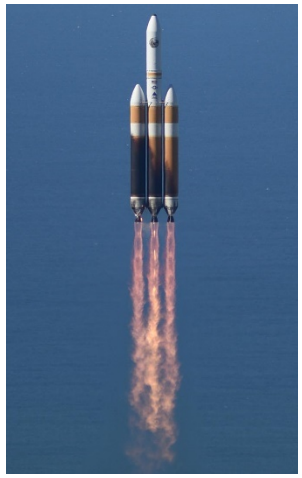
Mission Planetary Defense—Will You Save Earth?
Teacher Reference Guide

To Give Students Directions: You will need to figure out how to use your tools to protect Earth from NEOs. You will begin with experimenting on a few scenarios to learn how to use your resources. Remember, there are many ways to save Earth, but will you be able to do it with the least resources, or be the first to arrive, or the smallest budget? You decide!

Resources for the Mission
● The App Usage Guide the 2019 Scenario https://cneos.jpl.nasa.gov/pd/cs/pdc19/ ● Press Release https://cneos.jpl.nasa.gov/pd/cs/pdc19/pdc19_pr1.pdf

The Vehicles for The Mission		
Atlas V551	Delta IV Heavy	Falcon
		

For Teacher: Give the students the Mission Scenario 1.

Mission Scenario 1: Find the ***shortest number of days*** from discovery of the asteroid and the least number of days from launch to impact that would give the smallest missed distance. (How close can you launch to the potential Earth impact day, with moving the asteroid the smallest amount necessary to protect Earth.)

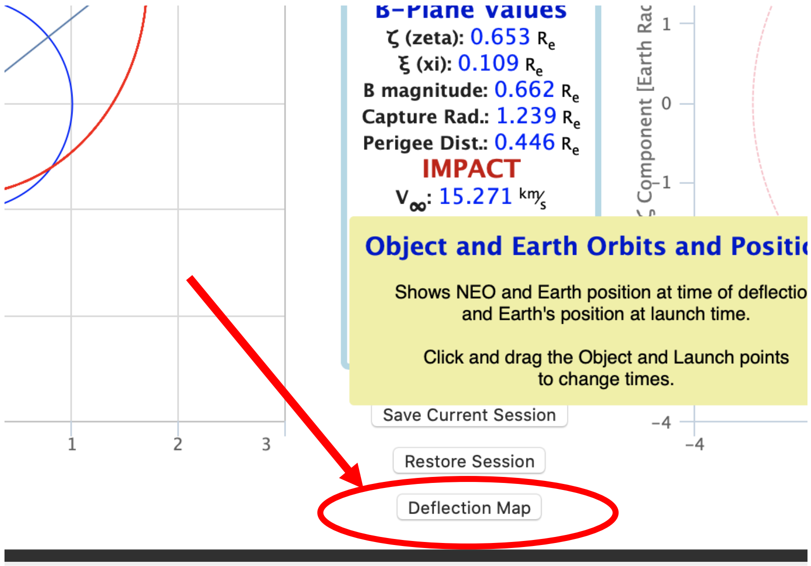
- Asteroid "2019 PDC" is discovered on March 26, 2019.
- The most potential impact with Earth occurs on April 29, 2027 - 8 years and 36 days away.
- The asteroid's mean size could be anywhere from roughly 100 meters to over 300 meters.
- Orbital mechanics can be explained as cars on a highway exiting and entering new lanes. The rocket can directly "go" to the correct destination, it needs to have transfer orbits to gain velocity, just like merging onto a highway. The car is originally 90 degrees off of the desired direction, but during a cloverleaf shaped on/off ramp the direction and speed of the car changes so it eventually gets to the desired direction and velocity wanted. If the exit is missed, the car has to circle back around and try again, which is similar to orbital mechanics and launch windows.

The Mission Control View: In the app, select the Intercept Mode, so it turns orange.

