Two planes on merging routes are:
-- traveling at the same speed.
An alternate route is available.

LineUp With Math™

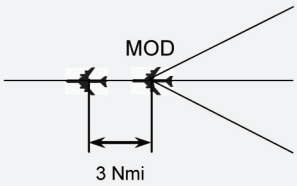
Math-Based Decisions in Air Traffic Control for Grades 5 - 9

Problem Set B

Resolving 2-Plane Traffic Conflicts by Changing Route

Teacher Guide with Answer Sheets

Overview of Problem Set B



Estimated class time: 1.5 to 2 hours

In this Problem Set, students will determine whether two 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 analyze an alternate route for one plane.

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

Of all the *LineUp With Math*™ Problem Sets, this is the simplest. There are only two planes and a simple route change will solve each problem. A speed change is not required to resolve a spacing conflict.

Each problem can be explored with the interactive Air Traffic Control (ATC) Simulator. Three of the problems can be more closely examined with Student Workbook B (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 a spacing conflict between two planes, each traveling at the same speed.
- Resolve the conflict by changing the route for one plane.

Prerequisites

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

Materials

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

Teachers access the materials by visiting the *LineUp With Math*™ website:

http://www.smartskies.nasa.gov/lineup

A separate **student** website gives students easy access to the Simulator and supporting materials (not to the answers and solutions on the teacher website):

http://www.atcsim.nasa.gov

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 first explore Problem Set B with the interactive ATC Simulator. Each problem features a 2-plane conflict that can be resolved by a route change.

The Simulator problems for Problem Set B are:

2-1*; 2-2*; 2-3*; 2-9; 2-10

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

For a complete set of solutions to all Problem Set B Simulator problems, see Appendix I of this document.

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

Student Workbook

It is recommended that you have a copy of Student Workbook B open while you read these notes.

The worksheet title is the same as the associated Simulator problem.

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

Simulator Problem	Worksheet Title
2-1*	Problem 2-1
2-2*	Problem 2-2
2-3*	Problem 2-3

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 2-1*

- Each plane starts at a different distance from MOD. The difference between the planes' starting distance from MOD represents a "headstart" for the closer plane.
- Since the planes are traveling at the same speed, the closer plane maintains its "headstart".
- With the new route, the planes' spacing at MOD will be greater than the Ideal Spacing. A route change may provide additional spacing, but does not guarantee Ideal Spacing. In a later Workbook, students will have the opportunity to change plane speeds as well as the route, and thus achieve Ideal Spacing exactly.

Worksheet: *Problem 2-2*

- This problem is similar to Problem 2-1, but students work more independently, with less guidance and structure.

Worksheet: *Problem 2-3*

- This problem is similar to Problems 2-1 and 2-2. However, in this problem, students are expected to analyze and identify the spacing conflict on their own. Minimal structure is provided to guide students to a solution.

Answer Sheets

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

Solutions for each of the Problem Set B Simulator problems can be found in Appendix I of this document.

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

LineUp With Math™

APPENDIX I

Air Traffic Control Simulator

Simulator Solutions for Problem Set B

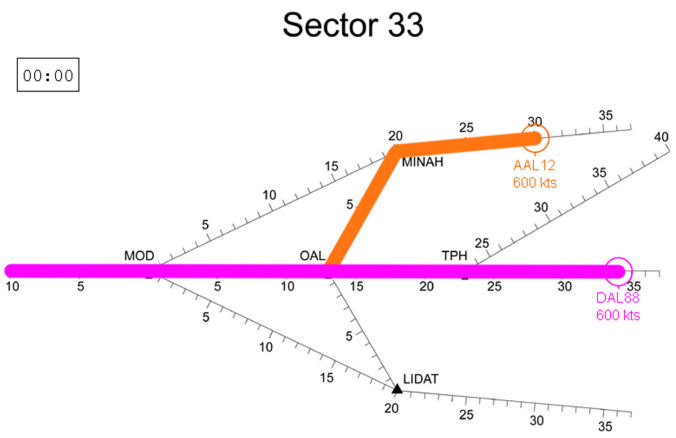
2-1*, 2-2*, 2-3*, 2-9, 2-10

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

Problem 2-1

Solution

Starting Conditions:



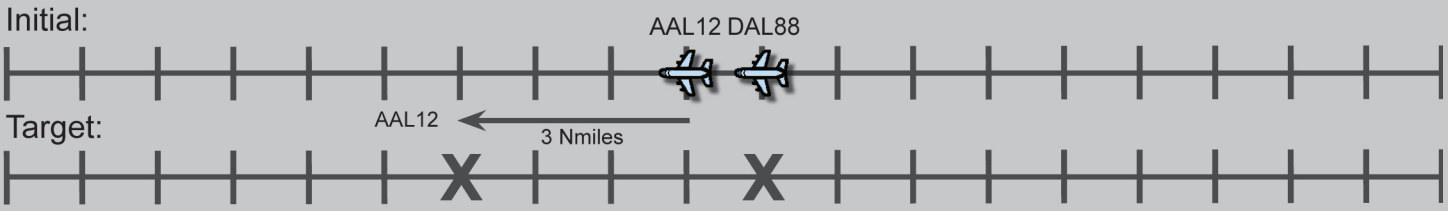
Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	33	600
DAL88	TPH	OAL	MOD	34	600

