The commissioning of the TNG telescope

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Abstract

This paper describes the TNG (Telescopio Nazionale Galileo) commissioning operations carried out during 1998. A brief description of the main telescope systems is provided, together with some results from the telescope and instruments at first light.

1 Introduction

In May 1997 the bulk of the telescope structure, systems and services were released by the various commercial and university contractors to the TNG *commissioning group*. The telescope itself was, with the exception of the Nasmyth derotators and all the optics systems, mechanically ready to accept the integration of all computer services and control equipment. Commencing from June 1998 (the telescope's first-light date), the telescope is routinely used during several nights of each week in order to test and tune the tracking and pointing systems, and to implement and test the first instruments. The first use of the TNG for science observations, resulting from successful programmes submitted in response to the first call for proposals, were begun during February 1999.

The commissioning milestones to date were:

- Engineering first light of the telescope in June–July 1998.
- First-light of the derotator A (with tracking and Shack-Hartmann cameras) in September–October 1998.
- Scientific instrumentation first-light with the visual imaging camera, the infrared camera, the speckle camera module and the tip-tilt module, in November–December 1998 and February 1999.

After the delivery of the telescope to the *commissioning group* and during the first three months of activity the group has dedicated a considerable part of its

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time to installing the structures and services (mechanical workshop, electronic lab, computers and network installations, basic safety) needed for the assembly of the optical train and, more generally, for the overall commissioning of TNG. Significant commissioning work of the telescope structure, in parallel with other major operations like those of the drive system, services controls and interfacing to the computer system, began in July 1997.

2 The optics system

The mount and alignment of the three major optical systems (M1, M2 and M3 mirrors plus supports) have been made in the following basic steps:

- The insertion of the mirrors inside the mirror frames (M2 and M3).
- The assembling of the mirror groups inside templates (M2 and M3).
- The mechanical alignment of the telescope mechanical axes.
- The insertion of the mirrors inside the telescope (M2, M1 and M3 in sequence).
- The definition of the telescope Optical Axis.
- The optical alignment of mirrors inside the supports and with the optical axis.

The main difficulties found during this commissioning phase came from the mirror-blank mounting procedures and from the cross-alignment between the Azimuth and Elevation axes, a procedure involving the use of a pentaprism tool. It should be noted that the primary (M1) mirror, which is not included in the above list, was already mounted and checked inside the telescope primary mirror cell several years ago, before shipment to La Palma, in the facility of Zeiss, the manufacturing company.

The precision in the final results obtained is affected substantially by the environmental seeing (10"). Better details on the alignment phase are given in (1),

3 The pointing and tracking system

The telescope drive system is now undergoing on sky commissioning. One problem found during the commissioning of this system was the incomplete cabling of the emergency systems during the construction phase.

The main area of concern though was the discovery that the hydrostatic bearing sliding stream was not within the planarity specification. As a consequence, points of increased friction resulted between the hydrostatic pads and the local irregularities in the bearing sliding stream. This led to abnormal, impulsive, Azimuth torque demands being applied to the motors to overcome these friction points. Thus poor tracking performance (limited to several tenths of an arcsec in the region near the highest torque peaks) and image quality resulted.

This problem was resolved in March–April 1998 after a complicated and delicate lapping operation made on the fixed ring itself and on each hydrostatic pad (see (5)). The outstanding problems to be completely fixed on this system are related to small oscillations (0.2 arcsec RMS) in the Azimuth axis, mostly due to distributed mechanical interactions with the dome motion during tracking (see (6)) and to the refinement of the control-loop parameters.

4 The informatic system

The informatic hardware configuration is based on a number of VME crates (presently totaling seven), dedicated to directly controlling the telescope subsystems and instrumentation. All the industrial equipment installed is supervised by a network of PLCs (profibus). All CCD cameras (tracking, Shack-Hartmann and scientific) are based on the same hardware, so every picture collected is handled by the informatic system in the same way. The network system is based on two main transport media: FFDI and Ethernet. The local area network is logically subdivided into three sub-nets, one for the telescope and instrumentation control, one for data archiving and one for public access.

