D09188

INSTRUMENTATION DIVISION

Next Generation detector Controller

Requirements

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CHANGE RECORD

ISSUE	DATE	SECTIONS AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
0.1	02-12-2003	All	First draft
0.2	15-12-2003	All	Input from INS; comments from CCU and JRE
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List of Abbreviations

AC	Alternating Current
AD	Applicable Document
ADC	Analog-to-Digital Converter
ADU	Analog-to-Digital Unit
ALMA	Atacama Large Millimeter Array
ASIC	Application-Specific Integrated Circuit
BOB	Broker of Observation Blocks
CAS	Central Alarm System
CCD	Charge-Coupled Device
CMOS	Complementary Metal Oxide Semiconductor
CPL	Common Pipeline Library
CTE	Charge Transfer Efficiency
DC	Direct Current
DFS	Data Flow System
EDA	Electronic Design Automation
EM	Electron Multiplication
ESO	European Southern Observatory
FDR	Final Design Review
FIERA	Fast Imager Control Electronics Readout Assembly
FITS	Flexible Image Transport System
IDL	Interactive Data Language
IR	Infra-Red
IRACE	Infrared Array Controller Electronics
LCU	Local Control Unit
LED	Light-Emitting Diode
LLL	Low Light Level
LRU	Line Replaceable Unit
NGC	Next Generation detector Controller
OS	VLT Observation Software
PDR	Preliminary Design Review
PTF	Pixel Transfer Function
RTD	Real Time Display
TBC	To Be Confirmed / To Be Completed
TBD	To Be Decided / To Be Done
Tcl/Tk	Tool command language / Tool kit
TRS	(VLT) Time Reference System
VLT	Very Large Telescope
VLTSW	VLT control SoftWare

Table of contents

1 Scope

The requirements compiled in this document concern all hard- and software of a future controller ('NGC') to be used with all forthcoming optical and infrared detector systems to be installed at ESO's observatories in the next 10-15 years. The foreseen applications include the recording of scientific data as well as sensing applications. The latter would only exceptionally include autoguiding or other simple supervisory functions for which commercial systems are more cost effective unless exceptionally high performance is needed.

The requirements aim for covering the needs of

- the users of the scientific data, incl. those of intermediate control loops, etc. such as adaptive optics or VLTI fringe tracking,
- operations and maintenance staff at the observatories,
- laboratory applications by detector engineers.

However, their association with one or more of these categories is not normally identified.

A large fraction of the instruments employing NGC will be conceived, designed, built and tested by ESO-external consortia. Their expected requirements also form part of this document.

The document tries to be complete at the top level while towards lower levels it relies progressively on experience gathered with NGC's (very successful) predecessors FIERA and IRACE, on common sense, and on the design review procedure. This appears acceptable because the addressees of this document are soft- and hardware engineers at ESO who all have been deeply involved in the maintenance or design of FIERA or IRACE. It is also expected that the required modularity, scalability and expandability of NGC will permit quite a few details to be handled at the configuration level without causing schedule or budget overruns. However, significant modifications of these requirements specifications will only be implemented following the acceptance of formal change requests.

These requirements specifications are color-blind in that, as far as possible, they do not distinguish between IR and optical requirements, i.e. many requirements result from one wavelength domain only without their origin being identified.

The intention of this document is to refrain from prescribing specific implementations unless explicitly stated otherwise.

Except for general ESO ground rules not intrinsic to detector controllers, no distinction is made between different priority levels. However, if the cost of the realization of a particular requirement turns out to be disproportionately high relative to its presumed benefits or other requirements, a waiver or change should be requested.

This document does not imply a requirement to actually design or build a new detector controller. Such a decision will be made separately.

The name Next Generation detector Controller and its acronym, NGC, are adopted for working purposes only. A more specific product name is TBD.

