# Writing an Mice (MATLAB) Based Program

March 2010

# Viewing This Tutorial

**Undefined variables are displayed in red; results are displayed in blue.**

# Introduction

First, let's go over the important steps in the process of writing a Mice-based program and putting it to work:

- Understand the geometry problem.
- Identify the set of SPICE kernels that contain the data needed to perform the computation.
- Formulate an algorithm to compute the quantities of interest using SPICE.
- Write and compile the program.
- Get actual kernel files and verify that they contain the data needed to support the computation for the time(s) of interest.
- Run the program.

To illustrate these steps, let's write a program that computes the apparent intersection of the boresight ray of a given CASSINI science instrument with the surface of a given Saturnian satellite. The program will compute:

- Planetocentric and planetodetic (geodetic) latitudes and longitudes of the intercept point.
- Range from spacecraft to intercept point.
- Illumination angles (phase, solar incidence, and emission) at the intercept point.

# Observation geometry

We want the boresight intercept on the surface, range from s/c to intercept, and illumination angles at the intercept point.

When? TIME (UTC, TDB or TT)

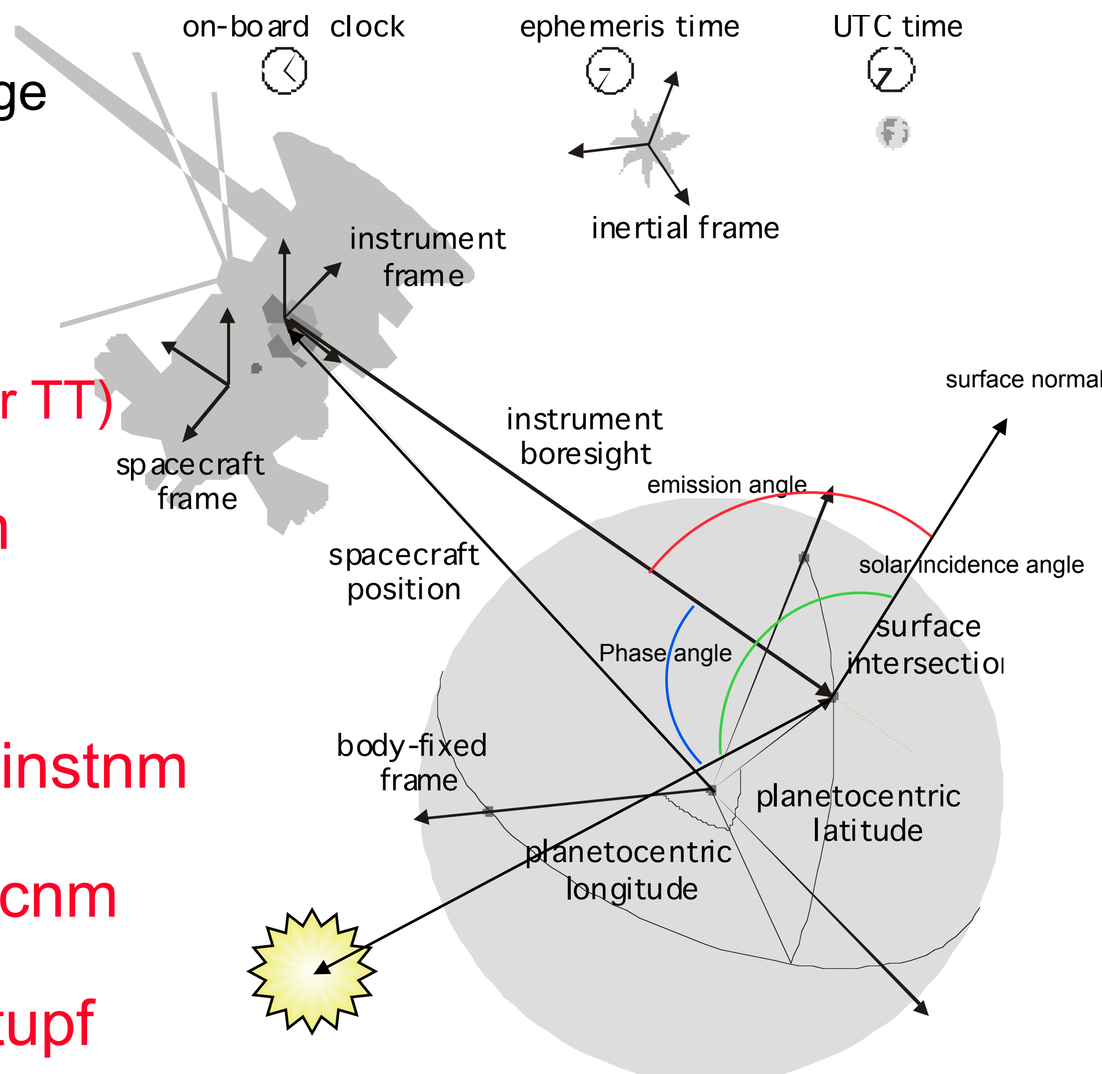
On what object? satnm

In what frame? fixref

For which instrument? instnm

For what spacecraft? scnm