The subsystems under supervision are:

- Active optics;
- Telescope movements;
- GPS time services;
- Nasmyth A rotator (DERA);
- Nasmyth B rotator (DERB);
- Dome and telescope services (PLCs);
- Climatization system;
- Hydrostatic Bearing System (HBS);
- Ancillary and instrumentation CCD cameras;
- Data archives.

Hewlett-Packard workstations are dedicated to the remote user interface, and some VME Personal Computers are dedicated to specific tasks needing graphical capabilities (autoguiders, mimics etc.). Basically all algorithmic and graphical interfaces have been implemented using the IDL (Interactive Data Language) environment.

5 Telescope first light

The telescope first light occurred in June 1998. After the first look at the focal plane, initial checks on the quality of the optical alignment were made. The inner and outer focus telescope pupil images of a single bright star (see (3)) were studied. The M2 mirror was commanded to move in such a way to correct its residual decentering after the alignment phase. After this correction the transverse coma aberration went down from about 0.59 arcsec. to about 0.22 arcsec. The spherical aberration was stable to about 0.10 arcsec; in such conditions the quality of the point spread function (PSF) was of 0.8 arcsec FWHM. After the first-light, several tests on the active-optics system of TNG have been made using an off-line system (Antares) and with the derotator Shack-Hartmann analyser; both the primary and the secondary mirror have been characterized during such tests. The values of the low-order aberrations and, in particular, the spherical aberration (0.13 arcsec) determined from the two methods used (i.e. out of focus image pairs and the Shack-Hartmann analysis (see (3)) were measured to be the same.

6 The TNG instrument plan and the instrument first light

It is well known that when observations are limited by the sky background, the minimum detectable flux depends only linearly on the mirror diameter while the seeing dependence is quadratic. Being a medium size telescope TNG has to take the maximum advantage of seeing and, more generally, PSF optimization. The TNG telescope allows the use of two f-11 Nasmyth focal stations selectable via a flat tertiary mirror. Nevertheless the structural design of the dome and of the top-ring has been made in a way to allow the implementation of an f-2.2 prime-focus observing station, in particular, the secondary and tertiary mirror systems can be easily dismounted via a dedicated crane equipped with a spreader platform.

At the present moment the instruments mounted and tested in the Nasmyth A arm (see Table 1) are the visual imager (OIG), the near IR camera (ARNICA) and the speckle and tip-tilt system part of the adaptive optics module. The other instruments mentioned in Table 1 will be in operation during the last quarter of the present year; some more technical details and references on the instruments shown can be found on the TNG WEB pages (http://www.tng.iac.es/).

Most of the imaging observing modes are covered by the Nasmyth A focal station with the possibility to insert into the beam a natural-guide star adaptive module with a f-32.2 output beam. The visual imager OIG, for instance, is

Table 1
TNG Nasmyth stations instrumentation plan

Instr.	mode	arm	sensor	spec. range (μm)	res power	scale ("/pix)	field (')
OIG	imag	A	CCD	0.32–1.1	-	0.07	5
ARNICA	imag	A	NICMOS	0.9–2.5	-	0.41	1.75
NICS	imag	A	NICMOS	0.9–2.5	-	0.25/0.13	4.3/2.2
NICS	spectr	A	NICMOS	0.9–2.5	300–1300	(0.25)	4.3
ADOPT	service	A	-	-	-	-	-
LRS	imag	B	CCD	0.32–1.1	-	0.28	9.4
LRS	spectr	B	CCD	0.3–1.1	1500–3500	-	10
SARG	spectr	B	CCD	0.35–1.1	19000–144000	-	8/30 (")

based on a mosaic of two EEV chips with the characteristics shown in Table 2.

It is clear, with the current pixel-size for most visual and near-IR detectors, that there is a difficulty in obtaining a good PSF sampling at the f-11 Nasmyth for good seeing conditions without the use of some extra optics. The use of the prime-focus could be a possible solution for large-field imaging needs.

Several studies of suitable prime-focus aspheric correctors have been made both for the visual (see (7)) and, recently, for the near-IR; they show the possibility of achieving field coverages of the order 0.5° with a PSF of 0.4 arcsec, with reasonable dimensions for the optical surfaces.

Table 2
Characteristics of the OIG CCD mosaic.