2 Documentation

2.1 Applicable documents

The following documents of the exact issue shown form part of these Requirements Specifications:

No.	Document Title	Identification	Issue	Date
AD 1	General Safety Requirements for Scientific Instrumentation	VLT-SPE-ESO-10000-0017	2	16.09.92
AD 2	Requirements for Safety Analyses	VLT-TRE-ESO-00000-0467	1	27.07.93
AD 3	VLT Environmental Specification	VLT-SPE-ESO-10000-0004	6	12.11.97
AD 4	VLT Electronic Design Specification	VLT-SPE-ESO-10000-0015	5	06.03.01
AD 5	VLT Electromagnetic Compatibility and Power Quality Specification - Part 1 (Environment)	VLT-SPE-ESO-10000-0002	2	11.03.92
AD 6	VLT Electromagnetic Compatibility and Power Quality Specification - Part 2 (Disturbance)	VLT-SPE-ESO-10000-0003	1	05.02.92
AD 7	VLT Observatory Requirements for Scientific Instruments	VLT-SPE-ESO-10000-2723	0.8	25.01.02
AD 8	VLT Software Requirements Specifications	VLT-SPE-ESO-10000-0011	2	30.09.92
AD 9	VLT Instrumentation Software Specification	VLT-SPE-ESO-17212-0001	2	12.04.95
AD 10	ESO Technical Standards	VLT-SPE-ESO-XXXXX-xxxx	??	??.??.??
AD 11	Directive for Preparation of Acceptance Test Procedures	VLT-INS-ESO-00000-1091	1	12.04.96
AD 12	Reliability Calculation Guidelines	VLT-SPE-ESO-10000-2107	1	30.03.00
AD 13	Handling of Change Requests	VLT-INS-ESO-00000-0863	2	04.01.96
AD 14	Handling of Requests for Waiver	VLT-INS-ESO-00000-0920	1	17.10.95
AD 15	VLT Time Reference System	VLT-MAN-ESO-17300-1580	1	04.03.98
AD 16	Data Interface Control Document	GEN-SPE-ESO-19940-0794	2.0/4	21.05.02
AD 17	Definition of Preliminary Design Phase, PDR Data Package, Preliminary Design Review	VLT-TRE-ESO-00000-0280	1	25.07.92
AD 18	Definition of Detailed Design Phase, FDR Data Package, Final Design Review	VLT-TRE-ESO-00000-0397	1	18.02.93

AD 19	VLT Real Time Display User Manual	VLT-MAN-ESO-17240-0866	2.8	16.05.99
AD 20	VLT HOS / Broker for Observations Blocks User Manual	VLT-MAN-ESO-17220-1332	3	24.03.03
AD 21	Reliability Calculation Guidelines	VLT-SPE-ESO-10000-2107	1	30.03.00

2.2 Reference documents

No.	Document Title	Identification	Issue	Date
RD 1	PULPO Upgrade - Statement of Work	INS-01/0044	N/A	16.10.01
RD 2	Quality Management and Quality System Elements - Guidelines	DIB ISO 9004	1	01.05.90

3 Requirements

3.1 General (project independent)

3.1.1 Standards vs. customized solutions

In each domain, where industry offers widely used off-the-shelf solutions, the non-adoption of any of them requires a specific justification. ☐

Similarly, if existing standard ESO utilities are not sufficient to meet the requirements of NGC, the upgrade of the utilities concerned shall be negotiated. Only if this fails are customized solutions acceptable. ☐

3.1.2 VLT compatibility

The VLT requirements for scientific instruments [AD 7] need to be fulfilled. ☐

3.1.3 Safety

The requirements of [AD 1] and [AD 2] must be strictly satisfied. ☐

3.1.4 Environmental conditions

NGC must be functional under the conditions, and to the extent as, specified in [AD 3]. ☐

3.1.5 Electronic design

The guidelines of [AD 4] and [AD 10] shall be followed. ☐

3.1.6 Electromagnetic compatibility

The conditions established in [AD 5] and [AD 6] shall be met. ☐

3.1.7 Control software

The design shall follow the rules layed out in the compilation provided in [AD 10]. ☐

3.1.8 Quality assurance

Standard ESO quality assurance procedures shall be followed [RD 2]. ☐

3.2 General (project specific)

Except for features not so far used in practice and not mentioned in this document, the capabilities of NGC shall be a superset of those of the combination of IRACE and FIERA. ☐

The quality of the data provided by NGC shall be the one of the applicable detectors.

3.2.1 Breakdown by subsystems

NGC is to be understood to comprise the following subsystems / functions:

- housing
- power supply
- cables

- temperature control of electronics (if any)
- pre-amplifier
- video grabbing/acquisition/digitisation
- video processors (if any)
- bias generators
- clock generators
- sequencer
- communicator
- backplane
- firmware (if any)
- control software
- computers and operating system(s) to support control software
- data pre-processing software
- computers and operating system(s) to support data pre-processing
- external interfaces

To this may be added peripheral devices, e.g., to control shutters or cryostats.

