ATF Observatory Mode Definition

26aug05: Versions:
1st - 3rd: Based on Robert Lucas' observe.py script and ATF notes. Comments from Jeff Mangum, Alan Bridger, & Leonardo Testi incorporated. Also added Philippe Salome's baseline calibration definitions.
4th: Incorporated Joe Schwarz' comments and results of discussion in CIPT –admin meeting.
5th: Comments by Ralph Marson, Jeff Mangum & Andreas Wicenec incorporated to create new version of Optical pointing use case. *In this version ONLY the Optical pointing use case has been rigorously reviewed, everything else must be taken with a grain of salt.*

Author: Debra Shepherd
Reviewers: Robert Lucas, Jeff Mangum, Leonardo Testi, Alan Bridger, Joe Schwarz
Approval: Brian Glendenning

To support ObsPrep development during R3 and R3.1, a list of observatory modes (e.g. holography, pointing) must be defined that will likely be used at the ATF and during early commissioning in Chile. The list should provide descriptions of each mode, and identify input parameters needed to run the mode at the ATF (and Chile). Observatory modes should have a development priority so ObsPrep knows what modes to prepare for in R3, R3.1 and later.

This document serves as a basis for discussion – modes and parameters are identified but there is little that addresses how these parameters are implemented. Thus, uncertainties about who provides what inputs and how the modes are implemented in the ALMA Project Data Model (APDM) should be negotiated between the ObsPrep, TelCal, Scheduling, Control, Offline (APDM), and HLA subsystems.

ObsPrep will then use the list to develop interfaces to create SBs for these modes for R3 R3.1, and beyond. One mode (optical pointing) will be tested during UT3 (in November) and a possible integrated operations test around July 2006. Additional modes will be developed in R3.1 or beyond.

In this 5th draft, details for optical pointing are fairly well specified since that is the mode to be implemented first for R3.1. The remaining Observatory Modes need more elaboration.

Timescale (rough estimate):

30Aug05 Debra to work with Robert Lucas and Jeff Mangum to create first draft of Observatory modes and input parameters – This document.

Jan06	ObsPrep team implement optical pointing Observatory mode in the Observing Tool (OT)
Feb06	Use the OT to create one or more SBs associated with the optical pointing mode. Internal testing only (Leonardo Testi, Robert Lucas, Jeff Mangum, Debra Shepherd, etc…). Test will focus on the System view of the OT.
1Apr06	Incorporate feedback from the test and deliver R3.1 OT software that is able to generate an SB for the optical pointing Observatory mode SBs.
~Jul06	Integrated operations test at the ATF involving the OT interface, Control GUIs, QuickLook display prototype, and Offline single baseline data reduction (and anything else that looks relevant in terms of commissioning and operations user interface testing).

A Proposal on Terminology:

On-the-fly (OTF) refers to a mode of operation in which the telescope slews along a given direction, integrating every X seconds (typically discrete integrations at, say, 0.1s intervals). If several OTF rows are built up to create a 2-dimensional area, this is considered to be an OTF map. OTF rows are typically separated by just-less than Nyquist spacing. Thus, OTF maps are over sampled along the scan direction and roughly Nyquist sampled perpendicular to it.

- A proposal to clarify terminology:
  - The term "OTF map" should refer to 2-D maps created with single dish integrations taken on-the-fly. A single row is an OTF raster scan while an OTF map is made of one or more OTF raster scans.
  - The term "OTF mosaic" should refer to maps created with an interferometer (same scanning procedures except that the antennas fringe while slewing).
  - The term "pointed mosaic" will be used to refer to interferometric observations in which Nyquist-spaced individual pointings are used to create a 2-D mosaic.

