Systems engineering applied to ELT instrumentation: The GMACS case

D. M. Faes*[a], A. Souza[b], C. Froning[c], L. Schmidt[d], D. Bortoletto[b], [e], E. Cook[d], D. L. DePoy[d], T.-G. Ji[f], D. Jones[g], H.-I. Lee[f], J. L Marshall[d], C. M. Oliveira [a], S. Pak[f], C. Papovich[d], T. Prochaska[d], R. A. Ribeiro [a], K. Taylor[h]

[a]Departamento de Astronomia, IAG, Universidade de São Paulo; [b]Universidade Federal de Minas Gerais; [c]McDonald Observatory, University of Texas at Austin; [d]Department of Physics and Astronomy, Texas A&M University; [e]Instituto Mauá de Tecnologia; [f]School of Space Research, Kyung Hee University; [g]Prime Optics; [h]Instruments4.

Abstract

An important tool for the development of the next generation of extremely large telescopes (ELTs) is a robust Systems Engineering (SE) methodology. GMACS is a first-generation multi-object spectrograph that will work at visible wavelengths on the Giant Magellan Telescope (GMT). In this paper, we discuss the application of SE to the design of next-generation instruments for ground-based astronomy and present the ongoing development of SE products for the GMACS spectrograph, currently in its Conceptual Design phase. SE provides the means to assist in the management of complex projects, and in the case of GMACS, to ensure its operational success, maximizing the scientific potential of GMT.

GMACS and spectroscopy on the ELT's

GMACS (Giant Magellan Telescope Multi-object Astronomical and Cosmological Spectrograph) is a multi-object optical spectrograph (MOS). Its main driving objective is to enable spectroscopy of targets that are currently only visible through images, like primordial stars and high-redshift galaxies. The construction of MOS instruments for the ELTs has a number of challenges: to Scale Up to keep Field of View (FoV), reach Competitive Resolution and Spectral Coverage, High Mechanical Stability, High Throughput and Integration with AO Capabilities. The concept for GMACS encompasses two modes of operation, summarized by Table 1. In sequence the applied SE tools are described.

Mode	Slit Mask	MANIFEST
Science	UV	IFUs
	High Throughput	Large FoV

Table 1. GMACS two main modes of operation and the characteristics favorable accordingly to the scientific cases.

Top Down Approach

The Top-down approach is a way of managing and designing the project so that engineers can address first architectural aspects of the project without focus on detail. As more information becomes available, details will be addressed in the design. To start this SE seeks to capture all subsystems necessary;

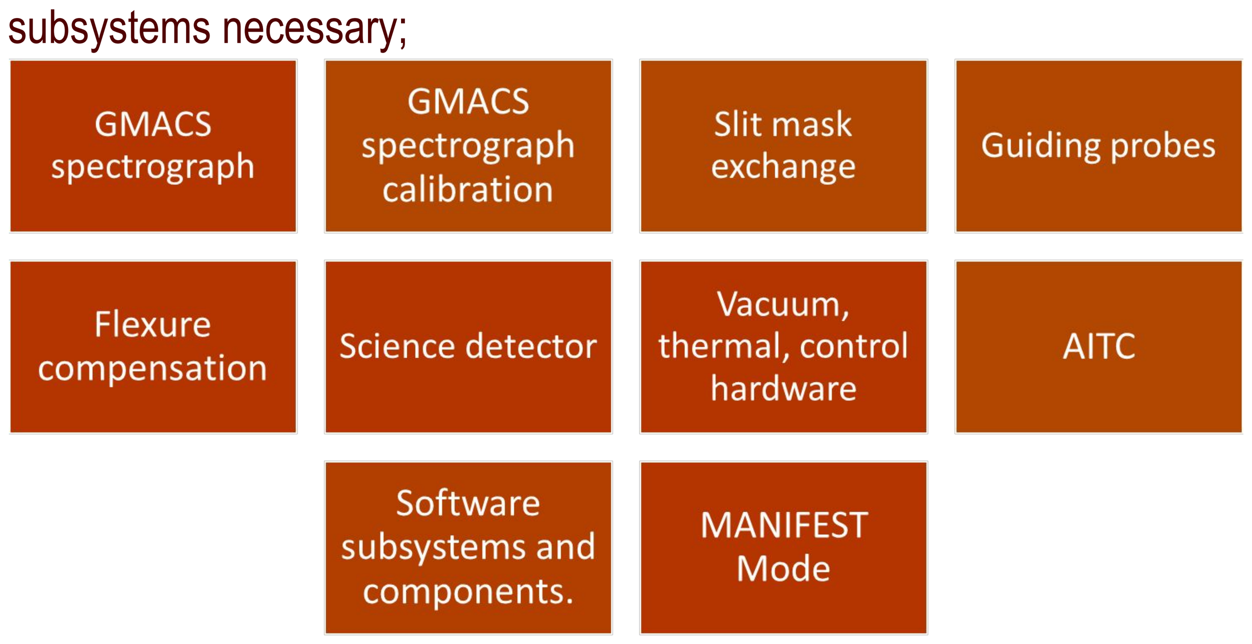

Figure 1. GMACS Functional Architectural Decomposition shows all capabilities the instrument has to fulfill

Requirements Traceability and Flow-Down

The requirements flow-down for GMACS starts from the identification of scientific cases, operational aspects and constraints imposed by the observatory, see Figure 2. From these, the first flow-down is written and the initial requirements that will guide the technical team captured.

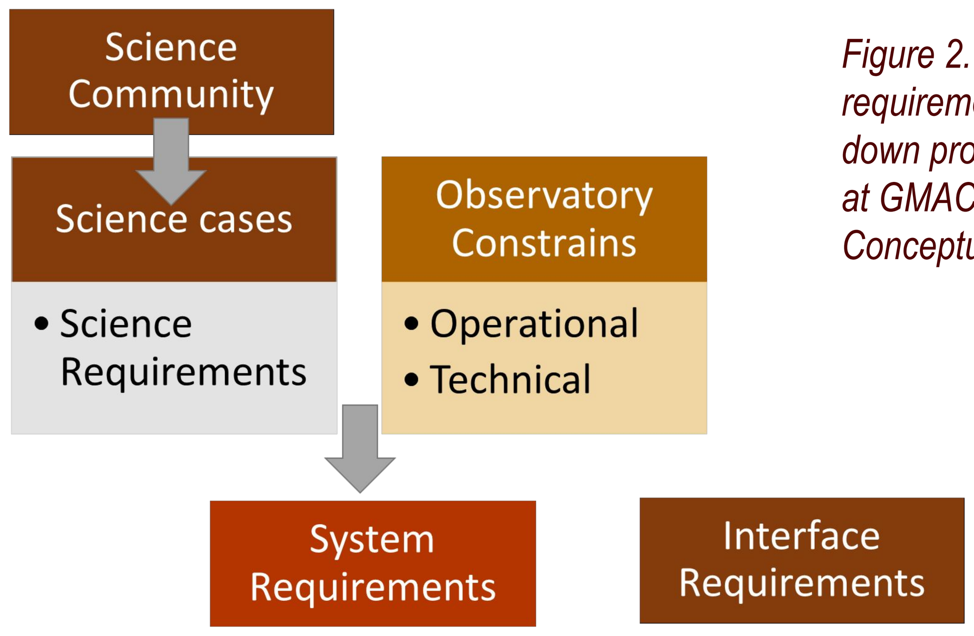

Figure 2. System requirements flow down process used at GMACS Conceptual Design

To date, we have captured almost a hundred requirements, classified as architecture, interface, and performance types, see figure 3. For the architecture requirements we have captured constraints, functions or quality aspects. For the interface requirements, constrains with the observatory, telescope, and other instruments. For the performance type we have requirements that concern instrument performance and can be directly linked to design solutions.

