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Status of Science Requirements for Pointing Scenarios

The main purpose of this is to summarize the current thinking about science requirements for guidance scenarios, document what was discussed at our meeting 6 weeks ago at APL, and identify unanswered questions. I only want to talk about basic capabilites, and not the details of how they will be commanded. A secondary purpose is to provide a set of examples for Karl and Wayne to look at which describe typical observing scenarios.

Since pointing for most of the CRISP observations will be accomplished with a combination of CRISP mirror commanding and guidance commanding, I've put in a short section that briefly explains the current vision of CRISP mirror commanding modes so that I can work through the examples at the end.

Guidance Scenarios
On CONTOUR, I believe we can do everything we need to do with a basic inertial hold command. To make it easier to describe, I'm going to use terms based on the NEAR guidance system. Wayne indicated the CONTOUR system might be similar so I hope this is ok.
On NEAR, there are two kinds of types of guidance commanding capabilities we have at our disposal for science planning. The first is one in which we may command the spacecraft to maneuver itself to point a particular part of the s/c at some target, AND THEN to continue to track that target in the inertial system specified (I will call that the 'inertial hold' capability). The roll about the pointing axis is also defined in that command structure. The second is one that allows us to command the spacecraft to oscillate in some defined pattern about that inertial hold position (we call this a 'scan'). As I said above, I believe that on CONTOUR we will only need the inertial hold. I have yet to find a case where we need the scan pattern (this is primarily because we will have the CRISP mirror to scan with for special cases where we need scanning).

On NEAR, the inertial hold is commanded by defining four vectors:

1. Virtual Boresight - this is a unit vector in the s/c body system which defines what part of the spacecraft we would like to point at the 'aimpoint'.
2. Aimpoint – this is a POINT in space at which the virtual boresight will point to continuously.
3. Roll Vector – this is another unit vector in the s/c body system which is used together with the roll reference to determine the s/c roll about the virtual boresight.
4. Roll Reference – this a s/c-centered unit vector that is essentially an RA/Dec (J2k centered in the s/c).   To determine the roll, the s/c rolls about the v.b. until the angle between the roll vector and roll reference is minimized. During the time that this inertial position is held, the roll condition is continuously updated to satisfy that condition.

The assumption here is that pointing the v.b. at the aimpoint is always satisfied first (higher priority). Roll orientation is determined with lesser priority, without taking the virtual boresight off the aimpoint.

Below is an attempt to list what capabilities we will need on CONTOUR, as described in this NEAR system. You may find a better way of packaging these capabilities. But hopefully the following will decribe well enough what we will need.

Inertial Hold:

1. **Virtual Boresight** – If this is a unit vector in the s/c body system then we can describe any of the instrument boresights. We could also put in slightly offset virtual boresights to put any of the instrumet fields-of-regard at a small angular distance from the target. We can use this to create 'mosaics' which we will want to do for the distant coma observations and some of the calibrations on moon and stars. The CRISP mosaics will require combination of s/c pointing and mirror motion to sequence (see examples).

2. **Aimpoint Coordinate System** – Coordinate system for aimpoint parameters. We will only need the following coordinate systems:
   1) J2000 – for opnavs and star calibrations
   2) Generic Inertial Body Centered – this is a non-rotating body-centered coordinate system that would be used for approach and closest approach observations at each comet, the earth observations, and the moon observations. Which target is used would depend on which ephemeris is loaded. We have no need to switch quickly between these targets, so I think this method would work.

   Comments:
   - I don't believe we will need any body-fixed coordinate systems, that is, a system which would allow us to target to a specific feature on a rotating body. If it WERE needed, this capability would also require having a body attitude file on board (a file that would give pole orientation, spin rate, etc). For comet activities, the CRISP tracking should take care of where we are pointing relative to comet center. And, for that matter, we won't even have any reliable predict information about spin rate or pole orientations for the comets. For the moon, it's not an issue because the moon will be very small relative to field of regard, and offset pointing can be accomplished by tweaking the virtual boresight. For the Earth, as long as we are not trying to target specific locations on the Earth (i.e., for public relations), then we will not need a rotating earth system. In the event that someone does want us to target specific features on the Earth, I think we can do it with the inertial system well enough to get us in the ball park. We should know the trajectory and observation timing well enough in advance to predict an Earth lat/lon using the inertial Earth-centered system (well, mabye well enough to get us on the right continent!). This is the only uncertainty. I think we can say that none of the science or calibration activities will need a target body fixed system.

