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Concept of Operations versus Operations Concept: How do you choose?

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ABSTRACT

Systems engineering as a discipline is relatively new in the ground-based astronomy community and is becoming more common as projects become larger, more complex and more geographically diverse. Space and defense industry projects have been using systems engineering for much longer, however those projects don't necessarily map well onto ground-based astronomy projects, for various reasons. Fortunately, many of the processes and tools have been documented by INCOSE, NASA, SEBoK and other organizations, however there can be incomplete or conflicting definitions within the process and implementation is not always clear. For ground-based systems engineers, adopting these existing processes can be confusing. One area of particular uncertainty involves how, when and where to document operations concepts in a way that captures astronomers' needs, translates them into concise and complete requirements without over-constraining the design teams or over-burdening the project with complex requirements and document management procedures.

We present the criteria and outcome of the solution(s) chosen from the perspective of two different projects: a new observatory that is planning its operations (Maunakea Spectrocopic Explorer, MSE) and a new instrument at a long-established observatory (Gemini - GIRMOS). Quite possibly, this will not answer the question in the title and may raise more questions. We welcome that discussion.

Keywords: Systems Engineering, concept of operations, ConOps, operations concept, OpsCon

1. INTRODUCTION

Systems engineering as a discipline is relatively new in the ground-based astronomy community and is becoming more common as projects become larger, more complex and more geographically diverse. Space and defense industry projects have been using systems engineering for much longer, however those projects don't necessarily map well onto ground-based astronomy projects, for various reasons.

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There is no standard definition of what constitutes a Concept of Operations (ConOps) or Operations Concept (OpsCon) document. Different organizations define these differently, and sometimes the definitions are contradictory.

Quoting from the American Institute of Aeronautics and Astronautics: “ANSI/AIAA G-043A-2012 identifies that the terms ‘concept of operations’ and ‘operational concept’ are used interchangeably but notes that an important distinction exists because each has a separate purpose and is used to meet different ends. It is essential that these terms are used so that they are consistent with ANSI/AIAA G-043A-2012 and ISO/IEC 29148, as well as the way in which the terms are used in the US DoD and many other defense forces.” [1]

Certainly there is overlap in the types of content between the two types of documents. Having a clear understanding of the purpose, intended audience and intended implementation of both document will help project decide when and how either a ConOps, and OpsCon or both. This paper describes examples from two different projects and the expected impact on the projects. The motivation for this paper is to give some insight for other projects that are heading down this path.

2. DEFINITIONS

ISO/IEC 29148 [2] defines the ConOps: “The ConOps, at the organization level, addresses the leadership’s intended way of operating the organization. It may refer to the use of one or more systems, as black boxes, to forward the organization’s goals and objectives. The ConOps document describes the organizations’ assumptions or intent in regard to an overall operation or series of operations of the business with using the system to be developed, existing systems, and possible future systems. This document is frequently embodies in long-range strategic plans and annual operational plans. The ConOps document serves as the basis for the organization to direct the overall characteristics of the future business and systems, for the process to understand its background, and for the users of this International Standard to implement the stakeholder requirements elicitation.”

ISO/IEC 29148 [2] defines the OpsCon: “A system OpsCon document describes what the system will do (not how it will do it) and why (rationale). An OpsCon is a user-oriented document that describes system characteristics of the to-be delivered system from the user’s viewpoint. The OpsCon document is used to communicate overall quantitative and qualitative system characteristics to the acquirer, user, supplier and other organizational elements.”

In this framework, the ConOps is developed by the leadership of the project, by gaining agreement with stakeholders about the goals of the project. The ConOps provides context for the OpsCon, which and is developed at a management level based on leadership statements given in the ConOps. And finally, the OpsCon becomes a resource and a forerunner for Operational Plans that are developed later.

3. MSE

3.1 Background

The Maunakea Spectroscopic Explorer (MSE) is a next-generation massively multiplexed ground-based spectroscopic survey facility. MSE is designed to enable truly transformative science, being completely dedicated to large-scale multi-object spectroscopic surveys, each studying thousands to millions of astrophysical objects. MSE will use an 11.25 m aperture telescope to feed 4,332 fibers over a 1.5 square degree field of view and has the capability to observe at a range of spectral resolutions, from R~3,000 to R~40,000, with all spectral resolutions available at all times across the entire field. The MSE project completed a Conceptual Design Review of the facility in 2018 (MSE Project 2018); the Conceptual Design of the facility is shown in Figure 1. With these capabilities, MSE will collect more than 10 million fiber-hours of 10m-class spectroscopic observations every year and is designed to excel at precision studies of large samples of faint astrophysical targets.

