Review of the Proposed Coordinate System of comet 67P/C-G as described in

“*Proposal about reference frames and mapping schemes of comet 67P/C-G for common use within the Rosetta project and for approval by the IAU*”

by Scholten et al

General Comments:

C-G represents an extreme bounding case, with technical issues that are novel and complex because the nucleus of 67P is highly irregular in shape, and because it has a changing, non-principal axis rotation state (though the current description of the rotation state is restricted to times before Early September 2014 so it does not address the temporal variability). Dealing with this, and future reviews in a thoughtful manner is essential because it will likely set precedent for future investigations.

The reviewers agree that with a few minor corrections, the basic coordinate system proposed here (Section A) is compliant with the IAU requirements and satisfies the PDS requirements for archiving. However, additional description and documentation of the design and how it was developed is needed.

Sections B and C are essentially elaborations on the coordinate system that aid in using the data, but are not bound by any specific requirements. However, additional documentation, as noted below, would help improve the usefulness of these sections as well.

Specific details

Section A:

* The proposal describes the definition of the coordinate axis directions relative to the surface of the nucleus and their orientation in inertial space but does not discuss the origin at all. If the center of mass defines the origin, there needs to be discussion about how it was obtained and what is its uncertainty, given the weak gravitational field. If the center of figure defines the origin, then more discussion is needed about how this was derived for such a complex shape. In either case, how was the unseen surface accounted for, and how sensitive is the origin to the topography in these areas.
* Were the principal moments of inertia derived, either from the gravity or shape model? If so, what are their uncertainties, and were they used in deriving the coordinate system?
* How was the Z-axis defined? The proposal discusses and gives parameters for the precession as well as spin of 67P. The statement near the top of p. 2 appears to say that the spin (angular velocity) vector precesses on a cone of half-angle 0.2° in inertial space (the herpolhode), which is about 5 m in radius at the surface. Rigid body dynamics tells us that the angular velocity vector will also move (along a different path called the polhode) relative to the body itself. This subtly different effect is not discussed; the coordinate axes are fixed by definition in the body and the Z-axis is equated with the spin axis. This raises the issue that the Z-axis ought properly to be taken as the long-term average of the rotation axis rather than an instantaneous location, and also potentially complicates the equations to transform from inertial to body-fixed coordinates. On a practical level, it would be good to provide an estimate of the size of the polhode (e.g., from dynamical considerations if it was not directly observed in the rotation modeling) and hopefully show that it is so small (even smaller than the herpolhode) that it is not significant for cartography.
* Rotational parameters are given in several locations throughout the document and then repeated in total on p. 5. Probably only one table is needed. Use of a NAIF convention to present the data is not required but it is certainly acceptable and practical. Note that values given for the BODY1000012\_RADII parameter at the top of page 5 disagree with those listed for the same parameter in the middle of the page, so the correct values should be used.
* The significant digits in the table are inconsistent. Although SPICE kernels often carry more digits than is meaningful, there should be parity between common values. e.g., currently the NUT\_PREC\_RA has 8 significant digits, while the corresponding NUT\_PREC\_DEC has only 2. Also carrying 12 decimal places for the precession angle seems excessive when the pole is defined to only 2.
* Reference [A7] is a personal communication. Should use a more useful reference. Possibly "SPICE PCK Required Reading"; latest version; <http://naif.jpl.nasa.gov/pub/naif/toolkit_docs/FORTRAN/req/pck.html>
* The definitions of the reference features should include the radius in addition to the lat/long.
* Using more than one reference feature to define the coordinate system is laudible, but for an active body with variable, non-principal axis rotation, surface erosion, flexure of the lobes, etc., it would be valuable to highlight many more features to provide a network that would minimize potential effects of the comet’s variability. Many features have presumably been defined in this work, and could be easily provided. The three features already defined can act as primary set listed in the document, with the full network added in a supplementary data file.
* It would be informative to quantify the extent to which the surface is multi-valued in the global coordinate system. Some basic statistics (“X% of the surface shares the same latitude-longitude values as two or more other locations”) as well as a map of the regions affected (e.g., shaded relief colored green where lat-lon is single valued and red where it is multi-valued).

Section B:

* Include a discussion about whether any of the body subsets have regions that are multi-valued, or if they were designed to avoid that problem. Also, is there overlap between the systems? If not, is there a way to address extended features that straddle the boundary?
* It should be clarified that the ellipsoids were fit to the lobes as a means of computing the center offset of the body subsets, but the coordinate axes remain parallel to the global system. With this clarification, it would also be useful to include the ellipsoid axial ratios and orientations, to allow coordinate transformations, if desired.
* Additional description of the neck subset would be useful, including an equation for the median plane that defines the center. (Currently there is only a brief mention that three points were selected manually to define the plane.)
* It makes sense to use a spherical reference surface for mapping the segments, but there should be a rationale for why they are used, as well as for the particular sizes of the spheres that were selected.
* It would be very useful to readers to have an idea of how much the shape model departs from the ellipsoids, and from the reference spheres.
* Given the different global and body subsets, a feature could potentially be described by several different systems. Some explicit suggestions on what system should be used in various circumstances would help to avoid confusion of different users using different coordinates. Also, is there a means of converting between the various systems?
* It is not clear what information is conveyed by Figs 3 and 4, other than the positions of the axes. Perhaps the figures could be revised to show the global ellipsoid (Fig. 3) and the 3 local spheres (Fig. 4) as transparent surfaces superimposed on the shape model?

Section C:

* The opening paragraph is well stated, but it should be made clear that this is a *de*scription of how the mission is planning to present their data in map form, rather than a *pre*scription to limit the acceptable presentations. Other types of projection might be quite useful, depending on the particular application (e.g., the orthographic projections shown in Figs. 3 and 4!)
* PDS 3 documentation includes “equidistant” in a list of admitted map projections but its meaning is not documented; there are equidistant cylindrical and equidistant azimuthal projections. As a result, several recent missions have adopted the term “equirectangular” for the simple cylindrical projection generalized to allow different grid spacing in latitude and longitude. The Rosetta team should follow this terminology.
* In the 3rd paragraph of p 8, “non star-like shape” should presumably be “non sphere-like shape”.
* It should be noted that the nominal “scales” for the digital maps apply on the reference sphere for the projection, and thus the true scale at most points on the surface is different.
* The maps for the “big lobe” are centered at 140°, 230°, etc. which is 40° offset from the default of 0°, 90°, 180°, 270°. There is no objection to this but it would be worth adding a sentence explaining that this is done to place the end of the lobe in the center of the map. Similar remarks apply to the equatorial aspect maps of the neck region.
* It might be especially useful to have a map of the neck region in transverse equirectangular projection with the “transverse equator” running down the centerline of the region, i.e., roughly 60° to 240°E.
* In the global map projection, describe how the multi-valued points are addressed. (Is the dark area the multi-valued data? It is not described).