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

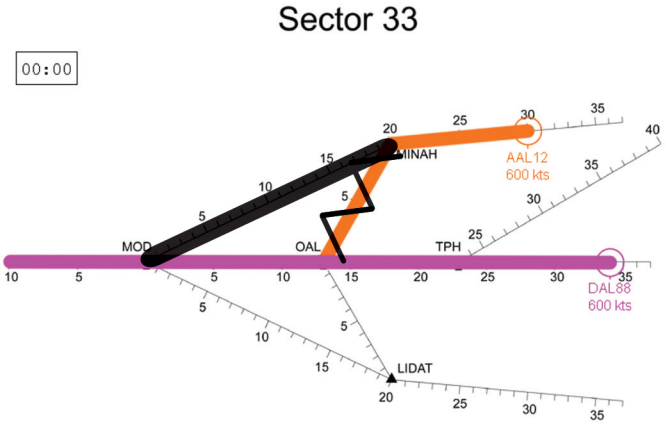
Analysis:

- **Conflict:** **DAL88** will arrive at OAL **1 nautical mile** behind **AAL12**.
- **AAL12** can take the shortcut to shorten its distance of travel by 3 nautical miles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	33	1
2nd	DAL88	34	



Solution:

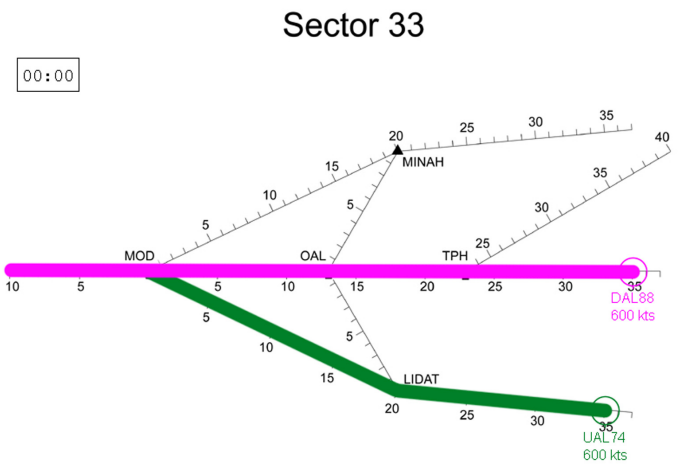


- **AAL12** - Reroute direct to MOD to move forward 3 nautical miles. Spacing at MOD is 4 nautical miles. This is greater than 3 nautical miles Ideal Spacing.
- **Target Time** - 3 minutes and 24 seconds.

Problem 2-2

Solution

Starting Conditions:



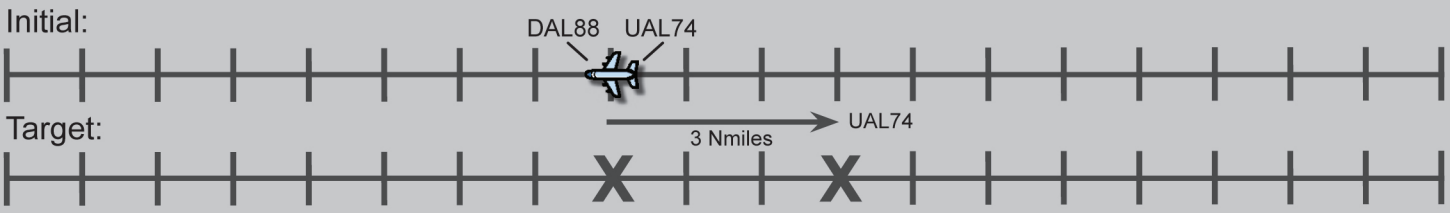
Plane	From	Through	To	Distance	Speed
DAL88	TPH	OAL	MOD	35	600
UAL74	LIDAT		MOD	35	600

