ALMA Memo 463

Audit of the MIRIAD Package for ALMA Off-line Data Processing

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1 General Considerations

This document presents the results of the auditing of the `MIRIAD` software Package for the purposes of ascertaining its compliance with the ALMA Offline Data Processing Requirements given in ALMA-SW Memo 18.

We build this `MIRIAD` audit following the AIPS++ audit. This is why we reproduce here most of the "General Consideration" section of the AIPS++ audit. This auditing is based on the current version of `MIRIAD` (as of March 2003) which is available on demand. Most of the functionnalities described here are extensively tested every day at Hat Creek, BIMA, ATCA, and other institutions.

A. We use a descriptive scheme, with a set of grade codes stating how well the Package fulfills a given requirement: Adequate (A), Inadequate (I), Not Available (N), and Unable to Evaluate (U). The latter is used for items could not be properly evaluated at this time (e.g. items related to the tbd ALMA data format). There is an additional qualifier for "adequate" items (A/E) that indicates desired enhancements to the package.

B. For each requirement, the tool or function in the Package fulfilling that requirement is listed, where possible.

C. For items deemed inadequate (I) or missing (N), or which are adequate but enhancements are desired (A/E), the reasons for this are listed. Where possible, a *severity level* for the failure is noted: low, medium, high. This is based upon the importance of the requirement and the margin of failure of the package for the requirement. Note that a subjective choice is made between items at are adequate but could use further improvement (A/E), and those deemed (I) but low severity.

For (U) items that the auditors felt they could not rate, the reason was noted (e.g. unfamiliarity with this part of the package, incomplete documentation). We will try to enlist expert help to evaluate this item, and update the audit to reflect this new information.

D. The priority codes, as given in ALMA-SW Memo 18 and repeated here, are:

1 = essential
2 = highly desirable
3 = desirable, but not critical

It is intended that Priority 1 items must be present in the Package and work with high efficiency. Priority 2 items should be in the Package, though there may have to be sacrifices in performance or availability may be delayed. We expect that the Package will fulfill all Priority 1 and 90% or more of Priority 2 requirements. Priority 3 items should be considered for upgrades or development.

E. The considerations during grading include the *functionality* (whether a feature is there and whether it does what is required), the *usability* (ease-of-use, efficiency, reliability), and the *documentation*. In this audit, grades are not given separately for these factors. Note that depending on the wording of the requirement, not all of these will apply to a given requirement. For example, some requirements only indicate the existence of a feature (functionality), while some in addition explicitly address the look and feel or ease of use (usability). Also, some of the performance issues will have to be deferred until a later cycle of auditing, when detailed testing and benchmarks will be available.

2 Offline Data Processing Requirements

2.1 General Requirements and Interaction with Other ALMA Elements

2.1.1 Goals of the Offline Package and Relation to the Pipeline

Note: An ALMA Offline Data Processing Package (or "the Package") is primarily intended to enable end-users of ALMA (e.g. observers or Archive users) to produce scientifically viable results that involve ALMA data products. The secondary use is to enable ALMA staff to assess the state of the array and derive calibration parameters for the system, although it is anticipated that the Pipeline will be the primary engine for Online Data Processing and system monitoring.

Also note that not all offline analysis tools will necessarily be in the Pipeline Package. For example, one of the important differences between Pipeline and Offline reduction path is that Offline one should have extensive interactive capabilities to merge and compare data with different resolution, coordinate system, data grid, and so on.

The SSR does feel that there is a great deal of synergy between the Offline Package and Pipeline that should be exploited by the designers of the respective software.

OL–1.1–R1 There must be an Offline Data Processing Package that fulfills the requirements laid forth in this document.

Priority: 1

Grade: A

Summary: That was the easy one!

OL–1.1–R2 All standard observing modes supported by ALMA must be processable by the Package.

Priority: 1

Grade: U

Summary: ALMA standard modes are not finalized at this time.

OL–1.1–R3 The Package shall be installable at the users home institution and available at ALMA regional centers (both locally and remotely). It shall be portable to **supported platforms designated by the ALMA Project**, including systems without network connections and laptops.

Priority: 1

Grade: A

Summary: The list of supported platforms is unavailable at this time. However, UNIX, Linux and VMS are currently supported by `MIRIAD`.

OL–1.1–R4 The performance of the Package shall be quantifiable and commensurate with the data processing requirements of ALMA output and the scientific needs of users at a given time. The timing and reproducibility of results for a fiducial set of reduction tasks on specified test data will be benchmarked (e.g. "AIPSmarks") and compared against other packages and **a list of benchmark specifications provided and maintained by the Project**.

Priority: 1

Grade: A

Summary: The benchmarking process was started, and benchmarks on "alma sized data sets" were submitted last year.

OL–1.1–R5 All standard processing functionality available in the Pipeline shall be available in the Package also as an offline analysis option.

Priority: 2

Grade: U

Summary: The pipeline functionality is being defined! A separate audit will use the updated SW-11 Pipeline requirements as a template.

2.1.2 Operational Issues

OL–1.2–R1 Installation of the Package by an end user must be straightforward, preferably without special (e.g. root) user permission.

Priority: 1

Grade: A

OL–1.2–R2 Error reporting and handling shall be user-understandable and non-destructive at all levels in the Package:

OL–1.2–R2.1 Error reporting messages shall be written for end users, not programmers.
Priority: 1
Grade: A
Summary: Error messages are generally understandable by the user.

OL–1.2–R2.2 There must be provision for job control such as interrupt and abort.
Priority: 1
Grade: A
Summary: CTRL-C

OL–1.2–R2.3 Error handling shall be non-destructive (data shall not be left corrupted, and recovery of recent changes be available). Common failure modes (as enumerated: invalid application parameters, exceeding of resource limits (disk/memory), and algorithm failure modes (e.g. no convergence) should be handled gracefully.
Priority: 2
Grade: A
Summary: Nobody is perfect. However stability of MIRIAD is generally good as estimated by the user.

OL–1.2–R2.4 Code traceback of execution errors shall be available. This should be geared to the effective reporting of failure modes and bugs by the user.
Priority: 3
Grade: A
Summary: There is traceback on errors, some are possible for non-programmers to figure out.

OL–1.2–R3 There shall be session logging, including the following features:

OL–1.2–R3.1 logging of commands and user inputs shall be provided
Priority: 1
Grade: A
Summary: The shell logs all commands.

OL–1.2–R3.2 logging of tool results such as success or error, files written, time of completion shall be provided
Priority: 1
Grade: A
Summary: Task logs go to task specific files.

OL–1.2–R3.3 logging of tool output such as summaries of results shall be provided
Priority: 2
Grade: A
Summary: Task logs go to task specific files

OL–1.2–R3.4 the session log shall be readable by the user (i.e. in a text file, not in a binary format)
Priority: 2
Grade: A

OL–1.2–R3.5 session logs shall be executable by the package UI, reproducing the entire session
Priority: 3
Grade: A
Summary: Easily done using any text editor. Users do it all the while.

OL–1.2–R4 There shall be comprehensive handling of multiple users and multi-tasking with access and process control.

Priority: 1

Grade: A

Summary: Multiple users are left to the operating system. Multi-tasking for a single user is available through the OS.

OL–1.2–R5 The Package providers shall provide support for the Package, with bug-fixing on timescales appropriate to the severity level of the defect (e.g. 1 week or less for catastrophic bugs with no work-around). **These defect levels and timescales should be delineated by the ALMA project**.

Priority: 1

Grade: U

Summary: The levels and timescales have yet to be provided by ALMA.

OL–1.2–R6 The Package providers shall provide timely improvements and updates based on user feedback. There shall be a path for the ALMA Project, for its own use and as a proxy for the users, to influence the development cycle of the Package. It is the responsibility of the Project to negotiate needed improvements with the Package providers.

Priority: 1

Grade: A

Summary: Historically the response has been excellent.

OL–1.2–R7 Backward compatibility of core package components should not be broken without compelling scientific reasons. Tools should be provided to parse user scripts and warn of package changes.

Priority: 2

Grade: A

Summary: Backward compatibility with data is good. Miriad has used the same data format since 1988.

OL–1.2–R8 Source code for the astronomical routines in the Package shall be available to the user.

Priority: 2

Notes: This does allow for the use of some proprietary data handling, output formatting, and special processing (e.g. Pixon) routines.

Grade: A

Summary: Source code: FORTRAN, C, and scripts are available in the distribution under CVS.

OL–1.2–R9 User installation of the basic package shall not be restricted by other issues such as expensive or unduly restrictive licenses. The Package license should convey all other necessary licenses (such as GNU) or they should be available to the user for only a nominal fee.

Priority: 2

Comment: This allows for the use of commercial components. However, a balance must be struck between excessive costs to the project and requiring some cost to be borne by the user, should this issue arise.

Grade: A

Summary: It is free with no extra licenses necessary.

OL–1.2–R10 There shall be the provision for the development and incorporation of user-supplied code.

Priority: 2

Grade: A

Summary: Incorporation of user scripts is straightforward. Incorporation of FORTRAN or C tasks is easy for most users; many users have contributed tasks to MIRIAD.

OL–1.2–R11 The application of successive stages of calibration, correction, flagging and editing shall not be destructive to the data. The Package should be able to recover and revert to earlier stages without resorting to saving of the entire dataset at intermediate states.

Priority: 2

Grade: A

Summary: Most operations add calibration tables. The original data are untouched, and the process can be repeated at will to change the calibration without needing to recreate the data. Calibrated datasets and images can also be saved on disk after creation.

2.2 Interface

2.2.1 General User Interface Requirements

Summary: Each Miriad task has a number of parameters which can be specified using keywords. Many of the keywords have default values if not specifically set by the user. Keyword parameters may be stored in a file, and input indirectly (keyword=@filename).

Miriad can be run from the command line, from a script, or using a front-end program, GUI or shell. With the command-line approach, you give the Miriad command directly at the system prompt, in the same way as any other operating system command. With the front-end approach, you interact with another program, which aids you in forming the command-line to a Miriad task.

OL–2.1–R1 User must be able to choose from a variety of interface styles, including:

OL–2.1–R1.1 A Command Line Interface (CLI) must be provided, with access via both an interactive input and via script.
Priority: 1
Grade: A
Summary: Miriad tasks can be run by specifying their parameters on the host command line. Most people use MIRIAD in standard CLI environments, e.g. Unix CSH. Miriad can use a language, such as PYTHON, by passing command lines to the host operating system.

OL–2.1–R1.2 A Graphical User Interface (GUI) must be provided for interactive processing. Actions taken under the GUI must be loggable, editable, and executable by the CLI.
Priority: 1
Grade: A
Summary: Miriad can be run using any language, shell or GUI which is able to parse a command line. There has been a simple MIRIAD shell since the begining. Several GUI's have been created over the 15 years Miriad has been in use. These were promoted by their creators but only used for a few years. Fashions change. It is easy to add a GUI. The MIRIAD shell is very easy for beginners. Most MIRIAD users prefer scripts. In the following we describe the properties of the MIRIAD shell which is popular with begining users.

OL–2.1–R2 The user shall be able to interact with the host operating system with command sequences invoked from the UI.

Priority: 1

Grade: A

Summary: Easy from within the standard shells and from within the MIRIAD shell

OL–2.1–R3 Multitasking for all interfaces shall be available where appropriate. It must be possible to run one or more long-running calculations in the background. While background tasks are running normal interactive activities must be possible.

Priority: 1

Grade: A

Summary: Multiple tools and windows can be run concurrently .

2.2.2 Graphical User Interface (GUI)

Note: The GUI is intended to be the primary interactive mode for users, especially neophyte users, and thus should be tailored for clarity and ease of use. Use of the Package GUIs should be a pleasurable, not a frustrating, experience!

OL–2.2–R1 The GUI shall provide real-time feedback via standard compact displays:

OL–2.2–R1.1 Window updating must be fast (less than 0.1s on same host).
Priority: 1
Grade: N Severity: high
Summary: The MIRIAD shell is not a GUI since it does not use Graphics, but is very friendly and fast.

OL–2.2–R1.2 Windows shall not take up excessive screen space, with full GUI controls visible on a window one-third the size of a standard view surface (or approximately 800×800 pixels).
Priority: 1
Grade: N Severity: high
Summary: not applicable.

OL–2.2–R1.3 Users shall have the choice of cascading windows or re-use of a single window for new operations.
Priority: 2
Grade: N Severity: high
Summary: not applicable.

OL–2.2–R1.4 Moving and resizing of all windows must be available, robust, and easy.
Priority: 2
Grade: N Severity: high
Summary: whatever the host windowing allows is available.

OL–2.2–R1.5 There shall be a master control GUI for process control which keeps track of sub-windows and tools.
Priority: 3
Grade: N Severity: high
Summary: not applicable.

OL–2.2–R2 It must be easy to run GUIs remotely from the host machine (e.g. via X displays).

Priority: 1

Grade: N Severity: high

Summary:

OL–2.2–R3 The use of the GUI shall not entail an excessive learning curve. Average users, with experience with the current generation of packages (e.g. AIPS, `MIRIAD`, IRAF, MIRIAD) shall be able to become proficient in GUI use in a timescale of approximately 12 hours dedicated use, and truly neophyte users (e.g. graduate students) should be reach proficiency with an investment not exceeding 40 hours of dedicated use.

Priority: 2

Grade: N Severity: low

Summary: 1-2 hours maximum. 12 hours is not an acceptable target if ALMA wants to attract users.

OL–2.2–R4 GUI-based tools shall be available for reduction of data taken in all standard ALMA observing modes.

Priority: 2

Grade: N Severity: high

Summary: standard ALMA observing modes not defined.

OL–2.2–R5 The look and feel of the GUI will be uniform throughout the entire package.

