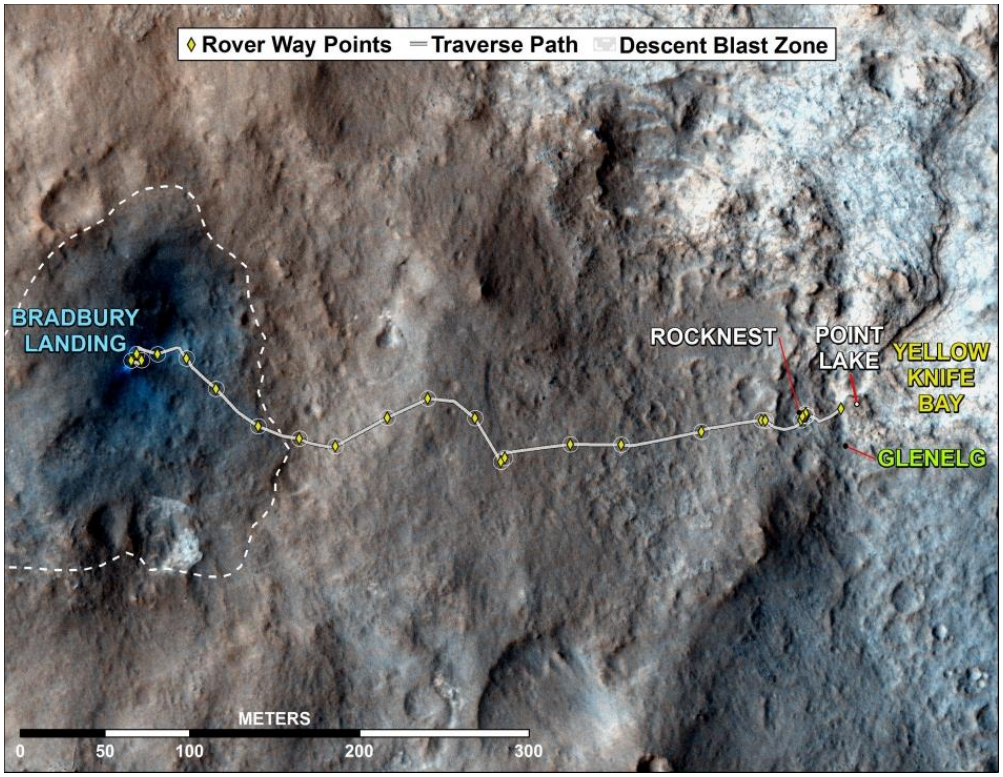
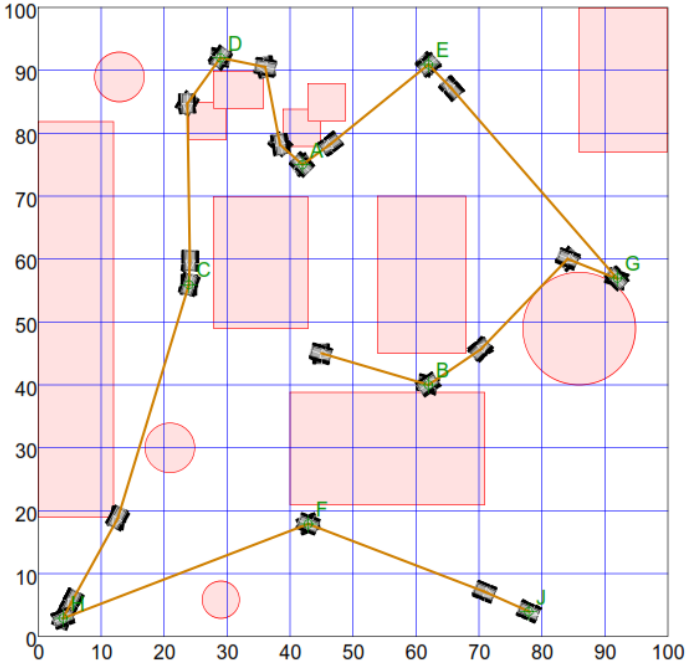
MARS ROVER

Science Olympiad
Trial Event



Event Description

- Mars Rover is a testing event, **not** a build event.
- The students need to determine the best path between experiments for a virtual rover on Mars
- The students will answer questions for each experiment the rover stops at



Skills

- Map reading
  - Read and understand a map
- Geometry and Trigonometry
  - Calculate the rover's path and location using map coordinates
- Order of Operations
  - Create a list of rover commands in the correct order to steer the rover between experiment locations
- Knowledge
  - Answer questions about Mars and the Mars space programs

Competition

- Timed test for 50 minutes
- Teams of up to 2 students
- Teams are supplied with a topographic map of a region of Mars with a list of experiment locations
- Goal is to determine the best path for the virtual rover and answer questions for each experiment

Scoring

- The lowest Final Score is ranked first
- Final Score = Path Score minus Experiment Score
- Path Score =

  Total Meters Traveled

  + Total Degrees Turned divided by 10

  + Total Experiment Position Error times 5
- Experiment Score is the total points awarded for correct answers at each experiment location
- A computer program is used to calculate the Path Score

The Best Rover Path

- The best path uses the least amount of rover energy
- The best path will take the rover to each experiment. An experiment preformed in the wrong location is a failed experiment.
- The best path is described as the combination of
  - Traveling the shortest distance between experiments
  - Least amount of degrees used turning the rover
  - Accurately positioning the rover over the experiment
- These items are combined to create the team's Path Score which is part of the Final Score

Experiment Questions

Experiment Questions will be based on the following web pages.

- http://en.wikipedia.org/wiki/Exploration_of_Mars
- http://mars.jpl.nasa.gov/msl/news/pdfs/MSL_Fact_Sheet.pdf
- http://mars.jpl.nasa.gov/allaboutmars/extreme/quickfacts/
- http://en.wikipedia.org/wiki/Mars_landing
- http://phoenix.lpl.arizona.edu/edu_water_ice_dirty_ice.php
- Mars Rover Clues to Atmosphere's Past
- http://mars.nasa.gov/education/modules/GS/GS26-37.pdf
- http://mars.nasa.gov/education/modules/GS/GS38-49.pdf

Because this is a trial event, the questions are limited to the material on these pages. The questions will be mainly multiple choice and/or true and false

Experiment Sample Questions

What is the name of the first NASA Mars Lander?

A) Spirit B) Pathfinder C) Viking 1 D) Mars 3

The Mars Climate Orbiter crashed into surface of Mars due to metric-imperial units mix-up

TRUE FALSE

Which instrument would Curiosity use to determine a rock's material from a distance?

A) Radiation Assessment Detector B) Mass Camera
C) ChemCam D) Mars Hand Lens Imager

Which rover has driven the farthest on Mars?

A) Spirit B) Pathfinder C) Opportunity D) Curiosity

Experiment Sample Questions

- The experiment questions will require answering questions using images similar to the ones show here

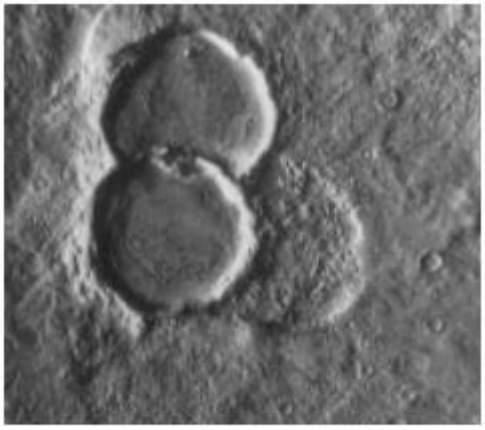
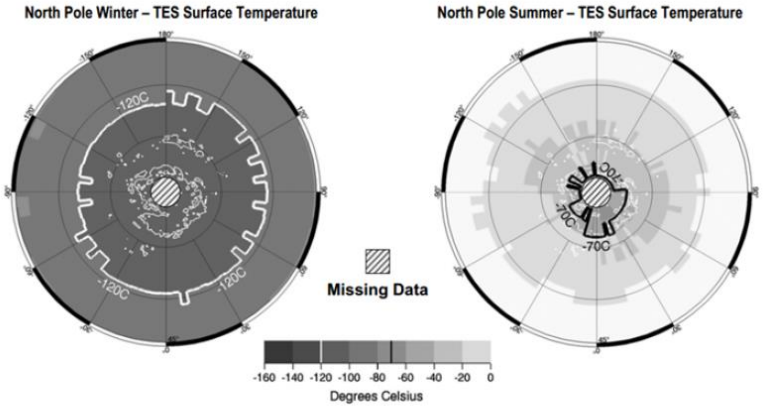
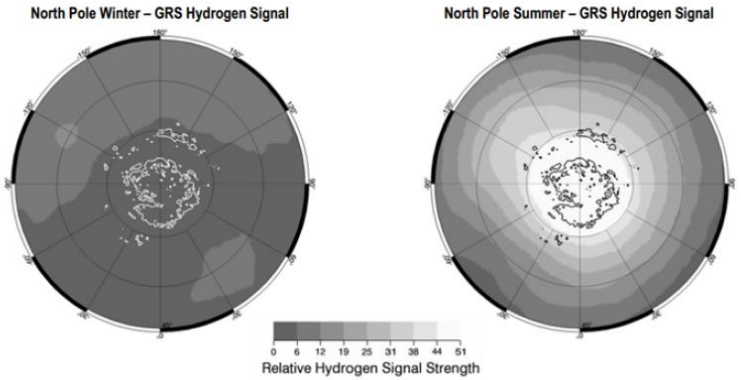


Figure 3.2: Notice the rays below the craters and the ejecta blanket, primarily to the left. Image Set image 2.