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

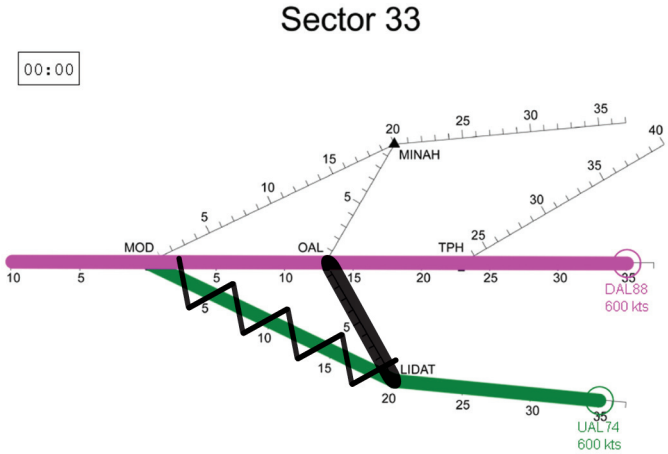
Analysis:

- **Conflict: DAL88 AND UAL74** will arrive at MOD at the same time.
- **UAL74** can take the long route through OAL to extend its travel distance by 3 nautical miles.

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



Solution:

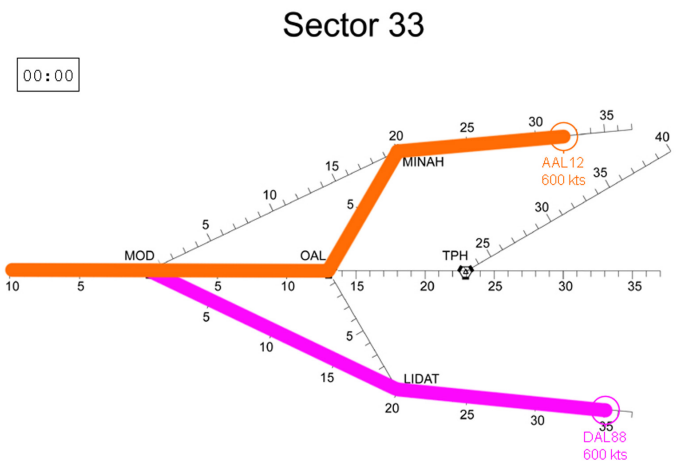


- **UAL74 -** Reroute through OAL to fall back 3 nautical miles.
- **Target Time** - 3 minutes and 48 seconds.

Problem 2-3

Solution

Starting Conditions:



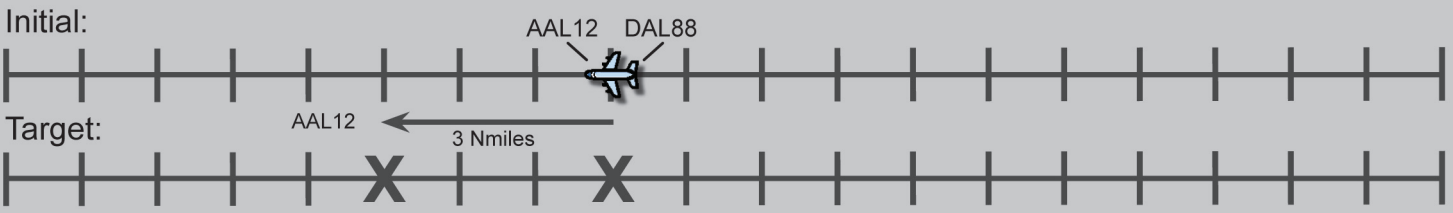
Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	35	600
DAL88	LIDAT		MOD	35	600

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

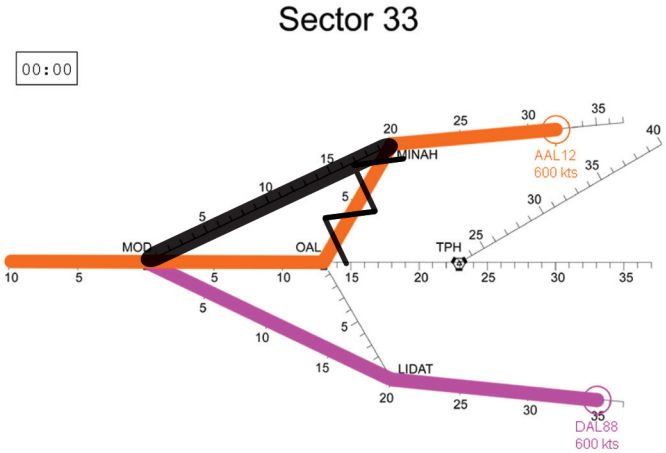
Analysis:

- **Conflict: DAL88 AND AAL12** will arrive at MOD at the same time.
- **AAL12** can take the shortcut to shorten its travel distance by 3 nautical miles.