Priority: 2

Grade: N Severity: low

Summary: The look and feel of the GUI should be uniform throughout on-line and off-line ALMA software.

OL–2.2–R6 The look and feel of the GUI must be acceptable to both novice and more advanced users. The GUI mode might be customizable (perhaps through menu selection for "novice" or "advanced" mode) or a different simpler set of GUI tools might be available for beginners. The GUI features for beginner mode shall include:

OL–2.2–R6.1 built-in help facility with access to novice-oriented help documents (e.g. sections in the cookbook)
Priority: 2
Grade: N Severity: low
Summary: task specific help from the Miriad shell; cookbooks are on-line.

OL–2.2–R6.2 sensible defaulting of values for parameters, with guidance for user choices where needed
Priority: 2
Grade: N Severity: low
Summary: The Miriad shell is good

OL–2.2–R6.3 integrated functionality built around common data analysis tasks (e.g. single-field spectroscopic observations with fast switching, OTF mosaicing in continuum mode, snapshot observations of a large number of targets in single-field continuum mode)
Priority: 2
Grade: A
Summary: There are several user-friendly scripts to do standard data reduction, deconvolution, mosaicing, simulations, etc. These have been written using VMS, CSH, and PYTHON scripts. Many have built in help and have the same look and feel as individual Miriad tasks.

OL–2.2–R7 It shall be easy for users to develop and include their own custom GUIs in the Package.

Priority: 3

Grade: A

Summary: This is straightforward, because GUI essentially control variable assignments, and activate a user-defined procedure.

2.2.3 Command Line Interface (CLI)

Note: the CLI is the primary mode for automatic reduction for ALMA, and it is anticipated that there will be a suite of "standard" scripts developed to help users in data reduction tasks. Thus it is important that the Package support all of its critical modes in the CLI.

OL–2.3–R1 The interface must have the facility to read in command files for batch processing of a sequence of CLI commands.

Priority: 1

Grade: A

Summary: scripts can be read in and executed easily.

OL–2.3–R2 The CLI shall have command-line recall and editing, with name completion where appropriate.

Priority: 1

Grade: A

Summary: Available through most standard shells.

OL–2.3–R3 All functionality of the GUI must also be available in CLI mode (although possibly with loss of simplicity in instances where the graphical selection is important).

Priority: 1

Grade: A

Summary: The CLI is the standard use.

OL–2.3–R4 The CLI shall be usable remotely over low-speed (14400 baud) modem lines or network connections, with ASCII terminal emulation.

Priority: 2

Grade: A

Summary: This works well.

OL–2.3–R5 A CLI mode menu for display and editing of input parameters and execution of tasks is desirable.

Priority: 3

Grade: A

Summary: This sounds like the MIRIAD shell. The shell inputs are implicitely derived from the the task parameters, and provides the user with a list of input parameters, help for the task, help for each input parameter, line editing is available, the parameters used for each task are saved inside the MIRIAD shell.

2.2.4 Interface Programming, Parameter Passing and Feedback

OL–2.4–R1 The UI must have basic programming facilities such as:

OL–2.4–R1.1 variable assignment and evaluation
Priority: 1
Grade: A

OL–2.4–R1.2 array handling
Priority: 1
Grade: A
Summary: depends on the shell

OL–2.4–R1.3 conditional statements
Priority: 1
Grade: A

OL–2.4–R1.4 control loops
Priority: 1
Grade: A

OL–2.4–R1.5 string manipulation
Priority: 1
Grade: A

OL–2.4–R1.6 user-defined functions and procedures with argument or parameter passing
Priority: 1
Grade: A

OL–2.4–R1.7 process control, interrupts, error handling
Priority: 1
Grade: A

OL–2.4–R1.8 standard mathematical operations and functions
Priority: 1
Grade: A

OL–2.4–R1.9 efficient special vector and matrix operations
Priority: 2
Grade: A
Summary: depends on the shell.

OL–2.4–R1.10 user-defined data structures
Priority: 2
Grade: A
Grade: A
Summary: depends on the shell.

OL–2.4–R2 Commands executed will be logged, with provision to re-execute the session.

Priority: 1

Grade: A

Summary: Standard usage for MIRIAD.

OL–2.4–R3 Input parameter and syntax checking shall be effected upon function calling or parsing with reporting of incorrect, suspicious or dangerous choices before execution where possible.

Priority: 1

Grade: A/E

Summary: Syntax checking is implemented. The parameter checking is inconsistent across tools, and seems to depend on whether the programmer bothered to implement this or not.

OL–2.4–R4 Parameters shall be passable between applications in as transparent a manner as possible. However, global variables should not be the default, unless designated specifically by the user-programmer.

Priority: 2

Grade: A

Summary: procedures can accept input arguments; these can be global or not, as needed.

OL–2.4–R5 Application variables shall be named consistently and as clearly as possible indicating their intended use using astronomical terms where appropriate.

Priority: 2

Grade: A/E

Summary: most variables have sensible names. However, there are cases where naming between tasks is not consistent.

OL–2.4–R6 Parameter inputs to tools shall be stored for later recall:

OL–2.4–R6.1 Tool inputs shall be saved on closure, and reinstated on the next instantiation of the tool.
Priority: 2
Grade: A
Summary: The task parameters are remember on a working directory basis when tasks are activated in their basic mode. For more integrated facilities, the usual behaviour is to return to the default values, but some tools (e.g. MIRIAD shell) have their own save/restore scripts.

OL–2.4–R6.2 It shall be possible for the user to save the state of the parameters for the entire package, as well as for individual tools, as a named set (e.g. SAVE/GET in AIPS), and to recall these when desired.
Priority: 3
Grade: A
Summary: This depends on the shell being used.

2.2.5 Documentation and Help Facility

OL–2.5–R1 There shall be a variety of help levels and documentation formats accessible from the UI and over the Internet, applicable to novices, experts, and technical users. These shall include:

OL–2.5–R1.1 user cookbooks with extensive examples
Priority: 1
Grade: A
Summary: The ATCA user manual is excellent. Several have been made for BIMA, but more is always possible here...

OL–2.5–R1.2 application descriptions and reference manual (with all inputs to functions and tools);
Priority: 1
Grade: A/E
Summary: As above...

OL–2.5–R1.3 online help, FAQ, email contacts;
Priority: 1
Grade: A
Summary: The documentation is available internally as well as on the WEB. The WEB version only refers the latest state of the documentation however, with no association to a specific release of the software.

OL–2.5–R1.4 release history, bug reports and tracking, patch descriptions;
Priority: 1
Grade: A/E
Summary: Available on the WEB; could be extended

OL–2.5–R1.5 programmer references and guides;
Priority: 2
Grade: A/E
Summary: There is a programming guide. The references would need some more work.

OL–2.5–R1.6 data format descriptions
Priority: 2
Grade: A
Summary: The uvdata and image formats are well documented. There is a reference programming manual on how to read and write these formats.

OL–2.5–R1.7 algorithm descriptions
Priority: 2
Grade: A/E
Summary: Sometimes lacking. References are given in the code, but often not in the documentation. This could be improved.

OL–2.5–R1.8 newsletters, email exploders, notes series
Priority: 3
Note: these would be maintained by the Package providers, with help from the ALMA project.
Grade: A/E
Summary: There are newsletters and memos.

OL–2.5–R2 The Package creators must ensure the documentation is up-to-date and complete for all parts of the Package.

Priority: 1

Grade: A

Summary: The documentation is derived from in-code documentation every time each task or subroutine is updated. This works well.

OL–2.5–R3 Help materials shall also be available in printable formats, including

OL–2.5–R3.1 standard document formats (pdf, postscript)
Priority: 1
Grade: A
Summary: Postscript and PDF are available for documentation.

OL–2.5–R3.2 printer-friendly versions of HTML pages
Priority: 2
Grade: A
Summary: The HTML pages have a link to the Postscript version. Also individual sections of the HTML pages print quite well.

OL–2.5–R3.3 popular proprietary formats (MS-Word)
Priority: 3
Grade: N Severity: low
Summary: Not available. PDF should be used. I agree.

OL–2.5–R4 Help shall be context-sensitive where relevant. In GUI mode, fly-over banners should indicate use of buttons and fields, and clickable help buttons should be available on all pages.

Priority: 2

Grade: A

Summary: Help inside the MIRIAD shell is context-sensitive. Fashions change; button and banners are the current fashion ?

OL–2.5–R5 In GUI mode, help functions may direct a browser to a Web page. In CLI mode, the Package must support in-line text based help also.

Priority: 2

Grade: A/E

Summary: In CLI mode, the text based help is available, as well as a WEB browser mode. In GUI mode, the help does not point to WEB URLs, but to files.

OL–2.5–R6 Full search capability must be built into the documentation library.

Priority: 2

Grade: N Severity: medium

2.3 Data Handling

2.3.1 General Data Requirements

Summary: There are two types of data structure in Miriad.

1. UVDATA

The uvdata structure is used for single source, multiple source or frequency, mosaiced, polarization, interferometer or single dish observations. The data can be stored as real or complex floating values, or scaled 16-bit integers. The metadata are stored as a stream of named variables and values. Source names, frequencies, pointing centers, are variables which can change throughout the uvdata. Miriad calibration tasks produce or use calibration tables and parameters which are stored in the uvdata structure. The history of observation and data reduction, including the steps and parameters used in observing and reducing the data are stored in the uvdata structure. Other structures, such as WVR data, and a copy of the observing script and parameters, have been easily added.

2. IMAGES

Miriad images use a FITS-like format to describe the multidimensional image data. The image is stored as floating point numbers. An image contains a bit-mask for pixel blanking. The history of observation and data reduction, including the steps and parameters used in observing and reducing the data is stored in the image format. The same format is used for single field maps, beams, multichannel, MFS, mosaiced, polarization, and model images deconvolved using clean, maxen, mfclean, mosmem, mossdi etc.

OL–3.1–R1 The Package must support data taken in any of the standard ALMA hardware modes.

Priority: 1

Grade: U

Summary: The standard ALMA hardware modes are undefined at this time.

OL–3.1–R2 The Package shall be able to handle the integrated data objects corresponding to the observational programs carried out by ALMA. These objects may be implemented in any manner appropriate, though relations between the components of the object must be maintained through some mechanism. These include:

OL–3.1–R2.1 Program header information;
Priority: 1
Grade: A
Summary: MIRIAD data structures are implemented as directory structures which are modified by the data aquisition and data reduction process. The MIRIAD data structures are quite flexible. Various data and information, such as WVR data, copies of the observing script, and on-line implementation have been easily added.

OL–3.1–R2.2 Observation status information (and schedules themselves);
Priority: 1
Grade: A
Summary: Almost anything can be added to the data structures. E.g:
- copies of the observing proposals or cover sheets.
- observing requirements, scheduling constraints.
- observational status as project is implemented.
- correlator settups, antenna configurations.
- dynamic scheduling implementation.
- scripts to be used for calibration and imaging
- calibration parameters, fluxes, ephemerides...
- models for science pipeline data analysis.

- published papers.
- archive implementation and history of data use.

OL–3.1–R2.3 Field information;
Priority: 1
Grade: A

OL–3.1–R2.4 Data from interferometer and single-dish organized by:

OL–3.1–R2.4.1 position;
Priority: 1
Grade: A

OL–3.1–R2.4.2 subreflector state;
Priority: 1
Grade: A

OL–3.1–R2.4.3 polarization products;
Priority: 1
Grade: A

OL–3.1–R2.4.4 spectral channels;
Priority: 1
Grade: A

OL–3.1–R2.4.5 frequency bands;
Priority: 1
Grade: A

OL–3.1–R2.4.6 IFs;
Priority: 1
Grade: A

OL–3.1–R2.4.7 subarray;
Priority: 1
Grade: A/E
Summary: could be easily defined. selection by antenna.

OL–3.1–R2.5 Coherence function (visibility) data from interferometer, including:

OL–3.1–R2.5.1 cross-correlations;
Priority: 1
Grade: A

OL–3.1–R2.5.2 auto-correlations;
Priority: 1
Grade: A

OL–3.1–R2.5.3 uncorrected and/or online WVR corrected (if chosen by user);
Priority: 1
Grade: A/E

OL–3.1–R2.5.4 phased-array data (if chosen by user);
Priority: 1
Grade: A/E
Summary: Can be computed , but is not stored.

OL–3.1–R2.6 Total power (autocorrelation) data from antennas in single-dish mode;
Priority: 1
Grade: A

OL–3.1–R2.7 Weights and/or data uncertainties;
Priority: 1
Grade: A

OL–3.1–R2.8 States indicating special modes (such as ON/OFF positions), for:

OL–3.1–R2.8.1 OTF scanning;
Priority: 1

Grade: A
Summary: used in holography

OL–3.1–R2.8.2 subreflector switching;
Priority: 1
Grade: I *Severity:* med
Summary: not used

OL–3.1–R2.8.3 frequency switching;
Priority: 1
Grade: A

OL–3.1–R2.9 Flagging data or masks;
Priority: 1
Grade: A

OL–3.1–R2.10 Diagnostic data and errors;
Priority: 1
Grade: A
Summary: System temperatures are available, as well as weather information, tracking errors, pointing corrections, focus corrections, and many other specific information. Special Diagnostic data have been easily added to the data structure on several occasions.

OL–3.1–R2.11 A priori calibration data, including:

OL–3.1–R2.11.1 bandpasses;
Priority: 1
Grade: A
Summary: Available in data.

OL–3.1–R2.11.2 source flux densities;
Priority: 1
Grade: A
Summary: Quasars in a file; planets in the data structure.

OL–3.1–R2.11.3 antenna polarization leakages;
Priority: 1
Grade: A

OL–3.1–R2.12 Derived calibration data, including:

OL–3.1–R2.12.1 gain tables;
Priority: 1
Grade: A
Summary: In data.