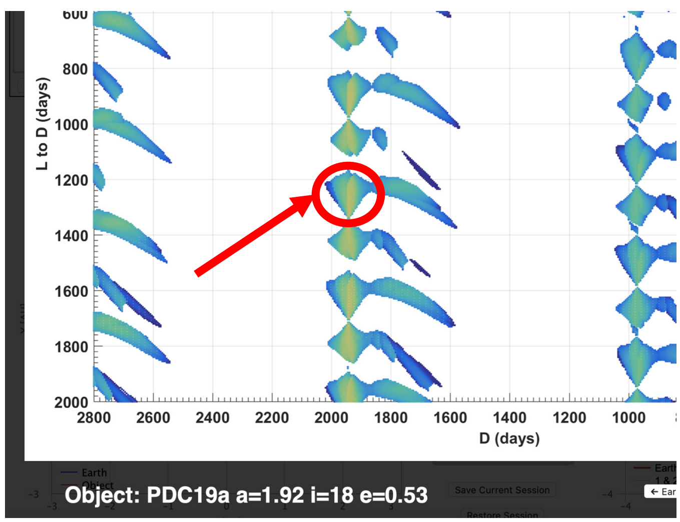
Process and Important Items to Know App and Helping Students: Working through the app and helping students starting their investigations.

1. Performance metric is the ratio of the miss distance (in Earth radii) to the total cost (in $B).
   It is the ratio of how many Earths from the center core to the atmosphere away the object was moved, then compared to how much did it cost the teams in billions of $

2. Use the ΔVA Sensitivity plot to pick advantageous deflection time, click ΔVA Sensitivity in the menu box above the plot. The app displays a handy sensitivity graph showing how much deflection you get in the b-plane for each mm/s of ΔVA velocity change you apply, as a function of Time of Deflection D. Moving the time D closer to one of the peaks in this plot should give you more deflection for a given ΔV.

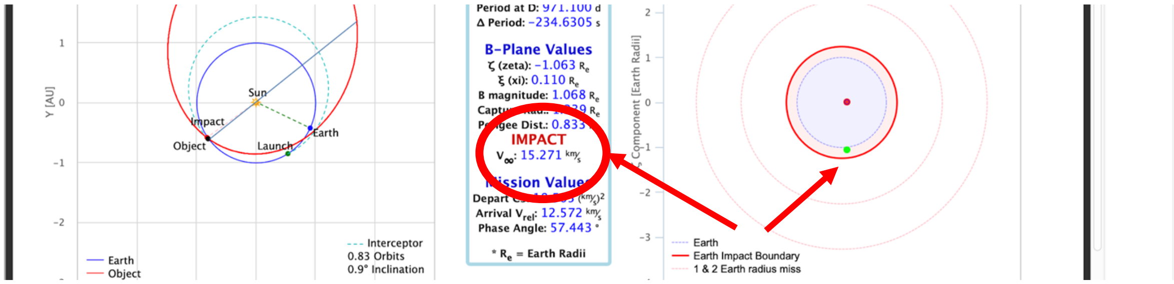


Since there are only 7 years to impact in the scenario app, there are only two peaks to choose from. Let's investigate deflecting at the peak at about 5 years before impact, even though that's only 2 years away and it might not be possible to get a KI spacecraft built, launched and hitting the asteroid in only 2 years. Ideally choose coordinates that are in the yellow for additional data sets.

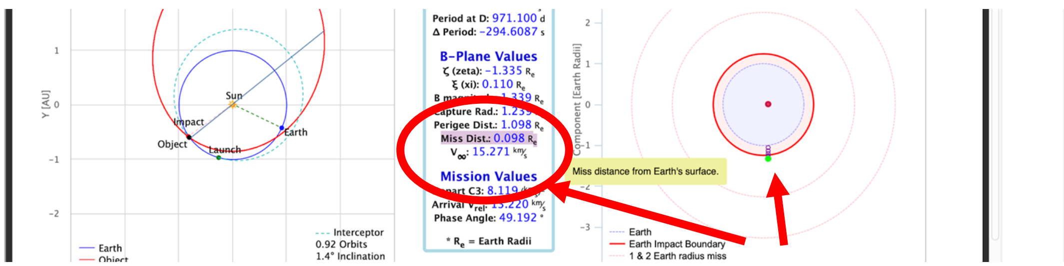


3. Use the deflection map to pick possible deflection time and transfer time.

4. A negative performance metric is marked in red font and signifies that the green dot is inside the red circle and impact to Earth will occur = Earth is impacted by NEO. This This is an unsuccessful mission = Earth it hit!