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



Solution:

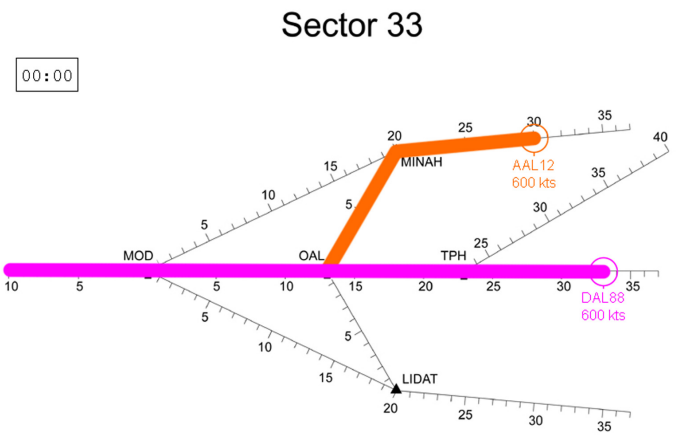


- **AAL12** - Reroute direct to MOD to move forward 3 nautical miles.
- **Target Time** - 3 minutes and 30 seconds.

Problem 2-9

Solution

Starting Conditions:



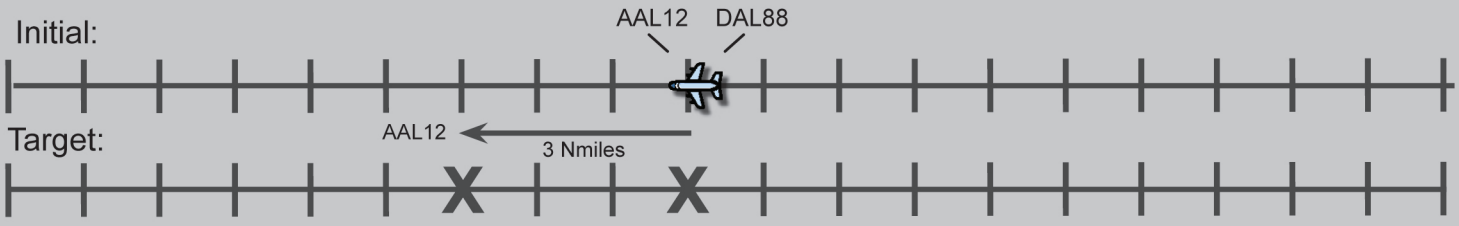
Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	33	600
DAL88	TPH	OAL	MOD	33	600

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

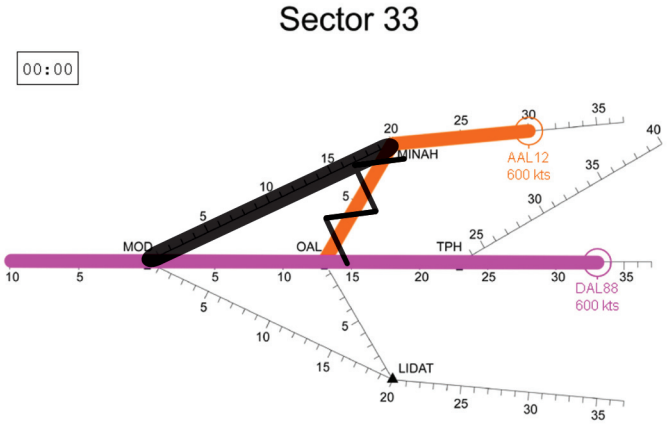
Analysis:

- **Conflict: AAL12 AND DAL88** will arrive at OAL at the same time.
- Send **AAL12** on the shortcut to shorten its travel distance by 3 nautical miles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	33	0
1st	DAL88	33	



Solution:

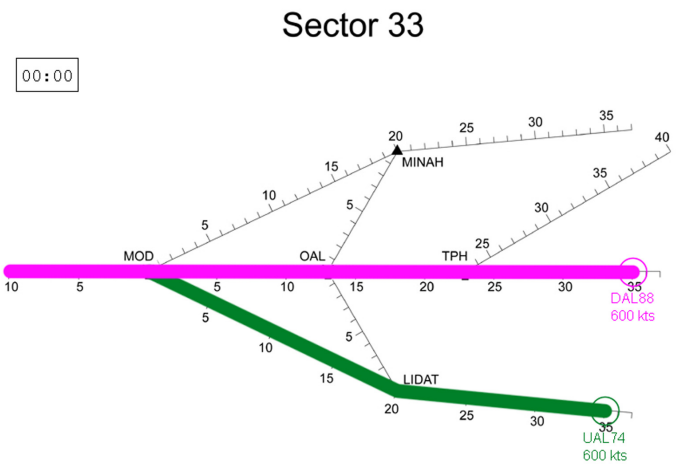


- **AAL12** - Reroute direct to MOD to move forward by 3 nautical miles.
- **Target Time** - 3 minutes and 18 seconds.

