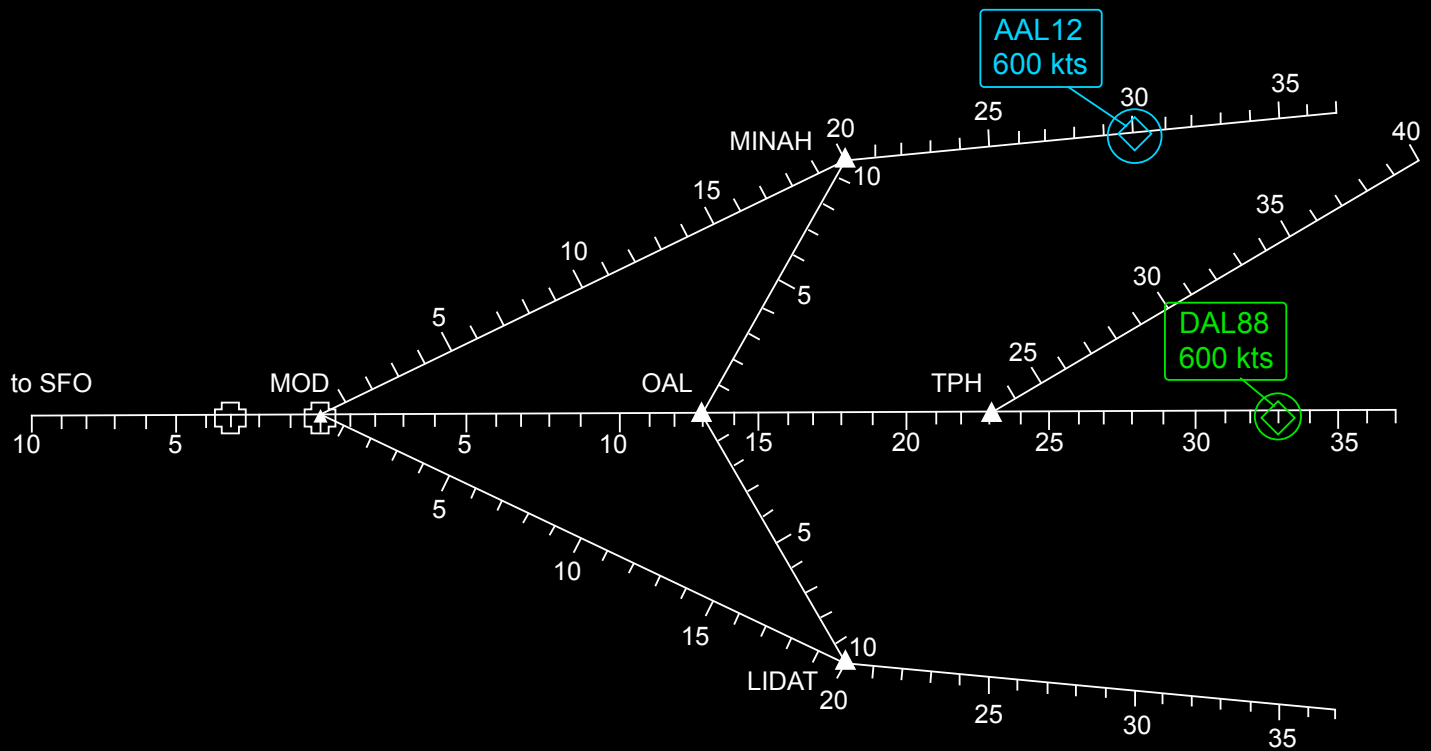




LineUp with Math

Math-Based Decisions in Air Traffic Control

FACILITATOR GUIDE E

Facilitator Guide with Answer Sheets

Resolving 2-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 E

Estimated class time: 1.5 to 2 hours

In Problem Set E, students will use the ATC simulator to explore changing the speed of one plane to achieve the proper spacing at MOD. Students will experience weather issues that prevent route changes.

Objectives

Students will:

- Analyze a flight plan to identify a spacing conflict between two planes traveling at the same speed.
- Resolve the spacing conflict by changing the speed of one plane.

Prerequisites

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

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 E:
 - Fillable PDF versions
 - Printed copies

ATC Simulator

Interactive Air Traffic Control Simulator

Each problem in this set features a 2-plane conflict that can be resolved by changing speeds. Problem Set E supported by Student Workbook E and the simulator are problems: 2-4, 2-5, 2-6, and 2-7.

