*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

MOD

3 Nmi

Goal
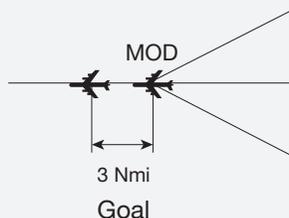
*Estimated class time: 1.5 to 2 hours.*

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:

https://www.nasa.gov/lineup-with-math

A separate student website gives students easy access to the Simulator and supporting materials (not to the answers and solutions 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 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 Problems 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.

**Worksheet: *Problem 2-1***

*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.*

- 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 Problem 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 1

*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:

### Sector 33

00:00
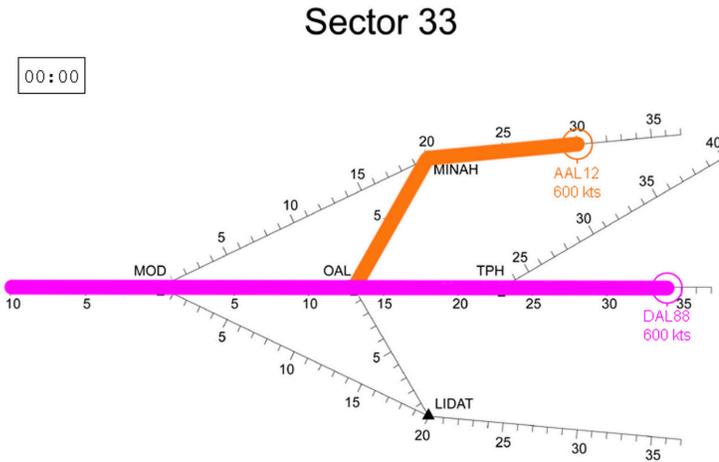
| Plane | From | Through | To | Distance | Speed |
|-------|------|---------|-----|----------|-------|
| aal12 | MINAH | OAL | MOD | 33 | 600 |
| DAL88 | TPH | OAL | MOD | 34 | 600 |

- 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.

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

Initial:

AAL12 DAL88

Target:

AAL12 ← 3 Nmiles

X                    X

## Solution

### Sector 33

00:00
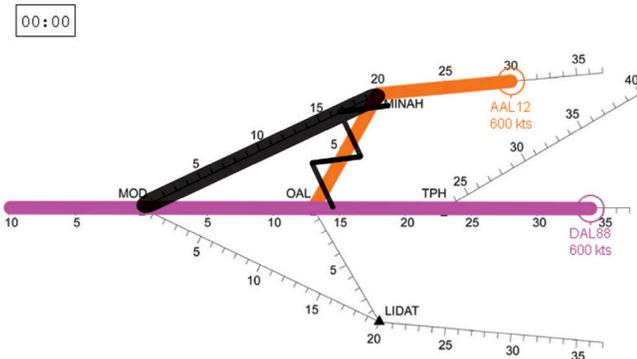
- **AAL12** - Reroute direct to MOD to move forward 3 nautical miles. Spacing at MOD is 4 nautical miles. This is greater than 3 nautical miles Ideal Spacing.

- **Target Time** - 3 minutes and 24 seconds.

**Solution**

Starting Conditions:

### Sector 33

`00:00`



| 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.

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### Analysis:

- **Conflict: DAL88 <u>AND</u> 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.

| Project Arrival | Plane | Distance Along Flight Plan | Initial Spacing |
|-----------------|-------|----------------------------|-----------------|
| 1st | DAL88 | 35 | |
| | UAL74 | LIDAT | 35 | 0 |

Initial:



Target:

---

### Solution

### Sector 33

`00:00`



- **UAL74** - Reroute through OAL to fall back by 3 nautical miles.