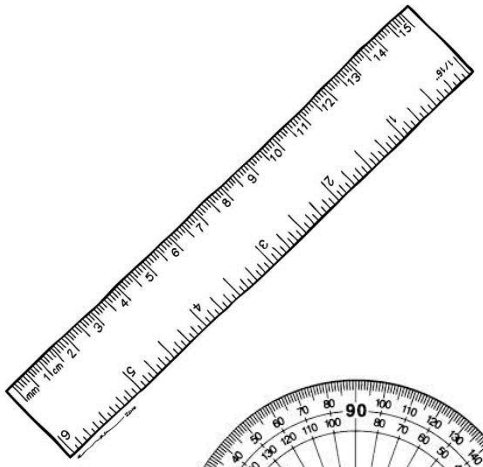


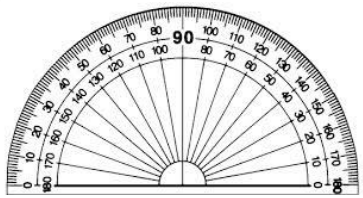


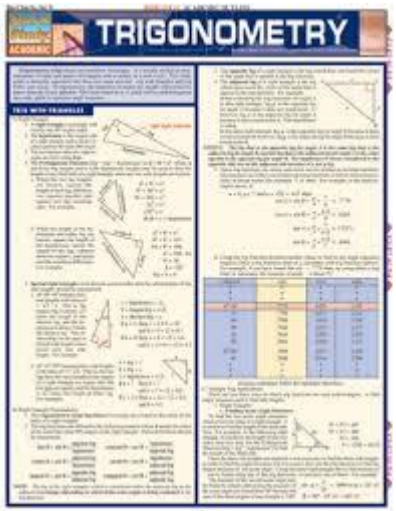
Tools Allowed

- Protractor*
- Ruler*
- Calculator (non-programmable)
- Unlimited notes allowed at the competition
- Pencil / pen (Required)
- Other non-electronic measuring devices

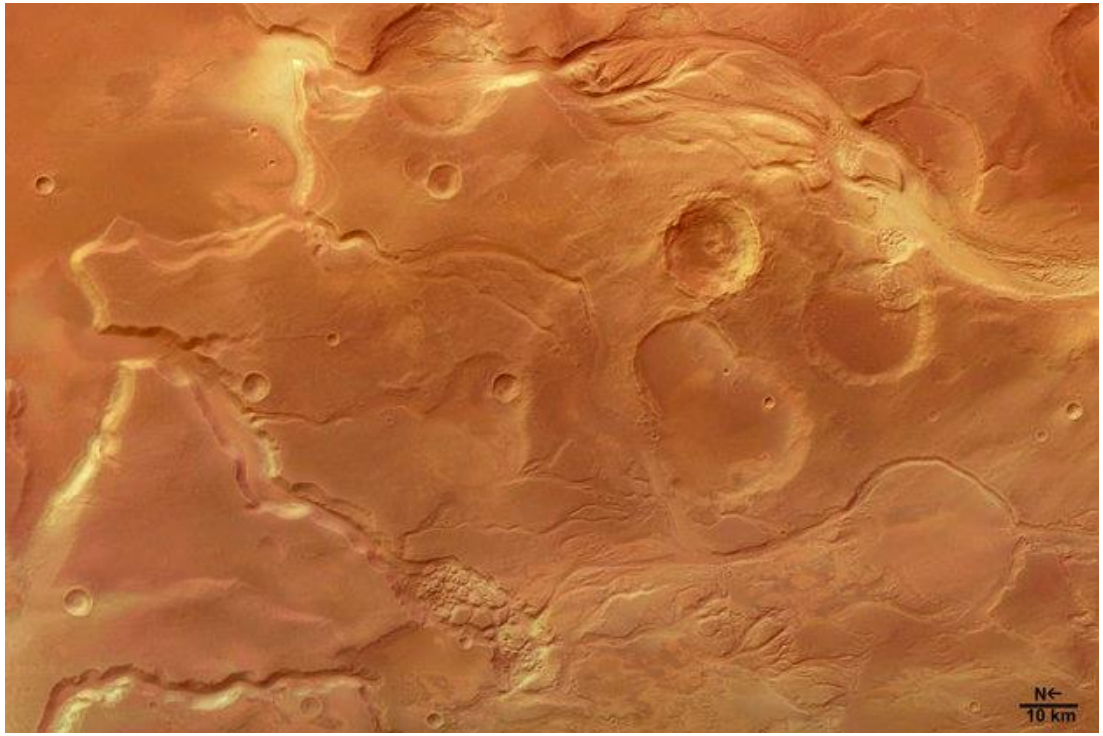
(* Recommend Tools)







Students Supplied with Area Map of Mars

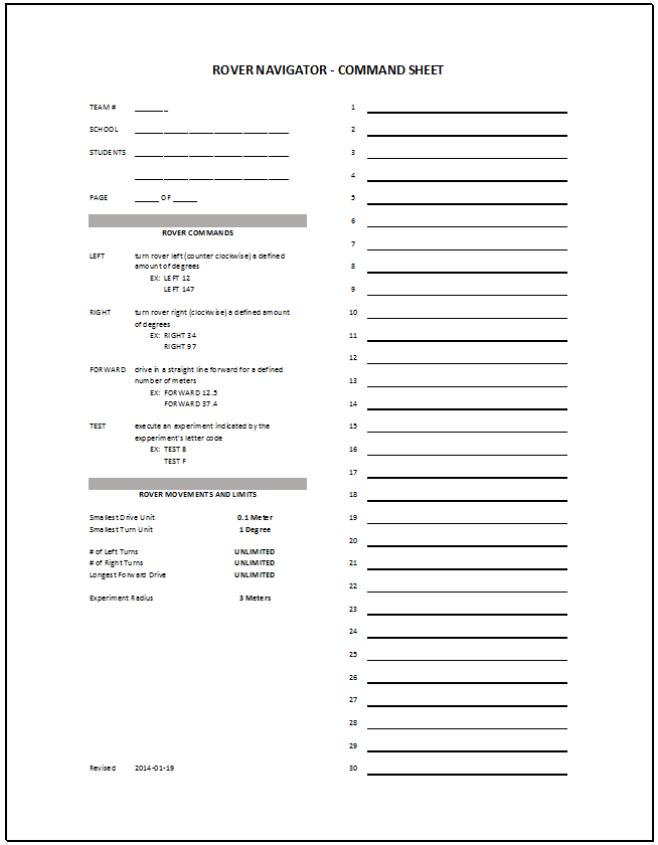


Map Contains

- The coordinate locations for the experiments
  - Experiment locations are listed as X & Y coordinates
  - Experiments are indicated by letters (A, B, C, ….)
  - All distances are in meters
    - No repeating the Mars Climate Orbiter
- Hazard Areas
  - Hazards are areas that have been determined to be unsafe for the rover to enter
  - Hazard areas will be shaded red with a red border
  - Hazards will have either a rectangular or circular shape
  - A rover that enters / crosses a hazard area will be Tier 2
  - Only the center point of the rover must not enter or cross a hazard. Wheels and/or the body of the rover do not count toward crossing a hazard.

Rover Command Sheet

- The command sheet will be filled out by the students during the testing period
- The virtual rover will execute the commands in the order listed on the sheet
- Notes and/or arrows changing the order of commands are a competition violation
- The commands with examples the rover accepts are shown on the sheet



ROVER NAVIGATOR - COMMAND SHEET

TEAM # _____

SCHOOL _____

STUDENTS _____

_____

PAGE ____ OF ____

ROVER COMMANDS

LEFT	turn rover left (counter clockwise) a defined amount of degrees EX: LEFT 12 LEFT 147
RIGHT	turn rover right (clockwise) a defined amount of degrees EX: RIGHT 34 RIGHT 97
FORWARD	drive in a straight line forward for a defined number of meters EX: FORWARD 12.5 FORWARD 37.4
TEST	execute an experiment indicated by the experiment's letter code EX: TEST B TEST F

ROVER MOVEMENTS AND LIMITS

Smallest Drive Unit	0.1 Meter
Smallest Turn Unit	1 Degree
# of Left Turns	UNLIMITED
# of Right Turns	UNLIMITED
Longest Forward Drive	UNLIMITED
Experiment Radius	3 Meters

Revised 2014-01-19

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Students Supplied With

Command Sheet

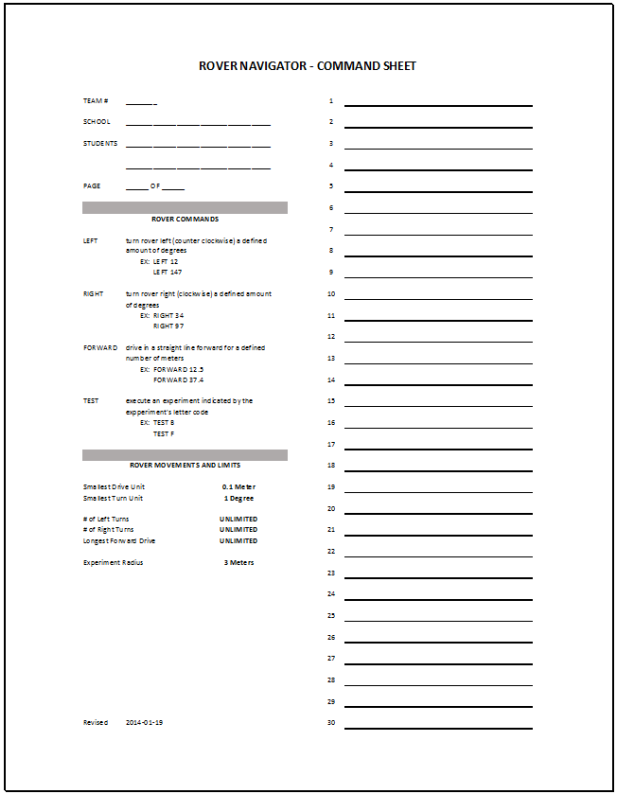
Experiment Locations

“A”	X: 37.0m	Y: 4.0m
“B”	X: 44.0m	Y: 75.0m
“C”	X: 82.5m	Y: 33.5m
“D”	X: 7.0m	Y: 63.5m
“E”	X: 92.0m	Y: 87.0m
“F”	X: 43.5m	Y: 32.0m

Rover Starting Location

X: 10.0 Y: 15.0

Heading: 0°



ROVER NAVIGATOR - COMMAND SHEET

TEAM # _____

SCHOOL _____

STUDENTS _____

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PAGE ____ OF ____

ROVER COMMANDS

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Ex: LEFT 12
LEFT 147

RIGHT turn rover right (clockwise) a defined amount of degrees
Ex: RIGHT 34
RIGHT 97

FORWARD drive in a straight like forward for a defined number of meters
Ex: FORWARD 12.5
FORWARD 37.4

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Experiment Questions

Sample Map

Map Size = 8.5” x 11”

