



NAV 100

Part III

Tricks of the Trade

Objectives

- Useful navigation skills beyond basic level
- Greater confidence and enjoyment of piloting (visual navigation)
- Reduced dependence on GPS
- Greater situational awareness
- Increased confidence and capability to teach and monitor crew navigation performance

Contents

- Piloting, Plotting, & Recording
- Tactical Considerations
- Strategic Considerations
- Salty Trivia

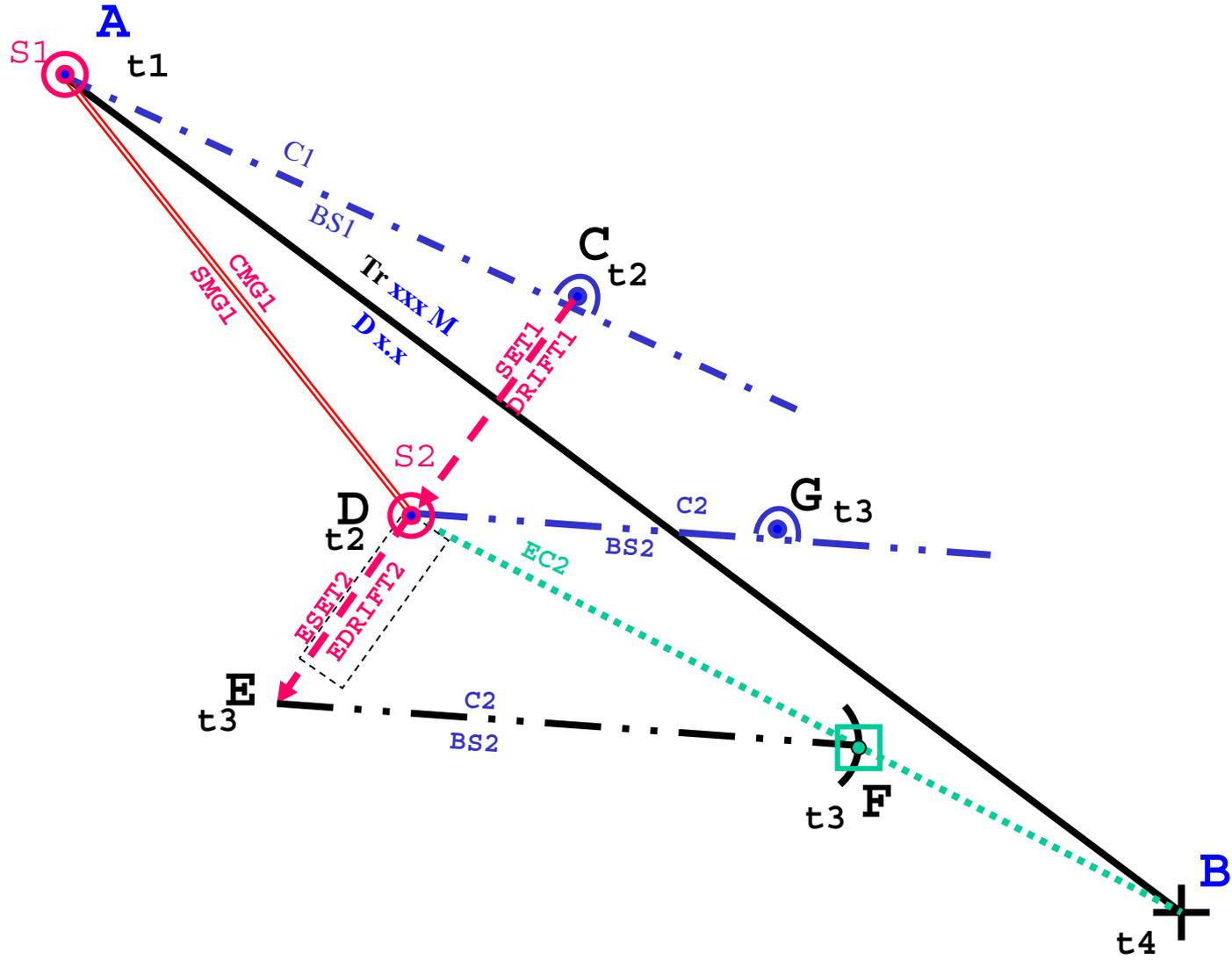
Piloting, Plotting, & Recording

- The six dimensions of Piloting (Visual Navigation)
- Comparisons
- Helm Orders (DR) and Estimated Positions (EP)
- Bearings
- Special Situations
- Critical info to the WC in narrow channels or fairways (e.g., Delaware River)
- Five Minute Rules
- Nav Log
- Integrating GPS with Piloting

The Six Dimensions of Piloting

- Depth
- Time
- Fix (Where the vessel actually was at discrete points in time.)
- Track (Where you want the vessel to go.)
- DR (The helm orders you gave: course and speed.)
- EP (Where you expect the vessel to be between fixes.)

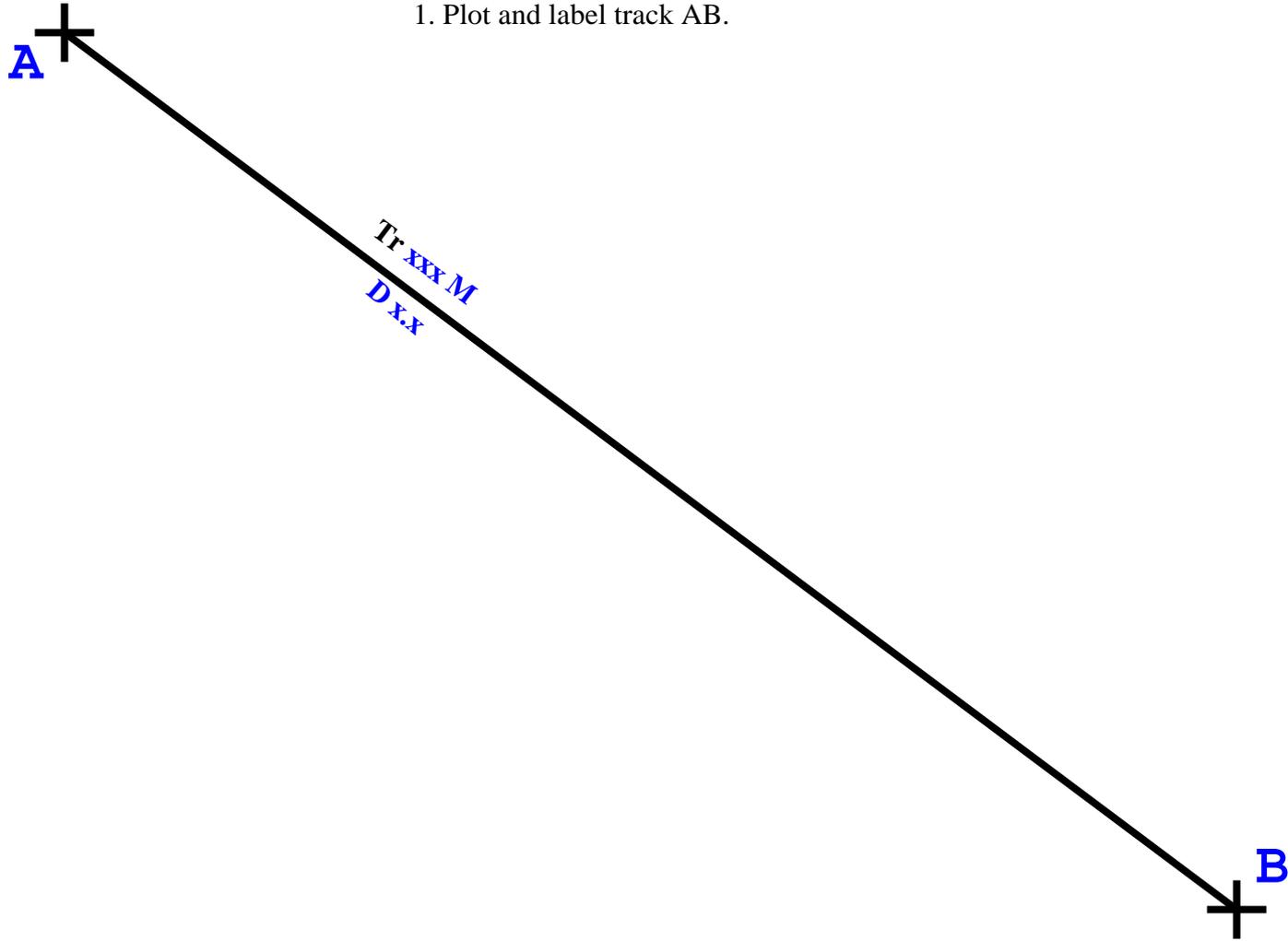
Common Piloting Problem



Common Piloting Problem

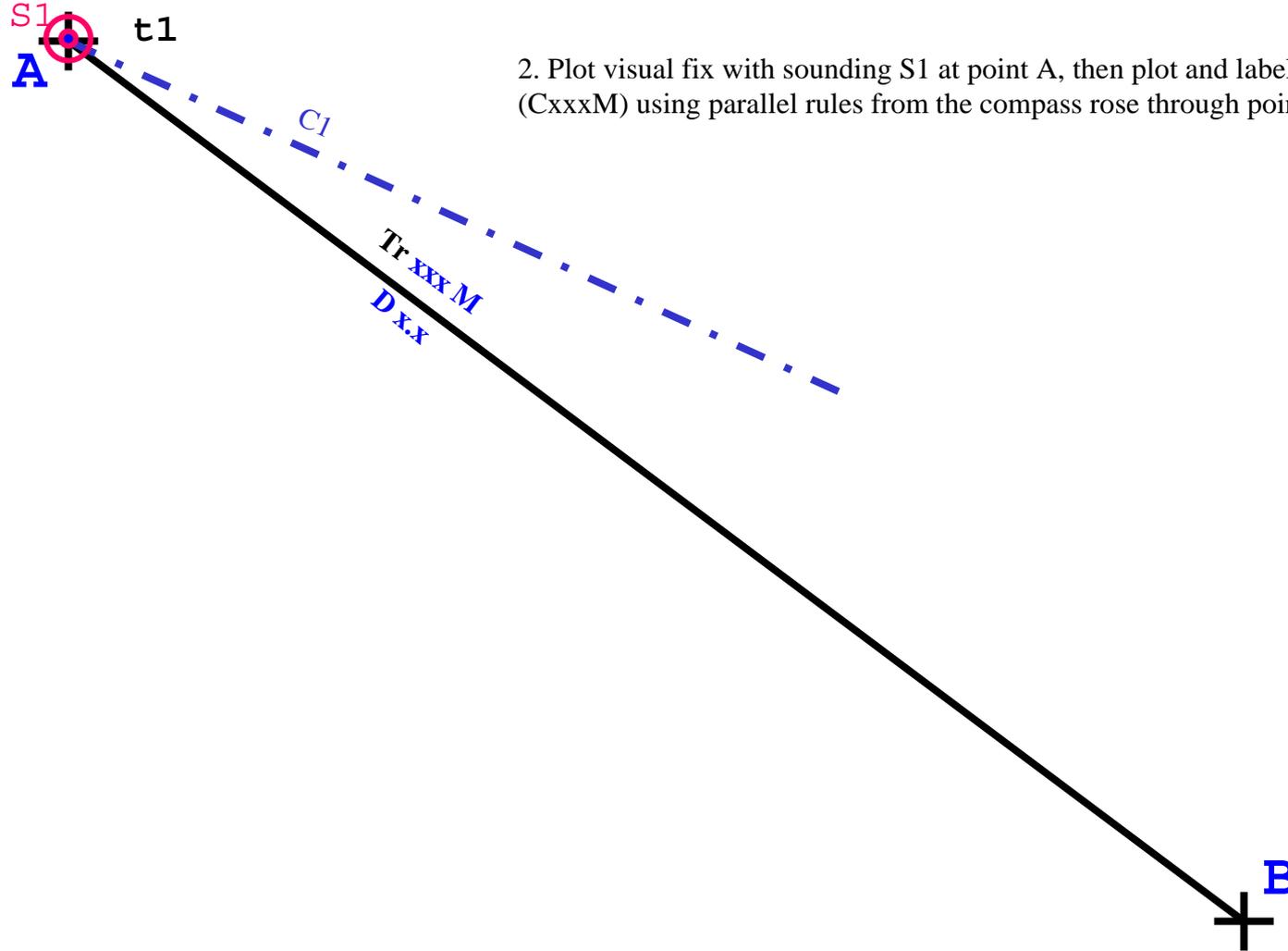
Step-By-Step Instructions

1. Plot and label track AB.



Common Piloting Problem

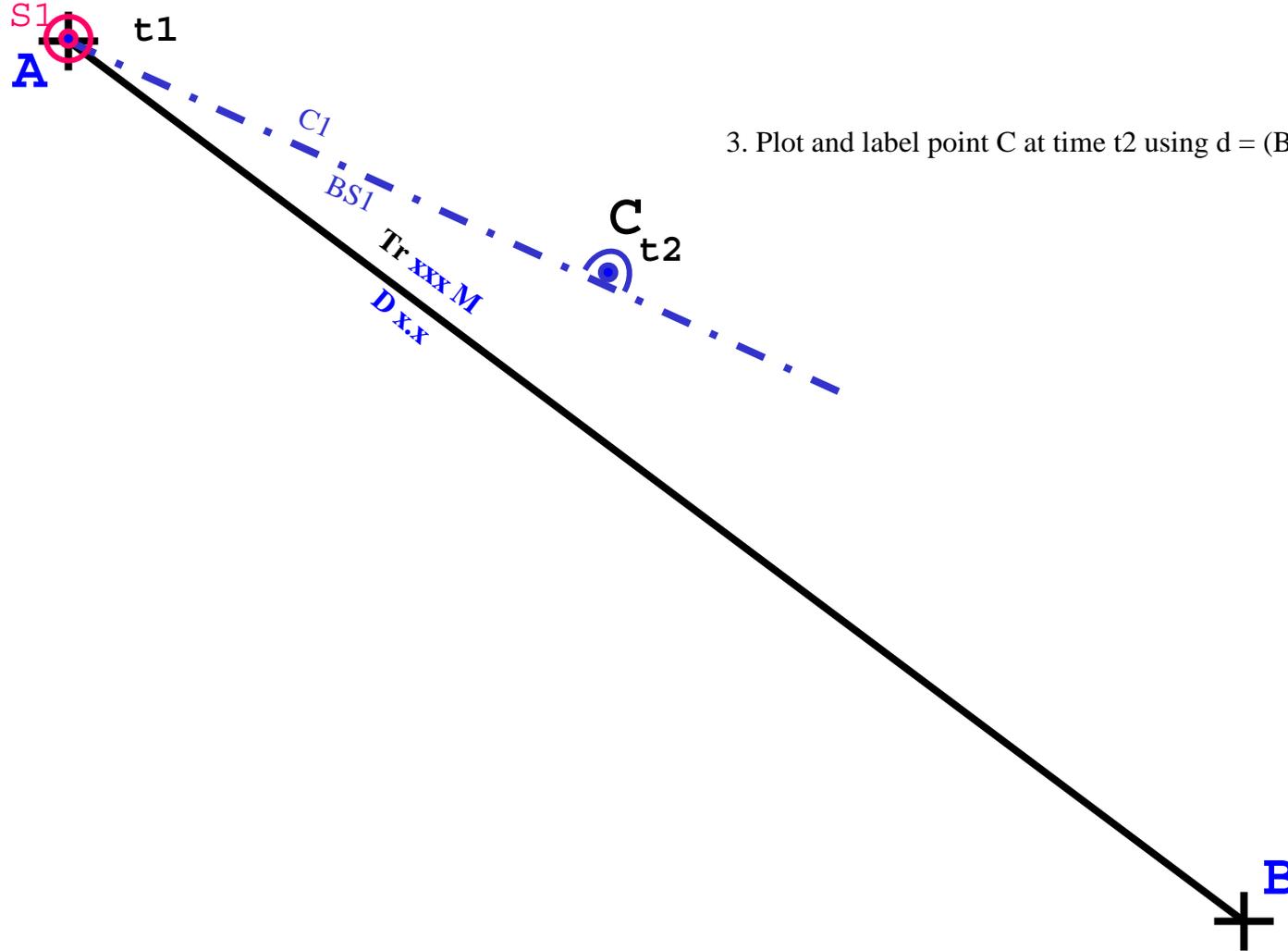
Step-By-Step Instructions



2. Plot visual fix with sounding S1 at point A, then plot and label DR with course C1 (CxxxM) using parallel rules from the compass rose through point A.

