EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

VERY LARGE TELESCOPE

INTERFEROMETER

Statement of Work and Technical Specifications for the Phase A Study of the VSI Instrument

Doc. No.: VLT-SPE-ESO-15870-0001

Issue: 1.0

Date: 29 May, 2006

	Name	Date	Signature
Prepared:	A.Richichi	29.5.06	
Approved:	M.Casali	2/6/06	
Released:	A. Moorwood	2/6/06	

CHANGE RECORD

Issue	Date	Section/Page affected	Reason/Initiation/Remarks
	2 May 2006	All	First Draft
	22 May 2006	All	Comments from Consortium
1.0	24 May 2006	All	First Issue
1.0	29 May 2006	All	First Issue Finalized

Table of Contents

1 INTRODUCTION

1.1 SCOPE

This document lists and describes the main specifications and requirements for the VLTI Spectro-Imager (VSI), to be used in the course of the Phase A study. Thus they should be intended to be limited in validity to the Phase A, and may be modified after the results from the study. Specifications are intended for the performance of the instrument, while requirements are in connection with its operation and environment.

The VLTI is intrinsically an evolving facility, and some of its characteristics may change with time in an effort to improve the interferometric performance. Naturally, the VSI instrument is not completely defined before the Phase A study. As a result of these factors, some of the specifications and requirements in the present document may not be precisely described at this time, and in a few cases (i.e. the fringe tracking capability) an open question is left to be evaluated in the course of the Phase A study.

1.2 DOCUMENT ORGANIZATION

This document is organized as follows. Both VSI and the VLTI are summarily described in Sect. 2. The technical requirements for VSI are outlined in Sect. 3, the specifications in Sect. 4. The procedures and conditions for the Phase A study and subsequent evaluation are described in Sect. 5.

1.3 APPLICABLE DOCUMENTS AND REFERENCES

[1] Proposals for Phase A studies of 2nd Generation VLTI Instruments, ESO-STC/402, April 6, 2006

[2] VLTI Spectro-Imager Technical Proposa; ESO-STC/402C-1, April 6, 2006

[3] VLTI Spectro-Imager Science Cases, ESO-STC/402C-2, April 6, 2006

[4] ICD between VLTI and Instruments VLT-ICD-ESO-15000-1826 v.4.0 11/08/2005

[5] Data Flow for VLT/VLTI Instruments Deliverables Specification VLT-SPE-ESO-19000-1618 v2.0 2004/05/22

[6] Proposed FITS File Formats for Optical/IR Interferometry Data, v1.2.4 October 2, 2000

1.4 ACRONYMS FREQUENTLY USED AT ESO/VLTI

AMBER	Astronomical Multi-BEam Recombiner
Apres-MIDI	Proposed extension of MIDI to four beams
AO	Adaptive Optics
ASTO	Archive Storage System
AT	Auxiliary Telescope (1.8m)

CCC	Closed-Cycle Cooler
DFS	Data Flow System
DHS	Data Handling System
DICB	Data Interface Control Board
DID	Data Interface Dictionary
DAS	Data Analysis Software
DRS	Data Reduction Software
ETC	Exposure Time Calculator
FITS	Flexible Image Transport System
FLUOR	Fiber Linked Unit for Optical Recombination
FSU	Fringe Sensor Unit
GTO	Guaranteed Time Observations
GENIE	The ground-based nulling demonstrator of DARWIN (ESA)
ICD	Interface Control Document
ITF	Interferometric Task Force
MIDI	Mid-Infrared interferometric instrument
OB	Observation Block
OPC	Observing Program Committee
OPD	Optical Path Difference
OS	Observation Software
P2PP	Phase 2 Proposal Preparation
PRIMA	Phase-Referenced Imaging and Microarcsecond Astrometry
PT	Pulse-Tube
QC	Quality Control
QC1	Quality Control Level 1
STC	ESO Science and Technology Committee
TBD	To Be Defined
UT	Unit Telescope of VLT
VCM	Variable Curvature Mirror
VINCI	VLT INterferometer Commissionning Instrument
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer
VSI	VLTI Spectro-Imager

2 VSI AT THE VLTI

2.1 VSI

VSI (VLTI Spectro-Imager) is a proposal for a 2nd generation instrument for the VLTI. A conceptual description of the instrument, including the main science cases, was presented to the ESO STC at their 62nd meeting in April 2006 [1],[2],[3], following which STC recommended to carry out a Phase A study.

VSI is a natural successor to AMBER, over which it represents an improvement both in terms of number of beams (4 to 6 in VSI versus 3 for AMBER) and in design (possible use of integrated optics in VSI, with benefits in instrument size and stability). The increased number of beams, in particular, will significantly boost the imaging capabilities of the VLTI. At present, the first generation VLTI instruments cannot make full use of the four UTs and the four ATs available. In addition, a fifth AT may become available in the future and also mixed combinations of ATs and UTs could be contemplated, as the beams received in the VLTI lab have identical characteristics except of course for the number of photons. The ultimate limit is represented by the six delay lines.

