Observing Operations Concept Documents
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1 INTRODUCTION

The W. M. Keck Observatory (WMKO) development process includes an Observing Operations Concept Document (OOCD) in the set of documentation to be prepared for the preliminary design (PD) phase and updated during the detailed design (DD) phase. This document describes the purpose and content of the OOCD. It should be noted that an OOCD may be written for a complex system, for example adaptive optics (AO) in conjunction with a science instrument, or written only for a science instrument. Throughout the discussion which follows the term "instrument" should be taken to apply to both a system and an individual instrument. It should also be understood that instrument is used here in the broadest possible sense, describing not just the observing hardware and software, but also including the tools needed for observing preparation and for post-observing data reduction.

2 OVERVIEW

The OOCD is written during the second design phase for a new instrument, preliminary design. It is the third major design document written for a new instrument and follows the creation of the System Requirements Document (SRD) and the System Design Manual (SDM), both of which are written during the first design phase, system design. The OOCD describes how the features and functions of the design described in the SDM will be used to carry out the observations described in the science case.

2.1 Background

A new instrument is developed in response to a need for a new observational capability. This observational capability is defined by a narrative description that identifies the astronomical science research problem or problems that will be addressed by the new observational capability. This description forms the "science case" for the instrument. The science case is usually expected to provide perspective on current knowledge about the scientific problems being investigated and to assess the probability of successful completion of the proposed research if the new capability is developed. It is also often necessary for the science case to provide support for the development of the new capability by illustrating the importance of the problems to be addressed in the broader context of astronomical science.

The science case usually identifies some specific technical performance requirements such as wavelength range, spectroscopic resolution, sensitivity, etc. Example observations or "scenarios" may also be provided to explain how the new capability will work in performing the observations required by the science case. Science cases are usually developed with a strong basis in the existing scientific literature, and often contain assumptions about how the observations will be conducted that are based on existing instruments or observing methods. The performance requirements and the observations described in the science case can be used to form a set of "science requirements" that can then be documented in a Science Case Requirements Document (SCRD).

Analysis of the science case leads to initial values for at least some of the key technical parameters. The proposed observations and observing methods described in the science case lead to the identification of specific features and functions that will be expected from the instrument's hardware and software. Using this analysis the first development phase for the instrument, system design, creates two key documents, the SRD and the SDM.

2.2 The System Requirements Document

The SRD is organized by discipline (optical, mechanical, electronic/electrical, safety, software and interfaces) and describes the new system in terms of the needed scientific and technical performance. The performance requirements expressed in the science case are the starting point for the development of the parametric performance requirements in the SRD. The proposed observations and observing methods described in the science case are the starting points for the development of the operational performance requirements in the SRD. The motivation of requirements in the SRD is established by explicitly referencing each requirement to the analysis of the science case. This establishes what is commonly called a "flow down" from the science case to the SRD.

The SRD attempts to state requirements in a manner that does not assume any particular design approach or implementation. Of course, because there are existing systems, practices, and standards at WMKO there are certain restrictions on design and implementation, and these are also recognized in the SRD.

2.3 The System Design Manual

The SDM follows the SRD and results from the principal activity of the system design phase, an iterative process that starts with the high level scientific and user requirements, proposes a design concept and then evaluates the ability of the concept to meet the requirements. The design concept includes an "architecture" that partitions the needed functions across subsystems or components. As the process of system design continues, a preferred design concept emerges, establishing a preferred architecture and defining all of the subsystems of that architecture. The SDM documents the preferred design concept and gives functional requirements for each of the design's subsystems.

3 THE OBSERVING OPERATIONS CONCEPT DOCUMENT

The OOCD is developed during the preliminary design phase and takes as its primary inputs the science case, the SDM, and to some extent the SRD. The purpose of the OOCD is to document the observing operations concepts for the instrument. The main objective in developing observing operations concepts is to connect the observations needed by the science case with the design concept and functional requirements established for the instrument.