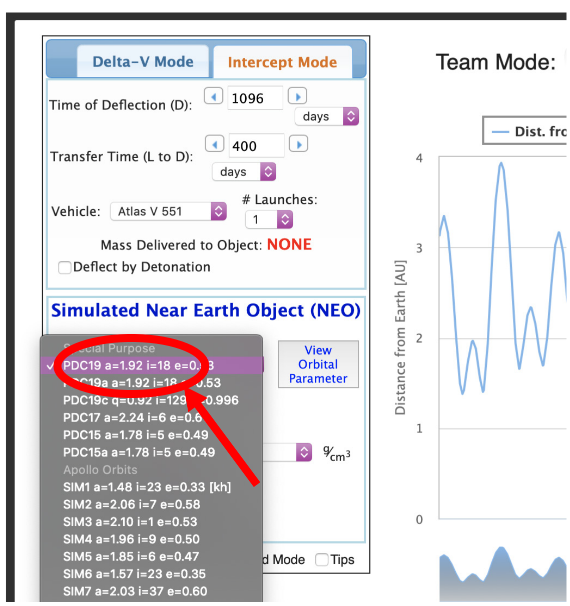


5. This is a successful completion = Earth is saved!

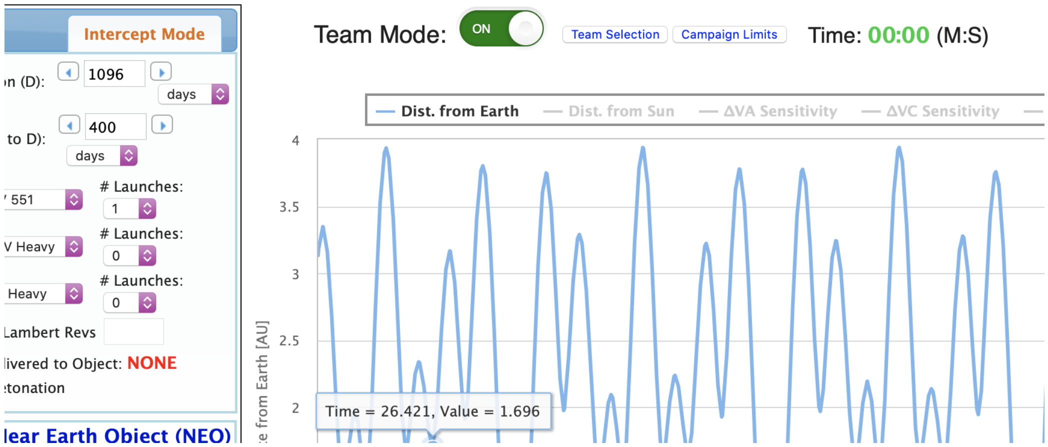


Student Team Round 1:

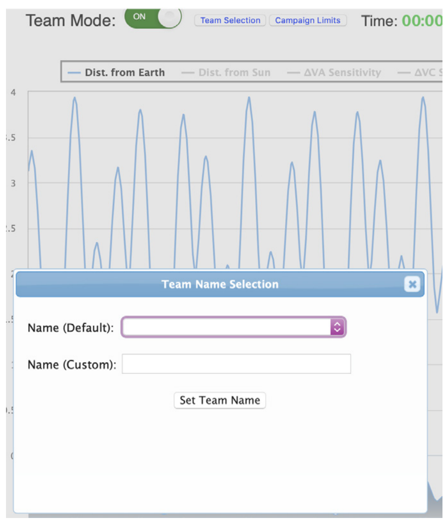
1. Setting up the Values for Round 1.
2. Select simulated NEO PDC19 from the dropdown menu.



