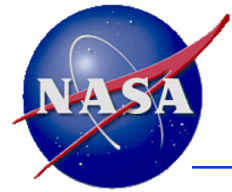


Navigation and Ancillary Information Facility

Two Easy Examples of Using WebGeocalc (WGC)

Minimum angular separation of Jupiter and Saturn as seen from Earth

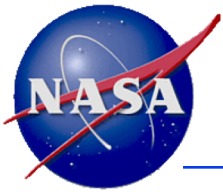
March 2018



Objective

Navigation and Ancillary Information Facility

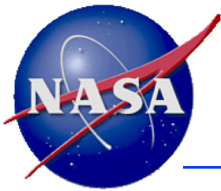
- **We start with a rather simple calculation, using two methods.**
 - We compare the results of these two methods.
- **We very briefly show a third, related kind of computation.**
- **See the document named “wgc_challenging_usage_example” for a more extensive example.**



Possible Differences

Navigation and Ancillary Information Facility

- **Your results could differ somewhat from those shown in this presentation if:**
 - the planet ephemeris used in the “solar_system_kernels” data set is different from the one used when this example was produced
 - new leap seconds have been declared and the leapseconds kernel used in the “solar_system_kernels” data set has been updated as compared to the one used when this example was produced
 - a future upgrade of the WGC server’s math libraries could result in round off of a last digit differently as compared to the round offs made when this example was produced



Getting Started

Navigation and Ancillary Information Facility

- **Open a web browser and start WebGeocalc**
 - <http://wgc.jpl.nasa.gov:8080/webgeocalc/>
- **You'll see a list of the calculations available, in three categories.**

Geometry Calculator

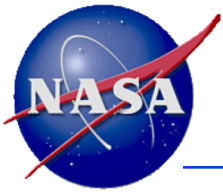
State Vector	Calculate the position and velocity of a target with respect to an observer.
Angular Separation	Calculate the angular separation between two targets as seen from an observer.
Angular Size	Calculate the angular size of a target as seen from an observer.
Frame Transformation	Calculate the transformation between two reference frames.
Illumination Angles	Calculate the emission, phase and solar incidence angles at a point on a target as seen from an observer.
Sub-solar Point	Calculate the sub-solar point on a target as seen from an observer.
Sub-observer Point	Calculate the sub-observer point on a target as seen from an observer.
Surface Intercept Point	Calculate the intercept point of a vector or vectors on a target as seen from an observer.
Orbital Elements	Calculate the osculating elements of the orbit of a target body around a central body.

Geometric Event Finder

Position Finder	Find time intervals when a coordinate of an observer-target position vector satisfies a condition.
Angular Separation Finder	Find time intervals when the angle between two bodies, as seen by an observer, satisfies a condition.
Distance Finder	Find time intervals when the distance between a target and observer satisfies a condition.
Sub-Point Finder	Find time intervals when a coordinate of the sub-observer point on a target satisfies a condition.
Occultation Finder	Find time intervals when an observer sees one target occulted by, or in transit across, another.
Surface Intercept Finder	Find time intervals when a coordinate of a surface intercept vector satisfies a condition.
Target in Field of View	Find time intervals when a target intersects the space bounded by the field-of-view of an instrument.
Ray in Field of View	Find time intervals when a specified ray is contained in the space bounded by an instrument's field-of-view.

Time Calculator

Time Conversion	Convert times from one time system or format to another.
---------------------------------	--

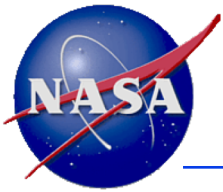


Your Problem Statement

Navigation and Ancillary Information Facility

**You wonder when will Jupiter and Saturn
come close together, as seen from Earth?**

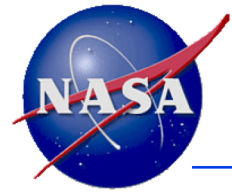
- **You could use a “Geometry Calculator” calculation, or you could use a “Geometric Event Finder” calculation.**
 - Try it both ways and then compare the results.
- **This question, using “will,” applies to the future, but it could also be computed for past times, or both.**
 - You’ll just need to ensure the data you will select for use in WGC cover the time span of interest to you.



Before Diving In...

Navigation and Ancillary Information Facility

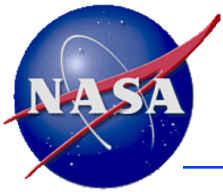
- **The “About the Data” link available on the WGC pages contains very important information about the data available to WGC. It’s a bit long but be sure to read this!**
 - “About the Data” also links to a WGC tutorial, and to a glossary of terms.
- **Some of the on-line SPICE tutorials might be helpful, especially:**
 - » **Fundamental concepts**
 - » **Conventions**
 - » **Time**
 - » **SPK**
 - » **Geometry finder**
 - These and many other SPICE tutorials are found here:
 - » <http://naif.jpl.nasa.gov/naif/tutorials.html>
 - Keep these in mind if you get stymied.



