Executive Summary:

We are very happy with the overall Herschel mission and NHSC's efforts to support the US community during Herschel operations, especially with the longer than expect helium lifetime. The Herschel Users Group Survey (HUG Survey) of the community indicates a general satisfaction with the mission and the tools developed to analyze the data. The instrument calibration efforts are really maturing.

NHSC Response: Thank you.

The end of cryogens is not the end of the mission, and the post-ops phase will be critical to establishing Herschel's legacy. The NUP focused its efforts on post-operations priorities as opposed to details concerning instrument performance on in-flight operations. There are two parts to the post-ops phase: continued user support and establishing Herschel's legacy. The Herschel Publications are showing an upswing but argue for the importance for a strong NHSC in the post-Ops phase. Many US investigators will just be getting their data at the end of helium and will need full NHSC support to see them through to publication. Herschel's legacy will be its science data archive and associated Herschel documentation on the instruments and calibration.

NHSC Response: Agreed--We have recently proactively pinged the PIs of all NASA funded PIs to gain an understanding of refereed publications—both already published and imminent. Results will be presented at the next NUP. Judging from the responses, the future for US papers on Herschel data is very positive.

An accessible archive with high quality data products is the

highest priority for Post-Ops effort. Below we provide some specific comments and recommendations on several post-Ops areas: Herschel Science Archive, HIPE, User help, scientific and public outreach, map-making workshop, synergies with other facilities, funding and future NHSC & IPAC staffing.

We acknowledge the NHSC, HSC and ICCs dedication and enthusiasm for the Herschel mission. Hence, we trust that the archive will be good on completion of the Post-Ops phase.

NHSC Response: Your comments are appreciated.

Post Operations Support by NHSC:

Herschel Science Archive

The HUG user survey suggests that many people find the HSA user interface unfriendly, and the current tarball way of accessing the data is inaccessible to non-experts. Making an accessible archive with high quality data products is the highest priority for Post-Ops effort.

NHSC Response: This has been addressed by the HSC, with significant changes to the archive having been implemented to address these issues (see below).

Expert-reduced data

The experts at the NHSC are uniquely qualified and knowledgeable to perform custom reductions of individual datasets that will be of higher quality than that provided by the baseline pipeline processing. However, there does not seem to be sufficient resources or time to perform this for a significant fraction of the existing data. It would be difficult to assess what data would be the highest priority for expert reduction. Most of

the large programs have teams of highly qualified people reducing their data and have a responsibility to deliver their products to the archive, so one does not need to duplicate that work. The HSC should work with the various large program teams to provide specifications on how to deliver the data to be able to easily integrate their products into the archive in a seamless way where the data can be easily browsed and searched, rather than just something like a tarball that someone will have to download and unpack to figure out what is in it.

NHSC Response: The HSA is aware of this, and is preparing new searchable metadata which will make searching easier (so called "expert panels"). Furthermore, the next version of the HSA will include new "stand alone" products (HSA 5.2), which include FITS files for high-level products (both images and spectral cubes). NHSC/IRSA is approaching this issue in parallel (see below and topic at upcoming NUP14 telecon).

In addition, the NHSC review of the user delivered data to the HSA by US led key programs would be useful to ensure they meet the HSC formatting standards and have a basic level of accessibility for the general astronomical community. This NHSC review service should be advertised to the US led key programs soon.

NHSC Response: As you know, NHSC provided significantly enhanced guidelines for teams submitting new User Reduced Data Sets (URDS). Furthermore we are systematically working closely with IRSA to incorporate fully searchable high-level products from these materials *stored at IPAC.* So far several US-led programs have been incorporated (roughly one per month) into the IRSA archive so that the full capabilities of the IRSA software can be utilized. (see for example http://irsa.ipac.caltech.edu/data/Herschel/ACMC/). We expect to eventually have a similar capability for science data products in

the archive (i.e. all level 2+ science data).