Common Piloting Problem

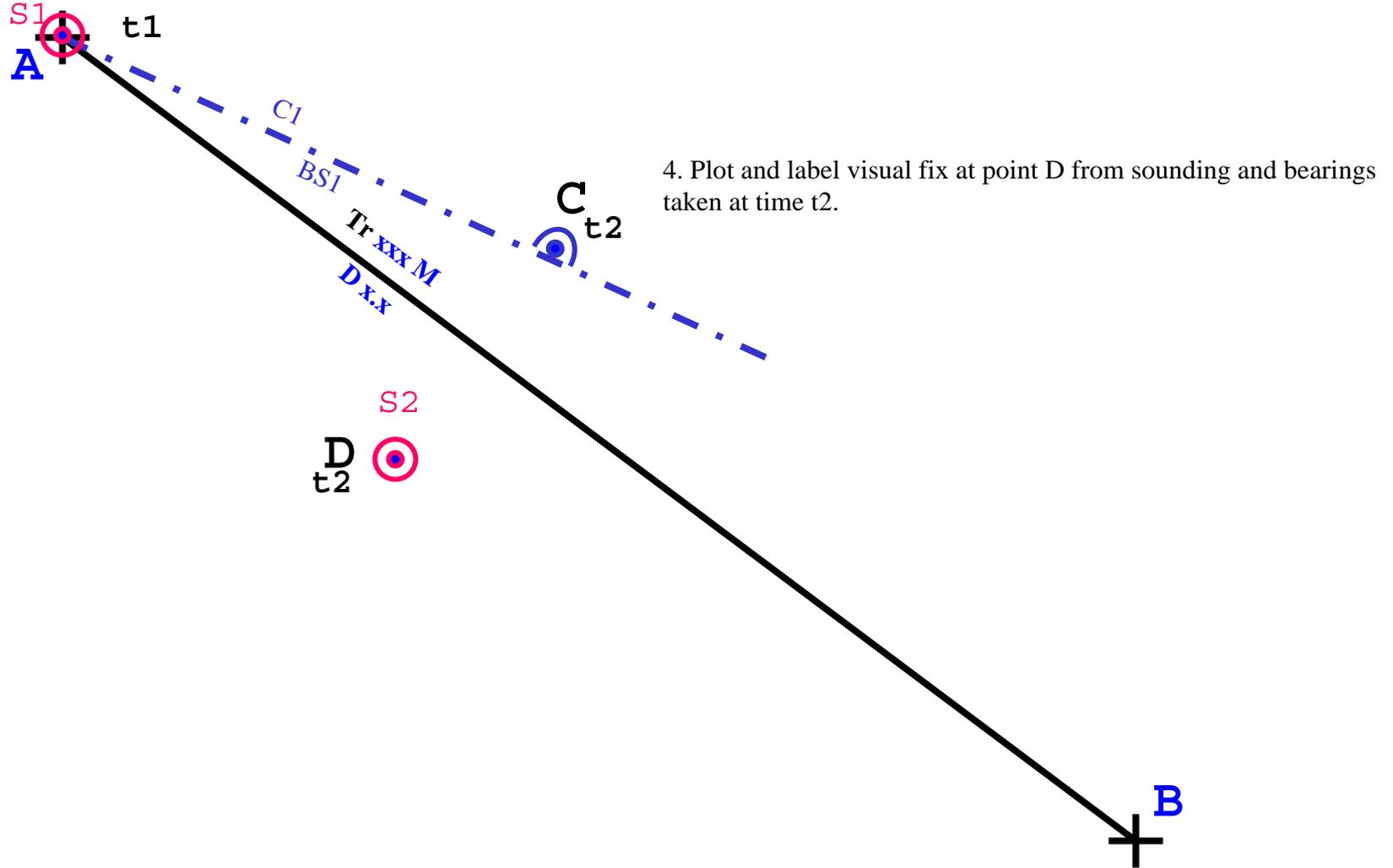
Step-By-Step Instructions



3. Plot and label point C at time t2 using $d = (BS1)(t2 - t1)/60$.

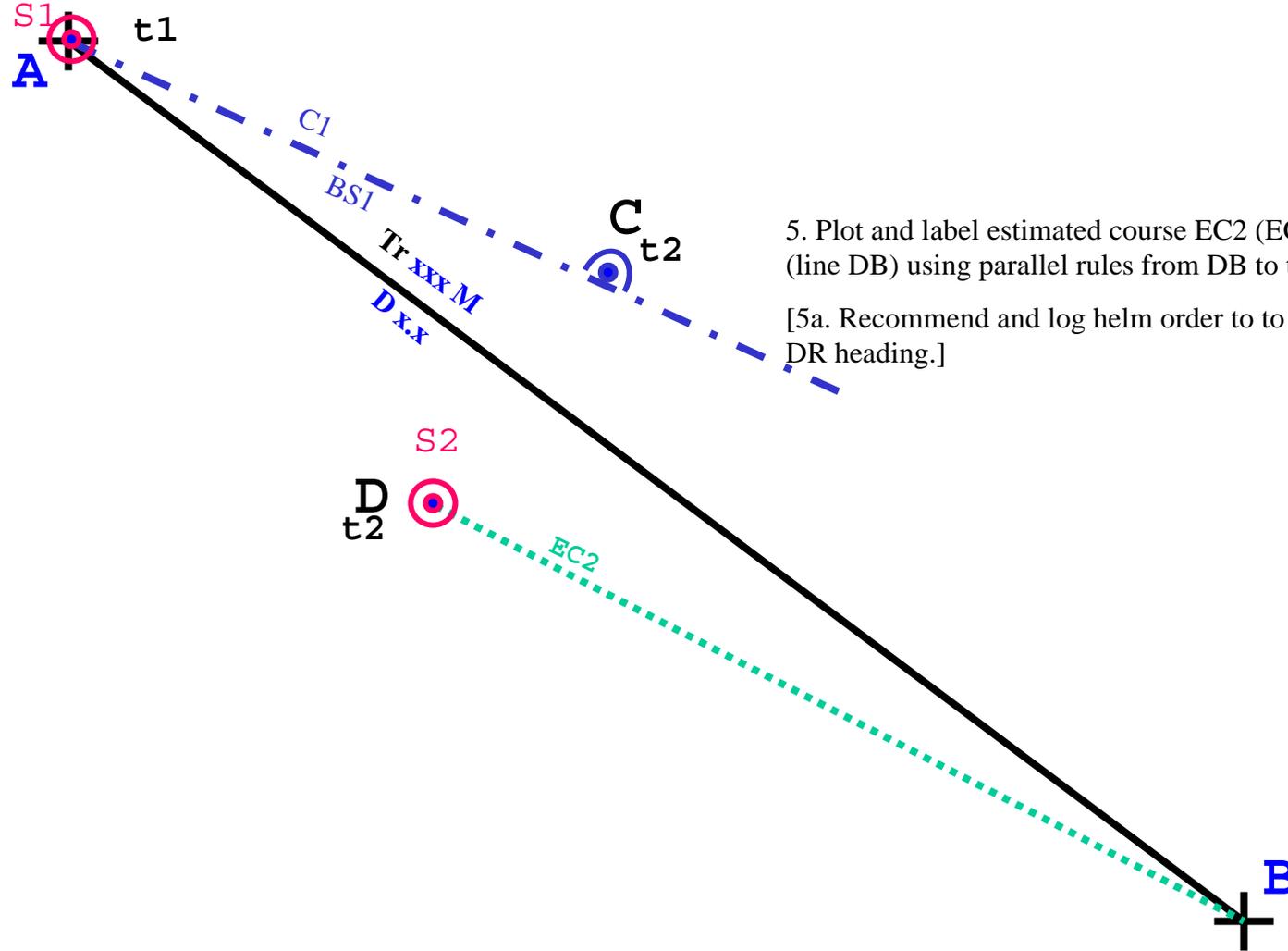
Common Piloting Problem

Step-By-Step Instructions



Common Piloting Problem

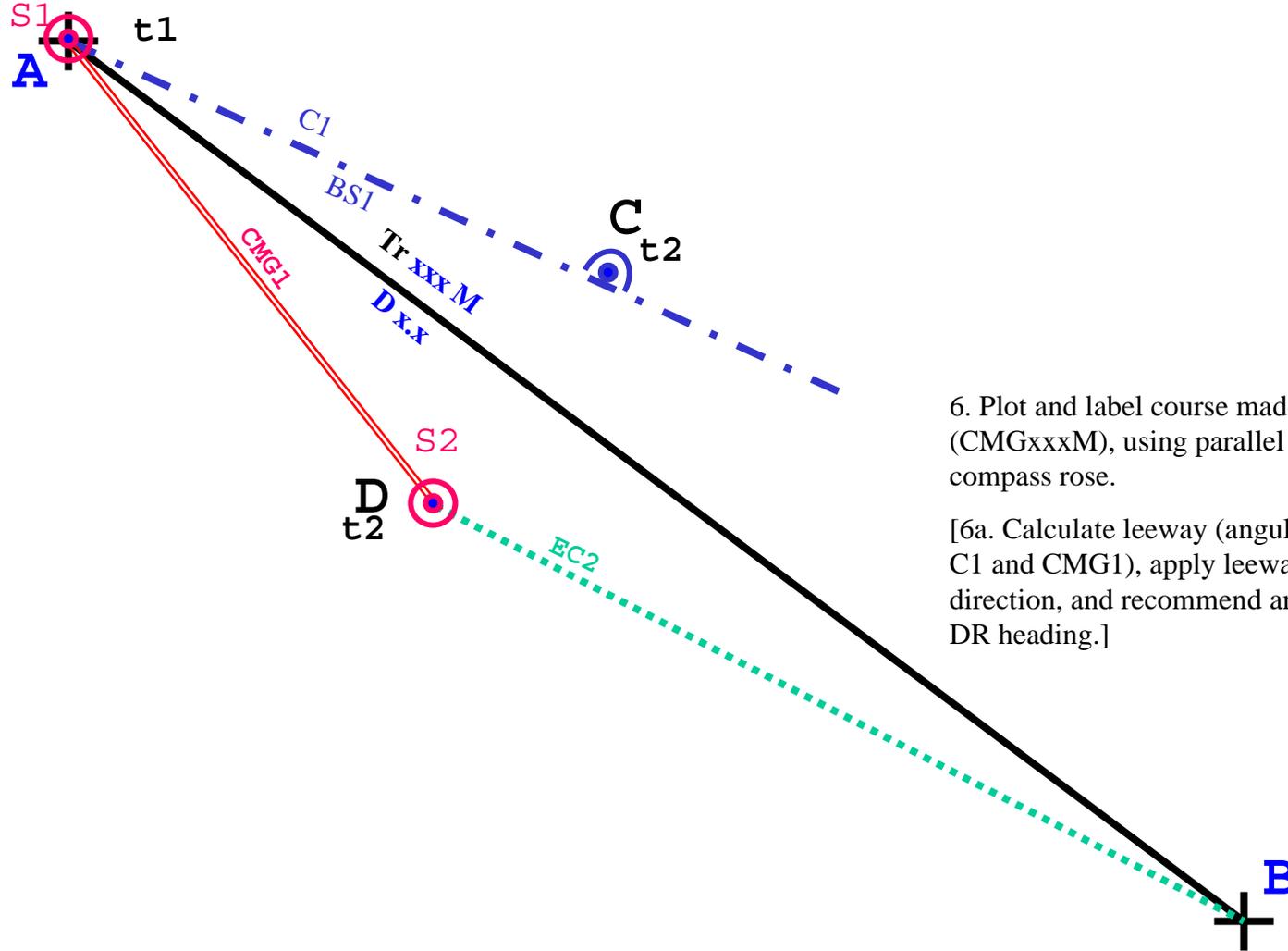
Step-By-Step Instructions



5. Plot and label estimated course EC2 (ECxxxM) from D to B (line DB) using parallel rules from DB to the compass rose.
[5a. Recommend and log helm order to to course EC2 as interim DR heading.]

Common Piloting Problem

Step-By-Step Instructions

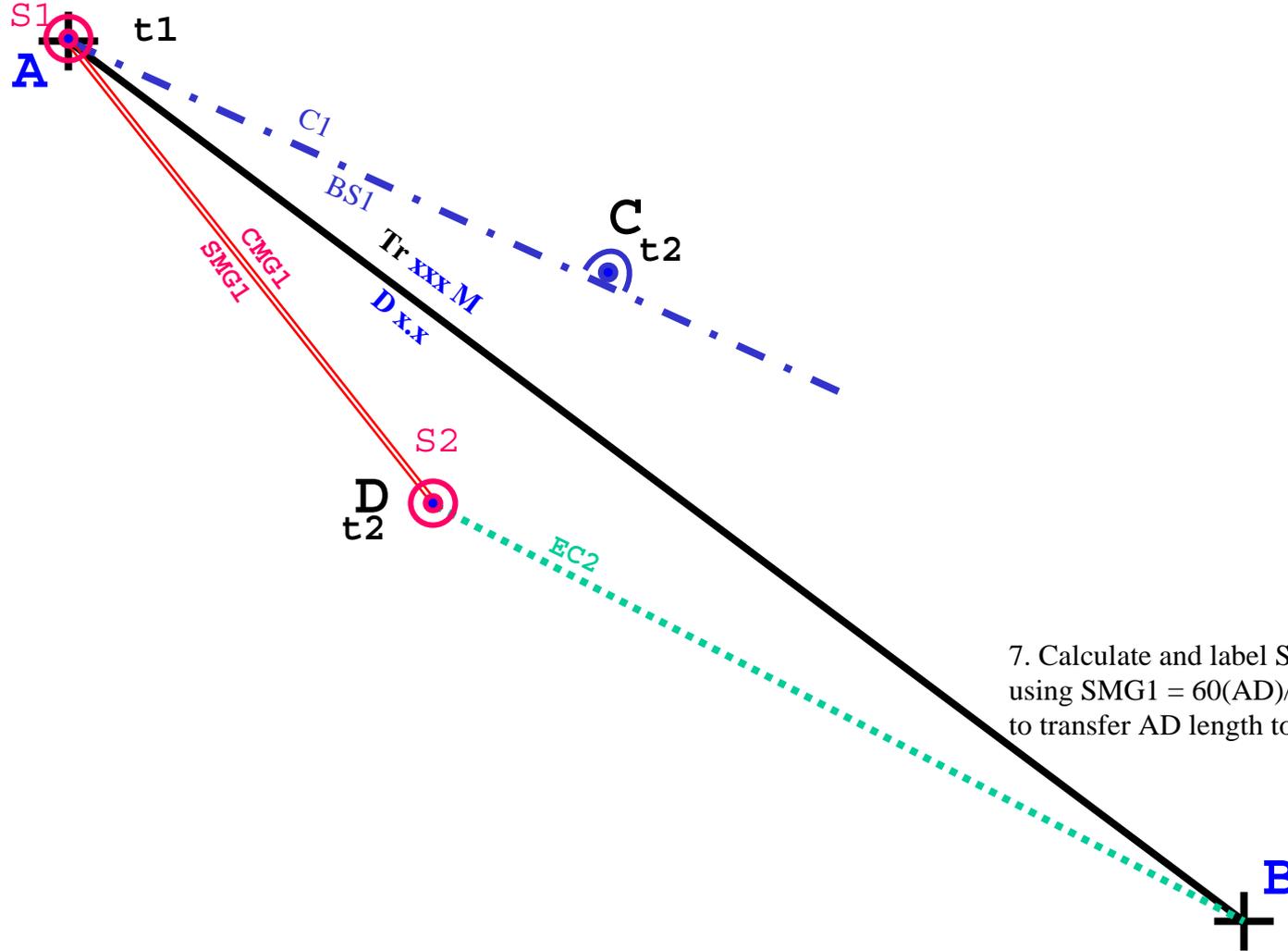


6. Plot and label course made good, CMG1 (CMGxxxM), using parallel rules from AD to the compass rose.

[6a. Calculate leeway (angular difference between C1 and CMG1), apply leeway to EC2 in opposite direction, and recommend and log as second interim DR heading.]

