

Orbit Defender 2-D: Rule Book



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Introduction

Orbit Defender 2-D (OD2D) is a two-dimensional board game style game for modeling non-cooperative satellite interactions. The game was developed originally by Massachusetts Institute of Technology Lincoln Laboratory (MITLL). The original game code can be found on GitHub here: <https://github.com/mit-ll/spacegym-od2d>

This game models a situation in which two opposing groups each have a value but unarmed geo-satellite (High Value Asset- HVA) that needs to complete its mission for Earth. There are also ten smaller (Patrol) satellites that can be used to attack the opposing geo-satellite and defend their own to complete the objective of the game.

Setup & Objective

The setup is fixed at the beginning of the game. Both players have the same initial conditions.

Board Setup

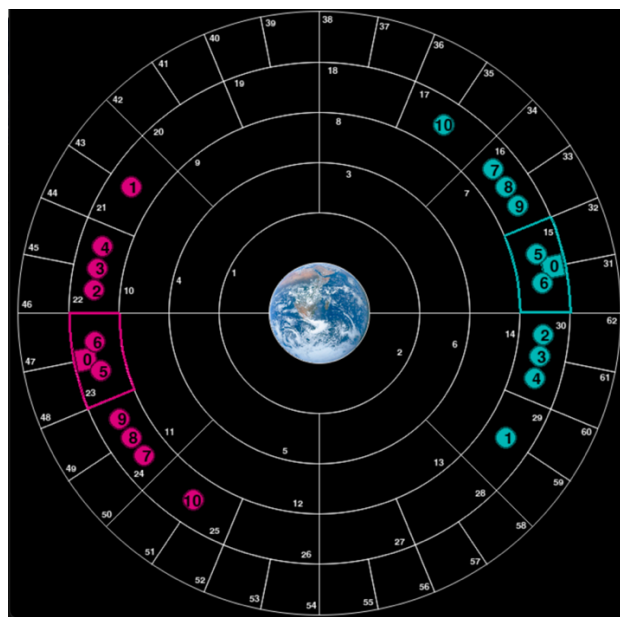
The five concentric circles represent the five different orbits. To represent the increase in time it takes to complete one revolution in an orbit farther from the earth, the higher orbits have more sectors, and the lower orbits have less sectors. All sectors are numbered to distinguish satellite locations.

Tokens

The pink satellites (Beta) represent your fleet, and the blue satellites represent the opposing fleet (Alpha). The larger, square satellites represent each player's "High Value Asset- HVA" (labeled 0), and the ten smaller ones represent the "Patrol" satellites (labeled 1-10). Each HVA and two of the player's Patrol satellites lie within a highlighted sector at the beginning of the game. This highlighted sector we will refer to as the goal sector.

Objective

To score the most points. Gain points by keeping your HVA in the goal sector and use your Patrol satellites to attack and destroy the opponent's satellites while defending your own before running out of fuel.



Game Play

Each turn consists of three phases: **Movement**, **Engagement**, and **Drift**. OD2D is a simultaneous move game; that is, both players select their moves for a given turn phase independently, and then the game engine executes the moves for the phase and advances gameplay to the next phase. All moves entered are irreversible.

The three phases are explained more in detail below.

Movement Phase

In the movement phase, you can choose to individually move each satellite, including the HVA. You may also choose to keep a satellite where it is. Note that it is beneficial to keep your HVA in the goal sector; see [Scoring](#) for details.

The five different actions you can take are **No-Op**, **Radial In**, **Radial Out**, **Prograde**, and **Retrograde**.

- **No-Op (NOOP)** – Short for No Operation. This keeps the satellite where it is.
- **Radial In** – This moves the satellite into a lower orbit, i.e. the next ring of sectors that is closer to the Earth.
- **Radial Out** – This moves the satellite into a higher orbit, i.e. the next ring of sectors that is farther from the Earth. Note that the satellite will always move to the outer sector with the lower number (the retrograde sector).
- **Prograde** – This moves the satellite into the next sector in the same orbit, counterclockwise (up one number).
- **Retrograde** – This moves the satellite into the previous sector in the same orbit, clockwise (down one number).