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

Starting Conditions:

### Sector 33

`00:00`
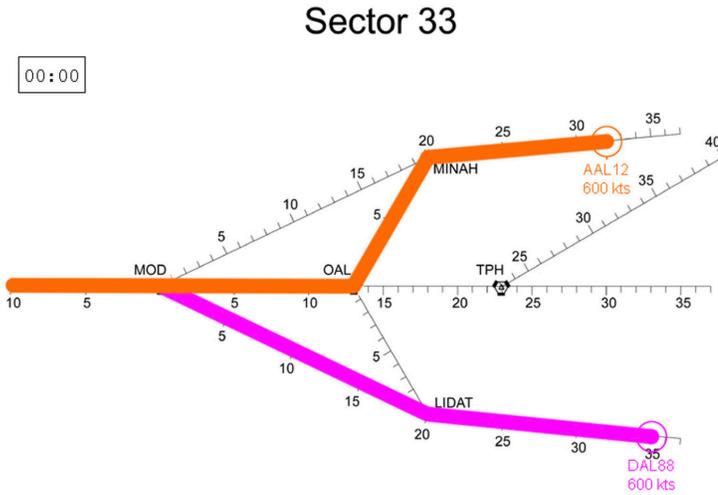


| Plane | From | Through | To | Distance | Speed |
|-------|------|---------|-----|----------|-------|
| AAL12 | MINAH | OAL | MOD | 35 | 600 |
| DAL88 | LIDAT | | MOD | 35 | 600 |

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

### Analysis:

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

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

Initial:



Target:

AAL12   3 Nmiles

### Solution

### Sector 33

`00:00`
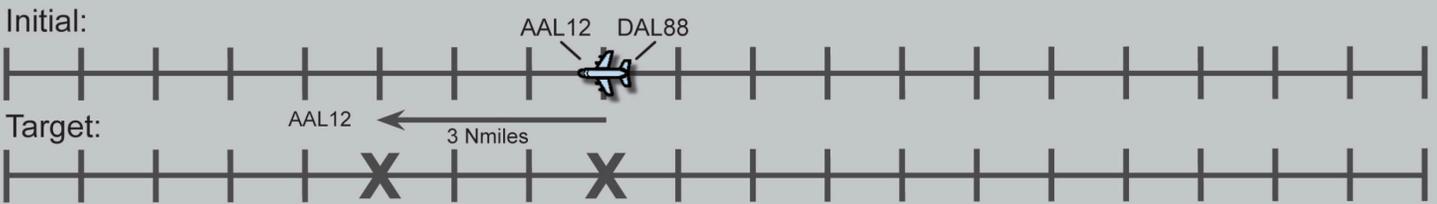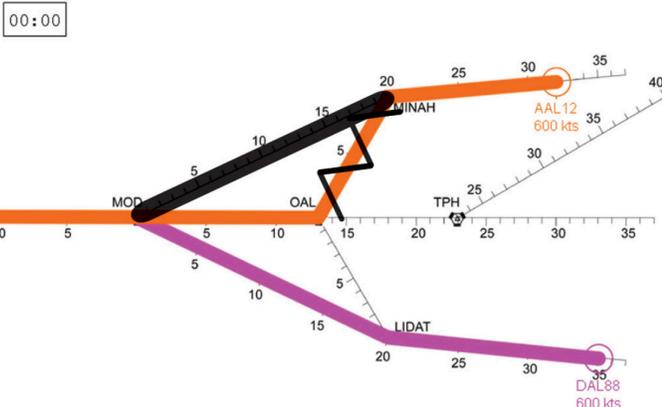


- **AAL12** - Reroute direct to MOD to move forward 3 nautical miles

- **Target Time** - 3 minutes and 30 seconds.