Facilitator Guide with Answer Sheets (cont'd)

Answer Sheets

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

Student Workbook

Student Workbook E consists of four worksheets, one for each problem: 2-4, 2-5, 2-6, and 2-7. Each problem features a spacing conflict with different starting conditions.

Worksheet #1: Problem 2-4

- Analyze the diagram to identify the spacing and weather conflict at MOD.
- Resolve the spacing conflict by reducing the speed of one plane by 60 knots.
- Understand how reducing speed for 3 minutes achieves ideal spacing.

Worksheet #2: Problem 2-5

- Analyze the diagram to identify the spacing conflict to determine if the decrease of the speed of one plane will achieve ideal spacing at MOD.
- Resolve the spacing conflict with a 120-knot speed decrease.
- The results are greater than ideal spacing. Use problem solving skills to suggest an alternative solution to achieve ideal spacing at MOD.

Worksheet #3: Problem 2-6

- Analyze the diagram to determine the conflict and notice one plane has a headstart.
- Determine which plane speed will be slowed to achieve ideal spacing.
- Calculate the number of minutes the trailing plane will be slowed down before increasing it back to the same speed as the leading plane to achieve ideal spacing.

Worksheet #4: Problem 2-7

- Analyze the problem, notice both planes pass through OAL before they arrive at MOD, so students must check for minimum separation (2 nautical miles).
- Check minimum separation at OAL, and determine a strategy to resolve any violations.
- Use mathematical conversions to determine the speed decrease for the trailing plane and how long before increasing speed back up to match the leading plane.

APPENDIX I

Simulator Solutions for Problem Set E

2-4, 2-5, 2-6, and 2-7

Problems are supported by Student Workbook E

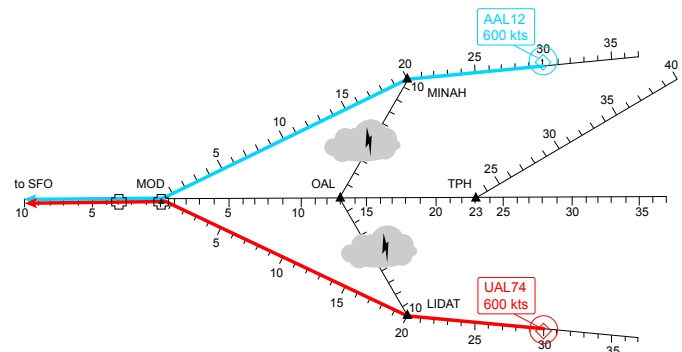
ANALYSIS OF WORKSHEET #1

Problem 2-4

STARTING CONDITIONS

Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	30	600
UAL74	LIDAT		MOD	30	600

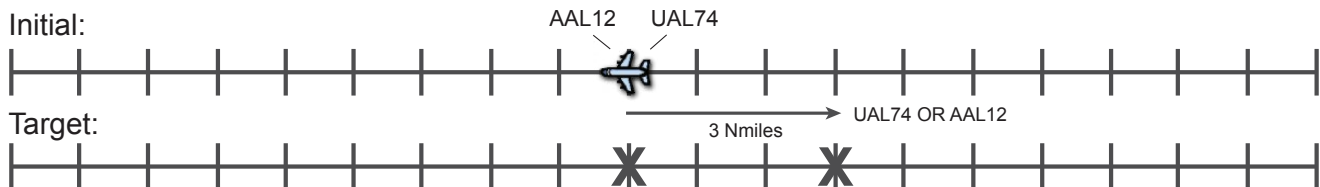
Route from **MINAH** to **OAL** is **closed**.
 Route from **LIDAT** to **OAL** is **closed**.
 Ideal spacing at **MOD** is 3 nautical miles.