Common Piloting Problem

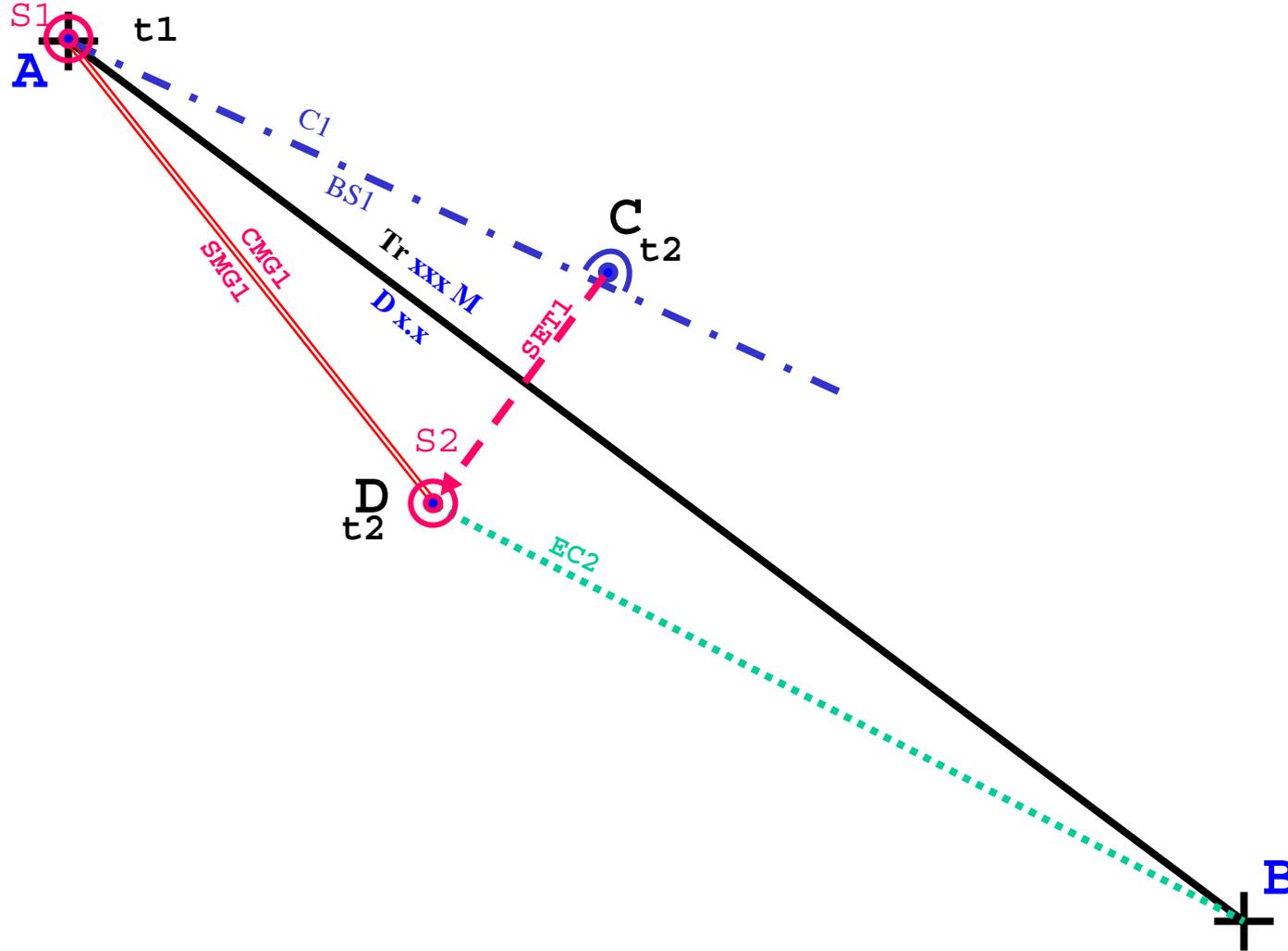
Step-By-Step Instructions



7. Calculate and label SMG1 (SMGxxxM) using $SMG1 = 60(AD)/(t2 - t1)$. Use dividers to transfer AD length to the distance scale.

Common Piloting Problem

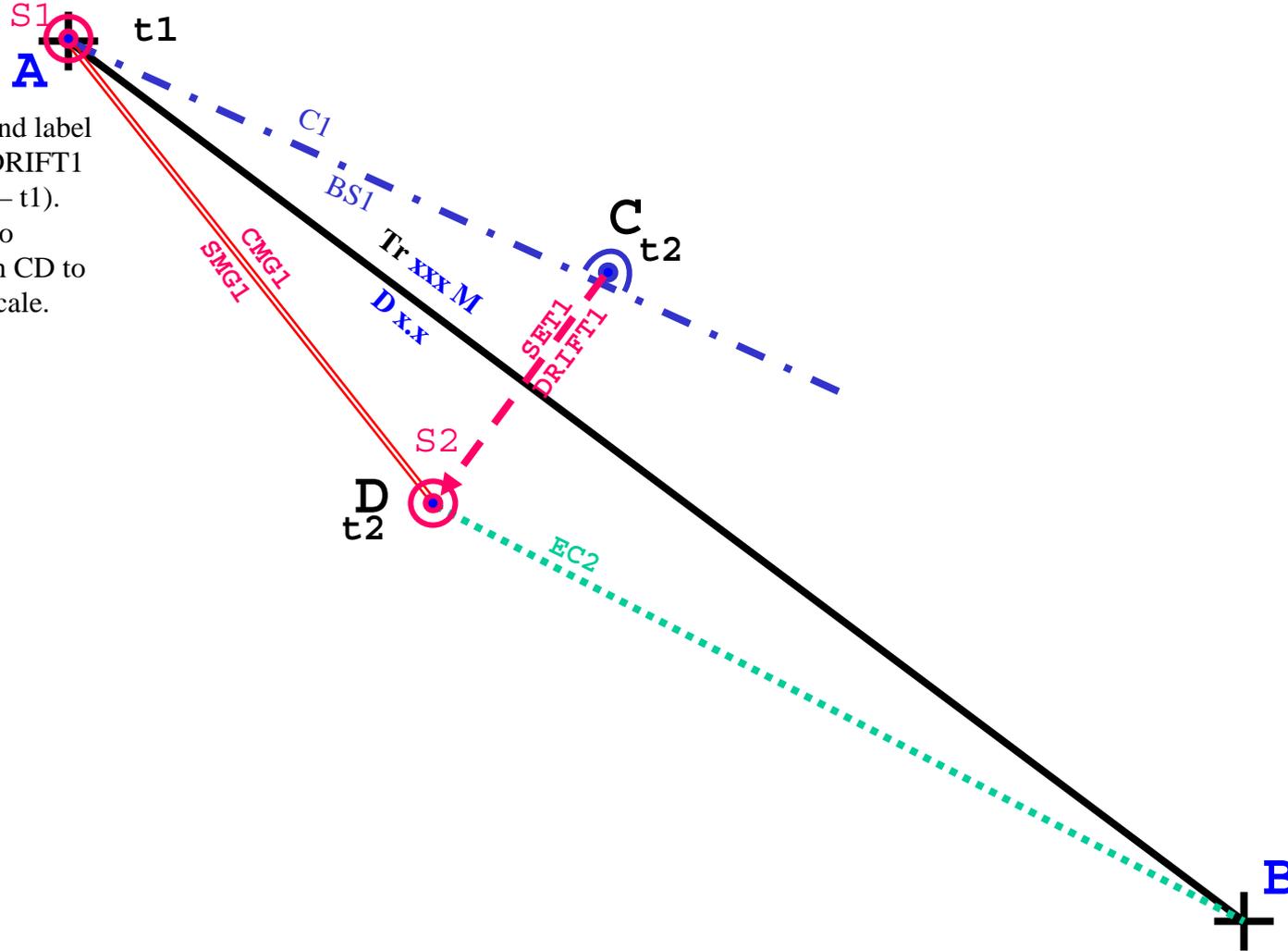
Step-By-Step Instructions



8. Plot and label arrow from DR position C to fix position D; determine SET1 (SETxxxM) using parallel rules from CD to the compass rose.

Common Piloting Problem

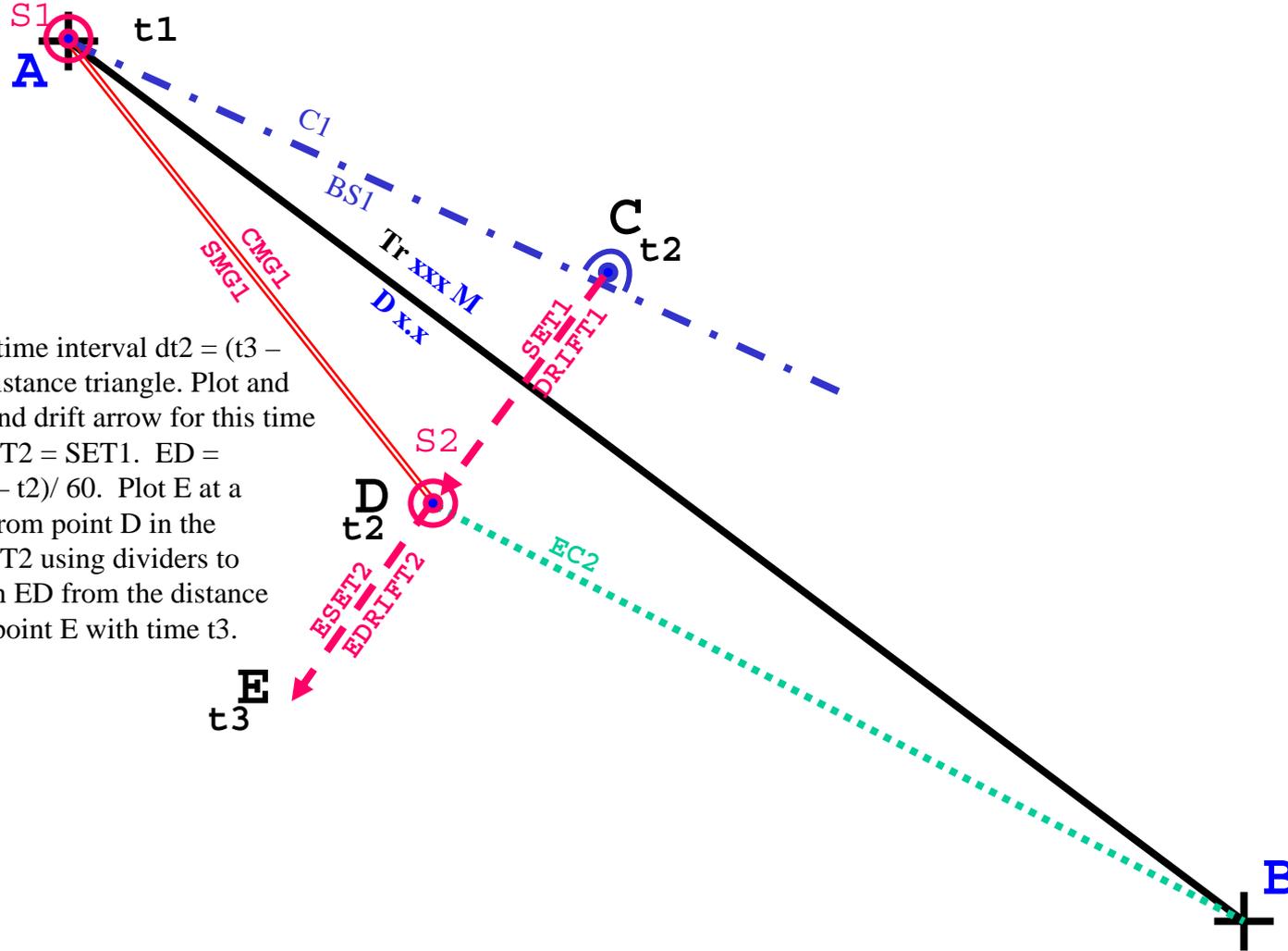
Step-By-Step Instructions



9. Calculate and label
 (DRIFT_{x.x}) DRIFT1
 $= 60(CD)/(t2 - t1)$.
 Use dividers to
 transfer length CD to
 the distance scale.

Common Piloting Problem

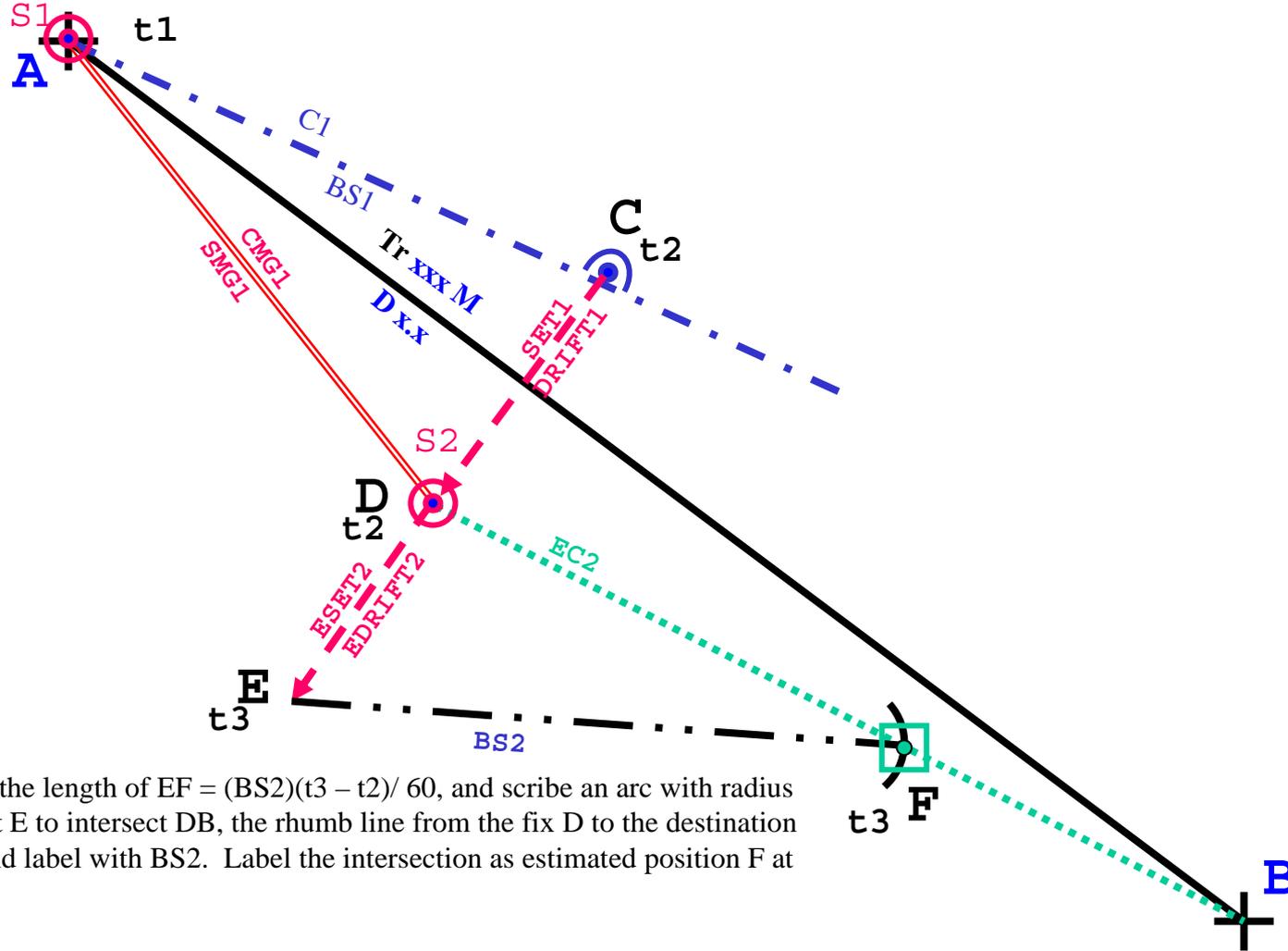
Step-By-Step Instructions



10. Choose a time interval $dt_2 = (t_3 - t_2)$ to plot a distance triangle. Plot and label the set and drift arrow for this time interval. $ESET_2 = SET_1$. $ED = (DRIFT_1)(t_3 - t_2) / 60$. Plot E at a distance ED from point D in the direction ESET2 using dividers to transfer length ED from the distance scale. Label point E with time t_3 .

