E-ELT requirements flow down

J.C. Gonzalez*, H. Kurlandczyk, C. Schmid, D. Schneller
European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748-Garching b. München, Germany

ABSTRACT

One of the critical activities in the systems engineering scope of work is managing requirements. In line with this, E-ELT devotes a significant effort to this activity, which follows a well-established process. This involves optimally deriving requirements from the user (Top-Level Requirements) through the system Level 1 Requirements and from here down to subsystems procurement specifications.

This paper describes the process, which is illustrated with some practical examples, including in particular the role of technical budgets to derive requirements on subsystems. Also, the provisions taken for the requirements verification are discussed.

Keywords: requirements, specifications, procurement, verification, compliance

1. INTRODUCTION

The several subsystems of the E-ELT are specified, designed and built by different entities (programme members and external companies or consortia of institutes) and at different timescales. E-ELT systems engineering has to ensure that all the subsystems match together as a single system meeting the top-level user requirements. At the same time, minimizing the risk of overruns in cost or schedule, which might originate from the lack of a system perspective and proper configuration control, is also a must.

As an essential duty to fulfil these objectives, systems engineering performs as the coordinator of the engineering activities. This includes in particular developing the system architecture, performing system-level trade-offs and leading the system-level engineering decision process, identifying and solving issues that transversely affect more than one subsystem, as well as providing support to the work package managers in system related issues.

As part of the system architecting process, systems engineering decomposes the whole system in several subsystems that, as already said, have to match each other in order to fulfill the user needs; such a decomposition follows mainly technical (i.e., functional) criteria but sometimes also attends to programmatic aspects. Properly specifying these subsystems (that are procured separately) as well as the interfaces between them, and keeping all the requirements under control is not an easy task, in particular when dealing with a very complex system like the E-ELT. A significant effort is devoted to this activity, which follows a well-established process. The goal is to optimally derive requirements from the user (Top-Level Requirements) through the system Level 1 Requirements and from here down to subsystems procurement specifications. A prominent aspect of the requirements management process is linking the requirements that are stated at the several levels, i.e., Level 1 Requirements are linked to Top-Level Requirements and subsystems requirements are linked to Level 1 Requirements. Linking the requirements is fundamental for configuration control since facilitates getting a more precise understanding of the impact that change requests may have at different levels of the system.

*jcgonzal@eso.org; phone +49 89 32006641; www.eso.org

Defining the right requirements applicable to each contract and making sure that these requirements are met are critical steps of the E-ELT adopted systems engineering approach. Ensuring that the right requirements are defined is the objective of review of requirements, which is thoroughly undertaken before releasing any procurement process. Checking that the requirements applicable to a given procurement are met by the contractor is the goal of the verification management process, which is spread out along the lifecycle of the procurement. Minimum verification methods (i.e., design, analysis, inspection and/or test) as well as specific verification constraints and temporal milestones on which verification evidence has to be provided are defined for every requirement.

The requirements management process is assisted by DOORS® software tool, which keeps record of the linking information, the rationale behind the requirements and the verification information associated to every requirement.

This paper describes the requirements management process, which is illustrated with some practical examples. The emphasis is made on the flowing-down of requirements. To help in understanding this process, the E-ELT documentation tree, showing the relationship between the several requirements specifications at different levels, is presented. Particular attention is given to the Level 1 Requirements specification, which is the highest level engineering document describing the actual baseline of the E-ELT. To provide the complete picture a short overview of its parent document (Top-Level Requirements) and of a typical (child) specification is given.

The special role of the technical budgets as tools to manage the Level 1 Requirements and to derive requirements on subsystems is also addressed. To better understand this role a summary of the technical budgets that are maintained at system level is given and the use of the budgets based on a particular case is explained.

In addition, the way the requirements specifications are reviewed as the final step before releasing for procurement is explained. To close the process, the provisions taken at system and subsystem level for the verification of requirements along the several milestones of the procurement contracts are discussed.

2. REQUIREMENTS FLOW-DOWN PROCESS

Figure 1 shows how the requirements flow-down process is performed. Apart from the top-down flow a bottom-up consolidation of requirements is done. This forms part of the design and relies on analyses, feasibility studies as well as Front-End Engineering Design (FEED) studies and inputs from industry in response to Request for Information procedures lunched by the E-ELT programme office. Consolidation of requirements is critical to come out with feasible specifications.

