Visible & Infrared Survey Telescope for Astronomy

Data Flow System

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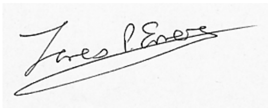
Document Released By:	**Jim Emerson** (VDFS Project Leader)	**Signature and Date:**	

Change Record

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1.0	2004-11-17	all	New document

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1 Introduction

1.1 Purpose

This document describes the functional specifications of the Survey Definition Tool (SDT) & Survey Progress Tool for VISTA derived from 'Requirements for Surveys: Planning, Scheduling and Progress' [AD01].

1.2 Scope

The SDT functionality covers sections 3.2, 3.3 and 3.6 of [AD01], i.e. *Survey Definition Tool*, *Guide & LOWFS Star Selection Tool*, *Survey Progress Tool*. The distinction between Survey Definition Tool and Guide & LOWFS Star Selection Tool which is used in [AD01] is no longer maintained here. From now on both are treated as part of a single tool called the Survey Definition Tool (SDT).

- Survey Definition Tool:
  - Calculates coordinates for VISTA tiles to fill given areas of sky
  - Displays survey area covered in tiles/pawprints.
  - Selects guide/aO stars for each pawprint.
  - Creates OB for each tile based on a parent OB.
- Survey Progress Tool
  - Overall Visualisation. Similar to the survey area display of the SDT: plots tiles in a colour indicating the status of the corresponding OB (e.g. done, not done etc).
  - Progress Data files and their visualisation: not yet completely defined
  - How such progress output feeds back into survey scheduling: not yet completely defined.

The latter two items in the Survey Progress Tool require clarification of the requirements and discussion with ESO in the light of [RD01].

The following two tools which are also described in [AD01] are **not covered here**:

- Survey Scheduling Tool (section 3.4 of [AD01])

  The specification of this is not given here as [RD01] addresses these issues. It is assumed that interaction with those implementing the design to meet the requirements in [RD01] will occur so that the Survey Progress Tool can interact appropriately.

- Photometric Calibration Field Scheduling Tool (section 3.5 of [AD01])

  Such a tool would have two main functions

  1. Providing the telescope operator (TO) with a list of suitable calibration observations at a given time.
     It is believed that this is covered by the existing VLT software. The VLT OT maintains OB queues several of which can be calibration queues containing appropriate calibration OBs.
  2. Ensuring that the VISTA TO does insert calibration OBs sufficient to reduce the science OBs.
     This is currently done manually at the VLT. There is no software to prompt/force the TO to insert a calibration at a certain point in time. If a set of rules is provided to the TO by the VISTA PI, and followed, this manual procedure should be

sufficient for VISTA observing. If not, then the calibration tool functionality would probably best be incorporated into the scheduling software (see above).

1.3 Applicable Documents

[AD01] *Requirements for Surveys: Planning, Scheduling and Progress*, VIS-SPE-QMU-20000-0007, Issue 1.0, 17 June 2004.

1.4 Reference Documents

[RD01] *Surveys at ESO telescopes: Execution principles and requirements on preparation and scheduling tools*, Draft ESO document, 2004

[RD02] Folger, M., Casali, M. M., & Vick, A. 2003, *Survey Definition Tool*, in ASP Conf. Ser., Vol. 314 Astronomical Data Analysis Software and Systems XIII, eds. F. Ochsenbein, M. Allen, & D. Egret (San Francisco: ASP), 716

[RD03] P2PP User Manual, VLT-MAN-ESO-19200-1644, Issue 5.

1.5 Abbreviations and Acronyms

AD
: Applicable document.

aO
: Active Optics.

IMPEX
: Functionality of the P2PP that allows OBs to be exported and imported as ASCII files.

LOWFS
: Low Order Wave Front Sensor.

OBX
: `obx` is the file suffix of the IMPEX ASCII files.

P2PP
: Phase 2 Proposal Preparation Tool

PAF file
: P2PP parameter file. Parameter files contain additional parameters that are not held in the normal OB template. A template can have entries referring to the name of the PAF files.

PI

Principal investigator.

RD
: Reference document.

SDT
: Survey Definition Tool (with guide/aO star selection).