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First method

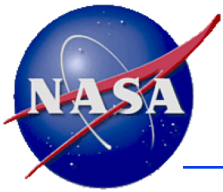
Using the Geometry Calculator



Getting Started

Navigation and Ancillary Information Facility

- Under the **Geometry Calculator** category, select the **“Angular separation”** calculation.
- Under the calculation title you’ll see a brief statement of what this calculation does:
 - “Calculate the angular separation between two targets as seen from an observer.”
- If you click on the help button to the right of this explanation  a more detailed description of the calculation will be shown, along with a graphic representation of the calculation.
 - Click on the small arrow next to the help button to close the help text and drawing.

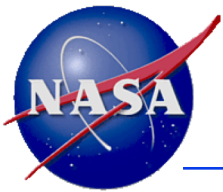


Selecting the Data

Navigation and Ancillary Information Facility

- **Since your question is not related to a mission, the generic kernels contained in the “Solar System Kernels” set should provide the needed data.**
- **Using the “Kernel selection” drop-down menu use your mouse to highlight “Solar System Kernels.”**
 - **If you hold down your cursor over the “Solar system kernels” menu item for a couple of seconds you’ll see a pop-up tool-tip display showing the time span covered by this kernel set: in this case it’s 1950 to 2050.***
- **When you release your cursor, “solar system kernels” will have been selected.**
 - **“Solar system kernels” appears in the drop down menu, and “Solar System Kernels kernel set” appears in the right-side panel entitled “Kernels Selected.”**
 - **You could hover your cursor over “Solar System Kernels” in the right side panel to again see the pop-up tool-tip showing the time period covered.**

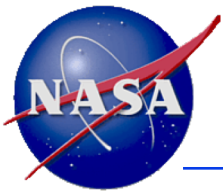
* The “Solar System Kernels” data set is a bit of a special case: the various kernels in this collection have widely varying coverage. The span 1950 to 2050 works for all kernels in this collection; some have a much longer time span.



What You've Learned So Far

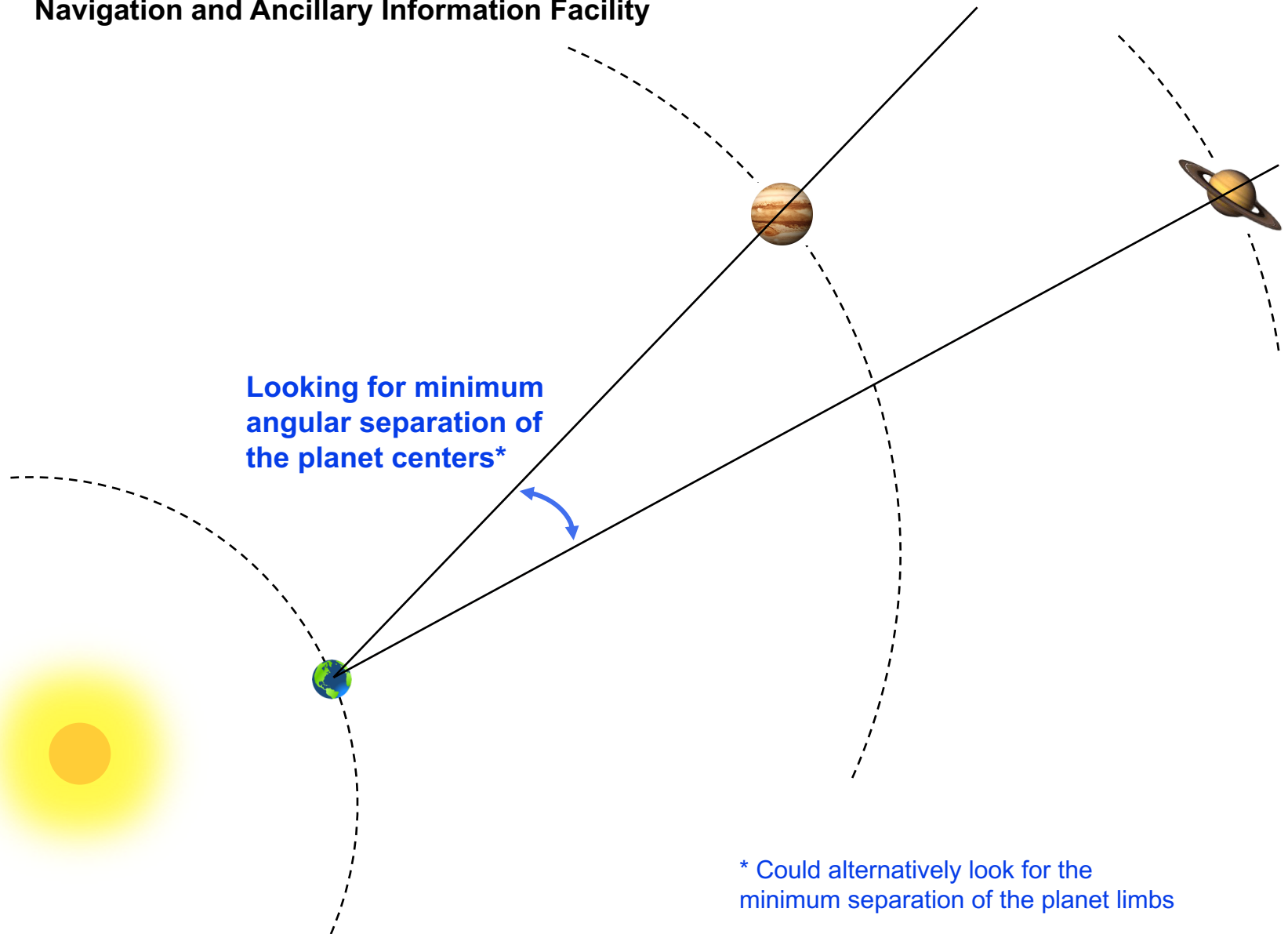
Navigation and Ancillary Information Facility

