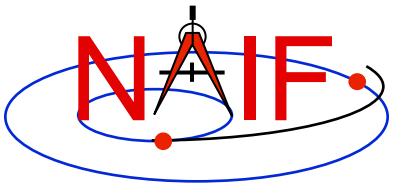
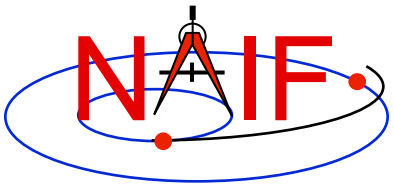


Navigation and Ancillary Information Facility

Writing a SPICE (FORTRAN) Based Program

January 2012

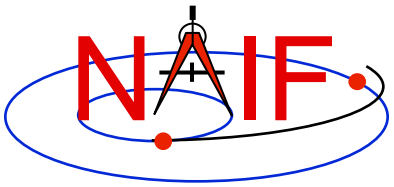


Viewing This Tutorial

Navigation and Ancillary Information Facility

Undefined variables are displayed in red

Results are displayed in blue



Introduction

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First, let's go over the important steps in the process of writing a SPICE-based Fortran 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 and from spacecraft to target center.
- Illumination angles (phase, solar incidence, and emission) at the intercept point.

Observation geometry

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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)

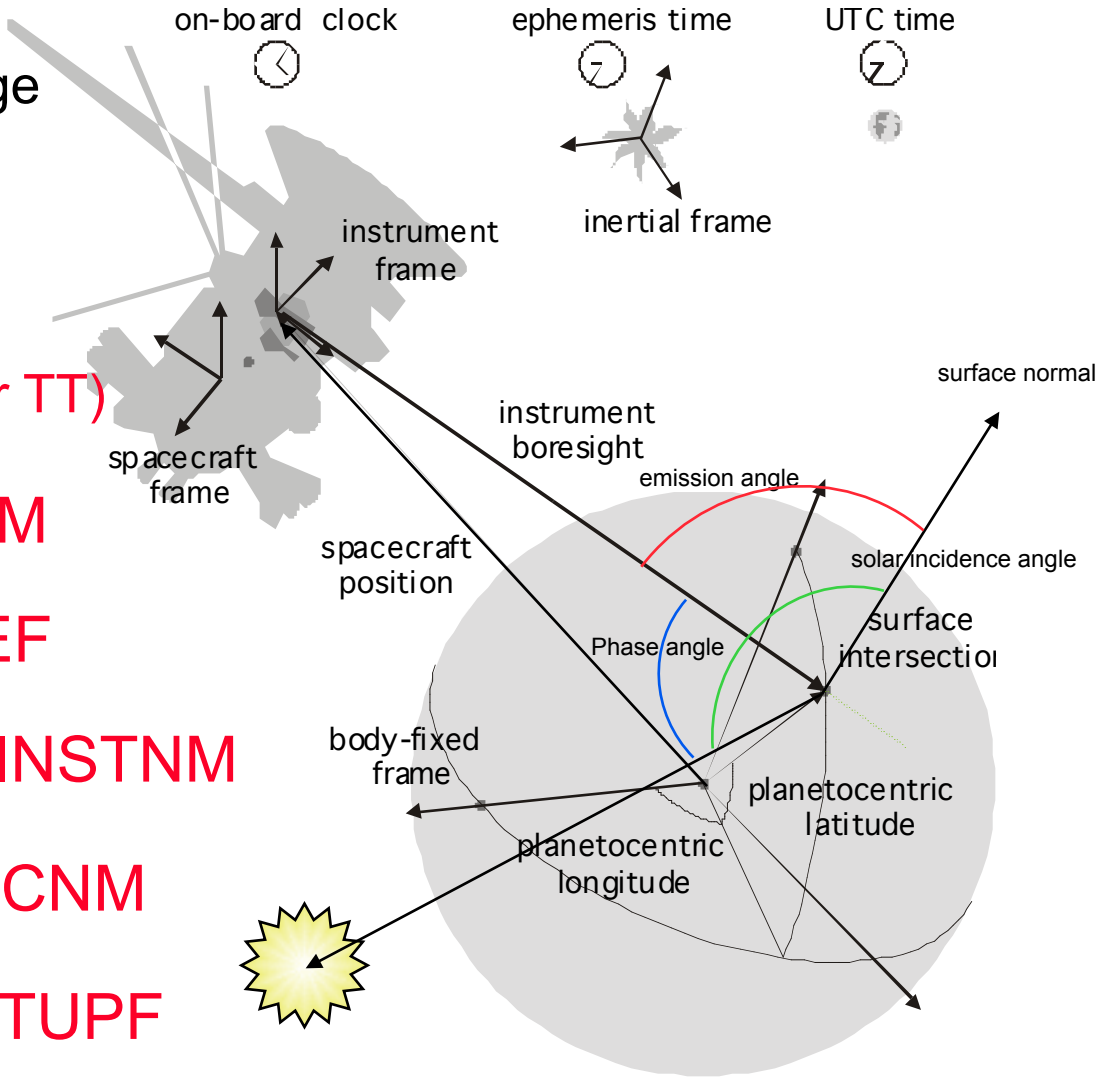
On what object? SATNM

In what frame? FIXREF

For which instrument? INSTNM

For what spacecraft? SCNM

Using what model? SETUPF



Needed Data

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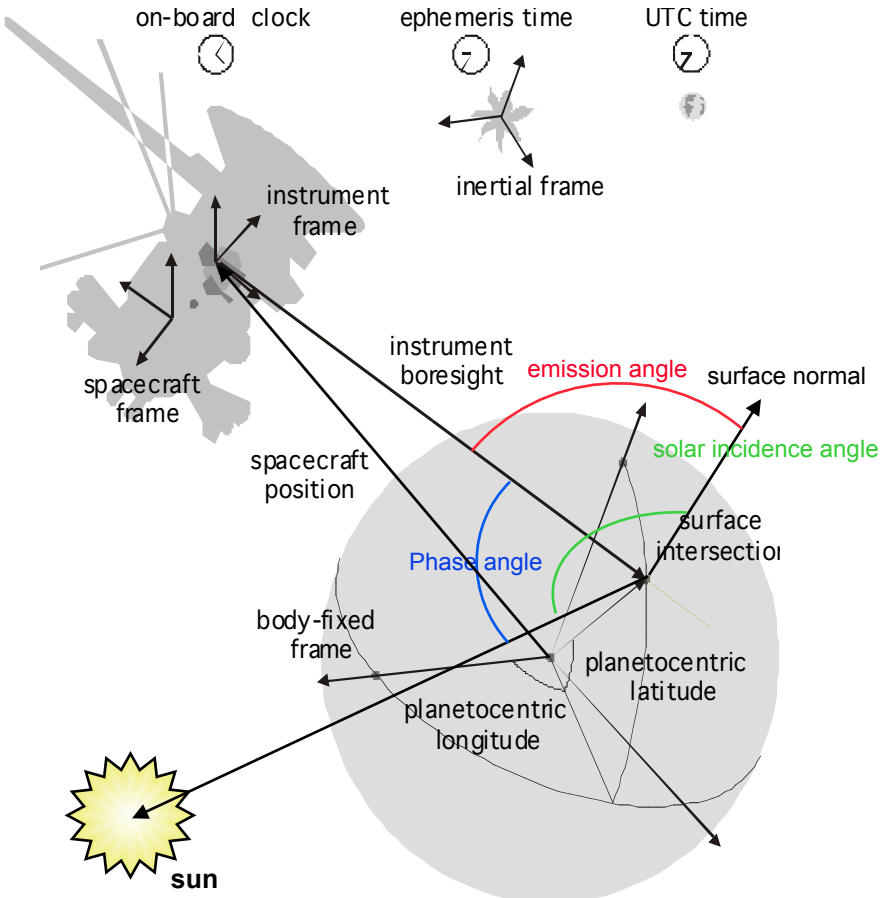
Time transformation kernels

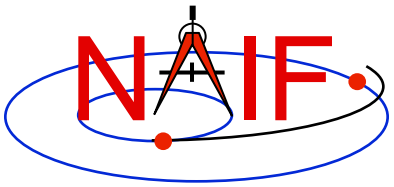
Orientation models

Instrument descriptions

Shapes of satellites, planets

Ephemerides for spacecraft, Saturn barycenter and satellites.





Which Kernels are Needed?

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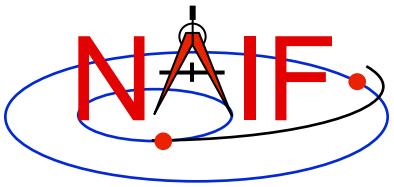
Data required to compute vectors, rotations and other parameters shown in the picture are stored in the SPICE kernels listed below.