3.2.2 Schedule

A first version of the controller shall be available at the end of 2006. As a minimum, it shall be able to support four of the MUSE spectrographs / detector systems. ☐

By the end of 2007, the minimum requirement is that all applicable functionalities of both FIERA and IRACE are fully supported with at least the same performance. ☐
At least so many copies of the hardware shall be available and tested as the MUSE project needs to progress (incl. spares). ☐

3.2.3 Lifetime

Electronic components shall be selected such as to maximize the chances of copies of NGC still being manufacturable at affordable cost in 2015. ☐

LRUs shall retain their performance for 10 years. ☐

3.2.4 Overall design philosophy

The design phase shall include an end-to-end analysis that identifies the main functions. On this basis, the main subsystems shall be defined along with their interfaces to other subsystems. This layout shall be iterated to reduce the number and complexity of these interfaces in order to reduce the dependencies of each subsystem on the others, giving special attention to throughput.

3.2.5 Modularity and scalability

For every detector system, to which NGC will be applicable, it shall be possible to assemble the controller hardware from a fixed set of standard subsystems (Sect. 3.2.1) which shall also serve as LRUs. ☐
Hardware configuration should be possible by software; only where this is impractical, or protection of the detectors becomes an issue, LRUs may have simple configurators such as jumpers. ☐

It can be advantageous to foresee that certain types of LRUs, such as clock drivers, are realized in different flavors in order to optimally serve special applications; this might include the combination of two or more LRUs into one. However, the number of such sub-types must be kept minimal. Wherever possible, this option should be avoided; add-on modules are preferred.

For complex detector systems, several housings may be required to accommodate the boards needed to support a sufficiently large number of channels. The control software should be unaffected by this as it basically should only need to know the numbers of boards and channels.

The architecture may be either hierarchical or parallel but the relative merits of the proposed solution shall be discussed.

Plug-in methodology for the addition of new software modules, e.g. to support additional detector types or operational modes, shall be utilized.
Likewise, the removal or upgrade of such modules shall not affect other modules.
Common functions shall be compiled to libraries.

3.2.6 Version control

Hard- and software shall be kept under version control.
Except, perhaps, for the first year of operation, new versions shall be synchronized with the VLT software releases.

Every new software version shall support all hardware releases that have not been formally decommissioned.

In any NGC system, it shall be possible to replace every LRU with another one of the same type of any later version unless the former version has been formally decommissioned.

3.2.7 Homogeneity

Replacement of any LRU shall not alter read noise, crosstalk, CTE, linearity, and other critical performance parameters by more than 10%.

3.2.8 Interfaces internal to NGC

Interfaces between NGC subsystems shall be governed by joint control documents. Of particular importance are interfaces between different types of LRUs.

3.2.9 Expandability

Non-core functions can be supplied later, one after the other, according to an NGC development plan. However, they shall be addable without a need for any other modifications of the hard- and software so that full backward compatibility with previous versions is maintained at all times.

3.2.10 Reliability

The expected reliability of NGC shall be estimated following the guidelines in [AD 21].

The actual NGC-induced telescope downtime (incl. mistakes by operations and maintenance staff) shall, averaged over all systems installed, not exceed 3% in the first year after coming into operation and be at most 0.5% after 3 years. ☐

3.2.11 Backward compatibility with predecessor systems

Backward compatibility with the predecessor systems FIERA and IRACE is not a requirement where this would unduly limit progress. However, in principle, NGC shall be able to replace both FIERA and IRACE in existing detector systems. Therefore, interfaces to their corresponding parameter files or a translation utility to NGC's own formats should be considered. ☐

3.2.12 Manufacturing

The electromechanical layout of each LRU shall be made with a strong view towards the manufacturing and electrical testing of a few dozen units by a commercial supplier. ☐

The time needed for the manufacturing of one typical NGC system, from the beginning of the ordering of the components through the completion of the ready-for-use tests, shall not exceed 4 person months. For 5 such systems, this time shall be at most 6 person months. ☐

3.2.13 Maintenance

Preventive maintenance of the hardware shall be restricted to annual inspections, and possible replacements, of hard disks, fans, and similar components. ☐