The OOCD is developed at the beginning of the preliminary design phase because it has as prerequisites the SRD and SDM. The initial assumption for the OOCD is that while during system design an initial set of features and functions for the instrument were identified, the way in which these features and functions will be used has not been fully or explicitly defined. By developing and documenting the operations concepts for the instrument the OOCD makes the user interactions with the instrument visible and provides guidance for further development of the instrument's features and functions.

Figure 1 illustrates the relationship between the preliminary design phase activity of developing the observing operations concept and the system design phase activities of developing the system requirements and the system design from the science case requirements.

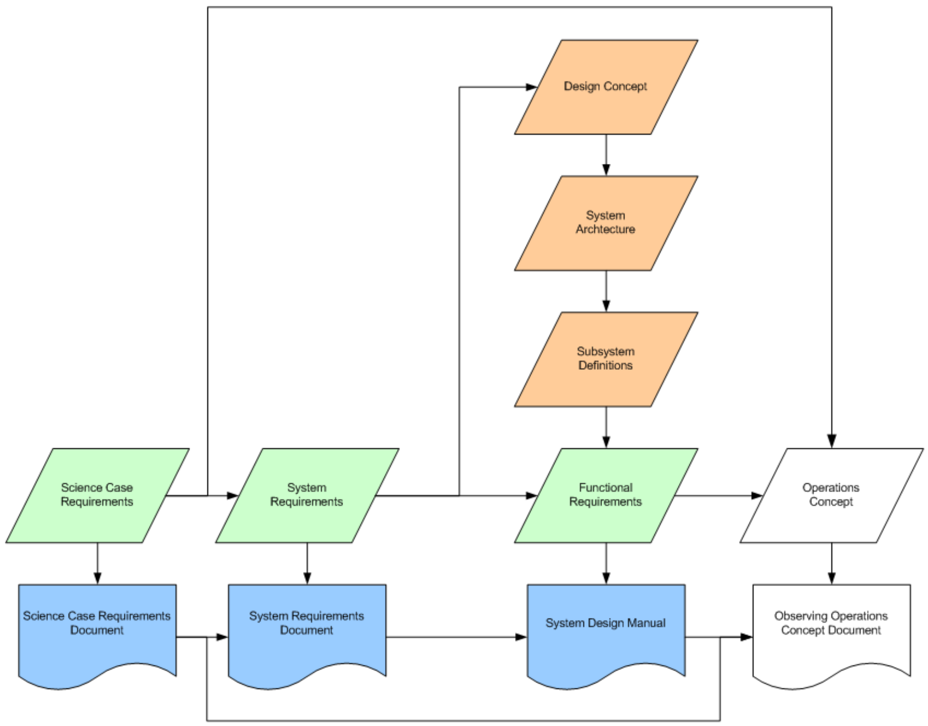

Figure 1: Design and documentation flowchart

The observing operations concepts describe how the instrument will be used to perform the observations required by the science case. This is done using example observations derived from the science case. The example observations are used to define the tasks that need to be performed in the observing process. The observing process tasks are divided into three groups, pre-observing tasks, observing tasks, and post-observing tasks. These tasks are then used to develop "use cases" to guide the development of the detailed hardware and software interactions between the user and the instrument.

3.1 Operations Concept Development Process

There are three major steps that need to be accomplished in order to complete the operations concept development process. These are the development of example observations, using the example observations along with the features and functions of the instrument to identify a series of tasks needed to perform the observation, and using the observing tasks to develop use cases.

3.1.1 Example Observations

The first step is to use the science case to develop example observations that are as specific as possible in order to help in reaching a detailed understanding of how the proposed instrument will be used to perform the observations. The example observations assume that the instrument will provide the performance described in the SRD and that the instrument will be implemented as described in the SDM. The example observations provide the basis for a subsequent analysis of the tasks needed to perform the observation, and they can provide a basis for evaluation of the anticipated performance of the instrument using simulations. This can provide important feedback on the suitability of the requirements, allowing issues to be uncovered that may require changes to the SRD or SDM while such changes can still have a meaningful impact on the final specifications for the instrument.