Common Piloting Problem

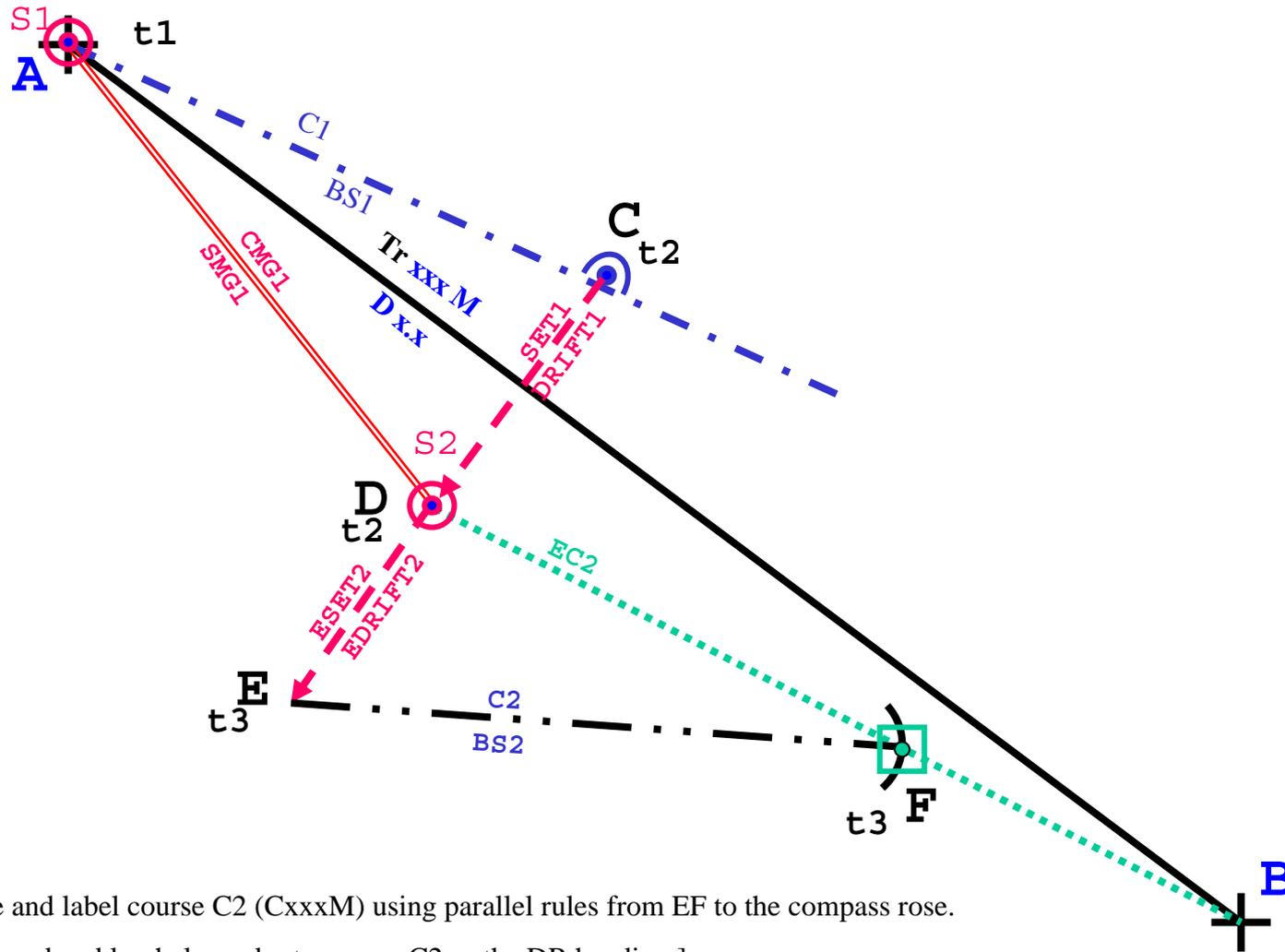
Step-By-Step Instructions



11. Calculate the length of $EF = (BS2)(t3 - t2) / 60$, and scribe an arc with radius EF from point E to intersect DB, the rhumb line from the fix D to the destination B. Plot EF and label with BS2. Label the intersection as estimated position F at time t3.

Common Piloting Problem

Step-By-Step Instructions

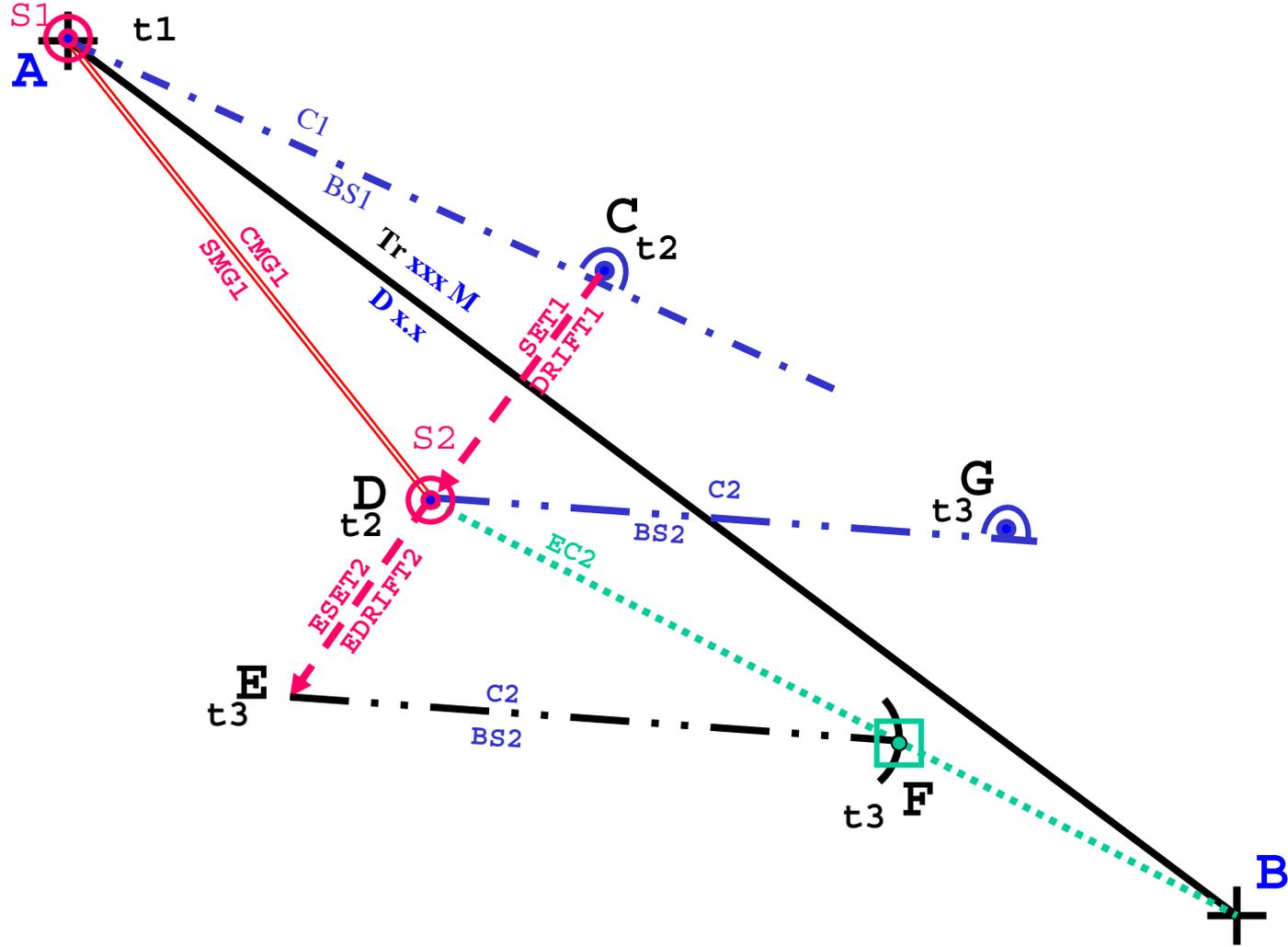


12. Determine and label course C2 (CxxxM) using parallel rules from EF to the compass rose.

[12a. Recommend and log helm order to course C2 as the DR heading.]