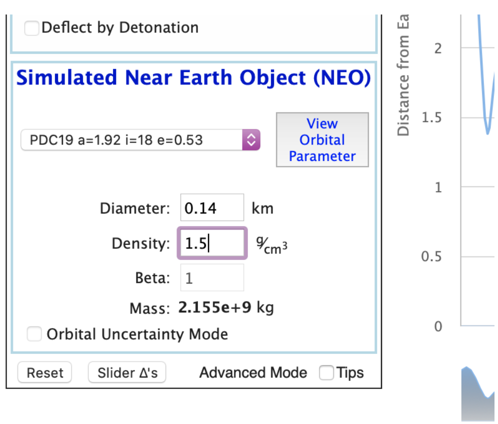
3. Turn on the Team Mode button.



4. Select team name.



5. Use the NEO diameter and density default values (140 meters, 1.5 g/cm³).



6. Set campaign/ vehicle limits to 2 Atlas V, 2 Delta IV, 2 Falcon Heavy, 1 NASA SLS.

7. Set **vehicle campaign** max to 4.

8. Set **campaign budget** max to $2.0B.

9. Set exercise time but do not press "**Set Limits**" yet.

10. Have All teams press "**Set Limits**" when ready at same time to start the timer for 10 minutes for students to work.

11. Have the teams change time of deflection, transfer time, and launch vehicle selection to maximize the performance metric.

12. Teams switch to hands-off when the timer expires, and each team reads out their performance metric (vehicles, $B, r, performance metric).

13. Choose a winner. See the Winner Table for possible winning criteria.

Student Team Round 2:

1. Select simulated NEO PDC19a and repeat the steps from Student Team Round 1 beginning at Step 3 and ending at Step 13.

2. Set a timer for 10 minutes.

Student Team Round 3:

1. Select any of the simulated NEO, then have students try to find as many different ways to Protect Earth as possible.

2. Give students an unlimited budget to work with.

3. Set timer for 10 minutes, then stop the simulation.

4. Have the students share and create the criteria for the class about how the winning team will be selected.

5. Have each team create a 1 minute "sales pitch/ commercial" share out why their solution is the best solution.

6. Have the students vote on the winning team.

Possible Expansions: Select from any of the options below for additional applications or scenarios for students to continue work on options for the NEO app.

1. Use the table below and provide students with a D or L-D day that is just 15-20 days off of the given value below to provide a starting point.
2. Have students try to minimize the # of Launches.
3. Give students a budget of a performance metric of a maximum of 1$B.
4. Have students try to adjust as close to Earth without impact.
5. Have students try to adjust as far away from Earth as possible.

Troubleshooting and Table of Scenarios that are Successful: Note other values can be found using the blue/yellow L to D, and D data. ***See #2 in Process for how to access***

Scenario Round	NEO	Vehicle	# Launches	D (days)	L-D (days)	Performance Metric (Re/$B)
1	PCD19	Atlas V551	1	986	410	-0.471
1	***PCD19***	***Atlas V551***	***1***	***974***	***449***	***This example pushes the green dot outside impact zone for a success***
1	PCD19	Atlas V551	2	986	410	2.407
2	PDC19a	Atlas V551	1	986	410	-3.695
2	PDC19a	Atlas V551	2	986	410	0.797
2	PDC19a	Atlas V551, Delta IV	2, 1	986	410	2.728
2	PDC19a	Atlas V551, Falcon	2, 1	986	410	4.084
2	PDC19a	Atlas V551, Delta IV, Falcon	2, 1, 1	986	410	**4.424**

Winner Table

Possible Winner Outcomes/Solutions
A. Team with most solutions
B. Team with fewest launches
C. Team with the closet r_e values to Earth
D. Team with smallest $B spent
E. Team that launched with the fewest numbers of days
F. Team with fastest solution
G. Team with the most creative solution