Draft Observatory modes required for ATF use are given below:

Priorities:
1 = Highest: must be done to support single baseline CSV activities at the ATF and first operations in Chile. Implement 1st.
2 = Must be done to support CSV activities at the ATF and first Operations in Chile. Implement 2nd (~R3.1+)
3 = Implement 3rd. (~R4.0+)
4 = lowest: will probably have to be done eventually in Chile

- **Optical Pointing** – Copy the current ATF design as much as possible: Use the optical telescope to derive antenna pointing based on observations of stars. Data to be reduced by TelCal using TPOINT software. Sources should be in a catalog (in the Archive) with known positions or specified in the SB with manual input of position. An observation consists of a CCD image of a star. Control commands the camera to get the frame then find the peak on the frame. Control then reports the star centroid position (offset relative to antenna position at the CCD frame center) and error, write that information to the ASDM for TelCal. See full Optical Pointing use case at: http://www.aoc.nrao.edu/~dshepher/alma/usecases/ObsMode.UC.OpticalPointing.html

    - **Priority: 1**
    - **Input Parameters from the OT:**
        - Filter selection – select appropriate filter for day (IR filter to reduce sky brightness) or night observing (Default = night).
        - Minimum integration time – select integration time desired for each source. (Default = 2s). The control script may increase the integration time if commissioning finds that it is better to integrate down to a specified SNR (this will be hard-coded into the control script if useful).
        - Total time to run in optical pointing mode (Default = 1 hour – assume 15s/star integrating and slewing, then you can do about 240 stars/hour)
        - Antenna position tolerance – how close the antenna must be to the commanded position before a CCD exposure should be taken. (Default = 0.1"). If all is OK, then use the default. Tolerance should be increased if:
            - It is very windy
            - If there are hardware/software problems (e.g. poor servo, inefficient M&C, poor optical camera properties such as a non-linear response).

          Note: A default of 0.5" was used during ATF operations because the OPT was limited by the robustness of the centroiding algorithm, and the non-linear response in position and intensity of the CCD. Higher S/R should allow determination of the centroid to better than 0.1 pixel (1" pixels), thus, the ALMA OPTs should be able to reach a tolerance of at least 0.1".
        - Name of the Archive list of standard sources to observe **OR** allow input of a list of sources and positions manually (type into the SB interface or upload a text file). The list should have the following columns:
            - source name
            - position (RA and Dec – J2000 Epoch)
            - visual magnitude

        - proper motion in RA and Dec (optional, default = 0,0)
        - Parallax (optional, default = 0)
    - Elevation limit – limit that a star can be observed, if below this limit, skip the source and move to the next. (Default = 15 degrees).
    - Magnitude range – High and Low limits for stars to be observed.
  - **Notes:**
    - S/N limit – control script will have a hardwired S/N limit that they may use to increase the integration time on a source (e.g. if the S/N is not high enough for low-magnitude stars to get a good estimate of the pointing offset). This is an optional control parameter and does not affect the OT inputs.
    - Antenna name is not used here – the assumption is that a subarray is first created with the antenna(s) that need optical pointing and the SB is submitted for that subarray.
    - Repeat count for star list in the archive – this parameter is not used. It is assumed that the SB will be submitted multiple times if a repeat of the star list is desired.

- **Radiometric Pointing** – Should be similar to optical pointing but not the same.
  - **Priority: 2**
  - **Input Parameters from the OT:** Need to define parameters – no input yet. Expect something like:
    - Frequency band (Default = 3mm – ***OK?***).
    - Integration time – select integration time desired for each source. (Default = 1 minute – ***reasonable?***)
    - Total time to run in radiometric pointing mode (Default = 15 minutes – ***OK?)***
    - Name of the Archive list of standard sources to observe OR allow input of a list of sources and positions manually (type or upload a text file). List should have
      - source name,
      - position,
      - expected flux density at the input frequency
      - proper motion ?
      - anything else?
    - Elevation limit – limit that a source can be observed, if below this limit, skip the source and move to the next. (Default = 15 degrees).
    - Minimum flux density – Lower limit on source flux density.

- **Baseline determination** – determine the baseline length between 2 or more antennas within a desired accuracy. To do this, a number of quasars should be selected in the sky in a specific pattern that minimizes errors in the baseline determination algorithm.
  - **Priority: 2**
  - **Input Parameters from the OT:**

        - Mode – partial or complete reconfiguration – is this really needed? Can't this be determined from the Array configuration file?
        - Required accuracy for the antenna position determination (default = 100 microns per baseline).
            - The accuracy required should be translated into a time sequence of max time to run, int time/source, number of cycles through the known calibrator list, etc…
        - Frequency (default = 90 GHz)
        - Correlator configuration (OT to provide a TBD default configuration that can be changed).
        - Optional Pre-conditions that should be satisfied before this SB can run. Defaults:
            - Maximum precipitable water vapor at 230 GHz – 1mm?
            - Maximum phase rms at 115 GHz – 20deg on baselines?
            - Pointing accuracy (Az, El rms) – 10% of the beam?
            - Focus accuracy (focus rms) – 0.2 mm?

