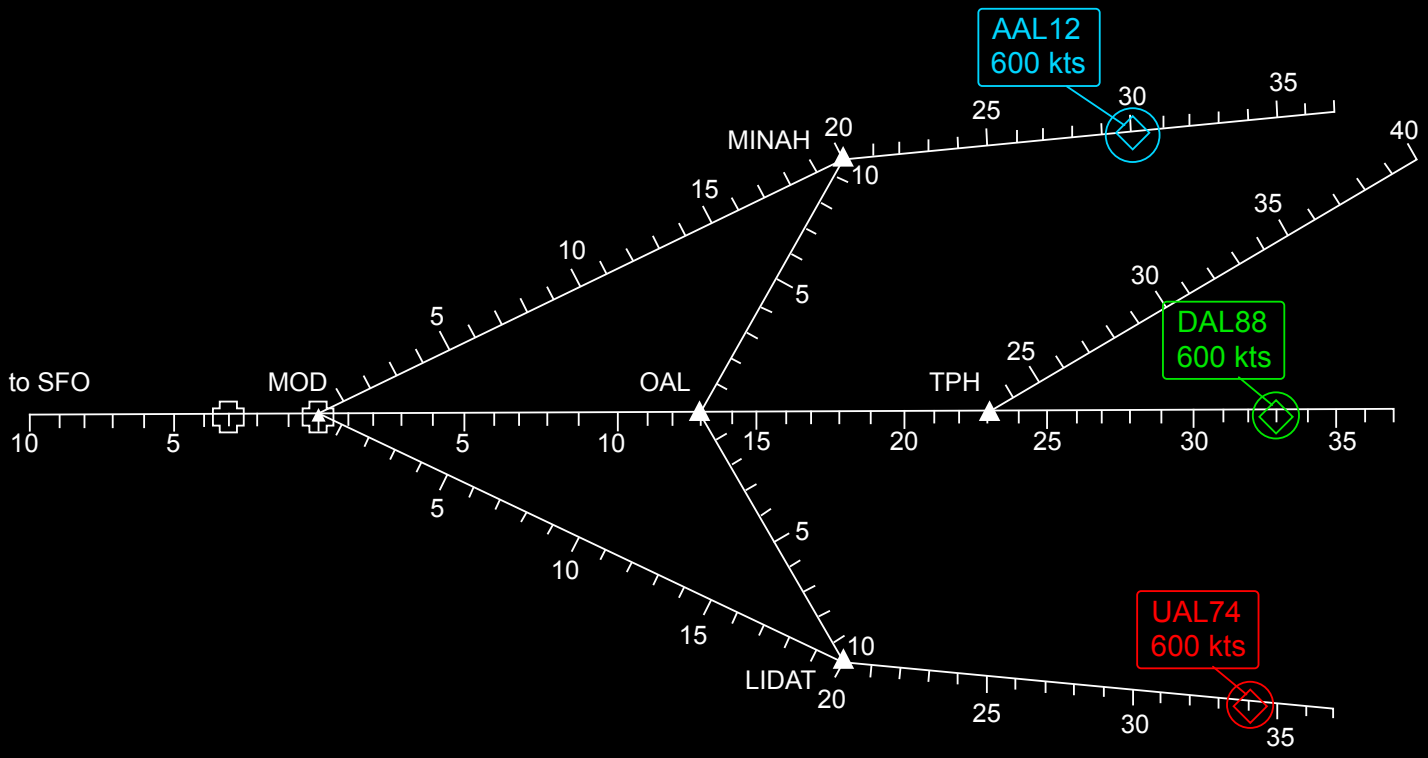
National Aeronautics and Space Administration



LineUp with Math

Math-Based Decisions in Air Traffic Control

FACILITATOR GUIDE F

Facilitator Guide with Answer Sheets
Resolving 3-Plane Traffic Conflicts by Changing Speed

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

Facilitator Guide with Answer Sheets

Overview of Problem Set F

Estimated class time: 1.5 to 2 hours

In Problem Set F, students will change the speed of one or more planes to achieve the proper spacing at MOD. Estimated class time is 1.5 to 2 hours.

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 speed of one or more planes.
- Resolve spacing conflicts by changing the speed or the speed and route of one or more planes.

Prerequisites

Complete Problem Set A, B, D, and E which provide essential air traffic control vocabulary, units of measurement, graphical representations, and familiarity with the ATC simulator.

Materials

Access the materials by visiting the Smart Skies: LineUp with Math™ website: https://www.nasa.gov/stem-content/smart-skies-lineup-with-math2/

- Smart Skies: LineUp with Math ATC simulator
  - use online
  - download
- Student Workbook F:
  - Fillable PDF versions
  - Printed copies

ATC Simulator

Interactive Air Traffic Control Simulator

Each problem in this set features a 3-plane conflict that can be resolved by speed changes or by route and speed changes. The simulator problems for Problem Set F are: 3-3*, 3-4*, 3-5*, 3-6*, 3-8, 3-9, 3-11, and 3-12.

Facilitator Guide with Answer Sheets (cont'd)

Problems with an asterisk (*) are supported by Student Workbook F. The remaining problems are recommended for guided learning (whole or small group).

Answer Sheets

Facilitator analysis and solutions for each of the problems can be found in Appendix I. The worksheet answer keys for Student Workbook F can be found in Appendix II.

Student Workbook

Student Workbook F consists of four worksheets, one for each problem: 3-3, 3-4, 3-5, and 3-6.

Worksheet #1: Problem 3-3

- ✈ Plot each plane on a number line to help picture the arrival order of the planes at MOD.
- ✈ Identify spacing conflicts to determine how many nautical miles of spacing are needed to achieve ideal spacing between all three planes.
- ✈ Determine which plane (or planes) need a speed decrease to achieve ideal spacing between the second and third planes.

Worksheet #2: Problem 3-4

- ✈ Identify spacing conflicts between the first and second planes, then use the new spacing of the second plane to identify the spacing conflict between the second and third planes.

Worksheet #3: Problem 3-5

- ✈ Identify and resolve spacing conflicts to achieve ideal spacing at MOD.
- ✈ Determine if resolution of spacing conflict violates the minimum separation requirement at OAL.
- ✈ Determine if the minimum separation requirement is met at OAL. A speed reduction will achieve minimum separation before OAL.

Worksheet #4: Problem 3-6

- ✈ The original positions of two planes, will give 4 nautical miles spacing at MOD. This is more than the ideal spacing which will require a reroute and a speed reduction.
- ✈ Analyze the new route to slow down the (now) trailing plane to maintain ideal spacing.

