Three planes on merging routes are:
-- different distances from the intersection,
-- traveling at the same speed.
An alternate route is available.

LineUp With Math™

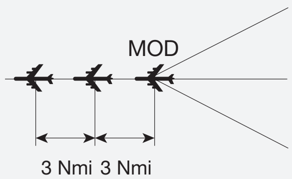
Math-Based Decisions in Air Traffic Control for Grades 5–9

Problem Set C

Resolving 3-Plane Traffic Conflicts by Changing Route

Teacher Guide with Answer Sheets

Overview of Problem Set C



Goal

If you do not have readily available Internet access, you can use the Workbooks only.

In this Problem Set, students will determine whether three planes traveling on different merging routes will line up with proper spacing at MOD (the last intersection before the planes leave the airspace sector). If the spacing is not adequate, students will use alternate routes for one or more planes to achieve at least the proper spacing.

The planes are traveling at the same altitude and the same constant (fixed) speeds.

In *LineUp With Math*™, this is the first Problem Set to address three planes. Speed changes are not required to resolve spacing conflicts.

Each problem can be explored with the interactive Air Traffic Control (ATC) Simulator. Two of the problems can be more closely examined with Student Workbook C (print-based). The Workbook provides a structured learning environment for exploring the problems with paper-and-pencil worksheets that introduce students to pertinent air traffic control concepts as well as problem analysis and solution methods.

Objectives

Students will:

- Analyze a sector diagram to identify spacing conflicts among three planes, each traveling at the same speed.
- Resolve spacing conflicts by changing the route for one or more planes.

Prerequisites

Before attempting the current Problem Set, it is *strongly* recommended that students complete Problem Set A that provides essential air traffic control vocabularly, units, and representations.

It is also recommended that students complete Problem Set B that introduces the ATC Simulator and enables students to explore the effects of a route change in a two-plane problem.

Materials

- ATC Simulator (web-based)
- Student Workbook C (print-based)

Teachers access the materials by visiting the LineUp With Math™ website:
https://www.nasa.gov/lineup-with-math

A separate student website gives students easy access to the Simulator only (and not to the answers and solutions provided on the teacher website):
https://atcsim.nasa.gov/simulator/sim2/sector33.html

ATC Simulator

A complete description of the ATC Simulator is contained in the Educator Guide for LineUp With Math™.

For a Simulator user guide and an animated tutorial, visit the LineUp With Math™ website.

Interactive Air Traffic Control Simulator

Students can explore Problem Set C with the interactive ATC Simulator. Each problem features a 3-plane conflict that can be resolved by route changes.

The Simulator problems for Problem Set C are:

3-1*; 3-2*; 3-7*

Problems with an asterisk (*) are supported by worksheets in Student Workbook C.

For a complete set of answers and solutions to all Problems Set C Simulator problems, see Appendix I of this document.

For a discussion of the key points associated with the first two Simulator problems, see the worksheet notes in the following Student Workbook section.

Student Workbook

The Student Workbook consists of two worksheets, one for each of the two featured Simulator problems listed below.

<u>Simulator Problem</u>

3-1*
3-2*

<u>Worksheet Title</u>

Problem 3-1
Problem 3-2

Each problem features a spacing conflict with different starting conditions. As students progress through the worksheets, they likely will require less guidance and structure, and the subsequent worksheets reflect this.

For a complete set of answers to each worksheet, see Appendix II of this document.

For each worksheet, the key points are briefly described as follows.

In the sector diagram, each route flows only ***towards*** *MOD. E.g., a plane may fly from MINAH to OAL, but cannot fly from OAL to MINAH.*

Worksheet: *Problem 3-1*

- On a number line, students plot each plane's travel distance from MOD to help picture the arrival order of planes at MOD, their relative spacing, and any spacing violations,
- After students resolve a spacing violation with a route change, they again use a number line to picture the planes' new arrival order and spacing.

Worksheet: *Problem 3-2*

- This problem is similar to Problem 3-1. However, in this problem, students are expected to analyze and identify the conflict on their own. Minimal structure is provided to guide the students to a solution.

Student Workbook

For a set of answers and solutions to all Simulator problems, visit the LineUp With Math™ website.

Answer sheets for each of the Problem Set C Simulator problems can be found in Appendix I of this document.