3.1.2 Observing Tasks

The user will expect to perform a series of steps, or tasks, to perform each observation. The tasks required for each example observation should be grouped into three major phases, pre-observing, observing, and post-observing. Each task should be described in sufficient detail to make the purpose of the task clear and to allow understanding the relationship of each task to its predecessors and/or successors.

For each example observation we need to be able to identify the things the user does and the things the instrument will do. For this reason it is recommended that each task describe not only what the user does, but what it is understood (from the SRD and SDM) that the instrument is expected to do. Each task should reference the specific instrument features or components (hardware or software) from the SDM involved in performing the task. Where the process of developing the OOCD results in the identification of missing requirements (in either the SRD or the SDM) the project's change management process should be used to insert those requirements in the appropriate document.

The nature of the tasks, and the definition of the user, is partly based on the operations context for the instrument. For WMKO instruments the baseline assumption is that the instrument will operate in a "classical" observing mode, where at least one astronomer involved in the science program is actually present during the observations, and either operates the instrument, or works with a support astronomer who operates the instrument. In addition there is at least one other person involved in the observing operations, an observing assistant who operates the telescope. Each task in the example observation is assigned to one of these users.

In order to make this more understandable we will develop the skeleton of an example observation for a science case[*] requiring a spectroscopic survey of high redshift galaxies in the redshift range $2.0 < z < 2.6$. The science case seeks to obtain precise redshifts for the target galaxies. Measurements are

[*] The example given here is based on an example MOSFIRE extragalactic science case developed by Chuck Steidel.

needed of the star formation rates in each galaxy, as well as measurement of chemical enrichment, and kinematic measurements for the determination of mass. Since it is a survey, requiring observations of perhaps 200 or more targets, a multi-object instrument capable of spectroscopic observations in the near-IR is needed.

The process of developing the example observation starts by defining how the observation will obtain the required astronomical data. This should be as clear and specific as possible. In this case, we can note that for the specified redshift range, the Hα transition for star forming galaxies will be shifted into the K-band. Measurement of Hα flux has been shown to be a robust method to determine star formation rate, and ratios such as [NII]/Hα (K-band) and [OIII]/Hβ (H-band at the target redshift) will provide measures of chemical enrichment. From this we can see that spectroscopic observations in H and K will be required. We then need to establish the required SNR by considering the accuracy needed for flux determination, and the precision needed for the selected spectroscopic line ratios. For the determination of dynamical masses we can specify a radial velocity precision for spectroscopy, and flow that down to the needed wavelength coverage, SNR, and spectral resolution. The example observation should include quantitative estimates for all of these parameters whenever possible.

The pre-observing phase starts by selecting the instrument, in this case a deployable integral field spectrograph (d-IFS) used with an adaptive optics (AO) system using laser guide star (LGS) tomography. The instrument's basic technical parameters, in particular sensitivity and background, will be needed to determine the required exposure times and other specifics of the observation such how background subtraction will be performed, for example by using dithered exposures.

The next step is target selection. In this example, targets at the desired redshift may be selected using J-K photometry of suitably deep near-IR images. We will require astrometry for each target, and since the targets are faint we will also want to select some brighter stars in the same field that can be used for initial acquisition of the field. We will also need astrometric measurements for the alignment stars, with all measurements in a common reference frame at an accuracy determined by the acceptable positioning error, this is set by the size on the sky of each of the deployable integral field units.

In addition to the science targets and alignment stars, we will also need to identify suitable tip-tilt stars, and we will have to select a configuration for the AO system's laser beacons.

Finally, we will need to plan the sequence of activities during the observation in detail, including the AO acquisition process (LGS and NGS), the d-IFS configuration (spatial scale, filter selection, pupil mask selection, image rotation, grating selection), the science target alignment process on the d-IFS probes, and the dithered exposure sequence. It may also be necessary to plan for specific calibrations such as arc-line spectra, and auxiliary exposures for sky or PSF measurements. Again, whenever possible quantitative estimates should be given for exposure times, number of dithers, etc.