Using what model? setupf



# Needed Data

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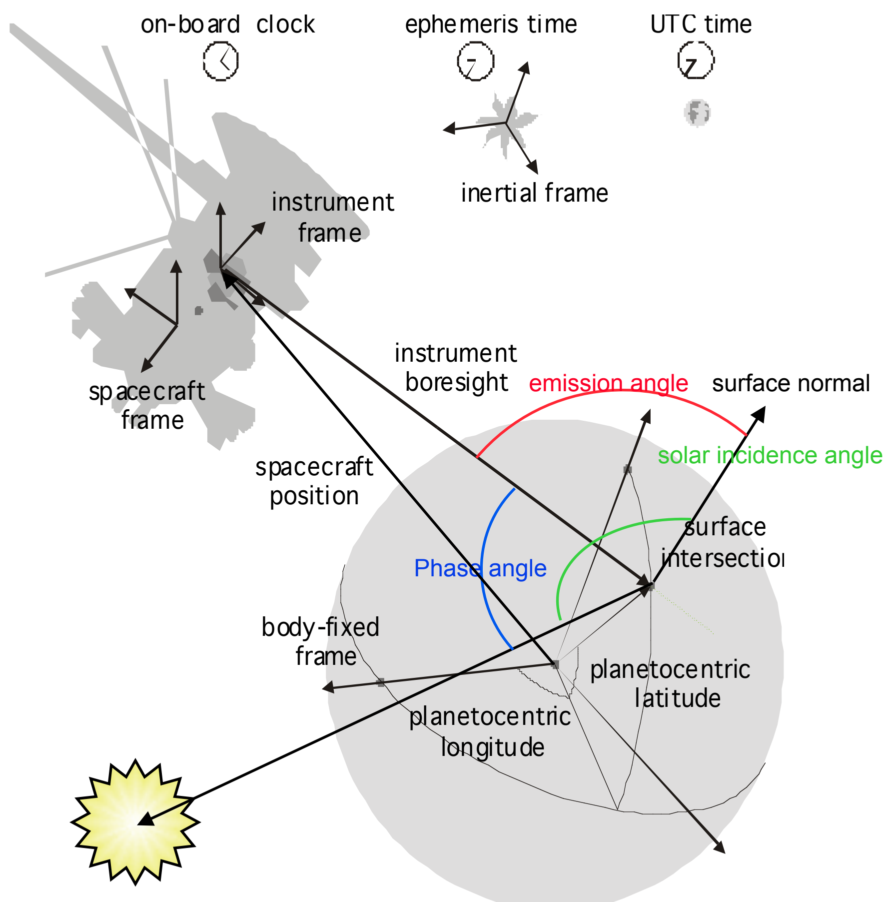
Time transformation kernels

Orientation models

Instrument descriptions

Shapes of satellites, planets

Ephemerides for spacecraft,
Saturn barycenter and satellites.



# Which Kernels are Needed?

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**Data required to compute vectors, rotations and other parameters shown in the picture are stored in the SPICE kernels listed below.**

**Note: these kernels have been selected to support this presentation; they should not be assumed to be appropriate for user applications.**

```
Parameter                   Kernel Type      File name
-----------------------     --------------   ------------
time conversions            generic LSK      naif0009.tls
                            CASSINI SCLK     cas00084.tsc
satellite orientation       CASSINI PCK      cpck05Mar2004.tpc
satellite shape             CASSINI PCK      cpck05Mar2004.tpc
satellite position          planet/sat
                            ephemeris SPK    020514_SE_SAT105.bsp
planet barycenter position  planet SPK       981005_PLTEPH-DE405S.bsp
spacecraft position         spacecraft SPK   030201AP_SK_SM546_T45.bsp
spacecraft orientation      spacecraft CK    04135_04171pc_psiv2.bc
instrument alignment        CASSINI FK       cas_v37.tf
instrument boresight        Instrument IK    cas_iss_v09.ti
```