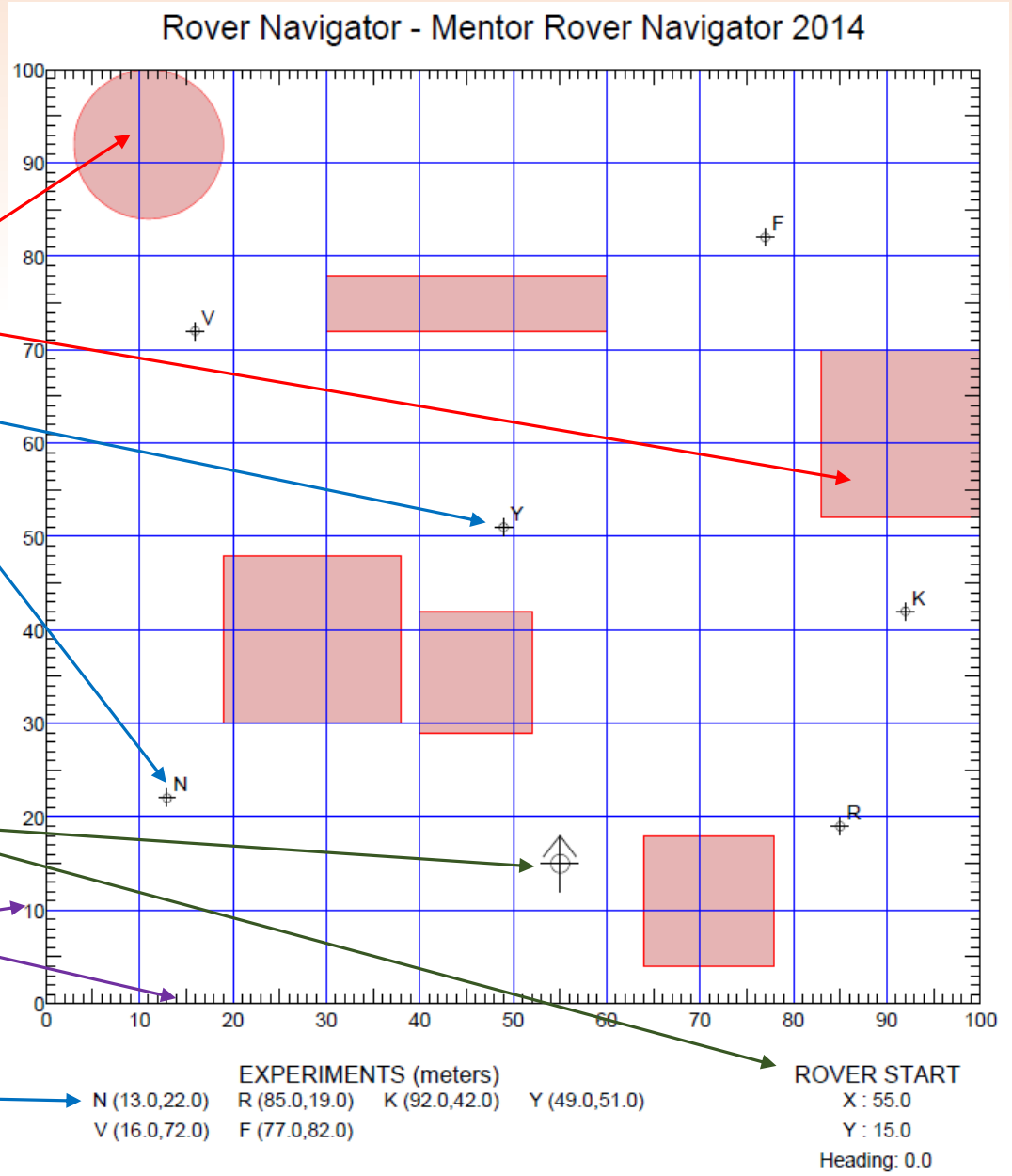
Hazards

Experiment Locations

Rover Starting Position

Map Scale
(Units are in Meters)

Experiment Locations



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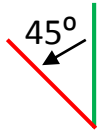
Virtual Rover Driving Commands

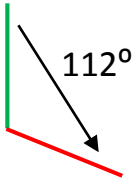
LEFT – Turn the rover left (counter clockwise) for a defined number of degrees from the rover's current heading

LEFT 45



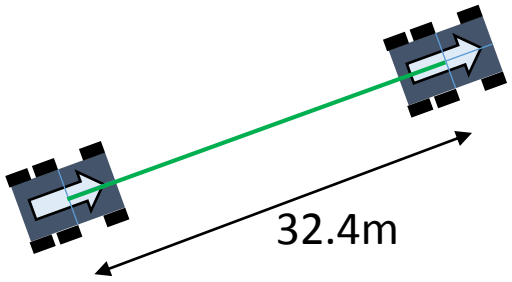
RIGHT – Turn the rover right (clockwise) for a defined number of degrees from the rover's current heading

RIGHT 112



FORWARD – Drive the rover in a straight line forward for a defined number of meters from the rover's current position

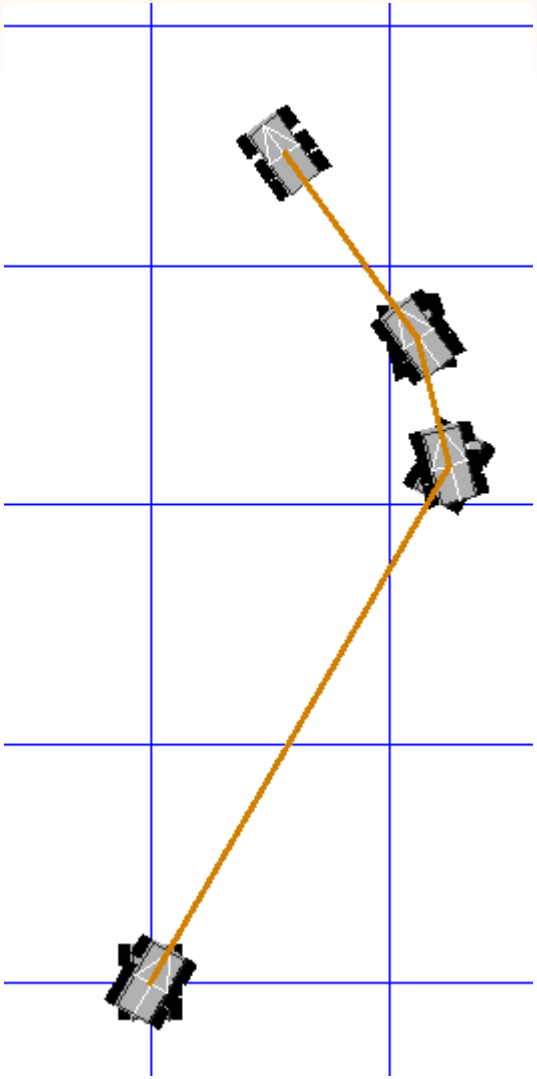
FORWARD 32.4



Note: All movements and distances are measured from the center of the rover

Driving Example

1. RIGHT 30
2. FORWARD 25.0
3. LEFT 44
4. FORWARD 5.5
5. LEFT 22
6. FORWARD 9.5

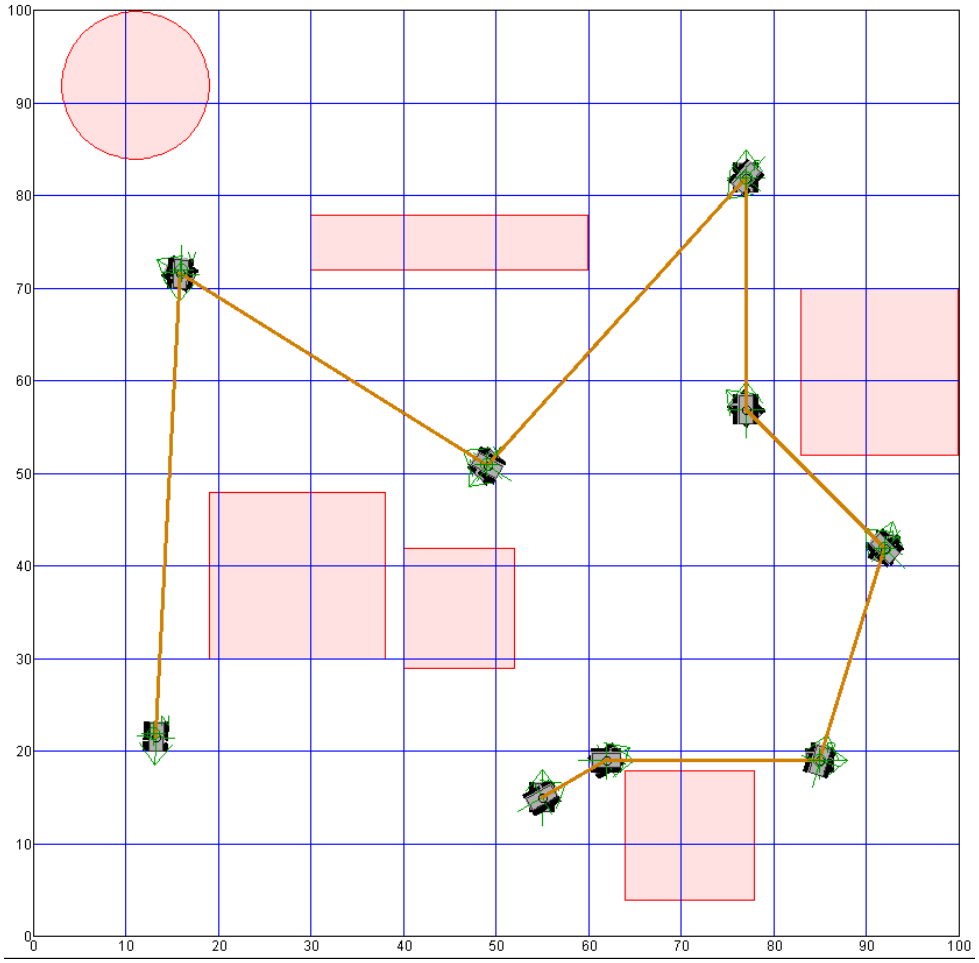


Note: All movements and distances are measured from the center of the rover

Sample Rover Path #1

Command List

RIGHT 60
FORWARD 8.0
RIGHT 30
FORWARD 23.1
TEST R
LEFT 73
FORWARD 24.0
TEST K
LEFT 62
FORWARD 21.2
RIGHT 45
FORWARD 25.0
TEST F
LEFT 138
FORWARD 41.8
TEST Y
RIGHT 80
FORWARD 39.1
TEST V
LEFT 119
FORWARD 50.1
TEST N