Answer sheets for each worksheet in Student Workbook C can be found in Appendix II of this document.

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Appendix I

Air Traffic Control Simulator

Simulator Solutions for Problem Set C

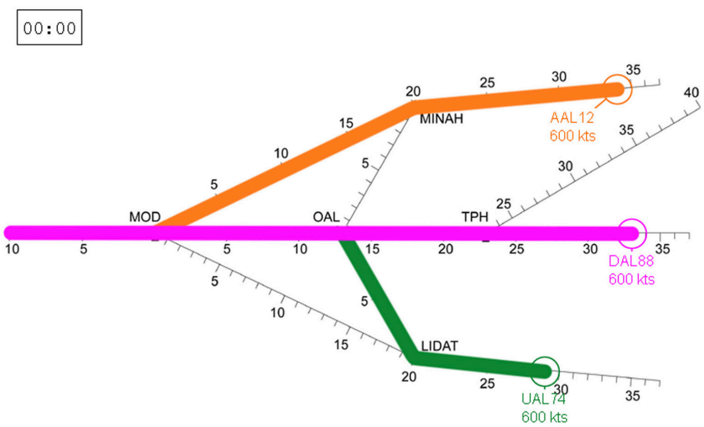
3-1*, 3-2*, 3-7

Problems with an asterisk (*) are supported by worksheets in Student Workbook C

Problem 3-1 Solution

Starting Conditions:

Sector 33



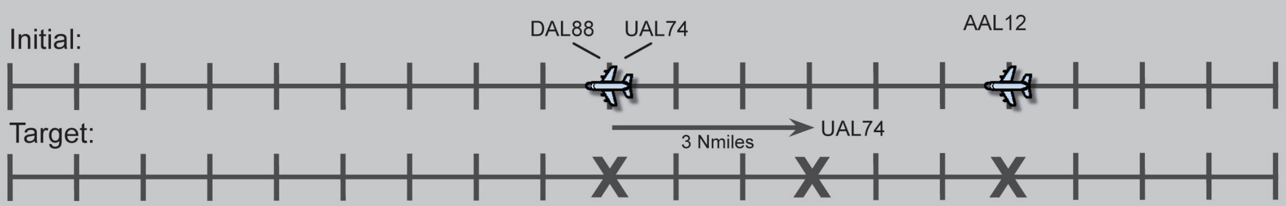
Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	34	600
DAL88	TPH	OAL	MOD	33	600
UAL74	LIDAT	OAL	MOD	32	600

- Ideal spacing at **MOD** is 3 nautical miles.

Analysis:

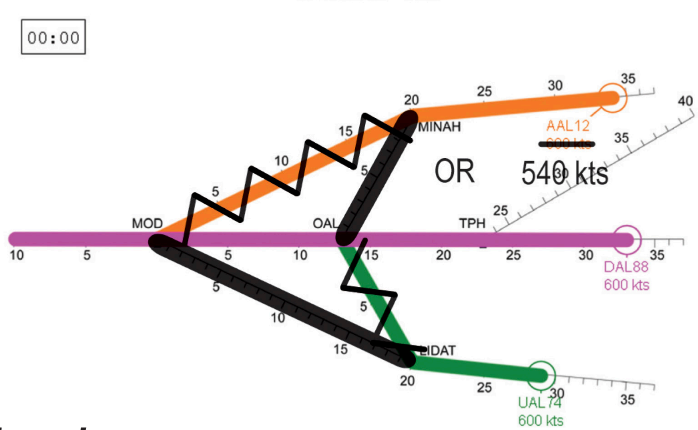
- **<u>Conflict</u>: UAL74, DAL88 <u>and</u> AAL12** will arrive at MOD each with 1 nautical mile separation.
- **UAL74** can take the shortcut to shorten its travel distance. AAL12 can go through OAL to lengthen its travel distance by 3 nautical miles. (or slow down to fall back 2 nautical miles - best solution)

Project Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	32	
			1
2nd	DAL88	33	
			1
3rd	AAL12	34	