What should the final formats of products and file directory structure look like? Both now and after project has ended

Some effort should be put into making the data products a more easily human-readable and understandable format. If the directory structure is not changed, one could populate the directories with README files that explain the contents and files. The data products in the end should make sure that reasonably simple FITS structures that are easily imported by a wide range of existing software. The documentation should be made complete in the online docs to explain the various structures.

NHSC Response: README files have been added to the tarballs. FITS structures have been reorganized slightly to make more logical.

Production of high-level products (e.g., point source and spectral line catalogs)

The question here is whether NHSC and HSC should perform tasks that are beyond producing fully processed data products, such as point-source catalogs and spectral line lists. Although we recognize that such high-level products would be highly valuable for the community, we believe that HSC and NHSC should first concentrate on making sure that fully processed data products are as good as they can be. Production of high-level products such as source catalogs/line lists should therefore be considered of lesser priority and should not interfere with the most important task of providing the best possible fully processed data products.

NHSC Response: We agree with this philosophy, and are moving cautiously in a staff-limited environment

Having said that, we envisage that HSA will probably be able to provide point-source catalogs together with fully-processed PACS and SPIRE images with available resources (at least for clean un-crowded fields). If this turns out to be the case, we would strongly encourage such effort . It will particularly be useful if these catalogs and corresponding images are ingested into IRSA, which will allow easy visualization and catalog query for general users. The success of this approach is already evident with the IRSA database/interface provided for the WISE and Planck missions.

NHSC Response: Agreed. Indeed IRSA is very capable of ingesting, relatively easily, such lists and catalogs. HSC and Konkoly Observatory have set up a working group which includes representatives from NHSC-PACS and SPIRE teams, to investigate what would be needed to create a useful catalog of sources. The investigations will end and a report will be generated in the Spring 2014. NHSC will provide an update at NUP14.

Production of spectral line lists may be more complicated. It needs to be discussed further whether such a task would be feasible within the available resources.

NHSC Response: Agreed—we are approaching this cautiously and is a subject of ongoing discussion.

Web portals for Herschel data at IRSA

The NHSC should keep pursuing this option and obtain permission from the HSC to keep local copies of the data for browsing and visualization in the IRSA software. When the

data are downloaded by the user, it can still point to the main

Herschel archive for obtaining the data. We assume that this effort will not require a large amount of NHSC resources, since it seems that the infrastructure exists at IRSA and some resources there can be utilized. The IRSA Web portal will provide more functionality for searching the database, and doesn't seem to duplicate the existing archive functionality at HSC. This project would significantly raise the visibility of the Herschel data to the astronomical community.

NHSC Response: Agreement has been reached. This will be part of a longer-term plan between NHSC and IRSA that is very much resource-limited on both sides. However, we feel that it is doable by the end of POPs.

HIPE

HIPE is the key to looking beneath the surface of the archived data, so future plans for HIPE are inextricably connected with the projected use of the archive. Experience has shown that most users will use pipeline processed data, but maintaining some access to original data is necessary to take full advantage of an archive. The NUP believes that a priority on providing well-calibrated pipeline-reduced data as a prime product for the archive will result in an advanced version of HIPE that will enable deeper exploration of the archive by scientists who find that necessary. No effort should be expended in lightweight improvements to presentation or ease of use at this stage.

NHSC Response: There is agreement that the lasting legacy of Herschel will be the best possible archive. The three instrument teams (primarily at the ICC level) have slightly different approaches on how to accomplish this, but the underlying aim is to provide the end-user with a best possible archive.

The NUP sees several ways that HIPE can continue to be useful for archival research past the end of active maintenance by the Herschel mission. For some years to come it is likely that a static final version of HIPE will be available on computers within the science centers and the community. Supporting HIPE operation on virtual machines, as demonstrated by the NHSC, may well continue for many years with minimal effort if financial support is available. This would be a very desirable outcome. A key element to HIPE's future use is that it is open-source software, and a copy of HIPE itself should be included in the archive. Advanced users could then adapt the code to new versions of packages on which it depends (e.g. JAVA) to keep it operational at a greater or lesser extent. At minimum, it will be possible to use its data-access infrastructure in other programs. It is quite likely that HIPE users in the open-source community will keep operating versions of HIPE available.