FLIGHT ANALYSIS

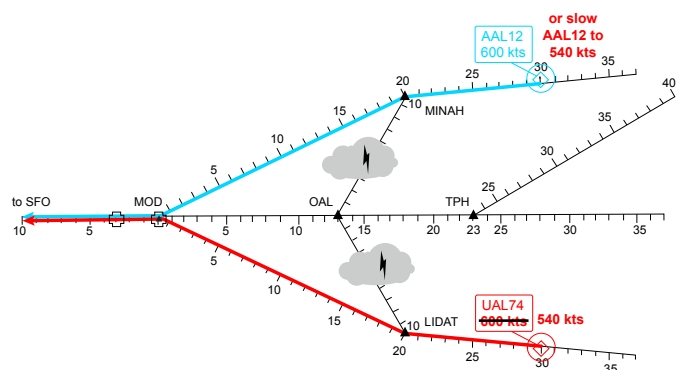
- ➔ **AAL12** and **UAL 74** will arrive at MOD at the same time.
- ➔ Weather prevents **AAL12** or **UAL74** from rerouting.
- ➔ **UAL74** or **AAL12** need to slow down to fall back 3 nautical miles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	30	→ 0
1st	UAL74	30	



SOLUTION

- ➔ **UAL74** or **AAL12**: Slow down to 540 knots for 3 minutes to lengthen travel distance to fall back 3 nautical miles, then speed back up to 600 knots.
- ➔ **Target Time**: 3 minutes and 18 seconds.



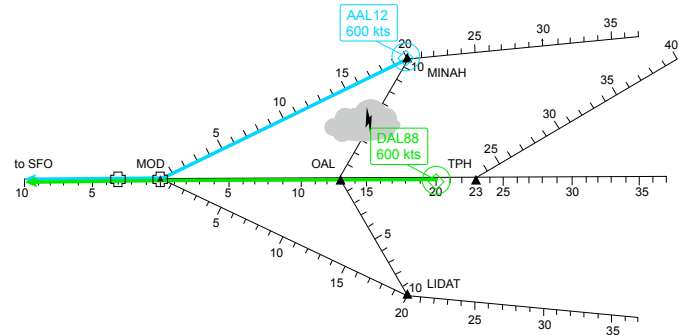
ANALYSIS OF WORKSHEET #2

Problem 2-5

STARTING CONDITIONS

Plane	From	Through	To	Distance	Speed
AAL12	MINAH		MOD	20	600
DAL88	OAL		MOD	20	600

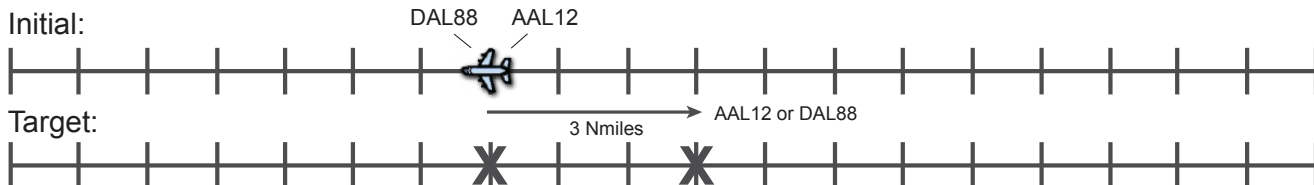
Route from **MINAH** to **OAL** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.



FLIGHT ANALYSIS

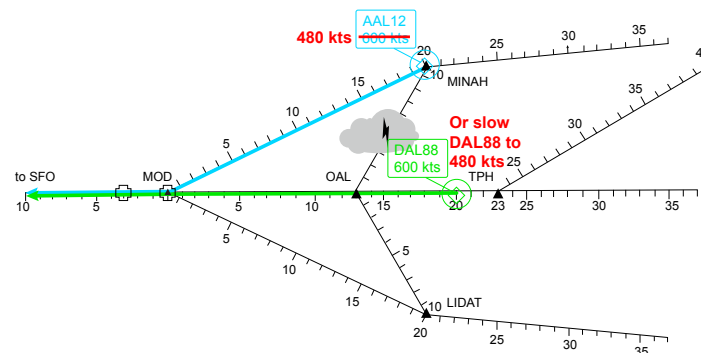
- **DAL88** and **AAL12** will arrive at MOD at the same time.
- Weather prevents **AAL12** from rerouting.
- **AAL12** or **DAL88** need to slow down to fall back 3 nautical miles.

Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	20	→ 0
1st	DAL88	20	



SOLUTION

- **AAL12** or **DAL88**: Slow down to 480 knots for 1 min 30 secs to lengthen travel distance to fall back 3 nautical miles, then speed back up to 600 knots.
- **Target Time**: 2 minutes and 18 seconds.