- **Three categories of calculations are available:**
 - “Geometry Calculator” (parameter value at time t)
 - “Geometric Event Finder” (time intervals when a condition is true, or when a parameter is in a specified range or has reached a min or max value)
 - “Time Calculator” (time system and time format conversions)
- **Each calculation has some expanded help text, and where appropriate, a graphic**
 - Sometimes the graphic indicates a subtle point about how the calculation works
- **Each Kernel set has an associated pop-up tool-tip, which often displays the time range of available data**
 - **Caution:** for archived mission data sets, the end time is typically several or many months in the past!

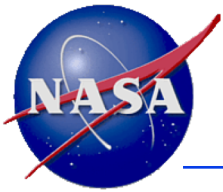


Find the Minimum Angular Separation of Jupiter and Saturn as Seen from Earth

Navigation and Ancillary Information Facility



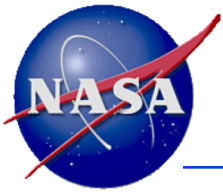
* Could alternatively look for the minimum separation of the planet limbs



Specifying Your Calculation - 1

Navigation and Ancillary Information Facility

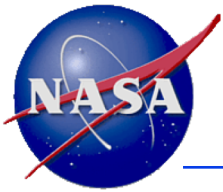
- **“Jupiter” and “Saturn” are the two targets of interest, and “Earth” is to be the observer.**
 - The SPK tutorial discusses the terms “target” and “observer.”
 - Start typing “jup...” in the “Target 1” entry box.
 - » Note: case is not important.
 - As you type more and more letters of the word “jupiter” you’ll see only names of solar system objects available in the “solar system kernels” data set that match what you’ve typed so far.
 - Once you have typed enough of “jupiter” (in this case, typing just “ju” will do it) you’ll see the item “jupiter in the drop-down box.
 - » Mouse over “jupiter” and click to select it.
 - Note: this is where you’ll need to understand the difference between “jupiter” and “jupiter barycenter.”
 - Using the radio buttons, select whether you wish Target 1 to be treated as a sphere or as a point.
 - » The associated help icon gives more information
 - » For this exercise let’s use “Point” as the shape for both target bodies
 - Later on, try using “SPHERE” as the target shapes and note the change in your results
 - Use the same approach to select “saturn” as Target 2
 - Note: it doesn’t matter which body is Target 1 and which is Target 2



Specifying Your Calculation - 2

Navigation and Ancillary Information Facility

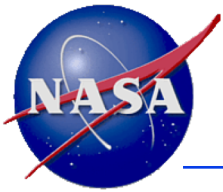
- **Specify the “observer.”**
- **Use the same approach to select the observer, Earth, as you did for the two targets.**
 - This will identify the center of the earth as the observing location.
- **Note: you could have selected a tracking station on the surface of the earth as the observer, for example NASA’s DSS-14.**
 - This would change your answer by a very small amount.
 - To do this you would have to load the “Ground Stations Kernels” set in addition to the “Solar Systems Kernels” set.



Specifying Your Calculation - 3

Navigation and Ancillary Information Facility

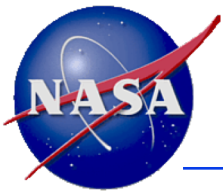
- **Select what aberration correction, if any, you'd like to be used in your calculations.**
 - Click on any of the associated help icons for more information.
 - The “Fundamental concepts” tutorial provides further information.
- **In this exercise we're just looking to get an approximation of when the angular separation of Jupiter and Saturn is at a minimum as seen from Earth.**
 - So it's safe to use “None” for corrections, thus making the calculation run a bit faster.
 - » On your own you could experiment with using various corrections to see what sort of effect this has.
 - » As mentioned on the previous page you could also try using a tracking station instead of “Earth” as the observer.