APPENDIX I

Simulator Solutions for Problem Set F

3-3*, 3-4*, 3-5*, 3-6*, 3-8, 3-9, 3-11, and 3-12

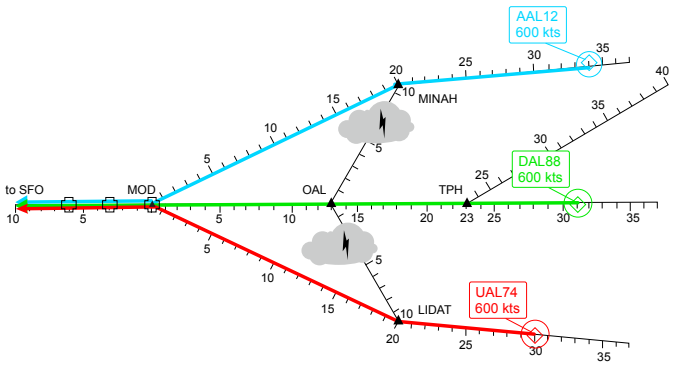
Problems with an asterisk (*) are supported by Student Workbook F

ANALYSIS OF WORKSHEET #1

Problem 3-3

STARTING CONDITIONS

Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	34	600
DAL88	TPH	OAL	MOD	31	600
UAL74	LIDAP		MOD	30	600

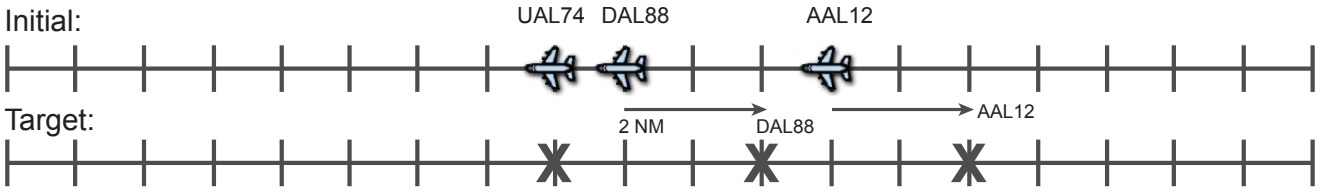


Route from **MINAH** to **OAL** is **closed**.
Route from **LIDAT** to **OAL** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.

FLIGHT ANALYSIS

- **DAL88** will arrive at MOD 1 nautical miles behind **UAL74**.
- Weather prevents **AAL12** and **UAL74** from rerouting.
- **One or more** planes must slow down to avoid collision and accomplish ideal spacing.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	30	1
2nd	DAL88	31	3
3rd	AAL12	34	

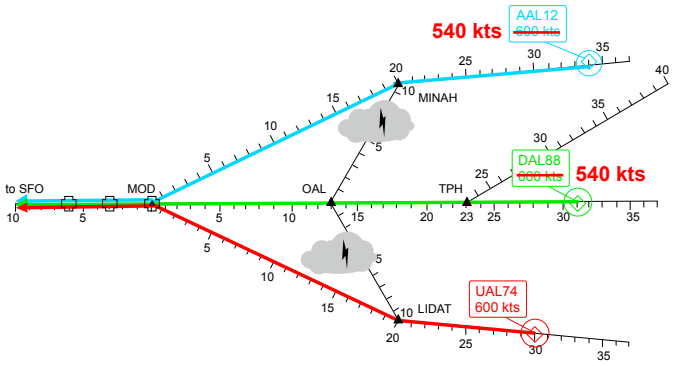


SOLUTION

- **DAL88:** Slow down to 540 knots for 2 minutes to fall back 2 nautical miles, then speed back up to 600 knots.

- **AAL12:** Slow down to 540 knots for 2 minutes to fall back 2 nautical miles, then speed back up to 600 knots.

  (d = r x t) 2 NM = 1 NM/min x t
  2 NM ÷ 1 NM/min = t
  2 mins = t



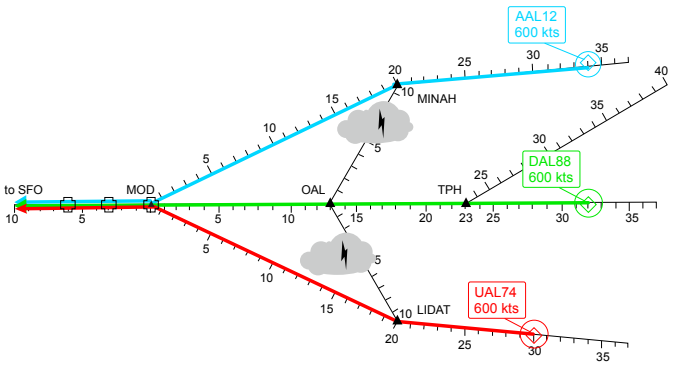
- **Target Time:** 3 minutes and 36 seconds.

ANALYSIS OF WORKSHEET #2

Problem 3-4

STARTING CONDITIONS

Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	34	600
DAL88	TPH	OAL	MOD	32	600
UAL74	LIDAT		MOD	30	600

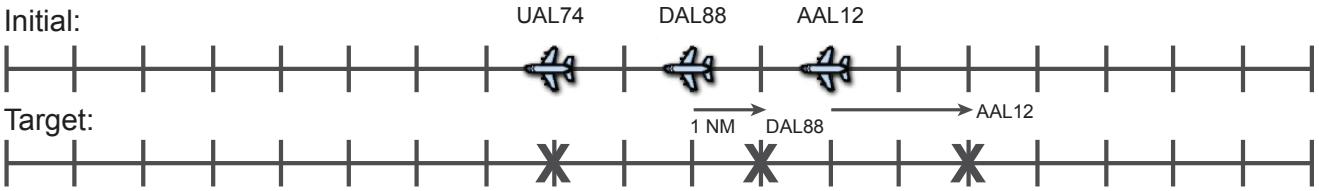


Route from **MINAH** to **OAL** is **closed**.
Route from **LIDAT** to **OAL** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.

FLIGHT ANALYSIS

- **DAL88** will arrive at MOD 2 nautical miles behind UAL74 and **AAL12** will arrive at MOD 2 nautical miles behind DAL88.
- Weather prevents **AAL** and **UAL74** from rerouting.
- **The trailing** planes will need to slow down to avoid collision and accomplish ideal spacing.

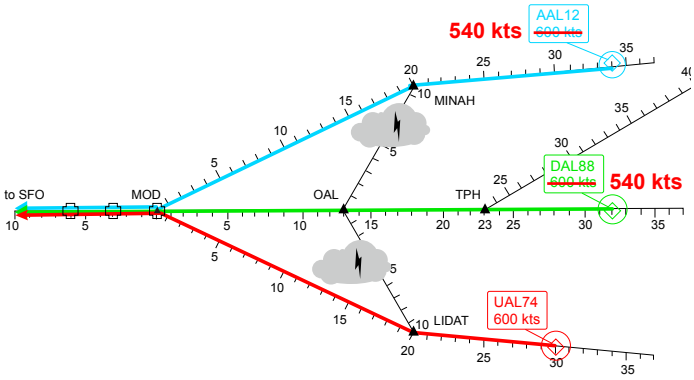
Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	30	
			→ 2
2nd	DAL88	32	
			→ 2
3rd	AAL12	34	



SOLUTION

- **DAL88:** Slow down to 540 knots for 1 minute to fall back 1 nautical mile, then speed back up to 600 knots.
  (d = r x t) 1 NM = 1 NM/min x t
  1 NM ÷ 1 NM/min = t
  1 mins = t

- **AAL12:** Slow down to 540 knots for 2 minutes to fall back 2 nautical miles, then speed back up to 600 knots.
  (d = r x t) 2 NM = 1 NM/min x t
  2 mins = t



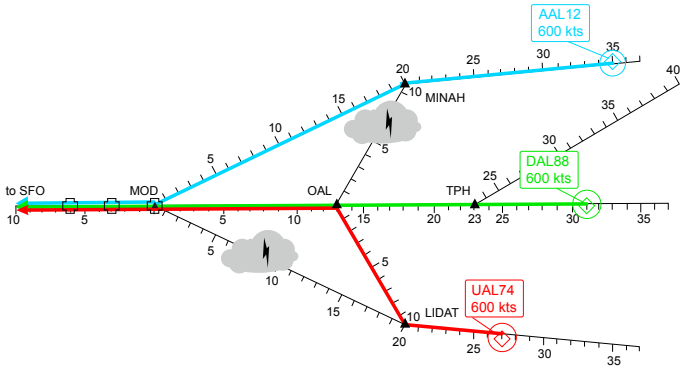
- **Target Time:** 3 minutes and 36 seconds.