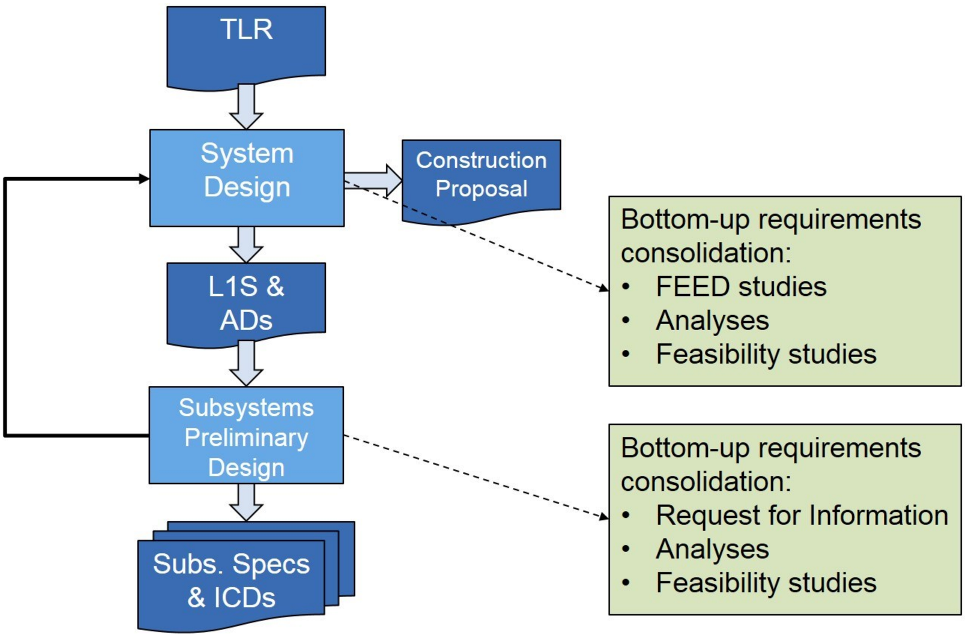


Figure 1. Requirements flown-down process. TLR: Top-Level Requirements. L1S: Level 1 Requirements Specification. ADs: Applicable Documents. ICDs: Interface Control Documents. FEED: Front-End Engineering Design.

As a result of the above process Figure 2 shows a complete view of the E-ELT documentation tree. This diagram helps in understanding how requirements flow-down is performed, since it shows the relationship between the several requirements specifications at different levels.

At the very top of the diagram one finds the E-ELT Observatory Top Level Requirements (TLR) which collects the needs of the E-ELT users. These are not only the ESO members' astronomy community but also the personnel in charge of running the facility in the Observatory. This document is intended to be quite stable in time, as it is proven by the fact that version 1 was released in July 2008 and version 2, the current one, in July 2012. It is a relatively simple document whose structure is shown in Figure 3. The several Instrument Top Level Requirements documents complement the Observatory TLR (as part of the level 0 documentation) by defining the user needs regarding the individual instruments.

The Observatory TLR document was the input for the system design phase of the E-ELT, whose trade-offs and adopted solutions were compiled in the Construction Proposal (upper right corner in the diagram). The latter was intended to be a document oriented to get the E-ELT programme approved by the ESO governing bodies and therefore was not conceived as a formal requirements specification of the system. To play this role, the E-ELT Level 1 Requirements Specification (L1S) was produced. It is the highest-level engineering document that specifies the high-level design constraints and requirements applicable to the construction phase of the E-ELT, as well as the operational assumptions considered in the design. As such, the L1S provides the reference against which the compliance of the E-ELT system at the end of the construction phase will be verified. By translating the TLR into the system-level engineering requirements, the L1S develops further the user needs and therefore the document becomes more complex than the TLR. The structure is presented in Figure 4.

Apart from the L1S, the level 1 documentation is composed of a number of applicable documents to the former, as for instance the Technical Budgets, Optical System Specification, Wavefront Control Plan, Environmental Specification, E-E-ELT Standards, etc.