TO
: Telescope operator

Refer to the Abbreviations and Acronyms section of [AD01] for more.

1.6 Glossary

Expert user
: Project scientist, support scientist, expert regarding certain aspects of survey definition and instrument setup.

Parent OB
: An OB containing a tile which is copied to all the tile positions created by the SDT. Calling it “Template OB” would have been ambiguous in the context of the VLT software where a “template” is the collection of parameters that are specified in an OB. Both the parent OB and the OBs generated from it by the SDT share the same template in the VLT software sense.

User
: Astronomer, PI, head of survey

Refer to the Glossary [AD01] for more.

2 Survey Definition Tool (SDT)

As mentioned earlier the Survey Definition and the Guide/aO star selection are both done by the same tool, the SDT. An analogous WFCAM SDT has been developed at the UK ATC. WFCAM is an IR wide field camera for the UK Infrared Telescope (UKIRT). For a more general description of the WFCAM SDT see [RD02]

2.1 Activity Diagram

The following UML diagram (Figure 1) depicts the steps taken by the user to define a survey. The tools used are the SDT and the P2PP as indicated by the corresponding columns in the diagram.

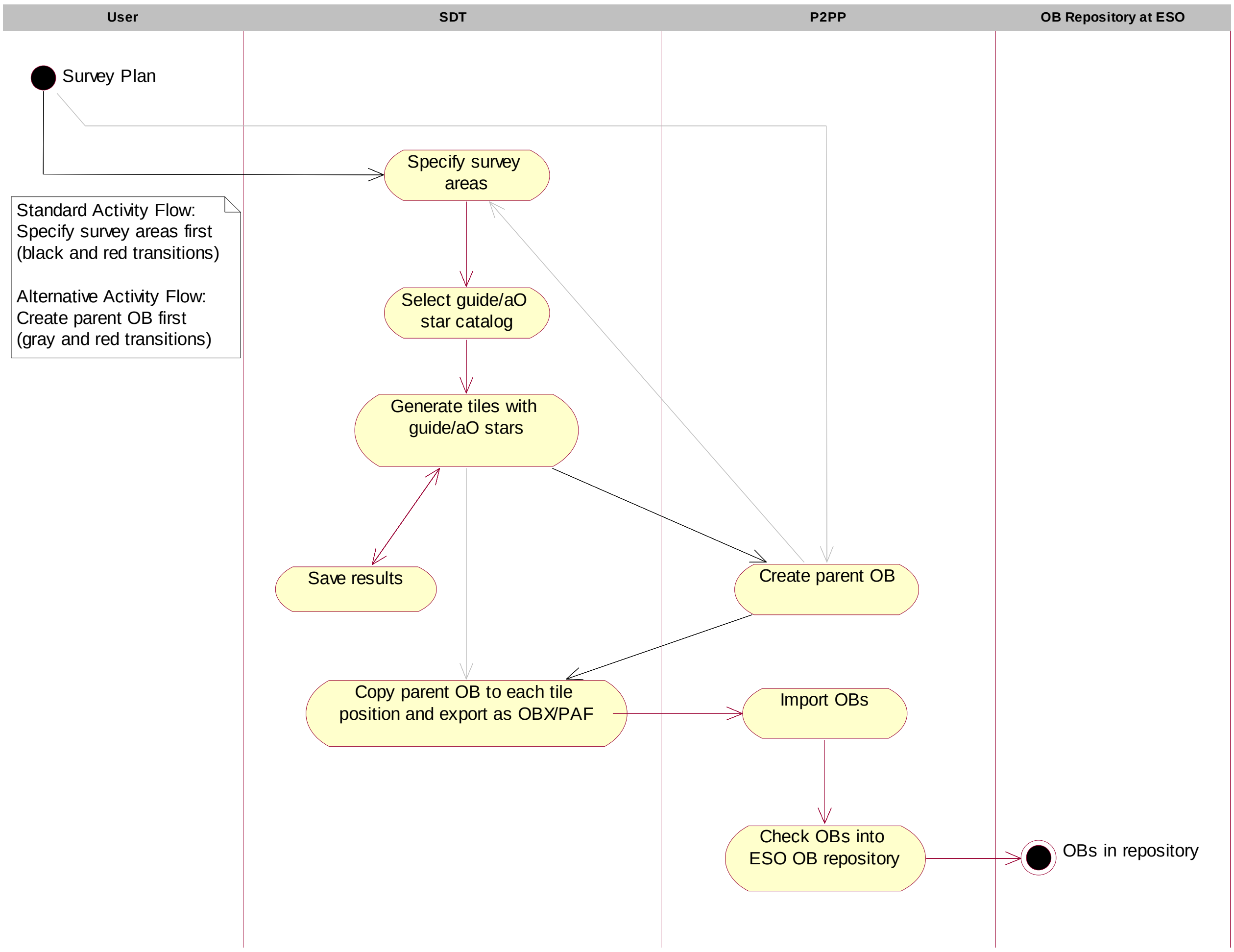

Figure 1

Note that the parent OB can be re-used for other survey areas and the generated tiles with guide/aO stars can be re-used with other parent OBs.

"Survey Plan": Which areas of sky are to be observed and what kind of observations should be used.

2.1.1 Specify survey areas

A list of rectangular or circular areas to be either included or explicitly excluded from the survey is defined in (an) input field(s) of the SDT. (See section about survey areas.)

There is a graphical display of the survey areas (see [RD2] for figures).

2.1.2 Select guide/aO star catalogue

A catalogue can be selected from a choice box on the SDT. The choices available are specified in a `skycat.cfg` style configuration file. Any catalogue that can be accessed by tools such as SkyCat, GAIA, JSkyCat, JSky can be used by the SDT. These can be online or local catalogues.

Additionally the WFCAM SDT can access a local installation of the USNO-A2.0 catalogue which is stored in the binary format in which the catalogue is distributed by the USNO (as opposed to the skycat format). But this functionality is currently not used as it is much slower than the online skycat catalogues and it would be cumbersome for users to locally install the entire binary USNO-A2.0 installation (11 CDs) on their local disk.

2.1.2.1 Proper Motion

