2004/10/25

NASA NAVIGATOR Sample Solutions

http://microgravity.grc.nasa.gov/outreach/navigator/game.html

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Sample solutions are presented on the following pages for:
Map 1 (Ahsonnutli Zone)
Home planet: D12

Educators and students should understand that there is a large diversity in the maximum scores that are possible, depending on both the system map and the home planet. Given the influence of the home planet on the possible score, it is important that the educator clearly identify the home planet when assigning a puzzle.

PLANETARY PROBE (page 3)

In the Planetary Probe game, there are 24 possible directions in which the probe can be launched, and therefore 24 correct solutions to each puzzle. However, most of those correct solutions will have low scores. The top-scoring solution for the sample puzzle yields a final score of 6 points, for 3 turns of short-range measurements of planet P17. The distribution of possible scores for this puzzle is as follows:

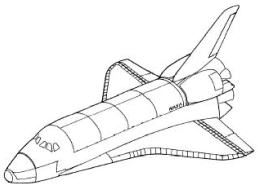
Final score (points)	6	5	4	0
Number of solutions	1	2	3	18 (including 3 crashes)

Given that the probe has no engines, the choice of launch direction is critical to the game. In fact, it is the only decision in the game. For the top-scoring solution, it can be seen how gravity causes the probe's path to bend toward the planet. Recall that gravity causes moons to orbit planets, and planets to orbit stars. However, in three of the solutions, gravity causes the probe to crash into a planet before any survey measurements can be made.

SPACESHIP COMMANDER (pages 4-7)

The addition of engines in the Spaceship Commander game leads to a great multitude of possible solutions to any puzzle. On any turn after launch, the engines can be used to create thrust in any of 8 directions or not at all. Sample solutions are provided for games that are 5, 10, 15, and 20 turns in duration. If we neglect (1) the end of the game that results when the spaceship crosses the edge of the map and (2) the number of possible solutions for the Spaceship Commander game is as follows:

# Turns	Possible Solutions
5	$24(9^4) \sim 1.6\times10^5$
10	$24(9^9) \sim 9.3\times10^9$
15	$24(9^{14}) \sim 5.5\times10^{14}$
20	$24(9^{19}) \sim 3.2\times10^{19}$



As one can see, for the assumptions listed above, the number of possible solutions for a game is on the order of $10^{(\#\ \text{turns})}$.

The sample solutions on the following pages all have high scores for the constraints of the puzzle. However, higher-scoring solutions may be possible especially for the longer games. It is also possible that there may be other flight paths (not shown) that could have equally high scores.

5-Turn Game

Comparison of the 5-turn sample mission with the Planetary Probe sample reveals the same flight path. It may not be beneficial to use the spaceship's engines after launch in short games, in part because of the microgravity experiments that the astronauts can conduct. The astronauts will feel weightless (assuming that the spaceship is not spinning) whenever the engines are not in use, whether or not the spaceship is a planet's gravity well. This is because an object in free fall, where gravity is the only (net) force acting on the object's motion, will behave as if there is no gravity regardless of the true gravity. Therefore, use of the engines

causes (1) a cost in fuel and (2) prevents the astronauts from conducting microgravity experiments. From another perspective, 1 point is earned for microgravity for each turn that the engines are not used, while 2 points are lost for each turn that the engines are used. It should quickly become obvious to players that frequent use of the engines will lead to poor scores.

10-Turn Game

In the 10-turn sample mission, the engines are only used once after launch, on turn 3, to enter into a circling path around planet P17. Note that although the spaceship was within the planet's gravity well for 8 turns, a maximum of 5 points can be earned for surveying each non-home planet. If the mission were extended beyond the tenth turn, the engines would have to be fired again to prevent the spaceship from crashing. This example illustrates that collision courses are acceptable in the game, as long as the spaceship doesn't crash before the end of the game.