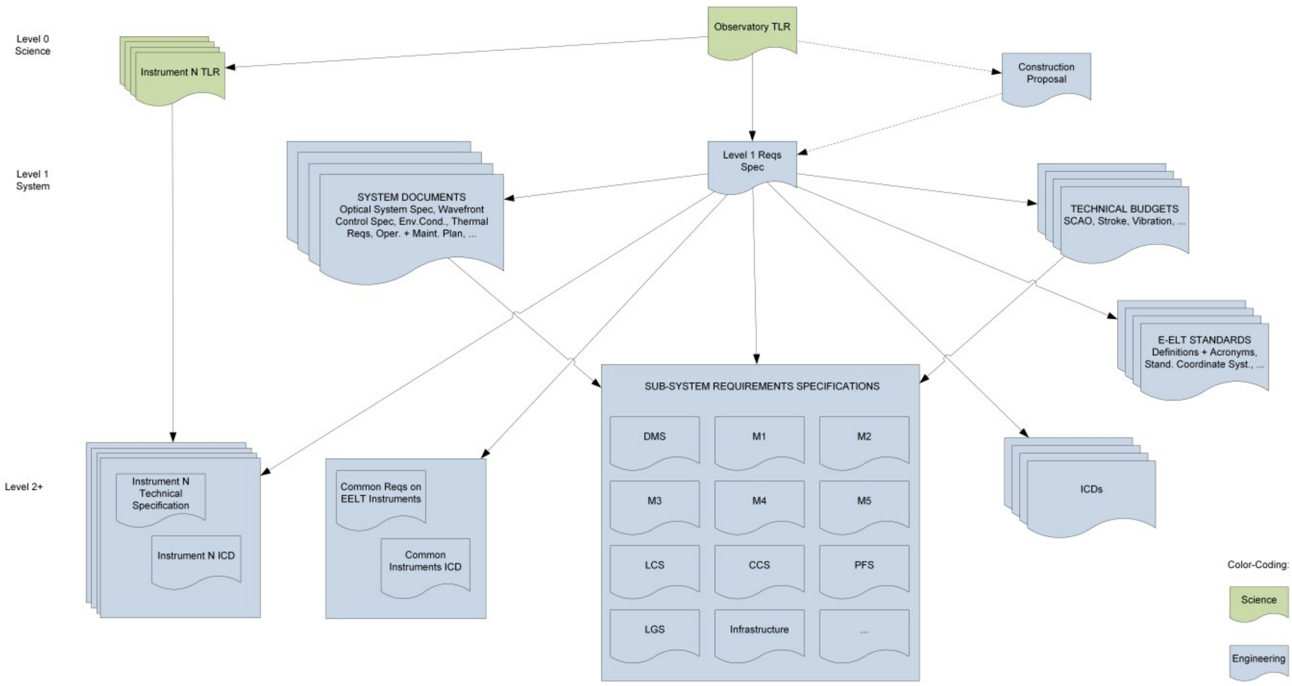
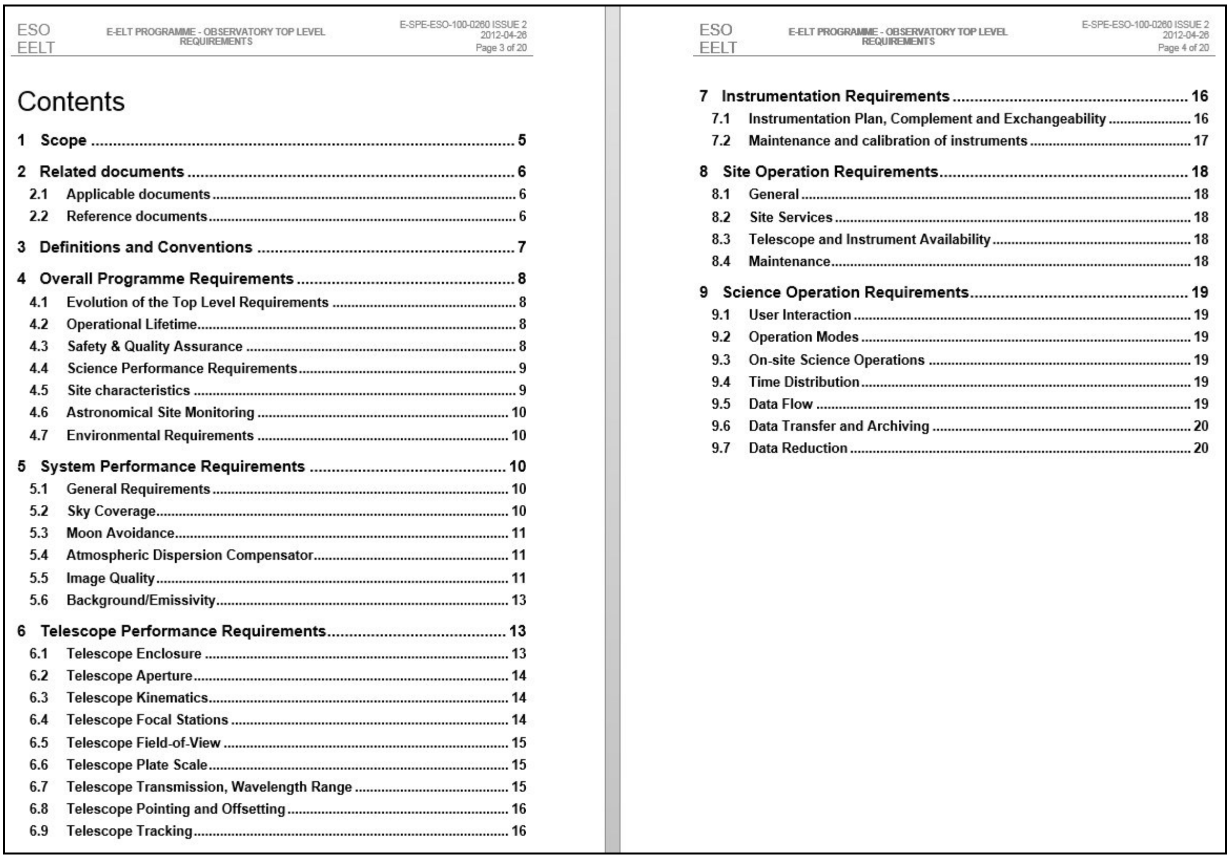


Figure 2. E-ELT documentation tree.



ESO EELT — E-ELT PROGRAMME - OBSERVATORY TOP LEVEL REQUIREMENTS — E-SPE-ESO-100-0260 ISSUE 2 — 2012-04-26 — Page 3 of 20

Contents

ESO EELT — E-ELT PROGRAMME - OBSERVATORY TOP LEVEL REQUIREMENTS — E-SPE-ESO-100-0260 ISSUE 2 — 2012-04-26 — Page 4 of 20

Figure 3. Structure of the E-ELT Observatory Top Level Requirements.

Down in the tree, belonging to the level 2 documentation and derived from the level 1 documents, one finds the various sub-system requirements specifications and the Interface Control Documents (ICDs). Both are the technical basis for procuring the several subsystems and along with the managerial requirements defined in the statement of work and the contract constitute the main set of documents for acquiring the said subsystems.

E-ELT Level 1 Requirements Specification

Doc. Number: ESO-264149
Doc. Version: 1
Released on: 2016-03-21
Page: 3 of 98

Contents

E-ELT Level 1 Requirements Specification

Doc. Number: ESO-264149
Doc. Version: 1
Released on: 2016-03-21
Page: 4 of 98

Figure 4. Structure of the E-ELT Level 1 Requirements Specification.

2.1 Example: Nasmyth platforms physical characteristics

To illustrate the requirements flow-down process the section in the TLR document defining the user needs regarding Nasmyth platforms physical characteristics is presented in Figure 5:

6.4.1 Nasmyth platform and focal stations

146	Each Nasmyth platform shall provide: 1. simultaneous access for at least three instruments to the telescope focal plane
147	2. free space (in particular, back-focal distance) around the focal plane to satisfy the instruments' needs
148	3. a total surface of the platform available for instruments of at least 120 m^2
149	4. clearance of at least 7 m in height
150	5. support for instruments up to 66 metric tons in total.

Figure 5. Section on Nasmyth platforms physical characteristics in the E-ELT Observatory Top Level Requirements.

Following the outcomes of the system design, the derived requirements in the L1S are presented in Figure 6. One of these requirements refers to drawing AD37 that fully specifies the minimum volume to be made available to the instruments in the Nasmyth platforms; this is shown in Figure 7. Note that as per the E-ELT standards a document (or drawing) being applicable to another one means that the contents of the former are an inclusion in the latter and therefore remain as an integral part of it.

