REVISED FINAL REPORT OF THE HEASARC USERS' GROUP

MEMBERS:
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HEASARC, or High Energy Astrophysics Science Archive Research Center is an archive containing - and enabling easy access to - data collected by essentially all current and past satellite-based missions sensitive in the X-ray and gamma-ray band from celestial sources. Recently, the HEASARC repository also incorporated much of the current and past observations aimed to study the Cosmic Microwave Background, via merging the original Legacy Archive for Microwave Background Data Analysis (LAMBDA) into the expanded HEASARC.

Right from the start, the Users' Group considers HEASARC to be an extremely valuable resource, and we unanimously agree that it must be maintained. It allows for "one-stop shopping" with transparent and easy-to-use interfaces and search engines. The data are well-organized, and documentation is generally very good. The archival data are well-screened, and are generally quite complete. Those are important achievements, since much of the data originates from sources / investigators working in the distant past - and thus those who might have ceased attending to the quality / accessibility of the data. HEASARC also includes data from missions where there was no direct US involvement (such as Exosat or BeppoSAX), or missions led by non-US partners, with more modest US involvement (such as Rosat, XMM-Newton, and Suzaku).

In addition, HEASARC provides and maintains a number of software tools needed not only to *reduce* the data, but also valuable and easy-to-use, well-documented tools facilitating the *analysis* of data. Famous examples are those included in the Xanadu suite - XSPEC, XRONOS, and XIMAGE. Importantly, the analysis tools are designed to appear quite similar to the user, and not very mission-dependent, allowing for uniform and often simultaneous analysis of multiple data sets originating from different missions. This is partially owing to the fact that HEASARC is also a repository of calibration data for those missions, an important part of its charter.

In the Users' Group opinion, HEASARC is run quite efficiently, and provides a good value for NASA's (and thus taxpayers') money to the scientific community. It is used very extensively, with multiple terabytes of data downloaded yearly (and this volume is increasing, as is shown in Figure 3.2 of the 2015 HEASARC Proposal for the Programmatic Review). The analysis tools are versatile: when data from a new mission are added to the portfolio, the tools sometimes need to be revised, but HEASARC's policy is to make sure that the revisions are

backward-compatible, which is a great plus. This is at least partially because the HEASARC team has developed a good and thorough set of standards (known as the HEASARC/OGIP FITS standards), which are clearly documented. In addition, the HEASARC team is quite proactive in working with essentially all potential (proposed, but not necessarily already selected) missions (such as NASA Explorers) to assure that the plans for ground system, pipelining, and data archiving are compatible with those standards. Of course not every proposed mission is selected, but we still think this is an excellent policy. Finally, HEASARC assists (and in many cases, organizes) reviews of the Guest Observer proposals, using a set of tools known as the Remote Proposal System, which, in the opinion of the Users' Group, is easy to use and works well.

Perhaps minor but important point: the UG is aware that the HEASARC personnel are generally scientists actively engaged in research in astrophysics. This assures that those scientists also are also active HEASARC users, and thus they provide ongoing "quality check" of HEASARC's functions. UG believes that allowing (and encouraging) HEASARC personnel to devote a part of their time to active research is prudent and valuable.

With all those well-deserved accolades, the Users' Group highlighted several (mainly minor) issues, and those are below. In the process of preparation of the report, it became clear that the Users' Group needed to better understand the functionality of the Virtual Observatory, and HEASARC provided an additional presentation to explain VO's functions. This was particularly helpful, since VO "works behind scenes" meaning that it aims to provide the interfaces between various data repositories that should be relatively transparent to the users. The points below reflect the answers provided in the supplementary presentation.

