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From Handicraft to Industry: Supporting Surveys at ESO Telescopes

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Abstract. The ESO observatory at Cerro Paranal will host two new telescopes dedicated to survey-type observations. While surveys have already been conducted with existing ESO facilities, the features of the new ESO Survey Telescopes are a challenge for the Observatory's users and operations teams as well, in terms of number of observations and data rate. A set of software tools are being developed to help astronomers define the observation strategy and sequencing, while observatory staff are given assistance in managing and executing projects including hundreds or thousands of observations, and producing highly homogeneous datasets. This paper presents the extensions to ESO's 'Phase II' tools that will be implemented in the context of survey support, and discusses some of the challenges faced by software developers when problem sizes scale up one or more orders of magnitude.

1. Surveys at ESO

The European Southern Observatory (ESO) has a long history of involvement with surveys. Examples include both imaging and spectroscopic projects, like *Search for the first stars to form in the Galaxy*, *Refine the extragalactic distance*, the *ESO Imaging Survey*, wide-area optical observations in support of XMM, GALEX, and Spitzer programs, the *VIRMOS Very Deep Survey* (VVDS, producing over 100,000 spectra of high-redshift galaxies) and ESO's contribution to the *Great Observatories Origins Deep Survey* (GOODS), with the FORS2, ISAAC, VIMOS and WFI instruments.

Two new survey telescopes facilities are going to play a very important role in the coming years. Both the *Visible and Infrared Survey Telescope for Astronomy* (VISTA), a 4m aperture telescope with a $1deg^2$ infrared camera, and the *VLT Survey Telescope* (VST), a 2.6m aperture unit sporting the $1deg^2$, 16K×16K OmegaCAM optical instrument, are going to be commissioned in 2006 and will require extensive support to be operated efficiently.

1.1. Survey Classes and Size

Surveys may cover a large area of the sky: a *wide* imaging survey, for instance, could cover 3000 deg^2 of the infrared sky in several bands, with exposure times of 4-8 min per band. A *deep* survey may instead concentrate on a relatively small area (say 100 deg^2), observing for a much longer time, 75-110 min, in each band.

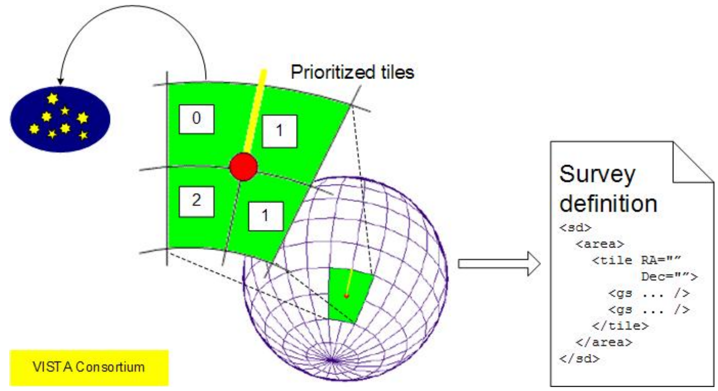

Figure 1. Survey Area Definition Tool

A *supernova search* survey would probably concern itself with a very small sky region, a few tiles at the most, but will return to those tiles over and over.

These few examples show that there is no simple definition for a survey. We can define a survey only in general terms and stressing its dimensions, as *a large set of imaging or spectroscopic observations taken over a long time.*

The size of survey projects strongly influence their operational requirements. While a common Service Mode (SM) program may include 10-20 individually crafted observations, totaling a few hours of observing time, a typical survey will often take months or years, and require execution of $10^2 - 10^4$ largely identical observations.

With surveys, observation preparation and execution must transition from handicraft to industry: from a few, individually prepared observations to a large number of very similar observations. In practical terms, ESO needs to upgrade its support tools to cope with a problem size that's 1–3 orders of magnitude larger than today's operational challenges.

2. Preparing Surveys

The unit observation at ESO's telescopes is called *Observation Block* (OB). The generation of hundreds or thousands of OBs can be simplified by separating the geometry of the survey (*i.e.* where to observe) from the specifics of each observation and from the timing constraints: ordering, sequencing and repetition of observations. The Cartesian product of the three components gives the set of needed observations.

2.1. Survey Area Definition Tool

The VISTA Consortium is developing the *Survey Area Definition Tool* (SADT), dedicated to defining the sky region in terms of atomic units called *tiles*. A schematic description of the tool is given in Fig. 1: individual tiles can be prioritized, and guide stars can be associated to them (where appropriate). The output of the tool is a hierarchical breakdown of the survey areas.

The SADT will be used for all ESO survey telescopes, not just VISTA.