SCORING

Total Distance ...	232.300
Total Degrees	607.0
Total Error (m)	1.260

Path Score = 305.598

Avg Error (m)	0.210
# of Commands	22
# of Hazard Hits	None
Exit Map	No
Tier	1

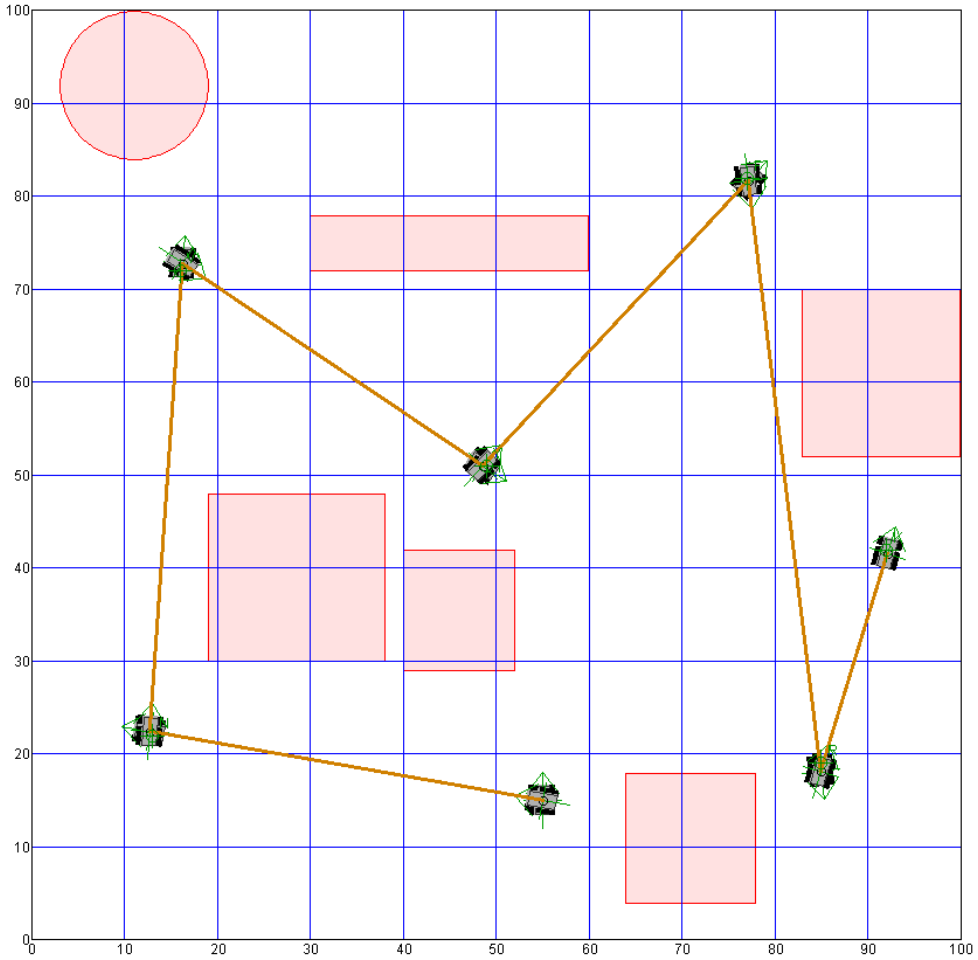
Experiment Results

ID	Completed	Error (m)
N	Yes	0.529
R	Yes	0.028
K	Yes	0.066
Y	Yes	0.148
V	Yes	0.408
F	Yes	0.080

Sample Rover Path #2

Command List

LEFT 80
FORWARD 42.9
TEST N
RIGHT 84
FORWARD 50.5
TEST V
RIGHT 120
FORWARD 39.0
TEST Y
LEFT 81
FORWARD 41.9
TEST F
RIGHT 130
FORWARD 64.0
TEST R
LEFT 156
FORWARD 24.5
TEST K



SCORING

Total Distance ...	262.800
Total Degrees	651.0
Total Error (m)	3.479
Path Score = 362.694	
Avg Error (m)	0.580
# of Commands	18
# of Hazard Hits	None
Exit Map	No
Tier	1

Experiment Results

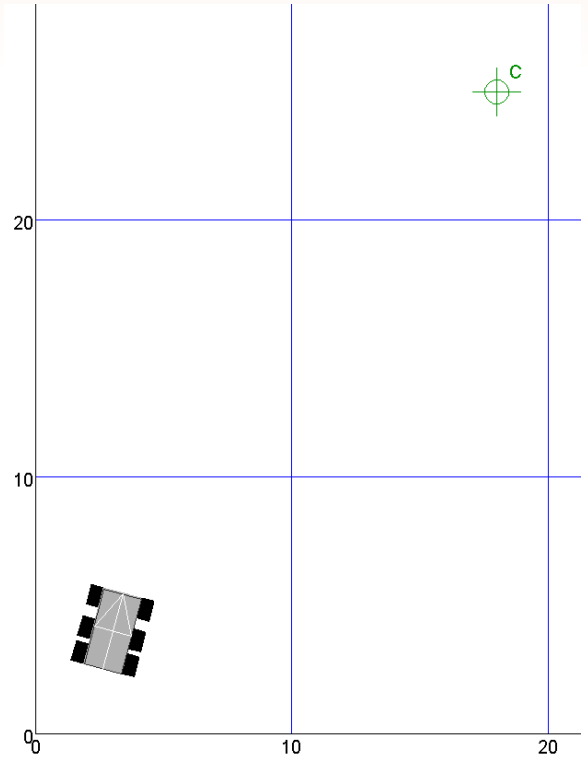
ID	Completed	Error (m)
N	Yes	0.514
R	Yes	0.861
K	Yes	0.456
Y	Yes	0.393
V	Yes	0.871
F	Yes	0.384

How to Determine a Rover Move

- There are several methods to determine how to calculate the rover's movements
- The most accurate method is to use math to calculate the angles, distances, and positions.
- A protractor and ruler is another method but can have a larger error. This method is faster than using math.

Sample Move – Protractor / Ruler

Here is a sample move using a protractor to find the angle and a ruler to find the distance



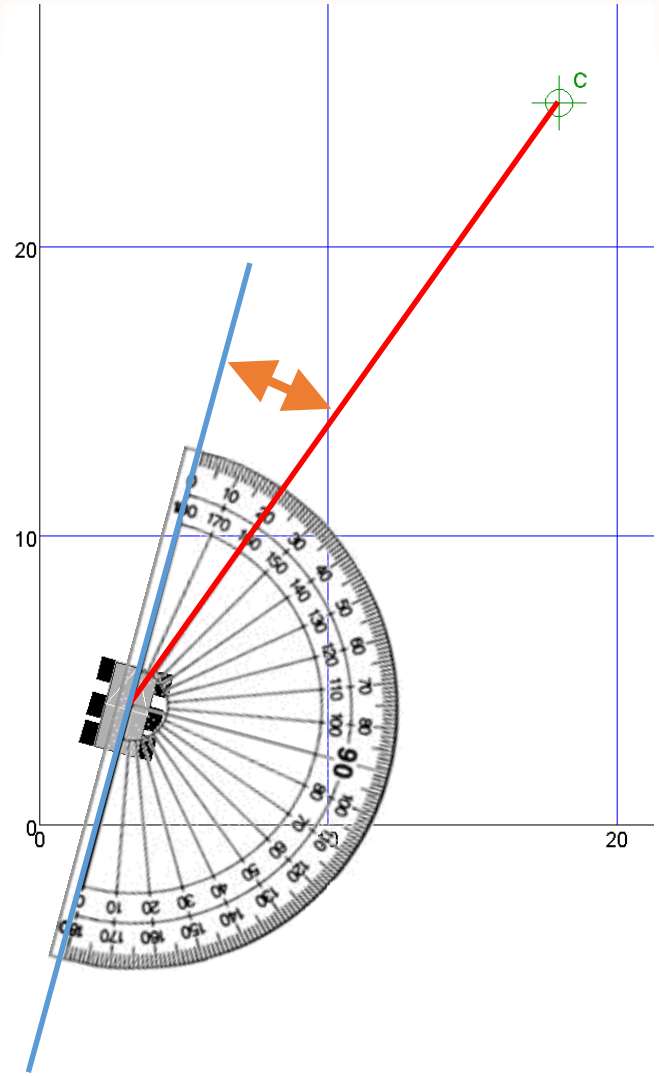
Rover's Current Location

- Location = (3,4)
- Heading = 15 Degrees

Experiment 'C'

- Location = (18,25)

Find Turn Angle using a Protractor



Step #1 – Draw a line between rover center and experiment

Step #2 – Place the protractor on the center of the rover and align 0 degrees with the current heading

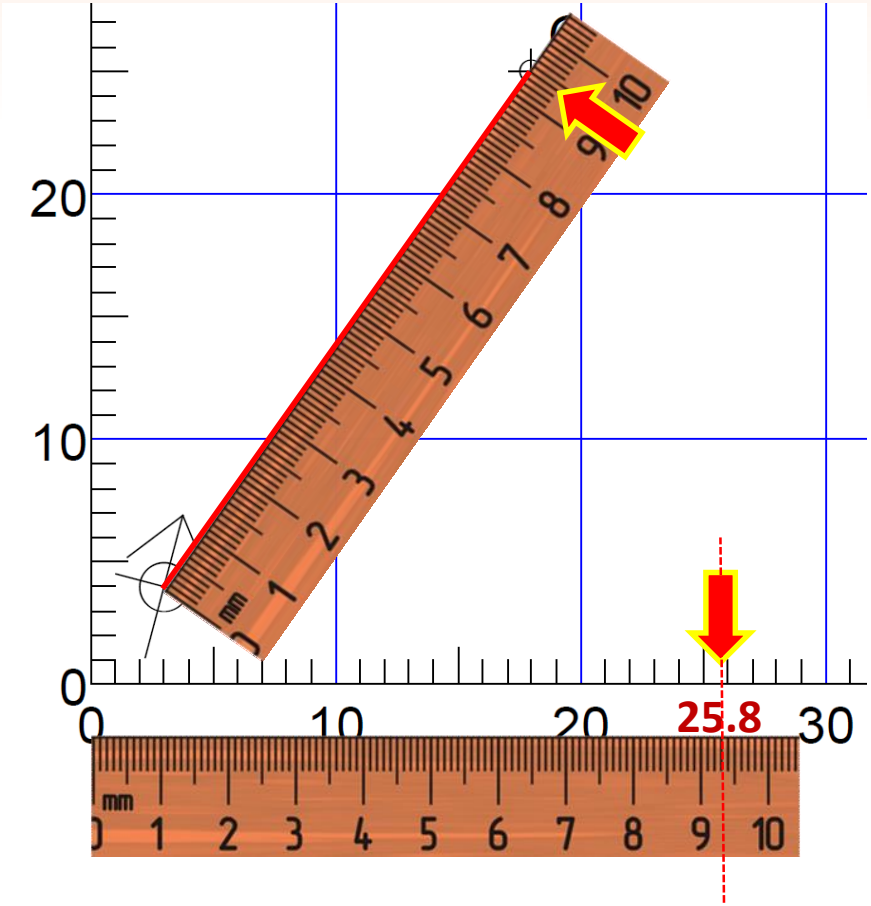
Step #3 – Measure angle between current heading and new heading