The scientific impact of MSE will be made possible and attainable by upgrading the existing Canada-France-Hawaii Telescope (CFHT) infrastructure on the Maunakea summit, Hawaii. CFHT is located at a world-class astronomical site with excellent free-atmosphere seeing (0.4 arcseconds median seeing at 500 nm). The Mauna Kea Science Reserve Comprehensive Management Plan (Ku‘iwalu 2009) for the Astronomy Precinct explicitly recognizes CFHT as one of the sites that can be redeveloped. In order to minimize environmental and cultural impacts to the site, and also to minimize cost, MSE will replace CFHT with an 11.25 m aperture telescope while retaining the current summit facility footprint. MSE will greatly benefit by building on the technical and cultural experience of CFHT throughout the development of the project.

MSE is designed to take advantage of the excellent site characteristics of Maunakea, which allows for an extremely sensitive, wide-field, and massively multiplexed facility (see Table 1). The MSE Conceptual Design positions 4,332 input fibers at MSE's prime focus, packed into a hexagonal array. The input fibers collect and transmit light to banks of spectrographs tens of meters away. One bank of spectrographs receives light from 3,249 fibers from the focal surface and may be used in either low resolution (R~2500) or moderate resolution (R~6000) mode, covering the optical to near-infrared wavelength range of 0.36–1.8 microns. Concurrently, the other bank of spectrographs receives light from 1,083 fibers from the focal surface and is dedicated to collecting the high resolution spectra in three targeted optical wavelength windows within the wavelength range of 0.36–0.5 microns at R~40,000 and 0.5–0.9 microns at R~20,000. All resolution modes have simultaneous full field coverage, and the massive multiplexing results in the ability to collect many thousands of spectra per hour and over a million spectra per month, all of which will be made available to the MSE user community. Moreover, an upgrade path to add an Integral Field Unit (IFU) system has been incorporated into the design as a second-generation capability for MSE.

Aside from the physical infrastructure, MSE's success is enabled by efficiently scheduled and executed surveys, by the quality of the data collected, and by MSE's ability to make the science products available to survey teams in a timely and efficient manner. MSE will devote 80% of available time to executing large, homogeneous surveys which will typically require several years to complete. More focused programs, which require smaller amounts of observing time and typically lead to more rapid publications, will occupy the remaining 20% of observing time. Proposals for both types of programs will be solicited from the MSE user community at regular intervals. MSE is operated solely in a queue-based mode, requiring sophisticated scheduling software. Data will be made available to the survey team immediately, and to the larger MSE community on a short timescale.