6.3.4 Hosting instruments at several locations around the Nasmyth focal planes

[R-L1S-659] /// The telescope shall provide room to host at least one instrument plus a post-focal AO capability (that can be part of the instrument or stand-alone) per Nasmyth focal station (note that each Nasmyth platform has three focal stations).

[R-L1S-660] /// The minimum volume available for instruments in each Nasmyth platform shall be as specified in AD37.

[R-L1S-661] /// The minimum back-focal distance (distance from the focal plane to the last mechanical surface of the telescope in the direction of the optical axis) shall be 1000mm.

Figure 6. Section on Nasmyth platforms physical characteristics in the E-ELT Level 1 Requirements specification.

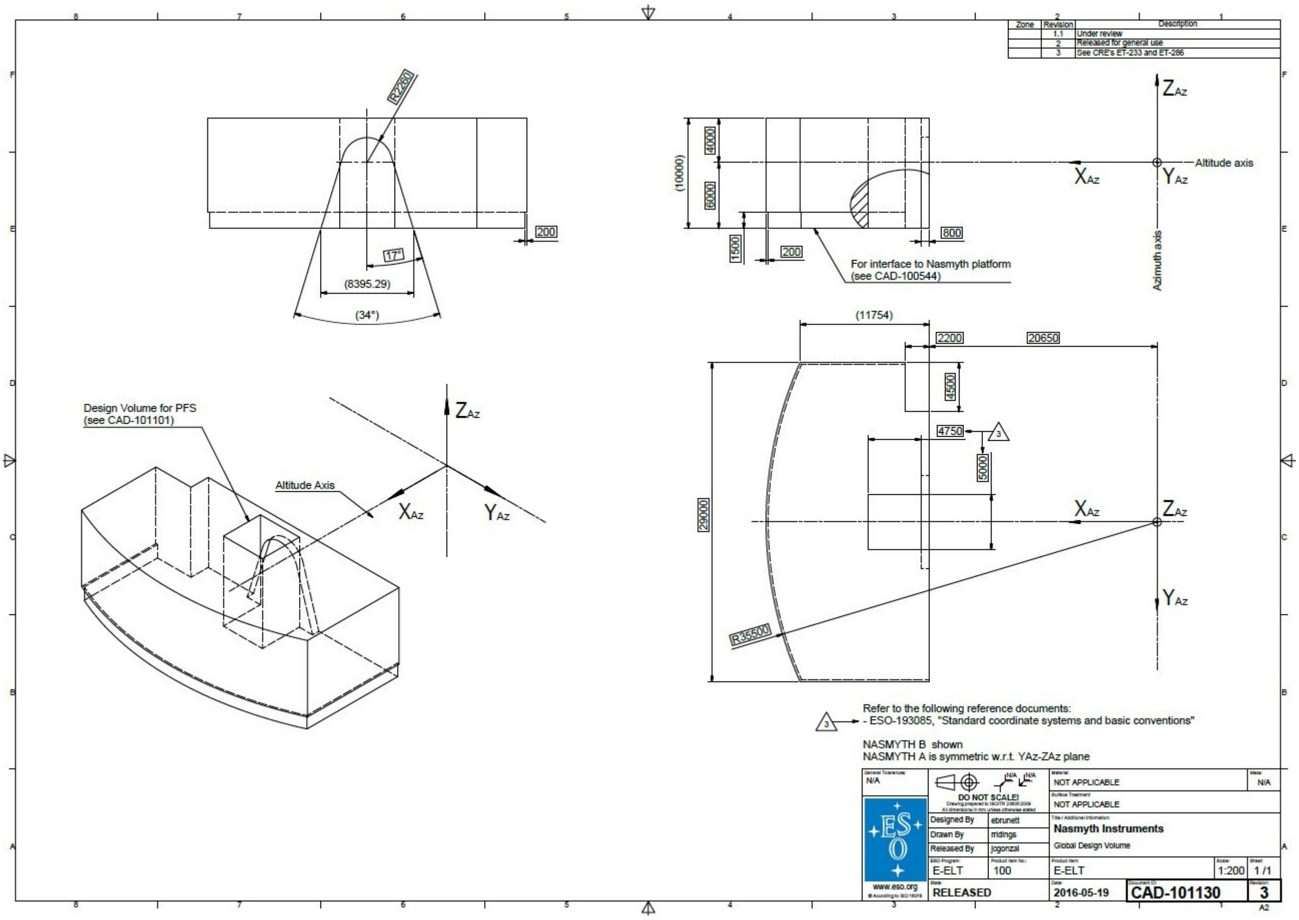


Figure 7. Applicable drawing (AD37) to E-ELT Level 1 Requirements Specification showing the design volume available for instruments in the Nasmyth platforms.

To close the requirements loop, all the information discussed above is incorporated into the DOORS® database: both the TLR and the L1S are modules forming part of the database; the flowing-down relationship between the requirements in the TLR (parent) and in the L1S (child) modules is implemented by means of links, as presented in Figure 8.