20 Degrees

Step #4 – Write turn on command sheet

Right 20

Find Distance using a Ruler



Step #1 – Draw a line between rover center and experiment

Step #2 – Measure distance between rover and experiment

Step #3 – Move ruler to scale at bottom of map and mark distance

Step #4 – Find map distance for mark

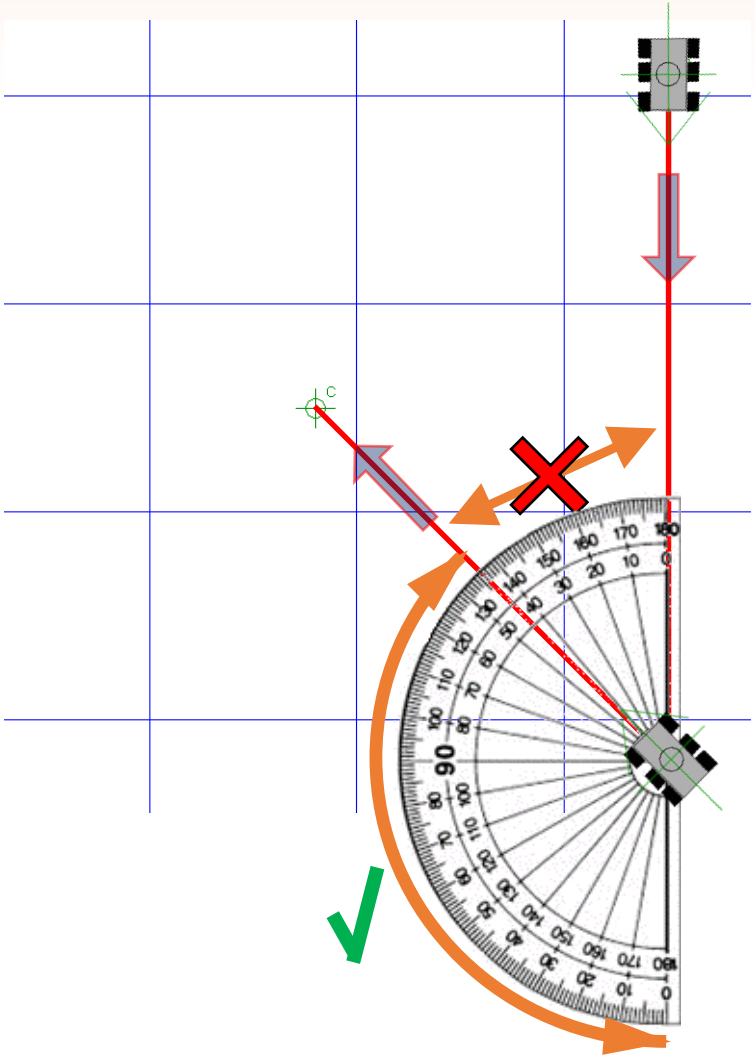
25.8 meters

Step #5 – Write drive command

FORWARD 25.8

Note: Since the rover accepts drive commands to a tenth of a meter, do not round to the nearest meter. Take a best guess to get closer to the experiment.

Measure the Correct Angle



- Measure the angle the rover needs to turn
- Not the angle between moves
- The angle is not always less than 90 degrees
- Read the correct angle number on the Protractor
  - (inside vs outside)
- Remember **Obtuse** vs **Acute** angles
- Double Check
  - Is the angle less than or greater than 90 degrees

Example: RIGHT 136

Sample Move - Using Math

(21,45) C

- For this example move, the virtual rover will start from the point 15,23
- The experiment “C” the rover needs to stop at is at point 21,45 in this example
- The rover is facing 8 degrees from North. The degrees increase clockwise

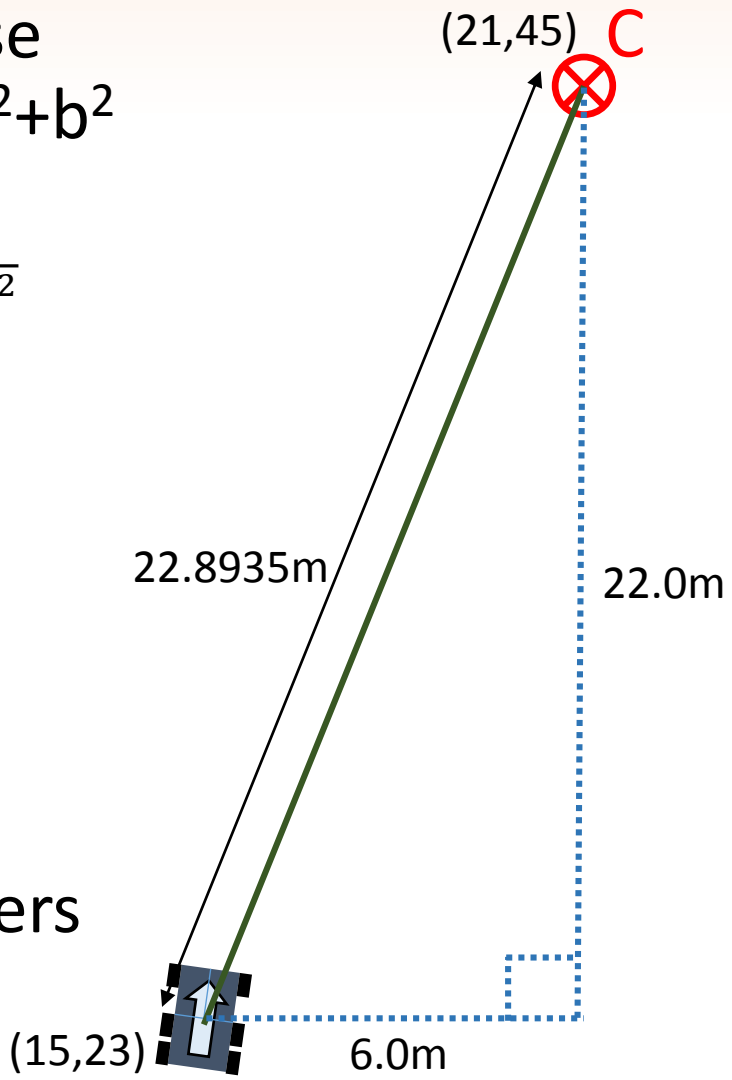
(15,23)

Sample Move - Distance

- To calculate the distance use Pythagorean theorem $c^2=a^2+b^2$

$$c= \sqrt{a^2 + b^2} = \sqrt{(y_0 - y_1)^2+(x_0 - x_1)^2}$$
$$= \sqrt{(45.0 - 23.0)^2+(21.0 - 15.0)^2}$$
$$= \sqrt{22.0^2 + 6.0^2}$$
$$= 22.8935\ meters$$

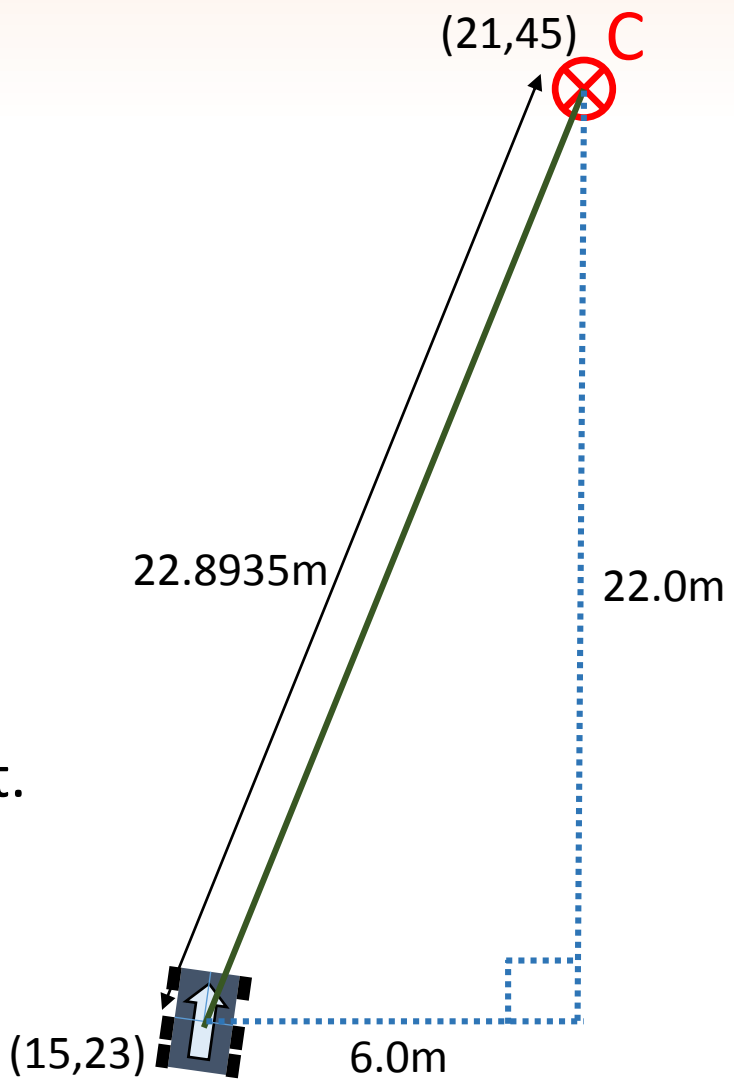
- The distance between the current location and the experiment is 22.8935 meters



Sample Move - Distance

- The exact distance between the rover's location and the experiment "C" is 22.8935 meters
- But the virtual rover can only move increments of 0.1 meters per the command sheet
- This means the drive Forward command will be rounded to 22.9 meters before writing the distance on the command sheet.

FORWARD 22.9



Sample Move – Angle
(Advanced Div B)

- To calculate the required angle to turn the rover, trigonometry functions are used.
- The next few slides explain how to use these functions.

Trigonometry Functions

(Advanced Div B)

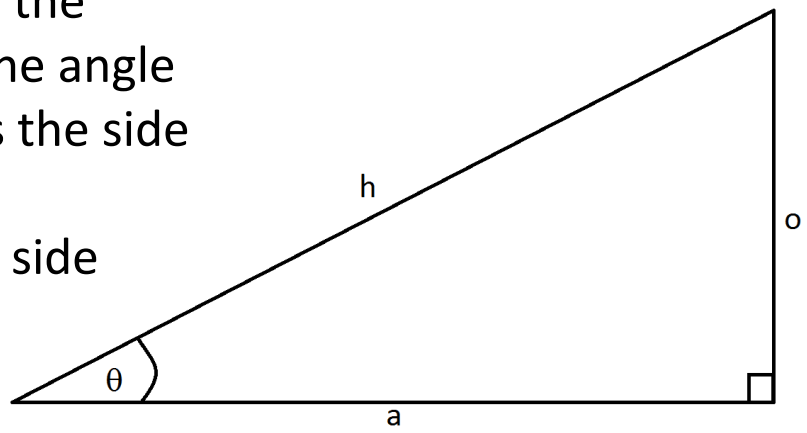
In mathematics, the trigonometric functions (also called the circular functions) are functions of an angle. They relate the angles of a triangle to the lengths of its sides. Trigonometric functions are important in the study of triangles.

$$\sin\theta = \frac{o}{h}$$

$$\cos\theta = \frac{a}{h}$$

$$\tan\theta = \frac{o}{a}$$

The most familiar trigonometric functions are the sine, cosine, and tangent. Sine is the relationship to the side opposite of the angle divided by the hypotenuse. Cosine is the side adjacent to the angle divided by the hypotenuse. Tangent is the opposite side divided by the adjacent side.



Sample Move – Angle

(Advanced Div B)

- The trig function used is the inverse tangent function. The inverse converts a the ratio of opposite divided by adjacent into an angle.