**Starting Conditions:**

## Sector 33

00:00
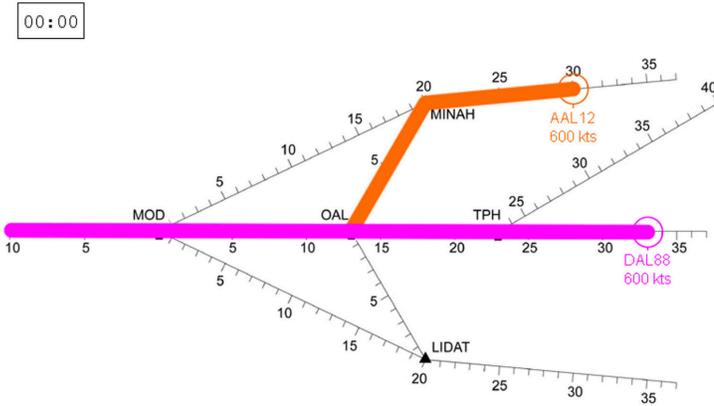
| Plane | From | Through | To | Distance | Speed |
|-------|------|---------|-----|----------|-------|
| AAL12 | MINAH | OAL | MOD | 33 | 600 |
| DAL88 | TPH | OAL | MOD | 33 | 600 |

- 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.

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

Initial: AAL12 DAL88

Target: AAL12 ← 3 Nmiles

## Solution

## Sector 33

00:00
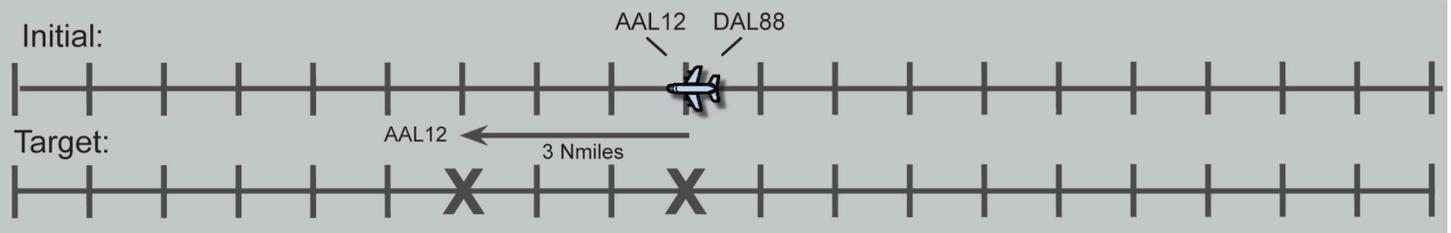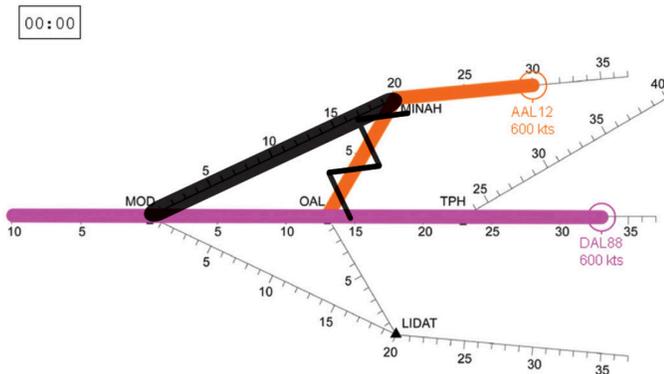
- **AAL12** - Reroute direct to MOD to move forward 3 nautical miles

- **Target Time** - 3 minutes and 18 seconds.