Problem 2-10

Solution

Starting Conditions:



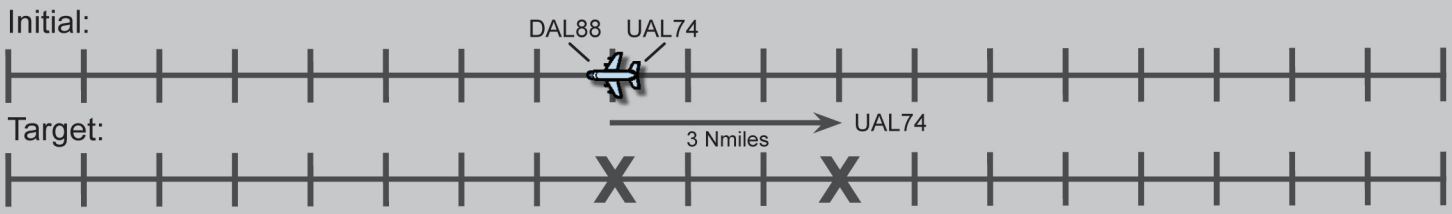
Plane	From	Through	To	Distance	Speed
DAL88	TPH	OAL	MOD	35	600
UAL74	LIDAT		MOD	35	600

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

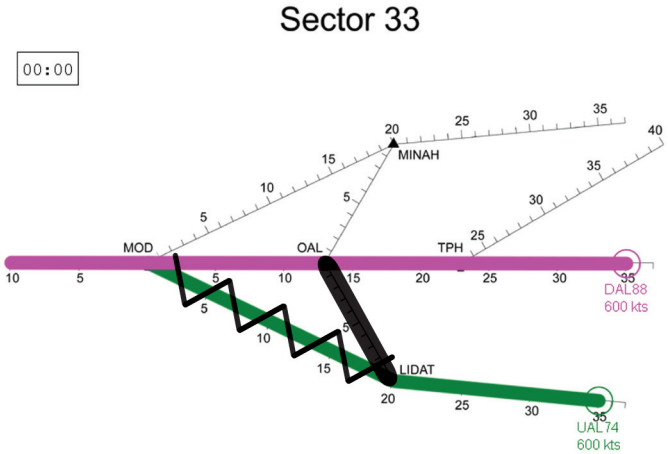
Analysis:

- **Conflict: DAL88 AND UAL74** will arrive at MOD at the same time.
- **UAL74** can take the long route through OAL to lengthen its travel distance by 3 nautical miles.

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



Solution:



- **UAL74** - Reroute through OAL to fall back by 3 nautical miles.
- **Target Time** - 3 minutes and 48 seconds.

LineUp With Math™

Math-Based Decisions in Air Traffic Control

Student Workbook B

Appendix II

- Resolving Air Traffic Conflicts by Changing Route
  - 2 planes, each at the same speed
  - Workbook and simulator problems 2-1, 2-2, 2-3