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

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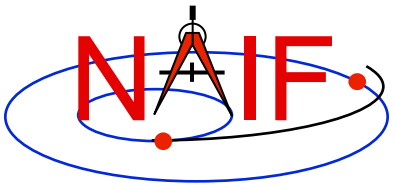
The easiest and most flexible way to make required kernels available to the program is via FURNSH. For this example we make a setup file (also called a "metakernel" or "furnsh kernel") containing a list of kernels to be loaded:

```
   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:

```
    CALL PROMPT ( 'Enter setup file name > ', SETUPF )
    CALL FURNSH ( SETUPF )
```



Programming Solution

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- 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 SPICELIB calls.

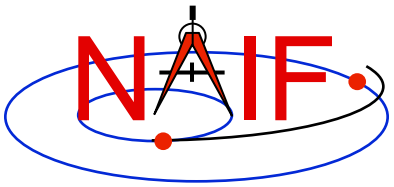
- Compute the intersection of the boresight direction ray with the surface of the satellite, presented as a triaxial ellipsoid.

  If there is an intersection,

  - Convert Cartesian coordinates of the intercept 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 next.



Compute Surface Intercept and Ranges

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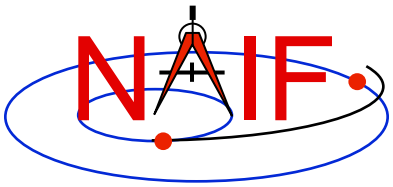
Compute the intercept point (POINT) of the boresight vector (INSITE) specified in the instrument frame (IFRAME) of the instrument mounted on the spacecraft (SCNM) with the surface of the satellite (SATNM) at the TDB time of interest (ET) in the satellite's body-fixed frame (FIXREF). This call also returns 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.

```
   CALL SINCPT ( 'Ellipsoid', SATNM, ET, FIXREF, 'CN+S', SCNM, IFRAME,
  .              INSITE, POINT, TRGEPC, SRFVEC, FOUND )
```

The range we want is obtained from the outputs of 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 SPICELIB function VNORM to obtain the norm:

```
   VNORM ( SRFVEC )
```

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



Compute Lat/Lon and Illumination Angles

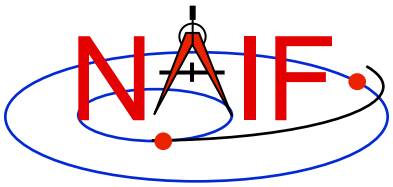
Navigation and Ancillary Information Facility

Compute the planetocentric latitude (PCLAT) and longitude (PCLON), as well as the planetodetic latitude (PDLAT) and longitude (PDLON) of the intersection point.

```
      IF ( FOUND ) THEN

         CALL RECLAT ( POINT, R, PCLON, PCLAT )

C        Let RE, RP, and F be the satellite's longer equatorial
C        radius, polar radius, and flattening factor.
         RE  =  RADII(1)
         RP  =  RADII(3)
         F   =  ( RE - RP ) / RE

         CALL RECGEO ( POINT, RE, F, PDLON, PDLAT, ALT )
```

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

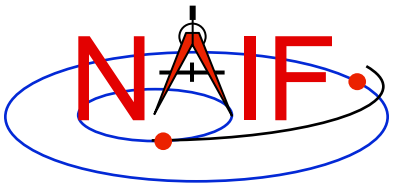
```
         CALL ILUMIN ( 'Ellipsoid', SATNM, ET, FIXREF,
        .              'CN+S', SCNM, POINT, TRGEPC, SRFVEC,
        .              PHASE, SOLAR, EMISSN )
```



Geometry Calculations: Summary

Navigation and Ancillary Information Facility

```
C     Compute the boresight ray intersection with the surface of the
C     satellite.

      CALL SINCPT ( 'Ellipsoid', SATNM, ET, FIXREF, 'CN+S', SCNM, IFRAME,
     .              INSITE, POINT, TRGEPC, SRFVEC, FOUND )

C     If an intercept is found, compute planetocentric and planetodetic
C     latitude and longitude of the point.

      IF( FOUND ) THEN

         CALL RECLAT ( POINT, R, PCLON, PCLAT )
C        Let RE, RP, and F be the satellite's longer equatorial
C        radius, polar radius, and flattening factor.
         RE   =  RADII(1)
         RP   =  RADII(3)
         F    =  ( RE - RP ) / RE
         CALL RECGEO ( POINT, RE, F, PDLON, PDLAT, ALT )

C        Compute illumination angles at the surface point.

         CALL ILUMIN ( 'Ellipsoid', SATNM, ET, FIXREF, 'CN+S', SCNM,
     .                 POINT, TRGEPC, SRFVEC, PHASE, SOLAR, EMISSN )
         ...
      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 SPICELIB 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):

```
CALL PROMPT ( 'Enter satellite name  > ', SATNM  )
CALL PROMPT ( 'Enter satellite frame > ', FIXREF )
CALL PROMPT ( 'Enter spacecraft name > ', SCNM   )
CALL PROMPT ( 'Enter instrument name > ', INSTNM )
CALL PROMPT ( 'Enter time            > ', TIME   )
```

Get Inputs - 2

Navigation and Ancillary Information Facility

Then we can get the rest of the inputs from SPICELIB calls:

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

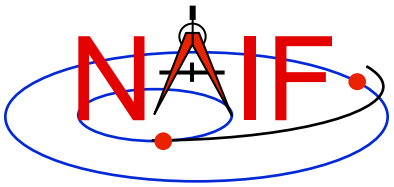
```
CALL STR2ET ( TIME, ET )
```

To get the satellite's ellipsoid radii (RADII):

```
CALL BODVRD ( SATNM, 'RADII', 3, I, RADII )
```

To get the instrument boresight direction (INSITE) and the name of the instrument frame (IFRAME) in which it is defined:

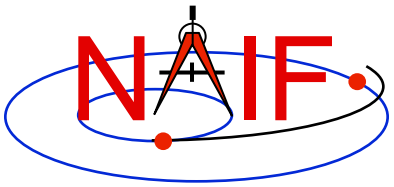
```
CALL BODN2C ( INSTNM, INSTID, FOUND )

IF ( .NOT. FOUND ) THEN
   CALL SETMSG ( 'Instrument name # could not be ' //
.                'translated to an ID code.'       )
   CALL ERRCH  ( '#',  INSTNM                     )
   CALL SIGERR ( 'NAMENOTFOUND'                   )
END IF

CALL GETFOV ( INSTID, ROOM, SHAPE,  IFRAME,
.             INSITE, N,    BUNDRY          )
```



Getting Inputs: Summary

Navigation and Ancillary Information Facility

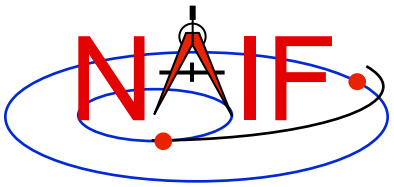
```
C     Prompt for the user-supplied inputs for our program.
      CALL PROMPT ( 'Enter setup file name > ', SETUPF )
      CALL FURNSH ( SETUPF )
      CALL PROMPT( 'Enter satellite name  > ', SATNM  )
      CALL PROMPT( 'Enter satellite frame > ', FIXREF )
      CALL PROMPT( 'Enter spacecraft name > ', SCNM   )
      CALL PROMPT( 'Enter instrument name > ', INSTNM )
      CALL PROMPT( 'Enter time            > ', TIME   )
C     Get the epoch corresponding to the input time:
      CALL STR2ET ( TIME, ET )

C     Get the radii of the satellite.
      CALL BODVRD ( SATNM, 'RADII', 3, I, RADII )

C     Get the instrument boresight and frame name.
      CALL BODN2C ( INSTNM, INSTID, FOUND )
      IF ( .NOT. FOUND ) THEN
         CALL SETMSG ( 'Instrument name # could not be ' //
     .                 'translated to an ID code.'       )
         CALL ERRCH  ( '#',  INSTNM                      )
         CALL SIGERR ( 'NAMENOTFOUND'                    )
      END IF
      CALL GETFOV ( INSTID, ROOM, SHAPE,  IFRAME,
     .              INSITE, N,    BUNDRY          )
```



Display Results

Navigation and Ancillary Information Facility

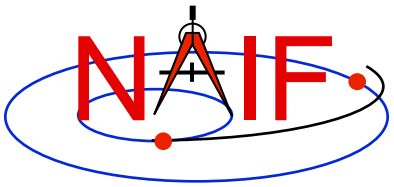
```
C        Display results.  Convert angles from radians to degrees
C        for output.
         WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept planetocentric longitude      (deg):  ',  DPR()*PCLON
         WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept planetocentric latitude       (deg):  ',  DPR()*PCLAT
         WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept planetodetic longitude        (deg):  ',  DPR()*PDLON
         WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept planetodetic latitude         (deg):  ',  DPR()*PDLAT
         WRITE ( *, '(1X,A,F12.6)' )
     .   'Range from spacecraft to intercept point (km):  ',
     .   VNORM(SRFVEC)
         WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept phase angle                   (deg):  ',  DPR()*PHASE
         WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept solar incidence angle         (deg):  ',  DPR()*SOLAR
         WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept emission angle                (deg):  ',
     .   DPR()*EMISSN

      ELSE
         WRITE (*,*) 'No intercept point found at '// TIME
      END IF
```



Complete the Program

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

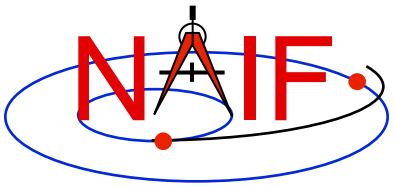
- **We'll highlight techniques used by NAIF programmers**
- **Add remaining Fortran code required to make a syntactically valid program**