Specifying Your Calculation - 4

Navigation and Ancillary Information Facility

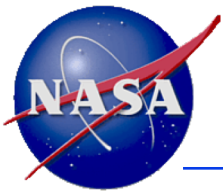
- **Enter the time span over which you wish to make the calculation; this is sometimes called the “confinement window.”**
 - **First, use the drop-down menu to indicate what time system will be used for these inputs.**
 - » **For this example let’s use UTC, which is the default.**
 - **Select “Single interval.”**
 - **Enter the Start time and Stop time using a UTC time format that SPICE (WGC) understands.**
 - » **As usual, the help icons can help a bit.**
 - » **For this example pick:**
 - **Start time: 2016 Jan 01**
 - **Stop time: 2030 Jan 01**
 - **Enter a time step size: type in the step size and select the units in the drop down menu.**
 - » **It’s often not very obvious what value to pick. Sometimes some experimentation is needed.**
 - » **Your time interval is not very long: about 15 years. On the other hand, Jupiter and Saturn don’t move very fast across the sky as seen from Earth.**
 - » **Try 1 day for starters.**



Specifying Your Calculation - 5

Navigation and Ancillary Information Facility

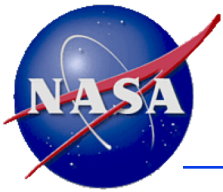
- **All required inputs have been entered.**
- **You may optionally request one or more plots be produced.**
 - **In this example you could plot angular separation as a function of time.**
 - » **Seems like a good idea: click the selection box next to the “Time series” “Angular Separation” item.**
 - **If the calculation request you’ve made returns more than a single quantity you could plot one parameter against another.**
 - » **In the case of “Angular separation,” only that one parameter is computed by WGC, so X-Y plotting cannot yield anything useful.**



“Calculate”

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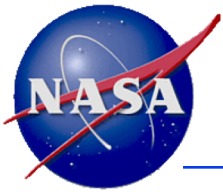
- **Press the “Calculate” button and see what happens!**
 - If you left out an input, or you provided an unusable or erroneous input, a red warning message will be displayed.
 - » In this case fix the problem and press “Calculate” again.
- **If your inputs are all acceptable, WGC will grey the screen and display a small window showing the progress of your calculation.**
- **When done, your results will be displayed below your inputs.**
 - Since you selected a time range of 14 years and there are about 365 days per year, the number of calculations made is close to:
$$(14 \times 365) + 1 = 5111 \text{ lines}$$
 - However, because there are four leap years within this range, you actually get four more lines: 5115
 - » The step number, the time of calculation and the angular separation are displayed on each line.



Your Results

Navigation and Ancillary Information Facility

- **When the calculation is completed, WGC will display:**
 - a summary of your inputs,
 - your numeric results, and
 - the optional plots you may have requested.
- **If your numeric results exceed about 14 time steps, the results will be contained in a scrollable window.**



Numeric Results

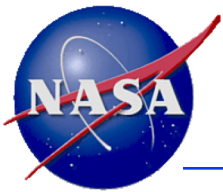
Navigation and Ancillary Information Facility

Note the scroll bar

Tabular Results

Click a value to save it for a subsequent calculation.

	UTC calendar date	Angular Separation (deg)
1	2016-01-01 00:00:00.000000 UTC	77.96587026
2	2016-01-02 00:00:00.000000 UTC	78.05280377
3	2016-01-03 00:00:00.000000 UTC	78.14228642
4	2016-01-04 00:00:00.000000 UTC	78.23431404
5	2016-01-05 00:00:00.000000 UTC	78.32886866
6	2016-01-06 00:00:00.000000 UTC	78.42595644
7	2016-01-07 00:00:00.000000 UTC	78.52555787
8	2016-01-08 00:00:00.000000 UTC	78.62766175
9	2016-01-09 00:00:00.000000 UTC	78.73225640
10	2016-01-10 00:00:00.000000 UTC	78.83931495
11	2016-01-11 00:00:00.000000 UTC	78.94881748
12	2016-01-12 00:00:00.000000 UTC	79.06072992
13	2016-01-13 00:00:00.000000 UTC	79.17504549
14	2016-01-14 00:00:00.000000 UTC	79.29172845



