Activity Exploring B-Plane

ASTR 220

Name: ______________________________

Team Name: ______________________________

Section: ____________

This activity is going to guide you in exploring certain aspects of the NEO Deflection App. The NEO Deflection App is at neo.jpl.nasa.gov/nda/nda.html

It is assumed that you'll be working with your team on this activity. Individual members will likely use the app on personal laptops; however, you should come to a consensus with your teammates about your answers. This should be done as a group!

1. Start the app. You should leave all of the sliders and drop-down menus in the default selections. If you change something, please reset back to the defaults using the "reset" button toward the left side.

   Previously, you used the used the long "time before impact" graph in the upper right and the "orbit and positions at deflection" diagram in the lower left. Today, you will be learning about the "B-plane" diagram in the lower right and about the control panel in the upper left.

2. Leave the app in the defaults (reset if needed) and look at the B-plane diagram. The central filled-in blue circle is the cross-section of the Earth in the B-plane. The red circle around it is the capture circle (look back at the video for Pre-lecture 17 if needed). The little green dot is the asteroid's trajectory through the B-plane if it is left with its orbit unchanged. (NOTE: this app doesn't account for the region of uncertainty of the asteroid. The app assumes that we know exactly where the asteroid is at all times. This is not realistic, but it makes everything easier to visualize within the app.)

   <u>In the default situation, does the asteroid impact the Earth or not? Explain your reasoning.</u>

3. We can prevent the asteroid from impacting the Earth if we can change its orbit enough. You can change the asteroid's orbit by giving the asteroid a ΔV - by changing its orbital velocity, which will change its orbital energy.

   In the control panel in the upper left, you will see sliders for ΔVA, ΔVC, and ΔVN (remind yourself what these represent by looking back at the previous discussion activity). You can also change each ΔV by typing a number into the box next to the slider.

   Try putting "50" into the box for ΔVA, hit return, and then look at the B-plane diagram. You should see two dots: the green dot is the asteroid's current trajectory (after you changed its velocity) and the red dot is the asteroid's original trajectory.

   <u>Did you change the asteroid's orbit enough to keep it from impacting the Earth?
Explain how you know.</u>

4. Reset the settings. Now put "50" in for ΔVC. Did the asteroid's orbit change as much as it did for when you put "50" for ΔVA?

5. Reset the settings. Put "50" in for ΔVN. Did the asteroid's orbit change as much as it did when you changed ΔVA? As much as it did when you changed ΔVC As much as it did when you changed both ΔVA and ΔVC?

6. Go ahead and try putting in different values for the different ΔVs (keeping the other parameters unchanged). Based on your testing, if you want to make the biggest change in the asteroid's orbit, which ΔV should you try to make the largest: ΔVA, ΔVC or ΔVN? Thinking about the orbital kinetic energy and orbital energy of an asteroid, does this make sense?

7. Now, on the control panel in the upper left, click on "intercept mode". You will now be using the app to launch a spacecraft to deflect the asteroid using the kinetic impactor deflection method, which we'll be learning about in class. In the control panel, you will now see these items:

   - Time of deflection: this is how much time BEFORE the impact the spacecraft will impact the asteroid and change its orbital velocity.
   - Transfer time: this is how long it takes after the spacecraft is launched before it gets to the asteroid to impact it; in other words, it is the travel time.
   - Vehicle: this is the type of launch rocket that is being used to launch your spacecraft.
   - # of Launches: the number of spacecraft you are launching to the asteroid
   - The "mass delivered to object" is how much mass the spacecraft will be carrying when it hits the asteroid.

   You should also look at the "time before impact" graph in the upper right. You should still see the vertical yellow line labeled "D" - this is the date before impact when the asteroid is deflected by the spacecraft you send. Now you will also see a blue vertical line labeled "L" - this is when your spacecraft is launched.

   Finally, you should also look at the "orbit and positions at deflection" graph in the lower left. The blue orbit is the Earth's orbit. The black dot labeled "impact" is where the Earth will be when the asteroid impacts it, assuming the asteroid's orbit isn't changed. The red orbit is the asteroid's UNDEFLECTED orbit. The red dot on the red orbit is the location of the asteroid when the spacecraft hits it. The light blue dashed line leads from the Earth's orbit at a spot marked "launch" to the asteroid's orbit - this is the path of the spacecraft that you launch.

Please reset your settings if you've changed anything from the defaults. For these settings, how long before the time of Earth impact is the spacecraft LAUNCHED? (trick question - think carefully!) Briefly explain your reasoning.

8. For the default settings, approximately where is the asteroid on its orbit when the spacecraft hits it? Near perihelion? Near aphelion? Somewhere in between?

9. Starting with the default settings, slowly increase the "time of deflection" - you can click on the right arrow to increment a small amount. In a few days, you will see the spacecraft's path (dashed blue line) disappear. To see what has happened, look at the box just to the right of the "orbits and positions at deflection" graph - it will say in red "infeasible launch window". That means that if the spacecraft is launched when the Earth and asteroid are in those orbital positions, the spacecraft would have to take a very impractical, long path in order to get to the asteroid - too expensive.

   Keep increasing the "time of deflection" until you get past the "infeasible launch window" warning. What do you have to increase the "time of deflection" to?

10. Now keep increasing the "time of deflection" click by click, and you will see on the "B-plane" diagram that the asteroid's path is changing. What do you have to increase the "time of deflection" to in order to change the asteroid's orbit enough that it passes outside of the capture circle?

11. Go back to the first "time of deflection" date that let you have a valid spacecraft launch after all of the "infeasible launch window" messages - that is, your answer for #9. Now increase the "time of deflection" again click-by-click, but as you do, watch this: in the information panel to the right of the "orbits and positions at deflection" graph, there is a list of "orbit changes" that lists the delta-Vs you are applying to the asteroid with your spacecraft. Remember that earlier in this activity, you determined that changing one of these delta-Vs in particular would cause a big orbital change. As you increase the "time of deflection", keep watching the delta-Vs and how much the asteroid's path is deflected.

    When the asteroid is finally deflected enough to miss the Earth, is the delta-V you suggested at its maximum value so far? Please describe what happened.

12. Please reset the app back to the default values and return to "intercept mode". Now you're going to compare the launch rockets that you can use to launch your spacecraft. The default launch rocket is the Atlas V 551. With the default settings, how much mass will this launch rocket deliver to the asteroid via your spacecraft?

13. Now switch to the Delta IV Heavy launch rocket. Notice that when you do, you change the amount of the asteroid's deflection on the "B-plane" diagram. <u>How much mass does this launch rocket deliver, and was the deflection more or less than with the previous launch rocket?</u>

14. Switch to the last two types of launch rockets. In the space below, make a little table listing each of the four launch rockets, how much mass each one delivered, and the relative amount of deflection (you can describe them as "most", "second-most" and so on).

15. Look at your table: <u>is there a correlation between the amount of mass the launch rocket delivered and how much deflection occurred? If so, what is that correlation?</u>