NHSC Response: The long-term status of HIPE is still quite unclear and will undoubtedly be a topic at the upcoming May 2014 Ground Segment. The question of open-source for HIPE ultimately a people-resources issue at the HSC level, and its not clear if these resources exist. NHSC's current take on this is to assume that HIPE will not live on beyond 2017. It is being discussed whether some parts of the toolboxes (such as the Cube analysis toolbox) could be made "stand alone" to allow users exploring the archive to investigate the contents of a spectral data cube quickly to ascertain whether it contains something they may be interested in. Cube inspection tools will be topic for discussion at the NUP14 telecon.

The NUP believes that effort for the type of on-demand processing we learned about at the meeting would be better spent on bringing data up to the highest standard for archiving.

Processing with a simpler interface that allows adjustment of a subset of parameters might be convenient for some users, but little expert effort should be expended for this purpose, and users should be encouraged to spend the time needed to understand their reductions at a higher level.

NHSC Response: We agree in general, but the special case of PACS maps has generated a need for a tool to help users quickly run several mapping algorithms on the same datasets without having to install many different forms of software. SIMPLE has thus been developed for this purpose and is quite popular. In general we agree that we should only spend time of something if a strong need presents itself.

User help (Documentation, videos)

Herschel documentation has improved greatly in terms of its quality and accessibility. The ESA Herschel website provides Quick Start and Data Reduction Guides in a web format that is easy to browse and search. A number of data processing tutorial videos are now available through YouTube.

We would particularly like to commend NHSC's efforts to provide additional documentation and videos that have been produced through various data processing workshops and webinars. The amount of NHSC-produced material is now quite substantial, and they benefit the world-wide Herschel user community greatly. The value of these documentation and videos will further increase as we move into the post- operation phase and many non-expert users start to dig into HSA.

NHSC Response: Thank you.

Improvements needed

At the same time, we also note some room for improvement. As seen in the HUG questionnaire report, the data processing documentation is graded significantly lower (in their Figure 4) than that of the instruments (i.e., manuals; in their Figure 1). This likely reflects the fact that users are struggling to learn HIPE and master its use. As pointed out in a previous NUP, these HIPE-related documents look more like being intended for computer programmers rather than astronomers. Although this shortcoming is partly compensated by the abundant data tutorials now available, it may be worthwhile to think about the possibility of revising HIPE-related documents so that they will be more accessible to astronomers. This may become an important issue as more non-expert users start to work with Herschel data in the post-operation phase. Online documentation is particularly important and has been noted as disorganized. Spending time to have really good streamlined web-pages would be worthwhile since a lot of people, particularly younger generations use the web.

NHSC Response: Documentation is a key element of the POP, and improvements have been made since NUP13, both for general HIPE documentation (launch pads) and instrument specific documentation. We believe there is still room for improvement. All three teams are working on cookbook ideas to streamline this. We will address documentation efforts specifically in NUP14.

One specific suggestion: as far as we are aware, there is no single place where we can find all the necessary information for aperture corrections (with respect to HIPE versions, mapmaker types, etc.). The lack of such aperture correction tables was also mentioned in the HUG questionnaire report. It would therefore be

good to produce something like a cheat sheet that complies such crucial and often-used information.

NHSC response: This is an active area of work within the teams (SPIRE is improving its beam profiles and PACS has been making corrections to its calibrations files (distortion of pixels not fully incorporated in previous versions). This is an acknowledged area of need that is strong being addressed.

Scientific and Community outreach

Scientific

The Herschel Publications are showing an upswing, but argue for the importance for a strong NHSC in the post-Ops phase. Many US investigators will just be getting their data at the end of helium and will need full NHSC support (workshops & webinars) to see it to publication. Another way to increase the publication output of Herschel is to have additional science conferences with a focus full or in part on Herschel data and results. The IPAC conference on Gas in Galaxies in March 2013 was very good in this regard. The IPAC conference, which was dominated by Herschel spectroscopy, was really excellent and showed that users feel confident enough in their spectral data to present it. This really shows advancements, since spectroscopic calibration often lags photometric and imaging calibration.