If a catalogue is used that contains information about proper motion (e.g. USNO B1.0, GSC-2 at STScI), then this information will be used in the following ways:

1. Do not use a star as guide/aO star if the proper motion exceeds a configurable limit.

2. Otherwise use the proper motion information to calculate the star's position for a configurable date.

2.1.3 Generate tiles with guide/aO stars

This step fills the survey areas, tile by tile, with coordinates for the pawprints such that the entire area is covered in pawprints/tiles. This is done on a row by row basis, i.e. rows of tiles are formed such that neighbouring tiles are horizontally aligned. This means that the tiles will not normally end up being aligned in columns. Guide/aO stars are allocated for each of the pawprints (see below). Each pawprint is treated as being part of a tile, i.e. its position in a tile is internally recorded.

The user can specify the offset between adjacent tiles and adjacent rows of tiles. By changing these offsets the overlap between tiles can be adjusted.

There are `Start` and `Stop` buttons on the SDT to start, stop and resume the creation of positions and selection of guide/aO stars. (It is possible to switch the guide/aO star allocation off. This is useful to testing the generation of pawprints/tiles and look at the general layout of survey areas.) The pawprints/tiles are plotted onto the survey area display as they are generated.

2.1.3.2 Guide/aO star selection

For each pawprint the SDT tries to select one guide star and two LOWFS stars (one for each sensor) from a catalogue. A configurable number of additional guide stars and pairs of LOWFS stars (one for each sensor) are then selected (if there are enough suitable stars in the catalogue) as alternatives to choose from during observing. They all have to be in range of one of there respective CCDs/sensors (in the range of one of the two autoguider CCDs in the case of the guide star) for all jitter and microstep positions. The user has to specify the maximum jitter steps and microsteps such the SDT can ensure that only stars are selected that will stay on their respective CCDs/sensors for all jitter and microstep positions.

Valid guide/aO stars must

- be in a magnitude range specified by the expert user
- not have another object closer than a given distance with less than a given magnitude difference beside them. (Minimum distance and magnitude difference are specified by the expert user.)

Note that the allowed ranges, distances etc. should be set separately for guide stars and LOWFS stars.