ANALYSIS OF WORKSHEET #3

Problem 3-5

STARTING CONDITIONS

Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	35	600
DAL88	TPH	OAL	MOD	31	600
UAL74	LIDAT	OAL	MOD	30	600

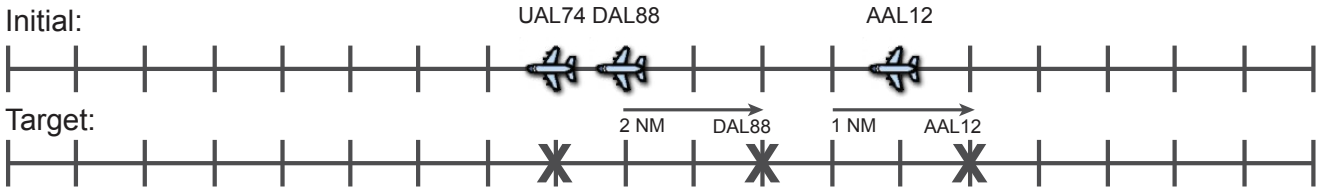


Route from **MINAH** to **OAL** is **closed**.
Route from **LIDAT** to **MOD** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.

FLIGHT ANALYSIS

- **DAL88** will arrive at MOD 1 nautical mile behind **UAL74**. **AAL12** will arrive at MOD 4 nautical miles behind **DAL88**.
- Weather prevents **AAL12** and **UAL74** from rerouting.
- **One or more** planes will need to slow down to avoid collision and accomplish ideal spacing.

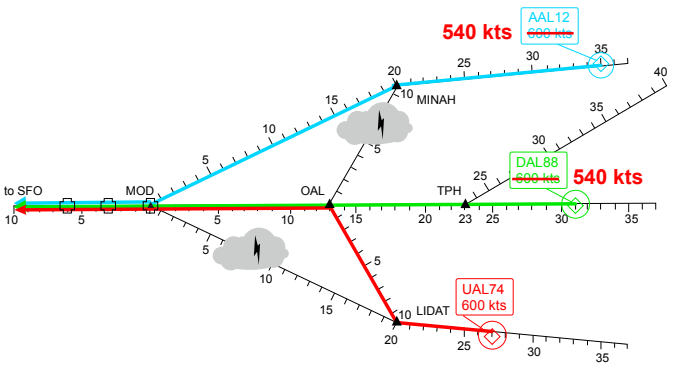
Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	30	
2nd	DAL88	31	→ 1
3rd	AAL12	35	→ 4



SOLUTION

- **DAL88:** Slow down to 540 kts for 2 minutes to fall back 2 nautical miles, then speed up to 600 knots.
  (d = r x t) 2 NM = 1 NM/min x t
  2 NM ÷ 1 NM/min = t
  2 mins = t

- **AAL12:** Slow down to 540 kts for 1 minute to fall back 1 nautical mile, then speed up to 600 knots.
  (d = r x t) 1 NM = 1 NM/min x t
  1 NM ÷ 1 NM/min = t
  1 mins = t



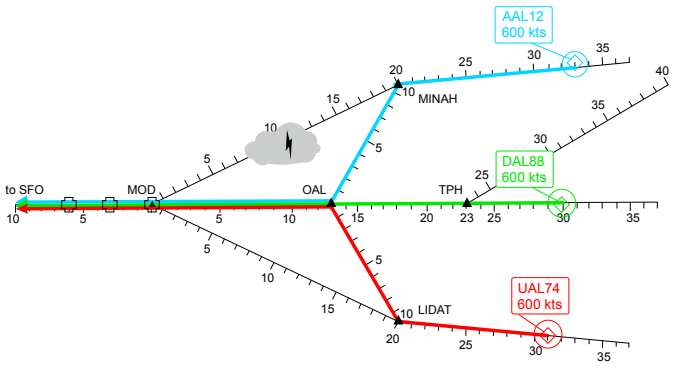
- **Target Time:** 3 minutes and 36 seconds.

ANALYSIS OF WORKSHEET #4

Problem 3-6

STARTING CONDITIONS

Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	36	600
DAL88	TPH	OAL	MOD	30	600
UAL74	LIDAT	OAL	MOD	34	600

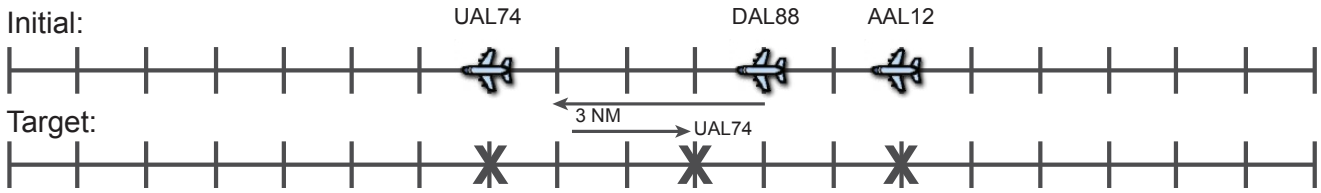


Route from **MINAH** to **MOD** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.

FLIGHT ANALYSIS

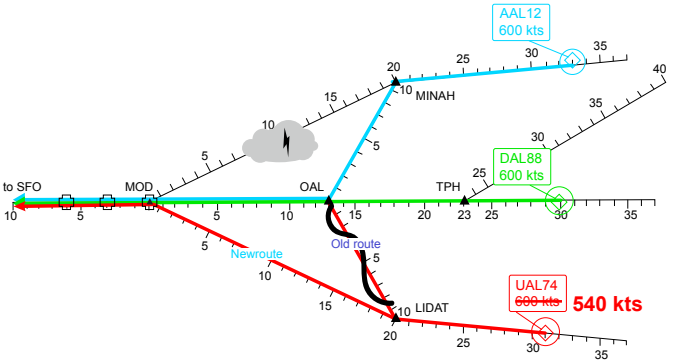
- **UAL74** will arrive 4 nautical miles behind **DAL88**. **AAL12** will arrive 2 nautical miles behind **UAL74**.
- Weather prevents **AAL12** from rerouting
- **One** plane will need to reroute and slow down to accomplish ideal spacing.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	DAL88	30	→ 4
2nd	UAL74	34	
3rd	AAL12	36	→ 2



SOLUTION

- **UAL74:** Reroute direct to MOD through LIDAT to move forward 3 nautical miles and slow down to 540 knots for 2 minutes to fall back 2 nautical miles, then speed back up to 600 kts.
  (d = r x t) 2 NM = 1 NM/min x t
  2 NM ÷ 1 NM/min = t
  2 mins = t

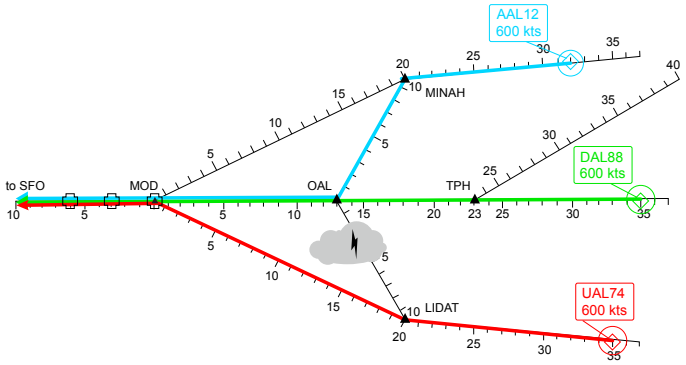


- **Target Time:** 3 minutes and 36 seconds.