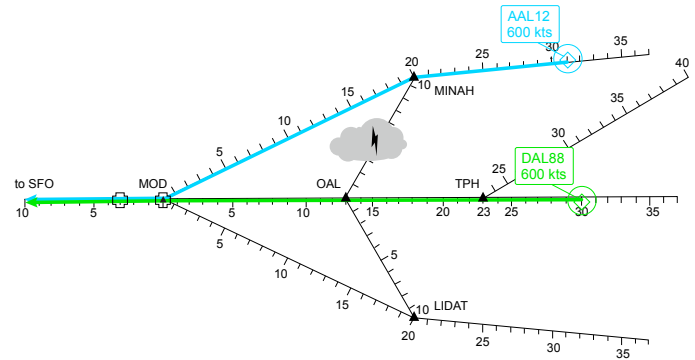
ANALYSIS OF WORKSHEET #3

Problem 2-6

STARTING CONDITIONS

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

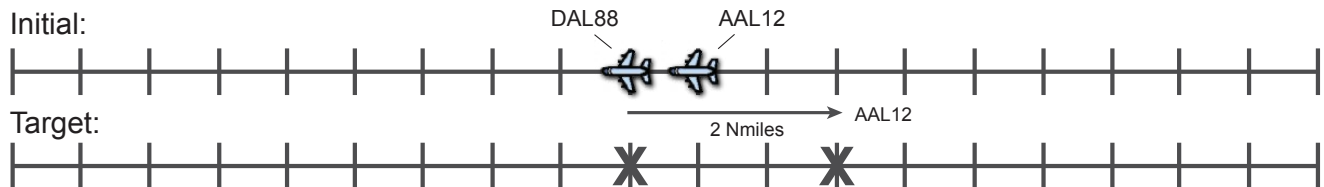
Route from **MINAH** to **OAL** is **closed**.
Ideal spacing at **MOD** is 3 nautical miles.



FLIGHT ANALYSIS

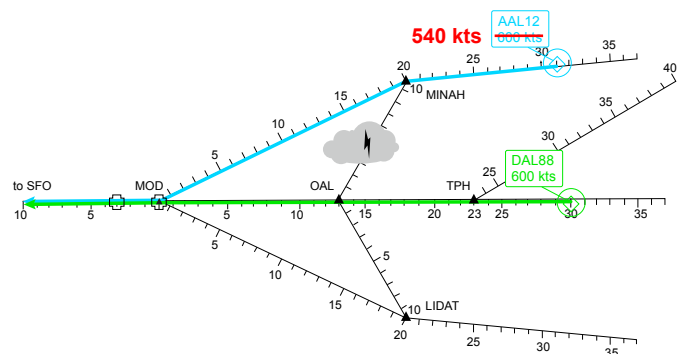
- **AAL12** will arrive at MOD 1 nautical mile behind **DAL88**.
- Weather prevents **AAL12** from rerouting.
- **AAL12** needs to slow down to fall back 2 nautical miles.

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



SOLUTION

- **AAL12**: Slow down to 540 knots for 2 minutes to lengthen travel distance to fall back 2 nautical miles, then speed back up to 600 knots.
- **Target Time**: 3 minutes and 18 seconds.



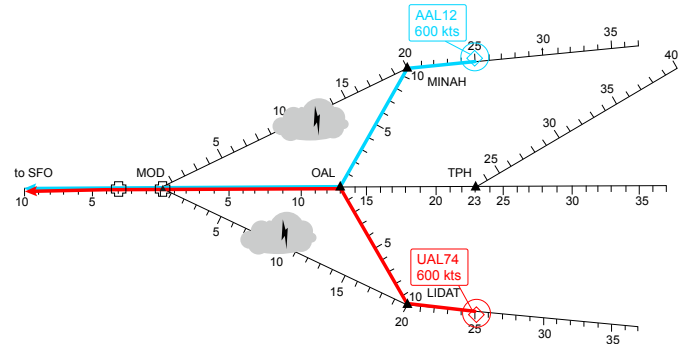
ANALYSIS OF WORKSHEET #4

Problem 2-7

STARTING CONDITIONS

Plane	From	Through	To	Distance	Speed
AAL12	MINAH	OAL	MOD	28	600
UAL74	LIDAT	OAL	MOD	28	600