3. **Aimpoint** – Point in space toward which you want to point the virtual boresight. (main discussion of this is above). On NEAR, the definition of parameters in this vector is a function of the coordinate system selected above.

4. **Roll Vector** – if this available as a parameter and is a unit vector in the spacecraft body system, then we can use this together with the roll reference vector to create specialized roll algorithms. It might be wise to have the flexibility to create very specialized roll algorithms.

5. **Roll Reference** – unit vector in J2000. On NEAR, the only option for this vector is to use J2000. If we wish to use a planetary body for roll reference (one whose trajectory is known

and on-board, such as the sun or earth), we must use one of the canned roll algorithms (see item 6) where a pre-selected roll vector is paired with a pre-selected roll reference. It might be useful to be able to specify a planetary body such as 'sun' as roll reference and then independently select the roll vector we want.

6. **Roll Algorithm** – On NEAR we have this option to select a 'canned' roll algorithm. If a non-zero value is given for this parameter, a short-cut is used to define the s/c roll about virtual boresight. This overrides values given in the roll vector and roll reference vectors. One advantage here is that it provides the opportunity to select a target body such as the sun or earth (ephemerides on-board) as the roll reference, and its location in J2000 relative to the s/c is continuously updated. As I said above, this is the only way we can do this on NEAR, because the roll reference vector is, by default, J2000.

However, here's a first cut on this for CONTOUR science :
1) roll vector = s/c y, roll reference is sun (for opnavs???, for earth or moon obs???)
2) roll algorithm for comet flybys where s/c rolls about v.b. to keep CRISP plane in comet-s/c trajectory plane (on-board feedback loop)

7. We might also want to have an **aimpoint short-cut**

CRISP commanding:

Tracking On : In this mode we will specify a target (inertial, or body-centered), and a sample value relative to the slit. The CRISP will then determine the mirror position required to put the slit (or rather, the sample value relative to the slit) on the target. Tracking on' means the software will keep the selected sample value trained on the target. Additional options exist:
- Motion removal – deadband motion is removed in the mirror scanning direction
- We may also 'scan' the mirror relative to the target at a specified rate (deg/sec) for a specified duration.

Fixed Mirror Position: In this mode, we simply specify which mirror position we wish to take data through. The tracking option would not be available in this mode.

EXAMPLES:
(see Scott Murchie's writeup on calibrations)

1. CRISP functionality test –

A. In this test we want to center the moon in the CRISP field-of-regard and keep it there while acquiring a set of images.
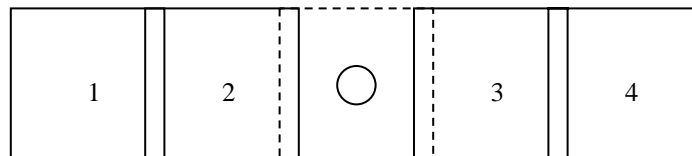
    Steps:
1) Orient s/c – Guidance Mode 5
    virtual boresight = any unvignetted CRISP boresight
    aimpt = moon center
    roll vector = [0,1,0]
    roll reference = Sun ok????

2) Set CRISP tracking 'on' (target = moon, boresight = center of imager, motion removal on). This will center the CRISP field-of-regard on the moon, and remove deadband motion.
3) Acquire images

B. Put CRISP field of view in 4 adjacent positions (in mirror scanning plane) relative to moon. At each position stop and acquire sets of images.

    Steps:
1) Continue s/c orientation same as above
2) Continuing with CRISP tracking on, we now also command scan mirror to move relative to the moon center so that the CRISP fov is at the position 1, at which point we pause scan, and then acquire images
3) Repeat on other positions

2. **CRISP imager/spectrometer coalignment, psf, etc. –**
In this test we will want to microstep the CRISP slit across the moon while acquiring CRISP spectrometer data.