Problem 3-8

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

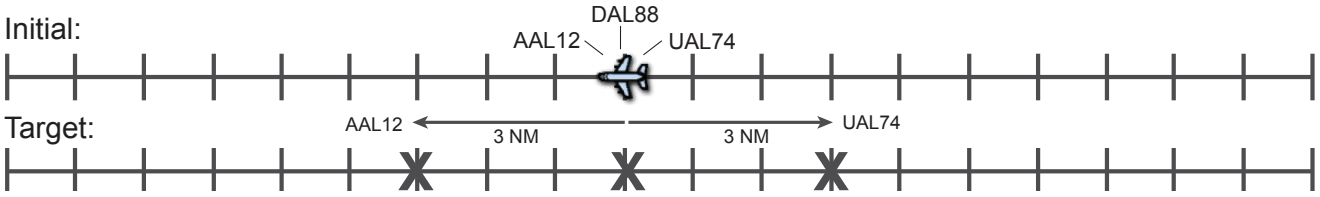


Route from **LIDAT** to **OAL** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.

FLIGHT ANALYSIS

- **All three** planes will arrive at MOD at the same time.
- Weather prevents **UAL74** from rerouting.
- **One or more** planes will need to reroute and slow down to accomplish ideal spacing**.**

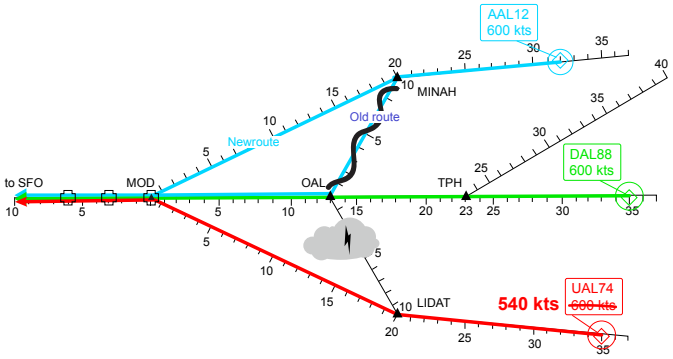
Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	UAL74	35	0
1st	DAL88	35	
1st	AAL12	35	0



SOLUTION

- **AAL12:** Reroute direct to MOD through MINAH to move forward 3 nautical miles.

- **UAL74:** Slow down to 540 kts for 3 minutes to fall back 3 nautical mile, then speed back up to 600 knots.
  (d = r x t) 3 NM = 1 NM/min x t
  3 NM ÷ 1 NM/min = t
  3 mins = t

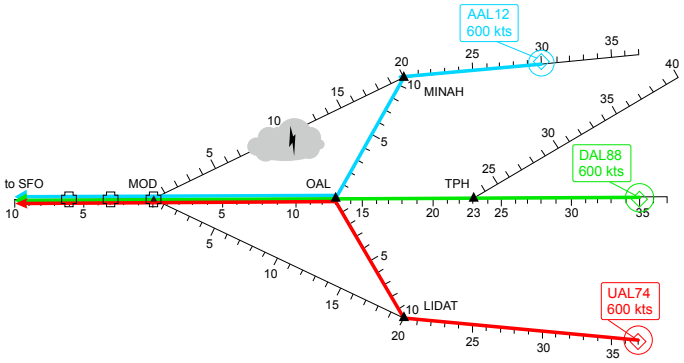


- **Target Time:** 3 minutes and 48 seconds.

Problem 3-9

STARTING CONDITIONS

Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	33	600
DAL88	TPH	OAL	MOD	35	600
UAL74	LIDAT	OAL	MOD	40	600

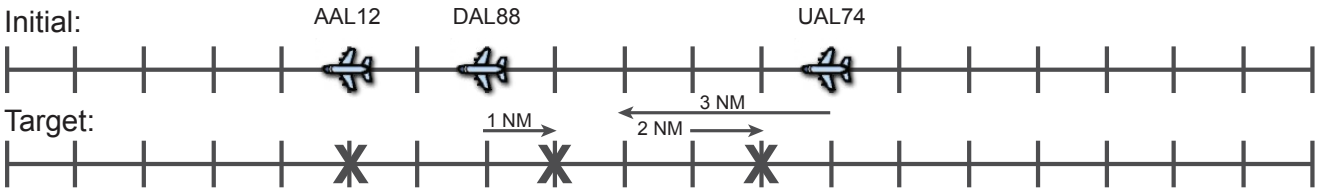


Route from **MINAH** to **MOD** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.

FLIGHT ANALYSIS

- **DAL88** will arrive at MOD 2 nautical miles behind AAL12 and **UAL74** will arrive at MOD 5 nautical miles behind DAL88.
- Weather prevents **AAL12** from rerouting.
- **One or more** planes will need to reroute and slow down to accomplish ideal spacing**.**

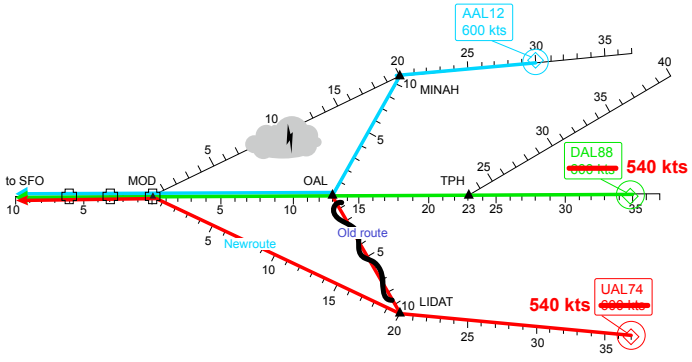
Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	33	
2nd	DAL88	35	→ 2
3rd	UAL74	40	→ 5



SOLUTION

- **DAL88:** Slow down to 540 kts for 1 minute to fall back 1 nautical mile, then speed back up to 600 knots.
  (d = r x t) 1 NM = 1 NM/min x t
  1 NM ÷ 1 NM/min = t
  1 mins = t

- **UAL74:** Reroute direct to MOD through LIDAT to move ahead 3 nautical miles and slow down to 540 kts for 2 minutes then speed back up to 600 knots.
  (d = r x t) 2 NM = 1 NM/min x t
  2 NM ÷ 1 NM/min = t
  2 mins = t

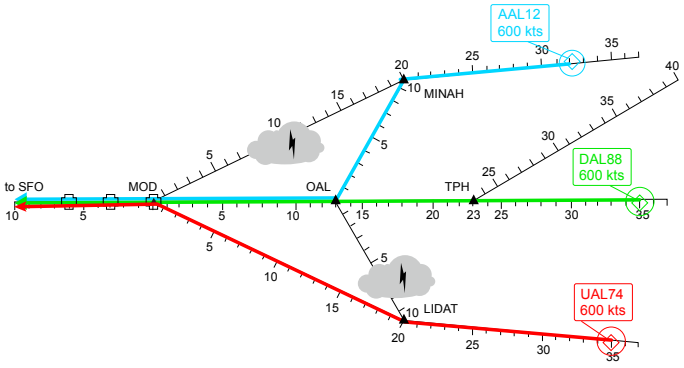


- **Target Time:** 3 minutes and 36 seconds.