Complete Source Code - 1

Navigation and Ancillary Information Facility

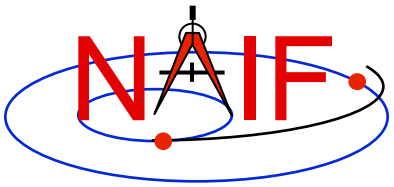
```
PROGRAM PROG26
IMPLICIT NONE

DOUBLE PRECISION     DPR
DOUBLE PRECISION     VNORM


INTEGER              FILESZ
PARAMETER          ( FILESZ =     255 )
INTEGER              WORDSZ
PARAMETER          ( WORDSZ =      40 )
INTEGER              ROOM
PARAMETER          ( ROOM   =      10 )

CHARACTER*(WORDSZ)   IFRAME
CHARACTER*(WORDSZ)   INSTNM
CHARACTER*(WORDSZ)   SATNM
CHARACTER*(WORDSZ)   FIXREF
CHARACTER*(WORDSZ)   SCNM
CHARACTER*(FILESZ)   SETUPF
CHARACTER*(WORDSZ)   SHAPE
CHARACTER*(WORDSZ)   TIME

DOUBLE PRECISION     ALT
DOUBLE PRECISION     BUNDRY(3, ROOM)
DOUBLE PRECISION     EMISSN
DOUBLE PRECISION     ET
DOUBLE PRECISION     F
DOUBLE PRECISION     INSITE(3)
DOUBLE PRECISION     SRFVEC(3)
DOUBLE PRECISION     PCLAT
DOUBLE PRECISION     PCLON
DOUBLE PRECISION     PDLAT
DOUBLE PRECISION     PDLON
DOUBLE PRECISION     PHASE
DOUBLE PRECISION     POINT (3)
DOUBLE PRECISION     R
DOUBLE PRECISION     RADII (3)
DOUBLE PRECISION     RE
DOUBLE PRECISION     RP
DOUBLE PRECISION     SOLAR
DOUBLE PRECISION     TRGEPC


INTEGER              I
INTEGER              INSTID
INTEGER              N

LOGICAL              FOUND
```



Complete Source Code - 2

Navigation and Ancillary Information Facility

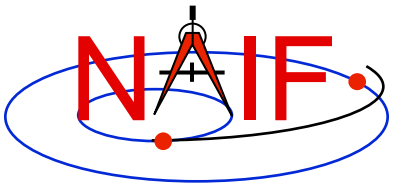
```
C      Prompt for the user-supplied inputs for our program.
       CALL PROMPT ( 'Enter setup file name > ', SETUPF )
       CALL FURNSH ( SETUPF )
       CALL PROMPT ( 'Enter satellite name  > ', SATNM  )
       CALL PROMPT ( 'Enter satellite frame > ', FIXREF )
       CALL PROMPT ( 'Enter spacecraft name > ', SCNM   )
       CALL PROMPT ( 'Enter instrument name > ', INSTNM )
       CALL PROMPT ( 'Enter time            > ', TIME   )

C      Get the epoch corresponding to the input time:
       CALL STR2ET ( TIME, ET )

C      Get the radii of the satellite.
       CALL BODVRD ( SATNM, 'RADII', 3, I, RADII )

C      Get the instrument boresight and frame name.
       CALL BODN2C ( INSTNM, INSTID, FOUND )
       IF ( .NOT. FOUND ) THEN
          CALL SETMSG ( 'Instrument name # could not be ' //
      .                 'translated to an ID code.'       )
          CALL ERRCH  ( '#',  INSTNM                      )
          CALL SIGERR ( 'NAMENOTFOUND'                    )
       END IF
       CALL GETFOV ( INSTID, ROOM, SHAPE,  IFRAME,
      .              INSITE, N,    BUNDRY          )
```



Complete Source Code - 3

Navigation and Ancillary Information Facility

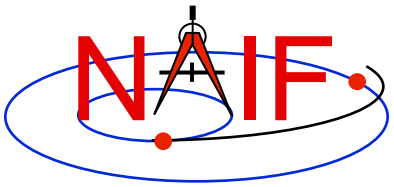
```
C      Compute the boresight ray intersection with the surface of the
C      satellite.
       CALL SINCPT ( 'Ellipsoid', SATNM, ET, FIXREF, 'CN+S', SCNM, IFRAME,
     .               INSITE, POINT, TRGEPC, SRFVEC, FOUND )
C      If an intercept is found, compute planetocentric and planetodetic
C      latitude and longitude of the point.
       IF( FOUND ) THEN
          CALL RECLAT ( POINT, R, PCLON, PCLAT )
C         Let RE, RP, and F be the satellite's longer equatorial
C         radius, polar radius, and flattening factor.
          RE   =  RADII(1)
          RP   =  RADII(3)
          F    =  ( RE - RP ) / RE
          CALL RECGEO ( POINT, RE, F, PDLON, PDLAT, ALT )
C         Compute illumination angles at the surface point.
          CALL ILUMIN ( 'Ellipsoid', SATNM, ET, FIXREF, 'CN+S', SCNM,
     .                  POINT, TRGEPC, SRFVEC, PHASE, SOLAR, EMISSN )
C         Display results.  Convert angles from radians to degrees
C         for output.
          WRITE ( *,  * )
          WRITE ( *, '(1X,A,F12.6)' )
     .    'Intercept planetocentric longitude      (deg):  ',  DPR()*PCLON
```



