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Moving Targets APT Hands-on

1. Creating an Asteroid Target

There are two basic kinds of moving targets that can be specified in the APT: ***standard targets*** *and* ***minor bodies****. Standard targets include the Sun, planets, dwarf planets, and all their named satellites (both regular and irregular). Minor bodies include near-Earth asteroids, Main Belt asteroids, Trojan asteroids, comets, Centaurs, trans-Neptunian objects, and interstellar asteroids. The process for creating standard targets and minor bodies is different, and we will first explore the creation of a minor body target.*

- Open the APT and create a new JWST proposal.
- Ignore the "Proposal Information" page and click on "Targets" in the tree editor.
- Click the "New Solar System Target" button. This creates a new "Unnamed Target."
- For this exercise, we will be using the numbered asteroid 4221 as our target.
- Type "4221" into the "Name in the Proposal" box.
- Leave the "Name for the Archive" blank. This will be auto-populated later.
- In the "Keyword" dropdown, select "Asteroid."
- Type anything relevant into the "Description" box to remove the red X. This could be "Asteroid" or "4221" or "Asteroid 4221."
- The selected entry in the "Extended" dropdown can either remain "Unknown" or you can select "NO." It is only important to select "YES" if the target is actually extended (such as Ceres or a giant planet) because this requires special handling in the data reduction pipeline.
- Now, for the "Level 1 Type" select "Asteroid" from the dropdown menu.
- This will take you to a new page. In the "Search" box at the top of the page, type "4221" and click the magnifying glass button on the right. This "Horizons Search" tool communicates with the JPL Horizons online ephemeris service (https://ssd.jpl.nasa.gov/horizons.cgi) and will return information on asteroid 4221.
- Specifically, a dialog box will appear with a list of retrieved objects. In this case, there is only one object that fits the search criteria, so click "OK." This

populates the "NAIF Name" (official IAU name, primary designation, or temporary designation) and "NAIF ID" (JPL Horizons internal bookkeeping number) boxes.

- Many red Xs still remain on this page for the target's orbital elements. These can be removed by either typing the values in by hand (not recommended) or by clicking the "Use Horizons for Orbital Elements Retrieval" checkbox.
- A dialog box will inform you that the current orbital elements will be overwritten. Click "OK." APT will now communicate with JPL Horizons to retrieve the most up-to-date orbital elements.
- If at any time you need to update the orbital elements, simply click the "Update Orbital Elements from Horizons" button.
- You have now successfully created a minor body target and can use it in observations. First, however, we will walk through how to create a standard target.

2. Creating a Standard Target

*Now we would like to define a standard target and explore the different options for **Level 2** and **Level 3** targets. Standard targets and minor bodies are considered **Level 1** targets, with Level 2 defined with respect to the Level 1 target, such as a satellite of that target or a specific coordinate on the surface. Level 3 targets are then defined with respect to the Level 2 target. For this example, we will define the Pele volcano on Jupiter's moon Io as our target.*

a. Click on the "Solar System Targets" folder in the tree editor.
b. Click the "New Solar System Target" button.
c. Fill out the "Name in the Proposal," "Keyword," and "Description" with relevant information for the target described above.
d. In this case, the target is extended, so "YES" should be selected from the "Extended" dropdown menu.
e. For the "Level 1 Type" select "Standard Target."
f. This will take you to a new page with a single dropdown menu containing all the Level 1 standard targets. Select "JUPITER" from the list.
g. Now return to the target definition page. In the "Level 2 Type" dropdown, again select "Standard Target." Note that there is an option for "Satellite," which should only be used if defining the properties of a newly discovered satellite that is not present in the "Standard Target" list.
h. This dropdown is populated with all the named satellites of Jupiter. Select "IO" from the dropdown, then return to the target definition page.
i. To define the volcano on Io's surface, we need to enter a latitude and longitude. There are two options for this in the "Level 3 Type" dropdown menu: "Planetographic" and "Planetocentric." The former is a non-spherical coordinate system that accounts for the oblateness of the body. The latter is a coordinate system defined for a body assumed to be spherical. Note that these options are only valid for objects with IAU-defined cartographic coordinates, which includes the planets and their major satellites, as well as Ceres, Pluto, and Charon.

j. Io is the most volcanically active body in the solar system due to extreme tidal heating caused by gravitational interaction with Jupiter and the other Galilean satellites. These stresses deform Io into a tri-axial ellipsoid. Thus, in order to appropriately define a position on the surface, select "Planetographic" for the "Level 3 Type."
k. This opens a new page where the only two required values are the "Longitude" and "Latitude" of the feature of interest. The Pele volcano is located at 255.3 degrees W and -18.7 degrees N. By leaving the "Altitude" box blank, APT assumes that the target is on the surface of the object, which in this case is appropriate.
l. You have now defined the Pele volcano on Io and can use it in observations. Let's now use this target to explore the "Solar System Target Windows."

