook.

Meet the time challenge.

LineUp With Math™

6 Workbook Problem Sets

Introduction to ATC

Speed Changes

Route Changes

4-plane and 5-plane **challenge problems** are available (without workbooks).

LineUp With Math™

Sector 33 Mobile Game

www.nasa.gov/sector33

A real-world extension to *LineUp With Math*:

- No pause or review mode.
- Student performance is scored.
- Includes pilot audio feedback.
- Designed to interest students in aeronautics-related careers.

for Apple & Android mobile devices

LineUp With Math™


www.smartskies.nasa.gov

Smart Skies Homepage

For Teachers


Free!

LineUp With Math™

www.smartskies.nasa.gov/lineup 


LineUp With Math™ **Free Online!**

For Teachers



Aligned to state math standards, grades 5-9


LineUp With Math™

LineUp With Math Educator Materials 

Free Online!

- 2-page Quick Start Guide
- Educator Guide
- Teacher Guide for each Problem Set with answers & solutions
- Animated simulator intro
- Simulator user guide (print)
- Answers & solutions to all simulator problems

LineUp With Math™

LineUp With Math Student Materials 

Free Online!

- Movies
- Workbook for each Problem Set
- ATC simulator
- Animated simulator intro
- Simulator user guide (print)

LineUp With Math™

www.atcsim.nasa.gov 


Simulator Homepage **Free!**

For Students & Teachers




Click here to access multiple representation simulator & materials

LineUp With Math™

www.smartskies.nasa.gov/flyby 


FlyBy Math **Free Online!**

For Teachers



Click here to access multiple representation simulator & materials

FlyBy Math™

FlyBy Math™ Educator Materials 

Free Online!

- 2-page Quick Start Guide
- Educator Guide
- Teacher Guide for each Problem Set (experiment & 6 calculation methods) with Answers & Solutions
- Quick Start Guide for Simulator
- Teacher Guide for Simulator
- Animated Simulator Introduction
- Answers & Solutions to Worksheets & Assessments

LineUp With Math™

FlyBy Math™ Student Materials

Free Online!

- Movies
- Workbook for each Problem Set (an experiment and a choice of 6 calculation methods)
- Role-Playing Signs
- Assessment for each Problem Set

- FlyBy Math Simulator (multiple representations)
- Animated Simulator Introduction
- Simulator Worksheets and Assessments

www.atcviztool.nasa.gov

Free!
For Students & Teachers

Click this image to open the multiple representation simulator.

FlyBy Math™

Materials for Teacher Workshops

www.smartskies.nasa.gov/trainer

LineUp With Math Video Workshop

www.smartskies.nasa.gov/trainer/videos.html

Expert Instruction

Watch anytime from anywhere!

Smart Skies Dissemination

- Professional development workshops: NCTM, NSTA, CMC,...
- MTMS cover article, August 2006

Smart Skies Dissemination

- National partnership with FAA
 - Classroom visits from air traffic controllers
 - Student visits to air traffic control facilities

www.faa.gov/education

Recent Recognition



Selected by the National Coalition for Aviation and Space Education (NCASE) to receive the:



2013 Dr. Mervin K. Strickler Award for Aerospace Education Leadership

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Please complete the presentation feedback form.

Thank you from



What's on your radar screen?