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

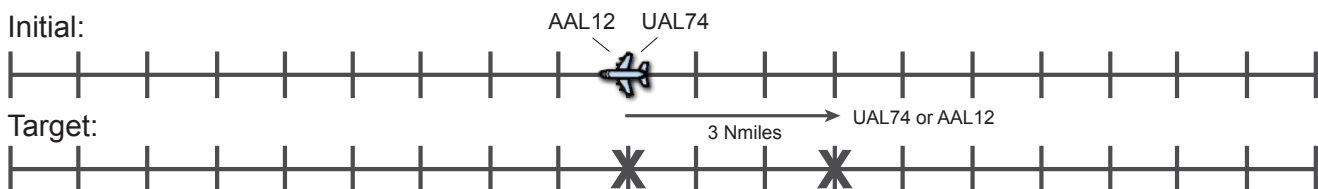


FLIGHT ANALYSIS

- **AAL12** and **UAL74** will arrive at OAL at the same time.
- Weather prevents **AAL12** and **UAL74** from rerouting
- **UAL74** or **AAL12** need to slow down to fall back 2 nautical miles by OAL and 3 nautical miles by MOD.

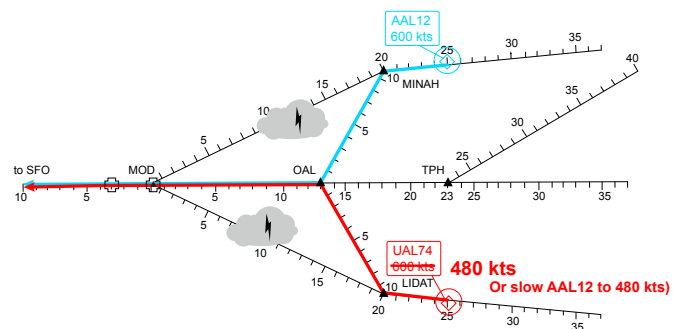
Projected Arrival	Plane	Distance Along Flight Plan	Initial Spacing
1st	AAL12	28	→ 0
1st	UAL74	28	

Initial:



SOLUTION

- **UAL74** or **AAL12**: Slow down to 480 knots for 1.5 minutes to lengthen travel distance to fall back 3 nautical miles, then speed back up to 600 knots.
- **Target Time**: 3 minutes and 6 seconds.



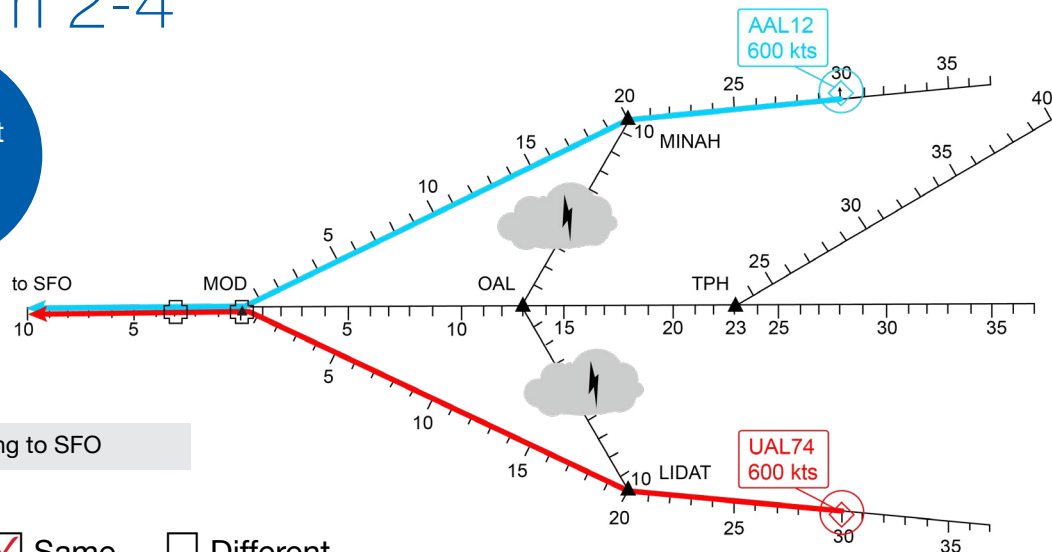
APPENDIX II

Answer Sheets

WORKSHEET #1

Problem 2-4

Ideal
Spacing at
MOD =
3 NM



Both planes are going to SFO

- Speeds: ☒ Same ☐ Different
- Headstart = 0 NM = separation at MOD
- Additional spacing needed for ideal spacing 3 NM

600 kts = 10 NM/Min

How Much Time Before You Need Ideal Spacing?