The brightest objects obtained from the catalogue which are valid and in range of one of their respective CCD/sensor are selected as guide and LOWFS stars, respectively.

2.1.3.3 Missing guide/aO stars

VISTA ideally requires 3 guide/aO stars for each pawprint (1 guide star and 2 LOWFS stars, all in different sky areas hence distinct). These 3 stars will be common to all jitter positions for a pawprint, but each new pawprint will require 3 new stars.

There are various failure cases, which however in most cases can be handled with minimal impact on image quality:

i. Failure to find a catalogue star at time of OB preparation.This should be rare since a mean of > 5 useful stars per sensor are expected at the Galactic poles, and many more at low Galactic latitude.

ii. A pre-selected star turning up bad when observed (e.g. a close binary, asteroid, catalogue error etc).

iii. Poor weather meaning that a normally usable star has insufficient SNR at the actual observing time.

iv. Hardware failure of one or more sensors.

(Combinations of these are also possible).

Case (i) will be known in advance when running the Survey Planning Tool, and may be avoided by modifying the OBs accordingly to adjust the telescope pointing. It is assumed that real-time re-pointing of the telescope to "hunt" for alternative guide/aO stars is not permitted.

Case (ii) is dealt with by selecting at least two candidate stars per sensor, e.g. a primary and a backup (see section about guide/aO star selection). Then if the 1st choice star on a sensor is found to be unusable during observing, the system should switch automatically to the 2nd best candidate (informing the operator of this, and optionally pausing to request confirmation). This means that case (ii) will not cause problems unless a sensor has exactly 1 candidate star and it is bad (very improbable).

Cases (iii) and (iv) may require postponing that specific OB until conditions improve or the defective sensor is repaired.

However, if moving tiles or postponing observing is undesirable it should be possible to observe at almost any pawprint position at almost any time as follows, with marginal image quality penalty.

If the problem is with autoguider star availability, the autoguider can be run at a reduced frame rate e.g. 2.5 Hz or 1 Hz, instead of the maximum of 10 Hz. At 1 Hz the autoguider is virtually certain to find a usable star (with marginal loss of image quality, but no severe trailing).

In the event of missing LOWFS star(s), reducing the frame rate is not practical, so some of the M2 axes must be controlled in open loop for the duration of that pawprint. One star gives closed-loop control of 3 M2 axes. This is expected to be adequate for a duration of at least 30 minutes with one LOWFS star or 5 minutes with no LOWFS star, so negligible degradation should occur if the per-pawprint exposure time does not exceed the above values. For short exposures (e.g. OBs which change pawprint each 5 minutes or less), occasional missing LOWFS stars are then unimportant. For long exposures (spending hours on the same pawprint), it is clearly desirable to have 2 LOWFS stars.

To simplify the procedures, it is suggested to have **two** user-selectable parameters in the Survey Definition Tool defining minimum acceptable requirements for sensor stars. The first one (e.g. MINSTAR_TILING) applies in survey definition, the second (e.g. MINSTAR_OBS) at observation time.

There should be 3 options for each of these, "low", "medium", and "high" threshold, defaulting to "medium". The exact cuts for these thresholds should be set by an expert user. For example:

a) Low: always fix tile centre and use best available stars.
b) Medium (DEFAULT): require >= 3 Hz guide star and at least 1 LOWFS star.

c) High: require >=7 Hz guide star and 2 stars on each LOWFS in at least 5 out of 6 pawprints.

The second flag MINSTAR_OBS should be propagated into the OB to define requirements on star availability when actually executing the OB: if these fail then the OB should not be started, or should be aborted. Note cases (iii) and (iv) can be anticipated before starting the OB, e.g. if a sensor is broken or there is a combination of a faint guide star and poor sky conditions, so the scheduler or the Telescope Operator preferably need to take account of this in selecting OBs.

Note MINSTAR_OBS should not be more stringent than MINSTAR_TILING (otherwise some OBs can get into the queue which can never be executed successfully). However in many circumstances MINSTAR_OBS can and should be looser: when defining a survey, it is usually desirable to move the tile centres as necessary to optimise the guide/AO stars, but once the survey has started the tiles usually must remain fixed; so if timely survey completion is important then MINSTAR_OBS needs a looser acceptance threshold than MINSTAR_TILE.