Problem 3-11

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

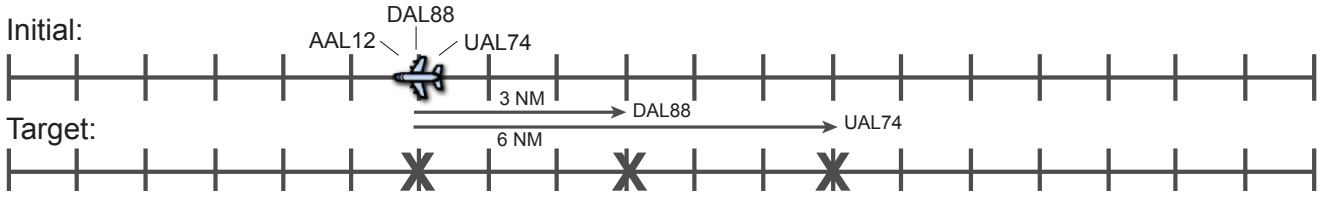


Route from **MINAH** to **MOD** is **closed**.
Route from **LIDAT** to **OAL** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.

FLIGHT ANALYSIS

- **All three** planes will arrive at MOD at the same time.
- Weather prevents **AAL12** and **UAL74** from rerouting.
- **One or more** planes must slow down to accomplish ideal spacing.

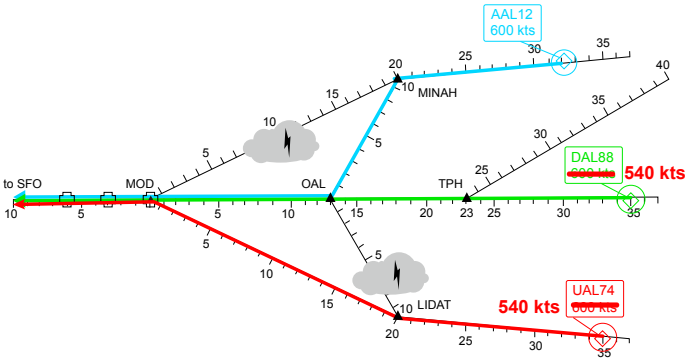
Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	35	0
1st	DAL88	35	
1st	UAL74	35	0



SOLUTION

- **UAL74:** Slow down to 540 kts for 3 minutes to fall back 3 nautical mile, then speed back up to 600 knots.

- **DAL88:** Slow down to 480 kts for 3 minutes to fall back 3 nautical mile, then speed back up to 600 knots.
  (d = r x t) 3 NM = 1 NM/min x t
  3 NM ÷ 1 NM/min = t
  3 mins = t

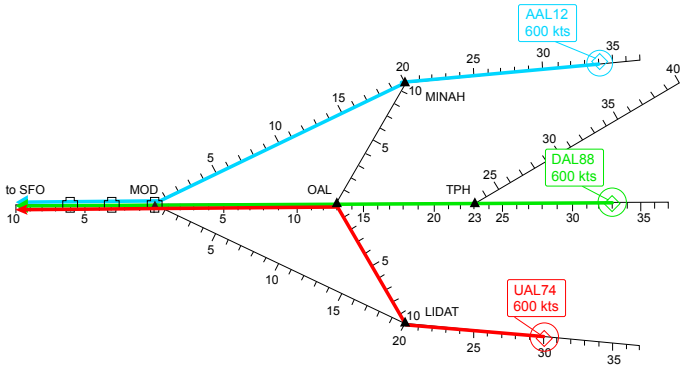


- **Target Time:** 4 minutes and 6 seconds.

Problem 3-12

STARTING CONDITIONS

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

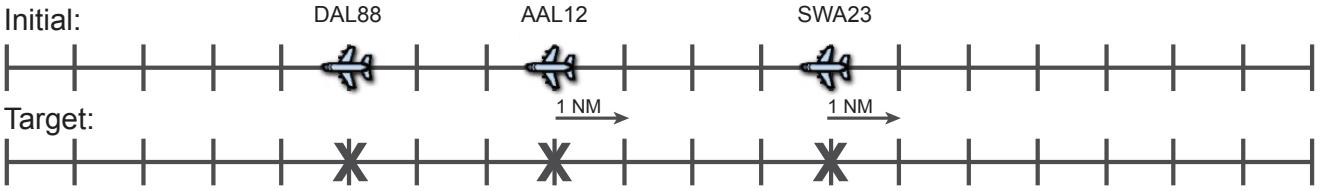


Ideal spacing at **MOD** is 3 nautical miles.
Minimum separation is 2 nautical miles.

FLIGHT ANALYSIS

- **DAL88** and **UAL74** will arrive at MOD at the same time and **AAL12** will arrive 1 nautical miles behind them.
- **One** plane needs to slow down and one plane needs to reroute to accomplish ideal spacing**.**

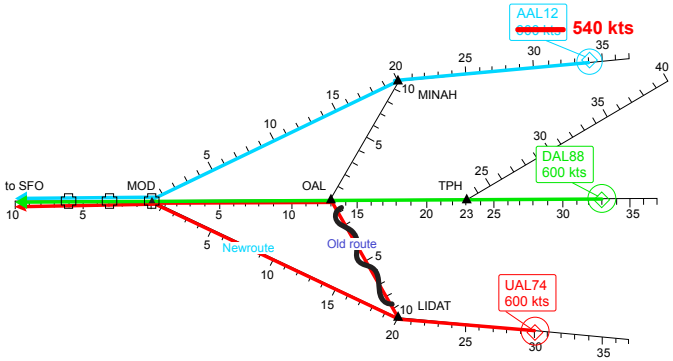
Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	DAL88	33	→ 0
1st	UAL74	33	
3rd	AAL12	34	→ 1



SOLUTION

- **UAL74:** Reroute direct to MOD through LIDAT to move forward 3 nautical miles.

- **AAL12**: Slow down to 540 kts for 2 minutes to fall back 2 nautical miles.
  (d = r x t) 2 NM = 1 NM/min x t
  2 NM ÷ 1 NM/min = t
  2 mins = t



- **Target Time:** 3 minutes and 36 seconds.

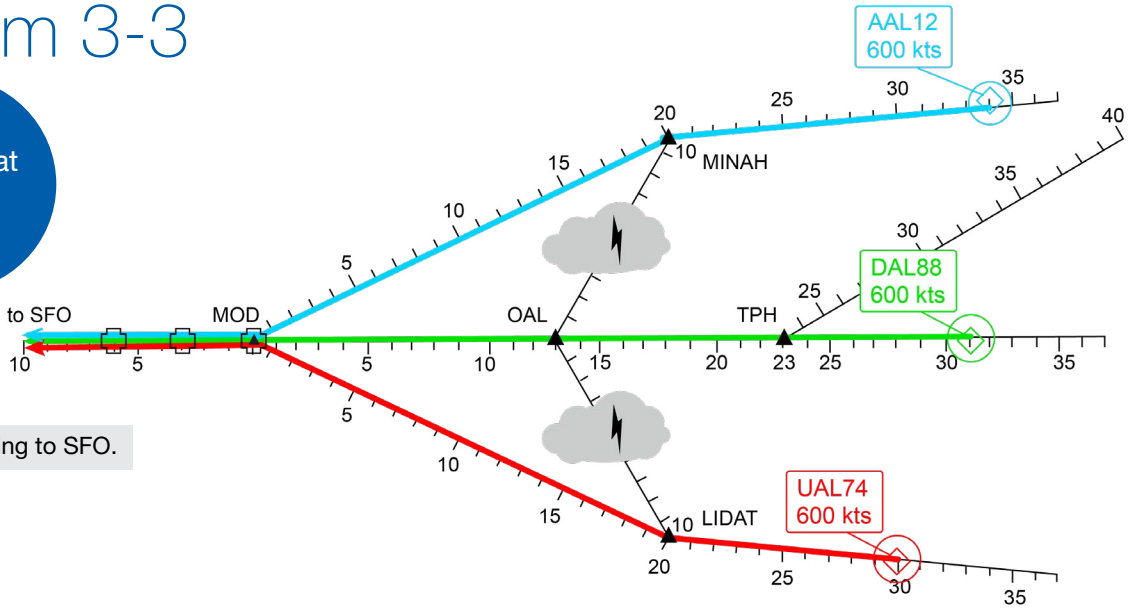
APPENDIX II

Answer Sheets

WORKSHEET #1

Problem 3-3

Ideal Spacing at MOD = 3 NM



All 3 planes are going to SFO.