Software maintenance shall only consist of following the updates of the computer operating system prescribed by the Technology Division. ☐
Incl. testing, this shall not require more than 0.3 FTE per year. ☐
These tasks shall not require developer-level familiarity with the code. ☐

3.2.14 Documentation

Comprehensive documentation shall be prepared for both hard- and software. The maintenance manuals shall (a) enable development engineers to troubleshoot, maintain, and further upgrade NGC and (b) permit maintenance and operations staff at the ESO observatories to optimally configure hard- and software and to resolve problems at this level. ☐

The user manuals shall enable instrument builders to seamlessly integrate hard- and software of ESO-supplied detector systems with their own products. ☐

Lengthy general discussions of the technologies employed should be avoided. Clickable links to relevant internal or external Web documents may be the preferred solution. ☐

Separate user manuals are required for all ancillary utilities. ☐

Documents shall be delivered in an electronic format with standard search capabilities. ☐
Paper copies should have an index. ☐

Documentation for the users of scientific images should not be necessary as NGC should be fully transparent to them. However, detailed recipes are required if special advice is necessary for data processing, e.g. on bias correction over and beyond the simple subtraction of the mean value of a bias frame. ☐

External interfaces, e.g. for signal sensing applications, must be comprehensively documented. ☐

3.2.15 Proto-typing

In key areas, for which technologies are foreseen that have not previously been used at ESO, the building of proto-type subsystems shall be considered. ☐

3.2.16 Parts list

A list of all parts with suppliers and approximate prices shall be maintained already during the design phase. It shall be used as a means to contain the number and diversity of components and to control cost. ☐

3.2.17 Review procedure

Standard ESO procedures for PDR [AD 17] and FDR [AD 18] are to be followed. ESO-external membership on the review panels is desirable.

Check boxes are included throughout this document which combine to a verification matrix. As such it shall be reproduced and used in the PDR and FDR documentation so that the fulfillment of these requirements can be traced. The matrix shall be augmented by columns indicating how the requirements are translated into the design and how the compliance is to be verified. ☐
The reference cases in Appendix A shall be projected onto the design so that for all essential features it becomes clear whether they are supported. ☐
If it becomes apparent that certain requirements cannot be satisfied, formal change requests or requests for waiver are to be issued. ☐

A risk analysis shall be part of the PDR and FDR documentation. For significant risk areas, alternatives and their consequences shall be discussed. ☐
Single-vendor dependencies shall be identified and justified. ☐

In addition to an analysis of the global performance and throughput, the same should be done at the sub-system level. If there are large differences between the ones of the latter, they should be justified. ☐

The PDR and FDR documentation shall provide evidence that the design is driven by these requirements, i.e. does not include additional features that increase the cost or complexity. ☐

The final documentation shall be accompanied by acceptance test reports so that the compliance with these requirements specifications becomes clear. ☐
To this end, a detailed test plan (see [AD 11]) shall be presented at FDR. ☐

3.3 Overall properties

3.3.1 Types of detectors

The baseline version of NGC shall support the following device categories (with or without ASICs):

- InSb ☐
- HgCdTe ☐
- Si:As ☐
- InGaAs ☐
- MOS CCDs ☐
- pn CCDs ☐

Later extensions shall be foreseen to:

- EM CCDs ☐
- orthogonal-transfer CCDs and arrays ☐
- CMOS devices ☐

3.3.2 Detector systems

A detector system shall be defined by any assembly of applicable detectors. There shall be no built-in hard limit to the number of detector systems one controller can handle. ☐

3.3.3 Number of channels

There shall be no built-in hard limit to the number of channels per detector system. ☐

A number of 1024 channels shall not require special efforts. ☐

3.3.4 Virtual cameras

Channels not sharing any electronics board shall be configurable as completely independent virtual cameras. E.g., one or more windows of a suitable detector shall be usable for autoguiding, wavefront tip/tilt corrections, or flexure compensation in actively controlled instruments. ☐

Different virtual cameras shall also be able to employ completely different detectors (e.g., CCD and Hawaii-2 RG). ☐

If a detector (e.g., Hawaii-2 RG) intrinsically supports multiple virtual cameras, this functionality must be preserved by NGC. ☐