Finally there is the case of failed science detectors: another flag e.g. MIN_DETS needs to go into each OB, such that it will not be observed unless this minimum number of science detectors are working.

Note that it is important to have at least some OBs in the queue at any time which can tolerate a failed LOWFS unit or failed science detector, to avoid unnecessary wastage of telescope time in the event of failure.

2.1.3.4 Avoiding very bright objects

Optionally, very bright objects are avoided by the SDT's tiling algorithm. To do this a gap is left in the row of tiles at the position of a very bright object (magnitude value lower than an expert user specified value). The best way of implementing this is probably to start tiling adjacent to the bright object and then to tile outwards.

2.1.3.5 Science detector failure

The user can specify whether a survey falls into one of the following categories: If one or more science detectors fail then:

1. Continue as normal

2. Do not execute an OB belonging to this survey.

If science detectors remain broken for an extended period of time then OBs might have to be re-created using the SDT and different parent OBs that use offsets and/or rotations that result in the gaps left by the broken detectors being covered by other detectors. In simple cases it might be sufficient to observe each pawprint twice, rotating it by 180 degrees the second time. For this it would not be necessary to create the OBs from scratch in the SDT. It would be sufficient to add a rotated OB for each existing OB in the repository.

2.1.4 Save results

Once the SDT has finished filling the survey areas a status report is displayed giving information about how many tiles/pawprints have been created, how many tiles had to be shifted due to missing guide/aO stars or for how many tiles a sufficient number of guide/aO stars could not be found. Additionally the “tiling efficiency” will be calculated as the ratio of the area of the defined survey area and the area covered by the created tiles. The tiling efficiency decreases if parts of the created tiles stick out beyond the boundaries of the survey area or if there is a lot of overlap due to shifting tiles as a result of missing guide/aO stars of very bright objects that had to be avoided.

The user is then prompted to save the survey areas and the generated tiles to a file. This is done by using the usual "File" -> "Save" or "File" -> "Save As ..." menu.

It is also possible to interrupt the generation of tiles, save the intermediate results and resume the generation of tiles and selection of guide/aO stars at a later stage.

2.1.5 Create parent OB

To export the created tiles to the P2PP a parent OB is required which contains all the relevant information for the observation (e.g. filter, exposure time, jitter pattern, microstep pattern etc.) except the Target Information and guide/aO stars. A parent OB is created using the P2PP, omitting Target Information and guide/aO stars. This is then exported to an OBX file using the IMPEX method of P2PP.

2.1.6 Copy parent OB to each tile position and export as OBX/PAF

The SDT has an export function which prompts the user to first import the parent OBX file that was previously exported from the P2PP. A copy of the parent OB contained in this OBX file is then generated for each of the tile positions that the SDT has created. Each of these generated OBs is then saved as an OBX file alongside a PAF file containing information about the guide/aO stars.

2.1.7 Import OBs

Import the OBX and PAF generated by the SDT in the previous step into the P2PP.

2.1.8 Submit OBs to ESO OB repository

Submit the imported OBs to the ESO OB repository.

