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E-ELT PROGRAMME

GENERAL DEFINITIONS AND BASIC CONVENTIONS RELATED TO INTERFACES

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Change record

Issue	Date	Section / Paragraph affected	Reason / Initiation Documents / Remarks
1	19/03/2012	All	First issue.
2	2013-04-02	§2	AD's and RD's issue numbers updated to latest issue
		§3	Bullets related to mass characteristics added in Table1
			Caption added to Table1 and table 2
		§4	Bullet#5 & 6 modified to remove specific reference to Main Structure.
		§5	First bullet: added '*...under nominal gravity load...*'
		§5	ADC and AOCU added in exception
		§10	Chapter 10 related to corrosion protection of matting surfaces added
		§11.1	Second bullet added
			4th bullet: '*... except if otherwise specified in the subsystem specifications*' added.
		§12	Chapter 12 related to mass characteristics added
		§13.2.3.2	Details added (simultaneous measurement with relative phase)
		§14	'*...section 3.3 of RD1*' replaced by *'...section 3.3 of AD5 of RD1*'

Contents

Abbreviations

See applicable document AD1 (see section 2.1 herein for references of applicable documents).

1 Scope

This document provides general definitions and basic conventions applicable to the description of inter-subsystem interfaces for the E-ELT project.

The current version does not cover yet definitions and conventions related to interfaces between subsystem local control systems and Telescope Control System (TCS). These may be added in future issue.

2 Applicable documents

2.1 Applicable documents

The following applicable documents form a part of the present document to the extent specified herein. In the event of conflict between applicable documents and the content of the present document, the content of the present document shall be taken as superseding.

AD1 Common definitions and acronyms
ESO-193178 Issue 5 (E-SPE-ESO-313-0066)

AD2 Standard Co-ordinate Systems and Basic Conventions
ESO-193058 Issue 5 (E-SPE-ESO-313-0102)

2.2 Reference documents

RD1 Design Specification for Electrical Systems
ESO-193871 Issue 3 (E-SPE-ESO-304-0051)

3 Classification of interfacing subsystems

Physically interfacing subsystems (i.e. those having a volume, a mass and a mechanical interface as opposed to pure logical subsystems such as software modules) can, in general, be classified in the categories defined in Table 1 below.

Category	Definition	Main functions/responsibilities (unless otherwise specified)
A **(carrier)**	Holds/carries subsystem B against gravity	1. Provides mechanical interfaces within the specified tolerances 2. Provides connection points for supplies (electricity, fluids, control signals, etc.) 3. Provides cable trays/feed through for cables between connection points and subsystem B 4. Ensure that subsystem B with its given mass characteristics can be safely carried in all circumstances with the specified performances (static and dynamic).
B **(passenger)**	is carried by subsystem A, i.e. it would fall down if subsystem A was not present.	1. Adapt to the interface provided by subsystem A and provides adjustment means, if necessary, to place itself to its nominal position. 2. Provides fastening elements (bolts, nuts, pins, etc.) necessary to fix subsystem B on subsystem A. 3. Provides specific tools for installation/removal, if necessary 4. Provides cables, flexible hoses and the like from the supply connection point(s) to its internal components. 5. Ensure that its complies with its given mass characteristics

Table 1: Categories of interfacing subsystems

Note: the above scheme intends to provide a default definition of the main roles/responsibilities valid for most cases. However, exceptions can occur (e.g. the PFS is a subsystem A when it interfaces with a rotating instrument attached to the PFS rotator but the SCP is provided directly by the Main Structure, not by the PFS).