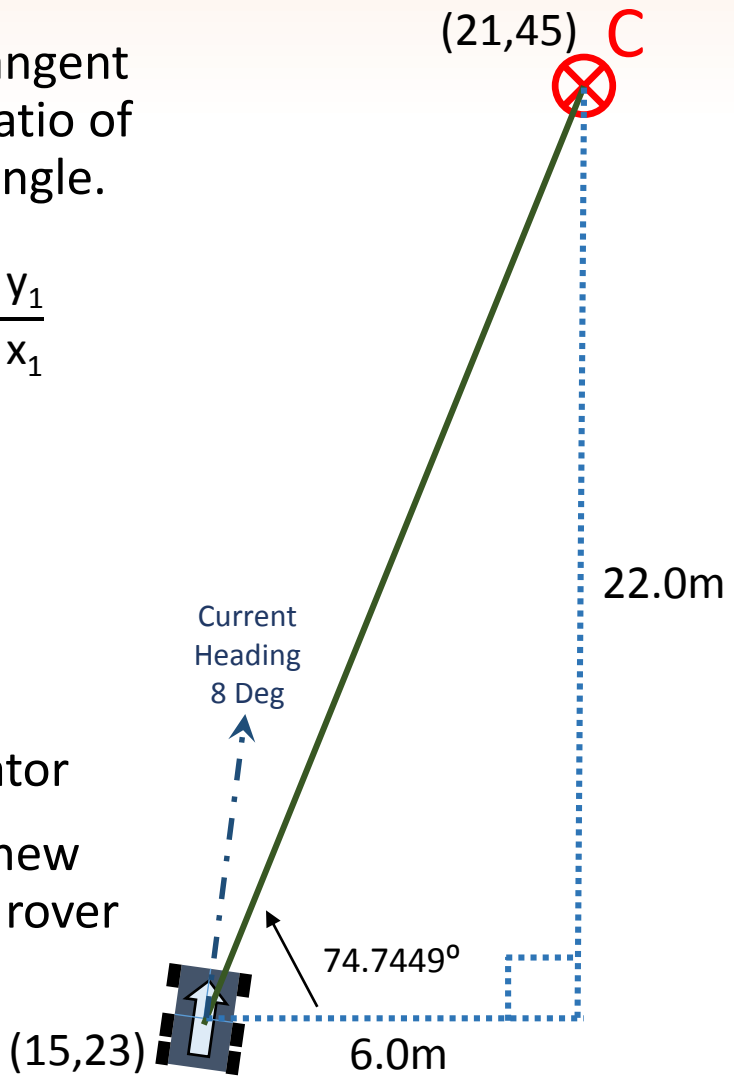
$$Angle = \tan^{-1}\frac{opposite}{adjacent} = \tan^{-1}\frac{y_0 - y_1}{x_0 - x_1}$$

$$= \tan^{-1}\frac{45.0 - 23.0}{21.0 - 15.0} = \tan^{-1}\frac{22.0}{6.0}$$

$$= 74.7449\ Degrees$$

- Try the above example on your calculator
- The angle 74.7449 degrees is not the new heading for the rover. Remember the rover has a current heading of 8 degrees.

Continued Next Slide



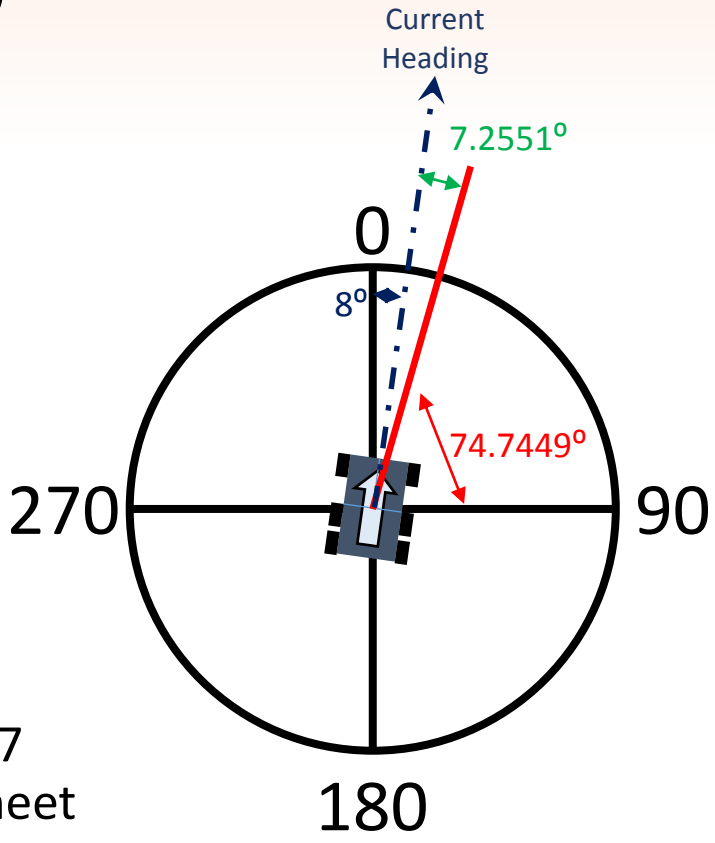
Sample Move – Angle

(Advanced Div B)

- The rover needs to turn to the right 7.2551 degrees

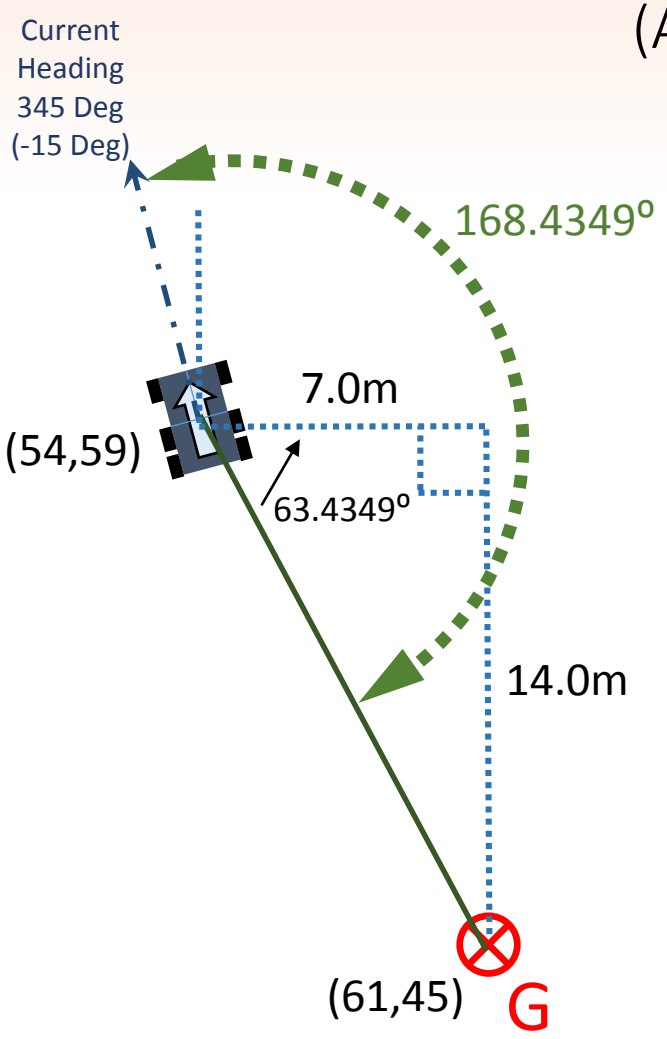
$$90 - 8 - 74.7449 = 7.2551$$

- Make sure you understand how this was calculated.
- **Using a protractor to verify the degrees is a very good idea.**
- The virtual rover can only turn in 1 degree increments
- The Right command needs to be rounded to 7 degrees before writing it on the command sheet
- The new heading will be 15 degrees
  - (Old heading + turn) = (8 + 7)
- Right turns add to the heading
- Left turns subtract from the heading



Sample Move Example #2 – Angle

(Advanced Div B)



$$Angle = \tan^{-1}\frac{opposite}{adjacent} = \tan^{-1}\frac{y_0 - y_1}{x_0 - x_1}$$

$$= \tan^{-1}\frac{59.0 - 45.0}{54.0 - 61.0} = \tan^{-1}\frac{14.0}{-7.0}$$

$$= -63.4349\ Degrees$$

Keep it simple: Ignore the negative sign

Angle = 63.4349 Degrees

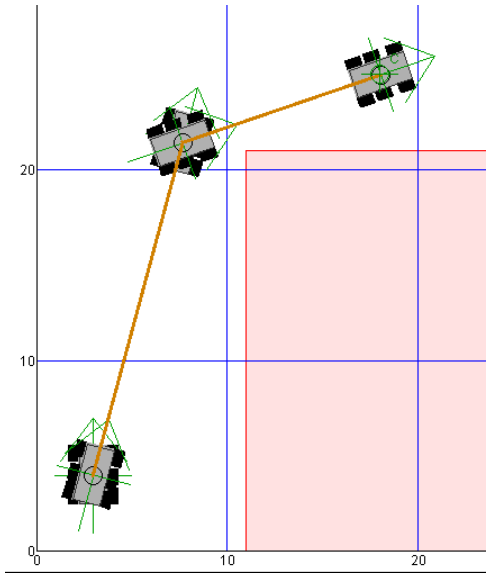
Rover Turn Angle = 63.4349 + 90 + 15

= 168.4349

Command: RIGHT 168

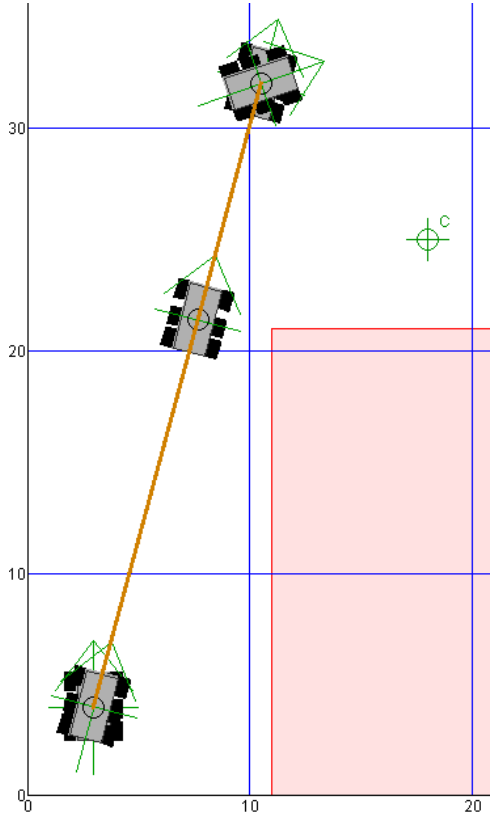
Order of commands

- The order of the commands are on the command sheet is very important. Always turn to the new heading before driving forward



Correct

RIGHT 15
FORWARD 18.0
RIGHT 56
FORWARD 11.0



Wrong

RIGHT 15
FORWARD 18.0
FORWARD 11.0
RIGHT 56

Rover is not in the correct position. Rover traveled in a straight line.

