4

DEC 23 1997

ESO-TP-73E
Jan 1997

# Results of studies on the environmental factors affecting the VLTI performance.

B. Koehler, S. Levêque, O. von der Lühe,

European Southern Observatory,
Karl-Schwarzschild Strasse 2,
D-85748 Garching

## ABSTRACT

We have undertaken a number of studies and experiments in the last few years to assess the impact of various environmental factors on the performance of the ESO Very Large Telescope Interferometer (VLTI). The topics include atmospheric turbulence, wind loads on the telescope structure, vibrations created by equipment, thermal environment along the beam paths, natural and man-made seismic noise, as well as acoustic noise.

This paper gives an overview of the final results obtained. A more detailed report of these activities can be found in a recent paper (Koehler, 1996).

The main result is the very good confidence that the VLT 8m telescope and the infrastructure design is adequate for interferometric use at optical wavelengths down to the visible.

**Keywords:** Interferometry, optical aperture synthesis, performance, environment, seeing, thermal effects, vibrations, wind load, seismic, acoustic.

ESO-TP-73E

## 1. INTRODUCTION

The technical challenge of coherently combining for the first time large multi-mode telescopes implies a thorough system analysis. A major element of it is the top-down generation and bottom-up validation of error budgets for each major performance characteristic of the interferometer which is required by the science objectives. Figure 1 illustrates this process. It constitutes the framework of the activities reported here which focus on the impact of environmental factors with the goal (i) to better understand the effects of the environment on the interferometer performance, (ii) to check that these effects can be maintained at a level compatible with the top-level requirements, and (iii) to specify, when necessary, various sub-system requirements and operational constraints aiming at reducing them.

## 2. STRUCTURAL DEFORMATION INSIDE THE UT.

When considering the use of the VLT 8m Unit Telescope (UT) in an interferometric mode, one of the first question is: will the UT be stable enough to ensure the very drastic requirement imposed by interferometry on the dynamic stability of the Optical Path Difference (OPD)? To answer this question, a complete and detailed Finite Element Model of the telescope (figure 2) has be used to compute its dynamic behaviour under a number of load cases. These include the wind load on the telescope structure, the ground motion due to natural and man-made micro seismic activity, as well as vibrations generated by equipment located on the telescope.

The static wind load on each structural element was computed using results from VLT wind tunnel tests and applying standard wind load computation methods. A Von Karman wind spectrum model with parameters derived from Paranal wind measurement statistics was used to define the load dynamic properties. The OPD response was then computed from the harmonic responses of each mirror of the optical train down to the Coudé focus. Thanks to the outstanding stiffness of the telescope structure and in spite of the relatively large loading, the results (Koehler, 1996) obtained are well within the stringent requirement imposed by observation in the visible (OPD fluctuation of 9 nm rms over an exposure time of 10 msec for a specification of 14 nm).

A more severe impact was found for the response to micro seismic loads (Koehler, 1996, 1994, 1995). A dedicated measurement campaign at Paranal provided the magnitude and statistics of micro earthquakes. It was found that the specified OPD stability limits is reached, on average, every 40 minutes and every 1 hour 40 minutes for observation in the visible and in the near-infrared respectively. This led us to implement a continuous seismic monitoring system as part of the VLT Astronomical Weather Station in order to flag observations disturbed by seismic events. This seemingly severe

Fermilab Library
0 1160 0064851 3

operational constraint and observation efficiency loss imposed by the site is actually offset by the outstanding atmospheric conditions at Paranal. The effect of several man-made seismic noise sources was also investigated. As an example, the disturbance from a car driving in the vicinity of the observatory top was measured. Its effect was found to remain small as long as the traffic stays off the Observatory Platform. This indicates the merits of having the Control Building away from the Observatory Platform.
Several types of vibration-generating equipment which are attached to the telescope structure and could degrade the OPD stability during interferometric observation have been identified. Among the most significant ones are the compressor and the cold heads of the closed cycle coolers for IR instruments. Their disturbance force spectrum was measured on the ISAAC lab prototype and applied to the telescope structure through de-coupling devices with variable characteristic frequency and damping property. Upper limits (5 Hz) of the characteristic frequencies were found necessary to ensure a negligible contribution to the OPD stability error budget of the telescope. These results have been implemented in the final design of the VLT IR instruments.

In addition to the above load cases, the vibration of the primary mirror due to acoustic loading has been investigated using a 3D elasto-acoustic model of the telescope placed inside the enclosure acoustic cavity (figure 3). The acoustic noise generated by the wind interacting with the dome entrance slit was measured on representative La Silla telescopes and acoustic noise from the closed cycle compressor and cold heads was measured in the lab. Results showed a negligible contribution (<2 nm) for the latter sources and a significant, but acceptable, effect due to wind-generated acoustic noise (10 nm rms over a 10 msec exposure for a 10 m/sec wind speed).