# Problem 2-10

## Solution

Starting Conditions:
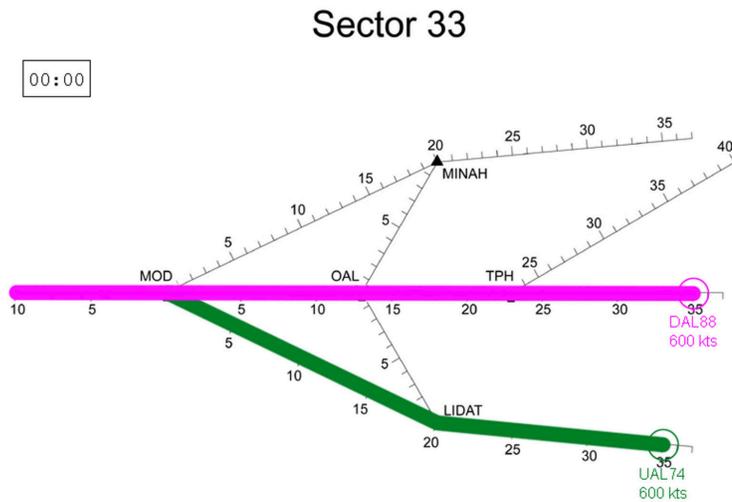
### Sector 33

`00:00`



| 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 <u>AND</u> 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.

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

Initial:



Target:

## Solution

### Sector 33

`00:00`
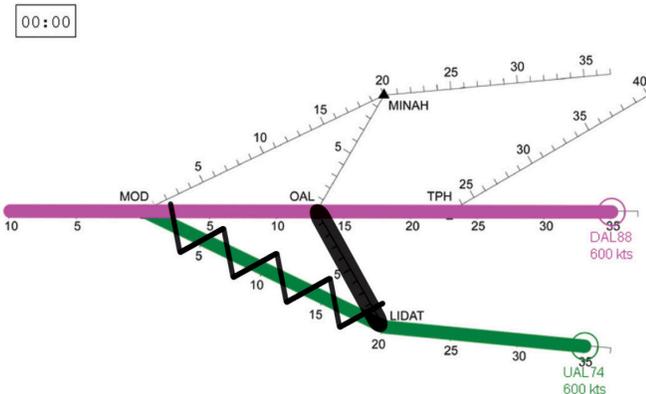


- **UAL74** - Reroute through OAL to fall back 3 nautical miles

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

*Smart Skies*™ *LineUp With Math*™ Simulator

# 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.
  - Worksheets for Simulator problems 2-1, 2-2, 2-3.

## Workbook Answers

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

American 12, cleared direct MINAH to Modesto.