OL–3.1–R2.12.2 flux bootstraps;
Priority: 1
Grade: A
Summary: These are not handled separately from the quasar fluxes and planet parameters

OL–3.1–R2.13 Images and/or models produced from data;
Priority: 1
Grade: A
Summary: These are separate files

OL–3.1–R2.14 Processing history;
Priority: 1
Grade: A
Summary: Processing history is kept in the data structure including the steps and parameters used in observing and reducing the data.

OL–3.1–R3 There must be a selection mechanism integrated within tools to choose between the various available data subsets such as:

Summary: The select keyword selects the subset of the visibility data to be processed. There are a number of subcommands, which may be abbreviated. Each may be prefixed with a plus or minus sign to indicate using or discarding the selected data. Many subcommands can be given (separate them by commas). User documentation: "select.doc". Subcommands include:

OL–3.1–R3.1 sourcenames, and user specified data qualifiers (with wildcarding);
Priority: 1
Grade: A
Summary: select=source(3c84,1058+012,....)

OL–3.1–R3.2 mosaic or scanning pointing centers;
Priority: 1
Grade: A
Summary: select=dra(10.58,16.79,...),ddec(0.3) etc.

OL–3.1–R3.3 polarization products or channels;
Priority: 1
Grade: A
Summary: select=pol(I,YY,LR,....)

OL–3.1–R3.4 bands (frequency bands, IFs);
Priority: 1
Grade: A

OL–3.1–R3.5 spectral channels;
Priority: 1
Grade: A
Summary: select=window(w1,w2,...) Select by spectral window (IF band in AIPS terminology). See the help on "window" for more information.

OL–3.1–R3.6 frequency-switched data;
Priority: 1
Grade: A
Summary: select=frequency(f1,f2) Select correlations, where the sky frequency of the first correlation is in the range f1 to f2 (in GHz). If only a single frequency is given, then correlations are selected if the first correlation is within 1% of the given frequency.

OL–3.1–R3.7 interferometer: subarrays;
Priority: 1
Grade: A
Summary: select=ant(a1,a2,...)(b1,b2...) Select all baselines pairs formed between first and second list of antennas. The second list is optional and defaults to all antennas.

OL–3.1–R3.8 interferometer: WVR-corrected or uncorrected baselines;
Priority: 1
Grade: A
Summary: Miriad task WVCAL estimates atmospheric phase corrections from the WVR measurements which are stored in the data structure. The WVR data are interpolated to the integration times of the interferometer data and written as antenna gains. The gains are applied when displaying, averaging, copying, or imaging the uvdata. There is no need to make a calibrated dataset, although it is sometimes convenient to do this. The WVR calibration can be selected by antenna. If the uvdata are averaged, then WVR-corrected or uncorrected baselines are stored in seperate files (could be in the same data structure), and selected by antennas.

OL–3.1–R4 Multiple pointing centers for mosaics must be supported.

Priority: 1

Grade: A

OL–3.1–R5 For polarization products, transformation must be provided to the desired Stokes output parameter(s).

Priority: 1

Grade: A

Summary: The stokes keyword specifies the Stokes/polarisations parameters that are to be processed. Tasks which use this keyword convert raw polarisations to Stokes parameters stokes. User documentation: "stokes.doc"

OL–3.1–R6 Averaging of data over time, bands and spectral channels shall be possible.

Priority: 1

Grade: A

OL–3.1–R7 Data taken in arbitrary (but parameterized) scanning patterns must be dealt with.

Priority: 1

Grade: A

OL–3.1–R8 All standard time systems shall be supported, including:

OL–3.1–R8.1 Universal Time (UT), also UT1;
Priority: 1
Grade: N Severity: low

OL–3.1–R8.2 Coordinated Universal Time (UTC);
Priority: 1
Grade: A

OL–3.1–R8.3 International Atomic Time (IAT);
Priority: 1
Grade: N Severity: low

OL–3.1–R8.4 Local Sidereal Time (LST);
Priority: 1
Grade: A

OL–3.1–R8.5 Greenwich Mean Sidereal Time (GMST);
Priority: 1
*Grade: N*low
Summary: Is that really useful?

OL–3.1–R8.6 Julian Date (JD), also Modified Julian Date (MJD);
Priority: 1
Grade: A

OL–3.1–R8.7 Dynamical Times (TDT, TDB).
Priority: 1
Grade: U

OL–3.1–R9 All standard coordinate systems shall be supported, including:

OL–3.1–R9.1 equatorial (RA, DEC);
Priority: 1
Grade: A

OL–3.1–R9.2 ecliptic (ELON, ELAT);
Priority: 1
Grade: N Severity: low

OL–3.1–R9.3 helioecliptic (HLON, HLAT);
Priority: 1
Grade: N Severity: low

OL–3.1–R9.4 galactic (GLON, GLAT);
Priority: 1
Grade: I Severity: med

OL–3.1–R9.5 supergalactic (SLON, SLAT);
Priority: 1
Grade: N Severity: low

OL–3.1–R9.6 terrestrial (AZ, EL);
Priority: 1
Grade: A

OL–3.1–R10 All standard coordinate reference frames and equinoxes shall be supported, including:

OL–3.1–R10.1 J2000 (and other FK5 equinoxes);
Priority: 1
Grade: A

OL–3.1–R10.2 B1950 (and other FK4 equinoxes);
Priority: 1
Grade: A

OL–3.1–R10.3 geocentric apparent place, coordinates of date;
Priority: 1
Grade: N Severity: low

OL–3.1–R10.4 topocentric coordinates;
Priority: 1
Grade: N Severity: low

OL–3.1–R10.5 International Celestial Reference System (ICRS);
Priority: 1
Grade: N Severity: low

OL–3.1–R11 All standard velocity definitions shall be supported, including:

OL–3.1–R11.1 radio;
Priority: 1
Grade: A

OL–3.1–R11.2 optical;
Priority: 1
Grade: A Severity:

OL–3.1–R11.3 redshift;
Priority: 1
Grade: N Severity: low

Summary: The default doppler frame is RADIO.

OL–3.1–R12 All standard velocity frames shall be supported, including:

OL–3.1–R12.1 topocentric;
Priority: 1
Grade: U

OL–3.1–R12.2 geocentric;
Priority: 1
Grade: U

OL–3.1–R12.3 barycentric;
Priority: 1
Grade: U

OL–3.1–R12.4 heliocentric;
Priority: 1
Grade: U

OL–3.1–R12.5 kinematic LSR;
Priority: 1
Grade: A

OL–3.1–R12.6 dynamic LSR;
Priority: 1
Grade: U

OL–3.1–R12.7 galactocentric;
Priority: 1
Grade: U

OL–3.1–R12.8 local group;
Priority: 1
Grade: U

Summary: MIRIAD works in the LSR frame, but tools may be available to go to other frames when needed.

OL–3.1–R13 Coordinates and locations (e.g. of the antennas, or the array center) defined with respect to the standard frames shall be supported, including:

OL–3.1–R13.1 topocentric;
Priority: 1
Grade: A/E

OL–3.1–R13.2 geocentric;
Priority: 1
Grade: A/E

OL–3.1–R14 Any existing flagging mask or table must be maintained and associated with the data it refers to during any subsequent operations (such as splitting of data sets).

Priority: 1

Grade: A

Summary: Flags are preserved, it is possible to save many levels of flags in the data structure, but this is not done.

OL–3.1–R14.1 The flagging mask or table shall be transferable to other equivalent data sets (e.g. flags derived for a continuum dataset should be transferable to a line dataset derived from the same observations).
Priority: 2
Grade: A

OL–3.1–R15 Calibration and ancillary monitoring data (e.g. weather information, WVR data, pointing) that are provided in standard ALMA formats must be preserved, if requested by the user.

Priority: 1

Grade: U

Summary: There are no ALMA standard formats yet, but almost anything could be added to the data structure.

OL–3.1–R16 Correlation products accumulated at multiple bit depths (16-bit,32-bit) or compressed data must be supported transparently (see ALMA-SW MEMO 11 3.2.3-R5).

Priority: 1

Grade: A

Summary: The data can be stored as real or complex floating values, or scaled 16-bit integers.

OL–3.1–R17 Comprehensive and understandable processing history information for the data must be maintained and be exportable (both as tables and as plain text).

Priority: 1

Grade: A

Summary: The history of observation and data reduction, including the steps and parameters used in observing and reducing the data is stored with the data in ACSII format.

OL–3.1–R18 Users shall have access to, and the ability to change, all aspects of the data including the header.

Priority: 1

Grade: A

Summary: Full access to all variables of the data header is available, the data is unchanged.

OL–3.1–R19 The Package must support locking data files so that there is no possibility of one process corrupting a file that is also being written to by another process in the Package. The default model should be: "one writer, multiple readers."

Priority: 1

Grade: A

OL–3.1–R20 Merging (e.g. concatenation) and splitting of datasets shall supported:

OL–3.1–R20.1 Extraction of specified subsets of data (e.g. by source, time, subarray) shall be supported.
Priority: 1
Grade: A
Summary: This is trivial through the selection process.

OL–3.1–R20.2 Merging and reinsertion of data subsets (e.g. combination of different configurations, different epochs, mosaic pointings) shall be supported.
Priority: 2
Grade: A
Summary: Concatenation is trivial

OL–3.1–R20.3 The merging and splitting process, including selection of data to be merged (e.g. merging of frequency channels which may be differently labeled) shall be straightforward and not overly complex.
Priority: 2
Grade: A
Summary: Most Miriad tasks support on-the-fly selection and averaging of the uvdata when displaying, averaging, copying, or imaging the uvdata using two keywords:
- select: uvdata can be selected by sources, times, frequencies, polarizations, uvranges, spectral windows, pointing centers, single dish or interferometer, etc.
- linetype: uvdata can be averaged and interpolated into user selected channel widths or velocity intervals.

These data selection features are efficient and very convenient for the user.

OL–3.1–R20.4 The use of merged or split data in the Package shall be robust and transparent to the user. Subsequent operations shall work the same, whether the data is in its original form or built from merged data subsets, where possible.
Priority: 2
Grade: A

OL–3.1–R20.5 The appropriate calibration and ancillary monitoring data for the merged or split data (e.g. keeping only the data relevant to sources split out) shall be preserved.
Priority: 3
Grade: A

OL–3.1–R21 Distinctions between single-source, multi-source, single-dish, and interferometer datasets shall be avoided with context built into the dataset or header.

Priority: 2

Grade: A

OL–3.1–R22 Tools for access to header information, scan summaries (e.g. LISTR in AIPS), antenna locations (e.g. PRTAN in AIPS) shall be available, with printable output.

Priority: 2

Grade: A

OL–3.1–R23 When sorting or indexing is needed for performance enhancement, it shall be carried out in a manner transparent to the user.

Priority: 3

Grade: A

OL–3.1–R24 Compression of the data, with a selectable level of loss, shall be possible at various stages of the processing path.

Priority: 3

Grade: A

2.3.2 Data Import and Export

OL–3.2–R1 A variety of data formats must be supported by the Package:

OL–3.2–R1.1 The **ALMA standard archival data format** must be supported for both input and output without loss of functionality or information.
Priority: 1
Grade: U
Summary: These have not yet been designated.

OL–3.2–R1.2 Other standard formats **as designated by the ALMA Project** shall also be supported for both input and output without loss of functionality or information.
Priority: 1
Grade: U
Summary: These have not yet been designated, though it is likely that these will consist of FITS. FITS is supported.

OL–3.2–R1.3 Other popular data formats may be supported as the Package sees fit, possibly with some loss in information content. Flexibility and wider use beyond ALMA is to be encouraged.
Priority: 3
Grade: A/E
Summary: There is a well used and flexible FITS task

OL–3.2–R2 Disk and offline data storage (e.g. DAT, DDS, DLT) must be supported. **The project will maintain a list of media which the Package must support.**

Priority: 1

Grade: A

Summary: Buffer to disk and use system. Anything else is a waste of time nowadays. Agreed.

OL–3.2–R3 The Package must be able to handle, efficiently and gracefully, datasets larger than main memory of the host system.

Priority: 1

Grade: A

OL–3.2–R4 The ability to drop flagged data on export shall be included.

Priority: 2

Grade: A

OL–3.2–R5 The Package internal data format, which may be independent of other supported formats, must not be "bloated" and the required storage should not exceed by more than 1.5× the raw data format.

Priority: 2

Grade: A

Summary: The data can be stored as real or complex floating values, or scaled 16-bit integers. The "header" overhead is typically less than 5%

2.3.3 Images and Other Data Products

OL–3.3–R1 Standard multi-dimensional images and arrays must be supported, including:

OL–3.3–R1.1 Spectra and image slices (1D);
Priority: 1
Grade: U

OL–3.3–R1.2 Planar images (2D);
Priority: 1
Grade: A

OL–3.3–R1.3 Spectral and Time Cubes (3D);
Priority: 1
Grade: A

OL–3.3–R1.4 Higher-dimensional Arrays (4D+).
Priority: 2
Grade: A/E
Summary: Not aware of any application task with more than 4-D, but don't know what the limit is.

Summary: I/O to and from FITS is also provided. The I/O from FITS is rather general (and could be made quite general with little effort).

OL–3.3–R2 Other standard derived data products must be supported, including:

OL–3.3–R2.1 Point (CLEAN) models;
Priority: 1
Grade: A

OL–3.3–R2.2 Pixel (gridded image) models;
Priority: 1
Grade: A

OL–3.3–R2.3 Elliptical Gaussian models;
Priority: 1
Grade: A

OL–3.3–R2.4 Uniform (optically thick) disk models;
Priority: 2
Grade: A

OL–3.3–R2.5 Optically thin disk models;
Priority: 2
Grade: N *Severity:* low

OL–3.3–R2.6 wavelets;
Priority: 3
Grade: N *Severity:* low

OL–3.3–R2.7 Pixons;
Priority: 3
Grade: N *Severity:* low

OL–3.3–R3 Blanking of pixels shall be maintained through the processing of images.