Examples of pairs A/B are given in Table 2 below:

Subsystem A	Subsystem B
Dome – Telescope concrete Foundation	Main Structure
Main Structure	Hosted units: M1 to M5 Units, PFS, Instruments
M2 Cell	M2 mirror

Table 2: Examples of pairs A/B of interfacing subsystems

4 Design Volumes

The design volume of a given subsystem is defined as follows:

1. No element of the concerned subsystem shall extend beyond its design volume
2. No other subsystem shall intrude inside that design volume
3. The two above statements shall be valid in any operational configurations (e.g. rotation angles or extension of mechanisms, cover or slit open or closed, etc) and any survival conditions (earthquake loads, wind load, etc.) of the concerned subsystem(s).
4. Violation of design volumes may be acceptable (subject to ESO approval) if unavoidable for maintenance activities.
5. Unless specified differently elsewhere, the interface areas on the 'carrier' may be assumed rigid when verifying that internal deflection of the 'passenger' under loads will not violate its design volume constraint.
6. The 'carrier' is responsible to avoid interferences that could result from the relative displacement of the 'passenger' due to the non-infinitely rigid interface areas. The 'passenger' shall be considered as a rigid body but without rigidifying the 'carrier' (e.g. using ANSYS/NASTRAN RBE3 connection elements)

5 Interface geometry

For subsystems attached to the telescope Main Structure, the following applies:

- As a general principle and unless otherwise specified, the geometry of the interface areas and areas defined in interface drawings shall be understood as applicable under nominal gravity load when the telescope is pointing to Zenith (±2º). Exceptions are: telescope at horizon pointing (Alt=0deg.) for ADC, AOCU, M2 and M4 units.

- As a general principle and unless otherwise specified, the geometry of the interface areas defined in interface drawings shall be understood as applicable when the ambient temperature is close (±5ºC) to the median night-time temperature at the site.
- The responsibility of the Main Structure is to provide the interface areas within the tolerances indicated in the relevant interface drawing(s).
- The responsibility of the Subsystem Supplier is to be able to install the subsystem at its nominal position (within the tolerances specified in the relevant document(s)) with the use, if necessary, of adjusting devices, shims, etc.

6 Telescope azimuth and altitude axis

The definition of telescope Azimuth and altitude axes during the design phase as well as during site installation/acceptance is given in AD2.

7 Cabling/piping

Cabling and piping interfaces are usually defined at the level of an intermediate connection point (e.g. a Service Connection Point –SCP-).

As defined in section 3 and unless otherwise specified, subsystem A shall provide the connection point as well as cable/pipe trays, routings and feed-through from the connection point until an entry point of the design volume of subsystem B. On the other hand, subsystem B shall provide and install the actual cables/pipes from the connection point to the subsystem B, using the above-mentioned cable/pipe trays, routing and feed-through.

8 Fastening elements

As defined in section 3 and unless otherwise specified, subsystem B shall provide the fastening elements (bolts, nuts, pins, etc.) that connects both subsystems together.

9 Access to interface areas

As a matter of principle, the access to all interface areas shall be provided by the subsystem A ‘supporting’ or ‘hosting’ to other subsystem B. For example, i) the Dome that supplies the telescope concrete pier shall provide access to the interface area with the Telescope Main Structure (azimuth tracks), ii) the Main Structure that hosts the various mirror units shall provide access to all interface areas of each mirror units or other hosted units.

Any deviation from this principle, either waiving or adding an access requirement to interface areas, shall be subject to a specific written agreement between ESO and both subsystems suppliers.

For some cases (e.g. PFS, Instruments…), access to attachment areas completely covered by the subsystem B after installation (e.g. attachment areas on the Nasmyth platform) may require access from inside the design volume of subsystem B.

10 Corrosion protection of mating surfaces

All interfacing (mating) surfaces shall be either corrosion insensitive (corrosion proof over the interface lifetime) or protected (applied protection matching, without damage, its performance requirements).