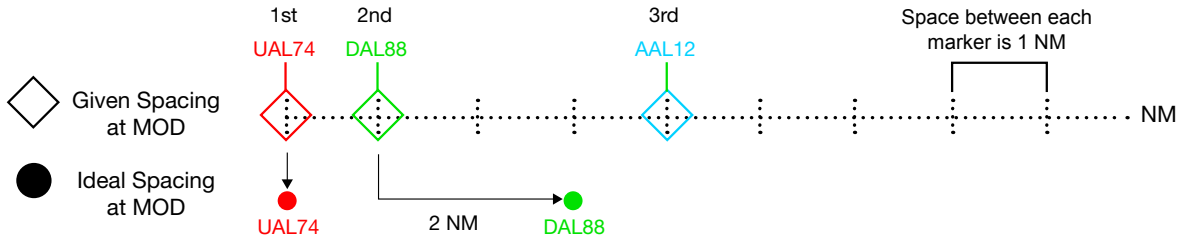
✈ Analyze the diagram to determine any spacing needs and notice the alternate routes are closed.

1. To find the arrival order of the 3 planes at MOD, fill in the blanks.

Plane	AAL12	DAL88	UAL74
Distance to MOD, NM	34	31	30
Arrival Order	3rd	2nd	1st

✈ To picture the arrival order and spacing of each plane, use a number line. Start with the first plane to arrive and work back to the last plane.

2. Use a ◇ to show the order and spacing for the 3rd plane. Label the ◇ (diamond symbol) with the plane's call sign.



It helps to picture the arrival order and spacing at MOD!

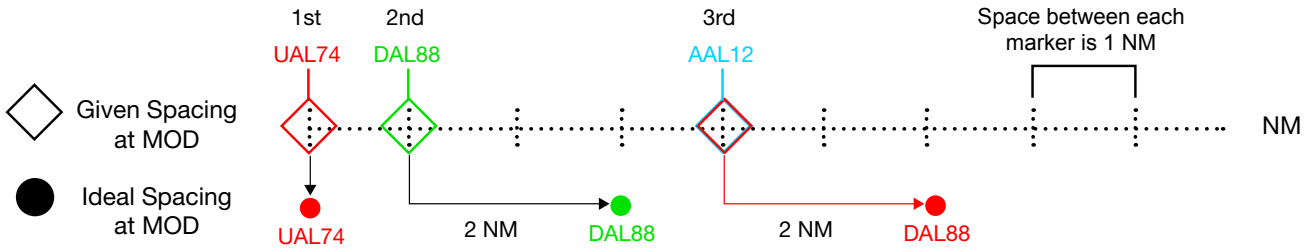
WORKSHEET #1 continued

Problem 3-3

✈ Next, determine the additional spacing needed to get ideal spacing at MOD.

3. How much spacing is needed between the first and second plane? ____2____ nautical miles.

✈ An arrow is used to show the additional spacing needed for the 2nd plane with a • (dot) at the end of the arrow labeled with the plane's call sign.



4. Based on the **NEW** position of the 2nd plane, how much additional spacing is needed between the second and third plane to get ideal spacing? ____2____ nautical miles

5. Use an arrow to show the additional spacing for the third plane. Put a • (dot) at the end of the arrow to show the new spacing and label it with the plane's call sign.

✈ Analyze the speed changes that need to be made. Begin with the second plane.

6. How much will you slow its speed? ____60____ knots

   What will the new speed be? ____540____ knots

A 60-knot difference in speed will cause a 1 NM difference in spacing **each minute**

7. How many minutes will it take to get the additional spacing?

   ____2____ minutes

   (d = r x t) 2 NM = 1 NM/min x t
   2 NM needed ÷ 1 NM/min = t
   2 mins = t

8. Will the planes get the additional spacing needed before MOD? ☑ Yes ☐ No

   (d = r x t) 31 NM = 9 NM/min x t
   31 NM needed ÷ 9 NM/min = t
   DAL88: $T_{\text{to MOD}}$ = 31 NM ÷ 9 NM/min ≈ 3.4 mins (which is > 2 mins)

540 kts = 9 NM/Min

WORKSHEET #1 continued

Problem 3-3

9. Now, what speed changes will be needed for the third plane? Fill in the blanks.

Plane Call Sign	Additional Spacing Needed	New Speed	Time Until Ideal Spacing	At or Before MOD?
AAL12	2 NM	540 Kts	2 Mins	☑ Yes ☐ No

✈ If Yes, Congratulations! If no, try again!

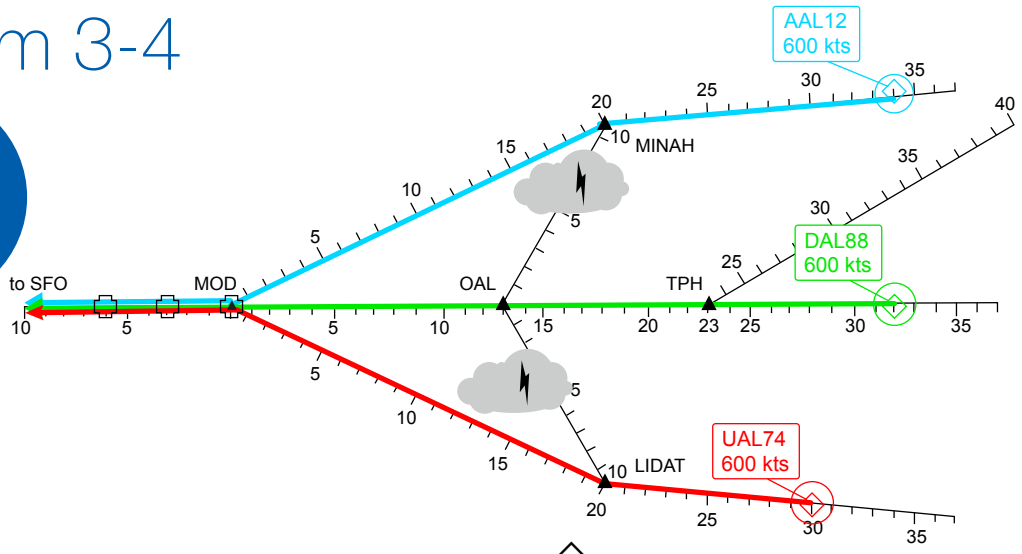
(d = r x t) 2 NM = 1 NM/min x t
2 NM needed ÷ 1 NM/min = t
2 mins = t

(d = r x t) 34 NM = 9 NM/min x t
34 NM needed ÷ 9 NM/min = t
AAL12: T to MOD = 31 NM ÷ 9 NM/min ≈ 3.8 mins (which is > 2 mins)