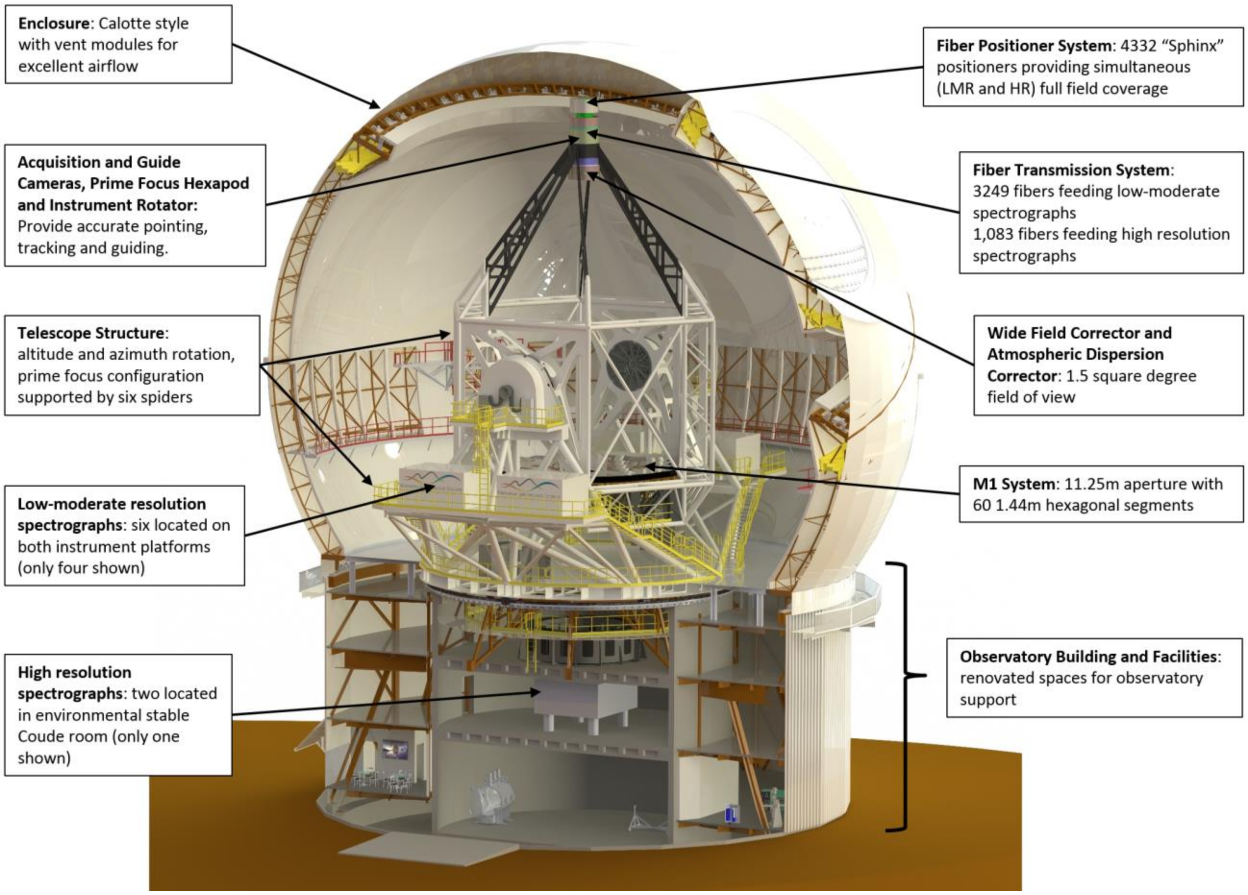
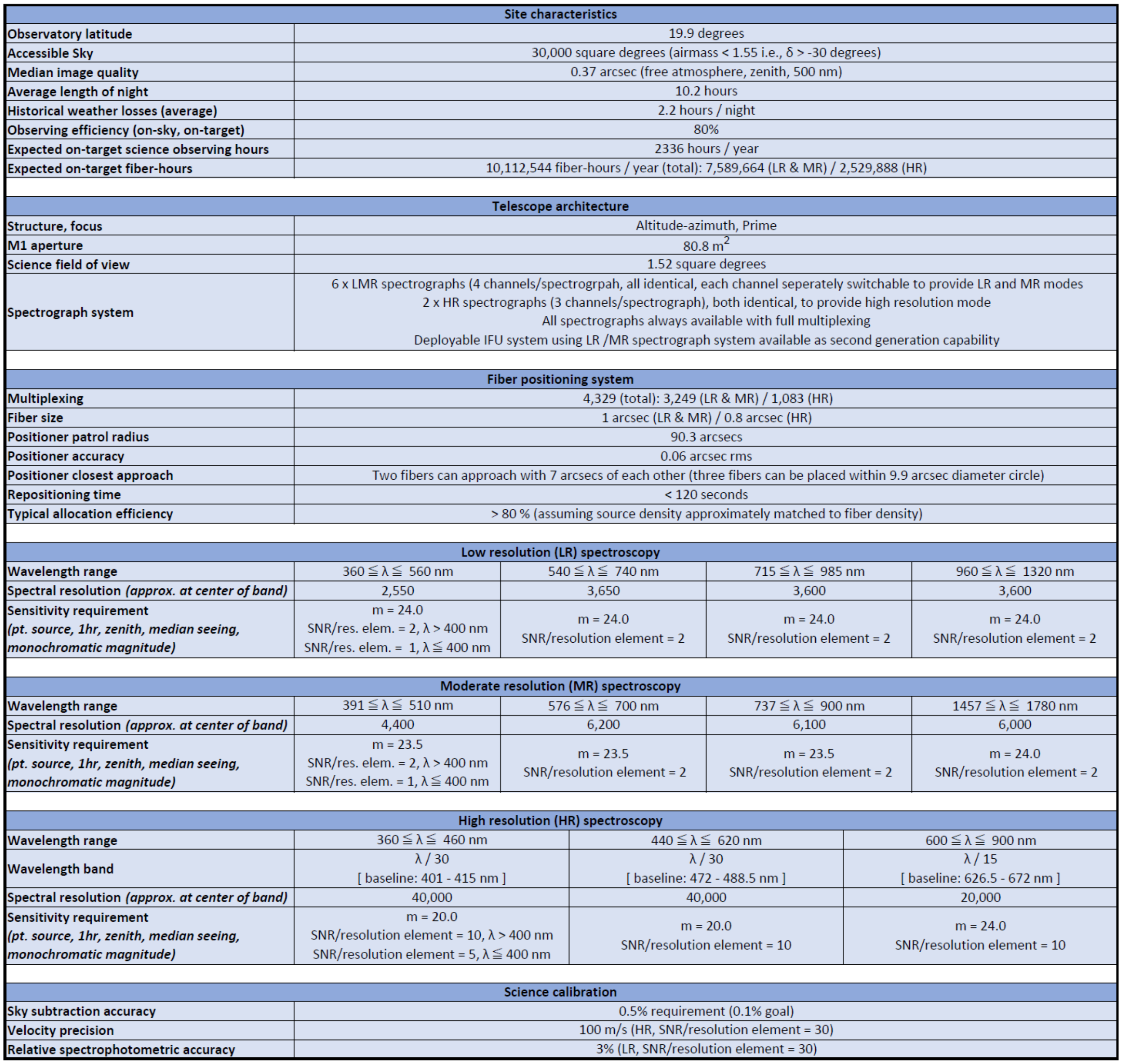