Solution

Sector 33

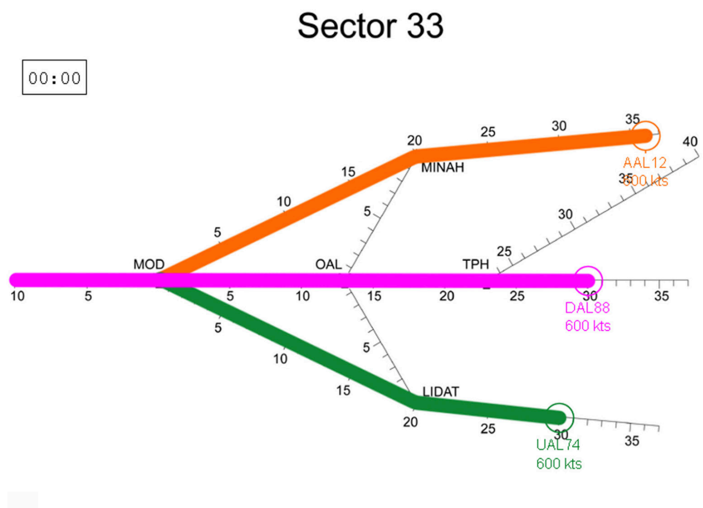


- **UAL74** - Reroute direct MOD to move forward 3 nautical miles.
- **AAL12** - Reroute through OAL to fall back 3 nautical miles. (**Or**, slow to 540 knots for 2 minutes to fall back 2 nautical miles.)

- **Target Time** - 3 minutes and 42 seconds. (route changes only)
  - 3 minutes and 36 seconds. (route and speed change)

Problem 3-2 Solution

Starting Conditions:



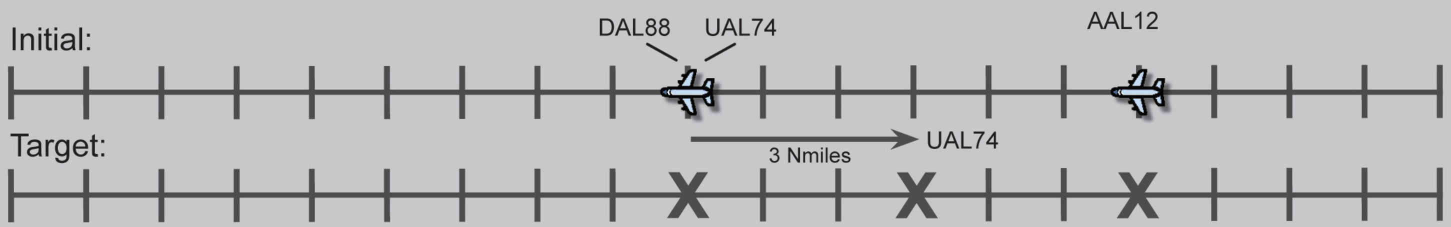
Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	34	600
DAL88	TPH	OAL	MOD	33	600
UAL74	LIDAT	OAL	MOD	32	600

- Ideal spacing at **MOD** is 3 nautical miles.

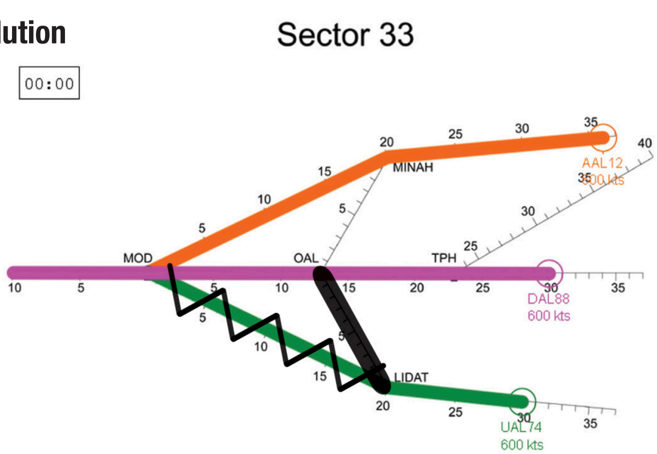
Analysis:

- **Conflict: UAL74 and DAL88** will arrive at MOD at the same time.
- **AAL12** will be **6 nautical miles** behind.
- **UAL74** can go through OAL to lengthen its travel distance by 3 nautical miles.