Steps:
1) Command spacecraft to the inertial orientation as in example 1A (Guidance Mode 5)
Virtual boresight = any unvignetted CRISP mirror position
Aimpoint = moon center
Roll Vector = [0,1,0]
Roll Reference = Sun ok?
4) Set CRISP tracking 'on' (target = moon, boresight = center of slit, dead-band motion removal on). This will center the CRISP field-of-regard on the moon, and remove deadband motion.

2) Begin CRISP mirror scanning relative to moon center, move slit away from moon, until moon is completely outside of slit, then pause. Then scan the mirror in reverse direction to cause slit to to move all the way across moon while acquiring spectrometer data and imaging data.

3. **CRISP mirror pointing and mirror plane test –**
Here we want to take CRISP images at 5 different mirror positions (2 aft, 3 forward) spread across the extent of the mirror plane. The purpose is to calibrate the geometry of the mirror plane.

Steps:
1) orient spacecraft in fixed inertial position such that the mirror plane will intersect a region of sky with many good star clusters: (Guidance Mode 4)
Virtual Boresight = Anything in y-z plane (default CRISP unvign. boresight ok)
Aimpoint = selectable inertial J2000 vector
Roll Vector = [0,1,0] (this'll work)
Roll Reference = selectable inertial J2000 vector
(Roll reference and aimpoint selected so that s/c is pinned in an orientation that will allow the CRISP mirror plane to view selected region of sky).
2) Command CRISP to first fixed mirror position, acquire data
3) Command CRISP to move to second mirror position acquire data
4) Repeat for remainder of the positions.

Note: it will not be necessary to remove deadband about x axis in this observation. A little smear in the stars will be good.

4. CFI Pointing Test and OPNAVs

Acquire CFI images of some star or star field (to be selected by NAV).

    Steps:

    1) orient s/c : (Guidance Mode 4, EXCEPT must change boresight to CFI)
       Virtual Boresight = center of CFI
       Aimpoint = inertal J2000 vector
       Roll Vector = [0,1,0] ok
       Roll Reference = anything (inertial ok)

    2) Acquire images

5. CFI Functionality Test

Put moon at center of CFI, then acquire a set of images. Then put center of CFI at 8 additional positions which make a 3x3 grid centered on the moon.

    Steps:

    1) Orient s/c : Guidance Mode 5, except need default boresight to be CFI
       Virtual Boresight = center of CFI
       Aimpoint = moon
       Roll Vector = [0,1,0] ok
       Roll Reference = sun ok?

    2) Acquire images

    3) Re-orient s/c: Guidance Mode 5, except need default boresight slightly offset from CFI
       Virtual Boresight = slight offset from CFI center to achieve position 1
       Aimpoint = moon
       Roll Vector = [0,1,0]
       Roll Reference = sun ok?

    4) Acquire images

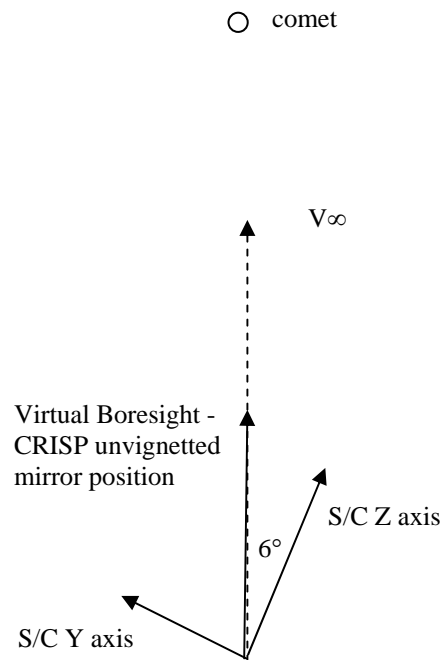   5) Repeat for all 7 remaining positions.
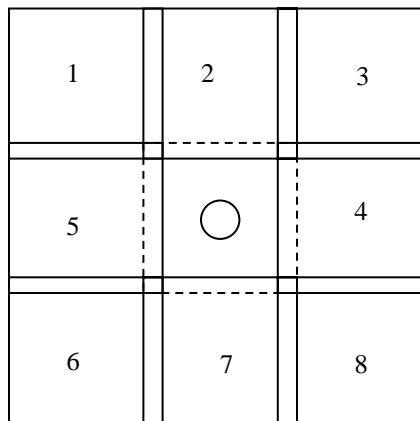
6. CRISP Comet Approach Observations

In these observations we will be orienting the s/c so that the z axis is slightly offset from the s/c trajectory direction, at an angle that will put CRISP viewing regard on the comet. For unvignetted/vignetted CRISP observations that angle would be about 6/3 deg from s/c V∞.