# Load kernels

The easiest and most flexible way to make these kernels available to the program is via cspice_furnsh. For this example we make a setup file (also called a "metakernel" or "furnsh kernel") containing a list of kernels to be loaded:

```
      Note:  these kernels have been selected to support this presentation; they
      should not be assumed to be appropriate for user applications.
\begindata

   KERNELS_TO_LOAD = ('naif0009.tls', 'cas00084.tsc', 'cpck05Mar2004.tpc',
                      '020514_SE_SAT105.bsp', '981005_PLTEPH-DE405S.bsp',
                      '030201AP_SK_SM546_T45.bsp', '04135_04171pc_psiv2.bc',
                      'cas_v37.tf', 'cas_iss_v09.ti')
\begintext
```

and we make the program prompt for the name of this setup file:

```
    setupf = input('Enter setup file name > ', 's');
    cspice_furnsh( setupf )
```

# Programming Solution

- Prompt for setup file ("metakernel") name; load kernels specified via setup file. (Done on previous chart.)

- Prompt for user inputs required to completely specify problem. Obtain further inputs required by geometry routines via Mice calls.

- Compute the intersection of the boresight direction ray with the surface of the satellite, presented as a triaxial ellipsoid.

- If there is an intersection:
  - Convert Cartesian coordinates of the intersection point to planetocentric latitudinal and planetodetic coordinates
  - Compute spacecraft-to-intercept point range
  - Find the illumination angles (phase, solar incidence, and emission) at the intercept point

- Display the results.

We discuss the geometric portion of the problem first.

# Compute surface intercept

Compute the intercept point (`point`) of the boresight vector (`insite`) specified in the instrument frame (`iframe`) of the instrument mounted on the spacecraft (`scnm`) with the surface of the satellite (`satnm`) at the TDB time of interest (`et`) in the satellite's body-fixed frame (`fixref`). This call also returns the light-time corrected epoch at the intercept point (`trgepc`), the spacecraft-to-intercept point vector (`srfvec`), and a flag indicating whether the intercept was found (`found`). We use "converged Newtonian" light time plus stellar aberration corrections to produce the most accurate surface intercept solution possible. We model the surface of the satellite as an ellipsoid.

```
[point, trgepc, srfvec, found] = cspice_sincpt( ...
     'Ellipsoid', satnm, et, fixref, 'CN+S', scnm, iframe, insite );
```

The range we want is obtained from the outputs of `cspice_sincpt`. These outputs are defined only if a surface intercept is found. If `found` is true, the spacecraft-to-surface intercept range is the norm of the output argument `srfvec`. Units are km. We use the MATLAB function `norm` to obtain the norm:

```
norm( srfvec )
```

We'll write out the range data along with the other program results.

# Compute Lat/Lon and Illumination Angles

Compute the planetocentric latitude (`pclat`) and longitude (`pclon`), as well as the planetodetic latitude (`pdlat`) and longitude (`pdlon`) of the intersection point.

```
if ( found )
      [r, pclon, pclat] = cspice_reclat( point );

       % Let re, rp, and f be the satellite's longer equatorial
       % radius, polar radius, and flattening factor.
       re = radii(1);
       rp = radii(3);
       f  = ( re - rp ) / re;

       [pdlat, pdlat, alt] = cspice_recgeo( point, re, f );
```

The illumination angles we want are the outputs of `cspice_ilumin`. Units are radians.

```
       [trgepc, srfvec, phase, solar, emissn] = cspice_ilumin( ...
                'Ellipsoid', satnm, et, fixref, 'CN+S', scnm, point );
```