15-Turn Game

The engines were used during 4 turns in the sample 15-turn mission. This allowed the spaceship to conduct surveys in 3 different non-home planets, for an exploration bonus of 9 points. The combination of that bonus with the additional survey opportunities more than made up for the additional fuel cost for this mission. However, it must be remembered that the engines should be used sparingly to achieve the highest scores.

20-Turn Game

The 20-turn sample mission is an extension of the 15-turn mission, where the engines are used once more (on turn 15) to allow surveys of the remaining non-home planet, H22.

For the sample missions presented here, the scores were as follows:

# Turns	5	10	15	20
Score	10	14	21	28

It can be seen that these scores are each several points greater than the number of game turns. Students should eventually discover that the highest possible score for a Spaceship Commander puzzle is often as high as the number of turns, regardless of the map and home (starting) planet.

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Map 1

PLANETARY PROBE

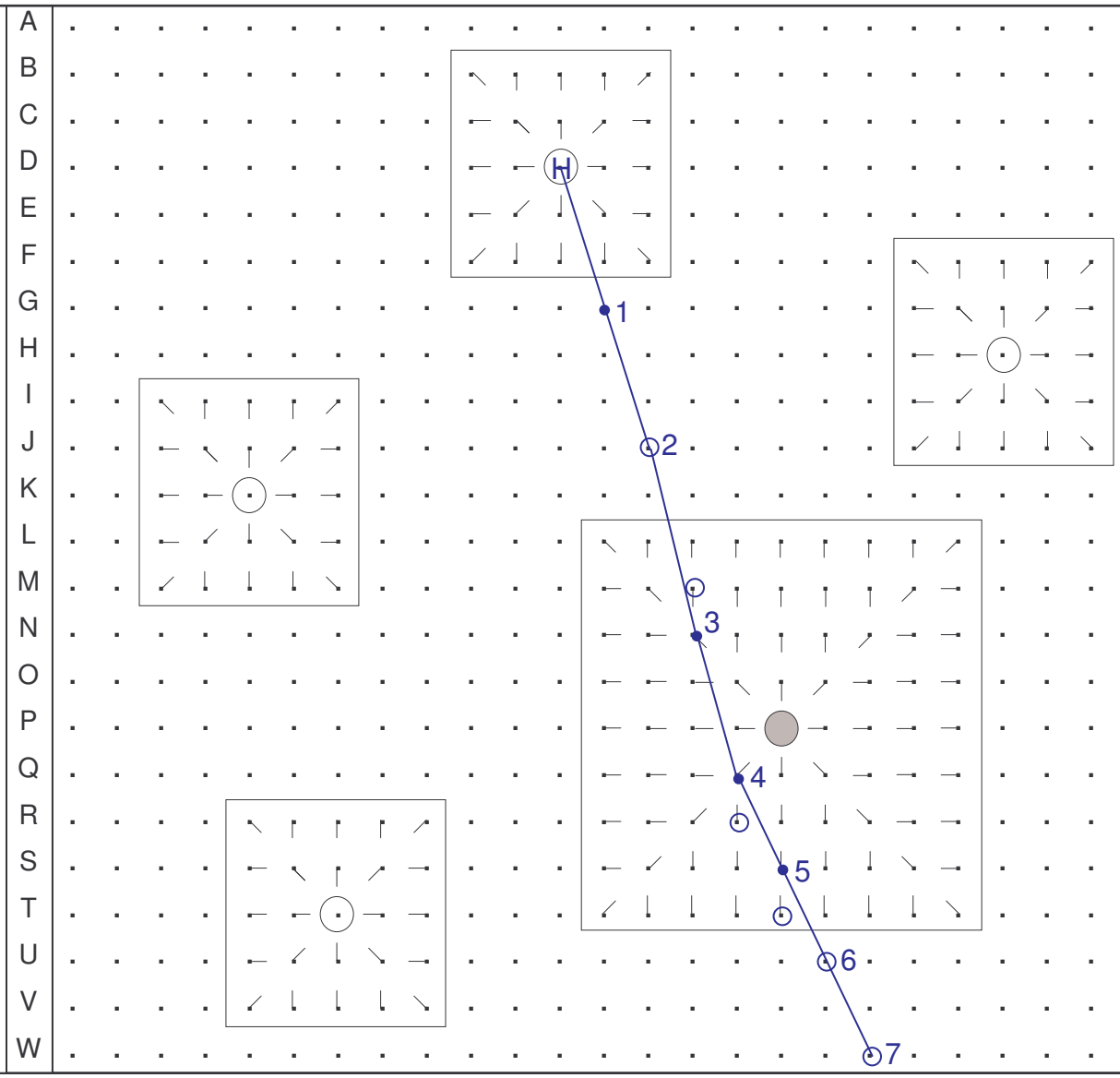
Ahsonnutli Zone

Home Planet (*circle one*): D12 H22 K5 T7

Flight Director Lewis N. Clark

(print name above)

MOVE	Turn 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	MOVE
U+/D-	-3	-3	-4	-3	-2	-2	-2														Up+/Down-					
R+/L-	+1	+1	+1	+1	+1	+1	+1														Right+/Left-					



Turn Sequence

COAST
+ GRAVITY
= MOVE

Do steps in order!

SCORE	Turn 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	#	SCORE
Survey	□		X		X		X	□	□	□	□	□	□	□	□	□	□	□	□	□	Explore* → new □ 1 x 3					3	
																					Survey					3	
																					TOTAL SCORE					6	

Survey = +1 per turn endpoint in a non-home □ (gravity well), *except during a crash turn*