Investigator: _____

An Airspace Systems
Program Product

# Problem 2-1

Investigator: _____

Ideal Spacing at MOD = 3 Nmiles
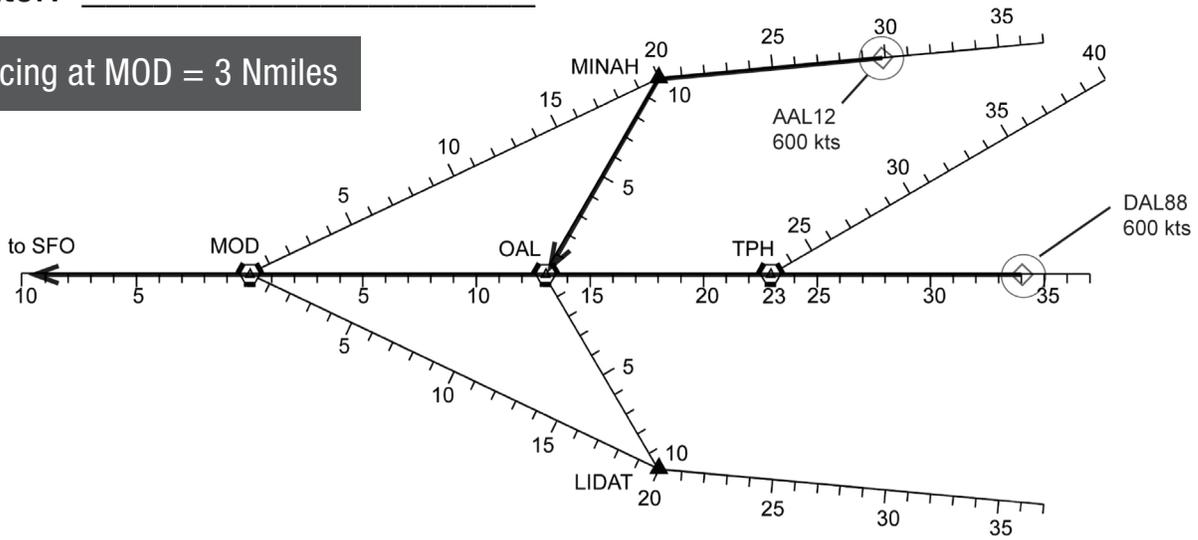


## Understand the Situation

1. The plane speeds are: **X** Same
   ☐ Different

2. The plane routes intersected first at: **OAL**

## Predict Aircraft Positions

3. Which plane is closer to OAL? (This plane has a "headstart".)  **AAL12** ▶▶ "Headstart"= *21-20 = 1* **1** nautical miles

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 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 airplane.***

**Continue to Next Page**

**Ideal Spacing at MOD = 3 Nmiles**
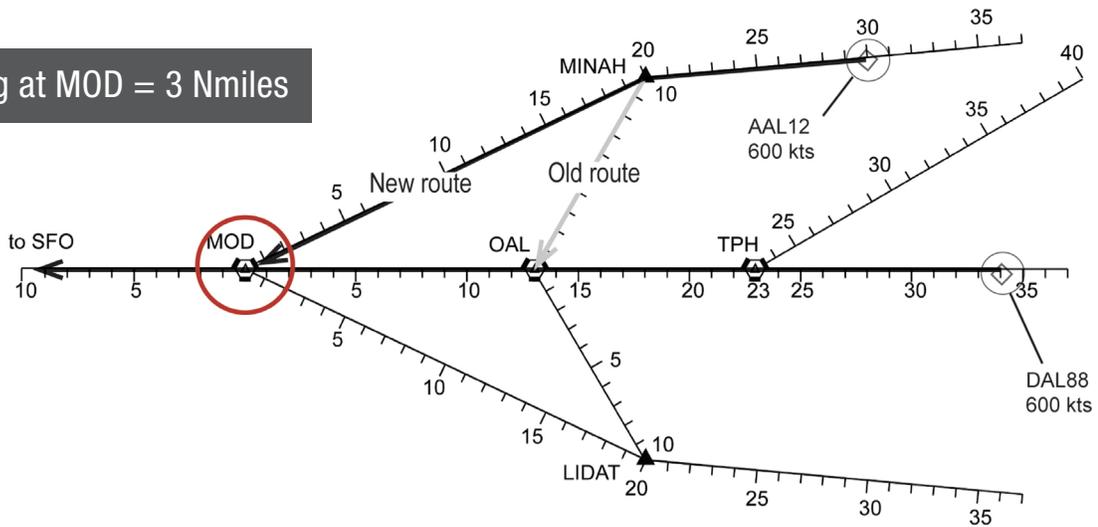
## Fix the Conflict

- One way to try to achieve the ideal spacing is to REROUTE AAL-12 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** ▶▶ 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!**