Figure 1. MSE Observatory architecture as described by the 2018 Conceptual Design (MSE Project 2018).

Table 1. The detailed science capabilities of MSE.



Site characteristics	
Observatory latitude	19.9 degrees
Accessible Sky	30,000 square degrees (airmass < 1.55 i.e., $\delta > -30$ degrees)
Median image quality	0.37 arcsec (free atmosphere, zenith, 500 nm)
Average length of night	10.2 hours
Historical weather losses (average)	2.2 hours / night
Observing efficiency (on-sky, on-target)	80%
Expected on-target science observing hours	2336 hours / year
Expected on-target fiber-hours	10,112,544 fiber-hours / year (total): 7,589,664 (LR & MR) / 2,529,888 (HR)

Telescope architecture	
Structure, focus	Altitude-azimuth, Prime
M1 aperture	80.8 m^2
Science field of view	1.52 square degrees
Spectrograph system	6 x LMR spectrographs (4 channels/spectrogrpah, all identical, each channel seperately switchable to provide LR and MR modes 2 x HR spectrographs (3 channels/spectrograph), both identical, to provide high resolution mode All spectrographs always available with full multiplexing Deployable IFU system using LR /MR spectrograph system available as second generation capability

Fiber positioning system	
Multiplexing	4,329 (total): 3,249 (LR & MR) / 1,083 (HR)
Fiber size	1 arcsec (LR & MR) / 0.8 arcsec (HR)
Positioner patrol radius	90.3 arcsecs
Positioner accuracy	0.06 arcsec rms
Positioner closest approach	Two fibers can approach with 7 arcsecs of each other (three fibers can be placed within 9.9 arcsec diameter circle)
Repositioning time	< 120 seconds
Typical allocation efficiency	> 80 % (assuming source density approximately matched to fiber density)

Low resolution (LR) spectroscopy				
Wavelength range	$360 \leqq \lambda \leqq 560$ nm	$540 \leqq \lambda \leqq 740$ nm	$715 \leqq \lambda \leqq 985$ nm	$960 \leqq \lambda \leqq 1320$ nm
Spectral resolution ***(approx. at center of band)***	2,550	3,650	3,600	3,600
Sensitivity requirement ***(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)***	m = 24.0 SNR/res. elem. = 2, $\lambda > 400$ nm SNR/res. elem. = 1, $\lambda \leqq 400$ nm	m = 24.0 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2

Moderate resolution (MR) spectroscopy				
Wavelength range	$391 \leqq \lambda \leqq 510$ nm	$576 \leqq \lambda \leqq 700$ nm	$737 \leqq \lambda \leqq 900$ nm	$1457 \leqq \lambda \leqq 1780$ nm
Spectral resolution ***(approx. at center of band)***	4,400	6,200	6,100	6,000
Sensitivity requirement ***(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)***	m = 23.5 SNR/res. elem. = 2, $\lambda > 400$ nm SNR/res. elem. = 1, $\lambda \leqq 400$ nm	m = 23.5 SNR/resolution element = 2	m = 23.5 SNR/resolution element = 2	m = 24.0 SNR/resolution element = 2