Project Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	30	
1st	DAL88	30	0
2nd	AAL12	36	6



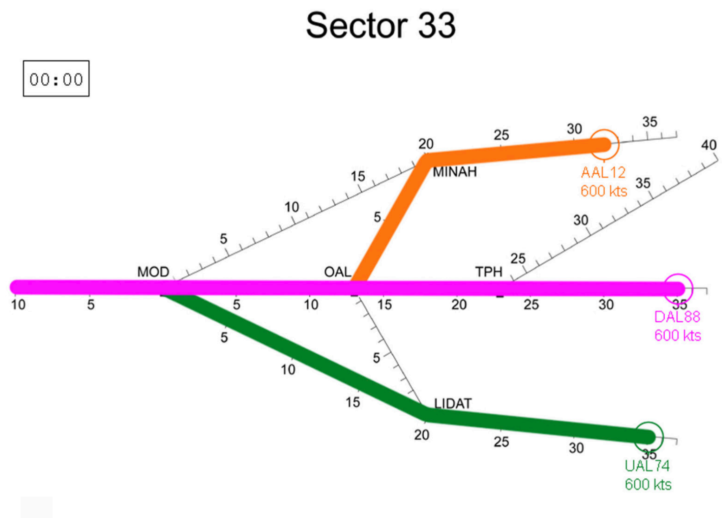
Solution



- **UAL74** - Reroute through OAL to fall back by 3 nautical miles.
- **Target Time** - 3 minutes and 36 seconds.

Problem 3-7 **Solution**

Starting Conditions:



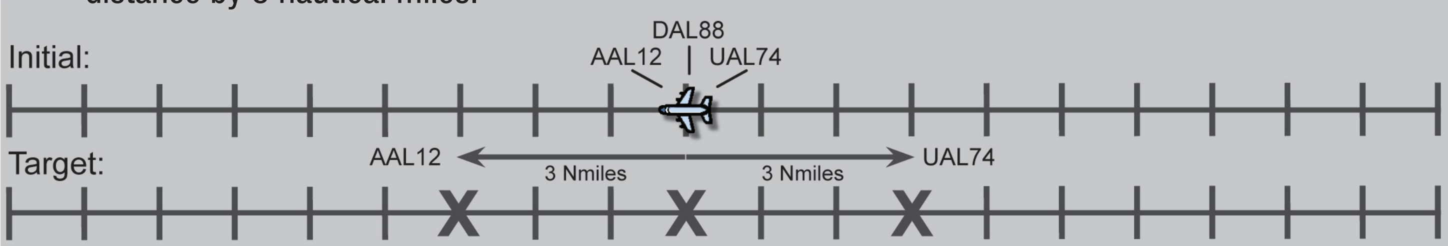
Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	35	600
DAL88	TPH	OAL	MOD	35	600
UAL74	LIDAT		MOD	35	600

- Ideal spacing at **MOD** is 3 nautical miles.

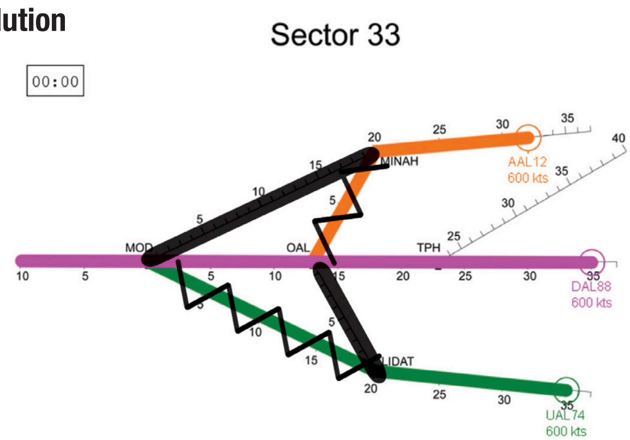
Analysis:

- **<u>Conflict</u>: AAL12, UAL74, <u>and</u> DAL88** will arrive at MOD at the same time.
- **AAL12** can take the shortcut to shorten its travel distance by 3 nautical miles. **UAL74** can take the long route through OAL to increase its travel distance by 3 nautical miles.

Project Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	35	0
1st	DAL88	35	0
1st	AAL12	35	



Solution



- **AAL12** - Reroute to MOD to move forward 3 nautical miles.
- **UAL74** - Reroute through OAL to fall back 3 nautical miles.

- **Target Time** - 3 minutes and 48 seconds.