## 3. ATMOSPHERIC AND INTERNAL SEEING

A number of VLTI-specific studies related to *external (atmospheric) seeing* and *internal seeing* effects have been carried out. These include the use of data from balloon-borne probes launched from Paranal during the PARSCA campaign in order to derive the spectrum of the atmospheric tilt and OPD disturbances both on-axis and off-axis (anisoplanatic effects). The results have been used to assess the performance of tilt and OPD active compensation as well as their related field limitations. Internal seeing is a concern for the VLTI since the delay lines are placed in air. Experiments have been undertaken in a long underground tunnel representative of the delay line tunnel at Paranal. Both the lateral beam wander and the OPD fluctuations due to air turbulence along long propagation paths were measured. Results of all these seeing-related studies can be found elsewhere (Koehler, 1996, Levêque 1995). The main outcome is the good confidence that the level of turbulence strength inside the delay line tunnel imposed by the error budget ($Cn^2<10^{-15}$ $m^{-2/3}$) can be achieved.

## 4. THERMAL ENVIRONMENT

Because of their impact on the wave front quality and beam geometry, the thermal conditions encountered along the internal beam path have been carefully investigated. An extensive thermal study has been undertaken with the goal to (i) assess the thermal environment under the *natural* outside conditions (daily & seasonal variations), (ii) evaluate the thermal influence of *artificial* heat sources (electronic equipment & heat dissipation during maintenance periods). Various 2D and 3D Finite Difference thermal models were built to investigate the situation in various parts of the VLTI infrastructure (auxiliary telescope station, light beam ducts, delay line tunnel, interferometric laboratory). After optimisation of the building insulation a satisfactory thermal stability and homogeneity all over the infrastructure could be achieved (vertical gradient within ±0.2 °C/m, longitudinal homogeneity 0.2 °C, daily variation <± 0.02 °C, seasonal variation ± 2.4 °C). A last part of the study focused on the simulation of air flow pattern (figure 4) and evaluation of $Cn^2$ under various conditions. A more detailed description of the investigations and results can be found elsewhere (Koehler, 1996).

## 5. CONCLUSION

A number of studies related to environmental factors have allowed us to *define* or *refine specifications* for several VLT/VLTI subsystems which are particularly critical for the VLTI operation. This has concerned, among others, the tunnel insulation, the heat dissipation inside the tunnel, the first axial eigenfrequency of the M2 unit, the stiffness of the Coudé mirror supports, the vibration de-coupling devices of the instrument close cycle coolers, and the need for seismic monitoring.

The results obtained have *confirmed that the performance requirements set for the VLTI are achievable*. They have shown that the design of the VLT Observatory and, in particular, the 8m Unit Telescopes is compatible with the stringent requirements imposed by visible interferometric observations.

The decisive confirmation of this conclusion on the real hardware has already started and will continue as hardware becomes available and commissioned on the site.

## 6. REFERENCES

B. Koehler, S. Levêque, O. von der Lühe, "Results of studies on the environmental factors affecting the VLTI performance", *Optical Telescopes of Today and Tomorrow*, being published in Proc. SPIE Vol. 2871, Landskrona 1996.

B. Koehler, "Hunting the Bad Vibes at Paranal!", *The Messenger* N°76 (June 1994), pp 4-9, 1994.

B. Koehler et al., "Impact of the Microseismic Activity on the VLT Interferometer", *The Messenger* N°79 (March 1995), pp 4-9, 1995. MESSE

S. Levêque et al., "Measurement of optical path fluctuations due to internal seeing for the VLTI", *Advanced Imaging Technologies and Commercial Applications*, N. Clark (Ed.), in Proc. SPIE Vol. 2566, pp 156-163, San Diego 1995.

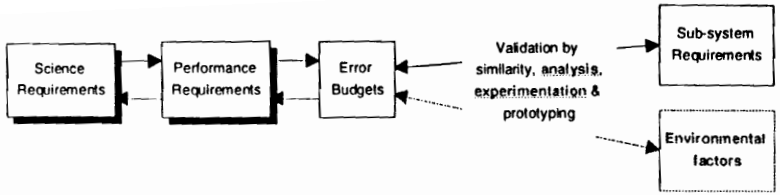


**Figure 1:** The requirement flow chart illustrating the need to address the effects of environmental factors as part of the validation of the top-level error budgets.