    - **Input Parameters from other subsystems, files in the archive, or from the operator:**
        - *Archive:* Array configuration file (ant station parameters) including the names/locations of antennas that have moved.
        - *Archive:* A catalog of point sources.
        - *Archive:* a set procedure for selecting and integrating on calibrators in an optimal observing sequence (defined in Baseline Determination Basic use case).

- **Tower Holography** – Use the tower signal to map the surface accuracy of a single dish. Assume only a few input parameters, the remaining parameters that control the holography should be set to defaults in a separate script that can be easily changed. The idea here is to have an SB that defines the mode for tower holography. When this SB is scheduled, it will first retrieve a script or list of parameters in the archive that specify the holography scan control. These control parameters can be considered 'engineering parameters' that the normal user would not see.
    - **Priority: 3**
    - **Input Parameter from the OT**:
        - Frequency – valid range at the ATF is 78.695 to 85.4 GHz and 96.155 to 104.35 GHz. There should be default settings for each band.
        - Map size – total map size for the scan (xy).
    - **Input parameter – TBD on who provides (choices include OT, Operator or Scheduling subsystems):** We need to decide on the use case here. Does the scheduler decide to run holography or any other 'single antenna' calibration on a subset of antennas (1 to all) using a single pre-defined SB (e.g. holography in this example) or should there be a different dedicated SB per antenna? Having a different SB per antenna seems too

complicated. Better to have variable inputs like antenna number to be defined separate from the OT.
    - Antenna number (at the ATF: 1=Vertex and 2=AEC). Set the default to antenna 1.
  - **Input parameters in a commissioning/maintenance script needed to fully describe the holography:** Issue raised by Alan Bridger: several of the parameters listed below are already supported by the OT meaning that they would be set in the SB. But operationally, Robert Lucas and Jeff Mangum suggest that these parameters should be set outside of the SB to make it easier to vary the holography inputs. Essentially, this is an operational decision that requires folks from the OT and Commissioning teams to discuss how this will be implemented.
    - Az/El position of the tower (it changes – "bore sight" position needs to be measured before each map). There should be a default position that can be changed before running the script if needed.
    - Rowsize – map dimension of coordinate given by "dir" (degrees)
    - Colsize – map dimension orthogonal to coordinate given by "dir" (degrees)
    - Numrows – number of passes to be made across the map in the scan direction
    - Startrows – scan starting row number (allows restarting at specified row)
    - Speed – rate at which antenna will move during data collection (arcsec/sec)
    - Rowscal – number of observations rows between periods spent acquiring signal calibration data
    - Caltime – time spent on each calibration observation (sec)
    - Calmode – boresight or 5point (default to 5point)
    - abmID – which antenna bus master to use (1-VertexRSI, 2-AEC)
    - Tune – 'auto' or 'manual' (default to 'auto'). Auto will set the frequency, while manual will not.
    - Direction – specify the direction of the scans: 'forward' = bottom to top row; 'backward' = from top to bottom.
    - Azscan, Elscan: Axis along which map rows are acquired

- **Skydip** – Total Power Integrations on sky at various elevations (85, 70, 55, 40, 30, 20, 15, and 12deg) to determine opacity at a given frequency
  - **Priority: 3**
  - **Input Parameters from the OT:**
    - Az – Azimuth setting to do the dip at
    - Freq – frequency to determine opacity

- **ObsTP** – (called NPointPattern with N=1 in Robert's observe.py script) – Single Field Observation in total power mode. Observe a source, then a reference position, repeat a number of times to build up integration time on source.
  - **Priority: 3**

- **Input Parameters from the OT:**
  - Source name (in catalog which has positions)
  - Xoff, Yoff – offset to central position (arcsec) – *default = 0,0*
  - Reference – do a reference position? (0/1) – *default = 1 (yes)*
  - Xref, Yref – offsets for reference position (arcsec*)*
    – default = 10 arcmin ?
  - Dwell – dwell time at position (sec) – *default = 1s ?*
  - Nrepeat – number of times to repeat sequence