# Geometry Calculations: Summary

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```
% Compute the boresight ray intersection with the surface of the
% target body.
[point, trgepc, srfvec, found] = cspice_sincpt( ...
      'Ellipsoid', satnm, et, fixref, 'CN+S', scnm, iframe, insite );
% If an intercept is found, compute planetocentric and planetodetic
% latitude and longitude of the point.
if ( found )
   [r, pclon, pclat] = cspice_reclat( point );
   % Let re, rp, and f be the satellite's longer equatorial
   % radius, polar radius, and flattening factor.
   re = radii(1);
   rp = radii(3);
   f  = ( re - rp ) / re;
   [pdlon, pdlat, alt] = cspice_recgeo( point, re, f );
   % Compute illumination angles at the surface point.
   [trgepc, srfvec, phase, solar, emissn] = cspice_ilumin( ...
                  'Ellipsoid', satnm, et, fixref, 'CN+S', scnm, point );
   ...
 else
   ...
```

# Get inputs - 1

The code above used quite a few inputs that we don't have yet:

- TDB epoch of interest ( `et` );
- satellite and s/c names (`satnm, scnm`);
- satellite body-fixed frame name (`fixref`);
- satellite ellipsoid radii (`radii`);
- instrument fixed frame name (`iframe`);
- instrument boresight vector in the instrument frame (`insite`);

Some of these values are user inputs; others can be obtained via CSPICE calls once the required kernels have been loaded.

Let's prompt for the satellite name (`satnm`), satellite frame name (`fixref`), spacecraft name (`scnm`), instrument name (`instnm`) and time of interest (`time`):

```
satnm  = input( 'Enter satellite name  > ', 's');
fixref = input( 'Enter satellite frame > ', 's');
scnm   = input( 'Enter spacecraft name > ', 's');
instnm = input( 'Enter instrument name > ', 's');
time   = input( 'Enter time            > ', 's');
```

# Get Inputs - 2

**Then we can get the rest of the inputs from Mice calls:**

**To get the TDB epoch (`et`) from the user-supplied time string (which may refer to the UTC, TDB or TT time systems):**

```
et = cspice_str2et( time );
```

**To get the satellite's ellipsoid radii (`radii`):**

```
radii = cspice_bodvrd( satnm, 'RADII', 3 );
```

**To get the instrument boresight direction (`insite`) and the name of the instrument frame (`iframe`) in which it is defined:**

```
[instid, found] = cspice_bodn2c( instnm );
if ( ~found )
   txt = sprintf( 'Unable to determine ID for instrument: %d', ...
                  instnm );
   error(txt)
end

[shape, iframe, insite, bundry] = cspice_getfov( instid, ROOM );
```

# Getting inputs: summary



```
% Prompt for the user-supplied inputs for our program.
setupf = input( 'Enter setup file name > ', 's');
cspice_furnsh( setupf )
satnm  = input( 'Enter satellite name  > ', 's');
fixref = input( 'Enter satellite frame > ', 's');
scnm   = input( 'Enter spacecraft name > ', 's');
instnm = input( 'Enter instrument name > ', 's');
time   = input( 'Enter time            > ', 's');

% Get the epoch corresponding to the input time:
et = cspice_str2et( time );

% Get the radii of the satellite.
radii = cspice_bodvrd( satnm, 'RADII', 3 );

% Get the instrument boresight and frame name.
[instid, found] = cspice_bodn2c( instnm );
if ( ~found )
   txt = sprintf( 'Unable to determine ID for instrument: %d', ...
                  instnm );
   error(txt)
end
[shape, iframe, insite, bundry] = cspice_getfov( instid, ROOM );
```

# Display results

```
    ...
   % Display results.  Convert angles from radians to degrees
   % for output.
   fprintf( 'Intercept planetocentric longitude      (deg):  %11.6f\n', ...
                                                     R2D*pclon )
   fprintf( 'Intercept planetocentric latitude       (deg):  %11.6f\n', ...
                                                     R2D*pclat )
   fprintf( 'Intercept planetodetic longitude        (deg):  %11.6f\n', ...
                                                     R2D*pdlon )
   fprintf( 'Intercept planetodetic latitude         (deg):  %11.6f\n', ...
                                                     R2D*pdlat )
   fprintf( 'Range from spacecraft to intercept point (km):  %11.6f\n', ...
                                                  norm(srfvec) )
   fprintf( 'Intercept phase angle                   (deg):  %11.6f\n', ...
                                                     R2D*phase )
   fprintf( 'Intercept solar incidence angle         (deg):  %11.6f\n', ...
                                                     R2D*solar )
   fprintf( 'Intercept emission angle                (deg):  %11.6f\n', ...
                                                    R2D*emissn )
else
   disp( ['No intercept point found at ' time ] )
end
```

# Complete the program

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To finish up the program we need to declare the variables we've used.

- We'll highlight techniques used by NAIF programmers
- Add remaining MATLAB code required to make a syntactically valid program