Priority: 1

Grade: A

OL–3.3–R4 The package shall support all standard projections, including:

- **OL–3.3–R4.1** sine or slant orthographic (SIN);
  Priority: 2
  Grade: A
- **OL–3.3–R4.2** tangent or gnomonic (TAN);
  Priority: 2
  Grade: U
- **OL–3.3–R4.3** cylindrical plate carrée (CAR);
  Priority: 2
  Grade: U
- **OL–3.3–R4.4** Mercator (MER);
  Priority: 2
  Grade: U
- **OL–3.3–R4.5** stereographic (STG);
  Priority: 2
  Grade: U
- **OL–3.3–R4.6** Hammer-Aitoff (AIT).
  Priority: 2
  Grade: U

2.3.4 Foreign Data

OL–3.4–R1 Data produced by other interferometers and single dishes in similar observing modes shall be importable and processable if provided in **ALMA standard archival data format** or an **ALMA supported data format**

Priority: 2

Grade: U

Summary: ALMA format currently undefined.

OL–3.4–R2 Imaging data in standard formats (e.g. FITS) from astronomical instruments at different wavelengths shall be importable, with the ability to combine (coadd) these with ALMA data where appropriate. This should be through a set of widely used formats, with a **minimal list of supported standards established by the project**.

Priority: 2

Grade: U

Summary: List of standards not available. FITS is currently supported.

2.3.5 Interaction with the Archive

OL–3.5–R1 Access from the archive (when such access is granted, e.g. when Package is run by ALMA staff) must be supported.

Priority: 1

Grade: U

Summary: Archive not available

OL–3.5–R2 The interface between the Package and archive must be able to provide data access (when such access is granted) without interfering with other access to the archive.

Priority: 1

Grade: U

Summary: Archive not available

OL–3.5–R3 Security and integrity of the archive must be ensured during these operations.

Priority: 1

Grade: U

Summary: Archive not available

2.4 Calibration and Editing

Summary: Miriad Calibration Model:

Calibration tables are produced from calibration observations. The tables can be displayed, copied, and to a limited extent edited or averaged.

- antenna gains: complex values. vary with time, but not frequency.

- antenna bandpass: complex values. vary with frequency but not time.

- antenna leakages: complex-valued terms which model the leakage between the polarizations. These do not vary with time or frequency.

2.4.1 General Calibration and Editing Requirements

OL–4.1–R1 The Package must be able to handle reliably all **designated ALMA standard calibration modes** , possibly including but not exclusive to: temperature controlled loads, semi-transparent vanes, apex calibration systems, WVR data, noise injection, fast-switching calibration transfer, planetary observations.

Priority: 1

Grade: U

Summary: These have not been defined yet. This item will require input from the ALMA Science IPT and the SSR.

OL–4.1–R2 Calibration, editing, flagging, and correction of data shall be easily reversible within the Package (i.e. not requiring re-reading of the data from the archive).

Priority: 1

Grade: A

Summary: The calibration tables are applied on-the-fly when displaying, averaging, copying, or imaging the uvdata. There is no need to make a calibrated dataset, although it is sometimes convenient to do this. The calibrations are applied by default, but can be switched off using any of the options=nocal,nopass,nopol.

OL–4.1–R2.1 Logging of editing steps will be clearly marked in a history table or data object (possibly distinct from a more readable history).
Priority: 2
Grade: A
Summary: history of observation and data reduction, including the steps and parameters used in observing and reducing the data is stored with the data.

OL–4.1–R2.2 Individual edit undo is desirable.
Priority: 3
Grade: A

OL–4.1–R3 Data calibration operations shall take into account the scan structure and switching scheme of the data. The user shall be able to request calibration solution intervals that correspond to and reference from scan boundaries, for example.

Priority: 1

Grade: A

OL–4.1–R4 Data editing and flagging shall be possible based upon array, environmental, astronomical, and calibration monitoring data, including:

OL–4.1–R4.1 pointing data;
Priority: 1
Grade: A
OL–4.1–R4.2 array tracking information (encoders);
Priority: 1
Grade: A
OL–4.1–R4.3 weather data (wind speed, temperature, relative humidity, pressure);
Priority: 1
Grade: A
OL–4.1–R4.4 T_{sys} data;
Priority: 1
Grade: A
OL–4.1–R4.5 WVR data;
Priority: 1
Grade: A
OL–4.1–R4.6 RFI monitoring;
Priority: 2
Grade: N Severity: low
Summary: The user may set the DATA flag based on his own identification of RFI, but none is automatically detected on site.
OL–4.1–R4.7 site-test interferometer (STI) and/or tipping radiometer;
Priority: 2
Grade: N Severity: low
Summary: No such equipment on site.
OL–4.1–R4.8 array monitoring points (e.g. dewar temperatures) if data provided in standard format;
Priority: 3
Grade: A
Summary: The user may flag the data using any monitored variable in the metadata
OL–4.1–R4.9 other site instrument (e.g. FTS) providing data in standard format.
Priority: 3
Grade: N Severity: low
Summary: No such equipment on site.

Summary: These are well handled, provided that the metadata is available in the data structure.

OL–4.1–R5 Calibration shall involve flexible averaging of data and calibration quantities with user-controllable interpolation, filtering, weighting, and application scope.

Priority: 1

Grade: A

Summary: Data can be averaged in time inside a scan if needed, and in frequency bins of time bins to evaluate frequency based or time-based solutions.

OL–4.1–R6 Interactive data editing, calibration, and display of calibration quantities shall be largely graphical and intuitive. Specialized editing display tools should include:

OL–4.1–R6.1 specification of data by selection on observational parameters, and/or plotting versus these parameters, including:
OL–4.1–R6.1.1 antenna;
Priority: 1
Grade: A
OL–4.1–R6.1.2 baseline;
Priority: 1
Grade: A

OL–4.1–R6.1.3 time range;
Priority: 1
Grade: A
OL–4.1–R6.1.4 uv range;
Priority: 1
Grade: A
OL–4.1–R6.1.5 pointing center;
Priority: 1
Grade: A
OL–4.1–R6.1.6 azimuth, elevation;
Priority: 1
Grade: A
OL–4.1–R6.1.7 hour angle range;
Priority: 1
Grade: A
OL–4.1–R6.1.8 parallactic angle;
Priority: 1
Grade: A
OL–4.1–R6.1.9 slice through data cube;
Priority: 1
Grade: I Severity: low
Summary: Plotting is possible but it does not allow editing.
OL–4.1–R6.2 displays of spectra and spectral cubes;
Priority: 1
Grade: A
OL–4.1–R6.3 display of closure quantities;
Priority: 1
Grade: A
OL–4.1–R6.4 display of and selection on monitor data quantities (e.g. Tatm, Tamb);
Priority: 1
Grade: I Severity: med
Summary: display can be easily done; selection is possible through flagging based on monitor data.
OL–4.1–R6.5 the above with baseline, time, band and/or channel averaging
Priority: 1
Grade: A
OL–4.1–R6.6 for interferometer data, amplitude (phase) vs. time on each baseline (Difmap vplot), vs. time-baseline (AIPS TVFLG) with interactive zoom, selection, and clipping;
Priority: 1
Grade: A/E
Summary: Amplitude and/or phase vs time is available, and amplitude and/or phase vs baseline.
OL–4.1–R6.7 editing of data points based on statistical quantities, including:
OL–4.1–R6.7.1 a data point versus a running mean over a timescale;
Priority: 1
Grade: N Severity: med
OL–4.1–R6.7.2 a data point versus a median over a timescale;
Priority: 1
Grade: N Severity: med
OL–4.1–R6.7.3 an rms scatter in a time range;
Priority: 1
Grade: N Severity: med

OL–4.1–R6.7.4 difference versus a model;
Priority: 1
Grade: A

Summary: Control of interactive editing and plotting versus statistical quantities is lacking; such plotting and thus editing would normally be done by custom scripts.

OL–4.1–R6.8 auto-scaling and user-specified scaling of axes;
Priority: 1
Grade: A

OL–4.1–R6.9 auto-scaled and user-specified colormap or greyscale;
Priority: 1
Grade: A

OL–4.1–R6.10 inclusion and marking of flagged data in plots and in auto-scaling;
Priority: 1
Grade: A/E
Summary: Yes for flagged; no for auto-scaled .

OL–4.1–R7 Non-interactive and automated editing tools shall be available in the Package, including:

OL–4.1–R7.1 direct editing of data based user-specified ranges for quantities available for plotting or editing in interactive mode
Priority: 1
Grade: A/E

OL–4.1–R7.2 automated editing with tunable criteria for automated selection of parameter ranges
Priority: 2
Grade: N Severity: med

OL–4.1–R8 Data calibration, correction and flagging shall be possible based upon standard or user-defined models in either functional or tabular form. Arbitrary user-specified scaling of data shall be simple.

Priority: 2

Grade: N Severity: high

Summary: Not available.

OL–4.1–R9 Access to time history of calibration information (e.g. source catalogs containing flux density histories) shall be built into calibration engines. Output of calibration procedures shall be exportable into similar structures.

Priority: 2

Grade: A

Summary: Quasar fluxes are in a file; time history can be plotted. models for planets are in the data structure.

OL–4.1–R10 The Package shall support the establishment and verification of the relative calibration of the various component epochs, configurations or other subsets for merged datasets.

Priority: 2

Grade: A

OL–4.1–R11 Data display and editing shall be effected through generic tools applicable to both single-dish and interferometer modes. These shall, as far as possible, present similar interfaces to the user and have the same look-and-feel.

Priority: 2

Grade: A/E

OL–4.1–R12 Editing shall be incorporated into most visualization tools where data or data-derived quantities are plotted, such as from calibration solutions, amplitude vs. uv-distance plots, or any number of other plots. A "see-it, flag-it" capability shall be the standard within the tools.

Priority: 2

Grade: U

2.4.2 Atmospheric Calibration

OL–4.2–R1 Atmospheric modeling shall be available in the Package. **The ALMA Project shall provide a standard model as used in the Pipeline processing of data which the package must support.** There shall be provision for the use of user-supplied models, or the package may have its own built-in models as an option.

Priority: 1

Grade: A

Summary: Atmospheric modeling is available online, (though not with the latest ATM model; the current model in used is limited in accuracy above 300 GHz).

OL–4.2–R2 The Package shall be able to predict the absorption, emission and path length on the line of sight through the atmosphere at all ALMA bands using the model. The prediction will be based on the following data:

OL–4.2–R2.1 measured atmospheric parameters at the site: temperature, pressure, humidity
Priority: 1
Grade: A

OL–4.2–R2.2 measured atmospheric emission in the observed ALMA bands
Priority: 1
Grade: A
Summary: But restricted in accuracy above 300 GHz.

OL–4.2–R2.3 data from site test interferometer or tipping radiometer
Priority: 2
Grade: N Severity: low
Summary: Not available at Hatcreek site so not developed.

OL–4.2–R2.4 measured FTS data (if FTS available for ALMA)
Priority: 3
Grade: U
Summary: Not available at Hatcreek site so not developed; pending ALMA FTS and format.

OL–4.2–R2.5 measured atmospheric profiles of temperature and water content if available from atmospheric sounders or other devices
Priority: 3
Grade: U
Summary: Pending ALMA scoping of this.

OL–4.2–R3 Atmospheric modeling shall be usable to derive the system temperatures corrected for atmospheric absorption in all astronomical bands in use, in order to correct the observed amplitudes at various elevations.

Priority: 1

Grade: A

Summary: This is available in the on-line system and in the Miriad task OBSTAU task.

OBSTAU computes tau, sky temperature and single sideband systemp from an atmospheric model. The program assumes scale height for water is 1.6 km. You must specify the water content of the atmosphere. This can be input as precipitable water (mm), or relative humidity (Output: zenith opacity, estimated skytemp at current airmass, and single sideband system temperature, Tsys.

OL–4.2–R4 Atmospheric modeling shall be also usable to provide the conversion factors between WVR data and the water contribution to the astronomical phase in the astronomical bands.

Priority: 1

Grade: A

Summary: The WVR data also has the conversion to mmh2o.

2.4.3 Interferometer Data

Note: Antenna-based determination of calibration quantities such as gains, polarization leakages, bandpasses, will be the primary form of calibration where appropriate. However, in addition to antenna-based calibration, baseline dependent corrections will be important in some cases. For example, coherence loss due to atmospheric phase fluctuation depends on baseline length (this aspect will be more important at higher frequencies) and orientation, and must be taken into account if some of the WVR corrections are discarded while others are applied. Also, in general, the bandpasses are baseline dependent and contain non-closing terms.

OL–4.3–R1 Antenna-based determination of calibration quantities shall be available, and are the default choice for calibration in tools where appropriate, for quantities including:

OL–4.3–R1.1 antenna gains;
Priority: 1
Grade: A

OL–4.3–R1.2 polarization leakages;
Priority: 1
Grade: A

OL–4.3–R1.3 antenna-dependent bandpasses;
Priority: 1
Grade: A

OL–4.3–R2 Baseline dependent corrections shall be supported for quantities including:

OL–4.3–R2.1 WVR corrections to subsets of baselines;
Priority: 1
Grade: A

OL–4.3–R2.2 closure errors;
Priority: 1
Grade: A
Summary: This is handled as 'baseline-based calibration'.

OL–4.3–R2.3 baseline-dependent bandpasses;
Priority: 1
Grade: A
Summary: This is handled as 'baseline-based calibration', both for amplitude and phases.