NHSC Response: Yes we are tracking this closely. It will be discussed in NUP14.

The Herschel project's Fall 2013 conference will be well timed to focus the community on finishing their Herschel projects or to get

preliminary results out for more recently acquired data. We support the idea for another AAS special session or splinter session at the Winter AAS 2014 in MD. Perhaps the focus should be on a different topic that the last one which focused on the Milky Way and its environment.

Public

Herschel Public Outreach is excellent. We recognize this is an ESA led and NHSC supported effort that has been evolving. Keep up the good work with ESA on keeping Herschel in the news. The press seems engaged with this mission and announcing the end of cryo. Consider a press releases to announce the opening of the Herschel archive of improved data products to demonstrate how missions live on after the hardware dies off. The astropix program is a really good idea and including Herschel data is great.

NHSC Response: Thank you.

Map-Making Workshop

The NHSC played a major role together with the HSC in organizing a workshop on map- making in 2013 January. The concept for the workshop was to discuss results from a large effort to compare results from a half-dozen different software packages for making maps from Herschel data. A variety of examples of real Herschel data were processed with these packages as well as several examples of synthetic data. We congratulate the workshop organizers and are looking forward to the "final" report (which is likely to be expanded, of course, as time goes by). We encourage the NHSC to consider this map-making report in deciding how to allocate resources for user tools that will be available for

producing maps in the final years of the mission, since it is likely that not all tools can be equally well supported.

NHSC Response: The reports are now all available online and PACS is actively updating its map-making to take account of improvements in several areas. An update to the November 2013 PACS document is planned for the end of March 2014.

Synergies with other facilities

There are a number of other current and future facilities whose science will complement and/or make excellent use of results from Herschel. These include such observatories as SOFIA, JWST, ALMA, CCAT, SMA, SPICA, etc. It will be important to develop features of Herschel data access that encourage the use of Herschel data, for both proposal planning and scientific analysis with these other facilities, e.g. access via IRSA. Joint scientific meetings between Herschel users and users/planners for these other observatories can increase the exchange of knowledge and technical expertise to make the fullest use of these other facilities, as well as to more completely exploit the legacy of the Herschel mission.

NHSC Response: Agreed. ALMA is a clear example and now that it is approaching more regular operations such collaborations are more likely to ensue.

Funding

The NUP was relieved to hear that NASA has maintained the commitment to supporting the observers from the Herschel project all the way up to head quarters. The NUP was satisfied to hear that the NHSC had a plan for the Priority 2 program funding. This plan will assess how many priority 2 programs were

completed once cryogens run out. The process is expected to be handled in a two month or so time period which is good news. Rules for distributing funds will be the same as for the Priority 1 programs. However, the amount per hour is expected to be less because the longer than expected Helium lifetime enabled many Priority 2 programs to be accomplished. The NUP anticipates disappointment from people with Priority 2 programs because they will have the little funding to accomplish the work. We understand that the NASA ADAP programs will cover all the Herschel data in the next round, including the priority 2 programs which only have 6 months proprietary time. The NHSC may want to consider wording the notice about the funding with some mention of ADAP as another option for additional funding support.

NHSC Response: We are actively promoting the ADAP connection within our newsletters and in the NHSC Project Scientist's letter to funded PIs, where we reminded them of the ADAP opportunities.

Future of NHSC Staff and IPAC

The NUP was concerned about NHSC staff attrition during the post-Ops phase of Herschel. We were glad to hear there is stability in IPAC's future because of several current and future possibilities. Current projects being NHSC work, warm Spitzer and the IRSA archive. Future work including possible efforts on the ESA led Euclid mission and some specialized JWST project support subcontracted from STScI.

NHSC Response: Some of these projects are beginning to provide stability for the team.