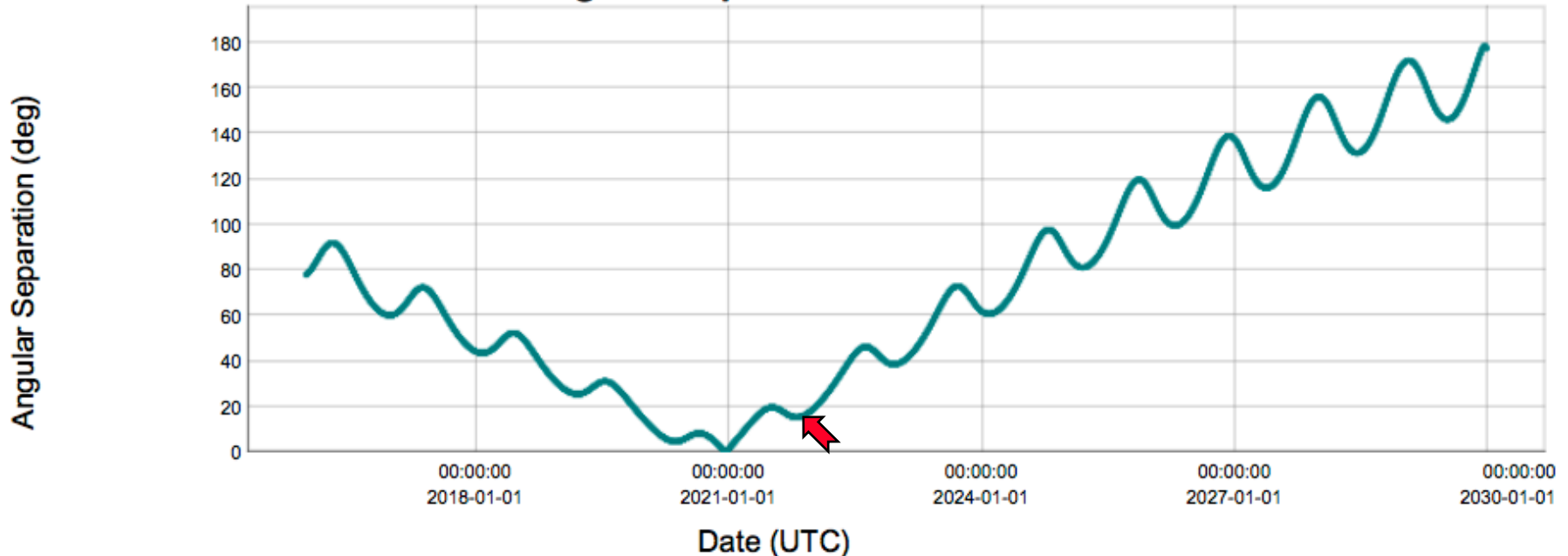
Plotted Results

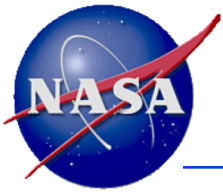
Navigation and Ancillary Information Facility

- If you hold your (**red**) cursor over any plotted point, the values will be displayed in the upper-right corner.

(2021-10-25 23:59:59.000, 15.42668390)

Angular Separation vs. Time

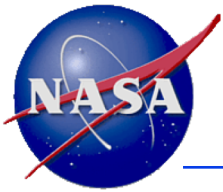




Examining Your Results

Navigation and Ancillary Information Facility

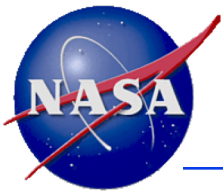
- **You can scroll through the table of numeric results to find the time of least angular separation and the corresponding separation value.**
- **You can hover your cursor over the plot to see the time and separation value at any point.**
 - **To make examination of the plot easier, you could click and drag your cursor horizontally or vertically over a portion of the plot to zoom in.**
 - » **This can be repeated multiple times.**
 - **Click “Prior zoom” to back out one zoom step.**
 - **Click “Reset Zoom” to jump back to the original plot.**



Results for This Example

Navigation and Ancillary Information Facility

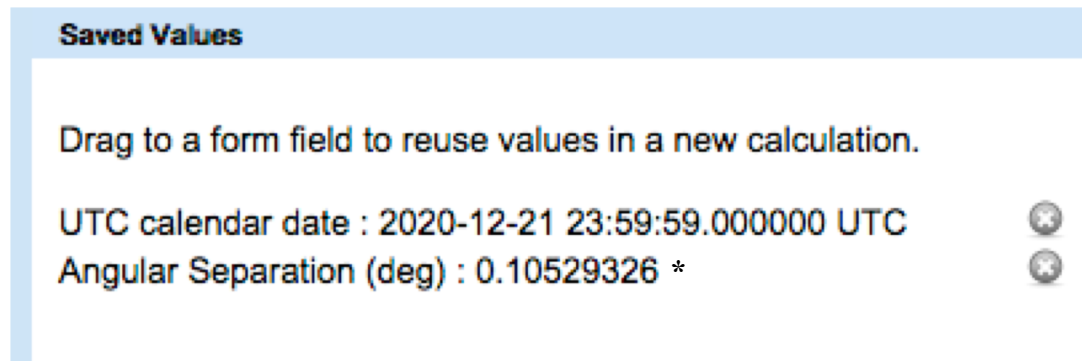
- **Using one day as the step size, you find that Jupiter and Saturn get within 0.10529326* degrees on 2020 Dec 21 23:59:59.000 UTC.**
 - This is the smallest separation appearing in the tabular results.
 - This can be seen by examining the rather large table of numeric results, or examining the plotted results.
- **If you wanted a more precise result, you could repeat the calculation over just the month of December 2020, using a ten minute step size.**
 - Now the minimum angular separation is shown as 0.10174090* degrees, occurring on 2020 Dec 21 18:10:00 UTC.
 - You could refine this still further if wanted.
- **These calculations were made treating Jupiter and Saturn as points.**
 - You might instead wish to treat them as spheres.
 - » As illustrated in the help graphic for this calculation, WGC cannot treat them as spheroids or ellipsoids.