Workbook Answers

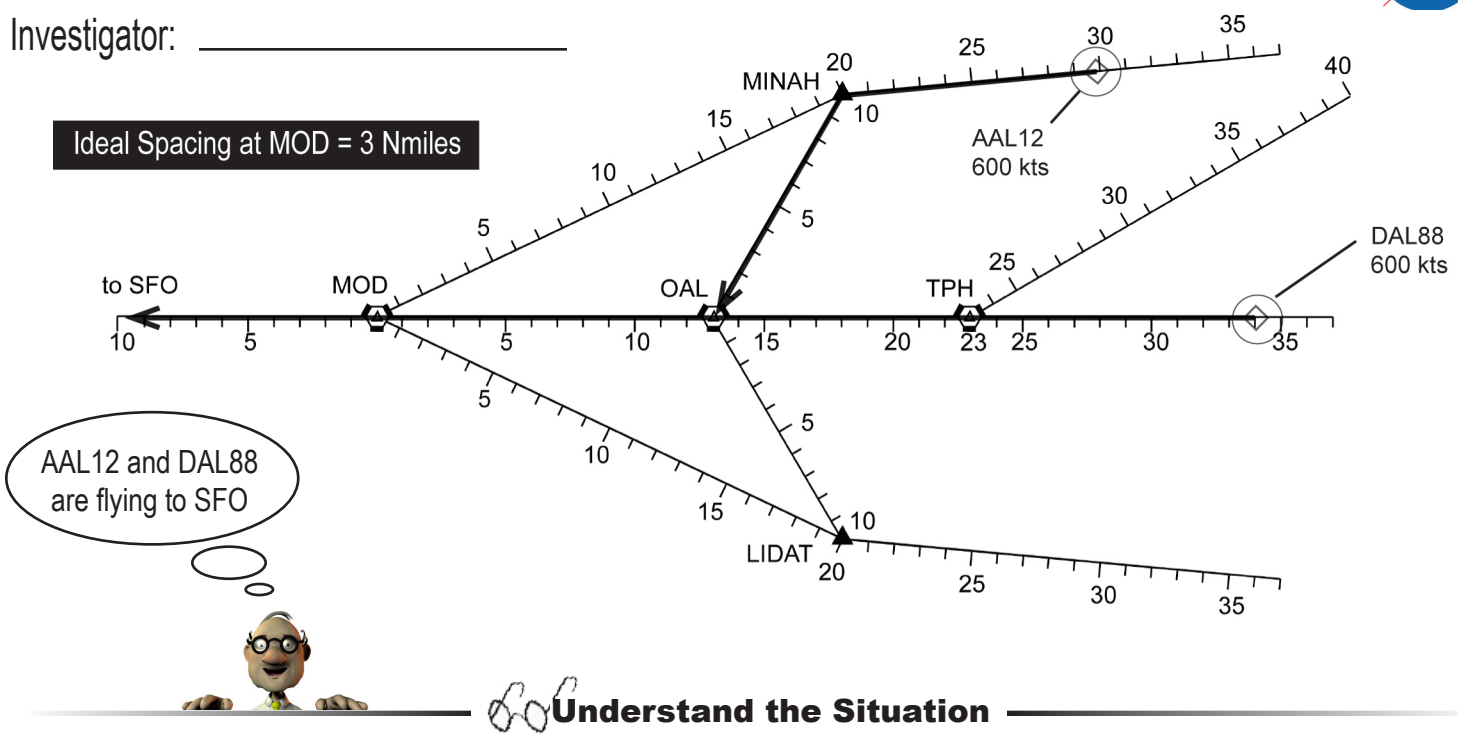
- Simulator at: www.atcsim.nasa.gov

Investigator: _____

An Airspace Systems Program Product

Problem 2-1

Investigator: _____



Understand the Situation

1 The plane speeds are: [X] Same [ ] Different

2 The plane routes intersect first at: **OAL**

Predict Aircraft Positions

3 Which plane is closer to OAL? (This plane has a "headstart".) **AAL12** "Headstart" = **1** nautical miles

21 - 20 = 1

4 Which plane will arrive first at OAL? **AAL12** Spacing = **1** nautical miles

5 When that plane arrives at OAL, the spacing will be [X] the same as [ ] different from the "headstart".

Check Separation

6 Will the spacing at OAL be at least the minimum separation of 2 nautical miles? [ ] Yes [X] No

7 How much extra spacing is needed to have the ideal spacing of 3 nautical miles? **2** nautical miles

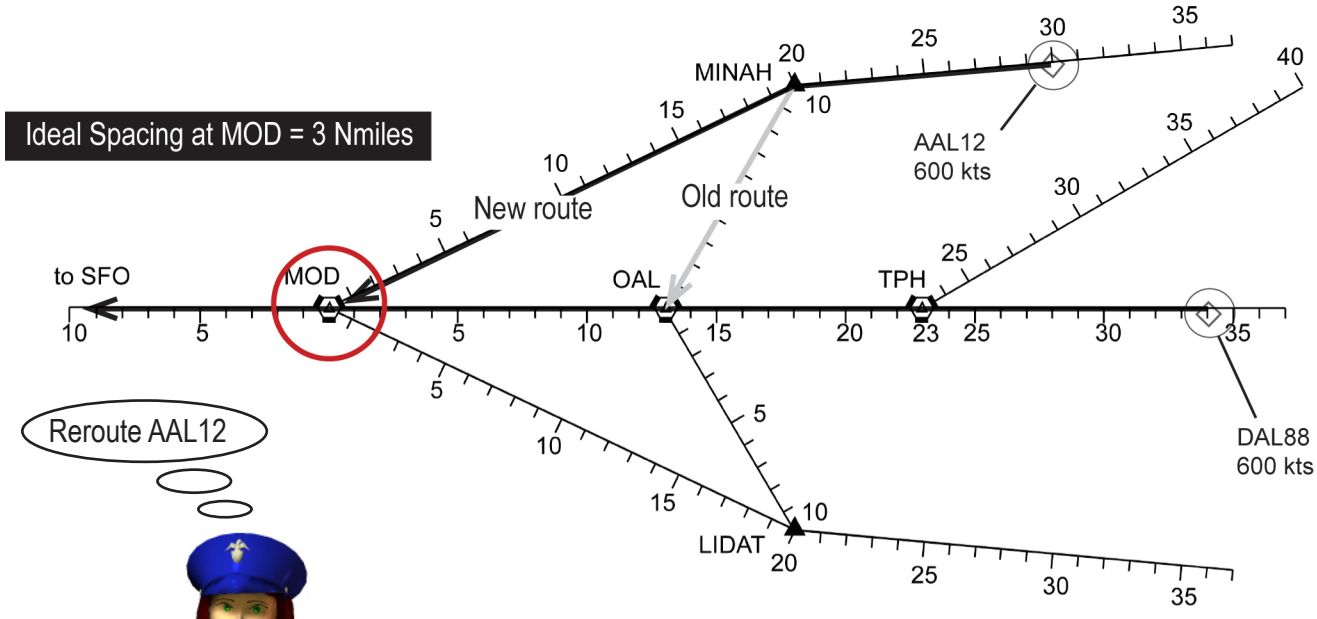
3 - 1 = 2

8 What could the controller do to achieve at least ideal spacing?

Change the route of AAL12 or change the speed of either plane.