VSI contemplates at present concepts for either an integrated optics or a bulk optics beam combiner. The choice will be made during Phase A. In either case, it is expected that VSI will fully address the issue of mechanical stability and ease of alignment and maintenance of optical quality. Based on the AMBER experience, it is not expected that VSI will face new technical challenges, since similar approaches will be used for the spatial filtering by means of monomode optical fibers and for the multi-axial beam combination.

A critical issue for the full scientific exploitation of VSI will be represented by the availability of a suitable fringe-tracker. As detailed in Sect. 2.2 below, the present-day VLTI does not offer this capability. A crucial aspect of the Phase A study will thus be to evaluate whether the needs of VSI would be better served by a common 4-way fringe tracker operating in any near-IR band (JHK), or by a dedicated fringe tracker which might be tuned in wavelength to the VSI requirements, in particular for the observation of extremely red sources. The former would be understood to be designed and developed by ESO for the whole VLTI, the latter would be assumed to be part of VSI. Another aspect of the VLTI which may need an extension is that of PRIMA (see Sect. 2.2 below). It is expected that Phase A will elucidate the pros and cons of extensions, or lack thereof, to the present PRIMA.

2.2 THE VLTI AND ITS SUBSYSTEMS

In the ESO call for proposals for Phase A studies of 2nd Generation VLTI Instruments, the VLTI has been summarized as being based on an array of the four identical, 8.2-m VLT Unit Telescopes (UT) and four dedicated 1.8-m Auxiliary Telescopes (AT).
The main elements of the VLTI infrastructure are:

- Four 8.2-m Unit Telescopes (UT), all with Adaptive Optics (AO) correction at their Coudé focus.

- Four 1.8-m Auxiliary Telescopes (AT). AO for ATs is being considered.
- Six Delay Lines (DL) installed. Variable Curvature Mirrors (VCM) in the cat's eye of the DL are used to relay the pupil. VCMs are currently operational on 2DLs, and will be extended to all DLs.
- Two Differential Delay Lines (DDL) units have been contracted and are under development.
- The Test instrument VINCI with an integrated optics beam combiner in the K-band (IONIC).
- A Fringe Tracker with on-axis guide star (FINITO) under extensive testing at Paranal.
- A near-infrared tip-tilt sensor (IRIS) in the lab.
- PRIMA is a dual-feed system to perform accurate relative phase measurements between objects separated by up to 1 arcminute. Star Separators Systems (STS) for two ATs and two UTs are under development; a third STS/UT (and possibly a fourth one) are externally financed; Fringe Sensor Units A&B in development. Metrology in development.

The characteristics of these systems, and of the VLTI environment in general, are described in the ICD [4]. It is commonly known that some aspects of the actual VLTI environment are at the moment outside the specifications stated in the ICD. In particular, the VLTI is suffering from vibrations especially at the UTs which currently prevent successful and continued fringe tracking on those telescopes. Other negative aspects are a relatively high level of tunnel turbulence, the incomplete deployment of VCMs on all delay lines, and the inaccuracy of OPD models for some configurations. However, thanks especially to the work of the ITF, significant progress has been made on all these issues recently, and it is hoped that the situation will be in the norm by the time the 2nd Generation VLTI Instruments will be in their crucial phase of construction.

It is expected that regular updates of the ICD will be provided to reflect the progress being made at the VLTI, with a first one planned by July 2006. During Phase A the best available information will be provided by ESO to permit the consortia to carry out their design under realistic assumptions.

Crucial issues of relevance for 2nd Generation VLTI Instruments are the possible extensions to the present level of fringe-tracking capability and of PRIMA.

The VLTI, as all the rest of VLT, will be offered to the community at large and it is expected that a new instrument concept will address not only the hardware and the control software, but also all aspects of routine science operations including:

- Tools or algorithms for proposal preparation (ETC, calibrator selection, visibility calculators, see also http://www.eso.org/observing/etc/)
- Calibration needs, both on a nightly basis and in the long term
- Data products issues (data structure and definition, data flow, archive, pipeline). See also [5], [6].

- o Specialized needs for data reduction, including insight into possible user-friendly, validated and supported packages for the community

A decision on which tools will be needed by the instrument and provided by the consortium will be taken after Phase A.

3 TECHNICAL REQUIREMENTS

As for any VLT/VLTI instrument, the proposed instrument shall follow the ESO standards of design and operation for software, hardware and safety as listed in [4].

The instrument will interface to the VLTI infrastructure, as described in the ICD [4] with the possible updates mentioned in Sect 2.2.

The instrument shall be designed for an expected life time of at least ten years, under normal operating conditions. The instrument will operate on both UTs and ATs. It should be stressed that ATs are going to represent the preferred option during commissioning of the instrument, and therefore planning should address operation on ATs from the start of operations.