- At 600 knots, how many minutes will it take the planes to reach MOD? 3 mins
($d = r \times t$) $30 \text{ NM} \div 10 \text{ NM/min} = 3 \text{ mins}$

What Speed Change Will Solve the Problem?

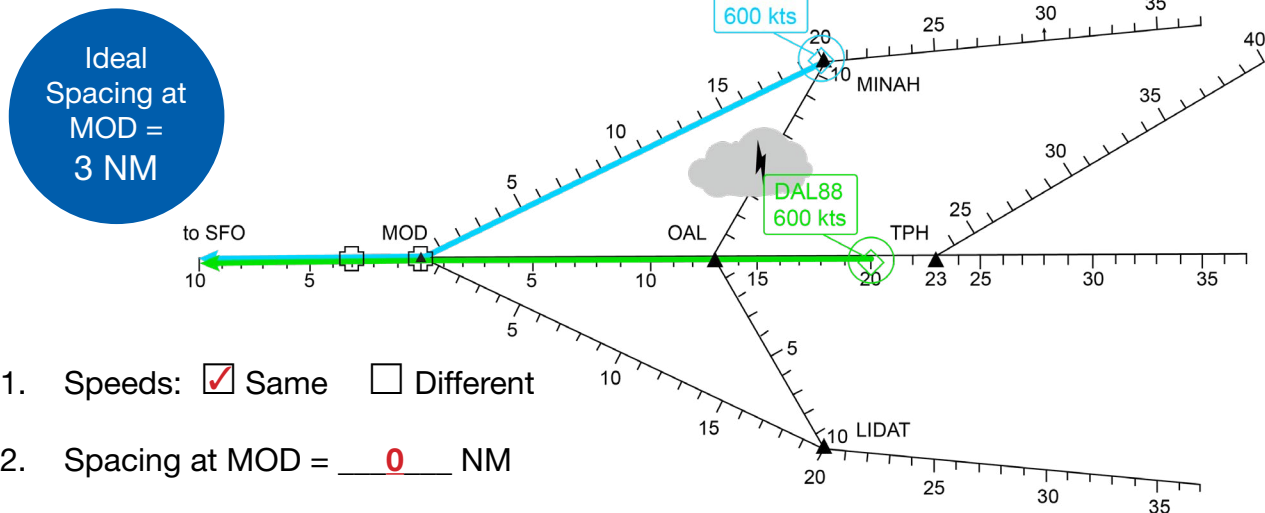
The planes are traveling at the maximum speed of 600 knots.

- Reduce the speed of one plane by 600 knots. Which plane will you choose to slow down to 540 knots? Choose either plane to slow to 540 knots
- At 540 knots, how many nautical miles less will this plane travel **each minute**? 1
nautical miles **per minute** ($r_1 - r_2 = \text{difference}$) $10 \text{ NM/min} - 9 \text{ NM/min} = 1 \text{ NM}$
- In 3 minutes, how much additional spacing will be gained due to the speed reduction?
3 nautical miles ($d = r \times t$) $1 \text{ NM/min} \times 3 \text{ mins} = 3 \text{ NM}$
- Does the 60-knot speed drop give ideal spacing at MOD? ☒ Yes ☐ No

Remember: A 60 knot difference
in speed causes 1 nautical mile
difference in distance each minute.

WORKSHEET #2

Problem 2-5



- Speeds: ☒ Same ☐ Different
- Spacing at MOD = 0 NM
- Additional spacing needed 3 NM
- At 600 knots, how many minutes will it take the planes to reach MOD? 2 minutes
($d = r \times t$) $20 \text{ NM} \div 10 \text{ NM/min} = 2 \text{ mins}$

Air traffic controllers change speed in 60-knot increments. A 60-knot difference in speed causes a 1 nautical mile difference in distance each minute.

→ First, slow AAL12 (or DAL88) by 60 knots, to 540 knots.