Common Piloting Problem

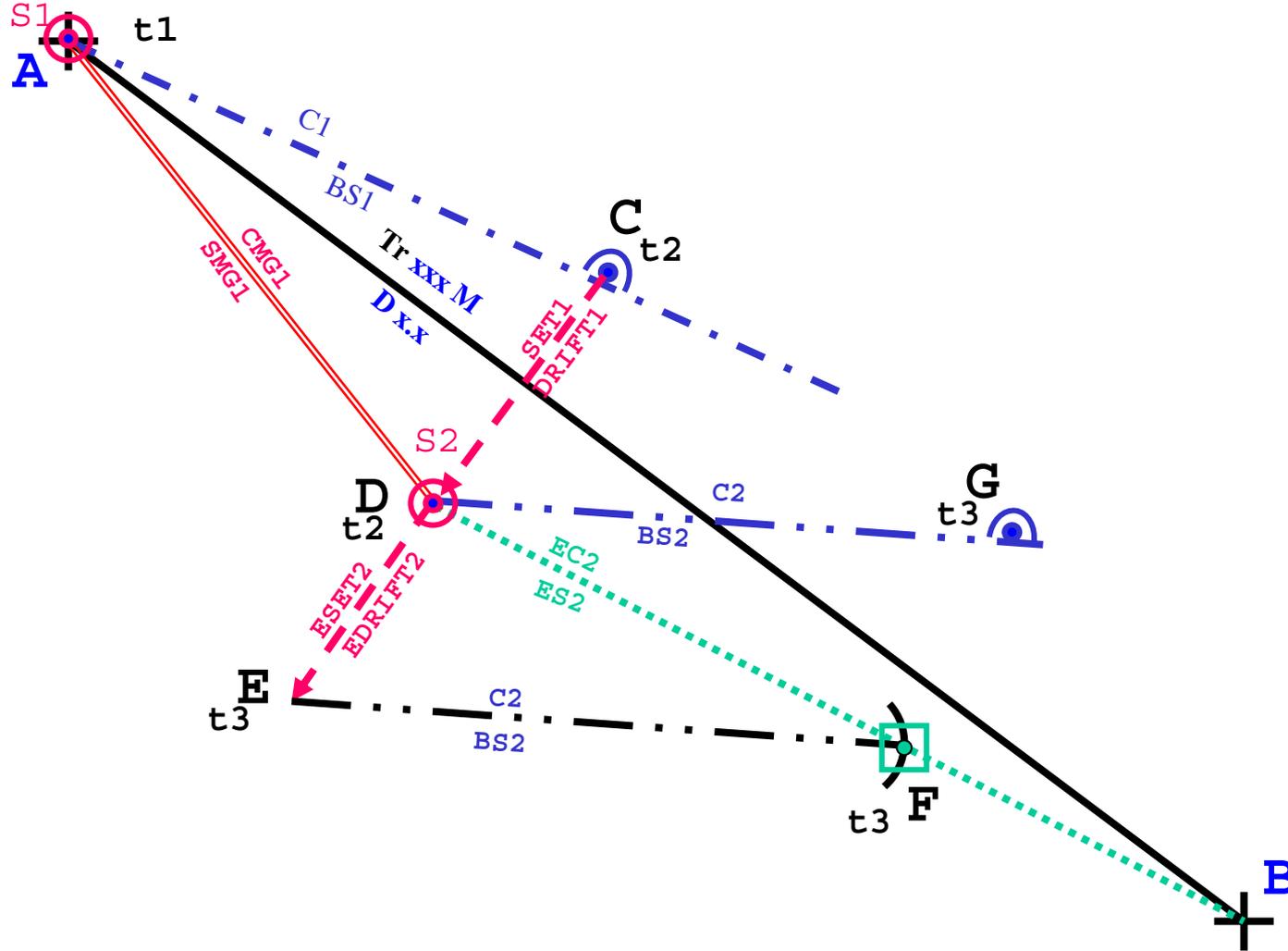
Step-By-Step Instructions



13. Plot and label a DR from D parallel to EF.

Common Piloting Problem

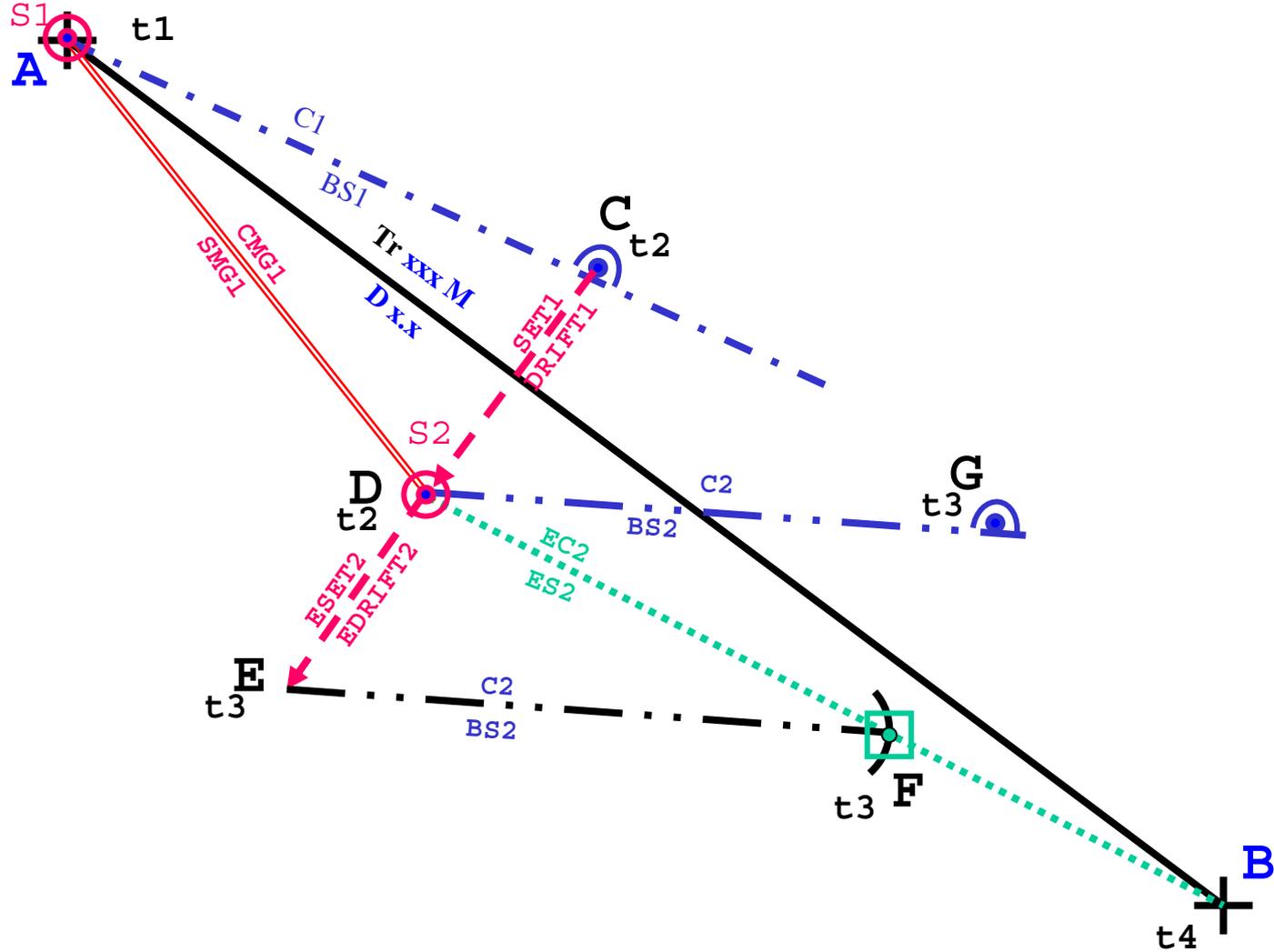
Step-By-Step Instructions



14. Calculate and label (ESxxxM) $ES2 = 60 (DF)/(t3 - t2)$.

Common Piloting Problem

Step-By-Step Instructions

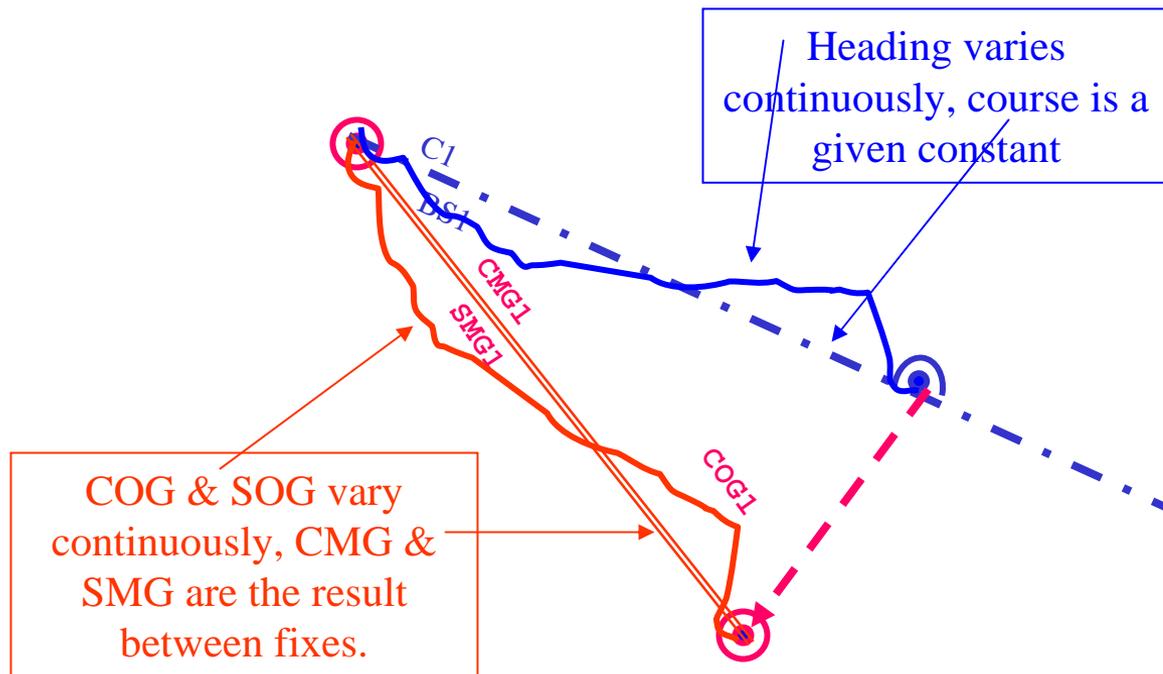


15. Calculate ETA at B = $t_4 = t_3 + dt_3$ where $dt_3 = 60 (DB) / ES2$.

Comparisons

- Course vs heading (DR)
- CMG vs COG (Fix to Fix)
- SMG vs SOG (Fix to Fix)

Comparisons



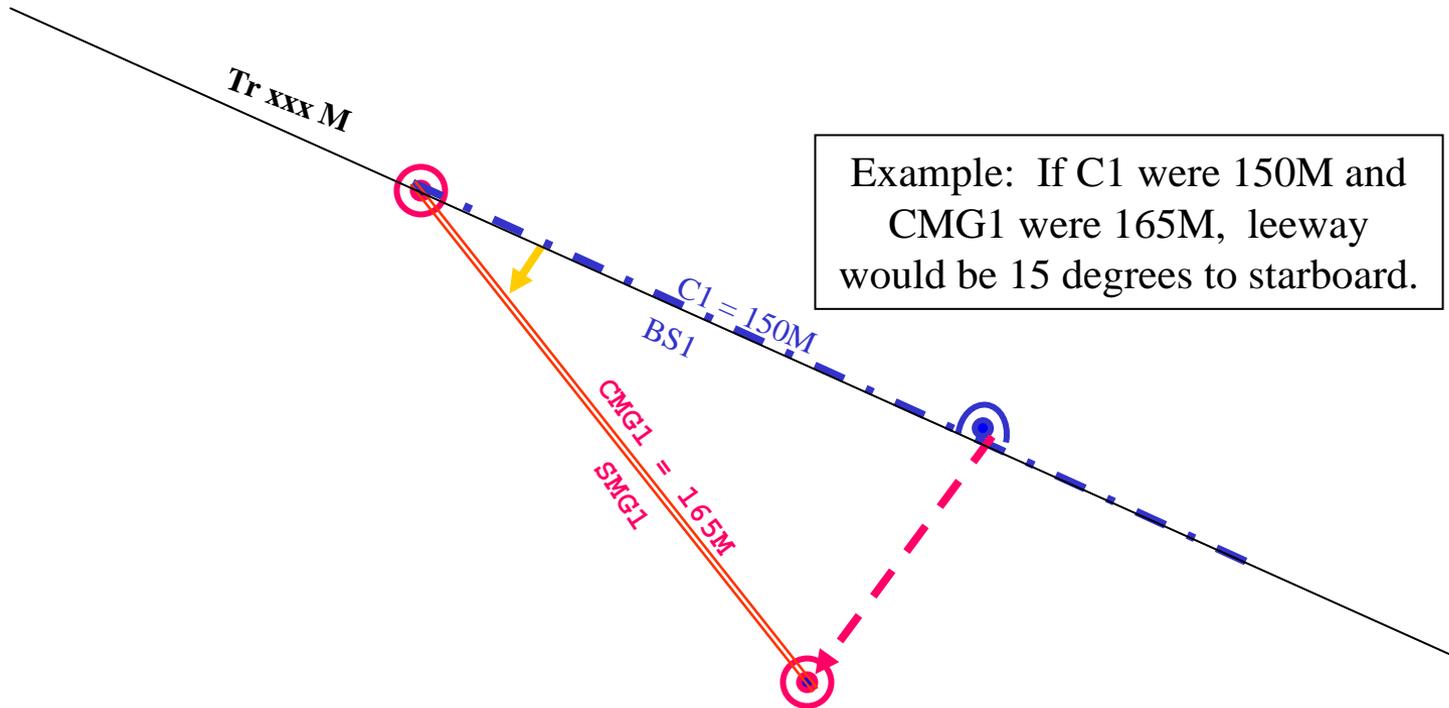
Helm Orders (DR) and Estimated Positions (EP)

- Leeway
- Windage
- Set & Drift

Leeway

- Leeway defined: Angular difference between DR course and CMG
- Measured by: Angular difference between DR course and CMG
- Used to
 - Modify helm orders
 - Parallel track by incorporating leeway in helm order.
 - Regain track by doubling leeway in helm order.

Leeway

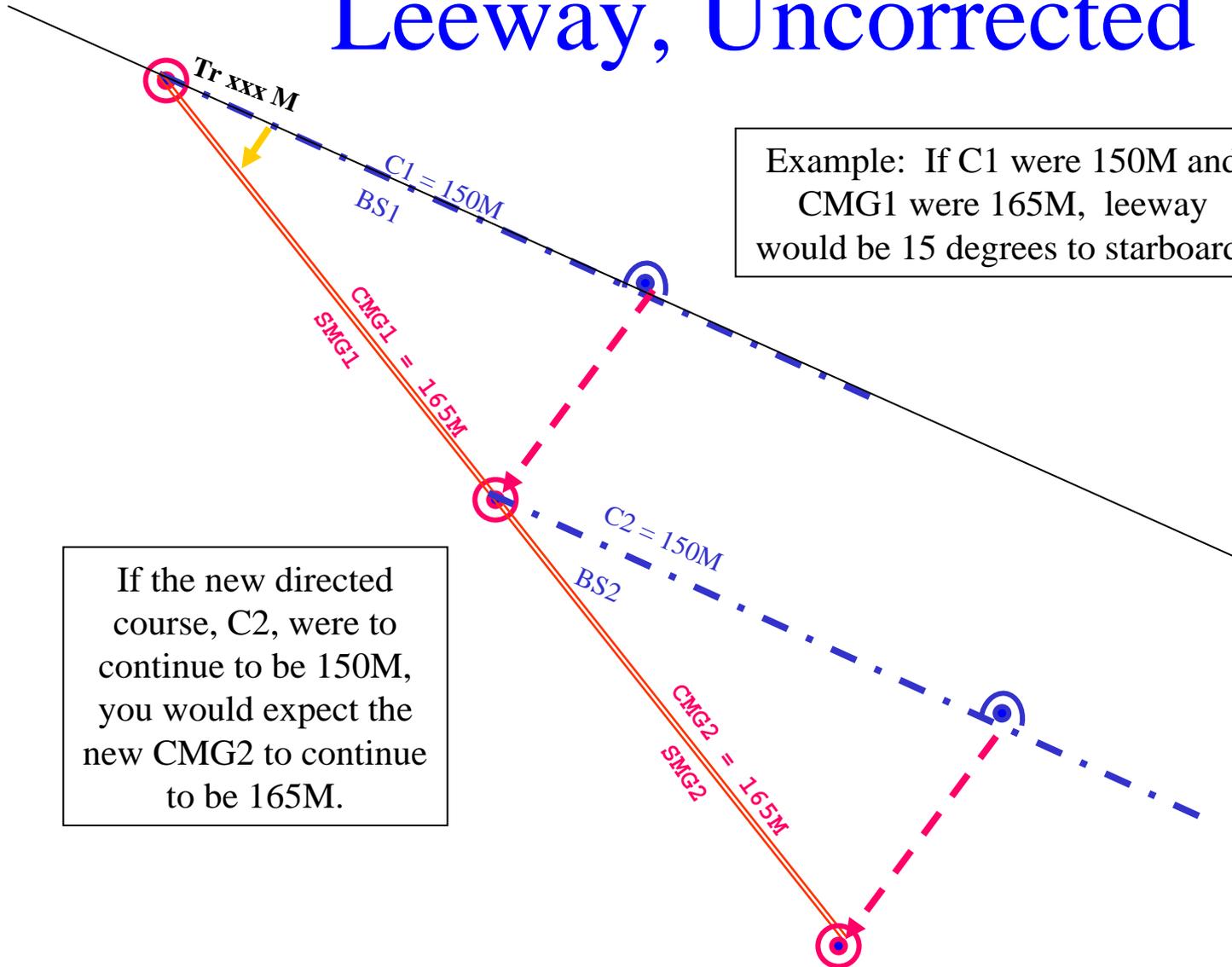


Example: If C1 were 150M and CMG1 were 165M, leeway would be 15 degrees to starboard.

Leeway, Uncorrected

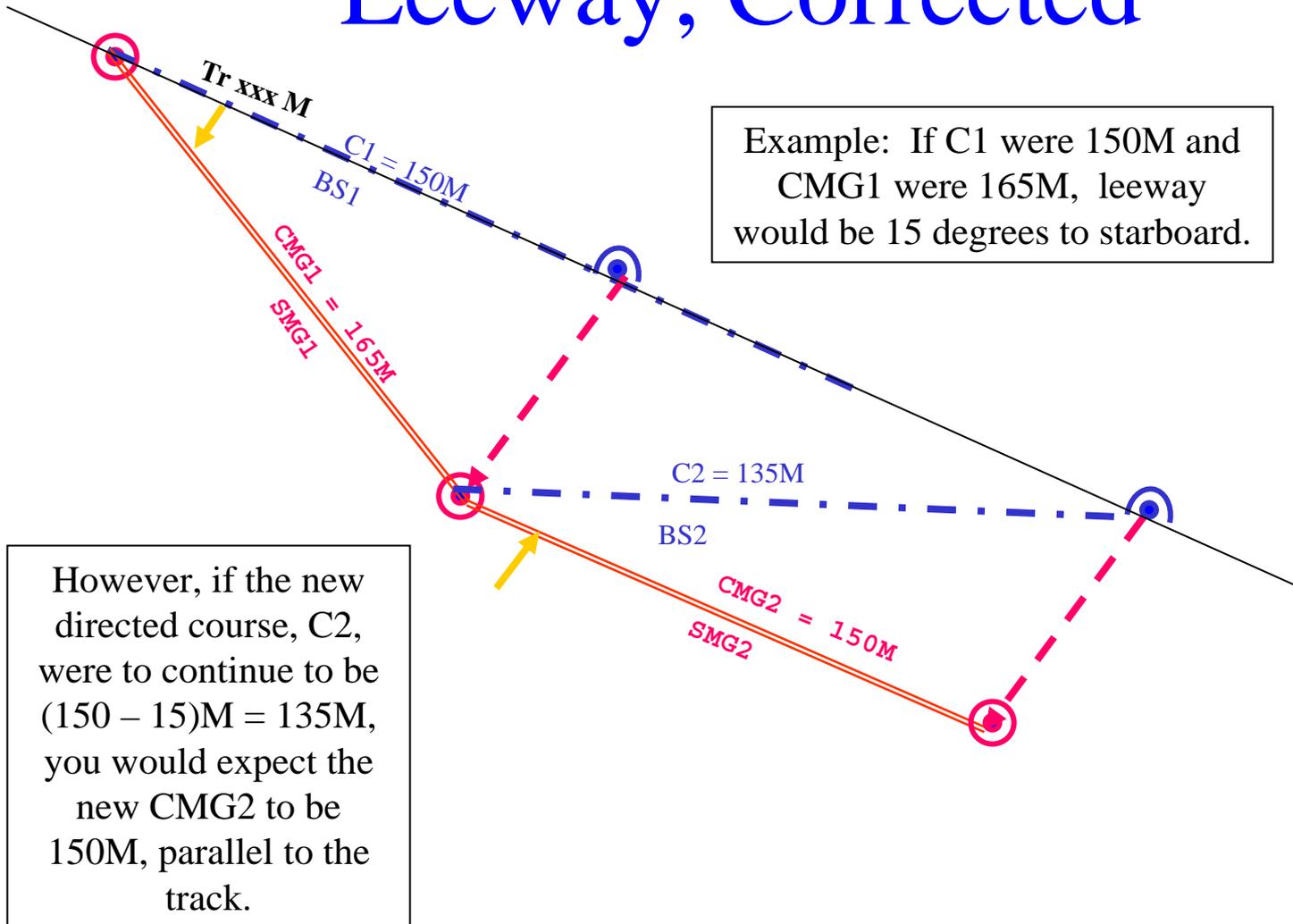
Example: If C1 were 150M and CMG1 were 165M, leeway would be 15 degrees to starboard.

If the new directed course, C2, were to continue to be 150M, you would expect the new CMG2 to continue to be 165M.