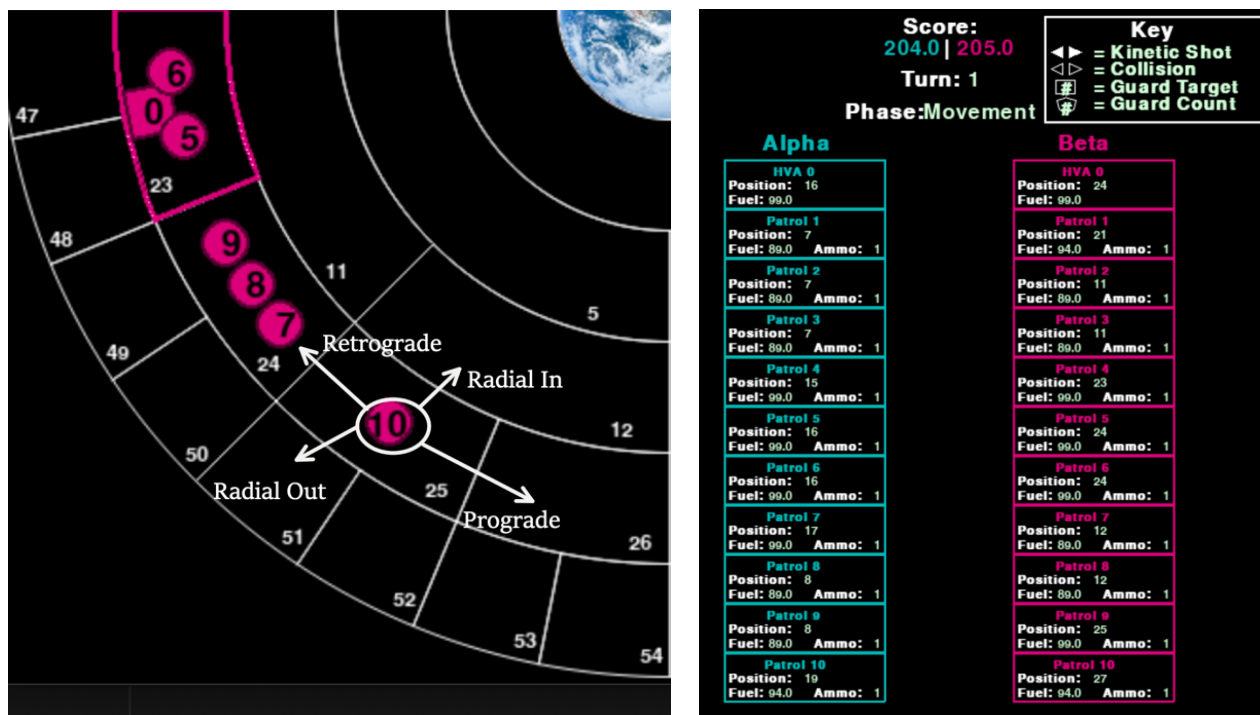
The following table shows fuel costs associated with different movement actions.

Movement Phase Fuel Costs	
No-Op	0
Radial In	10
Radial Out	10
Prograde	5
Retrograde	5

```
Turnphase: movement
Token: alpha:HVA:0
Select an action from the list
0 - NOOP
1 - Prograde
2 - Retrograde
3 - Radial In
4 - Radial Out
Select action: 0
```

Figure 2 shows what your terminal will look like when you start the game and enter the first movement phase. The “Token” line shows you which satellite you are selecting a movement for. The HVA is zero, and the Patrol satellites are numbers one through ten. To select an action, type the corresponding number and press enter. The game will automatically send you to the movement selection for the next satellite. Continue until you have selected a movement for all of your satellites.

There are two tables on the side of the board that tell you the current position of each satellite, along with its fuel and ammo status.



Engagement Phase

In the engagement phase, which occurs after both players have completed their movement phase, you can act against your opponent. These actions can only be completed if you are in the same or an adjacent sector as one of your opponent's satellites. Actions directed diagonally are illegal.

The three actions you can complete are **Guard**, **Shoot**, and **Collide**. The success of these actions depends on the probabilities shown in the tables on the next page. The game processes the engagement outcomes in the following order.

- **Guard** - This action allows a Patrol satellite to protect its HVA from enemy fire. If the enemy successfully shoots at a HVA the Patrol satellite protecting the HVA is destroyed instead of the HVA. Guarding takes fuel even if the target satellite is not attacked. Guarding, even if it is unsuccessful, moves your Patrol satellite into the guarded square.

If multiple shots are taken at a guarded HVA, the probability that the guard is successful is changed by $(probability\ of\ guard) * 0.5^{n-1}$, where n is the number of shots taken at the HVA. In essence, the more times the HVA is shot at, the less likely guard will be a successful move.