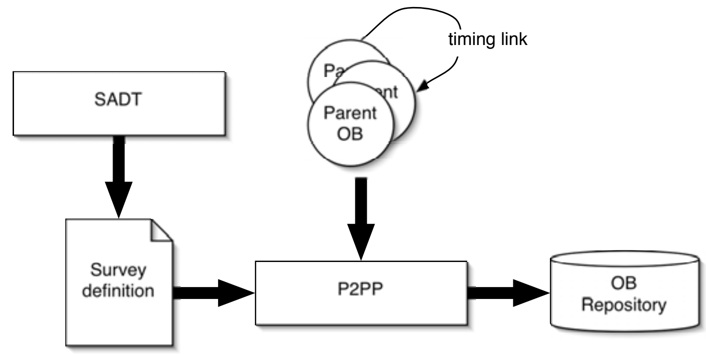

Figure 2. Integrating the SADT with P2PP

2.2. Extending P2PP

P2PP (short for *Phase II Proposal Preparation tool*) is in use since several years by the ESO astronomical community to prepare OBs for all ESO instruments. As shown in Fig. 2, the survey definition generated by the SADT is given as input to (the upcoming version of) P2PP. The tool combines the survey definition with the *parent OBs*; that is, OBs lacking pointing information but including observation specs like exposure time, filters, dithering patterns, observing constraints like seeing, etc.

Parent OBs can be given a priority, grouped and chained (one such link is shown in the figure), adding a timing dimension to the picture. The need for grouping and chaining of OBs was recognized early in the defining phases of the VLT's Data Flow System, and is mainly science-driven (e.g. by the need to obtain near-simultaneous measurements, by covering a field as large as possible, etc.). Grouping and chaining allow also to maximize the scientific output as early in the lifetime of the survey as possible — the benefits of that have been demonstrated in general by the use the community has made of incremental releases of 2MASS and SDSS. Until now, however, relationships among OBs could not be expressed in the system, and had to be specified in the documentation prepared by the investigator.

Tiles included in the survey area definition and the parent OBs can be combined at any time to produce the actual survey OBs, which are then stored in the central OB repository and made available for execution. It is in general not advisable to generate all survey OBs at once: on-demand generation is better suited to cope with the actual progress of the survey, changes in the observation strategy or equipment failures.

3. Executing Surveys

The survey execution problem can be simply stated: at any given time, the nighttime astronomer can choose from several hundred to several thousand candidate prioritized observations, possibly grouped and chained. Coping with a large and growing set of observation candidates is already proving to be a challenge for ESO staff astronomers, and the issue will grow in complexity once chains and groups of OBs must be taken into consideration.

The *OB Optimal Execution Selector* (OBOES) help the nighttime astronomer's keep the candidates OBs pool under control as the night progresses. OBOES can:

1. Remove "clutter" from the pool; that is, filter out all OBs that cannot be observed given their visibility, the current observing conditions (atmospheric conditions, moon phase and position, etc.), chaining and timing constraints, and other operational constraints (VLT unit telescopes cannot track across zenith, for instance). Filtering can be fine-tuned and repeated as needed, as observing conditions change.

2. Rank the remaining, "valid" OBs according to flexible criteria, including visibility and priority. For instance, OBs for targets that are about to set are ranked higher than those that just rose; similarly, operational considerations may privilege some program types at the beginning of the semester and other types toward the end. The ranking criteria will be coded in external configuration scripts, so that operators can change them, or create new ones, without the need for the intervention of software engineers.

The operator can finally choose among the few best-ranked candidate OBs what to observe next. OBOES does not attempt at suggesting an execution schedule in the classical short-term-scheduling sense: due to the quickly changing external conditions and other factors, that is best left to the ad-hoc judgment of the nighttime astronomers.

4. Conclusions and Plan

Supporting ESO's new survey-dedicated telescopes and instruments requires a change in the operational practices and the software tools to support them. ESO's current Phase II tools were designed with other requirements in mind than supporting large scale, industrial-style observations.

When ESO introduced the concept of Observation Block in 1997, the investigator's focus was shifted from the individual operations (acquiring the target, configuring the instrument, exposing, calibrating...) to the higher-level scientific goal of the observation. Today a similar paradigm shift is needed: the survey becomes the focus of the attention, and the OBs are simply the final, automatically generated product of the process.

During the observing night, on the other hand, powerful screening tools are required. The staff observer shouldn't need to concern themselves with a large amount of potential candidate observations, and should be given the freedom to concentrate on the survey itself, its quality and progress.

SADT, P2PP and OBOES provide a first implementation of a set of tools that will allow ESO to operate VISTA and the VST in 2006. A first, scaled-down prototype of OBOES called *OB Ranking Engine* (ORANG) will be delivered to ESO's observatories at the end of 2005, to help with the growing operational load and hopefully provide early feedback to the development team.