ID	Text	In Links	Out Links
658	**6.3.4 Hosting instruments at several locations around the Nasmyth focal planes**		
659	The telescope shall provide room to host at least one instrument plus a post-focal AO capability (that can be part of the instrument or stand-alone) per Nasmyth focal station (note that each Nasmyth platform has three focal stations).		**/E-ELT/Formal Documents/TLRs/Observatory Top Level Requirements:** Object 146. Object Text: Each Nasmyth platform shall provide: 1. simultaneous access for at least three instruments to the telescope focal plane 2. free space (in particular, back-focal distance) around the focal plane to satisfy the instruments' needs 3. a total surface of the platform available for instruments of at least 120 m2 4. clearance of at least 7 m in height 5. support for instruments up to 66 metric tons in total.
660	The minimum volume available for instruments in each Nasmyth platform shall be as specified in AD37.		**/E-ELT/Formal Documents/TLRs/Observatory Top Level Requirements:** Object 146. Object Text: Each Nasmyth platform shall provide: 1. simultaneous access for at least three instruments to the telescope focal plane 2. free space (in particular, back-focal distance) around the focal plane to satisfy the instruments' needs 3. a total surface of the platform available for instruments of at least 120 m2 4. clearance of at least 7 m in height 5. support for instruments up to 66 metric tons in total.
661	The minimum back-focal distance (distance from the focal plane to the last mechanical surface of the telescope in the direction of the optical axis) shall be 1000mm.		**/E-ELT/Formal Documents/TLRs/Observatory Top Level Requirements:** Object 146. Object Text: Each Nasmyth platform shall provide: 1. simultaneous access for at least three instruments to the telescope focal plane 2. free space (in particular, back-focal distance) around the focal plane to satisfy the instruments' needs 3. a total surface of the platform available for instruments of at least 120 m2 4. clearance of at least 7 m in height 5. support for instruments up to 66 metric tons in total.

Figure 8. Section of the E-ELT Level 1 Requirements module in the DOORS® database showing the parent requirements (right column) from where the level 1 requirements (left column) have been derived.

The flowing-down process does not stop at the level 1 requirements. After completing an additional step in the E-ELT design that normally corresponds to preliminary design (or phase B), the subsystems are ready to be specified for procurement. The parent-children requirements relationship goes now from L1S down to subsystems specifications and ICDs (level 2 in Figure 2). Figure 9 shows the requirements in the Common ICD between the Instruments and the rest of the E-ELT that have been derived from the corresponding parent requirements in L1S (Figure 6 and Figure 7).

7.2 Design Volume

[INFO-INS/ELT-233]	The design volume allocated to individual instruments will be specified in the corresponding instrument technical specification.
[I-INS/ELT-234] D/A/I/	No element of a Nasmyth Instrument shall extend beyond its design volume.
[I-INS/ELT-235] D/A/ /	The requirements for design volumes shall be valid in any operational configurations and any survival conditions (earthquake loads, wind load, etc.).
[I-INS/ELT-236] D/ /I/	With the exception of specifically designated access paths, the requirements for design volumes shall apply during installation and removal of the instrument and during maintenance.
[I-INS/ELT-237] /A/ /	The interface areas on the Nasmyth platform shall be assumed rigid when verifying that internal deflection of each Nasmyth Instrument under loads will not violate its design volume constraint.

Figure 9. Section in the Common ICD between the Instruments and the rest of the E-ELT stating the requirements on design volume that have been derived from the corresponding parent requirements in L1S.

This is complemented by the following drawing, from which the individual design volume allocated to every instrument is defined in the corresponding technical requirements specification.

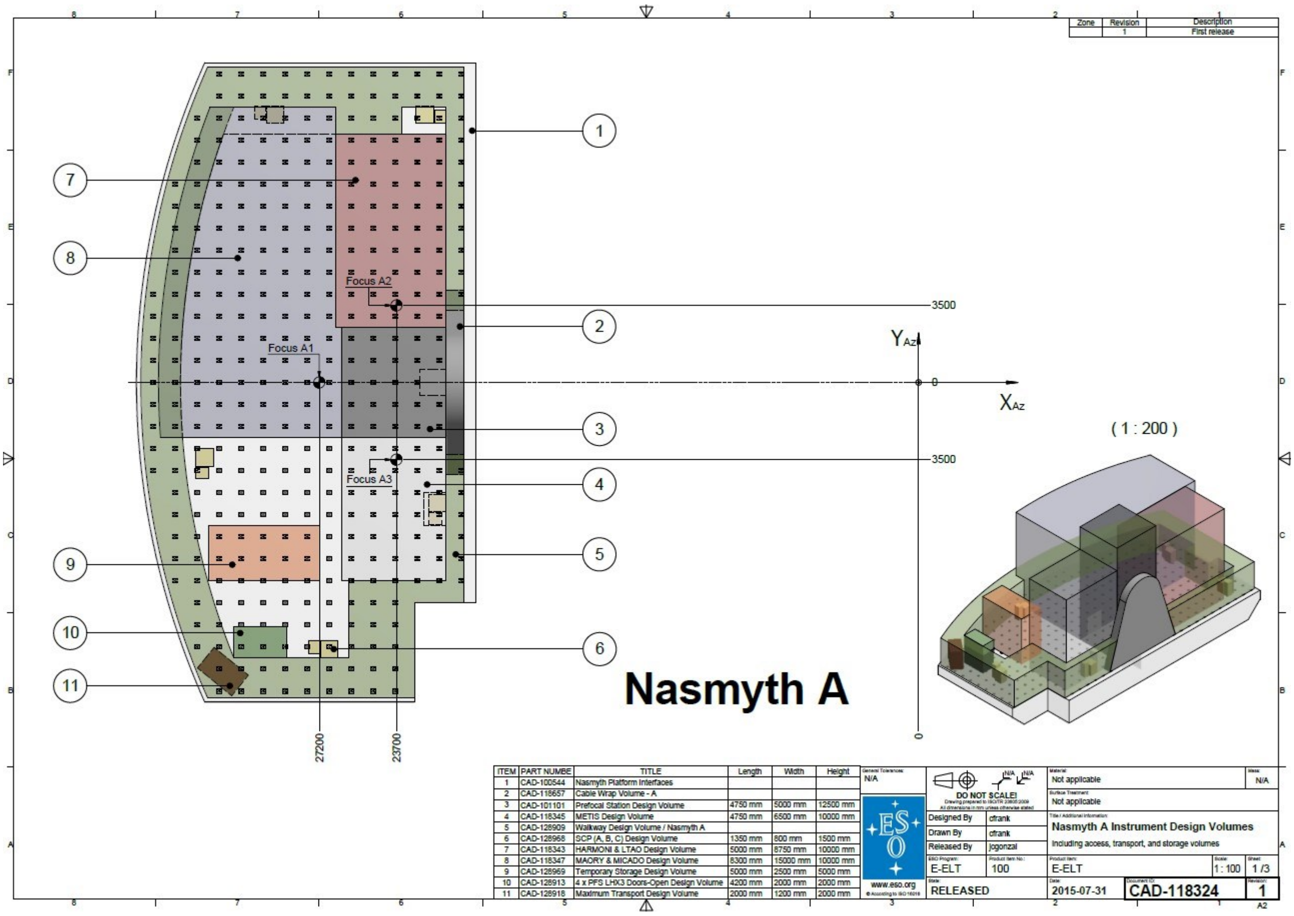


Figure 10. Allocation of design volume to the several instruments in Nasmyth A.

Just a final remark here: as can been seen in Figure 4, the L1S document contains a section stating the system requirements (section 4) and another one devoted to subsystems requirements (section 6). In many cases, the latter are derived from the former, meaning that there are parent-children relationships between the requirements in L1S document. An example is shown in Figure 11.

ID	Text	In Links	Out Links
787	**6.6 Dome Requirements**		
788	This section defines the requirements on the dome functions listed in section 2.4.4.		
789	**6.6.1 Telescope Sheltering**		
790	The dome shall consist of a fix part and a rotating part, the latter allowing unobstructed pointing of the telescope in any direction within the observing range specified in[R-L1S-638] and [R-L1S-639].		
791	The rotating part of the dome shall have an observing slit (able to be closed) allowing unobstructed pointing of the telescope in any direction within the observing range specified in [R-L1S-638].		
792	Even in case of normal power supply failure, the observing slit shall be able to completely close in no more than 12 minutes in operational conditions and less than 15 minutes in functional conditions (see section 3.1).		**/E-ELT/Formal Documents/SPEs/E-ELT Level 1 Requirements Specification:** Object 478. Object Text: The complete normal shut-down sequence needed to bring the E-ELT from its night-time configuration to its daytime configuration shall take not more than 15 min. **/E-ELT/Formal Documents/SPEs/E-ELT Level 1 Requirements Specification:** Object 479. Object Text: The emergency closing sequence needed to bring the E-ELT from its night-time configuration into a safe configuration (telescope protected from the outside environment) shall take not more than 15 min in case of main power supply failure and 17 min in case of backup power system failure.
793	Even in case of backup power supply failure, the observing slit shall be able to completely close in no more than 14 minutes in operational conditions and less than 17 minutes in functional conditions (see section 3.1).		**/E-ELT/Formal Documents/SPEs/E-ELT Level 1 Requirements Specification:** Object 479. Object Text: The emergency closing sequence needed to bring the E-ELT from its night-time configuration into a safe configuration (telescope protected from the outside environment) shall take not more than 15 min in case of main power supply failure and 17 min in case of backup power system failure.
794	The observing slit shall be able to completely open in no more than 12 minutes in operational conditions and less than 15 minutes in functional conditions (see section 3.1).		**/E-ELT/Formal Documents/SPEs/E-ELT Level 1 Requirements Specification:** Object 477. Object Text: The complete normal start-up sequence needed to bring the E-ELT from its daytime configuration to its night-time configuration shall take not more than 15 min.

Figure 11. Requirements flow-down within the E-ELT Level 1 Requirements document.

3. THE ROLE OF THE TECHNICAL BUDGETS

To help in managing the process of flowing down the critical level 1 requirements and to facilitate their allocation to the E-ELT subsystems, a number of technical budgets have been prepared. The list is presented In Table 1.

Table 1. List of technical budgets.

Name	Number
Technical Budget - M1 Segment Assembly Outgassing (SAO)	ESO-281097
Technical Budget - Segment Exchange Time (SGX)	ESO-264206
Technical Budget - Daytime Maintenance Access (MTC)	ESO-264205
Technical Budget - Emissivity and Stray Light (STY)	ESO-264204
Technical Budget - Polarization (PLZ)	ESO-264202
Technical Budget - Data Archive (DTA)	ESO-264201
Technical Budget - Instrument and Focus Switch Time (ISW)	ESO-264199
Technical Budget - Power Consumption (PWC)	ESO-264198
Technical Budget - Data Transfer (DTT)	ESO-264197
Technical Budget - Shimming (SHI)	ESO-254487
Technical Budget - MCAO Performance (MCA)	ESO-242324
Technical Budget - SCAO Performance (SCA)	ESO-242323
Technical Budget - Low-Order Optimization (LOO)	ESO-242322
Technical Budget - Seeing (SEE)	ESO-242321
Technical Budget - Heat Dissipation and Cooling Capacity (HTC)	ESO-242319
Technical Budget - Mass Balance (MAS)	ESO-242317
Technical Budget - Pupil Alignment and Stability (PPL)	ESO-242316
Technical Budget - Plate Scale (PLS)	ESO-242315

Technical Budget - Presetting and Acquisition (ACQ)	ESO-242314
Technical Budget - Optical Throughput (THR)	ESO-242313
Technical Budget - Vibration (VIB)	ESO-242311
Technical Budget - Optical Collision (OCL)	ESO-242310
Technical Budget - RAM (RAM)	ESO-242309
Technical Budget - Offsetting and Nodding (OFF)	ESO-242308
Technical Budget - Active Optics Positioning "Stroke Budget" (STR)	ESO-242307
Technical Budget - AO Loop Latency (LAT)	ESO-239910
Technical Budget - PACT Stroke (PAC)	ESO-239909
Technical Budget - Tracking (TRK)	ESO-239573
Technical Budget - Field Stabilisation (FST)	ESO-239572
Technical Budget - Blind Pointing (PNT)	ESO-239566
Technical Budget - Blind Alignment (BLI)	ESO-239565

To illustrate how technical budgets are used, the case of the “blind” image quality is discussed. L1S document states the following requirement:

The telescope shall deliver blindly (i.e., LOO control layer not running), after calibration, at the telescope wavefront sensing a geometric spot diameter less than 3 arcsec.