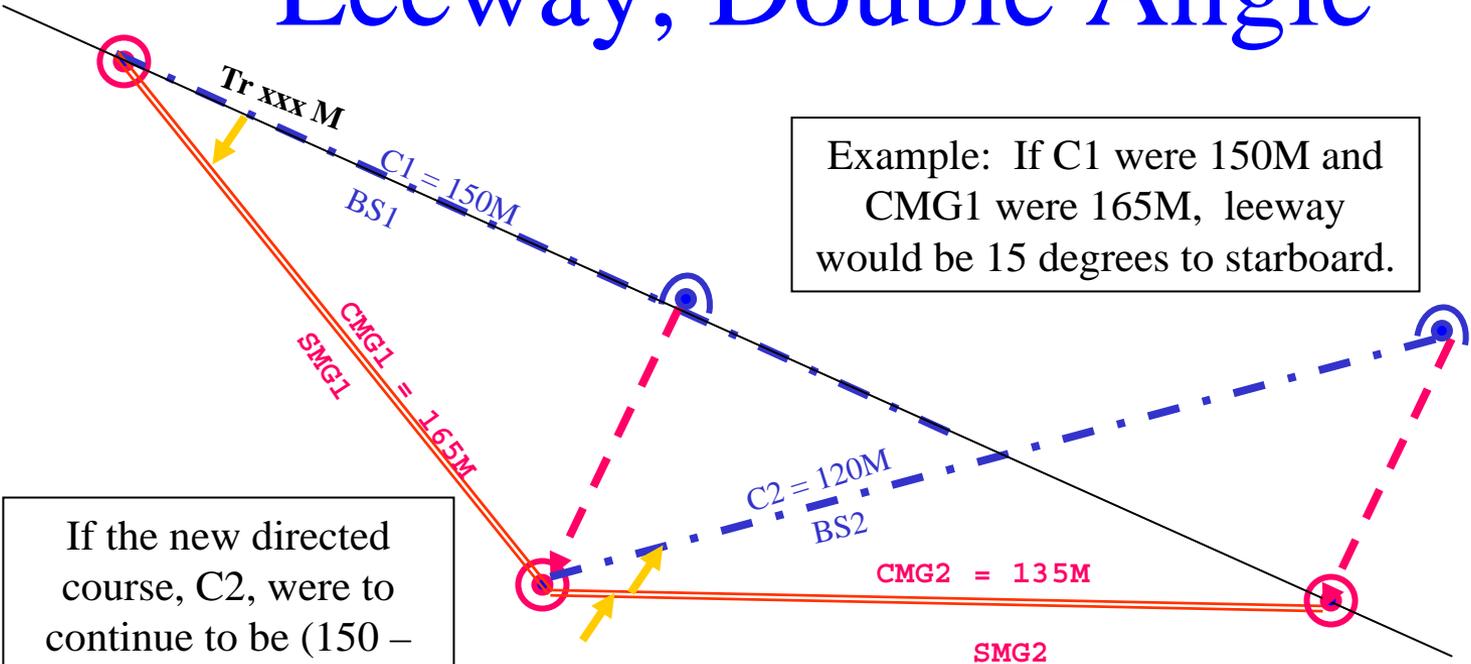
Leeway, Corrected

Example: If $C1$ were 150M and $CMG1$ were 165M, leeway would be 15 degrees to starboard.



Leeway, Double Angle

Example: If C1 were 150M and CMG1 were 165M, leeway would be 15 degrees to starboard.

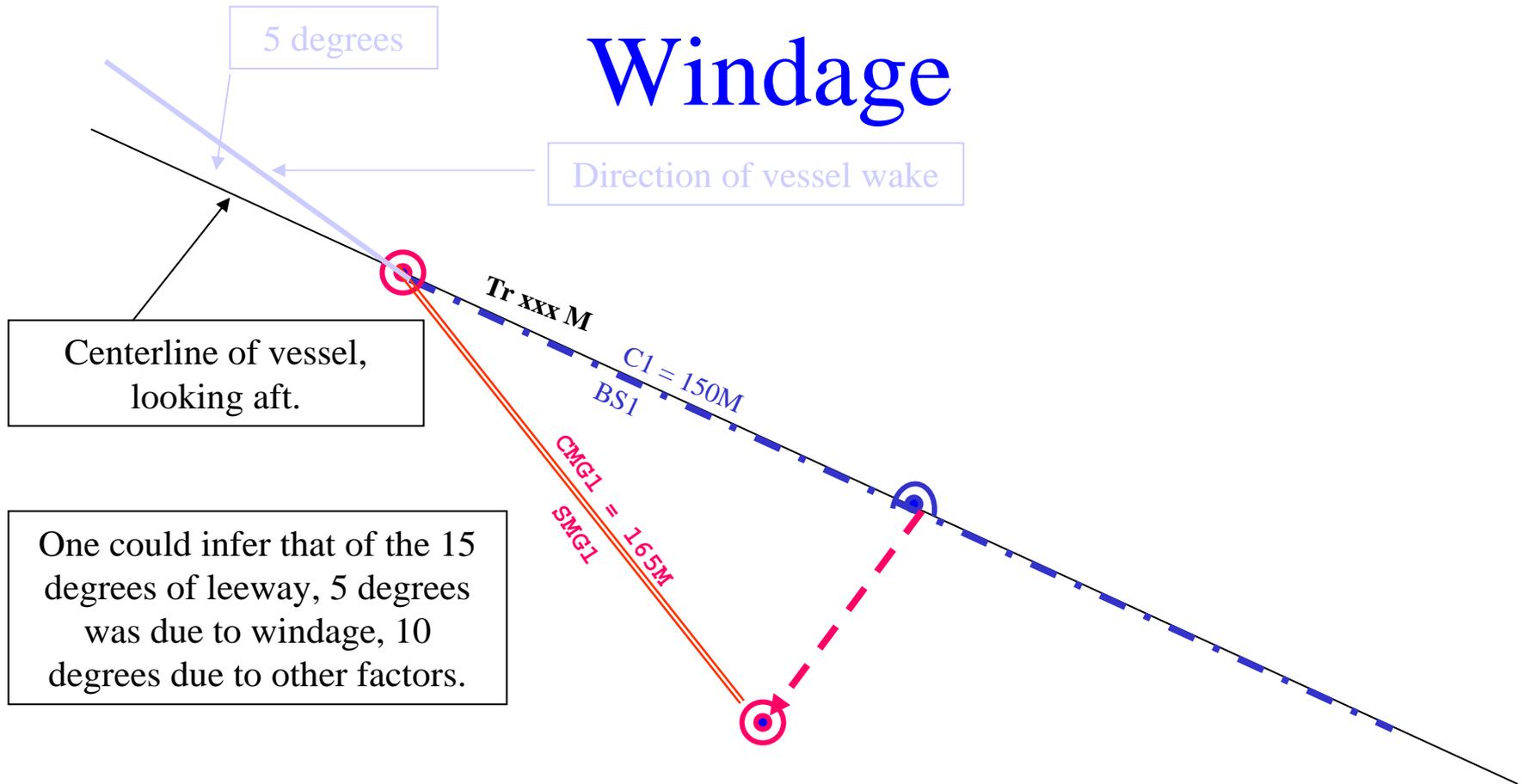


If the new directed course, C2, were to continue to be $(150 - 30)M = 120M$, you would expect the new CMG2 to be 135M, regaining track.

Windage

- Windage defined: That portion of Set & Drift due to wind.
- Measured by: Angle between centerline of vessel and direction of wake.
- Used to: Refine expected Set & Drift on next tack.

Windage



Set & Drift

- Set & Drift defined: Direction and rate of movement between DR and EP positions due to all causes (a speed vector).
- Measured by: Direction (from DR to Fix) and rate of movement (speed, knots) between DR and Fix
- Causes of Set & Drift
- Calculation of Set & Drift
- Uses

Set & Drift: Causes

- Ocean Current
- Tidal Current
- Wind Current
- Windage on vessel
- Heavy Seas
- Inaccurate steering
- Undetermined compass error
- Inaccurate determination of speed
- Error in log calibration
- Excessively fouled bottom
- Unusual conditions of trim

Set & Drift Calculation

- Set & Drift are accumulated during the time between two fixes.
- Set & Drift are calculated as the speed vector from the DR to the fix at the end of the fix interval.
- Set is the direction (expressed in CSNTS in degrees magnetic).
- Drift is the rate in knots = distance between the fix and DR in nm divided by the time between fixes in hours.

Set & Drift Examples

- 1644 Fix:
 - Fix time interval 1644 - 1620 = 24 minutes
 - Measure distance between DR and fix at 1644: .25 nm; therefore $S = d/t = .25 / (24/60) = 0.625 \Rightarrow 0.6$ kt drift.
 - Measure direction: approx 150M = Set
- 1753 Fix:
 - Fix interval = 30 min; dist = .25 nm \Rightarrow 0.5 kt drift
 - Direction approx 125M

Set & Drift: Uses

- To calculate EP from DR.
- As part of course determination from an off-track location to the next waypoint.

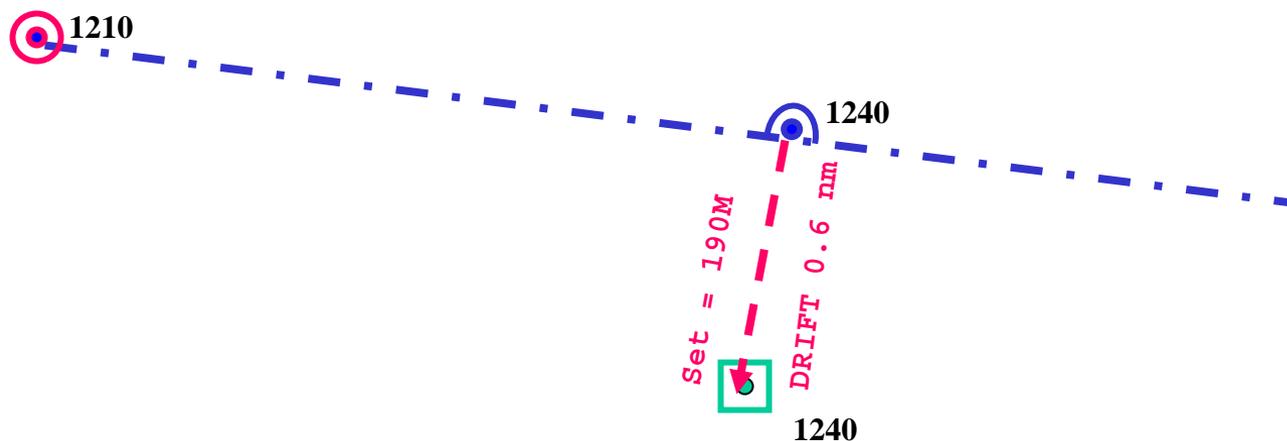
Set & Drift: EP from DR

Set remains constant, the direction from the DR to the EP.

The distance from the DR to the EP = the drift (in knots) multiplied by the time interval (in hours) from the fix where drift was determined to the DR position.

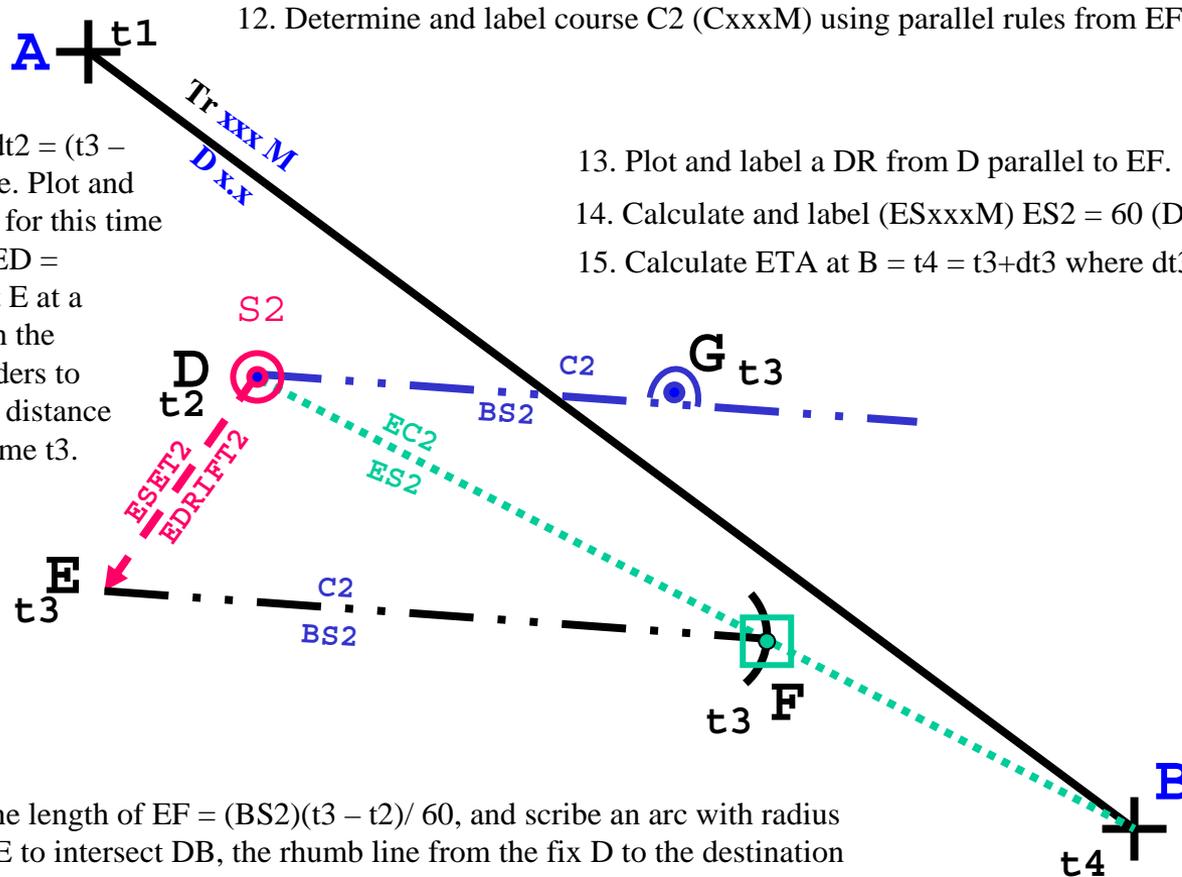
Example: Set = 190M, Drift = 1.2 kts, last fix at 1210, DR at 1240. Plot the 1240 EP.

$D = ST = 1.2 \times (30/60) = 0.6 \text{ nm}$. The 1240 EP is 0.6nm from the 1240 DR at 190M.