Different scenarios shall be considered:

-with an internal fringe tracker, or with a VLTI-provided common fringe tracker.

-with the current PRIMA (cfr. Sect. 2.2), or with various extensions as deemed desirable by the Consortium. As PRIMA includes different modes (a phase-referencing mode suitable to imaging, and an off-axis fringe-tracking mode suitable for faint sources), these should be treated separately.

A comparison of the performance of the instrument in the various scenarios is to be provided in the form of a performance matrix. If applicable, the corresponding estimates of cost and resources shall be indicated.

4 SPECIFICATIONS

For the purpose of the Phase A study, the following goals shall be considered. The figures below are intended for the instrument only, without VLTI and atmospheric effects.

- Number of beams: at least 4, up to 6. Cost and complexity considerations should be addressed to guide the final choice. Also the possibility of operation with 2 and 3 telescopes only should be contemplated.
- Wavelength coverage: K, H, J bands (in order of priority).
- Spectral resolution: at least three ranges, approximately around R~50, R~10^3 and R~10^4.
- Internal fringe tracking, autonomous from VLTI: possible (if not wished, please describe the reasons).
- Autonomous image acquisition, possibly in a range of wavelengths.
- Total efficiency (instrument only, in each band) ≥ 5% minimum, 10% goal.
- Interferometric Contrast (instrument only) 80% or better (K band); 70% or better (J band).
- Contrast Stability: better than 0.5% over 5 minutes (K band).
- Visibility accuracy (instrument only) 0.2% or better (K band), 0.5% or better (J band)
- Differential Phase stability (instrument only): 0.5° over 5 minutes
- Closure Phase accuracy (instrument only, per beam triplet): better than 1°
- The effects of instrumental polarization shall be discussed.

5 CONDITIONS GOVERNING THE PHASE A STUDY

The Phase A study shall have a maximum duration of 12 months, followed by a review which will be held at ESO within 3 months. Extensions to this duration will be subject to ESO approval, also in consideration of other decisive constraints such as dates of meetings of decisional committees. During the Phase A, meetings will be held between the Instrument Consortium and ESO, at dates and locations to be agreed. At least one such meeting will take place at the Consortium's premises, and will include detailed presentations. Minutes of each meeting shall be provided in written form, including action items.

The results of the Phase A study will, a.o. be reported to STC and, in case of recommendation, the instrument concept may be proposed to other decisional and financial bodies. In no way will the present Phase A study or the results thereof be binding for ESO with respect to the realization of the instrument.

The Phase A study shall address all issues stated in the present document, and in particular address the feasibility and projected characteristics of a full instrument to be operated at the VLTI according to ESO standards. The documentation provided in the final delivery will include:

- an advanced instrumental concept of demonstrated feasibilty, including hardware, optics, electronics, instrument control, software and data products.
- an evaluation of the performance, including the specifications listed in Sect. 4
- a detailed estimate of cost, total human resources, and project duration
- the items above shall be diversified in a matrix, addressing the scenarios listed in Sect. 3
- a list of requirements on the VLTI infrastructure and its performance, prioritized as far as possible, needed for the realization of the instrument and its science goals
- scientific objectives, in particular outlining those to be carried out during GTO
- outline of a plan for the scientific exploitation of the data, including a discussion of calibrations and prospects of data analysis

The results of the Phase A study shall be provided to ESO both in paper and electronic forms, in english language and following the ESO standards for documentation. The results will be the property of ESO. The consortium may decide the details of the type and number of documents presented for the review, also depending on its internal organization.

For the purpose of the study, the Consortium shall interface to ESO through a single contact point, the VLTI Instrument Scientist (IS). It will be the responsibility of the IS to direct the questions and requests by the consortium through the relevant channels, and to coordinate the answers and deliveries to the Consortium. ESO will devote sufficient resources to ensure that the Phase A study can be carried out, and in particular allocate scientists and engineers. ESO will endeavour to provide existing documentation as required. However, in general ESO cannot guarantee that specialized experiments, tests and other ad-hoc measurements, including material and hardware procurements, can be carried out by ESO for the purpose of the Phase A study.

At the end of the Phase A study, within a deadline agreed upon as above, the results shall be provided to ESO. ESO will nominate a board to evaluate the results, and agree with the Consortium on a date for a review which will take place at the ESO Headquarters within 3 months from the end of the study. ESO will provide to the Consortium, at least four weeks before the

review, written questions and comments. The Consortium shall provide written answers to the questions and comments, at least two weeks prior to the review.

The financial and contractual terms of the present Phase A study are defined in the respective Contract. It is assumed that the amount paid by ESO will primarily be used to finance networking and travelling of Consortium staff during the Phase A study. In accordance with the initial estimates [1][2], it is anticipated that approximately 10 FTE will be provided by the Consortium for the performance of the Phase A study.