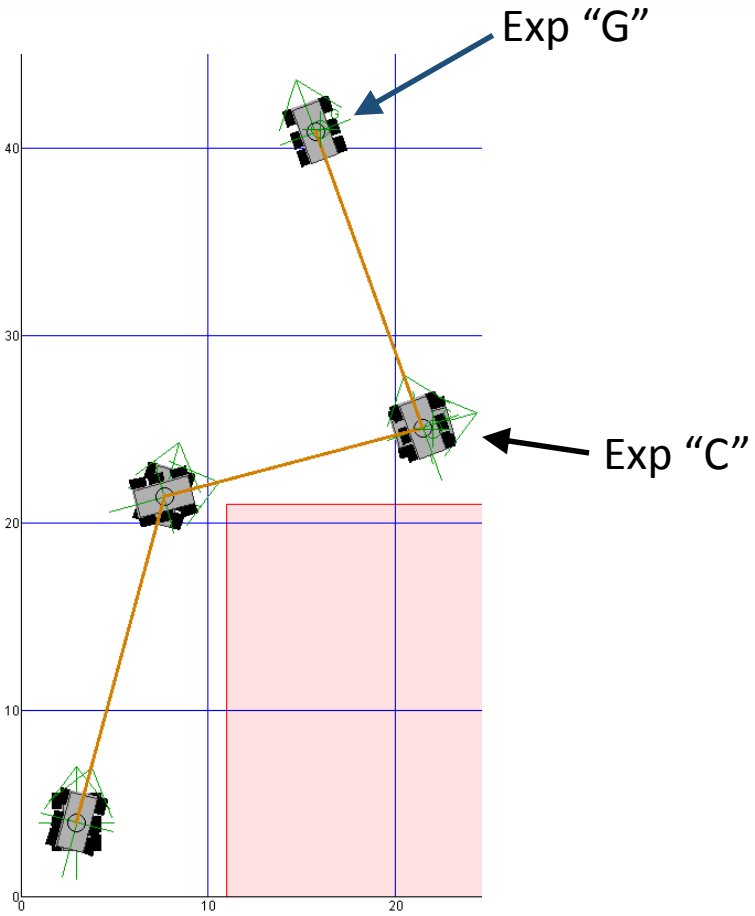
Next Move – Math Method

(Advanced – Div C)

- Because the rover's moves are 0.1 meter increments and turns are in 1 degree increments, the rover will not typically end up right on top of the experiment location.
- To more accurately position the rover on the next move, the start position should be calculated instead of using the last experiment location.
- Make sure to use enough decimal points to prevent a build up of error. Rounding too soon will cause positioning error. Too many causes extra work and lost time.

Next Move Example – Math

(Advanced – Div C)



RIGHT 15

FORWARD 18.0

RIGHT 60

FORWARD 14.3

TEST C

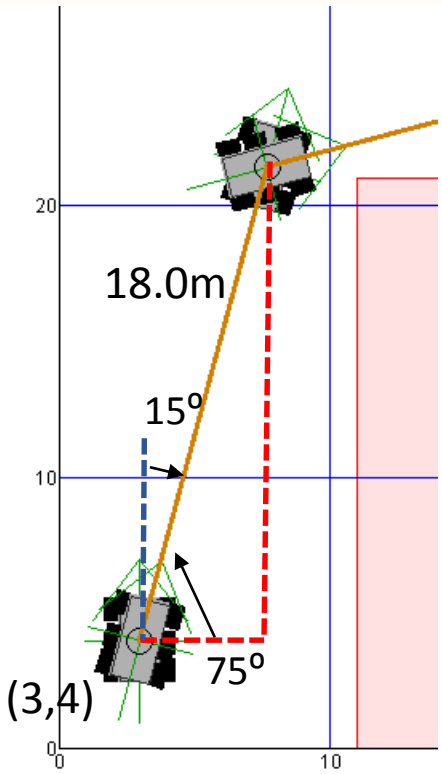
LEFT 95

FORWARD 16.8

TEST G

Next Move Example - Math

(Advanced – Div C)



RIGHT 15
FORWARD 18.0

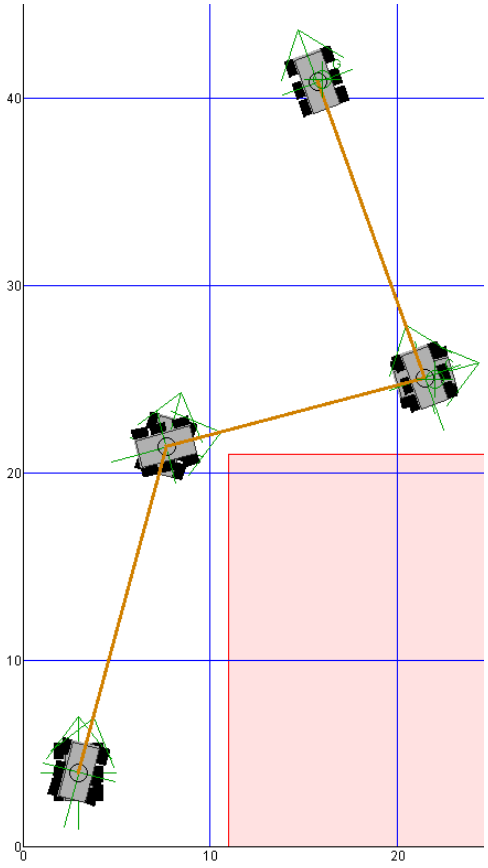
- Since the virtual rover's movement commands have been rounded, the rover will not stop exactly at the experiment
- Using other Trigonometric functions, the location of the rover at the end of the move can be calculated

$$New\ X\ Position$$
$$= Xstart + \cos(Triangle\ Angle) \times Move\ Distance$$
$$= 3.0 + \cos 75 \times 18.0 = 3.0 + 0.258819 \times 18.0$$
$$= 7.6587$$

$$New\ Y\ Position$$
$$= Ystart + \sin(Triangle\ Angle) \times Move\ Distance$$
$$= 4.0 + \sin 75 \times 18.0 = 4.0 + 0.965926 \times 18.0$$
$$= 21.3867$$

Next Move Example - Math

(Advanced – Div C)



	Delta X	Delta Y	X	Y	Heading
Start Point			3.0	4.0	0
RIGHT 15			3.0	4.0	15
FORWARD 18.0	4.6587	17.3867	7.6587	21.3867	15
RIGHT 60			7.6587	21.3867	75
FORWARD 14.3	13.8127	3.7011	21.4714	25.0878	75
TEST C			21.4714	25.0878	75
LEFT 95			21.4714	25.0878	-20
FORWARD 16.8	-5.7459	15.7868	15.7255	40.8746	-20
TEST G			15.7255	40.8746	-20

The functions sin() and cos() are used to calculate the Delta move distances. Try and duplicate this table yourself.

A table of this type could be to better position the rover.

Long Drive Corrections

(Very Advanced – Div C)

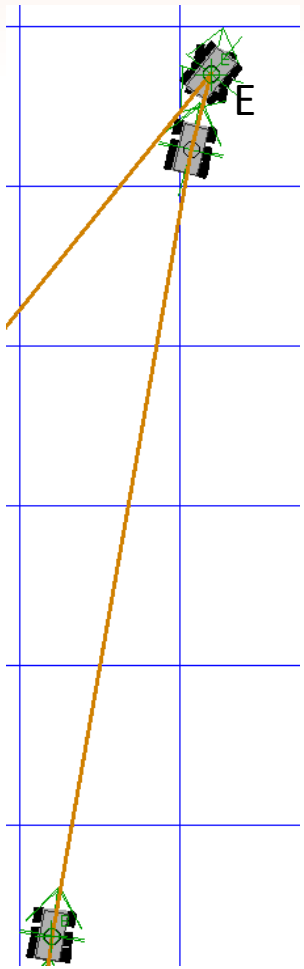
- The longer the drive command, then the larger the position error at the end of the drive could be because turns are to the nearest degree.
- To correct for the position error, a second set of turn and drive commands should be used before the rover reaches the final position
- How and when this is used is up to the team.
- Again this is very advanced!!!

With 2ND Move

FORWARD 50.0
RIGHT 5
FORWARD 4.9
TEST E
LEFT 156
FORWARD 30.0

Without

FORWARD 54.9
TEST E
LEFT 156
FORWARD 30.0



Position Error

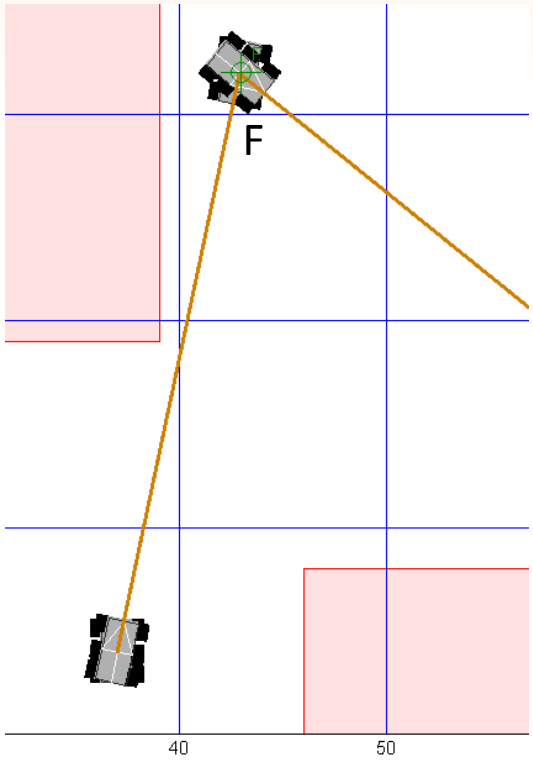
With 2nd Move = 0.042m
Without = 0.468m

Which Movement Method???

- Protractor/Ruler vs Math Calculation
  - Which is better?
- Use the method that you and your team member understand best. One mistake could send the rover into a crater (hazard area).
- Remember correct experiment answers are bonuses to your final score. Getting more correct answers could give a scoring advantage over a more accurate path
- Time is limited (answer questions or more math??)

Execute an Experiment

- Once the virtual rover is at the experiment, a command must be issued to execute the experiment
- The command includes the letter that labels which experiment is being executed
- The experiments can be completed in any order. Best path is the goal.
- Driving over an experiment location does not count. The TEST command must be on the command sheet to get credit for the experiment.