2.2 Survey Areas

2.2.1 Rectangular areas:

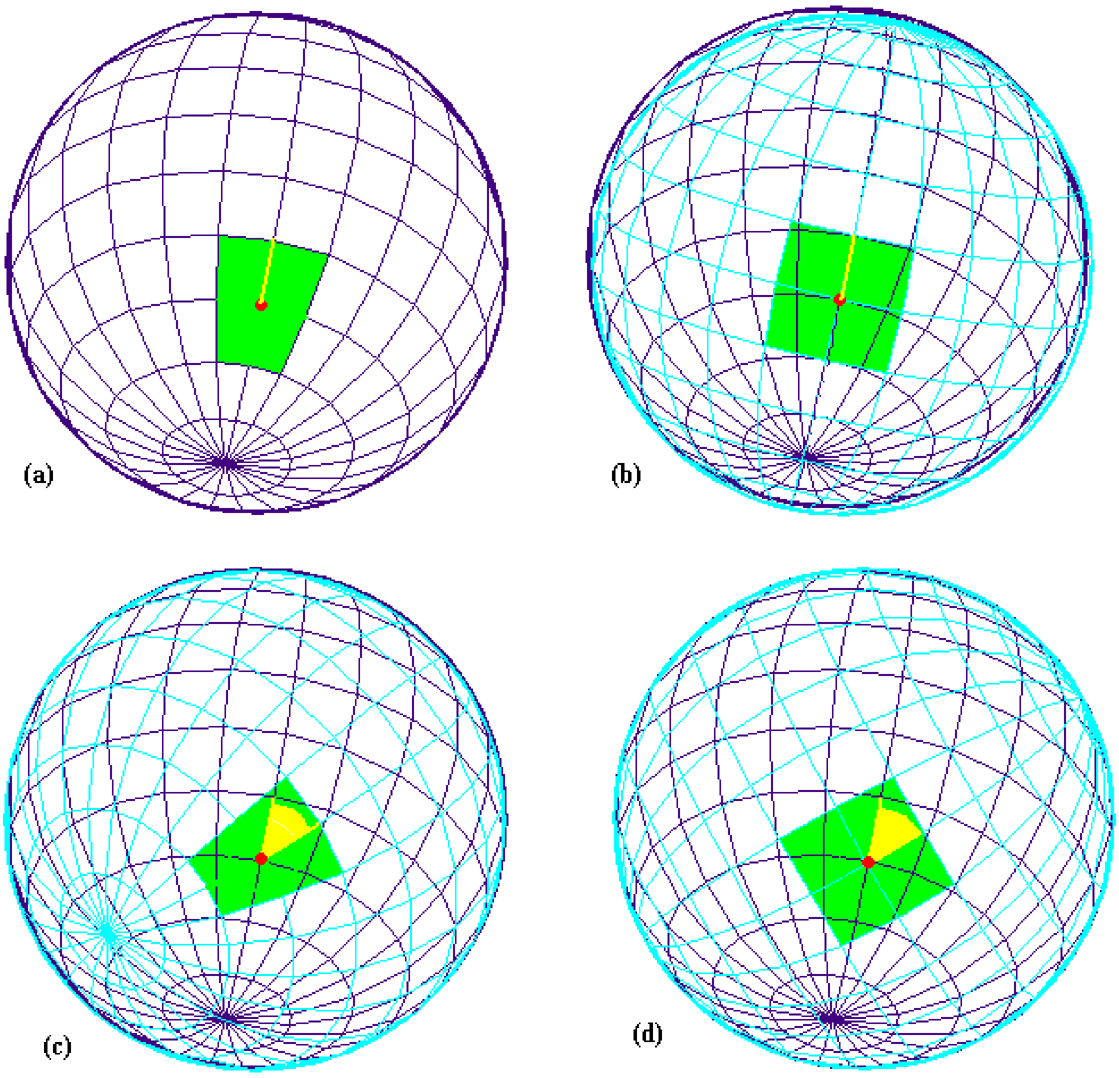

Figure 2

Parameters to be specified:

- `x`

  RA or Longitude of centre of rectangle (hours or degrees)

- `y`

  Dec or Latitude of centre of rectangle (degrees)

- `coordSys`

  Coordinate system in which x, y are specified. Choices: `J2000, B1950, galactic, SLOAN`

- `width`

  Width of survey rectangle in (degrees)

- `height`

  Height of survey rectangle in (degrees)

- `rotation angle`

  Angle by which the rectangle is rotated around its centre, in degrees, anticlockwise, North to East (see yellow "pie" in Figure 2). The `rotation angle` is measured relative to `coordSys`. This means that if the `rotation angle` is 0 then the upper and lower edge of the survey area are parallel to the equator of `coordSys`.

- `rectangle type`

  Assume for the moment that the rotation angle is 0 relative to the selected coordinate system (`coordSys`) and consider the two edges of the rectangle that are parallel to the equator of `coordSys`. The `rectangle type` specifies how the `width` should be interpreted:

  I. **Coordinate range ("Wedge/Cucumber")**

     `width` and `height` are interpreted as ranges of coordinates in of `coordSys.` See Figure 2 (a).