The technical budget prepared to help in allocating this requirement is shown in Table 2. Each row corresponds to an item that is then allocated to a certain characteristic of a given subsystem and the corresponding requirement in the subsystem requirements specification is stated. Since the total budgeted value is below the requirement it means that a contingency is in place, even if not explicitly stated in the table.

In order to establish the connection from the L1S to the subsystem requirement specifications the budgets are also kept in the DOORS® database. This allows defining a link from the level 1 requirement to the budgets items and from there to the subsystems requirements.

Table 2. Blind image quality technical budget.

Identifier	Budget Item	Image Quality (arcsec)
[TB-BLI-30]	Image quality degradation due to main axes pointing error	<0.001
[TB-BLI-31]	Image quality degradation due to main structure deformation	2.22
[TB-BLI-32]	Image quality degradation due to main structure deformation, uniform temperature M2-M1 only	1.07
[TB-BLI-33]	Image quality degradation due to main structure non-repeatable deformation	0.8
[TB-BLI-34]	Image quality degradation due to main structure ARU relocation accuracy	<0.001
[TB-BLI-35]	Image quality degradation due to main structure PFS deflection	0.02
[TB-BLI-36]	Image quality degradation due to M2 hexapod positioning error	0.65
[TB-BLI-37]	Image quality degradation due to M3 hexapod positioning error	0.02
[TB-BLI-38]	Image quality degradation due to M4 hexapod positioning error	<0.001
[TB-BLI-39]	Image quality degradation due to M5 positioning error	<0.001
[TB-BLI-40]	Image quality degradation due to M4 focus selection	<0.001
[TB-BLI-41]	Image quality degradation due to M5 focus selection	<0.001
[TB-BLI-42]	Image quality degradation due to M1 blind shape	0.6
[TB-BLI-43]	Image quality degradation due to M2 blind shape	0.01
[TB-BLI-44]	Image quality degradation due to M3 blind shape	<0.001

[TB-BLI-45]	Image quality degradation due to M4 blind shape	<0.001
[TB-BLI-46]	Image quality degradation due to M5 blind shape	<0.001
[TB-BLI-47]	Image quality degradation due to catalogue errors	n/a
[TB-BLI-48]	Image quality degradation due to repair free earthquake	<0.001
[TB-BLI-49]	Image quality degradation due to atmospheric turbulence	<0.001
[TB-BLI-50]	Image quality degradation due to internal main structure metrology	n/a
[TB-BLI-51]	**RSS**	**2.74**

4. REVIEW AND VERIFICATION OF REQUIREMENTS

4.1 Review of requirements

Once the flowing-down process concerning a particular subsystem is completed and the technical requirements specification draft is finished it is submitted to a thorough review aiming to ensure that the right product is specified ('is this what we really need?') and that the product is specified correctly ('do we communicate correctly what we need?'). To this end, the requirements must be complete (all the needed requirements, in particular the critical ones, has to be considered), feasible, properly formulated (metrics and boundary conditions well defined, non-ambiguous or subject to interpretation, understandable, non-incompatible and non-redundant) and verifiable (in particular, attention needs to be given to the verification methods and verification requirements).

In addition, the review aims to identify the requirements that are major cost drivers, the ones that are not sufficiently justified (i.e., they do not add any value to the product) and those contributing to significantly increase the technical risk. This allows optimizing the technical requirements specification before releasing the procurement.

The review of requirements specifications are conducted following a well-defined procedure which is based in a RIX process (Reviewer Item X, X being a comment, question, discrepancy or whatever else). Reviewers raise their RIXes which are then replied by the team in charge of the specification document and resolved when needed by the corresponding work package manager along with systems engineering.

4.2 Verification of requirements

Verification of requirements process checks whether the requirements applicable to a given procurement are met by the contractor. Minimum verification methods (i.e., design, analysis, inspection and/or test) as well as specific verification constraints are stated in the corresponding requirements specification. Based on this, once the contract is already in place, a compliance matrix template is provided to the contractor. This template normally defines also temporal milestones on which verification evidence has to be provided for every requirement. Based on all of this the concerned contractor produces a verification plan that has to be approved by the E-ELT programme office. The verification plan includes a verification matrix that shows the methods and milestones planned by the contractor. Any deviation from the constraints established in the compliance matrix template have to be highlighted and agreed with the E-ELT programme office. Figure 12 shows an excerpt of several parts of a verification matrix.

Based on the verification matrix (which in turn is based on the compliance matrix template provided by the E-ELT programme office) the contractor delivers an updated compliance matrix at each agreed milestone (Figure 13 shows an excerpt of a compliance matrix). It is the key document showing the status of compliance along the several procurement phases. It refers to the documented proof of compliance for every requirement and has to be very specific in this respect, i.e., has to unequivocally refer to the paragraph in the document where compliance is demonstrated. The last delivery of the compliance matrix, by the time of the subsystem acceptance, should obviously reflect compliance to all the requirements.