# Problem 2-2

Investigator: _____

**Ideal Spacing at MOD = 3 Nmiles**
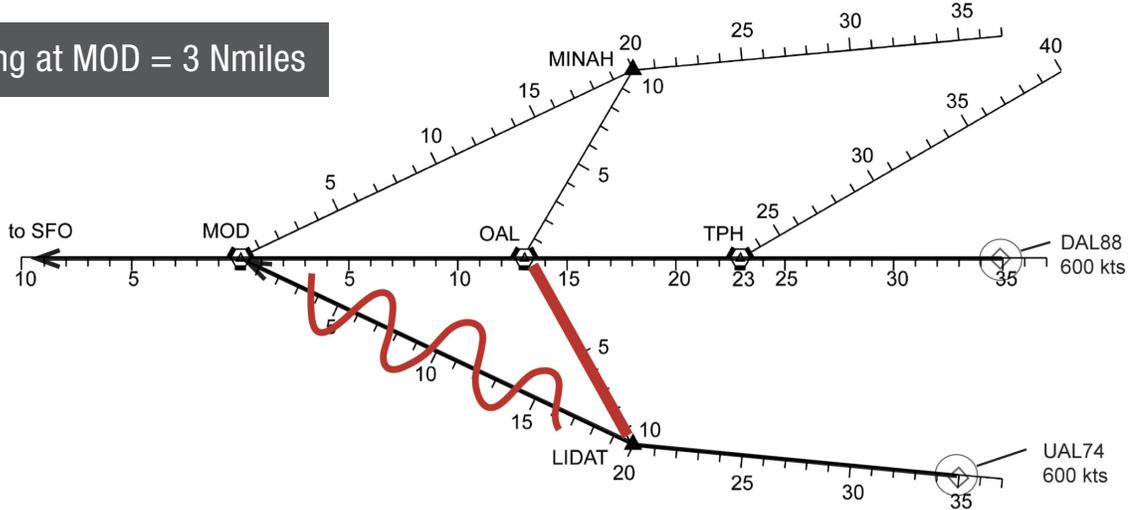


☁ **1** Fill in the table to determine if the 2 planes have the ideal spacing where the routes meet.

| 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 | Is Spacing at MOD Ideal? |
|---|---|---|---|---|
| *OAL* | *DAL88* | *3* | *3* | *Yes* |

*25-22=3*

If Yes, Congratulations!    If No, try again!

# Problem 2-3

Ideal Spacing at MOD = 3 Nmiles
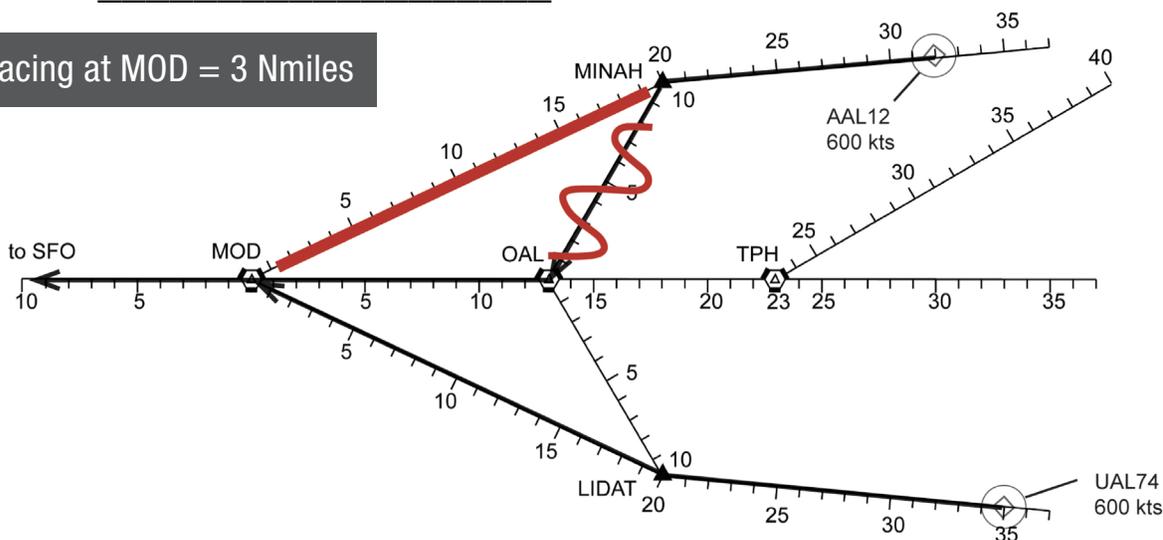


**1** What is the spacing at MOD?   **0**   nautical miles    *35-35=0*

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

**3** Does the spacing equal the ideal?   ☐ Yes   **X** 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?  _____

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

**X** Yes   ☐ No      If Yes, Congratulations!
If No, try again!