  II. **Rectangle**

     `width` and `height` are interpreted as ranges of coordinates in a "local" spherical coordinate system defined to have its (0, 0) coordinates at the centre of the rectangle such that its 0-meridian runs through the poles of `coordSys`. See Figure 2 (b): The light blue sphere is the "local" coordinate system and the purple sphere is `coordSys`.

2.2.1.6 Rotating rectangular areas

Rotating a rectangular survey area involves rotating coordSys in the case of the coordinate range (I) and rotating the "local" system in the case of the rectangle (II). See Figure 2 (c) and (d), respectively.

Note that the tiles within the survey area are rotated by the same angle as the survey area itself such that their upper and lower edges remain aligned with the upper and lower edges of the survey area. If `coordSys` is different from J2000 then this will in general result in a different rotation angle for each tile in J2000 (i.e. in the OB for that tile). This can be seen in Figure 3 where a rectangle is specified in some coordinate system other than J2000 (galactic, say) and than plotted on a (Cartesian) J2000 plot. The rotation angle of the survey area (green) and the tiles (black boxes) remains the same (the tiles are not rotated relative to the survey area) in galactic coordinates but changes from tile to tile in J2000.

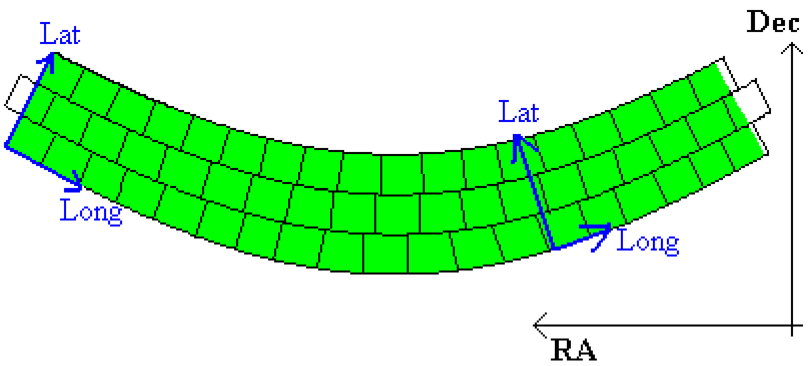

Figure 3

2.2.2 Circular areas:

Parameters to be specified:

- `x`

  RA or Longitude of centre of circle (hours or degrees)

- `y`

  Dec or Latitude of centre of circle (degrees)

- `coordSys`

  Coordinate system in which x, y are specified. Choices: `J2000, B1950, galactic, SLOAN`

- `radius`

  Radius of the circle in (degrees)

- `rotation angle`

  Rotating a circular area will not change the shape of the area itself but the orientation of the tiles within it.

Circular survey areas are always “geodesic”. Any diameter through the centre of the circle has the same geodesic length, regardless of coordinates of the centre of the circle and the coordinate system in which they are specified.

2.2.3 User defined tiles and pawprints

It will be possible for users to specify lists of pawprint or tile positions as coordinates, coordinate system rotation angle and guide/aO stars in a simple ASCII file which can be imported into the SDT. These pawprints/tiles are can be visualized and turned into OBs by the SDT in the same way as tiles that are created by the SDT itself to fill survey areas.

The SDT should then proceed to search for guide/aO stars and bright stars in the same way as for other tilings, and report the results back to the user. If guide/aO stars are below threshold or bright stars are found above threshold, the user should be warned on a case-by-case basis but the tile centres should not be adjusted.

At this point the user can either accept his/her defined list of tile centres and the SDT should generate the list of OBs; if user is not satisfied he/she will need to upload an alternative list of tile centres selected "by hand" or by user's private routine, and repeat as necessary.

2.3 OBs with absolute time constraints or relative time links

The strategy described in this section relies on the possibility of specifying absolute time constraints and relative time links for OBs and sets of OBs. Extending the existing VLT software to be able to handle this is currently being considered by ESO and is described in [RD01].