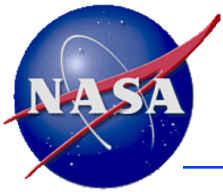
Saving Individual Numbers Inside WGC

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- You could save any individual number appearing in the table of numeric results by simply clicking on the value of interest.
 - That value will then appear in the “Saved Values” window on the right side of the WGC screen
 - For example, if you clicked on the time stamp and then the angular separation value in row number 1818 of the numeric results from this exercise, the “Saved Values” window would look something like this:



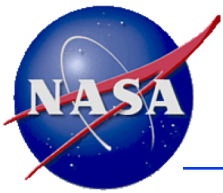
- You could later drag either of these saved values to an input field of a subsequent WGC calculation, a process called “chaining.”
 - » Clicking the  icon deletes that value from the saved results.



Downloading Output

Navigation and Ancillary Information Facility

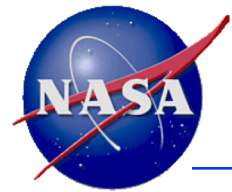
- **You can download the entire table of numeric output by clicking on the “Download Results” button appearing directly underneath the “Results” title.**
 - You’ll be given three formatting options:
 - » Excel
 - » Comma separated values
 - » Plain text
 - This option can be helpful if you wish to use the results in another application, or if you wish to include the results in a presentation or document.
- **You can download any of the optional plots by pressing the “Download Plot” button appearing just above the plots.**
 - The plots will be downloaded to your computer in PNG format, ready for inclusion in a presentation or document.



What New Things You've Learned

Navigation and Ancillary Information Facility

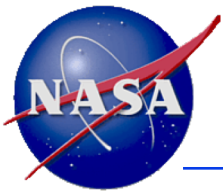
- **When a named kernel set is used, an auto-complete feature helps you pick valid objects and reference frames. (This also applies to instruments, when an instrument is involved.)**
- **Each input has associated HELP text.**
- **WGC will display an error message in red font in a red box whenever it detects a problem.**
- **The numeric results panel will contain a scroll bar if the number of lines exceeds approximately 14.**
- **Many calculations offer optional plotting, with available zoom features. Your cursor can be used to determine the coordinates for a given point.**
- **You can save numeric results for use later on.**
- **You can download plots for use elsewhere.**



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Second Method

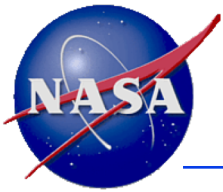
Using the Geometric Event Finder Approach



Second Method: Using the Geometric Event Finder Approach

Navigation and Ancillary Information Facility

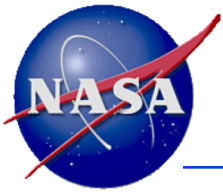
- **“Angular separation” of two objects as seen from a third is one of several computations available as both a tabulated Geometry Parameter—the computation you just made—and as a Geometric Event Finder search.**
- **Now use the Geometric Event Finder’s “Angular Separation Finder” computation to search for the time of minimum angular separation of Saturn from Jupiter as viewed from Earth.**
 - **Note: the majority of geometric event finder computations result in none, or one or more, intervals of time that meet your search criteria. But in the case of searches for maxima or minima, one or more discrete epochs in time will be found.**
- **The same kinds of help  are available for these calculations as for the Geometry Parameter calculations.**



Getting Started

Navigation and Ancillary Information Facility

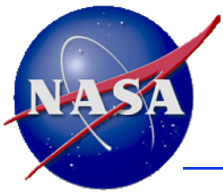
- **Click the “Calculation Menu” button at the top of your browser window to return to the WGC home page.**
- **Under the heading Geometric Event Finder click the Angular Separation Finder calculation.**
 - The input page for this calculation appears.
- **Note that a number of the inputs needed are already populated from your previous calculation.**
 - This “stickiness” feature is intended to make your job easier. But review each of these inputs to be sure no changes are needed. (“Stickiness” may not always work the way you expect.)