(1) One of the HEASARC goals that will be facilitated by the participation in the VO is the cross-disciplinary / cross-wavelength capability, and specifically, being able to access and use the spectroscopic data. The UG considers such efforts to be very valuable, and believes that the collaboration with other institutions (MAST, IPAC, CXC, …) - is on track. Since the VO design aims to be invisible to most end-users, most members of the Users' Group were somewhat unfamiliar whether they actually used the VO interfaces - but this is probably a good thing, highlighting the transparency of the interfaces.
   (a) One perhaps minor point is: How are updates in VO protocols communicated to the community that uses them explicitly? How is feedback obtained? We would like to task HEASARC to query the community that is using VO about its value and suggestions for valuable improved functionality.
(2) X-ray polarimetry. HEASARC might be already considering this, but clearly spelling out standards for reporting X-ray polarization is even more important now, given the selection of IXPE in the SMEX competition. Specifically, a primer, aimed for consistent reporting of X-ray polarization parameters / errors, might be quite valuable.
(3) The committee envisioned a possibility for HEASARC to host a repository for user-contributed tools, with all proper caveats that use of those is at users' risk. This has worked reasonably well in the case of Fermi SSC.

(4) HEASARC should secure adequate funding for the maintenance and modernization of software; this is already spelled out in the Senior Review.

(5) The committee had concerns regarding the Hera/Webhera access: is it basically a "teaching / outreach" tool, or is it really serving the broad science community? A committee member worked with HEASARC to implement software in Hera/Webhera. Communication was intermittent, and the software contributor was not made aware of the ongoing issues with Hera/Webhera. HEASARC should look into improving its communications with potential software contributors, to the quality level of its helpdesk responses.

(5.1) More specifically, one committee member comments: currently if I invoke Hera through fv I get the following error message "Regular Hera is currently undergoing major software upgrade. No updated information regarding to schedule at this time. Sorry for the inconvenience this may have caused." Apparently necessary updates are in the process of being implemented.

(6) Many HEASARC tools were designed in the era when scientists were analyzing one object at a time. The committee recommends new (or upgraded) tools which will be needed to analyze substantial number of objects simultaneously. For example, perhaps a better scripting tool is needed, with clear instructions. An easy change would be to have a single parameter to turn off all querying, which would make scripting much easier. Another example is the handling of parameter files which can cause problems if many objects are being analyzed in parallel.

(7) Possible (yearly?) occasional survey of the users, with key responses (both positive and negative!) posted on the HEASARC Web site - this would open the possibility of community input. Of course some screening would be necessary, to prevent rants, etc.

(8) While not tasked with an assessment of LAMBDA, the committee members queried colleagues who are involved in CMB work whether they had any comments about LAMBDA. One matter that came up on a couple of instances was the lack of community awareness about LAMBDA. It might be worthwhile to expand the outreach effort, specifically in major meetings such as the Winter AAS, or April APS meetings - for instance in the form of booths / workshops.

(9) The Committee considers the close collaboration between HEASARC and the recently established Astrophysical Multimessenger Observatory Network (AMON) to be very important. With the Ice Cube's detection of high energy neutrinos - almost surely of cosmic origin - and LIGO's detection of gravitational waves, we have entered the era of multi-messenger astrophysics. Close collaboration on standards, interfaces, etc., is strongly encouraged.

(10)   The committee conducted a mini-survey of Fermi (LAT & GBM) as well as Swift BAT GRB data users, and found that most users were quite happy and praised the HEASARC. The committee appreciates that some of the comments should be directed at the Fermi Science Support Center, but we include it here nonetheless.

(i)   Praises

1) They particularly like and frequently use the time, coordinate, and energy converter tools, although some would like scriptable versions.
2) They praised how well laid out and easy to navigate the pages were and how easy it was to get their desired data including legacy data.
3) It is easy to use for retrieving data through FTP.
    (ii)   Suggestions
1) Some of the Browse tables are difficult to quickly search and visualize. A user suggested considering an interface like http://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/3FGL-table/#aitoff
2) A user suggested that it would be helpful if there was a way to automatically get a list of all of the GRBs simultaneously observed by multiple missions.

Finally, there was some discussion amongst the committee members about value of having a mirror site for the whole HEASARC data repository outside of the US. For a variety of reasons (one of them being potential cyber-security threats), the committee considers establishing and securing the maintenance of such a mirror repository to be of priority.