3. Solar System Target Windows

We will now explore the ***Solar System Target Windows****, which are unique for moving targets. We will examine the* ***default*** *windows that are auto-generated for particular targets, typically the giant planets and their satellites, then use the* ***Visit Planner*** *to schedule a MIRI Imaging observation of the Pele volcano on Io.*

- In the tree editor, highlight the "Observations" item and select "New Observation Folder."
- In "Observation 1," fill out the "Instrument" and "Template" with "MIRI" and "MIRI Imaging", then select the Pele volcano as the "Target." (You can give the calculation a "Label" if you wish, but it is not important for this exercise.)
- For the "Subarray" select "FULL."
- Create a simple "2-Point" dither.
- Below the "Filters" box, click "Add" and select a "Filter" (any filter), the "FAST" readout pattern, 10 groups, 1 integration, 1 exposure, and "Dither 1."
- Now click on the "Solar System Target Windows" tab. You will see 5 default "Observing Windows" have been automatically generated. Two are in grey and cannot be edited or deleted; the other three can be edited and deleted.
- The two default windows start with "NOT OCCULTATION" and are auto-generated to prevent observations during a period of time when the target is not visible. In this case, the Pele volcano is the target, so the two windows exclude times when the volcano is on the opposite side of Io from JWST and when Io is behind Jupiter.
- The other three default windows can be helpful but are not always necessary and can decrease an observation's schedulability. For this observation, it is not important for the other three Galilean satellites to be a certain distance from Io. Delete these three default windows by highlighting each one and clicking the "Remove" button. Doing this will increase the schedulability of the observation.
- Now let's create a new "Observing Window." The default "NOT OCCULTATION" window that prevents the volcano from being on the unobserved side of Io does not prevent it from being on the limb of the

satellite. To ensure that the volcano is fully visible on the disk, click the "Add Observing Window…" button and select the "New Central Meridian Longitude Observing Window" option.

- A dialog box will appear with options to select. We would like the volcano to be close to the center of the satellite as viewed from JWST, so select, in order "Within," "IO," "JWST," "250," and "260." These last two options require the observation to occur when the volcano is within ~5° of the central meridian of Io. Think about why you select Io for the "Object" instead of your defined volcano target.
- Now highlight the observation and click on the "Visit Planner" icon in the top row of icons.
- Click the "Update Display" button and wait for the Visit Planner to finish running.
- When it is done running, you will see black vertical bars indicating the schedulable periods for your observation. Does the observation look overly constrained?
- Click on the "Form Editor" icon in the top row of icons.
- In the editor tree, click on the arrow to expand your observation. Below your observation should be an item called "Visit 1:1." Click on this to see the breakdown of time for your observation. Note that "3600" appears in the "Direct Scheduling Overheads" box. This indicates that your observation is constrained to occur within a 1-hour period and so incurs an additional 1-hour overhead, as per JWST policies.
- Given that Io's rotation period is 1.769 days, this means that it rotates through ~8.5° each hour. The current constraint is 10° so covers a period of time longer than 1 hour, yet still incurs the overhead. What might be going on here? If time allows, you can work through the bonus activity below to find out.

4. Bonus Activity: Comparing Constraints

a. To explore the issue with the Central Meridian Longitude constraint and the 1-hour overhead, return to your observation, click on the "Solar System Target Windows" tab, and delete the Central Meridian Longitude constraint.
b. Click on the "Special Requirements" tab, click the "Add…" button, hover your cursor over "Timing," and select the "Phase" constraint.
c. The phase constraint can be used to specify the same rotational constraint on Io, just using rotational phase instead of longitude. It also requires a few additional pieces of information.
d. The phase range is easy enough to calculate based on the longitudes specified for the previous constraint: the starting phase is 250°/360°=0.694 and the ending phase is 260°/360°=0.722. Enter these values in the first two boxes.
e. Next, enter "1.769" into the box for the "Period" and select "Days" from the dropdown menu, if it is not already selected.
f. The "Zero Phase HJD" corresponds to the heliocentric Julian date of the target at zero phase (0° longitude). For a real observation, a conversion tool

should be used to convert a standard Julian date along with the target's RA and DEC into an HJD value, but for this exercise we will choose a value that APT will accept. In this case, choose the value "2458570.0." Then click "OK."

g. Now return to the Visit Planner and click "Update Display." Then return to the "Visit 1:1" item in the tree editor to view the "Direct Scheduling Overheads."
h. You will see that the overhead has now decreased to 0 seconds, even though the "Phase" constraint is equivalent to the "Central Meridian Longitude" constraint!
i. It turns out that these two constraints, while specifying the same range of observable longitudes in different ways, operate differently in APT. While still in "Visit 1:1," note the times for "Science" and "Instrument Overheads" in seconds. If you calculate how much Io rotates in that combined amount of time and add it to the ~8.5°/hour that Io rotates through, you get a value of ~10.08°. If you were to increase the longitude range in the "Central Meridian Longitude" constraint by only 0.1°, you would find that the "Direct Scheduling Overheads" value has disappeared.
j. What is going on here is that the "Phase" constraint simply specifies when an observation should begin, while the "Central Meridian Longitude" constraint specifies the window during which the entire observation should execute. In other words, the "Central Meridian Longitude" constraint results in schedulability windows shorter than those for the "Phase" constraint by exactly the duration of the "Science" plus "Instrument Overheads." This time is subtracted off the back end of the schedulability window, with the end of the window in the Visit Planner indicating the latest time that the observation can start and still complete within the defined constraint.
k. So why ever choose the "Central Meridian Longitude" constraint over the "Phase" constraint if it is more likely to incur a 1-hour overhead? Imagine specifying an observation much longer than 56 seconds, as we have done in this example; let's say an observation lasting 2 hours. With the "Phase" constraint, your observation could begin at the very end of the phase range, with the observation executing for 2 hours *entirely outside your defined phase range*. On the other hand, the "Central Meridian Longitude" constraint ensures that the observation executes entirely within your defined range of longitudes. Ultimately, the choice of constraint comes down to the requirements for your science program.

Thank you for taking the time to explore the moving target capabilities of the APT. We hope you have enjoyed the journey!