3.3.5 Read speed and noise

Read rates of up to 50 Mpix/s/channel shall be supported. ☐

For the most commonly used detectors, the read noise shall be limited by their intrinsic noise. ☐

For CCDs, the read noise at 100 (1000) kpix/s/channel, the read noise shall be 1 (3.5) electrons or better. ☐

Within 5 s after readout, a 4k x 4k FITS file shall be available on disk and the RTD. ☐

For suitable detectors with 256 ports and 256x256 pixels, frame transfer to a real-time computer shall be possible at a rate of at least 2kframes/s. ☐

For very small frames, frame rates of up to 50 kHz are required. ☐

3.4 Electronics

[AD 5], [AD 6], and [AD 10] provide the general requirements.

3.4.1 EDA tools

Only one such system (e.g., ORCAD, Protel) shall be used throughout the project. ☐

3.4.2 Gain control

The gain shall be adjustable such that on-chip gains between 0.1 and 1000 µV/electron and conversion factors between 0.1 and 5 ADU/electron are covered. ☐

Bias levels shall be adjustable to values between 50 and 500 ADU (see also Sect. 3.7.14). ☐

At least part of this adjustment shall be possible by software alone. ☐

3.4.3 Dynamic range per pixel

The default shall be 16 bits with 18 bits being a goal for applications warranting higher resolution. 14 bits can be acceptable in case of very high requirements on speed. ☐

3.4.4 Linearity

Between 20 and 200,000 electrons, the non-linearity of the control electronics shall not exceed 0.2% (peak to peak) unless the detector-intrinsic non-linearity is worse than 0.5% when the latter shall be the dominating factor. ☐

3.4.5 Sensitivity to temperature changes

Bias level and gain shall not change by more than ±0.1% per degree (ambient temperature). ☐

3.4.6 Crosstalk

The controller-induced crosstalk between channels as well as between pixels should not exceed the 3-sigma controller read noise. ☐

3.4.7 Double-correlated sampling (for CCDs)

An effort should be made to implement double-correlated sampling in the digital rather than the analog chain. ☐

3.4.8 ASICs

A generalized interface to ASICs shall be developed. ☐

3.4.9 Programmable hardware components

For the selection of programmable hardware components, the proximity of the associated software environment (coding language, editor, debugging aids, operating system) to the one of the high-level control software shall be an important criterion. ☐

3.4.10 Synchronization with external triggers

An interface for external triggers shall be provided that permits detector and shutter operations to be synchronized with external events. ☐

In wait state, the latency shall not exceed 1 clock cycle. ☐

3.5 Electrical properties and capabilities

[AD 5], [AD 6], and [AD 10] provide the general requirements.

3.5.1 Power supply

To reduce mass, volume, and heat dissipation, usage of a switch-mode power supply is desirable. ☐

Proper power control (e.g., during switch-on, etc.) is required. ☐

If possible, the standard 220V networks at ESO's observatories shall be sufficient. Otherwise, specific requirements need to be defined and discussed for their feasibility. ☐

3.5.2 Voltages

The following ranges shall be covered:

- bias: TBD ☐
- clock: TBD ☐

3.5.3 Protection against electrostatic discharges

All critical LRUs and the detectors shall be protected against electrostatic discharges during storage, transport, and stand-by. ☐

3.6 Mechanics

3.6.1 Cooling

Water cooling is acceptable but a serious effort should be made to avoid it. ☐

3.6.2 Format of electronics boards

The 6U format is acceptable. But 3U is desirable. ☐
The default width should be a single slot. ☐

3.6.3 Housing

For the housing of the hardware, only one format shall be used in all applications. ☐
For the 3U (6U) format, the volume shall be less than 10 (30) l. ☐
The number of channels shall be at least 128. ☐
If possible, the power supply should also be accommodated in the same box. ☐

The housing shall be mountable in a standard 19" rack. ☐

Except, perhaps, for the backplane, custom-made components shall be avoided. ☐

Except for test and development purposes, all connectors should be placed on either the front- or the backside but not on both. ☐

3.6.4 Mass

The mass of one fully populated 3U (6U) housing shall not exceed 10 (25) kg. ☐

3.6.5 Distances

Up to distances of 3m between the detector head and the NGC housing, careful cable ducting and normal electrical shielding shall be sufficient to avoid degradation of the noise performance by more than 25%. ☐

Options permitting to install a major part of the backend electronics at a distance of 100 m (goal: 1 km) shall be studied. ☐

The requirements on mass, dimensions, and cooling of the controller are, then, not applicable to this part.

All computers used for detector control and data pre-processing shall be installable at a distance from the NGC electronics of at least 500 m. ☐

3.7 Software

Generally, software shall not limit the performance of the hardware. It shall be command driven and follow [AD 8], [AD 9], and [AD 10]. ☐

3.7.1 High-level operating systems

The high-level operating systems must be compliant with the VLT requirements. ☐

However, their number and diversity shall be kept to the minimum necessary for NGC. ☐

A careful attempt shall be made to define an interface layer between the NGC control software proper and the operating system(s) and so to enable porting of all software above this layer at reasonable cost. ☐

3.7.2 Configuration control

At all times, all software and all parameter files shall be kept under configuration control. ☐

For critical parameter files, an additional mechanism to ensure their integrity (e.g., check sums) should be considered. ☐

3.7.3 Programming

The usage of modern code-generating tools with a view towards testing, documenting, and debugging is encouraged. Their selection should be coordinated with the Technology Division. Island solutions shall be avoided. ☐

For each module, code and documentation shall be designed such that it can be maintained without analyzing other modules. ☐

3.7.4 Installation and start-up procedures

Fully automatic installation procedures and versatile configuration tools shall be provided. ☐

Execution of the standard control software in the telescope environment shall not require any special user privileges to be granted by the operating system. . ☐

The start-up procedure shall not require more than 15 s for auto-recognition of the hardware and the ready-for-use initialization of hard- and software. ☐

3.7.5 Resource checking

Software shall be able, prior to each exposure, to check the availability of all critical resources. ☐

3.7.6 Elementary functions

The set of elementary functions shall comprise those of IRACE and FIERA. ☐

The addition of further functions shall be possible without affecting the others. ☐

3.7.7 Tests

Test software shall be developed in parallel to the control software itself. ☐

The emulation of failures of other utilities (software, hardware, network, lack of resources, access denial) should be considered. ☐

Standardized tests of the software corresponding to any supported hardware configuration shall be possible by merely selecting a single set of parameters. ☐

A sequence of tests of several hardware settings (e.g., voltages, clock patterns) shall be possible without operator intervention. ☐

Means should be considered to let NGC keep track of the frequency of usage of its key functionalities as a way to set usage-oriented test priorities. ☐

3.7.8 Times and timings

Without the VLT Time Reference System (TRS) [AD 15], all absolute times shall be correct to within less than 0.1s. ☐

Relative synchronizations and time intervals shall be accurate to better than 0.1% or, for intervals less than 1s, to better than 0.005s. ☐

Stricter timing requirements shall be realized using the VLT TRS. ☐

3.7.9 Special modes

Support of the following techniques (in the order of decreasing priority) should be foreseen:

- nod and shuffle ☐
- subpixel sampling and digital filtering so that during an exposure the built-up of the S/N can be followed by performing a regression analysis for each pixel ☐
- drift scanning ☐
- non-destructive readout ☐
- on-chip charge shifts by a user-definable amount (e.g., for through-focus sequences) ☐

Device type-specific modes offered by state-of-the-art IR detectors shall be included. ☐

If centroiding functions need to be supported, this shall be possible at a frame rate of 10 Hz for data arrays of up to 256 x 256 pixels using a single Gaussian fit or similar. ☐

For much smaller data arrays, rates of up to 1000 Hz should be possible. ☐

Higher performances could require a dedicated real-time computer.

3.7.10 Consecutive exposures

If, e.g. due to on-line data processing, the time between end of detector readout and availability of the FITS file on disk becomes a significant overhead, it shall be possible to configure the software such that the next exposure begins right after the previous readout. ☐

3.7.11 Windowing and on-chip binning

Standard windowing and on-chip binning shall be provided. ☐

The number of windows should only be limited by the capabilities of the detectors. ☐

3.7.12 Pixel processor

A pixel processor shall be embedded in the system. Its interfaces to the remainder of the system shall be designed such that a replacement of the hardware plus operating system and/or of the processing software can be fully transparent to all other subsystems. ☐

The following operations shall be supported from the beginning:

- averaging of frames with and without removal of outliers (e.g., particle events) ☐
- bias subtraction ☐
- centroiding of point sources ☐
- TBC

(If performance reasons so require, the implementation may be detector dependent.)