**Survey non-home planets for a 3x bonus!*

2004/10/14 Map 1

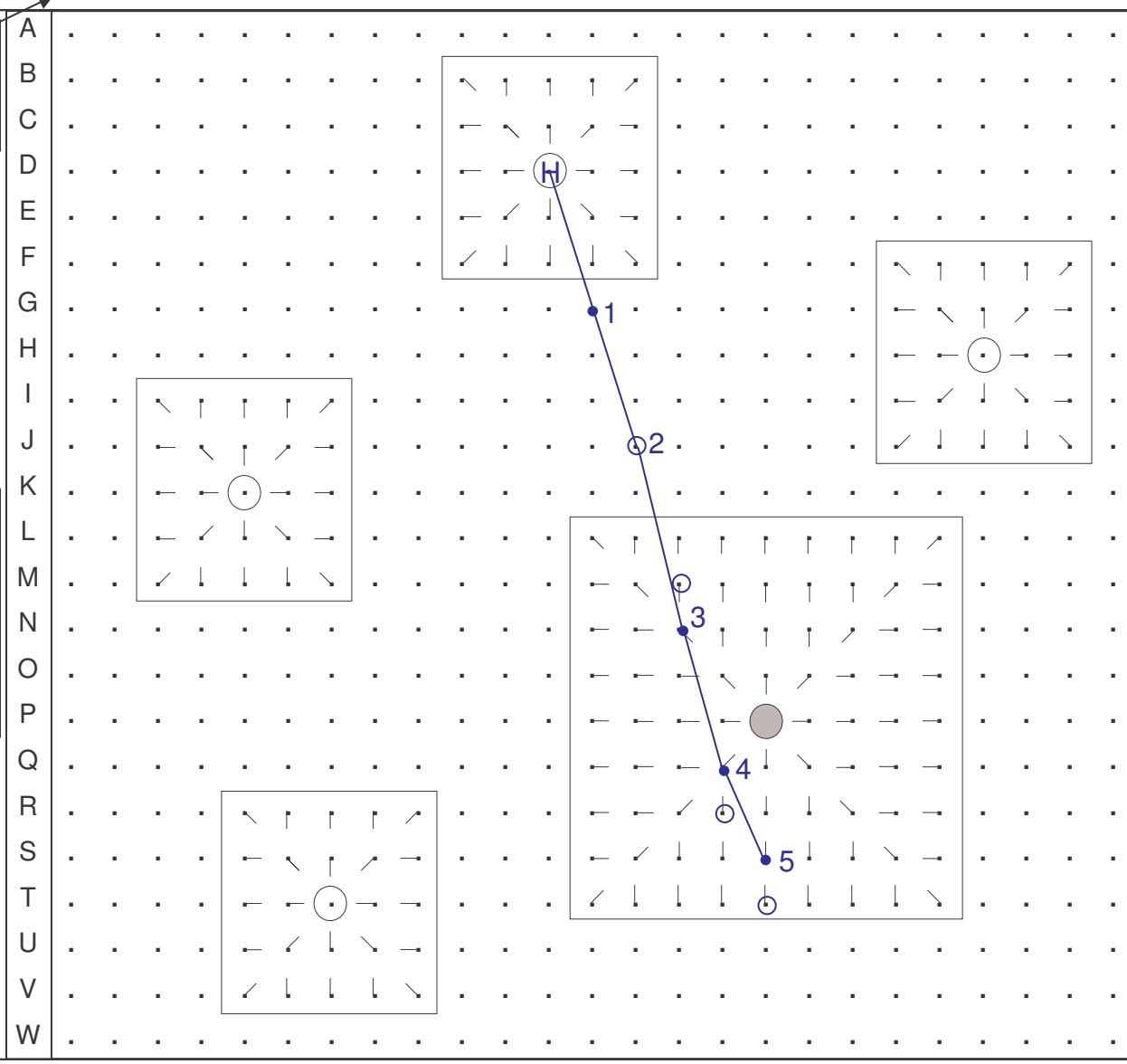
SPACESHIP COMMANDER

Commander *Sacagawea*
(print name above)

Ahsonnutli Zone
Home Planet (*circle one*): D12 H22 K5 T7
Game ends on turn (*circle one*): 5 10 15 20

MOVE																										MOVE
U+/D-	-3	-3	-4	-3	-2																				Up+/Down-	
R+/L-	+1	+1	+1	+1	+1																				Right+/Left-	
Turn	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	

Circle each turn # when engines are fired.



Turn Sequence

Coast
+ Gravity
+ Engines
= Move

Do steps in order!

SCORE	Turn 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	#	SCORE
Survey	□	X	X	X																							
Micro-g	X	X	X	X																							
Fuel	□	□	□	□																							

Explore* → new □ 1 x 3 = 3
Survey 3
Microgravity 4
Fuel 0 x 2 = -0
TOTAL SCORE 10

Survey = +1 per turn endpoint in a non-home □ *up to a max of 5 points for each* □

Micro-g = +1 per turn coasting ***OR*** **Fuel = -2** per turn using engines

**Survey non-home planets for a 3x bonus!*

Adv. rules? _____ **End at** _____ ***Land on*** _____ **Ltd. fuel** _____ **Race?** _____ ***Station*** _____ **Survey** _____

2004/10/14 Map 1

SPACESHIP COMMANDER

Commander Sacagawea
(print name above)