- **OTFmapTP** – (called bsmap (beam switched) and tpmap (total power) in Robert's observe.py script) – observe a raster map in single dish mode – used to create beam maps of, e.g., planets.
  - **Priority: 3**
  - **Input Parameters from the OT:**
    - Source name (in catalog which has positions)
    - Frequency
    - Mode – Parameter indicating whether this is a beam switched (BS) or total power (TP) measurement.
    - Size – size of the map in arcsec (default = 200")
    - Row_sep – separation of the rows (default = 12.5")
    - Vel – scanning velocity (arcsec/sec)
      - In bsmap, vel = 30"/s
      - In tpmap, vel = 200"/s
        - *Which should be default?*
    - Dir – direction 'lat' or 'long' (default = 'lat')

Observatory Modes related to standard TelCal procedures:

Telcal reduces calibration data taken in a standard way but there are several calibration procedures that will be run infrequently or intermittently as requested by the Operator or Scheduling subsystem.

Thus, there is the issue: how does the Operator request that a TelCal procedure be run? Here, I assume that the Operator requests a procedure via an SB that is generated by the OT. If this is not the case, then the procedure should be negotiated between the OT, Telcal, Scheduling, and Operations.

Given this assumption, the OT should be able to specify standard procedures to be run by TelCal (e.g. pointing, focus, telescope amplitude calibration). The output of the OT should be a call to a TelCal script on file. *The OT and TelCal should determine what are 'engineering parameters' (e.g. provided by TelCal somehow) and what should be provided by the OT.*

In the system view of the OT, the user should be able to select different kinds of calibrations to be performed (e.g. pointing: 'cross' or 'five'). In the science view, the user should be able to specify the science requirements (e.g. the desired pointing accuracy). This is then mapped to the system view which would select which calibrations are needed (e.g. 'five' point determination for a weak source) and what the default inputs should be. This category of 'TelCal' modes includes:

- **Calib** – Total Power Integrations on a load (source) and then sky to determine telescope amplitude calibration.
  - **Priority: 2**
  - **Input Parameters from the OT:**
    - Source
    - Frequency
    - No way to specify sky position? Or is it a constant throw here?

- **Cross** – cross pattern observation – raster scans along latitude and then longitude – uses the nutator to determine pointing (useful for pointing determination and one can see if something goes wrong better than the 5-point method)
  - **Priority: 1**
  - **Input Parameters from the OT:**
    - Source
    - Frequency
    - Nrow – *number of times to repeat the raster scan in each direction* (default = 4)
    - Mode – parameter to specify whether this should be:
      - TP: total power cross pattern observation
      - BS: total power, beam switched cross
      - MoonTP: total power Moon cross

- **Five** – 5 point pattern observation, used to determine pointing solutions – more sensitive than the cross method for weak sources.
  - **Priority: 1**
  - **Input Parameters from the OT:**
    - Source
    - Frequency
    - Integration time per point
    - Reference position (absolute or relative)
    - Mode – beam switched (BS) or total power (TP)

- **Focus** – determine focus in X, Y, and Z on an astronomical source at a frequency
  - **Priority: 3**
  - **Input Parameters from the OT:**
    - Source
    - Frequency

        - Mode – Beam switched (BS) or total power (TP)
    - **Input parameters from other subsystems:**
        - X0, Y0, Z0 – absolute starting position of the secondary
    - Note: there are also variants on this – to determine the focus only in X, Y, or Z – leave this to be run in script mode only by the commissioning team.

- **Astigm** – determine if there is any astigmatism in the focus, to be used by CSV to check the astigmatism of each antenna – can be done in scripts so this is very low priority, no real driving need to have this automatically set up from the OT.
    - **Priority: 4**
    - **Input Parameters from the OT:**
        - Source
        - Frequency
    - **Input Parameters from other subsystems:**
        - focusX – pre-determined focus position in mm
        - focusY
        - focusZ

- **Also need to identify more likely interferometric observatory modes to support tests and calibrator observations.**