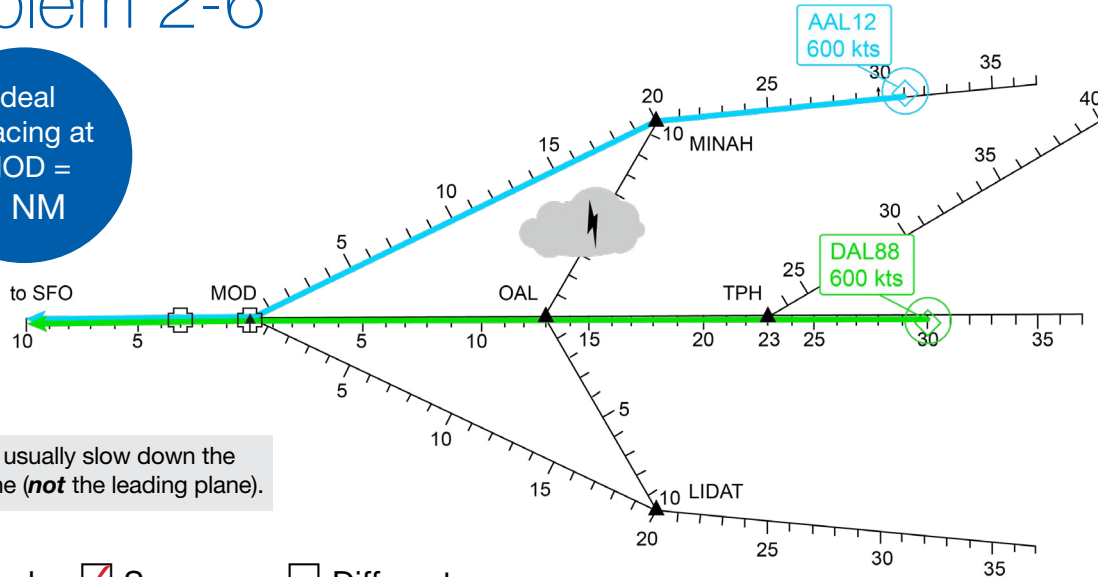
600 kts = 10 NM/Min

- At MOD, how much spacing will be gained? 2 nautical miles
($d = r \times t$) $1 \text{ NM/min} \times 2 \text{ mins} = 2 \text{ NM}$
- Did the 60-knot speed drop give ideal spacing at or before MOD? ☐ Yes ☒ No
Try a greater speed drop. Slow AAL12 by 60 more miles, totaling 120 knots. The new speed will be 480 knots.
- Now how much spacing will be gained at MOD? 4 nautical miles
 $2 \text{ NM/min} \times 2 \text{ mins} = 4 \text{ NM}$
- Did the 120-knot speed drop give ideal spacing at MOD? ☐ Yes ☒ No
- What could the controller do to achieve ideal spacing? Speed the plane back up sooner (at 1 min 30 seconds) when it has achieved 3 nautical mile separation. (or something similar).
($d = r \times t$) $3 \text{ NM} = 2 \text{ NM} \div \text{min} \times t$
 $3 \text{ NM} \div 2 \text{ NM/min} = t$
 $1.5 \text{ min} = t$

WORKSHEET #3

Problem 2-6

Ideal
Spacing at
MOD =
3 NM



Controllers usually slow down the trailing plane (**not** the leading plane).

- Speeds: ☒ Same ☐ Different
- Spacing at MOD = 1 NM **31-30 = 1 NM**
- Additional spacing needed = 2 NM
- At 600 knots, how many minutes will it take the **lead** plane to reach MOD? 3 NM
(d = r × t) 31 NM/min ÷ 10 NM/min = 3.1 mins
- Which plane would a controller slow down to 540 knots? AAL12 (**furthest from MOD**)
- At this speed, how many nautical miles less will this plane travel **each minute**? 1
nautical miles **per minute** (**r₁ - r₂ = difference**) **10 NM/min - 9 NM/min = 1 NM/min**
- At MOD, how much additional spacing will be gained due to the speed reduction?
3 nautical miles **(d = r × t) 1 NM/min × 3 mins = 3 NM**
- What is the new spacing at MOD? 4 nautical miles
- Is the spacing ideal? ☐ Yes ☒ No **3 NM + 1 NM headstart = 4 NM**
- If no, after how many minutes will the plane need to speed back up to 600 knots to make the spacing ideal at MOD? 2 minutes **With the 1 NM headstart, 2 NM are needed to achieve ideal spacing.**
If (d = r × t), then 2 NM = 1 NM/min × t
2 NM ÷ 1 NM/min = t
2 mins = t

