

# WEBGEOCALC: WEB INTERFACE TO SPICE

*Boris Semenov<sup>1</sup>, Charles Acton<sup>1</sup>, Nathaniel Bachman<sup>1</sup>, Mark Rose<sup>2</sup>, Edward Wright<sup>1</sup>*

<sup>1</sup>Jet Propulsion Laboratory/California Institute of Technology

<sup>2</sup>Ames Research Center/National Aeronautics and Space Administration

## ABSTRACT

The WebGeocalc tool (WGC) provides a web-based graphical user interface to many of the observation geometry calculations available from the “SPICE” system. WGC is based on client-server architecture. A user selects calculation parameters using GUI widgets in a Web browser. The request is sent to a WGC geometry server that performs the calculation and sends results back to the client. WGC can compute various geometric parameters such as positions, orientations, and surface intercept coordinates for a series of times; perform geometric event searches for time intervals when a geometric condition is met; and perform time conversions. WGC offers many features such as plotting and downloading results. Currently only the NAIF group at JPL operates a WGC server that has access to all data on the NAIF web site but WGC can be deployed on any computer that has Java, Apache Tomcat server, MySQL Community Server, and SPICE data.

## 1. INTRODUCTION

WGC provides a Graphical User Interface (GUI) front end to a SPICE server running a geometry computation engine. WGC makes it “easy” to do many kinds of SPICE computations. Users don’t need to write a program using SPICE Toolkit software and instead just use a web browser to enter inputs into forms and have results, including plots, appear in the browser window.

WGC can support planetary mission science and engineering in several ways:

- help a user check his/her own SPICE-based program under development
- help a user quickly solve a one-time space geometry problem
- allow those unable to write a SPICE-based program to nevertheless make some kinds of space geometry computations
- help a science data peer reviewer do spot checks of geometry parameters contained in an archive about to be submitted to an archive center

WGC uses client-server architecture. The user only needs a computer running a web browser. The browser connects via Internet to a WGC “computation engine”

running on a server and having access to a variety of SPICE kernel files.

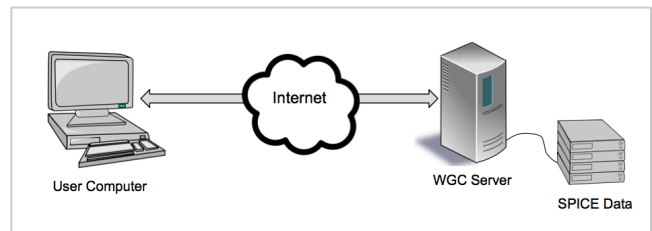


Fig 1. WGC architecture

## 2. SUPPORTED CALCULATIONS

WGC provides calculations in the following three categories: “Geometry Calculator” – compute various geometric parameters such as positions, orientations, and surface intercept coordinates for a single time or a series of times; “Geometry Finder” – perform geometric event searches for time intervals when a geometric parameter has a particular value or when a geometric condition is met; “Time Conversion” – convert time from one time system/format to a different time system/format.

### 2.1. Geometry Calculator calculations

WGC currently provides the following calculations in the “Geometry Calculator” category:

State Vector	Calculate the position and velocity of a target body with respect to an observer in specified reference frame
Angular Separation	Calculate the angular separation between two targets as seen from an observer, with targets modeled as points or spheres
Angular Size	Calculate the angular size of a target modeled as a sphere as seen from an observer
Frame Transformation	Calculate the transformation between two reference frames and output it as Euler angles, quaternions, or matrices

Illumination Angles	Calculate the emission, phase and solar incidence angles (illumination angles) at a specified point on a target body modeled as an ellipsoid as seen from an observer
Sub-solar Point	Calculate the sub-solar point on a target body modeled as an ellipsoid as seen from an observer, and illumination angles at that point
Sub-observer Point	Calculate the sub-observer point on a target body modeled as an ellipsoid as seen from an observer, and illumination angles at that point
Surface Intercept Point	Calculate the intercept point of a view vector or vectors on a target body modeled as an ellipsoid as seen from an observer, and illumination angles at that point
Orbital Elements	Calculate the osculating elements of the orbit of an orbiting body around a central body based on instantaneous state vectors and central body GM

All quantities in the “Geometry Calculator” calculation set can be computed at a single time, a set of times spaced with a fixed step within a single time interval, a set of user specified discrete times, or a set of times spaced with a fixed step within multiple intervals, specified in a variety of time systems – UTC, TDB, etc. In all calculations except “Orbital Elements” output quantities can be computed with light time and stellar corrections. In all calculations where outputs are position or velocity vectors – “State Vector”, “Sub-solar Point”, “Sub-observer Point”, “Surface Intercept Point” – outputs can be expressed in one of many supported coordinate systems – rectangular, planetocentric, cylindrical, etc.