Series:	CCD42-80-
Format:	2048 x 4096
Image Area (mm):	27.6 x 55.2
Pixel Size (mm):	13.5 x 13.5

The ADOPT module is presently working either as a speckle-camera (in the f-32.2 beam) or as a fast tip-tilt corrector. The full implementation of this system, foreseen for the end of the present year, will be based on a 8×8 sub-pupil analyser.

The instrument first-light phase started after mid-November 1998, when the instrument interface-adapter was mounted at the telescope Nasmyth A focus. This interface (see 6) is meant to support the optical imager (OIG, at the center on the straight optical axe), the infrared camera (ARNICA, at right looking through a folding mirror), to be later substituted by NICS, and the adaptive optics module (ADOPT@TNG, located on the white box at the left side of 6). The overall system, which weighs some 2.5 tons, rotates with the Nasmyth derotator creating a closed and stiff platform for the instruments and the adaptive-optics module.

Several results taken during the first-light phase of the instruments mounted on the Nasmyth-A focal plane are reported on the TNG WEB pages at http://www.tng.iac.es/

References

[1] TNG Commissioning Group: *OPTICS COMMISSIONING* (this and the following references can be found at http://www.tng.iac.es/).
[2] TNG Commissioning Group *SOFTWARE COMMISSIONING*
[3] TNG Commissioning Group *THE TELESCOPE FIRST-LIGHT*
[4] TNG Commissioning Group *THE TELESCOPE USER MANUAL*
[5] TNG Commissioning Group *THE HYDROSTATIC BEARING SYSTEM*
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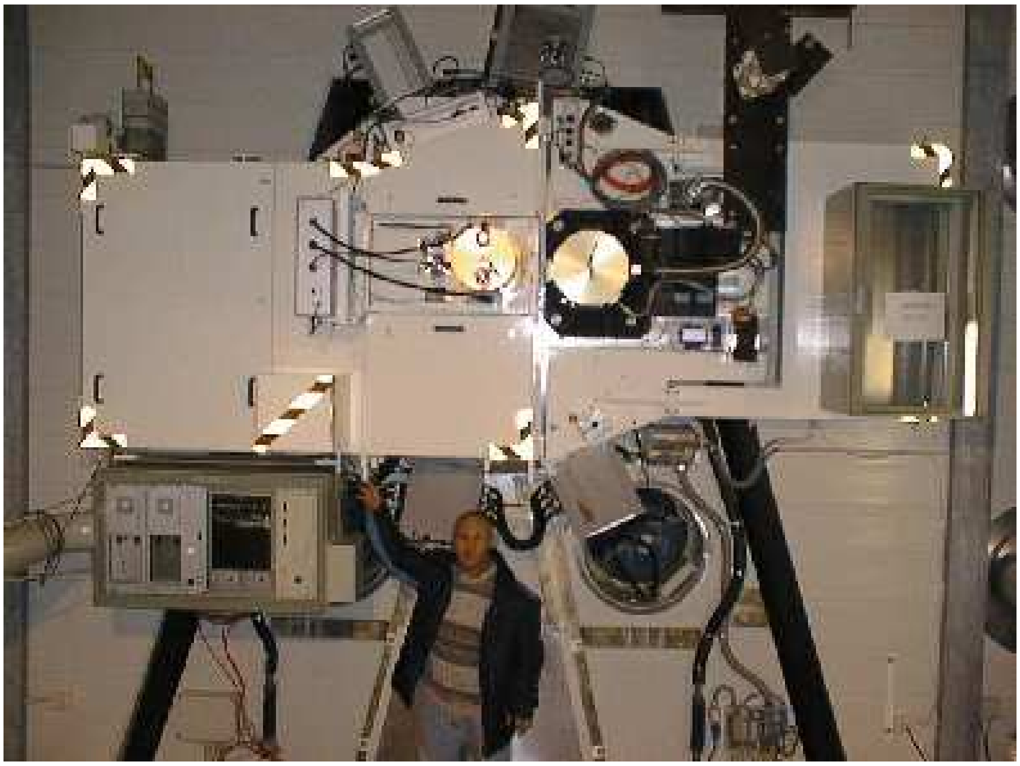

Fig. 1. The Nasmyth A instrument adapter. Supported instruments are visible: OIG at the center, ARNICA at the right and the adaptive optics module ADOPT@TNG at the left.