LineUp With Math™

Math-Based Decisions in Air Traffic Control

Student Workbook C

Appendix II

- Resolving Air Traffic Conflicts by Changing Route
  - 3 planes, each at the same speed.
  - Simulator problems 3-1, 3-2

Workbook Answers

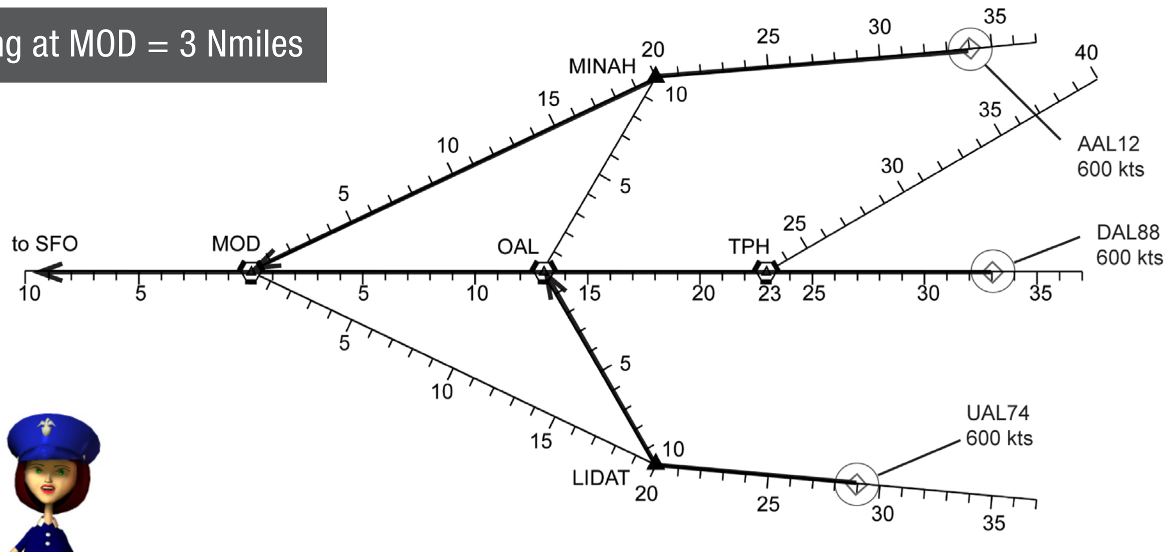
Simulator at: https://atcsim.nasa.gov/simulator/sim2/sector33.html

Investigator: ______________________

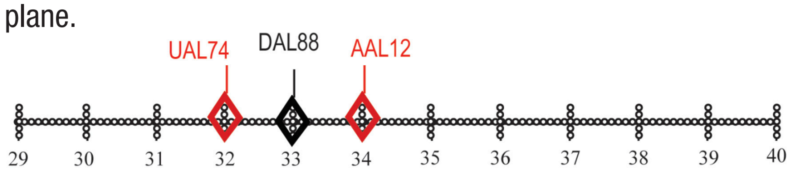
An Airspace Systems
Program Product

Investigator: ______________________

Ideal Spacing at MOD = 3 Nmiles



1
- Use the flight plans to find each plane's travel distance to MOD.
- On the line below, use a ◇ to plot the travel distance to MOD for each plane.
- Label each plane.



Distance to MOD (Nmiles)

2 To fill in the table below:
- Use your plot to figure out the arrival order and spacing at MOD.
- See if any spacing is less than minimum.
- See if extra spacing is needed to get the Ideal Spacing.

Arrival Order at MOD:	1st	2nd	3rd
Plane Call Sign	UAL74	DAL88	AAL12
Spacing at MOD	1 Nmi		1 Nmi
Spacing at MOD	X No ☐ Yes		X No ☐ Yes
Spacing at MOD	2 Nmi		2 Nmi

Continue to Next Page

Investigator: ______________________ **Problem 3-1 (Continued)**

3 What route changes would you make to solve any spacing problems?

Arrival Order	Plane	New Route (if needed)	New Distance to MOD	New Spacing at MOD
1st	*UAL74*	*LIDAT to MOD*	*29* Nmi	*4* Nmi
2nd	*DAL88*		*33* Nmi	
3rd	*AAL12*	*MINAH to OAL to MOD*	*37* Nmi	*4* Nmi

4 To picture the NEW arrival order and spacing, use a ◇ to plot the new distances to MOD for each plane on the line below. Label each plane.