Continue to Next Page

Investigator: _____ **Problem 2-1 (Continued)**



Fix the Conflict

- One way to try to achieve the ideal spacing is to **REROUTE** AAL12 directly from MINAH to MOD as shown above.

9 Circle the intersection where the new AAL12 route meets the DAL88 route.

Predict New Positions

34 - 30 = 4

10 Which plane now has a "headstart"? ***AAL12*** New "Headstart" = ***4*** nautical miles

11 Which plane will arrive first? ***AAL12*** New Spacing = ***4*** nautical miles

12 Why does the new route provide additional spacing?

With the new route to MOD, AAL12 now has a 4 nautical mile headstart.

Check New Separation

13 Is the new spacing at least the minimum of 2 nautical miles? [X] Yes [ ] No If No, try again!

14 Does the new spacing equal the ideal spacing of 3 nautical miles? [ ] Yes [X] No

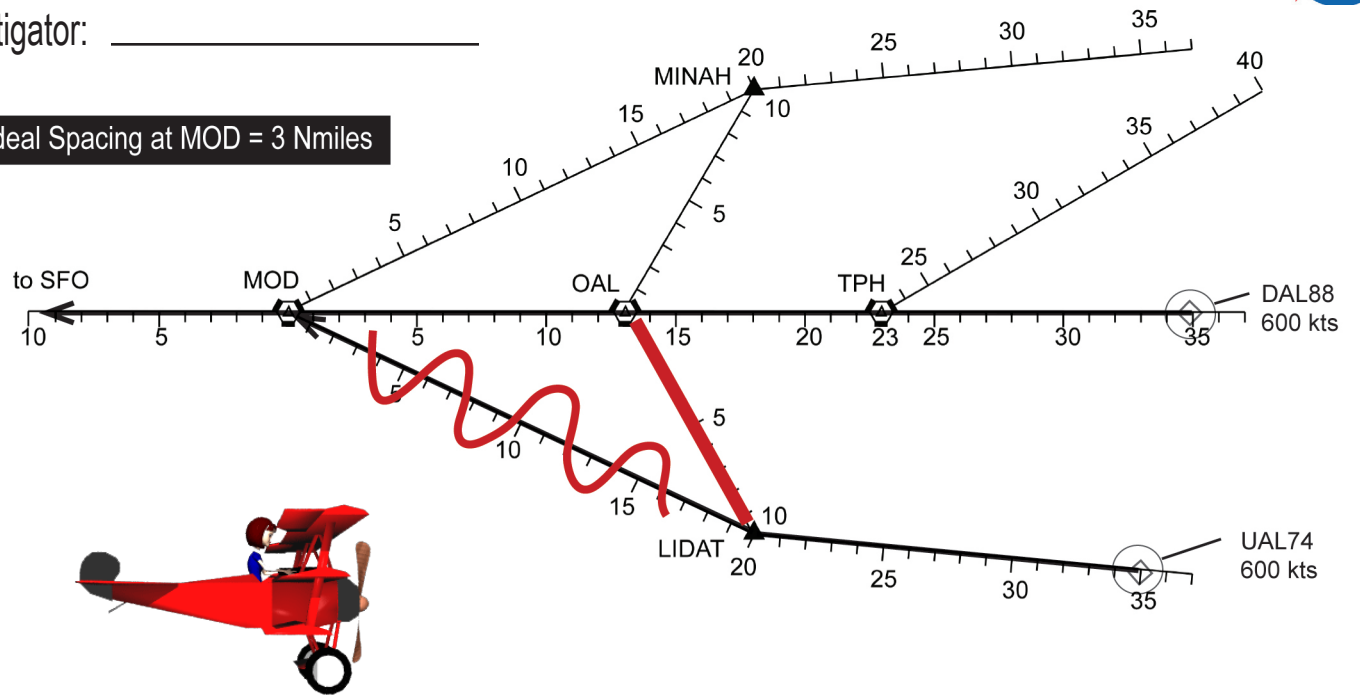
Route changes don't always give Ideal Spacing!