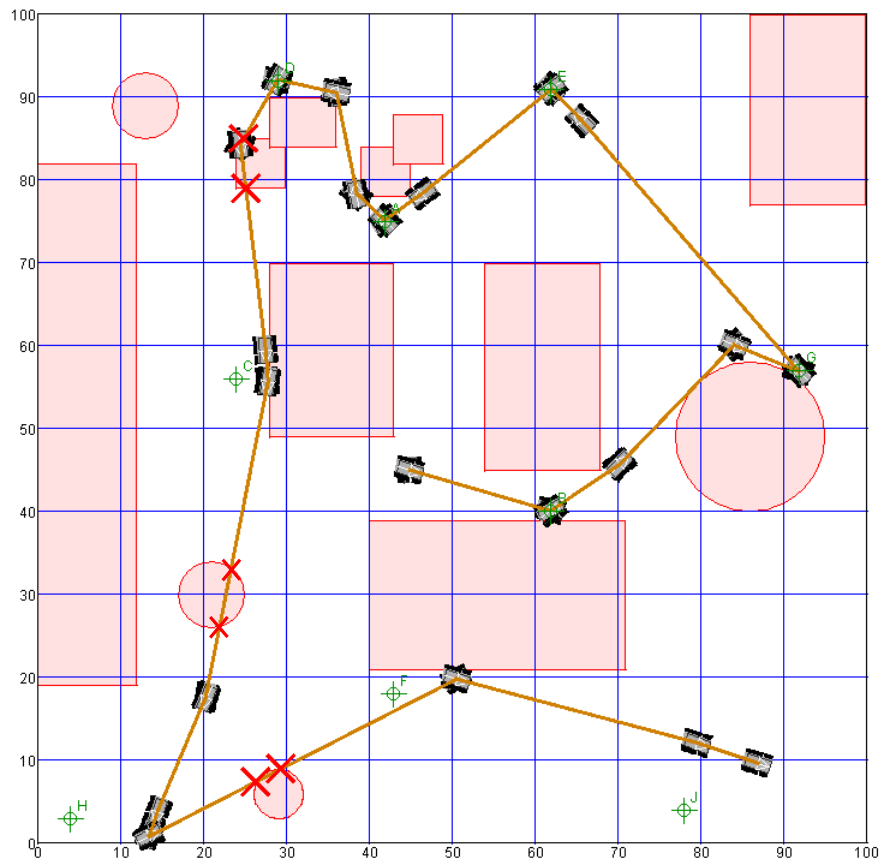


Right 12
Forward 28.6
Test F
Right 117
Forward 40.0

DO NOT FORGET

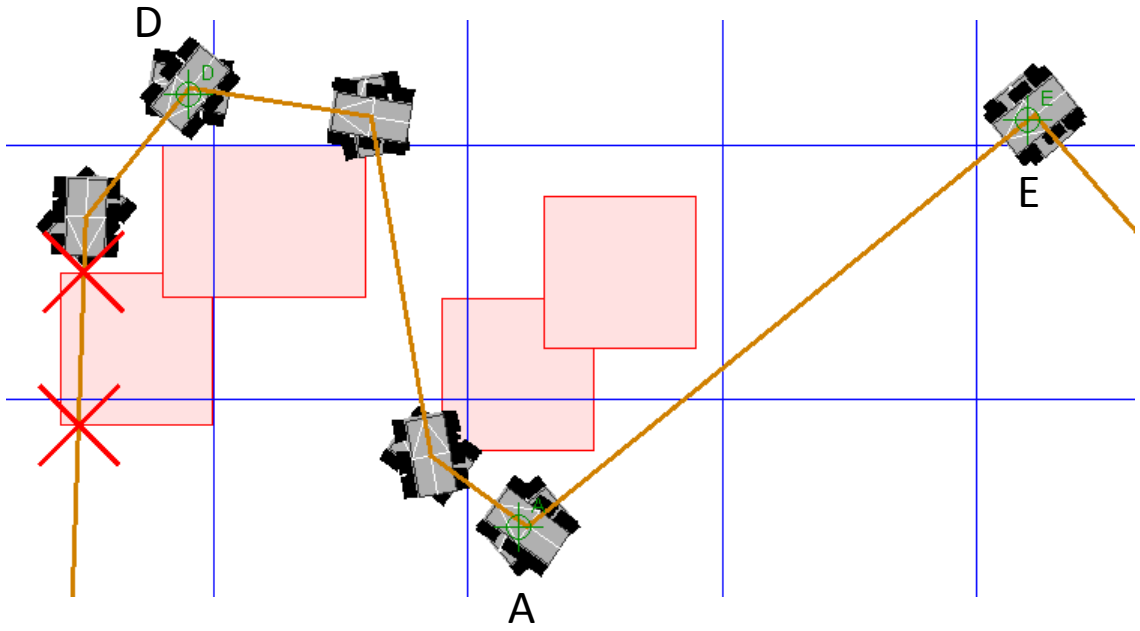
Double Check

- Double check your moves and command order
- One wrong distance/angle or command out of order will cause all following moves to be wrong
- This makes the event very challenging, but very accurate to a real rover where the math needs to be double checked
- Don’t get LEFT and RIGHT backwards!!



Hazards

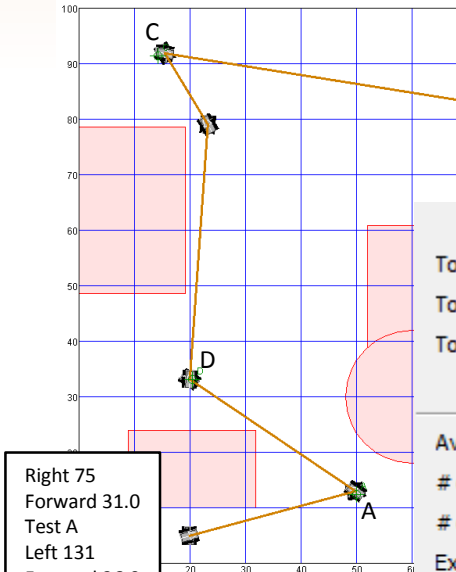
- Remember crossing a hazard is based on the center of the virtual rover. Not the wheels.
- It's not recommended to drive the rover close to a hazard unless you are very sure you can avoid the hazard



Forward 45.3
Test E
Left 88
Forward 25.6
Test A
Right 75
Forward 4.7
Right 44
Forward 13.5
Left 71
Forward 7.2
Test D
Left 60
Forward 6.5
Left 37
Forward 25.0

Path Score

- The scoring program will calculate the Path Score from the command list
- The total distance is the sum of all the FORWARD commands
- The total degrees is the sum of all the turn commands (LEFT/RIGHT)
- The total error or total experiment error is the sum of experiment errors.
- The experiment error is the distance the rover is from the experiment location when the experiment preformed via the TEST command



Right 75
Forward 31.0
Test A
Left 131
Forward 36.0
Test D
Right 60
Forward 46.0
Left 35
Forward 15.0
Test C
Right 130
Forward 60.0
Test B

SCORING

Total Distance (m)	188.000
Total Degrees	431.0
Total Error (m)	4.941
Path Score = 255.803	
Avg Error (m)	1.235
# of Commands	14
# of Hazard Hits	None
Exit Map	No
Tier	1

Experiment Results

ID	Completed	Error (m)
A	Yes	1.025
B	Yes	1.913
C	Yes	1.820
D	Yes	0.183

Path Score = 188.0 + 431.0 / 10 + 4.941 × 5

= 255.803

Experiment Score

- Correct answers for the experiment questions are added to the team's experiment score.
- The full point value for correct answers are awarded if the virtual rover is within the experiment radius.
- If the experiment position error is greater than the maximum allowed error on the command sheet, then half points are awarded for that experiment.
- Experiment position error is measured as a point to point measurement. (Center of rover to experiment location)

(An example scoring is shown on the next slide)

Sample Scoring

- Path Score = 255.803

Experiment Scores (Experiment Radius = 1.5 m)

Experiment	Question Points	Experiment Error	Award Full Points	Points
A	20	0.526	YES	20
B	15	1.843	NO	7.5 (Half)
C	12	1.342	YES	12
D	18	0.404	YES	18

Half points are awarded for correct answers on Experiment B because the rover was outside of Experiment Radius

Final Score = 255.803 – (20 + 7.5 + 12 + 18)

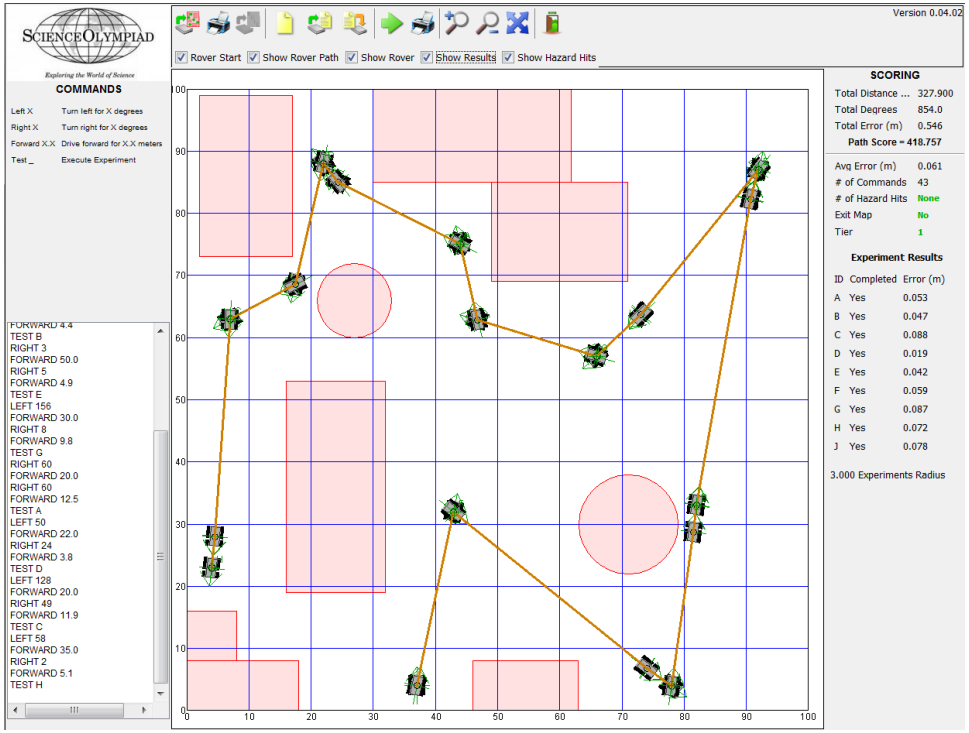
= 255.803 – 57.5 = **198.303**

Division Differences

Division	"B"	"C"
Experiment Radius	3 to 8 meters	1 to 4 meters
# of Hazards	4 to 10 Hazards	6 to 14 Hazards
# of Experiments	3 to 7	6 to 10
# of Questions	1 to 3 per Experiment	1 to 5 per Experiment
Experiment Coordinates shown on map	Nearest Meter (Ex: 5.0,18.0)	Nearest Tenth of Meter (Ex: 5.3,17.8)

Scoring Program

- A scoring program will take the commands from the Command Sheet and generate the rover's path with a Path Score
- The scoring program is free software created for this event. The web page has instructions for downloading and using the software



http://rover.leaguesync.com