OL–4.3–R3 Gain corrections will be made based on differences between observed and modeled data quantities, possibly with iteration (e.g. self-calibration and determination of gains using calibration sources). Where solutions are discrepant or poor, automatic editing shall be possible.

Priority: 1

Grade: A

OL–4.3–R4 Calibration quantities (possibly stored in tables or data structures) shall be transferable between sources and/or frequency bands, after any necessary interpolation, extrapolation or smoothing. This will be the primary method of phase calibration transfer using fast-switching between source and calibrator.

Priority: 1

Grade: A

Summary: This is the standard way of calibrating

OL–4.3–R5 Determination of the time-variable, complex bandpass using calibration source observations, and transfer to target sources, shall be simple and robust.

Priority: 1

Grade: A

Summary: supported in uvgains task, not much used

OL–4.3–R6 Determination of polarization calibration quantities such as leakage (D-term or Jones matrix) and complex gain difference shall be an integral part of the Package, with the capability of performing full matrix calculations.

Priority: 1

Grade: A

OL–4.3–R7 Determination of, correction for, examination of, and flagging based on closure errors shall be straightforward to carry out.

Priority: 2

Grade: A

Summary: Closure errors are checked for when solving for antenna based calibrations. Correction for the errors have to be done by using baseline-based calibrations.

OL–4.3–R8 Incorporation of standard models (e.g. planetary disks, models for HII region structure, known source spectra) shall be easy for calibration operations. User-supplied models in a standard format (e.g. ASCII table) for these quantities shall be supported.

Priority: 2

Grade: A/E

Summary: This is done through tasks uvmodel and selfcal .

OL–4.3–R9 Redundancy (e.g. same, similar, or crossing baselines) shall be used wherever possible to increase accuracy of or to check calibration solutions. Editing based on this comparison shall be possible.

Priority: 2

Grade: N Severity: low

Summary: There is no dedicated tool for this, though it is feasible using uv plots

OL–4.3–R10 Interferometric pointing, focus, baseline, and beam response fitting shall be available in the Package as a supplement to the on-line calibration.

Priority: 3

Grade: A

2.4.4 Single Dish Data

OL–4.4–R1 Straightforward and flexible fitting of spectral bandpass from calibration source observations is required.

Priority: 1

Grade: A/E

Summary: We can fit a baseline and transport it. A passband can be fitted too. transporting it is not implemented.

OL–4.4–R2 De-striping and adjustment of scan normalization factors must be available for single-dish OTF observations with overlapping and crossing scans.

Priority: 1

Grade: I Severity: med

Summary: Not available as a specific function or tool, but can be done by FFT-ing the data, filtering, and transforming back.

OL–4.4–R3 Calibration of system parameters such as temperature controlled loads and noise sources from observations of celestial sources shall be supported.

Priority: 3

Grade: A

OL–4.4–R4 Processing for pointing, focus, tipping, or beam-fitting data must be available for both single-scan calibration observations and for multiple datasets.

Priority: 3

Grade: A

Summary: Mostly for staff use, and can be done using custom scripts running low-level functions.

2.4.5 Mosaicing Considerations

OL–4.5–R1 Determination of and correction for pointing offsets and the polarized primary beam is critical to the ability to reliably mosaic using ALMA, and thus must be available in the Package, preferably in several algorithmic forms.

Priority: 1

Grade: A/E

Summary: There is a pointing fitting task PNT. The nominal pointing centers can be changed by known pointing corrections. This is a 1st order correction. It does not change amplitude and phase across the PB. Correcting the actual antenna pointing on-line is best. The polarized primary beam has been determined, but never used to correct data as far as I know.

OL–4.5–R2 Careful cross calibration of the flux scales between ALMA interferometric data and single dish data is required for high fidelity imaging. There must be tools to cross-check and correct the relative calibration between mosaics and different component observations. *Note: this is particularly important and more difficult for ACA data.*

Priority: 2

Grade: A

Summary: A lot of work has been. See ALMA memo 450 for ACA.

OL–4.5–R3 The Package shall allow user-input of scan information given a parameterized pattern or interpolated from a provided list of pointing centers versus time

Priority: 3

Grade: A

Summary: The pointing information is available in the headers, and you're free to change them by any data or formula if you believe they are wrong by any amount (as anything in the headers incidently).

2.4.6 Ancillary and Diagnostic Data

OL–4.6–R1 Output from the atmospheric monitoring (e.g. WVR, FTS) instrumentation provided in ALMA format shall be importable to the calibration software, for example to be used in flagging.

Priority: 1

Grade: U

Summary: An ALMA format needs to be detailed.

OL–4.6–R2 Derivation of calibration and correction of data based on pointing, focus and subreflector status information shall be available in the Package.

Priority: 1

Grade: I Severity: med

Summary: One can correct the visibilities for the phase effect of a mispositioned subreflector.

OL–4.6–R3 Environmental data such as weather (e.g. wind speed, temperature, dew point) supplied in ALMA format, as FITS extension tables, or as ASCII tables shall be importable for editing or calibration procedures, and easily incorporated into user-specified calibration models.

Priority: 2

Grade: U

Summary: The ALMA formats needs to be detailed. These parameters should be in the standard metadata (e.g. they are in MIRIAD format) and thus should not need be imported.

OL–4.6–R4 Engineering monitoring information such as temperature sensor readings and tilt-meter outputs, included in ALMA format, as FITS extension tables, or as ASCII tables, shall be readable and incorporated into the calibration and editing process.

Priority: 3

Grade: U

Summary: The ALMA formats needs to be detailed. We will want to include in the DRP native format all data that needed for calibration and editing. This is the strategy we used for MIRIAD.

2.5 Imaging

2.5.1 General Imaging Requirements

Because ALMA is inherently a multi-channel instrument, spectral cube mapping shall be built in as the primary mode from the beginning. Also, due to the high volume of data that can be produced by ALMA, it is imperative that the imaging and deconvolution tools in the Package be user-friendly, efficient, and flexible. This is the workhorse of the Package as far as most users will be concerned, and suitability and success of the Package will be judged with this in mind.

OL–5.1–R1 Imaging of data taken from any combination of ALMA exported data, the ALMA archive, or other instruments supporting common export formats must be provided. **A list of supported data and formats will be maintained by the project.**

Priority: 1

Grade: U

Summary: ALMA must supply a list.

OL–5.1–R2 Efficient selection of subsets of the imaging data must be provided.

Priority: 1

Grade: A

Summary: The "region" keyword selects a subregion of an image. Multiple subregions can be selected, which are "ored" together. The following subcommands are recognized (each of which can be abbreviated to uniqueness).

images(z1,z2) Select image planes z1 to z2 inclusive. z2 defaults to z1.

quarter(z1,z2) Select the inner quarter of the image planes z1 to z2 inclusive. If both z1 and z2 are missing, then all planes are selected. If only z2 is omitted, z2 defaults to z1.

boxes(xmin,ymin,xmax,ymax)(z1,z2) Select the pixels within a box with corners xmin,ymin,xmax,ymax. z1 and z2 are the same as in the "image" subcommand. If z1 and z2 are omitted, all planes are selected.

polygon(x0,y0,x1,y1,x2,y2,...)(z1,z2) Select the pixels within the polygon defined by the list of vertices. z1 and z2 are the same as in the "image" subcommand. If z1 and z2 are missing, all planes are selected. If only z2 is omitted, it defaults to z1.

mask(file) Select pixels according to the mask given in the file.

The units of the numbers given in the above commands are, in general, absolute pixels. But this can be changed (and rechanged) by using one of the following subcommands.

abspixel Coordinates are interpreted as absolute pixel values, the default. relpixel Coordinates are relative to the reference pixel of the map. relcenter Coordinates are relative to the central pixel of the map, (defined as (naxis1/2+1,naxis2/2+1)). arcsec Coordinates are in arcseconds, relative to the reference pixel. kms Coordinates in the third dimension are in km/s. .

OL–5.1–R3 Provision must be made for the utilization and development of a variety of imaging, deconvolution, and analysis algorithms, including:

Summary: Miriad's imaging task, INVERT, makes images from a collection of uvdata sets. The images may be spectral line, polarization, MFS, or mosaiced. Multiple frequencies, pointings, polarizations may be present in the same, or in multiple uvdata sets. Several weighting options are supported (natural, uniform, robust, tapering, systemp). Invert can make Stokes I,Q,U,V images after applying leak calibration. The default mode for invert is a conventional grid and FFT algorithm. The user can specify the image, and pixel size; by default invert images the FWHM of the telescope with 1.5 x Nyquist sampling.

OL–5.1–R3.1 raw ("dirty") images with selectable weighting (natural, uniform, Briggs robust);
Priority: 1
Grade: A
Summary: These are in Miriad's imaging task.

OL–5.1–R3.2 residual images after model subtraction;
Priority: 1
Grade: A
Summary: UVMODEL modifies a visibility dataset by a model. Allowed operations are adding, subtracting, multiplying, dividing, replacing, and polarization calibration or simulation. The model is specified in the image domain, so that its Fourier transform is first computed before application to the visibilities. The model may be either a deconvolved image or a point source. The output is a visibility dataset. .

OL–5.1–R3.3 single-scale CLEAN (Hogbom, Clark, Cotton-Schwab);
Priority: 1
Grade: A
Summary: CLEAN uses the Hogbom, Clark, or SDI algorithm, which take a dirty map and beam, and produce an output map which consists of the Clean components. By default CLEAN determines which is the best algorithm to use. The output can be input to SELFCAL to self-calibrate visibilities, or input to RESTOR to produce a "clean" image. An initial estimate, or model of the deconvolved image can be used. e.g. a planet model or output from a previous deconvolution task.

OL–5.1–R3.4 maximum entropy method (MEM);
Priority: 1
Grade: A
Summary: MAXEN uses a Maximum Entropy deconvolution algorithm. An initial estimate, or model of the deconvolved image can be used. A default image can be given, e.g. a single dish image. The final result will be influenced by this default if the constrains that the data put on the solution are weak. The entropy measure can be either "gull" (-p*log(p/e)) or "cornwell" (-log(cosh(p)).

OL–5.1–R3.5 linear mosaics;
Priority: 1
Grade: A
Summary: Miriad's imaging task, "invert options=mosaic" , makes images from a collection of uvdata sets. LINMOS is a MIRIAD task which performs a simple linear mosaicing of input cubes, to produce a single output cube. If only a single input cube is given, LINMOS essentially does primary beam correction on this input. When several, overlapping, inputs are given, then LINMOS combines the overlapping regions in such a way as to minimize the rms error in the output.

OL–5.1–R3.6 non-linear mosaics;
Priority: 1
Grade: A
Summary: MOSSDI performs an SDI CLEAN on a mosaiced image.
MOSMEM performs a Maximum Entropy deconvolution of a mosaiced image. Optionally it can also perform a joint deconvolution of a mosaic and single dish image. An initial estimate, or model of the deconvolved image can be used. A default image or a total flux estimate can be given.
PMOSMEM performs a joint maximum entropy deconvolution of polarized mosaiced images. Optionally it can perform a joint deconvolution with a single dish image as well.

OL–5.1–R3.7 non-negative least-squares (NNLS);
Priority: 2
Grade: N Severity: med

OL–5.1–R3.8 multi-scale CLEAN;

Priority: 2
Grade: A/E
Summary: done using a script with Miriad tasks clean and restor

OL–5.1–R3.9 modelfitting (point, Gaussian, disk);
Priority: 2
Grade: A
Summary: Available through the Miriad uvfit task.

OL–5.1–R3.10 multi-frequency synthesis with different spectral models;
Priority: 2
Grade: A
Summary: Miriad task invert options=mfs Perform multi-frequency synthesis. The causes all the channel data to be used in forming a single map. The frequency dependence of the uv coordinate is thus used to give better uv coverage and/or avoid frequency smearing. options=sdb Generate the spectral dirty beam as well as the normal beam, when MFS processing. MFCLEAN is a task to deconvolve a multi-frequency synthesis image. It can perform either Clark or Hogbom iterations. Invert options=mfs,sdb makes an MFS image and beam with two planes: the normal dirty beam, and the spectral dirty beam. The result of MFCLEAN is an image consisting of two planes. The first plane is the normal flux model. The second plane is an image of flux*alpha.

OL–5.1–R3.11 special function deconvolution (Pixon, wavelet);
Priority: 3
Grade: U
Summary:

OL–5.1–R4 Image pixel and spectral channel blanking must be supported.

Priority: 1

Grade: A

Summary: IMMASK is a MIRIAD task which allows you to mask an image dataset, or find out the number of masked pixels in an image.

OL–5.1–R5 Interactive graphical selection of deconvolution region masks shall be available.

Priority: 1

Grade: A

Summary: CGCURS displays an image via a contour plots or a pixel map representation (formerly called a "grey scale") on a PGPLOT device. The cursor is then used to read image values, or to evaluate image statistics in a polygonal region, or to write a polygonal region definition to a text file.

OL–5.1–R6 Multiple input datasets shall be supported directly in the tools, rather than requiring previous concatenation of the data.

Priority: 2

Grade: A/E

Summary: Most Miriad tasks use the following keywords which allow multiple input datasets.

Keyword vis: Input visibility data files. Several files can be given. Calibration tables are applied on-the-fly as the datasets are read.

Keyword in: The input images. Several file names can be entered, separated by commas.

OL–5.1–R7 An integrated deconvolution, self-calibration, and editing/filtering tool shall be available, especially for novice users with data taken in commonly used modes.

Priority: 2

Grade: A/E

Summary: Standard scripts are in common use as an integrated deconvolution, self-calibration, and editing/filtering tool, by novice users.

OL–5.1–R8 Images made on different coordinate systems (e.g. OL–3.1–R9), equinoxes (e.g. OL–3.1–R10), or projections (e.g. OL–3.3–R4) shall be transformed, merged and compared appropriately.