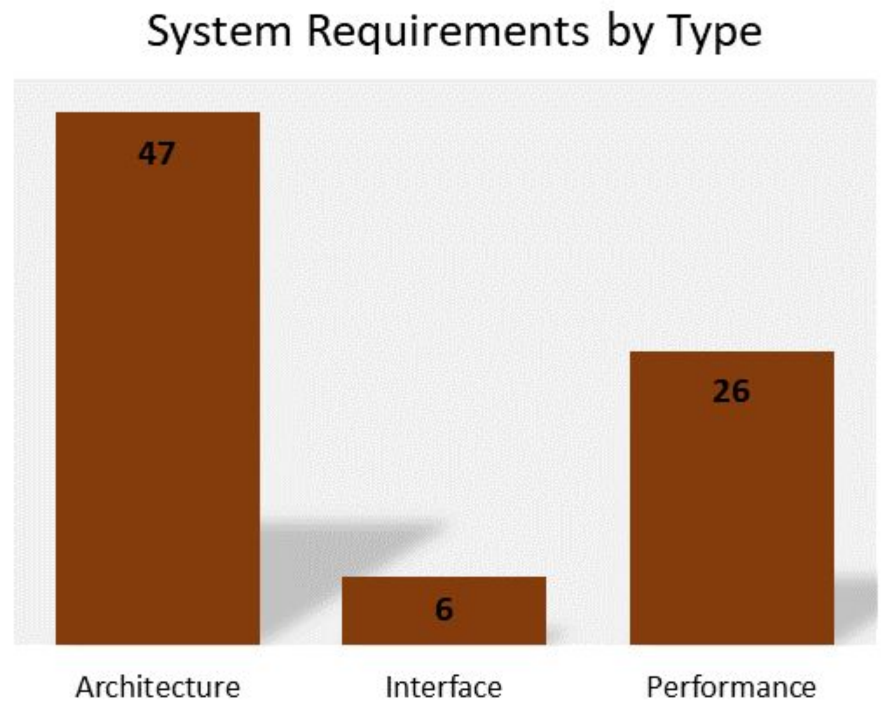

Figure 3. System requirements count from current Concept Design classified by type

Interfaces

The Interface is one of the most challenging aspects that SE deals with. It requires communication, organization, discipline and broad understanding of the overall aspects of the system, its subsystems, operation and environment, as illustrated in the context diagram in Fig. 4.

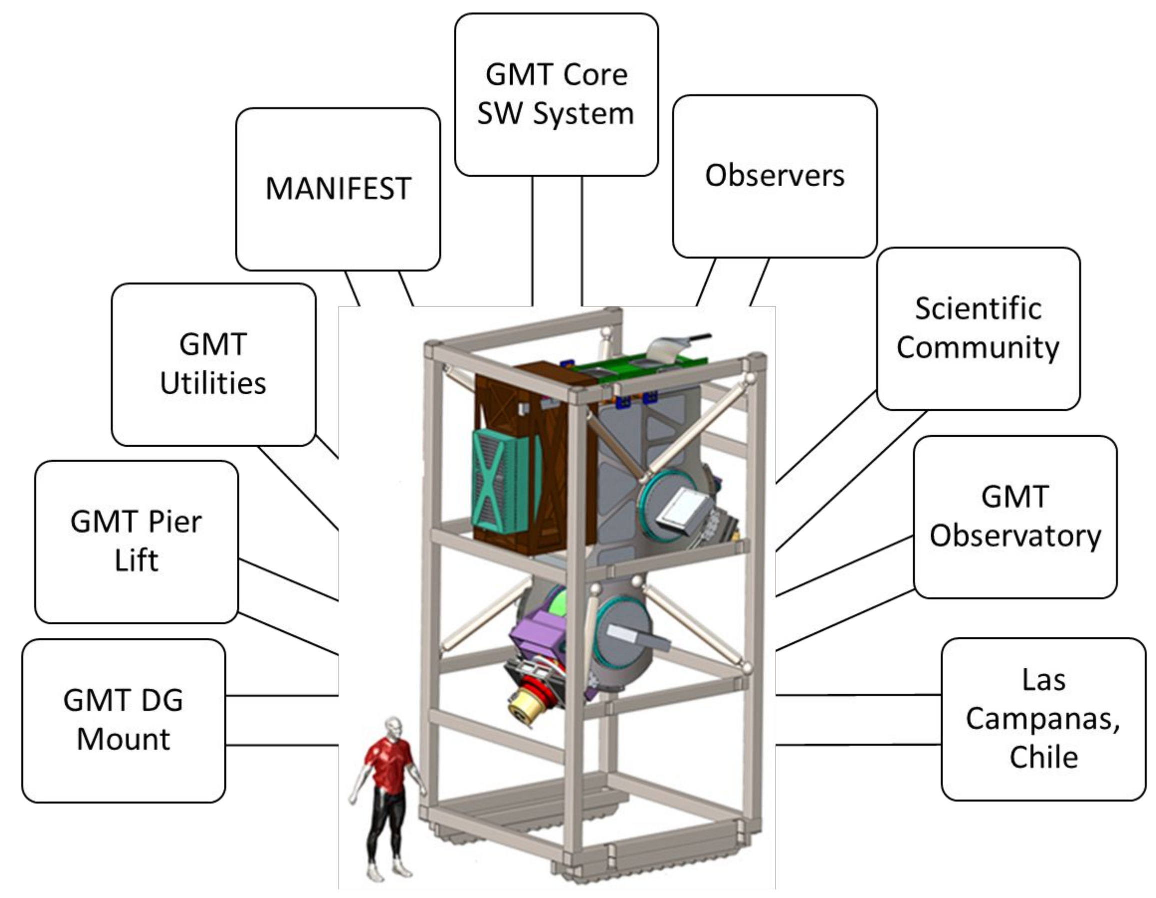

Figure 4. Context Diagram illustrates the broad aspects of GMACS interfaces.