High resolution (HR) spectroscopy			
Wavelength range	$360 \leqq \lambda \leqq 460$ nm	$440 \leqq \lambda \leqq 620$ nm	$600 \leqq \lambda \leqq 900$ nm
Wavelength band	$\lambda / 30$ [baseline: 401 - 415 nm]	$\lambda / 30$ [baseline: 472 - 488.5 nm]	$\lambda / 15$ [baseline: 626.5 - 672 nm]
Spectral resolution ***(approx. at center of band)***	40,000	40,000	20,000
Sensitivity requirement ***(pt. source, 1hr, zenith, median seeing, monochromatic magnitude)***	m = 20.0 SNR/resolution element = 10, $\lambda > 400$ nm SNR/resolution element = 5, $\lambda \leqq 400$ nm	m = 20.0 SNR/resolution element = 10	m = 24.0 SNR/resolution element = 10

Science calibration	
Sky subtraction accuracy	0.5% requirement (0.1% goal)
Velocity precision	100 m/s (HR, SNR/resolution element = 30)
Relative spectrophotometric accuracy	3% (LR, SNR/resolution element = 30)

3.2 Concept of Operations

As the observatory is being constructed, MSE's Project Office and all engineers and designers require a clear understanding of the operational intention of stakeholders, in language that can be understood by both stakeholders and MSE engineers and designers. To capture this understanding, MSE has created the Concept of Operations (ConOps) [3]. This is a plain language document, suitable for a technically competent but general audience.

The stated purpose of the document:

"**Concept of Operations Document (ConOps)** –describes the stakeholders' and owners' intention and needs for MSE. This includes high level operational objectives that describe what the observatory is expected to do." [3]

Stakeholders of course include partner scientists and the user community (mostly organized onto the science team) but also the partner and funding agencies who have a stake in making sure the observatory is built with agreed upon basic operations concepts and CFHT leadership and staff as well as local community representatives in Hawaii, USA. For the project to be successful, this content of this document must reflect the wishes of the stakeholders.

The contents are organized into:

- Overall governing statements. Mission Statement, Statements on Equity, Diversity and Inclusion as well as the Cultural Heritage of Maunakea and overall vision of the observatory as well as its heritage CFHT.
- High level governance. Defines the structure of stakeholder and their interactions with the project. Management and scientific direction are organized by committee and involvement by CFHT leadership involvement, CFHT observatory staff and local community representatives are described.
- Facilities and Instrumentation. Defines what is expected by stakeholders at first light as well as upgrade paths. This includes expectations about the transition from CFHT to MSE.
- Science Operations. Gives a high level overview of the types of programs and surveys available, and generally agreed principles (but not details) for time allocation and accounting, reviewing proposals via committee, scheduling observations and data management (including formats and processing), reduction and archiving, calibrations available and support for scientists (tools, tutorials, services, etc).
- Staffing and Outreach for the observatory.
- Operations Model and Technical Operations. This includes such topics as automated and/or remote operations and general expectations on technical operations, such as lifetime (both observatory and instrumentation), downtime, engineering time, instrument support, safety and environmental stewardship on Maunakea.
- Performance assessment. Broadly categorized into Science, Technical and Social measures of success.

Currently, at MSE, the ConOps is in a preliminary state with a first draft release expected in the first half of 2021.

This description demonstrates that MSE’s ConOps (intentionally) exists at a very high level in terms of the level of detail describing the observatory’s science operations and technical processes.

3.3 Operations Concept

The stated purpose of the document:

“**Operations Concept Document (OCD)** –describes in detail how MSE will be operated to meet operational objectives and SRD specifications. The OCD includes a high-level summary of Observatory behaviours and operator interactions.” [4]

The contents are organized into:

- Organization: Describes the roles and organizational structure of the staff at observatory, once MSE becomes operational.
- Operations model. Describes the survey team and types of programs as well the process by which science surveys are selected for observation with MSE and the associated phases of operations, from proposal submission to distribution of the data. Also includes descriptions of tools as and phases of operations by defining processes and identifies tools from the perspective of science team. This ranges from proposal submission and selection, survey planning and execution and data reduction and distribution. description of
- Science Scheduling. Describes the process and some tools, with which MSE surveys are defined, scheduled and queued for observations, including how complex an observation can be, what information it will need to contain, and how it will be executed.
- Science Calibrations. Describes the baseline operational plan for calibration at MSE, including general considerations and specific expected calibration procedures.