5 With your new routes, are the spacings at least the Minimum Spacing (2 nautical miles)?

☐ No ☒ Yes

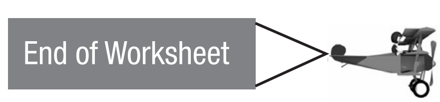
If No, try again.

6 With your new routes, are the spacings equal to the Ideal Spacing (3 nautical miles)?

☒ No ☐ Yes

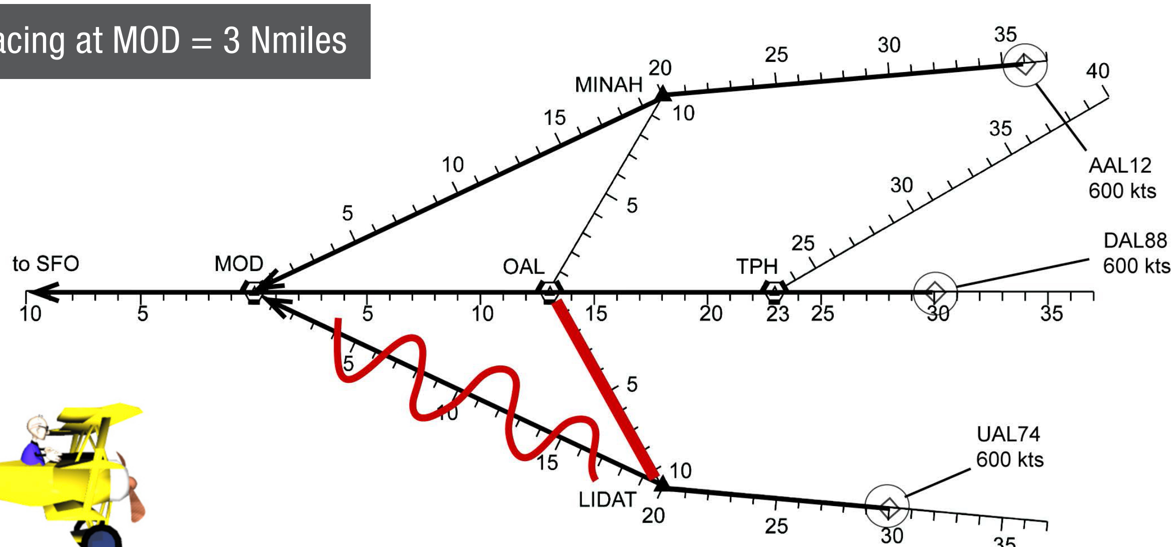
7 If No, what could the controller do to make the spacing ideal?

Change the speed of one or more planes.

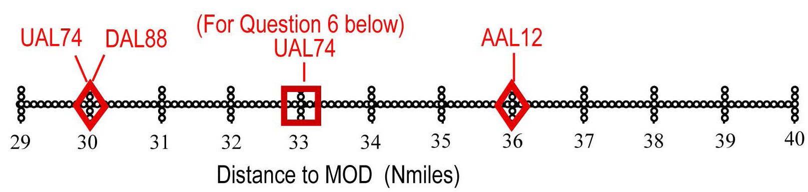


Investigator: ______________________

Ideal Spacing at MOD = 3 Nmiles



1
- Use the flight plans to find each plane's travel distance to MOD.
- On the line below, use a ◇ to plot the travel distance to MOD for each plane.
- Label each plane.



2 Are all the spacings at least the Minimum Separation? [X] No [ ] Yes

3 Which plane needs extra spacing to have ideal spacing? **UAL74** **(There are no reroutes possible for DAL88.)**

4 How much extra spacing is needed? **3** nautical miles

5 On the route diagram, show how you would reroute traffic to try to achieve the Ideal Spacing.

CAUTION **Be sure to mark out the old route and darken the new route.**

6 On the line in Question 1, use a □ to plot any NEW distances to MOD and cross out the old diamond for the old distance. Be sure to label each box with the plane's call sign.

7 Are all spacings now ideal? [ ] No [X] Yes

If yes, Congratulations!

End of Worksheet