End of Worksheet

Problem 2-2

Investigator: _____

Ideal Spacing at MOD = 3 Nmiles



1 Fill in the table to determine if the 2 planes have the ideal spacing where the routes meet.

Where do the routes meet?	Headstart Nmiles	Spacing at MOD, Nmi	Is Spacing at MOD Ideal?	Additional spacing required for Ideal Spacing (3 Nmi)
MOD	0	0	No	3 Nmi

35 - 35 = 0

2 If the spacing is NOT at least Ideal, enter the flight plan change you will use to get more spacing at MOD.

Plane: UAL74 Route change: LIDAT To: OAL To: MOD

CAUTION **Be sure to mark out the old route and darken the new route.**
This is so you won't use the wrong route by mistake when you check your solution.

3 To check your new route, fill in the following table.

Where do the routes meet?	Lead Plane?	Headstart Nmiles	Spacing at OAL, Nmi	Spacing at MOD, Nmi	Is Spacing at MOD Ideal?
OAL	DAL88	3	3	3	Yes

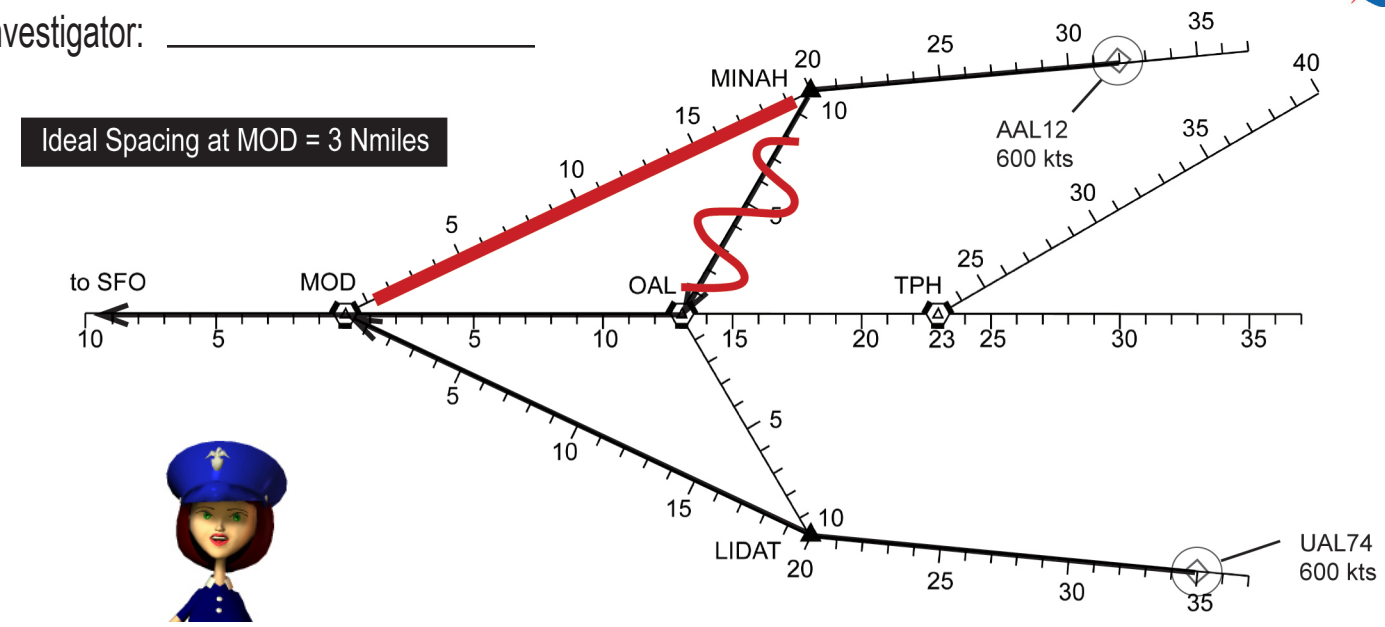
25 - 22 = 3

If Yes, Congratulations! If No, try again!

End of Worksheet

Problem 2-3

Investigator: _____



1 What is the spacing at MOD? **0** nautical miles *35 - 35 = 0*

2 Why? *The route lengths and the speeds are the same (35 nautical miles).*

3 Does the spacing equal the ideal? ☐ Yes ☒ No

4 If the spacing is NOT the ideal spacing, enter the flight plan change you will use to solve the problem.

Plane: *AAL12* New Route: *MINAH to MOD*

(If send UAL74 the long way, both planes will be delayed.)

CAUTION **Be sure to mark out the old route and darken the new route.**
This is so you won't use the wrong route by mistake when you check your solution.

5 What is the new spacing at MOD? **3** nautical miles *35 - 32 = 3*

6 Why? *The AAL12 route to MOD is now 3 nautical miles shorter than it was originally (32 Nmi versus 35 Nmi).*

7 Is the new spacing now ideal (3 nautical miles)?

☒ Yes ☐ No

If Yes, Congratulations!
If No, try again!

End of Worksheet