- Science Data Reduction Pipeline. Defines databases, user interfaces and specific data products needed, as well as data reduction, validation and distribution processes and tools.
- Observatory Operations. This includes descriptions of how MSE will operate/react in various environmental conditions, as well as describing expected technical operations such as maintenance expectations, on-sky engineering time and sequences of events during science operations.

The OpsCon should be considered preliminary, considering the conceptual stage of MSE as a whole. Even at this preliminary stage, the OpsCon is a comprehensive and very detailed document. Also, operational content of the OpsCon will be used to develop and refine observatory and subsystem requirements using such tools as use cases in future work. Finally, the OpsCon will eventually form the basis for the MSE Operations Plan, with some material being directly moved into that document.

3.4 Systems Engineering Context

Generally following the intent of, ISO/IEC 29148, MSE's ConOps is mainly used as a tool for capturing stakeholder needs and provides necessary "parenthood" statements for defining the very detailed OCD. The subsystems trace operational requirements through MSE's Observatory Requirements Document to the OCD.

Specifically, the ConOps have different approval and change controls processes, where the changes to the ConOps will require (lengthy!) stakeholder and Management Group approval while the OCD and subsystems has an approval process that is internally handled at the PO. Additionally, lower level subsystem requirements their changes and approval process is also internally handled.

4. GIRMOS

4.1 Background

The Gemini Infrared Multi-Object Spectrometer is a science instrument being developed for use on the Gemini North 8-meter optical/infrared telescope. Designed to make use of the Gemini North Adaptive Optics system (GNAO), GIRMOS will enable simultaneous spatially-resolved imaging and spectroscopy of multiple science targets at near-infrared wavelengths (1-2.4 µm) with near diffraction-limited resolution in H and K-bands. This will be achieved by four integral-field spectrometers that can independently observe four astrophysical objects. Each spectrograph will be equipped with an adaptive optics system that corrects for the atmospheric turbulence, in conjunction with GNAO, along its line-of-sight. This Multi-Object Adaptive Optics system (MOAO) will allow GIRMOS to observe targets within a large field of regard (FoR) while still achieving excellent AO correction. This will enable significant scientific gains in AO surveys of Milky Way phenomena, the local universe, and distant galaxies. With multiple spectral resolution modes (R=3,000 and 8,000), GIRMOS will be able to carry out highly sensitive measurements of faint emission line sources, as well as the kinematics and chemistry of astrophysical objects. [5]

GIRMOS consists of multiple subsystems that work together to achieve its overall design goals. The instrument block diagram that highlights the key systems, with the exception of instrument software, is shown in Figure 2. Figure 3 shows the subsystem components and mechanical layout, for reference.

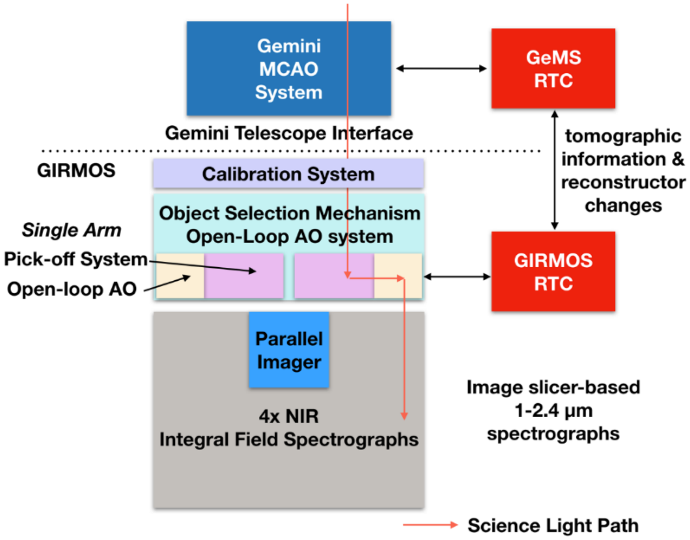


Figure 2. Block diagram of GIRMOS with the interactions of its subsystems highlighted.