- **Shoot** - This action uses a satellite's ammo against an enemy satellite. If successful, the opponent satellite will be shot down, and your satellite will survive this engagement.

Regardless of outcome, your satellite will lose one unit of ammunition and the fuel cost of shooting.

- **Collide** – This action allows you to have one of your own satellites collide with an enemy satellite. If successful, both your satellite and the enemy satellite will be destroyed. If unsuccessful, your satellite will now be in the sector of the enemy satellite it targeted. If a shot taken by a different satellite in the same turn successfully destroys the target of a collision, the collision will fail. The attacking satellite will remain but will lose fuel.

The following tables show the fuel costs associated with different engagement actions for the same and adjacent sectors, and the probability of success of these actions, respectively.

Fuel Costs for Actions WITHIN a Sector		Fuel Costs for Actions against an ADJACENT Sector	
Shoot	5	Shoot	7
Collide	20	Collide	30
Guard	5	Guard	10

Probability of Success for Actions WITHIN a Sector		Probability of Success for Actions against an ADJACENT Sector	
No-op	1.0	No-op	1.0
Shoot	0.7	Shoot	0.3
Collide	0.8	Collide	0.4
Guard	0.9	Guard	0.5

```
Token ID: alpha:Patrol:4
Select an action from the list
0 - NOOP
1 - Shoot
2 - Collide
3 - Guard
Select action: █
```

The image on the left shows what your terminal will look like when you start the game and enter the first engagement phase. To select an action, type the corresponding number and press enter. If you select NOOP, the game will automatically send you to the next engagement selection.

```
Token ID: alpha:Patrol:4
Select an action from the list
0 - NOOP
1 - Shoot
2 - Collide
3 - Guard
Select action: 2
Select target: █
```

For each action, the screen will look the same. For shoot or collide, enter the number of the opposing satellite you want to attack. For guard, enter the number of your own satellite that you want to protect. Press enter to save your choice, and repeat for all satellites.

```

Turnphase: engagement
Token ID: alpha:HVA:0
Select an action from the list
0 - NOOP
1 - Shoot
2 - Collide
3 - Guard
Select action: 1
Select target: 0
Invalid selection. Please select a legal action
Turnphase: engagement
Token ID: alpha:HVA:0
Select an action from the list
0 - NOOP
1 - Shoot
2 - Collide
3 - Guard
Select action: █

```

The image on the left shows what your screen will look like if you attempt to make an illegal move. In this picture, beta tried to use their HVA to shoot at alpha's HVA. This is illegal because the HVA has no ammo. Similar actions will result in an illegal move error.

ENGAGEMENT OUTCOMES:				
Action	Attacker	Guardian	Target	Result
guard	beta:Patrol:2	alpha:Patrol:6	alpha:HVA:0	Success
guard	beta:Patrol:3	alpha:Patrol:6	alpha:HVA:0	Success
guard		alpha:Patrol:5	alpha:HVA:0	Failure
shoot	beta:Patrol:4		alpha:Patrol:10	Success
shoot	alpha:Patrol:4		beta:Patrol:7	Failure
collide	beta:Patrol:2		alpha:Patrol:6	Failure
collide	beta:Patrol:3		alpha:Patrol:6	Success

The picture above shows the engagement outcomes after both players have completed the engagement phase. As stated before, the guard outcomes are determined before the shoot outcomes, and shoot is determined before collide. For guard, if it is successful, then the guardian becomes the target and the HVA will not be hit.

Drift Phase

The drift phase, which happens immediately after the engagement phase has been completed, the earth spins and every satellite on the board shifts one sector counterclockwise. This means that the two goal sectors for each player will always be directly across the board from one another, and satellites in different orbits will move different amounts due to varying sector size.

Scoring

Points are added to the total score for each player at the end of every turn.

The HVA starts the game in its goal sector, and it is to your benefit to keep it there for as much of the game as possible. The HVA models a geo-satellite which must maintain a specific longitude (the longitude of the goal sector) to perform its mission.

You will receive **ten points** at the end of your turn if the HVA is still in its goal sector. If you have moved your HVA, but it is in an adjacent sector to the goal sector, you will receive **three points**. If the HVA is in any other sector, you receive no points. The only way you can score points during the game is through the HVA's position.

The initial score is 200 points. Each satellite starts with fuel of 100. The total fuel of the Patrol satellites, 100, is divided by how many Patrol satellites there are, 10; these sum to 100 points. This is

then added to the total fuel from the HVA, which is also 100 points. ($100+100=200$) After each turn, the score is recalculated by the new fuel sum from the 11 satellites. When a satellite dies, its fuel is automatically decreased to 0.