Priority: 2

Grade: A

Summary: REGRID regrids an image by interpolating. The output coordinate system can be specified by a template image or by axis descriptors. Blanked input pixels are excluded from the interpolation. Regridding of any combination of the first three axes of an image is supported.

REGRID correctly handles conversion * Between different projection geometries (e.g. SIN,NCP,TAN etc). * Between equatorial and galactic coordinates. * From a B1950 input to J2000 output and visa versa, as well as B1950 to B1950, and J2000 to J2000. * Between radio/optical velocity definitions and LSR/barycentric velocity rest frames.

OL–5.1–R9 Image cubes using different velocity definitions (e.g. OL–3.1–R11) and velocity frames (e.g. OL–3.1–R12) shall be transformed and merged correctly.

Priority: 2

Grade: N Severity: low

2.5.2 Interferometer Imaging

OL–5.2–R1 High-fidelity imaging of the entire primary beam in all Stokes parameters is the primary goal — therefore, incorporation of the polarized primary beam response of the array is required.

Priority: 1

Grade: N Severity: high

Summary: Primary beams are modelized and used in imaging. However, no primary beam polarization correction has been needed so far, to my knowledge.

OL–5.2–R2 Imaging of direct polarization products (e.g. RR, LL, RL, LR) or Stokes polarization states (e.g. I, Q, U, V) must be selectable and interchangeable where possible given the data.

Priority: 1

gradeA

Summary: Miriad's imaging task, INVERT, makes images from a collection of uvdata sets. The data can be RR, LL, RL, LR, or XX XY YX YY, I, Q, U, V. The images may be spectral line, polarization, MFS, or mosaiced. Multiple frequencies, pointings, polarizations may be present in the same, or in multiple uvdata sets. Invert can make Stokes I,Q,U,V images after applying leak calibration.

OL–5.2–R3 There must be straightforward and seamless integration of data from multiple epochs and configurations.

Priority: 1

Grade: A

Summary: Multiple files may be input. calibration is applied on-the-fly. Coordinate conversions are handled by Miriad tasks uvcal, and regrid: Rotate uv-coordinates from current to standard epoch. The standard epoch, ra, dec can be changed using PUTHD. Miriad task REGRID correctly handles conversion * From a B1950 input to J2000 output and visa versa, as well as B1950 to B1950, and J2000 to J2000. .

OL–5.2–R4 Simultaneous multiple-field imaging and deconvolution must be supported.

Priority: 1

Grade: A

Summary: Invert options=mosaic; deconvolution using mossdi, mosmem are the standard deconvolution tasks.

OL–5.2–R5 Subtraction of continuum level from spectral data is required, in both the Fourier and image domain. In the case of uv-plane subtraction, flexible setting of the frequency channel ranges for the calculation of the continuum level and selection of the type of fitting (polynomial, spline) should be available in both GUI and CLI.

Priority: 1

Grade: A

Summary: Available in several Miriad tasks in both the Fourier and image domain.

OL–5.2–R6 There must be the ability to include "zero-spacing" values and short-spacing data taken in single-dish mode (both ALMA and non-ALMA data), with selectable weighting.

Priority: 1

Grade: A

Summary: MOSMEM performs a Maximum Entropy deconvolution of a mosaiced image. Optionally it can also perform a joint deconvolution of a mosaic and single dish image. An initial estimate, or model of the deconvolved image can be used. A default image or a total flux estimate can be given. One or two input dirty images (or cubes). These should have units of Jy/beam. The first should be produced by INVERTs mosaic mode. The optional second dirty map can be a single-dish image. It must be on exactly the same pixel grid as the first image. If necessary, use REGRID to make this so. If two inputs are given, then a joint deconvolution of the two is performed.

IMMERGE is a Miriad task to linearly merge together two images with different resolutions. The two images must be of the same field and use the same coordinate system.

OL–5.2–R7 There shall be the choice of FFT and DFT imaging (especially for small datasets).

Priority: 2

Grade: A

Summary: Miriad task INVERT Keyword: mode determines the algorithm to be used in imaging. Possible values are: fft The conventional grid-and-FFT approach. This is the default and by far the fastest. dft Use a discrete Fourier transform. This avoids aliasing but at a hugh time penalty. median This uses a median approach. This is generally robust to bad data and sidelobes, has a even larger time penalty and produces images that cannot be deconvolved. NOTE: Dft and median modes are not supported with options=mosaic.

OL–5.2–R8 There shall be the provision for the near-field imaging of solar-system objects. This can be done through the introduction of phase corrections based upon the sphericity of the incoming wave front.

Priority: 2

Grade: I Severity: low

Summary:

2.5.3 Mosaicing and Single Dish Imaging Considerations

OL–5.3–R1 Combination of interferometer and single-dish data into mosaic imaging is essential.

Priority: 1

Grade: A

Summary: Done routinely

OL–5.3–R1.1 The ACA (if and when it is scoped as part of ALMA) must be integrally supported by the Package.
Priority: 1
Grade: A
Summary: Implemented Miriad CSH and PYTHON simulations. See ALMA memo 450.

OL–5.3–R2 Careful (polarized) primary beam correction and pointing correction is critical for high fidelity mosaic imaging and must be incorporated into the mosaicing algorithms.

Priority: 1

Grade: I Severity: high

Summary: This overlaps with OL–5.2–R1, OL–4.5–R1, and OL–4.6–R2.

OL–5.3–R2.1 The primary beam calculation and correction must take into account the effect of on-the-fly scanning.
Priority: 1
Grade: N Severity: low

OL–5.3–R2.2 A set of **ALMA standard beam images** will be made available by the project and distributed with the Package, with updates available for download when appropriate.
Priority: 1
Grade: U
Summary: Must be provided by ALMA.

OL–5.3–R2.3 The user shall be able to specify the primary beam in a number of forms, both analytic and tabular, in addition to the ALMA provided primary beam.
Priority: 2
Grade: A/E
Summary: Available except for polarization.

OL–5.3–R3 Image plane and uv-plane gridding parameters and interpolation shall be selectable based on desired image criteria (e.g. field-of-view, accuracy)

Priority: 1

Grade: A/E

Summary: Default guess are good.

OL–5.3–R4 Scaling and de-striping of scans on image-plane combination shall be available.

Priority: 2

Grade: I Severity: med

Summary:

OL–5.3–R5 The Package must be able to produce an image by combining data observed on different rasters, possibly taken with different (regular or irregular) spacings and image centers.

Priority: 2

Grade: I Severity: high

Summary:

OL–5.3–R6 Pointing corrections (e.g. as determined by optical cameras or through monitoring data) shall be applicable to the data during imaging

Priority: 2

Grade: N Severity: med

Summary: This overlaps with OL–5.2–R1, OL–4.5–R1, and OL–4.6–R2, and further development is needed on algorithms.

OL–5.3–R7 The imaging tools shall allow the option for the mitigation of the effects of non-coplanar baselines and sky curvature.

Priority: 2

Grade: I Severity: med

Summary:

2.6 Data Analysis

2.6.1 General Analysis Requirements

OL–6.1–R1 Seamless transformation between image-plane and uv-plane analysis is necessary:

- **OL–6.1–R1.1** Analysis based on goodness-of-fit to models, in both uv-plane (for interferometry) and image plane, shall be available.
  Priority: 1
  Grade: A
  Summary: Fits in the UV plane use task UVFIT. Fits in the Image plane use task IMFIT.
- **OL–6.1–R1.2** Fourier transform of images between angular and uv domains shall be available.
  Priority: 2
  Grade: A
  Summary: The Fourier Transform between UV and Image planes is widely used in MIRIAD. It is available to the user in various implementations.

OL–6.1–R2 Spectral and scanning baseline removal facility is required:

- **OL–6.1–R2.1** Polynomial baseline fitting shall be supported
  Priority: 1
  Grade: A
  Summary: SINPOLY - Fit polynomial baselines to autocorrelation data. RF bandpass calibration of interferometric data is done in MFCAL.
- **OL–6.1–R2.2** Baseline fitting based on image statistics (e.g. median filtering) shall be supported
  Priority: 1
  Grade: U
  Summary: Don't know.
- **OL–6.1–R2.3** Fourier analysis of standing waves and their removal from spectra shall be available.
  Priority: 2
  Grade: I Severity: low
  Summary: Don't think we have one - but it sounds easy enough

OL–6.1–R3 Translation between various astronomical quantities and units shall be available, including:

- **OL–6.1–R3.1** flux density — Jy, mJy, μJy, mag
  Grade: A/E
  Summary: Several tasks support conversion, but not mag.
- **OL–6.1–R3.2** temperature — K, mK (Rayleigh-Jeans, Planck)
  Grade: A/E
  Summary: Several tasks support conversion, but not mag.
- **OL–6.1–R3.3** surface brightness — Jy/beam, Jy/sr, MJy/sr, mag/arcsec^2
  Grade: A/E
  Summary: Several tasks support conversion, but not mag.
- **OL–6.1–R3.4** frequency — Hz, MHz, GHz, cm^{-1} (wave number)
  Grade: N Severity: low
- **OL–6.1–R3.5** velocity — km/s, m/s, z (redshift)
  Grade: N Severity: low
- **OL–6.1–R3.6** wavelength — m, cm, mm
  Grade: N Severity: low

Priority: 2

OL–6.1–R4 The astronomer must have the capability to develop their own tools or tasks, with easy access to data and images, and straightforward interface with the Package.

Priority: 2

Grade: A

Summary: Developing new tasks and GUIs in MIRIAD is easy. Several users have developed tasks for data analysis. e.g. planetary models, radiative transfer... Developing scripts is trivial.

2.6.2 Spectral Line Analysis

ALMA will be a spectroscopic machine, and thus the ease and flexibility of spectral line analysis is likely to be a driver for the Package. Automatic and user-controlled fitting routines will need to be included. Note that there is necessarily some overlap with the image cube analysis, but here we concentrate on issues relevant to traditional 1-D spectra.

OL–6.2–R1 Automatic and user-controlled measurement of line parameters shall be available.

Priority: 1

Grade: A

Summary: There are several excellent packages in use, which could be included in the Miriad distribution. It is an option to write ASCII spectra from the relevant MIRIAD tasks, to use a variety of fitting programs. In addition some Miriad tasks support interactive fitting procedures, e.g. in VELPLOT

OL–6.2–R2 It shall be possible for the user to specify a velocity or frequency windowing region for line fitting.

Priority: 1

Grade: A

Summary: of course

OL–6.2–R3 Available line fitting parameters and profiles shall include:

OL–6.2–R3.1 Gaussian line parameters (central and integrated intensity, line width, line center) for single or multiple lines
Priority: 1
Grade: A
Summary:

OL–6.2–R3.2 Damping profiles (Lorentzian)
Priority: 2
Grade: N Severity: low
Summary: This does not appear to be supported.

OL–6.2–R4 A set of **ALMA standard line catalogs** shall be made available by the project and distributed with the Package, with updates available for download when appropriate.

Priority: 1

Grade: U

Summary: The ALMA standard line catalog has yet to be defined. LOVAS and JPL catalogs are used. LOVAS is disributed and used within Miriad

OL–6.2–R5 User importable line catalogs shall be supported by the Package as an ASCII table and in the **ALMA standard format**.

Priority: 2

Grade: U

Summary: The ALMA standard line catalog format has yet to be defined.

OL–6.2–R6 Setting of fit constraints (e.g. spacing for multiple lines) shall be available and flexible (i.e. by GUI or by parameter list).

Priority: 2

Grade: A

Summary: Available. No need to duplicate.

OL–6.2–R7 Export of fit results in ASCII-format is desirable.

Priority: 3

Grade: A

Summary: This is available in VELPLOT

2.6.3 Image Cube Analysis and Manipulation

Because ALMA is inherently a multi-channel instrument, and due to the design of the ALMA correlator, spectral image cubes can be considered to be the fundamental image structure. Single-channel or continuum images can be considered as subsets or instances of cubes. Note that the ability to pull lower-dimensional structures from larger-dimensional cubes is especially important.

OL–6.3–R1 The Package shall support the construction and analysis of image cubes with a variety of axis choices, including:

OL–6.3–R1.1 time (e.g. OL–3.1–R8);
Priority: 1
Grade: A

OL–6.3–R1.2 position (e.g. OL–3.1–R9 or general X,Y);
Priority: 1
Grade: A

OL–6.3–R1.3 Fourier (u,v);
Priority: 1
Grade: A

OL–6.3–R1.4 channel (frequency, velocity, channel number, band, IF);
Priority: 1
Grade: A

OL–6.3–R1.5 polarization;
Priority: 1
Grade: A

OL–6.3–R2 Basic cube rotation and transposition operations shall be available, including rotation not orthogonal to cube faces.

Priority: 1

Grade: A

Summary: REORDER is a MIRIAD task to reorder and reverse axes within an image. Rotation not orthogonal to cube face is not supported.

OL–6.3–R3 It shall be possible to define multi-dimensional regions of the cube for further processing, both interactively and by specifying coordinates manually.

Priority: 1

Grade: A

Summary: Keyword "region" selects a subregion of an image. Multiple subregions can be selected, which are "ored" together. The following subcommands are recognized: images(), quarter(), boxes(), polygon(), abspixel, relpixel, relcenter, arcsec, kms . Image bit masks are supported.