Specifying Your Calculation - 1

Navigation and Ancillary Information Facility

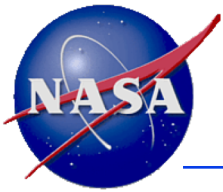
- **“Solar System Kernels” is still selected as the kernel set to be used – good.**
- **Jupiter, Saturn and Earth are still selected as the three objects to use – good.**
- **The Aberration Correction selection remains as “None” – that’s fine as long as very high precision is not needed.**
 - **Otherwise change this selection to “To observer,” use “Converged Newtonian” as the algorithm, and leave the “Include stellar aberration correction” box checked.**



Specifying Your Calculation - 2

Navigation and Ancillary Information Facility

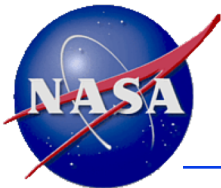
- **The Time system selection remains set to the default – UTC.**
- **Your single time interval used previously is still selected: 2016 JAN 01 to 2030 JAN 01.**
 - (This is called the “confinement window” in Geometry Finder terminology.)
- **The time step is still 1 day.**
 - Selecting the “right” time step for Geometry Finder calculations requires some thought, or trial-and-error.
 - » If too large, you might miss an event or a min or max.
 - » If too small, your calculation may take a long time, and thus likely be rejected by WGC.
 - » In any case, this selection will *NOT* affect the accuracy of any events found.
 - Let’s leave the step size set to one day for now; that seems a reasonable number.



Specifying Your Calculation - 3

Navigation and Ancillary Information Facility

- **What Event Condition will you search for?**
 - For this example you want to select “global minimum.”
 - Ignore use of “Adjustment value” for this simple search.
- **Since your search is intended to find a single epoch—not time intervals—you can ignore the “Output time units” selection since the interval length will be zero.**
- **Similarly you can ignore the remaining “Result Window” selections as these are also not applicable to answers that are discrete epochs.**



“Calculate”

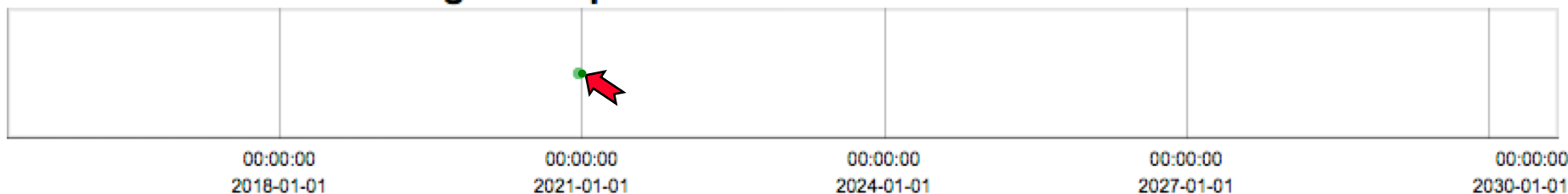
Navigation and Ancillary Information Facility

- Press the “Calculate” button and see what is returned.
 - As expected for a “maximum” or “minimum” search, the “Results” panel returns a single epoch, indicated by the Start and Stop times having the same value, and the Duration having a value of zero.

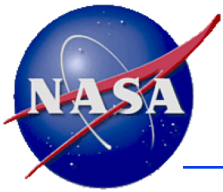
	Start Time	Stop Time	Duration (secs)
1	2020-12-21 18:11:13.895342 UTC	2020-12-21 18:11:13.895342 UTC	0.00000000E+00

- In addition to the “numeric” result above, you also see an event finder “plot” showing your results plotted on a timeline whose length is set by the Start and Stop times—the “confinement window”—you supplied as inputs. The “answer” is shown by the green dot. If you hover your **cursor** over this dot as shown below, WGC will display its **time tag**. (Since you were searching for a minimum, the interval start and stop times are identical.)

Angular Separation Finder Time Interval Plot 2020-12-21 18:11:13.895*



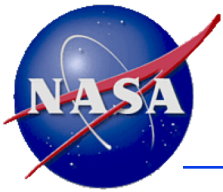
*Will change if/when new leap seconds occur



Zooming, Saving and Downloading

Navigation and Ancillary Information Facility

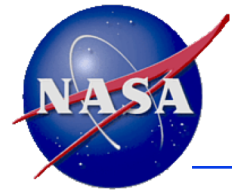
- **You may zoom in and out.**
 - To make examination of the plot easier, you could click and drag your cursor horizontally over a portion of the plot to enlarge the plot. (Vertical zoom doesn't accomplish anything.)
 - This can be repeated multiple times to gain further expansion.
 - » Click "Prior zoom" to back out one zoom step.
 - » Click "Reset Zoom" to jump back to the original plot.
- **You may save results for use in subsequent calculations.**
 - Save individual values to the "Saved Values" panel by clicking on any individual value.
 - Save the full set of intervals resulting from your calculation by clicking the "Save All Intervals" button.
- **You may download the time interval "plot" by clicking the "Download Plot" button.**
- **You may download the full set of intervals by clicking the "Download results" button found under the "Results" heading.**



