### **Planetary Probe** A Graphing Puzzle of Space Exploration

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



## What is **Planetary Probe?**

- A paper & pencil puzzle.
- A scored contest.



- The imaginary flight of a spacecraft through a planetary system.
- A way to learn about spaceflight, gravity, and forces & motions.
- An introductory game to prepare you for the **Spaceship Commander** game.

## Planetary Probe Objective

- Win by ending the game with the most points.
- Earn points by conducting surveys of planets.



• Win by flying close to planets!

## **Planetary Surveys**

- Spacecraft use cameras and other instruments to make remote measurements of a planet's surface.
- Better measurements are possible when the probe is close to planets.
- Survey points

+1 per turn endpoint in a non-home  $\Box$  (gravity well), except during a crash

Exploration points - for measurements of different planets
 +3 per each non-home planet surveyed, with at least one turn endpoint in the planet's 

 (gravity well)



## Navigation

- System map coordinates are given by row letter and column number, for example F16.
- The system map shows several planets:
  - weak-gravity planet
  - strong-gravity planet
- Each planet is surrounded by a gravity well, where spacecraft are pulled toward the planet.
- Planets with stronger gravity have bigger gravity wells.

## Launch (Turn 1)

- On the first turn, the probe launches from its home (starting) planet.
- The launch endpoint is any grid point just outside the planet's gravity well.
- In the game, the spaceship cannot launch from strong-gravity planets.
- Launch cost is free in this game.

• Landing is **not** allowed, so you can only launch on the first turn.



## Turn Sequence (after launch)



## Coasting

- The probe moves the same as last turn:
  - same direction
  - same distance

unless ...

- the probe crashes,
- the coast path ends within a gravity well,
  - causing the probe to be pulled one (1) grid toward the planet.
- Inertia makes objects tend to stay moving in the same way,
  - as explained by Newton's First Law of Motion.



## Crashing

• The probe crashes if:

- turn's endpoint is at a planet grid,
- turn's flight path exactly crosses a planet grid point.
  - A flight path which does not exactly cross the planet grid point does **not** result in a crash, even if the flight path crosses the planet symbol (circle).
- There is no penalty or bonus for crashing.
  - Points are not earned on a crash turn.
- Crashing ends the game.

## Turning the Probe

- The probe does not have engines, but gravity will change its flight path.
- If the probe is **not** in a gravity well  $(\Box)$ ,
  - then it <u>cannot change directions</u> and must go in a straight line at a constant speed,
    - duplicating last turn's movement.
- If the probe is in a gravity well  $(\Box)$ ,
  - then it is shifted one (1) grid toward the planet.

• The **only** decision in this introductory game is the choice of launch direction on the first turn.

## Game End

- The game ends when:
  - probe crashes,
  - probe's coast path goes outside the map's boundaries.
- There is no penalty or bonus for either end.
  - Points are not earned during the turn that the probe crashes or flies outside the boundaries.
- Total the scores to find out who won!

## Scoring

• Exploration

+3 per each non-home planet surveyed, with at least one turn endpoint in the planet's 

(gravity well)

• Survey

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



• This game is a puzzle, and you are allowed to erase and "do over."

# Planetary Probe Q&A

- Q: How far does the probe move?
- A: Same as last turn, unless shifted by gravity.
- Q: Which direction does the probe move?
- A: Same as last turn, unless shifted by gravity.
- Q: When does gravity shift the probe?
- A: When the coast path <u>ends</u> within gravity well  $(\Box)$ .
- Q: In what direction does gravity shift the probe?
- A: One (1) grid toward planet, as shown by markings on system map.
- Q: Can the spaceship come to a stop?
- A: Yes. Gravity can cause the spaceship to lose speed and come to a complete stop. When this happens, there is no coasting motion on the following turn. Otherwise, all normal rules apply.