11 Interface stiffness

11.1 General principle

Unless otherwise specified, the following basic assumptions apply concerning interface stiffness characteristics:

- The design and analysis activities of Subsystem A shall take into account the presence of subsystem B, as a minimum, as a mass (moment of inertia) located at the worst-case center of gravity location and attached in a way that does not stiffen subsystem A.
- In case the subsystem B transfers the load only along dedicated directions (e.g. an hexapod like system), this shall be considered in the way the subsystem B mass is attached to subsystem A. For example on a hexapod system, the 6 fixed pivot points and the hexapod leg directions define how the forces are transmitted to the interface flanges. The force direction should be considered at least for the rigid body motions in operational conditions, the earthquake accelerations of the subunit, the stiffness of the subunit and the load capacity of the flanges.
- In specific cases to be defined by ESO (e.g. when eigen-frequencies of both subsystems overlap and risk of cross-coupling is high), Subsystem A shall incorporate a representative FE model of subsystem B (see §11.3).
- The design and analysis activities of Subsystem B shall take into account the presence of subsystem A either by assuming infinitely rigid interface stiffness (e.g. for verifying eigen-frequency requirements or computing internal deformations, except if otherwise specified in the subsystem specifications) or by using the simplified interface stiffness characteristics described in section 11.2 below (e.g. for verification of vibration requirements).

- In specific cases to be defined by ESO (e.g. when eigen-frequencies of both subsystems overlap and risk of cross-coupling is high), Subsystem B shall incorporate a representative FE model of subsystem A (see §11.3).

11.2 Simplified interface stiffness characteristics

Whenever necessary, the stiffness at the level of a mechanical interface is defined in a simplified manner by global and local stiffness values defined as follows:

A unit force (1N) is applied at the center of gravity of subsystem A in each direction X, Y, Z successively. This force is transmitted to each interface area between subsystem A and subsystem B by means of fictive rigid elements (RBE3 in ANSYS) but without artificially stiffening the interface points.

The global displacement (Δx, Δy, Δz) of the center of gravity of subsystem A is monitored and the ratio (Fx/Δx, Fy/Δy, Fz/Δz) is computed to define the **global stiffness** in each direction.

In addition, the maximum deviation (δx, δy, δz) from the best fit rigid body motions of the interface areas is monitored in order to define the in-plane and out-of plane deformation of the interface area pattern. These deviations are used to define the so-called **local stiffness** values (in-plane and out-of plane).

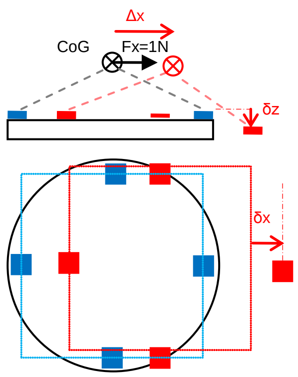


Figure 1: Principle of simplified interface stiffness definition

Note that an interface pattern with only three areas (e.g. for M5 Unit) will always define a best-fit plane and therefore the out-of-plane deformation is always zero.

Except when otherwise explicitly mentioned, interface stiffness values are given with telescope pointing to Zenith.

11.3 Detailed interface stiffness characteristics

Whenever necessary (e.g. dynamic cross-coupling, specific load cases needed for hexapod design,…), a representative FE model of one of the two interfacing subsystems shall be used by the other subsystem. Such model shall be formally defined (as part of the interface definition) and kept under configuration control by ESO.

12 Mass characteristics

The mass interface characteristics includes:

- Mass (maximum and minimum)
- Coordinate of the Center of gravity (CoG) with respect to specified coordinate system
- Moment of inertia with respect to specified coordinate system
- (if relevant, the principal moments of inertia and their orientation with respect to specified coordinate system)

The associated responsibilities of the interfacing subsystems are defined in Table 1.

13 Vibration interface requirements

13.1 General

The level of vibration acceptable at an interface is defined in terms of the **Power Spectral Density (PSD) of the acceleration (S_a)** as it would be 'measured' (averaged over 30 sec) by an accelerometer attached to any of the interface area between the two concerned subsystem.