The detailed sequence of activities to perform the observation describes the observing phase. Once the observations are completed, the post observing phase is where the data is processed and analyzed. For the example above, the tasks in this process would include processing of the raw spectroscopic data to perform sky subtraction and wavelength calibration, and additional processing steps to make the required flux measurements, line ratio measurements and radial velocity measurements.

The tasks identified for the pre-observing phase of this example observation are summarized in Table 1.

Pre-observing		
Instrument Selection		
Observer	Observing Assistant	Instrument
1. Review instrument performance parameters for available instruments and select instrument		1. Provides complete list of performance parameters and other information required to allow instrument selection.
2. Review set-up and calibration requirements for instrument		2. Provides manual and other information for set-up and calibration procedures
3. Review observing procedures for instrument		3. Provides manual for observing procedures
Target Selection		
Observer	Observing Assistant	Instrument
1. Using appropriate catalogs and other references identify target fields		
2. Obtain astrometry information when required		
3. If necessary plan and execute target qualification observations or reduce data from existing observations		
Acquisition and Alignment Stars Selection		
Observer	Observing Assistant	Instrument
1. Using the acquisition and alignment star selection tools, identify field acquisition and alignment stars in the selected target fields		1. Provide acquisition and alignment star selection tools, provide manual and other documentation for these tools
2. Obtain astrometry information for acquisition and alignment stars		2. Provide manual for acquisition and alignment procedures

Table 1: Example pre-observing tasks

Adaptive Optics Configuration		
Observer	Observing Assistant	Instrument
1. Using the tip/tilt star selection tool identify suitable tip/tilt stars in the selected target fields		1. Provide tip/tilt star selection tool, provide manual and other documentation for these tools
2. Determine observing requirements (various performance vs. FOV and sky coverage trades, etc.), use the LGS AO planning tool to select the required LGS configuration		2. Provide a LGS AO planning tool to allow selection of the LGS configuration based on observing requirements
Detailed Observing Plan		
Observer	Observing Assistant	Instrument
1. Determine calibrations and auxiliary observations required (PSF data, special calibration observations, etc.)		1. Provide manual and other information on calibration procedures, PSF measurement procedures, etc.
2. Using the observation planning tools prepare a detailed observing plan, includes exposure times, dithers, instrument configurations, etc.		2. Provide an observation planning tool, provide manual and other documentation for these tools
3. Test observing plan using instrument simulator		3. Provide instrument simulator to validate observing plan

Table 1, cont'd: Example pre-observing tasks

As we have noted, a part of developing the example observation is to reference the anticipated technical performance of the instrument. In some cases assumptions will have to be made about the expected performance, and when this is done these assumptions should be clearly identified and flowed down from the SRD. Assumptions regarding observing conditions and other factors should also be clearly described. It is also desirable to include results from performance simulation tools for the example observations. These simulations can then be used to validate the performance of data reduction tools and other post-observing software.

Finally, if the process of developing the example observation identifies missing or inadequate requirements (in either the SRD or the SDM) the project's change management process should be used to insert those requirements in the appropriate document.

3.1.3 Use Cases

The third step is the development of use cases based on the observing tasks identified for the example observation. The use cases describe how a clearly defined user will use the system, in this case the instrument, to accomplish a particular purpose. The formal language of use cases calls the user an "actor", and the purpose a "goal". In order to develop a use case there are four things that must be known at the beginning: a clear definition of the user, a specific realization for the system, the assumed initial state of the system, and a clear description of the goal.

As it is applied here, the definition of the user is either the astronomer, or an operator. We will assume that sufficient background is available to make these two classes of user clear. The specific realization of the instrument is defined in the SDM. At some level of detail the description of the instrument's design and the functional requirements presented in the SDM establish a set of behaviors that are visible to the user. It is important to understand that what goes on inside the instrument is not important to the use case; the use case is only concerned with the visible, external behaviors of the instrument. As this also implies, interactions between the instrument and other systems can also have use cases, and where those interactions are clearly related to the observing process they should also be included in the OOCD.