IFU spectrographs based on image slicers are baselined for the GIRMOS spectrographs because they offer a number of advantages over other technologies (e.g. fibres and lenslets). The core science goal of GIRMOS is to achieve the highest sensitivity measurements of faint and low surface brightness extended objects with excellent AO correction. Fibre-IFU spectrographs have not been able to demonstrate excellent sky subtraction, particularly in the NIR, due to variable pupil illumination due to focal ratio degradation; on the other hand, lenslet-IFUs do not have high etendue per NIR detector because of their inefficient use of detector pixels. [5]

Additional AO correction has been implemented because of the need to achieve a resolution much closer to the diffraction limit, and over a wider field, than GNAO can provide. An 8-m platform also allows for an ideal test bed for implementing such an instrument on a 30-m telescope, where the AO correction and calibration requirements are so much more stringent.

Movable pickoff arms were chosen to couple the light from individual objects into the MOAO system and spectrographs because they offer the most efficient method to achieve the multiplexing when a relatively small number of objects are to be selected over a 2’ field of regard.

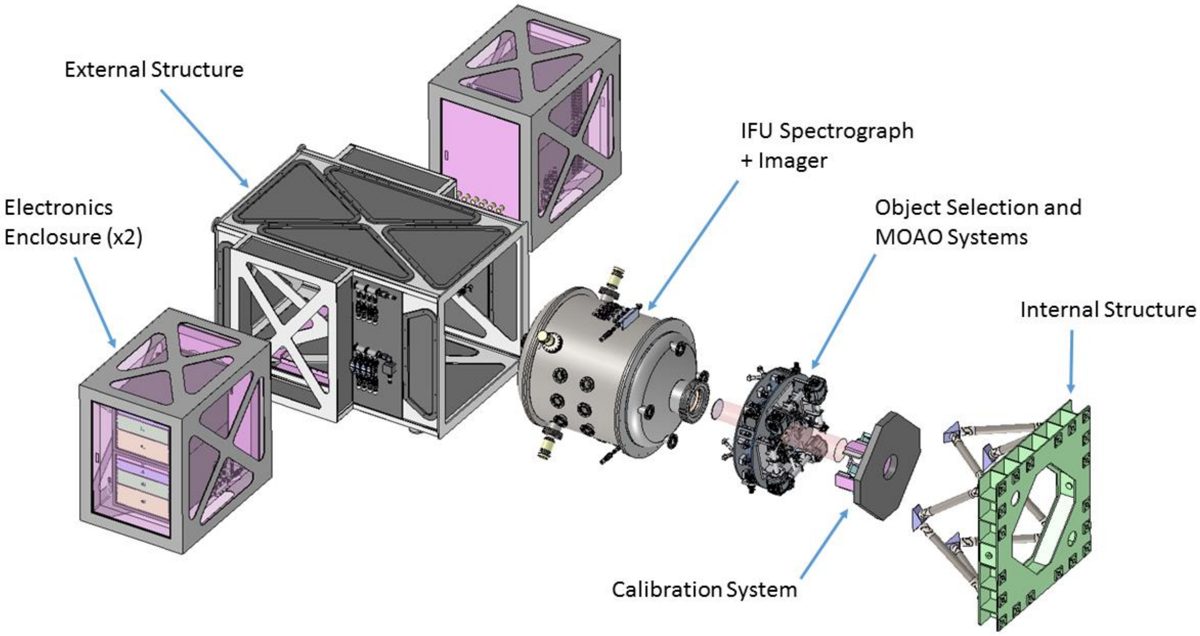


Figure 3. GIRMOS overall instrument mechanical design (exploded view)

Similar to MSE, as a survey instrument, GIRMOS will produce large amounts of data that must be calibrated, reduced and distributed among the users. This will require careful planning and coordination with Gemini Observatory.

4.2 Concept of Operations

As GIRMOS is being design and built, the design team requires a clear understanding of the operational intention of the end users and other stakeholders, described in a language that can be understood by both the end users and GIRMOS' design team. GIRMOS has created the Concept of Operations (ConOps) [5] to capture this information. Similar to MSE, this document is intended to be written in plain language and suitable for a technically competent but general audience.

The GIRMOS ConOps describes the end-to-end process of operating GIRMOS at the Gemini Observatory. This includes everything from preparing observing runs, performing instrument calibrations, and executing an observation to data reduction, validation and distribution.