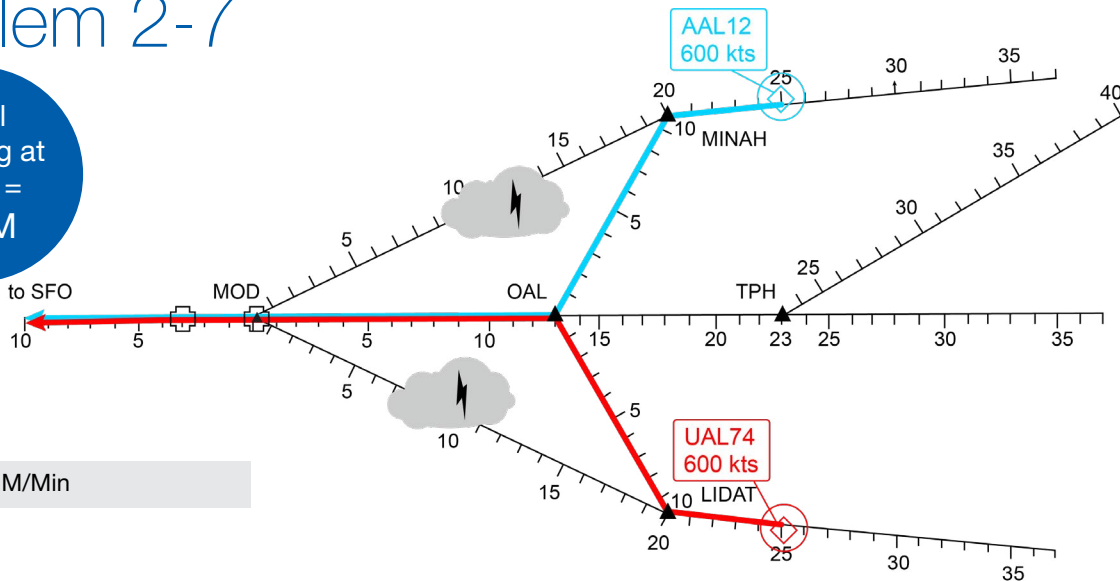
600 kts = 10 NM/Min

* A 60 knot difference in speed causes a 1 nautical mile difference in distance each minute.

WORKSHEET #4

Problem 2-7

Ideal
Spacing at
MOD =
3 NM



⚠ Air traffic controllers change speed in 60-knot increments. A 60-knot difference in speed causes a 1 nautical mile difference in distance each minute.

→ Analyze the problem at **OAL**. Does it meet or exceed **minimum separation**? ☒ Yes ☐ No

1. Spacing at **OAL** = 0 NM **15 NM – 15 NM = 0 NM**

Additional spacing needed for minimum separation = 2 NM

2. Solve the problem by slowing down one plane by 60 knots making the new speed 540 knots.

3. Which plane will slow down? Either plane

4. At **OAL**, how much additional spacing will be added due to the speed reduction?
1.5 NM **d = 1 NM × 1.5 (to reach OAL)** **d = 1.5 NM**

5. At 540 knots, will the planes have at least minimum separation?

☐ Yes ☒ No

If no, what will be the new speed? 480 knots

6. At the new speed, what will the separation be at **OAL**? 3 nautical miles

(d = 2 NM/min × 1.5 mins to reach OAL) **d = 3 NM**

7. At the final speed change, do the planes reach **minimum separation** at OAL? ☒ Yes ☐ No

8. If yes, when must the planes speed back up to 600 knots to get **ideal spacing** at MOD?

Speed plane back up at 1 min 30 seconds. (or something similar)

(d = r × t) 3 NM = 2 NM/min × t

3 NM ÷ 2 NM/min = t

1.5 mins = t

National Aeronautics and Space Administration

NASA Headquarters

300 E. Street, SW
Washington, DC 20546

[nasa.gov](https://www.nasa.gov)