Complete Source Code - 4

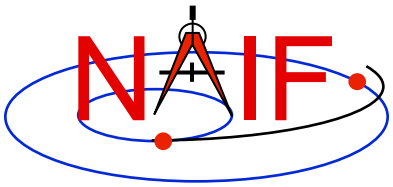
Navigation and Ancillary Information Facility

```
      WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept planetocentric latitude       (deg):  ',  DPR()*PCLAT
      WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept planetodetic longitude        (deg):  ',  DPR()*PDLON
      WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept planetodetic latitude         (deg):  ',  DPR()*PDLAT
      WRITE ( *, '(1X,A,F12.6)' )
     .   'Range from spacecraft to intercept point (km):  ',
     .   VNORM(SRFVEC)
      WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept phase angle                   (deg):  ',  DPR()*PHASE
      WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept solar incidence angle         (deg):  ',  DPR()*SOLAR
      WRITE ( *, '(1X,A,F12.6)' )
     .   'Intercept emission angle                (deg):  ',
     .   DPR()*EMISSN

   ELSE
      WRITE (*,*) 'No intercept point found at '// TIME
   END IF
   END
```



Compile and Link the Program - 1

- First be sure that both the SPICE Toolkit and a Fortran compiler are properly installed.
  - A "hello world" Fortran program must be able to compile, link, and run successfully in your environment.
  - Any of the mkprodct.* scripts in the toolkit/src/* paths of the SPICE Toolkit installation should execute properly.
- Ways to compile and link the program:
  - If you're familiar with the "make" utility, create a makefile. Use compiler and linker options from the mkprodct.* script found in the toolkit/src/cookbook path of your SPICE Toolkit installation.
  - Or, modify the cookbook mkprodct.* build script.
    - » Your program name must be *.pgm, for example demo.pgm, to be recognized by the script.
    - » Change the library references in the script to use absolute pathnames.
    - » Change the path for the executable to the current working directory.
    - » On some platforms, you must modify the script to refer to your program by name.



Compile and Link the Program - 2

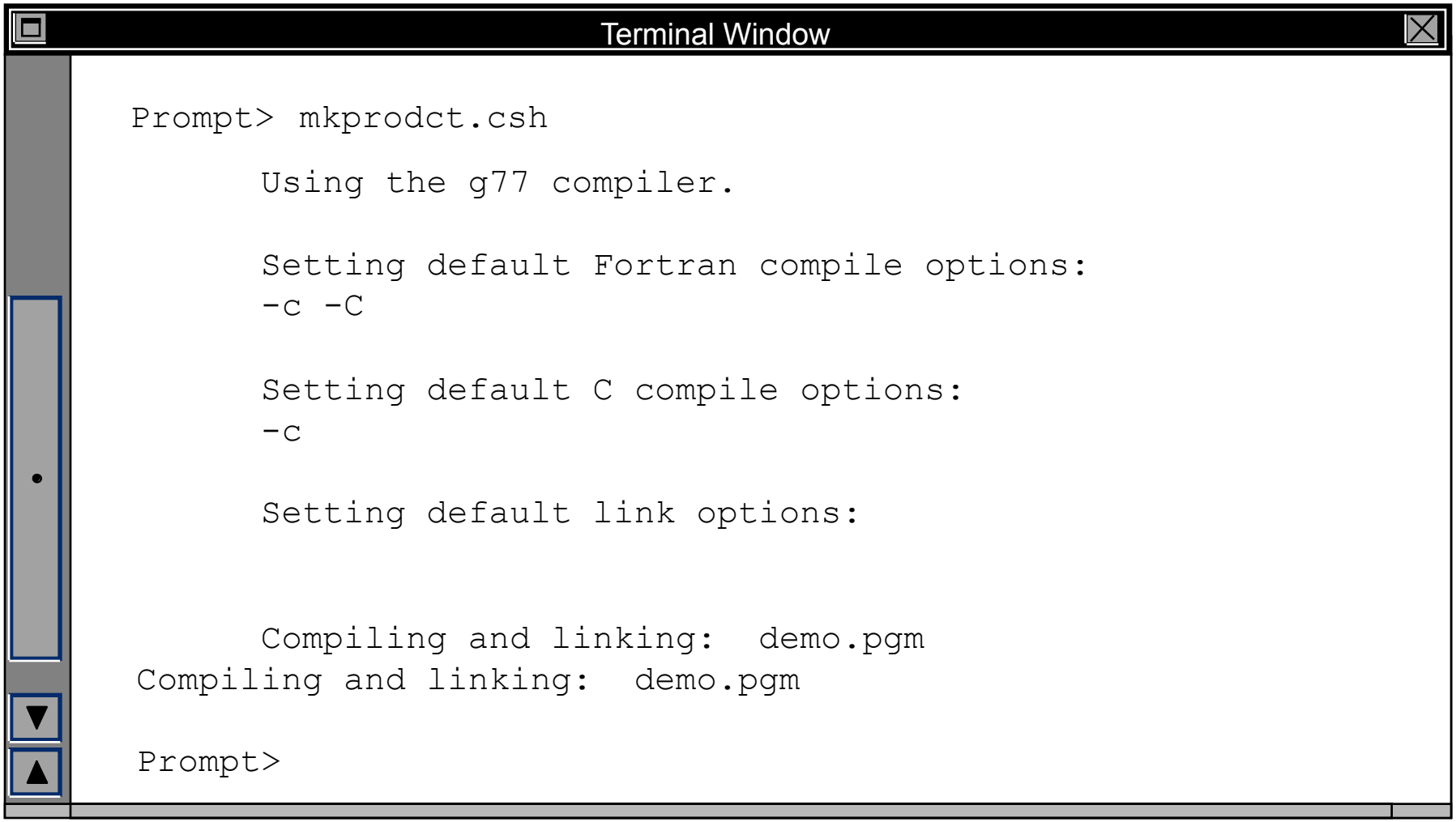
- Or, compile the program on the command line. The program must be linked against the SPICELIB object library spicelib.a (spicelib.lib under MS Windows systems). On a PC running Linux and g77, if
  - » The g77 compiler is in your path
    - As indicated by the response to the command "which g77"
  - » the Toolkit is installed in the path (for the purpose of this example) /myhome/toolkit
  - » You've named the program demo.f

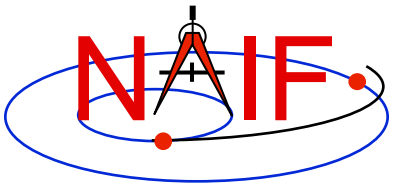
  then you can compile and link your program using the command

  - »
```
g77 -o demo  demo.f \
            /myhome/toolkit/lib/spicelib.a
```

Compile and Link the Program - 3

Navigation and Ancillary Information Facility





Running the Program - 1

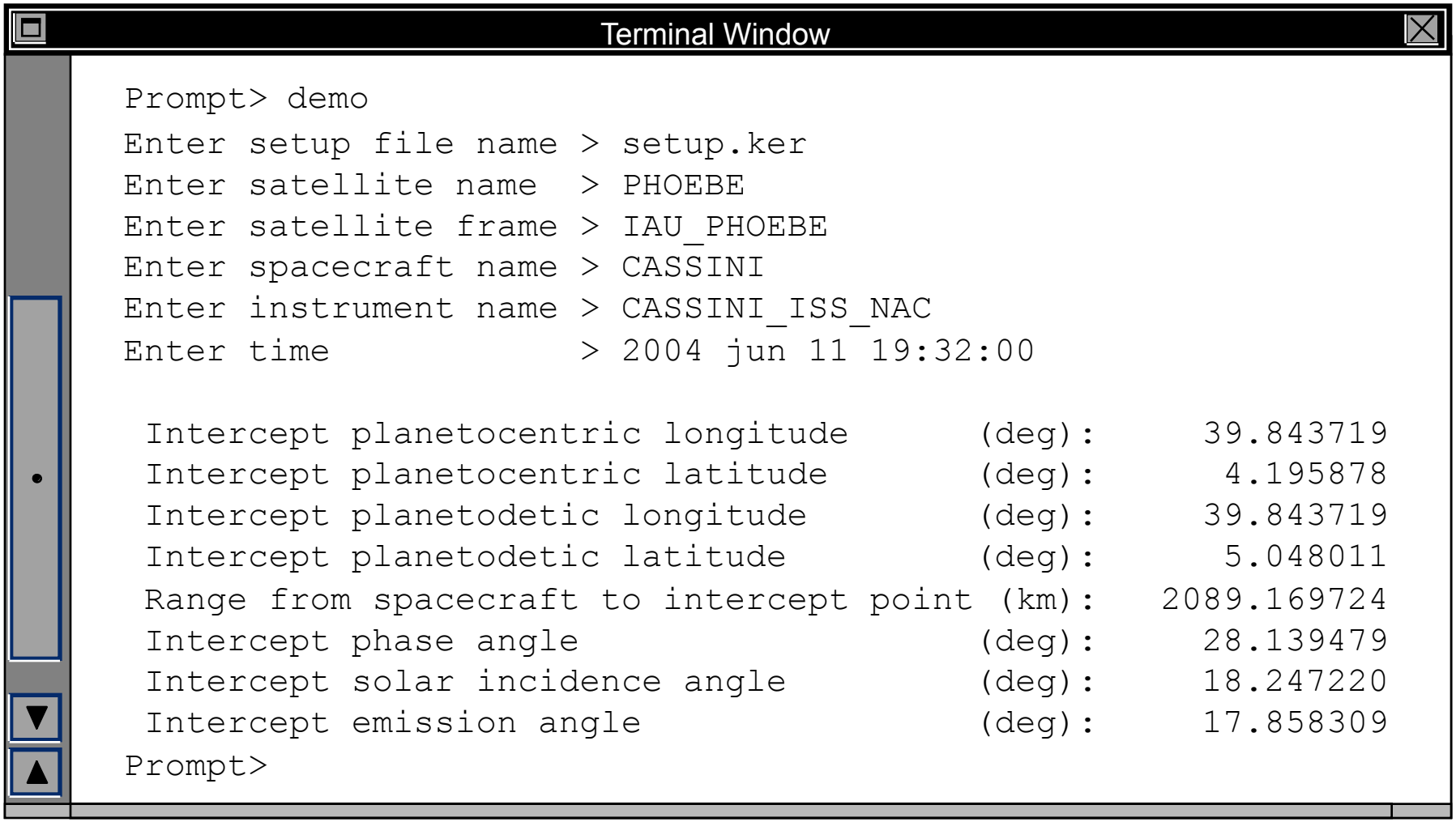
It looks like we have everything taken care of:

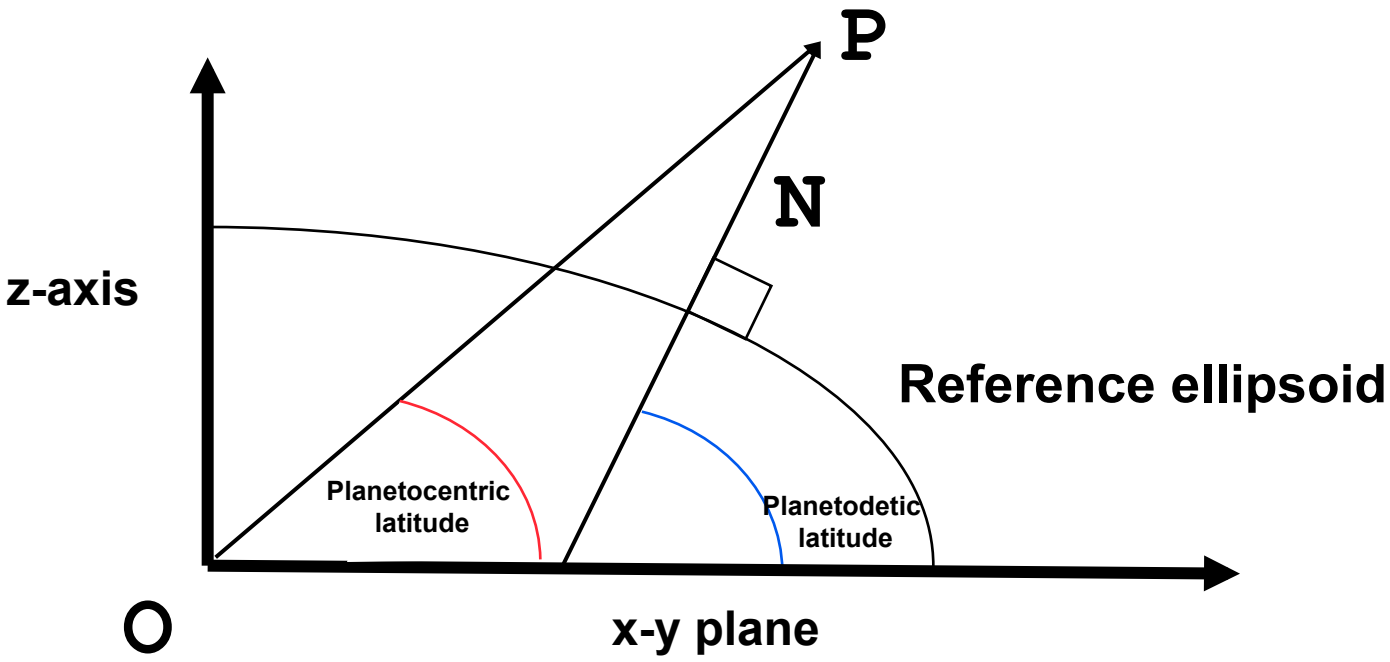
- **We have all necessary kernels**
- **We made a setup file (metakernel) pointing to them**
- **We wrote the program**
- **We compiled and linked it**

Let's run it.

Running the Program - 2

Navigation and Ancillary Information Facility



Backup

- **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).**