OL–6.3–R4 Identification and reporting of image features (e.g. as determined in processing operations) shall be available, and interactive (where appropriate). Features shall include:

OL–6.3–R4.1 output in pixel coordinates (e.g. row, column);
Priority: 1
Grade: A

OL–6.3–R4.2 output in world coordinates (e.g. RA, Dec, Vel);
Priority: 1
Grade: A

OL–6.3–R4.3 convertible to other supported coordinate systems (e.g. precessed to B1950);
Priority: 2
Grade: I Severity: med

OL–6.3–R4.4 exportable (e.g. as an ASCII file);
Priority: 3
Grade: A

OL–6.3–R5 The ability to extract same or lower-dimensional structures from higher-dimensional data cubes efficiently is required:

OL–6.3–R5.1 Extraction of "cubical" sub-structures aligned with the original cube axes must be straightforward.
Priority: 1
Grade: A
Summary: tasks in uv and image domain: UVCAT, IMSUB tasks.

OL–6.3–R5.2 User selection of extraction criteria must be possible through the GUI as well as scriptable.
Priority: 1
Grade: A
Summary:

OL–6.3–R5.3 User-selectable sub-structures with arbitrary orientation within the parent cube, with appropriate transformation or interpolation, shall be possible.
Priority: 2
Grade: N Severity: med
Summary: Arbitrary orientation not supported.

OL–6.3–R5.4 Extraction of data structures based on standard database (e.g. SQL) queries shall be available.
Priority: 3
Grade: N Severity: low
Summary: Not available.

OL–6.3–R6 The ability to collapse or integrate over sub-dimensions of data cubes in order to form "moments" is required. This shall be possible along any direction(s) in the cube aligned with the axes.

Priority: 1

Grade: A

Summary: Available in MOMENT task.

OL–6.3–R6.1 Moments along arbitrary user-specified directions in the cube shall be possible.
Priority: 3
Grade: N Severity: low
Summary: Arbitrary orientation not supported. But I don't see what would be the interest! neither do I.

OL–6.3–R7 The Package must have the capability of assembling lower-dimensional data structures into higher-dimension cubes.

Priority: 1

Grade: A

Summary: IMCAT is a MIRIAD task to concatenate several images together, along an axis (generally the frequency or velocity dimension).

OL–6.3–R8 Blanking of pixels must be maintained through the analysis process.

Priority: 1

Grade: A/E

Summary:

OL–6.3–R8.1 It must be possible to turn on and off different blanking (mask) levels, when blanking is set within the Package.
Priority: 1
Grade: A
Summary: The mask is a bit mask. The levels can be set using the maths task. Several masks could be saved, but it is easy enough to create a mask as needed.

OL–6.3–R8.2 Blanking shall not be destructive, and the original pixel value is retained (if defined).
Priority: 2
Grade: A
Summary: Yes, except the maths task which modifies the data to enable the calculation.

OL–6.3–R8.3 Interactive and automatic facilities for setting of any blanking parameters shall be provided.
Priority: 2
Grade: A/E
Summary: UVCHECK is a Miriad program to check uv-variable values and flag uv-data if variables or data are out of range. uv-data can be flagged if the uv-variable, the amplitude of a reference channel, the geometric delay, or the fringe frequency is outside a specified range.

OL–6.3–R9 A variety of image processing and filtering operations on the cube shall be available, including:

OL–6.3–R9.1 Smoothing and convolution, with kernels including:

OL–6.3–R9.1.1 Uniform (box-car or top-hat) kernel;
Priority: 1
Grade: A
Summary: CONVOL task.

OL–6.3–R9.1.2 Elliptical Gaussian kernel;
Priority: 1
Grade: A
Summary: CONVOL task.

OL–6.3–R9.1.3 Symmetric polynomial;
Priority: 2
Grade: A
Summary: CONVOL task can use any 2D function. Keyword: beam The input beam. This cannot be 3-dimensional. The beam is generally assumed to be symmetrical about its reference pixel, but see the "asymmetric" option if this is not so. If this is not given, then a gaussian beam must be specified by the fwhm and pa parameters. options="asymmetric" Normally the beam is assumed to be symmetric (as it normally is in radio astronomy). This options causes CONVOL to go through the extra steps to handle a possibly asymmetric beam. If the beam is asymmetric, and you go not give this option, CONVOL symmetrises the beam (i.e. discards the anti-symmetric component).

OL–6.3–R9.1.4 User-supplied;

Priority: 3
Grade: A
Summary: see above.

OL–6.3–R9.2 Clipping
Priority: 1
Grade: A
Summary: MATHS task

OL–6.3–R9.3 Windowing and boxing, with definitions of regions of interest recordable and passable for subsequent use
Priority: 1
Grade: A
Summary: The Keyword "region" selects a subregion of an image. Multiple subregions can be selected, which are "ored" together."

OL–6.3–R9.4 Arithmetical operations, including:

OL–6.3–R9.4.1 addition of uniform level;
Priority: 1
Grade: A

OL–6.3–R9.4.2 multiplicative scaling;
Priority: 1
Grade: A

OL–6.3–R9.4.3 logarithm;
Priority: 2
Grade: A

OL–6.3–R9.4.4 exponential;
Priority: 2
Grade: A

OL–6.3–R9.5 Statistical operations over a defined region, including:

OL–6.3–R9.5.1 mean
Priority: 1
Grade: A

OL–6.3–R9.5.2 rms
Priority: 1
Grade: A

OL–6.3–R9.5.3 standard deviation from mean
Priority: 1
Grade: A

OL–6.3–R9.5.4 median
Priority: 1
Grade: N Severity: low
Summary: Could easily been added.

OL–6.3–R9.5.5 mode
Priority: 2
Grade: U
Summary: What is it?

OL–6.3–R9.6 Fourier and correlation operations on cube or cubical sub-regions, including:

OL–6.3–R9.6.1 Fourier transform
Priority: 1
Grade: A
Summary: FFT task.

OL–6.3–R9.6.2 power spectrum
Priority: 1

Grade: A
Summary: FFT task.

OL–6.3–R9.6.3 autocorrelation
Priority: 1
Grade: A
Summary: FFT task.

OL–6.3–R9.6.4 structure function
Priority: 2
Grade: N Severity: med
Summary: Not available.

OL–6.3–R9.7 Scalar arithmetic between different regions (including treatment of masked regions and differently shaped regions), including:

OL–6.3–R9.7.1 sum (difference);
Priority: 1
Grade: U

OL–6.3–R9.7.2 product (division);
Priority: 1
Grade: U

OL–6.3–R9.7.3 spectral index;
Priority: 1
Grade: U

OL–6.3–R9.7.4 median;
Priority: 2
Grade: U

OL–6.3–R9.7.5 maximum (minimum);
Priority: 2
Grade: U

Summary: Unclear what these requirements means. But image manipulation is trivial in MIRIAD

OL–6.3–R9.8 Construction and comparison of vector quantities in the cube, including:

OL–6.3–R9.8.1 polarization (E) vector at each cube pixel;
Priority: 1
Grade: A
Summary: IMPOL task.

OL–6.3–R9.8.2 rotation measure between different frequencies;
Priority: 1
Grade: A
Summary: IMRM task.

OL–6.3–R9.9 Vector arithmetic between different regions (including treatment of masked regions and differently shaped regions), including:

OL–6.3–R9.9.1 sum (difference);
Priority: 1
Grade: U

OL–6.3–R9.9.2 dot product;
Priority: 2
Grade: U

OL–6.3–R9.9.3 cross product;
Priority: 2
Grade: U

OL–6.3–R9.10 Interpolation across blanked or masked regions
Priority: 1

Grade: U

OL–6.3–R9.11 Fitting of models, shapes, profiles and functions over regions including:

OL–6.3–R9.11.1 polynomials
Priority: 1
Grade: I Severity: low
Summary:

OL–6.3–R9.11.2 exponentials
Priority: 1
Grade: U
Summary:

OL–6.3–R9.11.3 Fourier modes
Priority: 1
Grade: A
Summary: FFT task.

OL–6.3–R9.11.4 elliptical Gaussian components
Priority: 1
Grade: A
Summary: Can be done in image plane using task IMFIT task.

OL–6.3–R9.11.5 uniform (multi-dimensional) spheres
Priority: 2
Grade: N Severity: med
Summary: What are these?

OL–6.3–R9.11.6 trigonometric functions
Priority: 2
Grade: I Severity: low
Summary:

OL–6.3–R9.11.7 Lorentzian profiles
Priority: 2
Grade: I Severity: low
Summary:

OL–6.3–R9.11.8 user-supplied functions
Priority: 3
Grade: I Severity: low
Summary:

OL–6.3–R9.12 Filtering, including:

OL–6.3–R9.12.1 Fourier (Wiener) filtering
Priority: 2
Grade: N Severity: low
Summary: Not available.

OL–6.3–R9.12.2 Sobel filtering
Priority: 3
Grade: N Severity: low
Summary: Not available.

OL–6.3–R9.12.3 unsharp mask
Priority: 3
Grade: U
Summary:

OL–6.3–R9.12.4 user-supplied filtering functions
Priority: 3
Grade: A
Summary: CONVOL task

OL–6.3–R9.13 Deconvolution

Priority: 2

Grade: A

Summary: Several Miriad tasks make deconvolved images. Miriad supports CLEAN, Maximum Entropy, and direct deconvolution. Separate Miriad tasks are used for single field, MFS, and mosaiced images.

OL–6.3–R9.14 Resampling (e.g. at lower temporal or spectral resolution) after processing

Priority: 2

Grade: A

Summary: This can be done by various tasks.

OL–6.3–R9.15 Calculus on scalar and vector fields in cube, including:

OL–6.3–R9.15.1 differentiation along paths;

Priority: 3

Grade: N Severity: low

OL–6.3–R9.15.2 integration over regions;

Priority: 3

Grade: N Severity: low

OL–6.3–R9.15.3 gradient of scalar fields;

Priority: 3

Grade: N Severity: low

OL–6.3–R9.15.4 divergence of vector fields;

Priority: 3

Grade: N Severity: low

OL–6.3–R9.15.5 curl of vector fields;

Priority: 3

Grade: N Severity: low

OL–6.3–R9.15.6 Laplacian of vector fields;

Priority: 3

Grade: N Severity: low

OL–6.3–R10 There shall be the capability to manipulate data cubes as general data structures, so that arithmetical and logical operations can be applied as object methods.

Priority: 3

Grade: I Severity: low

2.7 Visualization

This is intended as the purely graphical part of data analysis. There is by necessity some overlap with the functionality discussed under Data Analysis, particularly that for image cube manipulation, and it would in fact be ideal if visualization and analysis were so closely integrated that there were no effective difference. The intention here is that the user is not only able to display pre-calculated images (processed using tools from the Data Analysis suite), but also has the capability of doing some processing and display on-the-fly as an integral part of the visualization.

2.7.1 General Visualization and Plotting Requirements

OL–7.1–R1 Plotting and display capabilities shall be integrated into the GUI tools throughout the Package.

Priority: 1

Grade: A

Summary: Equally available through the miriad shell or CLI. It may be easier to call a plotting command inside the CLI than having to search it deeply hidden in the GUI. That's why in the following only CLI commands are cited (not their GUI counterpart).

OL–7.1–R2 Standard type of plots must be supported, such as:

OL–7.1–R2.1 X-Y plots;
Priority: 1
Grade: A
Summary: WIP.

OL–7.1–R2.2 histograms;
Priority: 1
Grade: A
Summary: WIP

OL–7.1–R2.3 contour plots;
Priority: 1
Grade: A
Summary: WIP, implot, cgdisp.

OL–7.1–R2.4 vector plots;
Priority: 1
Grade: A
Summary: cgdisp.

OL–7.1–R2.5 2D images;
Priority: 1
Grade: U
Summary: ??

OL–7.1–R2.6 wireframe 3D surfaces;
Priority: 1
Grade: U
Summary: ??

OL–7.1–R3 "Blinking" between two different images, or stepping through a set of ordered images, at a user-selected rate and with adjustable transfer functions must be possible.

Priority: 1

Grade: A/E

Summary: Run tasks implot or cgdisp and hit return at a user-selected rate. adjustable transfer functions are available in cgdisp.

OL–7.1–R4 Standard plotting formats shall be supported, both displayed (e.g. X window) and hardcopy:

- **OL–7.1–R4.1** There must be at least one designated standard output format (e.g. postscript) that can be converted by the user to a variety of formats using easily obtainable tools.
  Priority: 1
  Grade: A
  Summary: PostScript is `MIRIAD` standard.
- **OL–7.1–R4.2** The Package shall also support the output of a variety of commonly used formats such as FITS, postscript, pdf, gif and/or jpeg.
  Priority: 3
  Grade: A/E
  Summary: FITS, PS, GIF) are currently available. Adding others should not be a big deal.

OL–7.1–R5 Identification of cursor position shall be available for interactive plots. Where appropriate, this information shall be recordable and exportable. If you "see-it" you should be able to figure out where it came from.

Priority: 1

Grade: A/E

Summary: Available in velplot, implot, uvspect.

OL–7.1–R6 An extra "axis" of information shall be encodable on the standard plot types using color and/or intensity.

Priority: 2

Grade: A/E

Summary: Can be done using scripts.

OL–7.1–R7 The displays shall have similar look and feel to reduce the plotting learning curve.

Priority: 2

Grade: A

Summary: All MIRIAD programs use the same graphical library.

2.7.2 Display Appearance and Interactivity

OL–7.2–R1 Plot selection parameters (axes, limits, colormap) shall be conveniently controllable.

Priority: 1

Grade: A

Summary: Available through straightforward keywords .

OL–7.2–R2 There shall be interactive display zooming and unzooming capability within plot windows.

Priority: 1

Grade: I Severity: high

Summary:

OL–7.2–R3 The plot update speed shall not be a bottleneck. Speed shall be benchmarked, and should be commensurate with comparable plotting packages.

Priority: 1

Grade: A

Summary:

OL–7.2–R4 Different line styles, sizes, thicknesses and colors must be available. User shall be able to manipulate intensity and color scales, interactively for graphical displays. The setup shall be saveable and reloadable.