Requirement Tag	Requirement Text	Design	Analysis	Inspection	Test	Serial Prodcution (Optional)	Remarks
		Milestone	Milestone	Milestone	Milestone	This column serves to define on which item the test will be done	
[R-M4-98] D/ / /	Component with high risk of breakage to be evaluated by the Contractor and reviewed by ESO shall be packed in specifically designed boxes.	PDR-4w					
	3.5.2 M4 Unit in transport and box storage						
[R-M4-101] D/A/ /	In the transport, the M4 Unit shall be packed in dedicated transport boxes and handled as normal freight.	PDR-4w	PDR				
[R-M4-102] D/A/ /T	Very fragile components shall be transported with special handling and transport restrictions	PDR	PDR-4w		FDR-2w SRR	Test on #1, #2	Test will be done first on prototype at FDR and later on final prodcut at SRR
[INFO]	In the present document, unless otherwise specified the term *stroke* refers to the end result of activating the specified degree of freedom. For example, the *stroke* of an alignment mechanism does not necessarily refer to the stroke of the corresponding actuator(s), but to the total alignment range of the concerned item. Similarly, the *stroke* of a deformable mirror is not the stroke of the underlying actuators, but the total permitted deformation range of the mirror itself.						
	6. Design and Construction						
	6.1 General						
[R-M4-403] D/ / /	General requirements related to design and construction found in AD9 shall be applicable for all the sub-systems of the M4 Unit including auxiliary equipment.	PDR	PDR		FDR		
	1.1 Coordinate systems						
	Projects shall define unequivocal coordinates systems. Coordinates systems shall follow the right-hand rule. Where this is not possible (e.g. coordinates systems after optical propagation), explicit warning shall be given and transformation matrices provided.	PDR					
	8. Tools						
[R-CSD-33] D/ /I/	MATLAB/Simulink shall be used for the analysis of control systems (e.g. for performance assessment analysis and to support the definition of control algorithms).	PDR-2w		Inspect. not forseen			Inspection not required
[R-CSD-380] D/ /I/	Control algorithms developed with a numerical computing environment, which are to be integrated into control applications, must be done so using available cross-language support tools (e.g. mathscript nodes in LabVIEW).	PDR-2w		PDR			

Figure 12. Excerpt of several parts of a verification matrix.

5. CONCLUSIONS

Requirements management is one of the most critical processes in the scope of E-ELT systems engineering. Properly specifying the several parts of the system for procurement from industry and from consortia of institutes (in the case of the instruments) as well as properly following up compliance of the deliveries to the requirements is of paramount importance for the success of the E-ELT programme. As part of this process, flowing-down requirements from top level documents to subsystems specifications is crucial for the system to meet the user needs. This involves bottom-up consolidation of requirements that aims to specify feasible solutions and that fundamentally relies on information provided by industry.

Requirement Tag	Requirement Text	Compliance	Design				Analysis				Inspection				Test				Serial Prodcution (Optional)	Result (Optional)	CRE, RFW, NC	Remarks
		C-N/C-TBD-N/A	Milestone	Document	Version	Section	Milestone	Document	Version	Section	Milestone	Document	Version	Section	Milestone	Document	Version	Section	This column serves to define on which item the test will be done	This column could be used to add the achieved value or range.	Doc. Reference	
M4 Technical Requirements (ESO-32003)																						
[R-M4-98] D/ / /	Component with high risk of breakage to be evaluated by the Contractor and reviewed by ESO shall be packed in specifically designed boxes.	C	PDR-4w	6004	1	8																
	3.5.2 M4 Unit in transport and box storage																					
[R-M4-101] D/A/ /	In the transport, the M4 Unit shall be packed in dedicated transport boxes and handled as normal freight.	C	PDR-4w	6004	1	8	PDR	6008	1	8												
[R-M4-102] D/A/ /T	Very fragile components shall be transported with special handling and transport restrictions	C	PDR	6004	1	8	PDR-4w	6008	1	8					FDR-2w SRR	5003 5003	2 3	3 3	Test on #1, #2			Test will be done first on prototype at FDR and later on final prodcut at SRR
[INFO]	In the present document, unless otherwise specified the term *stroke* refers to the end result of activating the specified degree of freedom. For example, the *stroke* of an alignment mechanism does not necessarily refer to the stroke of the corresponding actuator(s), but to the total alignment range of the concerned item. Similarly, the *stroke* of a deformable mirror is not the stroke of the underlying actuators, but the total permitted deformation range of the mirror itself.	N/A																				
	6. Design and Construction																					
	6.1 General																					
[R-M4-403] D/ / /	General requirements related to design and construction found in AD9 shall be applicable for all the sub-systems of the M4 Unit including auxiliary equipment.	C	PDR	6004	1	8																
Mechanical Standards (ESO-192984)																						
	1.1 Coordinate systems																					
	Projects shall define unequivocal coordinates systems. Coordinates systems shall follow the right-hand rule. Where this is not possible (e.g. coordinates systems after optical propagation), explicit warning shall be given and transformation matrices provided.	C	PDR	6010	1	8																
Control System Development Standards																						
	8. Tools																					
[R-CSD-33] D/ /I/	MATLAB/Simulink shall be used for the analysis of control systems (e.g. for performance assessment analysis and to support the definition of control algorithms).	C	PDR-2w	6004	1	8					Inspect. not forseen											Inspection not required
[R-CSD-380] D/ /I/	Control algorithms developed with a numerical computing environment, which are to be integrated into control applications, must be done so using available cross-language support tools (e.g. mathscript nodes in LabVIEW).	N/C	PDR-2w	6004	1	8					PDR	6007	1	8							CRE-365 NCR-340923	

Figure 13. Excerpt of several parts of a compliance matrix.