Close integration with NGC of a general-purpose image processing system featuring a user-friendly scripting language could be considered. More desirable is an interface to the ESO DFS and the inclusion of general-purpose algorithms and recipes in the DFS CPL for re-use by data reduction pipelines. ☐

3.7.13 ALMA common software

If this is in the general interest of ESO and supported by the Technology Division, elements of the ALMA common software may be used.

3.7.14 Special utilities

For multi-port systems, bias equalization to within better than 1% shall be possible on demand but without any further operator supervision. ☐

3.8 External interfaces

Ideally, external interfaces (e.g., commands, databases) presently maintained by IRACE and FIERA would be supported by NGC with a minimum of changes so as to make the integration of NGC with the ESO operations scheme as seamless as possible. However, since in this regard the commonalities of FIERA and IRACE are very limited, this also limits backward compatibility. In no case shall NGC feature two different types of interfaces for the same purpose. ☐

3.8.1 Data format

The data format shall be compliant with [AD 16]. ☐

Comprehensive detector and electronics telemetry shall be included in the data headers. ☐

From the FITS headers, it shall be possible to uniquely infer the complete set of hard- and software configuration and all parameter values. ☐

3.8.2 Output to real-time computers

A generalized, moderately configurable interface to real-time computers, e.g. for adaptive optics or fringe tracking applications, shall be defined (in cooperation with ESO software engineers working downstream from such an interface). ☐

It could be advantageous that (a possibly special incarnation of) the pixel processor (Sect. 3.7.12) can serve as the real-time computer (or vice versa). ☐

Latency shall not exceed 100 μs. ☐

3.8.3 Real-time display

An interface to the RTD [AD 19] shall be provided. ☐

For high frame rates, it shall be possible to request only every nth frame to be displayed. ☐
Adaptive auto-selection shall be supported. ☐

3.8.4 VLT telescope control system

It shall be possible to synchronize detector operations with the following functions:

- Telescope nodding ☐
- M2 chopping ☐
- Non-sidereal tracking ☐
- TBC

3.8.5 VLT time distribution system

The possibility of an interface to the VLT Time Reference System [AD 15] shall be foreseen. ☐

3.9 Ancillary utilities

3.9.1 Waveform and clock-time pattern editors

A graphical design tool shall produce output in a user-friendly ASCII format that can be readily fine tuned also with any standard text editor. ☐

3.10 Control of auxiliary functions

The scope of NGC shall be restricted to the control of detectors. However, the control of auxiliary functions and devices shall be integrated into the overall concept.

A study shall be made whether, and for what reasons, some derivative of the present PULPO II device [RD 1], a set of commercially available controllers, or some new customized development is most promising. ☐

One unit shall support

- 32 temperature sensors ☐

- 8 temperature control loops ☐
- 8 shutters; it shall be possible to use all 8 either simultaneously or in two fully independent groups ☐
- 8 vacuum gauges
- 8 generic functions (e.g., control of an LED) that can be synchronized with the shutter operation ☐

An NGC-controlled detector system shall be able to employ at least 4 of such units. ☐

A generalized interface to such peripheral control functions, especially of shutters and for temperature stabilization, shall be considered. ☐

Shutters with more than one moving part shall be covered. ☐
For bi-directional shutters, the direction of motion shall be controllable. ☐
The case that the start of an exposure is not defined by the shutter motion but by the end of the wiping of the detector shall be included. ☐

Development of a generalized controller of standard ESO cooling systems, incl. compressor- or pulse tube-based systems, should be considered. ☐
Full support of the safety devices supplied with these cooling systems is vital. ☐
For alarm conditions with potentially serious consequences, an interface to the Paranal CAS is required. ☐

Logging of all functions with a resolution of 5 minutes shall be possible. ☐
Where practical, the VLT logging utilities shall be used. ☐
Any stand-alone log files shall have a capacity of at least 10 days and be cyclically overwritten. ☐

3.11 Diagnostic tools

3.11.1 Hardware self-test

The hardware shall be able to execute a comprehensive self-test. It shall be possible to start it by pressing a physical button as well as by software. ☐
Due consideration shall be given to the protection of the detectors. ☐
The execution shall not exceed 5 minutes. ☐
An automatic log shall be produced. ☐

In order to save space on the electronics boards, it is acceptable to let remote software (e.g., on the xLCU) execute these tests with hardware only reporting its status. ☐
This software shall be developed in parallel to the one of the hardware.