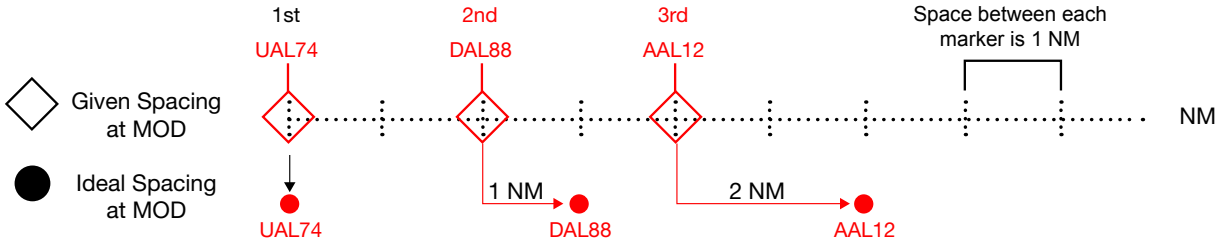
WORKSHEET #2

Problem 3-4

Ideal Spacing at MOD = 3 NM



1. Plot each plane's given spacing at MOD with a ◇. Use an arrow with a • (dot) at the end to show the additional spacing needed to get ideal spacing. Label each dot with the plane's call sign.



2. Fill in the table with the speed changes needed to get ideal spacing at MOD.

Order	Call Sign	Additional Spacing Needed	New Speed	Time Until Ideal Spacing	At or Before MOD?
2nd	DAL88	1 NM	540 Kts	1 Mins	☑ Yes ☐ No
3rd	AAL12	2 NM	540 Kts	2 Mins	☑ Yes ☐ No

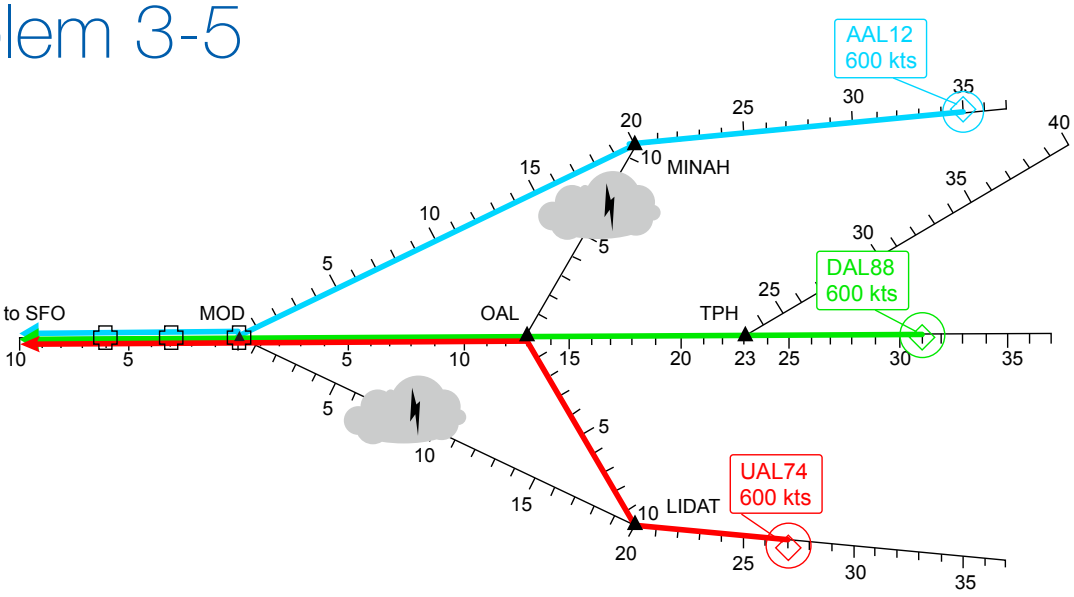
✈ If Yes, Congratulations! If no, try again!

DAL88: $T_{\text{to MOD}}$ = 32 NM ÷ 9 NM/min ≈ 3.6 mins (which is > 1 min)
(d = r x t) 1 NM = 1 NM/min x t
1 NM ÷ 1NM/min = t
1 min = t

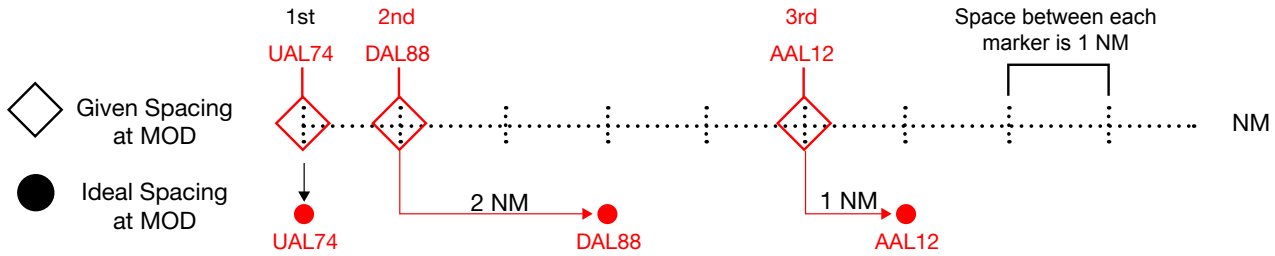
AAL12: = $T_{\text{to MOD}}$ = 34 NM ÷ 9 NM/min ≈ 3.8 mins (which is > 2 min)
(d = r x t) 2NM = 1 NM/min x t
2 NM ÷ 1NM/min = t
2 mins = t

WORKSHEET #3

Problem 3-5



1. Plot each plane's given spacing at MOD with a ◇. Use an arrow with a • (dot) at the end to show the additional spacing needed to get ideal spacing. Label each dot with the plane's call sign.



2. What speed changes will need to be made to get ideal spacing at MOD? Fill in the table.

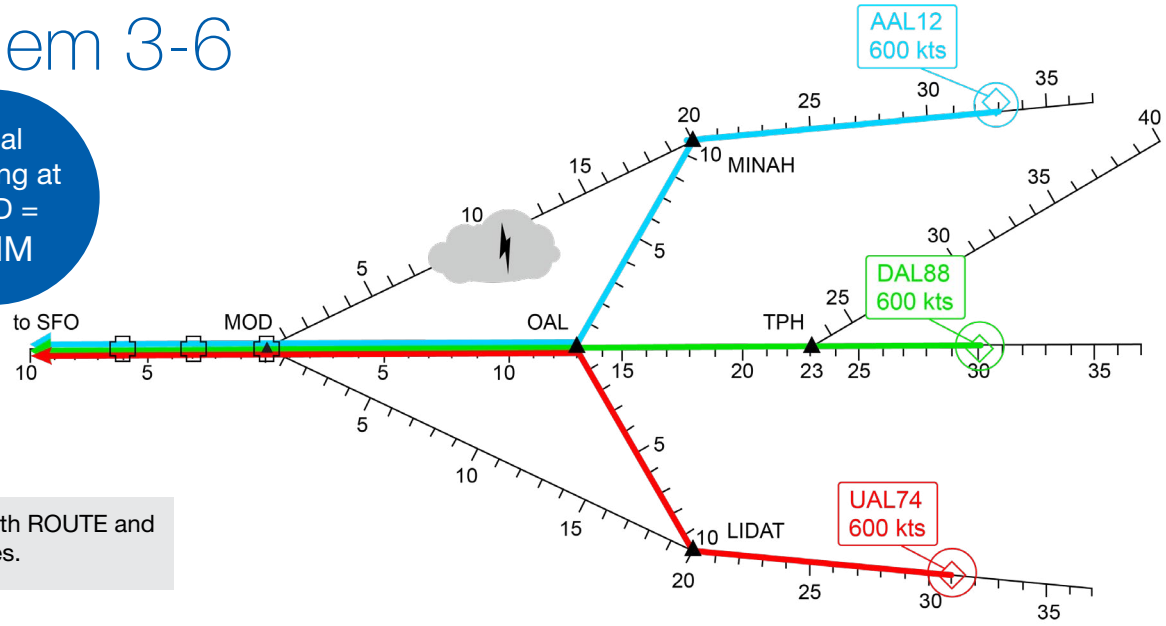
Order	Call Sign	Additional Spacing Needed	New Speed	Time Until Ideal Spacing	At or Before MOD?
2nd	DAL88	2 NM	540 Kts	2 Mins	☑ Yes ☐ No
3rd	AAL12	1 NM	540 Kts	1 Mins	☑ Yes ☐ No