## 2.2. Geometry Finder calculations

WGC provides the following calculations in the “Geometry Finder” category:

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, modeled as points or spheres, 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 modeled as an ellipsoid satisfies a condition
Occultation Finder	Find time intervals when an observer sees one target occulted by, or in transit across, another, with both targets modeled as points or ellipsoids
Surface Intercept Finder	Find time intervals when a coordinate of a surface intercept point of a view vector with the surface of a body modeled as an ellipsoid satisfies a condition
Target in Field of View	Find time intervals when a target modeled as a point or an ellipsoid 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

For calculations in the “Geometry Finder” set, intervals when the specified condition is satisfied can be found within a single time interval or a set of multiple time intervals, specified in a variety of time systems – UTC, TDB, etc. In calculations where searches involve specifying constraints on a geometric parameter – all except “Occultation Finder”, “Target in Field of View”, and “Ray in Field of View”, – the set of available constraints includes equality, greater than, less than, in range, and local and global maxima and minima. In all calculations where the search criteria is set for a particular coordinate – “Position Finder”, “Sub-point Finder”, “Surface Intercept Finder” – this coordinate can be any coordinate applicable to any of the supported coordinate systems, for example “X” for rectangular coordinates or “R” for planetocentric coordinates. In all calculations the resulting intervals can be determined taking light time and stellar corrections into account. The view vector(s) specified for the “Surface Intercept Finder” and “Ray in Field of View” can be specific directions associated with an instrument or arbitrary vectors in any supported reference frame. Output intervals returned by all “Geometry Finder” calculations can be altered to get their complements, be contracted or expanded, and filtered.

## 2.3. Time Calculator calculations

The “Time Conversion” category includes a single calculation converting times from one of the time systems supported in SPICE – UTC, TDB, TDT, or Spacecraft Clock (SCLK) – expressed as calendar dates, Julian dates or

seconds past J2000, to another of the time systems and formats supported in SPICE. The times provided on the input can be a single time, a set of times spaced with a fixed step within a single time interval, a set of discrete times, or a set of times spaced with a fixed step within multiple intervals. Where applicable the user can specify a custom output time format using the SPICE output time format specification notation.

### 3. WGC CLENT INTERFACE FEATURES

The WGC web client user interface is split into four areas – “top”, “left”, “right-middle”, and “right-bottom”. The “top” area does not change and always contains the WGC name and version, the “Calculation Menu” button returning users to the WGC front page, and links to the data description, WGC overview, WGC rules of use, and feedback pages. The “left” area shows either links to available calculations (on the WGC front page) or shows input parameter widgets and output results tables and plots (on a particular calculation page). The “right-middle” area titled “Saved Values” shows output values that the user specifically saved by clicking a value in an output results table or by clicking the “Save All Intervals” button in any “Geometry Finder” calculation results. The “right-bottom” area titled “Kernels Selected” shows the kernel sets and kernels that the user selected via the “Kernel Selection” widget. The sizes of all areas except the “top” area can be adjusted by dragging separators between them. All areas except the “top” area are scrollable in horizontal and vertical directions.

#### 3.1. Front page

The WGC front page contains links to all available calculations, arranged into three categories.

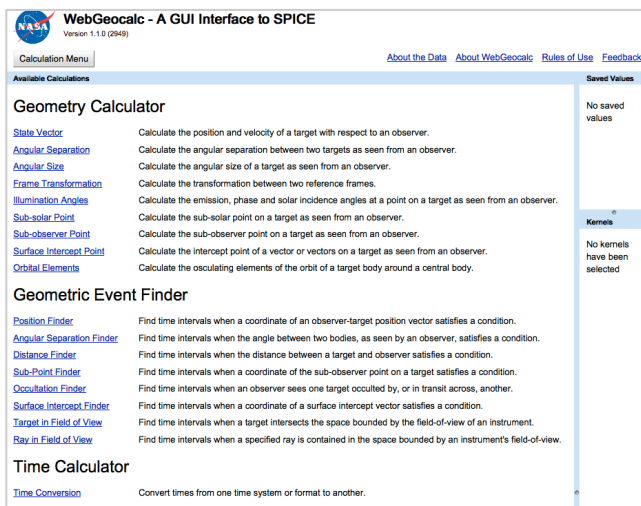


Fig 2. WGC front page

Users can return to the front page at any time by clicking the “Calculation Menu” button in the “top” area.