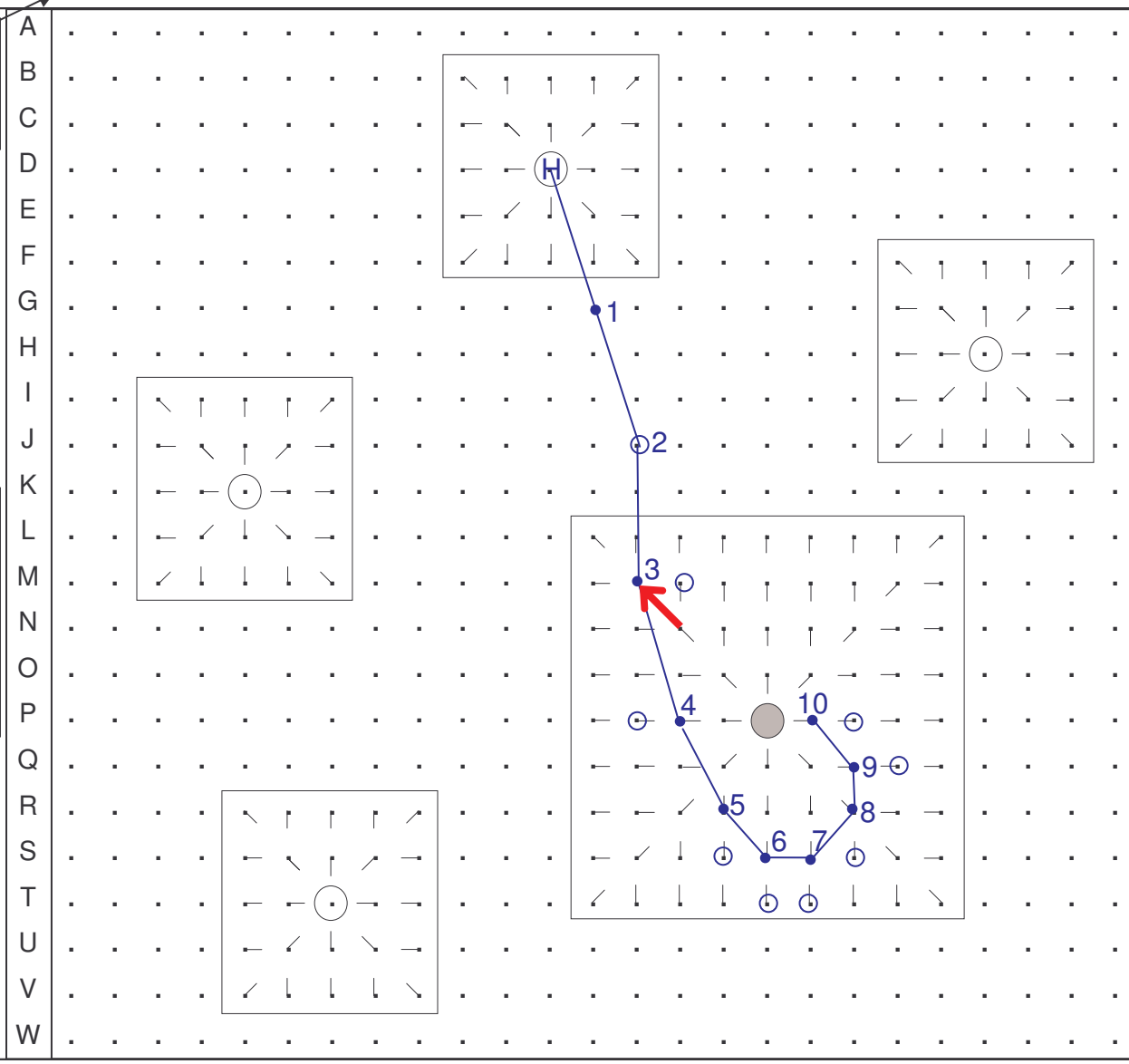
Ahsonnutli Zone

Home Planet (*circle one*): D12 H22 K5 T7

Game ends on turn (*circle one*): 5 10 15 20

MOVE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	MOVE
U+/D- (Up+/Down-)	-3	-3	-3	-3	-2	-1		+1	+1	+1																
R+/L- (Right+/Left-)	+1	+1		+1	+1	+1	+1	+1		-1																

Circle each turn # when engines are fired.



Turn Sequence

Coast
+ Gravity
+ Engines
= Move

Do steps in order!