Steps:
1) orient s/c : Guidance Mode 1 (must change default vir.bore to be CRISP unvign)
   Virtual Boresight = first unvignetted CRISP mirror position (including uncert.)
   Aimpoint = inertial vector of V∞
   Roll Vector = [0,1,0] ok
   Roll Reference = inertial
2) Set CRISP tracking 'on' (target = comet, boresight = center of slit, dead-band motion removal 'on'). This will center the CRISP field-of-regard on the moon, and remove deadband motion.
3) Acquire images or spectrometer data

7. CFI Comet Approach Observations

Same as above, except for CFI. Orient the s/c so that the z axis is slightly offset from the s/c trajectory direction, at an angle that will put CFI viewing regard on the comet.

Steps:

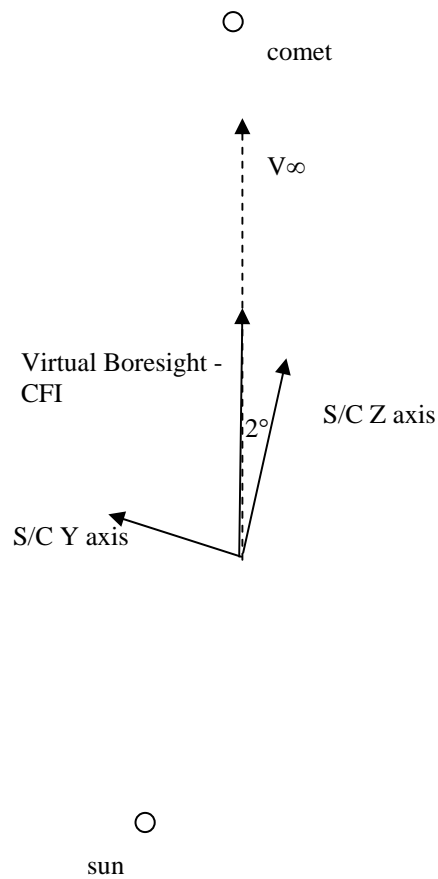1) orient s/c: Guidance Mode 1 (must change default vir.bore to be CFI)

Virtual Boresight = CFI center

Aimpoint = inertial vector of V∞

Roll Vector = [0,1,0] ok

Roll Reference = inertial?

2) Acquire images

○
comet

↑

V∞

Virtual Boresight - CFI

2°

S/C Z axis

S/C Y axis

○

sun

8. CFI/CRISP Comet Encounter Observations

In these observations we will be orienting the s/c so that the z axis is slightly offset from the s/c trajectory direction, at an angle that will put CRISP viewing regard on the comet.