The use case goal in this context is the desired outcome of a task in the example observation. The specifics of the instrument's behavior and the goal define the pre-requisites that the user must have in order to begin the interaction process described in the use case. These are called the "initial conditions". After the initial conditions the use case consists of a sequence of events, each involving an action by either the user or the instrument. When an event can have more than one outcome a new use case "scenario" is required for each outcome. The first scenario listed should be the so called "primary" scenario. Separate use cases are required for each of the two classes of user (observer and operator).

Figure 2 is an example use case for the selection of acquisition stars, as referenced in the acquisition and alignment stars task found in Table 1.

Use Case: Pre-observing acquisition star selection
User: Observer

Scenario	*User*	*Instrument*
Initial Conditions	Has catalog reference or other reduced images for target field, has coordinates for targets in field	Acquisition planning tool ready

1 (P)		Indicates ready
	Loads reference images and target coordinates	
		Displays reference images, flags targets, provides list of suitable acquisition stars in field
	Selects acquisition stars	
		Highlights each acquisition star
	Done with acquisition star selection	
		Requests observation information and file name to save acquisition star list
	Provides information and file name	
		Saves acquisition star list

2		Indicates ready
	Loads reference images and target coordinates	
		Indicates error(s) in image or target list
	Evaluates error message, corrects errors Acknowledges error, requests restart	
		Restarts acquisition selection process

Figure 2: Use case example

The example starts with the initial conditions needed to begin the use case sequence. In this example there is one primary scenario, identified with the letter P. Obviously this is a very simple example, and the second scenario, which represents an error condition, may actually need to be replaced with a number of error scenarios depending on the kinds of errors that may be produced by the instrument. When use cases become more complex it may be appropriate to resort to graphical representations such as flow charts (called "activity diagrams" in use case parlance).

While a given science case may require a number of different observations, analysis of the tasks in each observation will usually reveal a number of identical tasks. Each of these identical tasks should be represented by a common use case. It may also be possible to allow small variations in the tasks to be addressed by providing alternative paths, instead of developing a separate use case for each variation.

Use cases should document the entire series of events in detail. These event descriptions must be "implementation free", that is they should not assume a particular interface design or other technical and implementation details. The use cases are not user interface designs and they do not substitute for requirements. On the other hand, for more mature designs the SDM will give specific implementation details, and where these are important for clarity they should be included in the use case.

As the use cases are developed, problems may be identified with the existing behaviors or other characteristics of the instrument that need to be addressed. This will result in changes or additions to the requirements in the SRD or the SDM, and the project's change management process should be used to make these changes in the appropriate document.

3.2 Observing Phases and Related Requirements

The pre-observing phase includes tasks performed by the observer to prepare for the observation. Requirements for observing preparation will be determined by both the instrument and the target. The OOCD should clearly describe these requirements, and indicate what aspects of observing preparation such as observation planning tools, exposure time or signal to noise estimators, etc. are provided by the instrument. Calibrations to support science data reduction may be pre-observing tasks (such as daytime arc lamp images or dome flats) or may be part of the observations. Specific requirements for observation planning tools and calibration facilities are part of the SRD.

The observing phase includes all of the steps from initial target acquisition through the science exposures and any associated calibration or other data acquisitions. The OOCD should clearly indicate any specific auxiliary data such as PSF measurements, astrometric data, etc. that are required as part of the observation. Specific requirements for the instrument in support of the observation are part of the SRD.

The post-observing phase includes the processing of the science data to make it ready for analysis. Post observing activities include data reductions to remove instrumental signatures, sky features, and specialized tasks such as PSF deconvolution. The OOCD should clearly describe all of the post-observing support tools that are provided by the instrument. Specific requirements for these post-observing support tools are part of the SRD.