Risk Management

Risk Management for GMACS uses the same approach as GMT, only adapted for scaled scope, at metrics for cost and schedule impacts and likelihood. Following that approach, all risks are classified as technical, cost, and schedule and have the impacted requirement traced to it. When applied at conceptual design, such as GMACS, the awareness of the risks allows to mitigate most of them during the trade-off and decision process. For GMACS, the expectation at the end of the conceptual design is to have all risks in the green area (Figure 5), meaning that the risk will be much more manageable.

Risk Likelihood	Low (1)	Minor (2)	Moderate (3)	Substantial (4)	High (5)
Very Likely (E)	Low	Medium	High	High	High
Likely (D)	Low	Medium	Medium	High	High
Possible (C)	Low	Low	Medium	Medium	High
Unlikely (B)	Low	Low	Low	Medium	Medium
Very Unlikely (A)	Low	Low	Low	Low	Medium
	Risk Impact (Technical/Cost/Schedule)				

Figure 5. Example of risk matrix to identify and visualize the evolution of the risks. The higher the likelihood, more probable is its occurrence; the higher the impact, the greater the (negative) consequence in the project.

GMACS Next Phases

GMACS is finalizing its conceptual design and achieving its deliveries. After approval, GMACS will go through phases that will be supported by SE process and practices. At Preliminary Design, robust risk management will continuum, system requirements will be refined, interface descriptions will be detailed, analysis will be done to understand quality and hazard aspects, and verification and validation plans will be improved. At Critical Design, operational aspects will be detailed and finalized regarding process and integration. At Manufacturing Readiness, quality assurance and safety plans are established. At Test Readiness, Pre-Shipment and Site Acceptance system engineers overseas the process, ready to mitigate issues if necessary.

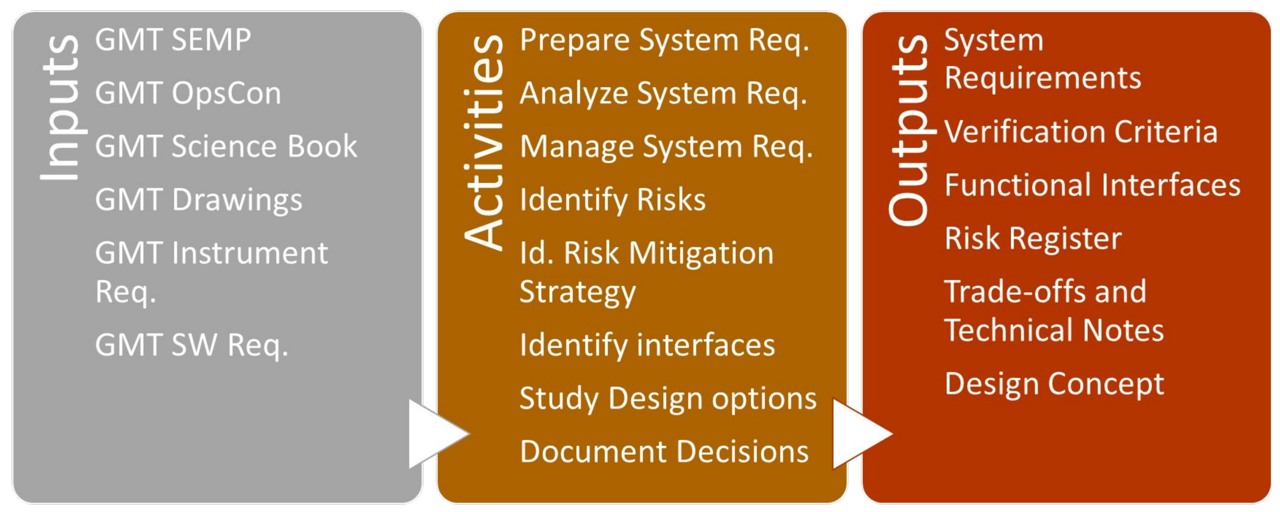

Figure 6. Example of risk matrix to identify and visualize the evolution of the risks. The higher the likelihood, more probable is its occurrence; the higher the impact, the greater the (negative) consequence in the project.

Final Remarks

This work pointed out how SE methods can assist the development of complex projects and maximize the scientific potential of big experiments, such as the ELTs. This is contextualized within SE processes recommended by GMT for GMACS.

References

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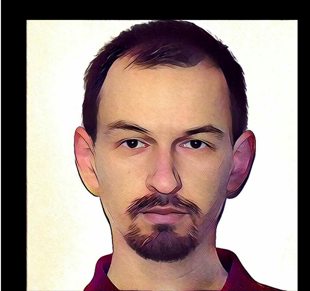

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