SCORE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	#
Survey	☐	X	X	X	X	X	X	-	-	-																
Micro-g	X	☐	X	X	X	X	X	X	X	X																
Fuel	☐	X	☐	☐	☐	☐	☐	☐	☐	☐																

Explore* → new ☐ 1 x 3 = 3
Survey = 5
Microgravity = 8
Fuel 1 x 2 = -2
TOTAL SCORE 14

Survey = +1 per turn endpoint in a non-home ☐ *up to a max of 5 points for each* ☐

Micro-g = +1 per turn coasting ***OR*** **Fuel = -2** per turn using engines

**Survey non-home planets for a 3x bonus!*

Adv. rules? _____ **End at** _____ ***Land on*** _____ **Ltd. fuel** _____ **Race?** _____ ***Station*** _____ **Survey** _____

2004/10/25 Map 1

SPACESHIP COMMANDER

Commander *Sacagawea*

(print name above)

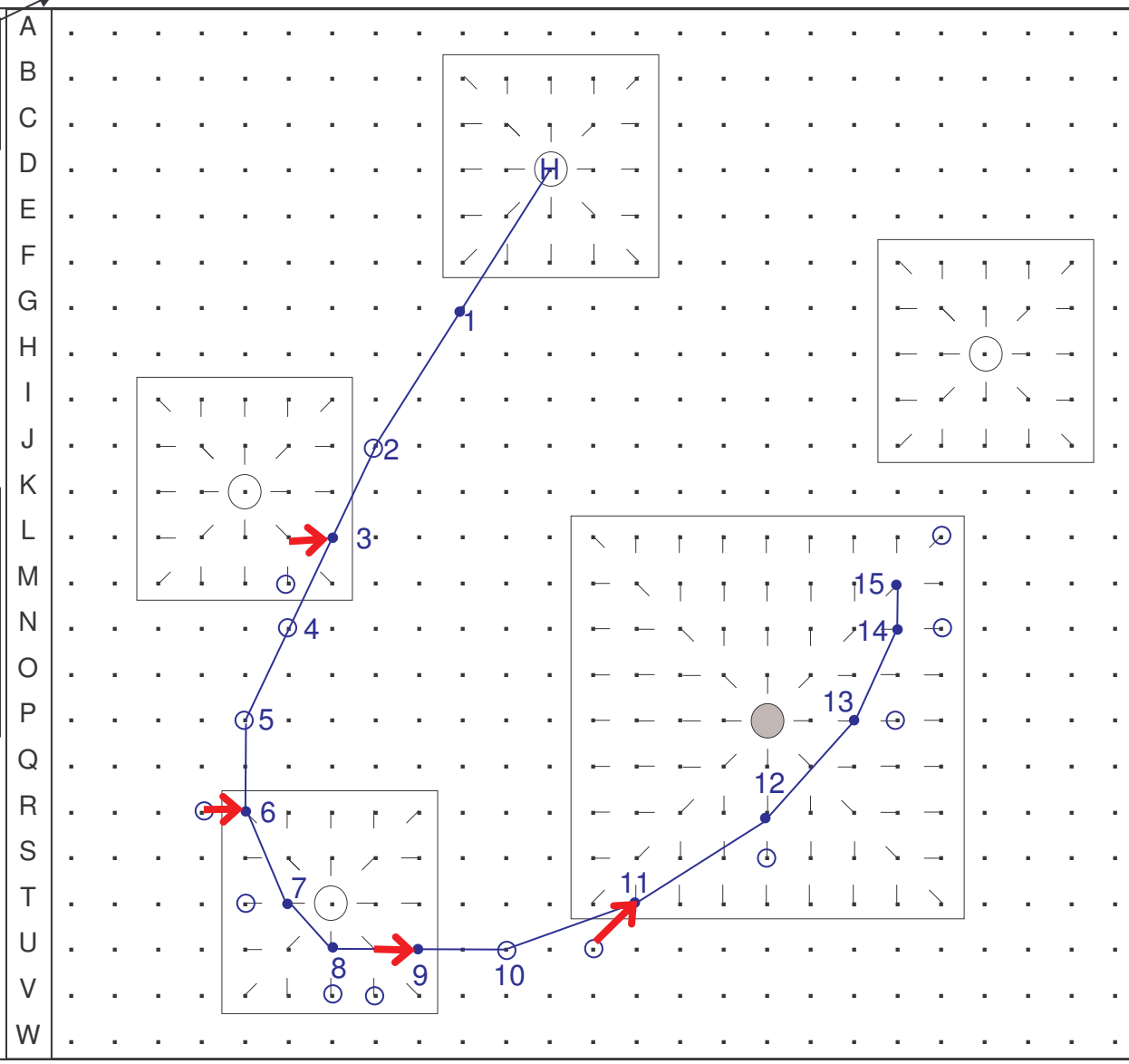
Ahsonnutli Zone

Home Planet (*circle one*): D12 H22 K5 T7

Game ends on turn (*circle one*): 5 10 15 20

MOVE																											MOVE
U+/D-	-3	-3	-2	-2	-2	-2	-2	-1			+1	+2	+2	+2	+1						Up+/Down-						
R+/L-	-2	-2	-1	-1	-1		+1	+1	+2	+2	+3	+3	+2	+1							Right+/Left-						
Turn	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		

Circle each turn # when engines are fired.



Turn Sequence

Coast
+ Gravity
+ Engines
= Move

Do steps in order!

SCORE	Turn	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	#	SCORE
	Survey	□	X	□	□	X	X	X	X	□	X	X	X	X	X	X	□	□	□	□	□	Explore* → new □ 3 x 3					9	
	Micro-g	X	□	X	X	□	X	X	□	X	□	X	X	X	X	□	□	□	□	□	□	Survey					10	
	Fuel	□	X	□	□	X	□	□	X	□	X	□	□	□	□	□	□	□	□	□	□	Microgravity					10	
																						Fuel 4 x 2					-8	
																						TOTAL SCORE					21	

Survey = +1 per turn endpoint in a non-home □ *up to a max of 5 points for each* □

Micro-g = +1 per turn coasting ***OR*** **Fuel = -2** per turn using engines

**Survey non-home planets for a 3x bonus!*

Adv. rules? _____ **End at** _____ ***Land on*** _____ **Ltd. fuel** _____ **Race?** _____ ***Station*** _____ **Survey** _____

2004/10/14 Map 1

SPACESHIP COMMANDER

Commander Sacagawea
(print name above)