#### 3.2. Calculation pages

Clicking the name of a particular calculation on the front page displays the input parameters widgets specific for that calculation in the “left” area, which changes title to “Calculation” and acts as the calculation inputs and results panel while leaving what’s shown in all other areas unchanged. The set of input widgets and fields varies depending on the calculation, with many widgets appearing and acting in the same way on all or most panels. All calculation panels have the “Calculate” button at the bottom; pressing this button after all necessary inputs are filled in starts the calculation.

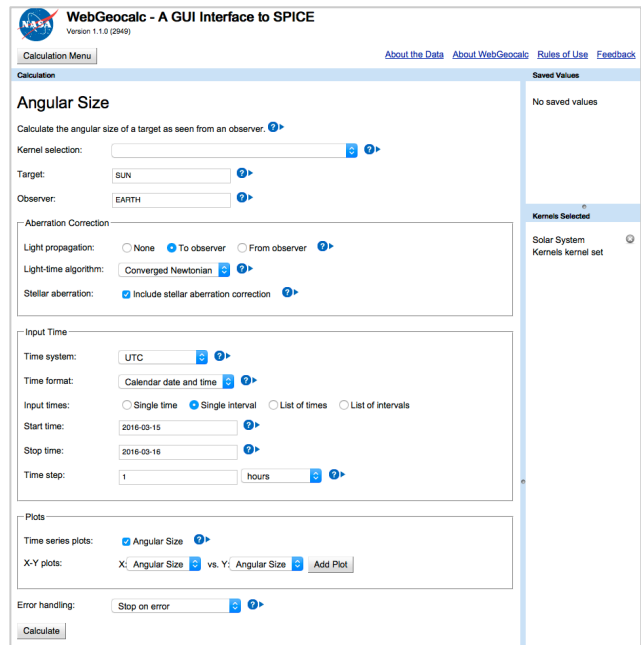


Fig 3. Calculation panel example

#### 3.3. Input parameter widgets and selectors

The following widgets and selectors are used to specify input parameters for calculations (in the left column, actual widget-selector names are shown in double quotes; the names without quotes indicate broad widget-selector categories):

“Kernel selection”	Selects kernels needed to perform calculation
Body selectors	Specifies bodies – planets, satellites, spacecraft, etc. – that act as targets and observers in the calculation.
“Target”	

“Target 1” “Target 2” “Orbiting object” “Front Body” “Back Body” “Observer”	Bodies are specified by typing their valid SPICE names or NAIF ID codes into the text fields. Specification of bodies is greatly simplified with the autocomplete feature available when named kernels sets containing data for bodies of interest are selected first
Frame selectors “Frame 1” “Frame 2” “Front body frame” “Back Body frame”	Specifies reference frames in which output parameters are to be computed or which should be used as body-fixed frames for targets with ellipsoidal shapes. Frames are specified by typing their valid SPICE names into the text fields. Specification of frames is greatly simplified with the autocomplete feature available when named kernels sets contain data for the frames of interest are selected first.
Body Shape selectors “Target 1 shape” “Target 2 shape” “Front body shape” “Back body shape”	Selects the body shape to be used in the calculation – point, sphere, or ellipsoid
Vector specification selectors “Coordinate System” “Latitude” “Longitude” “Intercept vector”	Specifies latitudinal coordinates for the position of the point of interest on the surface of the body at which to compute illumination angles or specifies the view direction vector(s) for which the surface intercept location computation or search for in Field-of-View condition is performed. The view direction vectors can be specified as instruments principal vectors (boresight, FOV boundary vectors) or arbitrary vectors in any reference frame
“Sub-point type”	Selects the sub-point type – near point on ellipsoid or intercept point on ellipsoid
“Occultation type”	Selects the occultation type – any, full, annular, or partial
“Aberration correction”	Selects aberration corrections to used in a calculation
“Input time”	Sets times or times interval for

	calculation
Search condition selectors “Coordinate condition” “Event condition”	In “Geometry Finder” calculations, sets search criteria such as conditions on individual coordinates or non-coordinate parameters, by specifying the parameter to be constrained and the constraint – equal to, greater then, less then, in range, local or global maxima or minima, and as a special case longitude-latitude coordinates, longitude-latitude box.
Output representation selectors “State representation” “Position representation”, “Orientation representation” “Angular velocity representation”	In some “Geometry Calculator” calculations, selects the coordinate system for output state vectors or position vectors, or the representation for orientation and angular velocity. For state and position vectors the supported coordinate systems include rectangular, RA/Dec/Range, planetocentric (latitudinal), planetodetic, planetographic, cylindrical, and spherical. For orientations the supported representations include Euler angles, quaternions, and matrices. For angular velocities the supported representations include Euler angle derivatives and vectors.
“Plots”	In “Geometry Calculator” calculations, selects optional plots
“Error handling”	In “Geometry Calculator” calculations, chooses action to be taken for error conditions
“Result window”	In “Geometry Finder” calculations, alters the result interval sets returned by the calculation

The “Kernel Selection”, “Input Time”, “Aberration correction”, “Plots”, “Error handling” and “Result window” widgets are described in more detail in subsequent subsections.

### 3.3. Kernel selection widget


The “Kernel Selection” widget appearing at the top of each calculation panel is used to select SPICE kernels sets and individual SPICE kernels. One or more kernel sets or

kernels containing data needed to support the calculation must be selected in order to perform a calculation.

The pull down “Kernel Selection” menu shows all “named” kernel sets that were pre-configured on the server side by the WGC administrator, as well as the “Manual” option at the very bottom. Clicking a particular kernel set selects it and makes it appear in the “bottom-right” “Kernels selected” area. Hovering the cursor over a kernel set name in the drop down menu or in the “Kernels selected” area brings up a floating box with a brief description of the kernel set. Clicking “Manual” shows the “Choose kernel” button on the right of the menu; clicking this button brings up a file browser window from which individual kernels or meta-kernels available for manual selection on the WGC server can be picked.

As many kernel sets and individual kernels as needed may be selected by sequentially picking them from the menu or the file browser. All selected kernels and kernel sets will appear in the order in which they were selected in the “bottom-right” “Kernels selected” area. Any of them can be removed from selection by clicking the “x” button on the right of their names. The kernel selection made on any calculation panel persists if the user switches to a different calculation panel.

### 3.4. Input Time widget

The “Input Time” widget present on all calculation panels is used to specify times (in “Geometry Calculator” and “Time Conversion” calculations) or time intervals (in “Geometry Finder” calculations) for which the calculation is to be done. With this widget users can specify the time system – UTC, TDB, TDT, or SCLK – and format – Calendar, Julian Date, or Seconds past J2000, or String or Ticks for SCLK – in which the times are given, select whether a single or multiple input times or time intervals are provided, set units for the time step, and type in the input time(s) and step. It is essential for the user to be aware of the formats in which times and time intervals for various time systems and formats selections should be specified. Examples of allowed formats are provided in the context help associated with this widget accessible by clicking the  buttons appearing to the right of widget fields.

### 3.5. Aberration correction widget

The “Aberration Correction” widget appearing on all calculation panels dealing with computing observation geometry parameters or performing searches with constraints on such parameters is used to specify whether computed geometry should be corrected for delays due to light traveling to or from the observer (light time correction) and the change in the light direction due to the observer

motion with respect to the solar system barycenter (stellar aberration). In this widget users can specify whether to compute pure geometric quantities (“None”) or to do corrections for light travelling to or from the observer, using one of the two algorithms supported in SPICE, and for stellar aberration.

### 3.6. Plots widget

The “Plots” widget appearing near the bottom of all “Geometry Calculator” calculation panels is used to select which of the output parameters computed by the calculation should be plotted. Time series plots can be chosen by simply checking the check box next to the parameter name. An X-Y plot of any output parameter against any other output parameter can be chosen by selecting two parameters in the menus and clicking the “Add plot” button.

### 3.7. Error handling selector

The “Error handling” selector appearing right above the “Calculate” button on all “Geometry Calculator” calculation panels is used to control what WGC does when it encounters an error such as lack of necessary SPICE data. The default selection is “Stop on error”, in which case upon encountering an error at any time step WGC returns no results or plots and will simply display the SPICE error message at the top of the “left” area. In many cases when errors are caused by small gaps in otherwise complete SPICE data and it is desirable to compute results at all times when it’s possible, users can select either “Report error and continue” or “Silently omit errors”. With the “Report error and continue” selection the output result table contains computed results for all times when the computation succeeded and a SPICE error message when it did not. With the “Silently omit errors” selection the output result table contains only computed results for all times when the computation succeeded. In both cases requested plots will show only successfully computed points.

### 3.8. Result Window widget

The “Result Window” widget appearing right above the “Calculate” button on all “Geometry Finder” calculation panels can be used to alter computed intervals when the condition is met in a number of ways. With this widget users can choose the units for the interval durations, request to return the intervals that complement computed intervals instead (i.e. intervals when specified condition is not met), have intervals contracted (ends adjusted inward) or expanded (ends adjusted outward) by the specified time delta, and have intervals with duration shorter than the specified value be excluded (filtered out) from the output.

## 4. RESULTS DISPLAY FEATURES

Once all inputs are filled in and the “Calculate” button is clicked the calculation request is sent to the server, which performs the calculation and sends results back to the client. The results are displayed in the “left” area below the “Calculate” button with all input widgets keeping their filled-in/selected values to allow making quick changes and repeating the calculation if necessary. The results consist of a header echoing all inputs provided to the calculation, a table with numeric values of all parameters computed by the calculation, any optionally selected plots, and the list of meta-kernels and kernels used to perform the calculation.

### 4.1. Tabular results

The tabular results are shown in a table scrollable in the vertical and horizontal directions with the row numbers appearing on the left. The set of output parameters included in the table is fixed for a particular calculation. The header of the table shows the names of the calculated parameters and their units. Clicking any value in the table saves that value in the “right-middle” area titled “Saved Values”.

Tabular Results		
Click a value to save it for a subsequent calculation.		
	UTC calendar date	Angular Size (deg)
1	2016-03-15 00:00:00.000000 UTC	0.53608444
2	2016-03-15 01:00:00.000000 UTC	0.53607845
3	2016-03-15 02:00:00.000000 UTC	0.53607247
4	2016-03-15 03:00:00.000000 UTC	0.53606648
5	2016-03-15 04:00:00.000000 UTC	0.53606050
6	2016-03-15 05:00:00.000000 UTC	0.53605451
7	2016-03-15 06:00:00.000000 UTC	0.53604852
8	2016-03-15 07:00:00.000000 UTC	0.53604253
9	2016-03-15 08:00:00.000000 UTC	0.53603653
10	2016-03-15 09:00:00.000000 UTC	0.53603054
11	2016-03-15 10:00:00.000000 UTC	0.53602455
12	2016-03-15 11:00:00.000000 UTC	0.53601855
13	2016-03-15 12:00:00.000000 UTC	0.53601255

Fig 4. Output table example

### 4.2. Plots

Any time series or X-Y plots optionally selected in “Geometry Calculator” calculations, or the time intervals plot always generated by “Geometry Finder” calculations, appear under the tabular results. Each plot appears in its own plot area with X and Y axis labels indicating parameters and their units. The plots are interactive and can be zoomed in both the horizontal and vertical directions by dragging left-right and top-down. Clicking the “Prior zoom” and “Reset Zoom” buttons above a plot returns the zoom to the previous and initial zoom levels, respectively. Hovering the cursor over a plot highlights the point nearest to the cursor and shows the X and Y values for that point on the right above the plot.

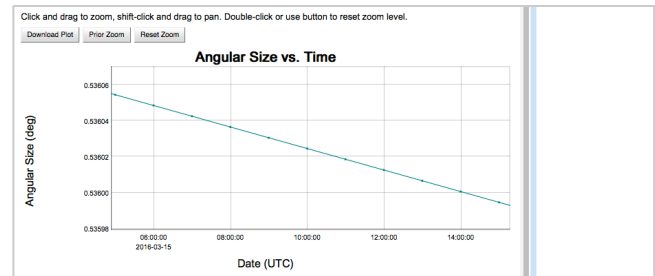


Fig 5. Time series plot example

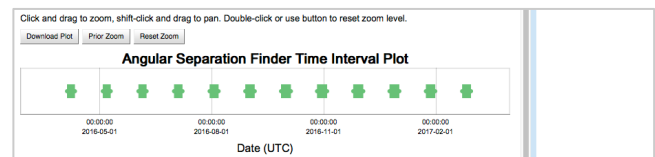


Fig 6. Time intervals plot example

### 4.3. Downloading results and plots

Both tabular results and plots can be downloaded to the user’s computer.

Users can download tabular results by clicking the “Download results” button appearing at the top of the results area. Clicking this button brings up a dialog allowing selection of one of the supported download formats – MS Excel, CSV, or plain text. After clicking “Download” in that dialog the file is downloaded to the user’s computer according to the download preferences set in the browser, sometimes bringing up another dialog allowing one to pick the download location and change the file name. In all cases in addition to the tabular results the downloaded files include complete information about inputs provided to the calculation and kernels used in the calculation.

Users can download any plot by clicking the “Download plot” button on the left above the plot. The plot image file is downloaded in PNG format with transparent background. The download dialog will depend on the preferences set in the browser, in some cases allowing one to pick the download location and change the file name, or opening the image in an image viewer application.

### 4.4. Saving results for use in other calculations

Any value appearing in the output result table of any calculation, or the complete set of intervals returned by a “Geometry Finder” calculation can be saved for use in subsequent calculations. Individual values from the results table are saved by simply clicking on them. The complete set of intervals is saved by clicking the “Save All Intervals” button appearing above the intervals table. All saved values appear in the “right-middle” area titled “Saved Values”.

	Start Time	Stop Time	Duration (secs)
1	2016-04-04 04:39:05.683908 UTC	2016-04-10 16:40:30.478376 UTC	561684.79446805
2	2016-05-03 13:49:08.854925 UTC	2016-05-10 02:07:12.781693 UTC	562683.92676818
3	2016-06-01 20:46:41.646610 UTC	2016-06-08 13:08:08.296367 UTC	577286.64975655
4	2016-07-01 02:25:47.466449 UTC	2016-07-08 02:10:18.304042 UTC	603870.83759362
5	2016-07-30 07:58:54.025547 UTC	2016-08-06 17:13:44.192865 UTC	638090.16731817

Fig 7. Saved intervals example

## 5. ADDITIONAL FEATURES

The WGC user interface includes many additional features facilitating easy and efficient use. These features include autocomplete in the type-in fields, persistence of filled-in input values and results, input parameter cross-initialization for similar fields in different calculation panels, using saved results as input for subsequent calculations, calculation queuing and progress reporting, and comprehensive context help for calculations and widgets.

### 5.1. Input auto-complete

Selecting any named kernel set in the “Kernel Selection” widget enables the WGC type-in field autocomplete feature in all body selector and frame selector widgets for all bodies and frames for which data is present in the selected data set. When the user starts typing a string in the type-in field of any of these widgets WGC brings up a pull down menu with SPICE body or frame names in which the string is present, allowing users to select the desired body or frame from the list rather than remembering and typing in its complete name. Simply typing a blank brings up a menu with all bodies available for autocomplete for the field. If more than one “named” kernel set is selected, the combined set of bodies and frames from all selected kernel sets is available for autocomplete.

Autocomplete is not available for bodies and frames from manually selected kernels unless they are also present in one of the selected “named” kernel sets. When bodies or frames of interest are not present in the autocomplete lists, the valid SPICE body names (or NAIF IDs) and SPICE frame names can be typed into the fields to be used as input parameters for a calculation.

### 5.2. Inputs and results persistence

Any inputs filled-in or selected in a calculation panel and any results returned by a successful calculation stay on the calculation panel when the user switches to a different panel or the front page and then returns back. This persistence makes it very easy to switch between calculations without losing any already filled-in/selected inputs – which greatly facilitates repeating a calculation with slightly changed input parameters or with a different set of selected kernels, –

and switching between calculations to examine numeric results and plots returned by them.

Similarly, the “named” kernel sets and manually picked kernels selected for a calculation persist and can be used for all calculations in a WGC session.

### 5.3. Input parameter cross-initialization

When the user selects an input parameter that is common to many different calculations – for example the names of the target body and the observing spacecraft, – on one of the calculation panels these names are automatically assigned to all uninitialized fields with the same meaning on all other calculations, eliminating the need to select/type-in the same values multiple times. This feature makes setting up inputs for a given mission in more than one calculation panel much more efficient. This initialization applies only to not yet initialized fields and does not affect similar fields in other calculations that the user deliberately set earlier.

### 5.4. Using saved results

Any saved values – scalars and lists of intervals – appearing in the “right-middle” area titled “Saved Values” can be dragged-n-dropped into any type-in input field to be used as input in a different calculation. This feature is very powerful as it allows using interval sets returned by a “Geometry Finder” calculation as input to any other calculation.

Using interval sets returned by a “Geometry Finder” calculation as input for the same or another “Geometry Finder” calculation facilitates sequential searches for multiple conditions in which the next condition is searched for in the set of intervals that satisfy a previous condition. For example, searching for intervals when a spacecraft orbiting Mars is in a particular ground station view can be done by first searching for the spacecraft to have positive declination in the ground station’s topocentric frame using the “Position Finder” calculation, saving all output intervals, switching to the “Occultation Event Finder” computation, selecting the “List of Intervals” check box in the “Input Time” widget, drag-n-dropping saved intervals from the “Saved Results” area into the “List of Intervals” input area, and searching for occultations of the spacecraft by Mars as seen from the station during the saved intervals (when the spacecraft is above station’s horizon) while selecting the complement (for not occulted) for output intervals.

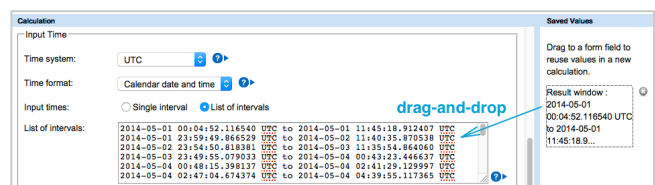


Fig 8. Saved interval use example

## 6. WGC AT NAIF

Similarly, saved interval sets returned by a “Geometry Finder” calculation can be used as input for the time domain for any “Geometric Calculator” calculations to compute parameters of interest only during the times when a particular condition was met.

### 5.5. Queuing, progress reporting, and cancelling

The WGC server queues calculations submitted by multiple GUI clients into a single sequential queue and reports back to the clients their calculation’s position in the queue as well the calculation progress in terms of which calculation step is being performed and, if applicable, the completed percentage for a given step. The report is shown in a small window that appears after the “Calculate” button is clicked, while the rest of the WGC client GUI becomes inactive. The progress window includes a “Cancel” button that can be clicked at any time to cancel the calculation.

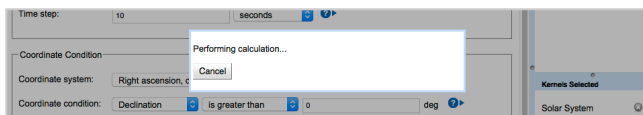



Fig 9. Progress window example

### 5.6. Built-in help

In each calculation panel the WGC GUI interface provides help information describing the calculation itself and each of the calculation widget input fields. Clicking the  icon located to the right of the fields makes help information, that includes brief descriptions, input examples, and in some cases links to additional detailed information, appear under the field. The help information can be hidden by clicking the symbol again.

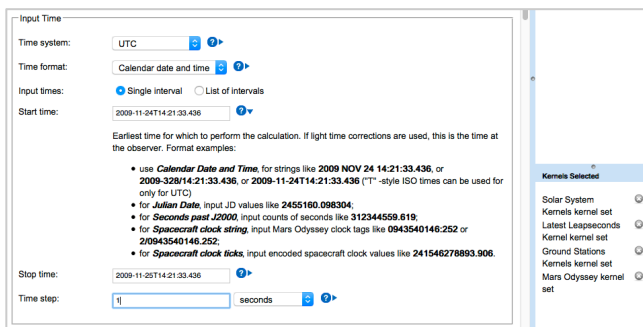


Fig 10. Context help example

The NAIF group at JPL currently operates a publicly accessible WGC server that has access to all generic kernels, archived planetary mission kernels, and recent mission kernels available on the public NAIF web server. The URL for WGC running on the NAIF server is:

<http://naif.jpl.nasa.gov/naif/webgeocalc.html>

The “About the Data” page linked at the top right of NAIF’s WGC provides important detailed information about all named kernel sets as well as about categories of kernels available for manual loading into WGC.