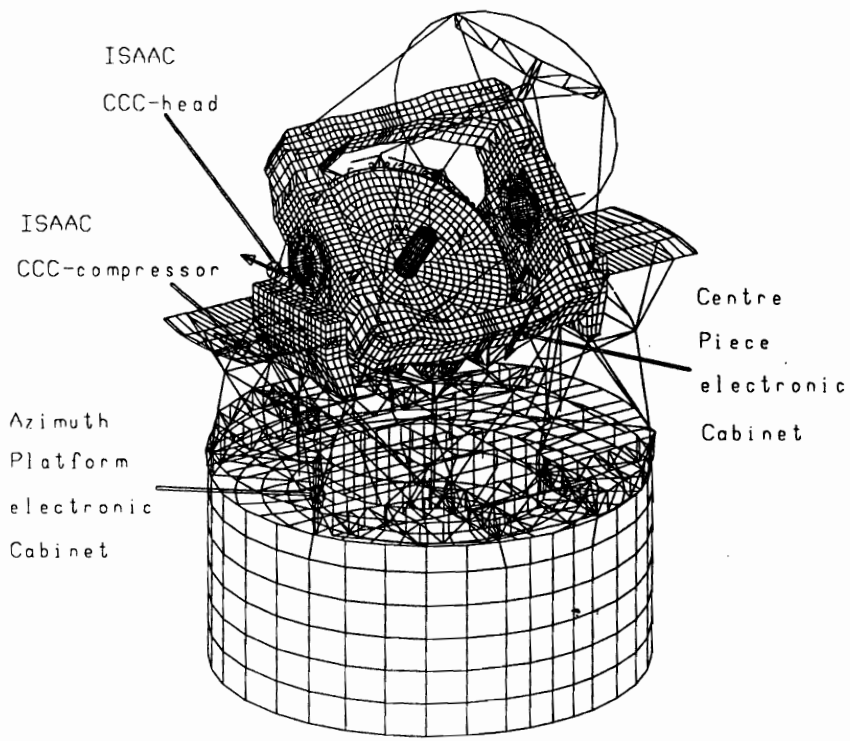


**Figure 2:** FEM of the VLT 8-meter Telescope used to evaluate the Optical Path Length Stability under dynamic wind load, seismic motion, and vibrating equipment.

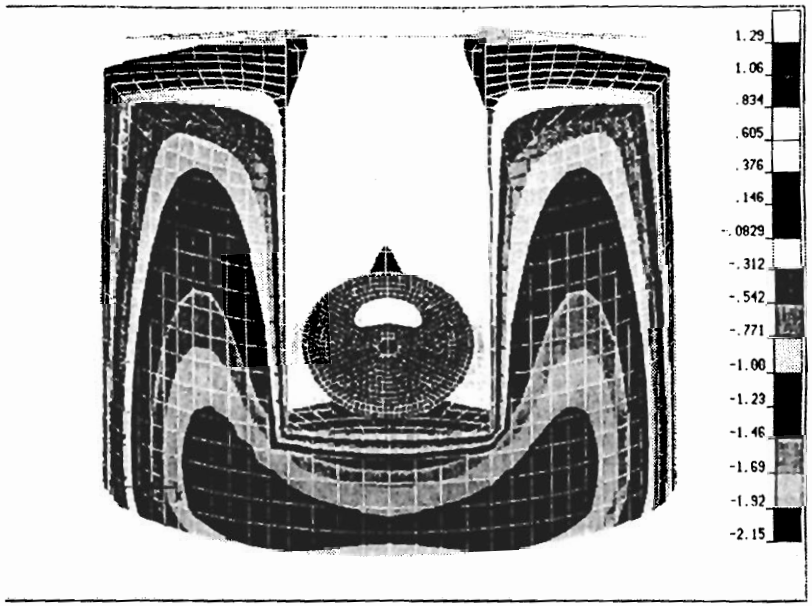


**Figure 3:** Dynamic acoustic loading (at 13 Hz) on the VLT enclosure and primary mirror due to the wind / entrance slit interaction.

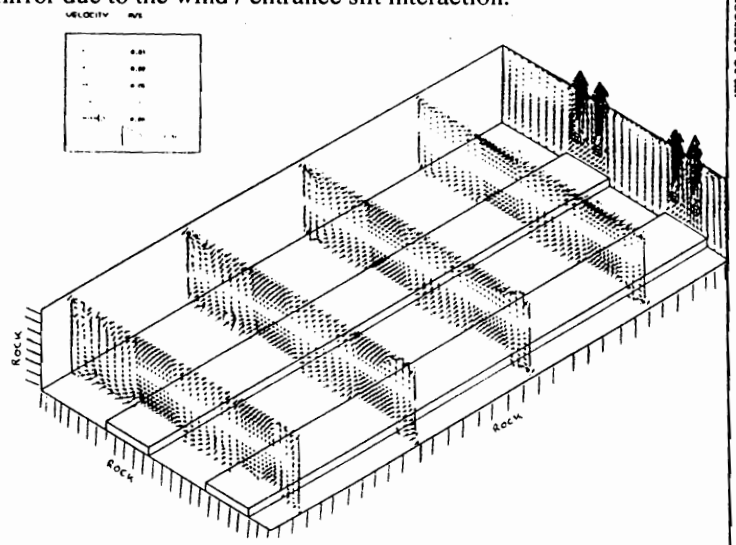


**Figure 4:** Flow pattern inside the Delay Line Tunnel created by four pieces of equipment dissipating 50 W each. The arrows represent the mean air velocity.