Each satellite will lose one fuel per turn regardless of which movements or actions that satellite completes.

To win the game, you must have a total score of 250 points.

Winning the Game

The game ends when one player's HVA is destroyed or when a HVA completes its mission (it attains the high score of 250 points). Alternatively, it can also end when the turn limit (50) is reached. There is a draw if both players have the same number of points when fuel runs out or when both players reach 250 points at the same time.

Strategies

Plan Ahead

The satellites will always drift one sector counterclockwise before the end of every turn (after the movement and engagement phases). Consider where you will drift ahead of time and where you want your satellites to end up.

Weigh Costs and Benefits

Satellites can be moved radially inward or outward. Though it costs fuel to move inward, the period of orbits closer to earth are much smaller. Therefore, it will take you less turns to move around the board.

Protect Your HVA

The HVA is your main asset; losing your HVA (either through running out of fuel or having it blown up) terminates the game. Avoid moving your HVA because you lose fuel in the process. With that in mind, consider keeping a few satellites in the same sector as your HVA avoid vulnerability.

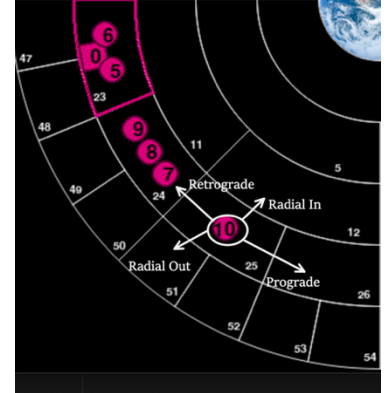
Quick Reference

Important Terms

- **HVA** – High value Asset. The large square satellite in the goal sector for each player; representative of a geo-satellite that must carry out a mission. Goal is to protect your own and destroy the opponent’s.
- **Patrol**– The small satellites that can be used to defend your own HVA and attack the other opponent’s Patrol satellites and HVA.

Movement Phase

- **No-Op (NOOP)** – Short for No Operation. Satellite doesn’t move.
- **Radial In** – This moves the satellite into a lower orbit, i.e. the next ring of sectors that is closer to the Earth.
- **Radial Out** – This moves the satellite into a higher orbit, i.e. the next ring of sectors that is farther from the Earth. Note that the satellite will always move to the outer sector with the lower number (the retrograde sector).
- **Prograde** – This moves the satellite into the next sector in the same orbit, counterclockwise (up one number).
- **Retrograde** – This moves the satellite into the previous sector in the same orbit, clockwise (down one number).



Engagement Phase

- **Guard** – Protect another friendly satellite from enemy fire. If the enemy successfully shoots at a guarded satellite the guard satellite is destroyed instead of the targeted satellite.
- **Shoot** – Fires a Patrols satellite’s single ammo against enemy. If successful, your satellite will survive this engagement.
- **Collide** – Collide with an enemy satellite. If successful, both your satellite and the enemy’s will be destroyed.

Winning the Game

- You receive 10 pts at the end of your turn if the HVA is still in its goal sector, 3 pts if it is in an adjacent sector. Initial score is 200 points (HVA Fuel (100) + 1/10*Patrol Satellite Fuel (100)). After each turn, the score is recalculated by the new fuel sum from the 11 satellites. When a satellite dies, it’s fuel is automatically decreased to 0. Each satellite will lose one fuel per turn regardless of its actions. The winning score is 250.

Fuel Costs and Engagement Probabilities

Fuel Costs for Actions WITHIN a Sector		Fuel Costs for Actions in an ADJACENT Sector	
Shoot	5	Shoot	7
Collide	20	Collide	30
Guard	5	Guard	10

Probability for Actions WITHIN a Sector		Probability for Actions in an ADJACENT Sector	
No-op	1.0	No-op	1.0
Shoot	0.7	Shoot	0.3
Collide	0.8	Collide	0.4
Guard	0.9	Guard	0.5

```
Turnphase: movement
Token: alpha:HVA:0
Select an action from the list
0 - NOOP
1 - Prograde
2 - Retrograde
3 - Radial In
4 - Radial Out
Select action: 0
```

```
Turnphase: engagement
Token ID: beta:HVA:0
Select an action from the list
0 - NOOP
1 - Shoot
2 - Collide
3 - Guard
Select action: █
```

Movement Phase Fuel Costs	
No-Op	0
Radial In	10
Radial Out	10
Prograde	5
Retrograde	5