## **Spaceship Commander** A Graphing Puzzle of Space Exploration

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



#### by Dennis P. Stocker

NASA Glenn Research Center MS 77-5, 21000 Brookpark Road Cleveland, OH 44135

dennis.p.stocker@nasa.gov

#### 216-433-2166



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#### Game Differences & Similarities Spaceship Commander (SC) vs. Planetary Probe\* (PP)

#### DIFFERENCES

<u> </u>	<u>SC</u>	<u>Attribute</u>
yes	no	crashing allowed
no	yes	engines use on turns after launch (-2 per turn)
no	yes	microgravity experiments (+1 per turn coasting)

#### SIMILARITIES

# PPSCAttributeyesyescoasting path due to inertiayesyesgravity shift (in □ around planet)yesyessurveys (+1 per turn in □ around planet)yesyesexploration (+3 per each non-home planet surveyed)

\*Planetary Probe (PP) = introductory game

## Spaceship Commander Objective

- Win by ending the game with the most points.
- Earn points by conducting:
  - Surveys of different planets,
  - Microgravity experiments.
- Lose points for:
  - Fuel when you use your spaceship's engines after launch.



• Win by flying close to planets!

## Microgravity

- Microgravity is the condition where gravity seems to be very low, because:
  - gravity *is* very low,
  - or the spaceship (or object) is in free fall.
- Spaceships are in free fall and experience microgravity whenever they are coasting and don't use their engines,
  - like the Space Shuttle as it orbits Earth.
- Scientists can make new discoveries when experiments are conducted in microgravity.
- One (1) point is earned for each turn that the spaceship does not fire its engines.



## Turn Sequence (after launch)



## Coasting

- The spaceship moves the same direction and distance as the last turn, unless:
  - the coast path ends within a gravity well (but not at the planet), causing the spaceship to be pulled one (1) grid toward the planet,
  - the engines are fired.
- For each turn that the spaceship is coasting:

+1 point for microgravity,

-0 points for fuel.



## Using the Engines

- Once per turn, the spaceship can use its engines **after**:
  - (1) coasting,
  - (2) gravitational shift, if in gravity well.
- When engines are used, the endpoint can be shifted one (1) grid in any direction,
  - diagonally, horizontally, or vertically.
- Fuel and speed are both unlimited.
- For each turn that the spaceship uses its engines:

+0 points for microgravity,

-2 points for fuel.



## Crashing

- Crashing is not allowed!
- Engines must be used to avoid:
  - turn's endpoint at a planet grid,
  - turn's flight path exactly crossing a planet grid point.
    - A flight path which does not exactly cross the planet grid point does **not** result in a crash, even if the flight path crosses the planet symbol (circle).



## Turning the Spaceship

- The spaceship **cannot turn** and must go in a straight line at a constant speed **unless** it:
  - is in a gravity well and is shifted one (1) grid toward the planet,
  - uses its engines to shift one (1) grid in any direction,
    - diagonal, horizontal, or vertical.
- The gravity and engine shifts to the coast path are made at the end of the turn in that order.
- The spaceship **cannot** make sharp turns unless it is moving very slowly,
  - because the turn's endpoint can only be shifted one
     (1) grid each for gravity and the engines.

## Game End

- The game ends when:
  - end of the pre-selected turn is reached,
  - spaceship's coast path goes outside the map's boundaries,
    - no penalty, but you can't earn more points
- Total the scores to find out who won!



## Scoring

• Exploration

+3 per each non-home planet surveyed, with at least one turn endpoint in the planet's  $\square$  (gravity well)

• Survey

+1 per turn endpoint in a non-home  $\square$  (gravity well), except during a crash

• Microgravity

+1 per turn when engines are not used

• After launch, Microgravity and Fuel score as shown here, depending on the use of the engines:

Engines	off	on
Microgravity	+1	+0
Fuel	-0	-2



• This game is a puzzle, and you are allowed to erase turns and "do over" to earn more points!!!

# Spaceship Commander Q&A

Q: How much fuel is in the spaceship?

A: Fuel is unlimited (just like the spaceship's speed).

Q: When can the spaceship's engines be fired?

- A: Once per turn, following (1) coasting, and (2) the gravity shift, if any.
- Q: Are microgravity points earned within gravity wells?
- A: Yes. The spaceship experiences microgravity on every turn that the engines are not used, whether it is in a gravity well or not.
- Q: Can the spaceship come to a stop?
- A: Yes. The spaceship can lose speed, due to gravity and/or engine firings, and come to a complete stop. When this happens, there is no coasting motion on the following turn. Otherwise, all normal rules apply.



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## Notes