3.3 Additional Operations Issues

The OOCD described here focuses on observing operations. In addition to observing operations we can also consider other operations activities related to the instrument. This might include daytime preparations such as telescope reconfigurations, and instrument check out and calibration. Operations can also be extended to include preventative maintenance and even repairs. From descriptions of such operations activities it is possible to develop costs for these aspects of operations, as well as time estimates for use in operations planning.

The problem is that at least some of these issues are not really part of observing, although they are needed to support it. It is also clear that somewhere in the process of developing the instrument we need to address what it will cost to operate and maintain once it is commissioned. These lifecycle costs definitely need to be considered and addressed as part of the design process. At this point we recommend that these issues be addressed either in a PD phase revision of the SDM, or included as an appendix to the OOCD.

3.4 Recommended OOCD Format

A recommended table of contents for the OOCD is given in Table 2.

1.0 Introduction

2.0 Scope and Applicability

3.0 Related Documents

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5.0 Background

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- 6.1 Science case 1
  - 6.1.1 Example Observation 1
    - 6.1.1.1 Description
    - 6.1.1.2 Assumptions and Pre-requisites
    - 6.1.1.3 Pre-observing Tasks
    - 6.1.1.4 Observing Tasks
    - 6.1.1.5 Post-observing Tasks
    - 6.1.1.6 Simulation Results[†]
    - 6.1.1.7 Issues Identified[‡]
  - 6.1.2 Example Observation 2
  - 6.1.3 Etc.
- 6.2 Science case 2
- 6.3 Etc.

7.0 Use Cases
- 7.1 Use case 1
- 7.2 Etc.

8.0 Glossary

Table 2: Recommended OOCD table of contents

[†] Where possible
[‡] Including issues that need to be addressed in other documents such as changes in the SRD or SDM, etc.

3.5 Introduction

This section should describe the purpose of the document and the intended audience.

3.6 Scope and Applicability

This section should clearly state what instrument the document applies to, the design phase it is prepared for, and the maturity level of the document (draft number or status). The release date and revision level should also be stated.

3.7 Related Documents

This section should cite all related documents or publications. Citations should be in a consistent style, the Modern Languages Association (MLA) style is recommended. References to documents available in print form are preferred, but web page references may be used where necessary provided that the URL given is tested.

3.8 Revision History

The revision history should be indicated in a table as follows:

Revision	Date	Author(s)	Reason for revision / remarks
1.0	July 16, 2008	SMA	Original Issue

A new line is added to the table with each revision.

The revision numbering starts at 1.0 and increments every circulated version. The minor digit indicates that edits or corrections have been made to text, figures or tables. The major digit is incremented when significant portions (more than a sentence in any section) of text are added or deleted or when tables or figures are added, replaced or deleted.

3.9 Background

This section should briefly describe the new instrument. It may also be helpful to describe the science cases, or to describe the key elements of the flow down from the science case to the SRD. It may also be useful to mention specific requirements in areas such as observing efficiency or operations workload. These should be provided for illustration only, with appropriate references to the documents where the current and complete versions of the requirements and other discussion will be found. This is essential in order to avoid the situation where a requirement appears in more than one location which would lead to undesirable problems with document maintenance and requirements versioning.

3.10 Example Observations

This section should summarize each science case and provide one or more example observations. Each observation forms a separate sub-section in which the example observation is described along with any pre-requisites needed for the observation (previous observations such as astrometry, calibrations, etc.) and any assumptions regarding instrument performance that are not based on the SRD/SDM, and assumptions about observing conditions and related maters. The tasks identified for each of the three observing phases then described, followed by results of simulations for the example observation (when available) and a discussion of any issues that need to be addressed in other documents such as changes to the SRD or SDM.

3.11 Use Cases

The use cases section distills the activities of the example observations into a set of use cases. These use cases should be described for each of the applicable user views.

3.12 Glossary

This section defines all of the acronyms or unique terms used in the document.