Set & Drift: Course Correction

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Bearings

- Natural ranges
- Danger bearings
- Choice for course (fore and aft) or speed (abeam) verification
- 90 degrees between bearing best for 2 LOP fix
- 120 degrees between bearings best for 3 LOP fix
- Down-track advanced choice
- Turning bearings
- Drop bearings
- Anchor circle bearings

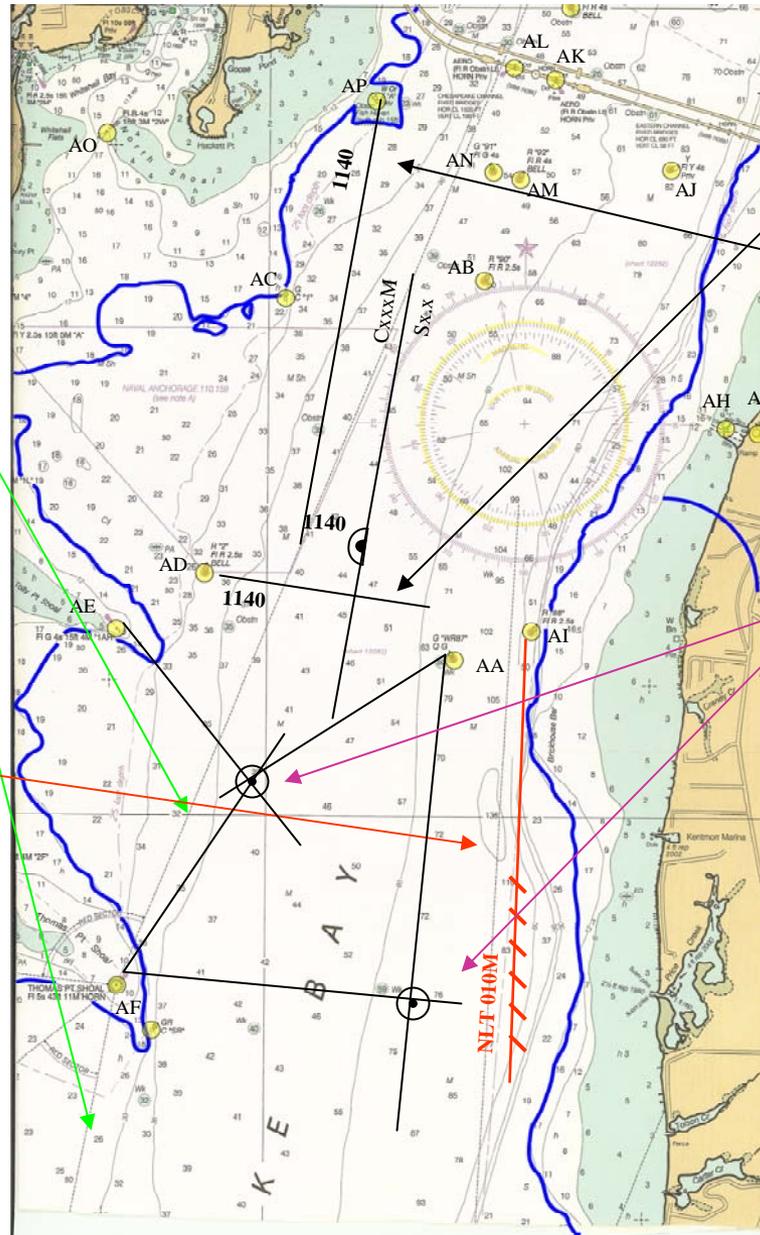
Bearings

Natural Ranges:

1. Edge line of Red Sector of fixed lights, e.g., TPL
2. Range of two daymarks, other fixed nav aids, or landmarks.
3. Tips of land and other fixed objects.

Danger Bearings:

1. Drawn on chart, feathered on danger side, originating at a fixed object beyond the danger for bearings.
2. Marked "NLT" (Not Less Than) or "NMT" (Not More Than) xxxM.
3. Mariners take bearings to stay on unfeathered side.



DR Course / Speed Verification:

1. LOP on AD shows speed less than DR estimate.
2. LOP on AP shows course west of DR estimate.

Best Bearing Angles for Fix:

1. Two at 90 degrees
2. Three at 120 degrees

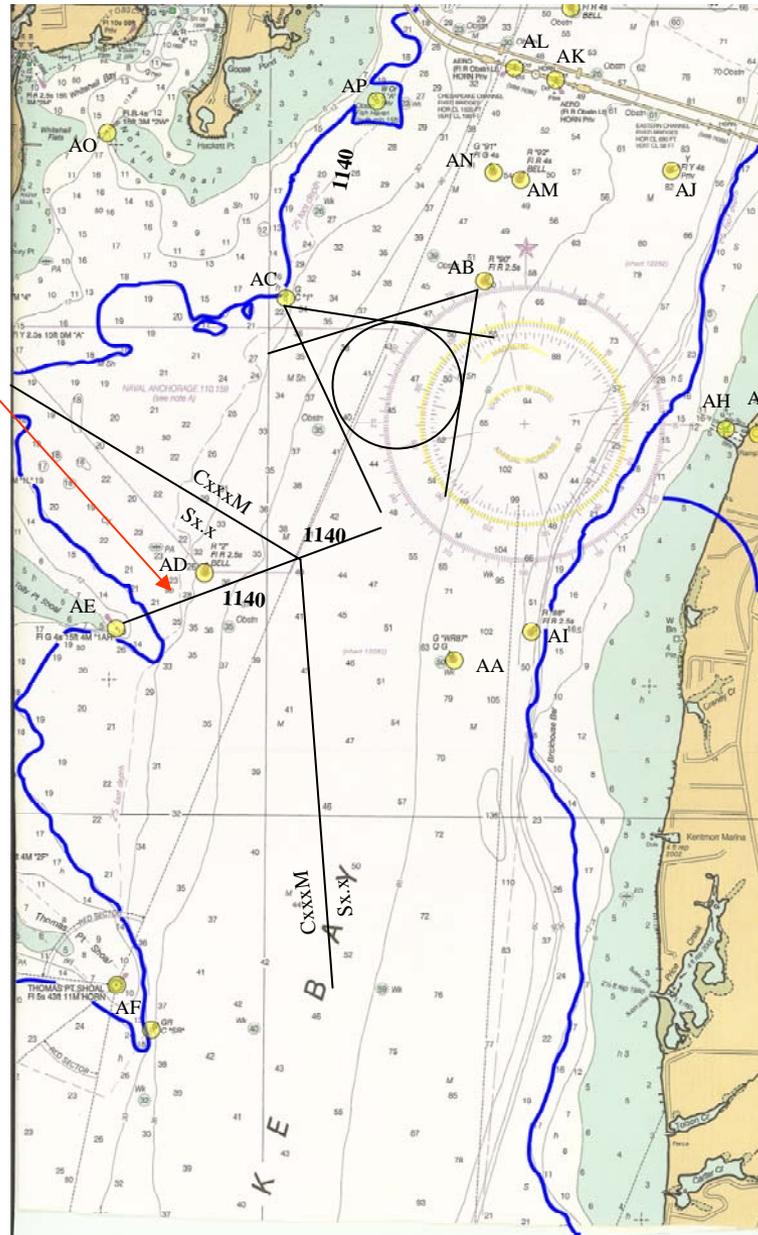
Down-Track Bearing Pre-Selection:

1. Buoys & daymarks are visible about 2.5 nm away in a STC.
2. Pre-choose targets for LOP bearings.
3. Work in targets one round ahead of need to verify through LOP convergence.

Bearings

Turning Bearings / Drop Bearings:

1. A turning bearing clarifies the point of turn.
2. A drop bearing is used with a heading bearing to drop anchor.



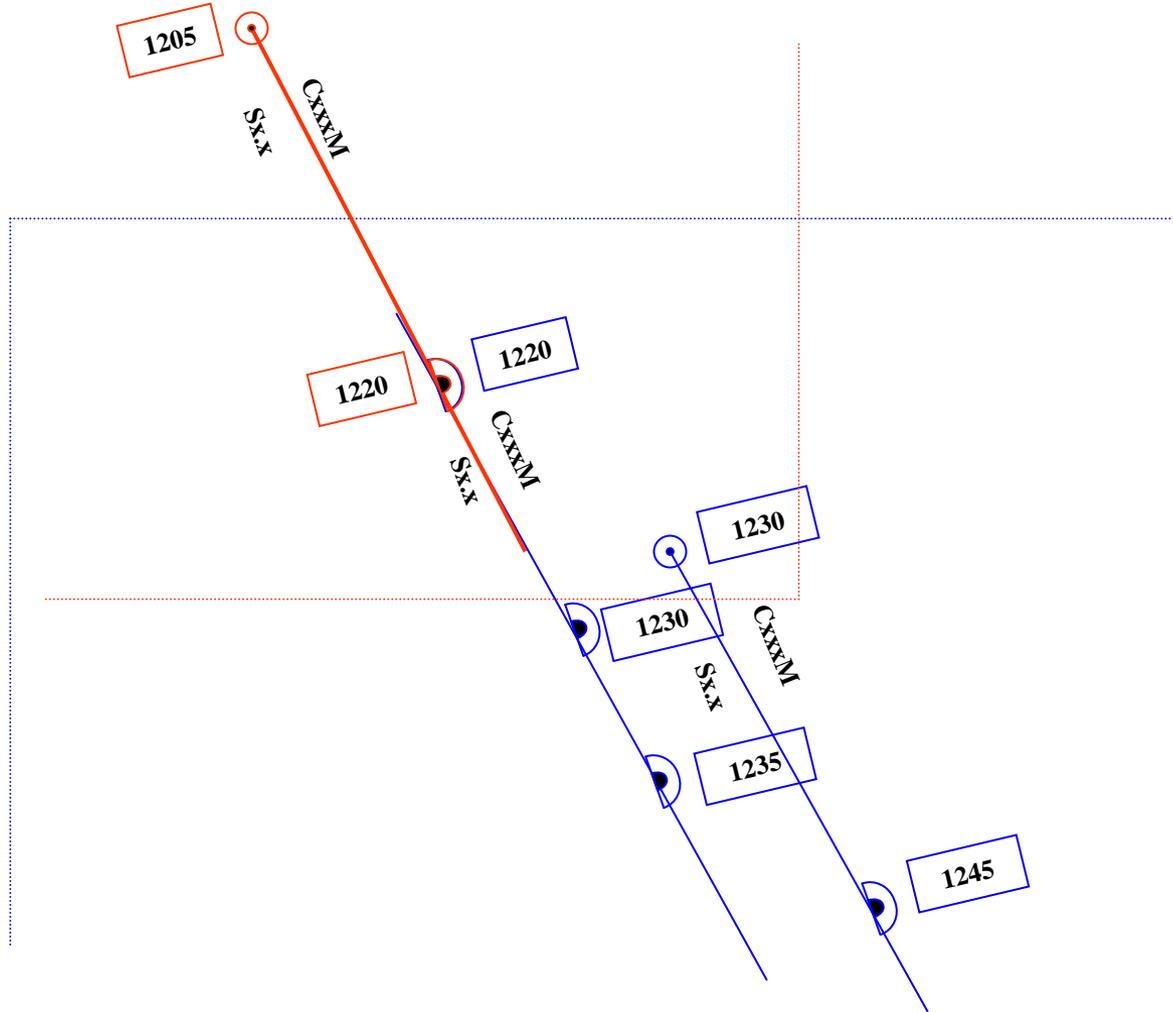
Anchor Bearings:

1. After dropping anchor, record the anchor location and plot the swing circle.
2. Plot tangents to the swing circle from two external, visible-at-night locations.
3. Determine from the compass rose the bearings for each pair of tangents.
4. Periodically during anchor watch take bearings on both locations.
5. If each bearing falls within the range of its tangent pair, the vessel is in the swing circle, and the anchor has not dragged.
6. If either bearing fall outside the range of its tangent pair, the anchor has dragged.

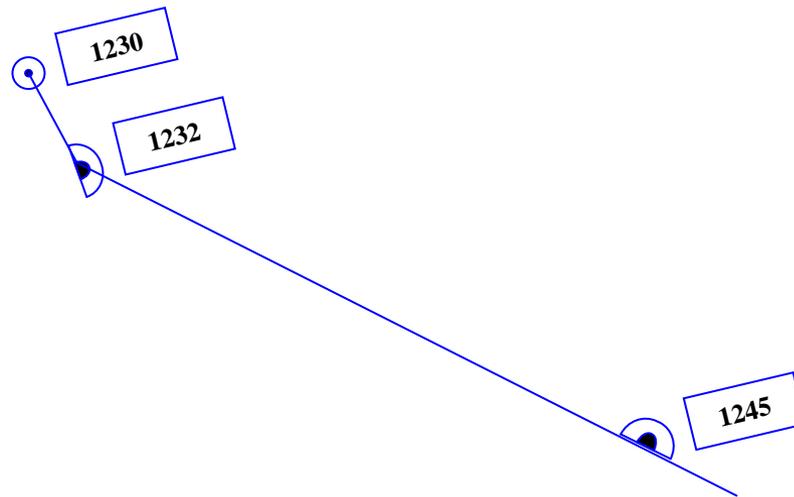
Special situations

- Radar LOPs
 - Distance: Good
 - Angle: Fair
- Shifting DR to a new chart
- DR from fix with lag in helm orders
- Running fix (advancing an LOP)
- Double angle fix from single landmark.
- Estimated Position based on a single LOP

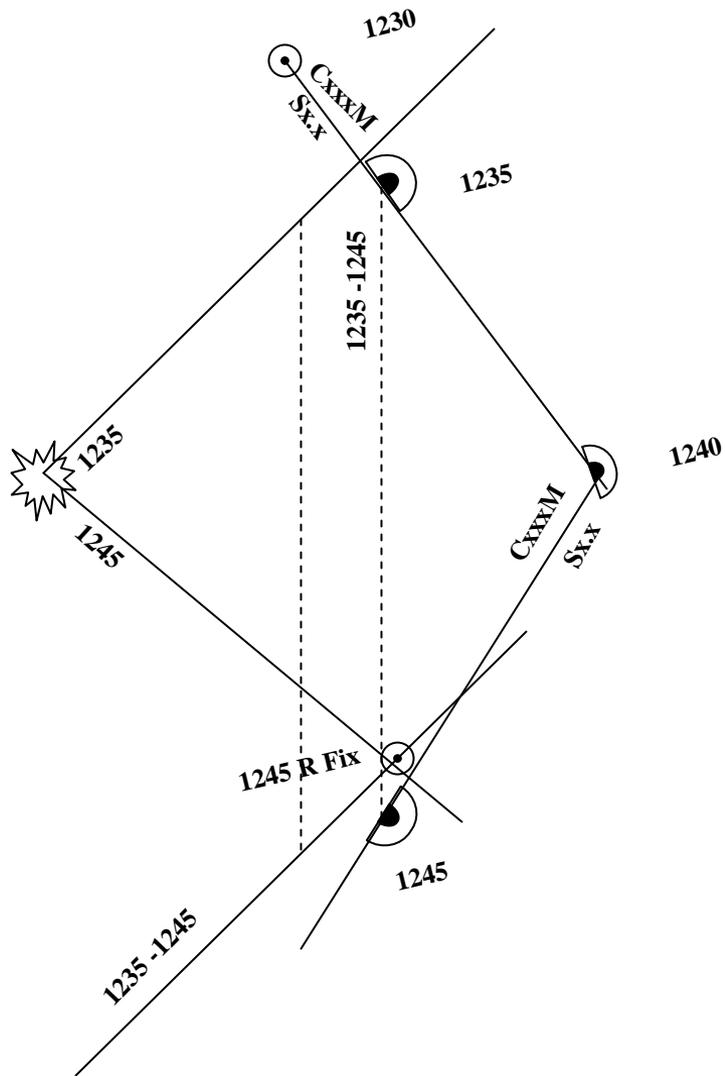
Shifting DR to a new chart



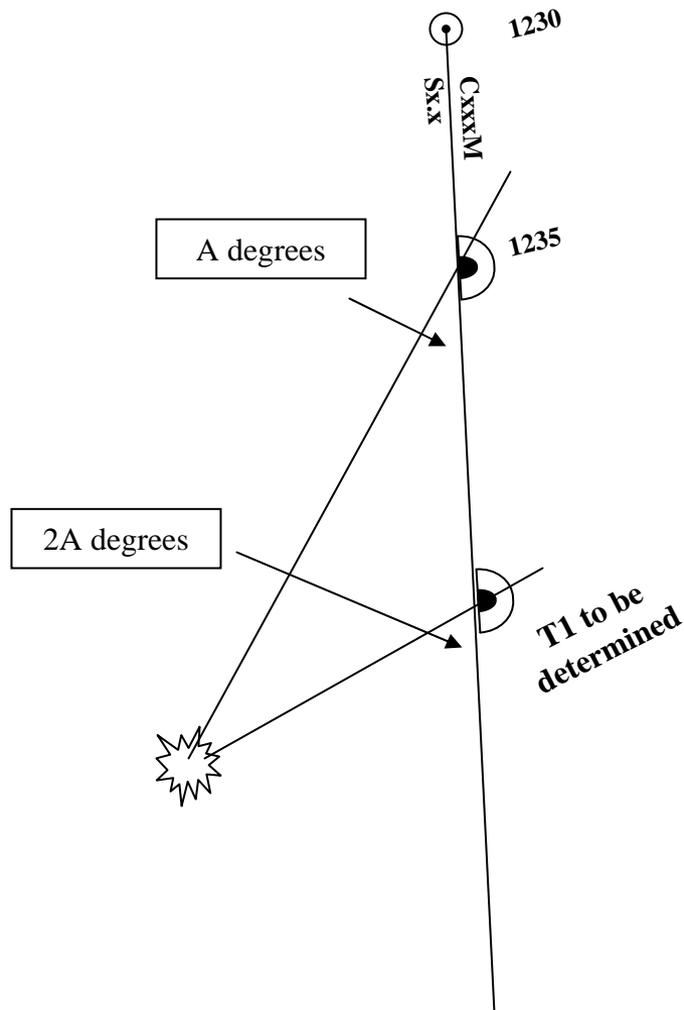
DR from fix with lag in helm orders



Running fix (advancing an LOP)