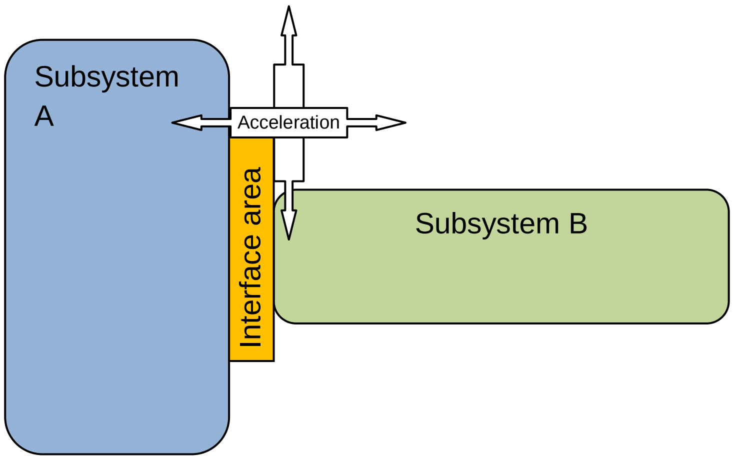


Figure 2: Principle of vibration level interface definition.

An example of interface requirement is shown below:

Vibration level	*The power spectral density (PSD) of the acceleration at any point of the interface due to vibrations generated by either the Main Structure or the Manipulator shall be ≤ 5e-3 g/√Hz in the frequency range 1-200Hz. (during operation of the crane) and ≤ 5e-6 g/√Hz in the frequency range 1-200Hz during the integration of the segment assembly (crane not moving).*

Table 3: Example of interface requirement related to vibration.
Note the unit conversion: S_{acc} $[(m/s^2)^2/Hz] = (S_{acc}$ $[g/\sqrt{Hz}] \times 9.81$ $[m/s^2])^2$.

This acceleration PSD is applicable to <u>both</u> *interfacing subsystems* in terms of <u>both</u> '*emission'* and *immunity'*. In other words, any of the two subsystems shall not create vibrations exceeding the specified PSD and both of them shall be able to withstand the specified level without any impact on functionality, performance, operation, maintenance, etc.

The 'emission' part of the requirement can also be expressed as follows: the difference between the acceleration PSD 'measured' with i) subsystem A switched ON and B switched OFF and ii) both switched OFF shall not exceed the specified level (subsystem A responsibility). The same holds for the difference with i) subsystem A switched OFF and B switched ON and ii) both switched OFF (subsystem B responsibility).

This can be represented by the following relations:

$$\begin{cases} S_{Subsystem\ A} = S_{A=ON,B=OFF} - S_{A=B=OFF} \leq S_{\text{vibration interface requirement}} \\ S_{Subsystem\ B} = S_{A=OFF,B=ON} - S_{A=B=OFF} \leq S_{\text{vibration interface requirement}} \end{cases}$$

where

S denotes the Power Spectral Density (PSD) of the acceleration at the interface in $[g^2/Hz]$ or $[(m/s^2)^2/Hz]$

Note that the requirement is expressed in terms of acceleration (second derivative of the displacement) of the interface areas and neither in terms of force nor energy introduced on the interface. In the simplified analysis or test procedures (see below), the conversion from acceleration to force and vice versa can be done using the global interface stiffness value.

13.2 Verification method ('emission' part)

The verification method(s) shall be defined on a case by case basis in the technical specifications and/or in the verification plans of the concerned subsystem. Due to the difficulty of simulating accurately vibration sources and transmission, preference shall be given to verification by test (preferably on-site). In any case, the verification method(s) shall be approved by ESO.

13.2.1 By Design

When a subsystem does not have any active element and cannot, by principle, generate any vibration even passively (e.g. due to wind buffeting on flexible elements of the subsystem), the vibration interface requirement can be considered verified by design.

13.2.2 By Analysis

Whenever a subsystem is likely to generate vibration at its interface with other subsystems (to be discussed and approved with ESO), verification by analysis shall be considered.