[AD01] describes various time related requirements for the scheduling of OBs. Scheduling itself is not dealt with in the current SDT document. However, there must be ways in which a user can convey information about scheduling constraints to those parts of the system that handle scheduling. A way of doing this is to specify this time information alongside the parent OB. In the normal cases described so far (i.e. no time information or only those absolute time constraints that can be handled by the current P2PP) the SDT copies the parent OB to each tile position. In the case of sets of OBs with relative time links the SDT will copy the whole set of OBs together with their relative time links to each tile position. The OBs are created in the P2PP as usual and the relative time links can be specified in the proposed tool OBLETER (see [RD01]). OBLETER can also be used to edit absolute time constraints.

3 Survey Progress Tool

3.1 OB repository information

The OB repository at ESO contains the OBs as well as information about whether and when they have been observed and which survey they are part of. The OBs themselves contain information about the target coordinates and the filter used.
From this the following information can be derived:

- Areas covered
- Depth of coverage
- Filters used
- Data Quality
- Absolute times of observations
- Intervals between observations
- Survey identifier

The best way of making this accessible is to provide a web page similar to the one at (http://www.eso.org/observing/usg/infopage_vlt.html which is currently used to provide feedback to VLT users.

3.2 Progress visualisation

A separate tool (derived from the SDT) can be used to plot the survey progress on a display similar to the survey area display of the SDT described above. To do this the description of the survey areas that was originally used to generate the tiles for the survey (see Specify survey areas) is used as one input to the survey progress tool. The other input is a list of OBs (including their coordinates, rotation angle and OB repository status) belonging to the same survey. The OB repository status is something like "DONE", "TO BE DONE" (details to be confirmed). The OBs are then plotted on the survey area display using a different colour for each status. If tiles are observed repeatedly as part of a survey (resulting in multiple OBs for that tile in the OB repository), then the number of times this tile has been observed, i.e. the number of OBs with status “DONE” for this tile can also be indicated in the display.

Visualisations can be provided for subsets of the OB repository selected on any of the criteria defined in 3.1 above.

The required information about the OBs (coordinates, rotation angle and status) is stored in ESO’s OB repository. There are several possible ways of accessing this information, e.g.:

- via a web interface to the OB repository similar to the VLT Service Mode Run Progress Reports (http://www.eso.org/observing/usg/infopage_vlt.html) currently offered to users, except the page should be geared towards automated processing, i.e. return the information in a standardized ASCII format (similar to the way skycat servers work, example: http://archive.eso.org/skycat/servers/usnoa-server?00:41:21.406+10:20:01.28&radius=0.0,2.905019574061209&&format=8&sort=mr.)

- via an offline progress report from ESO in the form of a list of OBs (with coordinates, rotation angle and status) generated form the OB repository at regular intervals and sent to PIs to be loaded into the Survey Progress Tool.

3.3 Progress Summaries, Statistics & Details from OB Repository

This web interface shall

- allow the export of information for off line analysis by the user
- provide histograms and position plots of defined subsets of OBs selected by various [TBD] parameters
- provide summary statistics of defined subsets of OBs selected by various [TBD] parameters
- provide a tool to query those histograms and statistics and identify OBs contributing to particular ranges [TBD] of values
- provide a tool to tag selected OBs and save them into user specified categories

It is recognised that the details of this aspect of the specification of progress measures needs further work when the relevant requirements in [RD01] are specified in greater detail.

3.4 Further Data quality measures

The Data Quality measures derived by the VDFS pipeline in Garching are accessible (for completed OBs) through the OB repository. These are based on analysis of the degree to which the OB met the requirements specified for it at execution time.

There is a potential further level of quality control in making a survey which provides quality measures of each frame which may both be on a different (finer) scale than in ESO QC, and may take account wider (post execution) issues relating to the needs of the survey as a whole. Such measures will be generated by the (UK) pipeline in Cambridge and the (UK) archive in Edinburgh. These additional quality control measures could in principle also be made available to the Survey Progress Tool. The importance of so doing remains TBD pending further definition of the way in which such measures could be useful in tracking survey progress.

4 Supported platforms and computing requirements

In principle the SDT can run on any platform for which a JDK 1.4.0 or later is available. Officially the following operating systems are supported:

- Linux Redhat 9
- HP-UX 11

A network connection is required to allow the use of online catalogues.