```
ABCORR = 'CN+S';
ROOM   = 10;
R2D    = cspice_dpr;

% Prompt for the user-supplied inputs for our program.
setupf = input( 'Enter setup file name > ', 's');
cspice_furnsh( setupf )

satnm  = input( 'Enter satellite name  > ', 's');
fixref = input( 'Enter satellite frame > ', 's');
scnm   = input( 'Enter spacecraft name > ', 's');
instnm = input( 'Enter instrument name > ', 's');
time   = input( 'Enter time            > ', 's');
```

# Complete source code - 1

```
% Get the epoch corresponding to the input time:
et = cspice_str2et( time );

% Get the radii of the satellite.
radii = cspice_bodvrd( satnm, 'RADII', 3 );

% Get the instrument boresight and frame name.
[instid, found] = cspice_bodn2c( instnm );

if ( ~found )
   txt = sprintf( 'Unable to determine ID for instrument: %d', ...
                  instnm );
   error(txt)
end

[shape, iframe, insite, bundry] = cspice_getfov( instid, ROOM );
```

# Complete source code - 2

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```
% Compute the boresight ray intersection with the surface of the
% target body.
[point, trgepc, srfvec, found] = cspice_sincpt( ...
      'Ellipsoid', satnm, et, fixref, 'CN+S', scnm, iframe, insite );

% If an intercept is found, compute planetocentric and planetodetic
% latitude and longitude of the point.
if ( found )
   [r, pclon, pclat] = cspice_reclat( point );

   % Let re, rp, and f be the satellite's longer equatorial
   % radius, polar radius, and flattening factor.
   re = radii(1);
   rp = radii(3);
   f  = ( re - rp ) / re;

   [pdlon, pdlat, alt] = cspice_recgeo( point, re, f );

   % Compute illumination angles at the surface point.
   [trgepc, srfvec, phase, solar, emissn] = cspice_ilumin( ...
                'Ellipsoid', satnm, et, fixref, 'CN+S', scnm, point );
```

# Complete source code - 3

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```
   % Display results.  Convert angles from radians to degrees
   % for output.
   fprintf( 'Intercept planetocentric longitude      (deg):  %11.6f\n',...
                                                 R2D*pclon )
   fprintf( 'Intercept planetocentric latitude       (deg):  %11.6f\n',...
                                                 R2D*pclat )
   fprintf( 'Intercept planetodetic longitude        (deg):  %11.6f\n',...
                                                 R2D*pdlon )
   fprintf( 'Intercept planetodetic latitude         (deg):  %11.6f\n',...
                                                         R2D*pdlat )
   fprintf( 'Range from spacecraft to intercept point (km):  %11.6f\n',...
                                              norm(srfvec) )
   fprintf( 'Intercept phase angle                   (deg):  %11.6f\n',...
                                                 R2D*phase )
   fprintf( 'Intercept solar incidence angle         (deg):  %11.6f\n',...
                                                 R2D*solar )
   fprintf( 'Intercept emission angle                (deg):  %11.6f\n',...
                                                R2D*emissn )
else
   disp( ['No intercept point found at ' time ]
end

% Unload the kernels and clear the kernel pool
cspice_kclear
```

# Running the program

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It looks like we have everything taken care of:

- We have all necessary kernels
- We made a setup file (metakernel) pointing to them
- We wrote the program

Let's run it.

# Running the program

Terminal Window

```
>>  prog_geometry
Enter setup file name > setup.ker
Enter satellite name  > PHOEBE
Enter satellite frame > IAU_PHOEBE
Enter spacecraft name > CASSINI
Enter instrument name > CASSINI_ISS_NAC
Enter time            > 2004 jun 11 19:32:00

Intercept planetocentric longitude      (deg):    39.843719
Intercept planetocentric latitude       (deg):     4.195878
Intercept planetodetic longitude        (deg):    39.843719
Intercept planetodetic latitude         (deg):     5.048011
Range from spacecraft to intercept point (km):  2089.169724
Intercept phase angle                   (deg):    28.139479
Intercept solar incidence angle         (deg):    18.247220
Intercept emission angle                (deg):    17.858309
```

- **Latitude definitions:**
  - Planetocentric latitude of a point P: angle between segment from origin to point and x-y plane (red arc in diagram).
  - Planetodetic latitude of a point P: angle between x-y plane and extension of ellipsoid normal vector N that connects x-y plane and P (blue arc in diagram).