13.2.2.1 Simplified procedure

A possible simplified procedure is the following:

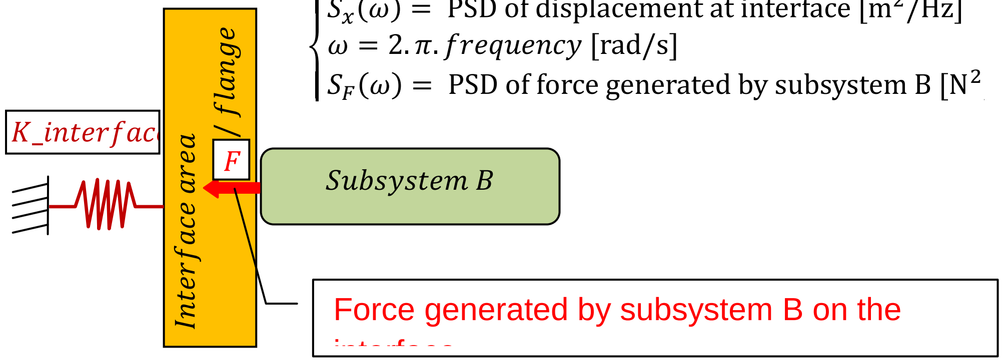
1. Assess the disturbance force applied at the interface by the subsystem as a function of frequency:
$$S_F = \text{ PSD of disturbance force in } [N^2/Hz]$$
2. Use the interface global stiffness values given in the relevant ICD to compute the associated displacement:
$$S_x(\omega) = \text{ PSD of displacement in } [m^2/Hz\ ] = \frac{S_F(\omega)}{K\_interface^2}$$
3. Convert the displacement into acceleration at the level of the interface area:
$$S_a(\omega) = \text{ PSD of acceleration in } [(\mathrm{m}/s^2)^2/Hz] = S_x(\omega) \times \omega^4$$
4. Compare with the requirement.

The analysis shall be performed in the frequency range 1-200Hz as a minimum.

$$S_a(\omega) = S_x(\omega) \cdot \omega^4 = \frac{S_F(\omega)}{(K_{interface})^2} \cdot \omega^4$$

Where

$$\begin{cases} S_a(\omega) = \text{PSD of acceleration at interface } [(\mathrm{m}/s^2)^2/\mathrm{H} \\ S_x(\omega) = \text{PSD of displacement at interface } [\mathrm{m}^2/\mathrm{Hz}] \\ \omega = 2.\pi.frequency \ [\mathrm{rad/s}] \\ S_F(\omega) = \text{PSD of force generated by subsystem B } [\mathrm{N}^2 \end{cases}$$



13.2.2.2 Detailed procedure

For critical cases (to be defined by ESO on a case by case) a more precise procedure shall be applied whereas the PSD of the disturbance force applied by subsystem B at the interface shall be directly input to the Finite Element Model (FEM) of the subsystem A in order to compute the acceleration PSD at the interface (and possibly the ultimate impact on relevant global performance).

Whenever the ranges of eigen-frequencies (relevant for vibration) of the interfacing subsystems are overlapping and the risk of cross-coupling is high, the vibration analysis should be performed on a global FEM combining both subsystems.

13.2.3 By test

13.2.3.1 Test in the laboratory

A possible simplified test procedure is the following:

1. Suspend the subsystem B on very soft springs/cables
2. Measure the acceleration at the level of the interface during representative operational conditions
3. Convert the acceleration into force knowing the total (suspended) mass of the subsystem.
4. Apply the analysis method described above in section 13.2.2.

13.2.3.2 Test on site

For critical cases (to be defined by ESO on a case by case) a detailed on-site measurement procedure shall be applied.

This procedure shall consist of simultaneous accelerometer measurement at the level of the interface using high-sensitive accelerometer (with internal noise ≤ 1/10 of the vibration requirement to be verified). This shall include the relative phase information as measured on each interface areas in order to derive overall displacement and tilt of the set of interfaces.

The measurement shall be performed in all relevant operational conditions. The background noise (when the subsystem is completely switched OFF) can be subtracted for the raw measurement.

13.3 Verification method (‘immunity’ part)

The verification that the subsystem is immune to the specified vibration level at the interface shall be carried out by design, analysis and/or test depending on the criticality of the vibration issue at subsystem and system level. The verification method shall be proposed by the relevant subsystem designer/builder and shall be approved by ESO.

14 EMC requirements

EMC definitions, requirements and verification methods are defined in section 3.3 of AD5 of RD1.