3.11.2 Read-back and telemetry of parameter values

It shall be possible to read back the actual values of all parameters set by software. ☐
Where applicable, telemetry shall be provided. ☐

3.11.3 Automatic identification of hardware components

All LRUs shall have a unique identification that is readable by software. ☐

An extension also to detectors shall be considered. ☐

Software shall be able to use this information for auto-configuration. ☐

3.11.4 Error handling

Meaningful error messages and log files are essential; they shall enable software staff not familiar with the software or its scope to identify and fix minor problems. Different severity levels shall be distinguished. The status and options for the next actions shall be clear at all times. ☐

It shall be possible to set the severity level up to which automatic recoveries from errors shall be attempted. ☐

After a failed data saving, the OS shall have the possibility to recover the last frame. ☐

After an interruption in the power supply, software should be able to automatically restore the status at the beginning of the last successful exposure. ☐

3.12 Support of engineering work

3.12.1 Engineering mode

There shall be a password-protectable engineering mode. It may contain extra modules and options while others may be omitted for reasons of convenience. ☐
However, modules used for normal operations shall be identical. ☐

This mode shall offer access to all essential elementary detector control functions and allow hardware engineers rapid proto-typing of experimental software. ☐

3.12.2 Change of parameters

A change of software-configurable parameters shall not require a re-start of the system and, where possible, be supported also during readout. ☐

This would also benefit multi-mode instruments where, e.g., imaging and spectroscopy require different parameter sets for optimal performance. Switching between modes shall not lead to any hysteresis. ☐

A mechanism shall be implemented to reduce the risk of out-of-range parameter values being set accidentally that could damage the connected detector(s). One possibility might be to let the controller hardware request a unique electronic ID (such as the serial number) from the detector (cf. Sect. 3.11.3). ☐
For all protective measures, priority must be given to pure hardware solutions. ☐

An interface to BOB [AD 20] shall be provided that permits parameter values to be set from dedicated observation blocks / observing templates. To take advantage of this, laboratory setups would need to be able to emulate VLT-compatible instruments to the extent that VLT control software Sequencer scripts can be executed. ☐

3.12.3 Detector library

A repository with parameter files for specific detector types and their baseline operating modes shall be offered. ☐
For engineering purposes, easy copying and editing of such files shall be supported. ☐

To the extent possible, different installations of comparable detector systems shall share these data. ☐

3.12.4 Disabling of components

It shall be possible to declare LRUs and channels defunct. In response to this, the software should be able to automatically adapt itself to the remaining hardware configuration. ☐

3.12.5 Special utilities

The following shall be foreseen:

- convenient connection (i.e., from the front side?) of monitoring equipment such as oscilloscopes, multimeters, and logic analysers; ☐
  this could include a digital video output to display images in stand-alone mode; ☐
  video, bias and clock voltages should be available via test points on each applicable board ☐
- pocket pumping ☐
- determination of PTF of DC-coupled IR and CMOS devices by a capacitive comparison technique ☐

3.12.6 Programming interface

Thought shall be given to the provision of an efficient programmer's interface, ideally with a standard scripting language such as Tcl/Tk or IDL, that permits engineers rapid proto-typing of detector control and data processing software. ☐

3.12.7 Test facility

A cost-effective test facility for all types of LRUs shall be supplied. It may either be integrated into the controller or stand-alone. ☐

Its software shall use the one of the NGC only. ☐
An expandable collection of standard test functions shall be considered. ☐

Where applicable, test results should also be offered in graphical form with an option for hardcopies. ☐

3.12.8 Simulation modes

Standard VLT simulation modes shall be supported (cf. [AD 10]). ☐
Simulation should be one of the standard modes of NGC rather than an add-on. ☐

To the greatest possible extent, simulation of key elements shall be supported in both soft- and hardware. ☐

Hardware simulators to generate programmable test pixel patterns and video waveforms shall be devised. ☐

Software simulators shall be hierarchically structured and permit the simulation of data streams with real numbers and realistic data rates so that relative timings, etc. can be tested. ☐

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Appendix A: Design reference cases

TBD