Priority: 1

Grade: A/E

Summary: Different line styles, sizes, thicknesses and colors are available for graphics in WIP .

OL–7.2–R5 Basic axis transformations shall be built in to plotting, such as:

OL–7.2–R5.1 Logarithmic amplitude and intensity scale
Priority: 1
Grade: A/E
Summary: Available in cgdisp, implot, WIP.

OL–7.2–R5.2 Different time and coordinate units and formats (e.g. hours, hhmmss, radians, ddmmss.s)
Priority: 1
Grade: A/E
Summary: Available in most plotting tasks.

OL–7.2–R6 User shall be able to augment plots and produce overlays of different data sets of standard formats:

OL–7.2–R6.1 Images with same axes, size and orientation shall be superposable directly, with basic control of colors and symbols.
Priority: 1
Grade: A
Summary: Available in WIP, cgdisp.

OL–7.2–R6.2 Overlay layer style shall be selectable, e.g. contours, greyscale, colormapped (RGB or HSV), or single color (i.e. one layer gets assigned intensity scales of red, another one of green, and one of blue).
Priority: 1
Grade: A/E
Summary: Contour and color are selectable.

OL–7.2–R6.3 Overlay of selectable coordinate grids (e.g. J2000, B1950, galactic, ecliptic, pixel number) shall be available. It must also be possible to overlay multiple grids.
Priority: 1
Grade: A/E
Summary: Available in WIP

OL–7.2–R6.4 The user must be able to overlay functional fits (e.g. polynomials) or points read in from standard tabular files
Priority: 2
Grade: I Severity: med
Summary:

OL–7.2–R6.5 It shall be possible to place data sets in "layers" be which can be interactively colormapped, and switched on and off.
Priority: 2
Grade: I Severity: med

OL–7.2–R6.6 It shall be possible to display and overlay data with different coordinate systems, i.e. the coordinate system of the display can be chosen independent of the system the data were observed in and the data transformed appropriately with pre-computation.
Priority: 3
Grade: N Severity: low
Summary:

OL–7.2–R6.7 It shall be possible to shift, rotate and scale the images interactively.
Priority: 3
Grade: A/E
Summary:

OL–7.2–R7 Users shall be able to synchronize multiple display windows, for example such that zooming to a given pixel in one image window will select the equivalent pixel in the slaved windows.

Priority: 2

Grade: I Severity: low

Summary: Not currently available.

OL–7.2–R8 Users shall be able to add annotation, both interactively and through scripts, including text with various fonts (including Greek letters), symbols (e.g. all the symbols provided by the LaTeX package with AMSTeX extension), arrows, geometrical figures like boxes and circles, etc.

Priority: 2

Grade: A

Summary: available in WIP

2.7.3 Visibility Data

OL–7.3–R1 Plotting of commonly used basic data and calibration quantities must be straightforward and easily accessible from all relevant tools. Any quantity should be displayable versus any other (or any two plus another encoded as a z-axis or intensity) as long as these quantities are defined for the same visibility or calibration solution interval.

These displayable quantities include:

OL–7.3–R1.1 real and/or imaginary;
Priority: 1
Grade: A

OL–7.3–R1.2 amplitude and/or phase;
Priority: 1
Grade: A

OL–7.3–R1.3 delay and/or rate;
Priority: 1
Grade: N Severity: low

OL–7.3–R1.4 time;
Priority: 1
Grade: A

OL–7.3–R1.5 hour angle;
Priority: 1
Grade: A

OL–7.3–R1.6 parallactic angle;
Priority: 1
Grade: A

OL–7.3–R1.7 uv distance;
Priority: 1
Grade: A

OL–7.3–R1.8 u and/or v;
Priority: 1
Grade: A

OL–7.3–R1.9 baseline;
Priority: 1
Grade: N Severity: med

OL–7.3–R1.10 channel or frequency or velocity;
Priority: 1
Grade: A
Summary:

OL–7.3–R1.11 azimuth and/or elevation;
Priority: 1
Grade: A
Summary:

OL–7.3–R2 Data selection parameters shall be understandable (e.g. by antenna name or number instead of antenna table entry number, polarization name RR or I) and straightforward, using graphical browsers (in GUI mode) and/or standard selection language (e.g. SQL queries) in script mode.

Priority: 1

Grade: A

Summary: Available through the powerful "select" keyword but there is no graphical browser.

OL–7.3–R3 It shall be possible to interpolate or extrapolate any tabulated quantity onto a visibility or calibration solution point, and then manipulate these like extra visibility information.

Priority: 3

Grade: N Severity: low

Summary: Is this a good requirement???

2.7.4 Other ALMA Data

Although the Package will not likely be the primary vehicle for the ALMA staff to assess the state of the array, it is intended that users (as well as staff) have the full capability of using ancillary data provided by ALMA to aid in the processing and understanding of their data. Therefore, the Package should be able to deal with this data in as user-friendly a manner as possible.

OL–7.4–R1 The Package shall be able to plot standard ALMA-format ancillary data, including:

OL–7.4–R1.1 amplitude or single-dish power versus AZ and EL;
Priority: 1
Grade: A
Summary: part of quality control script at hat creek

OL–7.4–R1.2 focus data and curves;
Priority: 2
Grade: A
Summary:

OL–7.4–R1.3 pointing data and offset vectors;
Priority: 2
Grade: A
Summary:

OL–7.4–R1.4 WVR output data;
Priority: 3
Grade: A/E
Summary:

OL–7.4–R1.5 holography and beam map data;
Priority: 3
Grade: A
Summary:

OL–7.4–R1.6 monitor point values (e.g. temperatures);
Priority: 3
Grade: A
Summary:

2.7.5 Image-cube Manipulation

OL–7.5–R1 Histograms of pixel values must be easily produced for selected regions of the cube.

Priority: 1

Grade: A

Summary: Works well

OL–7.5–R2 It shall be possible to view subsets or slices of data cubes:

OL–7.5–R2.1 for axes aligned with cube faces;
Priority: 1
Grade: A

OL–7.5–R2.2 for arbitrarily aligned axes.
Priority: 3
Grade: A/E
Summary: available in VELPLOT task

These shall be interactively selected in GUI mode.

OL–7.5–R3 It must be possible to plot values of the same pixel in different cube layers, or in different images, against each other.

Priority: 1

Grade: I Severity: low

Summary: Trivial but need a script to do so.

OL–7.5–R4 Data cubes must be viewable as movies with selectable frame rates and layer step directions.

Priority: 1

Grade: A/E

Summary: Available through IMPLOT and CGDISP ;the speed is not controled.

OL–7.5–R5 Interactive display of spectra corresponding to a pixel or region in a displayed image shall be supported.

Priority: 2

Grade: A

Summary: Available in VELPLOT

OL–7.5–R6 Interactive display of a 1D slice taken from a 2D image, such as dragging the line on the map to bring up a position-velocity diagram, shall be available.

Priority: 2

Grade: A

Summary: Available in VELPLOT

OL–7.5–R7 Plotting of spectra on a pseudo-grid corresponding to position on a raster (e.g. a "stamp map" or "profile map", basically thumbnail spectra in panels corresponding to position) shall be possible.

Priority: 2

Grade: I Severity: med

Summary:

2.8 Special Features

2.8.1 Simulation

Note: Inclusion of at least moderate simulation capability in the Package will benefit the user who may not have access to the more comprehensive simulator built into the Pipeline and Online systems. In the spirit of providing the user with offline options equivalent to those available in the project, it is desirable that some simulation capability also makes it into the Package albeit at low priority. The main goals would be to allow the user to simulate basic ALMA modes based on input models or images and to replace existing data in ALMA format with simulated data.

OL–8.1–R1 The Package shall inherit the basic simulation capability of the ALMA Online Data Processing Pipeline (Levels 1 and 2) as outlined in ALMA-SW Memo 11, as per (OL–1.1–R5).

Priority: 2

Grade: A

Summary: Basic simulation capabilities have already been implemented. see ALMA memos 428, 430, 450

2.8.2 VLBI

Note: It is assumed that VLBI data will be reduced in whatever package supports general VLBI observations, as ALMA will not be a stand-alone VLBI instrument. There are no VLBI requirements on the ALMA Offline Data Processing Package, though it may end up being the case that the Package also supports VLBI processing. This would have some advantage to users of the ALMA Package, and thus it is worth including a low-priority requirement to this effect.

OL–8.2–R1 It is desirable that the Package also support general VLBI processing suitable for dealing with ALMA data, in order to allow general ALMA users access to VLBI science without having to learn a completely new software package.

Priority: 3

Grade: N Severity: High

Summary: VLBI processing is not available in MIRIAD

2.8.3 Solar System Object Observing

The Sun and planets are likely to be important and interesting targets for ALMA observing. The requirements are likely to be strongest on the actual hardware (e.g. high frequency and time resolution) but software compatibility must also be considered. In particular, solar and planetary observations require a special effort in tracking and handling of ephemerides.

OL–8.3–R1 The Package must be able to calculate and compensate for the position of moving objects in the solar system:

OL–8.3–R1.1 Ephemerides must be provided for major solar system objects, including:

OL–8.3–R1.1.1 Sun;
Priority: 1
Grade: A
Summary: Ephemerides are available at the observatory

OL–8.3–R1.1.2 Moon;
Priority: 1
Grade: A
Summary: Ephemerides are available at the observatory

OL–8.3–R1.1.3 planets;
Priority: 1
Grade: A
Summary: Ephemerides are available at the observatory

OL–8.3–R1.1.4 major asteroids (all known with 50km dia. greater);
Grade: U
Summary:

OL–8.3–R1.1.5 known short period comets;
Priority: 1
Grade: A
Summary: Ephemerides are available at the observatory

OL–8.3–R1.2 Ephemerides must be calculated in all available reference frames (e.g. OL–3.1–R10)
Priority: 1
Grade: U
Summary:

OL–8.3–R1.3 The Package shall be able to import a user-supplied ephemeris in tabular form.
Priority: 2
Grade: U
Summary:

OL–8.3–R1.4 The Package shall calculate positions from user-provided orbital elements.
Priority: 2
Grade: U
Summary:

OL–8.3–R2 The Package must carry out astrometry for moving sources.

Priority: 1

Grade: A/E

Summary: MIRIAD has made comet images. Task EPHMEDIT can correct from one comet ephemeris to another. Is this what is implied ?

OL–8.3–R3 The distance visibility amplitude correction for distance (from ephemeris for major objects, or user-supplied) shall be computed.

Priority: 1

Grade: N Severity: low

Summary: I'm not sure this is useful at the ALMA frequencies. All objects may be in the far field?

OL–8.3–R4 The Package must calculate quantities for the "physical ephemeris" for the enumerated major solar system objects, including:

OL–8.3–R4.1 subearth latitude and longitude;
Priority: 2
Grade: N Severity: med

OL–8.3–R4.2 subsolar latitude and longitude;
Priority: 2
Grade: N Severity: med

OL–8.3–R4.3 position angle of North Pole;
Priority: 2
Grade: A

OL–8.3–R4.4 season;
Priority: 2
Grade: N Severity: med
OL–8.3–R4.5 phase angle;
Priority: 2
Grade: N Severity: med

OL–8.3–R5 The Package shall do coordinate transformations from plane-of-sky to planetocentric for a selection of projections, including those of OL–3.3–R4, and in addition:

OL–8.3–R5.1 3-D backprojection (onto the planetary sphere).

Priority: 2

Grade: N Severity: med

OL–8.3–R6 The imaging corrections for the near-field shall be included.

Priority: 2

Grade: N Severity: med

OL–8.3–R7 In addition to the standard models available in the data analysis tools, there shall be provision for:

OL–8.3–R7.1 prolate and oblate ellipsoids;
Priority: 2
Grade: A/E
Summary: Specific application tasks have been used for Saturn, Jupiter and Mercury
OL–8.3–R7.2 limb-darkened disks (polynomial, $\cos^n$, Legendre polynomial).
Priority: 2
Grade: A/E
Summary: Specific application tasks have been used for Saturn, Jupiter and Mercury

OL–8.3–R8 The Package shall support the 3-D reconstruction of the emission using observations of the target object at different aspect angles and/or rotational phases.

Priority: 3

Grade: A/E

Summary: Specific application tasks have been used for Saturn, Jupiter and Mercury

2.8.4 Pulsar Observing

ALMA's pulsar needs will be much easier to satisfy than those of centimeter-wave arrays since dispersion smearing is a non-issue at these frequencies. We expect the main out-of-the-ordinary requirement will be integration into multiple phase bins. A minimum of 16 phase bins would be scientifically interesting. Pulsars have periods as short as 1.6 ms, so a minimum bin size of 0.1 ms would probably suffice. The main use of this binning capability will likely be measuring the on-pulse and off-pulse brightness which can be used to estimate or place bounds on the temperature of the neutron star. Pulsar timing is unlikely to be done with ALMA, barring the installation of specialized hardware. It is conceivable that ALMA would be a great instrument for pulsar parallaxes, especially if pulsars are detectable at 900GHz, and will likely be the best instrument in the southern hemisphere for years to come. The minimal spec of 16 pulsar phase bins would be sufficient for this work.

OL–8.4–R1 The Package shall support the processing of time-series data by folding into multiple phase bins which are synchronous with a user-specified pulsar period.

Priority: 3

Grade: A

Summary: PSRFIX performs de-dispersion, bin averaging/differencing and ephemeris correction on an ATCA dataset observed in pulsar bin mode.

OL–8.4–R2 The Package shall support at least 16 phase-bins.

Priority: 3

Grade: A

Summary: PSRPLT plots pulsar visibility data as a function of bin number.

OL–8.4–R3 Interpolation onto the phase bins from the correlator output (integration times) shall be available.

Priority: 3

Grade: A

Summary: