Instrument Kernel
IK

March 2006

Purpose

Navigation and Ancillary Information Facility

- The Instrument kernel serves as a repository for instrument specific information that may be useful within the SPICE context.
  - Specifications for an instrument's field-of-view size, shape, and orientation.
  - Internal instrument timing parameters and other data relating to SPICE computations might also be placed in an I-kernel.

- Note: Instrument mounting alignment data are most often specified in a mission frames kernel (FK).

- The IK is a SPICE text kernel.

I-Kernel Structure

- **The format and structure of a typical I-Kernel is:**

```
KPL/IK

   Comments describing the keywords and values
   to follow, as well as any other pertinent
   information.

      \begindata
         Keyword = Value Assignments
      \begintext

   More descriptive comments.

      \begindata
         More Keyword = Value Assignments
      \begintext

   More comments, followed by more data, etc …
```


I-Kernel Contents (1)

- **The requirements on keywords in an IK are the following:**
  - **Keywords must begin with INS[#], where [#] is replaced with the NAIF instrument ID code (which is a negative number).**
  - **The total length of the keyword must be less than 32 characters.**
  - **Keywords are case-sensitive. (Keyword != KEYWORD)**

- **Some examples of IK keywords:**
  - **MGS MOC NA focal length:** **INS-94031_FOCAL_LENGTH**
  - **MEX HRSC SRC pixel angular size:** **INS-41220_IFOV**
  - **MEX ASPERA NPI number of sectors:** **INS-41130_NUMBER_OF_SECTORS**

- **The SPICE toolkit does not require any specific keywords to be present in IK**
  - **One exception is a set of keywords defining an instrument’s FOV if the GETFOV routine is planned to be used to retrieve the FOV attributes**
    - » **Keywords required by GETFOV will be covered later in this tutorial**

I-Kernel Contents (2)

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- IKs usually contain extensive comments including
  - Instrument overview
  - Reference source(s) for the data included in the IK
  - Names/IDs assigned to the instrument and its parts
  - Explanation of each keyword included in the file
  - Description of the FOV and detector layout
  - Sometimes descriptions of the algorithms in which parameters provided in the IK are used, and even fragments of source code implementing these algorithms
    - » For example optical distortion models or timing algorithms
- This documentation exists primarily to assist users in integrating I-Kernel data into their applications
  - One needs to know the keyword name to get its value from the loaded IK data
  - One needs to know what that value means in order to use it

I-Kernel Interface Routines

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- As with any SPICE kernel, IK files are loaded using FURNSH

```
CALL FURNSH ( 'ik_file_name.ti' )
```

- Knowing the name and type (DP, integer, or character) of a keyword of interest, the value of that keyword can be retrieved using G*POOL routines

```
CALL GDPOOL ( NAME, START, ROOM, N, VALUES, FOUND )
CALL GIPOOL ( NAME, START, ROOM, N, VALUES, FOUND )
CALL GCPOOL ( NAME, START, ROOM, N, VALUES, FOUND )
```

- When an instrument's FOV is defined in the IK using a special set of keywords discussed later in this tutorial, the FOV shape, reference frame, boresight vector, and boundary vectors can be retrieved by calling the GETFOV routine

```
CALL GETFOV ( INSTID, ROOM, SHAPE, FRAME, BSIGHT, N, BOUNDS)
```

FOV Definition Keywords (1)

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- **The following keywords defining FOV attributes for the instrument with NAIF ID (#) must be present in the IK for GETFOV to work:**
  - Keyword defining shape of the FOV

```
INS#_FOV_SHAPE      = 'CIRCLE' or 'ELLIPSE' or
                      'RECTANGLE' or 'POLYGON'
```

  - Keyword defining reference frame with respect to which the boresight vector and FOV boundary vectors are specified

```
INS#_FOV_FRAME      = 'frame name'
```

  - Keyword defining the boresight vector

```
INS#_FOV_BORESIGHT = ( X, Y, Z )
```


FOV Definition Keywords (2)

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- Keyword(s) defining FOV boundary vectors, in either of two ways
  - » By specifying boundary vectors explicitly

```
INS#_FOV_CLASS_SPEC       = 'CORNERS' (optional)
INS#_FOV_BOUNDARY_CORNERS = ( X(1), Y(1), Z(1),
                               …     …     …
                              X(n), Y(n), Z(n) )
```

  - » By providing half angular extents of the FOV (possible only for circular, elliptical or rectangular FOVs)

```
INS#_FOV_CLASS_SPEC       = 'ANGLES'
INS#_FOV_REF_VECTOR       = ( X, Y, Z )
INS#_FOV_REF_ANGLE        = halfangle1
INS#_FOV_CROSS_ANGLE      = halfangle2
INS#_FOV_ANGLE_UNITS      = 'DEGREES' or 'RADIANS' or …
```

FOV Definition Keywords (3)

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- **Neither boresight nor reference vectors have to be co-aligned with one of the FOV frame's axes**
  - But for convenience they are frequently defined to be along one of the axes
- **Neither boresight nor corner or reference vectors have to be unit vectors**
  - But they frequently are defined as unit vectors
- **When FOV is specified using the half angular extents method, boresight and reference vectors have to be linearly independent but they don't have to be perpendicular**
  - But for convenience the reference vector is usually picked to be normal to the boresight
- **Half angular extents for a rectangular FOV specify the angles between the boresight and the FOV sides, i.e. they are for the middle of the FOV**

Circular Field of View

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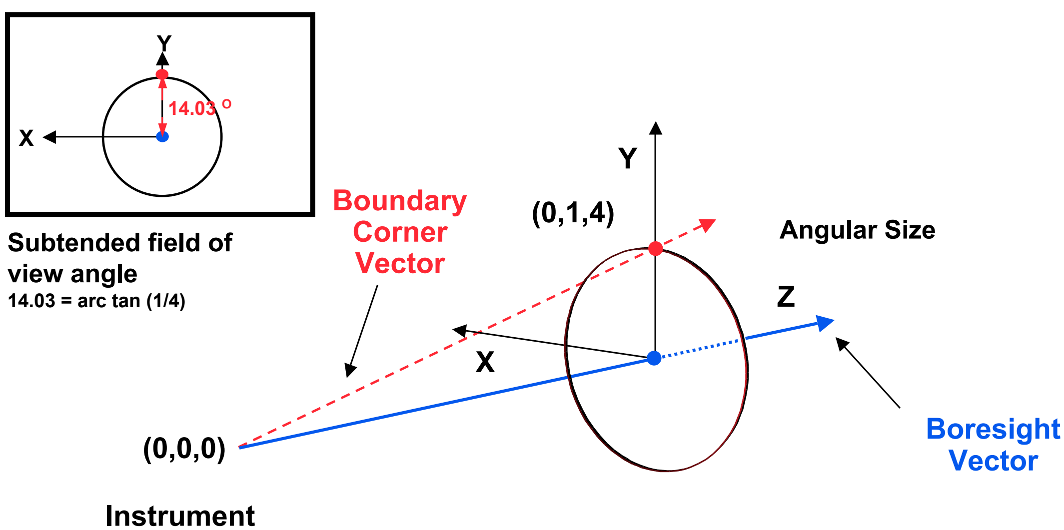
Consider an instrument with a circular field of view.



Circular FOV Definition

The following sets of keywords and values describe this circular field of view:

Specifying boundary vectors explicitly:

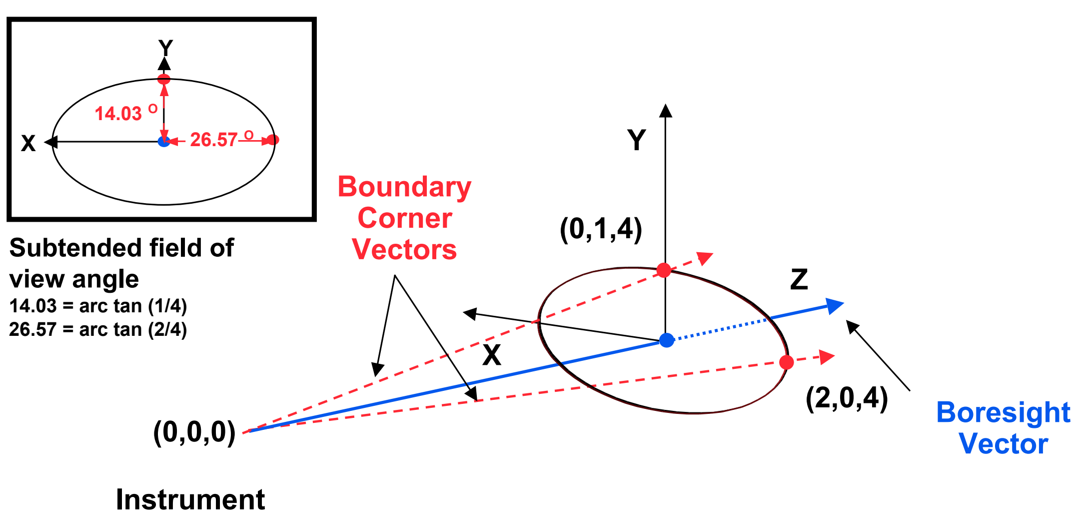
```
INS-11111_FOV_SHAPE            = 'CIRCLE'
INS-11111_FOV_FRAME            = 'FRAME_FOR_INS-11111'
INS-11111_FOV_BORESIGHT        = ( 0.0   0.0   1.0 )
INS-11111_FOV_BOUNDARY_CORNERS = ( 0.0   1.0   4.0 )
```

Specifying half angular extents of the FOV:

```
INS-11111_FOV_SHAPE            = 'CIRCLE'
INS-11111_FOV_FRAME            = 'FRAME_FOR_INS-11111'
INS-11111_FOV_BORESIGHT        = ( 0.0   0.0   1.0 )
INS-11111_FOV_CLASS_SPEC       = 'ANGLES'
INS-11111_FOV_REF_VECTOR       = ( 0.0   1.0   0.0 )
INS-11111_FOV_REF_ANGLE        = 14.03624347
INS-11111_FOV_ANGLE_UNITS      = 'DEGREES'
```


Elliptical Field of View

Consider an instrument with an elliptical field of view.



Elliptical FOV Definition

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The following sets of keywords and values describe this elliptical field of view:

Specifying boundary vectors explicitly:

```
INS-22222_FOV_SHAPE            = 'ELLIPSE'
INS-22222_FOV_FRAME            = 'FRAME_FOR_INS-22222'
INS-22222_FOV_BORESIGHT        = ( 0.0   0.0   1.0 )
INS-22222_FOV_BOUNDARY_CORNERS = ( 0.0   1.0   4.0
                                   2.0   0.0   4.0 )
```

Specifying half angular extents of the FOV:

```
INS-22222_FOV_SHAPE            = 'ELLIPSE'
INS-22222_FOV_FRAME            = 'FRAME_FOR_INS-22222'
INS-22222_FOV_BORESIGHT        = ( 0.0   0.0   1.0 )
INS-22222_FOV_CLASS_SPEC       = 'ANGLES'
INS-22222_FOV_REF_VECTOR       = ( 0.0   1.0   0.0 )
INS-22222_FOV_REF_ANGLE        = 14.03624347
INS-22222_FOV_CROSS_ANGLE      = 26.56505118
INS-22222_FOV_ANGLE_UNITS      = 'DEGREES'
```


Rectangular Field of View

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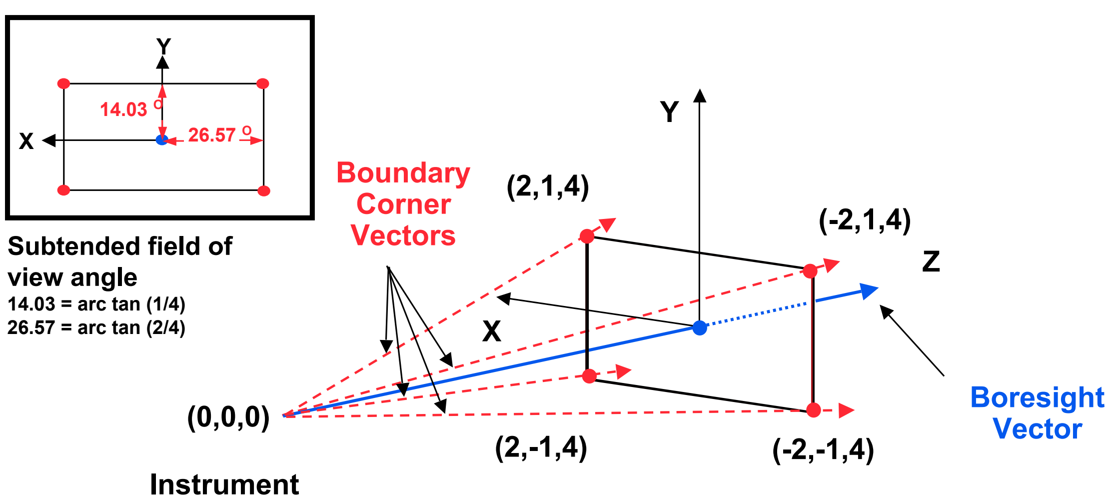
Consider an instrument with a rectangular field of view.



Rectangular FOV Definition

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The following sets of keywords and values describe this rectangular field of view:

Specifying boundary vectors explicitly:

```
INS-33333_FOV_SHAPE            = 'RECTANGLE'
INS-33333_FOV_FRAME            = 'FRAME_FOR_INS-33333'
INS-33333_FOV_BORESIGHT        = ( 0.0   0.0   1.0 )
INS-33333_FOV_BOUNDARY_CORNERS = ( 2.0   1.0   4.0
                                  -2.0   1.0   4.0
                                  -2.0  -1.0   4.0
                                   2.0  -1.0   4.0 )
```

Specifying half angular extents of the FOV:

```
INS-33333_FOV_SHAPE            = 'RECTANGLE'
INS-33333_FOV_FRAME            = 'FRAME_FOR_INS-33333'
INS-33333_FOV_BORESIGHT        = ( 0.0   0.0   1.0 )
INS-33333_FOV_CLASS_SPEC       = 'ANGLES'
INS-33333_FOV_REF_VECTOR       = ( 0.0   1.0   0.0 )
INS-33333_FOV_REF_ANGLE        = 14.03624347
INS-33333_FOV_CROSS_ANGLE      = 26.56505118
INS-33333_FOV_ANGLE_UNITS      = 'DEGREES'
```


Polygonal Fields of View

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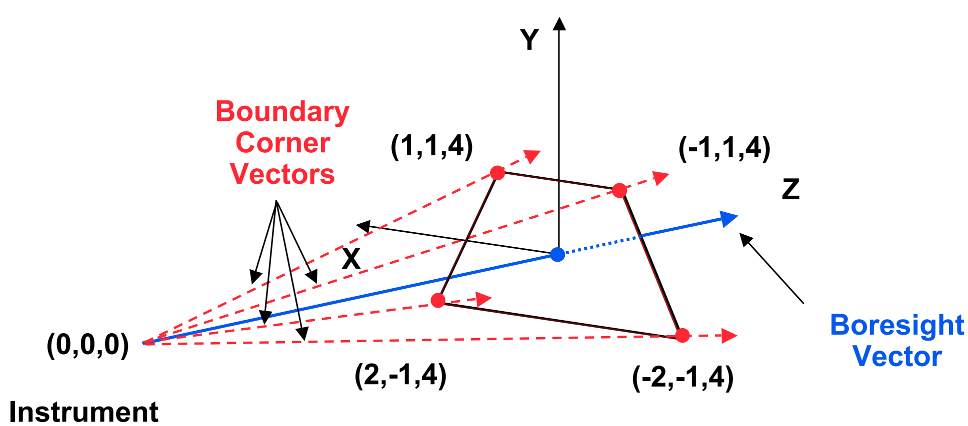
Consider an instrument with a trapezoidal field of view.



Polygonal FOV Definition

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The following sets of keywords and values describe this polygonal field of view:

Specifying boundary vectors explicitly:

```
INS-44444_FOV_SHAPE              = 'POLYGON'
INS-44444_FOV_FRAME              = 'FRAME_FOR_INS-44444'
INS-44444_FOV_BORESIGHT          = ( 0.0  0.0  1.0 )
INS-44444_FOV_BOUNDARY_CORNERS = ( 1.0  1.0  4.0
                                  -1.0  1.0  4.0
                                  -2.0 -1.0  4.0
                                   2.0 -1.0  4.0 )
```

Polygonal FOV cannot be specified using half angular extents

Backup

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- **IK file example**
- **Computing angular extents from corner vectors returned by GETFOV**

The following LEMMS1 FOV definition was taken from the Cassini MIMI IK (cas_mimi_v11.ti):

```
Low Energy Magnetospheric Measurements System 1 (LEMMS1)

   Since the MIMI_LEMMS1 detector's FOV is circular and it's diameter is 15.0
   degrees, looking down the X-axis in the CASSINI_MIMI_LEMMS1 frame, we have:
   (Note we are arbitrarily choosing a vector that terminates in the Z=1
   plane.)


                                  ^ Y
                                  |  ins
                                  |
                                  |         /|
                                  |      /   |
                                  |    /     |
                                  |  /     o |
                                  |/  7.50   |
                                  x---------------->
                                X  \          |   Z
                                 ins \        |    ins
                                       \      |
                                         \    |
                                           \  |
                                             \|

                                  |-- 1.0 --|
```

continues

FOV definition from the Cassini MIMI IK (continued):

```
The Y component of one 'boundary corner' vector is:

           Y Component = 1.0 * tan ( 7.50 degrees )
                       = 0.131652498

   The boundary corner vector as displayed below is
   normalized to unit length:
\begindata

 INS-82762_FOV_FRAME   = 'CASSINI_MIMI_LEMMS1'
 INS-82762_FOV_SHAPE   = 'CIRCLE'
 INS-82762_BORESIGHT   = (

  0.0000000000000000   0.0000000000000000  +1.0000000000000000

                      )
 INS-82762_FOV_BOUNDARY_CORNERS = (

  0.0000000000000000  +0.1305261922200500  +0.9914448613738100

                                )

\begintext
```

Circular FOV Angular Size

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The angular separation between the boundary corner vector and the boresight is the angular size.

FORTRAN EXAMPLE

```
C     Retrieve FOV parameters.
      CALL GETFOV(-11111, 1, SHAPE, FRAME, BSGHT, N, BNDS)

C     Compute the angular size.
      ANGSIZ = VSEP( BSGHT, BNDS(1,1) )
```

C EXAMPLE

```
/*  Define the string length parameter. */
    #define STRSIZ         80

/*  Retrieve the field of view parameters. */
    getfov_c(-11111, 1, STRSIZ, STRSIZ, shape, frame,
             bsght, &n, bnds);

/*  Compute the angular separation. */
    angsiz = vsep_c( bsght, &(bnds[0][0]));
```


Elliptical FOV Angular Size - 1

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The angular sizes are the angular separations between the boresight and the boundary vectors.

FORTRAN EXAMPLE

```
C     Retrieve the FOV parameters from the kernel pool.
      CALL GETFOV(-22222, 2, SHAPE, FRAME, BSGHT, N, BNDS)

C     Compute the angular separations.
      ANG1   = VSEP( BSGHT, BNDS(1,1) )
      ANG2   = VSEP( BSGHT, BNDS(1,2) )

C     The angle along the semi-major axis is the larger
C     of the two separations computed.
      LRGANG = MAX( ANG1, ANG2)
      SMLANG = MIN( ANG1, ANG2)
```

Elliptical FOV Angular Size - 2

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C EXAMPLE

```
/*  Define the string length parameter. */
    #define STRSIZ          80

/*  Retrieve the FOV parameters from the kernel pool. */
    getfov_c(-22222, 2, STRSIZ, STRSIZ, shape, frame,
             bsght, &n, bnds);

/*  Compute the angular separations. */
    ang1 = vsep_c( bsght, &(bnds[0][0]));
    ang2 = vsep_c( bsght, &(bnds[1][0]));

/*  The angle along the semi-major axis is the larger of the
    two separations computed. */
    if ( ang1 > ang2 ) {
       lrgang = ang1; smlang = ang2; }
    else {
       lrgang = ang2; smlang = ang1; }
```


Rectangular FOV Angular Size - 1

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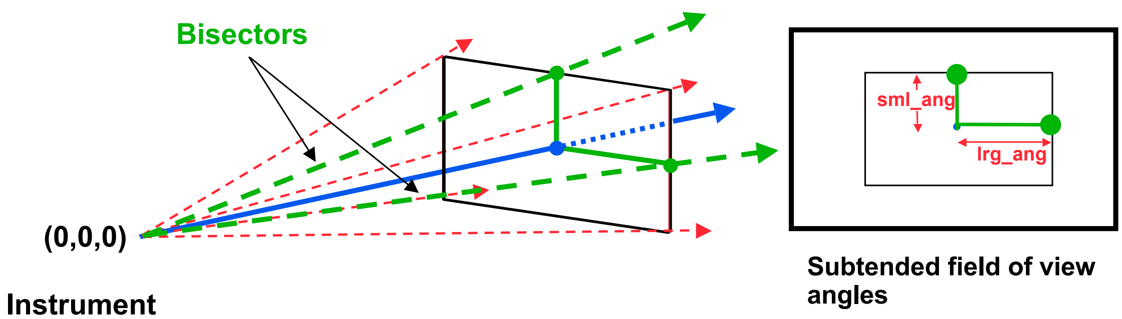
The angular extents of the FOV are computed by calculating the angle between the bisector of adjacent unit boundary vectors and the boresight.



Rectangular FOV Angular Size - 2

FORTRAN EXAMPLE

```
C     Retrieve FOV parameters from the kernel pool.
      CALL GETFOV(-33333, 4, SHAPE, FRAME, BSGHT, N, BNDS)

C     Normalize the 3 boundary vectors
      CALL UNORM(BNDS(1,1), UNTBND(1,1), MAG)
      CALL UNORM(BNDS(1,2), UNTBND(1,2), MAG)
      CALL UNORM(BNDS(1,3), UNTBND(1,3), MAG)

C     Compute the averages.
      CALL VADD(UNTBND(1,1), UNTBND(1,2), VEC1)
      CALL VSCL(0.5, VEC1, VEC1)

      CALL VADD(UNTBND(1,2), UNTBND(1,3), VEC2)
      CALL VSCL(0.5, VEC2, VEC2)

C     Compute the angular separations
      ANG1   = VSEP( BSGHT, VEC1 )
      ANG2   = VSEP( BSGHT, VEC2 )

C     Separate the larger and smaller angles.
      LRGANG = MAX( ANG1, ANG2)
      SMLANG = MIN( ANG1, ANG2)
```


Rectangular FOV Angular Size - 3

C EXAMPLE

```
/*  Define the string length parameter. */
    #define STRSIZ         80

/*  Retrieve the FOV parameters from the kernel pool. */
    getfov_c(-33333, 4, STRSIZ, STRSIZ, shape, frame,
              bsght, &n, bnds);

/*  Normalize the 3 boundary vectors. */
    unorm_c(&(bnds[0][0]), &(untbnd[0][0]), &mag);
    unorm_c(&(bnds[1][0]), &(untbnd[1][0]), &mag);
    unorm_c(&(bnds[2][0]), &(untbnd[2][0]), &mag);

/*  Compute the averages */
    vadd_c(&(untbnd[0][0]), &(untbnd[1][0]), vec1);
    vscl_c(0.5, vec1, vec1);
    vadd_c(&(untbnd[1][0]), &(untbnd[2][0]), vec2);
    vscl_c(0.5, vec2, vec2);

/*  Compute the angular separations. */
    ang1 = vsep_c( bsght, vec1);
    ang2 = vsep_c( bsght, vec2);

/*  Separate the larger and smaller angles. */
    if ( ang1 > ang2 ) {
       lrgang = ang1; smlang = ang2; }
    else {
       lrgang = ang2; smlang = ang1; }
```