Compare the Two Approaches

Navigation and Ancillary Information Facility

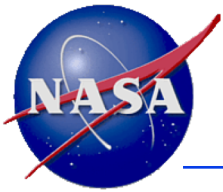
- **You obtained different answers!**
 - Minimum observed angular separation using the Geometry Parameter approach:
 - » 2020 Dec 21 23:59:59, using a one day step size, or...
 - » 2020 Dec 21 18:10:00, using a ten minute step size
 - Minimum calculated angular separation using the Geometric Event Finder approach:
 - » 2020 Dec 21 18:11:13.895
- **The second approach, Geometric Event Finder, is more accurate than the first.**
 - The answer obtained using the first approach, manual review of a Geometry Parameter computation, could be refined further by using a still smaller interval and smaller step size.
 - » Try this to see if you can more closely match the Geometric Event Finder result.



Other Differences

Navigation and Ancillary Information Facility

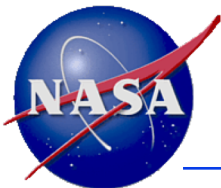
- **The first approach was (at least without doing iterations) less accurate in terms of finding the exact time of minimum separation.**
 - But the first method also allowed you to see the actual angular separation values.
- **The second method provided the greatest accuracy, given use of a sensible step size.**
 - But it did not show what the actual separation angle was at the time of minimum separation.
- **One could save the answer (the epoch) from the second approach and use it as the single input time in the Angular Separation calculation.**
 - The minimum separation determined this way is 0.10174086 deg.



A Related Calculation

Navigation and Ancillary Information Facility

- **The first calculation you made used the Geometric Parameter's Angular Separation selection.**
- **The second calculation you made used the Geometric Event Finder's Angular Separation Finder, searching for a global minimum.**
- **You might, instead, have searched for time intervals when the angular separation of Jupiter and Saturn as seen from Earth is less than some value – say, 5 degrees. See the next page.**



A Search Resulting in Multiple Intervals

Navigation and Ancillary Information Facility

- **Within the confinement window of 2016-JAN-01 to 2030-JAN-01, when is the separation of Jupiter and Saturn as seen from Earth less than 5 degrees?**
 - Again, for this exercise let's treat Jupiter and Saturn as points, not spheres.
 - Request the output time units to be in days since the durations will be rather long.

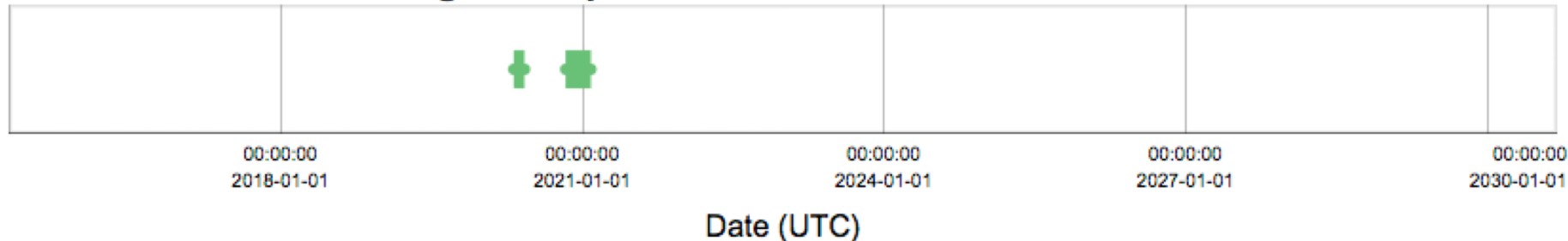
Tabular Results

Click a value to save it for a subsequent calculation.

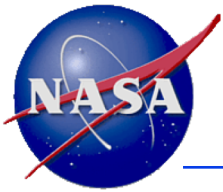
Save All Intervals

	Start Time	Stop Time	Duration (days) *
1	2020-04-28 05:25:18.468194 UTC	2020-06-07 00:58:04.397760 UTC	39.81442048
2	2020-11-02 23:39:51.801164 UTC	2021-02-02 19:21:50.177766 UTC	91.82081454

Angular Separation Finder Time Interval Plot



*Will change if/when new leap seconds occur



What More You Have Learned

Navigation and Ancillary Information Facility

- **It can be helpful to use the results—the output time intervals—of one Geometric Event Finder search for use as the constraints on a second search, a process called cascading searches.**
- **Picking a good step size for a Geometric Event Finder search often takes some thought, and perhaps some experimentation.**
- **There may be more than one way to use WGC to get the results you are looking for.**