Steps:
1) orient s/c : <mark>Guidance Mode 0 (need change default vir.bore slightly off from Z)</mark> <mark>(or should use GM 1? Can you use GM1 with non-Z boresight??????)</mark>
   Virtual Boresight = <mark>slightly offset from Z in the direction of Y axis</mark> for the small angular offsets required at different times
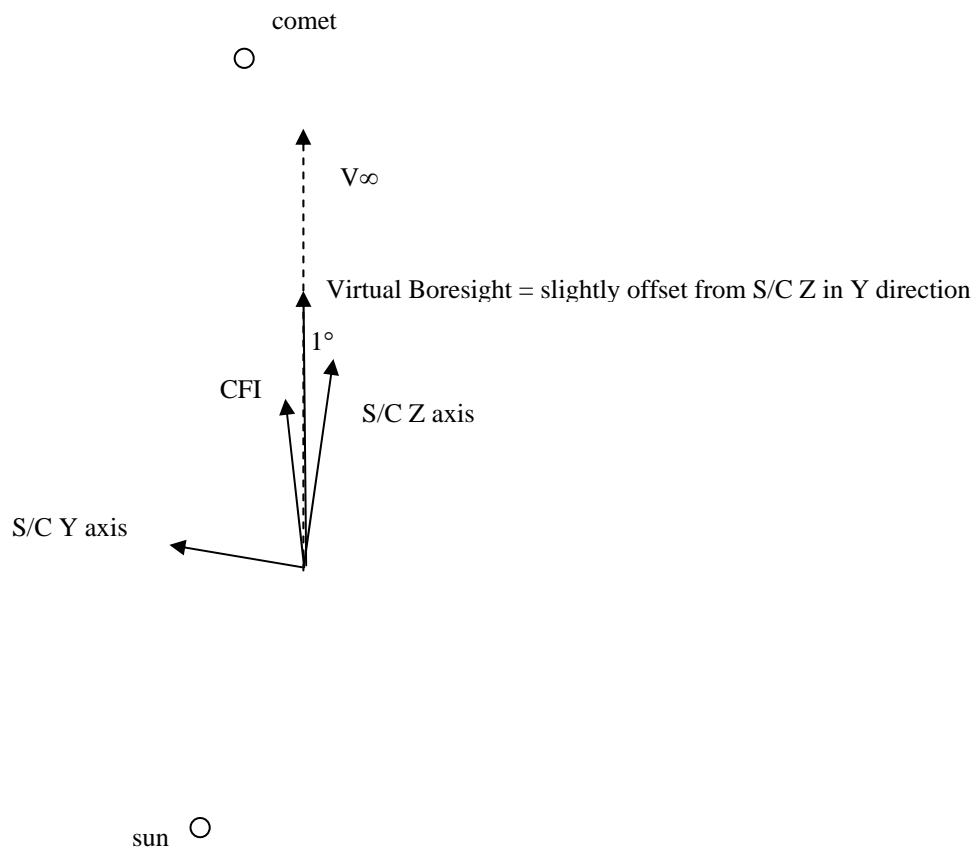   Aimpoint = inertial vector of V∞
   Roll Vector = <mark>[0,1,0]</mark>
   Roll Reference = <mark>comet</mark>
2) Acquire images and spectrometer data

This first diagram shows example at about 3 minutes before closest approach where we want Z to be slightly offset from V∞ to allow CFI to view comet.

comet ○

↑

V∞

Virtual Boresight = slightly offset from S/C Z in Y direction

1°

CFI

S/C Z axis

S/C Y axis

sun ○

Next diagram shows case where we want Z to be exactly aligned with V∞ for the final approach sequence.

V∞

comet
○

CRISP Mirror
pointing direction

Virtual Boresight =
S/C Z axis

>6°

S/C Y axis

○
sun
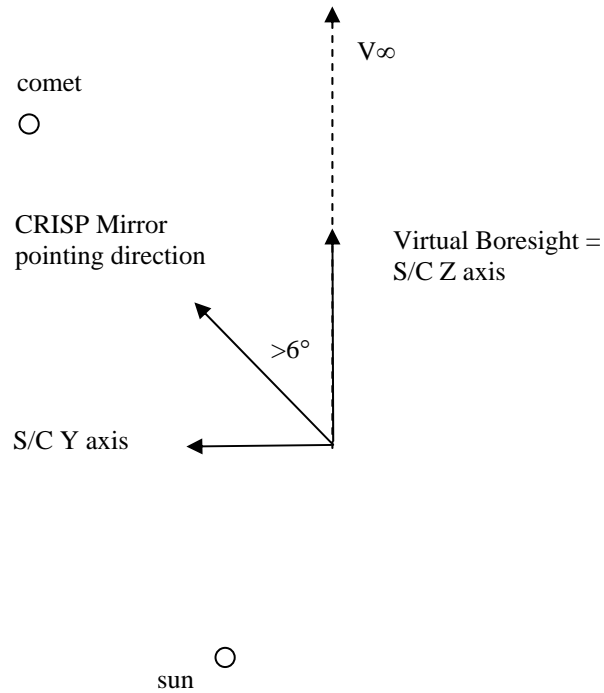
That covers all of the different observations I can think of right now. I might have missed one. Please look this over and let me know what you all think. Thanks, Ann