### 6.1. Generic kernel sets

The generic kernels sets available to NAIF’s WGC and appearing at the top of the “Kernel selection” dropdown menu include:

Solar System Kernels	The latest JPL planet and satellite ephemerides, earth high precision orientation and allied reference frame specifications, high precision moon orientation and associated reference frame specifications (for both the Principle Axes and Mean Earth frames), a planet masses file supporting calculation of orbital elements, and the latest leapseconds kernel and text-style planetary constants kernel.
Ground Stations Kernels	Tracking station locations and topocentric frames specification kernels for NASA Deep Space Network stations, all stations listed in the NASA Directory of Station Locations (NDOSL, dated 30 May 2014), selected European Space Agency stations, and the high precision earth orientation binary planetary constants kernel used in conjunction with the station locations kernels.
Latest Leapseconds Kernel	The leapseconds tabulation needed in nearly every SPICE computation. This file could be a more current version than that available in an archival WGC kernel set. Selecting this kernel set last will ensure the very latest SPICE leapseconds kernel gets used instead of any earlier version included in another loaded kernel set.
Latest Planetary	Contains the IAU-sanctioned data providing size, shape and orientation of



Constants Kernel	planets and satellites, plus a few comets and asteroids that are frequently needed in SPICE computations. This file could be a more current version than that available in an archival WGC kernel set.
------------------	--

Normally users interested in computing geometry only for the solar system’s natural bodies would select just the “Solar System Kernels” set while anyone interested in computing geometry with respect to a ground station would select the “Ground Stations Kernels” in addition to any archived or current mission kernels.

### 6.2. Mission archive kernel sets

The kernel sets for all PDS SPICE archives in the NAIF holdings (25 total archives as of March 2016) appear right under the generic kernel sets in the “Kernel selection” menu. Hovering the cursor over any of the archive kernel set name brings up a pop-up box with a brief description that includes the archive data coverage start and stop dates. For past missions this coverage is normally for the whole mission. For missions that are still in operation the archive end dates are normally 6-12 months before the current time.

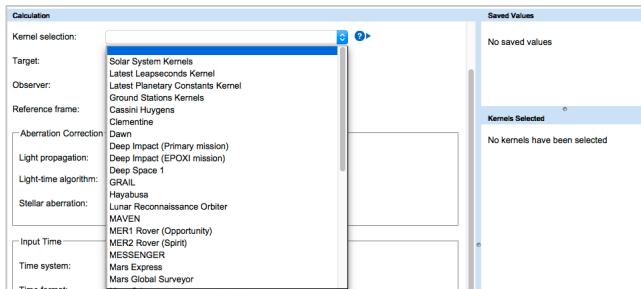


Fig 11. NAIF WGC kernel sets

### 6.3. Current mission kernels

All current mission kernels publicly available on the NAIF Web/FTP server are available for manual selection in NAIF’s WGC. Selecting “Manual” at the bottom of the WGC “Kernel selection” menu and clicking the “Choose kernels” button on the right allows users to navigate their way to any kernel available in the public NAIF Web/FTP server directory tree and select any number of kernels of interest. Some familiarity with the recent mission kernels set is needed to make proper selections. In cases when recent mission kernels of interest are for a mission that has an archived kernel set it is beneficial to select that mission’s archived kernel set first even if it does not provide recent data to ensure that the autocomplete capability based on the mission data is available in all applicable type-in fields.

## 7. PROGRAMMATIC INTERFACE

The most recent addition to the WGC capabilities is the WGC programmatic interface (API). This interface allows access to WGC calculations over HTTP/HTTP(S) using Representational State Transfer (REST) request URLs with JSON payloads and results, allowing one to use WGC as a Web service. Any programming language capable of sending and receiving HTTP(S) data can call WGC APIs over the network to use the full WGC server functionality, including retrieving a list of kernel sets available to WGC; requesting specific details about a kernel set; and requesting, monitoring the progress of, and retrieving results from any calculation available in WGC.

## 8. WGC DEPLOYMENT

WGC server is a Web application that runs inside a Tomcat J2EE web container and makes use of a MySQL database. It can be installed on any workstation that has Java, Apache Tomcat, and MySQL Community Server. The WGC server installation and configuration process includes the following steps:

- creating meta-kernels needed to support the “named” kernel sets
- creating a CSV configuration file defining the “named” kernel sets
- creating a text properties file defining WGC deployment attributes
- creating and loading a MySQL database with the “named” kernel set information
- configuring the WGC WAR file
- deploying the WGC WAR file to the Tomcat server Web application directory

The NAIF group does not plan to distribute the WGC server software to the general public but might make the WGC server software available to organizations involved in planetary exploration, with significant experience with SPICE and a clear need to manage their own kernel sets used by WGC. In this case NAIF will provide the WGC server binary distribution package together with the installation and kernel database configuration instructions. If interested contact the NAIF manager, Charles Acton, to discuss this possibility (Charles.Acton(at)jpl.nasa.gov).

The research described in this publication was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Copyright 2016 California Institute of Technology. U.S. Government sponsorship acknowledged.