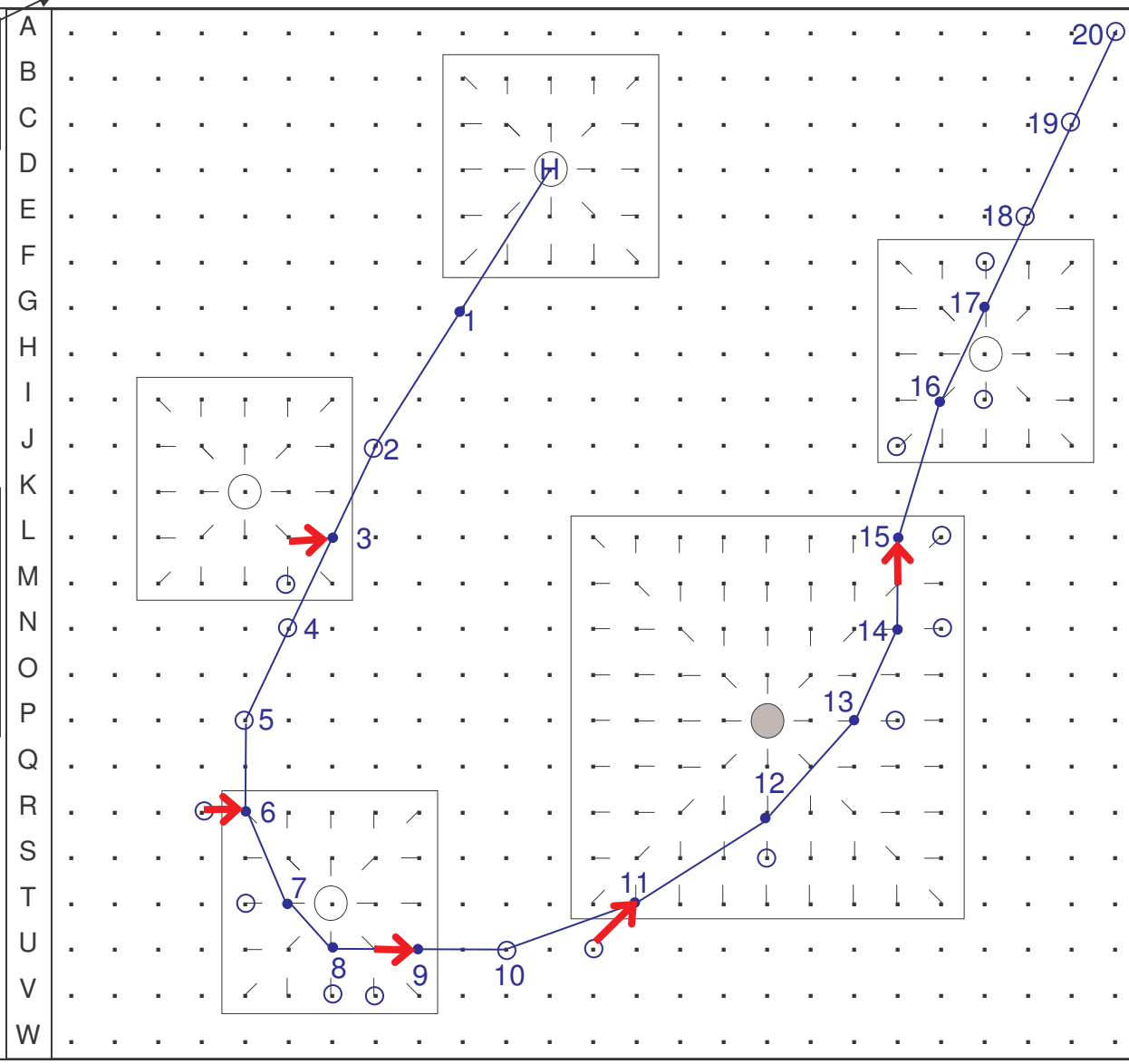
Ahsonnutli Zone

Home Planet (*circle one*): D12 H22 K5 T7

Game ends on turn (*circle one*): 5 10 15 20

MOVE																										MOVE
U+/D-	-3	-3	-2	-2	-2	-2	-2	-1			+1	+2	+2	+2	+2	+3	+2	+2	+2	+2	Up+/Down-					
R+/L-	-2	-2	-1	-1	-1		+1	+1	+2	+2	+3	+3	+2	+1		+1	+1	+1	+1	+1	Right+/Left-					
Turn	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	

Circle each turn # when engines are fired.



Turn Sequence

Coast
+ Gravity
+ Engines
= Move

Do steps in order!

SCORE	Turn 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	#	SCORE
Survey	□	X	□	□		X	X	X	X	□	X	X	X	X	X	X	X	□	□	□							
Micro-g	X	□	X	X		□	X	X	□	X	□	X	X	X	□	X	X	X	X	X							
Fuel	□	X	□	□		X	□	□	X	□	X	□	□	□	X	□	□	□	□	□							

Explore*	new □ 4 x 3	12	
Survey		12	
Microgravity		14	
Fuel 5 x 2		-10	
TOTAL SCORE		28	

Survey = +1 per turn endpoint in a non-home □ *up to a max of 5 points for each* □

Micro-g = +1 per turn coasting ***OR*** **Fuel = -2** per turn using engines

**Survey non-home planets for a 3x bonus!*

Adv. rules? _____ **End at** _____ ***Land on*** _____ **Ltd. fuel** _____ **Race?** _____ ***Station*** _____ **Survey** _____