The contents are organized into:

- Instrument description. Defines the Operational States and Modes and System-level Observing Configurations for GIRMOS to perform its science, in the Gemini context.
- Preparation of observations. Defines target and guide star selection, specific configurations, acquisition sequences, dithering methods, calibrations required, details of observing overheads and definitions for observing conditions, strategies and performance optimization and tools for observation planning.
- Mechanical alignment and installation at Gemini.
- Executing Science Observations. Describes acquisition and guiding procedures, adaptive optics set and how to execute science observations using specific procedures.
- Calibrations. Describes what and how to calibrate the instrument.
- Real-time data validation. Describes the tools and processes available.
- Data reduction. Defines in some detail the data reduction stages, the process and tools used and the resulting form of the data output.

- Example observing scenarios. Based on GIRMOS Science Cases.
- Instrument Monitoring and Maintenance. Defines what should be measured in order to track changes to performance over time and a concept for what instrument maintenance will be needed (and how often it should be expected).

This description demonstrates that, for GIRMOS, the ConOps is clearly a comprehensive document and includes both high level definition and detailed description of the operations processes and products.

The GIRMOS ConOps is written by the end user of the system, and specifies WHAT operations need to be supported, and WHY these operations are required.

4.3 Operations Concept

For GIRMOS, an “OpsCon” is interpreted to describe how the instrument team intends for the instrument to be operated. This will be the content of the Hardware and Software User Manuals which are deliverable as first drafts in Final Design Phase. The User Manuals will be written by the instrument development team, and specify HOW the operations are to be performed.

4.4 System Engineering Context

The purpose of the GIRMOS ConOps is to capture stakeholder expectations regarding how the instrument is intended to be operated. Within the documents, stakeholders define the operations/modes/states/configurations that they want or need within GIRMOS in order to perform their intended observations. These expectations are written in plain language, and should be able to be understood by a general audience. The job of the Systems Engineering Team is then to interpret these wishes into a set of formal Level 1 Instrument Requirements. Because it is a critical part of the requirements generation process, the ConOps is ideally written during the Conceptual Design Phase. The User Manuals are typically written in the Final Design Phase.

5. COMPARISON AND CONCLUSION

In the MSE project, it appears to be very much worthwhile, to have both a ConOps and OpsCon (OCD in this case), considering the large project scope, longer timeline and need to define high level concepts and have them approved by a large group of diverse and disparate stakeholders. The ConOps and OCD include the same basic topics. The ConOps is a driver of the very detailed OCD which will then drive observatory requirements and form the basis for detailed transition and operational plans. The benefit to this approach is so that it will be possible to gain agreement and approval at a high level about the major goals and outcomes of the project without having to be involved in the nitty gritty details of the implementation. It is critical that this process be decoupled from the ConOps because it would be very time consuming to get stakeholder approval for every instance of a change within the OCD that does not impact high level stakeholder needs.

For GIRMOS, however, Gemini provides much of the high level operational concepts “baked in”. As a smaller and comparatively less complex project, it makes sense in this case to compile all of the operational concepts and currently known detailed operational procedures together in one ConOps, especially considering they generally have the same audience. These then are flowed down into the instrument requirements and in the future, details of user manual and specific procedures will derive from the content in the ConOps. The team is small enough that the change control process for the ConOps is simple and agile.

For any project that is planning to write either one of these documents, it is important to keep in mind the main goals of both a ConOps and OpsCon document, which is to capture astronomers’ needs, translate them into concise and complete requirements and then decompose them further into testable specifications. Ideally, this is done without over-constraining the design teams or with change control and document management procedures that are too complex for the specific team’s composition. For ground-based astronomy projects, quite often following ISO/IEC/IEEE standard strictly can cause expensive overhead that does not warrant the effort.

In both cases, the intent described in ISO/IEC 29148 [2] is preserved - the difference being which document contains the content and who controls and manages it.

This may be an obvious conclusion but hopefully can be helpful to future projects that struggle with the same concepts.

REFERENCES

[1] ANSI/AIAA G-043A-2012, "*Guide for the Preparation of Operational Concept Descriptions*," American National Standards Institute, American Institute of Aeronautics and Astronautics (sponsor), 2012.

[2] "ISO/IEC/IEEE 29148:2018 Systems and Software Engineering – Life Cycle Processes – Requirements Engineering," International Organization for Standardization, 2018.

[3] MSE Project Team, "MSE Concept of Operations MSE.PO.MGT.DOC-MGT-014," (unreleased) 05 March 2020.

[4] MSE Project Team, "Operations Concept Document MSE.PO.ENG.DOC-REQ-002," 12 October 2018.

[5] GIRMOS Project Team, "GIRMOS Concept of Operations v10," 15 July 2020.