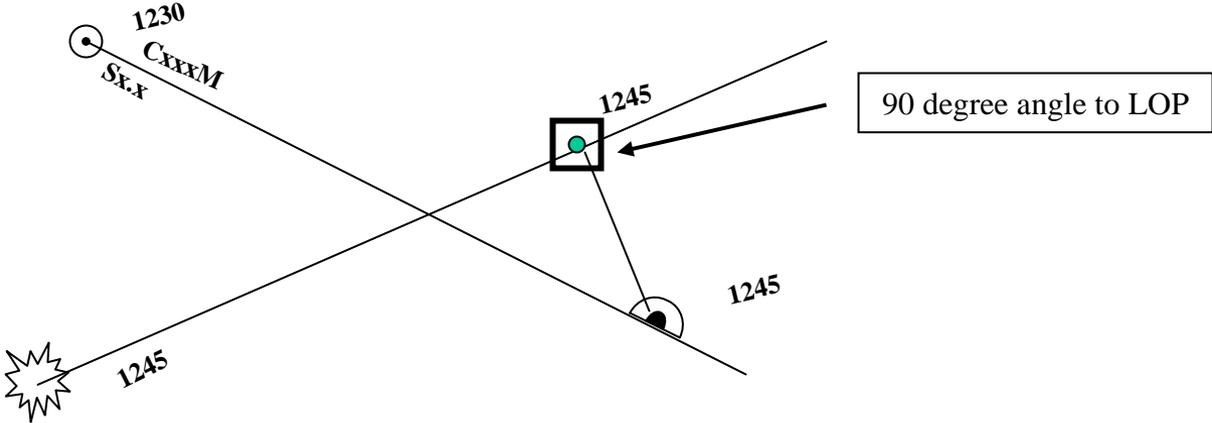


Double angle fix from single landmark



1. Maintain constant course and speed from first LOP to second.
2. After first LOP @ angle of A DEGREES, determine HBC direction for angle of 2A degrees
3. HBC operator marks the time at 2A.
4. From A to 2A, $D = ST$
5. This is an isosceles triangle, so the distance from 2A to the landmark is the same as the distance timed along the route.
6. You have a bearing and a distance; this is a running fix
7. Example: For C180M and first LOP measured at 202M, the difference, $A = 202 - 180 = 22$ degrees. $2A = 44$ degrees, or a measured LOP at $180 + 44 = 224M$

Estimated Position based on a single LOP



Critical info to the WC in narrow channels or fairways

- Which leg of the channel are we in, e.g., Cross Ledge?
- Which side of the channel are we running?
- What is the minimum distance to shoal water outside of the channel on the side we are running?
- What buoy number are we approaching/ have we just passed?
- Where is the next unlit buoy on our side of the channel?

Five Minute Rules

- Five Minute Rules
 - Wait five minutes to insure wind direction changes are permanent. Helm adjusts the heading to small, short-duration vagaries in wind direction.
 - Change the DR notation (course and/ or speed) in the Nav Log for sustained (at least five minutes) changes of
 - Speed changes of at least 0.5 knots
 - Course changes of at least five degrees

Integrating GPS with Piloting

- Bearing and direction to next waypoint
- Set & Drift between DR position and GPS position
- Leeway between previous DR course and CMG between last and current GPS position.
- VMG for best sail angle
- Matching COG to course to next waypoint
- Cross track error tells you the perpendicular distance the vessel is from the track

Tactical Considerations

- Recovery from loss of navigational awareness
- Speed triangle applications
- Increased seas
- Staying in the squadron box
- Shift to next waypoint

Recovery from loss of navigational awareness

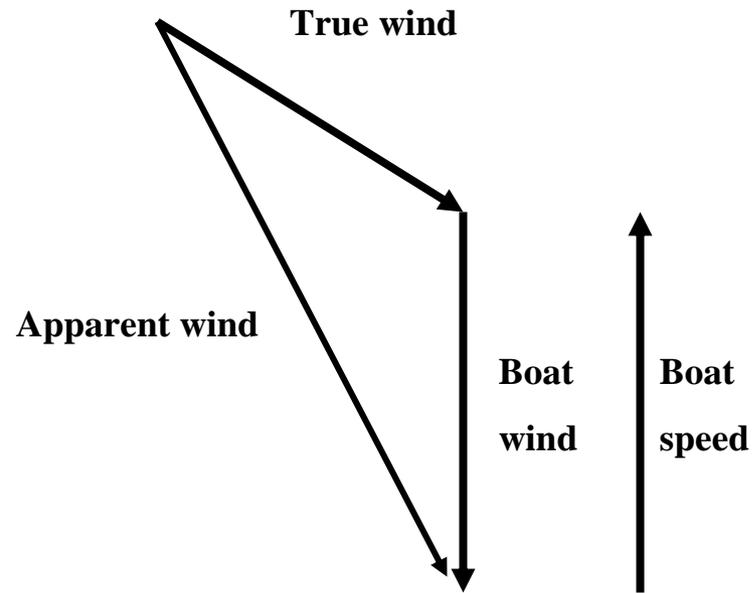
- Backtrack immediately from shoal water
- Do circles in good water

Speed Triangle Applications

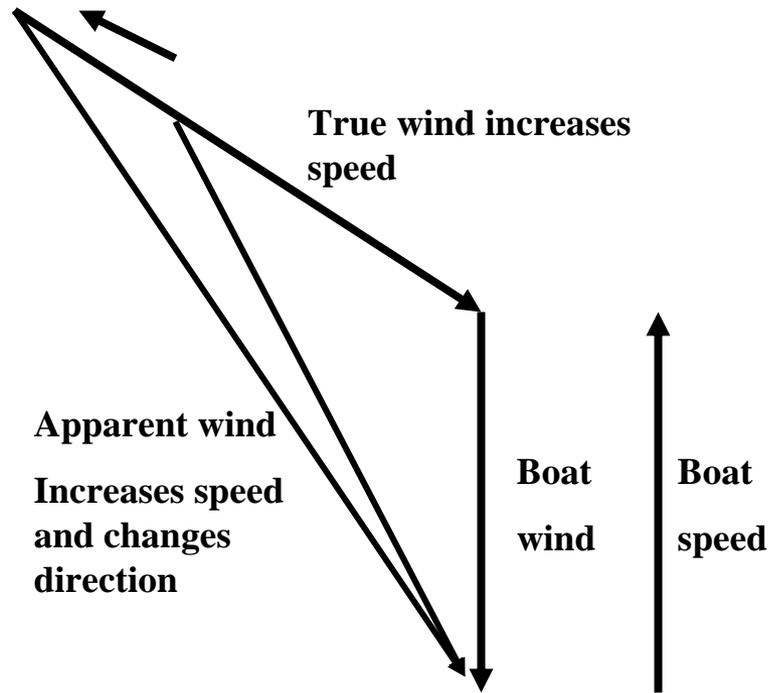
[Boat Wind + True Wind = Apparent Wind]

- Head up in puff (increase in true wind)
- Fall off in hole (decrease in true wind)
- Sail must be twisted to match wind direction

Wind Speed Triangle

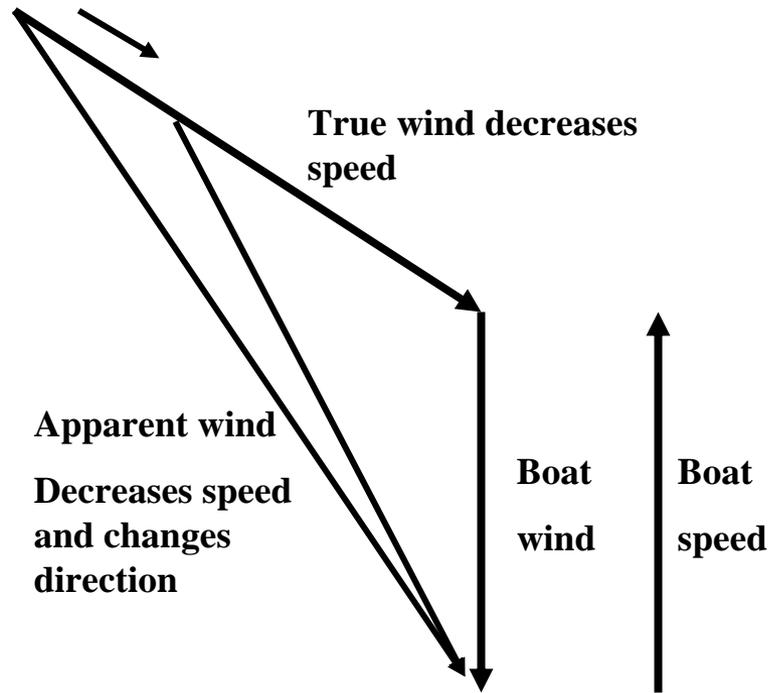


Wind Speed Triangle: Puff



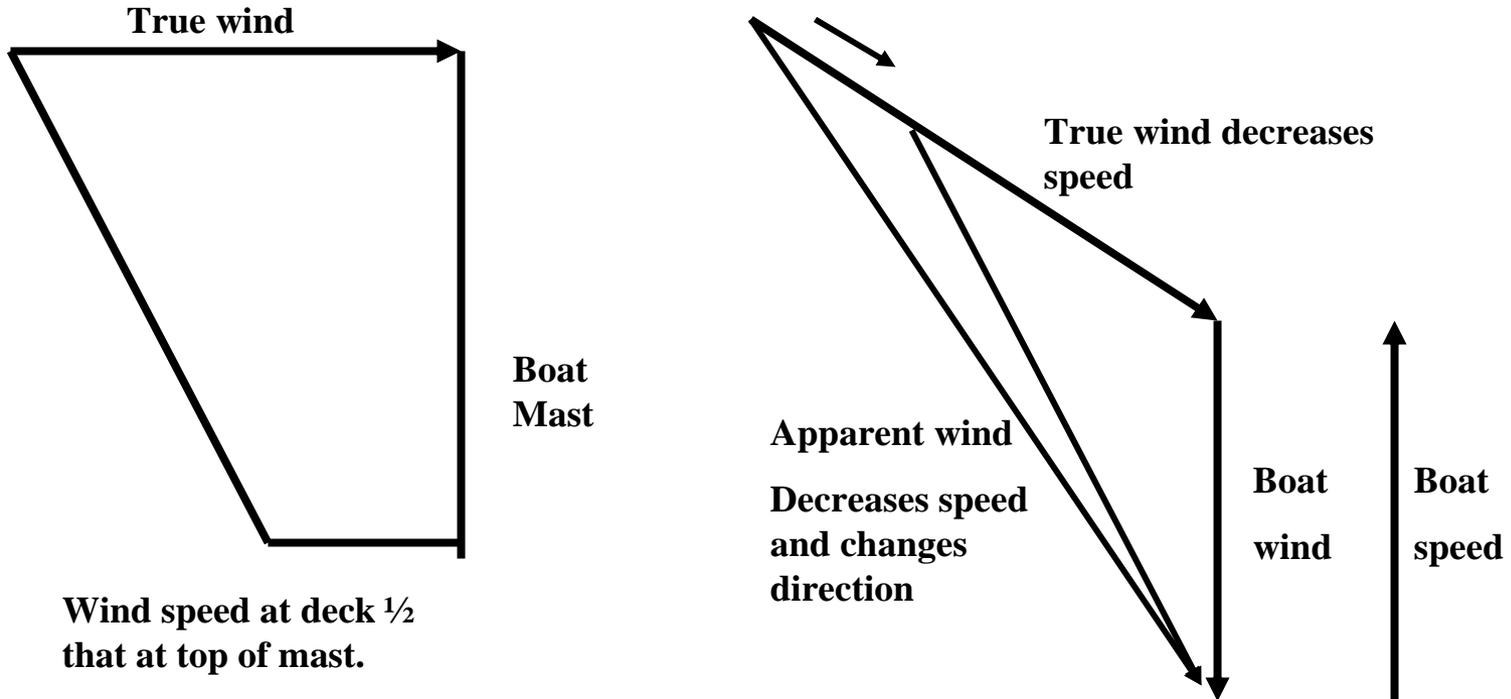
Apparent wind shifts aft; helm heads boat up to maintain original wind angle

Wind Speed Triangle: Header



**Apparent wind shifts forward;
helm falls off to maintain original
wind angle**

Wind Speed Triangle: Shear



Because True Wind decreases as it approaches deck level, the apparent wind decreases but also changes direction as it approaches deck level.

We adjust sail shape with twist to match the changing direction of apparent wind. Tell tales all flying horizontally.

Increased Seas

- Fall off and adjust sail trim to keep boat speed up.
- Choose the heading which maximizes VMG in GPS.
- You will ride with less bounce, have less tired crew, and get there faster.
- Motoring will be slower and tend to make crew seasick

Staying in the squadron box

- Cross track error lets you know if you are still in the squadron box. The box is usually defined in OTC orders. For example:
 - Stay within 5 miles of track
 - Stay within VHF range of OTC (nominally 20 miles)
 - Stay within sight of another squadron STC (Why? If your mast breaks, you can call for help on handheld VHF.)

Shift to next waypoint

- If you are off track, as you get close to the next waypoint, VMG will force you to the waypoint.
- Often it is more efficient to shift to next waypoint so that you do not take extra time and miles to cross the nearer waypoint.

Strategic Considerations

- Strategic positioning in the ocean
- Use of consumables

Strategic positioning in the ocean

- If there is a forecast wind shift, move early to the side of track from which the new wind will come.
- You will have better sailing angles, less use of engine, faster boat speeds, and shorter distance to travel.

Use of consumables

- Distance to go and fuel remaining
- Water

Distance to go and fuel remaining

- When do I have enough fuel to get to destination if the wind dies?
 - Fuel efficiency: (seas 1 ft or less):
 - at 1800 rpm: 0.75 gal/hr, 4.8 – 5.0 kts
 - at 2000 rpm :1.0 gal/hr, 5.4 – 5.6 kts
 - at 2200 rpm :1.5 gal/hr, 5.7 – 6.1 kts
- And also run the engine enough to keep the batteries charged?
 - Battery charging takes 2-3 hrs per day

Water

- With
 - No use of electric water pump,
 - Crew showering every other day,
 - Sponge bathing critical areas (head, arm pits, crotch, and feet) on alternate days:
- Day tank (23 gal) used in 26 – 33 hrs.

Salty Trivia

- “Knot” origin
- How to measure boat speed without electricity
- Why red and green lights are 112.5 degrees arcs

“Knot” origin

- There were two “hour glasses” on the bridge. One was 30 minutes, the other much less, perhaps 15 seconds. The quick one was for measuring speed.
- 6000 ft in 60 min = 1 knot
- 100 ft in 1 min = 1 knot
- 25 ft in 15 sec = 1 knot.
- Make a drag, tie a line to it, tie knots in the line every 25 feet, throw it overboard and count the knots that pass through your hand in 15 sec; that is the speed of the vessel in knots.

How to measure boat speed without electricity

- Make the device in the previous slide, or
- Measure the time a small piece of paper in the water takes to pass a known distance down the hull. Use $D = ST$ to calculate S .

Why red and green lights are 112.5 degrees arcs

- Old compasses were divided into 32 points.
- $360 / 32 = 11.25$ degrees per point.
- The arcs of red & green running lights were 10 points, 112.5 degrees.
- The arc of the stern light was the remaining 12 points, or 135 degrees.

Questions?

Comments

- Please help me make this document more responsive to your needs and the volunteers who follow you.
- Comments by email to rknell@cox.net
- Thanks