3. At the new speeds, will UAL74 and DAL88 have at least minimum separation at **OAL**? Yes
UAL74: $T_{\text{to OAL}}$ = 17 NM ÷ 10 NM/min = 1.7 mins (which is < 2 mins)

WORKSHEET #4

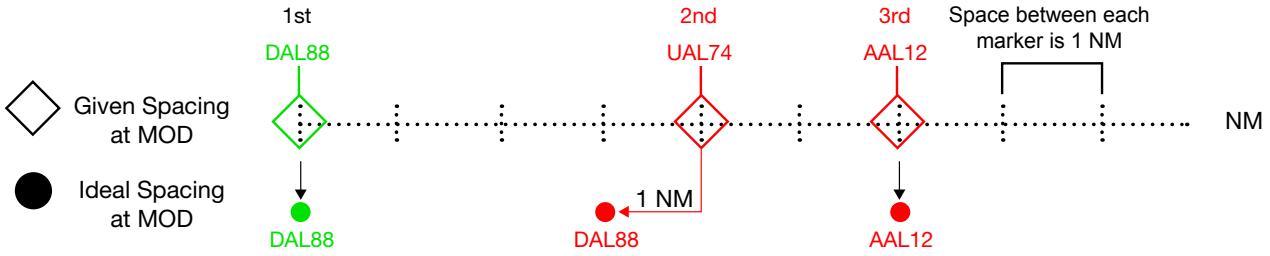
Problem 3-6

Ideal Spacing at MOD = 3 NM



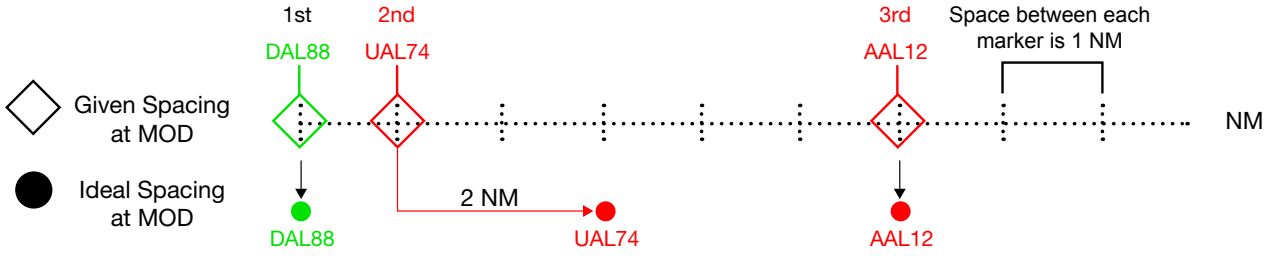
You will use both ROUTE and SPEED changes.

1. Plot each plane's given spacing at MOD with a ◇. Use an arrow with a • (dot) at the end to show the additional spacing needed to get ideal spacing. Label each dot with the plane's call sign.



2. For the second plane, what route change and speed change will give ideal spacing at MOD?
   Changes: Route: **Direct from LIDAT to MOD** Speed: ____**540**____ knots

3. With the new route and speed changes, plot the second and third plane's new position and any new spacing needed.

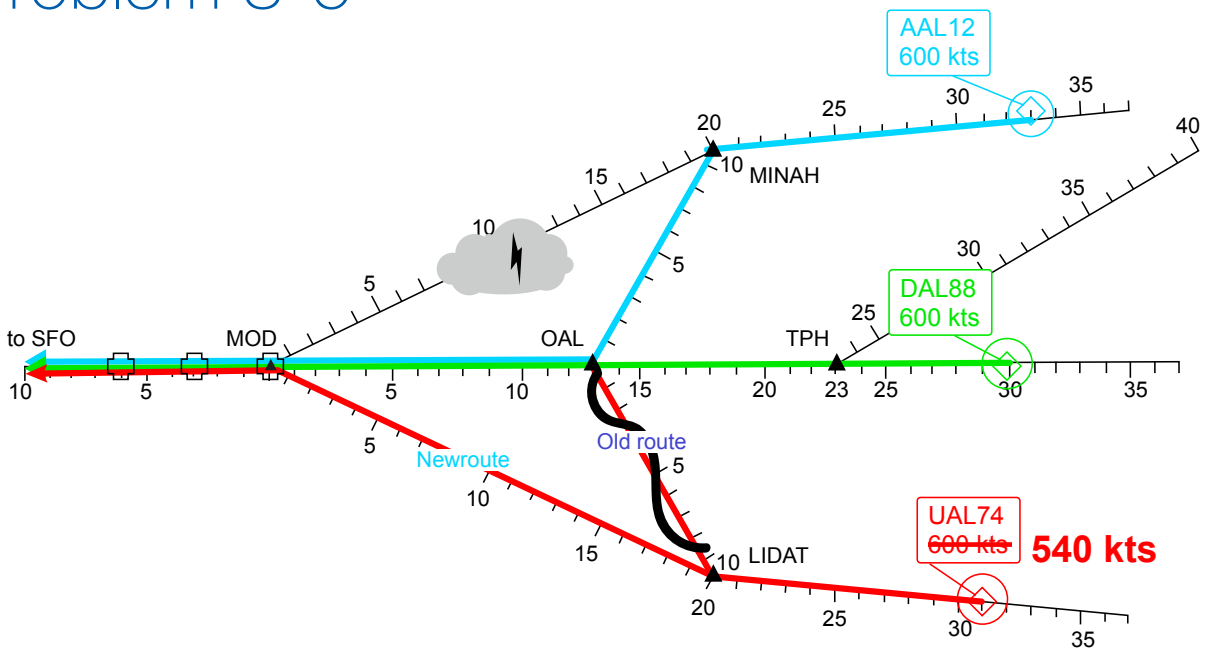


4. How many minutes will the plane slow down until it needs to speed back up to 600 knots?
   _____**2**_____ minutes **(d = r x t) 2 NM = 1 NM/min × t**

   $2\ NM_{needed} \div 1\ NM/min = t$
   2 mins = t

WORKSHEET #4 continued

Problem 3-6



5. Mark the route and speed changes on the diagram above.

6. If the speed changed, after how many minutes will the plane need to speed back up to 600 knots to maintain **ideal spacing** at MOD? _____2_____ minutes

7. With the new speeds, will the other planes have **minimum separation** at **OAL**?
   ☐ No ☑ Yes

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